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Bulletin Home

2015-2016

Mission, Vision and Values

Colorado statutes define the role of the Colorado School of Mines as:
The Colorado School of Mines shall be a specialized baccalaureate and graduate research institution with high admission standards. The Colorado School of Mines shall have a unique mission in energy, mineral, and materials science and engineering and associated engineering and science fields. The school shall be the primary institution of higher education offering energy, mineral and materials science and mineral engineering degrees at both the graduate and undergraduate levels. (Colorado revised Statutes: Section 23-41-105).

The Board of Trustees of the Colorado School of Mines has elaborated on this statutory role with the following statement of the School's mission, vision and values.

Mission

Education and research in engineering and science to solve the world's challenges related to the earth, energy and the environment

- Colorado School of Mines educates students and creates knowledge to address the needs and aspirations of the world's growing population.
- Mines embraces engineering, the sciences, and associated fields related to the discovery and recovery of the Earth's resources, the conversion of resources to materials and energy, development of advanced processes and products, fundamental knowledge and technologies that support the physical and biological sciences, and the economic, social and environmental systems necessary for a sustainable global society.
- Mines empowers, and holds accountable, its faculty, students, and staff to achieve excellence in its academic programs, its research, and in its application of knowledge for the development of technology.

Vision

Mines will be the premier institution, based on the impact of its graduates and research programs, in engineering and science relating to the earth, energy and the environment

- Colorado School of Mines is a world-renowned institution that continually enhances its leadership in educational and research programs that serve constituencies throughout Colorado, the nation, and the world.
- Mines is widely acclaimed as an educational institution focused on stewardship of the earth, development of materials, overcoming the earth's energy challenges, and fostering environmentally sound and sustainable solutions.

Values

A student-centered institution focused on education that promotes collaboration, integrity, perseverance, creativity, life-long learning, and a responsibility for developing a better world

- The Mines student graduates with a strong sense of integrity, intellectual curiosity, demonstrated ability to get a job done in

collaborative environments, passion to achieve goals, and an enhanced sense of responsibility to promote positive change in the world.

- Mines is committed to providing a quality experience for students, faculty, and staff through student programs, excellence in pedagogy and research, and an engaged and supportive campus community.
- Mines actively promotes ethical and responsible behaviors as a part of all aspects of campus life.

(Colorado School of Mines Board of Trustees, 2013)

Undergraduate

2015-2016

To Mines Students:

This Bulletin is for your use as a source of continuing reference. Please save it.

Published by Colorado School of Mines. 1500 Illinois Street, Golden, CO 80401.

Address correspondence to: Colorado School of Mines, Golden, CO 80401

Main Telephone: 303-273-3000 Toll Free: 800-446-9488

Inquiries to Colorado School of Mines should be directed as follows:

Admissions: Director of Admissions, admit@mines.edu

Student Life: Dan Fox, Vice President for Student Life & Dean of Students

Financial Aid: Jill Robertson, Director of Financial Aid, finaid@mines.edu

Registrar: Lara Medley, Registrar, registrar@mines.edu

Academic Affairs: Terry Parker, Provost and Executive Vice President

Welcome

2015-2016

The Academic Environment

We strive to fulfill this educational mission through our undergraduate curriculum and in an environment of commitment and partnership among students and faculty. The commitment is directed at learning, academic success and professional growth, it is achieved through persistent intellectual study and discourse, and it is enabled by professional courtesy, responsibility and conduct. The partnership invokes expectations for both students and faculty. Students should expect access to high quality faculty and to appropriate academic guidance and counseling; they should expect access to a high quality curriculum and instructional programs; they should expect to graduate within four years if they follow the prescribed programs successfully; and they should expect to be respected as individuals in all facets of campus activity and should expect responsive and tactful interaction in their learning endeavors. Faculty should expect participation and dedication from students, including attendance, attentiveness, punctuality and demonstrable contribution of effort in the learning process; and they should expect respectful interaction in a spirit of free inquiry and orderly discipline. We believe that these commitments and expectations establish the academic culture upon which all learning is founded.

CSM offers the Bachelor of Science degree in Applied Mathematics & Statistics, Chemical Engineering, Chemical & Biochemical Engineering, Chemistry, Civil Engineering, Computer Science, Economics, Electrical Engineering, Engineering Physics, Environmental Engineering, Geological Engineering, Geophysical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, Mining Engineering, and Petroleum Engineering. A pervasive institutional goal for all of these programs is articulated in the *Profile of the Colorado School of Mines Graduate*:

- All CSM graduates must have depth in an area of specialization, enhanced by hands-on experiential learning, and breadth in allied

fields. They must have the knowledge and skills to be able to recognize, define and solve problems by applying sound scientific and engineering principles. These attributes uniquely distinguish our graduates to better function in increasingly competitive and diverse technical professional environments.

- Graduates must have the skills to communicate information, concepts and ideas effectively orally, in writing, and graphically. They must be skilled in the retrieval, interpretation and development of technical information by various means, including the use of computer-aided techniques.
- Graduates should have the flexibility to adjust to the ever changing professional environment and appreciate diverse approaches to understanding and solving society's problems. They should have the creativity, resourcefulness, receptivity and breadth of interests to think critically about a wide range of cross-disciplinary issues. They should be prepared to assume leadership roles and possess the skills and attitudes which promote teamwork and cooperation and to continue their own growth through life-long learning.
- Graduates should be capable of working effectively in an international environment, and be able to succeed in an increasingly interdependent world where borders between cultures and economies are becoming less distinct. They should appreciate the traditions and languages of other cultures, and value diversity in their own society.
- Graduates should exhibit ethical behavior and integrity. They should also demonstrate perseverance and have pride in accomplishment. They should assume a responsibility to enhance their professions through service and leadership and should be responsible citizens who serve society, particularly through stewardship of the environment.

History of CSM

In 1865, only six years after gold and silver were discovered in the Colorado Territory, the fledgling mining industry was in trouble. The nuggets had been picked out of streams and the rich veins had been worked, and new methods of exploration, mining, and recovery were needed.

Early pioneers like W.A.H. Loveland, E.L. Berthoud, Arthur Lakes, George West and Episcopal Bishop George M. Randall proposed a school of mines. In 1874, the Territorial Legislature appropriated \$5,000 and commissioned Loveland and a Board of Trustees to found the Territorial School of Mines in or near Golden. Governor Routt signed the Bill on February 9, 1874, and when Colorado became a state in 1876, the Colorado School of Mines was constitutionally established. The first diploma was awarded in 1883.

As CSM grew, its mission expanded from the rather narrow initial focus on nonfuel minerals to programs in petroleum production and refining as well. Recently it has added programs in materials science and engineering, energy and environmental engineering, and a broad range of other engineering and applied science disciplines. CSM sees its mission as education and research in engineering and applied science with a special focus on the earth science disciplines in the context of responsible stewardship of the earth and its resources.

CSM long has had an international reputation. Students have come from nearly every nation, and alumni can be found in every corner of the globe.

Unique Programs

Colorado School of Mines is an institution of engineering and applied science with a special focus in Earth, Energy, Environment and Materials. As such, it has unique programs in many fields. This is the only institution in the world, for example, that offers doctoral programs in all five of the major earth science disciplines: Geology and Geological Engineering, Geophysics, Geochemistry, Mining Engineering and Petroleum Engineering. It has one of the few Metallurgical and Materials Engineering programs in the country that still focuses on the complete materials cycle from mineral processing to finished advanced materials.

In addition to these traditional programs which define the institutional focus, the school is pioneering programs in interdisciplinary areas. One of the most successful of these is the Engineering Division program, which currently claims more than one-third of the undergraduate majors. This program combines civil, electrical, environmental and mechanical engineering in a nontraditional curriculum that is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012 – telephone (410) 347-7700. Another, at the graduate level, is the Master of International Political Economy of Resources. Such programs serve as models at CSM.

While many of the programs at CSM are firmly grounded in tradition, they are all experiencing continual evolution and innovation. Recent successes in integrating aspects of the curriculum have spurred similar activity in other areas such as the geosciences. There, through the medium of computer visualization, geophysicists and geologists are in the process of creating a new emerging discipline. A similar development is occurring in geo-engineering through the integration of aspects of civil engineering, geology and mining. CSM has played a leadership role in this kind of innovation over the last decade. Many degree programs offer CSM undergraduate students the opportunity to begin work on a Graduate Certificate, Professional Master's Degree, or Master's Degree while completing the requirements for their Bachelor's Degree. These combined Bachelors-Masters programs have been created by CSM faculty in those situations where they have deemed it academically advantageous to treat BS and MS degree programs as a continuous and integrated process. These are accelerated programs that can be valuable in fields of engineering and applied science where advanced education in technology and/or management provides the opportunity to be on a fast track for advancement to leadership positions. These programs also can be valuable for students who want to get a head start on graduate education.

Location

Golden, Colorado has been the home for CSM since its inception. Located 20 minutes west of Denver, this community of 18,000 is located in the foothills of the Rockies. Skiing is an hour away to the west. Golden is a unique community that serves as home to CSM, the Coors Brewing Company, the National Renewable Energy Laboratory, a major U.S. Geological Survey facility that also contains the National Earthquake Center, and the seat of Jefferson County. Golden once served as the territorial capital of Colorado.

Accreditation

Mines is accredited through the doctoral degree by the Higher Learning Commission (HLC) of the North Central Association, 230 South LaSalle Street, Suite 7-500, Chicago, Illinois 60604-1413 – telephone (312) 263-0456. The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111

Market Place, Suite 1050, Baltimore, MD 21202-4012 – telephone (410) 347-7700, accredits undergraduate degree programs in Chemical Engineering, Chemical and Biochemical Engineering, Civil Engineering, Electrical Engineering, Engineering, Engineering Physics, Environmental Engineering, Geological Engineering, Geophysical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, Mining Engineering and Petroleum Engineering. The American Chemical Society has approved the degree program in the Department of Chemistry and Geochemistry.

Administration

General management of the School is vested by State statute in a Board of Trustees, consisting of seven members appointed by the governor. A non-voting student member is elected annually by the student body and a non-voting faculty member is elected to serve a two-year term by the academic faculty. Financial support comes from student tuition and fees and from the State through annual appropriations. These funds are augmented by government and privately sponsored research, private gift support from alumni, corporations, foundations and other friends.

Colorado School of Mines Non-Discrimination Statement

In compliance with federal law, including the provisions of Titles VI and VII of the Civil Rights Act of 1964, Title IX of the Education Amendment of 1972, Sections 503 and 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, the ADA Amendments Act of 2008, Executive Order 11246, the Uniformed Services Employment and Reemployment Rights Act, as amended, the Genetic Information Nondiscrimination Act of 2008, and Board of Trustees Policy 10.6, the Colorado School of Mines does not discriminate against individuals on the basis of age, sex, sexual orientation, gender identity, gender expression, race, religion, ethnicity, national origin, disability, military service, or genetic information in its administration of educational policies, programs, or activities; admissions policies; scholarship and loan programs; athletic or other school-administered programs; or employment.

Inquiries, concerns, or complaints should be directed by subject content as follows:

The Employment-related EEO and discrimination contact is:

Mike Dougherty, Associate Vice President for Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for employment is:

Ann Hix, Benefits Manager, Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for students and academic educational programs is:

Kristen Wieggers, Coordinator of Student Disability Services
Student Wellness Center, 1770 Elm Street
Golden, Colorado 80401
(Telephone: 303.273.3377)

The Title IX Coordinator is:

Karin Ranta-Curran, Assistant Director of HR for EEO and Equity
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.384.2558)
(E-Mail: krcurran@mines.edu)

The ADA Facilities Access Coordinator is:

Gary Bowersock, Director of Facilities Management
1318 Maple Street
Golden, Colorado 80401
(Telephone: 303.273.3330)

Student Life

2015-2016

Facilities

Student Center

The Ben H. Parker Student Center contains the offices for the Vice President of Student Life and Dean of Students, Associate Dean of Students, Student Activities and Greek Life, Student Government (USG and GSG), Financial Aid, Cashier, International Student and Scholar Services, Career Center, Registrar, Conference Services, and student organizations. The Student Center also contains The Periodic Table food court, bookstore, student lounges, meeting rooms, and banquet facilities.

Student Recreation Center

Completed in May 2007, the 108,000 square foot Student Recreation Center, located at the corner of 16th and Maple Streets in the heart of campus, provides a wide array of facilities and programs designed to meet student's recreational and leisure needs while providing for a healthy lifestyle. The Center contains a state-of-the-art climbing wall, an eight-lane, 25 meter swimming and diving pool, a cardiovascular and weight room, two multi-purpose rooms designed and equipped for aerobics, dance, martial arts programs and other similar activities, a competition gymnasium containing three full-size basketball courts as well as seating for 2500 people, a separate recreation gymnasium designed specifically for a wide variety of recreational programs, extensive locker room and shower facilities, and a large lounge intended for relaxing, playing games or watching television. In addition to housing the Outdoor Recreation Program as well as the Intramurals and Club Sports Programs, the Center serves as the competition venue for the Intercollegiate Men and Women's Basketball Programs, the Intercollegiate Volleyball Program and the Men and Women's Intercollegiate Swimming and Diving Program.

W. Lloyd Wright Student Wellness Center

The W. Lloyd Wright Student Wellness Center, 1770 Elm Street, houses several health and wellness programs for Mines students: the Coulter Student Health Center, the Student Health Benefits Plan, the Counseling Center, the Dental Clinic and Student Disability Services. The wellness center is open from 8:00 am to 5:00 pm, Monday through Friday, during the fall and spring semesters. Check the website for summer and holiday hours.

Coulter Student Health Center: Services are provided to all students who have paid the student health center fee. The Coulter Student Health Center (303) 273-3381, FAX (303) 273-3623 is located on the first floor

of the W. Lloyd Wright Student Wellness Center at the corner of 18th and Elm Streets (1770 Elm Street). Nurse practitioners and registered nurses provide services Monday through Friday 8:00 am to 12:00 pm and 1:00 pm to 4:45 pm. Family medicine physicians provide services by appointment several days a week. After hours students can call New West Physicians at (303) 278-4600 to speak to the physician on call (identify yourself as a CSM student). The Health Center offers primary health care. For X-rays, specialists or hospital care, students are referred to appropriate providers in the community. More information is available at <http://healthcenter.mines.edu>.

Dental Clinic: The Dental Clinic is located on the second floor of the W. Lloyd Wright Wellness Center. Services include cleanings, restoratives, and x-rays. Students who have paid the student health fee are eligible for this service. The dental clinic is open Tuesdays, Wednesdays, and Fridays during the academic year with fewer hours in the summer. Services are by appointment only and can be made by calling the Dental Clinic - 303-273-3377. Dental care is on a fee-for-service basis, and students enrolled in the CSM Student Health Insurance Plan pay lower rates for dental care. The Dental Clinic takes cash or checks, no credit/debit cards.

Fees: *Students are charged a mandatory Health Services fee each semester, which allows them access to services at the Health Center. Spouses of enrolled CSM students can choose to pay the health center fee and are eligible for services. Dental services are not available to spouses.*

Immunization Requirement: *The State of Colorado requires that all students enrolled have proof of two MMRs (measles, mumps and rubella). A blood test showing immunity to all three diseases is acceptable. History of disease is not acceptable.*

Student Health Benefits Plan: *The SHBP office is located on the second floor of the W. Lloyd Wright Student Wellness Center.*

Adequate Health Insurance Requirement: *All degree seeking U.S. citizen and permanent resident students, and all international students regardless of degree status, are required to have health insurance. Students are automatically enrolled in the Student Health Benefits Plan and may waive coverage if they have comparable coverage under a personal or employer plan. International students must purchase the SHBP, unless they meet specific requirements. Information about the CSM Student Health Benefits Plan, as well as the criteria for waiving, is available online at <http://studentinsurance.mines.edu> or by calling 303.273.3388. Enrollment confirmation or waiver of the CSM Student Health Benefits Plan is done online for U.S. Citizens and Permanent Residents. International students must complete a paper enrollment/waiver form. The deadline is Census Day.*

Counseling Center: *Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Services are available for students who have paid the Student Services fee. Individual personal, academic, and career counseling is offered on a short-term basis to all enrolled CSM students. In cases where a student requires longer-term counseling, referrals are made to providers in the local community. The Counseling Center also provides education and assessment on alcohol and other drug use. More information is available at <http://counseling.mines.edu/>.*

Student Disability Services: *Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Student Disability Services provides students with disabilities an equal opportunity to access the institution's courses, programs and activities. Services*

are available to students with a variety of disabilities, including but not limited to attention deficit hyperactivity disorders, learning disorders, psychological disorders, vision impairment, hearing impairment, and other disabilities. A student requesting disability accommodations at the Colorado School of Mines must comply with the Documentation Guidelines and submit required documents, along with a completed Request for Reasonable Accommodations form to Student Disability Services.

Documentation Guidelines and the Request form are available at <http://disabilities.mines.edu/>.

Services

Academic Advising & Support Services Center for Academic Services and Advising (CASA)

Academic Advising: All students entering CSM are assigned an Academic Advising Coordinator. This assignment is made by last name. This Coordinator serves as the student's academic advisor until they formally declare their major or intended degree. This declaration occurs in their sophomore year. Incoming students have only noted an interest and are not declared.

The Coordinators will host individual, walk-in, and group advising sessions throughout the semester. Every student is required to meet with their Coordinator at least once per semester. The Coordinator will administer a PIN for course registration, each semester. Students unsure of their academic path (which major to choose) should work with their Coordinator to explore all different options.

Students are encouraged to utilize the CASA Peer Advisors. Students may walk-in and speak with a fellow student on various issues pertaining to course registration, course enrollment, majors, and minors.

The Registrar's Office creates the first-semester schedule for incoming transfer students. CASA advises undecided transfer students during their first year who have successfully completed 30.0 or more semester hours.

CSM101: The First-Year Symposium, CSM101, is a required, credit-bearing class. CSM101 aims to facilitate the transition from high school to college; create community among peers and upper-class students; assess and monitor academic progress; and provide referrals to appropriate campus resources. CSM101 is taught by 45 professional staff members (including faculty) and 90 Peer Mentor students.

Transfer students who have successfully completed fewer than 30.0 transcribed semester hours at an institution of higher education after high school graduation will automatically be enrolled in the First-Year Advising and Mentoring Program in their first semester at CSM.

Tutoring Services: CASA offers weekly tutoring services for all core-curriculum courses. Our services run Sunday through Thursday and are hosted in CASA and the Library. There is more information about tutoring services available via our website at <http://casa.mines.edu>.

Academic Support Services: Routinely, CASA offers great support workshops and events. CASA hosts pre-finals workshops as well as mid-term exam prep session. As well, students can work with our staff to develop the skills and technique of studying well in college – such as test-prep and cognitive learning development.

CASA hosts late-night programs in the residence halls and Greek houses.

Core Supplemental Instruction (CSI): First-Year students are encouraged to attend our CSI workshops. These workshops run concurrent to many of the first-year classes (Calc, Chem, Physics, etc.) and reiterate/strengthen material taught in class. They are offered in the evening and are free to all students.

Faculty in CASA: Faculty from various departments host their regular office hours in CASA. Students are encouraged to utilize these professors for assistance with material and/or questions on course planning.

Website and Additional Services: In addition to the aforementioned services, CASA offers assistance with readmission to the institution, intensive academic support programs, and specialized courses in spatial modeling and visualization.

CASA maintains an extensive website with resources, helpful tips, and guides. Check out CASA at <http://casa.mines.edu>.

Motor Vehicles Parking

All motor vehicles on campus must be registered with the campus Parking Services Division of Facilities Management, 1318 Maple Street, and must display a CSM parking permit. Vehicles must be registered at the beginning of each semester or upon bringing your vehicle on campus, and updated whenever you change your address.

Public Safety

The Colorado School of Mines Department of Public Safety is a full service, community oriented law enforcement agency, providing 24/7 service to the campus. It is the mission of the Colorado School of Mines Police Department to make the Mines campus the safest campus in Colorado.

The department is responsible for providing services such as:

- Proactive patrol of the campus and its facilities
- Investigation and reporting of crimes and incidents
- Motor vehicle traffic and parking enforcement
- Crime and security awareness programs
- Alcohol / Drug abuse awareness / education
- Self defense classes
- Consultation with campus departments for safety and security matters
- Additional services to the campus community such as: vehicle unlocks and jumpstarts, community safe walks (escorts), authorized after-hours building and office access, and assistance in any medical, fire, or other emergency situation.

The police officers employed by the Department of Public Safety are fully trained police officers in accordance with the Peace Officer Standards and Training (P.O.S.T.) Board and the Colorado Revised Statute.

Career Center

The Mines Career Center mission is to assist students in developing, evaluating, and/or implementing career, education, and employment decisions and plans. Career development is integral to the success of Mines graduates and to the mission of Mines. All Colorado School of Mines graduates will be able to acquire the necessary job search

and professional development skills to enable them to successfully take personal responsibility for the management of their own careers.

Services are provided to all students and for all recent graduates, up to 24 months after graduation. Students must adhere to the ethical and professional business and job searching practices as stated in the Career Center Student Policy, which can be found in its entirety on the Student's Homepage of DiggerNet.

In order to accomplish our mission, we provide a comprehensive array of career services:

Career, Planning, Advice, and Counseling

- "The Mines Strategy" a practical, user-friendly career manual with interview strategies, resume and cover letter examples, career exploration ideas, and job search tips;
- Online resources for exploring careers and employers at <http://careers.mines.edu>;
- Individual resume and cover letter critiques;
- Individual job search advice;
- Practice video-taped interviews;
- Job Search Workshops - successful company research, interviewing, resumes, business etiquette, networking skills;
- Salary and overall outcomes data;
- Information on applying to grad school;
- Career resource library.

Job Resources and Events

- Career Day (Fall and Spring);
- Online and in-person job search assistance for internships, CO-OPs, and full-time entry-level job postings;
- Virtual Career Fairs and special recruiting events;
- On-campus interviewing - industry and government representatives visit the campus to interview students and explain employment opportunities;
- General employment board;
- Company research resource;
- Cooperative Education Program - available to students who have completed three semesters at Mines (two for transfer students). It is an academic program which offers 3 semester hours of credit in the major for engineering work experience, awarded on the basis of a term paper written following the CO-OP term. The type of credit awarded depends on the decision of the department, but in most cases is additive credit. CO-OP terms usually extend from May to December, or from January to August, and usually take a student off campus full time. Students must apply for CO-OP before beginning the job (a no credit, no fee class), and must write learning objectives and sign formal contracts with their company's representative to ensure the educational component of the work experience.

Identification Cards (Blaster Card Office)

All new students must have a Blaster Card made as soon as possible after they enroll. The Blaster Card office also issues RTD College Passes, which allows students to ride RTD buses and light rail free of charge (or for a reduced fee for airport bus service). Students can replace lost, stolen, or damaged Blaster Cards for a small fee.

The Blaster Card can be used for student meal plans, to check material out of the CSM Library, to access certain electronic doors, and may be required to attend various CSM campus activities.

Student Publications

Two student publications are published at CSM by the Associated Students of CSM. Opportunities abound for students wishing to participate on the staffs. A Board of Student Publications acts in an advisory capacity to the publications staffs and makes recommendations on matters of policy.

The *Oredigger* is the student newspaper, published weekly during the school year. It contains news, features, sports, letters and editorials of interest to students, faculty, and the Golden community.

The literary magazine, *High Grade*, is published each semester. Contributions of poetry, short stories, drawings, and photographs are encouraged from students, faculty and staff.

Veterans Services

The Registrar's Office provides veterans services for students attending the School and using educational benefits from the Veterans Administration.

Activities

Student Activities Office

The Office of Student Activities coordinates the various activities and student organizations on the Mines campus. Student government, professional societies, living groups, honor societies, interest groups and special events add a balance to the academic side of the CSM community. Participants take part in management training, event planning, and leadership development. To obtain an up-to-date listing of the recognized campus organizations or more information about any of these organizations, contact the Student Activities office.

Student Government

The Associated Students of Colorado School of Mines (ASCSM) is sanctioned by the Board of Trustees of the School. The purpose of ASCSM is, in part, to advance the interest and promote the welfare of CSM and all of the students and to foster and maintain harmony among those connected with or interested in the School, including students, alumni, faculty, trustees and friends. Undergraduate Student Government (USG) and Graduate Student Government (GSG) are the governing bodies recognized by CSM through ASCSM as the representative voice of their respective student bodies. The goal of these groups is to improve the quality of education and offer social programming and academic support.

Through funds collected as student fees, ASCSM strives to ensure a full social and academic life for all students with its organizations, publications, and special events. As the representative governing body of the students ASCSM provides leadership and a strong voice for the student body, enforces policies enacted by the student body, works to integrate the various campus organizations, and promotes the ideals and traditions of the School.

The Mines Activity Council (MAC) serves as the campus special events board. The majority of all-student campus events are planned by MAC. Events planned by MAC include comedy shows to the campus on most Fridays throughout the academic year, events such as concerts,

hypnotists, and one time specialty entertainment; discount tickets to local sporting events, theater performances, and concerts, movie nights bringing blockbuster movies to the Mines campus; and E-Days and Homecoming.

Special Events

Engineering Days festivities are held each spring. The three day affair is organized entirely by students. Contests are held in drilling, hand-spiking, mucking, and oil-field olympics to name a few. Additional events include a huge fireworks display, the Ore-Cart Pull to the Colorado State Capitol, the awarding of scholarships to outstanding Colorado high school seniors and a concert.

Homecoming weekend is one of the high points of the year. Events include a football rally and game, campus decorations, election of Homecoming queen and beast, parade, burro race, and other contests.

International Day is planned and conducted by the International Student Council and the International Student and Scholar Services Office. It includes exhibits and programs designed to further the cause of understanding among the countries of the world. The international dinner and entertainment have come to be one of the campus social events of the year.

Winter Carnival, sponsored by Blue Key, is an all-school ski day held each year at one of the nearby ski areas. In addition to skiing, there are also fun competitions (snowman contest, sled races, etc.) throughout the day.

Outdoor Recreation Program

The Outdoor Recreation Program is housed at the Student Recreation Center. The Program teaches classes in outdoor activities; rents mountain bikes, climbing gear, backpacking and other equipment; and sponsors day and weekend activities such as camping, snowshoeing, rock climbing, and mountaineering.

Residence Hall Association (RHA)

Residence Hall Association (RHA) is a student-run organization developed to coordinate and plan activities for students living in the Residence Halls. Its membership is represented by students from each hall floor. Officers are elected each fall for that academic year. For more information, go to RHA (<http://inside.mines.edu/RSL-Residence-Hall-Association>).

Student Organizations

For a complete list of all currently registered student organizations, please visit the Student Activities office or website at <http://studentactivities.mines.edu/>.

Social Fraternities and Sororities - There are seven national fraternities and three national sororities active on the CSM campus. Fraternities and Sororities offer the unique opportunity of leadership, service to one's community, and fellowship. Greeks are proud of the number of campus leaders, athletes and scholars that come from their ranks. Colorado School of Mines chapters are:

- Alpha Phi
- Alpha Tau Omega
- Beta Theta Pi
- Kappa Sigma
- Phi Gamma Delta

- Pi Beta Phi
- Sigma Alpha Epsilon
- Sigma Kappa
- Sigma Nu
- Sigma Phi Epsilon

Honor Societies - Honor societies recognize the outstanding achievements of their members in the areas of scholarship, leadership, and service. Each of the CSM honor societies recognizes different achievements in our students.

Special Interest Organizations - Special interest organizations meet the special and unique needs of the CSM student body by providing co-curricular activities in specific areas.

International Student Organizations - The International Student Organizations provide the opportunity to experience a little piece of a different culture while here at Mines, in addition to assisting the students from that culture adjust to the Mines campus.

Professional Societies - Professional Societies are generally student chapters of the national professional societies. As a student chapter, the professional societies offer a chance for additional professional development outside the classroom through guest speakers, trips, and interactive discussions about the current activities in the profession. Additionally, many of the organizations offer internship, fellowship and scholarship opportunities.

Recreational Organizations - The recreation organizations provide the opportunity for students with similar interests to participate as a group in these recreational activities. Most of the recreational organizations compete on both the local and regional levels at tournaments throughout the year.

International Student Services

2015/2016

The International Students & Scholar Services Office (ISSS) serves approximately 800 international students and scholars at CSM.

ISSS provides the following services:

- Admission of undergraduate international students
- Advise on immigration regulations by individual appointment and group seminars
- Prepare legal documents that allow international students to gain work experience through a period of practical training
- Provide forms required by international students and their dependents to travel outside the U.S.
- Process legal documents required for the admission of all international students (including undergraduate, graduate, special, exchange, and visiting scholars)
- Organize orientation programs for entering international undergraduate and graduate students

ISSS also sponsors events and programs to help students adjust to life in the U.S. and CSM, and provides counseling related to emergencies and unexpected immigration problems.

For more information see www.issm.mines.edu

Multicultural Engineering Program

Multicultural Engineering Program

The Multicultural Engineering Program is located at 1400 Maple Street. MEP provides support that contributes to the recruitment, retention and graduation of historically under-represented students. MEP offers academic support, leadership opportunities, and professional development through programming, tutoring, community outreach, and cultural and social activities.

Working through student professional societies-American Indian Science and Engineering Society (AISES), National Society of Black Engineers (NSBE), Out in Science, Technology, Engineering and Mathematics (oSTEM), Society of Asian Scientists and Engineers (SASE), and the Society of Hispanic Professional Engineers (SHPE), the Multicultural Engineering Program is a center for student, faculty and staff support, and a place for students to become a community of scholars with common goals and objectives in a welcoming learning environment.

American Indian Science and Engineering Society (AISES) chapter was established at the Colorado School of Mines in 1992. It is a peer support group for Native American students pursuing science and engineering careers. Its main goal is to help the students get through college so they can then use those new skills to create a better life for themselves and other Native Americans.

National Society of Black Engineers (NSBE) is a non-profit organization managed by students. It was founded to promote the recruitment, retention and successful graduation of Black and other under-represented groups in the field of engineering. NSBE operates through a university-based structure coordinated through regional zones, and administered by the National Executive Board. The local chapters, which are the center of NSBE activity, create and conduct projects in the areas of pre-college student interaction, university academic support mechanisms and career guidance programs. "We instill pride and add value to our members which causes them to want to give back to NSBE in order to produce a continuum of success."

Out in Science, Engineering, Technology & Mathematics (oSTEM) is a national society dedicated to educating and fostering leadership for LGBTQA communities in the STEM fields. Originally established at Mines in 1997, and formally Sigma Lambda.

Society of Asian Scientists and Engineers (SASE) is a branch of the Minority Engineering Program which acknowledges the Asian heritage by involvement in various school activities, social activities, and activities with the other Minority Engineering chapters. SASE allows students with an Asian heritage or students interested in Asian heritage to assemble and voice shared interests and associate in organized group activities which include attending Nuggets games, bowling, ice skating and numerous other activities.

Society of Hispanic Professional Engineers (SHPE) is a non-profit organization that exists for the advancement of Hispanic engineering (sciences) students to become professional engineers and scientists, to increase the number of Hispanics entering into the field of engineering, and to develop and implement programs benefiting Hispanics seeking to become engineers and scientists. Anyone interested in joining may do so. SHPE is a national organization with student and professional chapters in nearly 100 cities across the country. The organization is divided into five regions representing 76 student chapters. The SHPE organization is

governed by a National Board of Directors which includes representatives from all regions including two student representatives.

For further information, contact:

Andrea Salazar Morgan, Director, Multicultural Engineering Program
Colorado School of Mines
1400 Maple Street
Golden, CO 80401
Phone: (303)273-3021
asalazar@mines.edu

Office of International Programs/ Study Abroad/International Fellowships

The Office of International Programs (OIP) fosters and facilitates international education, research and outreach at CSM. OIP is administered by the Office of Academic Affairs.

OIP also advises students interested in applying for one or more of the nationally competitive scholarships, such as Rhodes, Marshall, Churchill, Fulbright, or Mitchell and will work with individual students to prepare competitive application packages.

OIP is located at 1706 Illinois Street. For more specific information about study abroad and other international programs, contact OIP at 384-2121 or visit the OIP web page (<http://OIP.mines.edu>).

The office works with the departments and divisions of the School to:

1. Help develop and facilitate study abroad opportunities for CSM students while serving as an informational and advising resource for them;
2. Assist in attracting new international students to CSM;
3. Serve as a resource for faculty and scholars of the CSM community, promoting faculty exchanges, faculty-developed overseas learning opportunities, and the pursuit of collaborative international research activities;
4. Foster international outreach and technology transfer programs;
5. Facilitate arrangements for official international visitors to CSM; and
6. In general, helps promote the internationalization of CSM's curricular programs and activities.

OIP promotes and coordinates the submission of Fulbright, Rhodes, Churchill, Goldwater, Morris K. Udall and Marshall Scholarship programs on campus.

<http://inside.mines.edu/OIP-home>

Office of Women in Science, Engineering and Mathematics (WISEM)

The WISEM office in Academic Affairs is located in 300 Guggenheim Hall. The mission of WISEM is to enhance opportunities for women in science and engineering careers, to increase retention of women at CSM, and to promote equity and diversity in higher education. The office

sponsors programs and services for the CSM community regarding gender and equity issues, and produces the Chevron Lecture Series.

For further information, contact:

Stephanie Berry
 Director of the Women in Science, Engineering and Mathematics Program
 Colorado School of Mines
 1133 17th Street
 Golden, CO 80401-1869
 Phone (303) 273-3097
 E-Mail stberry@mines.edu

Tuition, Fees, Financial Assistance, Housing & Dining Rates

2015-2016

Tuition and fees are established by the Board of Trustees of Colorado School of Mines following the annual budget process and action by the Colorado General Assembly and Governor.

Undergraduate Tuition

The official tuition and approved charges for the 2015-2016 academic year will be available prior to the start of the 2015-2016 academic year and can be found at: <https://inside.mines.edu/UserFiles/File/finance/budget/FY15/FY15%20Tuition%20Schedule.pdf>.

Fees

The official fees, approved charges, and fee descriptions for the 2015-2016 academic year will be available prior to the start of the 2015-2016 academic year.

Please note that in all instances, the costs to collect fees are not reimbursed to the Student Receivables Office. Colorado School of Mines does not automatically assess any optional fees or charges.

Housing & Dining Rates

Room and board charges are established by the Board of Trustees and are subject to change. Payment of room and board charges falls under the same guidelines as payment of tuition and fees. Rates below are in effect for the 2015-2016 Academic Year. For more information, go to Student Housing (http://inside.mines.edu/Student_Housing) or Mines Dining (<http://inside.mines.edu/CampusDining>).

Payments and Refunds

Payment Information

A student is expected to complete the registration process, including the payment of tuition and fees, room and board, before attending class. Students can mail their payment to:

Cashier
 1600 Maple Street
 Colorado School of Mines
 Golden, CO 80401-1887

Financial Responsibility

It is important for students to recognize their financial responsibilities when registering for classes at the school. If students do not fulfill their financial obligations by published deadlines:

- Late payment penalties will accrue on any outstanding balance.
- Transcripts will not be issued.
- Past due accounts will be turned over to Colorado Central Collection Services in accordance with Colorado law.
- Collection costs will be added to a student's account.
- The student's delinquency may be reported to national credit bureaus.

Late Payment Penalties

A penalty will be assessed against a student if payment is not received in full by the official day of registration. The penalty is described in the schedule of courses for each semester. If payment is not completed by the sixth week of class, the student may be officially withdrawn from classes. Students will be responsible for all collection costs.

Encumbrances

A student will not be permitted to register for future classes, graduate, or secure an official transcript of his/her academic record while indebted in any way to CSM. Students will be responsible for payment of all reasonable costs of collection.

Refunds

Refunds for tuition and fees are made according to the following policy:

- The amount of tuition and fee assessments is based primarily on each student's enrolled courses. In the event a student withdraws from a course or courses, assessments will be adjusted as follows:
- If the withdrawal is made prior to the end of the add/drop period for the term of enrollment, as determined by the Registrar, tuition and fees will be adjusted to the new course level without penalty.
- If the withdrawal from a course or courses is made after the add/drop period, and the student does not officially withdraw from school, no adjustment in charges will be made.
- If the withdrawal from courses is made after the add/drop period, and the student withdraws from school, tuition and fee assessments will be reduced according to the following schedule:
- Within the 7 calendar days following the end of the add/drop period, 60 percent reduction in charges.
- Within the next following 7 calendar days, a 40 percent reduction in charges.
- Within the next following 7 calendar days, a 20 percent reduction in charges.
- After that period, no reduction of charges will be made.

The schedule above applies to the Fall and Spring semesters. The time periods for the Summer sessions - Summer I and Summer II - will be adjusted in proportion to the reduced number of days in these semesters.

Room and board refunds are pro-rated to the date of checkout from the Residence Hall. Arrangements must be made with the Housing Office. Student health insurance charges are not refundable. The insurance remains in effect for the entire semester.

PLEASE NOTE: Students receiving federal financial aid under the Title IV programs may have a different refund determined as required by federal law or regulations.

Late Fee for Application to Graduate after Stated Deadlines - \$250 Beginning Fall 2015

Undergraduates:

The deadline to apply to graduate and participate in commencement is the first day of class of the term in which the student intends to graduate/participate.

Any request to be added to the graduation list and/or commencement ceremony after the first day of class (and before November 10th for fall or April 10th for spring and summer) may be made in writing and will be considered by the Registrar's Office. If the request is denied, the student will be required to apply for the next available graduation/ceremony. If the request is approved and all other conditions are met (i.e. degree requirements can be met, required forms are turned in, and outstanding hours limitations are not exceeded), a mandatory \$250 fee will be applied to the student's account. This fee cannot be waived and cannot be refunded if the student does not meet the graduation check-out deadlines.

For late requests that are approved, tickets to the commencement ceremony for family and friends of the graduate are not guaranteed, as they may have already been distributed or assigned. Additionally, the student's name may not appear in the commencement program due to publishing deadlines.

No undergraduate student will be added to a graduation or commencement when the request is made after November 10th for the fall commencement (which includes December graduation), or April 10th for the spring and summer commencement ceremony (which includes May and August graduations).

College Opportunity Fund

The College Opportunity Fund provides State financial support to eligible students for higher education. It was created by an Act of the Colorado State Legislature and signed into law by Governor Owens in May 2004.

What does it mean? In the past, the State gave money directly to the colleges. Now, if you authorize use of the stipend for any given term, the college you are attending will receive the funding, and you will see it appear as a credit on your tuition bill.

Who is eligible? Undergraduate students who are eligible for in-state tuition, and who apply for COF, are admitted to and enrolled in an eligible institution of higher education, and who authorize the institution to collect the funds on their behalf. Once enrolled at the Colorado School of Mines, the student must authorize the School to collect these funds from the state on the student's behalf. Once authorized, the School will continue to collect these funds on the student's behalf unless and until the student chooses to revoke the authorization.

How much is the stipend? It will vary. The amount will be determined each year by the Colorado Legislature.

For additional information please refer to:

Colorado School of Mines website:

<http://inside.mines.edu/College-Opportunity-Fund-Application-Authorization>

Colorado Department of Higher Education's website:
<http://highered.colorado.gov/Finance/COF/default.html>

The College Opportunity Fund website:
<https://cof.college-assist.org/>

Financial Aid and Scholarships

2015/2016

Undergraduate Student Financial Assistance

The role of the CSM Financial Assistance Program is to enable students to enroll and complete their educations, regardless of their financial circumstances. In fulfilling this role, the Office of Financial Aid administered over \$40 million in total assistance in 2013-2014, including over \$22.7 million in grants and scholarships. Additional information may be found at the CSM financial aid web site, finaid.mines.edu.

Applying for Assistance

The CSM Application for Admission serves as the application for CSM merit-based scholarships for new students (except for the Engineers' Days Scholarship which is an essay contest run by a student government committee, and the Athletic and Military Science Departments which have their own application procedures for their scholarships). Continuing students may be recommended by their major department for scholarships designated for students from that department. To apply for need-based CSM, federal and Colorado assistance, students should complete the Free Application for Federal Student Aid.

Once evaluated, a financial aid award notification will be sent to the student. New students are sent a paper award letter beginning in early March. Continuing students are notified in mid May via their Mines email.

Types of Financial Assistance

Need-based assistance will typically include grants, part-time employment, and student loans. Grants are provided by CSM, by the State of Colorado (Colorado State Grants), and by the federal government (Pell Grants and Supplemental Educational Opportunity Grants).

Work Study funds also come from CSM, Colorado and the federal government. Students work between 8 and 10 hours a week, and typically earn between \$500 to \$1,500 to help pay for books, travel, and other personal expenses.

Student Loans may be offered from two federal programs: the Perkins Student Loan, or the Federal Direct Student Loan.

Supplemental student loans may also be offered through private bank loan programs.

The Alumni Association of CSM administers a loan program designed to assist juniors and seniors who have exhausted their other sources of funds. These are short term loans which require repayment within three years after graduation, and have been made available through the contributions of CSM alumni.

Merit-based assistance is offered to recognize students for their achievements. Academic awards to new students are made on the basis of their high school GPA and SAT or ACT composite test scores. Continuing students can receive departmental scholarships based on their academic performance at CSM, particularly in their major field of study, and on financial need.

Alumni Association Grants are awarded to students who are children of alumni who have been active in the CSM Alumni Association for the two years prior to the student's enrollment. The one-year grants carry a value of \$1,000. The students may also receive a senior award, based on their academic scholarship, and the availability of funds.

Engineers' Day Scholarships are available to Colorado residents. Based on high school records, an essay, and other information, a CSM Student Government committee selects students for these four-year awards.

Athletic scholarships may be awarded to promising student-athletes in seventeen men's and women's sports. The scholarships are renewable for up to three years, based on the recommendation of the Athletics Department.

Army ROTC scholarships are available from CSM and the U.S. Army for outstanding young men and women who are interested in a military career. The one, two, three, and four-year scholarships can provide up to full tuition and fees, a book allowance, and a monthly stipend for personal expenses. The CSM Military Science Department assists students in applying for these scholarships.

U.S. Navy Scholarships through the Civil Engineering Program, Nuclear Power Officer Program, and Baccalaureate Degree Completion Program are also available to CSM students. The local Navy Recruiting District Office provides information about these scholarships.

U.S. Air Force ROTC Scholarships are available from CSM and the U.S. Air Force. The three and four year scholarships can provide up to full tuition, fees, a book allowance, and a stipend. Further information is available through the Department of Aerospace Studies at the University of Colorado Boulder (the official home base for the CSM detachment).

In addition to scholarships through CSM, many students receive scholarships from their hometown civic, religious or other organizations. All students are urged to contact organizations with which they or their parents are affiliated to investigate such scholarships. The Financial Aid Office reserves the right, unless otherwise instructed by the student, to release the student's information to scholarship providers for the purpose of assisting students in obtaining scholarships.

Financial Aid Policies

General

CSM students requesting or receiving financial assistance sponsored by the U.S. Government, the State of Colorado, or the Colorado School of Mines are required to report to the CSM Financial Aid Office all financial assistance offered or received from all sources including CSM immediately upon receipt or notification of such assistance. For the purpose of this paragraph, "financial assistance" shall include, but not be limited to, grants, scholarships, fellowships, or loans funded by public or private sources, as well as all income not considered taxable income by the Internal Revenue Service. Upon receipt of this information, CSM shall evaluate, and may adjust any financial assistance provided to the student from CSM, Colorado, or federal funds. No student shall receive

financial assistance from CSM if such student's total assistance from all sources exceeds the total cost of the student's education at CSM. For the purpose of this paragraph, the "total cost of education" shall be defined to include the cost of tuition, fees, books, room and board, transportation, and personal expenses.

Funds for the Federal Pell Grant, Federal Supplemental Educational Opportunity Grant, Federal College Work-Study Program, Federal Perkins Loan, Federal Direct Stafford Loan, and Federal Direct PLUS Loans are provided in whole or part by appropriations of the United States Congress. The Colorado General Assembly provides funds for the Colorado Grant and Colorado Work-Study programs. These programs are all subject to renewed funding each year.

Satisfactory Academic Progress

CSM students receiving scholarships must make satisfactory academic progress as specified in the rules and regulations for each individual scholarship.

Students receiving assistance from federal, Colorado or need-based CSM funds must make satisfactory academic progress toward their degree. Satisfactory progress is defined by maintaining adequate pace towards graduation and maintaining a 2.0 cumulative GPA at all times. Pace is measured by dividing the overall credit hours attempted by the overall credit hours completed. Students will be required to maintain a 75% completion rate at all times. Satisfactory standing is determined after each semester, including summer. If students are deficient in either the pace or grade average measure, they will receive a one semester warning period during which they must return to satisfactory standing.

If this is not done, their eligibility will be terminated until such time as they return to satisfactory standing. In addition, if students receive grades of F or INC in all of their courses, their future financial aid eligibility will be terminated without a warning period. Financial aid eligibility termination may be appealed to the Financial Aid Office on the basis of extenuating or special circumstances having negatively affected the student's academic performance. If approved, the student will receive a probationary period of one semester to regain satisfactory standing.

Study Abroad

Students wishing to pursue study abroad opportunities should contact the Office of International Programs (OIP), listed under the Services section of this Bulletin. Colorado School of Mines encourages students to include an international study/work experience in their undergraduate education. CSM maintains student exchange programs with engineering universities in South America, Europe, Australia, Africa, and Asia. Courses successfully passed abroad can be substituted for their equivalent course at CSM. Overall GPA is not affected by courses taken abroad. A well-planned study abroad program will not delay graduation. In addition, study abroad can be arranged on an individual basis at universities throughout the world.

Financial aid and selected scholarships and grants can be used to finance approved study abroad programs. The OIP has developed a resource center for study abroad information in its office, 1706 Illinois St., phone 303-384-2121. Students are invited to use the resource materials and meet with staff to discuss overseas study opportunities.

Withdrawals

We understand that unexpected events occur in life that will cause a student to withdraw from classes at Colorado School of Mines. Federal regulation requires financial aid to be awarded under the assumption

that a student will attend the institution for the entire period in which federal assistance was disbursed. The following policies will help you to understand the impact a withdrawal may have if you are receiving financial aid. The tuition and fees refund policy set by CSM is separate from the return calculation required by federal regulation.

An official withdrawal will be recorded once the withdrawal process has been completed by the student. Students who withdraw from the University should come to the financial aid office before completing the withdrawal process to determine what effect this will have on their financial aid. A withdrawal requires the financial aid office to determine how much of the federal, state and institutional financial aid the student has earned. Financial aid is not considered earned until the 60% point of the semester. The unearned portion will be returned to the program from which it came (i.e. student loans to the lender, Pell to the federal department of education, etc). Students need to be aware that they may owe Colorado School of Mines for unearned federal, state and/or institutional aid even if they are receiving a refund in tuition and fees.

Federal regulations consider a student to be an unofficial withdrawal if the student receives all failing grades for the term. If the student has not completely withdrawn and has failed to earn a passing grade in at least one class for the term, CSM is required to determine whether the student established eligibility for financial aid by attending at least one class or participating in any CSM academic-related activity. An unofficial withdrawal calculation will be performed and funds returned to their respective federal, state and/or institutional aid programs if there is not documentation supporting the student's last day of attendance, or the documentation indicates the student stopped attending prior to the 60% point of the semester.

Residence Halls

Residence Halls (Yearly Rate)

*Meal plans required. Room rates include \$50 Residence Hall Association fee.

Morgan/Thomas/Bradford/Randall/Aspen Halls

Room Type	Rate
Double/Triple Room	\$5,362
Single Room	\$6,668
Temporary Triple	\$4,288

Weaver Towers/ Maple / Elm Halls

Room Type	Rate
Double Room	\$6,554
Single Room	\$7,570
Temporary Triple	\$5,244

Campus-Owned Fraternity & Sorority Houses

Fraternity/Sorority House	Rate
Alpha Phi Sorority	\$5,730
FIJI Fraternity	\$5,730
Pi Phi Sorority	\$5,730
Sigma Kappa Sorority	\$5,730
All CSM-owned Fraternity and Sorority Houses - Summer	\$90 / week

Meal Plans

() indicates commuter meal plans available:

Meal Plan	Rate
Marble (Gold): Unlimited meals in Slate Cafe + \$100 Munch Money per semester	\$2,618 per semester
Quartz (Blue): 14 meals/week + \$200 Munch Money per semester	\$2,556 per semester
Granite (Bronze): 160 meals/semester + \$250 Munch Money per semester	\$2,401 per semester
Agate (commuter only): 30 meal block and \$120 in Munch Money	\$290 per block purchased

Summer Session Residence Hall Housing (Weekly Rate)

Room Type	Rate
Double Room	\$90/Week
Single Room	\$140/week

Apartment Housing (Monthly Rate)

Family Housing at Mines Park

Rates includes \$2 per month Community Development fee per resident

# of Bedrooms	Rate
1 Bedroom	\$913
2 Bedroom	\$1000

Single Student Apartments at Mines Park

Rates includes \$2 per month Community Development fee per resident

# of Bedrooms	Rate
1 Bedroom	\$913
2 Bedroom	\$1,200
3 Bedroom	\$1,644

* Mines Park resident pays gas and electric utilities. CSM provides free wireless and wired internet, basic expanded cable, water, sewer, public electric, unlimited laundry, and Mines Park parking permit.

Housing Application

Information and application for residence hall space is included in the packet offering admission to the student. Colorado School of Mines has a First Year Residency Requirement (<http://inside.mines.edu/UserFiles/File/studentLife/ResidenceLife/First-year%20residency%20requirement.pdf>). All housing assignments are based on the date of the enrollment deposit with Admissions.

After the first year, upperclass students may apply for the limited number of spots on the upperclass/transfer student floors in the residence halls. Residence Life encourages upperclass students to apply for the residence halls (<http://inside.mines.edu/RSL-Residence-Halls>) along with the Apartments at Mines Park (<http://inside.mines.edu/Apartments-at-Mines-Park>). Additionally, students associated with Greek Housing may apply for housing through Residence Life in partnership with Greek Life(Student Activities). The submission of a room application for all

housing areas can be done in Trailhead (<https://trailhead.mines.edu/cp/home/displaylogin>).

Contracts are issued for the full academic year and no cancellation will be accepted after an agreement has been done, except for those who decide not to attend CSM. Those contracts separately issued only for entering students second semester may be cancelled no later than December 1. After that date no cancellation will be accepted except for those who decide not to attend CSM.

State of Colorado Residency Qualifications

2015/2016

A student is classified as a resident or nonresident for tuition purposes at the time admission is granted and upon completion of the CSM Colorado Residency for Tuition Classification Form. The classification is based upon information furnished by the student. The student who, due to subsequent events, becomes eligible for resident tuition must make formal application to the Registrar for a change of status. The Petition for In-State Tuition Classification can be found on the Registrar's Office website (<http://inside.mines.edu/Petitioning-for-In-State-Tuition-Classification>).

A student who willfully gives wrong information to evade payment of nonresident tuition shall be subject to serious disciplinary action. The final decision regarding tuition status rests with the Tuition Appeals Committee of Colorado School of Mines.

Resident Students

A person whose legal residence is permanently established in Colorado may continue to be classified as a resident student so long as such residence is maintained even though circumstances may require extended absences from the state.

Qualification for resident tuition requires both

1. proof of adoption of the state as a fixed and permanent home, demonstrating physical presence within the state at the time of such adoption, together with the intention of making Colorado the true home; and
2. living within the state for 12 consecutive months immediately prior to the first day of classes for any given term.

These requirements must be met by one of the following:

1. the father, mother, or guardian of the student if an unemancipated minor, or
2. the student if married or over 22, or
3. the emancipated minor.

The home of the unemancipated minor is assumed to be that of the parents, or if there is a legal guardian of the student, that of such guardian. If the parents are separated or divorced and either separated or divorced parent meet the Colorado residency requirements, the minor also will be considered a resident. Statutes provide for continued resident status, in certain cases, following parents' moving from Colorado. Please check Colorado Revised Statutes 1973, 23-7-103(2)(m)(II) for exact provisions. In a case where a court has appointed a guardian or granted custody, it shall be required that the court certify that the primary purpose

of such appointment was not to qualify the minor for resident tuition status.

Nonresident Students

To become a resident of Colorado for tuition classification under state statutes, a student must be domiciled in Colorado for one year or more immediately preceding the first day of class for the semester for which such classification is sought. A person must be emancipated before domicile can be established separate from the domicile of the parents. Emancipation for tuition purposes takes place automatically when a person turns 23 years of age or marries.

The establishment of domicile for tuition purposes has two inseparable elements:

1. a permanent place of habitation in Colorado and
2. intent to remain in Colorado with no intent to be domiciled elsewhere.

The twelve-month waiting period does not begin until both elements exist. Documentation of the following is part of the petitioning process to document physical presence: copies of rental arrangements, rent receipts, copy of warranty deed if petitioner owns the personal residence property and verification of dates of employment. Documentation of the following is part of the petitioning process to document intent: Colorado drivers license, motor vehicle registration (as governed by Colorado Statute), voter registration, payment of Colorado state income taxes, ownership of residential real estate property in the state (particularly if the petitioner resides in the home), any other factor peculiar to the individual which tends to establish the necessary intent to make Colorado one's permanent place of habitation.

Nonresident students wishing to obtain further information on the establishment of residency or to apply for resident status should contact the Registrar's Office. The "Petition for In-State Tuition Classification" is due in the Registrar's Office by the first day of classes of the term the student is requesting resident status.

Housing & Dining

2015-2016

<http://inside.mines.edu/Residence-Life>

Residence Halls (<http://inside.mines.edu/Residence-Life>)

Residence hall living is an integral part of the Colorado School of Mines experience, although no students are required to live on campus. The "Traditional" residence halls (Morgan, Thomas, Bradford and Randall halls) house about 380 students in mostly double rooms with a community style restroom/shower facility on each floor. Weaver Towers has living space for 230 students in suites with single and double rooms, a common living area, and two single restroom/shower facilities. There are a limited number of single rooms available. Weaver Towers features seven or eight person suites with each suite containing both single and double bedrooms, a living/study room and two bathrooms. Maple Hall is our 290-bed facility that houses 2- and 4-person suites, with single and double bedrooms and a private bathroom in each suite. Five social lounges, nine study rooms, community kitchen and activity room, central living room with fireplace, music practice room, student storage and workshop space, laundry facilities, vending, mailroom, and desk assistant services are available to all residents of Maple Hall. Elm Hall is

a neighborhood style facility offering space for 205 students in single and double bedrooms with community bathrooms that offer private options on each floor. Located across the street from Maple Hall, Elm Hall offers four social lounges, three study rooms, courtesy phones on each floor, creativity and design workshop, community kitchen and laundry rooms on each floor, central social lounge, and rent-able indoor bike and storage units.

All residence hall spaces are equipped with a bed, desk, chair, dresser and closet for each student, as well as wired and wireless internet connections. Television services are included. The student is responsible for damage to the room or furnishings. Colorado School of Mines assumes no responsibility for loss or theft of personal belongings, and residents are encouraged to carry personal property insurance.

Additionally, Residence Life offers students an option to live and learn within a theme learning community that is a partnership between Residence Life, administrative departments, and faculty across campus. Theme Learning Communities consists of intentionally designed living experiences centered around a variety of educational, cultural, organizational, and personal interests. These communities allow students with common interests and pursuits to live together and support each other through planned activities and informal interactions. Communities include Adventure Leadership Community (Outdoor Recreation), Oredigger Leadership Community, Visual and Performing Arts, Athleticism and Wellness, Nucleus Scholars, and Grand Challenges. For more information, please see the Theme Learning Community Webpage (<http://inside.mines.edu/RSL-Theme-Housing>).

For all Housing & Dining rates, please see the Residence Halls (p. 15) page.

Mines Dining (<http://inside.mines.edu/CampusDining>)

Mines Dining operates a main dining hall and four retail dining facilities on campus. Mines Market features all-you-care-to-eat dining, adjacent to Elm Hall. Additional retail dining facilities, including The Periodic Table food court in the Student Center, Subway in the Student Recreation Center, Starbucks in Brown Hall, and Einstein Bros. Bagels in CTLM take student meal plans, as well as cash or credit card. Residence hall students are required to maintain a resident meal plan. Students not living in a residence hall may purchase any one of several commuter meal plans which best meets their individual needs. Dining options are limited during breaks (Thanksgiving, Fall, Winter and Spring Break). For more information and hours, go to Mines Dining (<http://inside.mines.edu/CampusDining>).

For all Housing & Dining rates, please see the Residence Halls (p. 15) page.

Apartment Housing (<http://inside.mines.edu/Apartments-at-Mines-Park>)

The Mines Park apartment complex is located west of the 6th Avenue and 19th Street intersection on 55 acres owned by Mines. The complex houses upperclass undergraduate students, graduate students, and families. Residents must be full-time students. Additionally, residents are provided with student and professional staff that live within the community for any assistance, advice, support, and community building.

Units are complete with refrigerators, stoves, dishwashers, cable television, wired and wireless internet connections, and an optional

campus phone line for an additional fee. There are two community centers which contain the laundry facilities, recreational and study space, and meeting rooms. For more information or to apply for apartment housing, go to the Apartment Housing website (<http://inside.mines.edu/Apartments-at-Mines-Park>). Additionally, the Apartment Housing office is located within Community Center 2 for any additional assistance you may need.

For all Housing & Dining rates, please see the Residence Halls (p. 15) page.

Fraternities, Sororities

Any non-freshman student who is a member of one of the national Greek organizations on campus is eligible to live in Fraternity or Sorority housing after their freshman year. Several of the Greek Houses are owned and operated by the School, while the remaining houses are owned and operated by the organizations. All full time, undergraduate students are eligible to join these organizations. For information, go to Greek Life (<http://studentactivities.mines.edu/greeklife>).

For all Housing & Dining rates, please see the Residence Halls (p. 15) page.

Off-Campus Housing

Click here for Off-Campus Housing Resources (<http://inside.mines.edu/Off-Campus-Housing-Resources>).

Undergraduate Information

2015-2016

Undergraduate Bulletin

It is the responsibility of the student to become informed and to observe all regulations and procedures required by the program the student is pursuing. Ignorance of a rule does not constitute a basis for waiving that rule. The Undergraduate Bulletin, current at the time of the student's most recent admission, gives the academic requirements the student must meet to graduate. However, a student can change to the requirements in a later Bulletin published while the student is enrolled as an undergraduate. Changes to administrative policies and procedures become effective for all students as soon as the campus community is notified of the changes. The Undergraduate Bulletin is available to students in electronic format. Electronic versions of the Undergraduate Bulletin may be updated more frequently to reflect changes approved by, and communicated to, the campus community. As such, students are encouraged to refer to the most recently available electronic version of the Undergraduate Bulletin. This version is available at the CSM website. The electronic version of the Undergraduate Bulletin is considered the official version of this document. In case of disagreement between the electronic and print versions (if available), the electronic version will take precedence.

Admission Requirements

Colorado School of Mines admits students who have demonstrated the ability to accomplish classroom and laboratory work and benefit from our programs. The decision to admit a student is based on his or her ability to earn a degree at CSM. Criteria considered in evaluating students include:

1. pattern of course work in high school or college,
2. grades earned in those courses,

3. ACT or SAT test scores,
4. rank in class, and
5. other available test scores.

No single criterion for admission is used; however, the most important factor is the academic record in high school or college.

The admission requirements below are minimum requirements which may change after a catalog has been finalized. The Board of Trustees, CSM governing board, reserves the right to deviate from published admission requirements. In such cases, changes in admission policy would be widely publicized.

Freshmen

Admission is competitive. The minimum requirements for admission consideration for all high school graduates who have not attended a college or university are as follows:

1. An applicant must be a graduate of an accredited high school.
2. An applicant should rank in the upper quartile of their graduating class. Consideration will be given to applicants below this level on evidence of strong motivation, superior test scores, and recommendation from principal or counselor.
3. The following 17 units of secondary school work must be completed upon graduation from high school:

Algebra	2.0
Geometry	1.0
Advanced Mathematics (including Trigonometry)	1.0
English	4.0
History or Social Studies	3.0
Academic Elective	2.0
Laboratory Science	3.0
Foreign Language	1.0
Total Semester Hrs	17.0

One unit of laboratory science must be either chemistry or physics. The second and third units may be chemistry, physics, biology, zoology, botany, geology, etc. with laboratory. Both physics and chemistry are recommended for two of the three required units. General Science is not acceptable as a science unit, however it is acceptable as an academic elective unit.

4. The 2 units of academic electives (social studies, mathematics, English, science, or foreign language) must be acceptable to the applicant's high school to meet graduation requirements. For applicants submitting GED Equivalency Diplomas, these units may be completed by the GED test.
5. Applicants from the United States and Canada are required to submit the scores of either the Scholastic Aptitude Test (SAT) of the College Entrance Examination Board or the American College Test (ACT) battery. Applications for either the SAT or ACT may be obtained from the high school counselors, or by writing to:

Educational Testing Service
P.O. Box 592
Princeton, NJ 08541 for the SAT

or to the: American College Testing Program
P.O. Box 168
Iowa City, IA 52243 for the ACT

You may also register online at www.collegeboard.com (<http://www.collegeboard.com>) (SAT) and www.act.org (<http://www.act.org>) (ACT).

Transfer Students

Admission is competitive. An applicant to CSM is considered to be a transfer student if he or she has enrolled in coursework at another college after graduating from high school. The minimum requirements for admission consideration for all transfer students are as follows:

1. Students transferring from another college or university must have completed the same high school course requirements as entering freshmen. A transcript of the applicant's high school record is required. ACT or SAT test scores are not required if the student has completed a minimum of 30 credit hours of college credit.
2. Applicants must present official college transcripts from all colleges attended. Applicants must have an overall, cumulative college grade point average of 2.75 or better. Students presenting a lower GPA will be given careful consideration and acted on individually.
3. An applicant who cannot re-enroll at the institution from which he or she wishes to transfer, or from any previously attended institution because of scholastic record or other reason will be evaluated on a case-by-case basis.
4. Completed or "in progress" college courses - which meet CSM graduation requirements - are eligible for transfer credit if the institution is regionally accredited, and the course is not remedial or vocational, and the grade earned is a "C" or better.

Former Students

The minimum admission requirements for those students who have previously attended CSM are as follows:

1. Any student who has attended another college or university since last enrolling at CSM must re-apply for admission through the Admissions Office.
2. Any student who did not complete the semester immediately preceding the beginning of the period for which he or she wishes to enroll must be re-admitted to CSM by the Admissions Office.
3. A former student, returning after a period of suspension, must apply for admission to the Admissions Office and must furnish an approval for such re-enrollment from the Readmissions Committee of Colorado School of Mines. Appropriate forms to apply for admission may be obtained from the Admissions Office. Official transcripts for all coursework completed while away from Mines must be submitted to the Registrar's Office for review of transferability of the credit.

Exchange Students

All students participating in the CSM Exchange Program (coming to CSM and CSM students going abroad) must be enrolled in a minimum of 15 semester credit hours at CSM or the foreign exchange university.

International Students

For purposes of admission, international applicants are students in a non-immigrant status who are not U.S. citizens or do not have approved and finalized U.S. permanent residence, refugee status or political asylum. International students usually need an F1 or J1 visa to study in the United States.

Generally, international applicants seeking admission to Colorado School of Mines must meet the same academic standards for admission as those required of American applicants. Admission is competitive. There are wide variations, however, between educational systems throughout the world that make exact comparisons of educational standards difficult. International applicants are selected on the basis of their prior academic work, probability of success in the chosen curriculum (as evidenced by prior work in the academic area involved) and proof of English proficiency. After admission but prior to enrollment, certification of adequate financial resources is required.

International applicants must submit a completed international application form; a \$45 nonrefundable international document processing fee; translated secondary schooling records, and/or a credentials evaluation report; notarized affidavit of financial sponsorship; and when applicable, translated college transcripts.

TOEFL/English Proficiency

Student applicants whose primary language is not English, must prove proficiency in the English language by achieving one of the following:

1. A TOEFL (Test of English as a Foreign Language) score of 550 on the paper-based test, or a score of 79 on the internet Based TOEFL (iBT).

Subject	Internet TOEFL (iBT)	Paper TOEFL (PBT)
Reading	20	54
Writing	17	55
Listening	21	55
Speaking	21	N/A
Total	79	550

2. An IELTS (International English Language Testing System) Score of 6.5, with no band below a 6.0.
3. Pearson Test of English/PTE Academic: Minimum overall score of 53 with no communicative skills score below 50.
4. Transferable credit from an accredited US institution of higher education equivalent to 30 credits or more including 6 credits of freshman English composition at a U.S. college or university with a cumulative GPA of 3.0 or higher..

The above English Proficiency requirement applies to students currently studying in the United States and for students outside the country.

Advanced Credit for International Evaluation

The following methods are used by Colorado School of Mines to validate the awarding of advanced standing credit for international students who have completed work in their home countries at the postsecondary level:

1. Credit is granted based upon recommendation by recognized academic publications, primarily the World Education Series of American Association of Collegiate Registrars and Admissions Officers.
2. Validation by a comparable credit-granting department at Colorado School of Mines. Validation by one of the following two options will be at the discretion of the credit-granting department.
 - a. Option A: Course-by-course evaluation examination by comparable Colorado School of Mines academic department.
 - b. Option B: The adviser and/or academic dean's office makes a preliminary evaluation of the level a student has completed and begins the student at that level. Upon successful completion

of that course, all related lower-level courses in that area, as determined by the department granting credit, would be validated and credit awarded.

Enrollment Requirement - English Language

All new students whose primary language is not English must demonstrate English Language proficiency before enrolling for the first time at the university. This requirement applies to international and non-international, permanent residents, immigrants, transfer and non-transfer students alike.

Enrollment Requirement - All Admitted Students

All admissions are ultimately contingent upon successful completion and submission of final transcripts reflecting academic achievement similar to assessment at the time of admission. Students are expected to continue to prepare at a similar level of academic rigor, and with similar or better results as the enrollment date approaches. If final transcripts/documents are received that reflect information different from the admission assessment, Colorado School of Mines reserves the right to review the admission offer again, and to take appropriate action. This may include a change in conditions or terms of admission, or a rescission of the admission offer.

Fraudulent Applications

Individuals who withhold or provide fraudulent information on applications for undergraduate admissions or readmissions are subject to immediate dismissal from the university. The decision for immediate dismissal will be made by the Associate Vice President of Enrollment Management and/or the Director of International Admissions. This decision will be made after a complete and thorough review of the situation and an individual conference with the student involved. The individual dismissed has the right to appeal the decision to the committee on academic policy and procedure, whose decision will be final.

Nondegree Students

A nondegree student is one who has not applied to pursue a degree program at CSM but wishes to take courses regularly offered on campus. Such students may take any course for which they have the prerequisites as listed in the CSM Bulletin or have the permission of the instructor. Transcripts or evidence of the prerequisites are required. An applicant for admission to the undergraduate school who does not meet admission requirements may not fulfill deficiencies through this means. Exception to this rule can be made only by the Associate Vice President of Enrollment Management. A maximum of 12 hours of nondegree credit from Colorado School of Mines may be used toward an undergraduate degree program. A nondegree student who has completed a Bachelor degree or higher, regardless of course level in which one wishes to enroll, must utilize the graduate nondegree process. Courses completed as a non-degree student at the undergraduate level will be included in the overall undergraduate grade point average.

Academic Regulations

2015-2016

Deficiencies

The curricula at Colorado School of Mines have been especially designed so that the course work flows naturally from course to course and year to

year. Thus, it is important that deficiencies in lower numbered courses be scheduled in preference to more advanced work.

Prerequisites

It is the responsibility of each student to make certain that the proper prerequisites for all courses have been met. Registration in a course without the necessary prerequisite may result in dismissal from the class or a grade of F (Failed) in the course.

Remediation

The Colorado Department of Higher Education specifies a remedial programs policy in which any first-time freshmen admitted to public institutions of higher education in Colorado with ACT (or equivalent) scores of less than 18 in reading or English, or less than 19 in mathematics, are required to participate in remedial studies. At the Colorado School of Mines, these remedial studies will be conducted through required tutoring in Nature and Human Values for reading and writing, and *Calculus for Scientists and Engineers I* for mathematics, and the consequent achievement of a grade of C or better.

Transfer Credit

In all cases, requests for transfer credit are processed by the Registrar. Credits must be submitted on an official transcript from a regionally accredited institution and be academic in nature. Vocational and theological credit is not accepted. Only courses completed with grades of "C" or better will be accepted.

New Transfer Students

Upon matriculation, a transfer student will receive the prescribed academic credit for courses taken at another institution if these courses are listed in a current articulation agreement and transfer guide between CSM and that institution. Credits earned more than 10 years in advance of admission will not transfer. When an articulation agreement does not exist with another institution, the transfer student may receive credit for a course taken at another institution, subject to review by the appropriate CSM department head or designate to ensure course equivalency.

Continuing Students

Students who are currently enrolled at CSM may transfer credit in required courses only in extenuating circumstances, upon the advance approval of the Registrar, the department head of the appropriate course, and the department head of the student's option/major. Upon return, credit will be received subject to review by the Registrar. Physics courses are subject to post-approval from the department. Forms for this purpose are available in the Registrar's Office (<http://inside.mines.edu/Transfer-Credit-Approvals>), and the process is reviewed periodically by the Office of the Executive Vice President for Academic Affairs (EVPAA).

Returning Students

Students who have matriculated at CSM, withdrawn, applied for readmission and wish to transfer in credit taken at an institution while they were absent from CSM, must obtain approval, upon return, of the department head of the appropriate course, the department head of the student's option/major, and the Registrar.

Prior Learning Credit - Military and EPICs

Students with experience in the military who have a DD214 showing a general or honorable discharge will receive a total of two credit hours in

PAGN101, PAGN102, and PAGN2XX. This will complete the Physical Activity requirements for the undergraduate degree.

Students who have technical experience outside of the classroom may be eligible to substitute a different technical elective course in place of EPIC251. In order to pursue this course of action, the student must provide information and materials describing the experience and how it applies to the program to the EPICs program director. If approved, the student will complete the substitution form and turn it in to the Registrar's Office to be placed in the academic file.

Course Withdrawals, Additions and Drops

Courses may be added or dropped without fee or penalty during the first 11 school days of a regular academic term (first 4 school days of a 6-week field course or the first 6 school days of the 8-week summer term).

Continuing students may withdraw from any course after the eleventh day of classes through the twelfth week for any reason with a grade of W. After the twelfth week, no withdrawals are permitted except in cases of withdrawal from school or for extenuating circumstances under the auspices of the Office of Academic Affairs and the Office of the Registrar. A grade of F will be given in courses which are withdrawn from after the deadline without approval.

Freshmen and transfer students in their first and second semesters are permitted to withdraw from courses through the Friday prior to the last week of classes.

All adds/drops are initiated in the Registrar's Office. To withdraw from a course (with a "W") a student must obtain the appropriate form from the Registrar's office, have it signed by the instructor and signed by the student's advisor to indicate acknowledgment of the student's action, and return it to the Registrar's Office by close of business on the last day that a withdrawal is authorized. Acknowledgment (by signature) by the division/department is required in only 2 cases:

1. when a course is added after the 11th day of the semester and
2. when the Registrar has approved, for extenuating circumstances, a withdrawal after the last date specified (a "late withdrawal").

Approval of a late withdrawal can be given by the Registrar acting on behalf of the Office of Academic Affairs in accordance with CSM's refund policy, and in compliance with federal regulations.

A \$5.00 fee will be charged for any change in class schedule after the first 11 days of class, except in cases beyond the student's control or withdrawal from school.

Independent Study

For each semester credit hour awarded for independent study a student is expected to invest approximately 25 hours of effort in the educational activity involved. To register for independent study, a student should get from the Registrar's Office (<http://inside.mines.edu/Independent-Study-Registration>) the form provided for that purpose, have it completed by the instructor involved and the appropriate department/ division head, and return it to the Registrar's Office.

Off-Campus Study

A student must enroll in an official CSM course for any period of off-campus, course-related study, whether U.S. or foreign, including faculty-led short courses, study abroad, or any off-campus trip sponsored by CSM or led by a CSM faculty member. The registration must occur in

the same term that the off-campus study takes place. In addition, the student must complete the necessary release, waiver, and emergency contact forms, transfer credit pre-approvals, and FERPA release, and provide adequate proof of current health insurance prior to departure. For additional information concerning study abroad requirements, contact the Office of International Programs (<http://oip.mines.edu>) at (303) 384-2121; for other information, contact the Registrar's Office.

Absenteeism

Class attendance is required of all undergraduates unless the student has an official excused absence. Excused absences are granted for three general reasons:

1. Student is a varsity athlete and is representing the School in a varsity athletics activity.
2. Student is representing the School in an authorized activity related to a club or academic endeavor (academic competitions, student professional society conferences, club sport competition, program-sponsored competitions, etc.)
3. Student has a documented personal reason (illness, injury, jury duty, life-threatening illness or death in the immediate family, etc.).

Students who miss academic work (including but not limited to exams, homework, and labs) for one of the reasons listed above may be issued an excused absence. If an excused absence is received, the student must be given the opportunity to make up the missed work in a reasonable period of time without penalty. While the student is not responsible for actually issuing the excused absence, the student is responsible for making sure documentation is submitted appropriately and for contacting his/her faculty member(s) to initiate arrangements for making up any missed work.

Varsity Athletics Absences

The Athletics Department will authorize excused absences for all approved varsity athletics related absences. The Athletics Department will send notice of excused absences to faculty members on or before Census Day each semester. The student is responsible for contacting his/her faculty member(s) prior to the absence occurring to initiate arrangements for making up any missed work. The Faculty Oversight Committee on Sports and Athletics oversees the number of excused absences permitted per semester by varsity athletes.

Authorized Activity Absences

The Associate Dean of Students may authorize excused absences upon receipt of proper documentation of the school related activity. All excused absences for school-sponsored activities must be documented with the Associate Dean of Students by Census Day of each semester. If the absence will occur prior to Census Day, then the documentation should be received at least two weeks prior to the absence. Once documentation has been received and approved, the Associate Dean of Students will send notice of excused absences to faculty members. The student is responsible for contacting his/her faculty member(s) prior to the absence occurring to initiate arrangements for making up any missed work.

Requests for excused absence(s) related to an authorized activity received after Census Day may be denied or be documented as an excused/unexcused absence at the discretion of the faculty member.

Personal Reason Absences

The Associate Dean of Students may authorize excused absences upon receipt of proper documentation of the illness, injury, or other incident. The student must provide the documentation to the Associate Dean of Students within one week of returning to class. Once documentation has been received and approved, the Associate Dean of Students will send notice of excused absences to faculty members. The student is responsible for contacting his/her faculty member(s) to initiate arrangements for making up any missed work.

Important Note: Every effort will be made by the faculty to honor all excused absences. However, class attendance is essential for understanding of the material and for learning to take place. Excessive absence, regardless of reason, may result in a reduced or failing grade in the course based on course content and delivery. As content and delivery differ among the faculty and with each class, it is important for a student missing class to discuss the absences, excused or unexcused, with his/her faculty member(s) to determine what will be considered excessive.

Unexcused Absences

All absences that are not documented as excused absences are considered unexcused absences. Faculty members may deny a student the opportunity to make up some or all of the work missed due to unexcused absence(s). However, the faculty members do have the discretion to grant a student permission to make up any missed academic work for an unexcused absence. The faculty member may consider the student's class performance, as well as their attendance, in the decision.

Withdrawal from School

A student may officially withdraw from CSM by processing a *Withdrawal from School* form available through the Center for Academic Services & Advising (CASA). Completion of the form prior to the last day of scheduled classes for that term will result in W's being assigned to courses in progress. Failure to officially withdraw will result in the grades of courses in progress being recorded as F's. Leaving the School without having paid tuition and fees will result in a hold being placed against the transcript. Either of these actions would make future enrollment at CSM or another college more difficult.

Admissions Procedures

2015/2016

All Applicants

Documents received by CSM in connection with applications for admission or transfer of credit will not be duplicated, returned to the applicant, or forwarded to any agency or any other institution.

A \$45.00 non-refundable application fee is required from all applicants.

Applications for undergraduate study cannot be accepted later than 21 days prior to the date of registration confirmation for any academic semester or summer session. Admission for any semester or term may close whenever CSM's budgeted number of students has been met.

High School Students

Applicants are encouraged to apply online at www.mines.edu. Questions can be directed to the Admissions Office via e-mail: admit@mines.edu; or via postal mail:

Admissions Office
 Colorado School of Mines
 1200 - 16th Street
 Golden, CO 80401

(Please note: The Admissions Office will move to the Starzer Welcome Center, 1812 Illinois Street in early fall 2015)

A student may apply for admission any time after completing the 11th grade. The application will be evaluated upon receipt of the completed application form, a high school transcript showing courses completed, courses remaining to be completed, ranking in class, other pertinent data, and SAT or ACT test scores. High school seniors are encouraged to apply early in the fall term of senior year. Additionally, it is recommended that the ACT and/or SAT be taken during this term. In some cases, the grades or marks received in courses taken during the first half of the senior year may be required. Freshman admission is competitive. Applicants who are determined to meet freshman admission requirements are admitted subject to completion of all entrance requirements and high school graduation.

Transfer Students

Guaranteed Transfer

Colorado School of Mines is a signatory to the Colorado Statewide Engineering Articulation Agreement, which can be viewed at www.state.co.us/cche (<http://www.state.co.us/cche>). Beginning with admissions in 2003–2004, this agreement determines transferability of coursework for engineering students in the State of Colorado. All students transferring into CSM under the terms of the statewide agreement are strongly encouraged to be advised by the CSM Admissions Office on their planned course of study. Credits earned more than 10 years prior will not transfer.

Additionally, Colorado School of Mines has formal transfer agreements with Red Rocks Community College (RRCC), Front Range Community College (FRCC), Community College of Denver (CCD), Community College of Aurora (CCA), and Arapahoe Community College. Students are encouraged to contact the Admissions Office at these institutions for additional information.

Transfer by Review

Undergraduate students at another college or university who wish to transfer to CSM should apply online at www.mines.edu.

A transfer student should apply for admission at the beginning of the final semester of attendance at his or her present college. The application will be evaluated upon receipt of the completed application form and application fee, official final high school transcript (or GED), transcripts from each university or college attended, and a list of courses in progress. The Admissions Office will then notify the student of his or her admission status. Admission is subject to satisfactory completion of current courses in progress and submission of a final, official transcript(s).

Advanced Placement and International Baccalaureate

Course work completed for select subjects under the Advanced Placement Program in a high school may be accepted for college credit provided that the Advanced Placement Program Test grade is either 5 (highest honors) or 4 (honors).

In special cases, advanced placement may be granted for course work not completed under the College Entrance Examination Board Program. Students wishing such credit may demonstrate competence by writing the Advanced Placement Examination on the subject. Information can be secured from:

the College Entrance Examination Board
 P.O. Box 592
 Princeton, NJ 08541

More information on which subjects are accepted can be found on the web at www.mines.edu.

Course work completed for select subjects under the International Baccalaureate Program in high school may be accepted for college credit provided that the International Baccalaureate Program Exam grade is a 5, 6, or 7 on selected standard and higher level exams. In some cases, departmental approval is required before credit is granted. More information on which subjects are accepted can be found on the web at www.mines.edu.

Declaration of Option (Major)

The curriculum during the first semester at CSM is generally the same across majors. Students are not required to choose a major before the end of the freshman year. All students must have declared a major by the beginning of the junior year.

Medical Record

A health history prepared by the student, a medical examination performed by the student's physician and an updated immunization record completed by the student and the physician, nurse or health authority comprise the medical record. A medical record is required for full time students entering CSM for the first time, or following an absence of more than 12 calendar months.

The medical record will be sent to the student after acceptance for admission. The medical record must be updated and completed and then returned to the Student Health Center before permission to enroll is granted. Proof of immunity consists of an official Certificate of Immunization signed by a physician, nurse, or public health official which documents measles, mumps and rubella immunity. The Certificate must specify the type of vaccine and the dates (month, day, year) of administration or written evidence of laboratory tests showing immunity to measles, mumps and rubella.

The completed medical record is confidential and will be kept in the Student Health Center. The record will not be released unless the student signs a written release.

Veterans

Colorado School of Mines is approved by the Colorado State Approving Agency for Veteran Benefits under chapters 30, 31, 32, 33, 35, 1606, and 1607. Undergraduate students must register for and maintain 12.0 credit hours, and graduate students must register for and maintain 9.0 credit hours of graduate work in any semester to be certified as a full-time student for full-time benefits. Any hours taken under the full-time category will decrease the benefits to 3/4 time, 1/2 time, or tuition payment only.

All changes in hours, program, addresses, marital status, or dependents are to be reported to the Veterans Certifying Officer as soon as possible so that overpayment or underpayment may be avoided. Veterans must see the Veteran's Certifying Officer each semester to be certified for any

benefits for which they may be eligible. In order for veterans to continue to receive benefits, they must make satisfactory progress as defined by Colorado School of Mines.

An honorably or generally discharged military veteran providing a copy of his/her DD214 is awarded two credit hours to meet the physical education undergraduate degree requirement at CSM. Additionally, veterans may request substitution of a technical elective for the institution's core EPICS course requirement in all undergraduate degree programs.

For more information, please visit the Veterans Services (<http://inside.mines.edu/Veterans-Services>) web page.

Combined Undergraduate/ Graduate Degree Programs

A. Overview

Many degree programs offer CSM undergraduate students the opportunity to begin work on a Graduate Certificate, Professional Master's Degree, Master's Degree or Doctoral Degree while completing the requirements for their Bachelor's Degree. These combined Bachelors-Masters/Doctoral programs have been created by Mines faculty in those situations where they have deemed it academically advantageous to treat undergraduate and graduate degree programs as a continuous and integrated process. These are accelerated programs that can be valuable in fields of engineering and applied science where advanced education in technology and/or management provides the opportunity to be on a fast track for advancement to leadership positions. These programs also can be valuable for students who want to get a head start on graduate education.

The combined programs at Mines offer several advantages to students who choose to enroll in them:

1. Students can earn a graduate degree in their undergraduate major or in a field that complements their undergraduate major.
2. Students who plan to go directly into industry leave Mines with additional specialized knowledge and skills which may allow them to enter their career path at a higher level and advance more rapidly. Alternatively, students planning on attending graduate school can get a head start on their graduate education.
3. Students can plan their undergraduate electives to satisfy prerequisites, thus ensuring adequate preparation for their graduate program.
4. Early assignment of graduate advisors permits students to plan optimum course selection and scheduling in order to complete their graduate program quickly.
5. Early acceptance into a Combined Degree Program leading to a Graduate Degree assures students of automatic acceptance into full graduate status if they maintain good standing while in early-acceptance status.
6. In many cases, students will be able to complete both a Bachelor's and a Master's Degrees in five years of total enrollment at Mines.

Certain graduate programs may allow Combined Degree Program students to fulfill part of the requirements of their graduate degree by including up to six hours of specified course credits which also were used in fulfilling the requirements of their undergraduate degree. These courses may only be applied toward fulfilling Doctoral degree or, Master's degree requirements beyond the institutional minimum Master's degree requirement of 30 credit hours. Courses must meet all requirements

for graduate credit, but their grades are not included in calculating the graduate GPA. Check the departmental section of the Bulletin to determine which programs provide this opportunity.

B. Admission Process

A student interested in applying into a graduate degree program as a Combined Degree Program student should first contact the department or division hosting the graduate degree program into which he/she wishes to apply. Initial inquiries may be made at any time, but initial contacts made soon after completion of the first semester, Sophomore year are recommended. Following this initial inquiry, departments/ divisions will provide initial counseling on degree application procedures, admissions standards and degree completion requirements.

Admission into a graduate degree program as a Combined Degree Program student can occur as early as the first semester, Junior year, and must be granted no later than the end of registration, last semester Senior year. Once admitted into a graduate degree program, students may enroll in 500-level courses and apply these directly to their graduate degree. To apply, students must submit the standard graduate application package for the graduate portion of their Combined Degree Program. Upon admission into a graduate degree program, students are assigned graduate advisors. Prior to registration for the next semester, students and their graduate advisors should meet and plan a strategy for completing both the undergraduate and graduate programs as efficiently as possible. Until their undergraduate degree requirements are completed, students continue to have undergraduate advisors in the home department or division of their Bachelor's Degrees.

C. Requirements

Combined Degree Program students are considered undergraduate students until such time as they complete their undergraduate degree requirements. Combined Degree Program students who are still considered undergraduates by this definition have all of the privileges and are subject to all expectations of both their undergraduate and graduate programs. These students may enroll in both undergraduate and graduate courses (see section D below), may have access to departmental assistance available through both programs, and may be eligible for undergraduate financial aid as determined by the Office of Financial Aid. Upon completion of their undergraduate degree requirements, a Combined Degree Program student is considered enrolled full-time in his/her graduate program. Once having done so, the student is no longer eligible for undergraduate financial aid, but may now be eligible for graduate financial aid. To complete their graduate degree, each Combined Degree Program student must register as a graduate student for at least one semester.

Once admitted into a graduate program, undergraduate Combined Degree Program students must maintain good standing in the Combined Degree Program by maintaining a minimum semester GPA of 3.0 in all courses taken. Students not meeting this requirement are deemed to be making unsatisfactory academic progress in the Combined Degree Program. Students for whom this is the case are subject to probation and, if occurring over two semesters, subject to discretionary dismissal from the graduate portion of their program as defined in the Unsatisfactory Academic Performance (p. 204) section of this Bulletin.

Upon completion of the undergraduate degree requirements, Combined Degree Program students are subject to all requirements (e.g., course requirements, departmental approval of transfer credits, research credits,

minimum GPA, etc.) appropriate to the graduate program in which they are enrolled

D. Enrolling in Graduate Courses as a Senior in a Combined Program

As described in the Undergraduate Bulletin, seniors may enroll in 500-level courses. In addition, undergraduate seniors who have been granted admission through the Combined Degree Program into thesis-based degree programs (Masters or Doctoral) may, with graduate advisor approval, register for 700-level research credits appropriate to Masters-level degree programs. With this single exception, while a Combined Degree Program student is still completing his/her undergraduate degree, all of the conditions described in the Undergraduate Bulletin for undergraduate enrollment in graduate-level courses apply. 700-level research credits are always applied to a student's graduate degree program.

If an undergraduate Combined Degree Program student would like to enroll in a 500-level course and apply this course directly to his/her graduate degree, he/she must be formally accepted as a combined program student through the Office of Graduate Studies and notify the Registrar of the intent to do so at the time of enrollment in the course. The Registrar will forward this information to Financial Aid for appropriate action. Be aware that courses taken as an undergraduate student but applied directly toward a graduate degree are not eligible for undergraduate financial aid or the Colorado Opportunity Fund. If prior consent is not received or if the student has not been accepted by OGS as a combined program student, all 500-level graduate courses taken as an undergraduate Combined Degree Program student will be applied to the student's undergraduate degree transcript. If these are not used toward an undergraduate degree requirement, they may, with program consent, be applied to a graduate degree program as transfer credit. All regular regulations and limitations regarding the use of transfer credit to a graduate degree program apply to these credits.

Core Requirements

Core Curriculum

The Core Curriculum at Mines forms the foundation for advanced study in the major fields. It is designed to give students the fundamental knowledge and skills they will need and put to use in their majors and in careers after graduation. Core courses provide students with fundamental technical, mathematical, and writing skills. In Core courses, students learn basic scientific procedures, principles, concepts, laws, and theories relevant to all applied sciences. In addition, Core courses in the humanities and social sciences help students develop interdisciplinary perspectives on the ethical, social, and cultural contexts within which engineering takes place.

The variety of courses in the Core Curriculum also provide students with opportunities to develop skills in problem solving, critical thinking, teamwork, design, and communication. Students who complete the Core are well prepared to be lifelong learners and leaders who can work effectively in an increasingly globalized world.

The Core Curriculum has three parts, the details of which can be found below. All CSM students complete the courses in the Common Core. Courses required in the Science Requirement and Engineering Requirement vary according to the major field of study. Finally, all

students have a number of Free Elective courses. Free Electives are usually taken in the last two years.

Refer to the Degree Requirements section for each major program under Undergraduate Programs and Departments (p. 35) for a listing of Core courses students should take each semester.

Overview: Core Course Requirements

Core & distributed course requirements for Bachelor of Science degrees are comprised of the four following groups:

1. **Core Curriculum** - Students in all degree options are required to complete all course requirements listed in this group.
2. **Humanities and Social Sciences Requirement** - Students in all degree options must complete this requirement.
3. **Science Requirement** - Students in all degree options are required to complete a minimum of three out of five courses from this list. For some majors the three courses are prescribed, while other majors leave the choices to the student. See the Science Requirement chart to determine the courses allowed for your particular major program.
4. **Engineering Requirement** - Students pursuing an engineering-based degree are required to complete the courses in this list. However, each engineering program will place the courses in the sophomore year or later based on the flow of the particular program. These are not considered freshman year courses.

1) The Core Curriculum

Core requirements are applicable to all undergraduate students:

In Mathematics and the Basic Sciences

MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATH225	DIFFERENTIAL EQUATIONS *	3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
PHGN100	PHYSICS I - MECHANICS	4.5

In Design

EPIC151	DESIGN (EPICS) I	3.0
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In Humanities and the Social Sciences

LAIS100	NATURE AND HUMAN VALUES	4.0
LAIS200	HUMAN SYSTEMS	3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0

In Physical Education (four separate semesters including the following) **

PAGN101	PHYSICAL EDUCATION	0.5
PAGN102	PHYSICAL EDUCATION	0.5
PAGN2XX	PHYSICAL EDUCATION	0.5
PAGN2XX	PHYSICAL EDUCATION	0.5

In Freshman Orientation & Success

CSM101	FRESHMAN SUCCESS SEMINAR	0.5
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Free Electives ***

Total Semester Hrs	39.0
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- * 2.0 semester hours are required in Differential Equations for Geological Engineering majors. (MATH222)
- ** A minimum of 2.0 credit hours. Neither PAGN101 or PAGN102 may be repeated for credit. See the Physical Education and Athletics (<http://bulletin.mines.edu/undergraduate/programs/additionalprograms/physicaleducationandathletics>) section for specifics.
- *** A minimum of 9.0 hours are included with each degree-granting program. With the exception of the restrictions mentioned below, the choice of free elective courses to satisfy degree requirements is unlimited. The restrictions are:
1. The choice must not be in conflict with any Graduation Requirements (p. 34).
 2. Free electives to satisfy degree requirements may not exceed three semester hours (3.0) in activity courses such as band, choir, studio art, physical education, and athletics courses combined.

2) Humanities and Social Science Requirement

H&SS Requirements are applicable to all undergraduate students:

Two courses from the approved list of requirements *	6.0
At least one course at the 400-level from the approved list of requirements *	3.0
Total Semester Hrs	9.0

- * See the approved list in the Liberal Arts and International Studies (<https://nextbulletin.mines.edu/undergraduate/programs/earthscieng/liberalartsandinternationalstudies>) section of this Bulletin.

3) Science Requirement

The Science Requirement is applicable to all undergraduate students:

Complete a minimum of three of the courses below according to your degree requirements as listed further on in this section:

BIOL110	FUNDAMENTALS OF BIOLOGY I	4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS	4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.5
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)	4.0
CHGN125	MOLECULAR ENGINEERING & MATERIALS CHEMISTRY	4.0
CSCI101	INTRODUCTION TO COMPUTER SCIENCE	3.0

4) Engineering Requirement (see degree program listing)

Engineering Requirements are applicable to undergraduate students in engineering disciplines as specified by the degree program. See Department and Division program descriptions in this Bulletin for specific courses required.

One of the following Thermodynamics courses may be required:	3.0	
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS	
CBEN210	INTRO TO THERMODYNAMICS	
MEGN361	THERMODYNAMICS I	
CEEN241	STATICS	3.0

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER	3.0
Total Semester Hrs		9.0

The Freshman Year

Freshmen in all programs normally take similar subjects, as listed below:

Freshman		lec	lab	sem.hrs
Fall				
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
EBGN201	PRINCIPLES OF ECONOMICS *			3.0
LAIS100	NATURE AND HUMAN VALUES *			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			0.5
PAGN101	PHYSICAL EDUCATION			0.5
				16.0
Spring				
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EPIC151	DESIGN (EPICS) I *			3.0
PHGN100	PHYSICS I - MECHANICS			4.5
PAGN102	PHYSICAL EDUCATION			0.5
SCI	Science Requirement *			4.0
				16.0

Total Semester Hrs: 32.0

- * For scheduling purposes, registration in combinations of GEGN101, BIOL110, LAIS100, EBGN201, and EPIC151 will vary between the fall and spring semesters. Students admitted with acceptable advanced placement credits will be registered in accordance with their advanced placement status.

Course Descriptions for Core Courses

1) Core Curriculum - Mathematics and the Basic Sciences

Chemistry

CHGN121	PRINCIPLES OF CHEMISTRY I	4.0
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Mathematics

MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0
MATH113	CALCULUS FOR SCIENTISTS AND ENGINEERS II - SHORT FORM	1.0
MATH122	CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS	4.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0
MATH214	CALCULUS FOR SCIENTIST AND ENGINEERS III - SHORT FORM	1.0

MATH222	INTRODUCTION TO DIFFERENTIAL EQUATIONS FOR GEOLOGISTS & GEOLOGICAL ENGINEERS *	2.0
MATH223	CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS	4.0
MATH224	CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS	4.0
MATH225	DIFFERENTIAL EQUATIONS *	3.0
MATH235	DIFFERENTIAL EQUATIONS HONORS	3.0
Physics		
PHGN100	PHYSICS I - MECHANICS	4.5
Design - Engineering Practices Introductory Course Sequence (EPICS)		
EPIC151	DESIGN (EPICS) I	3.0
EPIC155	EPICS I GRAPHICS **	1.0
Humanities and the Social Sciences		
EBGN201	PRINCIPLES OF ECONOMICS	3.0
LAIS100	NATURE AND HUMAN VALUES	4.0
LAIS200	HUMAN SYSTEMS	3.0
Physical Education		
PAGN101	PHYSICAL EDUCATION	0.5
PAGN102	PHYSICAL EDUCATION	0.5
Freshman Orientation and Success		
CSM101	FRESHMAN SUCCESS SEMINAR	0.5

* Only one of MATH222 and MATH225 can be counted toward graduation. Any student who completes MATH222 and then changes majors out of Geology and Geological Engineering will be expected to complete MATH225 to meet graduation requirements. (In this case, MATH222 cannot be counted toward graduation in any manner - even as a free elective.)

** Completion of EPIC155 in lieu of EPIC151 is by permission only and does not alter the total hours required for completion of the degree.

2) Humanities and Social Science Requirement

See Liberal Arts and International Studies (<http://lais.mines.edu/LAIS-HSS-Requirements>) section for the list of approved courses and the associated descriptions.

3) Science Requirement

The Science Requirement is applicable to all undergraduate students. Complete a minimum of three courses as outlined for your degree below.

APPLIED MATH & STATISTICS

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CSCI101	INTRODUCTION TO COMPUTER SCIENCE
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)
or GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
or BIOL110	FUNDAMENTALS OF BIOLOGY I

CHEMISTRY

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
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CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)
BIOL110	FUNDAMENTALS OF BIOLOGY I
or GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS

CHEMICAL ENGINEERING

BIOL110	FUNDAMENTALS OF BIOLOGY I
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

CHEMICAL & BIOCHEMICAL ENGINEERING

BIOL110	FUNDAMENTALS OF BIOLOGY I
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

CIVIL ENGINEERING

GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

COMPUTER SCIENCE

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CSCI101	INTRODUCTION TO COMPUTER SCIENCE
BIOL110	FUNDAMENTALS OF BIOLOGY I
or GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
or CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

ECONOMICS

CHOOSE THREE FROM BELOW

BIOL110	FUNDAMENTALS OF BIOLOGY I
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)
CSCI101	INTRODUCTION TO COMPUTER SCIENCE

ELECTRICAL ENGINEERING

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
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CHOOSE TWO FROM BELOW

BIOL110	FUNDAMENTALS OF BIOLOGY I
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)
CSCI101	INTRODUCTION TO COMPUTER SCIENCE

ENVIRONMENTAL ENGINEERING

GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

GEOLOGICAL ENGINEERING

GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)

GEOPHYSICAL ENGINEERING

GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS
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PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

BIOL110 FUNDAMENTALS OF BIOLOGY I
or CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)
or CSCI101 INTRODUCTION TO COMPUTER SCIENCE

MECHANICAL ENGINEERING

PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)

BIOL110 FUNDAMENTALS OF BIOLOGY I
or GEGN101 EARTH AND ENVIRONMENTAL SYSTEMS

METALLURGICAL & MATERIALS ENGINEERING

PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)
or CHGN125 MOLECULAR ENGINEERING & MATERIALS CHEMISTRY

BIOL110 FUNDAMENTALS OF BIOLOGY I
or GEGN101 EARTH AND ENVIRONMENTAL SYSTEMS

MINING ENGINEERING

GEGN101 EARTH AND ENVIRONMENTAL SYSTEMS

PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)

PETROLEUM ENGINEERING

GEGN101 EARTH AND ENVIRONMENTAL SYSTEMS

PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)

ENGINEERING PHYSICS

PHGN200 PHYSICS II-ELECTROMAGNETISM AND OPTICS

CHGN122 PRINCIPLES OF CHEMISTRY II (SC1)

BIOL110 FUNDAMENTALS OF BIOLOGY I
or GEGN101 EARTH AND ENVIRONMENTAL SYSTEMS
or CSCI101 INTRODUCTION TO COMPUTER SCIENCE

4) Engineering Requirement

CEEN241	STATICS	3.0
CBEN210	INTRO TO THERMODYNAMICS	3.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS	3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER	3.0
MEGN361	THERMODYNAMICS I	3.0

NOTE: Beginning Fall 2011, EPIC2xx courses can be taken in lieu of EPIC251, subject to approval by academic departments granting ABET-accredited engineering degrees. These courses adhere to the Design EPICS II learning objectives, which are described for each course.

General Information

2015-2016

Academic Calendar

The academic year is based on the early semester system. The first semester begins in late August and closes in mid-December; the second semester begins in early January and closes in mid-May.

Classification of Students

Degree seeking undergraduates are classified as follows according to semester credit hours earned:

Undergraduate Year	Semester Credit Hours Earned
Freshman	0 to 29.9 semester credit hours
Sophomore	30 to 59.9 semester credit hours
Junior	60 to 89.9 semester credit hours
Senior	90 or more semester credit hours

Course Numbering & Subject Codes

Numbering of Courses

Course numbering is based on the content of material presented in courses:

Material	Level	Division
100-199	Freshman Level	Lower Division
200-299	Sophomore Level	Lower Division
300-399	Junior Level	Upper Division
400-499	Senior Level	Upper Division
500-699	Graduate Level	
Over 700	Graduate Research or Thesis Level	

Subject Codes:

Course Code	Course Title
BIOL	Biology
CBEN	Chemical & Biological Engineering
CEEN	Civil & Environmental Engineering
CHGC	Geochemistry
CHGN	Chemistry
CSCI	Computer Science
CSM	General Studies; Skills Courses
DCGN	Core Science & Engineering Fundamentals
EBGN	Economics & Business
EENG	Electrical Engineering & Computer Sciences
EGES	Engineering Systems (Engineering)
EGGN	Engineering - General
ENGY	Energy
EPIC	EPICs
ESGN	Environmental Science & Engineering
GEGN	Geological Engineering
GEGX	Geochemical Exploration (Geology)
GEOC	Oceanography (Geology)

GEOL	Geology
GOGN	Geo-Engineering (Mining)
GPGN	Geophysical Engineering
HNRS	Honors Program
LAIS	Liberal Arts & International Studies
LICM	Communication
LIFL	Foreign Languages
LIMU	Band; Choir
MATH	Mathematics
MEGN	Mechanical Engineering
MNGN	Mining Engineering
MSGN	Military Science
MLGN	Materials Science
MTGN	Metallurgical & Materials Engineering
NUGN	Nuclear Engineering
PAGN	Physical Education & Athletics
PEGN	Petroleum Engineering
PHGN	Physics
SYGN	Core Sequence in Systems

The Sophomore Year

Requirements for the sophomore year are listed within each degree-granting program. Continuing requirements for satisfying the core are met in the sophomore, junior, and senior years. It is advantageous that students select one of the undergraduate degree programs early in the sophomore year.

Curriculum Changes

In accordance with the statement on Curriculum Changes, the Colorado School of Mines makes improvements in its curriculum from time to time. To confirm that they are progressing according to the requirements of the curriculum, students should consult their academic advisors on a regular basis, reference the online degree evaluation, and carefully consult any Bulletin Addenda that may be published.

Part-Time Degree Students

A part-time degree student may enroll in any course for which he or she has the prerequisites or the permission of the department. Part-time degree students will be subject to all rules and regulations of Colorado School of Mines, but they may not:

1. Live in student housing;
2. Receive financial help in the form of School-sponsored scholarships or grants;
3. Participate in any School-recognized activity unless fees are paid;
4. Take advantage of activities provided by student fees unless such fees are paid.

Course work completed by a part-time degree student who subsequently changes to full-time status will be accepted as meeting degree requirements.

Seniors in Graduate Courses

With the consent of the student's department/division and the Dean of Graduate Studies, a qualified senior may enroll in 500-level courses without being a registered graduate student. At least a 2.5 GPA is

required. The necessary forms for attending these courses are available in the Registrar's Office (<http://inside.mines.edu/500-Level-Course-Enrollment>). Seniors may not enroll in 600-level courses. Credits in 500-level courses earned by seniors may be applied toward an advanced degree at CSM only if:

1. The student gains admission to the Graduate School.
2. The student's graduate committee agrees that these credits are a reasonable part of his graduate program.
3. The student provides proof that the courses in question were not counted toward those required for the Bachelor's Degree.
4. Graduate courses applied to a graduate degree may not count toward eligibility for undergraduate financial aid. This may only be done if a student has been admitted to a Combined BS/MS degree program and has received the appropriate prior approvals.

Undergraduate students enrolled in graduate-level courses (500-level) are graded using the graduate grading system. See the CSM Graduate Bulletin (p. 201) for a description of the grading system used in graduate-level courses.

Course Substitution

To substitute credit for one course in place of another course required as part of the approved curricula in the catalog, a student must receive the approval of the Registrar, the heads of departments of the two courses, the head of the student's option department. There will be a periodic review by the Office of the Executive Vice President for Academic Affairs. Forms for this purpose are available in the Registrar's Office (<http://inside.mines.edu/Course-Substitutions>).

Change of Bulletin

It is assumed that each student will graduate under the requirements of the bulletin in effect at the time of most recent admission. However, it is possible to change to any subsequent bulletin in effect while the student is enrolled in a regular semester.

To change bulletins, a form obtained from the Registrar's Office is presented for approval to the head of the student's option department. Upon receipt of approval, the form must be returned to the Registrar's Office (<http://inside.mines.edu/Bulletin-Change>).

Students' Use of English

All Mines students are expected to show professional facility in the use of the English language.

English skills are emphasized, but not taught exclusively, in most of the humanities and social sciences courses and EPICS as well as in option courses in junior and senior years. Students are required to write reports, make oral presentations, and generally demonstrate their facility in the English language while enrolled in their courses.

The LAIS Writing Center (<http://inside.mines.edu/LAIS-Writing-Center>) is available to assist students with their writing. For additional information, contact the LAIS Division, Stratton 301; 303-273-3750.

Summer Sessions

The summer term is divided into two independent units. Summer Session I is a 6-week period beginning on Monday following Spring Commencement. Summer Session II is a 6-week session which immediately follows Summer Session I.

Dead Day

No required class meetings, examinations or activities may take place on the Friday immediately preceding final exams for the fall and spring terms. At their own discretion, faculty members may hold additional office hours or give a review session on Dead Day provided these activities are strictly optional. This day has been created as a break from regularly scheduled and/or required academic activities to allow students to prepare for their final examinations as they see fit.

Final Examinations Policy

Final examinations are scheduled by the Registrar. With the exception of courses requiring a common time, all finals will be scheduled on the basis of the day and the hour the course is offered.

In general, all final examinations will be given only during the stated final examination period and are to appear on the Registrar's schedule. Faculty policy adopted in January 1976 provides that no exams (final or otherwise) may be scheduled during the week preceding final examinations week, with the possible exception of laboratory exams. The scheduling by an individual faculty member of a final exam during the week preceding final examinations week is to be avoided because it tends to hinder the students' timely completion of other course work and interfere with the schedules of other instructors. Faculty members should not override this policy, even if the students in the class vote to do so.

Academic activities that are explicitly disallowed by this policy include:

- Scheduling an in-class examination (final or otherwise, with the possible exception of laboratory exams) for any course during the week preceding final exams
- Scheduling an early make-up final examination - unless the student needs to miss the regularly scheduled final for school related business (athletics, school-related travel, etc...) and requested by the student and approved by the instructor.
- Assigning a take-home final examination for any course that is due during the week preceding final exams – unless the student needs to miss the regularly scheduled final for school related business (athletics, school-related travel, etc...) and requested by the student and approved by the instructor.

Academic activities that are allowable during the week preceding final exams include:

- The introduction of new materials
- Laboratory finals
- Required homework
- Required in-class assignments such as quizzes or worksheets (NO EXAMS)
 - Quizzes are shorter exercises which take place on a fairly regular basis (e.g. 15-30 minutes in duration, 6-10 times a semester).
 - Exams are major exercises which take place only a few times a semester (e.g. 50-120 minutes in duration, 2-4 times a semester).
- Major course assignments such as Final Presentations or Term Projects provided the assignment was assigned at least 4 weeks in advance or was clearly indicated in the course syllabus (Presentations must not be scheduled in conflict with regularly scheduled courses in departments outside of the one scheduling the presentation.)
- Take home finals (provided they are not due prior to finals week)

- Make-up exams for students who miss a scheduled exam in the prior week due to emergency, illness, athletic event, or other CSM sanctioned activity (provided this absence has been approved by the Associate Dean of Students)

(Note: These policies apply only to undergraduate courses. Students enrolled in graduate courses, are bound by policies outlined in the Graduate Bulletin.)

Full-time Enrollment

Full-time enrollment for certification for Veterans Benefits, athletics, loans, most financial aid, etc. is 12.0 credit hours per semester for the fall and spring semesters. Full-time enrollment for Summer Session I and Summer Session II combined is 12.0 credit hours.

Good Standing, Honor Roll & Dean's List, Graduation Awards, Probation & Suspension

2015/2016

Good Standing

A student is in Good Standing at CSM when he or she is enrolled in class(es) and is not on either academic or disciplinary probation, suspension, or dismissal.

Honor Roll & Dean's List

To be placed on the academic honor roll, a student must complete at least 14.0 semester hours with a 3.0-3.499 grade point for the semester, have no grade below C, and no incomplete grade. Those students satisfying the above criteria with a semester grade-point average of 3.5 or above are placed on the Dean's List.

Students are notified by the Dean of Students of the receipt of these honors. The Dean's List notation appears on the student's transcript.

Graduation Awards

Colorado School of Mines awards the designations of Cum Laude, Magna Cum Laude, and Summa Cum Laude upon graduation. These designations are based on the following overall grade-point averages:

Grade-point average	Designation
3.500 - 3.699	Cum Laude
3.700 - 3.899	Magna Cum Laude
3.900 - 4.000	Summa Cum Laude

Commencement ceremony awards are determined by the student's cumulative academic record at the end of the preceding semester. For example, the overall grade-point average earned at the end of the fall term determines the honor listed in the May commencement program.

Final honors designations are determined once final grades have been awarded for the term of graduation. The final honors designation appears on the official transcript and is inscribed on the metal diploma. Official transcripts are available approximately one to two weeks after the term grades have been finalized. Metal diplomas are sent to the student approximately two months after final grades are posted. Mailing arrangements are made during Graduation Salute.

Undergraduate students are provided one metal diploma at no cost. Additional metal diplomas and parchment diplomas can be ordered online at the Registrar's Office (<http://inside.mines.edu/Diplomas>) webpage for an additional charge. Graduating students should order these items before the end of the graduation term in order to ensure delivery approximately two months after final grades are awarded.

Academic Probation & Suspension

Probation

A student whose cumulative grade-point average falls below the minimum requirements specified (see table below) will be placed on probation for the following semester. A student on probation is subject to the following restrictions:

1. The student may not register for more than 15.0 credit hours;
2. The student may be required to withdraw from intercollegiate athletics;
3. The student may not run for, or accept appointment to, any campus office or committee chairmanship. A student who is placed on probation while holding a position involving significant responsibility and commitment may be required to resign after consultation with the Associate Dean of Students or the President of Associated Students. A student will be removed from probation when the cumulative grade-point average is brought up to the minimum, as specified in the table below.

Suspension

A student on probation who fails to meet both the last semester grade period requirements and the cumulative grade-point average given in the table below will be placed on suspension. A student who meets the last semester grade period requirement but fails to achieve the required cumulative grade-point average will remain on probation.

total Quality Hours	Required Cumulative G.P. Average	Last Semester G.P. Average
0 - 18.5	1.7	--
19 - 36.5	1.8	2.0
37 - 54.5	1.8	2.0
55 - 72.5	1.9	2.1
73 - 90.5	1.9	2.1
91 - 110.5	2.0	2.2
111 - 130.5	2.0	2.2
131 - end of program	2.0	2.3

A freshman or transfer student who fails to make a grade-point average of 1.5 during the first grade period will be placed on suspension.

Suspension becomes effective immediately when it is imposed. Readmission after suspension requires written approval from the Readmissions Committee. While a one semester suspension period is normally the case, exceptions may be granted, particularly in the case of first-semester freshmen and new transfer students.

No student who is on suspension may enroll in any regular academic semester without the written approval of the Readmissions Committee. However, a student on suspension may enroll in a summer session (field camp, academic session, or both) with the permission of the Associate Dean of Students. Students on suspension who have been given permission to enroll in a summer session by the Associate Dean may not

enroll in any subsequent term at CSM without the written permission of the Readmissions Committee. Readmissions Committee meetings are held prior to the beginning of each regular semester and at the end of the spring term.

A student who intends to appear in person before the Readmissions Committee must contact the Associate Dean of Students at least one week prior to the desired appointment. Between regular meetings of the Committee, in cases where extensive travel would be required to appear in person, a student may petition in writing to the Committee, through the Associate Dean of Students.

Appearing before the Readmissions Committee by letter rather than in person will be permitted only in cases of extreme hardship. Such cases will include travel from a great distance, e.g. overseas, or travel from a distance which requires leaving a permanent job.

The Readmissions Committee meets on six separate occasions throughout the year. Students applying for readmission must appear at those times except under conditions beyond the control of the student. Such conditions include a committee appointment load, delay in producing notice of suspension, or weather conditions closing highways and airports.

All applications for readmission after a minimum period away from school, and all appeals of suspension or dismissal, must include a written statement of the case to be made for readmission.

A student who, after being suspended and readmitted twice, again fails to meet the academic standards shall be automatically dismissed. The Readmissions Committee will hear a single appeal of automatic dismissal. The appeal will only be heard after demonstration of substantial and significant changes. A period of time sufficient to demonstrate such a change usually elapses prior to the student attempting to schedule this hearing. The decision of the Committee on that single appeal will be final and no further appeal will be permitted.

Readmission by the Committee does not guarantee that there is space available to enroll. A student must process the necessary papers with the Admissions Office prior to seeing the Committee.

Notification

Notice of probation, suspension, or dismissal will be mailed to each student who fails to meet catalog requirements.

Repeated Failure

A student who twice fails a required course at Colorado School of Mines and is not subject to academic suspension will automatically be placed on "special hold" status with the Registrar, regardless of the student's cumulative or semester GPA. The student must meet with the subject advisor and receive written permission to remove the hold before being allowed to register.

In the case of three or more Fs in the same course, the student must meet with the faculty Readmissions Committee and receive permission to remove the hold before being allowed to register.

Transfer credit from another school will not be accepted for a twice-failed course.

Grading System, Grade-Point Average (GPA), and Grade Appeals

2015/2016

Undergraduate grading system

Grades

When a student registers in a course, one of the following grades will appear on his/her academic record. If a student registered as NC (audit) fails to satisfy all conditions, no record of his registration in the course will be made. The assignment of the grade symbol is based on the level of performance, and represents the extent of the student's demonstrated mastery of the material listed in the course outline and achievement of the stated course objectives.

Symbol	Interpretation
A	Excellent
A-	
B+	
B	Good
B-	
C+	
C	Satisfactory
C-	
D+	
D	
D-	Poor (lowest passing)
F	Failed
S	Satisfactory, C or better, used at mid-term
U	Unsatisfactory, below C, used at mid-term
PRG	Satisfactory Progress
PRU	Unsatisfactory Progress

In addition to these performance symbols, the following is a list of registration symbols that may appear on a CSM transcript:

Symbol	Interpretation
WI	Involuntary Withdrawal
W	Withdrew, no penalty
T	Transfer Credit
INC	Incomplete
NC	Not for Credit (Audit)
Z	Grade not yet submitted

Incomplete Grade

If a student, because of illness or other reasonable excuse, fails to complete a course, a grade of INC (incomplete) is given. The grade INC indicates deficiency in quantity of work and is temporary.

A GRADE OF INC MUST BE REMOVED NOT LATER THAN THE END OF THE FOURTH WEEK OF THE FIRST MAJOR TERM OF ATTENDANCE FOLLOWING THAT IN WHICH IT WAS RECEIVED. A grade of INC will be converted to an F grade by the Registrar in the fifth

week if it has not been updated by the instructor prior to this date. This conversion only occurs during the Spring and Fall terms (not summer). In the event that an INC grade remains upon completion of degree, the INC will be converted to an F and included in the final GPA.

NC Grade (Not for Credit or Audit)

A student may, for special reasons and with the instructor's permission, register in a course on the basis of NC (Not for Credit). To have the grade NC appear on his/her transcript, the student must enroll at registration time as a NC student in the course and comply with all conditions stipulated by the course instructor, except that if a student registered as NC fails to satisfy all conditions, no record of this registration in the course will be made. The Registration Action Form is used to request that a course be recorded as an audit. The form is available in the Registrar's Office (<http://inside.mines.edu/Auditing-a-Course>).

Transfer Credit

Transfer credit earned at another institution will have a T grade assigned but no grade points will be recorded on the student's permanent record. Calculation of the grade-point average will be made only from the courses completed at Colorado School of Mines.

GPA Hours and Quality Points

For graduation a student must successfully complete a certain number of required semester hours and must maintain grades at a satisfactory level. The system for expressing the quality of a student's work is based on quality points and GPA hours. The numerical value associated with the specific grades are:

Grade	Numerical Value
A	4.000
A-	3.700
B+	3.300
B	3.000
B-	2.700
C+	2.300
C	2.000
C-	1.700
D+	1.300
D	1.000
D-	0.700
F	0.000

The number of quality points earned in any course is the number of semester hours assigned to that course multiplied by the numerical value of the grade received. To compute an overall or major grade-point average, the number of cumulative GPA hours is divided into the cumulative quality points received. Grades of W, WI, INC, PRG, PRU, or NC are not counted in quality hours.

Midterm Grading

Midterm grading is conducted using Satisfactory (S) and Unsatisfactory (U) grades. Certain foundational courses are required to be graded between the 6th and 8th weeks of the term to provide students an early warning with time to recover. If the midterm grade is blank in these specific courses, the grade for the student is Satisfactory (S) by default,

or C- or better. Faculty will enter Unsatisfactory (U) grades for those students currently earning grades of D+ or lower.

Courses include: All Core Curriculum and Distributed Science Elective courses with the exception of H&SS Mid-Level Cluster and 400-Level. Additionally, the following courses will also be included: CEEN241 (Statics), CEEN311 (Mechanics of Materials), MEGN361 (Thermodynamics 1), CSC1261 (Programming Concepts), CHGN209 (Chemical Thermodynamics), and CBEN210 (Intro to Thermodynamics) as they are key pre-requisite courses for many students.

Semester Hours

The number of times a class meets during a week (for lecture, recitation, or laboratory) determines the number of semester hours assigned to that course. Class sessions are normally 50 minutes long and represent one hour of credit for each hour meeting. A minimum of three hours of laboratory work per week are equivalent to 1-semester hour of credit. For the average student, each hour of lecture and recitation requires at least two hours of preparation. No full-time undergraduate student may enroll for more than 19 credit hours in one semester. Physical education, advanced ROTC and Honors Program in Public Affairs courses are excepted. However, upon written recommendation of the faculty advisor, the better students may be given permission by the Registrar on behalf of Academic Affairs to take additional hours.

Grade-Point Averages

Grade-Point Averages shall be specified, recorded, reported, and used to three figures following the decimal point for any and all purposes to which said averages may apply.

Overall Grade-Point Average

Beginning Fall 2011, all attempts at every CSM course will count in the overall grade point average. No repeat exclusions apply.

The overall grade-point average includes all attempts at courses taken at Colorado School of Mines with the exception of courses which fall under the repeat policy in effect from Fall 2007 through Summer 2011.

If a course completed during the Fall 2007 term through Summer 2011 was a repeat of a course completed in any previous term and the course was not repeatable for credit, the grade and credit hours earned for the most recent occurrence of the course will count toward the student's grade-point average and the student's degree requirements. The most recent course occurrence must be an exact match to the previous course completed (subject and number). The most recent grade is applied to the overall grade-point average even if the previous grade is higher.

Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average, and cannot be used under this repeat policy. Only courses originally completed and subsequently repeated at Colorado School of Mines during Fall 2007 through Summer 2011 with the same subject code and number apply to this repeat policy.

All occurrences of every course taken at Colorado School of Mines will appear on the official transcript along with the associated grade.

Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average.

Option (Major) Grade-Point Average

The grade-point average calculated for the option (major) is calculated in the same manner as the overall grade-point average. Starting Fall 2011 the repeat policy is no longer in effect and all attempts at major courses completed in the major department or division are included. However, the major grade point average includes only the most recent attempt of a repeated course if the most recent attempt of that course occurs from Fall 2007 through Summer 2011.

The major grade point average includes every course completed in the major department or division at Colorado School of Mines. In some cases, additional courses outside of the major department are also included in the major GPA calculation. The minimum major grade-point average required to earn a Mines undergraduate degree is a 2.000. For specifics concerning your major GPA, reference your online degree audit (<http://inside.mines.edu/Degree-Audit-Information>) or contact your major department.

Grade Appeal Process

CSM faculty have the responsibility, and sole authority for, assigning grades. As instructors, this responsibility includes clearly stating the instructional objectives of a course, defining how grades will be assigned in a way that is consistent with these objectives, and then assigning grades. It is the student's responsibility to understand the grading criteria and then maintain the standards of academic performance established for each course in which he or she is enrolled.

If a student believes he or she has been unfairly graded, the student may appeal this decision first to the instructor of the course, and if the appeal is denied, to the Faculty Affairs Committee of the Faculty Senate. The Faculty Affairs Committee is the faculty body authorized to review and modify course grades, in appropriate circumstances. Any decision made by the Faculty Affairs Committee is final. In evaluating a grade appeal, the Faculty Affairs Committee will place the burden of proof on the student. For a grade to be revised by the Faculty Affairs Committee, the student must demonstrate that the grading decision was unfair by documenting that one or more of the following conditions applied:

1. The grading decision was based on something other than course performance, unless the grade was a result of penalty for academic dishonesty.
2. The grading decision was based on standards that were unreasonably different from those applied to other students in the same section of that course.
3. The grading decision was based on standards that differed substantially and unreasonably from those previously articulated by the instructor.

To appeal a grade, the student should proceed as follows:

1. The student should prepare a written appeal of the grade received in the course. This appeal must clearly define the basis for the appeal and must present all relevant evidence supporting the student's case.
2. After preparing the written appeal, the student should deliver this appeal to the course instructor and attempt to resolve the issue directly with the instructor. Written grade appeals must be delivered to the instructor no later than 10 business days after the start of the regular (fall or spring) semester immediately following the semester in which the contested grade was received. In the event that the course instructor is unavailable because of leave, illness, sabbatical, retirement, or resignation from the university, the course coordinator

(first) or the Department Head/Division Director (second) shall represent the instructor.

3. If after discussion with the instructor, the student is still dissatisfied, he or she can proceed with the appeal by submitting three copies of the written appeal plus three copies of a summary of the instructor/student meetings held in connection with the previous step to the President of the Faculty Senate. These must be submitted to the President of the Faculty Senate no later than 25 business days after the start of the semester immediately following the semester in which the contested grade was received. The President of the Faculty Senate will forward the student's appeal and supporting documents to the Faculty Affairs Committee, and the course instructor's Department Head/Division Director.
4. The Faculty Affairs Committee will request a response to the appeal from the instructor. On the basis of its review of the student's appeal, the instructor's response, and any other information deemed pertinent to the grade appeal, the Faculty Affairs Committee will determine whether the grade should be revised. The decision rendered will be either:
 - a. the original grading decision is upheld, or
 - b. sufficient evidence exists to indicate a grade has been assigned unfairly.

In this latter case, the Faculty Affairs Committee will assign the student a new grade for the course. The Committee's decision is final. The Committee's written decision and supporting documentation will be delivered to the President of the Faculty Senate, the office of the EVPAA, the student, the instructor, and the instructor's Department Head/Division Director no later than 15 business days following the Senate's receipt of the grade appeal.

The schedule, but not the process, outlined above may be modified upon mutual agreement of the student, the course instructor, and the Faculty Affairs Committee.

Class Rank

Colorado School of Mines does not calculate class rank. The Registrar's Office will provide a letter stating this fact upon request if necessary for the submission of scholarship applications.

Minor Programs / Areas of Special Interest (ASI)

Established Minor Programs/Areas of Special Interest (ASI) are offered by undergraduate degree-granting departments and the Military Science Department. Additionally CSM offers interdisciplinary minors (p. 167) and ASIs.

A Minor Program/Area of Special Interest declaration (which can be found in the Registrar's Office (<http://inside.mines.edu/Minor-or-ASI-Declaration>)) should be submitted for approval at the time of application for graduation. If the minor or ASI is added after the application to graduate, it must be submitted to the Registrar's Office by the first day of the term in which the student is graduating.

Once the declaration form is submitted to the Registrar's Office, the student deciding not to complete the minor/ASI must officially drop the minor/ASI by notifying the Registrar's Office in writing. Should minor/ASI requirements not be complete at the time of graduation, the minor/ASI program will not be awarded. Minors/ASIs are not added after the BS degree is posted. Completion of the minor/ASI will be recorded on

the student's official transcript. Please see the Department for specific course requirements. For questions concerning changes in the sequence of minor/ASI courses after the declaration form is submitted, contact the Registrar's Office for assistance.

No more than half of the hours used for the minor or ASI may be transferred from other colleges or universities including AP, IB, or other high school or non-Mines credit. Some minor/ASI programs, however, have been established in collaboration with other institutions through formal articulation agreements and these may allow transfer credit exceeding this limit. For additional information on program-specific transfer credit limits, refer to the programs section (p. 35) of this Bulletin.

As a minimum, CSM requires that any course used to fulfill a minor/ASI requirement be completed with a passing grade. Some programs offering minors/ASIs may, however, impose higher minimum grades for inclusion of the course in the minor/ASI. In these cases, the program specified minimum course grades take precedence. For additional information on program-specific minimum course grade requirements, refer to the programs section (p. 35) of this Bulletin. As a minimum, to be awarded a minor/ASI, CSM requires students obtain a cumulative GPA of 2.0 or higher in all minor/ASI courses completed at CSM. All attempts at required minor/ASI courses are used in computing this minor/ASI GPA. Some programs offering minors/ASIs may, however, require a higher minimum cumulative GPA. In these cases, the program specified GPA takes precedence. For additional information on program specific GPA requirements, refer to the programs section (p. 35) of this Bulletin.

Each department or minor-oversight authority (in the case of interdisciplinary minors) defines a list of requirements that constitute a minor. The lists of requirements clearly delineate any specific courses needed for the minor, may include a set of courses from which the rest of the credits must be completed, and will clearly outline any other specific restrictions and/or requirements for obtaining the minor. Once recommended by Undergraduate Council and approved by Faculty Senate, the minor requirements will appear in the appropriate department or interdisciplinary sections of this bulletin so that courses may be planned in advance in order for a student to receive a given minor/s.

The objective of a minor is to provide a depth of understanding and expertise to an area outside of, or complementary to, a student's degree. A minor is a thematically-related set of academic activities leading to a transcript designation in addition to but separate from that granted by the student's degree.

Minors

All minors are created and awarded based on the following minimum requirements and limitations:

MINIMUM CREDIT HOURS - 18.0

MINIMUM HOURS OUTSIDE OF DEGREE REQUIREMENTS - 9.0

At least 9.0 of the hours required for the minor must not be used for any part of the degree other than Free Electives.

MINIMUM GPA - 2.0

A 2.0 grade point average, including all CSM graded courses used for the minor, must be met in order to receive the minor designation on the

transcript. Transfer credit hours do not factor into the minor grade point average.

LEVEL - At least 9.0 credits must be at the 300-level or above.

CONTENT

There must be sufficient distinction between a degree and a minor obtained by the same student. In general, students may earn minors offered by the same department as their degree program, but the minor may not have the same name as the degree. For example, an Electrical Engineering degree-seeking student may earn a minor in Computer Science. However, degree granting programs, with recommendation by Undergraduate Council and approval by Faculty Senate, may 1) specify minors that are excluded for their students due to insufficient distinction, and/or 2) add restrictions or additional requirements to the minimal requirements for their students to obtain a specific minor. Any approved exclusions and/or additional restrictions will appear in this Bulletin under both the associated degree and minor sections.

Areas of Special Interest (ASIs)

All ASIs are created and awarded based on the following minimum requirements and limitations:

MINIMUM CREDIT HOURS - 12.0

MINIMUM HOURS OUTSIDE OF DEGREE REQUIREMENTS - 9.0

At least 9.0 of the hours required for the ASI must not be used for any part of the degree other than Free Electives.

MINIMUM GPA - 2.0

A 2.0 grade point average, including all CSM graded courses used for the ASI, must be met in order to receive the ASI designation on the transcript. Transfer credit hours do not factor into the ASI grade point average.

LEVEL - At least 9.0 credits must be at the 300-level or above.

Undergraduate Degree Requirements

2015/2016

Bachelor of Science Degree

Upon completion of the requirements and upon being recommended for graduation by the faculty, and approved by the Board of Trustees, the undergraduate receives one of the following degrees:

- Bachelor of Science (Applied Mathematics and Statistics)
- Bachelor of Science (Chemical Engineering)
- Bachelor of Science (Chemical & Biochemical Engineering)
- Bachelor of Science (Chemistry)
- Bachelor of Science (Civil Engineering)
- Bachelor of Science (Computer Science)
- Bachelor of Science (Economics)
- Bachelor of Science (Electrical Engineering)

- Bachelor of Science (Engineering Physics)
- Bachelor of Science (Environmental Engineering)
- Bachelor of Science (Geological Engineering)
- Bachelor of Science (Geophysical Engineering)
- Bachelor of Science (Mechanical Engineering)
- Bachelor of Science (Metallurgical & Materials Engineering)
- Bachelor of Science (Mining Engineering)
- Bachelor of Science (Petroleum Engineering)

Degree Retirement Notification and Requirement Definition

Admission into the following degree program is suspended after the Fall 2012 semester:

- Bachelor of Science (Mathematical and Computer Sciences)

Both continuing students and students admitted into this degree program Fall, 2012 are encouraged to change programs to the newly approved programs replacing this older program (either Applied Mathematics and Statistics or Computer Science). Program requirements for students admitted Fall, 2012 wishing to remain in the older program are as defined in the 2011-2012 Undergraduate Bulletin.

Admission into the following degree program is suspended after the Fall 2013 semester:

- Bachelor of Science (Engineering) with specialty/specialties

Both continuing students and students admitted into this degree program Fall, 2013 are encouraged to change programs to the newly approved programs replacing this older program (Civil Engineering, Electrical Engineering, Environmental Engineering, or Mechanical Engineering). Program requirements for students admitted Fall, 2013 wishing to remain in the older program are as defined in the 2013-2014 Undergraduate Bulletin.

Graduation Requirements

To qualify for a Bachelor of Science degree from Colorado School of Mines, all candidates must satisfy the following requirements:

1. A minimum cumulative grade-point average of 2.000 for all academic work completed in residence.
2. A minimum cumulative grade-point average of 2.000 for courses in the candidate's major.
3. A minimum of 30 hours credit in 300 and 400 series technical courses in residence, at least 15 of which are to be taken in the senior year.
4. A minimum of 19 hours in humanities and social sciences courses.
5. The recommendation of their degree-granting department/ division to the faculty.
6. The certification by the Registrar that all required academic work is satisfactorily completed.
7. The recommendation of the faculty and approval of the Board of Trustees.

Seniors must submit an Application to Graduate (<http://inside.mines.edu/Application-to-Graduate>) upon completion of 90 hours (upon obtaining Senior class standing). Applications are completed online through the student's Trailhead account.

Completed Minor and ASI forms are normally due to the Registrar's Office at the same as the application to graduate. If the Minor or ASI is

added later, it is due no later than Census Day of the term in which the students is graduating.

The Registrar's Office provides the service of doing preliminary degree audits. *Ultimately, however, it is the responsibility of students to monitor the progress of their degrees.* It is also the student's responsibility to contact the Registrar's Office when there appears to be a discrepancy between the degree audit and the student's records.

All graduating students must officially check out of the School. Checkout cards, available at Graduation Salute and in the Dean of Student's Office, must be completed and returned one week prior to the expected date of completion of degree requirements.

No students, graduate or undergraduate, will receive diplomas until they have complied with all the rules and regulations of Colorado School of Mines and settled all accounts with the School. Transcript of grades and other records will not be provided for any student or graduate who has an unsettled obligation of any kind to the School.

Multiple Degrees

A student wishing to complete two Bachelor of Science degrees must complete the first degree plus a minimum of thirty hours specific to the second degree program. The thirty (or more) hours required for the second degree may not include free electives and may not be double counted with any credit used to complete the first degree. The degree plan for the second degree must be approved by the advisor, the department head, and the Registrar's Office representing Academic Affairs.

When two degrees are completed concurrently, the first degree is the one with fewer total hours required for graduation. In the case of a returning student, the first degree is the original completed degree. The two degrees may be in different colleges. The degree plan may include courses from multiple departments. Different catalogs may be used, one for each degree program. The student receives two separate diplomas. The transcript lists both degrees.

A student may not earn two degrees in the same content area because the course requirements, content, and titles do not significantly differ.

The following combinations are not allowable:

BS in Engineering, Mechanical Specialty & BS in Mechanical Engineering

BS in Engineering, Electrical Specialty & BS in Electrical Engineering

BS in Engineering, Environmental Specialty & BS in Environmental Engineering

BS in Engineering, Civil Specialty & BS in Civil Engineering

BS in Mathematics & Computer Science & BS in Applied Math and Statistics

BS in Mathematics & Computer Science & BS in Computer Science

BS in Chemical Engineering & BS in Chemical and Biochemical Engineering

Degree Posting and Grade Changes

Once the degree is posted, grade changes will be accepted for six weeks only. After six weeks has passed, no grade changes will be allowed for any courses on the official transcript.

Commencement Participation

To participate in May Commencement, no more than 6 semester credit hours can remain outstanding after the spring term. The student must show proof of summer registration for these 6 or fewer credits in order to be placed on the list for August completion. To participate in December convocation, the undergraduate student must be registered for all courses that lead to completion of the degree at the end of the same fall term.

Courses Older Than 10 Years

For returning students who wish to use courses completed more than 10 years prior, contact the Registrar's Office. These courses will not apply to current degrees without special approval from the degree-granting department or division, and the department in which the course is taught.

Late Fee for Application to Graduate after Stated Deadlines - \$250 Beginning Fall 2014

Undergraduates:

The deadline to apply to graduate and participate in commencement is the first day of class of the term in which the student intends to graduate/participate.

Any request to be added to the graduation list and/or commencement ceremony after the first day of class (and before November 10th for fall or April 10th for spring and summer) may be made in writing and will be considered by the Registrar's Office. If the request is denied, the student will be required to apply for the next available graduation/ceremony. If the request is approved and all other conditions are met (i.e. degree requirements can be met, required forms are turned in, and outstanding hours limitations are not exceeded), a mandatory \$250 fee will be applied to the student's account. This fee cannot be waived and cannot be refunded if the student does not meet the graduation check-out deadlines.

For late requests that are approved, tickets to the commencement ceremony for family and friends of the graduate are not guaranteed, as they may have already been distributed or assigned. Additionally, the student's name may not appear in the commencement program due to publishing deadlines.

No undergraduate student will be added to a graduation or commencement when the request is made after November 10th for the fall commencement (which includes December graduation), or April 10th for the spring and summer commencement ceremony (which includes May and August graduations).

Programs and Departments

Please select a department or program from the list on the right.

College of Engineering & Computational Sciences

For department bulletin pages, please select from the list of links on the left to locate more information.

CECS comprises four of the academic units and one program at CSM:

1. Department of Applied Mathematics and Statistics
2. Department of Civil and Environmental Engineering
3. Department of Electrical Engineering and Computer Science
4. Department of Mechanical Engineering
5. EPICS Program

Through these departments CECS is proud to offer rigorous and highly-regarded educational programs as well as cutting-edge research that matters. As Dean of the school, my vision is that CECS will

*... house educational, research, and outreach **programs of distinction**... known for their high quality, innovation, and impact on improving the lives of people ... through a focus on engineering design and research challenges related to earth, energy, and the natural and built environments ... with departments and programs that are **destinations of choice** for undergraduate and graduate students, employers, and funding agencies from around the world ...*

Today over 2100 students and more than 100 faculty members are working toward this vision. If you are looking for a challenge though a world class education, if you want the skills you need to make a difference in the world, if you are interested in pursuing original research, or if you want to be part of the rich traditions of an institution that has been committed to serving the people of Colorado, the nation, and the global community since the 1870's, I invite you to join us in the College of Engineering and Computational Sciences at the Colorado School of Mines.

Sincerely, Kevin L. Moore, Dean

Courses

EGGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EGGN205. PROGRAMMING CONCEPTS AND ENGINEERING ANALYSIS. 3.0 Semester Hrs.

(I,II) This course provides an introduction to techniques of scientific computation that are utilized for engineering analysis, with the software package MATLAB as the primary computational platform. The course focuses on methods data analysis and programming, along with numerical solutions to algebraic and differential equations. Engineering applications are used as examples throughout the course. Prerequisite: MATH112 or MATH113 or MATH122. 3 hours lecture; 3 semester hours.

EGGN250. MULTIDISCIPLINARY ENGINEERING LABORATORY. 1.5 Semester Hr.

(I, II) (WI) Laboratory experiments integrating instrumentation, circuits and power with computer data acquisitions and sensors. Sensor data is used to transition between science and engineering science. Engineering Science issues like stress, strains, thermal conductivity, pressure and flow are investigated using fundamentals of equilibrium, continuity, and conservation. Prerequisites: PHGN200. 4.5 hours lab; 1.5 semester hour.

EGGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EGGN301. HUMAN-CENTERED PROBLEM DEFINITION. 3.0 Semester Hrs.

(I, II) This class will equip students with the knowledge, skills and attitudes needed to identify, define, and begin solving real problems for real people, within the socio-technical ambiguity that surrounds all engineering problems. The course will focus on problems faced in everyday life, by people from different backgrounds and in different circumstances, so that students will be able to rise to the occasion presented by future workplace challenges. By the end of this course, students will be able to recognize design problems around them, determine whether they are worth solving, and employ a suite of tools to create multiple solutions. The follow up course --"Design for People" -- will enable students to take the best solutions to the prototype phase. 3.0 hours lecture; 3.0 semester hours.

EGGN350. MULTIDISCIPLINARY ENGINEERING LABORATORY II. 1.5 Semester Hr.

(I, II) (WI) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Fluid mechanics issues like compressible and incompressible fluid flow (mass and volumetric), pressure losses, pump characteristics, pipe networks, turbulent and laminar flow, cavitation, drag, and others are covered. Experimental stress analysis issues like compression and tensile testing, strain gage installation, Young's Modulus, stress vs. strain diagrams, and others are covered. Experimental stress analysis and fluid mechanics are integrated in experiments which merge fluid power of the testing machine with applied stress and displacement of material specimen. Prerequisites: EGGN250. Co-requisites: MEGN351 or CEEN310 and CEEN311 or MEGN312. 4.5 hours lab; 1.5 semester hour.

EGGN398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EGGN401. PROJECTS FOR PEOPLE. 3.0 Semester Hrs.

(I, II) Work with innovative organizations dedicated to community development to solve major engineering challenges. This course is open to juniors and seniors interested in engaging a challenging design problem and learning more about Human Centered Design (HCD). The course will be a mixture of lecture and lab aiming at developing engineering solutions to real problems affecting real people in areas central to their lives. Repeatable for elective credit with a Maximum of 6 Total Hours. 1.0 hour lecture; 4.0 hours lab; 3.0 semester hours.

EGGN408. INTRODUCTION TO SPACE EXPLORATION. 1.0 Semester Hr.

(I) Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminar-style class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector. Prerequisites: None; 1 hour lecture; 1 semester hour.

EGGN450. MULTIDISCIPLINARY ENGINEERING LABORATORY III. 1.0 Semester Hr.

(I, II) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Students will design experiments to gather data for solving engineering problems. Examples are recommending design improvements to a refrigerator, diagnosing and predicting failures in refrigerators, computer control of a hydraulic fluid power circuit in a fatigue test, analysis of structural failures in an off-road vehicle and redesign, diagnosis and prediction of failures in a motor/generator system. Prerequisites: EGGN350 or EENG382, MEGN351, MEGN312 or CEEN311; Co-requisites: EENG307. 3 hours lab; 1 semester hour.

EGGN491. SENIOR DESIGN I. 3.0 Semester Hrs.

(I, II) (WI) This course is the first of a two-semester capstone course sequence giving the student experience in the engineering design process. Realistic open-ended design problems are addressed for real world clients at the conceptual, engineering analysis, and the synthesis stages and include economic and ethical considerations necessary to arrive at a final design. Students are assigned to interdisciplinary teams and exposed to processes in the areas of design methodology, project management, communications, and work place issues. Strong emphasis is placed on this being a process course versus a project course. This is a writing-across-the-curriculum course where students' written and oral communication skills are strengthened. The design projects are chosen to develop student creativity, use of design methodology and application of prior course work paralleled by individual study and research. Prerequisite: CEEN330 or CEEN331 or EENG334 or MEGN201. For BSE Mechanical Specialty and BSME students completion of MEGN481. For BSE Civil Specialty and BSCE students, concurrent enrollment or completion of any one of CEEN443, CEEN445, CEEN440, or CEEN415. 2 hour lecture; 3 hours lab; 3 semester hours.

EGGN492. SENIOR DESIGN II. 3.0 Semester Hrs.

(I, II) (WI) This course is the second of a two-semester sequence to give the student experience in the engineering design process. Design integrity and performance are to be demonstrated by building a prototype or model, or producing a complete drawing and specification package, and performing pre-planned experimental tests, wherever feasible, to verify design compliance with client requirements. Prerequisite: EGGN491. 1 hour lecture; 6 hours lab; 3 semester hours.

EGGN497. SUMMER PROGRAMS. 15.0 Semester Hrs.**EGGN498. SPECIAL TOPICS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EGGN499. INDEPENDENT STUDY. 6.0 Semester Hrs.

Applied Mathematics & Statistics 2015-16

Program Description

The Applied Mathematics and Statistics Department (AMS) offers an undergraduate degree in which students are exposed to a breadth of coursework in computational mathematics, applied mathematics, and statistics. In the senior year, students may choose an area of emphasis in either Computational and Applied Mathematics (CAM) or Statistics (STAT). Both of these options emphasize technical competence, problem solving, teamwork, projects, relation to other disciplines, and verbal, written, and graphical skills.

In a broad sense, these programs stress the development of practical applications and techniques to enhance the overall attractiveness of applied mathematics and statistics majors to a wide range of employers in industry and government. More specifically, AMS utilizes a summer field session program to introduce concepts and techniques in advanced mathematics and the senior capstone experiences in Computational and Applied Mathematics and Statistics to engage high-level undergraduate students in problems of practical applicability for potential employers. These courses are designed to simulate an industrial job or research environment. The close collaboration with potential employers and professors improves communication between our students and the private sector as well as with sponsors from other disciplines on campus.

Applied Mathematics and Statistics majors can use free elective courses to gain knowledge in another discipline and incorporate either an Area of Special Interest (ASI) or a minor in one of the following:

- Computational and Applied Mathematics
- Statistics
- Mathematical Sciences

This adds to the flexibility of the program and qualifies students for a wide variety of careers.

In addition to offering undergraduate and graduate degree programs, the Department provides the teaching skills and technical expertise to develop capabilities in computational mathematics, applied mathematics, and statistics for all Colorado School of Mines (CSM) students.

Program Educational Objectives

(Bachelor of Science in Applied Mathematics and Statistics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the Accreditation Board for Engineering and Technology's (ABET) accreditation criteria, the Applied Mathematics and Statistics Program at CSM has established the following program educational objectives:

Students will demonstrate technical expertise within mathematics and statistics by:

- Designing and implementing solutions to practical problems in science and engineering; and,

- Using appropriate technology as a tool to solve problems in mathematics.

Students will demonstrate a breadth and depth of knowledge within mathematics by:

- Extending course material to solve original problems,
- Applying knowledge of mathematics to the solution of problems,
- Identifying, formulating and solving mathematics problems, and
- Analyzing and interpreting statistical data.

Students will demonstrate an understanding and appreciation for the relationship of mathematics to other fields by:

- Applying mathematics and statistics to solve problems in other fields,
- Working in cooperative multidisciplinary teams, and
- Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate mathematics effectively by:

- Giving oral presentations,
- Completing written explanations,
- Interacting effectively in cooperative teams, and
- Understanding and interpreting written material in mathematics.

Curriculum

The calculus sequence emphasizes mathematics applied to problems students are likely to see in other fields. This supports the curricula in other programs where mathematics is important, and assists students who are under prepared in mathematics. Priorities in the mathematics curriculum include: applied problems in the mathematics courses and ready utilization of mathematics in the science and engineering courses.

This emphasis on the utilization of mathematics continues through the upper division courses. Another aspect of the curriculum is the use of a spiraling mode of learning in which concepts are revisited to deepen the students' understanding.

The applications, teamwork, assessment and communications emphasis directly address ABET criteria and the CSM graduate profile. The curriculum offers the following two areas of emphases:

Degree Requirements (Applied Mathematics and Statistics)

Computational and Applied Mathematics (CAM) EMPHASIS

Freshman

Fall		lec	lab sem.hrs	
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CSCI101	INTRODUCTION TO COMPUTER SCIENCE	3.0		3.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
LAIS100	NATURE AND HUMAN VALUES	4.0		4.0
PAGN101	PHYSICAL EDUCATION	0.5		0.5
CSM101	FRESHMAN SUCCESS SEMINAR	0.5		0.5
				16.0

Spring		lec	lab sem.hrs	
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.5
SCI	SCIENCE REQUIREMENT ¹	4.0		4.0
EPIC151	DESIGN (EPICS) I	3.0		3.0
PAGN102	PHYSICAL EDUCATION	0.5		0.5
				16.0

Sophomore

Fall		lec	lab sem.hrs	
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
CSCI261	PROGRAMMING CONCEPTS	3.0		3.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.5
PAGN2XX	PHYSICAL EDUCATION	0.5		0.5
				15.0

Spring		lec	lab sem.hrs	
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0		3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
CSCIxxx	COMPUTER ELECTIVE ²	3.0		3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
LAIS200	HUMAN SYSTEMS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION	0.5		0.5
				15.5

Summer		lec	lab sem.hrs	
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS	4.0		4.0
				4.0

Junior

Fall		lec	lab sem.hrs	
MATH301	INTRODUCTION TO ANALYSIS	3.0		3.0
MATH331	MATHEMATICAL BIOLOGY	3.0		3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
LAIS/EBGN	H&SS ELECTIVE I	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
				18.0

Spring		lec	lab sem.hrs	
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0		3.0
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0		3.0
MATH454	COMPLEX ANALYSIS	3.0		3.0
MATH458	ABSTRACT ALGEBRA	3.0		3.0
LAIS/EBGN	H&SS ELECTIVE II	3.0		3.0
FREE	FREE ELECTIVE	1.0		1.0
				16.0

Senior

		lec	lab sem.hrs	
Fall				
MATH424	INTRODUCTION TO APPLIED STATISTICS	3.0	3.0	
MATH440	PARALLEL SCIENTIFIC COMPUTING (CAM required)	3.0	3.0	
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0	3.0	
FREE	FREE ELECTIVE	3.0	3.0	
FREE	FREE ELECTIVE	3.0	3.0	
		15.0		
Spring				
MATH	MATHEMATICS-CAM ELECTIVE ³	3.0	3.0	
MATH	MATHEMATICS-CAM ELECTIVE ³	3.0	3.0	
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0	3.0	
LAIS/EBGN	H&SS ELECTIVE III	3.0	3.0	
FREE	FREE ELECTIVE	3.0	3.0	
		15.0		

Total Semester Hrs: 130.5

¹ Students may choose from the following courses to fulfill the Science Requirement: GEGN101, BIOL110, CHGN122.

² May be satisfied by CSC1262 or any other approved computationally intensive course.

³ CAM area of emphasis electives include: Functional Analysis, Complex Analysis II, Numerical PDEs, Integral Equations, Modeling with Symbolic Software, and other appropriate courses with departmental approval.

Statistics (STATS) EMPHASIS**Freshman**

		lec	lab sem.hrs	
Fall				
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0	4.0	
CSCI101	INTRODUCTION TO COMPUTER SCIENCE	3.0	3.0	
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
LAIS100	NATURE AND HUMAN VALUES	4.0	4.0	
PAGN101	PHYSICAL EDUCATION	0.5	0.5	
CSM101	FRESHMAN SUCCESS SEMINAR	0.5	0.5	
		16.0		
Spring				
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0	4.0	
PHGN100	PHYSICS I - MECHANICS	3.0	3.0	4.5
EPIC151	DESIGN (EPICS) I	3.0	3.0	
SCI	SCIENCE REQUIREMENT ¹	4.0	4.0	
PAGN102	PHYSICAL EDUCATION	0.5	0.5	
		16.0		

Sophomore

		lec	lab sem.hrs	
Fall				
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0	4.0	

MATH225	DIFFERENTIAL EQUATIONS	3.0	3.0	
CSCI261	PROGRAMMING CONCEPTS	3.0	3.0	
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.5
PAGN2XX	PHYSICAL EDUCATION	0.5	0.5	
		15.0		
Spring				
MATH332	LINEAR ALGEBRA or 342	3.0	3.0	
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0	3.0	
CSCIXXX	COMPUTER SCIENCE ELECTIVE ²	3.0	3.0	
LAIS200	HUMAN SYSTEMS	3.0	3.0	
EBGN201	PRINCIPLES OF ECONOMICS	3.0	3.0	
PAGN2XX	PHYSICAL EDUCATION	0.5	0.5	
		15.5		
Summer				
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS	4.0	4.0	
		4.0		

Junior

		lec	lab sem.hrs	
Fall				
MATH301	INTRODUCTION TO ANALYSIS	3.0	3.0	
MATH331	MATHEMATICAL BIOLOGY	3.0	3.0	
MATH334	INTRODUCTION TO PROBABILITY	3.0	3.0	
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0	3.0	
LAIS/EBGN	H&SS ELECTIVE I	3.0	3.0	
FREE	FREE ELECTIVE	3.0	3.0	
		18.0		
Spring				
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0	3.0	
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0	3.0	
MATH454	COMPLEX ANALYSIS	3.0	3.0	
MATH458	ABSTRACT ALGEBRA	3.0	3.0	
LAIS/EBGN	H&SS ELECTIVE II	3.0	3.0	
FREE	FREE ELECTIVE	1.0	1.0	
		16.0		

		lec	lab sem.hrs	
Senior				
Fall				
MATH424	INTRODUCTION TO APPLIED STATISTICS	3.0	3.0	
MATH432	SPATIAL STATISTICS	3.0	3.0	
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0	3.0	
FREE	FREE ELECTIVE	3.0	3.0	
LAIS/EBGN	H&SS FREE ELECTIVE III	3.0	3.0	
		15.0		
Spring				
MATH	STAT ELECTIVE ³	3.0	3.0	

MATH	STAT ELECTIVE ³	3.0	3.0
MATH482	STATISTICS PRACTICUM (STAT Capstone)	3.0	3.0
FREE	FREE ELECTIVE	3.0	3.0
FREE	FREE ELECTIVE	3.0	3.0
			15.0

Total Semester Hrs: 130.5

- ¹ Students may choose from the following courses to fulfill the Science Requirement: GEGN101, BIOL110, CHGN122.
- ² May be satisfied by CSCI262 or any other approved computationally intensive course.
- ³ STAT area of emphasis electives include: Advanced Statistical Modeling, Multivariate Analysis, Stochastic Modeling, Survival Analysis, and other appropriate courses with departmental approval.

General CSM Minor/ASI requirements can be found here (<http://bulletin.mines.edu/undergraduate/undergraduateinformation/minorasi>). An important policy for all CSM Minor/ASI programs is that 9.0 credit hours must occur outside of a student's degree program. The Department of Applied Mathematics and Statistics also requires that one course must be at the 400-level. The following options are available:

1. Minor/ASI in Computational and Applied Mathematics (CAM)
2. Minor/ASI in Statistics (STAT)
3. Minor in Mathematical Sciences, which can include a combination of CAM and STAT coursework

For each of these options, there is a list of required courses and a list of elective courses which a student can choose from to complete his/her Minor/ASI requirements.

Minor/ASI Computational and Applied Mathematics (CAM)

For an Area of Special Interest (ASI) in Computational and Applied Mathematics (CAM), the student should take the following:

MATH225	DIFFERENTIAL EQUATIONS	3.0
or MATH235	DIFFERENTIAL EQUATIONS HONORS	
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0
MATH332	LINEAR ALGEBRA	3.0
or MATH342	HONORS LINEAR ALGEBRA	

3 credit hours of CAM courses (1 course) from the CAM Courses List below.

For a Minor in Computational and Applied Mathematics (CAM), the student should take the following:

MATH225	DIFFERENTIAL EQUATIONS	3.0
or MATH235	DIFFERENTIAL EQUATIONS HONORS	
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0
MATH332	LINEAR ALGEBRA	3.0
or MATH342	HONORS LINEAR ALGEBRA	

9 credit hours of CAM courses (3 courses) from the CAM Courses List below.

CAM Courses

MATH301	INTRODUCTION TO ANALYSIS	3.0
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0
MATH331	MATHEMATICAL BIOLOGY	3.0
MATH348	ADVANCED ENGINEERING MATHEMATICS	3.0
MATH406	ALGORITHMS	3.0
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH441	COMPUTER GRAPHICS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH498	SPECIAL TOPICS (in CAM)	3.0
MATH5XX	GRADUATE CAM ELECTIVE	3.0

Minor/ASI Statistics

For an Area of Special Interest (ASI) in Statistics, the student should take the following:

MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH424	INTRODUCTION TO APPLIED STATISTICS	3.0

For a Minor in Statistics, the student should take the following:

MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH424	INTRODUCTION TO APPLIED STATISTICS	3.0

6 credit hours of Statistics courses (2 courses) from the Statistics Courses List below.

MATH432	SPATIAL STATISTICS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH439	SURVIVAL ANALYSIS	3.0
MATH498	SPECIAL TOPICS (in STATISTICS)	3.0
MATH5XX	GRADUATE STATISTICS ELECTIVE	3.0

Mathematical Sciences (could include a mixture of CAM and STATISTICS courses).

For an Area of Special Interest (ASI) in Mathematical Sciences, the student should take the following:

MATH225	DIFFERENTIAL EQUATIONS	3.0
or MATH235	DIFFERENTIAL EQUATIONS HONORS	

9 credit hours of Mathematics courses (3 courses) from either the CAM or STATISTICS Courses listed above, including one course at the 400-level.

For a Minor in Mathematical Sciences, the student should take the following:

MATH225	DIFFERENTIAL EQUATIONS	3.0
or MATH235	DIFFERENTIAL EQUATIONS HONORS	

15 credit hours of Mathematics courses (5 courses) from either the CAM or STATISTICS Courses listed above, including one course at the 400-level.

Department Head

Willy Hereman, Professor

Professors

Bernard Bialecki

Mahadevan Ganesh

Paul A. Martin

Barbara M. Moskal

William C. Navidi

Associate Professor

Luis Tenorio

Assistant Professors

Paul Constantine

Cecilia Diniz Behn

Amanda Hering

Stephen Pankavich

Aaron Porter

Teaching Professors

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Scott Strong

Teaching Associate Professors

Terry Bridgman

Debra Carney

Holly Eklund

Mike Mikucki

Mike Nicholas

Jennifer Strong

Rebecca Swanson

Emeriti Professors

William R. Astle

Norman Bleistein

Ardel J. Boes

Austin R. Brown

John A. DeSanto

Graeme Fairweather

Raymond R. Gutzman

Frank G. Hagin

Donald C.B. Marsh

Steven Pruess

Emeriti Associate Professors

Barbara B. Bath

Ruth Maurer

Robert G. Underwood

Courses

MATH100. INTRODUCTORY TOPICS FOR CALCULUS. 2.0 Semester Hrs.

(S) An introduction and/or review of topics which are essential to the background of an undergraduate student at CSM. This course serves as a preparatory course for the Calculus curriculum and includes material from Algebra, Trigonometry, Mathematical Analysis, and Calculus. Topics include basic algebra and equation solving, solutions of inequalities, trigonometric functions and identities, functions of a single variable, continuity, and limits of functions. Does not apply toward undergraduate degree or g.p.a. Prerequisite: none. 2 hours lecture, 2 semester hours.

MATH111. CALCULUS FOR SCIENTISTS AND ENGINEERS I. 4.0 Semester Hrs.

Equivalent with MACS111,

(I, II, S) First course in the calculus sequence, including elements of plane geometry. Functions, limits, continuity, derivatives and their application. Definite and indefinite integrals; Prerequisite: precalculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH112. CALCULUS FOR SCIENTISTS AND ENGINEERS II. 4.0 Semester Hrs.

Equivalent with MACS112, MATH122,

(I, II, S) Vectors, applications and techniques of integration, infinite series, and an introduction to multivariate functions and surfaces. Prerequisite: Grade of C or better in MATH111. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH113. CALCULUS FOR SCIENTISTS AND ENGINEERS II - SHORT FORM. 1.0 Semester Hr.

(I, II) This is a bridge course for entering freshmen and new transfer students to CSM who have either a score of 5 on the BC AP Calculus exam or who have taken an appropriate Calculus II course at another institution (determined by a departmental review of course materials). Two, three and n-dimensional space, vectors, curves and surfaces in 3-dimensional space, cylindrical and spherical coordinates, and applications of these topics. Prerequisites: none. 1 hour lecture; 1 semester hour.

MATH122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS. 4.0 Semester Hrs.

Equivalent with MATH112,

(I) Same topics as those covered in MATH112 but with additional material and problems. Prerequisite: none. 4 hours lecture; 4 semester hours.

MATH198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH201. PROBABILITY AND STATISTICS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with MATH323,

(I,II,S) This course is an introduction to Probability and Statistics, including fundamentals of experimental design and data collection, the summary and display of data, elementary probability, propagation of error, discrete and continuous probability models, interval estimation, hypothesis testing, and linear regression with emphasis on applications to science and engineering. Prerequisites: MATH112, MATH122 or concurrent enrollment in MATH113. 2 hours lecture; 3 hours lab; 3 semester hours.

MATH213. CALCULUS FOR SCIENTISTS AND ENGINEERS III. 4.0 Semester Hrs.

Equivalent with MACS213,MATH214,

(I, II, S) Multivariable calculus, including partial derivatives, multiple integrals, and vector calculus. Prerequisites: Grade of C or better in MATH112 or MATH122 or Concurrent Enrollment in MATH113. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH214. CALCULUS FOR SCIENTIST AND ENGINEERS III - SHORT FORM. 1.0 Semester Hr.

Equivalent with MATH213,

(I, II) This is a bridge course for entering freshmen and new transfer students to CSM who have taken an appropriate Calculus III course at another institution (determined by a departmental review of course materials). Vector Calculus including line and surface integrals with applications to work and flux, Green's Theorem, Stokes' Theorem and the Divergence Theorem. Prerequisites: none. 1 hour lecture; 1 semester hour.

MATH222. INTRODUCTION TO DIFFERENTIAL EQUATIONS FOR GEOLOGISTS & GEOLOGICAL ENGINEERS. 2.0 Semester Hrs.

(II) An introduction to differential equations with a special emphasis on problems in the earth related fields. Topics include first and second order ordinary differential equations, Laplace Transforms, and applications relevant to the earth related fields. Prerequisites: MATH112 or MATH122. Student must also be a declared major in Geology and Geological Engineering. 2 hours lecture; 2 semester hours. **Note: Only one of MATH222 and MATH225 can be counted toward graduation in GE. Any student who completes MATH222 and then changes majors out of Geology and Geological Engineering, will be expected to complete MATH225 to meet graduation requirements. (In this case, MATH222 cannot be counted toward graduation in any manner ? even as a free elective.

MATH223. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.

Equivalent with MACS223,

(II) Same topics as those covered in MATH213 but with additional material and problems. Prerequisite: Grade of C or better in MATH122. 4 hours lecture; 4 semester hours.

MATH224. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.

(I) Early introduction of vectors, linear algebra, multivariable calculus. Vector fields, line and surface integrals. Prerequisite: none. 4 hours lecture; 4 semester hours.

MATH225. DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

Equivalent with MACS225,MACS315,

(I, II, S) Classical techniques for first and higher order equations and systems of equations. Laplace transforms. Phase-plane and stability analysis of non-linear equations and systems. Applications from physics, mechanics, electrical engineering, and environmental sciences. May not also receive credit for MATH222. Prerequisites: Grade of C or better in MATH112 or MATH122 or Concurrent Enrollment in MATH113. 3 hours lecture; 3 semester hours.

MATH235. DIFFERENTIAL EQUATIONS HONORS. 3.0 Semester Hrs.

Equivalent with MACS325,

(II) Same topics as those covered in MATH225 but with additional material and problems. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH300. FOUNDATIONS OF ADVANCED MATHEMATICS. 4.0 Semester Hrs.

(S) (WI) This course is an introduction to communication in mathematics as well computational tools for mathematics. This writing intensive course provides a transition from the Calculus sequence to the upper-division mathematics curriculum at CSM. Topics include logic and recursion, techniques of mathematical proofs, reading and writing proofs, mathematics software. Prerequisites: MATH213, MATH223 or MATH224. 2 hours lecture, 1 hour seminar, 2 hours lab; 4 semester hours.

MATH301. INTRODUCTION TO ANALYSIS. 3.0 Semester Hrs.

Equivalent with MATH401,

(I) This course is a first course in real analysis that lays out the context and motivation of analysis in terms of the transition from power series to those less predictable series. The course is taught from a historical perspective. It covers an introduction to the real numbers, sequences and series and their convergence, real-valued functions and their continuity and differentiability, sequences of functions and their pointwise and uniform convergence, and Riemann-Stieltjes integration theory. Prerequisite: MATH213, MATH223 or MATH224, and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH307. INTRODUCTION TO SCIENTIFIC COMPUTING. 3.0 Semester Hrs.

Equivalent with CSCI407, MATH407,
(I, II) This course is designed to introduce scientific computing to scientists and engineers. Students in this course will be taught various numerical methods and programming techniques to solve basic scientific problems. Emphasis will be made on implementation of various numerical and approximation methods to efficiently simulate several applied mathematical models. Prerequisites: MATH213, MATH223, or MATH224 and MATH225 or MATH235. 3 hours lecture; 3 semester hours.

MATH323. SEE MATH201. 3.0 Semester Hrs.

Equivalent with MATH201,

MATH331. MATHEMATICAL BIOLOGY. 3.0 Semester Hrs.

Equivalent with BELS331, BELS433, MACS433, MATH433,
(I) This course will discuss methods for building and solving both continuous and discrete mathematical models. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Modern Control Theory will be introduced and used to model living systems. Some concepts related to self-organizing systems will be introduced. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH332. LINEAR ALGEBRA. 3.0 Semester Hrs.

Equivalent with MACS332,
(I, II) Systems of linear equations, matrices, determinants and eigenvalues. Linear operators. Abstract vector spaces. Applications selected from linear programming, physics, graph theory, and other fields. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH334. INTRODUCTION TO PROBABILITY. 3.0 Semester Hrs.

Equivalent with MACS334, MACS434,
(I) An introduction to the theory of probability essential for problems in science and engineering. Topics include axioms of probability, combinatorics, conditional probability and independence, discrete and continuous probability density functions, expectation, jointly distributed random variables, Central Limit Theorem, laws of large numbers. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH335. INTRODUCTION TO MATHEMATICAL STATISTICS. 3.0 Semester Hrs.

Equivalent with MACS435,
(II) An introduction to the theory of statistics essential for problems in science and engineering. Topics include sampling distributions, methods of point estimation, methods of interval estimation, significance testing for population means and variances and goodness of fit, linear regression, analysis of variance. Prerequisite: MATH334. 3 hours lecture, 3 semester hours.

MATH340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

MATH342. HONORS LINEAR ALGEBRA. 3.0 Semester Hrs.

Equivalent with MACS342,
(II) Same topics as those covered in MATH332 but with additional material and problems as well as a more rigorous presentation. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH348. ADVANCED ENGINEERING MATHEMATICS. 3.0 Semester Hrs.

Equivalent with MACS348,
(I, II, S) Introduction to partial differential equations, with applications to physical phenomena. Fourier series. Linear algebra, with emphasis on sets of simultaneous equations. This course cannot be used as a MATH elective by MCS or AMS majors. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.

Equivalent with CSCI358, MACS358,
(I, II) This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines and regular languages. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH398. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH406. ALGORITHMS. 3.0 Semester Hrs.

Equivalent with CSCI406, MACS406,
(I, II) Divide-and-conquer: splitting problems into subproblems of a finite number. Greedy: considering each problem piece one at a time for optimality. Dynamic programming: considering a sequence of decisions in problem solution. Searches and traversals: determination of the vertex in the given data set that satisfies a given property. Techniques of backtracking, branch-and-bound techniques, techniques in lower bound theory. Prerequisite: CSCI262 and (MATH213, MATH223 or MATH224, and MATH358/CSCI358). 3 hours lecture; 3 semester hours.

MATH408. COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

(II) This course is designed to introduce computational methods to scientists and engineers for developing differential equations based computer models. Students in this course will be taught various numerical methods and programming techniques to simulate systems of nonlinear ordinary differential equations. Emphasis will be on implementation of various numerical and approximation methods to efficiently simulate several systems of nonlinear differential equations. Prerequisite: MATH307. 3 hours lecture, 3 semester hours.

MATH424. INTRODUCTION TO APPLIED STATISTICS. 3.0 Semester Hrs.

(I) Linear regression, analysis of variance, and design of experiments, focusing on the construction of models and evaluation of their fit. Techniques covered will include stepwise and best subsets regression, variable transformations, and residual analysis. Emphasis will be placed on the analysis of data with statistical software. Prerequisites: MATH201 or MATH335. 3 hours lecture; 3 semester hours.

MATH432. SPATIAL STATISTICS. 3.0 Semester Hrs.

(I) Modeling and analysis of data observed in a 2- or 3-dimensional region. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes. Prerequisite: MATH335. Corequisite: MATH424. 3 hours lecture; 3 semester hours.

MATH436. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.

(II) Modern methods for constructing and evaluating statistical models. Topics include generalized linear models, generalized additive models, hierarchical Bayes methods, and resampling methods. Time series models, including moving average, autoregressive, and ARIMA models, estimation and forecasting, confidence intervals. Prerequisites: MATH335 and MATH424. 3 hours lecture; 3 semester hours.

MATH437. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.

(II) Introduction to applied multivariate techniques for data analysis. Topics include principal components, cluster analysis, MANOVA and other methods based on the multivariate Gaussian distribution, discriminant analysis, classification with nearest neighbors. Prerequisites: MATH335 or MATH201. 3 hours lecture; 3 semester hours.

MATH438. STOCHASTIC MODELS. 3.0 Semester Hrs.

(II) An introduction to stochastic models applicable to problems in engineering, physical science, economics, and operations research. Markov chains in discrete and continuous time, Poisson processes, and topics in queuing, reliability, and renewal theory. Prerequisite: MATH334. 3 hours lecture, 3 semester hours.

MATH439. SURVIVAL ANALYSIS. 3.0 Semester Hrs.

(I) Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, hypothesis testing, the proportional hazards model, model diagnostics. Prerequisite: MATH335. 3 hours lecture; 3 semester hours.

MATH440. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.

Equivalent with CSCI440,
(I) This course is designed to facilitate students' learning of parallel programming techniques to efficiently simulate various complex processes modeled by mathematical equations using multiple and multi-core processors. Emphasis will be placed on implementation of various scientific computing algorithms in FORTRAN 90 and its variants using MPI and OpenMP. Prerequisite: MATH307/CSCI407. 3 hours lecture; 3 semester hours.

MATH441. COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with CSCI441,
(I) Data structures suitable for the representation of structures, maps, three-dimensional plots. Algorithms required for windowing, color plots, hidden surface and line, perspective drawings. Survey of graphics software and hardware systems. Prerequisite: CSCI262. 3 hours lecture, 3 semester hours.

MATH444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with CSCI444,
(I, II) This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techniques that can be used to develop high-quality computer graphics software. In particular, the course will cover global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Prerequisites: Basic understanding of computer graphics and prior exposure to graphics-related programming, for example, MATH441. 3 lecture hours, 3 credit hours.

MATH447. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.

Equivalent with CSCI447,
(I) Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on modern visualization techniques applicable to spatial data such as scalar, vector and tensor fields. In particular, the course will cover volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Basic understanding of computer graphics and analysis of algorithms required. Prerequisites: CSCI262 and MATH441. 3 lecture hours, 3 semester hours.

MATH454. COMPLEX ANALYSIS. 3.0 Semester Hrs.

Equivalent with MACS454,
(II) The complex plane. Analytic functions, harmonic functions. Mapping by elementary functions. Complex integration, power series, calculus of residues. Conformal mapping. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH455. PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

(I) Linear partial differential equations, with emphasis on the classical second-order equations: wave equation, heat equation, Laplace's equation. Separation of variables, Fourier methods, Sturm-Liouville problems. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH457. INTEGRAL EQUATIONS. 3.0 Semester Hrs.

(I) This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Prerequisites: MATH332 or MATH342, and MATH455. 3 hours lecture; 3 semester hours.

MATH458. ABSTRACT ALGEBRA. 3.0 Semester Hrs.

(II) This course is an introduction to the concepts of contemporary abstract algebra and applications of those concepts in areas such as physics and chemistry. Topics include groups, subgroups, isomorphisms and homomorphisms, rings, integral domains and fields. Prerequisites: MATH213, MATH223 or MATH224, and MATH300. 3 hours lecture; 3 semester hours.

MATH474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with CSCI474,

(II) This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisites: CSCI262, MATH334/MATH335, MATH358. 3 credit hours.

MATH482. STATISTICS PRACTICUM (CAPSTONE). 3.0 Semester Hrs.

(II) This is the capstone course in the Statistics option. Students will apply statistical principles to data analysis through advanced work, leading to a written report and an oral presentation. Choice of project is arranged between the student and the individual faculty member who will serve as advisor. Prerequisites: MATH335 and MATH424. 3 hours lecture; 3 semester hours.

MATH484. MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE). 3.0 Semester Hrs.

(II) This is the capstone course in the Computational and Applied Mathematics option. Students will apply computational and applied mathematics modeling techniques to solve complex problems in biological, engineering and physical systems. Mathematical methods and algorithms will be studied within both theoretical and computational contexts. The emphasis is on how to formulate, analyze and use nonlinear modeling to solve typical modern problems. Prerequisites: MATH331, MATH307, and MATH455. 3 hours lecture; 3 semester hours.

MATH491. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with CSCI491,MACS491,

(I) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Prerequisite: none. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH492. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

(II) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Prerequisite: none. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Civil and Environmental Engineering

2015-2016

Program Description

The Department of Civil & Environmental Engineering (CEE) offers design-oriented and interdisciplinary undergraduate programs in Civil Engineering and Environmental Engineering. The degrees build upon fundamental engineering principles and provide specialization within Civil and Environmental Engineering. Graduates are positioned for a broad range of professional opportunities, and are well-prepared for an engineering career in a world of rapid technological change. The Civil Engineering and Environmental Engineering BS degrees are accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

The Civil Engineering degree offers breadth in four traditional sub-fields of Civil Engineering: Geotechnical Engineering, Structural Engineering, Water Resources, and Construction Engineering. Civil students can elect to further specialize in one or more of these areas by selecting related courses to fulfill their Civil Engineering Technical Electives.

The Environmental Engineering degree introduces students to the fundamentals of environmental engineering including the scientific and regulatory basis of public health and environmental protection. The degree is designed to prepare students to investigate and analyze environmental systems and assess risks to public health and ecosystems as well as evaluate and design natural and engineered solutions to mitigate risks and enable beneficial outcomes. Topics covered include water reclamation and reuse, hazardous waste management, contaminated site remediation, environmental science, and regulatory processes.

Curriculum

During the first two years at the Colorado School of Mines (CSM), students complete a set of core courses that includes mathematics, basic sciences, and engineering sciences. Course work in mathematics is an essential part of the curriculum which gives engineering students tools for modeling, analyzing, and predicting physical and chemical phenomena. The basic sciences of physics and chemistry provide an appropriate foundation in the physical sciences; engineering science then builds upon these basic sciences and focuses on applications.

The core curriculum also includes engineering design course work within the Engineering Practice Introductory Course Sequence (EPICS I and II). These courses emphasize design methodology and stress the creative and synthesis aspects of the engineering profession. The core curriculum also includes complementary courses in the humanities and social sciences which explore the links between the environment, human society, and engineering.

In the final two years, students complete discipline-specific advanced engineering courses. The Civil Engineering students explore soil mechanics, structural theory, design of foundations, design of steel or concrete structures, and Civil Engineering technical electives. The Environmental Engineering students explore water chemistry and water quality, air pollution, the fate and transport of chemicals in the environment (air, water, and soil), water resources, environmental policy, and Environmental Engineering technical electives. The discipline-specific curriculum is complemented by courses in advanced engineering

design methodology, economics, and additional studies in liberal arts topics. At the student's discretion, free electives (9 to 12 credits) can be used to either satisfy his/her personal interest in a topic or the credits can be used to pursue an "area of special interest" (12 semester hours) or a minor (at least 18 semester hours). All students complete a capstone engineering design course which is focused on an in-depth, realistic, and multi-disciplinary engineering project.

Engineering analysis and design is emphasized with interdisciplinary project applications. For example, our unique Multidisciplinary Engineering Laboratory sequence promotes life-long learning skills using state-of-the-art instrumentation funded through a combination of grants from the U.S. Department of Education, private industry contributions, and investment by CSM.

Students interested in a research experience, in addition to their undergraduate curriculum, are encouraged to work on an Independent Study project with one of the Civil & Environmental Engineering faculty. These projects can offer an applied experience that is relevant to future graduate studies and a professional career.

Bachelor of Science in Civil Engineering Degree Requirements:

Freshman

Fall		lec	lab	sem.hrs
PAGN101	PHYSICAL EDUCATION			0.5
LAIS100	NATURE AND HUMAN VALUES			4.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			0.5
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
				17.0

Spring		lec	lab	sem.hrs
PAGN102	PHYSICAL EDUCATION			0.5
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
PHGN100	PHYSICS I - MECHANICS			4.5
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EPIC151	DESIGN (EPICS) I			3.0
				16.0

Sophomore

Fall		lec	lab	sem.hrs
EBGN201	PRINCIPLES OF ECONOMICS			3.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.5
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
CEEN241	STATICS			3.0

CSCI260	FORTRAN PROGRAMMING, 261, or EGGN 205			2.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				17.0
Spring		lec	lab	sem.hrs
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
LAIS200	HUMAN SYSTEMS			3.0
EGGN250	MULTIDISCIPLINARY ENGINEERING LABORATORY			1.5
EPIC251	DESIGN (EPICS) II			3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				17.0
Summer		lec	lab	sem.hrs
CEEN331	ENGINEERING FIELD SESSION, CIVIL			3.0
				3.0

Junior		lec	lab	sem.hrs
Fall				
LAIS/EBGN	H&SS Restricted Elective I			3.0
CEEN312	SOIL MECHANICS			3.0
CEEN312L	SOIL MECHANICS LABORATORY			1.0
CEEN314	STRUCTURAL THEORY			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
MEGN424	COMPUTER AIDED ENGINEERING			3.0
				16.0

Spring		lec	lab	sem.hrs
CE ELECT	Civil Engineering Elective *			3.0
FREE	Free Elective			3.0
CEEN415	FOUNDATION ENGINEERING			3.0
CEEN443	DESIGN OF STEEL STRUCTURES or 445			3.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I or 302			3.0
				15.0

Senior		lec	lab	sem.hrs
Fall				
LAIS/EBGN	H&SS Restricted Elective II			3.0
EGGN350	MULTIDISCIPLINARY ENGINEERING LABORATORY II			1.5
MEGN315	DYNAMICS			3.0
EGGN491	SENIOR DESIGN I			3.0
CE ELECT	Civil Engineering Elective *			3.0
CE ELECT	Civil Engineering Elective*			3.0
				16.5
Spring		lec	lab	sem.hrs
CE ELECT	Civil Engineering Elective *			3.0
LAIS/EBGN	H&SS Restricted Elective III			3.0

FREE	Free Elective	3.0
FREE	Free Elective	3.0
FREE	Free Elective	3.0
EGGN492	SENIOR DESIGN II	3.0
		18.0

Total Semester Hrs: 135.5

Required Civil Engineering Courses

CEEN241	STATICS	3.0
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING	3.0
CEEN311	MECHANICS OF MATERIALS	3.0
CEEN312	SOIL MECHANICS	3.0
CEEN312L	SOIL MECHANICS LABORATORY	1.0
CEEN314	STRUCTURAL THEORY	3.0
CEEN331	ENGINEERING FIELD SESSION, CIVIL	3.0
CEEN415	FOUNDATION ENGINEERING	3.0

Selected Electives - Civil Engineering students must take one of CEEN 443 or 445 and one of CEEN 301 or 302. These courses may also count as List A Electives if not used as a required course.

CEEN443	DESIGN OF STEEL STRUCTURES	3.0
CEEN445	DESIGN OF REINFORCED CONCRETE STRUCTURES	3.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II	3.0

List A Electives - Civil Engineering students must take 4 electives, with two of these from List A.

CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN410	ADVANCED SOIL MECHANICS	3.0
CEEN411	SOIL DYNAMICS	3.0
CEEN423	SURVEYING II	3.0
CEEN430	ADVANCED STRUCTURAL ANALYSIS	3.0
CEEN440	TIMBER AND MASONRY DESIGN	3.0
CEEN441	INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES	3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
CEEN474	SOLID WASTE MINIMIZATION AND RECYCLING	3.0
CEEN475	SITE REMEDIATION ENGINEERING	3.0
CEEN477	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CEEN481	HYDROLOGIC AND WATER RESOURCES ENGINEERING	3.0

CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN451	FLUID MECHANICS II	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0

List B Electives

CEEN476	POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE	3.0
CEEN477	SUSTAINABLE ENGINEERING DESIGN	3.0
CEEN492	ENVIRONMENTAL LAW	3.0
GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
MNGN404	TUNNELING	3.0
MNGN405	ROCK MECHANICS IN MINING	3.0
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0

Bachelor of Science in Environmental Engineering Degree Requirements:

Freshman

Fall		lec	lab	sem.hrs
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS			4.0
LAIS100	NATURE AND HUMAN VALUES			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			0.5
PAGN101	PHYSICAL EDUCATION			0.5
				17.0

Spring

Spring		lec	lab	sem.hrs
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EPIC151	DESIGN (EPICS) I			3.0
PHGN100	PHYSICS I - MECHANICS			4.5
PAGN102	PHYSICAL EDUCATION			0.5
				16.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS, CBEN 210, or MEGN 361			3.0

PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS		4.5	EVE ELECT	Environmental Engineering Elective*	3.0
CEEN241	STATICS		3.0	EVE ELECT	Environmental Engineering Elective*	3.0
PAGN2XX	PHYSICAL EDUCATION		0.5	LAIS/EBGN	H&SS Restricted Elective II	3.0
			15.0			
Spring			lec	lab	sem.hrs	Spring
MATH225	DIFFERENTIAL EQUATIONS		3.0	EGGN492	SENIOR DESIGN II	3.0
CEEN311	MECHANICS OF MATERIALS		3.0	CEEN492	ENVIRONMENTAL LAW	3.0
EGGN250	MULTIDISCIPLINARY ENGINEERING LABORATORY		1.5	EVE ELECT	Environmental Engineering Elective*	3.0
EPIC251	DESIGN (EPICS) II		3.0	LAIS/EBGN	H&SS Restricted Elective III	3.0
EBGN201	PRINCIPLES OF ECONOMICS		3.0	FREE	Free Elective	3.0
PAGN2XX	PHYSICAL EDUCATION		0.5			
LAIS200	HUMAN SYSTEMS		3.0			
			17.0			
Junior				Required Environmental Engineering Courses		
Fall			lec	lab	sem.hrs	
BIOSCI ELECT	Bioscience Elective**		3.0	CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I		3.0	CEEN302	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II	3.0
CSCI260	FORTRAN PROGRAMMING or 261		2.0	CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY	3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS		3.0	or CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY	
CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING		3.0	CEEN310	FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING	3.0
FREE	Free Elective		3.0	CEEN330	ENGINEERING FIELD SESSION, ENVIRONMENTAL	3.0
			17.0	CEEN481	HYDROLOGIC AND WATER RESOURCES ENGINEERING	3.0
Spring			lec	lab	sem.hrs	CEEN492
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II		3.0	or LAIS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
CEEN303	ENVIRONMENTAL ENGINEERING LABORATORY or 482		3.0	*Elective Courses - Environmental Engineering students are required to take five electives from the following list. Note - CEEN 482 Hydro & Water Resources Lab cannot be used to meet the Env Lab requirement and as an elective.		
EGGN350	MULTIDISCIPLINARY ENGINEERING LABORATORY II		1.5	CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
EVE ELECT	Environmental Engineering Elective*		3.0	CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
EVE ELECT	Environmental Engineering Elective*		3.0	CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
LAIS/EBGN	H&SS Restricted Elective I		3.0	CEEN472	ONSITE WATER RECLAMATION AND REUSE	3.0
			16.5	CEEN474	SOLID WASTE MINIMIZATION AND RECYCLING	3.0
Summer			lec	lab	sem.hrs	CEEN475
CEEN330	ENGINEERING FIELD SESSION, ENVIRONMENTAL		3.0	CEEN476	POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE	3.0
			3.0	CEEN477	SUSTAINABLE ENGINEERING DESIGN	3.0
Senior				CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
Fall			lec	lab	sem.hrs	CEEN482
EGGN491	SENIOR DESIGN I		3.0	CEEN482	HYDROLOGY AND WATER RESOURCES LABORATORY	3.0
CEEN481	HYDROLOGIC AND WATER RESOURCES ENGINEERING		3.0	CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
FREE	Free Elective		3.0			

GEGN466	GROUNDWATER ENGINEERING	3.0
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****Bio-science Elective Courses - Environmental Engineering students are required to take one Bio-science elective course from the following list.**

BIOL110	FUNDAMENTALS OF BIOLOGY I	4.0
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CHGN462	MICROBIOLOGY	3.0

Please note - CEEN461 Fundamentals of Ecology cannot be used to meet both the Environmental Elective and the Biology Elective requirements.

Professor and Department Head

John E. McCray

Professor and James R. Paden Distinguished Chair

Marte Gutierrez

Professor and AMAX Distinguished Chair

Tissa Illangasekare

Professor and Grewcock Distinguished Chair

Michael Mooney

University Emeritus Professor

Robert L. Siegrist

Professors

D.V. Griffiths

Terri Hogue

Ning Lu

John R. Spear

Timothy Strathmann

Associate Professors

Tzahi Y. Cath

Ronald R.H. Cohen

Linda A. Figueroa

Christopher Higgins

Panos Kioussis

Junko Munakata Marr

Jonathan O. Sharp

Kamini Singha, (Joint appointment with Geology and Geological Engineering)

Assistant Professors

Christopher Bellona

Reza Hedayat

Shiling Pei

Kathleen Smits

Teaching Professors

Joseph Crocker

Candace Sulzbach, Emeritus Teaching Professor

Teaching Associate Professors

Andres Guerra

Hongyan Liu

Susan Reynolds

Alexandra Wayllace

Teaching Assistant Professor

Jeffrey Holley

Adjunct Faculty

Sidney Innerebner

Paul B. Queneau

Tanya Rauch

Patrick Ryan

Research Assistant Professors

Mengistu Geza

Lee Landkamer

Dong Li

Courses

CEEN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN241. STATICS. 3.0 Semester Hrs.

Equivalent with DCGN241,
(I, II, S) Forces, moments, couples, equilibrium, centroids and second moments of areas, volumes and masses, hydrostatics, friction, virtual work. Applications of vector algebra to structures. Prerequisite: PHGN100 and credit or concurrent enrollment in MATH112. 3 hours lecture; 3 semester hours.

CEEN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN301. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I. 3.0 Semester Hrs.

Equivalent with EGGN353,ESGN353,

(I, II) Topics covered include history of water related environmental law and regulation, major sources and concerns of water pollution, water quality parameters and their measurement, material and energy balances, water chemistry concepts, microbial concepts, aquatic toxicology and risk assessment. Prerequisite: CHGN122, PHGN100 and MATH213. 3 hours lecture; 3 semester hours.

CEEN302. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II. 3.0 Semester Hrs.

Equivalent with EGGN354,ESGN354,

(I, II) Introductory level fundamentals in atmospheric systems, air pollution control, solid waste management, hazardous waste management, waste minimization, pollution prevention, role and responsibilities of public institutions and private organizations in environmental management(relative to air, solid and hazardous waste). Prerequisite: CHGN122, PHGN100 and MATH213. 3 hours lecture; 3 semester hours.

CEEN303. ENVIRONMENTAL ENGINEERING LABORATORY. 3.0 Semester Hrs.

Equivalent with ESGN355,

(I) This course introduces the laboratory and experimental techniques used for generating and interpreting data in environmental science and engineering related to water, land, and environmental health. An emphasis is placed on quantitative chemical and microbiological analysis of water and soil samples relevant to water supply and wastewater discharge. Topics include basic water quality measurements (pH, conductivity, etc.) and quantitative analysis of chemicals by chromatographic and mass spectrometric techniques. Advanced topics include quantitative and qualitative analysis of bioreactor performance, bench testing for water treatment, and measurement and control of disinfection by-products. Prerequisites: CEEN301 or CEEN302. 1 hour lecture, 6 hour lab. 3 semester hours.

CEEN310. FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING. 3.0 Semester Hrs.

(I, II) The study and application of principles of incompressible fluid mechanics. Topics include: hydrostatic forces on submerged surfaces, buoyancy, control volume analysis, conservation of mass, fluid motion, Bernoulli's equation and conservation of energy, momentum, dimensional analysis, internal flow (pipe systems), external flow (drag and lift), flow in open channels, and hydraulic jumps. The course will also introduce concepts about municipal water supply networks and storm water drainage and wastewater collection and treatment systems. May not also receive credit for PEGN251 or MEGN351. Prerequisites: PHGN100. Co-requisites: CEEN241. 3 lecture hours, 3 semester hours.

CEEN311. MECHANICS OF MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN320,

(I, II, S) Fundamentals of stresses and strains, material properties including axial, torsional, bending, and combined loadings. Stress at a point; stress transformations and Mohr's circle for stress; beam deflections, thin-wall pressure vessels, columns and buckling, and stress concentrations. May not also receive credit for MEGN312. Prerequisite: CEEN241 or MNGN317. 3 hours lecture; 3 semester hours.

CEEN312. SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN361,

(I, II) An introductory course covering the engineering properties of soil, soil phase relationships and classification. Principle of effective stress. Seepage through soils and flow nets. Soil compressibility, consolidation and settlement prediction. Shear strength of soils. Prerequisite: CEEN311. 3 hours lecture; 3 semester hours.

CEEN312L. SOIL MECHANICS LABORATORY. 1.0 Semester Hr.

Equivalent with EGGN363,

(I, II) Intro duction to laboratory testing methods in soil mechanics. Classification, permeability, compressibility, shear strength. Prerequisite: CEEN312 or concurrent enrollment. 3 hours lab; 1 semester hour.

CEEN314. STRUCTURAL THEORY. 3.0 Semester Hrs.

Equivalent with EGGN342,

(I, II) Analysis of determinate and indeterminate structures for both forces and deflections. Influence lines, work and energy methods, moment distribution, matrix operations, computer methods. Prerequisite: CEEN311. 3 hours lecture; 3 semester hours.

CEEN330. ENGINEERING FIELD SESSION, ENVIRONMENTAL. 3.0 Semester Hrs.

Equivalent with EGGN335,

(S) The environmental module is intended to introduce students to laboratory and field analytical skills used in the analysis of an environmental engineering problem. Students will receive instruction on the measurement of water quality parameters (chemical, physical, and biological) in the laboratory and field. The student will use these skills to collect field data and analyze a given environmental engineering problem. Prerequisites: CEEN301, EPIC251, MATH201. Three weeks in summer session; 3 semester hours.

CEEN331. ENGINEERING FIELD SESSION, CIVIL. 3.0 Semester Hrs.

Equivalent with EGGN234,

(S) The theory and practice of modern surveying. Lectures and hands-on field work teaches horizontal, vertical, and angular measurements and computations using traditional and modern equipment. Subdivision of land and applications to civil engineering practice, GPS and astronomic observations. Prerequisite: EPIC251. Three weeks (6 day weeks) in summer field session; 3 semester hours.

CEEN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

Equivalent with EGGN340,EGGN340C,

(I,II,S) Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.

CEEN398. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN405. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN460,

(S) Introduction to the use of numerical methods in the solution of problems encountered in engineering analysis and design, e.g. linear simultaneous equations (e.g. analysis of elastic materials, steady heat flow); roots of nonlinear equations (e.g. vibration problems, open channel flow); eigen-value problems (e.g. natural frequencies, buckling and elastic stability); curve fitting and differentiation (e.g. interpretation of experimental data, estimation of gradients); integration (e.g. summation of pressure distributions, finite element properties, local averaging); ordinary differential equations (e.g. forced vibrations, beam bending). All course participants will receive source code consisting of a suite of numerical methods programs. Prerequisite: CSCI260 or CSCI261, MATH225, CEEN311. 3 hours lecture; 3 semester hours.

CEEN406. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN442,

(II) A course combining finite element theory with practical programming experience in which the multi-disciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple structural element, solid elasticity, steady state analysis, transient analysis. Students get a copy of all the source code published in the course textbook. Prerequisite: CEEN311. 3 hours lecture; 3 semester hours.

CEEN410. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN448,

Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength and probabilistic methods. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisite: CEEN312. 3 hour lectures; 3 semester hours. Fall even years.

CEEN411. SOIL DYNAMICS. 3.0 Semester Hrs.

Equivalent with CEEN512,EGGN431,

(II) Soil Dynamics combines engineering vibrations with soil mechanics, analysis, and design. Students will learn to apply basic principles of dynamics towards the analysis and design of civil infrastructure systems when specific issues as raised by the inclusion of soil materials must be considered. Prerequisites: CEEN311, CEEN312, and MATH225. 3 hours lecture; 3 semester hours.

CEEN412. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with CEEN511,

(II) Systematic introduction of soil mechanics under partially saturated conditions. Topics include principles of seepage under variably saturated conditions, principle of the effective stress, shear strength theory, and hydraulic and mechanical properties. When this course is cross-listed and concurrent with CEEN511, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 lecture hours, 3 semester hours.

CEEN415. FOUNDATION ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN464,

(I, II) Techniques of subsoil investigation, types of foundations and foundation problems, selection of basis for design of foundation types. Open-ended problem solving and decision making. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN421. HIGHWAY AND TRAFFIC ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN435,

The emphasis of this class is on the multi-disciplinary nature of highway and traffic engineering and its application to the planning and design of transportation facilities. In the course of the class the students will examine design problems that will involve: geometric design, surveying, traffic operations, hydrology, hydraulics, elements of bridge design, statistics, highway safety, transportation planning, engineering ethics, soil mechanics, pavement design, economics, environmental science. 3 credit hours. Taught on demand.

CEEN423. SURVEYING II. 3.0 Semester Hrs.

Equivalent with EGGN333,EGGN433,

(I) Engineering projects with local control using levels, theodolites and total stations, including surveying applications of civil engineering work in the "field". Also includes engineering astronomy and computer generated designs; basic road design including centerline staking, horizontal and vertical curves, slope staking and earthwork volume calculations. Use of commercial software for final plan/profile and earthwork involved for the road project data collected in the field. Conceptual and mathematical knowledge of applying GPS data to engineering projects. Some discussion of the principles and equations of projections (Mercator, Lambert, UTM, State Plane, etc.) and their relationship to the databases of coordinates based on (North American Datum) NAD '27, NAD '83 and (High Accuracy Reference Network) HARN. Prerequisite: CEEN331. 2 hours lecture; 8-9 field work days; 3 semester hours.

CEEN430. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN441,

(II) Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. Prerequisite: CEEN314. 3 hour lectures; 3 semester hours.

CEEN433. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.

Equivalent with CEEN533,

(II) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN533, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisite: CEEN314. 3 lecture hours, 3 semester hours.

CEEN440. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.

Equivalent with EGGN447,

(II) The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Prerequisite: CEEN311 or equivalent. 3 hours lecture: 3 semester hours. Spring odd years.

CEEN441. INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES. 3.0 Semester Hrs.

Equivalent with EGGN494,

(I) This course provides students with an introduction to seismic design as it relates to structures. Students will become familiar with the sources of seismic disturbances, the physics of seismic energy transmission, and the relationship between ground disturbance and the resulting forces experienced by structures. The theory and basis for existing building code provisions relating to seismic design of structures will be introduced. Building code requirements and design methodologies will be examined and applied. Prerequisites: CEEN443, or CEEN445, or CEEN440. 3 hours lecture; 3 semester hours.

CEEN443. DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.

Equivalent with EGGN444,

(I, II) To learn application and use the American Institute of Steel Construction (AISC) Steel Construction Manual. Course develops an understanding of the underlying theory for the design specifications. Students learn basic steel structural member design principles to select the shape and size of a structural member. The design and analysis of tension members, compression members, flexural members, and members under combined loading is included, in addition to basic bolted and welded connection design. Prerequisite: CEEN314. 3 hours lecture; 3 semester hours.

CEEN445. DESIGN OF REINFORCED CONCRETE STRUCTURES. 3.0 Semester Hrs.

Equivalent with EGGN445,

(I, II) This course provides an introduction to the materials and principles involved in the design of reinforced concrete. It will allow students to develop an understanding of the fundamental behavior of reinforced concrete under compressive, tensile, bending, and shear loadings, and gain a working knowledge of strength design theory and its application to the design of reinforced concrete beams, columns, slabs, and footings. Prerequisite: CEEN314. 3 hours lecture; 3 semester hours.

CEEN461. FUNDAMENTALS OF ECOLOGY. 3.0 Semester Hrs.

Equivalent with ESGN401,

(II). Biological and ecological principles discussed and industrial examples of their use given. Analysis of ecosystem processes, such as erosion, succession, and how these processes relate to engineering activities, including engineering design and plant operation. Criteria and performance standards analyzed for facility siting, pollution control, and mitigation of impacts. North American ecosystems analyzed. Concepts of forestry, range, and wildlife management integrated as they apply to all of the above. Three to four weekend trips will be arranged during the semester. 3 lecture hours, 3 semester hours.

CEEN470. WATER AND WASTEWATER TREATMENT PROCESSES. 3.0 Semester Hrs.

Equivalent with BELS453,EGGN453,ESGN453,

(I) The goal of this course is to familiarize students with the unit operations and processes involved in water and wastewater treatment. This course will focus on the physical, chemical, and biological processes for water and wastewater treatment and reclamation. Treatment objectives, process theory, and practice are considered in detail. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN471. WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN. 3.0 Semester Hrs.

(II) The goal of this course is to familiarize students with the design of domestic and industrial water and wastewater treatment systems. This course will focus on the combination of physical, chemical, and biological processes and technologies to form a water or wastewater treatment system. Source water quality, treatment objectives, water reuse, multi-barrier approaches, and water and energy efficiency are considered in detail. Prerequisites: CEEN470, or CEEN570, or other water or wastewater treatment design courses (for graduate students enrolled in this course). 3 hours lecture; 3 semester hours.

CEEN472. ONSITE WATER RECLAMATION AND REUSE. 3.0 Semester Hrs.

Equivalent with ESGN460,

(II). Appropriate solutions to water and sanitation in the U.S. and globally need to be effective in protecting public health and preserving water quality while also being acceptable, affordable and sustainable. Onsite and decentralized systems have the potential to achieve these goals in rural areas, peri-urban developments, and urban centers in small and large cities. Moreover they can improve water use efficiency, conserve energy and enable distributed energy generation, promote green spaces, restore surface waters and aquifers, and stimulate new green companies and jobs. A growing array of approaches, devices and technologies have evolved that include point-of-use water purification, waste source separation, conventional and advanced treatment units, localized natural treatment systems, and varied resource recovery and recycling options. This course will focus on the engineering selection, design, and implementation of onsite and decentralized systems for water reclamation and reuse. Topics to be covered include process analysis and system planning, water and waste stream attributes, water and resource conservation, confined unit and natural system treatment technologies, effluent collection and clustering, recycling and reuse options, and system management. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN473. HYDRAULIC PROBLEMS. 3.0 Semester Hrs.

Equivalent with EGGN451,

(I) Review of fundamentals, forces on submerged surfaces, buoyancy and flotation, gravity dams, weirs, steady flow in open channels, backwater curves, hydraulic machinery, elementary hydrodynamics, hydraulic structures. Prerequisites: MEGN351. 3 hours lecture; 3 semester hours.

CEEN474. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.

Equivalent with ESGN462,

(I) The course objective is to put the student into the shoes of a plant manager having process responsibility for waste minimization, focusing on recycling. Emphasis is on proven and emerging solutions, especially those associated with heavy metals. Waste minimization generally requires a solid understanding of alternative raw materials and process technologies, in combination with creativity and sensitivity to economics. Prerequisites: Senior standing 3 hours lecture; 3 semester hours.

CEEN475. SITE REMEDIATION ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN457,ESGN457,

(II) This course describes the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. Common isolation and containment and in-situ and ex-situ treatment technology will be covered. Computerized decision-support tools will be used and case studies will be presented. Prerequisites: CEEN302. 3 hours lecture; 3 semester hours.

CEEN476. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.

Equivalent with ESGN463,

(II) The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. Prerequisite: CEEN301 or CEEN302. 3 hours lecture; 3 semester hours.

CEEN477. SUSTAINABLE ENGINEERING DESIGN. 3.0 Semester Hrs.

Equivalent with EGGN490,

(I) This course is a comprehensive introduction into concept of sustainability and sustainable development from an engineering point of view. It involves the integration of engineering and statistical analysis through a Life Cycle Assessment tool, allowing a quantitative, broad-based consideration any process or product design and their respective impacts on environment, human health and the resource base. The requirements for considering social implications are also discussed. Prerequisites: Senior or graduate standing; 3 hours lecture, 3 semester hours.

CEEN480. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN440,

(I) This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN481. HYDROLOGIC AND WATER RESOURCES ENGINEERING. 3.0 Semester Hrs.

Equivalent with ESGN459,

(II) This course introduces the principles of physical hydrology in the framework of hydrologic and water resources engineering. Topics include groundwater, surface water, infiltration, evapotranspiration, sediment transport, flood and drought analysis, lake and reservoir analysis, water-resources planning, water quality engineering, and storm-sewer hydraulics, water-wastewater distribution /collection, engineering design problems. Prerequisites: CEEN301. 3 hour lecture; 3 semester hours.

CEEN482. HYDROLOGY AND WATER RESOURCES LABORATORY. 3.0 Semester Hrs.

(I) This course introduces students to the collection, compilation, synthesis and interpretation of data for quantification of the components of the hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Students will use hydrologic variables and parameters to evaluate watershed processes and behavior. Students will also survey and apply measurement techniques necessary for watershed studies. Advanced topics include development, construction, and application of analytical models for selected problems in hydrology and water resources. Prerequisites: CEEN481. 2 hour lecture; 3 hour lab; 3 semester hours.

CEEN492. ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with ESGN490,

(I) Specially designed for the needs of the environmental quality engineer, scientist, planner, manager, government regulator, consultant, or advocate. Highlights include how our legal system works, environmental law fundamentals, all major US EPA/state enforcement programs, the National Environmental Policy Act, air and water pollutant laws, risk assessment and management, and toxic and hazardous substance laws (RCRA, CERCLA, TSCA, LUST, etc). Prerequisites: CEEN301 or CEEN302. 3 hours lecture; 3 semester hours.

CEEN497. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**CEEN498. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Electrical Engineering and Computer Science

2015-2016

Program Description

The Department of Electrical Engineering and Computer Science develops graduates who enable the management of tremendous amounts of data and energy around the world. The department offers two undergraduate degrees: Bachelor of Science in Computer Science and Bachelor of Science in Electrical Engineering. Graduates of both programs are in a position to take advantage of a broad variety of professional opportunities, and are well-prepared for a career in a world of rapid technological change.

BS in Computer Science

Computing has become ubiquitous, impacting almost every aspect of modern life, and playing an important role in many technological advances. Computing jobs are among the highest paid, and computing professionals generally report high job satisfaction. Graduates from our program have found employment with many different types of companies including technology, engineering, and financial companies.

The CS degree at CSM is designed to be accessible to students with or without prior programming experience. The Introduction to Computer Science course introduces students to the building blocks of CS and provides a brief introduction to procedural programming in Python. The second computing course, Programming Concepts, emphasizes development of programming skills in an object-oriented language. The third introductory course, Data Structures, provides an understanding of the classic data representation schemes, algorithms, and algorithm analysis that form the foundation for all advanced work in computing.

Required CS courses provide the fundamental skills and knowledge that are critical to success in computing. These courses reflect a mixture of theory and practice, including discrete structures, design and analysis of algorithms, principles of programming languages, computer architecture, operating systems, and software engineering. In the required Elements of Computing Systems course, students consolidate their understanding of CS by constructing a simulator for an entire modern computer from the ground up. The capstone field session course provides students an opportunity to work in teams to create software products for real clients.

Elective courses in CS allow students to explore a variety of important computing topics, such as graphics and visualization, human computer interaction, artificial intelligence, database management, and web programming. Elective courses often relate to recent trends in computing, covering topics such as security, high performance computing, wireless sensor networks, and mobile applications.

Computing is a broad field with applicability to most science and engineering domains. The CS minor is designed for students in other

disciplines to receive a solid grounding in the basics, which should enable them to apply their computing skills to solve problems in other domains.

Program Educational Objectives (*Bachelor of Science in Computer Science*)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Computer Science Program at CSM has established the following program educational objectives:

Students will demonstrate technical expertise within computer science by:

- Designing and implementing solutions to practical problems in science and engineering,
- Using appropriate technology as a tool to solve problems in computer science, and
- Creating efficient algorithms and well-structured computer programs.

Students will demonstrate a breadth and depth of knowledge within computer science by:

- Extending course material to solve original problems,
- Applying knowledge of computer science to the solution of problems, and
- Identifying, formulating and solving computer science problems.

Students will demonstrate an understanding and appreciation for the relationship of computer science to other fields by:

- Applying computer science to solve problems in other fields,
- Working in cooperative multidisciplinary teams, and
- Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate computer science effectively by:

- Giving oral presentations,
- Completing written explanations,
- Interacting effectively in cooperative teams,
- Creating well-documented programs, and
- Understanding and interpreting written material in computer science.

BS in Electrical Engineering

A distinguishing feature of the EE program at CSM is a focus in three specific areas: energy and power systems; antennas and wireless communications; and information and systems sciences, which includes embedded processors, signal processing and control systems. Graduates from our program find employment in the power industry, engineering consulting firms, renewable energy companies, aerospace and communications firms, as well as a wide variety of companies that rely on embedded intelligence to manage data and systems. Another popular choice of our students after graduation is graduate school, where an advanced degree will open up opportunities in corporate and government research labs or academia, and the opportunity to become technological leaders.

Students in the Electrical Engineering program complete a set of core courses that include mathematics, basic sciences, and engineering sciences during their first two years. Course work in mathematics is an essential part of the curriculum, which gives engineering students essential tools for modeling, analyzing, and predicting physical phenomena. The basic sciences are represented by physics and

chemistry, which provide an appropriate foundation in the physical sciences. Engineering sciences build upon the basic sciences and are focused on applications.

Students get early-hands-on-design experience in the first year through the Engineering Practice Introductory Course (EPIC I). This experience teaches design methodology and stresses the creative and synthesis aspects of the engineering profession. Finally, the first two years includes systems-oriented courses with humanities and social sciences content; these courses explore the linkages within the environment, human society, and engineered devices.

In the final two years, students complete an advanced core that includes circuit analysis, electronics, electromagnetic fields and waves, and digital systems. Because of our program focus, the core curriculum also includes courses in signal processing, embedded microprocessor systems design, machines and power systems, and control systems. Students can also take specialized electives that further develop their expertise in one of these focus areas, or in other areas such as robotics, biomedical engineering, and computing.

In their final year, students complete a capstone design course that is focused on an in-depth engineering project. The projects are generated by customer demand, and include experiential verification to ensure a realistic design experience.

The Bachelors of Science degree in Electrical Engineering is accredited by ABET.

Program Educational Objectives (Bachelor of Science in Electrical Engineering)

The Electrical Engineering program contributes to the educational objectives described in the CSM Graduate Profile. In addition, the Electrical Engineering Program at CSM has established the following program educational objectives:

Within three years of attaining the BSEE degree:

1. Graduates will be working in their chosen field or will be successfully pursuing a graduate degree.
2. Graduates will be situated in growing careers, generating new knowledge, and exercising leadership in the field of electrical engineering.
3. Graduates will be contributing to the needs of society through professional practice, research, and service.

Bachelor of Science in Computer Science Degree Requirements:

Freshman

Fall		lec	lab	sem.hrs
CSCI101	INTRODUCTION TO COMPUTER SCIENCE			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
LAIS100	NATURE AND HUMAN VALUES			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			0.5
PAGN101	PHYSICAL EDUCATION			0.5
				16.0

Spring		lec	lab	sem.hrs
CSCI261	PROGRAMMING CONCEPTS			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EPIC151	DESIGN (EPICS) I			3.0
PHGN100	PHYSICS I - MECHANICS			4.5
PAGN102	PHYSICAL EDUCATION			0.5
				15.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.5
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS, BIOL 110, or CHGN 122 (Distributed Science Elective)			4.0
CSCI262	DATA STRUCTURES			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				16.0

Spring		lec	lab	sem.hrs
CSCI341	COMPUTER ORGANIZATION			3.0
CSCI358	DISCRETE MATHEMATICS			3.0
EBGN201	PRINCIPLES OF ECONOMICS			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
LAIS200	HUMAN SYSTEMS			3.0
				15.5

Junior

Fall		lec	lab	sem.hrs
CSCI306	SOFTWARE ENGINEERING			3.0
MATH332	LINEAR ALGEBRA			3.0
CSCI403	DATA BASE MANAGEMENT			3.0
FREE	Free Elective			3.0
FREE	Free Elective			3.0
				15.0

Spring		lec	lab	sem.hrs
CSCI406	ALGORITHMS			3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS			3.0
CSCI ELECT	Computer Science Elective*			3.0
LAIS/EBGN	H&SS Restricted Elective I			3.0
FREE	Free Elective			3.0
FREE	Free Elective			1.0
				16.0

Summer		lec	lab	sem.hrs
CSCI370	ADVANCED SOFTWARE ENGINEERING			6.0
				6.0

Senior

Fall		lec	lab	sem.hrs
CSCI442	OPERATING SYSTEMS			3.0

CSCI ELECT	Computer Science Elective*	3.0
CSCI ELECT	Computer Science Elective*	3.0
LAIS/EBGN	H&SS Restricted Elective II	3.0
FREE	Free Elective	3.0

15.0

Spring		lec	lab sem.hrs
CSCI400	PRINCIPLES OF PROGRAMMING LANGUAGES		3.0
CSCI ELECT	Computer Science Elective*		3.0
LAIS/EBGN	H&SS Restricted Elective III		3.0
FREE	Free Elective		3.0
FREE	Free Elective		3.0

15.0**Total Semester Hrs: 129.5**

* CSCI Electives can be chosen from any 400-level CSCI course. Please see the Courses Tab for course listings.

Combined BS/MS in Computer Science

The Department of Electrical Engineering and Computer Science offers a combined Bachelor of Science/Master of Science program in Computer Science that enables students to work on a Bachelor of Science and a Master of Science simultaneously. Normally a Master's Degree requires 36 credit hours and takes two years to complete. Under the Combined Program, students will count two courses (CSCI406 and CSCI442) toward both degrees, so only 30 additional credit hours are needed to complete the degree. One additional 400-level course may be counted toward the graduate degree. Students selecting the Thesis option will be required to complete 18 hours of coursework and a thesis (12 credit hours). Students selecting the Non-Thesis option will be required to complete 30 credit hours of coursework. There are two required graduate-level courses: CSCI564 (Advanced Architecture) and CSCI561 (Theory of Computation). The remaining courses are all electives. Descriptions can be found in the EECS Graduate Bulletin.

Students may not apply for the combined program until they have taken five or more Computer Science classes at CSM (classes transferred from other universities will not be considered). This requirement may be met by any 200-level or above course with a CSCI prefix (e.g., CSCI261, CSCI306, CSCI442, etc.). Since CSCI370 (Field Session) is based almost exclusively on team work, it may not be counted as one of the five courses. Independent study courses (i.e., CSCI499) are also not included in the five courses. CSCI274 is a one credit hour course which also may not be counted as one of the five courses.

Students should have an overall GPA of at least 2.5 and a GPA of 3.2 for courses in the major. The calculation of GPA in the major will be based on *all* 200-level or above CSCI courses except those excluded above (i.e., CSCI274, CSCI370 and CSCI499). If a course is taken multiple times, all of the grades will be included into the GPA calculation. Interested students with a lower GPA must write an essay to explain why they should be admitted to the program.

Bachelor of Science in Electrical Engineering Degree Requirements:

Freshman

Fall		lec	lab sem.hrs
CHGN121	PRINCIPLES OF CHEMISTRY I		4.0
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS, BIOL 110, CSCI 101, or CHGN 122 (Distributed Science 1)		4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I		4.0
LAIS100	NATURE AND HUMAN VALUES		4.0
CSM101	FRESHMAN SUCCESS SEMINAR		0.5
PAGN101	PHYSICAL EDUCATION		0.5

17.0

Spring

		lec	lab sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II		4.0
EPIC151	DESIGN (EPICS) I		3.0
PHGN100	PHYSICS I - MECHANICS		4.5
PAGN102	PHYSICAL EDUCATION		0.5
CSCI101	INTRODUCTION TO COMPUTER SCIENCE, BIOL 110, CHGN 122, or GEGN 101 (Distributed Science 2)		3.0

15.0

Sophomore

Fall		lec	lab sem.hrs
LAIS200	HUMAN SYSTEMS		3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS		4.5
CSCI261	PROGRAMMING CONCEPTS		3.0
PAGN2XX	PHYSICAL EDUCATION		0.5

15.0

Spring

		lec	lab sem.hrs
MATH225	DIFFERENTIAL EQUATIONS		3.0
EBGN201	PRINCIPLES OF ECONOMICS		3.0
PAGN2XX	PHYSICAL EDUCATION		0.5
EENG284	DIGITAL LOGIC		4.0
EENG282	ELECTRICAL CIRCUITS		4.0

14.5

Junior

Fall		lec	lab sem.hrs
MATH332	LINEAR ALGEBRA		3.0
MEGN361	THERMODYNAMICS I or CEEN 241		3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS		3.0

EENG310	INFORMATION SYSTEMS SCIENCE I		4.0
EENG383	MICROCOMPUTER ARCHITECTURE AND INTERFACING		4.0
			17.0
Spring		lec	lab sem.hrs
EENG385	ELECTRONIC DEVICES AND CIRCUITS		4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS		3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY		4.0
EENG311	INFORMATION SYSTEMS SCIENCE II (Information Systems Science II)		3.0
			14.0
Summer		lec	lab sem.hrs
EENG334	ENGINEERING FIELD SESSION, ELECTRICAL		3.0
			3.0
Senior			
Fall		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective I		3.0
LAIS/EBGN	H&SS Restricted Elective II		3.0
EGGN450	MULTIDISCIPLINARY ENGINEERING LABORATORY III		1.0
EGGN491	SENIOR DESIGN I		3.0
ELEC Elective	Electrical Engineering Elective *		3.0
ELEC Elective	Electrical Engineering Elective *		3.0
			16.0
Spring		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective III		3.0
EGGN492	SENIOR DESIGN II		3.0
ELEC Elective	Electrical Engineering Elective *		3.0
FREE	Free Elective		3.0
FREE	Free Elective		3.0
FREE	Free Elective		3.0
			18.0

Total Semester Hrs: 129.5

* Electrical Engineering students are required to take three Electrical Engineering Electives from the following list:

Electrical Engineering Electives:

CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CSCI410	ELEMENTS OF COMPUTING SYSTEMS	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
EENG411	DIGITAL SIGNAL PROCESSING	3.0

EENG413	ANALOG AND DIGITAL COMMUNICATION SYSTEMS	4.0
EENG417	MODERN CONTROL DESIGN	3.0
EENG470	INTRODUCTION TO HIGH POWER ELECTRONICS	3.0
EENG472	PRACTICAL DESIGN OF SMALL RENEWABLE ENERGY SYSTEMS	3.0
EENG480	POWER SYSTEMS ANALYSIS	3.0
EENG481	ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS	3.0
EENG489	COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS	3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN441	INTRODUCTION TO ROBOTICS (Introduction to Mathematical Physics)	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN440	SOLID STATE PHYSICS	3.0
PHGN441	SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA	3.0
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS	3.0

*Additional EENG or CSCI 400 level and graduate level classes taught in the EECS department can be considered as tech electives. Talk to your advisor for further guidance. 300 level or higher courses from other departments can be considered by the Department Head.

Combined BS/MS in Electrical Engineering

The Department of Electrical Engineering and Computer Science offers a combined Bachelor of Science/Master of Science program in Electrical Engineering that enables students to work on a Bachelor of Science and a Master of Science simultaneously. This allows undergraduate students to take courses that will count for their graduate degree requirements, while still finishing their undergraduate degree requirements. This will be especially attractive to students who intend to go on to the graduate program, and have availability in their schedules even while fulfilling the undergraduate requirements. Another advantage is that there is an expedited graduate school application process, as described below.

Students must be admitted into the Combined BS/MS degree program prior to the close of registration of the term in which any course toward the MS degree will be applied. Typically this is the beginning of the student's Senior year, but students may apply as early as the first semester of their Junior year. Admissions must be granted no later than the end of registration in the last semester of the Senior year. In order to apply for the combined program, a pro forma graduate school application

is submitted, and as long as the undergraduate portion of the program is successfully completed and the student has a GPA above 3.0, the student is admitted to the non-thesis Master of Science degree program in Electrical Engineering.

Students are required to take an additional 30 credit hours for the M.S. degree. Up to nine of the 30 credit hours beyond the undergraduate degree requirements can be 400-level courses. The remainder of the courses will be at the graduate level (500-level and above). There is no limit on the number of graduate level (500-level and above) courses a student may take beyond the undergraduate degree requirements, but a student must complete at least one semester as a registered graduate student after completion of the undergraduate degree before being awarded a graduate degree. Students must declare graduate courses through the Registrar's Office at time of registration. Grades count toward the graduate GPA and must meet the minimum grade requirements (C# or higher) to be counted toward graduation requirements. Courses may not be used to meet undergraduate financial aid requirements. Students will declare course work as regular graduate courses on Admission to Candidacy Form. Students should follow the MS Non-thesis degree requirements based on their track in selecting appropriate graduate degree courses. Students may switch from the combined program which includes a non-thesis Master of Science degree to an M.S. degree with a thesis optional, however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

Combined Engineering Physics Baccalaureate and Electrical Engineering Masters Degrees

The Department of Electrical Engineering and Computer Science, in collaboration with the Department of Physics, offers a five-year program in which students have the opportunity to obtain specific engineering skill to complement their physics background. Physics students in this program fill in their technical and free electives over their standard four year Engineering Physics B.S. program with a reduced set of Electrical Engineering classes. At the end of the fourth year, the student is awarded an Engineering Physics B.S degree. Course schedules for this five-year program can be obtained in the Physics Departmental Offices.

General CSM Minor/ASI requirements can be found here (p. 33).

Computer Science

For an **Area of Special Interest in Computer Science**, the student should take:

CSCI262	DATA STRUCTURES	3.0
CSCI306	SOFTWARE ENGINEERING	3.0

and either

CSCI358	DISCRETE MATHEMATICS	3.0
CSCI406	ALGORITHMS	3.0

or

CSCI341	COMPUTER ORGANIZATION	3.0
CSCI442	OPERATING SYSTEMS	3.0

For a **Minor in Computer Science**, the student should take:

CSCI262	DATA STRUCTURES	3.0
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CSCI306	SOFTWARE ENGINEERING	3.0
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and either

CSCI358	DISCRETE MATHEMATICS	3.0
CSCI406	ALGORITHMS	3.0

or

CSCI341	COMPUTER ORGANIZATION	3.0
CSCI442	OPERATING SYSTEMS	3.0

along with two 400-level Computer Science courses, which may not be languages transferred from another university.

Electrical Engineering

ASI in Electrical Engineering

The following twelve credit sequence is required for an ASI in Electrical Engineering: (See Minor/ASI section of the Bulletin for all rules for ASIs at CSM.)

EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG417	MODERN CONTROL DESIGN	3.0
or EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	

Minor in Electrical Engineering

A minimum of eighteen credits are required for a Minor in Electrical Engineering as follows. (See Minor/ASI section of the Bulletin for all rules for minors at CSM.)

Students must complete an eighteen credit hour sequence as described below for a minor in EE. All students seeking a minor in EE will need to take one of two possible versions of Electrical Circuits and EENG 307 (3 credits) after which they can pick an emphasis area to complete the remaining minor requirements. The four emphasis areas are as follows

1. Information Systems and Science (ISS), 18 or 18.5 credits

EENG282	ELECTRICAL CIRCUITS	4.0
or EENG281 & EGGN250	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER and MULTIDISCIPLINARY ENGINEERING LABORATORY	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG310	INFORMATION SYSTEMS SCIENCE I	4.0
EENG311	INFORMATION SYSTEMS SCIENCE II	3.0

2. Energy Systems and Power (ESPE), 18 credits

EENG282	ELECTRICAL CIRCUITS	4.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0

EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0

3. Digital Systems, 18 or 18.5 credits

EENG282	ELECTRICAL CIRCUITS	4.0
or EENG281 & EGGN250	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER and MULTIDISCIPLINARY ENGINEERING LABORATORY	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG383	MICROCOMPUTER ARCHITECTURE AND INTERFACING	4.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0

4. General Electrical Engineering, 19 or 19.5 credits

EENG282	ELECTRICAL CIRCUITS	4.0
or EENG281 & EGGN250	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER and MULTIDISCIPLINARY ENGINEERING LABORATORY	
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG284	DIGITAL LOGIC	4.0
EENG310	INFORMATION SYSTEMS SCIENCE I	4.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0

Interim Department Head & Professor

Atef Elsherbeni, Dobelman Chair

Professors

Kevin Moore, College Dean

Tracy Camp

Randy Haupt

Dinesh Mehta

P.K. Sen

Tyrone Vincent

Associate Professors

Qi Han

William Hoff

Kathryn Johnson

Marcelo Simoes

Michael Wakin

Assistant Professors

Salman Mohagheghi

Payam Nayeri

Gongguo Tang

Hua Wang

Bo Wu

Dejun Yang

Hao Zhang

Teaching Professors

Ravel Ammerman

Vibhuti Dave

Cyndi Rader

Jeffrey Schowalter

Teaching Associate Professors

Stephanie Claussen

Keith Hellman

Christopher Painter-Wakefield

Jeffrey Paone

Emerita Associate Professor

Catherine Skokan

Courses

CSCI101. INTRODUCTION TO COMPUTER SCIENCE. 3.0 Semester Hrs.

(I, II) An introductory course to the building blocks of Computer Science. Topics include conventional computer hardware, data representation, the role of operating systems and networks in modern computing, algorithm design, relational databases, structured queries, and computer simulations. A popular procedural programming language will be learned by students and programming assignments will explore ideas from algorithm development, optimization, and computer simulation. Prerequisite: none. 3 hours lecture; 3 semester hours.

CSCI198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI260. FORTRAN PROGRAMMING. 2.0 Semester Hrs.

Equivalent with MACS260,

(I) Computer programming in Fortran90/95 with applications to science and engineering. Program design and structure, problem analysis, debugging, program testing. Language skills: arithmetic, input/output, branching and looping, functions, arrays, data types. Introduction to operating systems. Prerequisite: none. 2 hours lecture; 2 semester hours.

CSCI261. PROGRAMMING CONCEPTS. 3.0 Semester Hrs.

Equivalent with MACS261,

(I, II) This course introduces fundamental computer programming concepts using a high-level language and a modern development environment. Programming skills include sequential, selection, and repetition control structures, functions, input and output, primitive data types, basic data structures including arrays and pointers, objects, and classes. Software engineering skills include problem solving, program design, and debugging practices. Prerequisite: none. 3 hours lecture; 3 semester hours.

CSCI262. DATA STRUCTURES. 3.0 Semester Hrs.

Equivalent with MACS262,

(I, II, S) Defining and using data structures such as linked lists, stacks, queues, binary trees, binary heap, hash tables. Introduction to algorithm analysis, with emphasis on sorting and search routines. Language skills: abstract data types, templates and inheritance. Prerequisite: CSCI261 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI274. INTRODUCTION TO THE LINUX OPERATING SYSTEM. 1.0 Semester Hr.

(I,II) Introduction to the Linux Operating System will teach students how to become proficient with using a Linux operating system from the command line. Topics will include: remote login (ssh), file system navigation, file commands, editors, compilation, execution, redirection, output, searching, processes, usage, permissions, compression, parsing, networking, and bash scripting. Prerequisites: CSCI 261. 1 hour lecture; 1 semester hour.

CSCI298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI306. SOFTWARE ENGINEERING. 3.0 Semester Hrs.

Equivalent with MACS306,

(I, II) Introduction to software engineering processes and object-oriented design principles. Topics include the Agile development methodology, test-driven development, UML diagrams, use cases and several object-oriented design patterns. Course work emphasizes good programming practices via version control and code reviews. Prerequisite: CSCI262 with grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

CSCI341. COMPUTER ORGANIZATION. 3.0 Semester Hrs.

Equivalent with MACS341,

(I, II) Covers the basic concepts of computer architecture and organization. Topics include machine level instructions and operating system calls used to write programs in assembly language, computer arithmetics, performance, processor design, and pipelining techniques. This course provides insight into the way computers operate at the machine level. Prerequisite: CSCI261. Co-requisites: CSCI262. 3 hours lecture; 3 semester hours.

CSCI358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.

Equivalent with MACS358, MATH358,

(I, II) This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines and regular languages. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

CSCI370. ADVANCED SOFTWARE ENGINEERING. 6.0 Semester Hrs.

(S) (WI) This capstone course has three primary goals: (1) to enable students to apply their course work knowledge to a challenging applied problem for a real client, (2) to enhance students' verbal and written communication skills, and (3) to provide an introduction to ethical decision making in computer science. Ethics and communication skills are emphasized in a classroom setting. The client work is done in small teams, either on campus or at the client site. Faculty advisors provide guidance related to the software engineering process, which is similar to Scrum. By the end of the course students must have a finished product with appropriate documentation. Prerequisite: CSCI306. 6-week summer session; 6 semester hours.

CSCI398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI400. PRINCIPLES OF PROGRAMMING LANGUAGES. 3.0 Semester Hrs.

Equivalent with MACS400,

(I, II) Study of the principles relating to design, evaluation and implementation of programming languages, including basic compiler techniques and context-free grammars. Students will be exposed to different categories of programming languages, such as functional, imperative, object-oriented and scripting. Best practices for programming will be explored, including effective use of exceptions and threads. The primary languages discussed are: Java, C++, Scheme, and Perl. Prerequisite: CSCI306. 3 hours lecture; 3 semester hours.

CSCI403. DATA BASE MANAGEMENT. 3.0 Semester Hrs.

Equivalent with MACS403,

(I) Design and evaluation of information storage and retrieval systems, including defining and building a database and producing the necessary queries for access to the stored information. Relational database management systems, structured query language, and data storage facilities. Applications of data structures such as lists, inverted lists and trees. System security, maintenance, recovery and definition. Interfacing host languages to database systems and object-relational mapping tools. NoSQL databases and distributed databases. Prerequisite: CSCI262 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI404. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.

Equivalent with MACS404,

(I) General investigation of the Artificial Intelligence field. Several methods used in artificial intelligence such as search strategies, knowledge representation, logic and probabilistic reasoning are developed and applied to practical problems. Fundamental artificial intelligence techniques are presented, including neural networks, genetic algorithms, and fuzzy sets. Selected application areas, such as robotics, natural language processing and games, are discussed. Prerequisite: CSCI262 with a grade of C- or higher and MATH201. 3 hours lecture; 3 semester hours.

CSCI406. ALGORITHMS. 3.0 Semester Hrs.

Equivalent with MACS406, MATH406,

(I, II) Reasoning about algorithm correctness (proofs, counterexamples). Analysis of algorithms: asymptotic and practical complexity. Review of dictionary data structures (including balanced search trees). Priority queues. Advanced sorting algorithms (heapsort, radix sort). Advanced algorithmic concepts illustrated through sorting (randomized algorithms, lower bounds, divide and conquer). Dynamic programming. Backtracking. Algorithms on unweighted graphs (traversals) and weighted graphs (minimum spanning trees, shortest paths, network flows and bipartite matching); NP-completeness and its consequences. Prerequisite: CSCI262 with a grade of C- or higher, MATH213, MATH223 or MATH224, MATH/CSCI358. 3 hours lecture; 3 semester hours.

CSCI410. ELEMENTS OF COMPUTING SYSTEMS. 3.0 Semester Hrs.

(I, II) This comprehensive course will help students consolidate their understanding of all fundamental computer science concepts. Topics include symbolic communication, Boolean logic, binary systems, logic gates, computer architecture, assembly language, assembler construction, virtual machines, object-oriented programming languages, software engineering, compilers, language design, and operating systems. Using a hardware simulator and a programming language of their choice, students construct an entire modern computer from the ground up, resulting in an intimate understanding of how each component works. Prerequisites: CSCI341 or EENG383. 3 lecture hours, 3 credit hours.

CSCI422. USER INTERFACES. 3.0 Semester Hrs.

Equivalent with MACS422,

(I) User Interface Design is a course for programmers who want to learn how to create more effective software. This objective will be achieved by studying principles and patterns of interaction design, critiquing existing software using criteria presented in the textbooks, and applying criteria to the design and implementation of one larger product. Students will also learn a variety of techniques to guide the software design process, including Cognitive Walkthrough, Talk-aloud and others. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI423. COMPUTER SIMULATION. 3.0 Semester Hrs.

(I) A first course in computer simulation. A project based course emphasizing the rigorous development of simulation applications. Topics will include random number generation, Monte Carlo simulation, discrete event simulation, and the mathematics behind their proper implementation and analysis. To a lesser extent we may discuss, time-step simulations and parallel simulations. The course uses journaling, programming projects and exams for assessment. Prerequisite: CSCI306, and MATH323 or MATH201, and CSCI274. 3 hours lecture; 3 semester hours.

CSCI440. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.

Equivalent with MATH440,

(II) This course is designed to introduce the field of parallel computing to all scientists and engineers. The students will be taught how to solve scientific problems using parallel computing technologies. They will be introduced to basic terminologies and concepts of parallel computing, learn how to use MPI to develop parallel programs, and study how to design and analyze parallel algorithms. Prerequisite: CSCI262 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI441. COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH441,

(I) This class focuses on the basic 3D rendering and modeling techniques. In particular, it covers ray tracing, graphics pipeline, modeling techniques based on polynomial curves and patches, subdivision for curves and surfaces, scene graphs, BSP trees and their applications, and elements of global illumination. Prerequisite: CSCI262 with a grade of C- or higher. 3 hours lecture, 3 semester hours.

CSCI442. OPERATING SYSTEMS. 3.0 Semester Hrs.

Equivalent with MACS442,

(I, II) Introduces the essential concepts in the design and implementation of operating systems: what they can do, what they contain, and how they are implemented. Despite rapid OS growth and development, the fundamental concepts learned in this course will endure. We will cover the following high-level OS topics, roughly in this order: computer systems, processes, processor scheduling, memory management, virtual memory, threads, and process/thread synchronization. This course provides insight into the internal structure of operating systems; emphasis is on concepts and techniques that are valid for all computers. We suggest the student takes "Introduction to the Linux Operating System" before this course (if the student is new to the Unix/Linux environment). Prerequisite: CSCI262 with a grade of C- or higher, CSCI341. 3 hours lecture; 3 semester hours.

CSCI443. ADVANCED PROGRAMMING CONCEPTS USING JAVA. 3.0 Semester Hrs.

Equivalent with MACS443,

(I, II) This course will quickly review programming constructs using the syntax and semantics of the Java programming language. It will compare the constructs of Java with other languages and discuss program design and implementation. Object oriented programming concepts will be reviewed and applications, applets, servlets, graphical user interfaces, threading, exception handling, JDBC, and networking as implemented in Java will be discussed. The basics of the Java Virtual Machine will be presented. Prerequisite: CSCI306. 3 hours lecture; 3 semester hours.

CSCI444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH444,

(I, II) This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techniques that can be used to develop high-quality computer graphic software. In particular, the course will cover global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Prerequisites: Basic understanding of computer graphics and prior exposure to graphics-related programming, for example, MACS 441. 3 lecture hours, 3 credit hours.

CSCI445. WEB PROGRAMMING. 3.0 Semester Hrs.

Equivalent with MACS445,

(I) Web Programming is a course for programmers who want to develop web-based applications. It covers basic website design extended by client-side and server-side programming. Students should acquire an understanding of the role and application of web standards to website development. Topics include Cascading Style Sheets (CSS), JavaScript, PHP and database connectivity. At the conclusion of the course students should feel confident that they can design and develop dynamic Web applications on their own. Prerequisites: CSCI262. Co-requisite: CSCI403. 3 hours lecture, 3 semester hours.

CSCI446. WEB APPLICATIONS. 3.0 Semester Hrs.

(II) Web Applications is a course for programmers who want to learn how to move beyond creating dynamic web pages and build effective web-based applications. At the completion of this course, students should know HTTP, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Ajax, Ruby, RESTful architectures and Web services. Additionally students should have considered a variety of issues related to web application architecture, including but not limited to security, performance and cloud-based deployment environments. Prerequisites: CSCI445. Co-requisites: CSCI400. 3 hours lecture, 3 semester hours.

CSCI447. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.

Equivalent with MATH447,

(I) Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on modern visualization techniques applicable to spatial data such as scalar, vector and tensor fields. In particular, the course will cover volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Basic understanding of computer graphics and analysis of algorithms required. Prerequisites: CSCI262 and MATH441. 3 lecture hours, 3 semester hours.

CSCI448. MOBILE APPLICATION DEVELOPMENT. 3.0 Semester Hrs.

(I) This course covers basic and advanced topics in mobile application development. Topics include the mobile application lifecycle, user interface components and layouts, storing persistent data, accessing network resources, using location and sensor APIs including GPS and accelerometer, starting and stopping system services, and threading. This is a project-based course where students will design and develop complete applications. Prerequisite: CSCI306 with a grade of C- or higher. Repeatable: Yes, if taught on a different platform (e.g., Android vs. iPhone) up to 6 hours. 3 hours lecture; 3.0 semester hours.

CSCI471. COMPUTER NETWORKS I. 3.0 Semester Hrs.

(I) This introduction to computer networks covers the fundamentals of computer communications, using TCP/IP standardized protocols as the main case study. The application layer and transport layer of communication protocols will be covered in depth. Detailed topics include application layer protocols (HTTP, FTP, SMTP, and DNS), transport layer protocols (reliable data transfer, connection management, and congestion control), network layer protocols, and link layer protocols. In addition, students will program client/server network applications. Prerequisite: CSCI442. 3 hours lecture, 3 semester hours.

CSCI473. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.

Equivalent with CSCI573,

(I) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.

Equivalent with MATH474,

(II) This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisites: CSCI262, (MATH334 or MATH335), MATH358. 3 hours lecture; 3 semester hours.

CSCI475. INFORMATION SECURITY AND PRIVACY. 3.0 Semester Hrs.

(I) Information Security and Privacy provides a hands-on introduction to the principles and best practices in information and computer security. Lecture topics will include basic components of information security including threat assessment and mitigation, policy development, forensics investigation, and the legal and political dimensions of information security. Prerequisite: CSCI 262 and CSCI 341 (required); CSCI 274 (recommended). 3 hours lecture; 3 semester hours.

CSCI498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG281. INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER. 3.0 Semester Hrs.

Equivalent with DCGN381,EGGN281,EGGN381,
(I, II) This course provides an engineering science analysis of electrical circuits. DC and single-phase AC networks are presented. Transient analysis of RC, RL, and RLC circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and single-phase AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and ideal transformers. The course features PSPICE, a commercial circuit analysis software package. May not also receive credit for EENG282. Prerequisites: PHGN200; 3 hours lecture; 3 semester hours.

EENG282. ELECTRICAL CIRCUITS. 4.0 Semester Hrs.

(I, II) This course provides an engineering science analysis of electrical circuits. DC and AC (single-phase and three-phase) networks are presented. Transient analysis of RC and RL circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and steady-state analysis of single-phase and three-phase ac power circuits. May not also receive credit for EENG281. Prerequisites: PHGN 200; 3 hours lecture; 3 lab hours; 4 semester hours.

EENG284. DIGITAL LOGIC. 4.0 Semester Hrs.

Equivalent with EGGN284,EGGN384,
(I, II) Fundamentals of digital logic design. Covers combinational and sequential logic circuits, programmable logic devices, hardware description languages, and computer-aided design (CAD) tools. Laboratory component introduces simulation and synthesis software and hands-on hardware design. Prerequisites: CSCI261. Co-requisites: EENG282 or EENG281 or PHGN215. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG298. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG307. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN307,EGGN407,
(I, II) System modeling through an energy flow approach is presented, with examples from linear electrical, mechanical, fluid and/or thermal systems. Analysis of system response in both the time domain and frequency domain is discussed in detail. Feedback control design techniques, including PID, are analyzed using both analytical and computational methods. Prerequisites: EENG281 or EENG282 or PHGN215, and MATH225. 3 hours lecture; 3 semester hours.

EENG310. INFORMATION SYSTEMS SCIENCE I. 4.0 Semester Hrs.

Equivalent with EENG388,EGGN388,
(I, II) The interpretation, representation and analysis of time-varying phenomena as signals which convey information and noise; applications are drawn from filtering, audio and image processing, and communications. Topics include convolution, Fourier series and transforms, sampling and discrete-time processing of continuous-time signals, modulation, and z-transforms. Prerequisites: (EENG281 or EENG282 or PHGN215) and MATH225. 3 hours lecture; 1 hour recitation, 4 semester hours.

EENG311. INFORMATION SYSTEMS SCIENCE II. 3.0 Semester Hrs.

(I,II) This course covers signals and noise in electrical systems. Topics covered include information theory, signal to noise ratio, random variables, probability density functions, statistics, noise, matched filters, coding and entropy, power spectral density, and bit error rate. Applications are taken from radar, communications systems, and signal processing. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

EENG334. ENGINEERING FIELD SESSION, ELECTRICAL. 3.0 Semester Hrs.

Equivalent with EGGN334,
(S) Experience in the engineering design process involving analysis, design, and simulation. Students use engineering, mathematics and computers to model, analyze, design and evaluate system performance. Teamwork emphasized. Prerequisites: EENG284, EENG385 and EENG389. Three weeks in summer session; 3 semester hours.

EENG340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

Equivalent with EGGN340,EGGN340E,
(I,II,S) Supervised, full-time engineering related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Department Head prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisites: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EENG340, Cooperative Education, may be used as free elective credit hours if, in the judgment of the Department Head, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives requires the student to submit a Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements form obtained from the Career Center to the Department Head.

EENG382. ENGINEERING CIRCUIT ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN382,

(I, II) This course provides for the continuation of basic circuit analysis techniques developed in EENG281, by providing the theoretical and mathematical fundamentals to understand and analyze complex electric circuits. The key topics covered include: (i) Steady-state analysis of single-phase and three-phase AC power circuits, (ii) Laplace transform techniques, (iii) Frequency response of active and passive filter circuits, (iv) Circuit Analysis using Fourier Series, (v) Circuit Analysis using Fourier Transforms, (vi) Two-port networks. The course features PSPICE, a commercial circuit analysis software package. Prerequisites: EENG281. 3 Semester Hours.

EENG383. MICROCOMPUTER ARCHITECTURE AND INTERFACING. 4.0 Semester Hrs.

Equivalent with EGGN383, EGGN482,

(I, II) Microprocessor and microcontroller architecture focusing on hardware structures and elementary machine and assembly language programming skills essential for use of microprocessors in data acquisition, control, and instrumentation systems. Analog and digital signal conditioning, communication, and processing. A/D and D/A converters for microprocessors. RS232 and other communication standards. Laboratory study and evaluation of microcomputer system; design and implementation of interfacing projects. Prerequisites: (EENG281 or EENG282 or PHGN215) and EENG284. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG385. ELECTRONIC DEVICES AND CIRCUITS. 4.0 Semester Hrs.

Equivalent with EGGN385,

(I, II) Semiconductor materials and characteristics, junction diode operation, bipolar junction transistors, field effect transistors, biasing techniques, four layer devices, amplifier and power supply design, laboratory study of semiconductor circuit characteristics. Prerequisites: EENG382 or EENG307. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS. 3.0 Semester Hrs.

Equivalent with EGGN386,

(I, II) This course provides an introduction to electromagnetic theory as applied to electrical engineering problems in wireless communications, transmission lines, and high-frequency circuit design. The theory and applications are based on Maxwell's equations, which describe the electric and magnetic force-fields, the interplay between them, and how they transport energy. Matlab and PSPICE will be used in homework assignments, to perform simulations of electromagnetic interference, electromagnetic energy propagation along transmission lines on printed circuit boards, and antenna radiation patterns. Prerequisites: EENG281 or EENG282 or EENG382, and MATH225. 3 hours lecture; 3 semester hours.

EENG389. FUNDAMENTALS OF ELECTRIC MACHINERY. 4.0 Semester Hrs.

Equivalent with EGGN389,

(I, II) This course provides an engineering science analysis of electrical machines. The following topics are included: DC, single-phase and three-phase AC circuit analysis, magnetic circuit concepts and materials, transformer analysis and operation, steady-state and dynamic analysis of rotating machines, synchronous and poly-phase induction motors, and laboratory study of external characteristics of machines and transformers. Prerequisites: EENG282 or EENG382. Co-requisite: EENG386. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG398. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG411. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.

Equivalent with EGGN481,

(II) This course introduces the mathematical and engineering aspects of digital signal processing (DSP). An emphasis is placed on the various possible representations for discrete-time signals and systems (in the time, z-, and frequency domains) and how those representations can facilitate the identification of signal properties, the design of digital filters, and the sampling of continuous-time signals. Advanced topics include sigma-delta conversion techniques, multi-rate signal processing, and spectral analysis. The course will be useful to all students who are concerned with information bearing signals and signal processing in a wide variety of application settings, including sensing, instrumentation, control, communications, signal interpretation and diagnostics, and imaging. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

EENG413. ANALOG AND DIGITAL COMMUNICATION SYSTEMS. 4.0 Semester Hrs.

Equivalent with EGGN483,

(II) Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EENG310. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG417. MODERN CONTROL DESIGN. 3.0 Semester Hrs.

Equivalent with EGGN417,

(I) Control system design with an emphasis on observer-based methods, from initial open-loop experiments to final implementation. The course begins with an overview of feedback control design technique from the frequency domain perspective, including sensitivity and fundamental limitations. State space realization theory is introduced, and system identification methods for parameter estimation are introduced. Computerbased methods for control system design are presented. Prerequisite: EENG307. 3 lecture hours, 3 semester hours.

EENG421. SEMICONDUCTOR DEVICE PHYSICS AND DESIGN. 3.0 Semester Hrs.

(I) This course will explore the field of semiconductors and the technological breakthroughs which they have enabled. We will begin by investigating the physics of semiconductor materials, including a brief foray into quantum mechanics. Then, we will focus on understanding pn junctions in great detail, as this device will lead us to many others (bipolar transistors, LEDs, solar cells). We will explore these topics through a range of sources (textbooks, scientific literature, patents) and discuss the effects they have had on Western society. As time allows, we will conclude with topics of interest to the students (possibilities include quantum devices, MOSFETs, lasers, and integrated circuit fabrication techniques). Prerequisite: EENG385. 3 hours lecture; 3 semester hours.

EENG425. INTRODUCTION TO ANTENNAS. 3.0 Semester Hrs.

(II) This course provides an introduction to antennas and antenna arrays. Theoretical analysis and use of computer programs for antenna analysis and design will be presented. Experimental tests and demonstrations will also be conducted to complement the theoretical analysis. Students are expected to use MATLAB to model antennas and their performance. Prerequisites: EENG386.

EENG427. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.

(I, II, S) This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. Prerequisites: EENG386, EENG311, and EENG310. 3 hours lecture; 3 semester hours.

EENG470. INTRODUCTION TO HIGH POWER ELECTRONICS. 3.0 Semester Hrs.

Equivalent with EGGN485,

(II) Power electronics are used in a broad range of applications from control of power flow on major transmission lines to control of motor speeds in industrial facilities and electric vehicles, to computer power supplies. This course introduces the basic principles of analysis and design of circuits utilizing power electronics, including AC/DC, AC/AC, DC/DC, and DC/AC conversions in their many configurations. Prerequisites: EENG282. 3 hours lecture; 3 semester hours.

EENG472. PRACTICAL DESIGN OF SMALL RENEWABLE ENERGY SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN486,

(Taught on Demand) This course provides the fundamentals to understand and analyze renewable energy powered electric circuits. It covers practical topics related to the design of alternative energy based systems. It is assumed the students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, electronics, and fundamentals of electric power systems. One of the main objectives of this course is to focus on the interdisciplinary aspects of integration of the alternative sources of energy, including hydropower, wind power, photovoltaic, and energy storage for those systems. Power electronic systems will be discussed and how those electronic systems can be used for stand-alone and grid-connected electrical energy applications. Prerequisite: EENG382. 3 hours lecture; 3 semester hours.

EENG480. POWER SYSTEMS ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN484,

(I) 3-phase power systems, per-unit calculations, modeling and equivalent circuits of major components, voltage drop, fault calculations, symmetrical components and unsymmetrical faults, system grounding, power-flow, selection of major equipment, design of electric power distribution systems. Prerequisite: EENG389. 3 hours lecture; 3 semester hours.

EENG481. ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN487,

(II) The course investigates the design, operation and analysis of complex interconnected electric power grids, the basis of our electric power infrastructure. Evaluating the system operation, planning for the future expansion under deregulation and restructuring, ensuring system reliability, maintaining security, and developing systems that are safe to operate has become increasingly more difficult. Because of the complexity of the problems encountered, analysis and design procedures rely on the use of sophisticated power system simulation computer programs. The course features some commonly used commercial software packages. Prerequisites: EENG480. 2 Lecture Hours, 3 Laboratory Hours, 3 Semester Hours.

EENG489. COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS. 3.0 Semester Hrs.

(II) The course presents a unified approach for understanding and applying computational methods, computer-aided analysis and design of electric power systems. Applications will range from power electronics to power systems, power quality, and renewable energy. Focus will be on how these seemingly diverse applications all fit within the smart-grid paradigm. This course builds on background knowledge of electric circuits, control of dc/dc converters and inverters, energy conversion and power electronics by preparing students in applying the computational methods for multi-domain simulation of energy systems and power electronics engineering problems. Prerequisites: EENG282 or EENG382. 1 hour lecture, 2 lab hours, 3 semester hours.

EENG497. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**EENG498. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Mechanical Engineering

2015-2016

Program Description

The Mechanical Engineering Department offers a design-oriented undergraduate program that emphasizes fundamental engineering principles. Students receive a strong foundation in mechanical engineering disciplines, and a working knowledge of modern engineering tools. Classroom education is augmented with extensive practical laboratory experiences. Successful graduates are well-prepared for a mechanical engineering career in a world of rapid technological change.

Bachelor of Science in Mechanical Engineering

During the freshman and sophomore years, students complete a set of core courses that include mathematics, basic sciences, and fundamental engineering disciplines. These years also include engineering design coursework within Engineering Practice Introductory Course (EPIC 151) and Introduction to Mechanical Engineering (MEGN 200). This experience teaches design methodology and stresses the creative aspects of the mechanical engineering profession. Additionally in the first two years, courses in humanities and social sciences allow students to explore the linkages between the environment, human society, and engineered devices.

In the junior and senior years, students complete an advanced engineering core that includes fluid mechanics, thermodynamics, heat transfer, numerical methods, control theory, machine design, computational engineering, and manufacturing processes. This

engineering core is complemented by courses in economics and elective courses in humanities and social sciences. Students must also take three advanced technical electives and three additional free electives to explore specific fields of interest. In the senior year, all students must complete a capstone design course focused on a multidisciplinary engineering project.

Students in mechanical engineering spend considerable time in laboratories, including the Design Lab with a variety of prototyping and testing equipment. Students are also encouraged to become involved in research that is being conducted within the Department of Mechanical Engineering. These research areas include: biomechanics; solid mechanics and materials; thermal-fluid systems; and robotics, automation, and design.

The Bachelor of Science in Mechanical Engineering degree is accredited by ABET.

Program Educational Objectives (Bachelor of Science in Mechanical Engineering)

The Mechanical Engineering program contributes to the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria. Accordingly, the Mechanical Engineering Program at CSM has established the following program educational objectives for the B.S. in Mechanical Engineering degree:

Within three to five years of completing their degree, graduates will be:

- Applying their Mechanical Engineering education as active contributors in the workforce or graduate school;
- Effective at communicating technical information in a diverse and globally integrated society;
- Demonstrating their commitment to continued professional development through training, coursework, and/or professional society involvement; and
- Exemplifying ethical and social responsibility in their professional activities.

Bachelor of Science in Mechanical Engineering Degree Requirements:

Freshman

Fall		lec	lab sem.hrs
PAGN101	PHYSICAL EDUCATION		0.5
LAIS100	NATURE AND HUMAN VALUES		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I		4.0
CSM101	FRESHMAN SUCCESS SEMINAR		0.5
BIOL110	FUNDAMENTALS OF BIOLOGY I or GEGN 101		4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I		4.0
			17.0

Spring		lec	lab sem.hrs
PAGN102	PHYSICAL EDUCATION		0.5
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)		4.0
PHGN100	PHYSICS I - MECHANICS		4.5
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II		4.0
EPIC151	DESIGN (EPICS) I		3.0
			16.0

Sophomore

Fall		lec	lab sem.hrs
PAGN2XX	PHYSICAL EDUCATION		0.5
LAIS200	HUMAN SYSTEMS		3.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS		4.5
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III		4.0
CEEN241	STATICS		3.0
MEGN200	INTRODUCTION TO MECHANICAL ENGINEERING		3.0
			18.0

Spring		lec	lab sem.hrs
PAGN2XX	PHYSICAL EDUCATION		0.5
MTGN202	ENGINEERED MATERIALS		3.0
MEGN361	THERMODYNAMICS I		3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER		3.0
MATH225	DIFFERENTIAL EQUATIONS		3.0
MEGN312	INTRODUCTION TO SOLID MECHANICS		3.0
			15.5

Summer		lec	lab sem.hrs
MEGN201	MECHANICAL FIELD SESSION		3.0
			3.0

Junior

Fall		lec	lab sem.hrs
EBGN201	PRINCIPLES OF ECONOMICS		3.0
EGGN250	MULTIDISCIPLINARY ENGINEERING LABORATORY		1.5
MEGN351	FLUID MECHANICS		3.0
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING		3.0
MEGN315	DYNAMICS		3.0
MEGN424	COMPUTER AIDED ENGINEERING		3.0
			16.5

Spring		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective I		3.0
EGGN350	MULTIDISCIPLINARY ENGINEERING LABORATORY II		1.5
MEGN471	HEAT TRANSFER		3.0

EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS		3.0
MEGN481	MACHINE DESIGN		4.0
MEGN381	MANUFACTURING PROCESSES		3.0
			17.5
Senior			
Fall		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective II		3.0
FREE	Free Elective		3.0
EGGN450	MULTIDISCIPLINARY ENGINEERING LABORATORY III		1.0
EGGN491	SENIOR DESIGN I		3.0
MECH ELECT	Mechanical Engineering Elective		3.0
MECH ELECT	Mechanical Engineering Elective		3.0
			16.0
Spring		lec	lab sem.hrs
FREE	Free Elective		3.0
LAIS/EBGN	H&SS Restricted Elective III		3.0
MECH ELECT	Mechanical Engineering Elective*		3.0
FREE	Free Elective		3.0
EGGN492	SENIOR DESIGN II		3.0
			15.0

Total Semester Hrs: 134.5

* Mechanical Engineering students are required to take three Mechanical Engineering elective courses. At least one of these courses must be from List A, the remaining must be from List B.

Mechanical Engineering List A Electives:

MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN451	FLUID MECHANICS II	3.0
MEGN461	THERMODYNAMICS II	3.0

Mechanical Engineering List B Electives:

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN406	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN443	DESIGN OF STEEL STRUCTURES	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
EENG383	MICROCOMPUTER ARCHITECTURE AND INTERFACING	4.0
EENG385	ELECTRONIC DEVICES AND CIRCUITS	4.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS	3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	4.0
EENG417	MODERN CONTROL DESIGN	3.0
EGGN401	PROJECTS FOR PEOPLE	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0

MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
MEGN436	COMPUTATIONAL BIOMECHANICS	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MEGN466	INTRODUCTION TO INTERNAL COMBUSTION ENGINES	3.0
MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	3.0
MEGN493	ENGINEERING DESIGN OPTIMIZATION	3.0
MEGN498	(SPECIAL TOPICS)	1-6
MEGN5XX	ANY 500-LEVEL MEGN COURSE	
MNGN444	EXPLOSIVES ENGINEERING II	3.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
MTGN464	FORGING AND FORMING	2.0
MTGN464L	FORGING AND FORMING LABORATORY	1.0
MTGN475	METALLURGY OF WELDING	2.0
MTGN475L	METALLURGY OF WELDING LABORATORY	1.0
MTGN560	ANALYSIS OF METALLURGICAL FAILURES	3.0
PEGN311	DRILLING ENGINEERING	4.0
PEGN361	COMPLETION ENGINEERING	3.0
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN350	INTERMEDIATE MECHANICS	4.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN440	SOLID STATE PHYSICS	3.0

Combined Mechanical Engineering Baccalaureate and Masters Degrees

Mechanical Engineering offers a five year combined program in which students have the opportunity to obtain specific engineering skills supplemented with graduate coursework in mechanical engineering. Upon completion of the program, students receive two degrees, the Bachelor of Science in Mechanical Engineering and the Master of Science in Mechanical Engineering.

Admission into a graduate degree program as a Combined Undergraduate/Graduate degree student may occur as early as the first semester Junior year and *must be granted no later than the end of registration the last semester Senior year*. Students must meet minimum GPA admission requirements for the graduate degree.

Students are required to take an additional thirty credit hours for the M.S. degree. Up to nine of the 30 credit hours beyond the undergraduate degree requirements can be 400-level courses. The remainder of the courses will be at the graduate level (500-level and above). The Mechanical Engineering Graduate Bulletin provides detail into the graduate program and includes specific instructions regarding required and elective courses. Students may switch from the combined program, which includes a non-thesis Master of Science degree to a M.S. degree with a thesis option; however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

General CSM Minor/ASI requirements can be found here (p. 33).

Mechanical Engineering Areas of Special Interest (ASI)

and Minor Programs

General Requirements

The Mechanical Engineering Department offers minor and ASI programs. Students who elect an ASI or minor, must fulfill all prerequisite requirements for each course in a chosen sequence. Students in the sciences or mathematics must be prepared to meet prerequisite requirements in fundamental engineering and engineering science courses. Students in engineering disciplines are better positioned to meet the prerequisite requirements for courses in the minor and ASI Mechanical Engineering program. (See Minor/ASI section of the Bulletin for all requirements for a minor/ASI at CSM.)

For an Area of Special Interest in Mechanical Engineering, the student must complete a minimum of 12 hours from the following:

MEGN312	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0
MEGN361	THERMODYNAMICS I	3.0

For a Minor in Mechanical Engineering, the student must complete a minimum of 18 hours from the following:

1. Required Courses (choose three, 9 credit hours)

MEGN312	INTRODUCTION TO SOLID MECHANICS	3.0
MEGN315	DYNAMICS	3.0
MEGN351	FLUID MECHANICS	3.0
MEGN361	THERMODYNAMICS I	3.0

2. Tracks (choose one track):

Robotics, Automation & Design Track (10 credit hours)

MEGN424	COMPUTER AIDED ENGINEERING	3.0
MEGN481	MACHINE DESIGN	4.0
MEGN381	MANUFACTURING PROCESSES	3.0
or MEGN441	INTRODUCTION TO ROBOTICS	
or MEGN416	ENGINEERING VIBRATION	
or MEGN485	MANUFACTURING OPTIMIZATION WITH NETWORK MODELS	

Solid Materials Track (9 credit hours)

MEGN412	ADVANCED MECHANICS OF MATERIALS	3.0
MEGN416	ENGINEERING VIBRATION	3.0
MEGN424	COMPUTER AIDED ENGINEERING	3.0

Thermal-Fluids Track (9 credit hours)

MEGN451	FLUID MECHANICS II	3.0
MEGN461	THERMODYNAMICS II	3.0
MEGN471	HEAT TRANSFER	3.0

Biomechanical Engineering Minor

General Requirements

To obtain a Biomechanical Engineering Minor, students must take at least 18.0 credits from the courses listed below. Fundamentals of Biology I (BIOL110), General Biology II (CBEN303) and associated Laboratory (CBEN323), and Introduction to Biomechanical Engineering (MEGN330)

are required (11.0 credits). Three more courses may be chosen from the proposed list of electives. The list of electives will be modified as new related courses become available.

Required Courses (11.0 credits)

BIOL110	BIOLOGY I	4.0
CBEN303	GENERAL BIOLOGY II	3.0
CBEN323	GENERAL BIOLOGY II LABORATORY	1.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0

Biomechanical Engineering Elective Courses

MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
or MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	
MEGN436	COMPUTATIONAL BIOMECHANICS	3.0
or MEGN536	COMPUTATIONAL BIOMECHANICS	
MEGN530	BIOMEDICAL INSTRUMENTATION	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MEGN553	INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA	3.0
MEGN x98, x99	SPECIAL TOPICS *	3.0
MTGN472	BIOMATERIALS I	3.0
or MTGN572	BIOMATERIALS	
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN306	ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN	3.0
CBEN309	ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN LABORATORY	1.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	
MATH331	MATHEMATICAL BIOLOGY	3.0
PHGN333	INTRODUCTION TO BIOPHYSICS	3.0

* As the content of these courses varies, the course must be noted as relevant to the biomechanical engineering minor.

Professor and Department Head

Gregory S. Jackson

George R. Brown Distinguished Professor

Robert J. Kee

Professors

John R. Berger

Cristian V. Ciobanu

Graham G. W. Mustoe

Alexandra Newman

Associate professors

Joel M. Bach

Robert Braun

Anthony Petrella

John P. H. Steele

Neal Sullivan

Cameron Turner

Ruichong "Ray" Zhang

Assistant professors

Gregory Bogin

Ozkan Celik

Steven DeCaluwe

Jason Porter

Anne Silverman

Aaron Stebner

Paulo Tabares-Velasco

Nils Tilton

Douglas Van Bossuyt

Xiaoli Zhang

Teaching Associate Professors

Robert Amaro

Jenifer Blacklock

Jered Dean

Ventzi Karaivanov

Leslie M. Light

Derrick Rodriguez

Emeriti Professors

Robert King

Michael B. McGrath

Emerita Professor

Joan P. Gosink

Emeritus Associate Professor

David Munoz

Research Professor

George Gilmer

Research Associate Professor

Huayang Zhu

Research Assistant Professors

Christopher B. Dryer

Branden Kappes

Sandrine Ricote

Affiliate Professor of Mechanical Engineering

Michael Mooney

Courses

EGGN399MB. INDEPENDENT STUDY. 1-6 Semester Hr.

EGGN399MC. INDEPENDENT STUDY. 1-6 Semester Hr.

MEGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN200. INTRODUCTION TO MECHANICAL ENGINEERING. 3.0 Semester Hrs.

(I, II) Students will learn the fundamentals behind mechanical engineering, design and drafting. The course will include an introduction to solid modeling using CAD and/or SolidWorks. Students will also gain understanding of how to visualize and present technical data. Understanding of the design process will be expanded from the previous course by understanding how drawing and prototyping are implemented through practice in a common team design project. Teamwork, presentations, and technical writing will be an integral part of this course. Prerequisite: EPIC151. 3 hours lecture; 3.0 semester hours.

MEGN201. MECHANICAL FIELD SESSION. 3.0 Semester Hrs.

Equivalent with EGGN235,

(S) This course provides the student with hands-on experience in the use of modern engineering tools as part of the design process including modeling, fabrication, and testing of components and systems. Student use engineering, mathematics and computers to conceptualize, model, create, test, and evaluate components and systems of their creation. Teamwork is emphasized by having students work in teams. Prerequisites: EENG281, MEGN200, and MEGN312 or CEEN311. Three weeks in summer field session; 3 semester hours.

MEGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN312. INTRODUCTION TO SOLID MECHANICS. 3.0 Semester Hrs.

(I, II, S) Introduction to the theory and application of the principles of Solid Mechanics by placing an early focus on free body diagrams, stress and strain transformations, and failure theories. Covered topics include: stress and stress transformation, strain and strain transformation, mechanical properties of materials, axial load, torsion, bending, transverse shear, combined loading, pressure vessels, failure theories, stress concentrations, thermal stress, deflection of beams and shafts, and column buckling. Upon completion of the course, students will be able to apply the principles of Solid Mechanics to the analysis of elastic structures under simple and combined loading, use free body diagrams in the analysis of structures, use failure theories to assess safety of design, and effectively communicate the outcomes of analysis and design problems. May not also receive credit for CEEN311. Prerequisites: CEEN241. Co-requisites: MEGN200. 3 hours lecture; 3 semester hours.

MEGN315. DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN315,

(I, II, S) Absolute and relative motions. Kinetics, work-energy, impulse-momentum, vibrations. Prerequisites: CEEN241 and MATH225. 3 hours lecture; 3 semester hours.

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with BELS325, BELS420, EGGN325, EGGN420,

(I) The application of mechanical engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering (more specifically, Biomechanical Engineering) has evolved over the past 50 years to address these challenges. Biomechanical Engineering includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomechanical Engineering and to prepare the student for more advanced Biomechanical coursework. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various mechanical engineering principles to the human body. Prerequisites: MEGN312 or CEEN311 and PHGN200. Co-requisites: MEGN315. 3 hours lecture; 3 semester hours.

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

Equivalent with EGGN340, EGGN340M,

(I, II, S) Supervised, full-time engineering related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Department Head prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisites: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in MEGN340, Cooperative Education, may be used as free elective credit hours if, in the judgment of the Department Head, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives requires the student to submit a Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements form obtained from the Career Center to the Department Head.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN351,

(I, II, S) Fluid properties, fluid statics, control-volume analysis, Bernoulli equation, differential analysis and Navier-Stokes equations, dimensional analysis, internal flow, external flow, open-channel flow, and turbomachinery. May not also receive credit for CEEN310 or PEGN251. Prerequisite: CEEN241 or MNGN317. 3 hours lecture; 3 semester hours.

MEGN361. THERMODYNAMICS I. 3.0 Semester Hrs.

Equivalent with EGGN371,

(I, II, S) A comprehensive treatment of thermodynamics from a mechanical engineering point of view. Thermodynamic properties of substances inclusive of phase diagrams, equations of state, internal energy, enthalpy, entropy, and ideal gases. Principles of conservation of mass and energy for steady-state and transient analyses. First and Second Law of thermodynamics, heat engines, and thermodynamic efficiencies. Application of fundamental principles with an emphasis on refrigeration and power cycles. May not also receive credit for CHGN209 or CBEN210. Prerequisite: MATH213/MATH223/MATH224. 3 hours lecture; 3 semester hours.

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.

Equivalent with EGGN390, MEGN380,

(I, II, S) Introduction to a wide variety of manufacturing processes with emphasis on process selection and laboratory measurements of process conditions with product variables. Consideration of relations among material properties, process settings, tooling features and product attributes. Design and implementation of a process for manufacture of a given component. Manual and Automated manufacturing and their implementation in plant layouts. Understanding how to eliminate waste in manufacturing processes and enhance scheduling and satisfying client needs. Quality, tolerances and standards will be discussed along with their importance in a manufacturing setting. Prerequisites: MEGN312 or CEEN311 and MTGN202. 3 lecture hours, 3 semester hours.

MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN422,

(I, II) General theories of stress and strain; stress and strain transformations, principal stresses and strains, octahedral shear stresses, Hooke's law for isotropic material, and failure criteria. Introduction to elasticity and to energy methods. Torsion of noncircular and thin-walled members. Unsymmetrical bending and shear-center, curved beams, and beams on elastic foundations. Introduction to plate theory. Thick-walled cylinders and contact stresses. Prerequisite: CEEN311 or MEGN312. 3 hours lecture; 3 semester hours.

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.

Equivalent with EGGN478,

(II) Theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Analysis of free and forced vibrations to different types of loading - harmonic, impulse, periodic and general transient loading. Derive model systems using D'Alembert's principle, Lagrange's equations and Hamilton's principle. Analysis of natural frequencies and mode shapes. Role of damping in machines and structures. Analysis and effects of resonance. Use of the modal superposition method and the transient Duhamel integral method. Prerequisite: MEGN315. 3 hours lecture; 3 semester hours.

MEGN424. COMPUTER AIDED ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN413,

(I, II, S) This course introduces the student to the concept of computer-aided engineering. The major objective is to provide the student with the necessary background to use the computer as a tool for engineering analysis and design. The Finite Element Analysis (FEA) method and associated computational engineering software have become significant tools in engineering analysis and design. This course is directed to learning the concepts of FEA and its application to civil and mechanical engineering analysis and design. Note that critical evaluation of the results of a FEA using classical methods (from statics and mechanics of materials) and engineering judgment is employed throughout the course. Prerequisite: MEGN312 or CEEN311. 3 hours lecture; 3 semester hours.

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.

Equivalent with BELS425,EGGN425,

(II) This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisites: MEGN315, CEEN311 or MEGN312, MEGN330. 3 hours lecture; 3 semester hours.

MEGN435. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.

Equivalent with BELS426,EGGN426,

(II) Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties and interactions with the environment to construct detailed computer models and simulations. The course will culminate in individual class projects related to each student's individual interests. Prerequisites: MEGN315 and MEGN330. 3 hours lecture; 3 semester hours.

MEGN436. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.

Equivalent with BELS428,BELS428,EGGN428,

Computational Biomechanics provides an introduction to the application of computer simulation to solve some fundamental problems in biomechanics and bioengineering. Musculoskeletal mechanics, medical image reconstruction, hard and soft tissue modeling, joint mechanics, and inter-subject variability will be considered. An emphasis will be placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of computational techniques. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is demonstrated. Prerequisites: MEGN424, MEGN330. 3 hours lecture, 3 semester hours. Fall odd years.

MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.

Equivalent with EGGN400,

(I, II) Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. Prerequisites: CSC1261 and EENG281. 2 hours lecture; 1 hour lab; 3 semester hours.

MEGN451. FLUID MECHANICS II. 3.0 Semester Hrs.

Equivalent with EGGN473,

(II) Review of elementary fluid mechanics and engineering, two-dimensional external flows, boundary layers, flow separation; Compressible flow, isentropic flow, normal and oblique shocks, Prandtl-Meyer expansion fans, Fanno and Rayleigh flow; Introduction to flow instabilities (e.g., Kelvin-Helmholtz instability, Raleigh Benard convection). Prerequisite: MEGN351. 3 hours lecture; 3 semester hours.

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.

Equivalent with EGGN403,

(I) This course extends the subject matter of Thermodynamics I (MEGN 361) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Phase equilibrium, ionization, and the thermodynamics of compressible flow (nozzles and shock) are also introduced. Concepts of the above are explored through the analysis of advanced thermodynamic systems, such as cascaded and absorption refrigeration systems, cryogenics, and advanced gas turbine and combined power cycles. Prerequisite: MEGN351, MEGN361. 3 hours lecture plus discussion section; 3 semester hours.

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.

(II) Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one ? semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisites: MEGN351, MEGN361. Co-requisites: MEGN471. 3 hours lecture; 1.0 hour lab; 3 semester hours.

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CBEN469, CHEN469, EGGN469, MTGN469,
 (I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: MEGN361 or CBEN357 or MTGN351. 3 hours lecture; 3 semester hours.

MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.

Equivalent with EGGN471,
 (I, II) Engineering approach to conduction, convection, and radiation, including steady-state conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. Prerequisite: MATH225 or MATH235, and MEGN351, and MEGN361 or PHGN341. 3 hours lecture; 3 semester hours.

MEGN481. MACHINE DESIGN. 4.0 Semester Hrs.

Equivalent with EGGN411,
 (I, II) This course is an introduction to the principles of mechanical design. Methods for determining static, fatigue and surface failure are presented. Analysis and selection of machine components such as shafts, keys, couplings, bearings, gears, springs, power screws, and fasteners is covered. Prerequisites: MEGN315 or PHGN350, and MEGN424. 3 hours lecture, 3 hours lab; 4 semester hours.

MEGN482. MECHANICAL DESIGN USING GD&T. 3.0 Semester Hrs.

Equivalent with EGGN410,
 (II) The mechanical design process can be broadly grouped into three phases: requirements and concept, design and analysis, details and drawing package. In this class students will learn concepts and techniques for the details and drawing package phase of the design process. The details of a design are critical to the success of a design project. The details include selection and implementation of a variety of mechanical components such as fasteners (threaded, keys, retaining rings), bearing and bushings. Fits and tolerances will also be covered. Statistical tolerance analysis will be used to verify that an assembly will fit together and to optimize the design. Mechanical drawings have become sophisticated communication tools that are used throughout the processes of design, manufacturing, and inspection. Mechanical drawings are interpreted either by the ANSI or ISO standard which includes Geometric Dimensioning and Tolerancing (GD&T). In this course the student will learn to create mechanical drawings that communicate all of the necessary information to manufacture the part, inspect the part, and allow the parts to be assembled successfully. Prerequisite: MEGN201. 3 hours lecture, 3 semester hours.

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.

Equivalent with EBG456,
 (I) We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Prerequisites: MATH111. 3 hours lecture; 3 semester hours.

MEGN493. ENGINEERING DESIGN OPTIMIZATION. 3.0 Semester Hrs.

Equivalent with EGGN493,
 (II) The application of gradient, stochastic and heuristic optimization algorithms to linear and nonlinear optimization problems in constrained and unconstrained design spaces. Students will consider problems with continuous, integer and mixed-integer variables, problems with single or multiple objectives and the task modeling design spaces and constraints. Design optimization methods are becoming of increasing importance in engineering design and offer the potential to reduce design cycle times while improving design quality by leveraging simulation and historical design data. Prerequisites: MATH213 and MATH225 (Required), CSCI260 or CSCI261 or other experience with computer programming languages (Suggested). 3 hours lecture; 3 semester hours.

MEGN497. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Design -- EPICS (Engineering Practices Introductory Course Sequence)

Design EPICS is designed to prepare students for their upper-division courses and to develop some of the key skills of the professional engineer: the ability to solve complex, open-ended problems, the ability to work in teams, the ability to select a solution from competing alternatives, and the ability to communicate effectively. The first semester course, EPIC151, is required by all undergraduate options. The second semester course, EPIC251, is required by all undergraduate engineering options according to ABET requirements. EPIC251 is not required for majors in Chemistry, Applied Mathematics and Statistics, Electrical Engineering and Computer Science, Mechanical Engineering, and Economics and Business.

An award-winning program, Design EPICS replaces the traditional core courses in introductory computing skills, graphics, and technical communication. Whenever possible, instruction in these subjects is "hands-on" and experimental, with the instructor serving as both mentor and lecturer.

Problem-solving skills are developed through open-ended design problems organized as semester-long "projects," which the students solve in teams. Projects grow in content and complexity as the program applies a guided methodology to projects submitted by an external client. The projects require extensive library research and self-education in appropriate technical areas; they also require students to consider non-technical constraints (economic, ethical, political, societal, etc.) and incorporate them into their solutions.

Written and oral communications skills are studied and practiced as an integral part of the project work. Specific graphics and computing skills are integrated within projects wherever applicable.

Director

Leslie Light, Program Director and Teaching Associate Professor of Mechanical Engineering

Teaching Professor

Joel G. Duncan, (also in Geology & Geological Engineering)

Teaching Associate Professor

Natalie Van Tyne

Teaching Assistant Professor

Martin J. Spann

Courses

EPIC151. DESIGN (EPICS) I. 3.0 Semester Hrs.

(I,II,S). Design EPICS I introduces students to a design process that includes open-ended problem solving and teamwork integrated with the use of computer software as tools to solve engineering problems. Computer applications emphasize graphical visualization and production of clear and coherent graphical images, charts, and drawings. Teams assess engineering ethics, group dynamics and time management with respect to decisionmaking. The course emphasizes written technical communications and introduces oral presentations. 3 semester hours.

EPIC155. EPICS I GRAPHICS. 1.0 Semester Hr.

(I,II). Instruction and practice in mechanical sketching and computer-aided drafting methods. Specific lessons include perspective sketching, geometric construction, isometric and orthographic views, dimensions, and sections. Homework is assigned weekly. Each unit culminates in one in-class proficiency examination or extended written assignment, plus one capstone design portfolio. Prerequisites: None. 1 hour lecture, 1 hour laboratory, 1 semester hour.

EPIC198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EPIC199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EPIC251. DESIGN (EPICS) II. 3.0 Semester Hrs.

(I,II,S). Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communications with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Teams analyze team dynamics through weekly team meetings and progress reports. The course emphasizes oral presentations and builds on written communications techniques introduced in Design EPICS I Prerequisite: EPIC151 or EPIC155. 3 semester hours.

EPIC252. LEADERSHIP DESIGN II. 4.0 Semester Hrs.

(I,II). EPIC252 can be taken in place of EPIC251. Students integrate teamwork, communications, computer software applications and project management skills to solve engineering problems, and the deliverables are equivalent to those for EPICS 251. In addition, students examine the global nature of modern engineering design by combining a project of global interest with an emphasis on leadership and communications skills across a variety of cultures. To support these objectives, students conduct research in the effect of international influences and cultural diversity on the acceptance and implementation of their design solutions. Prerequisite: EPIC151. 4 semester hours.

EPIC261. EPICS II: GIS. 3.0 Semester Hrs.

(I,II,S): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. EPICS 261 GIS incorporates instruction and practice in ArcView, a geographic information system software package, to enable students to capture, manage, analyze and display geographic information in maps, charts or tables, with projects that depend on GIS for their design solutions. Recent projects involving the use of GIS include campus emergency management and room usage maps, groundwater testing well analysis and reporting for the Colorado Department of Agriculture and trail maps for the Foothills Recreation District. Prerequisite: EPIC151 or EPIC155. 3 semester hours.

EPIC262. EPICS II: AUTO CAD. 3.0 Semester Hrs.

(I,II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. EPICS 262-AutoCAD incorporates semester-long instruction and practice in AutoCAD computer-aided drawing, with projects involving the use of AutoCAD in design solutions. Recent projects include remodeling plans for the Ford Building, a solar tree house education center, an environmentally sustainable house, and new structural designs for use in Haiti following the January 2010 earthquake in Haiti. Students in the Civil Engineering and Environmental Engineering or in Mining Engineering, should consider registering for this course. Prerequisite: EPIC151 or EPIC155. 3 semester hours.

EPIC263. EPICS II: DRILLING ENGINEERING. 3.0 Semester Hrs.

(S): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. This course implements the design process with drilling technology and automated drilling processes to solve multidisciplinary drilling project issues. Based on the project conditions set by the client, various alternatives and configurations are possible to meet the project objectives. Teams select and build a body of evidence to market their most desirable alternatives. Prerequisite: EPIC151. 3 semester hours.

EPIC264. EPICS II: GEOLOGY GIS. 3.0 Semester Hrs.

(II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. There are typically eight geology-based projects in the course, based on the needs of multiple outside clients. Many of the course deliverables are maps with associated data sets. Prerequisite: EPIC151 or EPIC155. 3 semester hours.

EPIC265. EPIC II: BIOCHEMICAL PROCESSES. 3.0 Semester Hrs.

(I,II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. This course emphasizes steady-state design in biochemical production processes and provides exposure to information about various manufacturing and research segments. Projects are selected to represent real-world biochemical engineering problems in biofuels, food sciences and pharmaceuticals, wherein creative and critical thinking skills are necessary. These projects may often involve computer-based optimization to obtain a solution. Students are exposed to the range of core engineering computation skills that are utilized in both the chemical and biochemical engineering disciplines, and subsequently employ these skills to their design projects. This approach also integrates the content of future courses with the application of engineering design. Prerequisite: EPIC151. 3 semester hours.

EPIC266. EPICS II: CHEMICAL PROCESSES. 3.0 Semester Hrs.

(I, II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. This course emphasizes steady-state design in chemical production processes and provides exposure to information about various manufacturing and research segments. Projects are selected to represent realworld chemical engineering problems in the energy sectors, chemicals and environmental stewardship, wherein creative and critical thinking skills are necessary. These projects may often involve computer-based optimization to obtain a solution. Students are exposed to the range of core engineering computation skills that are utilized in both the chemical and biochemical engineering disciplines, and subsequently employ these skills to their design projects. This approach also integrates the content of future courses with the application of engineering design. Prerequisite: EPIC151. 3 semester hours.

EPIC267. EPICS II: CIVIL ENGINEERING. 3.0 Semester Hrs.

(II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Prerequisite: EPIC151 or EPIC155. 3 semester hours.

EPIC269. EPICS II: ENGINEERING PHYSICS. 3.0 Semester Hrs.

(I) Design EPICS II builds on the design process introduced in Design EPICS I, and focuses on open-ended problem solving in which students use teamwork to develop computer software as a tool to solve problems related to engineering physics. Students will learn basic programming skills and apply them to projects that relate to current research and applications of physics. Projects are selected to represent real world physics problems wherein creative and critical thinking skills are necessary. These projects often involve computer-based optimization to obtain a solution. Students will learn how to analyze errors in data, and their effects on data interpretation and decision-making. Engineering Physics majors are encouraged to take this course in the sophomore year. It is open to other students on a space-available basis. Prerequisites: EPIC151. 2 lecture hours, 3 lab hours, 3 semester hours.

EPIC271. EPICS II MATERIALS. 3.0 Semester Hrs.

(II) Design Epics II Materials builds on the design process introduced in Design Epics I, which focuses on open-ended problem solving in student integrate teamwork and communication with the use of computer software as tools to solve materials engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a materials problem and where to find the information efficiently. Teams analyze team dynamics through weekly team meetings and progress reports. The course emphasizes oral presentations and builds on written communications techniques introduced in Design EPICS I. Prerequisite: EPIC151 or EPIC155. 2 hours lecture; 3 hours lab; 3 semester hours.

EPIC298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EPIC299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EPIC398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EPIC399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EPIC497. SPECIAL SUMMER COURSE. 6.0 Semester Hrs.**EPIC498. SPECIAL TOPICS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EPIC499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

College of Earth Resource Sciences and Engineering

Please select from the list of links on the left to locate more information.

Economics and Business

2015-16

Program Description

The economy is becoming increasingly global and dependent on advanced technology. In such a world, private companies and public organizations need leaders and managers who understand economics and business, as well as science and technology.

Programs in the Division of Economics and Business are designed to bridge the gap that often exists between economists and managers, on the one hand, and engineers and scientists, on the other. All Mines undergraduate students are introduced to economic principles in a required course, and many pursue additional course work in minor programs or elective courses. The courses introduce undergraduate students to economic and business principles so that they will understand the economic and business environments, both national and global, in which they will work and live.

In keeping with the mission of the Colorado School of Mines, the Division of Economics and Business offers a Bachelor of Science in Economics. Most economics degrees at other universities are awarded as a Bachelor of Arts, with a strong liberal arts component. Our degree is grounded in mathematics, engineering and the sciences. We graduate technologically literate economists with quantitative economics and business skills that give them a competitive advantage in today's economy.

Economics majors have a range of career options following their undergraduate studies. Some pursue graduate degrees in economics, business, or law. Others begin careers as managers, economic advisors, and financial officers in business or government, often in organizations that deal with engineering, applied science, and advanced technology.

Program Educational Objectives (Bachelor of Science in Economics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the educational objectives of the undergraduate program in economics and business are:

1. To provide students with a strong foundation in economic theory and analytical techniques, taking advantage of the mathematical and quantitative abilities of CSM undergraduate students; and
2. To prepare students for the work force, especially in organizations in CSM's areas of traditional strength (engineering, applied science, mathematics and computer science), and for graduate school, especially in economics, business, and law.

Curriculum

All economics majors take forty-five percent of their courses in math, science, and engineering, including the same core required of all CSM undergraduates. Students take another forty percent of their courses in economics and business. The remaining fifteen percent of the course work can come from any field. Many students complete minor programs in a technical field, such as computer science, engineering, geology or environmental science. A number of students pursue double majors.

To complete the economics major, students must take 45 hours of 300 and 400 level economics and business courses. Of these, 18 hours must be at the 400 level. At least 30 of the required 45 hours must be taken in residence in the home department. For students participating in an approved foreign study program, up to 19 hours of the 30 hours in residence requirement may be taken abroad.

Degree Requirements in Economics

Freshman		lec	lab	sem.hrs
CORE	Common Core			33.0
				33.0
Sophomore		lec	lab	sem.hrs
Fall				
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
DIST SCI	Distributed Science III*	3.0		3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
LAIS200	HUMAN SYSTEMS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
FREE	Free Elective	3.0		3.0
				16.5
Spring				
EBGN301	INTERMEDIATE MICROECONOMICS	3.0		3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0		3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
FREE	Free Elective			3.0
EBGN	EBGN Elective I**	3.0		3.0
				15.5
Junior		lec	lab	sem.hrs
Fall				
EBGN302	INTERMEDIATE MACROECONOMICS	3.0		3.0
EBGN325	OPERATIONS RESEARCH	3.0		3.0
EBGN	EBGN Elective II**	3.0		3.0
LAIS/EBGN	H&SS GenEd Restricted Elective I	3.0		3.0
FREE	Free Elective	3.0		3.0
				15.0
Spring				
EBGN303	ECONOMETRICS	3.0		3.0
EBGN321	ENGINEERING ECONOMICS	3.0		3.0
EBGN409	MATHEMATICAL ECONOMICS*** or EBGN Elective III**	3.0		3.0

LAIS/EBGN	H&SS GenEd Restricted Elective II	3.0	3.0
FREE	Free Elective	3.0	3.0
		15.0	
Summer		lec	lab sem.hrs
EBGN403	FIELD SESSION	3.0	3.0
		3.0	
Senior			
Fall		lec	lab sem.hrs
EBGN401	ADVANCED TOPICS IN ECONOMICS	3.0	3.0
EBGN455	LINEAR PROGRAMMING*** or EBGN Elective III**	3.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective III	3.0	3.0
EBGN	EBGN Elective IV**	3.0	3.0
FREE	Free Elective	3.0	3.0
		15.0	
Spring		lec	lab sem.hrs
EBGN	EBGN Elective V**	3.0	3.0
EBGN	EBGN Elective VI**	3.0	3.0
EBGN	EBGN Elective VII**	3.0	3.0
FREE	Free Electives	6.0	6.0
		15.0	
Total Semester Hrs: 128.0			

* Students in all degree options (majors) are required to complete a minimum of three out of five courses from the list of Distributed Science Requirements. For Economics Majors, students have a choice of three of the following: BIOL110, GEGN101, PHGN200, CHGN122, and CSCI101.

** At least 2 EBGN elective courses must be at the 400-level or above.

*** Students must take either EBGN409 or EBGN455.

Degree Requirements (Energy and Environmental Economics specialization)

Freshman

		lec	lab sem.hrs
CORE	Common Core		33.0
		33.0	

Sophomore

		lec	lab sem.hrs
Fall			
EBGN201	PRINCIPLES OF ECONOMICS	3.0	3.0
DIST SCI	Distributed Science III*	3.0	3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0	4.0
LAIS200	HUMAN SYSTEMS		3.0
PAGN2XX	PHYSICAL EDUCATION		0.5
FREE	Free Elective	3.0	3.0
		16.5	
Spring			
EBGN301	INTERMEDIATE MICROECONOMICS	3.0	3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0	3.0

MATH225	DIFFERENTIAL EQUATIONS	3.0	3.0
PAGN2XX	PHYSICAL EDUCATION		0.5
FREE	Free Elective		3.0
EBGN	EBGN Elective I	3.0	3.0
		15.5	

Junior

		lec	lab sem.hrs
Fall			
EBGN302	INTERMEDIATE MACROECONOMICS	3.0	3.0
EBGN325	OPERATIONS RESEARCH	3.0	3.0
EBGN330	ENERGY ECONOMICS	3.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective I	3.0	3.0
FREE	Free Elective	3.0	3.0
		15.0	

		lec	lab sem.hrs
Spring			
EBGN303	ECONOMETRICS	3.0	3.0
EBGN321	ENGINEERING ECONOMICS	3.0	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS		3.0
LAIS/EBGN	H&SS GenEd Restricted Elective II	3.0	3.0
FREE	Free Elective	3.0	3.0
		15.0	

		lec	lab sem.hrs
Summer			
EBGN403	FIELD SESSION	3.0	3.0
		3.0	

Senior

		lec	lab sem.hrs
Fall			
EBGN401	ADVANCED TOPICS IN ECONOMICS	3.0	3.0
EBGN430	ADVANCED ENERGY ECONOMICS		3.0
EBGN455	LINEAR PROGRAMMING** or EBGN Elective II	3.0	3.0
EBGN	EBGN Elective III	3.0	3.0
FREE	Free Elective	3.0	3.0
		15.0	

		lec	lab sem.hrs
Spring			
EBGN409	MATHEMATICAL ECONOMICS** or EBGN Elective II	3.0	3.0
EBGN470	ENVIRONMENTAL ECONOMICS	3.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective III	3.0	3.0
FREE	Free Electives	6.0	6.0
		15.0	

Total Semester Hrs: 128.0

* Students in all degree options (majors) are required to complete a minimum of three out of five courses from the list of Distributed Science Requirements. For Economics Majors, students have a choice of three of the following: BIOL110, GEGN101, PHGN200, CHGN122, and CSCI101.

** Students must take either EBGN409 or EBGN455.

General CSM Minor/ASI requirements can be found here (p. 33).

Minor Program in Economics

The minor in Economics requires that students complete 6 economics courses, for a total of 18.0 credit hours. Minors are required to take Principles of Economics (EBGN201) and either Intermediate Microeconomics (EBGN301) or Intermediate Macroeconomics (EBGN302). Students must complete 4 additional courses from the lists below. Students may choose courses from either the economics focus or the business focus list (or both). Regardless of their course selection, the minor remains "Economics." Economics courses taken as part of the Humanities and Social Sciences electives can be counted toward the minor.

Area of Special Interest in Economics

The area of special interest in Economics requires that students complete Principles of Economics (EBGN201) and 3 other courses in economics and business chosen from the lists below, for a total of 12 credit hours. Except for Principles of Economics (EBGN201), economics courses taken to complete any other graduation requirement may not be counted toward the area of special interest.

Area of Special Interest in Entrepreneurship

The objective of the Area of Special Interest in Entrepreneurship is to supplement an engineering or applied science education with tools and processes to recognize and evaluate entrepreneurial opportunities.

These tools include financial forecasting, business models and the interrelationships of business functions including accounting, marketing, finance, human resources and operations. The processes include developing feasibility studies and business plans.

The area of Special Interest in Entrepreneurship requires that students complete Principles of Economics (EBGN201), Business Principles for Entrepreneurs (EBGN361), Introduction to Entrepreneurship (EBGN360) and Business Plan Development (EBGN460), for a total of 12 credit hours.

Economics Focus

EBGN301	INTERMEDIATE MICROECONOMICS	3.0
EBGN302	INTERMEDIATE MACROECONOMICS	3.0
EBGN303	ECONOMETRICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN315	BUSINESS STRATEGY	3.0
EBGN320	ECONOMICS AND TECHNOLOGY	3.0
EBGN330	ENERGY ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EBGN342	ECONOMIC DEVELOPMENT	3.0
EBGN401	ADVANCED TOPICS IN ECONOMICS	3.0
EBGN409	MATHEMATICAL ECONOMICS	3.0
EBGN437	REGIONAL ECONOMICS	3.0
EBGN441	INTERNATIONAL ECONOMICS	3.0
EBGN443	PUBLIC ECONOMICS	3.0
EBGN470	ENVIRONMENTAL ECONOMICS	3.0
EBGN495	ECONOMIC FORECASTING	3.0

Business Focus

EBGN304	PERSONAL FINANCE	3.0
EBGN305	FINANCIAL ACCOUNTING	3.0

EBGN306	MANAGERIAL ACCOUNTING	3.0
EBGN314	PRINCIPLES OF MANAGEMENT	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
EBGN325	OPERATIONS RESEARCH	3.0
EBGN345	PRINCIPLES OF CORPORATE FINANCE	3.0
EBGN360	INTRODUCTION TO ENTREPRENEURSHIP	3.0
EBGN361	BUSINESS PRINCIPLES FOR ENTREPRENEURS	3.0
EBGN455	LINEAR PROGRAMMING	3.0
EBGN459	SUPPLY CHAIN MANAGEMENT	3.0
EBGN460	BUSINESS PLAN DEVELOPMENT	3.0
EBGN461	STOCHASTIC MODELS IN MANAGEMENT SCIENCE	3.0
EBGN474	INVENTING, PATENTING AND LICENSING	3.0

Professors

John T. Cuddington , Research Professor

Roderick G. Eggert

Graham A. Davis, William Jesse Coulter Professor

Michael R. Walls, Division Director and Professor

Associate Professors

Edward J. Balistreri

Jared C. Carbone

Michael B. Heeley

Steffan Rebennack

Assistant professors

Harrison Fell

Ian Lange

Peter Maniloff

Teaching Associate Professors

Scott Houser

Becky Lafrancois

Mark Mondry

John Stermole

Professors Emeriti

Carol A. Dahl

John E. Tilton

Franklin J. Stermole

Courses

EBGN198. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN199. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN201. PRINCIPLES OF ECONOMICS. 3.0 Semester Hrs.

(I,II,S) Introduction to microeconomics and macroeconomics. This course focuses on applying the economic way of thinking and basic tools of economic analysis. Economic effects of public policies. Analysis of markets for goods, services and resources. Tools of cost-benefit analysis. Measures of overall economic activity. Determinants of economic growth. Monetary and fiscal policy. Prerequisites: None. 3 hours lecture; 3 semester hours.

EBGN298. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN301. INTERMEDIATE MICROECONOMICS. 3.0 Semester Hrs.

Equivalent with EBG411,

(I,II) This course introduces the theoretical and analytical foundations of microeconomics and applies these models to the decisions and interactions of consumers, producers and governments. Develops and applies models of consumer choice and production with a focus on general equilibrium results for competitive markets. Examines the effects of market power and market failures on prices, allocation of resources and social welfare. Prerequisites: EBG201 and MATH213. 3 hours lecture; 3 semester hours.

EBGN302. INTERMEDIATE MACROECONOMICS. 3.0 Semester Hrs.

Equivalent with EBG412,

(I,II) Intermediate macroeconomics provides a foundation for analyzing both short-run and long-run economic performance across countries and over time. The course discusses macroeconomic data analysis (including national income and balance of payments accounting), economic fluctuations and the potentially stabilizing roles of monetary, fiscal and exchange rates policies, the role of expectations and intertemporal considerations, and the determinants of long-run growth. The effects of external and internal shocks (such as oil price shocks, resource booms and busts) are analyzed. Prerequisites: EBG201 and MATH213. 3 hours lecture; 3 semester hours.

EBGN303. ECONOMETRICS. 3.0 Semester Hrs.

Equivalent with EBG390,

(II) (WI) Introduction to econometrics, including ordinary least-squares and single- equation models; two-stage least-squares and multiple-equation models; specification error, serial correlation, heteroskedasticity, and other problems; distributive-lag models and other extensions, hypothesis testing and forecasting applications. Prerequisites: EBG201 and MATH201. 3 hours lecture; 3 semester hours.

EBGN304. PERSONAL FINANCE. 3.0 Semester Hrs.

(S) The management of household and personal finances. Overview of financial concepts with special emphasis on their application to issues faced by individuals and households: budget management, taxes, savings, housing and other major acquisitions, borrowing, insurance, investments, meeting retirement goals, and estate planning. Survey of principles and techniques for the management of a household's assets and liabilities. Study of financial institutions and their relationship to households, along with a discussion of financial instruments commonly held by individuals and families. 3 hours lecture; 3 semester hours.

EBGN305. FINANCIAL ACCOUNTING. 3.0 Semester Hrs.

(I, II) Survey and evaluation of balance sheets and income and expense statements, origin and purpose. Evaluation of depreciation, depletion, and reserve methods for tax and internal management purposes. Cash flow analysis in relation to planning and -decision making. Inventory methods and cost controls related to dynamics of production and processing. Prerequisite: EBG201. 3 hours lecture; 3 semester hours.

EBGN306. MANAGERIAL ACCOUNTING. 3.0 Semester Hrs.

(II) Introduction to cost concepts and principles of management accounting including cost accounting. The course focuses on activities that create value for customers and owners of a company and demonstrates how to generate cost-accounting information to be used in management decision making. Prerequisite: EBG201, EBG305. 3 hours lecture; 3 semester hours.

EBGN310. ENVIRONMENTAL AND RESOURCE ECONOMICS. 3.0 Semester Hrs.

(I) (WI) Application of microeconomic theory to topics in environmental and resource economics. Topics include analysis of pollution control, benefit/cost analysis in decision-making and the associated problems of measuring benefits and costs, non-renewable resource extraction, measures of resource scarcity, renewable resource management, environmental justice, sustainability, and the analysis of environmental regulations and resource policies. Prerequisite: EBG201. 3 hours lecture; 3 semester hours.

EBGN314. PRINCIPLES OF MANAGEMENT. 3.0 Semester Hrs.

(II) Introduction of underlying principles, fundamentals, and knowledge required of the manager in a complex, modern organization. Prerequisite: EBG201. 3 hours lecture; 3 semester hours.

EBGN315. BUSINESS STRATEGY. 3.0 Semester Hrs.

(II) An introduction to game theory and industrial organization (IO) principles at a practical and applied level. Topics include economies of scale and scope, the economics of the make-versus-buy decision, market structure and entry, dynamic pricing rivalry, strategic positioning, and the economics of organizational design. Prerequisite: EBG201. 3 hours lecture; 3 semester hours.

EBGN320. ECONOMICS AND TECHNOLOGY. 3.0 Semester Hrs.

(II) The theoretical, empirical and policy aspects of the economics of technology and technological change. Topics include the economics of research and development, inventions and patenting, the Internet, e-commerce, and incentives for efficient implementation of technology. Prerequisite: EBG201. 3 hours lecture; 3 semester hours.

EBGN321. ENGINEERING ECONOMICS. 3.0 Semester Hrs.

Equivalent with CHEN421,

(II) Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics on proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, (4) mutually exclusive alternative analysis and service producing alternatives. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN325. OPERATIONS RESEARCH. 3.0 Semester Hrs.

(I) This survey course introduces fundamental operations research techniques in the optimization areas of linear programming, network models (i.e., maximum flow, shortest path, and minimum cost flow), integer programming, and nonlinear programming. Stochastic (probabilistic) topics include queuing theory and simulation. Inventory models are discussed as time permits. The emphasis in this applications course is on problem formulation and obtaining solutions using Excel Software. Prerequisite: Junior Standing, EBGN201, MATH112. 3 hours lecture; 3 semester hours.

EBGN330. ENERGY ECONOMICS. 3.0 Semester Hrs.

Equivalent with ENGY330,

(I) Study of economic theories of optimal resource extraction, market power, market failure, regulation, deregulation, technological change and resource scarcity. Economic tools used to analyze OPEC, energy mergers, natural gas price controls and deregulation, electric utility restructuring, energy taxes, environmental impacts of energy use, government R&D programs, and other energy topics. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN340. ENERGY AND ENVIRONMENTAL POLICY. 3.0 Semester Hrs.

This course considers the intersection of energy and environmental policy from an economic perspective. Policy issues addressed include climate change, renewable resources, externalities of energy use, transportation, and economic development and sustainability. Prerequisites: EBGN201. 3 hours lecture; 3 semester hours.

EBGN342. ECONOMIC DEVELOPMENT. 3.0 Semester Hrs.

(II) (WI) Theories of development and underdevelopment. Sectoral development policies and industrialization. The special problems and opportunities created by an extensive mineral endowment, including the Dutch disease and the resource-curse argument. The effect of value-added processing and export diversification on development. Prerequisite: EBGN201. 3 lecture hours; 3 semester hours. Offered alternate years.

EBGN345. PRINCIPLES OF CORPORATE FINANCE. 3.0 Semester Hrs.

(II) Introduction to corporate finance, financial management, and financial markets. Time value of money and discounted cash flow valuation, risk and returns, interest rates, bond and stock valuation, capital budgeting and financing decisions. Introduction to financial engineering and financial risk management, derivatives, and hedging with derivatives. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN360. INTRODUCTION TO ENTREPRENEURSHIP. 3.0 Semester Hrs.

(I) This course introduces students to the entrepreneurial process, focusing on the concepts, practices, and tools of the entrepreneurial world. This will be accomplished through a combination of readings, cases, speakers, and projects designed to convey the unique environment of entrepreneurship and new ventures. The mastery of concepts covered in this course will lead to an initial evaluation of new venture ideas. In this course students will interact with entrepreneurs, participate in class discussion, and be active participants in the teaching/learning process. Prerequisite: EBGN201. Corequisite: EBGN361. 3 hours lecture; 3 semester hours.

EBGN361. BUSINESS PRINCIPLES FOR ENTREPRENEURS. 3.0 Semester Hrs.

(I) Students will be introduced to each of the functional areas of an entrepreneurial business, including marketing, accounting, finance, operations, human resources management, and business operations. The course is designed to help students appreciate the interrelationship of these business functions and, understand how they operate in an entrepreneurial start-up business. In this course students are expected to participate in class discussion, and be active participants in the teaching/learning process. The class will be highly interactive and your engaged participation and presence will be required. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN398. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN401. ADVANCED TOPICS IN ECONOMICS. 3.0 Semester Hrs.

(I) Application of economic theory to microeconomic and macroeconomic problems. This course will involve both theoretical and empirical modeling. Specific topics will vary by semester depending on faculty and student interest. Topics may include general equilibrium modeling, computational economics, game theory, the economics of information, intertemporal allocations, economic growth, microfoundations of macroeconomic models and policy simulation. Prerequisites: EBGN301, EBGN302 and EBGN303. 3 hours lecture; 3 semester hours.

EBGN403. FIELD SESSION. 3.0 Semester Hrs.

Equivalent with EBGN402,

(S) (WI) An applied course for students majoring in economics. The field session may consist of either participation in a computer simulation or an independent research project under the supervision of a faculty member. In the computer simulation, students work as part of the senior executive team of a company and are responsible for developing and executing a strategy for their company with on-going decisions on everything from new product development, to marketing, to finance and accounting. Prerequisites: EBGN301, EBGN302, EBGN303. 3 semester hours.

EBGN404. ADVANCED TOPICS IN MICROECONOMICS. 3.0 Semester Hrs.

(I) Application of economic theory to microeconomic problems. This course will involve both theoretical and empirical modeling of consumers, producers and markets. Topics may include game theory, risk and uncertainty, the economics of information, intertemporal allocations and general equilibrium modeling. Prerequisites: EBGN301, EBGN302 and EBGN303. 3 hours lecture; 3 semester hours.

EBGN405. ADVANCED TOPICS IN MACROECONOMICS. 3.0 Semester Hrs.

(I) This course is a sequel to Intermediate Macroeconomics. The course will cover (i) modern economic growth theory and empirics; (ii) microfoundations and econometric estimation of macroeconomic relationships, such as consumption, gross fixed investment, inventory behavior and the sustainability of fiscal deficits; and (iii) multi-sectoral models of international trade and finance. Other topics may include real business cycle models, macroeconomic policy simulation, macroeconomic policy efficacy in globally integrated economies, foreign repercussions effects, empirical relationships between interest rates and exchange rates, and interactions between resource industries and the rest of the economy. Prerequisites: EBGN301, ENG302, EBGN303. 3 hours lecture; 3 semester hours.

EBGN409. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.

(II) Application of mathematical tools to economic problems. Coverage of mathematics needed to read published economic literature and to do graduate study in economics. Topics from differential and integral calculus, matrix algebra, differential equations, and dynamic programming. Applications are taken from mineral, energy, and environmental issues, requiring both analytical and computer solutions using programs such as GAMS and MATHEMATICA. Prerequisites: MATH213, EBGN301, EBGN302. 3 hours lecture; 3 semester hours.

EBGN430. ADVANCED ENERGY ECONOMICS. 3.0 Semester Hrs.

(I) Application of economic models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques and applications include market structure, energy efficiency, demand-side management, energy policy and regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: EBGN301, EBGN330. 3 hours lecture; 3 semester hours.

EBGN437. REGIONAL ECONOMICS. 3.0 Semester Hrs.

(I) (WI) Analysis of the spatial dimension of economies and economic decisions. Interregional capital and labor mobility. Location decisions of firms and households. Agglomeration economies. Models of regional economic growth. Measuring and forecasting economic impact and regional growth. Local and regional economic development policy. Urban and regional spatial structure. Emphasis on application of tools and techniques of regional analysis. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN441. INTERNATIONAL ECONOMICS. 3.0 Semester Hrs.

(II) (WI) Theories and determinants of international trade, including static and dynamic comparative advantage and the gains from trade. The history of arguments for and against free trade. The political economy of trade policy in both developing and developed countries. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN443. PUBLIC ECONOMICS. 3.0 Semester Hrs.

(I) (WI) This course covers public-sector economics, including the fundamental institutions and relationships between the government and private decision makers. It covers the fundamental general equilibrium welfare theorems and their interaction with government policy instruments that affect efficiency and distribution. Normative topics include an intensive study of the causes and consequences of, and policy prescriptions for, market failure due to public goods, or other problems associated with externalities and income distribution. Positive analysis focuses on policy formation in the context of political- economy and public choice theories. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN455. LINEAR PROGRAMMING. 3.0 Semester Hrs.

(I) This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming, an introduction to linear integer programming, and the interior point method are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisites: MATH332 or MATH348 or EBGN409. 3 hours lecture; 3 semester hours.

EBGN459. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.

(II) As a quantitative managerial course, the course will explore how firms can better organize their operations so that they more effectively align their supply with the demand for their products and services. Supply Chain Management (SCM) is concerned with the efficient integration of suppliers, factories, warehouses and retail-stores (or other forms of distribution channels) so that products are provided to customers in the right quantity and at the right time. Topics include managing economies of scale for functional products, managing market- mediation costs for innovative products, make-to order versus make-to-stock systems, quick response strategies, risk pooling strategies, supply-chain contracts and revenue management. Additional "special topics" will also be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN460. BUSINESS PLAN DEVELOPMENT. 3.0 Semester Hrs.

(II) This course leads students through the process of developing a detailed business plan for a start-up company. The creation of a business plan can be challenging, frustrating, fascinating and will lead to a more in-depth understand of how businesses start and operate. Most new ventures are started by teams, with complementary skills and experience sets. In this class, therefore, students will work in teams to develop and write a business plan. This class is also about identifying a new product or service with a viable market and potential to develop into a profitable enterprise by expanding the feasibility study work from EBGN360. This course is the hands-on work of developing a business plan, and as such is intense and demanding. Additionally, this course will integrate previous entrepreneurship, business and economics classes. In this course students are expected to participate in class discussion, and be active participants in the teaching/learning process. The class will be highly interactive and engaged participation and presence will be required. Prerequisites: EBGN360, EBGN361; 3 hours lecture; 3 semester hours.

EBGN461. STOCHASTIC MODELS IN MANAGEMENT SCIENCE. 3.0 Semester Hrs.

(II) As a quantitative managerial course, the course is an introduction to the use of probability models for analyzing risks and economic decisions and doing performance analysis for dynamic systems. The difficulties of making decisions under uncertainty are familiar to everyone. We will learn models that help us quantitatively analyze uncertainty and how to use related software packages for managerial decision-making and to do optimization under uncertainty. Illustrative examples will be drawn from many fields including marketing, finance, production, logistics and distribution, energy and mining. The main focus of the course is to see methodologies that help to quantify the dynamic relationships of sequences of "random" events that evolve over time. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN470. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.

(II) (WI) This course considers the role of markets as they relate to the environment. Topics discussed include environmental policy and economic incentives, market and non-market approaches to pollution regulation, property rights and the environment, the use of benefit/cost analysis in environmental policy decisions, and methods for measuring environmental and nonmarket values. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN474. INVENTING, PATENTING AND LICENSING. 3.0 Semester Hrs.

(S) (WI) This course provides an introduction to the legal framework of inventing and patenting and addresses practical issues facing inventors. The course examines patent law, inventing and patenting in the corporate environment, patent infringement and litigation, licensing, and the economic impact of patents. Methods and resources for market evaluation, searching prior art, documentation and disclosure of invention, and preparing patent applications are presented. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN495. ECONOMIC FORECASTING. 3.0 Semester Hrs.

(II) An introduction to the methods employed in business and econometric forecasting. Topics include time series modeling, Box-Jenkins models, vector autoregression, cointegration, exponential smoothing and seasonal adjustments. Covers data collection methods, graphing, model building, model interpretation, and presentation of results. Topics include demand and sales forecasting, the use of anticipations data, leading indicators and scenario analysis, business cycle forecasting, GNP, stock market prices and commodity market prices. Includes discussion of links between economic forecasting and government policy. Prerequisites: EBGN301, EBGN302, EBGN303. 3 hours lecture; 3 semester hours.

EBGN497. SUMMER PROGRAMS. 6.0 Semester Hrs.**EBGN498. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Geology and Geological Engineering

2015-2016

Program Description

A Bachelor of Science degree in Geological Engineering is the basis for careers concentrating on the interaction of humans and the earth. Geological Engineers deal with a wide variety of the resource and environmental problems that come with accommodating more and more people on a finite planet. Geologic hazards and conditions must be recognized and considered in the location and design of foundations for buildings, roads and other structures; waste disposal facilities must be properly located, designed and constructed; contaminated sites and ground water must be accurately characterized before cleanup can be accomplished; water supplies must be located, developed and protected; and new mineral and energy resources must be located and developed in an environmentally sound manner. Geological Engineers are the professionals trained to meet these challenges.

The Geological Engineering curriculum provides a strong foundation in the basic sciences, mathematics, geological science and basic engineering along with specialized upper level instruction in integrated applications to real problems. Engineering design is integrated throughout the four year program, beginning in Design I (Freshman year) and ending with the capstone design courses in the senior year. The program is accredited by the:

Engineering Accreditation Commission of Accreditation Inc
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
Telephone: (410) 347-7700.

Students have the background to take the Fundamentals of Engineering Exam, the first step in becoming a registered Professional Engineer.

Graduates follow five general career paths:

Engineering Geology and Geotechnics. Careers in site investigation, design and stabilization of foundations and slopes; site characterization, design, construction and remediation of waste disposal sites or contaminated sites; and assessment of geologic hazards for civil, mining or environmental engineering projects.

Ground-Water Engineering. Careers in assessment and remediation of ground-water contamination, design of ground-water control facilities for geotechnical projects and exploration for and development of ground-water supplies.

Petroleum Exploration and Development Engineering. Careers in search for and development of oil and gas and their efficient extraction.

Mineral Exploration and Development Engineering. Careers in search for and development of natural deposits of metals, industrial materials and rock aggregate.

Geological Science. Students are also well prepared to pursue careers in basic geoscience. Graduates have become experts in fields as divergent as global climate change, the early history of the Earth, planetary science, fractal representation of ground-water flow and simulation of sedimentary rock sequences, to name a few. Careers are available in research and education.

The curriculum may be followed along two concentration paths with slightly different upper division requirements. Both concentrations are identical in the first two years as students study basic science, mathematics, engineering science, and geological science. In the junior year those students pursuing careers in ground-water engineering, engineering geology and geotechnics, or geoenvironmental engineering applications follow the Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration. Students anticipating careers in resource exploration and development or who expect to pursue graduate studies in geological sciences follow the Mineral and Petroleum Exploration Engineering Concentration.

At all levels the Geological Engineering Program emphasizes laboratory and field experience. All courses have a laboratory session, and after the junior year students participate in a field course, which is six weeks of geologic and engineering mapping and direct observation. The course involves considerable time outdoors in the mountains and canyons of Utah and southwestern Colorado.

At the senior level, students begin to focus on a career path by taking course sequences in at least two areas of geological engineering specialization. The course sequences begin with a 4 unit course in the fundamentals of a field of geological engineering which is followed by a 3 unit design-oriented course that emphasizes experience in direct application of principles through design projects.

Combined Undergraduate/Graduate Programs

Several degree programs offer CSM undergraduate students the opportunity to begin work on a Graduate Certificate, Professional Degree, or Master Degree while completing the requirements for their Bachelor Degree. These programs can give students a head start on graduate education. An overview of these combined programs and description of the admission process and requirements are found in the Graduate Degrees and Requirements section of the Graduate Bulletin.

Program Educational Objectives (Bachelor of Science in Geological Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Geological Engineering Program at CSM has established the following program educational objectives, which students are expected to attain within a few years of graduation:

1. Demonstrate a high level of technical competence
2. Demonstrate prowess in written, oral and graphical communication
3. Experience good teamwork and leadership practices

Program Requirements

In order to achieve the program goals listed above, every student working toward the Bachelor of Science Degree in Geological Engineering must complete the following requirements:

Degree Requirements (Geological Engineering)

Following the sophomore year, Geological Engineering students choose from one of two concentrations:

1. Minerals and Petroleum Exploration Engineering

2. Environmental, Engineering Geology and Geotechnics, and Ground-water Engineering

Minerals and Petroleum Exploration Engineering Concentration

Recommended for students intending careers in exploration and development of mineral and fuels resources, or intending careers in geoscience research and education.

Freshman

Fall		lec	lab	sem.hrs
PAGN101	PHYSICAL EDUCATION	0.5		0.5
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS	3.0	3.0	4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
EPIC151	DESIGN (EPICS) I	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR	0.5		0.5

16.0

Spring

		lec	lab	sem.hrs
PAGN102	PHYSICAL EDUCATION	0.5		0.5
PHGN100	PHYSICS I - MECHANICS	3.5	3.0	4.5
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)	3.0	3.0	4.0
LAIS100	NATURE AND HUMAN VALUES	4.0		4.0

17.0

Sophomore

Fall		lec	lab	sem.hrs
GEGN203	ENGINEERING TERRAIN ANALYSIS	2.0		2.0
GEGN204	GEOLOGIC PRINCIPLES AND PROCESSES	2.0		2.0
GEGN205	ADVANCED PHYSICAL GEOLOGY LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
CEEN241	STATICS	3.0		3.0
LAIS200	HUMAN SYSTEMS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION	0.5		0.5

15.5

Spring

		lec	lab	sem.hrs
EPIC264	EPICS II: GEOLOGY GIS	2.0	3.0	3.0
GEGN206	EARTH MATERIALS	2.0	3.0	3.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
MATH222	INTRODUCTION TO DIFFERENTIAL EQUATIONS FOR GEOLOGISTS & GEOLOGICAL ENGINEERS [^]	2.0		2.0
CEEN311	MECHANICS OF MATERIALS	3.0		3.0

PAGN2XX	PHYSICAL EDUCATION	0.5	0.5	
				16.0

Junior

Fall		lec	lab	sem.hrs
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	3.0	3.0	4.0
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	2.0	3.0	3.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
CEEN312	SOIL MECHANICS or MNGN 321			3.0
				16.0

Spring

		lec	lab	sem.hrs
GEGN307	PETROLOGY	2.0	3.0	3.0
GEGN317	GEOLOGIC FIELD METHODS	1.0	8.0	2.0
GEOL314	STRATIGRAPHY	3.0	3.0	4.0
GEGN351	GEOLOGICAL FLUID MECHANICS	3.0		3.0
LAIS/EBGN	H&SS GenEd Restricted Elective I	3.0		3.0
TECH ELECT	Tech Elective II*	3.0		3.0
				18.0

Summer

		lec	lab	sem.hrs
GEGN316	FIELD GEOLOGY		6.0	6.0
				6.0

Senior

Fall		lec	lab	sem.hrs
GEGN ELECT	GEGN4xx Option Elective	3.0	3.0	4.0
GEGN ELECT	GEGN4xx Option Elective	3.0	3.0	4.0
GEGN432	GEOLOGICAL DATA MANAGEMENT	1.0	6.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective II	3.0		3.0
FREE	Free Elective			3.0
				17.0

Spring

		lec	lab	sem.hrs
GEGN ELECT	GEGN4xx Design Elective	2.0	3.0	3.0
GEGN ELECT	GEGN 4xx Design Elective	2.0	3.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective III	3.0		3.0
FREE	Free Elective			3.0
FREE	Free Elective			3.0
				15.0

Total Semester Hrs: 136.5

* Technical Electives I & II: Either MNGN321 or CEEN312 is required as ONE of the technical electives. An additional technical elective must be selected from a department list of approved courses. The technical elective credits must total a minimum of 6 hours of engineering topics with a minimum of 3 credit hours of engineering design.

^ Only one of MATH222 and MATH225 can be counted toward graduation in GE. Any student who completes MATH222 and then changes majors out of Geology and Geological Engineering will be expected to complete MATH225 to meet graduation requirements. (In this case, MATH222 cannot be counted toward graduation in any manner - even as a free elective.)

Option Electives

Student must take TWO of the following four courses: 8.0

GEGN401	MINERAL DEPOSITS
GEGN438	PETROLEUM GEOLOGY
GEGN467	GROUNDWATER ENGINEERING
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS

Design Electives

Students must take TWO of the following design courses, corresponding in subject area to the Option Elective: 6.0

GEGN403	MINERAL EXPLORATION DESIGN
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN
GEGN469	ENGINEERING GEOLOGY DESIGN
GEGN470	GROUND-WATER ENGINEERING DESIGN

Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration

Recommended for students intending careers in geotechnical engineering, hydrogeology, or other environmental engineering careers.

Freshman

Fall		lec	lab	sem.hrs
PAGN101	PHYSICAL EDUCATION	0.5		0.5
GEGN101	EARTH AND ENVIRONMENTAL SYSTEMS	3.0	3.0	4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I	4.0		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I	3.0	3.0	4.0
EPIC151	DESIGN (EPICS) I	3.0		3.0
CSM101	FRESHMAN SUCCESS SEMINAR	0.5		0.5
				16.0

Spring

		lec	lab	sem.hrs
PAGN102	PHYSICAL EDUCATION	0.5		0.5
PHGN100	PHYSICS I - MECHANICS	3.5	3.0	4.5
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II	4.0		4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)	3.0	3.0	4.0
LAIS100	NATURE AND HUMAN VALUES	4.0		4.0
				17.0

Sophomore

Fall		lec	lab	sem.hrs
GEGN203	ENGINEERING TERRAIN ANALYSIS	2.0		2.0
GEGN204	GEOLOGIC PRINCIPLES AND PROCESSES	2.0		2.0
GEGN205	ADVANCED PHYSICAL GEOLOGY LABORATORY		3.0	1.0

MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0	4.0	
CEEN241	STATICS	3.0	3.0	
LAIS200	HUMAN SYSTEMS	3.0	3.0	
PAGN2XX	PHYSICAL EDUCATION	0.5	0.5	

15.5

Spring		lec	lab sem.hrs	
EPIC264	EPICS II: GEOLOGY GIS	3.0		3.0
GEGN206	EARTH MATERIALS	2.0	3.0	3.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
MATH222	INTRODUCTION TO DIFFERENTIAL EQUATIONS FOR GEOLOGISTS & GEOLOGICAL ENGINEERS [^]	2.0		2.0
CEEN311	MECHANICS OF MATERIALS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION	0.5		0.5

16.0**Junior**

Fall		lec	lab sem.hrs	
GEGN212	PETROGRAPHY FOR GEOLOGICAL ENGINEERS	1.0	3.0	2.0
GEOL309	STRUCTURAL GEOLOGY AND TECTONICS	3.0	3.0	4.0
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS or MEGN 361			3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
CEEN312	SOIL MECHANICS			3.0
CEEN312L	SOIL MECHANICS LABORATORY			1.0

16.0

Spring		lec	lab sem.hrs	
GEGN317	GEOLOGIC FIELD METHODS	1.0	8.0	2.0
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0		3.0
GEOL314	STRATIGRAPHY	3.0	3.0	4.0
GEGN351	GEOLOGICAL FLUID MECHANICS	3.0		3.0
LAIS/EBGN	H&SS GenEd Restricted Elective I	3.0		3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	2.0	3.0	3.0

18.0

Summer		lec	lab sem.hrs	
GEGN316	FIELD GEOLOGY		6.0	6.0

6.0**Senior**

Fall		lec	lab sem.hrs	
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	3.0	3.0	4.0
GEGN467	GROUNDWATER ENGINEERING	3.0	3.0	4.0
GEGN432	GEOLOGICAL DATA MANAGEMENT	1.0	6.0	3.0
LAIS/EBGN	H&SS GenEd Restricted Elective II	3.0		3.0
FREE	Free Elective	3.0		3.0

17.0

Spring		lec	lab sem.hrs	
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0		3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0		3.0
LAIS/EBGN	H&SS GenEd Restricted Elective III	3.0		3.0
FREE	Free Elective	3.0		3.0
FREE	Free Elective	3.0		3.0

15.0**Total Semester Hrs: 136.5**

[^] Only one of MATH222 and MATH225 can be counted toward graduation in GE. Any student who completes MATH222 and then changes majors out of Geology and Geological Engineering will be expected to complete MATH225 to meet graduation requirements. (In this case, MATH222 cannot be counted toward graduation in any manner - even as a free elective.)

Students in the Environmental, Engineering Geology and Geotechnics, and Ground-Water Engineering Concentration may further specialize by utilizing their free elective courses to emphasize a specific specialty. Suggested courses are presented below and should be selected in consultation with the student's advisor. The emphasis area is an informal designation only and it will not appear on the transcript.

Engineering Geology and Geotechnics Emphasis

CEEN415	FOUNDATION ENGINEERING	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
GEGN399	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEGN307	PETROLOGY	3.0
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	3.0
CSCI261	PROGRAMMING CONCEPTS	3.0
MNGN404	TUNNELING	3.0
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	2.0
MNGN410	EXCAVATION PROJECT MANAGEMENT	2.0
MNGN445/545	ROCK SLOPE ENGINEERING	3.0

Water Engineering Emphasis

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CEEN302	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II	3.0
CEEN461	FUNDAMENTALS OF ECOLOGY	3.0
CEEN470	WATER AND WASTEWATER TREATMENT PROCESSES	3.0
CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
CEEN475	SITE REMEDIATION ENGINEERING	3.0

CEEN480	CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT	3.0
CSCI260	FORTRAN PROGRAMMING	2.0
CSCI261	PROGRAMMING CONCEPTS	3.0
EBGN321	ENGINEERING ECONOMICS	3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CEEN492	ENVIRONMENTAL LAW	3.0
GEGN475	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN481	ADVANCED HYDROGEOLOGY	3.0
GEGN483	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
GEOL321	MINERALOGY AND MINERAL CHARACTERIZATION	3.0
LAIS487	ENVIRONMENTAL POLITICS AND POLICY	3.0
LAIS488	WATER POLITICS AND POLICY	3.0
MATH332	LINEAR ALGEBRA	3.0
MEGN451	FLUID MECHANICS II	3.0

General CSM Minor/ASI requirements can be found here (p. 33).

Geological Engineering Minor and Area of Special Interest

To receive a minor or ASI, a student must take at least 12 (ASI) or 18 (minor) hours of a logical sequence of courses. This may include GEGN101 (4 hours) and up to 4 hours at the 200-level.

Students must consult with the Department to have their sequence of courses approved before embarking on a minor program.

Professor and Department Head

Paul M. Santi

Professors

Wendy J. Harrison

Murray W. Hitzman, Charles F. Fogarty Professor of Economic Geology

Reed M. Maxwell

Stephen A. Sonnenberg, Charles Boettcher Distinguished Chair in Petroleum Geology

Richard F. Wendlandt

Lesli J. Wood, Weimer Distinguished Chair and Professor, Geology

Associate Professors

David A. Benson

Jerry D. Higgins

John D. Humphrey

Thomas Monecke

Piret Plink-Bjorklund

Kamini Singha, Joint appointment with Civil and Environmental Engineering

Bruce Trudgill

Wei Zhou

Assistant Professors

Alexander Gysi

Yvette Kuiper

Alexis Stichter

Gabriel Walton

Teaching Professor

Christian V. Shorey

Research Professors

David Pyles

J. Fredrick Sarg

Research Associate Professors

Donna S. Anderson

Nicholas B. Harris

Research Assistant Professors

Jennifer L. Aschoff

Jeremy Boak

Maeve Boland

Mary Carr

Brian Ebel

Karin Hoal

Nigel Kelly

Professors Emerita

Eileen Poeter

Professors Emeriti

John B. Curtis

Thomas L.T. Grose

John D. Haun

Neil F. Hurley

Keenan Lee

Samuel B. Romberger

A. Keith Turner

John E. Warme

Robert J. Weimer

Associate Professors Emeriti

L. Graham Closs

Timothy A. Cross

Gregory S. Holden

Joint Appointment

Stephen M. Enders

John E. McCray

Courses

GEGN101. EARTH AND ENVIRONMENTAL SYSTEMS. 4.0 Semester Hrs.

Equivalent with SYGN101,

(I, II, S) Fundamental concepts concerning the nature, composition and evolution of the lithosphere, hydrosphere, atmosphere and biosphere of the earth integrating the basic sciences of chemistry, physics, biology and mathematics. Understanding of anthropological interactions with the natural systems, and related discussions on cycling of energy and mass, global warming, natural hazards, land use, mitigation of environmental problems such as toxic waste disposal, exploitation and conservation of energy, mineral and agricultural resources, proper use of water resources, biodiversity and construction. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN203. ENGINEERING TERRAIN ANALYSIS. 2.0 Semester Hrs.

(I) Analysis of landforms, geologic processes, principles of geomorphology, mapping, air photo and map interpretation, and engineering uses of geologic information.. Geomorphology of glacial, volcanic, arid, karst, and complex geological landscapes. Introduction to weathering, soils, hillslopes, and drainage systems. Prerequisite: GEGN101. Must be taken concurrently with GEGN204 and GEGN205 for GE majors. 2 hours lecture, 2 semester hours.

GEGN204. GEOLOGIC PRINCIPLES AND PROCESSES. 2.0 Semester Hrs.

(I) Introduction to advanced concepts of physical and historical geology from a scientific perspective. Development of the geologic time scale, relative time, and geochronology. Chemical composition and cycling of elements in the Earth. Plate tectonics and how tectonics influence sea-level history and sedimentation patterns. Evolution and the fossil record. Critical events in Earth history with a focus on North America and Colorado geology. Prerequisite: GEGN101. Must be taken concurrently with GEGN203 and GEGN205 for GE majors. 2 hours lecture, 2 semester hours.

GEGN205. ADVANCED PHYSICAL GEOLOGY LABORATORY. 1.0 Semester Hr.

(I) Basic geologic mapping and data gathering skills, with special emphasis on air photos and topographic and geologic maps. Course will include fieldwork in geomorphic regions of Colorado, with analysis of landforms and geologic processes. Applications of geologic information to solve geologic engineering problems. Prerequisite: GEGN101. Must be taken concurrently with GEGN203 and GEGN204 for GE majors. 3 hours laboratory, 1 semester hour.

GEGN206. EARTH MATERIALS. 3.0 Semester Hrs.

(II) Introduction to Earth Materials, emphasizing the structure, composition, formation, and behavior of minerals. Laboratories emphasize the recognition, description, and engineering evaluation of earth materials. Prerequisite: GEGN101, GEGN203, GEGN204, GEGN205. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN212. PETROGRAPHY FOR GEOLOGICAL ENGINEERS. 2.0 Semester Hrs.

(I) Introduction to concepts of rock forming processes as a basis for rock classification. The course will teach practical skills allowing identification of common rock types in hand specimen and in outcrop. Subsurface and nearsurface alteration and weathering processes will be covered, emphasizing recognition of secondary mineral products and the changes to the physical properties of these minerals in the rock masses. Prerequisites: GEGN206 or equivalent. 1 hour lecture, 3 hours lab; 2 semester hours.

GEGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN299. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN307. PETROLOGY. 3.0 Semester Hrs.

Equivalent with GEOL307,

(II) An introduction to igneous, sedimentary and metamorphic processes, stressing the application of chemical and physical mechanisms to study the origin, occurrence, and association of rock types. Emphasis on the megascopic and microscopic classification, description, and interpretation of rocks. Analysis of the fabric and physical properties. Prerequisite: GEOL321, CHGN209. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN316. FIELD GEOLOGY. 6.0 Semester Hrs.

(S) Six weeks of field work, stressing geology of the Southern Rocky Mountain Province. Mapping of igneous, metamorphic, and sedimentary terrain using air photos, topographic maps, and other methods. Diversified individual problems in petroleum geology, mining geology, engineering geology, structural geology, and stratigraphy. Formal reports submitted on several problems. Frequent evening lectures and discussion sessions. Field trips emphasize regional geology as well as mining, petroleum, and engineering projects. Prerequisites: GEGN203, GEGN204, GEGN205, GEGN206, GEGN212 or GEGN307, GEOL314, GEOL309, and GEGN317. 6 semester hours (Summer Term).

GEGN317. GEOLOGIC FIELD METHODS. 2.0 Semester Hrs.

(II) Methods and techniques of geologic field observations and interpretations. Lectures in field techniques and local geology. Laboratory and field project in diverse sedimentary, igneous, metamorphic, structural, and surficial terrains using aerial photographs and topographic maps. Geologic cross sections, maps, and reports. Weekend exercises required. Prerequisites: GEGN203, GEGN204, GEGN205, GEOL309 or GEOL308, GEGN212 or completion or concurrent enrollment in GEGN307, and completion or concurrent enrollment in GEOL314. 1 hour lecture, 8 hours field; 2 semester hours.

GEGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

GEGN342. ENGINEERING GEOMORPHOLOGY. 3.0 Semester Hrs.

(I) Study of interrelationships between internal and external earth processes, geologic materials, time, and resulting landforms on the Earth's surface. Influences of geomorphic processes on design of natural resource exploration programs and siting and design of geotechnical and hydrogeologic projects. Laboratory analysis of geomorphic and geologic features utilizing maps, photo interpretation and field observations. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN351. GEOLOGICAL FLUID MECHANICS. 3.0 Semester Hrs.

(II) Properties of fluids; Bernoulli's energy equation, the momentum and mass equations; laminar and turbulent flow in pipes, channels, machinery, and earth materials; subcritical and supercritical flow in channels; Darcy's Law; the Coriolis effect and geostrophic flow in the oceans and atmosphere; sediment transport. Prerequisite: CEEN241. 3 hours lecture; 3 semester hours.

GEGN398. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN399. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN401. MINERAL DEPOSITS. 4.0 Semester Hrs.

(I) Introductory presentation of magmatic, hydrothermal, and sedimentary metallic ore deposits. Chemical, petrologic, structural, and sedimentological processes that contribute to ore formation. Description of classic deposits representing individual deposit types. Review of exploration sequences. Laboratory consists of hand specimen study of host rock-ore mineral suites and mineral deposit evaluation problems. Prerequisite: CHGN209, GEGN307, GEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN403. MINERAL EXPLORATION DESIGN. 3.0 Semester Hrs.

(II) (WI) Exploration project design: commodity selection, target selection, genetic models, alternative exploration approaches and associated costs, exploration models, property acquisition, and preliminary economic evaluation. Lectures and laboratory exercises to simulate the entire exploration sequence from inception and planning through implementation to discovery, with initial ore reserve calculations and preliminary economic evaluation. Prerequisite: GEGN401 and EPIC251. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN404. ORE MICROSCOPY. 3.0 Semester Hrs.

(II) Identification of ore minerals using reflected light microscopy, micro-hardness, and reflectivity techniques. Interpretation of common ore mineral textures, including those produced by magmatic segregation, open space filling, replacement, exsolution, and recrystallization. Guided research on the ore mineralogy and ore textures of classical ore deposits. Prerequisite: GEOL321, GEGN401. 6 hours lab; 3 semester hours.

GEGN432. GEOLOGICAL DATA MANAGEMENT. 3.0 Semester Hrs.

(I) Techniques for managing and analyzing geological data, including statistical analysis procedures and computer programming. Topics addressed include elementary probability, populations and distributions, estimation, hypothesis testing, analysis of data sequences, mapping, sampling and sample representativity, linear regression, and overview of univariate and multivariate statistical methods. Practical experience with principles of software programming and statistical analysis for geological applications via supplied software and data sets from geological case histories. Prerequisites: Senior standing in Geological Engineering. 1 hour lecture, 6 hours lab; 3 semester hours.

GEGN438. PETROLEUM GEOLOGY. 4.0 Semester Hrs.

(I) Source rocks, reservoir rocks, types of traps, temperature and pressure conditions of the reservoir, theories of origin and accumulation of petroleum, geology of major petroleum fields and provinces of the world, and methods of exploration for petroleum. Term report required. Laboratory consists of study of well log analysis, stratigraphic correlation, production mapping, hydrodynamics and exploration exercises. Prerequisite: GEOL308 or GEOL309 and GEOL314 or GEOL315; and GEGN316 or GPGN486 or PEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN439. MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.

Equivalent with PEGN439,

(II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GE Majors: GEOL309, GEOL314, GEGN438, and EPIC264; GP Majors: GPGN302, GPGN303, and EPIC268; PE Majors: GEOL308, PEGN316 and PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN466. GROUNDWATER ENGINEERING. 3.0 Semester Hrs.

(I) Theory of groundwater occurrence and flow. Relation of groundwater to surface; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Prerequisites: Calc III (MATH213 or MATH223 or MATH224) and DiffEQ (MATH225 or MATH235) and GEGN351 or MEGN351. 3 hours lecture, 3 semester hours.

GEGN467. GROUNDWATER ENGINEERING. 4.0 Semester Hrs.

(I) Theory of groundwater occurrence and flow. Relation of groundwater to surface water; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Laboratory sessions on water budgets, water chemistry, properties of porous media, solutions to hydraulic flow problems, analytical and digital models, and hydrogeologic interpretation. Prerequisites: Calc III (MATH213, MATH223 or MATH224) and DiffEQ (MATH225 or MATH235) and GEGN351 or MEGN351. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN468. ENGINEERING GEOLOGY AND GEOTECHNICS. 4.0 Semester Hrs.

(I) Application of geology to evaluation of construction, mining, and environmental projects such as dams, water ways, tunnels, highways, bridges, buildings, mine design, and land-based waste disposal facilities. Design projects including field, laboratory, and computer analysis are an important part of the course. Prerequisite: MNGN321 and CEEN312/CEEN312L. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN469. ENGINEERING GEOLOGY DESIGN. 3.0 Semester Hrs.

(II) (WI) This is a capstone design course that emphasizes realistic engineering geologic/geotechnics projects. Lecture time is used to introduce projects and discussions of methods and procedures for project work. Several major projects will be assigned and one to two field trips will be required. Students work as individual investigators and in teams. Final written design reports and oral presentations are required. Prerequisite: GEGN468 or equivalent and EPIC264. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN470. GROUND-WATER ENGINEERING DESIGN. 3.0 Semester Hrs.

(II) (WI) Application of the principles of hydrogeology and ground-water engineering to water supply, geotechnical, or water quality problems involving the design of well fields, drilling programs, and/or pump tests. Engineering reports, complete with specifications, analysis, and results, will be required. Prerequisite: GEGN467 or equivalent and EPIC264. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN473. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.

(II) Methods of field investigation, testing, and monitoring for geotechnical and hazardous waste sites, including: drilling and sampling methods, sample logging, field testing methods, instrumentation, trench logging, foundation inspection, engineering stratigraphic column and engineering soils map construction. Projects will include technical writing for investigations (reports, memos, proposals, workplans). Class will culminate in practice conducting simulated investigations (using a computer simulator). 3 hours lecture; 3 semester hours.

GEGN475. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.

(II) An introduction to Geographic Information Systems (GIS) and their applications to all areas of geology and geological engineering. Lecture topics include: principles of GIS, data structures, digital elevation models, data input and verification, data analysis and spatial modeling, data quality and error propagation, methods of GIS projects, as well as video presentations. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN481. ADVANCED HYDROGEOLOGY. 3.0 Semester Hrs.

(I) Lectures, assigned readings, and discussions concerning the theory, measurement, and estimation of ground water parameters, fractured-rock flow, new or specialized methods of well hydraulics and pump tests, tracer methods, and well construction design. Design of well tests in variety of settings. Prerequisites: GEGN467. 3 hours lecture; 3 semester hours.

GEGN483. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.

(II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of analytical and finite-difference solutions to ground water flow problems as well as an introduction to inverse modeling. Design of computer models to solve ground water problems. Prerequisites: Familiarity with computers, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN497. SUMMER PROGRAMS. 15.0 Semester Hrs.**GEGN498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN499. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOC407. ATMOSPHERE, WEATHER AND CLIMATE. 3.0 Semester Hrs.

(II) An introduction to the Earth's atmosphere and its role in weather patterns and long term climate. Provides basic understanding of origin and evolution of the atmosphere, Earth's heat budget, global atmospheric circulation and modern climatic zones. Long- and short-term climate change including paleoclimatology, the causes of glacial periods and global warming, and the depletion of the ozone layer. Causes and effects of volcanic eruptions on climate, El Nino, acid rain, severe thunderstorms, tornadoes, hurricanes, and avalanches are also discussed. Microclimates and weather patterns common in Colorado. Prerequisite: Completion of CSM freshman technical core, or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOC408. INTRODUCTION TO OCEANOGRAPHY. 3.0 Semester Hrs.

(II) An introduction to the scientific study of the oceans, including chemistry, physics, geology, biology, geophysics, and mineral resources of the marine environment. Lectures from pertinent disciplines are included. Recommended background: basic college courses in chemistry, geology, mathematics, and physics. 3 hours lecture; 3 semester hours. Offered alternate years.

GEO102. INTRODUCTION TO GEOLOGICAL ENGINEERING. 1.0 Semester Hr.

(II) Presentations by faculty members and outside professionals of case studies to provide a comprehensive overview of the fields of Geology and Geological Engineering and the preparation necessary to pursue careers in those fields. A short paper on an academic professional path will be required. Prerequisite: GEGN101 or concurrent enrollment. 1 hour lecture; 1 semester hour.

GEOL198. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL199. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL299. INDEPENDENT STUDY. 1-6 Semester Hr.

GEOL308. INTRODUCTORY APPLIED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.

(II) Nature and origin of structural features of Earth's crust emphasizing structural controls on oil and gas entrapment. Structural patterns and associations are discussed in context of plate tectonic theories, using examples from across the globe. In class exercises and field projects in structural geometry, mapping and cross section construction and seismic reflection data interpretation. Course required of all PEGN and GPGN students. Prerequisite: GEGN101. 3 hours lecture; 3 semester hours.

GEOL309. STRUCTURAL GEOLOGY AND TECTONICS. 4.0 Semester Hrs.

(I) (VI) Recognition, habitat, and origin of deformational structures related to stresses and strains (rock mechanics and microstructures) and plate tectonics. Structural development of mountain belts, rift, strike-slip and salt systems. Comprehensive field and laboratory projects use descriptive geometry, stereographic projection, structural contours, map and cross section construction, air photo interpretation, and seismic reflection data analysis. Required of Geological Engineers. Prerequisite: GEGN101, GEGN203, GEGN204, GEGN205 and GEGN206 or GPGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL310. EARTH MATERIALS AND RESOURCES. 4.0 Semester Hrs.

(I) Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals, rocks and ores. Laboratories emphasize the recognition, description and engineering evaluation of natural materials. Lectures present the knowledge of natural materials, processes and resources necessary for mining engineering careers. Prerequisite: GEGN101. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL311. STRUCTURAL GEOLOGY FOR MINING ENGINEERS. 2.0 Semester Hrs.

(II) Nature and origin of structural features of Earth's crust emphasizing structural controls of ore deposits and analysis of structures related to rock engineering and mining. Structural features and processes are related to stress/strain theory and rock mechanics principles. Lab and field projects include deformation experiments, geologic map, cross section, and orientation data analysis of structural features including fractures, faults, folds, and rock cleavages. Prerequisite: GEGN101 and GEOL310. 1 hour lecture; 3 hours lab; 2 semester hours.

GEOL314. STRATIGRAPHY. 4.0 Semester Hrs.

(II) Lectures and laboratory and field exercises in concepts of stratigraphy and biostratigraphy, facies associations in various depositional environments, sedimentary rock sequences and geometries in sedimentary basins, and geohistory analysis of sedimentary basins. Prerequisites: GEGN101, GEGN203 or GEGN204, GEGN205. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL315. SEDIMENTOLOGY AND STRATIGRAPHY. 3.0 Semester Hrs.

(I) Integrated lecture, laboratory and field exercises on the genesis of sedimentary rocks as related to subsurface porosity and permeability development and distribution for non-geology majors. Emphasis is placed on siliciclastic systems of varying degrees of heterogeneity. Topics include diagenesis, facies analysis, correlation techniques, and sequence and seismic stratigraphy. Application to hydrocarbon exploitation stressed throughout the course. Required of all PEGN students. Prerequisite: GEGN101, PEGN308. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL321. MINERALOGY AND MINERAL CHARACTERIZATION. 3.0 Semester Hrs.

(I) Principles of mineralogy and mineral characterization. Crystallography of naturally occurring materials. Principles of crystal chemistry. Interrelationships among mineral structure, external shape, chemical composition, and physical properties. Introduction to mineral stability. Laboratories emphasize analytical methods, including X-ray diffraction, scanning electron microscopy, and optical microscopy. Prerequisite: GEGN101, CHGN122, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL410. PLANETARY GEOLOGY. 2.0 Semester Hrs.

(II) Geology of the terrestrial planets and moons, specifically the Moon and Mars. Emphasis will be placed on the geomorphology, planetary materials, geologic structure, geologic history, and natural resource potential of terrestrial planetary bodies. Lectures present the knowledge of materials, geomorphic processes, and geologic history. Prerequisite: GEGN101. 2 hours lecture; 2 semester hours.

GEOL443. UNDERGRADUATE FIELD SEMINAR. 1-3 Semester Hr.

Special advanced classroom and field programs emphasizing detailed study of some aspects of the geology of an area or region. Field studies normally conducted away from the Golden campus. Classroom course content dependent on area of study. Fees assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL444. INVERTEBRATE PALEONTOLOGY. 3.0 Semester Hrs.

(II) Fossils are the basis for establishing global correlation among Phanerozoic sedimentary rocks, and thus are critical to the reconstruction of the past 550 million years of Earth history. This is a lecture elective course that will aid in rounding out undergraduate Earth science/engineering geological knowledge. Fossil preservation, taphonomy, evolution, mass extinctions, biostratigraphy, graphic correlation, invertebrate phyla and their geologic history and evolution. Prerequisites: GEGN204, GEGN205, GEGN206. 3 hours lecture; 3 semester hours.

GEOL470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

GEOL497. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**GEOL498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL499. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Geophysics

2015-2016

Program Description

Founded in 1926, the Department of Geophysics at the Colorado School of Mines is recognized and respected around the world for its programs in applied geophysical research and education. With nearly 20 active faculty and smaller class sizes, students receive individualized attention in a close-knit department. The mission of the geophysical engineering program is to educate undergraduates in the application of geophysics to help meet global needs for energy, water, food, minerals, and the mitigation of natural hazards by exploring and illuminating the dynamic processes of the Earth, oceans, atmosphere and solar system.

Geophysicists study the Earth's interior through physical measurements collected at the Earth's surface, in boreholes, from aircraft, or from satellites. Using a combination of mathematics, physics, geology, chemistry, hydrology, and computer science, both geophysicists and geophysical engineers analyze these measurements to infer properties and processes within the Earth's complex interior. Noninvasive imaging beneath the surface of Earth and other planets by geophysicists is analogous to noninvasive imaging of the interior of the human body by medical specialists.

The Earth supplies all materials needed by our society, serves as the repository for used products, and provides a home to all its inhabitants. Geophysics and geophysical engineering have important roles to play in the solution of challenging problems facing the inhabitants of this planet, such as providing fresh water, food, and energy for Earth's growing population, evaluating sites for underground construction and containment of hazardous waste, monitoring noninvasively the aging infrastructures of developed nations, mitigating the threat of geohazards (earthquakes, volcanoes, landslides, avalanches) to populated areas, contributing to homeland security (including detection and removal of unexploded ordnance and land mines), evaluating changes in climate and managing humankind's response to them, and exploring other planets.

Energy companies and mining firms employ geophysicists to explore for hidden resources around the world. Engineering firms hire geophysical engineers to assess the Earth's near-surface properties when sites are chosen for large construction projects and waste-management operations. Environmental organizations use geophysics to conduct groundwater surveys and to track the flow of contaminants. On the global scale, geophysicists employed by universities and government agencies (such as the United States Geological Survey, NASA, and the National Oceanographic and Atmospheric Administration) try to understand such Earth processes as heat flow, gravitational, magnetic, electric, thermal, and stress fields within the Earth's interior. For the past decade, nearly 100% of CSM's geophysics graduates have found employment in their chosen field, with about 70% choosing to pursue graduate studies.

Bachelor of Science Program in Geophysical Engineering

The Colorado School of Mines offers one of only two undergraduate geophysical engineering programs in the entire United States accredited by:

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
Telephone: (410) 347-7700

Geophysical Engineering undergraduates who may have an interest in professional registration as engineers are encouraged to take the Engineer in Training (EIT)/Fundamentals of Engineering (FE) exam as seniors. The Geophysical Engineering Program has the following objectives and associated outcomes:

Program Objective 1: Graduates will be competent geophysical engineers who are capable of independent and innovative problem solving.

Program Objective 2: Graduates can design and execute experiments effectively with appropriate treatment of the resulting data.

Program Objective 3: Graduates will be competent in scientific computing.

Program Objective 4: Graduates will be effective communicators, both orally and in writing.

Program Objective 5: Graduates will exhibit good team skills, be able to lead and to follow effectively.

Student Outcomes (from ABET Criterion 3):

- a. An ability to apply knowledge of mathematics, science, and engineering.
- b. An ability to design and conduct experiments, as well as to analyze and interpret data.
- c. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, safety, manufacturability, and sustainability.
- d. An ability to function on multidisciplinary teams.
- e. An ability to identify, formulate, and solve engineering problems.
- f. An understanding of professional and ethical responsibility.
- g. An ability to communicate effectively.
- h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
- i. A recognition of the need for, and an ability to engage in life-long learning.
- j. Knowledge of contemporary issues.
- k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Program Specific Outcomes

1. Expanded perspective of applied geophysics as a result of participating in employment or research.
2. An ability to analyze, quantitatively, the errors, limitations, and uncertainties in data.

Geophysics Field Camp

Each summer, a base of field operations is set up for four weeks, usually in the mountains of Colorado, for students who have completed their junior year. Students prepare geological maps and cross sections and then use these as the basis for conducting seismic, gravimetric, magnetic, electrical, and electromagnetic surveys. After acquiring these various geophysical data-sets, the students process the data and develop an interpretation that is consistent with all the information. In addition to the required four-week program, students can also participate in other diverse field experiences. In recent years these have included cruises on seismic ships in the Gulf of Mexico, studies at an archeological site, investigations at an environmental site, a ground-penetrating radar survey on an active volcano in Hawaii, and a well-logging school offered by Baker Hughes.

Study Abroad

The Department of Geophysics encourages its undergraduates to spend one or two semesters studying abroad. At some universities, credits can be earned that substitute for course requirements in the geophysical engineering program at CSM. Information on universities that have established formal exchange programs with CSM can be obtained from either the Department of Geophysics or the Office of International Programs.

Combined BS/MS Program

Undergraduate students in the Geophysical Engineering program who would like to continue directly into the Master of Science program in Geophysics or Geophysical Engineering, are allowed to fulfill part of the requirements of their graduate degree by including up to six hours of specified course credits, which also were used in fulfilling the requirements of their undergraduate degree. Students interested to take advantage of this option should meet with their advisor or department head as early as possible in their undergraduate program to determine which elective courses will be acceptable and advantageous for accelerating them through their combined BS/MS studies.

Summer Jobs in Geophysics

In addition to the summer field camp experience, students are given opportunities every summer throughout their undergraduate career to work as summer interns within the industry, at CSM, or for government agencies such as the U.S. Geological Survey. Students have recently worked outdoors with geophysics crews in various parts of the U.S., South America, and offshore in the Gulf of Mexico.

Undergraduate Research

Students are encouraged to try their hand at research by working on a project with a CSM faculty member, either part-time during the semester, or full-time during the summer. As an alternative to a summer internship, students may wish to participate in a Research Experience for Undergraduates (REU), either at Mines or at another university. REU's are typically sponsored by the National Science Foundation (NSF) and are listed on the NSF website.

The Cecil H. and Ida Green Graduate and Professional Center

The lecture rooms, laboratories, and computer-aided instruction areas of the Department of Geophysics are located in the Green Center. The Department maintains equipment for conducting geophysical field measurements, including magnetometers, gravity meters, ground-penetrating radar, and instruments for recording seismic waves. Students have access to the Department petrophysics laboratory for measuring properties of porous rocks.

Curriculum

Geophysics is an applied and interdisciplinary science; students therefore must have a strong foundation in physics, mathematics, geology and computer sciences. Superimposed on this foundation is a comprehensive body of courses on the theory and practice of geophysical methods. As geophysics and geophysical engineering involve the study and exploration of the entire earth, our graduates have great opportunities to work anywhere on, and even off, the planet. Therefore, the curriculum includes electives in the humanities and social sciences that give students an understanding of international issues and different cultures. Every student who obtains a Bachelor's Degree in Geophysical Engineering completes the CSM Core Curriculum plus the courses listed below. We recommend students download the current curriculum flowchart from the Departmental webpage, <http://geophysics.mines.edu/GEO-Undergraduate-Program>.

Degree Requirements (Geophysical Engineering)

Freshman

		lec	lab sem.hrs	
CORE	Common Core		32.0	
			32.0	

Sophomore

Fall		lec	lab sem.hrs	
GEGN203	ENGINEERING TERRAIN ANALYSIS or 204 ¹	2.0	3.0	2.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
PAGN2XX	PHYSICAL EDUCATION			0.5
GEGN205	ADVANCED PHYSICAL GEOLOGY LABORATORY			1.0
GPGN200	INTRODUCTION TO GEOPHYSICS			3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
			18.0	

Spring

		lec	lab sem.hrs	
LAIS200	HUMAN SYSTEMS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
GPGN221	THEORY OF FIELDS I: STATIC FIELDS	3.0		3.0
CSCI261	PROGRAMMING CONCEPTS ²	3.0		3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
GPGN268	GEOPHYSICAL DATA ANALYSIS			3.0
			15.5	

Junior

Fall		lec	lab sem.hrs	
GPGN304	INTRO TO GRAVITY AND MAGNETIC METHODS	2.0	3.0	3.0
GPGN315	SUPPORTING GEOPHYSICAL FIELD INVESTIGATIONS			1.0
GPGN322	THEORY OF FIELDS II: TIME-VARYING FIELDS	3.0		3.0
MATH348	ADVANCED ENGINEERING MATHEMATICS or PHGN 311	3.0		3.0
ELECT	Electives ³	6.0		6.0
			16.0	

Spring

		lec	lab sem.hrs	
GPGN305	INTRODUCTION TO SEISMIC EXPLORATION	2.0	3.0	3.0
GPGN308	INTRODUCTION TO ELECTRICAL AND ELECTROMAGNETIC METHODS	2.0	3.0	3.0
GPGN320	ELEMENTS OF CONTINUUM MECHANICS AND WAVE PROPAGATION	3.0		3.0
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY or 309 ⁴	2.0	3.0	3.0

ELECT	Electives ³	6.0	6.0	
			18.0	

Summer

		lec	lab sem.hrs	
GPGN486	GEOPHYSICS FIELD CAMP		4.0	4.0
			4.0	

Senior

Fall		lec	lab sem.hrs	
GPGN404	DIGITAL SIGNAL ANALYSIS	3.0		3.0
GP ELECT	GPGN Advanced Elective ⁵	3.0	3.0	4.0
GP ELECT	GPGN Advanced Elective ⁵	3.0	3.0	4.0
GPGN438	GEOPHYSICS PROJECT DESIGN or 439 (in Spring Semester) ⁶			3.0
ELECT	Electives ³	3.0		3.0
			17.0	

Spring

		lec	lab sem.hrs	
GPGN409	INVERSION	3.0		3.0
GP ELECT	GPGN Advanced Elective ⁵	3.0		3.0
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY or 314			3.0
ELECT	Electives ³	3.0		3.0
			12.0	

Total Semester Hrs: 132.5

- Students must take GEGN205 (1 credit hour) with either GEGN203 or GEGN204 (2 credit hours).
- Students should enroll in the Java section of CSCI261, although C++ is accepted.
- Electives must include at least 9 hours that meet LAIS core requirements. The Department of Geophysics encourages its students to consider organizing their electives to form a Minor or an Area of Special Interest (ASI). A guide suggesting various Minor and ASI programs can be obtained from the Department office.
- Students must take either GEOL308 or GEOL309, and either GEOL314 or GEOL315.
- Students must take 11 credits of advanced GPGN elective courses at the 400- or 500-level.
- Students can take either GPGN438 or GPGN439 to satisfy the senior design requirement. The multidisciplinary design course GPGN439, a 3-credit course offered only in Spring semester, is strongly recommended for students interested in petroleum exploration and production. Students interested in non-petroleum applications of geophysics take GPGN438 for 3 credit hours, either by enrolling for all 3 credit hours in one semester (Fall or Spring) or by enrolling for a portion of the 3 hours in Fall and the remainder in Spring.

General CSM Minor/ASI requirements can be found here (p. 33).

Minor in Geophysics/Geophysical Engineering

Geophysics plays an important role in many aspects of civil engineering, petroleum engineering, mechanical engineering, and mining engineering, as well as mathematics, physics, geology, chemistry, hydrology, and computer science. Given the natural connections between these various fields and geophysics, it may be of interest for students in other majors to consider choosing to minor in geophysics, or to choose geophysics as an area of specialization. The core of courses taken to satisfy the minor

requirement typically includes some of the following geophysics methods courses.

GPGN200	INTRODUCTION TO GEOPHYSICS	3.0
GPGN404	DIGITAL SIGNAL ANALYSIS	3.0
GPGN409	INVERSION	3.0
GPGN432	FORMATION EVALUATION	4.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0

The remaining hours can be satisfied by a combination of other geophysics courses, as well as courses in geology, mathematics, and computer science depending on the student's major. Students must consult with the Department of Geophysics to have their sequence of courses approved before embarking on a minor program.

Professors

Terence K. Young, Professor and Department Head

Thomas L. Davis

Roelof K. Snieder, Keck Foundation Professor of Basic Exploration Science

Ilya D. Tsvankin

Associate Professors

Jeffrey Andrews-Hanna

Thomas M. Boyd, Dean of Graduate Studies

Yaoguo Li

Andre Revil

Paul C. Sava, C.H. Green Chair of Exploration Geophysics

Assistant Professors

Edwin Nissen

Andrei Swidinsky

Whitney Trainor-Guitton

Professors Emeriti

Frank A. Hadsell

Alexander A. Kaufman

Gary R. Olhoeft

Phillip R. Romig, Jr.

Research Professors

Norman Bleistein, University Emeritus Professor

Dave Hale

Kenneth L. Larner, University Emeritus Professor

Research Associate Professor

Robert D. Benson

Research Assistant Professor

Richard Krahenbuhl

Adjunct Faculty

Timothy Collett

Gavin P. Hayes

Stephen J. Hill

Walter S. Lynn

Charles P. Oden

Bruce VerWest

David J. Wald

Distinguished Senior Scientists

Warren B. Hamilton

Misac N. Nabighian

Courses

GPGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN200. INTRODUCTION TO GEOPHYSICS. 3.0 Semester Hrs.

(I) (WI) This is a discovery course designed to introduce sophomores to the science of geophysics in the context of the whole-earth system. Students will explore the fundamental observations from which physical and mathematical inferences can be made regarding the Earth's origin, structure, and processes. Examples of such observations are earthquake records; geodetic and gravitational data, such as those recorded by satellites; magnetic measurements; and greenhouse gases in the atmosphere. Learning will take place through the examination of selected topics that may vary from one semester to the next. Examples of such topics are: earthquake seismology, geomagnetism, geodynamics, and climate change. 3 hours, lecture, 3 semester hours.

GPGN221. THEORY OF FIELDS I: STATIC FIELDS. 3.0 Semester Hrs.

Equivalent with GPGN321,

(II) Introduction to the theory of gravitational, magnetic, and electrical fields encountered in geophysics. Emphasis on the mathematical and physical foundations of the various phenomena and the similarities and differences in the various field properties. Physical laws governing the behavior of the gravitational, electric, and magnetic fields. Systems of equations of these fields. Boundary value problems. Uniqueness theorem. Influence of a medium on field behavior. Prerequisites: PHGN200, MATH213, and concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

GPGN268. GEOPHYSICAL DATA ANALYSIS. 3.0 Semester Hrs.

Equivalent with EPIC268,

(II) Geophysical Data Analysis focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Students work on projects from the geophysical engineering practice in which they analyze (process, model, visualize) data. In their projects, students encounter limitations and uncertainties in data and learn quantitative means for handling them. They learn how to analyze errors in data, and their effects on data interpretation and decision making. 3 lecture hours; 3 semester hours.

GPGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN303. SEE GPGN304. 4.0 Semester Hrs.**GPGN304. INTRO TO GRAVITY AND MAGNETIC METHODS. 3.0 Semester Hrs.**

(I) This is an introductory study of gravity and magnetic methods for imaging the earth's subsurface. The course begins with the connection between geophysical measurements and subsurface materials. It introduces basic concepts, mathematics, and physics of gravity and magnetic fields, emphasizing similarities with the equations and physics that underlie all geophysical methods. These methods are employed in geotechnical and environmental engineering and resources exploration for base and precious metals, industrial minerals, geothermal and hydrocarbons. The discussion of each method includes the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Prerequisites: PHGN200, MATH213, MATH225, and concurrent enrollment in MATH348 or PHGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN305. INTRODUCTION TO SEISMIC EXPLORATION. 3.0 Semester Hrs.

(II) This is an introductory study of seismic methods for imaging the Earth's subsurface. The course begins with the connection between geophysical measurements and subsurface materials. It introduces basic concepts, mathematics, and physics of seismic wave propagation, emphasizing similarities with the equations and physics that underlie all geophysical methods. These methods are employed in geotechnical and environmental engineering and resources exploration for base and precious metals, industrial minerals, geothermal and hydrocarbons. The discussion of each method includes the principles, instrumentation, procedures of data acquisition, analysis, and interpretation. Prerequisites: GPGN322, PHGN200, MATH213, MATH225, and MATH348 or PHGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN308. INTRODUCTION TO ELECTRICAL AND ELECTROMAGNETIC METHODS. 3.0 Semester Hrs.

(II) This is an introductory course on electrical and electromagnetic methods in applied geophysics. Methods covered include: natural-source methods (self-potential, telluric, magnetotelluric, audio-magnetotelluric) and artificial-source methods (direct current resistivity, induced polarization, ground/airborne/marine electromagnetic methods, ground penetrating radar, as well as laboratory and borehole methods). The fundamental theory of electrical and electromagnetic exploration is introduced, along more practical aspects such as field acquisition procedures, data processing, and data interpretation. The application of these methods is demonstrated for a large variety of exploration goals including environmental, mining, groundwater, petroleum, geothermal, basin studies, and deep crustal investigations. Prerequisites: GPGN304, PHGN200, MATH213, MATH225, and concurrent enrollment in MATH348 or PHGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN315. SUPPORTING GEOPHYSICAL FIELD INVESTIGATIONS. 1.0 Semester Hr.

(I) Prior to conducting a geophysical investigation, geophysicists often need input from related specialists such as geologists, surveyors, and land-men. Students are introduced to the issues that each of these specialists must address so that they may understand how each affects the design and outcome of geophysical investigations. Students learn to use and understand the range of applicability of a variety of surveying methods, learn the tools and techniques used in geological field mapping and interpretation, and explore the logistical and permitting issues directly related to geophysical field investigations. 3 hours lab, 1 semester hours.

GPGN320. ELEMENTS OF CONTINUUM MECHANICS AND WAVE PROPAGATION. 3.0 Semester Hrs.

(II) Introduction to continuum mechanics and elastic wave propagation with an emphasis on principles and results important in seismology and earth sciences in general. Topics include a brief overview of elementary mechanics, stress and strain, Hooke's law, notions of geostatic pressure and isostasy, fluid flow and Navier-Stokes equation. Basic discussion of the wave equation for elastic media, plane wave and their reflection/transmission at interfaces. Prerequisites: MATH213, PHGN200. 3 hours lecture; 3 semester hours.

GPGN322. THEORY OF FIELDS II: TIME-VARYING FIELDS. 3.0 Semester Hrs.

(I) Constant electric field. Coulomb's law. System of equations of the constant electric field. Stationary electric field and the direct current in a conducting medium. Ohm's law. Principle of charge conservation. Sources of electric field in a conducting medium. Electromotive force. Resistance. System of equations of the stationary electric field. The magnetic field, caused by constant currents. Biot-Savart law. The electromagnetic induction. Faraday's law. Prerequisite: GPGN221. 3 hours lecture; 3 semester hours.

GPGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

GPGN398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN404. DIGITAL SIGNAL ANALYSIS. 3.0 Semester Hrs.

(I) The fundamentals of one-dimensional digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of the sampling theorem, convolution, deconvolution, the Z and Fourier transforms, windows, and filters. Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues. This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture. Prerequisites: MATH213, MATH225, and MATH348 or PHGN311. Knowledge of a computer programming language is assumed. 2.5 hours lecture; 1.5 hours lab, 3 semester hours.

GPGN409. INVERSION. 3.0 Semester Hrs.

(II) The fundamentals of inverse problem theory as applied to geophysical investigation are studied. Students explore the fundamental concepts of inversion in a Bayesian framework as well as practical methods for solving discrete inverse problems. Topics studied include Monte Carlo methods, optimization criteria, convex optimization methods, and error and resolution analysis. Weekly homework assignments addressing either theoretical or numerical problems through programming assignments illustrate the concepts discussed in class. Prerequisites: MATH213, MATH225, GPGN404 and MATH348 or PHGN311. Knowledge of a programming language is assumed. 3 hours lecture, 3 semester hours.

GPGN411. ADVANCED GRAVITY AND MAGNETIC METHODS. 4.0 Semester Hrs.

Equivalent with GPGN414,

(I) Instrumentation for land surface, borehole, sea floor, sea surface, and airborne operations. Reduction of observed gravity and magnetic values. Theory of potential field effects of geologic distributions. Methods and limitations of interpretation. Prerequisite: GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION. 3.0 Semester Hrs.

Equivalent with PEGN419,

(I) The basics of core analysis and the principles of all common borehole instruments are reviewed. The course shows (computer) interpretation methods that combine the measurements of various borehole instruments to determine rock properties such as porosity, permeability, hydrocarbon saturation, water salinity, ore grade, ash content, mechanical strength, and acoustic velocity. The impact of these parameters on reserves estimates of hydrocarbon reservoirs and mineral accumulations are demonstrated. In spring semesters, vertical seismic profiling, single well and cross-well seismic are reviewed. In the fall semester, topics like formation testing, and cased hole logging are covered. Prerequisites: MATH225, MATH348 or PHGN311, GPGN302 and GPGN303. 3 hours lecture, 2 hours lab; 3 semester hours.

GPGN420. ADVANCED ELECTRICAL AND ELECTROMAGNETIC METHODS. 4.0 Semester Hrs.

Equivalent with GPGN422,

(II) In-depth study of the application of electrical and electromagnetic methods to crustal studies, minerals exploration, oil and gas exploration, and groundwater. Laboratory work with scale and mathematical models coupled with field work over areas of known geology. Prerequisite: GPGN302 and GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN432. FORMATION EVALUATION. 4.0 Semester Hrs.

(II) The basics of core analysis and the principles of all common borehole instruments are reviewed. The course teaches interpretation methods that combine the measurements of various borehole instruments to determine rock properties such as porosity, permeability, hydrocarbon saturation, water salinity, ore grade and ash content. The impact of these parameters on reserve estimates of hydrocarbon reservoirs and mineral accumulations is demonstrated. Geophysical topics such as vertical seismic profiling, single well and cross-well seismic are emphasized in this course, while formation testing, and cased hole logging are covered in GPGN419/PEGN419 presented in the fall. The laboratory provides on-line course material and hands-on computer log evaluation exercises. Prerequisites: MATH225, MATH348 or PHGN311, GPGN302, and GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours. Only one of the two courses GPGN432 and GPGN419/ PEGN419 can be taken for credit.

GPGN438. GEOPHYSICS PROJECT DESIGN. 1-3 Semester Hr.

(I, II) (WI) Complementary design course for geophysics restricted elective course(s). Application of engineering design principles to geophysics through advanced work, individual in character, leading to an engineering report or senior thesis and oral presentation thereof. Choice of design project is to be arranged between student and individual faculty member who will serve as an advisor, subject to department head approval. Prerequisites: GPGN302 and GPGN303 and completion of or concurrent enrollment in geophysics method courses in the general topic area of the project design. Credit variable, 1 to 3 hours. Repeatable for credit up to a maximum of 3 hours.

GPGN439. GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.

Equivalent with GEGN439, PEGN439,

(II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GE Majors: GEOL309, GEOL314, GEGN438, and EPIC264; GP Majors: GPGN302, GPGN303, and EPIC268; PE Majors: GEOL308, PEGN316 and PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN461. SEISMIC DATA PROCESSING I. 4.0 Semester Hrs.

Equivalent with GPGN452,

(I) This course covers the basic processing steps required to create images of the earth using 2-D and 3-D reflection seismic data. Topics include data organization and domains, signal processing to enhance temporal and spatial resolution, identification and suppression techniques of incoherent and coherent noises, velocity analysis, velocity conversion, near-surface statics, datuming, common-midpoint stacking, imaging principles and methods used for post-stack and prestack time and depth imaging, migration-velocity analysis and post-imaging enhancement techniques. Examples from field data are extensively used. A three-hour lab introduces the student to hands-on seismic data processing using Seismic Unix. The final exam consists of a presentation of the data processing a 2-D seismic line. Prerequisites: GPGN302 and GEOL308. Co-requisites: GPGN404. 3 hour lecture, 3 hour lab; 4 semester hours.

GPGN470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GPGN471. GEODYNAMICS AND GEOLOGY. 2.0 Semester Hrs.

(I) Earth's evolving internal dynamics and properties have controlled time-varying crustal geologic processes and their products. All terrestrial planets fractionated synchronously with accretion, but only Earth continued strongly active. Much geology, from ancient granite and greenstone to recently enabled plate-tectonics, will be illustrated in the context of coevolving deep and shallow processes. Integration of geophysics, geology, and planetology will allow evaluation of popular and alternative explanations, but the sum will be contrarian, not conventional. Math and specialist vocabularies will be minimized. PREREQUISITES: CHGN121, PHGN100, PHGN200, and GEGN101. 2 lecture hours, 2 semester hours.

GPGN475. PLANETARY GEOPHYSICS. 3.0 Semester Hrs.

(I) Of the solid planets and moons in our Solar System, no two bodies are exactly alike. This class will provide an overview of the observed properties of the planets and moons, cover the basic physical processes that govern their evolution, and then investigate how the planets differ and why. The overarching goals are to develop a quantitative understanding of the processes that drive the evolution of planetary surfaces and interiors, and to develop a deeper understanding of the Earth by placing it in the broader context of the Solar System. Prerequisites: PHGN100, MATH225, and GEGN205 or GEOL410. Senior or graduate standing recommended. 3 hours lecture; 3 semester hours.

GPGN486. GEOPHYSICS FIELD CAMP. 4.0 Semester Hrs.

(S) Introduction to geological and geophysical field methods. The program includes exercises in geological surveying, stratigraphic section measurements, geological mapping, and interpretation of geological observations. Students conduct geophysical surveys related to the acquisition of seismic, gravity, magnetic, and electrical observations. Students participate in designing the appropriate geophysical surveys, acquiring the observations, reducing the observations, and interpreting these observations in the context of the geological model defined from the geological surveys. Prerequisites: GPGN268, GEOL308 or GEOL309, GPGN304, GPGN305, GPGN308, and GPGN315. 12 hours lab; 4 semester hours.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN499. GEOPHYSICAL INVESTIGATION. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Liberal Arts and International Studies

2015-2016

Program Description

As the 21st century unfolds, individuals, communities, and nations face major challenges in energy, natural resources, and the environment. While these challenges demand practical ingenuity from engineers and applied scientists, solutions must also take into account social, political, economic, cultural, ethical, and global contexts. CSM students, as citizens and future professionals, confront a rapidly changing society that demands core technical skills complemented by flexible intelligence, original thought, and cultural sensitivity.

Courses in Liberal Arts and International Studies (LAIS) expand students' professional and personal capacities by providing opportunities to explore the humanities, social sciences, and fine arts. Our curricula encourage the development of critical thinking skills that will help students make more informed choices as national and world citizens - promoting more complex understandings of justice, equality, culture, history, development, and sustainability. Students, for example, study ethical reasoning, compare and contrast different economies and cultures, develop arguments from data, and interrogate globalization. LAIS courses also foster creativity by offering opportunities for self-discovery. Students conduct literary analyses, improve communication skills, play music, learn media theory, and write poetry. These experiences foster intellectual agility, personal maturity, and respect for the complexity of our world.

Required Undergraduate Core Courses

Two of three required undergraduate core courses in the Humanities and Social Sciences are delivered by LAIS, namely, LAIS100, Nature and Human Values; and LAIS200, Human Systems. The third HSS core

course, EBG201, Principles of Economics, is delivered by the Division of Economics & Business.

Freshman

Fall		lec	lab	sem.hrs
LAIS100	NATURE AND HUMAN VALUES			4.0
				4.0

Spring		lec	lab	sem.hrs
EBGN201	PRINCIPLES OF ECONOMICS			3.0
				3.0

Sophomore

		lec	lab	sem.hrs
LAIS200	HUMAN SYSTEMS			3.0
				3.0

Junior

Fall		lec	lab	sem.hrs
LAIS2xx or 3xx	200- or 300-level Restricted H&SS Elective			3.0
				3.0

Spring		lec	lab	sem.hrs
LAIS2xx or 3xx	200- or 300-level Restricted H&SS Elective			3.0
				3.0

Senior

Fall		lec	lab	sem.hrs
LAIS 4xx	400-level Restricted H&SS Elective			3.0
				3.0

Total Semester Hrs: 19.0

Undergraduate Humanities and Social Sciences Requirement

Beyond the core, LAIS offers the majority of the courses that meet the 9 credit-hour Humanities and Social Science (HSS) requirement. The Division of Economic and Business also offers courses that may be used to meet the HSS requirement.

Music (LIMU)

Courses in Music do not count toward the Humanities & Social Sciences General Education restricted elective requirement, but may be taken for **Free Elective credit only**. **A maximum of 3.0 semester hours of concert band, chorus, physical education, athletics or other activity credit combined may be used toward free elective credit in a degree granting program.**

Foreign Language (LIFL)

Four foreign languages are taught through the LAIS Division. In order to gain basic proficiency from their foreign language study, students are encouraged to enroll for at least two semesters in whatever language(s) they elect to take. **No student is permitted to take a foreign language that is either his/her native language or second language.**

Undergraduate Minors

At the undergraduate level, LAIS offers minors in Literature, Society, and the Environment; International Political Economy; Science, Technology, Engineering, and Policy; Humanitarian Engineering; and an Individualized

Undergraduate minor. See the minor tab for details. LAIS also is the home for the minor in the McBride Honors Program in Public Affairs.

Graduate Degree and Programs

At the graduate level, LAIS offers a 36-hour degree, a Master of International Political Economy of Resources (MIPER). It also offers Graduate Certificates and Graduate minors in International Political Economy and Science and Technology Policy. See the Graduate Bulletin for details.

Hennebach Program in the Humanities

The Hennebach Program in the Humanities, supported by a major endowment from Ralph Hennebach (CSM Class of 1941), sponsors a regular series of Visiting Professors and the general enhancement of the Humanities on campus. Recent visiting professors have included scholars in Classics, Creative Writing, Environmental Studies, Ethics, History, Literature, Philosophy, and Social Theory as well as the interdisciplinary fields of Environmental Policy, and Science, Technology, and Society Studies. The Program is dedicated to enriching the lives of both students and faculty through teaching and research, with visiting scholars offering courses, giving lectures, conducting workshops, and collaborating on projects. In addition, the Hennebach Program is exploring opportunities for meeting the needs of Undergraduate students who would especially benefit from more focused study in the Humanities that would appropriately complement technical degree curricula.

Writing Center

The LAIS Division operates the LAIS Writing Center, which provides students with tutoring tailored to their individual writing problems (including non-native speakers of English). It also provides faculty with support for courses associated with the Writing Across the Curriculum program. Faculty and staff are welcome to make use of the Writing Center's expertise for writing projects and problems. The Writing Center Staff also offers tutoring hours at CASA. The Writing Center is located on the 1st floor of Alderson Hall in room AH133.

Program Educational Objectives

In addition to contributing to the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the coursework in the Division of Liberal Arts and International Studies is designed to help CSM develop in students the ability to engage in life-long learning and recognize the value of doing so by acquiring the broad education necessary to

1. Understand the impact of engineering solutions in contemporary, global, international, societal, political, and ethical contexts;
2. Understand the role of Humanities and Social Sciences in identifying, formulating, and solving engineering problems;
3. Prepare to live and work in a complex world;
4. Understand the meaning and implications of "stewardship of the Earth"; and
5. Communicate effectively in writing and orally.

Curriculum

Key to courses offered by the LAIS Division:

Course Code	Course Title
LAIS	Humanities and Social Sciences
LIFL	Foreign Language

LIMU Music

CSM students in all majors must take 19 credit-hours in Humanities and Social Sciences, ranging from freshman through senior levels of coursework. These courses are housed in the Division of Liberal Arts and International Studies and in the Division of Economics and Business.

Required Core Courses

- All Undergraduate students are required to take the following two core courses from the Division of Liberal Arts & International Studies:
 - LAIS100 Nature and Human Values 4 semester hours
 - LAIS200 Human Systems 3 semester hours
- All Undergraduate students are also required to take EBGN201 Principles of Economics (3 semester hours) from the Division of Economics and Business.
- Students in the McBride Honors Program must take LAIS100, Nature and Human Values and EBGN201. Please see the McBride Honors Program web site for further information.

Humanities and Social Sciences Requirement

Beyond the core, all Undergraduate students must take an additional three courses (9 semester hours) from the list below. The following restrictions apply to these three courses:

- At least one** of the three courses must be taken from the Division of Liberal Arts and International Studies.
- At least one of the three courses must be a 400-level course.** In any given semester, either LAIS or EB may offer 400-level Special Topics courses that will be numbered as either LAIS498 or EBGN498. Even though no Special Topics courses appear in the list below, these courses may be used to fulfill the H&SS General Education restricted electives requirement as follows:
 - All courses numbered LAIS498 will satisfy the requirement.
 - Some EBGN498 courses as determined on a case-by-case basis will satisfy the requirement. Consult EBGN in any given semester for EBGN498 courses that satisfy the requirement.
- Typically, the other two courses are midlevel courses, i.e., 200 or 300 level classes. The only exception to this rule are Foreign Language courses (see below).
- A maximum of two Foreign Language courses (LIFL) may be applied toward satisfying the DHSS requirement. LIFL 498 or 499 may not be used to satisfy the 400-level course requirement.
- Music (LIMU) courses **may not** be used to meet the DHSS requirement. They may be used for Free Elective credit only. **A maximum of 3 semester hours of concert band chorus, physical education, athletics, or other activity credit combined may be used toward free elective credit in a degree granting program.**
- Single majors in Economics may not use Economics courses to meet the DHSS requirement. Economics majors must meet this requirement with courses from the Division of Liberal Arts and International Studies, as per the above restrictions and requirements. Students other than single majors in Economics may take up to 6 semester hours (2 courses) of approved EBGN courses, listed below, to satisfy the DHSS requirement.
- During Pre-Registration each semester, only students with senior standing or instructor's permission are initially allowed to register for 400-level LAIS courses. If 400-level courses do not fill up during Pre-Registration or soon thereafter, the Division Director may elect to open course registration to sophomores and juniors who have met

the LAIS100 pre-requisite and LAIS200 co-requisite for 400-level courses.

- Except for foreign languages, **NO AP or IB credit can be used to meet the General Education Restricted Elective requirements.** AP/IB credits will be applied as free electives.

List of LAIS and EB Courses Satisfying the DHSS Requirement

EBGN301	INTERMEDIATE MICROECONOMICS	3.0
EBGN302	INTERMEDIATE MACROECONOMICS	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
EBGN320	ECONOMICS AND TECHNOLOGY	3.0
EBGN330	ENERGY ECONOMICS	3.0
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	3.0
EBGN342	ECONOMIC DEVELOPMENT	3.0
EBGN437	REGIONAL ECONOMICS	3.0
EBGN441	INTERNATIONAL ECONOMICS	3.0
EBGN443	PUBLIC ECONOMICS	3.0
EBGN470	ENVIRONMENTAL ECONOMICS	3.0
LAIS220	INTRODUCTION TO PHILOSOPHY	3.0
LAIS221	INTRODUCTION TO RELIGIONS	3.0
LAIS286	INTRODUCTION TO GOVERNMENT AND POLITICS	3.0
LAIS298	SPECIAL TOPICS	1-6
LAIS300	CREATIVE WRITING: FICTION	3.0
LAIS301	CREATIVE WRITING: POETRY I	3.0
LAIS324	AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE	3.0
LAIS326	MUSIC THEORY	3.0
LAIS327	MUSIC TECHNOLOGY	3.0
LAIS328	BASIC MUSIC COMPOSITION AND ARRANGING	1.0
LAIS330	MUSIC TECHNOLOGY CAPSTONE	3.0
LAIS305	AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT	3.0
LAIS307	EXPLORATIONS IN COMPARATIVE LITERATURE	3.0
LAIS309	LITERATURE AND SOCIETY	3.0
LAIS310	MODERN EUROPEAN LITERATURE	1-3
LAIS311	BRITISH LITERATURE: MEDIEVAL TO MODERN	3.0
LAIS315	MUSICAL TRADITIONS OF THE WESTERN WORLD	3.0
LAIS320	ETHICS	3.0
LAIS322	LOGIC	3.0
LAIS323	INTRODUCTION TO SCIENCE COMMUNICATION	3.0
LAIS325	CULTURAL ANTHROPOLOGY	3.0
LAIS335	INTERNATIONAL POLITICAL ECONOMY OF LATIN AMERICA	3.0
LAIS337	INTERNATIONAL POLITICAL ECONOMY OF ASIA	3.0
LAIS339	INTERNATIONAL POLITICAL ECONOMY OF THE MIDDLE EAST	3.0

LAIS341	INTERNATIONAL POLITICAL ECONOMY OF AFRICA	3.0
LAIS344	INTERNATIONAL RELATIONS	3.0
LAIS345	INTERNATIONAL POLITICAL ECONOMY	3.0
LAIS365	HISTORY OF WAR	3.0
LAIS370	HISTORY OF SCIENCE	3.0
LAIS371	HISTORY OF TECHNOLOGY	3.0
LAIS375	ENGINEERING CULTURES	3.0
LAIS377	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
LAIS398	SPECIAL TOPICS	1-6
LAIS401	CREATIVE WRITING: POETRY II	3.0
LAIS404	WOMEN, LITERATURE, AND SOCIETY	3.0
LAIS406	THE LITERATURE OF WAR AND REMEMBRANCE	3.0
LAIS407	SCIENCE IN LITERATURE	3.0
LAIS408	LIFE STORIES	3.0
LAIS409	SHAKESPEAREAN DRAMA	3.0
LAIS410	CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE	3.0
LAIS411	LITERATURES OF THE AFRICAN WORLD	3.0
LAIS412	LITERATURE AND THE ENVIRONMENT	3.0
LAIS415	MASS MEDIA STUDIES	3.0
LAIS416	FILM STUDIES	3.0
LAIS418	NARRATING THE NATION	3.0
LAIS419	MEDIA AND THE ENVIRONMENT	3.0
LAIS421	ENVIRONMENTAL PHILOSOPHY AND POLICY	3.0
LAIS423	ADVANCED SCIENCE COMMUNICATION	3.0
LAIS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
LAIS431	RELIGION & SECURITY	3.0
LAIS435	LATIN AMERICAN DEVELOPMENT	3.0
LAIS437	ASIAN DEVELOPMENT	3.0
LAIS439	MIDDLE EAST DEVELOPMENT	3.0
LAIS440	WAR AND PEACE IN THE MIDDLE EAST	3.0
LAIS441	AFRICAN DEVELOPMENT	3.0
LAIS442	NATURAL RESOURCES AND WAR IN AFRICA	3.0
LAIS446	GLOBALIZATION	3.0
LAIS448	GLOBAL ENVIRONMENTAL ISSUES	3.0
LAIS450	POLITICAL RISK ASSESSMENT	3.0
LAIS452	CORRUPTION AND DEVELOPMENT	3.0
LAIS453	ETHNIC CONFLICT IN GLOBAL PERSPECTIVE	3.0
LAIS460	GLOBAL GEOPOLITICS	3.0
LAIS475	ENGINEERING CULTURES IN THE DEVELOPING WORLD	3.0
LAIS485	CONSTITUTIONAL LAW AND POLITICS	3.0
LAIS486	SCIENCE AND TECHNOLOGY POLICY	3.0
LAIS487	ENVIRONMENTAL POLITICS AND POLICY	3.0
LAIS488	WATER POLITICS AND POLICY	3.0
LAIS489	NUCLEAR POWER AND PUBLIC POLICY	3.0
LAIS490	ENERGY AND SOCIETY	3.0
LAIS498	SPECIAL TOPICS	1-6
LIFL113	SPANISH I	3.0
LIFL123	SPANISH II	3.0

LIFL114	ARABIC I	3.0
LIFL119	FRENCH I	3.0
LIFL124	ARABIC II	3.0
LIFL115	GERMAN I	3.0
LIFL125	GERMAN II	3.0
LIFL129	FRENCH II	3.0
LIFLx98	Special Topics	

General CSM Minor/ASI requirements can be found here (p. 33).

Minor Programs

The Division of Liberal Arts and International Studies offers several minor programs. Students who elect to pursue a minor **usually** will satisfy the HSS requirements; however, the Music Technology ASI will not satisfy these requirements. Students will need to use their free elective hours to complete a minor.

A minor requires a minimum of 18 credit-hours; an area of special interest (ASI) requires a minimum of 12 credit hours. No more than half the credits to be applied towards an LAIS minor or ASI may be transfer credits. The LAIS Undergraduate Advisor must approve all transfer credits that will be used for an LAIS minor or ASI.

Prior to the completion of the sophomore year, a student wishing to declare an LAIS Minor must fill out an LAIS Minor form (available in the LAIS Office) and obtain approval signatures from the appropriate minor advisor in LAIS and from the LAIS Director. The student must also fill out a Minor/Area of Special Interest Declaration (available in the Registrar's Office) and obtain approval signatures from the student's CSM advisor, from the Head or Director of the student's major department or division, and from the LAIS Director. Students should consult the listed advisors for the specific requirements of each minor.

The six minors or ASI available and their advisors are

Literature, Society, and the Environment Minor and ASI

Program Advisors: Prof. Tina Gianquitto and Prof. Jay Straker.

The Literature, Society, and the Environment Minor and ASI are designed for students with a passion for literature, and an interest in exploring relationships between literary traditions and the broader social and environmental processes that have helped inspire and shape them. The minor's inter-disciplinary emphasis creates unique opportunities for students to forge connections between literary studies and diverse fields of inquiry, spanning the humanities and qualitative and quantitative sciences. In the process of acquiring the minor, students will develop forms of intellectual creativity and sensitivity to social and environmental dynamics increasingly expected of twenty-first century scientists and engineers.

International Political Economy Minor and ASI

Program Advisor: Prof. James Jesudason.

This minor and ASI are ideal for students anticipating careers in the earth resources industries. The International Political Economy Program at CSM was the first such program in the U.S. designed with the engineering and applied science student in mind, and it remains one of the very few international engineering programs with this

focus. International Political Economy is the study of the interplay among politics, the economy, and culture. In today's global economy, international engineering and applied science decisions are fundamentally political decisions made by sovereign nations. Therefore, International Political Economy theories and models are often used in evaluating and implementing engineering and science projects. Project evaluations and feasibilities now involve the application of such IPE methods as political risk assessment and mitigation. The IPE minor is also a gateway to the Graduate Program in International Political Economy.

Science, Technology, Engineering, and Policy Minor and ASI

The Science, Technology, Engineering, and Policy Minor focuses on science, technology, and engineering in the societal and policy context: how STE influence society, politics, and policy, and how society, politics, and policy influence STE. Courses provide historical, social scientific, ethical, and policy approaches to issues that inevitably confront professional applied scientists, engineers, managers, and administrators in both public and private sectors. Such issues concern, for example, professional ethical responsibilities, intellectual property rights, regulatory regimes, assessments of societal impacts, science policy implementation, and the roles of technical innovation in economic development or international competitiveness. LAIS486 Science and Technology Policy is required. Students work with the STEP Advisor to tailor a sequence of other courses appropriate to their background and interests.

Humanitarian Engineering Minor and ASI

LAIS Advisor: Prof. Juan Lucena.

The Humanitarian Studies Minor and ASI focuses on the intersection of science, technology, and engineering in humanitarian projects. Scientific, technological, and engineering oriented humanitarian projects are intended to help marginalized communities meet basic human needs (such as water, food, and shelter) when these are missing or inadequate. LAIS320 Ethics is required. Other HS courses are offered through LAIS along with selected technical electives by other academic units across campus. Students may also wish to investigate the 28-credit minor in Humanitarian Engineering offered in cooperation with the Division of Engineering.

Music, Audio Engineering, and the Recording Arts

Program Advisor: Robert Klimek. Program Co-Advisor: Jonathan Cullison.

The Music, Audio Engineering, and the Recording Arts Minor is designed for students interested in the crossover field between music and related technical skills. Technical emphasis within this minor creates an opportunity for the student to research/experience the impact of their specific majors upon both music as an art form and music as an industry.

Throughout the minor, students are exposed to the refinements and developments that technology has created in the field of recording, production, sound reinforcement and product design, as well as, the interplay between the arts and technology. The discovery of connections between current music and sound engineering practices is stressed. The final outcome is a skilled and informed studio musician/technician in present day studio conditions. Finally, this minor is not designed to expand any current engineering curriculum, but to complement a student's education.

Students desiring a Music, Audio Engineering, and the Recording Arts Minor must complete 18 hours of courses as follows:

Four *required* music courses (12 credit-hours):

LAIS324	AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE	3.0
LAIS327	MUSIC TECHNOLOGY	3.0
LAIS315	MUSICAL TRADITIONS OF THE WESTERN WORLD	3.0
LAIS330	MUSIC TECHNOLOGY CAPSTONE	3.0
Total Semester Hrs		12.0

One 400 level *required* course (3 credit hours):

LAIS429	REAL WORLD RECORDING/RESEARCH	3.0
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Three additional credit-hours:

LAIS326	MUSIC THEORY	3.0
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Performance Enhancement (3 credit hours total)

LIMU	ENSEMBLE <small>Two semesters</small>	
LIMU189	INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION <small>One semester</small>	

Individualized Undergraduate Minor

Program Advisor: Prof. Sandy Woodson. Students declaring an Undergraduate Individual Minor in LAIS must choose 18 restricted elective hours in LAIS with a coherent rationale reflecting some explicit focus of study that the student wishes to pursue. A student desiring this minor must design it in consultation with a member of the LAIS faculty who approves the rationale and the choice of courses, eg., pre-law or pre-med courses.

Area of Special Interest in Music Technology

Program Advisor: Prof. Bob Klimek. The Area of Special Interest in Music Technology is comprised of a sequence of courses that allows students to combine interests and abilities in both the science and theory of music production. Completion of this ASI will train students in the technical aspects of the music recording industry, including sound and video recording, sound effects, and software design.

The Guy T. McBride, Jr. Honors Program in Public Affairs

Program Director: Prof. Kenneth Osgood. The curriculum of the McBride Honors Program in Public Affairs offers an honors minor consisting of seminars, courses, and off-campus activities that has the primary goal of providing a select number of students the opportunity to cross the boundaries of their technical expertise into the ethical, cultural, socio-political, and environmental dimensions of human life. Students will develop their skills in communication, critical thinking, and leadership through seminar style classes that explore diverse aspects of the human experience. The seminars allow for a maximum degree of discussion and debate on complex topics. Themes and perspectives from the humanities and the social sciences are integrated with science and engineering to develop in students a sophisticated understanding of the social context in which scientists and engineers work.

Professors

Elizabeth Van Wie Davis

Linda Layne, Division Director

Juan C Lucena

Carl Mitcham, Retired

Kenneth Osgood, Director of McBride Honors Program

Associate Professors

Hussein A. Amery

Tina L. Gianquitto

Kathleen J. Hancock

John R. Heilbrunn

Jon Leydens

James D. Straker

Assistant Professors

Derrick Hudson, Director MIPER Program

Jessica Smith, Hennebach Assistant Professor

Teaching Professors

Sandy Woodson , Undergraduate Advisor

James V. Jesudason

Robert Klimek

Toni Lefton

Teaching Associate Professors

Jonathan H. Cullison

Paula A. Farca

Sarah J. Hitt

Cortney E. Holles

Rose Pass

Teaching Assistant Professors

James Bishop

Olivia Burgess

Joseph Horan

Rachel Osgood

Seth Tucker

Professors Emeriti

W. John Cieslewicz

Wilton Eckley

T. Graham Hereford

Barbara M. Olds

Eul-Soo Pang

Anton G. Pegis

Thomas Philipose, University professor emeriti

Arthur B. Sacks

Joseph D. Sneed

Associate Professors Emeriti

Betty J. Cannon

Kathleen H. Ochs

Laura J. Pang

Karen B. Wiley

Courses

HNRS198. SPECIAL TOPICS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS199. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS298. SPECIAL TOPICS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.

(I, II) (WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. Prerequisite: Admission to the Program and LAIS100: Nature & Human Values. 3 lecture hours, 3 credit hours.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.

(I, II) (WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. Prerequisite: Admission to the Program and LAIS100: Nature & Human Values. 3 lecture hours, 3 credit hours.

HNRS398. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.

(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student's learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS497. SUMMER COURSE. 6.0 Semester Hrs.**HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.**

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

LAIS100. NATURE AND HUMAN VALUES. 4.0 Semester Hrs.

Equivalent with LIHU100,

Nature and Human Values will focus on diverse views and critical questions concerning traditional and contemporary issues linking the quality of human life and Nature, and their interdependence. The course will examine various disciplinary and interdisciplinary approaches regarding two major questions: 1) How has Nature affected the quality of human life and the formulation of human values and ethics? (2) How have human actions, values, and ethics affected Nature? These issues will use cases and examples taken from across time and cultures. Themes will include but are not limited to population, natural resources, stewardship of the Earth, and the future of human society. This is a writing-intensive course that will provide instruction and practice in expository writing, using the disciplines and perspectives of the Humanities and Social Sciences. 4 hours lecture/seminar; 4 semester hours.

LAIS198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS200. HUMAN SYSTEMS. 3.0 Semester Hrs.

Equivalent with SYGN200,

(I, II) Part of the CSM core curriculum, following the first-year requirement of LAIS 100 Nature and Human Values. This course examines political, economic, social, and cultural systems on a global scale during the modern era. Topics covered include development patterns in key regions of the world; the causes and outcomes of globalization; and the influence of energy, technology, and resources on development. Course material presented by instructors with social science and humanities disciplinary backgrounds, with weekly readings and evaluation through exams and written essays. Prerequisite: LAIS 100. 3 hours lecture; 3 semester hours.

LAIS220. INTRODUCTION TO PHILOSOPHY. 3.0 Semester Hrs.

A general introduction to philosophy that explores historical and analytic traditions. Historical exploration may compare and contrast ancient and modern, rationalist and empiricist, European and Asian approaches to philosophy. Analytic exploration may consider such basic problems as the distinction between illusion and reality, the one and the many, the structure of knowledge, the existence of God, the nature of mind or self. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 credit hours.

LAIS221. INTRODUCTION TO RELIGIONS. 3.0 Semester Hrs.

This course has two focuses. We will look at selected religions emphasizing their popular, institutional, and contemplative forms; these will be four or five of the most common religions: Hinduism, Buddhism, Judaism, Christianity, and/or Islam. The second point of the course focuses on how the Humanities and Social Sciences work. We will use methods from various disciplines to study religion-history of religions and religious thought, sociology, anthropology and ethnography, art history, study of myth, philosophy, analysis of religious texts and artifacts (both contemporary and historical), analysis of material culture and the role it plays in religion, and other disciplines and methodologies. We will look at the question of objectivity; is it possible to be objective? We will approach this methodological question using the concept ?standpoint.? For selected readings, films, and your own writings, we will analyze what the ?standpoint? is. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS286. INTRODUCTION TO GOVERNMENT AND POLITICS. 3.0 Semester Hrs.

Introduction to Government and Politics is a beginning- level course intended to familiarize students with the study of politics across societies. The method is comparative in that it approaches the task of studying the world's different political systems by contrasting and comparing them along different dimensions, and by seeking generalizations about them. The class focuses on cases, topics, and methodologies in American and comparative politics. No background in political science is required or expected. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS300. CREATIVE WRITING: FICTION. 3.0 Semester Hrs.

Students will write weekly exercises and read their work for the pleasure and edification of the class. The midterm in this course will be the production of a short story. The final will consist of a completed, revised short story. The best of these works may be printed in a future collection. Prerequisite: LAIS 100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS301. CREATIVE WRITING: POETRY I. 3.0 Semester Hrs.

This course focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and stimulate the development of the student?s craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students ?try on? various styles and contexts in order to develop their own voice. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS305. AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT. 3.0 Semester Hrs.

This course offers an overview of American literature from the colonial period to the present. The texts of the class provide a context for examining the traditions that shape the American nation as a physical, cultural and historical space. As we read, we will focus on the relationships between community, landscape, history, and language in the American imagination. We will concentrate specifically on conceptions of the nation and national identity in relation to race, gender, and class difference. Authors may include: Rowlandson, Brown, Apess, Hawthorne, Douglass, Melville, Whitman, James, Stein, Eliot, Hemingway, Silko, and Auster. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS307. EXPLORATIONS IN COMPARATIVE LITERATURE. 3.0 Semester Hrs.

This course examines major figures and themes in the modern literatures of Africa, the Caribbean, and Latin America. Reading, discussion and writing will focus on fiction and poetry representing Francophone, Arabic, and Hispanophone traditions within these world regions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic debates that have informed cultural practices in diverse colonial territories and nation-states. Thematic and stylistic concerns will include imperialism, nationalism, existentialism, Orientalism, negritude, and social and magical realisms. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS309. LITERATURE AND SOCIETY. 3.0 Semester Hrs.

Before the emergence of sociology as a distinct field of study, literary artists had long been investigating the seemingly infinite complexity of human societies, seeking to comprehend the forces shaping collective identities, socio-cultural transformations, technological innovations, and political conflicts. Designed to enrich recognition and understanding of the complex interplay of artistic creativity and social inquiry over time, this course compares influential literary and social-scientific responses to the Enlightenment, the Industrial Revolution, and other dynamic junctures integral to the forging of "modernity" and the volatile world we inhabit today. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS310. MODERN EUROPEAN LITERATURE. 1-3 Semester Hr.

This course will introduce students to some of the major figures and generative themes of post-Enlightenment European and British literature. Reading, discussion, and writing will focus on fiction, poetry, drama, and critical essays representing British, French, Germanic, Italian, Czech, and Russian cultural traditions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic movements and debates that have shaped modern European society and culture. Thematic concerns will include the French Enlightenment and its legacies, imperialism within and beyond Europe, comparative totalitarianisms, the rise of psychoanalytic theory and existentialism, and modernist and postmodern perspectives on the arts. Prerequisite: LAIS100, prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS311. BRITISH LITERATURE: MEDIEVAL TO MODERN. 3.0 Semester Hrs.

This course surveys British literature from the Middle Ages to early modernists in light of major developments in scientific thought. It considers topics such as medieval medicine and astrology in *The Canterbury Tales*, reflections of Copernicus' new astronomy in Shakespearean tragedy and John Donne's poetry, the tumultuous career of Newtonian physics across the Enlightenment and Romanticism, the struggle with Darwinian evolution in Victorian literature, and early 20th century reactions to anthropology and psychoanalysis. Pre-requisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS315. MUSICAL TRADITIONS OF THE WESTERN WORLD. 3.0 Semester Hrs.

An introduction to music of the Western world from its beginnings to the present. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS320. ETHICS. 3.0 Semester Hrs.

Equivalent with BELS320,

A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS322. LOGIC. 3.0 Semester Hrs.

A general introduction to logic that explores its analytic and historical traditions. Coverage will commonly consider informal and formal fallacies, syllogistic logic, sentential logic, and elementary quantification theory. Reference will commonly be made to the work of such logical theorists as Aristotle, Frege, Russell and Whitehead, Quine, and others. Prerequisite: LAIS100. Co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS323. INTRODUCTION TO SCIENCE COMMUNICATION. 3.0 Semester Hrs.

This course will explore the relationship between science and the public through an examination of science writing and communication on current events. Students will study various forms of science communication, including essays, blogs, news segments, media clips, and radio programs in order to understand the ways in which science is communicated beyond the lab or university and into the public consciousness. Science writing often explores the human condition, reflects on hopes and worries about technology, and informs our collective knowledge about the world. Students will discuss the implications of this kind of communication, analyze breakdowns in communication through case studies, and write for peer and popular audiences, including turning a lab report into a short feature article and writing a science essay. Prerequisites: LAIS100, and pre- or co-requisite of LAIS200 hours lecture; 3 semester hours.

LAIS324. AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE. 3.0 Semester Hrs.

(I) Audio/acoustical engineering and science teaches concepts surrounding the production, transmission, manipulation and reception of audible sound. These factors play a role in many diverse areas such as the design of modern music technology products, recording studios and loudspeakers, civil engineering and building design, and industrial safety. This course will explore and concepts of this field and the physics/mechanics that are involved, as well as aesthetic impacts related to the subject matter. Discussion of human anatomy and psycho acoustic phenomena are also presented. 3 hours lecture; 3 credit hours. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200.

LAIS325. CULTURAL ANTHROPOLOGY. 3.0 Semester Hrs.

A study of the social behavior and cultural development of humans. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS326. MUSIC THEORY. 3.0 Semester Hrs.

(I) The course begins with the fundamentals of music theory and moves into more complex applications. Music of the common practice period (18th century) and beyond is considered. Aural and visual recognition of harmonic material is emphasized. 3 hours lecture; 3 credit hours. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200.

LAIS327. MUSIC TECHNOLOGY. 3.0 Semester Hrs.

(I, II) An introduction to the physics of music and sound. The history of music technology from wax tubes to synthesizers. Construction of instruments and studio. 3 hours lecture. 3 semester hours. Prerequisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS328. BASIC MUSIC COMPOSITION AND ARRANGING. 1.0 Semester Hr.

(I) This course begins with the fundamentals of music composition and works towards basic vocal and instrumental arrangement skills. Upon completion of this course the student should: 1) Demonstrate basic knowledge of (music) compositional techniques; 2) Demonstrate primary concepts of vocal and instrumental ensemble arrangement; 3) Demonstrate an ability to use notational software and Midi station hardware. 1 semester hour; repeatable for credit. Pre-requisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS330. MUSIC TECHNOLOGY CAPSTONE. 3.0 Semester Hrs.

(II) Project-based course designed to develop practical technological and communication skills for direct application to the music recording. 3 credit hours. Prerequisites: LAIS100, LAIS324, LAIS326, and LAIS327. Prerequisite or corequisite: LAIS200.

LAIS335. INTERNATIONAL POLITICAL ECONOMY OF LATIN AMERICA. 3.0 Semester Hrs.

A broad survey of the interrelationship between the state and economy in Latin America as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS337. INTERNATIONAL POLITICAL ECONOMY OF ASIA. 3.0 Semester Hrs.

A broad survey of the interrelationship between the state and economy in East and Southeast Asia as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS339. INTERNATIONAL POLITICAL ECONOMY OF THE MIDDLE EAST. 3.0 Semester Hrs.

A broad survey of the interrelationships between the state and market in the Middle East as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS341. INTERNATIONAL POLITICAL ECONOMY OF AFRICA. 3.0 Semester Hrs.

A broad survey of the interrelationships between the state and market in Africa as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS344. INTERNATIONAL RELATIONS. 3.0 Semester Hrs.

This course surveys major topics and theories of international relations. Students will evaluate diverse perspectives and examine a variety of topics including war and peace, economic globalization, human rights and international law, international environmental issues, and the role of the US as the current superpower. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS345. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.

International Political Economy is a study of contentious and harmonious relationships between the state and the market on the nation-state level, between individual states and their markets on the regional level, and between region-states and region-markets on the global level. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS365. HISTORY OF WAR. 3.0 Semester Hrs.

History of War looks at war primarily as a significant human activity in the history of the Western World since the times of Greece and Rome to the present. The causes, strategies, results, and costs of various wars will be covered, with considerable focus on important military and political leaders as well as on noted historians and theoreticians. The course is primarily a lecture course with possible group and individual presentations as class size permits. Tests will be both objective and essay types. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS370. HISTORY OF SCIENCE. 3.0 Semester Hrs.

An introduction to the social history of science, exploring significant people, theories, and social practices in science, with special attention to the histories of physics, chemistry, earth sciences, ecology, and biology. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours lecture; 3 semester hours.

LAIS371. HISTORY OF TECHNOLOGY. 3.0 Semester Hrs.

A survey of the history of technology in the modern period (from roughly 1700 to the present), exploring the role technology has played in the political and social history of countries around the world. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours lecture; 3 semester hours.

LAIS375. ENGINEERING CULTURES. 3.0 Semester Hrs.

This course seeks to improve students' abilities to understand and assess engineering problem solving from different cultural, political, and historical perspectives. An exploration, by comparison and contrast, of engineering cultures in such settings as 20th century United States, Japan, former Soviet Union and presentday Russia, Europe, Southeast Asia, and Latin America. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS376. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student's learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

LAIS377. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.

(I) This course is an introduction to the relationship between engineering and sustainable community development (SCD) from historical, political, ideological, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of community and sustainable development and the role that engineering might play in them. Also students will critically explore strengths and limitations of dominant methods in engineering problem solving, design, and research for working in SCD. Students will learn to research, describe, analyze and evaluate case studies in SCD and develop criteria for their evaluation. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS401. CREATIVE WRITING: POETRY II. 3.0 Semester Hrs.

This course is a continuation of LAIS301 for those interested in developing their poetry writing further. It focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and simulate the development of the student's craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students try on various styles and contexts in order to develop their own voice. Prerequisite: LAIS100 and LAIS301. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS404. WOMEN, LITERATURE, AND SOCIETY. 3.0 Semester Hrs.

This reading and writing intensive course examines the role that women writers have played in a range of literary traditions. Far from residing in the margins of key national debates, women writers have actively contributed their voices to demands for social, racial, economic, and artistic equality. We will examine the writing produced by women from a diversity of racial, ethnic, and social backgrounds, as we examine the ways in which women writers respond to the various pressures placed on them as artists and activists. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours seminar; 3 semester hours.

LAIS406. THE LITERATURE OF WAR AND REMEMBRANCE. 3.0 Semester Hrs.

In "The Literature of War and Remembrance," students survey poetry, prose, and film ranging from classical to contemporary war literature. The course considers literary depictions of the individual and society in war and its aftermath. Critical reading and writing skills are demonstrated in creative presentations and analytical essays. Students will investigate war literature and commemorative art inspired by recent world conflicts, and place a contemporary work into the thematic structure of the course. Prerequisite: LAIS100. Co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS407. SCIENCE IN LITERATURE. 3.0 Semester Hrs.

Science fiction often serves as a cautionary tale that deals with the darker side of humanity's desires in order to find a better understanding of who we are and what we hope to become. This class examines scientific and social progress as it is imagined by some of the greatest authors of the genre. We will examine the current events that may have influenced the writing and position our lens to the scientific and technological breakthroughs, as well as the social, cultural, and political state of the world at the time of our readings. This course focuses on classic science fiction from the late 1800's to the present which may include: Jules Verne, H.G. Wells, Sir Arthur Conan Doyle, Jack Williamson, Isaac Asimov, Robert Heinlein, Alfred Bester, Philip Jose Farmer, Marion Zimmer Bradley, Ray Bradbury, Philip K. Dick, William Gibson, Arthur C. Clarke, Ursula K. LeGuin and Mary Doria Russell, among others. Prerequisite: LAIS100, Co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS408. LIFE STORIES. 3.0 Semester Hrs.

Using texts by published authors and members of the class, we will explore the pleasures and challenges of creating and interpreting narratives based on "real life." The class will consider critical theories about the relationship between the self and the stories we tell. Prerequisite: LAIS100. Pre-requisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS409. SHAKESPEAREAN DRAMA. 3.0 Semester Hrs.

Shakespeare, the most well known writer in English and perhaps the world, deals with universal themes and the ultimate nature of what it is to be a human being. His plays are staged, filmed, and read around the globe, even after 400 years. This seminar will explore why Shakespeare's plays and characters have such lasting power and meaning to humanity. The seminar will combine class discussion, lecture, and video. Grades will be based on participation, response essays, and a final essay. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS410. CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE. 3.0 Semester Hrs.

This course introduces students to texts and cultural productions of the 20th Century literature. We will examine a diverse collection of materials, including novels and short stories, poems, plays, films, painting, and sculpture. Science, technology, violence, history, identity, language all come under the careful scrutiny of the authors we will discuss in this course, which may include Conrad, Fanon, Achebe, Eliot, Kafka, Barnes, Camus, Borges, and Marquez, among others. We will also screen films that comment upon the fragility of individual identity in the face of modern technology. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS411. LITERATURES OF THE AFRICAN WORLD. 3.0 Semester Hrs.

This course examines wide-ranging writers' depictions of collective transformations and conflicts integral to the making and remaking of African and Afro-diasporic communities worldwide. Fiction, poetry, and essays representing diverse linguistic, aesthetic, and philosophical traditions will constitute the bulk of the reading. Alongside their intrinsic expressive values, these texts illuminate religious and popular cultural practices important to social groups throughout much of sub-Saharan Africa, the Caribbean, Latin America, and the United States. Primary socio-historical themes may include the slave trade, plantation cultures, generational consciousness, ethnicity, gender relations, urbanization, and collective violence. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS412. LITERATURE AND THE ENVIRONMENT. 3.0 Semester Hrs.

This reading and writing intensive course investigates the human connection to the environment in a broad range of literary materials. Discussions focus on the role of place - of landscape as physical, cultural, moral, historical space - and on the relationship between landscape and community, history, and language in the environmental imagination. Readings include texts that celebrate the natural world, those that indict the careless use of land and resources, and those that predict and depict the consequences of that carelessness. Additionally, we investigate philosophical, legal, and policy frameworks that shape approaches to environmental issues. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours seminar; 3 semester hours.

LAIS415. MASS MEDIA STUDIES. 3.0 Semester Hrs.

This introduction to mass media studies is designed to help students become more active interpreters of mass media messages, primarily those that emanate from television, radio, the Internet, sound recordings (music), and motion pictures (film, documentary, etc.). Taking a broad rhetorical and sociological perspective, the course examines a range of mass media topics and issues. Students should complete this course with enhanced rhetorical and sociological understandings of how media shapes individuals, societies, and cultures as well as how those groups shape the media. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS416. FILM STUDIES. 3.0 Semester Hrs.

This course introduces students to the basics of film history, form, and criticism. Students will be exposed to a variety of film forms, including documentary, narrative, and formalist films, and will be encouraged to discuss and write about these forms using critical film language. Students will have an opportunity to work on their own film projects and to conduct research into the relationship between films and their historical, cultural, and ideological origins. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS418. NARRATING THE NATION. 3.0 Semester Hrs.

The novel, nationalism, and the modern nation-state share the same eighteenth and nineteenth-century roots. Relationships between the works of novelists, local nationalisms, and state politics have, however, always been volatile. These tensions have assumed particularly dramatic expressive and political forms in Latin America and postcolonial South Asia and Africa. This course examines the inspirations, stakes, and ramifications of celebrated novelists' explorations of the conflicted and fragmentary character their own and/or neighboring nationstates. Beyond their intrinsic literary values, these texts illuminate distinctive religious, ritual, and popular cultural practices that have shaped collective imaginings of the nation, as well as oscillations in nationalist sentiment across specific regions and historical junctures. Studies in relevant visual media -films, paintings, and telenovelas - will further our comparative inquiry into the relationships between artistic narrative and critical perspectives on "the nation." Alongside the focal literary and visual texts, the course will address major historians' and social theorists' accounts of the origins, spread, and varied careers of nationalist thought and practice across our modern world. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS419. MEDIA AND THE ENVIRONMENT. 3.0 Semester Hrs.

This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in environmental communication, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of environmentalism and the natural world are constructed. Students will analyze their role as science communicators and will participate in the creation of communication projects related to environmental research on campus or beyond. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours seminar; 3 semester hours.

LAIS421. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.

A critical examination of environmental ethics and the philosophical theories on which they depend. Topics may include preservation/conservation, animal welfare, deep ecology, the land ethic, eco-feminism, environmental justice, sustainability, or non-western approaches. This class may also include analyses of select, contemporary environmental issues. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS423. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.

This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS424. RHETORIC, ENERGY AND PUBLIC POLICY. 3.0 Semester Hrs.

(I) This course will examine the ways in which rhetoric shapes public policy debates on energy. Students will learn how contemporary rhetorical and public policy theory illuminates debates that can affect environmental, economic and/or socio-cultural aspects of energy use, transportation and production. 3 hour seminar; 3 credit hours. Prerequisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS426. SCIENTIFIC CONTROVERSIES. 3.0 Semester Hrs.

(I, II) Examines national and international, historical and contemporary scientific and engineering controversies. In particular, the course provides students with a window into how scientific controversies arise, evolve, and are resolved both within scientific circles and in the public arena. By exploring case studies of such controversies, students gain a better understanding about how scientific controversies shape and are shaped by communication as well as by public policy. Prerequisite: LAIS100. Corequisite: LAIS200. 3 hours lecture, 3 semester hours.

LAIS429. REAL WORLD RECORDING/RESEARCH. 3.0 Semester Hrs.

(WI) This reading and writing-intensive course explores the acoustical, musical, and technical aspects of recording a variety of live ethnomusicological music genres and/or performances, towards the purpose of learning how to research, document and capture the most accurate and authentic recording. Historical research, non-traditional recording techniques; archival documentation, and editing will all be a part of this course. Prerequisites: LAIS100 and either LAIS315 or LAIS327. Co-requisites: LAIS200. 3 semester hours.

LAIS430. CORPORATE SOCIAL RESPONSIBILITY. 3.0 Semester Hrs.

Businesses are largely responsible for creating the wealth upon which the well-being of society depends. As they create that wealth, their actions impact society, which is composed of a wide variety of stakeholders. In turn, society shapes the rules and expectations by which businesses must navigate their internal and external environments. This interaction between corporations and society (in its broadest sense) is the concern of Corporate Social Responsibility (CSR). This course explores the dimensions of that interaction from a multi-stakeholder perspective using case studies, guest speakers and field work. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS431. RELIGION & SECURITY. 3.0 Semester Hrs.

This course introduces students to the central topics in religion and society. It defines civil society in 21st century contexts and connects this definition with leading debates about the relationship of religion and security. IT creates an understanding of diverse religious traditions from the perspective of how they view security. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture and discussion; 3 semester hours.

LAIS435. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.

A seminar designed to explore the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization, institution-building, corporate-community-state interfaces, neoliberalism, privatization, democracy, and public policy formulation as it relates to development goals. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS437. ASIAN DEVELOPMENT. 3.0 Semester Hrs.

This international political economy seminar deals with the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS439. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.

This international political economy seminar analyzes economic, political and social dynamics that affect the progress and direction of states, markets, and peoples of the region. It examines the development of the Middle East from agrarian to post-industrial societies; economic, political and cultural transformations since World War II; contemporary security issues that both divide and unite the region; and the effects of globalization processes on economies and societies in the Middle East. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS440. WAR AND PEACE IN THE MIDDLE EAST. 3.0 Semester Hrs.

This course introduces students to theories of war and then discusses a select number of historical wars and contemporary ones. It also analyzes efforts at peace-making efforts and why some fail and others succeed. The global consequences of war and peace in the Middle East will be explored in terms of oil supply and of other geostrategic interests that America has in that region. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS441. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.

This course provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS442. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.

Africa possesses abundant natural resources yet suffers civil wars and international conflicts based on access to resource revenues. The course examines the distinctive history of Africa, the impact of the resource curse, mismanagement of government and corruption, and specific cases of unrest and war in Africa. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS446. GLOBALIZATION. 3.0 Semester Hrs.

This international political economy seminar is an historical and contemporary analysis of globalization processes examined through selected issues of world affairs of political, economic, military, and diplomatic significance. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS448. GLOBAL ENVIRONMENTAL ISSUES. 3.0 Semester Hrs.

Critical examination of interactions between development and the environment and the human dimensions of global change; social, political, economic, and cultural responses to the management and preservation of natural resources and ecosystems on a global scale. Exploration of the meaning and implications of ?Stewardship of the Earth? and ?Sustainable Development.? Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS450. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.

This course will review the existing methodologies and techniques of risk assessment in both country-specific and global environments. It will also seek to design better ways of assessing and evaluating risk factors for business and public diplomacy in the increasingly globalized context of economy and politics wherein the role of the state is being challenged and redefined. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. Prerequisite: At least one IPE 300- or 400-level course. 3 hours seminar; 3 semester hours.

LAIS451. POLITICAL RISK ASSESSMENT RESEARCH SEMINAR. 1.0 Semester Hr.

This international political economy seminar must be taken concurrently with LAIS450, Political Risk Assessment. Its purpose is to acquaint the student with empirical research methods and sources appropriate to conducting a political risk assessment study, and to hone the students' analytical abilities. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. Concurrent enrollment in LAIS450. 1 hour seminar; 1 semester hour.

LAIS452. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.

This course addresses the problem of corruption and its impact on development. Readings are multi disciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or bribe taking might occur. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS453. ETHNIC CONFLICT IN GLOBAL PERSPECTIVE. 3.0 Semester Hrs.

Many scholars used to believe that with modernization, racial, religious, and cultural antagonisms would weaken as individuals developed more rational outlooks and gave primacy to their economic concerns. Yet, with the waning of global ideological conflict of the left-right nature, conflict based on cultural and "civilization" differences have come to the fore in both developing and developed countries. This course will examine ethnic conflict, broadly conceived, in a variety of contexts. Case studies will include the civil war in Yugoslavia, the LA riots, the antagonism between the Chinese and "indigenous" groups in Southeast, the so-called war between the West and Islam, and ethnic relations in the U.S. We will consider ethnic contention in both institutionalized, political processes, such as the politics of affirmative action, as well as in non-institutionalized, extra-legal settings, such as ethnic riots, pogroms, and genocide. We will end by asking what can be done to mitigate ethnic conflict and what might be the future of ethnic group identification. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS456. POWER AND POLITICS IN EURASIA. 3.0 Semester Hrs.

This seminar covers the major internal and international issues confronting the fifteen states that once comprised the Soviet Union. After an overview of the USSR and its collapse in 1991, the course explores subsequent economic and security dilemmas facing the "new" nations of Eurasia. Special attention will be paid to oil, natural gas, and other energy sectors in the region. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS457. INTRODUCTION TO CONFLICT MANAGEMENT. 3.0 Semester Hrs.

This course introduces students to central topics in conflict management. It assesses the causes of contemporary conflicts with an initial focus on weak states, armed insurgencies, and ethnic conflict. It then examines a range of peace-building efforts, and strategies for reconstructing post-conflict states. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS460. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.

This seminar examines geopolitical competition between great and aspiring powers for influence, control over land and natural resources, critical geo-strategic trade routes, or even infrastructure. Using empirical evidence from case studies, students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of foreign policies, as well as issues of war and peace. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 credit hours.

LAIS464. HISTORY OF ENERGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

(II) This course examines the major patterns of human energy use and interaction with the natural environment on a global scale from the origins of civilization to the present day. Topics analyzed include the dynamics of historical change in energy and resource use, the ways in which energy and the environment have shaped the development of past societies, cultural perceptions of energy and the environment during different historical eras, and the impact of past human activities on natural systems. Analysis of historical trends will also serve as a basis for discussions related to current issues in energy and the environment. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture/seminar; 3 semester hours.

LAIS467. HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES. 3.0 Semester Hrs.

This course provides an overview of the history of some of the key sciences that help us understand the world we inhabit: geology, climatology, evolutionary biology, and ecology. As we investigate key scientific discoveries of the modern era, we will also consider the philosophical and cultural impacts of those scientific discoveries. Thus, our reading will include not only original texts by scientists, but also key literary, historical and other texts inspired by those discoveries. Prerequisites: LAIS100. Co-requisites: LAIS200. 3 hours lecture; 3 semester hours.

LAIS475. ENGINEERING CULTURES IN THE DEVELOPING WORLD. 3.0 Semester Hrs.

An investigation and assessment of engineering problem-solving in the developing world using historical and cultural cases. Countries to be included range across Africa, Asia, and Latin America. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS478. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.

(II) This course offers students the opportunity to explore the relationships between engineering and social justice. The course begins with students' exploration of their own social locations, alliances and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Then the course helps students to understand what constitutes social justice in different areas of social life and the role that engineers and engineering might play in these. Finally, the course gives students an understanding of why and how engineering has been aligned and/or divergent from social justice issues and causes. 3 hours lecture and discussion; 3 semester hours. Prerequisite: LAIS100; pre- or co-requisite: LAIS200.

LAIS485. CONSTITUTIONAL LAW AND POLITICS. 3.0 Semester Hrs.

This course presents a comprehensive survey of the U.S. Constitution with special attention devoted to the first ten Amendments, also known as the Bill of Rights. Since the Constitution is primarily a legal document, the class will adopt a legal approach to constitutional interpretation. However, as the historical and political context of constitutional interpretation is inseparable from the legal analysis, these areas will also be covered. Significant current developments in constitutional jurisprudence will also be examined. The first part of the course deals with Articles I through III of the Constitution, which specify the division of national governmental power among the executive, legislative, and judicial branches of government. Additionally, the federal nature of the American governmental system, in which governmental authority is apportioned between the national government and the state governments, will be studied. The second part of the course examines the individual rights specifically protected by the amendments to the Constitution, principally the First, Fourth, Fifth, Sixth, Eighth, and Fourteenth Amendments. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS486. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.

An examination of current issues relating to science and technology policy in the United States and, as appropriate, in other countries. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS487. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.

Seminar on environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS488. WATER POLITICS AND POLICY. 3.0 Semester Hrs.

Seminar on water policies and the political and governmental processes that produce them, as an exemplar of natural resource politics and policy in general. Group discussion and independent research on specific politics and policy issues. Primary but not exclusive focus on the U.S. Pre requisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS489. NUCLEAR POWER AND PUBLIC POLICY. 3.0 Semester Hrs.

A general introduction to research and practice concerning policies and practices relevant to the development and management of nuclear power. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS490. ENERGY AND SOCIETY. 3.0 Semester Hrs.

Equivalent with ENGY490, MNGN490,

(I,II) An interdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development as these affect particular communities and societies. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL113. SPANISH I. 3.0 Semester Hrs.

Fundamentals of spoken and written Spanish with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Spanish American culture. 3 semester hours.

LIFL114. ARABIC I. 3.0 Semester Hrs.

Fundamentals of spoken and written Arabic with an emphasis on vocabulary, idiomatic expressions of daily conversation, and culture of Arabic-speaking societies. 3 semester hours.

LIFL115. GERMAN I. 3.0 Semester Hrs.

Fundamentals of spoken and written German with an emphasis on vocabulary, idiomatic expressions of daily conversation, and German culture. 3 semester hours.

LIFL119. FRENCH I. 3.0 Semester Hrs.

(I) French I provides basic instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Successful completion of French I will allow students to further their french studies in level 2. 3 hours lecture, 3 semester hours.

LIFL123. SPANISH II. 3.0 Semester Hrs.

Continuation of Spanish I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL124. ARABIC II. 3.0 Semester Hrs.

Continuation of Arabic I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and culture of Arabic speaking societies. 3 semester hours.

LIFL125. GERMAN II. 3.0 Semester Hrs.

Continuation of German I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL129. FRENCH II. 3.0 Semester Hrs.

(II) French 2 provides continued instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Prerequisites: LIFL119. 3 hours lecture.

LIFL198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL213. SPANISH III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL214. ARABIC III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and culture of Arabic-speaking societies. 3 semester hours.

LIFL215. GERMAN III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL299. INDEPENDENT STUDY. 6.0 Semester Hrs.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU101. BAND - FRESHMAN. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU102. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU111. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU112. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU189. INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION. 1.0 Semester Hr.

(I, II) The course affords the student an opportunity to study privately with CSM music faculty on a wide range of instruments including guitar, piano, bass guitar, voice, saxophone, flute, drums and world instruments. Students will be required to practice regularly and demonstrate proficiency on their instrument/voice. Topics of this class will include performance etiquette, musicianship, musical styles, stylistic vocabulary, foreign language and basic music theory. 1 credit hour.

LIMU198. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU201. BAND - SOPHOMORE. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU202. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU211. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU212. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU301. BAND - JUNIOR. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU302. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU311. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU312. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU401. BAND - SENIOR. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU402. JAZZ ENSEMBLE/PEP BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU411. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU412. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU421. JAZZ ENSEMBLE/PEP BAND - FALL. 1.0 Semester Hr.

FALL The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance (s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU422. JAZZ ENSEMBLE/PEP BAND - SPRING. 1.0 Semester Hr.

SPRING The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU423. JAZZ LAB. 1.0 Semester Hr.

The Jazz Lab provides an opportunity for students to participate in a musical ensemble in the jazz combo format. Jazz music is a unique American art form. The jazz combo format is an exciting way for students to experience the joy and sense of achievement of performing this great American music form. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU450. MUSIC TECHNOLOGY CAPSTONE COURSE. 3.0 Semester Hrs.

Project-based course designed to develop practical technological and communication skills for direct application to the music recording. Prerequisite: LIMU340 and LIMU350. 3 hours seminar; 3 semester hours.

LIMU498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Mining Engineering

Program Description

Mining engineering is a broad profession, which embraces all required activities to facilitate the recovery of valuable minerals and products from the earth's crust for the benefit of humanity. It is one of the oldest engineering professions, which continues to grow in importance. It has often been said: "If it can't be grown then it must be mined." An adequate supply of mineral products at competitive prices is the life-blood of the continuing growth of industrialized nations and the foundation of the progress for the developing countries.

The function of the mining engineer is to apply knowledge of pertinent scientific theory, engineering fundamentals, and improved technology to recover natural resources. Mining is a world-wide activity involving the extraction of non-metallics, metal ores of all kinds, and solid fuel and energy sources such as coal and nuclear materials. In addition to mineral extraction, the skills of mining engineers are also needed in a variety of fields where the earth's crust is utilized, such as the underground construction industry. The construction industry, with its requirements of developing earth (rock) systems, tunnels and underground chambers, and the hazardous waste disposal industry are examples of such applications. These are expanding needs, with a shortage of competent people; the mining engineer is well qualified to meet these needs.

The importance of ecological and environmental planning is recognized and given significant attention in all aspects of the mining engineering curriculum.

CSM mining engineering students study the principles and techniques of mineral exploration, and underground and surface mining operations, as well as, mineral processing technologies. Studies include rock mechanics, rock fragmentation, plant and mine design, mine ventilation, surveying, valuation, industrial hygiene, mineral law, mine safety, computing, mineral processing, solution mining and operations research. Throughout the mining engineering curriculum, a constant effort is made to maintain a balance between theoretical principles and their engineering applications. The mining engineering graduate is qualified for positions in engineering, supervision, and research.

The Department recognizes the high expectations that industry has for our graduates as well as the responsibility we have to prepare our students for successful professional careers. To be successful, it is imperative that mining graduates possess an ever-growing set of

technical skills, knowledge, and expertise. Beyond the technical aspects of basic sciences, engineering fundamentals, and problem-solving, mining engineering graduates must also acquire a host of other skills which are essential in today's global economy.

These include:

- The ability to work in interdisciplinary teams and communicate effectively to different types of audiences,
- An appreciation of the social, political, and economic realities of different cultures, countries, and indigenous peoples,
- An understanding of the global role mineral extraction and resource development have on local, regional, and international levels,
- The desire for continuing and life-long education, intellectual and professional development, analysis, and creativity,
- The need to maintain high professional and ethical standards,
- The importance of self-confidence, conviction, and compassion, and
- The skills critical to leadership and supervision.

Put simply, our vision for the Mining Engineering Department is to be internationally recognized as the World's premiere center for education and applied research in the diverse fields of mining and underground construction and tunneling. This vision spans across numerous interdisciplinary areas of study. Through collaborations with other CSM departments, academic institutions, government agencies, and industry, we are committed to expanding the international reputation of the Department for excellence in education, research, industry service, and community outreach.

The Mining Engineering Department's program objectives are:

1. Have knowledge of, and skills in, engineering fundamentals to solve complex and open-ended mining and earth systems-related problems.
2. Demonstrate teamwork and leadership skills relevant to their chosen profession.
3. Several years after leaving CSM, our graduates will achieve professional growth.

The program leading to the degree Bachelor of Science in Mining Engineering is accredited by:

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
Telephone (410) 347-7700

Program Educational Objectives (Bachelor of Science in Mining Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate profile and the ABET Accreditation Criteria, the educational objectives which the Mining Engineering Department aspires to accomplish can be seen in the attributes of our graduates. The graduate is equipped with:

- A sound knowledge in the required basic sciences and engineering fundamentals;
- Knowledge and experience in the application of engineering principles to the exploitation of earth's resources and construction

of earth (rock) systems in an engineering systems orientation and setting;

- Ability to solve complex mining and earth systems related problems;
- Capability for team work and decision making;
- Appreciation of the global role of minerals in the changing world;
- Desire for continuing education, intellectual and professional development, analysis and creativity;
- Self confidence and articulation, with high professional and ethical standards.

Curriculum

The mining engineering curriculum is devised to facilitate the widest employability of CSM graduates. The curriculum is based on scientific engineering and geologic fundamentals and the application of these fundamentals to design and operate mines and to create structures in rock and prepare mine products for the market. To achieve this goal, the curriculum is designed to ensure that the graduates:

- become broad based mining engineers who can tackle the problems of both hard and soft rock mining, regardless of whether the mineral deposit requires surface or underground methods of extraction,
- have an opportunity, through elective courses, to specialize in one or more aspects of the mining engineering profession,
- are interested in an academic or research career, or wish to pursue employment in related fields, have a sufficiently sound scientific and engineering foundation to do so effectively.

This purpose permeates both the lower and upper division courses. Another important aspect of the curriculum is the development of the students' capabilities to be team members, with the added objective of preparing them for leadership in their professional life. The curriculum focuses on the application of engineering principles to solving problems, in short, engineering design in an earth systems approach.

Degree Requirements (Mining Engineering)

Freshman

		lec	lab	sem.hrs
CORE	Common Core			33.0
				33.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
CEEN241	STATICS			3.0
EPIC251	DESIGN (EPICS) II	2.0	3.0	3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				18.0

Spring		lec	lab	sem.hrs
MEGN351	FLUID MECHANICS			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
MNGN210	INTRODUCTORY MINING	3.0		3.0
LAIS200	HUMAN SYSTEMS			3.0

MNGN317	DYNAMICS FOR MINING ENGINEERS	1.0		1.0
CEEN311	MECHANICS OF MATERIALS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				16.5

Summer		lec	lab	sem.hrs
MNGN308	MINE SAFETY	1.0		1.0
MNGN300	SUMMER FIELD SESSION	3.0		3.0
				4.0

Junior

Fall		lec	lab	sem.hrs
MEGN361	THERMODYNAMICS I			3.0
MNGN309	MINING ENGINEERING LABORATORY	8.0		2.0
MNGN312	SURFACE MINE DESIGN	2.0	3.0	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	2.0	3.0	3.0
GEOL310	EARTH MATERIALS AND RESOURCES	4.0		4.0
FREE	Free Elective	3.0		3.0
				18.0

Spring		lec	lab	sem.hrs
LAIS/EBGN	H&SS Restricted Elective I	3.0		3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER			3.0
MNGN314	UNDERGROUND MINE DESIGN	3.0		3.0
MNGN316	COAL MINING METHODS	2.0	3.0	3.0
GEOL311	STRUCTURAL GEOLOGY FOR MINING ENGINEERS	2.0		2.0
FREE	Free Elective	3.0		3.0
				17.0

Senior

Fall		lec	lab	sem.hrs
MNGN414	MINE PLANT DESIGN	2.0	3.0	3.0
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	2.0		2.0
MNGN428	MINING ENGINEERING EVALUATION AND DESIGN REPORT I	3.0		1.0
MNGN438	GEOSTATISTICS	2.0	3.0	3.0
MNGN322	INTRODUCTION TO MINERAL PROCESSING AND LABORATORY	3.0	2.0	3.0
LAIS/EBGN	H&SS Restricted Elective II	3.0		3.0
FREE	Free Elective	3.0		3.0
				18.0

Spring		lec	lab	sem.hrs
MNGN429	MINING ENGINEERING EVALUATION AND DESIGN REPORT II		3.0	2.0
MNGN433	MINE SYSTEMS ANALYSIS I	3.0		3.0
MNGN427	MINE VALUATION	2.0		2.0
MNGN424	MINE VENTILATION	2.0	3.0	3.0

MNGN410	EXCAVATION PROJECT MANAGEMENT	2.0	2.0
LAIS/EBGN	H&SS Restricted Elective III	3.0	3.0
			15.0

Total Semester Hrs: 139.5

General CSM Minor/ASI requirements can be found here (p. 33).

Minor Programs

The Mining Engineering Department offers three minor programs; the traditional mining engineering program for non-mining majors, underground construction and tunneling and explosive engineering.

Mining Engineering Minor

The minor program in mining engineering requires students to take:

MNGN210	INTRODUCTORY MINING	3.0
Select two of the following:		6.0
MNGN312	SURFACE MINE DESIGN	
MNGN314	UNDERGROUND MINE DESIGN	
MNGN316	COAL MINING METHODS	
Other courses from mining engineering		9.0
Total Semester Hrs		18.0

The list of available courses can be found in the mining engineering department office.

Area of Specialization in mining engineering (12 credit hours of course work) is also available and should be discussed with a faculty member in the mining engineering department and approved by the Department Head.

Explosive Engineering Minor

Program Advisor: Dr. Mark Kuchta

There are very few academic explosive engineering programs world wide. In fact, Colorado School of Mines is the only educational institution that offers an explosive engineering minor program in the U.S.A. Developed in the CSM tradition of combining academic education with hands-on experience, this minor program will prepare students for new and developing applications involving the use of explosives in the mining and materials engineering, underground construction, oil and gas operations, demolition, homeland security, military, forensic investigations, manufacturing and material synthesis.

With the proper program development of courses and basic knowledge in explosive engineering, students enrolled in this program will discover and gain insight into the exciting industrial applications of explosives, selection of explosives, and the correct and safe use of the energetic materials. With the help of the program advisor, the students will design and select the proper course sequence and complete a hands-on research project under the supervision of a faculty advisor.

An explosives minor requires 18 credit hours of specially selected courses. The list of available courses can be found in the mining engineering department office.

Explosive Engineering Area of Special Interest (ASI)

Program Advisor: Dr. Vilem Petr

A total of 12 credit hours are needed to complete the Area of Special Interest in Explosive Engineering Program. This is the preferred route for students that would like to specialize in explosive engineering. The first three (required) courses will provide the students with basic knowledge in explosive engineering. And the fourth course will provide the students with mining application such for surface, underground or underground construction. No more than 3 credit hours used for the ASI may be required for the degree-granting program in which the student is graduating.

Required of All Students

MNGN429	MINING ENGINEERING EVALUATION AND DESIGN REPORT II	2.0
MNGN407	ROCK FRAGMENTATION	3.0
MNGN444	EXPLOSIVES ENGINEERING II	3.0
Select at least one of the following:		3.0
MNGN210	INTRODUCTORY MINING	
MNGN308	MINE SAFETY	
MNGN309	MINING ENGINEERING LABORATORY	
MNGN312	SURFACE MINE DESIGN	
MNGN314	UNDERGROUND MINE DESIGN	
MNGN316	COAL MINING METHODS	
MNGN321	INTRODUCTION TO ROCK MECHANICS	
MNGN404	TUNNELING	
MNGN405	ROCK MECHANICS IN MINING	
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	

Total Semester Hrs

11.0

Department Head

Priscilla P. Nelson

Professors

Kadri Dagdelen

Priscilla P. Nelson

M. Ugur Ozbay

Associate Professors

Mark Kuchta

Hugh B. Miller

Masami Nakagawa

Assistant Professors

Elizabeth A. Holley

Rennie Kaunda

Research Professors

Jurgen F. Brune

M. Stephen Enders

Research Associate Professor

Vilem Petr

Adjunct Faculty

John W. Grubb

Wm. Mark Hart

Raymond Henn

Paul Jones

Andy Schissler

D. Erik Spiller

William R. Wilson

Courses

MNGN198. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN210. INTRODUCTORY MINING. 3.0 Semester Hrs.

INTRODUCTORY MINING (I, II) Survey of mining and mining economics. Topics include mining law, exploration and sampling, reserve estimation, project evaluation, basic unit operations including drilling, blasting, loading and hauling, support, shaft sinking and an introduction to surface and underground mining methods. Prerequisite: None. 3 hours lecture; 3 semester hours.

MNGN222. INTRODUCTION TO EXPLOSIVES ENGINEERING. 3.0 Semester Hrs.

(S) A basic introduction to explosives engineering and applied explosives science for students that recently completed their freshman or sophomore years at CSM. Topics covered will include safety and explosives regulations, chemistry of explosives, explosives physics, and detonation properties. The course features a significant hands-on practical laboratory learning component with several sessions held at the Explosives Research Laboratory (ERL) in Idaho Springs. Students completing this course will be well prepared for more advanced work in MNGN333 and MNGN444. Prerequisites: PHGN100, CHGN121, CHGN122, MATH111, and MATH112. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN298. SPECIAL TOPICS IN MINING ENGINEERING. 6.0

Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN300. SUMMER FIELD SESSION. 3.0 Semester Hrs.

(S) Classroom and field instructions in the theory and practice of surface and underground mine surveying. Introduction to the application of various computer-aided mine design software packages incorporated in upper division mining courses. Prerequisite: completion of sophomore year; Duration: first three weeks of summer term; 3 semester hours.

MNGN308. MINE SAFETY. 1.0 Semester Hr.

(I) Causes and prevention of accidents. Mine safety regulations. Mine rescue training. Safety management and organization. Prerequisite: MNGN210. 1 hour lecture; 1 semester hour. Taken as the first week of summer session.

MNGN309. MINING ENGINEERING LABORATORY. 2.0 Semester Hrs.

(I, II) Training in practical mine labor functions including: operation of jackleg drills, jumbo drills, muckers, and LHD machines. Training stresses safe operation of equipment and safe handling of explosives. Introduction to front-line management techniques. Prerequisite: MNGN210, MNGN308. 2 semester hours.

MNGN312. SURFACE MINE DESIGN. 3.0 Semester Hrs.

(I) (WI) Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore estimates, unit operations, equipment selection, final pit determinations, short- and longrange planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN314. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.

(II) Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost estimates. Prerequisite: MNGN210 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN316. COAL MINING METHODS. 3.0 Semester Hrs.

(II) (WI) Devoted to surface and underground coal mining methods and design. The surface mining portion emphasizes area-mining methods, including pertinent design-related regulations, and overburden removal systems. Pit layout, sequencing, overburden equipment selection and cost estimation are presented. The underground mining portion emphasizes general mine layout; detailed layout of continuous, conventional, longwall, and shortwall sections. General cost and manning requirements; and production analysis. Federal and state health and safety regulations are included in all aspects of mine layout. Pre - requisite: MNGN210. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN317. DYNAMICS FOR MINING ENGINEERS. 1.0 Semester Hr.

(II) For mining engineering majors only. Absolute and relative motions, kinetics, work-energy, impulse-momentum and angular impulse-momentum. Prerequisite: MATH213/223, CEEN241. 1 hour lecture; 1 semester hour.

MNGN321. INTRODUCTION TO ROCK MECHANICS. 3.0 Semester Hrs.

Physical properties of rock, and fundamentals of rock substance and rock mass response to applied loads. Principles of elastic analysis and stress-strain relationships. Elementary principles of the theoretical and applied design of underground openings and pit slopes. Emphasis on practical applied aspects. Prerequisite: CEEN241 or MNGN317. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN322. INTRODUCTION TO MINERAL PROCESSING AND LABORATORY. 3.0 Semester Hrs.

(I) Principles and practice of crushing, grinding, size classification; mineral concentration technologies including magnetic and electrostatic separation, gravity separation, and flotation. Sedimentation, thickening, filtration and product drying as well as tailings disposal technologies are included. The course is open to all CSM students. Prerequisite: PHGN200/ 210, MATH213/223. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN333. EXPLOSIVES ENGINEERING I. 3.0 Semester Hrs.

(I) This course gives students in engineering and applied sciences the opportunity to examine and develop a fundamental knowledge including terminology and understanding of explosives science and engineering concepts. Student learning will be demonstrated by assignments, quizzes, and exams. Learning assistance will come in the form of multidisciplinary lectures complemented by a few lectures from experts from government, industry and the explosives engineering community. Pre-requisites: None. 2 hours lecture; 3 hours lab. 3 semester hours.

MNGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MNGN350. INTRODUCTION TO GEOTHERMAL ENERGY. 3.0 Semester Hrs.

Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. Prerequisites: ENGY200. 3 hours lecture; 3 semester hours.

MNGN398. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) (WI)) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN404. TUNNELING. 3.0 Semester Hrs.

(I) Modern tunneling techniques. Emphasis on evaluation of ground conditions, estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN405. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.

(I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN406. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.

Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of in situ and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN407. ROCK FRAGMENTATION. 3.0 Semester Hrs.

(II) Theory and application of rock drilling, rock boring, explosives, blasting, and mechanical rock breakage. Design of blasting rounds, applications to surface and underground excavation. Prerequisite: CEEN241, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN408. UNDERGROUND DESIGN AND CONSTRUCTION. 2.0 Semester Hrs.

(I) Soil and rock engineering applied to underground civil works. Tunneling and the construction of underground openings for power facilities, water conveyance, transportation, and waste disposal; design, excavation and support of underground openings. Emphasis on consulting practice, case studies, geotechnical design, and construction methods. Prerequisite: CEEN312 OR MNGN321. 2 hours of lecture; 2 semester hours.

MNGN410. EXCAVATION PROJECT MANAGEMENT. 2.0 Semester Hrs.

(II) Successful implementation and management of surface and underground construction projects, preparation of contract documents, project bidding and estimating, contract awarding and notice to proceed, value engineering, risk management, construction management and dispute resolution, evaluation of differing site conditions claims. Prerequisite: MNGN 210, 2-hour lecture, 2 semester hours.

MNGN414. MINE PLANT DESIGN. 3.0 Semester Hrs.

(I) Analysis of mine plant elements with emphasis on design. Materials handling, dewatering, hoisting, belt conveyor and other material handling systems for underground mines. Prerequisite: MNGN312 and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hour.

MNGN418. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.

Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. In-situ stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours.

MNGN421. DESIGN OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.

(II) Design of underground openings in competent and broken ground using rock mechanics principles. Rock bolting design and other ground support methods. Coal, evaporite, metallic and nonmetallic deposits included. Prerequisite: MNGN321, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN422. FLOTATION. 2.0 Semester Hrs.

Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN423. FLOTATION LABORATORY. 1.0 Semester Hr.

(I) Experiments to accompany the lectures in MNGN422. Co-requisite: MNGN421. 3 hours lab; 1 semester hour.

MNGN424. MINE VENTILATION. 3.0 Semester Hrs.

(II) Fundamentals of mine ventilation, including control of gas, dust, temperature, and humidity; ventilation network analysis and design of systems. Prerequisite: MEGN351, MEGN361 and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN427. MINE VALUATION. 2.0 Semester Hrs.

(II) Course emphasis is on the business aspects of mining. Topics include time valuation of money and interest formulas, cash flow, investment criteria, tax considerations, risk and sensitivity analysis, escalation and inflation and cost of capital. Calculation procedures are illustrated by case studies. Computer programs are used. Prerequisite: Senior in Mining, graduate status. 2 hours lecture; 2 semester hours.

MNGN428. MINING ENGINEERING EVALUATION AND DESIGN REPORT I. 1.0 Semester Hr.

(I) (WI) Preparation of phase I engineering report based on coordination of all previous work. Includes mineral deposit selection, geologic description, mining method selection, ore reserve determination, and permit process outline. Emphasis is on detailed mine design and cost analysis evaluation in preparation for MNGN429. Prerequisites: MNGN210, MNGN300, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, MNGN316, GEOL310, GEOL311. Concurrent: MNGN438. 1 hour lecture; 1 semester hour.

MNGN429. MINING ENGINEERING EVALUATION AND DESIGN REPORT II. 2.0 Semester Hrs.

(II) (WI) Preparation of formal engineering report based on all course work in the mining option. Emphasis is on mine design, equipment selection, production scheduling, evaluation and cost analysis. Prerequisite: MNGN428, MNGN210, MNGN300, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, MNGN316, GEOL310, GEOL311, MNGN438, MNGN414; Concurrent: MNGN322/MNGN323, MNGN427, and MNGN433. 2 hours lecture; 2 semester hours.

MNGN431. MINING AND METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.

This course covers studies of the interface between mining and metallurgical process engineering and environmental engineering areas. Wastes, effluents and their point sources in mining and metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for some examples chosen. The ratio of fundamentals applications coverage is about 1:1. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN433. MINE SYSTEMS ANALYSIS I. 3.0 Semester Hrs.

(II) Application of statistics, systems analysis, and operations research techniques to mineral industry problems. Laboratory work using computer techniques to improve efficiency of mining operations. Prerequisite: Senior or graduate status. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN434. PROCESS ANALYSIS. 1.0 Semester Hr.

Projects to accompany the lectures in MNGN422. Prerequisite: MNGN422. 3 hours lab; 1 semester hour.

MNGN436. UNDERGROUND COAL MINE DESIGN. 3.0 Semester Hrs.

(II) Design of an underground coal mine based on an actual coal reserve. This course shall utilize all previous course material in the actual design of an underground coal mine. Ventilation, materials handling, electrical transmission and distribution, fluid mechanics, equipment selection and application, mine plant design. Information from all basic mining survey courses will be used. Prerequisite: MNGN316, MNGN321, MNGN414, EGGN329 and MNGN381 or MNGN384. 3 hours lecture, 3 hours lab; 3 semester hours.

MNGN438. GEOSTATISTICS. 3.0 Semester Hrs.

(I) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MATH112. 2 hours of lecture and 3 hours of lab. 3 semester hours.

MNGN440. EQUIPMENT REPLACEMENT ANALYSIS. 2.0 Semester Hrs.

(I) Introduction to the fundamentals of classical equipment replacement theory. Emphasis on new, practical approaches to equipment replacement decision making. Topics include: operating and maintenance costs, obsolescence factors, technological changes, salvage, capital investments, minimal average annual costs, optimum economic life, infinite and finite planning horizons, replacement cycles, replacement vs. expansion, maximization of returns from equipment replacement expenditures. Prerequisite: MNGN427, senior or graduate status. 2 hours lecture; 2 semester hours.

MNGN444. EXPLOSIVES ENGINEERING II. 3.0 Semester Hrs.

(II) This course gives students in engineering and applied sciences the opportunity to acquire the fundamental concepts of explosives engineering and science applications as they apply to industry and real life examples. Students will expand upon their MNGN333 knowledge and develop a more advanced knowledge base including an understanding of the subject as it applies to their specific project interests. Assignments, quizzes, concept modeling and their project development and presentation will demonstrate student's progress. Prerequisite: MNGN333. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN445. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.

Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN452. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.

(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status; none. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN460. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.

(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregates industries. The course will cover resource definition, quarry planning and design, extraction, and processing of material for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth. Prerequisite: MNGN312, MNGN322, MNGN323. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN470. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.

(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN482. MINE MANAGEMENT. 3.0 Semester Hrs.

(II) Basic principles of successful mine management including supervision skills, administrative policies, industrial and human relations, improvement engineering, risk management, conflict resolution and external affairs. Prerequisite: Senior or graduate status. 2 hours lecture and 1 hour case study presentation and discussion per week; 3 hours lecture; 3 semester hours.

MNGN490. ENERGY AND SOCIETY. 3.0 Semester Hrs.

Equivalent with ENGY490, LAIS490,
(II) A transdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development. Prerequisites: ENGY330/EBGN330 and one of either ENGY310, ENGY320, or ENGY340. 3 hours lecture/seminar; 3 semester hours.

MNGN498. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Petroleum Engineering

Program Description

The primary objectives of petroleum engineering are the safe and environmentally sound exploration, evaluation, development, and recovery of oil, gas, geothermal, and other fluids in the earth. Skills in this branch of engineering are needed to meet the world's ever-increasing demand for hydrocarbon fuel, thermal energy, and waste and pollution management.

Graduates of our program are in great demand in private industry, as evidenced by the strong job market and high salaries. The petroleum industry offers a wide range of employment opportunities for Petroleum Engineering students during summer breaks and after graduation. Exciting experiences range from field work in drilling and producing oil and gas fields to office jobs in small towns or large cities. Worldwide travel and overseas assignments are available for interested students.

One of our objectives in the Petroleum Engineering Department is to prepare students to succeed in an energy industry that is evolving into an industry working with many energy sources. Besides developing technical competence in petroleum engineering, you will learn how your education can help you contribute to the development of alternative energy sources such as geothermal. In addition to exciting careers in the petroleum industry, many petroleum engineering graduates find rewarding careers in the environmental arena, law, medicine, business, and many other walks of life.

The department offers semester-abroad opportunities through formal exchange programs with the Petroleum Engineering Department at the Montanuniversität Leoben in Austria, Technical University in Delft, Holland, the University of Adelaide, Adelaide, Australia, and the Petroleum Institute in Abu Dhabi, UAE. Qualified undergraduate

and graduate students from each school can attend the other for one semester and receive full transfer credit back at the home university.

Graduate courses emphasize the research aspects of the profession, as well as advanced engineering applications. Qualified students may continue their education and earn a Master of Science, Master of Engineering, and Doctor of Philosophy degrees.

To facilitate classroom instruction and the learning experience, the Petroleum Engineering faculty recommend that all petroleum engineering students have notebook computers. Recommended specifications for the computer can be obtained from the CSM Academic Computing & Networking web site.

The Petroleum Engineering Department encourages student involvement with the Society of Petroleum Engineers, the American Association of Drilling Engineers, and the American Rock Mechanics Association. The department provides some financial support for students attending the annual technical conferences for these professional societies.

In the fall of 2012, the new Petroleum Engineering building, Marquez (pronounced "Marcus") Hall, was opened. The new home for the Petroleum Engineering Department is a prominent campus landmark, showcasing Mines' longstanding strengths in its core focus areas and our commitment to staying at the forefront of innovation. The new building is designed using aggressive energy saving strategies and is LEED certified. Marquez Hall is the first building on the Colorado School of Mines Campus that is funded entirely by private donations.

New laboratory and computer equipment added to Marquez Hall include:

Computer Laboratory

This computer laboratory is available for general use and classroom instruction. It is continuously open for student use. Software includes more than \$5.0 million in donated industry software used by oil and gas companies and research labs around the world.

Drilling Simulator Laboratory

Rare on university campuses, this lab contains an up-to-date computer controlled, full-scale, graphic intensive drilling rig simulator. It includes drilling controls that can be used to simulate onshore and offshore drilling operations and well control situations. This lab also has three small scale drilling rig simulators, identical to those used in industrial well control training facilities.

Reservoir Characterization Laboratory

Rock properties are measured that affect economic development of reservoir resources of oil and gas. Measured properties include permeability, porosity, and relative permeability. "Hands on" experiences with simple and sophisticated equipment are provided.

Drilling Fluids Laboratory

Modern equipment found on drilling rigs world-wide enables students to evaluate and design fluid systems required in drilling operations.

Fluids Characterization Laboratory

A variety of properties of fluids from oil and gas reservoirs are measured for realistic conditions of elevated temperature and pressure. This laboratory accentuates principles studied in lectures.

Petroleum Engineering Summer Sessions

Two summer sessions, one after the completion of the sophomore year and one after the junior year, are important parts of the educational experience. The first is a two-week session designed to introduce the student to the petroleum industry. Various career opportunities are highlighted as well as showing petroleum field and office operations and geology. In addition, students are indoctrinated in health, safety, and environmental awareness. Petroleum Engineering, a truly unique and exciting engineering discipline, can be experienced by visiting petroleum operations. Historically, the areas visited have included Europe, Alaska, Canada, the U.S. Gulf Coast, California, the Midcontinent, the Northeast US, and the Rocky Mountain Region.

The second two-week session, after the junior year, is an in-depth study of the Rangely Oil Field and surrounding geology in Western Colorado. The Rangely Oil Field is the largest oil field in the Rocky Mountain region and has undergone primary, secondary, and enhanced recovery processes. Field work in the area provide the setting for understanding the complexity of geologic systems and the environmental and safety issues in the context of reservoir development and management.

Other Opportunities

It is recommended that all students considering majoring or minoring in Petroleum Engineering sign up for the elective course PEGN102, Introduction to the Petroleum Industry in the spring semester. Also, seniors may take 500-level graduate courses that include topics such as drilling, reservoir, and production engineering; reservoir simulation and characterization, and economics and risk analysis with instructor concurrence (see the CSM Graduate Bulletin (p. 189) for course offerings).

Program Educational Objectives (Bachelor of Science in Petroleum Engineering)

The Petroleum Engineering Department is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

The Mission of the Petroleum Engineering Program continues to evolve over time in response to the needs of the graduates and industry; in concert with the Colorado School of Mines Institutional Mission Statement and the Profile of the Future Graduate; and in recognition of accreditation requirements specified by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The Mission of the Petroleum Engineering Program is:

To educate engineers for the worldwide petroleum industry at the undergraduate and graduate levels, perform research that enhances the state-of-the-art in petroleum technology, and to serve the industry and public good through professional societies and public service. This mission is achieved through proactive leadership in providing a solid foundation for both the undergraduate and graduate programs. Students are well prepared for life-long learning, an international and diverse career, further education, and public service. The program emphasizes integrated and multi-disciplinary teamwork in classroom instruction and in research, and actively pursues interdisciplinary activities with many other CSM departments, particularly the Earth Science/Engineering programs.

As part of the that process, the faculty of the department has objectives that they want to see their alumni accomplish within three to five years from graduation. Therefore, the Petroleum Engineering Department's faculty has affirmed the following Program Educational Objectives as follows:

- Our Alumni will practice their professions in an ethical, social, and environmentally responsible manner.
- Our Alumni will serve society and individuals through professional societies, educational institutions, and governmental organizations.
- Our Alumni will have a high-level competency in engineering principles and practices.
- Our Alumni will pursue successful and diverse professional careers, or will continue education in the US or abroad.
- Our Alumni will work on multidisciplinary teams across multitude of cultures.
- Our Alumni will be effective communicators.

To accomplish these objectives, the Petroleum Engineering program has, in addition to the school's Graduate Profile and the overall objectives, certain student objectives particular to the Department. These include:

- A broad education, based on science, technology, engineering, and mathematics basics, effective communication skills, the skills necessary for diverse and international professional career, and the recognition of need and ability to engage in lifelong learning.
- A solid foundation in engineering principles and practices, based upon the Society of Petroleum Engineer's ABET Guidelines, a strong petroleum engineering department faculty with diverse backgrounds, and various technical seminars, field trips, and our field sessions.
- Applying problem solving skills, as demonstrated by designing and conducting experiments, analyzing and interpreting data, developing problem solving skills in engineering practice by working real world problems.
- An understanding of ethical, social, environmental, and professional responsibilities as demonstrated by following established department and Colorado School of Mines honor codes, integrating ethical and environmental issues into real world problems, and developing an awareness of health and safety issues.
- And by developing multidisciplinary team skills, as demonstrated by the ability to integrate information and data from multiple sources and to enhance critical team skills sets.

These program objectives and student outcomes can be found on the Petroleum Engineering Department's website under the Colorado School of Mines website. These are also found publicly posted in the ABET bulletin board outside the department offices.

Curriculum

All disciplines within petroleum engineering are covered to great depth at the undergraduate and graduate levels, both in the classroom and laboratory instruction, and in research. Specific areas include fundamental fluid and rock behavior, drilling, formation evaluation, well completions and stimulation, well testing, production operations and artificial lift, reservoir engineering, supplemental and enhanced oil recovery, economic evaluation of petroleum projects, environmental and safety issues, and the computer simulation of most of these topics.

The Petroleum Engineering student studies mathematics, computer science, chemistry, physics, general engineering, geology, the humanities, technical communication (including researching subjects,

report writing, oral presentations, and listening skills), and environmental topics. A unique aspect is the breadth and depth of the total program structured in a manner that prepares each graduate for a successful career from the standpoints of technical competence, managerial abilities, and multidisciplinary experiences. The needs for continued learning and professionalism are stressed.

The strength of the program comes from the high quality of students and professors. The faculty has expertise in teaching and research in all the major areas of petroleum engineering listed above. Additionally, the faculty members have significant industrial backgrounds that lead to meaningful design experiences for the students. Engineering design is taught throughout the curriculum including a senior design course on applying the learned skills to real world reservoir development and management problems. The senior design course is truly multidisciplinary with students and professors from the Petroleum Engineering, Geophysics, and Geology and Geological Engineering departments.

As of August 2012 the program has new facilities and equipment for laboratory instruction and experimental research. To maintain leadership in future petroleum engineering technology, decision making, and management, computers are incorporated into every part of the program, from undergraduate instruction through graduate student and faculty research.

The department is close to oil and gas field operations, petroleum companies, research laboratories, and geologic out-crops of nearby producing formations. There are many opportunities for short field trips and for summer and part-time employment in the oil and gas industry.

Degree Requirements (Petroleum Engineering)

Freshman

	lec	lab	sem.hrs
Common Core			33.0
			33.0

Sophomore

Fall		lec	lab	sem.hrs
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
EPIC251	DESIGN (EPICS) II, 252, 261, 262, 263, 264, 265, 266, 267, or GPGN 268	3.0		3.0
CEEN241	STATICS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
PAGN2XX	PHYSICAL EDUCATION			0.5
				18.0

Spring

		lec	lab	sem.hrs
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CEEN311	MECHANICS OF MATERIALS			3.0
PEGN251	FLUID MECHANICS	3.0		3.0
PEGN308	RESERVOIR ROCK PROPERTIES	2.0	3.0	3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0

LAIS200	HUMAN SYSTEMS		3.0		
			18.0		
Summer		lec	lab	sem.	hrs
PEGN315	SUMMER FIELD SESSION I	2.0		2.0	
			2.0		
Junior					
Fall		lec	lab	sem.	hrs
GEOL315	SEDIMENTOLOGY AND STRATIGRAPHY	2.0	3.0	3.0	
PEGN305	COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING	2.0		2.0	
PEGN310	RESERVOIR FLUID PROPERTIES	2.0		2.0	
PEGN311	DRILLING ENGINEERING	3.0	3.0	4.0	
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	2.0	3.0	3.0	
LAIS/EBGN	H&SS Restricted Elective I	3.0		3.0	
PAGN2XX	PHYSICAL EDUCATION			0.5	
			17.5		
Spring		lec	lab	sem.	hrs
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	2.0	3.0	3.0	
PEGN438	PETROLEUM GEOSTATISTICS	2.0	3.0	3.0	
PEGN361	COMPLETION ENGINEERING	3.0		3.0	
PEGN411	MECHANICS OF PETROLEUM PRODUCTION	3.0		3.0	
LAIS/EBGN	H&SS Restricted Elective II	3.0		3.0	
FREE	Free Elective	3.0		3.0	
			18.0		
Summer		lec	lab	sem.	hrs
PEGN316	SUMMER FIELD SESSION II	2.0		2.0	
			2.0		
Senior					
Fall		lec	lab	sem.	hrs
PEGN481	PETROLEUM SEMINAR	2.0		2.0	
PEGN423	PETROLEUM RESERVOIR ENGINEERING I	3.0		3.0	
PEGN413	GAS MEASUREMENT AND FORMATION EVALUATION LAB		6.0	2.0	
PEGN414	WELL TEST ANALYSIS AND DESIGN	3.0		3.0	
PEGN422	ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS	3.0		3.0	
FREE	Free Elective	3.0		3.0	
			16.0		
Spring		lec	lab	sem.	hrs
PEGN424	PETROLEUM RESERVOIR ENGINEERING II	3.0		3.0	
PEGN426	WELL COMPLETIONS AND STIMULATION	3.0		3.0	
PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	2.0	3.0	3.0	
LAIS/EBGN	H&SS Restricted Elective III	3.0		3.0	

FREE	Free Elective	3.0	3.0
		15.0	

Total Semester Hrs: 139.5

Five Year Combined Baccalaureate and Masters Degree

The Petroleum Engineering Department offers the opportunity to begin work on a Master of Engineering or Master of Science Degree while completing the requirements for the Bachelor's Degree. These degrees are of special interest to those planning on studying abroad or wanting to get a head start on graduate education. These combined programs are individualized and a plan of study should be discussed with the student's academic advisor any time after the Sophomore year.

General CSM Minor/ASI requirements can be found here (p. 33).

Professors

Hazim Abass

Ramona M. Graves, Dean, College of Earth Resource Sciences and Engineering

Hossein Kazemi, Chesebro' Distinguished Chair

Erdal Ozkan, Interim Department Head

Azra N.Tutuncu, Harry D. Campbell Chair

Yu-Shu Wu, CMG Chair

Associate Professors

Alfred W. Eustes III

Jorge H. B. Sampaio Jr.

Manika Prasad

Xiaolong Yin

Assistant Professors

Rosmer Maria Brito

Luis Zerpa

Teaching Professor

Linda A. Battalora

Teaching Associate Professors

Mansur Ermila

Carrie J. McClelland

Mark G. Miller

Teaching Assistant Professor

Elio S. Dean

Research Associate Professor

Philip H. Winterfeld

Research Assistant Professor

Wendy Wempe

Adjunct Professor

William W. Fleckenstein

Professor Emeritus

Craig W. Van Kirk

Associate Professor Emeritus

Richard Christiansen

Courses

PEGN102. INTRODUCTION TO PETROLEUM INDUSTRY. 3.0 Semester Hrs.

(II) A survey of the elements comprising the petroleum industry—exploration, development, processing, transportation, distribution, engineering ethics and professionalism. This elective course is recommended for all PE majors, minors, and other interested students. 3 hours lecture; 3 semester hours.

PEGN198. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN251. FLUID MECHANICS. 3.0 Semester Hrs.

(II) Fundamental course in engineering fluid flow introducing flow in pipelines, surface facilities and oil and gas wells. Theory and application of incompressible and compressible flow, fluid statics, dimensional analysis, laminar and turbulent flow, Newtonian and non-Newtonian fluids, and two-phase flow. Lecture format with demonstrations and practical problem solving, coordinated with PEGN308. May not also receive credit for MEGN351 Fluid Mechanics or CEEN310 Fluid Mechanics for Civil & Environmental Engineering. Prerequisite: MATH213. Co-requisites: PEGN308, CHGN209, CEEN241. 3 hours lecture; 3 semester hours.

PEGN298. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN305. COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING. 2.0 Semester Hrs.

(I) This course is an introduction to computers and computer programming applied to petroleum engineering. Emphasis will be on learning Visual Basic programming techniques to solve engineering problems. A toolbox of fluid property and numerical techniques will be developed. Prerequisite: MATH213. Co-Requisite: PEGN310. 2 hours lecture; 2 semester hours.

PEGN308. RESERVOIR ROCK PROPERTIES. 3.0 Semester Hrs.

(II) (WI) Intro duction to basic reservoir rock properties and their measurements. Topics covered include: porosity, saturations, volumetric equations, land descriptions, trapping mechanism, pressure and temperature gradients, abnormally pressured reservoirs. Darcy?s law for linear horizontal and tilted flow, radial flow for single phase liquids and gases, multiphase flow (relative permeability). Capillary pressure and formation compressibility are also discussed. This course is designated as a writing intensive course (WI). Co-requisites: CEEN241, PEGN251. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN310. RESERVOIR FLUID PROPERTIES. 2.0 Semester Hrs.

(I) Properties of fluids encountered in petroleum engineering. Phase behavior, density, viscosity, interfacial tension, and composition of oil, gas, and brine systems. Interpreting lab data for engineering applications. Flash calculations with k-values and equation of state. Introduction to reservoir simulation software. Prerequisites: PEGN308 (grade of C- or higher), CHGN209 (grade of C- or higher). 2 hours lecture; 2 semester hours.

PEGN311. DRILLING ENGINEERING. 4.0 Semester Hrs.

(I) Study of drilling operations, fluid design, hydraulics, drilling contracts, rig selection, rotary system, well control, bit selection, drill string design, directional drilling, and casing seat selection. Prerequisites: PEGN251 (grade of C- or higher), PEGN315, CEEN241. 3 hours lecture, 3 hours lab; 4 semester hours.

PEGN315. SUMMER FIELD SESSION I. 2.0 Semester Hrs.

(S) This twoweek course taken after the completion of the sophomore year is designed to introduce the student to oil and gas field and other engineering operations. Engineering design problems are integrated throughout the two-week session. On-site visits to various oil field operations in the past included the Rocky Mountain region, the U.S. Gulf Coast, California, Alaska, Canada and Europe. Topics covered include drilling, completions, stimulations, surface facilities, production, artificial lift, reservoir, geology and geophysics. Also included are environmental and safety issues as related to the petroleum industry. Prerequisite: PEGN308. 2 semester hours.

PEGN316. SUMMER FIELD SESSION II. 2.0 Semester Hrs.

(S) This twoweek course is taken after the completion of the junior year. Emphasis is placed on the multidisciplinary nature of reservoir management. Field trips in the area provide the opportunity to study eolian, fluvial, lacustrine, near shore, and marine depositional systems. These field trips provide the setting for understanding the complexity of each system in the context of reservoir development and management. Petroleum systems including the source, maturity, and trapping of hydrocarbons are studied in the context of petroleum exploration and development. Geologic methods incorporating both surface and subsurface data are used extensively. Prerequisites: PEGN315, PEGN411, PEGN419, GEOL308, and GEOL315. 2 semester hours.

PEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

PEGN350. SUSTAINABLE ENERGY SYSTEMS. 3.0 Semester Hrs.

(I or II) A sustainable energy system is a system that lets us meet present energy needs while preserving the ability of future generations to meet their needs. Sustainable Energy Systems introduces undergraduate students to sustainable energy systems that will be available in the 21st century. The course focuses on sustainable energy sources, especially renewable energy sources and nuclear energy (e.g., fusion). Students are introduced to the existing energy infrastructure, become familiar with finite energy sources, and learn from a study of energy supply and demand that sustainable energy systems are needed. The ability to improve energy use efficiency and the impact of energy sources on the environment are discussed. Examples of sustainable energy systems and their applicability to different energy sectors are presented. The course is recommended for students who plan to enter the energy industry or students who would like an introduction to sustainable energy systems. Prerequisites: EPIC 151. 3 hours lecture; 3 semester hours.

PEGN361. COMPLETION ENGINEERING. 3.0 Semester Hrs.

(II) (WI) This class is a continuation from drilling in PEGN311 into completion operations. Topics include casing design, cement planning, completion techniques and equipment, tubing design, wellhead selection, and sand control, and perforation procedures. This course is designed as a writing intensive course (WI). Prerequisite: PEGN311, CEEN311, and EPIC251. 3 hours lecture; 3 semester hours.

PEGN398. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN411. MECHANICS OF PETROLEUM PRODUCTION. 3.0 Semester Hrs.

(II) Nodal analysis for pipe and formation deliverability including single and multiphase flow. Natural flow and design of artificial lift methods including gas lift, sucker rod pumps, electrical submersible pumps, and hydraulic pumps. Prerequisites: PEGN251, PEGN308 (grade of C- or higher), PEGN310, and PEGN311. 3 hours lecture; 3 semester hours.

PEGN413. GAS MEASUREMENT AND FORMATION EVALUATION LAB. 2.0 Semester Hrs.

(I) (WI) This lab investigates the properties of a gas such as vapor pressure, dew point pressure, and field methods of measuring gas volumes. The application of well logging and formation evaluation concepts are also investigated. This course is designated as a writing intensive course (WI). Prerequisites: PEGN308 and PEGN310. Corequisite: PEGN423. 6 hours lab; 2 semester hours.

PEGN414. WELL TEST ANALYSIS AND DESIGN. 3.0 Semester Hrs.

(I) Solution to the diffusivity equation. Transient well testing: build-up, drawdown, multi-rate test analysis for oil and gas. Flow tests and well deliverabilities. Type curve analysis. Super position, active and interference tests. Well test design. Prerequisites: MATH225 and PEGN419. 3 hours lecture; 3 semester hours.

PEGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION. 3.0 Semester Hrs.

Equivalent with GPGN419,

(I) An introduction to well logging methods, including the relationship between measured properties and reservoir properties. Analysis of log suites for reservoir size and content. Graphical and analytical methods will be developed to allow the student to better visualize the reservoir, its contents, and its potential for production. Use of the computer as a tool to handle data, create graphs and log traces, and make computations of reservoir parameters is required. Prerequisites: PEGN 308 (grade of C- or higher); PHGN 200 (grade of C- or higher). Co-requisites: GEOL315 or GEOL308 . 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN422. ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.

(I) Project economics for oil and gas projects under conditions of certainty and uncertainty. Topics include time value of money concepts, discount rate assumptions, measures of project profitability, costs, taxes, expected value concept, decision trees, gambler's ruin, and Monte Carlo simulation techniques. 3 hours lecture; 3 semester hours.

PEGN423. PETROLEUM RESERVOIR ENGINEERING I. 3.0 Semester Hrs.

(II) Data requirements for reservoir engineering studies. Material balance calculations for normal gas, retrograde gas condensate, solution-gas and gas-cap reservoirs with or without water drive. Primary reservoir performance. Forecasting future recoveries by incremental material balance. Prerequisites: PEGN419 and (MATH225 or MATH235 or MATH222 only for non PE majors). 3 hours lecture; 3 semester hours.

PEGN424. PETROLEUM RESERVOIR ENGINEERING II. 3.0 Semester Hrs.

(II) Reservoir engineering aspects of supplemental recovery processes. Introduction to liquid-liquid displacement processes, gas-liquid displacement processes, and thermal recovery processes. Introduction to numerical reservoir simulation, history matching and forecasting. Prerequisite: PEGN423 and PEGN438. 3 hours lecture; 3 semester hours.

PEGN426. WELL COMPLETIONS AND STIMULATION. 3.0 Semester Hrs.

(II) Completion parameters; design for well conditions. Skin damage associated with completions and well productivity. Fluid types and properties; characterizations of compatibilities. Stimulation techniques; acidizing and fracturing. Selection of proppants and fluids; types, placement and compatibilities. Estimation of rates, volumes and fracture dimensions. Reservoir considerations in fracture propagation and design. Prerequisite: PEGN361 and PEGN411. 3 hours lecture; 3 semester hours.

PEGN428. ADVANCED DRILLING ENGINEERING. 3.0 Semester Hrs.

(II) Rotary drilling systems with emphasis on design of drilling programs, directional and horizontal well planning. This elective course is recommended for petroleum engineering majors interested in drilling. Prerequisite: PEGN311, PEGN361. 3 hours lecture; 3 semester hours.

PEGN438. PETROLEUM GEOSTATISTICS. 3.0 Semester Hrs.

(I) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: PEGN423 and PEGN316. 2 hours lecture; 3 hours lab; 3 semester hours.

PEGN439. MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.

Equivalent with GEGN439,GPGN439,

(II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GE Majors: GEOL309, GEOL314, GEGN438, and EPIC264; GP Majors: GPGN302, GPGN303, and EPIC268; PE Majors: GEOL308, PEGN316 and PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN450. ENERGY ENGINEERING. 3.0 Semester Hrs.

(I or II) Energy Engineering is an overview of energy sources that will be available for use in the 21st century. After discussing the history of energy and its contribution to society, we survey the science and technology of energy, including geothermal energy, fossil energy, solar energy, nuclear energy, wind energy, hydro energy, bio energy, energy and the environment, energy and economics, the hydrogen economy, and energy forecasts. This broad background will give you additional flexibility during your career and help you thrive in an energy industry that is evolving from an industry dominated by fossil fuels to an industry working with many energy sources. Prerequisite: MATH213, PHGN200. 3 hours lecture; 3 semester hours.

PEGN481. PETROLEUM SEMINAR. 2.0 Semester Hrs.

(I) (WI) Written and oral presentations by each student on current energy topics. This course is designated as a writing intensive course (WI). Prerequisite: none. 2 hours lecture; 2 semester hours.

PEGN490. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.

(I) The course provides an introduction to fundamental rock mechanics and aims to emphasize their role in oil and gas exploration, drilling, completion and production engineering operations. Deformation as a function of stress, elastic moduli, in situ stress, stress magnitude and orientation, pore pressure, strength and fracture gradient, rock characteristic from field data (seismic, logging, drilling, production), integrated wellbore stability analysis, depletion and drilling induced fractures, compaction and associated changes in rock properties, hydraulic fracturing and fracture stability are among the topics to be covered. Pre-requisites: CEEN311. 3 hours lecture; 3 hours lab, 3 semester hours.

PEGN498. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

College of Applied Science and Engineering

The College of Applied Science and Engineering (CASE) comprises four academic departments and two interdisciplinary programs:

Department of Chemical and Biological Engineering
 Department of Chemistry and Geochemistry
 Department of Metallurgical and Materials Engineering
 Department of Physics

Through these departments and programs CASE is proud to offer rigorous and highly-regarded educational programs, featuring an emphasis on problem solving and critical thinking, that address professional and societal needs. CASE departments and programs are also leaders in the creation of knowledge, recognizing the critical role research plays both in building a dynamic and rigorous intellectual learning community and in the advancement of humankind. The college structure facilitates collaboration among our departments, allowing our faculty and students to tackle the most challenging problems, with a particular emphasis on analysis of relevant systems at the molecular level.

The students and faculty in CASE are working collaboratively toward a shared vision of academic excellence. I am honored to serve as their Dean and invite you to learn more about each department's extraordinary capabilities and accomplishments by visiting their websites.

Please select from the list of links on the right or above to locate more information.

Chemical and Biological Engineering

2015-2016

Program Description

The Chemical and Biological Engineering Department offers two different degrees:

- Bachelor of Science in Chemical Engineering and
- Bachelor of Science in Chemical and Biochemical Engineering.

Generally, the fields of chemical and biochemical engineering are extremely broad, and encompass all technologies and industries where chemical processing is utilized in any form. Students with baccalaureate (BS) Chemical Engineering or Chemical and Biochemical Engineering degrees from CSM can find employment in many diverse fields, including: advanced materials synthesis and processing, product and process research and development, food and pharmaceutical processing and synthesis, biochemical and biomedical materials and products, microelectronics manufacturing, petroleum and petrochemical processing, and process and product design. A student seeking the degree of BS in Chemical and Biochemical Engineering graduates as a

fully-qualified Chemical Engineer with additional training in bioprocessing technologies that are of interest in renewable energy and other emerging fields.

The practice of chemical engineering draws from the fundamentals of biology, chemistry, mathematics, and physics. Accordingly, undergraduate students must initially complete a program of study that stresses these basic fields of science. Chemical engineering coursework blends these four disciplines into a series of engineering fundamentals relating to how materials are produced and processed both in the laboratory and in large industrial-scale facilities. Courses such as fluid mechanics, heat and mass transfer, thermodynamics, reaction kinetics, and chemical process control are at the heart of the chemical engineering curriculum at CSM. In addition, it is becoming increasingly important for engineers to understand how biological and microscopic, molecular-level properties can influence the macroscopic behavior of materials, biological, and chemical systems. This somewhat unique focus is first introduced at CSM through the physical and organic chemistry sequences, and the theme is continued and developed within the chemical engineering curriculum via material and projects introduced in advanced courses. Our undergraduate program at CSM is exemplified by intensive integration of computer-aided simulation and computer-aided process modeling in the curriculum and by our unique approach to teaching of the unit operations laboratory sequence. The unit operations lab course is offered only in the summer as a 6-week intensive session. Here, the fundamentals of heat, mass, and momentum transfer and applied thermodynamics are reviewed in a practical, applications-oriented setting. The important skills of teamwork, critical thinking, time management, and oral and written technical communications skills are also stressed in this course.

Facilities for the study of chemical engineering or chemical and biochemical engineering at the Colorado School of Mines are among the best in the nation. Our modern in-house computer laboratory supports nearly 70 workstations for students to use in completing their assigned coursework. In addition, specialized undergraduate laboratory facilities exist for studying polymer properties, measuring reaction kinetics, characterizing transport phenomena, and for studying several typical chemical unit operations. Our honors undergraduate research program is open to highly qualified students and provides our undergraduates with the opportunity to carry out independent research or to join a graduate research team. This program has been highly successful and our undergraduate chemical engineering and chemical and biochemical engineering students have won several national competitions and awards based on research conducted while pursuing their baccalaureate degrees. We also have a cooperative (Co-Op) education program in which students can earn course credit while gaining work experience in industry.

Programs leading to the degree of Bachelor of Science in Chemical Engineering and to the degree of Bachelor of Science in Chemical and Biochemical Engineering are both accredited by:

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET)
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
telephone (410) 347-7700

2015-2016

Program Educational Objectives (Bachelor of Science in Chemical Engineering and Bachelor of Science in Chemical and Biochemical Engineering)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the Chemical and Biological Engineering Department at CSM has established 3 program educational objectives for all of its graduates and one additional objective specifically for its Chemical and Biochemical Engineering graduates. Our graduates within 3 to 5 years of completing their degree will:

- be in graduate school or in the workforce utilizing their education in chemical engineering fundamentals
- be applying their knowledge of and skills in engineering fundamentals in conventional areas of chemical engineering and in contemporary and growing fields
- have demonstrated both their commitment to continuing to develop personally and professionally and an appreciation for the ethical and social responsibilities associated with being an engineer and a world citizen

Additionally, our Chemical and Biochemical Engineering graduates within 3 to 5 years of completing their degree will be applying their knowledge of and skills in biochemical engineering fundamentals.

Combined Baccalaureate/Masters Degree Program

The Chemical and Biological Engineering Department offers the opportunity to begin work on a Master of Science (with or without thesis) degree while completing the requirements of the BS degree. These combined BS/MS degrees are designed to allow undergraduates engaged in research, or simply interested in furthering their studies beyond a BS degree, to apply their experience and interest to an advanced degree. Students may take graduate courses while completing their undergraduate degrees and count them towards their graduate degree. The requirements for the MS degree consist of the four core graduate courses:

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
CBEN568	INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING	3.0
Additional credits		18.0
Total Semester Hrs		30.0

It is expected that a student would be able to complete both degrees in 5 to 5 1/2 years. To take advantage of the combined program, students are encouraged to engage in research and take some graduate coursework during their senior year. The application process and requirements are identical to our normal MS degree programs. Applications may be completed online and require 3 letters of recommendation, a statement of purpose, and completion of the graduate record exam (GRE). For students who intend to begin the BS/MS program in Fall, applications are due by April 1st. The deadline is November 1st for students intending to

enroll in the Spring semester. Students must have a GPA greater than 3.0 to be considered for the program. Interested students are encouraged to get more information from their advisor and/or the current faculty member in charge of Graduate Affairs.

Curriculum

The Chemical Engineering and Chemical and Biochemical Engineering curricula are structured according to the goals outlined above.

Accordingly, the programs of study are organized to include 3 semesters of science and general engineering fundamentals followed by 5 semesters of chemical/biochemical engineering fundamentals and applications.

A. Chemical/Chemical and Biochemical Engineering Fundamentals

The following courses represent the basic knowledge component of the Chemical Engineering curriculum at CSM.

CBEN201	MATERIAL AND ENERGY BALANCES	3.0
CBEN307	FLUID MECHANICS	3.0
CBEN308	HEAT TRANSFER	3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN375	MASS TRANSFER	3.0
CBEN430	TRANSPORT PHENOMENA	3.0

B. Chemical/Chemical and Biochemical Engineering Applications

The following courses are applications-oriented courses that build on the student's basic knowledge of science and engineering fundamentals:

CBEN312/313	UNIT OPERATIONS LABORATORY	6.0
CBEN402	CHEMICAL ENGINEERING DESIGN	3.0
CBEN403	PROCESS DYNAMICS AND CONTROL	3.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0

Technical Electives for Chemical Engineering

C. Technical Electives for Chemical Engineering

Whereas Chemical and Biochemical Engineering majors have specific additional required courses to give them the biochemical engineering training they need, Chemical Engineering majors have technical electives credit requirements that may be fulfilled with several different courses.

Requirements (Chemical Engineering)

There are 10 credits specifically required for Chemical and Biochemical Engineering that are not specified for Chemical Engineering. Three of these may be any CHGN or CBEN 3XX or higher credits, 6 must be CBEN engineering credits, and 1 is an additional elective credit.

NOTE: Below is a suggested curriculum path. Electives may be taken any time they fit into your schedule, but note that not all courses are offered all semesters. Please refer to http://chemeng.mines.edu/undergraduate_program.html for the most updated flowsheet.

Freshman

Fall		lec	lab	sem.hrs
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0

CSM101	FRESHMAN SUCCESS SEMINAR			0.5
EPIC151	DESIGN (EPICS) I			3.0
BIOL110	BIOLOGY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
PAGN101	PHYSICAL EDUCATION			0.5

16.0

Spring		lec	lab	sem.hrs
LAIS100	NATURE AND HUMAN VALUES			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
PHGN100	PHYSICS I - MECHANICS			4.5
PAGN102	PHYSICAL EDUCATION			0.5

17.0

Sophomore

Fall		lec	lab	sem.hrs
CBEN210	INTRO TO THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0	4.5
PAGN2XX	PHYSICAL EDUCATION			0.5

16.0

Spring		lec	lab	sem.hrs
CBEN201	MATERIAL AND ENERGY BALANCES			3.0
CBEN202	CHEMICAL PROCESS PRINCIPLES LABORATORY			1.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
EPIC265	EPIC II: BIOCHEMICAL PROCESSES			3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION			0.5

16.5

Junior

Fall		lec	lab	sem.hrs
CBEN307	FLUID MECHANICS			3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS			3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
LAIS200	HUMAN SYSTEMS			3.0
FREE	FREE ELECTIVE*			3.0

16.0

Spring		lec	lab	sem.hrs
CBEN308	HEAT TRANSFER			3.0
CBEN375	MASS TRANSFER			3.0

CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY		1.0	
CBEN/CHGN ELECT	CHEMISTRY OR CHEMICAL ENGINEERING ELECTIVE**	3.0	3.0	
LAIS/EBGN	H&SS RESTRICTED ELECTIVE I	3.0	3.0	
FREE	FREE ELECTIVE*		3.0	
			16.0	
Summer		lec	lab sem.hrs	
CBEN312/313	UNIT OPERATIONS LABORATORY		6.0	
			6.0	
Senior				
Fall		lec	lab sem.hrs	
CBEN418	KINETICS AND REACTION ENGINEERING		3.0	
CBEN430	TRANSPORT PHENOMENA		3.0	
CBEN ELECT	CHEMICAL ENGINEERING ELECTIVE***		3.0	
LAIS/EBGN	H&SS RESTRICTED ELECTIVE II	3.0	3.0	
FREE	FREE ELECTIVE*		4.0	
			16.0	
Spring		lec	lab sem.hrs	
CBEN402	CHEMICAL ENGINEERING DESIGN		3.0	
CBEN403	PROCESS DYNAMICS AND CONTROL		3.0	
CBEN ELECT	400-LEVEL CHEMICAL ENGINEERING ELECTIVE***		3.0	
EBGN321	ENGINEERING ECONOMICS		3.0	
LAIS/EBGN	H&SS RESTRICTED ELECTIVE III		3.0	
			15.0	

Total Semester Hrs: 134.5

* Six of the technical electives credits must be CBEN courses with engineering content (http://chemeng.mines.edu/undergraduate_program.html), at least 3 of which must be at the 400 level.

** Three of the technical electives credits may be any CBEN or CHGN credits at the 300-or higher level.

*** Note the 10 free electives credits may be taken as any combination of eligible courses (http://chemeng.mines.edu/undergraduate_program.html)

Requirements (Chemical and Biochemical Engineering)

Freshman

Fall		lec	lab sem.hrs
CHGN121	PRINCIPLES OF CHEMISTRY I		4.0
CSM101	FRESHMAN SUCCESS SEMINAR		0.5
EPIC151	DESIGN (EPICS) I		3.0
BIOL110	FUNDAMENTALS OF BIOLOGY I		4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I		4.0

PAGN101	PHYSICAL EDUCATION		0.5
			16.0
Spring		lec	lab sem.hrs
LAIS100	NATURE AND HUMAN VALUES		4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)		4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II		4.0
PHGN100	PHYSICS I - MECHANICS		4.5
PAGN102	PHYSICAL EDUCATION		0.5
			17.0

Sophomore

Fall		lec	lab sem.hrs
CBEN210	INTRO TO THERMODYNAMICS		3.0
CHGN221	ORGANIC CHEMISTRY I	3.0	3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0 1.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0	4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.5	3.0 4.5
PAGN2XX	PHYSICAL EDUCATION		0.5
			16.0
Spring		lec	lab sem.hrs
CBEN201	MATERIAL AND ENERGY BALANCES		3.0
CBEN202	CHEMICAL PROCESS PRINCIPLES LABORATORY		1.0
CHGN222	ORGANIC CHEMISTRY II	3.0	3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0	3.0
EPIC265	EPIC II: BIOCHEMICAL PROCESSES	3.0	3.0
MATH225	DIFFERENTIAL EQUATIONS	3.0	3.0
PAGN2XX	PHYSICAL EDUCATION		0.5
			16.5

Junior

Fall		lec	lab sem.hrs
CBEN307	FLUID MECHANICS		3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS		3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0 4.0
LAIS200	HUMAN SYSTEMS		3.0
FREE	FREE ELECTIVE	3.0	3.0
			16.0
Spring		lec	lab sem.hrs
CBEN308	HEAT TRANSFER		3.0
CBEN358	CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY		1.0
CBEN375	MASS TRANSFER		3.0
CHGN428	BIOCHEMISTRY	3.0	3.0
CHGN462	MICROBIOLOGY	3.0	3.0

LAIS/EBGN	H&SS RESTRICTED ELECTIVE I	3.0	3.0		
			16.0		
Summer		lec	lab sem.hrs		
CBEN312/313	UNIT OPERATIONS LABORATORY		6.0		
			6.0		
Senior					
Fall		lec	lab sem.hrs		
CBEN418	KINETICS AND REACTION ENGINEERING		3.0		
CBEN430	TRANSPORT PHENOMENA		3.0		
CBEN460	BIOCHEMICAL PROCESS ENGINEERING		3.0		
CBEN461	BIOCHEMICAL PROCESS ENGINEERING LABORATORY		1.0		
LAIS/EBGN	H&SS RESTRICTED ELECTIVE II	3.0	3.0		
FREE	FREE ELECTIVE	3.0	3.0		
			16.0		
Spring		lec	lab sem.hrs		
CBEN402	CHEMICAL ENGINEERING DESIGN		3.0		
CBEN403	PROCESS DYNAMICS AND CONTROL		3.0		
EBGN321	ENGINEERING ECONOMICS		3.0		
LAIS/EBGN	H&SS RESTRICTED ELECTIVE III	3.0	3.0		
FREE	FREE ELECTIVE	3.0	3.0		
			15.0		

Total Semester Hrs: 134.5

General CSM Minor/ASI requirements can be found here (p. 33).

Biomedical Engineering Minor

To obtain a Biomedical Engineering (BME) minor, students must take at least 18 credits related to Biomedical Engineering. Two courses (8 credits) of biology are required. Two restricted requirements include Intro to Biomedical Engineering (required) and at least 3 credits of engineering electives related to BME. Two more courses (or at least 4 credits) may be chosen from the engineering and/or additional electives. The lists of electives will be modified as new related courses that fall into these categories become available.

REQUIRED courses (11 credits):

BIOL110	BIOLOGY I	4.0
CBEN303/323	GENERAL BIOLOGY II/LABORATORY	4.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0

Plus at least 3 credits of engineering electives:

CBEN35x/45x/x98/x99	HONORS UNDERGRADUATE RESEARCH, SPECIAL TOPICS, INDEPENDENT STUDY*	1-4
CBEN432	TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS	3.0
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
CBEN555	POLYMER AND COMPLEX FLUIDS COLLOQUIUM	1.0

MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
MEGN435	MODELING AND SIMULATION OF HUMAN MOVEMENT	3.0
or MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT	
MEGN436	COMPUTATIONAL BIOMECHANICS	3.0
or MEGN536	COMPUTATIONAL BIOMECHANICS	
MEGN530	BIOMEDICAL INSTRUMENTATION	3.0
MEGN531	PROSTHETIC AND IMPLANT ENGINEERING	3.0
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS	3.0
MEGN537	PROBABILISTIC BIOMECHANICS	3.0
MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0

Plus at least 4 more credits from the list above and/or the list below:

Additional elective courses related to BME:

CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN305	ANATOMY AND PHYSIOLOGY LAB	1.0
CBEN306	ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN	3.0
CBEN309	ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN LABORATORY	1.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0
CBEN333	INTRODUCTION TO BIOPHYSICS	3.0
or PHGN333	INTRODUCTION TO BIOPHYSICS	
CBEN35x/45x/x98/x99	HONORS UNDERGRADUATE RESEARCH, SPECIAL TOPICS, INDEPENDENT STUDY	1-4
CBEN411	NEUROSCIENCE, MEMORY, AND LEARNING (NEUROSCIENCE, MEMORY, AND LEARNING)	3.0
CBEN412	INTRODUCTION TO PHARMACOLOGY (INTRODUCTION TO PHARMACOLOGY)	3.0
CHGN428	BIOCHEMISTRY	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
or CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	
CHGN429	BIOCHEMISTRY II	3.0
CHGN462	MICROBIOLOGY	3.0
MATH331	MATHEMATICAL BIOLOGY	3.0
MTGN472	BIOMATERIALS I	3.0
or MTGN572	BIOMATERIALS	

*As the content of these courses varies, the course must be noted as relevant to the BME minor to count toward the minor, and noted as having sufficient engineering content to count as an engineering elective course as the engineering electives.

Dean of the College of Applied Sciences and Engineering

Michael J. Kaufman

Professors

John R. Dorgan

Andrew M. Herring

Carolyn A. Koh

David W. M. Marr, Department Head

J. Douglas Way

Colin A. Wolden, Weaver Distinguished Professor

David T. W. Wu, by courtesy

Associate Professors

Sumit Agarwal

Moises A. Carreon, Coors Developmental Chair

Keith B. Neeves

Amadeu K. Sum

Assistant Professors

Nanette R. Boyle, Coors Developmental Chair

Kevin J. Cash

Melissa D. Krebs

C. Mark Maupin

Ning Wu

Teaching Associate Professors

Jason C. Ganley, Assistant Department Head

Tracy Q. Gardner

Rachel M. Morrish

Cynthia L. Norrgran

Paul D. Ogg

John M. Persichetti

Judith N. Schoonmaker

Charles R. Vestal

Teaching Assistant Professor

C. Joshua Ramey

Research Associate Professor

Angel Abbud-Madrid

Research Assistant Professor

Stephanie Villano

Adjunct Faculty

John L. Jechura

Sarah M. Ryan

Professors Emeriti

Robert M. Baldwin

Annette L. Bunge

James F. Ely, University Professor Emeritus

John O. Golden

J. Thomas McKinnon

Ronald L. Miller

E. Dendy Sloan, Jr., University Professor Emeritus

Victor F. Yesavage

Courses

BIOL110. FUNDAMENTALS OF BIOLOGY I. 4.0 Semester Hrs.

Equivalent with BELS311,

(I, II) Fundamentals of Biology with Laboratory I. This course will emphasize the fundamental concepts of biology and use illustrative examples and laboratory investigations that highlight the interface of biology with engineering. The focus will be on (1) the scientific method; (2) structural, molecular, and energetic basis of cellular activities; (3) mechanisms of storage and transfer of genetic information in biological organisms; (4) a laboratory "toolbox" that will carry them forward in their laboratory-based courses. This core course in biology will be interdisciplinary in nature and will incorporate the major themes and mission of this school - earth, energy, and the environment. Prerequisite: none. Lecture Hours: 3; Lab Hours: 3; Semester Hours: 4.

CBEN110. SEE BIOL110. 4.0 Semester Hrs.

CBEN198. SPECIAL TOPICS. 6.0 Semester Hrs.

Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN199. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN200. COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN200,

Fundamentals of computer programming as applied to the solution of chemical engineering problems. Introduction to Visual Basic, computational methods and algorithm development. Prerequisite: MATH112. 3 hours lecture; 3 semester hours.

CBEN201. MATERIAL AND ENERGY BALANCES. 3.0 Semester Hrs.

Equivalent with CHEN201,

(II) Introduction to the formulation and solution of material and energy balances on chemical processes. Establishes the engineering approach to problem solving, the relations between known and unknown process variables, and appropriate computational methods. Corequisites: CBEN210 (or equivalent); CBEN202, MATH213, MATH225. 3 hours lecture; 3 semester hours.

CBEN202. CHEMICAL PROCESS PRINCIPLES LABORATORY. 1.0 Semester Hr.

Equivalent with CHEN202,

(II) Laboratory measurements dealing with the first and second laws of thermodynamics, calculation and analysis of experimental results, professional report writing. Introduction to computer-aided process simulation. Corequisites: CBEN210 (or equivalent), CBEN201, MATH225, EPIC265 or EPIC266 or EPIC251. 3 hours laboratory; 1 credit hour.

CBEN210. INTRO TO THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with DCGN210,

(I, II) Introduction to the fundamental principles of classical engineering thermodynamics. Application of mass and energy balances to closed and open systems including systems undergoing transient processes. Entropy generation and the second law of thermodynamics for closed and open systems. Introduction to phase equilibrium and chemical reaction equilibria. Ideal solution behavior. May not also receive credit for CHGN209 or MEGN361. Prerequisites: CHGN121, CHGN122, MATH111. Co-requisites: MATH112, PHGN100. 3 hours lecture; 3 semester hours.

CBEN250. INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.

Equivalent with CHEN250,

Introduction to chemical process industries and how analysis and design concepts guide the development of new processes and products. Use of simple mathematical models to describe the performance of common process building blocks including pumps, heat exchangers, chemical reactors, and separators. Prerequisites: Concurrent enrollment in CBEN210. 3 hours lecture; 3 semester hours.

CBEN265. SEE EPIC265. 3.0 Semester Hrs.**CBEN298. SPECIAL TOPICS. 1-6 Semester Hr.**

Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN299. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN303. GENERAL BIOLOGY II. 3.0 Semester Hrs.

Equivalent with BELS303,ESGN303,

(I, II) This is the continuation of General Biology I. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues, and systems) and how it functions. Prerequisite: General Biology I, or equivalent. 3 hours lecture; 3 semester hours.

CBEN304. ANATOMY AND PHYSIOLOGY. 3.0 Semester Hrs.

Equivalent with BELS404,CBEN404,

(II) This course will cover the basics of human anatomy and physiology of the cardiovascular system and blood, the immune system, the respiratory system, the digestive system, the endocrine system, the urinary system and the reproductive system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Prerequisite: General Biology I. 3 hours lecture; 3 semester hours.

CBEN305. ANATOMY AND PHYSIOLOGY LAB. 1.0 Semester Hr.

Equivalent with BELS405,CBEN405,

(II) In this course we explore the basic concepts of human anatomy and physiology using simulations of the physiology and a virtual human dissector program. These are supplemented as needed with animations, pictures and movies of cadaver dissection to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology. Corequisite: CBEN404. 3 lab hours, 1 semester hour.

CBEN306. ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN. 3.0 Semester Hrs.

Equivalent with BELS406,CBEN406,

(I) This course will cover the basics of human anatomy and physiology of the tissues, skeletal system, muscular system, central nervous system and peripheral nervous system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Prerequisite: General Biology I. 3 hour lecture; 3 semester hours.

CBEN307. FLUID MECHANICS. 3.0 Semester Hrs.

Equivalent with CHEN307,

(I) This course covers theory and application of momentum transfer and fluid flow. Fundamentals of microscopic phenomena and application to macroscopic systems are addressed. Course work also includes computational fluid dynamics. Prerequisites: MATH225, grade of C- or better in CBEN201. 3 hours lecture; 3 semester hours.

CBEN308. HEAT TRANSFER. 3.0 Semester Hrs.

Equivalent with CHEN308,

(II) This course covers theory and applications of energy transfer: conduction, convection, and radiation. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat transfer problems. Prerequisites: MATH225, grade of C- or better in CBEN307. 3 hours lecture; 3 semester hours.

CBEN309. ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN LABORATORY. 1.0 Semester Hr.

Equivalent with BELS407,CBEN407,

(I) In this course we explore the basic concepts of human anatomy and physiology of the tissue types, skeletal system, muscular system, and nervous system using anatomical models and medical tissue microscope slides. These are supplemented as needed with pictures, chalk talks, handouts, ultrasound for muscle and skeleton, and EEG recording of brain waves to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology and to reinforce the material from the lecture course. Prerequisite: General Biology 1 [BIOL110]. Co-requisites: must either have taken or currently taking Anatomy and Physiology BMB [CBEN406]. 3 hour lab; 1 semester hour.

CBEN310. INTRODUCTION TO BIOMEDICAL ENGINEERING. 3.0 Semester Hrs.

(I) Introduction to the field of Biomedical Engineering including biomolecular, cellular, and physiological principles, and areas of specialty including biomolecular engineering, biomaterials, biomechanics, bioinstrumentation and bioimaging. Prerequisites: BIOL110 and (CBEN210 or CHGN209 or MEGN361). 3 hours lecture, 3 semester hours.

CBEN311. INTRODUCTION TO NEUROSCIENCE. 3.0 Semester Hrs.

(I, II) This course is the general overview of brain anatomy, physiology, and function. It includes perception, motor, language, behavior, and executive function. This course will review what happens with injury and abnormalities of thought. It will discuss the overview of brain development throughout one's lifespan. Prerequisites: BIOL110, CHGN121, CHGN122, PHGN100, PHGN200. 3 hours lecture; 3 semester hours.

CBEN312. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.

Equivalent with CHEN312,

(S) (WI) Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 6 hours lab, 6 semester hours. Prerequisites: CBEN201, CBEN202, CBEN307, CBEN308, CBEN357, CBEN375, EPIC265 or equivalent.

CBEN313. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.

Equivalent with CHEN313,

(S) (WI) Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. 6 hours lab, 6 semester hours. Prerequisites: CBEN201, CBEN202, CBEN307, CBEN308, CBEN357, CBEN375, EPIC265 or equivalent.

CBEN320. CELL BIOLOGY AND PHYSIOLOGY. 3.0 Semester Hrs.

Equivalent with BELS402, CBEN410, ESGN402,

(II) An introduction to the morphological, biochemical, and biophysical properties of cells and their significance in the life processes. Prerequisite: General Biology I or equivalent. 3 hours lecture; 3 semester hours.

CBEN321. INTRO TO GENETICS. 4.0 Semester Hrs.

Equivalent with BELS321, ESGN321,

(II) A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. Prerequisite: General biology I or equivalent. 3 hours lecture, 3 hours laboratory; 4 semester hours.

CBEN323. GENERAL BIOLOGY II LABORATORY. 1.0 Semester Hr.

Equivalent with BELS313, ESGN313,

(I, II) This Course provides students with laboratory exercises that complement lectures given in CBEN303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Co-requisite or Prerequisite: CBEN303 or equivalent. 3 hours laboratory; 1 semester hour.

CBEN333. INTRODUCTION TO BIOPHYSICS. 3.0 Semester Hrs.

Equivalent with BELS333, PHGN333,

This course is designed to show the application of physics to biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: PHGN200 and BIOL110. 3 hours lecture, 3 semester hours.

CBEN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

Equivalent with CHEN340,

Cooperative work/education experience involving employment of a chemical engineering nature in an internship spanning at least one academic semester. Prerequisite: none. 1 to 3 semester hours. Repeatable to a maximum of 6 hours.

CBEN350. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Equivalent with CHEN350,

Scholarly research of an independent nature. Prerequisite: Junior standing. 1 to 3 semester hours.

CBEN351. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Equivalent with CHEN351,

Scholarly research of an independent nature. Prerequisite: junior standing. 1 to 3 semester hours.

CBEN357. CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with CHEN357,

(I) Introduction to non-ideal behavior in thermodynamic systems and their applications. Phase and reaction equilibria are emphasized. Relevant aspects of computer-aided process simulation are incorporated. Prerequisites: CBEN210 (or equivalent), MATH225, grade of C- or better in CBEN201. 3 hours lecture; 3 semester hours.

CBEN358. CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY. 1.0 Semester Hr.

Equivalent with CHEN358,

(II) This course includes an introduction to process modeling as well as hands-on laboratory measurements of physical data. Methods and concepts explored include calculation and analysis of physical properties, phase equilibria, and reaction equilibria and the application of these concepts in chemical engineering. Prerequisite: CBEN202. Corequisites: CBEN357, EPIC265 or EPIC266 or EPIC251. 3 hours laboratory; 1 semester hour.

CBEN368. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.

Equivalent with CHEN368,

(I, II) Introduction to Undergraduate Research. This course introduces research methods and provides a survey of the various fields in which CBE faculty conduct research. Topics such as how to conduct literature searches, critically reading and analyzing research articles, ethics, lab safety, and how to write papers are addressed. Prerequisites: None. 1 hour lecture; 1 semester hour.

CBEN375. MASS TRANSFER. 3.0 Semester Hrs.

Equivalent with CHEN375,

(II) This course covers fundamentals of stage-wise and diffusional mass transport with applications to chemical engineering systems and processes. Relevant aspects of computer-aided process simulation and computational methods are incorporated. Prerequisites: grade of C- or better in CBEN357. 3 hours lecture; 3 semester hours.

CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.

Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN399. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN401. INTRODUCTION TO CHEMICAL PROCESS DESIGN. 3.0 Semester Hrs.

Equivalent with CHEN401,

(I) This course introduces skills and knowledge required to develop conceptual designs of new processes and tools to analyze troubleshoot, and optimize existing processes. Prerequisites: CBEN201, CBEN308, CBEN307, CBEN357, CBEN375. 3 hours lecture; 3 semester hours.

CBEN402. CHEMICAL ENGINEERING DESIGN. 3.0 Semester Hrs.

Equivalent with CHEN402,

(II) (WI) This course covers simulation, synthesis, analysis, evaluation, as well as costing and economic evaluation of chemical processes. Computer-aided process simulation to plant and process design is applied. 3 hours lecture; 3 Semester hours. Prerequisites: CBEN307, CBEN308, CBEN357, CBEN375, CBEN418 (co-requisite), CBEN421 (co-requisite).

CBEN403. PROCESS DYNAMICS AND CONTROL. 3.0 Semester Hrs.

Equivalent with CHEN403,

(II) Mathematical modeling and analysis of transient systems. Applications of control theory to response of dynamic chemical engineering systems and processes. 3 hours lecture, 3 semester hours. Prerequisites: CBEN201, CBEN307, CBEN308, CBEN375, MATH225.

CBEN408. NATURAL GAS PROCESSING. 3.0 Semester Hrs.

Equivalent with CHEN408,

(II) Application of chemical engineering principles to the processing of natural gas. Emphasis on using thermodynamics and mass transfer operations to analyze existing plants. Relevant aspects of computer-aided process simulation. Prerequisites: CHGN221, CBEN201, CBEN307, CBEN308, CBEN357, CBEN375. 3 hours lecture, 3 semester hours.

CBEN409. PETROLEUM PROCESSES. 3.0 Semester Hrs.

Equivalent with CHEN409,

(I) Application of chemical engineering principles to petroleum refining. Thermodynamics and reaction engineering of complex hydro carbon systems. Relevant aspects of computer-aided process simulation for complex mixtures. Prerequisite: CHGN221, CBEN201, CBEN357, CBEN375. 3 hours lecture; 3 semester hours.

CBEN411. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.

(I) This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. When this course is cross-listed and concurrent with CBEN511, students that enroll in CBEN511 will complete additional and/or more complex assignments. Pre-requisites are the completion of freshmen levels of the three courses: Biology, Chemistry, and Physics. Prerequisites: BIOL110, CBEN303, CHGN121, CHGN122, PHGN100, PHGN200 or consent of instructor. 3 hours lecture, 3 semester hours.

CBEN412. INTRODUCTION TO PHARMACOLOGY. 3.0 Semester Hrs.

(II) This course introduces the concepts of pharmacokinetics and biopharmaceuticals. It will discuss the delivery systems for pharmaceuticals and how they change with disease states. It will cover the modeling of drug delivery, absorption, excretion, and accumulation. The course will cover the different modeling systems for drug delivery and transport. Prerequisites: BIOL110, CBEN303, CHGN121, CHGN122. 3 hours lecture, 3 semester hours.

CBEN415. POLYMER SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with BELS415, CHEN415, CHGN430, MLGN530, Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. Prerequisite: CHGN221, MATH225, CBEN357. 3 hours lecture; 3 semester hours.

CBEN416. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN416, Polymer fluid mechanics, polymer rheological response, and polymer shape forming. Definition and measurement of material properties. Interrelationships between response functions and correlation of data and material response. Theoretical approaches for prediction of polymer properties. Processing operations for polymeric materials; melt and flow instabilities. Prerequisite: CBEN307, MATH225. 3 hours lecture; 3 semester hours.

CBEN418. KINETICS AND REACTION ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN418,

(I) (WI) This course emphasizes applications of the fundamentals of thermodynamics, physical chemistry, organic chemistry, and material and energy balances to the engineering of reactive processes. Key topics include reactor design, acquisition and analysis of rate data, and heterogeneous catalysis. Computational methods as related to reactor and reaction modeling are incorporated. Prerequisites: CBEN308, CBEN357, MATH225, CHGN221, CHGN351. 3 hours lecture; 3 semester hours.

CBEN420. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN420,

Formulation and solution of chemical engineering problems using numerical solution methods within the Excel and MathCAD environments. Setup and numerical solution of ordinary and partial differential equations for typical chemical engineering systems and transport processes. Prerequisite: MATH225, CHGN209 or CBEN210, CBEN307, CBEN357. 3 hours lecture; 3 semester hours.

CBEN430. TRANSPORT PHENOMENA. 3.0 Semester Hrs.

Equivalent with CHEN430,

(I) This course covers theory and applications of momentum, energy, and mass transfer based on microscopic control volumes. Analytical and numerical solution methods are employed in this course. Prerequisites: CBEN307, CBEN308, CBEN357, CBEN375, MATH225. 3 hours lecture; 3 semester hours.

CBEN431. IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS. 3.0 Semester Hrs.

Equivalent with BELS431,

(II) This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies, immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry. Prerequisites: General Biology [BIOL110] or equivalent. 3 Lecture hours, 3 semester hours.

CBEN432. TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with BELS432, CHEN432,

The goal of this course is to develop and analyze models of biological transport and reaction processes. We will apply the principles of mass, momentum, and energy conservation to describe mechanisms of physiology and pathology. We will explore the applications of transport phenomena in the design of drug delivery systems, engineered tissues, and biomedical diagnostics with an emphasis on the barriers to molecular transport in cardiovascular disease and cancer. Prerequisites: CBEN430 or equivalent. 3 lecture hours, 3 credit hours.

CBEN435. INTERDISCIPLINARY MICROELECTRONICS. 3.0 Semester Hrs.

Equivalent with CHEN435, CHEN535, MLGN535, PHGN435, PHGN535,

(II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CBEN, MTGN, or EGGN. Due to lab, space the enrollment is limited to 20 students. 1.5 hours lecture, 4 hours lab; 3 semester hours.

CBEN440. MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN440,

Applications of statistical and quantum mechanics to understanding and prediction of equilibrium and transport properties and processes. Relations between microscopic properties of materials and systems to macroscopic behavior. Prerequisite: CBEN307, CBEN308, CBEN357, CBEN375, CHGN351 and CHGN353, CHGN221 and CHGN222, MATH225. 3 hours lecture; 3 semester hours.

CBEN450. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Equivalent with CHEN450,

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN451. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Equivalent with CHEN451,

Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN454. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.

Equivalent with BELS454,

(II) In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. Prerequisites: General Biology [BIOL110]. 3 hour lecture; 3 semester hours.

CBEN460. BIOCHEMICAL PROCESS ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN460,

(I) The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. Prerequisites: CBEN375, CHGN428, CHGN462. 3 hours lecture; 3 semester hours.

CBEN461. BIOCHEMICAL PROCESS ENGINEERING LABORATORY. 1.0 Semester Hr.

Equivalent with CHEN461,

(I) This course emphasizes bio-based product preparation, laboratory measurement, and calculation and analysis of bioprocesses including fermentation and bio-solids separations and their application to biochemical engineering. Computer-aided process simulation is incorporated. Prerequisites: CBEN375, CHGN428, CHGN462. Co-requisite: CBEN460, 3 hours laboratory, 1 semester hour.

CBEN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN469, EGGN469, MEGN469, MTGN469,

(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials-science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: MEGN361 or CBEN357 or MTGN351. 3 hours lecture; 3 semester hours.

CBEN470. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.

Equivalent with BELS470, CHEN470,

This course introduces the basic principles and applications of microfluidic systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Prerequisites: CBEN307 (or equivalent) or MEGN351 (or equivalent). 3 semester hours.

CBEN472. INTRODUCTION TO ENERGY TECHNOLOGIES. 3.0**Semester Hrs.**

Equivalent with CHEN472,

(II) In this course the student will gain an understanding about energy technologies including how they work, how they are quantitatively evaluated, what they cost, and what is their benefit or impact on the natural environment. There will be discussions about proposed energy systems and how they might become a part of the existing infrastructure. However, to truly understand the impact of proposed energy systems, the student must also have a grasp on the infrastructure of existing energy systems. Prerequisites: CBEN357 Chemical Engineering Thermodynamics (or equivalent). 3 lecture hours, 3 credit hours.

CBEN480. NATURAL GAS HYDRATES. 3.0 Semester Hrs.

Equivalent with CHEN480,

The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co-authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN497. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**CBEN498. SPECIAL TOPICS. 1-6 Semester Hr.**

Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN499. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: none, submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

Chemistry and Geochemistry

2014-2015

Program Description

Chemistry is the field of science associated with atoms and molecules. It focuses on the behavior and properties of matter, the reactions and transformations that dictate chemical processes, and the creation of new substances. Chemistry is the primary field that deals with nanoscience and nanotechnology. It is often considered the central science, linking the physical sciences with engineering, medicine, and life sciences. The subject of chemistry is typically organized into more focused subdisciplines, including organic chemistry, physical chemistry, inorganic chemistry, biochemistry, analytical chemistry, theoretical and computational chemistry, and materials chemistry. A degree in chemistry examines these topics to promote a fundamental understanding of the world and an application toward technological problems. Professional chemists apply their knowledge in many different areas ranging from environmental processes to the development of new materials and renewable energy. They work in academic environments, high-tech start-ups, and research and development laboratories associated with practically every advanced technological field including medicine, energy, biotechnology, computing, and agriculture.

The B.S. degree program in chemistry is approved by the American Chemical Society (ACS) and is designed to educate professionals for the varied career opportunities this central scientific discipline affords. The curricula are therefore founded in rigorous fundamental science complemented by application of these principles to the materials, energy, minerals, or environmental fields. For example, specific curricular

tracks emphasizing environmental chemistry or biochemistry are offered along with a more flexible chemistry track that can be tailored to optimize preparation consistent with a student's individual career goals. Those aspiring to enter Ph.D. programs in chemistry are strongly advised to include undergraduate research among their elective hours. Others interested in industrial chemistry choose area of special interest courses, for example in chemical engineering or metallurgy. A significant number of students complete degrees in both chemistry and chemical engineering as an excellent preparation for industrial careers.

The instructional and research laboratories located in Coolbaugh Hall are state-of-the-art facilities with modern instrumentation for synthesis and characterization of molecules and materials. Instrumentation includes: gas chromatographs (GC), high-performance liquid chromatographs (HPLC), inductively-coupled-plasma-atomic emission spectrometers (ICP-AES), field-flow fractionation (FFF) equipment, mass spectrometry equipment (MS, GC/MS, GC/MS/MS, PY/MS, PY/GC/MS, SFC/MS, MALDI-TOF), 400 MHz and 500 MHz nuclear magnetic resonance spectrometers (NMR), infrared spectrometers (FTIR), ultraviolet-visible (UV) spectrometers, thermogravimetric analyzers (TGA), differential scanning calorimeters (DSC), and others including equipment for microscopy, light scattering, and elemental analysis. In addition, the campus provides access to the CSM 2,144 core 23 teraflop supercomputer for computational research.

Program Educational Objectives (Bachelor of Science in Chemistry)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile and the ABET Accreditation Criteria, the B.S. curricula in chemistry are designed to:

- Impart mastery of chemistry fundamentals;
- Develop ability to apply chemistry fundamentals in solving open-ended problems;
- Impart knowledge of and ability to use modern tools of chemical analysis and synthesis;
- Develop ability to locate and use pertinent information from the chemical literature;
- Develop ability to interpret and use experimental data for chemical systems;
- Develop ability to effectively communicate in both written and oral formats;
- Prepare students for entry to and success in professional careers;
- Prepare students for entry to and success in graduate programs; and
- Prepare students for responsible contribution to society.

Curriculum

The B.S. chemistry curricula, in addition to the strong basis provided by the common core, contain three components: chemistry fundamentals, laboratory and communication skills, and applications courses.

Chemistry fundamentals

- Analytical chemistry - sampling, method selection, statistical data analysis, error sources, theory of operation of analytical instruments (atomic and molecular spectroscopy, mass spectrometry, nuclear magnetic resonance spectroscopy, chromatography and other separation methods, electroanalytical methods, and thermal methods), calibration, standardization, stoichiometry of analysis, equilibrium and kinetic principles in analysis.

- Inorganic chemistry - atomic structure and periodicity, crystal lattice structure, molecular geometry and bonding (VSEPR, Lewis structures, VB and MO theory, bond energies and lengths), metals structure and properties, acid-base theories, main-group element chemistry, coordination chemistry, term symbols, ligand field theory, spectra and magnetism of complexes, organometallic chemistry, and nanomaterials chemistry and design.
- Organic chemistry - bonding and structure, structure- physical property relationships, reactivity-structure relationships, reaction mechanisms (nucleophilic and electrophilic substitution, addition, elimination, radical reactions, rearrangements, redox reactions, photochemical reactions, and metal-mediated reactions), chemical kinetics, catalysis, major classes of compounds and their reactions, and design of synthetic pathways.
- Physical chemistry - thermodynamics (energy, enthalpy, entropy, equilibrium constants, free energy, chemical potential, non-ideal systems, standard states, activity, phase rule, phase equilibria, phase diagrams), electrochemistry, kinetic theory (Maxwell-Boltzmann distribution, collision frequency, effusion, heat capacity, equipartition of energy), kinetics (microscopic reversibility, relaxation processes, mechanisms and rate laws, collision and absolute rate theories), quantum mechanics (Schroedinger equations, operators and matrix elements, particle-in-a-box, simple harmonic oscillator, rigid rotor, angular momentum, hydrogen atom, hydrogen wave functions, spin, Pauli principle, LCAO method, MO theory, bonding), spectroscopy (dipole selection rules, rotational spectra, term symbols, atomic and molecular electronic spectra, magnetic spectroscopy, Raman spectroscopy, multiphoton selection rules, lasers), statistical thermodynamics (ensembles, partition functions, Einstein crystals, Debye crystals), group theory, surface chemistry, X-ray crystallography, electron diffraction, dielectric constants, dipole moments, and elements of computational chemistry.

Laboratory and communication skills

- Analytical methods - gravimetry, titrimetry, sample dissolution, quantitative spectroscopy, GC, HPLC, GC/MS, potentiometry, NMR, AA, ICP-AES
- Synthesis techniques - batch reactor assembly, inert-atmosphere manipulations, vacuum line methods, high-temperature methods, high-pressure methods, distillation, recrystallization, extraction, sublimation, chromatographic purification, product identification
- Physical measurements - refractometry, viscometry, colligative properties, FTIR, NMR
- Information retrieval - Chemical Abstracts online searching, CA registry numbers, Beilstein, Gmelin, handbooks, organic syntheses, organic reactions, inorganic syntheses, primary sources, ACS Style Guide
- Reporting - lab notebook, experiment and research reports, technical oral reports
- Communication - scientific reviews, seminar presentations, publication of research results

Applications

- Elective courses - application of chemistry fundamentals in chemistry elective courses or courses in another discipline; e.g. chemical engineering, environmental science, materials science
- Internship - summer or semester experience in an industrial or governmental organization working on real-world problems

- Undergraduate research - open-ended problem solving in the context of a research project

Students are strongly encouraged to go to <http://chemistry.mines.edu> for the most up-to-date curriculum flowcharts and degree requirements.

Degree Requirements (Chemistry Track)

Freshman

	lec	lab	sem.hrs
Common Core			33.0
			33.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	2.0	4.0	4.5
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				16.0

Spring		lec	lab	sem.hrs
LAIS200	HUMAN SYSTEMS			3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY		3.0	1.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
CHGN335	INSTRUMENTAL ANALYSIS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				16.5

Junior

Fall		lec	lab	sem.hrs
CHGN336	ANALYTICAL CHEMISTRY	3.0		3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY		3.0	1.0
CHGN341	INORGANIC CHEMISTRY I	3.0		3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0	4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH		3.0	1.0
LAIS/EBGN	H&SS Restricted Elective I	3.0		3.0
FREE	Free Elective	3.0		3.0
				18.0

Spring		lec	lab	sem.hrs
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II	3.0	3.0	4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY	1.0	3.0	2.0

CHGN428	BIOCHEMISTRY	3.0	3.0
TECH ELECT	Technical Elective*	3.0	3.0
TECH ELECT	Technical Elective*	3.0	3.0

15.0

Summer		lec	lab sem.hrs
CHGN490	CHEMISTRY FIELD SESSION	18.0	6.0

6.0**Senior**

Fall		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective II	3.0	3.0
CHGN	Chemistry Elective**		3.0
ELECT			
TECH ELECT	Technical Elective*	3.0	3.0
TECH ELECT	Technical Elective*	3.0	3.0
FREE	Free Elective	3.0	3.0

15.0

Spring		lec	lab sem.hrs
LAIS/EBGN	H&SS Restricted Elective III	3.0	3.0
CHGN401	INORGANIC CHEMISTRY II	3.0	3.0
CHGN	Chemistry Elective**		2.0
ELECT			
TECH ELECT	Technical Elective*	3.0	3.0
FREE	Free Elective	3.0	3.0

14.0**Total Semester Hrs: 133.5**

* Technical Electives are courses in any technical field. LAIS, PAGN, Military Science, ROTC, McBride and the business courses of EBGN are **not** accepted technical electives. Examples of possible electives that will be recommended to students are:

CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CHGN411	APPLIED RADIOCHEMISTRY	3.0
CHGN430	INTRODUCTION TO POLYMER SCIENCE	3.0
CHGN462	MICROBIOLOGY	3.0
EBGN305	FINANCIAL ACCOUNTING	3.0
EBGN306	MANAGERIAL ACCOUNTING	3.0
EBGN310	ENVIRONMENTAL AND RESOURCE ECONOMICS	3.0
GEGN206	EARTH MATERIALS	3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0
MATH332	LINEAR ALGEBRA	3.0
MNGN210	INTRODUCTORY MINING	3.0
MTGN311	STRUCTURE OF MATERIALS	3.0
PEGN102	INTRODUCTION TO PETROLEUM INDUSTRY	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0

** Chemistry Electives are non-required courses taught within the Chemistry Department. In addition, graduate level Chemistry and Geochemistry courses taught within the Department are acceptable.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter Ph.D. programs in

Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495. Up to 5 credit hours of CHGN495 can be taken.

Students are strongly encouraged to go to <http://chemistry.mines.edu> for the most up-to-date curriculum flowcharts and degree requirements.

Environmental Chemistry Track**Freshman**

		lec	lab sem.hrs
Common Core			33.0
			33.0

Sophomore

Fall		lec	lab sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0	4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	2.0	4.0 4.5
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS		3.0
CHGN221	ORGANIC CHEMISTRY I	3.0	3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0 1.0
PAGN2XX	PHYSICAL EDUCATION		0.5
			16.0

Spring		lec	lab sem.hrs
LAIS200	HUMAN SYSTEMS		3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0	3.0
CHGN222	ORGANIC CHEMISTRY II	3.0	3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY		3.0 1.0
MATH225	DIFFERENTIAL EQUATIONS	3.0	3.0
CHGN335	INSTRUMENTAL ANALYSIS	3.0	3.0
PAGN2XX	PHYSICAL EDUCATION		0.5
			16.5

Junior

Fall		lec	lab sem.hrs
CHGN336	ANALYTICAL CHEMISTRY	3.0	3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY	3.0	1.0 1.0
CHGN341	INORGANIC CHEMISTRY I	3.0	3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	3.0 4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH	3.0	1.0 1.0
LAIS/EBGN	H&SS Restricted Elective I	3.0	3.0
CHEV	Environmental Elective**	3.0	3.0
ELECT			

18.0

Spring		lec	lab	sem.hrs
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II	3.0	3.0	4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY	1.0	3.0	2.0
CHGN428	BIOCHEMISTRY	3.0		3.0
CHEV ELECT	Environmental Elective **	3.0		3.0
TECH ELECT	Technical Elective *	3.0		3.0

15.0

Summer		lec	lab	sem.hrs
CHGN490	CHEMISTRY FIELD SESSION		18.0	6.0

6.0**Senior**

Fall		lec	lab	sem.hrs
CHEV ELECT	Environmental Elective **	3.0		3.0
CHEV ELECT	Environmental Elective **	3.0		3.0
LAIS/EBGN	H&SS Restricted Elective II	3.0		3.0
FREE	Free Elective	3.0		3.0

12.0

Spring		lec	lab	sem.hrs
CHGN410	SURFACE CHEMISTRY	3.0		3.0
LAIS/EBGN	H&SS Restricted Elective III	3.0		3.0
CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0		3.0
CHGN ELECT	Chemistry Elective **			2.0
FREE	Free Elective	3.0		3.0

14.0**Total Semester Hrs: 130.5**

* Technical Electives are courses in any technical field. LAIS, PAGN, Military Science and ROTC, McBride and the business courses of EBGN are **not** accepted technical electives.

** Chemistry Electives are non-required courses taught within the Chemistry Department. In addition, graduate level Chemistry and Geochemistry courses taught within the Department are acceptable.

Environmental Electives are courses that are directly or indirectly related to Environmental Chemistry. Examples include environmental CEEN courses and CHGN462 Microbiology. Students can consult their advisors for further clarification.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter Ph.D. programs in Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495. Up to 5 credit hours of CHGN495 can be taken.

Students are strongly encouraged to go to <http://chemistry.mines.edu> for the most up-to-date curriculum flowcharts and degree requirements.

Biochemistry Track**Freshman**

	lec	lab	sem.hrs
Common Core			33.0

33.0**Sophomore**

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	2.0	4.0	4.5
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
CHGN221	ORGANIC CHEMISTRY I	3.0		3.0
CHGN223	ORGANIC CHEMISTRY I LABORATORY		3.0	1.0
PAGN2XX	PHYSICAL EDUCATION			0.5

16.0

Spring		lec	lab	sem.hrs
LAIS200	HUMAN SYSTEMS			3.0
EBGN201	PRINCIPLES OF ECONOMICS	3.0		3.0
CHGN222	ORGANIC CHEMISTRY II	3.0		3.0
CHGN224	ORGANIC CHEMISTRY II LABORATORY		3.0	1.0
MATH225	DIFFERENTIAL EQUATIONS	3.0		3.0
CHGN335	INSTRUMENTAL ANALYSIS	3.0		3.0
PAGN2XX	PHYSICAL EDUCATION			0.5

16.5**Junior**

Fall		lec	lab	sem.hrs
BIOL110	BIOLOGY I			4.0
CHGN336	ANALYTICAL CHEMISTRY	3.0		3.0
CHGN337	ANALYTICAL CHEMISTRY LABORATORY		3.0	1.0
CHGN341	INORGANIC CHEMISTRY I	3.0		3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	3.0	4.0	4.0
CHGN395	INTRODUCTION TO UNDERGRADUATE RESEARCH		3.0	1.0

16.0

Spring		lec	lab	sem.hrs
CHGN353	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II	3.0	3.0	4.0
CHGN323	QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY	1.0	3.0	2.0
CHGN428	BIOCHEMISTRY	3.0		3.0
LAIS/EBGN	H&SS Restricted Elective I	3.0		3.0
CBEN303	GENERAL BIOLOGY II			3.0

CBEN323	GENERAL BIOLOGY II LABORATORY		1.0	
			16.0	
Summer		lec	lab	sem.hrs
CHGN490	CHEMISTRY FIELD SESSION		18.0	6.0
			6.0	
Senior				
Fall		lec	lab	sem.hrs
CHGN429	BIOCHEMISTRY II	3.0		3.0
CHGN ELECT	Chemistry Elective**			3.0
LAIS/EBGN	H&SS Restricted Elective II	3.0		3.0
TECH ELECT	Technical Elective*	3.0		3.0
FREE	Free Elective	3.0		3.0
			15.0	
Spring		lec	lab	sem.hrs
LAIS/EBGN	H&SS Restricted Elective III	3.0		3.0
CHGN401	INORGANIC CHEMISTRY II	3.0		3.0
CHGN ELECT	Chemistry Elective**			2.0
FREE	Free Elective	3.0		3.0
FREE	Free Elective	3.0		3.0
			14.0	
Total Semester Hrs: 132.5				

* Technical Electives are courses in any technical field. LAIS, PAGN, Military Science and ROTC, McBride and the business courses of EBGN are **not** accepted technical electives. * Possible technical electives that will be recommended to students are:

CHGN403	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0
CHGN462	MICROBIOLOGY	3.0
CBEN304	ANATOMY AND PHYSIOLOGY	3.0
CBEN320	CELL BIOLOGY AND PHYSIOLOGY	3.0
CBEN321	INTRO TO GENETICS	4.0

** Chemistry Electives are non-required courses taught within the Chemistry Department. In addition, graduate level Chemistry and Geochemistry courses taught within the Department are acceptable.

CHGN495 SENIOR UNDERGRADUATE RESEARCH is taught as a possible chemistry elective. Those aspiring to enter Ph.D. programs in Chemistry or related fields are strongly advised to include undergraduate research in their curricula. The objective of CHGN495 is that students successfully perform an open-ended research project under the direction of a CSM faculty member. Students must demonstrate through the preparation of a proposal, prepared in consultation with the potential faculty research advisor and the CHGN495 instructor, that they qualify for enrollment in CHGN495. Up to 5 credit hours of CHGN495 can be taken.

Students are strongly encouraged to go to <http://chemistry.mines.edu> for the most up-to-date curriculum flowcharts and degree requirements.

General CSM Minor/ASI requirements can be found here (p. 33).

Chemistry Minor and ASI Programs

No specific course sequences are suggested for students wishing to include chemistry minors or areas of special interest in their programs. Rather, those students should consult with the Chemistry department head (or designated faculty member) to design appropriate sequences. For the purpose of completing a minor in Chemistry, the Organic Chemistry sequence is exempt from the 100-200 level limit.

ASI programs include Chemistry, Polymer Chemistry, Environmental Chemistry, and Biochemistry. Refer to the main ASI section of the Bulletin for applicable rules for Areas of Special Interest (<http://bulletin.mines.edu/undergraduate/undergraduateinformation/minorasi>).

Professors

Mark E. Eberhart

Mark P. Jensen, Grandey University Chair in Nuclear Science & Engineering

Daniel M. Knauss

James F. Ranville

Ryan M. Richards

Bettina M. Voelker

Kim R. Williams

David T. Wu, Department Head

Associate Professors

Stephen G. Boyes

Matthew C. Posewitz

Alan S. Sellinger

Assistant Professors

Jenifer C. Braley

Svitlana Pylypenko

Brian G. Trewyn

Shubham Vyas

Yongan Yang

Teaching Professors

Renee L. Falconer

Mark R. Seger

Teaching Associate Professor

Angela Sower

Teaching Assistant Professors

Allison G. Caster

Edward A. Dempsey

Research Professors

Donald L. Macalady

Kent J. Voorhees

Research Assistant Professors

Christopher Cox

Fiona Davies

Yuan Yang

Research Faculty

Jesse Hensley

Bryan Pivovar

Robert Rundberg

Affiliated Faculty

Joseph Meyer

Professors Emeriti

Scott W. Cowley

Stephen R. Daniel

Dean W. Dickerhoof

Kenneth W. Edwards

Ronald W. Klusman

Donald Langmuir

Patrick MacCarthy

Michael J. Pavelich

E. Craig Simmons

Thomas R. Wildeman

John T. Williams

Robert D. Witters

Courses

CHGN111. INTRODUCTORY CHEMISTRY. 3.0 Semester Hrs.

(S) Introductory college chemistry. Elementary atomic structure and the periodic chart, chemical bonding, chemical reactions and stoichiometry of chemical reactions, chemical equilibrium, thermochemistry, and properties of gases. Must not be used for elective credit. Does not apply toward undergraduate degree or g.p.a. 3 hours lecture and 3 hours lab; 3 semester hours.

CHGN121. PRINCIPLES OF CHEMISTRY I. 4.0 Semester Hrs.

(I, II) Study of matter and energy based on atomic structure, correlation of properties of elements with position in periodic chart, chemical bonding, geometry of molecules, phase changes, stoichiometry, solution chemistry, gas laws, and thermochemistry. 3 hours lecture, 3 hours lab; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

CHGN122. PRINCIPLES OF CHEMISTRY II (SC1). 4.0 Semester Hrs.

(I, II, S) Continuation of CHGN121 concentrating on chemical kinetics, gas laws, thermodynamics, electrochemistry and chemical equilibrium (acid-base, solubility, complexation, and redox). Laboratory experiments emphasizing quantitative chemical measurements. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab, 4 semester hours.

CHGN125. MOLECULAR ENGINEERING & MATERIALS CHEMISTRY. 4.0 Semester Hrs.

(I,II) Studies of the interactions of matter and energy in chemical reactions and physical processes. Building on principles from CHGN121, the course systematically explores the relationships between processes, structures and properties, starting from the atomic and molecular level. It provides a framework to apply knowledge of chemical bonding and material properties to engineering design, with an emphasis on the Engineering Grand Challenges and the discovery of new process-structure-property relationships. There is a strong focus on the underlying principles of kinetics and equilibrium, and their general applicability, strongly rooted in the first and second law of thermodynamics. Examples of these principles come primarily from solid-state systems. Laboratory experiments emphasize conceptual understanding of structure-property relationships through both hands-on and computational analysis, reinforced by quantitative chemical measurements. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab, 4 semester hours.

CHGN198. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN198LA. SPECIAL TOPICS. 6.0 Semester Hrs.

CHGN198LB. SPECIAL TOPICS. 6.0 Semester Hrs.

CHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN209. INTRODUCTION TO CHEMICAL THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with DCGN209,

(I, II, S) Introduction to the fundamental principles of classical thermodynamics, with particular emphasis on chemical and phase equilibria. Volume-temperature-pressure relationships for solids, liquids, and gases; ideal and non-ideal gases. Introduction to kinetic molecular theory of ideal gases and the Maxwell-Boltzmann distributions. Work, heat, and application of the First Law to closed systems, including chemical reactions. Entropy and the Second and Third Laws; Gibbs Free Energy. Chemical equilibrium and the equilibrium constant; introduction to activities & fugacities. One- and two-component phase diagrams; Gibbs Phase Rule. May not also receive credit for CBEN210 or MEGN361. Prerequisites: CHGN121, CHGN122, MATH111, MATH112, PHGN100. 3 hours lecture; 3 semester hours.

CHGN221. ORGANIC CHEMISTRY I. 3.0 Semester Hrs.

(I, S) Structure, properties, and reactions of the important classes of organic compounds, introduction to reaction mechanisms. Prerequisites: Grade of C- or better in CHGN122. 3 hours lecture; 3 semester hours.

CHGN222. ORGANIC CHEMISTRY II. 3.0 Semester Hrs.

(II, S) Continuation of CHGN221. Prerequisites: Grade of C- or better in CHGN221. 3 hours lecture; 3 semester hours.

CHGN223. ORGANIC CHEMISTRY I LABORATORY. 1.0 Semester Hr.

(I,II, S) Laboratory exercises including purification techniques, synthesis, and characterization. Experiments are designed to support concepts presented in the CHGN221. Students are introduced to Green Chemistry principles and methods of synthesis and the use of computational software. Prerequisites: CHGN221 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN224. ORGANIC CHEMISTRY II LABORATORY. 1.0 Semester Hr.

(II, S) Laboratory exercises using more advanced synthesis techniques. Experiments are designed to support concepts presented in CHGN222. Prerequisites: CHGN221, CHGN223, and CHGN222 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN323. QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY. 2.0 Semester Hrs.

(II) Identification, separation and purification of organic compounds including use of modern physical and instrumental methods. Prerequisite: Grade of C- or better in CHGN222, CHGN224. 1 hour lecture; 3 hours lab; 2 semester hours.

CHGN335. INSTRUMENTAL ANALYSIS. 3.0 Semester Hrs.

(II) Principles of AAS, AES, Visible-UV, IR, NMR, XRF, XRD, XPS, electron, and mass spectroscopy; gas and liquid chromatography; data interpretation. Prerequisite: Grade of C- or better in CHGN122. 3 hours lecture; 3 semester hours.

CHGN336. ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.

(I) Theory and techniques of gravimetry, titrimetry (acid-base, complexometric, redox, precipitation), electrochemical analysis, chemical separations; statistical evaluation of data. Prerequisite: Grade of C- or better in both CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN337. ANALYTICAL CHEMISTRY LABORATORY. 1.0 Semester Hr.

(I) (WI) Laboratory exercises emphasizing sample preparation and instrumental methods of analysis. Prerequisite: CHGN336 or concurrent enrollment. 3 hours lab; 1 semester hour.

CHGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) Supervised, full-time, chemistry-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

CHGN341. INORGANIC CHEMISTRY I. 3.0 Semester Hrs.

(I) The chemistry of the elements and periodic trends in reactivity is discussed. Particular concepts covered include group theory, symmetry, bonding in ionic and metallic crystal, acid-base theories, coordination chemistry, ligand field theory and radioactivity. Prerequisite: CHGN222 and CHGN209. 3 hours lecture; 3 semester hours.

CHGN351. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I. 4.0 Semester Hrs.

(I) A study of chemical systems from a molecular physical chemistry perspective. Includes an introduction to quantum mechanics, atoms and molecules, spectroscopy, bonding and symmetry, and an introduction to modern computational chemistry. Prerequisite: MATH225; PHGN200; Grade of C- or better in both CHGN 122 and CHGN209 or CBEN210. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CHGN353. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II. 4.0 Semester Hrs.

(II) A continuation of CHGN351. Includes statistical thermodynamics, chemical kinetics, chemical reaction mechanisms, electrochemistry, and selected additional topics. Prerequisite: CHGN351. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CHGN395. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.

(I) (WI) Introduction to Undergraduate Research is designed to introduce students to the research endeavor. Topics include ethics, hypothesis testing, critical evaluation of the scientific literature, scientific writing, bibliographic software, and proposal preparation. Prerequisites: Completion of the chemistry curriculum through the Spring semester of the sophomore year. Credit: 1 semester hour.

CHGN396. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.

(I,II,S) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Prerequisites: None. Variable credit; 1 to 5 credit hours. Repeatable for credit. Seniors should take CHGN495 instead of CHGN396.

CHGN398. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN398LA. SPECIAL TOPICS LAB. 1-6 Semester Hr.**CHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.**

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN401. INORGANIC CHEMISTRY II. 3.0 Semester Hrs.

(II) The chemistry of the elements and several applications are related to inorganic chemistry are considered in this course. Particular concepts covered include experimental techniques, chemistry specific to groups of elements, catalysis and industrial processes, inorganic materials and nanotechnology, and other applications of inorganic chemistry. Prerequisite: CHGN341. 3 hours lecture; 3 semester hours.

CHGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.

Equivalent with CHGC505,

(II) Processes by which natural and anthropogenic chemicals interact, react and are transformed and redistributed in various environmental compartments. Air, soil and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized environments such as waste treatment facilities and the upper atmosphere. Prerequisites: CHGN222, CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN410. SURFACE CHEMISTRY. 3.0 Semester Hrs.

Equivalent with MLGN510,

(II) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and micro-emulsions, the solid/gas interface, surface analytical techniques, van der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: CHGN209. 3 hours lecture; 3 semester hours.

CHGN411. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.

(II) This course is designed for those who have a budding interest in radiochemistry and its applications. A brief overview of radioactivity and general chemistry will be provided in the first three weeks of the course. Follow-on weeks will feature segments focusing on the radiochemistry in the nuclear fuel cycle, radioisotope production, nuclear forensics and the environment. Prerequisite: CHGN121 and CHGN122. 3 hours lecture, 3 semester hours.

CHGN422. POLYMER CHEMISTRY LABORATORY. 1.0 Semester Hr.

(I) Prerequisites: CHGN221, CHGN223. 3 hours lab; 1 semester hour.

CHGN428. BIOCHEMISTRY. 3.0 Semester Hrs.

(I) Introductory study of the major molecules of biochemistry: amino acids, proteins, enzymes, nucleic acids, lipids, and saccharides- their structure, chemistry, biological function, and biosynthesis. Stresses bioenergetics and the cell as a biological unit of organization. Discussion of classical genetics, molecular genetics, and protein synthesis. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN429. BIOCHEMISTRY II. 3.0 Semester Hrs.

(I) A continuation of CHGN428. Topics include: nucleotide synthesis; DNA repair, replication and recombination; transcription, translation and regulation; proteomics; lipid and amino acid synthesis; protein target and degradation; membranes; receptors and signal transduction. Prerequisites: CHGN428. 3 hours lecture; 3 semester hours.

CHGN430. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.

Equivalent with CHEN415, MLGN530,

(I) An introduction to the chemistry and physics of macromolecules. Topics include the properties and statistics of polymer solutions, measurements of molecular weights, molecular weight distributions, properties of bulk polymers, mechanisms of polymer formation, and properties of thermosets and thermoplastics including elastomers. Prerequisite: CHGN222. 3 hour lecture, 3 semester hours.

CHGN462. MICROBIOLOGY. 3.0 Semester Hrs.

Equivalent with CHGN562, ESGN580,

(II) This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of microorganisms; microbial metabolism, energetics, genetics, growth and diversity, microbial interactions with plants, animals, and other microbes. Special focus will be on pathogenic bacteriology, virology, and parasitology including disease symptoms, transmission, and treatment. Prerequisite: none. 3 hours lecture, 3 semester hours.

CHGN475. COMPUTATIONAL CHEMISTRY. 3.0 Semester Hrs.

(II) This class provides a survey of techniques of computational chemistry, including quantum mechanics (both Hartree-Fock and density functional approaches) and molecular dynamics. Emphasis is given to the integration of these techniques with experimental programs of molecular design and development. Prerequisites: CHGN351, CHGN401. 3 hours lecture; 3 semester hours.

CHGN490. CHEMISTRY FIELD SESSION. 6.0 Semester Hrs.

(S) (WI) Professional-level chemistry experience featuring modules including organic/polymer synthesis and characterization, inorganic nanomaterial investigations, computational chemistry, environmental chemical analysis, biochemistry and technical report writing. Prerequisites: CHGN323, CHGN341, and CHGN353. 6-week summer session; 6 semester hours.

CHGN495. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.

(I, II, S) (WI) Individual research project under direction of a member of the Departmental faculty. Prerequisites: selection of a research topic and advisor, preparation and approval of a research proposal, completion of chemistry curriculum through the junior year. Variable credit; 1 to 5 credit hours. Repeatable for credit.

CHGN496A. SPECIAL SUMMER COURSE. 16.0 Semester Hrs.**CHGN497. INTERNSHIP. 1-6 Semester Hr.**

(I, II, S) Individual internship experience with an industrial, academic, or governmental host supervised by a Departmental faculty member. Prerequisites: Completion of chemistry curriculum through the junior year. Variable credit; 1 to 6 credit hours.

CHGN498. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN499. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Metallurgical and Materials Engineering

2015-2016

Program Description

Metallurgical and materials engineering plays a role in all manufacturing processes which convert raw materials into useful products adapted to human needs. The primary goal of the Metallurgical and Materials Engineering program is to provide undergraduates with a fundamental knowledge base associated with materials-processing, their properties, and their selection and application. Upon graduation, students will have acquired and developed the necessary background and skills for successful careers in materials related industries. Furthermore, the benefits of continued education toward graduate degrees and other avenues, and the pursuit of knowledge in other disciplines should be well inculcated.

The emphasis in the Department is on materials processing operations which encompass: the conversion of mineral and chemical resources into metallic, ceramic or polymeric materials; the synthesis of new materials; refining and processing to produce high performance materials for applications from consumer products to aerospace and electronics; the development of mechanical, chemical and physical properties of materials related to their processing and structure; and the selection of materials for specific applications.

The metallurgical and materials engineering discipline is founded on fundamentals in chemistry, mathematics and physics which contribute to building the knowledge base and developing the skills for the processing of materials so as to achieve specifications requested for a particular industrial or advanced product. The engineering principles in this discipline include: crystal structure and structural analysis, thermodynamics of materials, reaction kinetics, transport phenomena, phase equilibria, phase transformations, microstructural evolution, mechanical behavior, and properties of materials.

The core-discipline fundamentals are applied to a broad range of materials processes including extraction and refining of materials, alloy development, casting, mechanical working, joining and forming, ceramic particle processing, high temperature reactions and synthesis of engineered materials. In each stage of processing, the effects of resultant microstructures and morphologies on materials properties and performance are emphasized.

Laboratories, located in Nathaniel Hill Hall, are among the finest in the nation. The laboratories, in conjunction with classroom instruction, provide for a well-integrated education of the undergraduates working towards their baccalaureate degrees. These facilities are well equipped and dedicated to: particulate and chemical/extraction, metallurgical and materials processing, foundry science, corrosion and hydro/electro-metallurgical studies, physical and mechanical metallurgy, welding and joining, forming, processing and testing of ceramic materials. Mechanical testing facilities include computerized machines for tension, compression, torsion, toughness, fatigue and thermo-mechanical testing.

There are also other highly specialized research laboratories dedicated to: vapor deposition, and both plasma and high-temperature reaction systems. Supporting analytical laboratories also exist for surface analysis, emission spectrometry, X-ray analysis, optical microscopy and image analysis, scanning and transmission electron microscopy, and micro-thermal-analysis/mass spectrometry. Metallurgical and materials engineering involves all of the processes that transform precursor materials into final engineered products adapted to human needs. The objective of the metallurgical and materials engineering program is to impart a fundamental knowledge of materials processing, properties, selection and application in order to provide graduates with the background and skills needed for successful careers in materials-related industries, for continued education toward graduate degrees and for the pursuit of knowledge in other disciplines.

The Engineering Accreditation Commission of ABET
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
Telephone (410) 347-7700

The Departments of Metallurgical and Materials Engineering and Physics collaborate to offer a five-year program designed to meet the needs of the electronics and similar high-tech industries. Students who satisfy the requirements of the program obtain an undergraduate degree in either Engineering Physics or in Metallurgical and Materials Engineering in four years and a Master of Engineering degree in Metallurgical and Materials Engineering at the end of the fifth year. The program is designed to provide a strong background in science fundamentals, as well as specialized training in the materials-science and processing needs of these industries. Thus, the educational objective of the program is to provide students with the specific educational requirements to begin a career in microelectronics and, at the same time, a broad and flexible background necessary to remain competitive in this exciting and rapidly changing industry. The undergraduate electives which satisfy

the requirements of the program and an overall curriculum need to be discussed with the student's advisor and approved by the Physics or Metallurgical and Materials Engineering Departments. A Program Mentor in each Department can also provide counseling on the program.

Metallurgical and Materials Engineering (MME) Program Educational Objectives

The Metallurgical and Materials Engineering (MME) program emphasizes the structure, properties, processing and performance of materials. Program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The Metallurgical and Materials Engineering program at CSM prepares graduates who:

1. obtain a range of positions in industry or positions in government facilities or pursue graduate education in engineering, science, or other fields;
2. demonstrate advancement in their chosen careers;
3. engage in appropriate professional societies and continuing education activities.

The three MME program educational objectives were determined by using inputs from program constituencies (faculty, students, visiting committee, industry recruiters and alumni). These objectives are consistent with those of the Colorado School of Mines (CSM). CSM is an engineering and applied science institution, dedicated to the education and training of students who will be stewards of the earth's resources.

Curriculum

The Metallurgical and Materials Engineering (MME) curriculum is organized to educate students in the fundamentals of materials (MME Basics) and their applications (MME Applications) with the option of pursuing a track in one of four focus areas.

A. MME Basics: The basic curriculum in the Metallurgical and Materials Engineering program will provide a background in the following topic areas:

1. Crystal Structures and Structural Analysis: crystal systems; symmetry elements and Miller indices; atomic bonding; metallic, ceramic and polymeric structures; x-ray and electron diffraction; stereographic projection and crystal orientation; long range order; defects in materials.
2. Thermodynamics of Materials: heat and mass balances; thermodynamic laws; chemical potential and chemical equilibrium; solution thermodynamics & solution models; partial molar and excess quantities; solid state thermodynamics; thermodynamics of surfaces; electrochemistry.
3. Transport Phenomena and Kinetics: Heat, mass and momentum transport; transport properties of fluids; diffusion mechanisms; reaction kinetics; nucleation and growth kinetics.
4. Phase Equilibria: phase rule; binary and ternary systems; microstructural evolution; defects in crystals; surface phenomena; phase transformations: eutectic, eutectoid, martensitic, nucleation and growth, recovery; microstructural evolution; strengthening mechanisms; quantitative stereology; heat treatment.
5. Properties of Materials: mechanical properties; chemical properties (oxidation and corrosion); electrical, magnetic and optical properties; failure analysis.

B. MME Applications: The course content in the Metallurgical and Materials Engineering program emphasizes the following applications:

1. Materials Processing: particulate processing; thermo- and electro-chemical materials processing; hydrometallurgical processing; synthesis of materials; deformation processing; solidification and casting; welding and joining.
2. Design and Application of Materials: materials selection; ferrous and nonferrous metals; ceramics; polymers; composites; electronic materials.
3. Statistical Process Control and Design of Experiments: statistical process control; process capability analysis; design of experiments.

C. MME Curriculum Requirements: The Metallurgical and Materials Engineering course sequence is designed to fulfill the program educational objectives. In addition, there are four focus areas within the Metallurgical and Materials Engineering curriculum. Students have the option to select one of these focus areas by pursuing one of four tracks. A track is not required to obtain a degree in Metallurgical and Materials Engineering. Only a single track can be taken as part of the degree. The track designation will only appear on the transcript and it does not appear on the diploma. To pursue a track, the student must file appropriate paper work with the registrar and the student will need to fulfill the curricular requirements for that track as listed below. Once a track has been declared the student can change their track or return to the basic curriculum by submitting appropriate paperwork to the registrar.

The four focus areas (tracks) in MME are:

1. Physical and Manufacturing Metallurgy
2. Ceramic and Electronic Materials
3. Physicochemical Processing of Materials
4. Biomaterials

D. MME Curriculum Requirements: The Metallurgical and Materials Engineering course sequence is designed to fulfill the program goals and to satisfy the curriculum requirements. The time sequence of courses organized by degree program, year and semester, is listed below.

Degree Requirements (Metallurgical and Materials Engineering)

The B.S. curricula in metallurgical and materials engineering are outlined below:

Freshman

	lec	lab	sem.hrs
Common Core			33.0
			33.0

Sophomore

Fall		lec	lab	sem.hrs
CHGN209	INTRODUCTION TO CHEMICAL THERMODYNAMICS			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.5
MTGN202	ENGINEERED MATERIALS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
TECH ELECT	Restricted Technical Elective**			3.0
CEEN241	STATICS			3.0
EPIC251	DESIGN (EPICS) II			3.0
EBGN201	PRINCIPLES OF ECONOMICS			3.0
LAIS200	HUMAN SYSTEMS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5
				18.5

Summer		lec	lab	sem.hrs
MTGN272	PARTICULATE MATERIALS PROCESSING			3.0
				3.0

Junior

Fall		lec	lab	sem.hrs
MTGN311	STRUCTURE OF MATERIALS			3.0
MTGN311L	STRUCTURE OF MATERIALS LABORATORY			1.0
MTGN351	METALLURGICAL AND MATERIALS THERMODYNAMICS			3.0
MTGN381	INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS			2.0
CEEN311	MECHANICS OF MATERIALS			3.0
LAIS/EBGN	H&SS Elective I			3.0
FREE	Free Elective			3.0
				18.0

Spring		lec	lab	sem.hrs
MTGN334	CHEMICAL PROCESSING OF MATERIALS			3.0
MTGN334L	CHEMICAL PROCESSING OF MATERIALS LABORATORY			1.0
MTGN348	MICROSTRUCTURAL DEVELOPMENT			3.0
MTGN348L	MICROSTRUCTURAL DEVELOPMENT LABORATORY			1.0
MTGN352	METALLURGICAL AND MATERIALS KINETICS			3.0
LAIS/EBGN	H&SS Elective II			3.0
FREE	Free Elective			3.0
				17.0

Senior

Fall		lec	lab	sem.hrs
MTGN445	MECHANICAL PROPERTIES OF MATERIALS			3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY			1.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS			3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS			2.0

MTGN461L	TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY	1.0
MTGN	MTGN Elective	3.0
LAIS/EBGN	H&SS Elective III (400 Level)	3.0

		lec	lab sem.hrs
Spring			16.0
MTGN415	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS		3.0
MTGN466	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION		3.0
MTGN	MTGN Elective		3.0
MTGN	MTGN Elective		3.0
MTGN	MTGN Elective		3.0
FREE	Free Elective		3.0
			18.0

Total Semester Hrs: 138.5

**** Restricted Electives:**

CBEN303	GENERAL BIOLOGY II	3.0
CEEN301	FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I	3.0
CHGN221	ORGANIC CHEMISTRY I	3.0
CHGN335	INSTRUMENTAL ANALYSIS	3.0
CHGN336	ANALYTICAL CHEMISTRY	3.0
CHGN351	PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I	4.0
CSCI261	PROGRAMMING CONCEPTS	3.0
EENG281	INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER	3.0
ENGY200	INTRODUCTION TO ENERGY	3.0
MATH201	PROBABILITY AND STATISTICS FOR ENGINEERS	3.0
MATH332	LINEAR ALGEBRA	3.0
MATH348	ADVANCED ENGINEERING MATHEMATICS	3.0
PHGN215	ANALOG ELECTRONICS	4.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0

Physical and Manufacturing Metallurgy Track requires:

Sophomore and Junior Year is the same as the MME degree

Freshman

	lec	lab sem.hrs
Common Core		33.0
		33.0

Sophomore

	lec	lab sem.hrs
Sophomore Year		36.5
		36.5

Junior

		lec	lab sem.hrs
Junior Year			35.0
			35.0

Senior

		lec	lab sem.hrs
Fall			
MTGN445	MECHANICAL PROPERTIES OF MATERIALS		3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY		1.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS		3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS		2.0
MTGN461L	TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY		1.0
MTGN	Track MTGN Elective [#]		3.0
LAIS/EBGN	H&SS Cluster Elective		3.0
			16.0

		lec	lab sem.hrs
Spring			
MTGN466	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION		3.0
MTGN415	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS		3.0
MTGN442	ENGINEERING ALLOYS		3.0
MTGN	Track MTGN Elective [#]		3.0
MTGN	Track MTGN Elective [#]		3.0
FREE	Free Elective		3.0
			18.0

Total Semester Hrs: 138.5

Track MTGN Electives must be selected from the following courses:

MTGN300	FOUNDRY METALLURGY	2.0
MTGN300L	FOUNDRY METALLURGY LABORATORY	1.0
MTGN456	ELECTRON MICROSCOPY	2.0
MTGN456L	ELECTRON MICROSCOPY LABORATORY	1.0
MTGN464	FORGING AND FORMING	2.0
MTGN464L	FORGING AND FORMING LABORATORY	1.0
MTGN475	METALLURGY OF WELDING	2.0
MTGN475L	METALLURGY OF WELDING LABORATORY	1.0

Ceramic and Electronic Materials Track requires:

Sophomore and Junior Year is the same as the MME degree

Freshman

		lec	lab sem.hrs
Common Core			33.0
			33.0

Sophomore

	lec	lab	sem.hrs
Sophomore Year			36.5
			36.5

Junior

	lec	lab	sem.hrs
Junior Year			35.0
			35.0

Senior

Fall		lec	lab	sem.hrs
MTGN445	MECHANICAL PROPERTIES OF MATERIALS			3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY			1.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS			3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS			2.0
MTGN461L	TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY			1.0
MTGN412	CERAMIC ENGINEERING			3.0
MTGN	Restricted Track MTGN Elective ^{##}			3.0
				16.0

Spring		lec	lab	sem.hrs
MTGN466	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			3.0
MTGN415	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS			3.0
MTGN	Track MTGN Elective [#]			3.0
MTGN	MTGN Elective			3.0
FREE	Free Elective			3.0
LAIS/EBGN	H&SS Cluster Elective			3.0
				18.0

Total Semester Hrs: 138.5

Track MTGN Electives must be selected from the following courses:

MTGN414	PROCESSING OF CERAMICS	3.0
MTGN456	ELECTRON MICROSCOPY	2.0
MTGN456L	ELECTRON MICROSCOPY LABORATORY	1.0
MTGN465	MECHANICAL PROPERTIES OF CERAMICS	3.0
MTGN469	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
CHGN410	SURFACE CHEMISTRY	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0

Restricted Track MTGN Elective must be selected from the following courses:

MTGN414	PROCESSING OF CERAMICS	3.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0

Physicochemical Processing of Materials Track requires:

Sophomore and Junior Year is the same as the MME degree

Freshman

	lec	lab	sem.hrs
Common Core			33.0
			33.0

Sophomore

	lec	lab	sem.hrs
Sophomore Year			36.5
			36.5

Junior

	lec	lab	sem.hrs
Junior Year			35.0
			35.0

Senior

Fall		lec	lab	sem.hrs
MTGN445	MECHANICAL PROPERTIES OF MATERIALS			3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY			1.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS			3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS			2.0
MTGN461L	TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY			1.0
MTGN	Track MTGN Elective [#]			3.0
MTGN	Track MTGN Elective [#]			3.0
				16.0

Spring		lec	lab	sem.hrs
MTGN466	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION			3.0
MTGN415	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS			3.0
MTGN	Track MTGN Elective [#]			3.0
MTGN	MTGN Elective			3.0
LAIS/EBGN	H&SS Restricted Elective			3.0
FREE	Free Elective			3.0
				18.0

Total Semester Hrs: 138.5

Track MTGN Electives must be selected from the following courses:

MTGN430	PHYSICAL CHEMISTRY OF IRON AND STEELMAKING	3.0
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MTGN431	HYDRO- AND ELECTRO-METALLURGY	3.0
MTGN432	PYROMETALLURGY	3.0
MTGN532	PARTICULATE MATERIAL PROCESSING I - COMMUNITION AND PHYSICAL SEPARATIONS	3.0
MTGN533	PARTICULATE MATERIAL PROCESSING II - APPLIED SEPARATIONS	3.0

Biomaterials Track requires:

Sophomore and Junior Year is the same as the MME degree

Freshman

	lec	lab	sem.hrs
Common Core			33.0
			33.0

Sophomore

	lec	lab	sem.hrs
Sophomore Year			36.5
			36.5

Junior

	lec	lab	sem.hrs
Junior Year			35.0
			35.0

Senior

	lec	lab	sem.hrs
MTGN445	MECHANICAL PROPERTIES OF MATERIALS		3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY		1.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS		3.0
MTGN461	TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS		2.0
MTGN461L	TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY		1.0
MTGN472	BIOMATERIALS I		3.0
MTGN	Track MTGN Elective [#]		3.0
			16.0

Spring

	lec	lab	sem.hrs
MTGN466	MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION		3.0
MTGN415	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS		3.0
MTGN463	POLYMER ENGINEERING		3.0
MTGN570	BIOCOMPATIBILITY OF MATERIALS		3.0
LAIS/EBGN	H&SS Restricted Elective		3.0

FREE	Free Elective	3.0
		18.0

Total Semester Hrs: 138.5

Track MTGN Elective must be selected from the following courses:

MTGN412	CERAMIC ENGINEERING	3.0
MTGN451	CORROSION ENGINEERING	3.0

Five Year Combined Metallurgical and Materials Engineering Baccalaureate and Master of Engineering in Metallurgical and Materials Engineering, with an Electronic-Materials Emphasis.*

The Departments of Metallurgical and Materials Engineering and Physics collaborate to offer a five-year program designed to meet the needs of the electronics and similar high-tech industries. Students who satisfy the requirements of the program obtain an undergraduate degree in either Engineering Physics or in Metallurgical and Materials Engineering in four years and a Master of Engineering degree in Metallurgical and Materials Engineering at the end of the fifth year. The program is designed to provide a strong background in science fundamentals, as well as specialized training in the materials-science and processing needs of these industries. Thus, the educational objective of the program is to provide students with the specific educational requirements to begin a career in microelectronics and, at the same time, a broad and flexible background necessary to remain competitive in this exciting and rapidly changing industry. The undergraduate electives which satisfy the requirements of the program and an overall curriculum need to be discussed with the student's advisor and approved by the Physics or Metallurgical and Materials Engineering Departments. A Program Mentor in each Department can also provide counseling on the program.

Application for admission to this program should be made during the first semester of the sophomore year (in special cases, later entry may be approved, upon review, by one of the program mentors). Undergraduate students admitted to the program must maintain a 3.0 grade-point average or better. The graduate segment of the program requires a case study report, submitted to the student's graduate advisor. Additional details on the Master of Engineering can be found in the Graduate Degree and Requirements section of the Graduate Bulletin. The case study is started during the student's senior design-project and completed during the year of graduate study. A student admitted to the program is expected to select a graduate advisor, in advance of the graduate-studies final year, and prior to the start of their senior year. The case-study topic is then identified and selected in consultation with the graduate advisor. A formal application, during the senior year, for admission to the graduate program in Metallurgical and Materials Engineering must be submitted to the Graduate School. Students who have maintained all the standards of the program requirements leading up to this step, can expect to be admitted.

* Additional "Emphasis" areas are being developed in conjunction with other Departments on Campus.

General CSM Minor/ASI requirements can be found here (p. 33).

Minor in Metallurgical and Materials Engineering

A minor program in metallurgical and materials engineering consists of a minimum of 18 credit hours of a logical sequence of courses. Students

majoring in metallurgical and material engineering are not eligible to earn a minor in the department.

A minor program declaration (available in the Registrar's Office) must be submitted for approval prior to the student's completion of half of the hours proposed to constitute the program. Approvals are required from the department head of metallurgical and materials engineering, the student's advisor, and the department head or division director in the department or division in which the student is enrolled.

Recommended Courses: The following courses are recommended for students seeking to earn a minor in metallurgical and materials engineering:

MTGN202	ENGINEERED MATERIALS	3.0
MTGN311	STRUCTURE OF MATERIALS	3.0
MTGN311L	STRUCTURE OF MATERIALS LABORATORY	1.0
MTGN348	MICROSTRUCTURAL DEVELOPMENT	3.0
MTGN348L	MICROSTRUCTURAL DEVELOPMENT LABORATORY	1.0
MTGN445	MECHANICAL PROPERTIES OF MATERIALS	3.0
MTGN445L	MECHANICAL PROPERTIES OF MATERIALS LABORATORY	1.0
300- or 400- level course in metallurgical and materials engineering		3.0
Total Semester Hrs		18.0

Other sequences are permissible to suit the special interests of individual students. These other sequences need to be discussed and approved by the department head in metallurgical and materials engineering.

Explosive Processing of Materials Minor

Program Advisor: Dr. Stephen Liu

There are very few academic explosive engineering-related programs in the United States of America and around the world. In fact, Colorado School of Mines is the only educational institution that offers an explosive processing of materials minor program in the U.S.A. Built to the tradition of combining academic education with hands-on experience of CSM, this minor program will prepare the students for new and developing applications in materials joining, forming and synthesis that involve the use of explosives.

Under proper development of courses and background in explosives, students enrolled in this program will apply these energetic materials to the processing of traditional and advanced materials. The program focuses on the microstructural and property development in materials as a function of deformation rate. Selection of suitable explosives and proper parameters, selection of specific materials for explosive processing and application, and optimization of post-processing properties are the three major attributes acquired at the completion of this minor program. With the help of the program advisor, the students will design and select the proper course sequence and complete a hands-on research project under the supervision of a faculty advisor.

Professors

Ivar E. Reimanis, Interim Department Head, Herman F. Coors Distinguished Professor of Ceramics

Corby G. Anderson, Harrison Western Professor

Michael J. Kaufman, Dean of CASE

Stephen Liu, Interim American Bureau of Shipping Endowed Chair Professor of Metallurgical and Materials Engineering

Ryan P. O'Hayre

John G. Speer, John Henry Moore Distinguished Professor of Metallurgical and Materials Engineering

Patrick R. Taylor, George S. Ansell Distinguished Professor of Chemical Metallurgy

Chester J. Van Tyne, Associate Department Head, FIERF Professor

Associate Professors

Kip O. Findley

Brian P. Gorman

Jeffrey C. King

Steven W. Thompson

Assistant Professors

Geoff L. Brennecka

Emmanuel De Moor

Corinne E. Packard

Teaching Associate Professors

Gerald Bourne

John P. Chandler

Emeriti Professors

George S. Ansell, President Emeritus

W. Rex Bull

Glen R. Edwards, University Professor Emeritus

John P. Hager, University Professor Emeritus

George Krauss, University Professor Emeritus

Gerard P. Martins

David K. Matlock, University Professor Emeritus

Brajendra Mishra

John J. Moore

David L. Olson, University Professor Emeritus

Dennis W. Readey, University Professor Emeritus

Emeriti Associate Professors

Gerald L. DePoorter

Robert H. Frost

Courses

MTGN198. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN199. INDEPENDENT STUDY. 1-3 Semester Hr.

(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN202. ENGINEERED MATERIALS. 3.0 Semester Hrs.

Equivalent with SYGN202,

(I,II,S) Introduction to the structure, properties, and processing of materials. The historical role that engineered and natural materials have made on the advance of civilization. Engineered materials and their life cycles through processing, use, disposal, and recycle. The impact that engineered materials have on selected systems to show the breadth of properties that are important and how they can be controlled by proper material processing. Recent trends in materials development mimicking natural materials in the context of the structure and functionality of material in living systems. Prerequisites: CHGN122 or CHGN125, MATH112, PHGN100. 3 hours lecture; 3 semester hours.

MTGN272. PARTICULATE MATERIALS PROCESSING. 3.0 Semester Hrs.

(S) Summer session. Characterization and production of particles. Physical and interfacial phenomena associated with particulate processes. Applications to metal and ceramic powder processing. Laboratory projects and plant visits. Prerequisites: CHGN209 and PHGN200. 3 weeks; 3 semester hours.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN299. INDEPENDENT STUDY. 1-3 Semester Hr.

(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN300. FOUNDRY METALLURGY. 2.0 Semester Hrs.

(II) Design and metallurgical aspects of casting, patterns, molding materials and processes, solidification processes, risers and gating concepts, casting defects and inspection, melting practice, cast alloy selection. Prerequisite: PHGN200 or PHGN210. Co-requisite: MTGN300L. 2 hours lecture; 2 semester hours.

MTGN300L. FOUNDRY METALLURGY LABORATORY. 1.0 Semester Hr.

Equivalent with MTGN302,

(II) Experiments in the foundry designed to supplement the lectures of MTGN300. Co-requisite: MTGN300. 3 hours lab; 1 semester hour.

MTGN311. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.

(I) Principles of crystallography and crystal chemistry. Characterization of crystalline materials using X-ray diffraction techniques. Applications to include compound identification, lattice parameter measurement, orientation of single crystals, and crystal structure determination. Prerequisites: PHGN200 or PHGN210 and MTGN202. Co-requisite: MTGN311L. 3 hours lecture, 3 semester hours.

MTGN311L. STRUCTURE OF MATERIALS LABORATORY. 1.0 Semester Hr.

(I) (WI) Experiments in structure of materials to supplement the lectures of MTGN311. Co-requisite: MTGN311. 3 hours lab; 1 semester hour.

MTGN334. CHEMICAL PROCESSING OF MATERIALS. 3.0 Semester Hrs.

(II) Development and application of fundamental principles related to the processing of metals and materials by thermochemical and aqueous and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical processing systems. The general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisites: MTGN272, MTGN351 and (EPIC251 or EPIC252 or EPIC261 or EPIC262 or EPIC263 or EPIC264 or EPIC265 or EPIC266 or EPIC267 or EPIC268 or EPIC269 or EPIC271). Co-requisites: MTGN334L. 3 hours lecture, 3 semester hours.

MTGN334L. CHEMICAL PROCESSING OF MATERIALS LABORATORY. 1.0 Semester Hr.

(II) Experiments in chemical processing of materials to supplement the lectures of MTGN334. Co-requisite: MTGN334. 3 hours lab; 1 semester hour.

MTGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Cooperative education credit does not count toward graduation except under special conditions. Repeatable.

MTGN348. MICROSTRUCTURAL DEVELOPMENT. 3.0 Semester Hrs.

(II) An introduction to the relationships between microstructure and properties of materials, with emphasis on metallic and ceramic systems; Fundamentals of imperfections in crystalline materials on material behavior; recrystallization and grain growth; strengthening mechanisms: grain refinement, solid solution strengthening, precipitation strengthening, and microstructural strengthening; and phase transformations. Prerequisite: MTGN311 and MTGN351. Co-requisite: MTGN348L. 3 hours lecture, 3 semester hours.

MTGN348L. MICROSTRUCTURAL DEVELOPMENT LABORATORY. 1.0 Semester Hr.

(II) (WI) Experiments in microstructural development of materials to supplement the lectures of MTGN348. Co-requisite: MTGN348. 3 hours lab; 1 semester hour.

MTGN351. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.

(I) Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models, calculation of activities from phase diagrams, and measurements of thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of phase diagrams in material systems, defect equilibrium and interactions. Prerequisite: CHGN209. 3 hours lecture, 3 semester hours.

MTGN352. METALLURGICAL AND MATERIALS KINETICS. 3.0 Semester Hrs.

(II) Introduction to reaction kinetics: chemical kinetics, atomic and molecular diffusion, surface thermodynamics and kinetics of interfaces and nucleation-and-growth. Applications to materials processing and performance aspects associated with gas/solid reactions, precipitation and dissolution behavior, oxidation and corrosion, purification of semiconductors, carburizing of steel, formation of p-n junctions and other important materials systems. Prerequisite: MTGN351. 3 hours lecture; 3 semester hours.

MTGN381. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 2.0 Semester Hrs.

(I) Review of the concepts of chemical equilibrium and derivation of the Gibbs phase rule. Application of the Gibbs phase rule to interpreting one, two and three component phase equilibrium diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisite/Co-requisite: MTGN351. 2 hours lecture; 2 semester hours.

MTGN398. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN399. INDEPENDENT STUDY. 1-3 Semester Hr.

(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN403. SENIOR THESIS. 3.0 Semester Hrs.

(I, II) Two semester individual research under the direction of members of the Metallurgical and Materials Engineering faculty. Work may include library and laboratory research on topics of relevance. Oral presentation will be given at the end of the second semester and written thesis submitted to the committee for evaluation. Prerequisites: Senior standing in the Department of Metallurgical and Materials Engineering. 3 hours per semester. Repeatable for credit to a maximum of 6 hours.

MTGN407. STEEL BAR MANUFACTURING. 1.0 Semester Hr.

(I) Facilities and metallurgical principles for manufacturing carbon and low alloy steel bars that are further transformed into high performance parts. Discussion of steel melting, ladle refining, casting, hot rolling, heat treatment, final processing, inspection and testing methods. Implications of process design and control on chemical uniformity, macrostructure, microstructure, internal quality, surface quality, mechanical properties and residual stresses. Review of customer processes and requirements for manufacturing parts from bars by hot or cold forging, machining, surface treating, and heat treating. Applications include crankshafts, gears, axles, drive shafts, springs, bearings, rails, line pipe, oil well casing, etc. Prerequisite: MTGN348. 1 hour lecture; 1.0 semester hour.

MTGN412. CERAMIC ENGINEERING. 3.0 Semester Hrs.

(I) Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN414. PROCESSING OF CERAMICS. 3.0 Semester Hrs.

(II) Principles of ceramic processing and the relationship between processing and microstructure. Raw materials and raw materials preparation, forming and fabrication, thermal processing, and finishing of ceramic materials will be covered. Principles will be illustrated by case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Field trips to local ceramic manufacturing operations. Prerequisite: MTGN311. 3 hours lecture; 3 semester hours.

MTGN415. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.

(II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing and microstructure on the electrical properties. Functions, performance requirements and testing methods of materials for each type of circuit component. General topics covered are conductors, resistors, insulators, capacitors, energy converters, magnetic materials and integrated circuits. Prerequisites: PHGN200, MTGN311 or MLGN501. 3 hours lecture; 3 semester hours.

MTGN419. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.

(II) Introduction to the principles of glass science-and-engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisites: MTGN311 or MLGN501, MLGN512/ MTGN412. 3 hours lecture; 3 semester hours.

MTGN429. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.

(I) Examination of the interface between metallurgical process engineering and environmental engineering. Wastes, effluents and their point sources in metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of metallurgical unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for selected examples. Fundamentals and applications receive equal coverage. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING. 3.0 Semester Hrs.

(I) Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN431. HYDRO- AND ELECTRO-METALLURGY. 3.0 Semester Hrs.

(I) Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Prerequisites: MTGN334, MTGN351 and MTGN352. Co-requisite: MTGN461. 3 hours lecture; 3 semester hours.

MTGN432. PYROMETALLURGY. 3.0 Semester Hrs.

(II) Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN442. ENGINEERING ALLOYS. 3.0 Semester Hrs.

(II) This course is intended to be an important component of the physical metallurgy sequence, to reinforce and integrate principles from earlier courses, and enhance the breadth and depth of understanding of concepts in a wide variety of alloy systems. Metallic systems considered include iron and steels, copper, aluminum, titanium, superalloys, etc. Phase stability, microstructural evolution and structure/property relationships are emphasized. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN445. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.

(I) Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Prerequisite: MTGN348. Co-requisite: MTGN445L. 3 hours lecture, 3 semester hours.

MTGN445L. MECHANICAL PROPERTIES OF MATERIALS LABORATORY. 1.0 Semester Hr.

(I) (WI) Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures of MTGN445. Co-requisite: MTGN445. 3 hours lab; 1 semester hour.

MTGN450. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.

(I) Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments. Prerequisite: none. 3 hours lecture, 3 semester hours.

MTGN451. CORROSION ENGINEERING. 3.0 Semester Hrs.

(II) Principles of electrochemistry. Corrosion mechanisms. Methods of corrosion control including cathodic and anodic protection and coatings. Examples, from various industries, of corrosion problems and solutions. Prerequisite: CHGN209. 3 hours lecture; 3 semester hours.

MTGN456. ELECTRON MICROSCOPY. 2.0 Semester Hrs.

(II) Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. Prerequisite: MTGN311. Co-requisite: MTGN456L. 2 hours lecture; 2 semester hours.

MTGN456L. ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.

Equivalent with MTGN458,

(II) Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. Co-requisite: MTGN456. 3 hours lab; 1 semester hour.

MTGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS. 2.0 Semester Hrs.

(I) Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: continuous- flow/batch reactors with uniform dispersion and plug flow reactors. Digital computer methods for the design of metallurgical systems. Prerequisites: MATH225, MTGN334 and MTGN352. Co-requisite: MTGN461L. 2 hours lecture, 2 semester hours.

MTGN461L. TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY. 1.0 Semester Hr.

(II) Experiments in transport phenomena and reactor design to supplement the lectures of MTGN461. Co-requisite: MTGN461. 3 hours lab; 1 semester hour.

MTGN462. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.

(I) This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: CEEN301, CEEN302, and CHGN403. 3 hours lecture; 3 semester hours.

MTGN463. POLYMER ENGINEERING. 3.0 Semester Hrs.

(II) Introduction to the structure and properties of polymeric materials, their deformation and failure mechanisms, and the design and fabrication of polymeric end items. Molecular and crystallographic structures of polymers will be developed and related to the elastic, viscoelastic, yield and fracture properties of polymeric solids and reinforced polymer composites. Emphasis on forming and joining techniques for end-item fabrication including: extrusion, injection molding, reaction injection molding, thermoforming, and blow molding. The design of end-items in relation to: materials selection, manufacturing engineering, properties, and applications. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN464. FORGING AND FORMING. 2.0 Semester Hrs.

(II) Introduction to plasticity. Survey and analysis of working operations of forging, extrusion, rolling, wire drawing and sheet-metal forming. Metallurgical structure evolution during working. Prerequisites: CEEN311 and MTGN348 or EGGN350. Co-requisite: MTGN-464L. 2 hours lecture; 2 semester hours.

MTGN464L. FORGING AND FORMING LABORATORY. 1.0 Semester Hr.

(II) Experiments in forging and forming to supplement the lectures of MTGN464. Co-requisite: MTGN464. 3 hours lab; 1 semester hour.

MTGN465. MECHANICAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.

(II) Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisites: MTGN445, MTGN412. 3 hours lecture; 3 semester hours.

MTGN466. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 3.0 Semester Hrs.

(II) (WI) Application of fundamental materials-engineering principles to the design of systems for extraction and synthesis, and to the selection of materials. Systems covered range from those used for metallurgical processing to those used for processing of emergent materials. Microstructural design, characterization and properties evaluation provide the basis for linking synthesis to applications. Selection criteria tied to specific requirements such as corrosion resistance, wear and abrasion resistance, high temperature service, cryogenic service, vacuum systems, automotive systems, electronic and optical systems, high strength/weight ratios, recycling, economics and safety issues. Materials investigated include mature and emergent metallic, ceramic and composite systems used in the manufacturing and fabrication industries. Student-team design activities including oral- and written? reports. Prerequisite: MTGN351, MTGN352, MTGN445 and MTGN461. 1 hour lecture, 6 hours lab; 3 semester hours.

MTGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN469, EGGN469,

(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: MEGN361 or CBEN357 or MTGN351. 3 hours lecture; 3 semester hours.

MTGN472. BIOMATERIALS I. 3.0 Semester Hrs.

(I) This course covers a broad overview on materials science and engineering principles for biomedical applications, and is organized around three main topics: 1) The fundamental properties of biomaterials; 2) The fundamental concepts in biology; 3) The interactions between biological systems with exogenous materials. Particular emphasis will be put on understanding surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; Biomaterials implantation and acute inflammation; blood-materials interactions and thrombosis; biofilm and biomaterials-related pathological reactions. In addition to the reign of biomedical materials, this course also introduces the basic principles of bio-mimetic materials synthesis and assembly. Prerequisites: MTGN202 3 hours lecture; 3 semester hours.

MTGN475. METALLURGY OF WELDING. 2.0 Semester Hrs.

(I) Introduction to welding processes; thermal aspects; selection of filler metals; stresses; stress relief and annealing; pre- and postweld heat treating; weld defects; welding ferrous and nonferrous alloys; weld metal phase transformations; metallurgical evaluation of resulting weld microstructures and properties; and welding tests. Prerequisite: MTGN348. Co-requisite: MTGN475L. 2 hours lecture; 2 semester hours.

MTGN475L. METALLURGY OF WELDING LABORATORY. 1.0 Semester Hr.

Equivalent with MTGN477,

(I) Experiments designed to supplement the lectures in MTGN475. Co-requisite: MTGN475. 3 hours lab; 1 semester hour.

MTGN497. SUMMER PROGRAMS. 6.0 Semester Hrs.**MTGN498. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN498LB. SPECIAL TOPICS LAB. 1-3 Semester Hr.**MTGN498LC. SPECIAL TOPICS LAB. 1-3 Semester Hr.****MTGN499. INDEPENDENT STUDY. 1-3 Semester Hr.**

(I, II, S) Independent advanced-work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Selection of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit to a maximum of 6 hours.

Physics

2015-2016

Program Description - Engineering Physics

Physics is the most basic of all sciences and the foundation of most of the science and engineering disciplines. As such, it has always attracted those who want to understand nature at its most fundamental level. Engineering Physics is not a specialized branch of physics, but an interdisciplinary area wherein the basic physics subject matter, which forms the backbone of any undergraduate physics degree, is taken further toward application to engineering. The degree is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). At CSM, the required engineering physics curriculum includes all of the undergraduate physics courses that

would form the physics curriculum at any good university, but in addition to these basic courses, the CSM requirements include pre-engineering and engineering courses, which physics majors at other universities would not ordinarily take. These courses include engineering science, design, systems, summer field session, and a capstone senior design sequence culminating in a senior thesis.

This unique blend of physics and engineering makes it possible for the engineering physics graduate to work at the interface between science and technology, where new discoveries are continually being put to practice. While the engineering physicist is at home applying existing technologies, he or she is also capable of striking out in different directions to develop new technologies. It is the excitement of being able to work at this cutting edge that makes the engineering physics degree attractive to many students.

Career paths of CSM engineering physics graduates vary widely, illustrating the flexibility inherent in the program. More than half of the graduating seniors go on to graduate school in physics or a closely related field of engineering. Some go to medical, law, or other professional post-graduate schools. Others find employment in fields as diverse as electronics, semiconductor processing, aerospace, materials development, biomedical applications, nuclear energy, solar energy, and geophysical exploration.

The Physics Department maintains modern well-equipped laboratories for general physics, modern physics, electronics, and advanced experimentation. There are research laboratories for the study of condensed matter physics, surface physics, materials science, optics, and nuclear physics, including an NSF-funded laboratory for solar and electronic materials processing. The Department also maintains electronic and machine shops.

Program Educational Objectives (Bachelor of Science in Engineering Physics)

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Physics Department is dedicated to additional educational objectives.

The program prepares graduates who, based on factual knowledge and other skills necessary to construct an appropriate understanding of physical phenomena in applied contexts, will:

1. Obtain a range of positions in industry or positions in government facilities or pursue graduate education in engineering, science or related fields;
2. Communicate and perform effectively within the criteria of their chosen careers;
3. Engage in appropriate professional societies and continuing education activities;
4. Participate ethically as members of the global society.

Degree Requirements (Engineering Physics)

Freshman

	lec	lab	sem.hrs
CORE Common Core			33.0
			33.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS			4.5
EPIC251	DESIGN (EPICS) II			3.0
LAIS200	HUMAN SYSTEMS			3.0
PAGN2XX	PHYSICAL EDUCATION			0.5

15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH332	LINEAR ALGEBRA			3.0
CBEN210	INTRO TO THERMODYNAMICS			3.0
PHGN300	PHYSICS III-MODERN PHYSICS I			3.0
PHGN215	ANALOG ELECTRONICS			4.0
PAGN2XX	PHYSICAL EDUCATION			0.5

16.5

Summer		lec	lab	sem.hrs
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS			6.0

6.0

Junior

Fall		lec	lab	sem.hrs
PHGN315	ADVANCED PHYSICS LAB I			2.0
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS			3.0
LAIS/EBGN	H&SS GenEd Restricted Elective I			3.0
PHGN317	SEMICONDUCTOR CIRCUITS-DIGITAL			3.0
PHGN350	INTERMEDIATE MECHANICS			4.0

15.0

Spring		lec	lab	sem.hrs
PHGN361	INTERMEDIATE ELECTROMAGNETISM			3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS			4.0
PHGN326	ADVANCED PHYSICS LAB II			2.0
PHGN341	THERMAL PHYSICS			3.0
EBGN201	PRINCIPLES OF ECONOMICS			3.0

15.0

Senior

Fall		lec	lab	sem.hrs
PHGN471	SENIOR DESIGN PRINCIPLES I			0.5
PHGN481	SENIOR DESIGN PRACTICE			2.5
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS			3.0
LAIS/EBGN	H&SS GenEd Restricted Elective II			3.0
FREE	Free Elective I			3.0
FREE	Free Elective II			3.0

15.0

Spring		lec	lab	sem.hrs
PHGN472	SENIOR DESIGN PRINCIPLES II			0.5
PHGN482	SENIOR DESIGN PRACTICE			2.5
LAIS/EBGN	H&SS GenEd Restricted Elective III			3.0
ENG SCI	Engineering Science Elective			3.0
FREE	Free Elective III			3.0
FREE	Free Elective IV			3.0
				15.0

Total Semester Hrs: 130.5

Combined Baccalaureate/Masters and Baccalaureate/Doctoral Degree Programs

The Physics Department, independently, and in collaboration with the Department of Applied Mathematics and Statistics, the Department of Mechanical Engineering, the Department of Electrical Engineering and Computer Science, the Materials Science Program, and the Nuclear Science and Engineering Program offers combined BS/MS degree programs in which students obtain an undergraduate degree in Engineering Physics, in as few as four years, as well as a masters degree in Applied Physics, in an Engineering discipline, in Materials Science, or in Mathematics, after an additional year of study. There are three engineering tracks, three physics tracks, a materials science track, and a mathematics track. These programs emphasize a strong background in fundamentals of science, in addition to practical experience within an applied science, engineering, or mathematics discipline. Many of the undergraduate electives of students involved in each track are specified. For this reason, students are expected to apply to the program during the first semester of their sophomore year (in special cases late entry can be approved by the program mentors). A 3.0 grade point average must be maintained to guarantee admission into the physics, engineering, and materials science graduate programs. A 3.3 grade point average must be maintained to guarantee admission into the mathematics graduate program.

Students in the engineering tracks must complete a report or case study during the last year. Students in the physics, materials science, and mathematics tracks must complete a master's thesis. Students in the nuclear engineering program can choose between thesis and non-thesis options. The case study or thesis should begin during the senior year as part of the Senior Design experience. Participants must identify an engineering or physics advisor as appropriate prior to their senior year who will assist in choosing an appropriate project and help coordinate the senior design project with the case study or thesis completed in the last year.

It is also possible for undergraduate students to begin work on a doctoral degree in Applied Physics while completing the requirements for their bachelor's degree. Students in this combined baccalaureate/doctoral program may fulfill part of the requirements of their doctoral degree by including up to six hours of specified course credits that are also used to fulfill the requirements of their undergraduate degree. These courses may only be applied toward fulfilling doctoral degree requirements. Courses must meet all requirements for graduate credit, but their grades are not included in calculating the graduate GPA.

Interested students can obtain additional information and detailed curricula from the Physics Department or from the participating engineering departments.

General CSM Minor/ASI requirements can be found here (p. 33).

Minor and Area of Special Interest

The department offers a Minor and Area of Special Interest for students not majoring in physics. The requirements are as follows:

Area of Special Interest (12 semester hours minimum)

PHGN100	PHYSICS I - MECHANICS	3.0
or PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	

Minor (18 semester hours minimum)

PHGN100	PHYSICS I - MECHANICS	3.0
or PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	
PHGN300/310	PHYSICS III-MODERN PHYSICS I	3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0

Select one of the following: 3-4

PHGN341	THERMAL PHYSICS	
PHGN350	INTERMEDIATE MECHANICS	
PHGN361	INTERMEDIATE ELECTROMAGNETISM	

Selected courses to complete the Minor: Upper division (400-level) and/or graduate (500-level) courses which form a logical sequence in a specific field of study as determined in consultation with the Physics Department and the student's option department.

Biophysics Minor

To obtain a Biophysics Minor, students must take at least 18.0 credits related to Biophysics. Two courses (8.0 credits) of Biology are required. Two additional requirements include Intro to Biophysics (PHGN333) and Laser Physics (PHGN480). Two more courses (or at least 4.0 credits) may be chosen from the list below. The list of electives will be modified as new related courses that fall into these categories become available. While the current emphasis of the Biophysics Minor is on optical techniques, we intend to add alternative tracks, for example radiologic (nuclear) techniques.

Required Courses (14.0 Credits)

BIOL110	BIOLOGY I	4.0
CBEN303	GENERAL BIOLOGY II	3.0
CBEN323	GENERAL BIOLOGY II LABORATORY	1.0
PHGN333	INTRODUCTION TO BIOPHYSICS	3.0
PHGN480	LASER PHYSICS	3.0

Two Elective courses (at least 4.0 credits) from the list below:

PHGN466	MODERN OPTICAL ENGINEERING	3.0
or PHGN566	MODERN OPTICAL ENGINEERING	
PHGN570	FOURIER AND PHYSICAL OPTICS	3.0
CBEN310	INTRODUCTION TO BIOMEDICAL ENGINEERING	3.0
CBEN311	INTRODUCTION TO NEUROSCIENCE	3.0
CBEN431	IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS	3.0
or CBEN531	IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS	
CBEN454	APPLIED BIOINFORMATICS	3.0
or CBEN554	APPLIED BIOINFORMATICS	

MATH331	MATHEMATICAL BIOLOGY	3.0
NUGN535	INTRODUCTION TO HEALTH PHYSICS	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
CHGN428	BIOCHEMISTRY	3.0
MEGN430	MUSCULOSKELETAL BIOMECHANICS	3.0
or MEGN530	BIOMEDICAL INSTRUMENTATION	
CBEN470	INTRODUCTION TO MICROFLUIDICS	3.0
MEGN530	BIOMEDICAL INSTRUMENTATION	3.0
MEGN436	COMPUTATIONAL BIOMECHANICS	3.0
or MEGN536	COMPUTATIONAL BIOMECHANICS	

Professors

Lincoln D. Carr

Reuben T. Collins

Charles G. Durfee III

Uwe Greife

Frank V. Kowalski

Mark T. Lusk

Frederic Sarazin

John A. Scales

Jeff A. Squier, Department Head

P. Craig Taylor

Associate Professors

Timothy R. Ohno

Lawrence R. Wiencke

David M. Wood

Assistant Professors

Kyle G. Leach

Susanta K. Sarkar

Eric S. Toberer

Zhigang Wu

Jeremy D. Zimmerman

Teaching Professors

Alex T. Flournoy

Patrick B. Kohl

H. Vincent Kuo

Todd G. Ruskell

Charles A. Stone

Matt Young

Teaching Associate Professor

Kristine E. Callan

Research Professors

Mark W. Coffey

Jonathan L. Mace

Zeev Shayer

Research Associate Professors

Joseph D. Beach

James E. Bernard

Research Assistant Professor

P. David Flammer

Professors Emeriti

F. Edward Cecil

Thomas E. Furtak

James A. McNeil

Don L. Williamson

Associate Professors Emeriti

William B. Law

Arthur Y. Sakakura

Courses

PHGN100. PHYSICS I - MECHANICS. 4.5 Semester Hrs.

(I, II, S) A first course in physics covering the basic principles of mechanics using vectors and calculus. The course consists of a fundamental treatment of the concepts and applications of kinematics and dynamics of particles and systems of particles, including Newton's laws, energy and momentum, rotation, oscillations, and waves. Prerequisite: MATH111 and concurrent enrollment in MATH112 or MATH113 or MATH122. 2 hours lecture; 4 hours studio; 4.5 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

PHGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN200. PHYSICS II-ELECTROMAGNETISM AND OPTICS. 4.5 Semester Hrs.

(I, II, S) Continuation of PHGN100. Introduction to the fundamental laws and concepts of electricity and magnetism, electromagnetic devices, electromagnetic behavior of materials, applications to simple circuits, electromagnetic radiation, and an introduction to optical phenomena. Prerequisite: Grade of C- or higher in PHGN100, concurrent enrollment in MATH213 or MATH214 or MATH223. 2 hours lecture; 4 hours studio; 4.5 semester hours.

PHGN215. ANALOG ELECTRONICS. 4.0 Semester Hrs.

(II) Introduction to analog devices used in modern electronics and basic topics in electrical engineering. Introduction to methods of electronics measurements, particularly the application of oscilloscopes and computer based data acquisition. Topics covered include circuit analysis, electrical power, diodes, transistors (FET and BJT), operational amplifiers, filters, transducers, and integrated circuits. Laboratory experiments in the use of basic electronics for physical measurements. Emphasis is on practical knowledge gained in the laboratory, including prototyping, troubleshooting, and laboratory notebook style. Prerequisite: PHGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

PHGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN300. PHYSICS III-MODERN PHYSICS I. 3.0 Semester Hrs.

Equivalent with PHGN310,

(I) Our technical world is filled with countless examples of modern physics. This course will discuss some historic experiments that led to the key discoveries, and the basic concepts, theories, and models behind some of our present day technologies. Topics may include special relativity, quantum physics, atomic and molecular physics, solid-state physics, semiconductor theory and devices, nuclear physics, particle physics and cosmology. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

PHGN310. HONORS PHYSICS III-MODERN PHYSICS. 3.0 Semester Hrs.

Equivalent with PHGN300,

(II) The third course in introductory physics with in depth discussion on special relativity, wave-particle duality, the Schroedinger equation, electrons in solids, quantum tunneling, nuclear structure and transmutations. Registration is strongly recommended for declared physics majors and those considering majoring or minoring in physics. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS. 3.0 Semester Hrs.

Demonstration of the unity of diverse topics such as mechanics, quantum mechanics, optics, and electricity and magnetism via the techniques of linear algebra, complex variables, Fourier transforms, and vector calculus. Prerequisite: PHGN300/310, MATH225, and MATH332. 3 hours lecture; 3 semester hours.

PHGN315. ADVANCED PHYSICS LAB I. 2.0 Semester Hrs.

(I) (WI) Introduction to laboratory measurement techniques as applied to modern physics experiments. Experiments from optics and atomic physics. A writing-intensive course with laboratory and computer design projects based on applications of modern physics. Prerequisite: PHGN300/310, PHGN384. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL. 3.0 Semester Hrs.

(I) Introduction to digital devices used in modern electronics. Topics covered include logic gates, flip-flops, timers, counters, multiplexing, analog-to-digital and digital-to-analog devices. Emphasis is on practical circuit design and assembly. Prerequisite: PHGN215. 2 hours lecture, 3 hours lab; 3 semester hours.

PHGN320. MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS. 4.0 Semester Hrs.

(II) Introduction to the Schroedinger theory of quantum mechanics. Topics include Schroedinger's equation, quantum theory of measurement, the uncertainty principle, eigenfunctions and energy spectra, angular momentum, perturbation theory, and the treatment of identical particles. Example applications taken from atomic, molecular, solid state or nuclear systems. Prerequisites: PHGN300/310 and PHGN311. 4 hours lecture; 4 semester hours.

PHGN324. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS. 3.0 Semester Hrs.

(II) Celestial mechanics; Kepler's laws and gravitation; solar system and its contents; electromagnetic radiation and matter; stars: distances, magnitudes, spectral classification, structure, and evolution. Variable and unusual stars, pulsars and neutron stars, supernovae, black holes, and models of the origin and evolution of the universe. Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

PHGN326. ADVANCED PHYSICS LAB II. 2.0 Semester Hrs.

(II) (WI) Continuation of PHGN315. A writing-intensive course which expands laboratory experiments to include nuclear and solid state physics. Prerequisite: PHGN315. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN333. INTRODUCTION TO BIOPHYSICS. 3.0 Semester Hrs.

Equivalent with BELS333,

(II) This course is designed to show the application of physics to biology. It will assess the relationships between structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: PHGN 200 and BIOL110. 3 hours lecture, 3 semester hours.

PHGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Repeatable up to 3 credit hours.

PHGN341. THERMAL PHYSICS. 3.0 Semester Hrs.

(II) An introduction to statistical physics from the quantum mechanical point of view. The microcanonical and canonical ensembles. Heat, work and the laws of thermodynamics. Thermodynamic potentials; Maxwell relations; phase transformations. Elementary kinetic theory. An introduction to quantum statistics. Prerequisite: CHGN209 or CBEN210 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN350. INTERMEDIATE MECHANICS. 4.0 Semester Hrs.

(I) Begins with an intermediate treatment of Newtonian mechanics and continues through an introduction to Hamilton's principle and Hamiltonian and Lagrangian dynamics. Includes systems of particles, linear and driven oscillators, motion under a central force, two-particle collisions and scattering, motion in non-inertial reference frames and dynamics of rigid bodies. Prerequisite: PHGN200. Corequisite: PHGN311. 4 hours lecture; 4 semester hours.

PHGN361. INTERMEDIATE ELECTROMAGNETISM. 3.0 Semester Hrs.

(II) Theory and application of the following: static electric and magnetic fields in free space, dielectric materials, and magnetic materials; steady currents; scalar and vector potentials; Gauss's law and Laplace's equation applied to boundary value problems; Ampere's and Faraday's laws. Prerequisite: PHGN200 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN384. FIELD SESSION TECHNIQUES IN PHYSICS. 1-6 Semester Hr.

(S1) Introduction to the design and fabrication of engineering physics apparatus. Intensive individual participation in the design of machined system components, vacuum systems, electronics, optics, and application of computer interfacing systems and computational tools. Supplementary lectures on safety, laboratory techniques and professional development. Visits to regional research facilities and industrial plants. Prerequisite: PHGN300/310, PHGN215. (6 credit hours).

PHGN398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN401. THEORETICAL PHYSICS SEMINAR. 1.0 Semester Hr.

(I,II) Students will attend the weekly theoretical physics seminar. Students will be responsible for presentation and discussion. Corequisite: PHGN300/PHGN310. 1 hour lecture; 1 semester hour.

PHGN418. GENERAL RELATIVITY. 3.0 Semester Hrs.

(II) Introduction to Einstein's theory of gravitation. Requisite mathematics introduced and developed including tensor calculus and differential geometry. Formulation of Einstein field and geodesic equations. Development and analysis of solutions including stellar, black hole and cosmological geometries. Prerequisite: PHGN350. 3 hours lecture; 3 semester hours.

PHGN419. PRINCIPLES OF SOLAR ENERGY SYSTEMS. 3.0 Semester Hrs.

Review of the solar resource and components of solar irradiance; principles of photovoltaic devices and photovoltaic system design; photovoltaic electrical energy production and cost analysis of photovoltaic systems relative to fossil fuel alternatives; introduction to concentrated photovoltaic systems and manufacturing methods for wafer-based and thin film photovoltaic panels. Prerequisite: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

PHGN422. NUCLEAR PHYSICS. 3.0 Semester Hrs.

Introduction to subatomic (particle and nuclear) phenomena. Characterization and systematics of particle and nuclear states; symmetries; introduction and systematics of the electromagnetic, weak, and strong interactions; systematics of radioactivity; liquid drop and shell models; nuclear technology. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN423. PARTICLE PHYSICS. 3.0 Semester Hrs.

(II) Introduction to the Standard Model of particle physics including: experimental methods, motivation and evaluation of amplitudes from Feynman diagrams with applications to scattering cross-sections and decay rates, organization of interactions based on underlying gauge-symmetry principles, Dirac equation and relativistic spinors, C, P and T symmetries, renormalization, spontaneous symmetry breaking and the Higgs mechanism for mass generation. Prerequisites: PHGN350. Co-requisites: PHGN320. 3 hour lecture.

PHGN424. ASTROPHYSICS. 3.0 Semester Hrs.

(II) A survey of fundamental aspects of astrophysical phenomena, concentrating on measurements of basic stellar properties such as distance, luminosity, spectral classification, mass, and radii. Simple models of stellar structure evolution and the associated nuclear processes as sources of energy and nucleosynthesis. Introduction to cosmology and physics of standard big-bang models. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN435. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.

Equivalent with CBEN435, CBEN535, CHEN435, CHEN535, MLGN535, PHGN535, Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CHGN, MTGN, or EGGN. 1.5 hours lecture, 4 hours lab; 3 semester hours.

PHGN440. SOLID STATE PHYSICS. 3.0 Semester Hrs.

An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. (Graduate students in physics may register only for PHGN440.) Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

PHGN441. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA. 3.0 Semester Hrs.

Continuation of PHGN440/ MLGN502 with an emphasis on applications of the principles of solid state physics to practical properties of materials including: optical properties, superconductivity, dielectric properties, magnetism, noncrystalline structure, and interfaces. (Graduate students in physics may register only for PHGN441.) Prerequisite: PHGN440 or MLGN502. 3 hours lecture; 3 semester hours.

PHGN450. COMPUTATIONAL PHYSICS. 3.0 Semester Hrs.

Introduction to numerical methods for analyzing advanced physics problems. Topics covered include finite element methods, analysis of scaling, efficiency, errors, and stability, as well as a survey of numerical algorithms and packages for analyzing algebraic, differential, and matrix systems. The numerical methods are introduced and developed in the analysis of advanced physics problems taken from classical physics, astrophysics, electromagnetism, solid state, and nuclear physics. Prerequisites: Introductory-level knowledge of C, Fortran, or Basic; and PHGN311. 3 hours lecture; 3 semester hours.

PHGN462. ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS. 3.0 Semester Hrs.

(I) Solutions to the electromagnetic wave equation are studied, including plane waves, guided waves, refraction, interference, diffraction and polarization; applications in optics; imaging, lasers, resonators and wave guides. Prerequisite: PHGN361. 3 hours lecture; 3 semester hours.

PHGN466. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.

Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors and optical system examples. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN471. SENIOR DESIGN PRINCIPLES I. 0.5 Semester Hrs.

(I) (WI) The first of a two semester sequence covering the principles of project design. Class sessions cover effective team organization, project planning, time management, literature research methods, record keeping, fundamentals of technical writing, professional ethics, project funding and intellectual property. Prerequisites: PHGN384 and PHGN326. Co-requisites: PHGN481 or PHGN491. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN472. SENIOR DESIGN PRINCIPLES II. 0.5 Semester Hrs.

(II) (WI) Continuation of PHGN471. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN482 or PHGN492. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN480. LASER PHYSICS. 3.0 Semester Hrs.

(I) Theory and application of the following: Gaussian beams, optical cavities and wave guides, atomic radiation, detection of radiation, laser oscillation, nonlinear optics and ultrafast pulses. Prerequisite: PHGN320. Co-requisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN481. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.

(I) (WI) The first of a two semester program covering the full spectrum of project design, drawing on all of the student's previous course work. At the beginning of the first semester, the student selects a research project in consultation with the Senior Design Oversight Committee (SDOC) and the Project Mentor. The objectives of the project are given to the student in broad outline form. The student then designs the entire project, including any or all of the following elements as appropriate: literature search, specialized apparatus or algorithms, block-diagram electronics, computer data acquisition and/or analysis, sample materials, and measurement and/or analysis sequences. The course culminates in a formal interim written report. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN471. 6 hour lab; 2.5 semester hours.

PHGN482. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.

(II) (WI) Continuation of PHGN481. The course culminates in a formal written report and poster. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN472. 6 hour lab; 2.5 semester hours.

PHGN491. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.

(I) (WI) Individual work on an advanced research topic that involves more challenging demands than a regular senior design project. Honors students will devote more time to their project, and will produce an intermediate report in a more advanced format. Prerequisite: PHGN384 and PHGN326. Corequisite: PHGN471. 7.5 hour lab; 2.5 semester hours.

PHGN492. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.

(II) (WI) Continuation of PHGN481 or PHGN491. The course culminates in a formal written report and poster. The report may be in the form of a manuscript suitable for submission to a professional journal. Prerequisite: PHGN481 or PHGN491. Corequisite: PHGN472. 7.5 hour lab; 2.5 semester hours.

PHGN497. SUMMER PROGRAMS. 6.0 Semester Hrs.**PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Additional Programs

Please select from the list of links on the right to locate more information.

Aerospace Studies

Air Force ROTC (AFROTC)

The Department of Aerospace Studies offers programs leading to an officer's commission in the Air Force in conjunction with an undergraduate or graduate degree.

Aerospace science courses are designed to supplement a regular degree program by offering practical leadership and management experience. The Aerospace Studies Program at the Colorado School of Mines (CSM) is offered in conjunction with the University of Colorado at Boulder (CUB).

Four-Year Program

The four-year program consists of two phases: the general military course (freshman and sophomore years) and the professional officer course (junior and senior years). This program is designed for incoming freshmen or any student with four years remaining until degree completion. It consists of three parts: the General Military Course (GMC) for lower division (normally freshmen and sophomore) students; the Professional Officer Course (POC) for upper division students (normally juniors and seniors); and Leadership Laboratory (LLAB-attended by all cadets). Completion of a four-week summer training course is required prior to commissioning.

Leadership Lab

All AFROTC cadets must attend Leadership Lab (2 hours per week). The laboratory involves a study of Air Force customs and courtesies, drill and ceremonies, career opportunities, and the life and work of an Air Force officer.

General Military Course (GMC)

The basic course covers Air Force history and organization as well as military leadership and management. Laboratory sessions provide the opportunity to apply leadership skills while learning basic military skills. Enrollment in the basic course incurs no military obligation except for Air Force scholarship recipients.

Professional Officer Course (POC)

The advanced course covers military officership, leadership and unit operations, training techniques, military law, and professional ethics, and includes a leadership practicum each semester. A Field Training encampment provides challenging leadership training and is a prerequisite for commissioning. Advanced course students must have completed the basic course and obtain permission from the Professor of Aerospace Studies (PAS) to enroll in the POC.

Three-Year Program

The three-year program consists of the first two years of GMC courses taken concurrently in one year. The student then attends a Field Training encampment, and completes two years of advanced POC courses.

Scholarship Programs

Two-year, Three-year and Four-year college scholarships are available to eligible high school seniors, who apply before December 1 of their senior year. Scholarship students receive tuition assistance and mandatory laboratory fees, a book allowance, and a monthly stipend. Students interested in the scholarship program should contact the AFROTC Unit Admissions Officer no later than the beginning of the spring semester to apply for the following academic year. A complete listing of all available AFROTC scholarships is available at www.afrotc.com (<http://www.afrotc.com>).

Registration and Credits

Air Force ROTC serves as free-elective credit in most departments. Elective course credit toward your degree for AFROTC classes will be determined by your individual academic advisor. Students who wish to register for Air Force ROTC classes do so through the normal course registration process at CSM. AFROTC classes begin with the AFGN prefix. For more information about AFROTC, contact the Air Force ROTC Unit Admissions Officer at afrotc.colorado.edu (<http://www.colorado.edu/afrotc>), or the department on campus directly at 303-273-3380. The department is located in the Military Science building on West Campus Road. For information about CSM, call 303-273-3380.

Other AFROTC Programs

Other programs are frequently available based on current Air Force needs. Contact a Det 105 representative at afrotc.colorado.edu (<http://afrotc.colorado.edu>).

General CSM Minor/ASI requirements can be found here (p. 33).

Aerospace Studies Minor

Air Force ROTC cadets desiring to receive a minor in Aerospace Studies must complete at least 20 hours of Aerospace Studies courses as follows:

AFGN101	FOUNDATIONS OF THE UNITED STATES AIR FORCE	1.5
AFGN102	FOUNDATIONS OF THE UNITED STATES AIR FORCE	1.5
AFGN201	THE EVOLUTION OF USAF AIR AND SPACE POWER	1.5
AFGN202	THE EVOLUTION OF USAF AIR AND SPACE POWER	1.5
AFGN301	AIR FORCE LEADERHIP STUDIES	3.5
AFGN302	AIR FORCE LEADERHIP STUDIES	3.5

AFGN401	NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY	3.5
AFGN402	NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY	3.5
Total Semester Hrs		20.0

Courses

AFGN101. FOUNDATIONS OF THE UNITED STATES AIR FORCE. 1.5 Hour.

Two semesters, 1.5 hours per semester. This survey course briefly covers topics relating to the Air Force and defense. It focuses on the structure and missions of Air Force organizations, officership and professionalism. It is also a good introduction into the use of communication skills. Weekly Leadership Lab for this course (to be taken in conjunction with AS 101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN102. FOUNDATIONS OF THE UNITED STATES AIR FORCE. 1.5 Hour.

Two semesters, 1.5 hours per semester. This survey course briefly covers topics relating to the Air Force and defense. It focuses on the structure and missions of Air Force organizations, officership and professionalism. It is also a good introduction into the use of communication skills. Weekly Leadership Lab for this course (to be taken in conjunction with AS 101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN201. THE EVOLUTION OF USAF AIR AND SPACE POWER. 1.5 Hour.

Two semesters, 1.5 hours per semester. This survey course is concerned with the beginnings of manned flight and the development of aerospace power in the United States, including the employment of air power in WWI, WWII, Korea, Vietnam, the Gulf War and the peaceful employment of U.S. air power in civic actions, scientific missions and support of space exploration. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN202. THE EVOLUTION OF USAF AIR AND SPACE POWER. 1.5 Hour.

Two semesters, 1.5 hours per semester. This survey course is concerned with the beginnings of manned flight and the development of aerospace power in the United States, including the employment of air power in WWI, WWII, Korea, Vietnam, the Gulf War and the peaceful employment of U.S. air power in civic actions, scientific missions and support of space exploration. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN301. AIR FORCE LEADERSHIP STUDIES. 3.5 Hours.

Two semesters, 3.5 hours per semester. This course is a study in the anatomy of leadership, the need for quality and management leadership, the role of discipline in leadership situations and the variables affecting leadership. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts. Deal with actual problems and complete projects associated with planning and managing the Leadership Laboratory. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN302. AIR FORCE LEADERSHIP STUDIES. 3.5 Hours.

Two semesters, 3.5 hours per semester. This course is a study in the anatomy of leadership, the need for quality and management leadership, the role of discipline in leadership situations and the variables affecting leadership. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts. Deal with actual problems and complete projects associated with planning and managing the Leadership Laboratory. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN401. NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY. 3.5 Hours.

Two semesters, 3.5 hours per semester. Learn about the role of the professional military leader in a democratic society; societal attitudes toward the armed forces; the requisites for maintaining adequate national defense structure; the impact of technological and international developments on strategic preparedness and the overall policy-making process; and military law. In addition, you will study topics that will prepare you for your first active-duty assignment as an officer in the Air Force. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

AFGN402. NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY. 3.5 Hours.

Two semesters, 3.5 hours per semester. Learn about the role of the professional military leader in a democratic society; societal attitudes toward the armed forces; the requisites for maintaining adequate national defense structure; the impact of technological and international developments on strategic preparedness and the overall policy-making process; and military law. In addition, you will study topics that will prepare you for your first active-duty assignment as an officer in the Air Force. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

Military Science

Army ROTC-AROTC

The Department of Military Science offers programs leading to an officer's commission in the active Army, Army Reserve, or National Guard in conjunction with an undergraduate or graduate degree. Military science courses are designed to supplement a regular degree program by offering practical leadership and management experience. The Military Science Program at the Colorado School of Mines (CSM) is offered in

conjunction with the University of Colorado at Boulder (CU-B). Students attend classes at the Colorado School of Mines in Golden.

Four-Year Program

The four-year program consists of two phases: the basic course (freshman and sophomore years) and the advanced course (junior and senior years).

Basic course

The basic course offers a 2- or 3-credit course each semester, covering Army history and organization as well as military leadership and management. Laboratory sessions provide the opportunity to apply leadership skills while learning basic military skills. Enrollment in the basic course incurs no military obligation except for Army scholarship recipients.

Advanced course

The advanced course covers leadership, tactics and unit operations, training techniques, military law, and professional ethics, and includes a leadership practicum each semester. A 33-day summer advanced camp at Fort Knox, Kentucky, provides challenging leadership training and is a prerequisite for commissioning. Advanced course students must have completed the basic course and obtain permission from the Professor of Military Science (PMS).

Two-Year Program

The two-year program consists of the advanced course, preceded by attending the Leaders Training course (a four-week summer ROTC basic course at Ft. Knox, Kentucky). Veterans, or Active Army Reserve/Army National Guard Soldiers, or students who have participated in three years of Junior ROTC or Civil Air Patrol, may be eligible to enroll in the advanced course without attendance at basic camp or completion of the basic course. Advanced course students must obtain permission from the Professor of Military Science (PMS) at 303-492-6495.

Scholarship Programs

Three-year and Four-year college scholarships are available to eligible high school seniors, who apply before December 1 of their senior year. Competition for two- and three- year scholarships is open to all university students. Scholarship students receive full tuition and mandatory laboratory fees, a book allowance, and an allowance of \$300- \$500 per month during the academic year. Students interested in the scholarship program should contact the AROTC Enrollment and Scholarship Officer at 303-492-3549 no later than the beginning of the spring semester to apply for the following academic year.

Simultaneous Membership Program

Students currently in the Army Reserves or Army National Guard and entering either the second year of the basic course or the advanced course may participate in the Simultaneous Membership Program (SMP). Students participating in this program will receive \$450 to \$500 monthly stipend plus their unit pay at the E-5 grade. SMP participants may be eligible for Army Reserve or Army National Guard tuition assistance benefits.

Leadership Laboratories

Leadership labs provide cadets with practical leadership experience and performance-oriented, hands-on instruction outside the classroom.. Diagnostic evaluations of cadets in leadership roles are frequently

administered. Leadership labs are compulsory for enrolled cadets. Physical training is conducted three times a week with the purpose of developing muscular strength, endurance, and cardio-respiratory endurance.

Veterans

Veterans who have served on active duty or in the Army Reserve/National Guard are also eligible for the ROTC program. Although veterans are not required to take the Basic Course, they are encouraged to do so. A minimum of 60 credit hours are required prior to enrolling in the Advanced Course.

Registration and Credits

Army ROTC serves as free-elective credit in most departments. Elective course credit toward your degree for AROTC classes will be determined by your individual academic advisor. Students who wish to register for Army ROTC classes do so through the normal course registration process at CSM. AROTC classes begin with the MSGN prefix.

For more information about AROTC, contact:

the Army ROTC Enrollment and Scholarship Officer at:
303-492-3549 or 303-492-6495

or the department on campus directly at:
303-273-3380

The department is located in the Military Science building, 1232 West Campus Road.

You can also go to <http://www.colorado.edu/AROTC>.

For information about ROTC at CSM, call 303-273-3398 or 303-273-3380.

General CSM Minor/ASI requirements can be found here (p. 33).

Military Science Minor

Army ROTC cadets desiring to receive a minor in Military Science must complete at least 22 hours of Military Science courses as follows:

MSGN103	ADVENTURES IN LEADERSHIP I	2.0
MSGN104	ADVENTURES IN LEADERSHIP II	2.0
MSGN203	METHODS OF LEADERSHIP	2.0
MSGN204	METHODS OF LEADERSHIP AND MANAGEMENT II	2.0
MSGN301	MILITARY OPERATIONS AND TRAINING I	3.0
MSGN302	MILITARY OPERATIONS AND TRAINING II	3.0
MSGN303	LEADERSHIP LABORATORY	0.5
MSGN304	LEADERSHIP LABORATORY	0.5
MSGN401	OFFICER LEADERSHIP AND DEVELOPMENT I	3.0
MSGN402	OFFICER LEADERSHIP AND DEVELOPMENT II	3.0
MSGN403	LEADERSHIP LABORATORY	0.5
MSGN404	LEADERSHIP LABORATORY	0.5
Total Semester Hrs		22.0

Note: In order to Commission as a 2nd Lieutenant in the US Army, completion of a Military History Course (LAIS365) is also required.

MSGN103. ADVENTURES IN LEADERSHIP I. 2.0 Hours.

(I) Introduces fundamentals of leadership and the United States Army. Examines its organization, customs, and history as well as its current relevance and purpose. Students also investigate basic leadership and management skills necessary to be successful in both military and civilian settings. Includes fundamentals of Army leadership doctrine, teambuilding concepts, time and stress management, an introduction to cartography and land navigation, marksmanship, briefing techniques, and some basic military tactics. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Fall).

MSGN104. ADVENTURES IN LEADERSHIP II. 2.0 Hours.

(II) Continues the investigation of leadership in small organizations. Covers selected topics such as basic troop leading procedures, military first aid and casualty evacuation concepts, creating ethical work climates, an introduction to Army organizations and installations, and a further examination of basic military tactics. Introduces students to effective military writing styles. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Spring).

MSGN198. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Hour.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN199. INDEPENDENT STUDY. 1-6 Hour.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN203. METHODS OF LEADERSHIP. 2.0 Hours.

(I) Comprehensively reviews advanced leadership and management concepts including motivation, attitudes, communication skills, problem solving, human needs and behavior, and leadership self development. Students continue to refine effective written and oral communications skills and to explore topics such as the basic branches of the Army, and officer and NCO duties. Students conduct classroom and practical exercises in small unit light infantry tactics and are prepared to perform as midlevel leaders in the cadet organization. Lab fee: 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Fall).

MSGN204. METHODS OF LEADERSHIP AND MANAGEMENT II. 2.0 Hours.

(II) Focuses on leadership and management functions in military and corporate environments. Studies various components of Army leadership doctrine to include the four elements of leadership, leadership principles, risk management and planning theory, the be-know-do framework, and the Army leadership evaluation program. Continue to refine communication skills. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80hours field training; 2 semester hours. (Spring).

MSGN298. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Hour.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN299. INDEPENDENT STUDY. 1-6 Hour.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN301. MILITARY OPERATIONS AND TRAINING I. 3.0 Hours.

(I) Further explores the theory of managing and leading small military units with an emphasis on practical applications at the squad and platoon levels. Students examine various leadership styles and techniques as they relate to advanced small unit tactics. Familiarizes students with a variety of topics such as cartography, land navigation, field craft, and weapons systems. Involves multiple, evaluated leadership opportunities in field settings and hands-on experience with actual military equipment. Students are given maximum leadership opportunities in weekly labs. Prerequisite: Consent of the Professor of Military Science. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN302. MILITARY OPERATIONS AND TRAINING II. 3.0 Hours.

(II) Studies theoretical and practical applications of small unit leadership principles. Focuses on managing personnel and resources, the military decision making process, the operations order, and oral communications. Exposes the student to tactical unit leadership in a variety of environments with a focus on preparation for the summer advance camp experience. Prerequisite: Consent of the Professor of Military Science. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN303. LEADERSHIP LABORATORY. 0.5 Hours.

(I) Development of military leadership techniques to include preparation of operation plans, presentation of instruction, and supervision of underclass military cadets. Instruction in military drill, ceremonies, and customs and courtesies of the Army. Must be taken in conjunction with MSGN301. Prerequisite: Consent of department. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Fall).

MSGN304. LEADERSHIP LABORATORY. 0.5 Hours.

(II) Continued development of military leadership techniques with the major emphasis on leading an Infantry Squad. Training is "hands-on." Practical exercises are used to increase understanding of the principles of leadership learned in MSGN302. Must be taken in conjunction with MSGN302. Prerequisite: Consent of department. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Spring).

MSGN398. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Hour.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN399. INDEPENDENT STUDY. 1-6 Hour.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN401. OFFICER LEADERSHIP AND DEVELOPMENT I. 3.0 Hours.

(I) Examines management and leadership concepts and techniques associated with planning and executing military training and operations at company and higher echelons. Includes analyses of professional ethics and values, effective training principles and procedures, subordinate counseling, and effective staff officer briefing techniques. Also investigates other subjects such as counter terrorism, modern peacekeeping missions, and the impact of the information revolution on the art of land warfare. Conducted both in and out of classroom setting and with multiple practical leadership opportunities to organize cadet training and activities. Prerequisite: Consent of the Professor of Military Science. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN402. OFFICER LEADERSHIP AND DEVELOPMENT II. 3.0 Hours.

(II) Continues MSGN401 study of management and leadership concepts and techniques, providing practical leadership experiences in the classroom and during multiple cadet-run activities. Also examines varied topics such as theory and practice of the military justice system, law of war, military-media relations, support mechanisms for soldiers and their families, operational security considerations, and historical case studies in military leadership in the context of 21st century land warfare. Prerequisite: Consent of the Professor of Military Science. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN403. LEADERSHIP LABORATORY. 0.5 Hours.

(I) Continued development of leadership techniques by assignment in the command and staff positions in the Cadet Battalion. Cadets are expected to plan and execute much of the training associated with the day-to-day operations within the cadet battalion. Utilizing the troop leading and management principles learned in previous classes, cadets analyze the problems which the battalion faces, develop strategies, brief recommendations, and execute the approved plan. Prerequisite: Consent of department. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Fall).

MSGN404. LEADERSHIP LABORATORY. 0.5 Hours.

(II) Continued leadership development by serving in the command and staff positions in the Cadet Battalion. Cadets take a large role in determining the goals and direction of the cadet organization, under supervision of the cadre. Cadets are required to plan and organize cadet outings and much of the training of underclassmen. Lab Fee. Prerequisite: Consent of department. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Spring).

MSGN498. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Hour.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: Instructor consent. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN499. INDEPENDENT STUDY. 1-6 Hour.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Physical Education and Athletics

2015-2016

The Department of Physical Education and Athletics offers a four-fold physical education and athletics program which includes:

1. Required physical education classes;
2. Intercollegiate athletics;
3. Intramural athletics and club sports; and
4. Recreational athletics.

A large number of students use the institution's facilities for recreational purposes, including swimming, tennis, soccer, basketball, volleyball, weight lifting, softball, and racquetball.

Russell H. Volk Gymnasium

A tri-level complex containing a NCAA regulation basketball arena, two racquetball/handball courts, wrestling room, weight training facility, locker space, and offices for the Physical Education Department.

Steinhauer Field House

A facility of 35,000-sq. ft., which provides for the needs of intercollegiate athletics and physical education classes.

Darden Baseball Field

Newly renovated with dugouts, fencing, 10 inning score-board, netted backstop, press-box and lights for night games. Located west of Brooks Field and has seating accommodations for 500 spectators.

Softball Field

Newly constructed dugouts, batting cage, perimeter fencing, sound system and new irrigation system. Located west of Darden Field seating for 200 people.

Harry D. Campbell Field

Includes a synthetic surface named in honor of Harry D. Campbell, Class of 1939. Currently under renovation.

Tennis Courts

The Department maintains four tennis courts.

Student Recreation Center

A three-level, 108,000 square foot facility that features an 8 lane, 25 yard swimming pool with 2 diving boards and a 14 person hot tub. There are men's and women's locker rooms, a 4,000 square foot climbing wall, a full service juice bar, an elevated jogging track, a 5,500 square foot fitness area, 2 multi-purpose rooms, a recreational gym and an arena that seats 3,000 for varsity athletic contests.

Swenson Intramural Complex

Two fields are available for intramural/recreation sports.

Stermole Track and Field Complex

Nine lane metric track with all field event components necessary to host NCAA, RMAC sanctioned events. Seating for 800 spectators.

CSM Soccer Stadium

Synthetic surface which provides opportunities for Men's and Women's NCAA, RMAC sanctioned events. Seating for 500 spectators.

Required Physical Education

Each student at Colorado School of Mines is required to complete four separate semesters of Physical Education classes (PAGN):

PAGN101	PHYSICAL EDUCATION (prerequisite)	0.5
PAGN102	PHYSICAL EDUCATION (prerequisite)	0.5
PAGN2XX	PHYSICAL EDUCATION	0.5
PAGN2XX	PHYSICAL EDUCATION	0.5
Total Semester Hrs		2.0

Exceptions:

1. A medical excuse verified by a physician;
2. Veterans, honorably or generally discharged from the armed forces;
3. New students entering CSM for the first time who are 26 years or older prior to the first day of class;
4. Students holding a bachelor's degree.

Normally, it is fulfilled during the first two years of attendance. Transfer students should check with the Admissions Office regarding advanced standing in physical education. Participation in intercollegiate athletics may be substituted for required semesters and hours of physical education. ROTC students can waive the physical education requirement when a similar four-semester physical activity is required in their respective ROTC Programs.

Upper-class students who wish to continue taking physical education after completing graduation requirements may re-enroll in any of the 200-level courses.

Some of the 200-level courses may require off campus transportation, please check with Department of Athletics. All students enrolled in physical education shall provide their own gym uniform, athletic shoes, sunscreen or swimming suit. Students are encouraged to rent a locker and lock in Volk for a \$10 rental fee.

Intercollegiate Athletics

The School is a charter member of the Rocky Mountain Athletic Conference (RMAC) and the National Collegiate Athletic Association (NCAA). Sports offered include: football, men's and women's basketball, wrestling, men's and women's track, men's and women's cross country, baseball, men's golf, men's and women's swimming and diving, men's and women's soccer, and women's volleyball and softball. An athlete can register each semester for one hour physical activity credit to meet their graduation requirements.

Through a required athletic fee, all full-time students attending CSM become members of the CSM Athletic Association, which financially supports the intercollegiate athletic program. With this fee, each CSM student receives free admission to all home athletic events. The Director of Athletics administers this program.

Intramural and Club Sports

The intramural program features a variety of activities ranging from those offered in the intercollegiate athletic program to more recreational type activities. They are governed by the CSM Rec. Sports Department. All activities are offered in the following categories: men, women and co-ed.

The club sport program is governed by the CSM Sport Club Council. There are 14 competitive groups currently under this umbrella. Some teams engage in intercollegiate competition at the non-varsity level,

some serve as instructional/recreational entities, and some as strictly recreational interest groups. They are funded through ASCSM. Some of the current organizations are Cycling, Ice Hockey, Lacrosse, Men's Rugby, Women's Rugby, Ski Team, Men's Soccer, Women's Soccer, Men's Ultimate Frisbee, Women's Ultimate Frisbee, Men's Volleyball, Women's Volleyball, Water Polo, Bowling and In-Line Hockey.

Athletic Director

David Hansburg, Director of Athletics

Associate Athletic Director

Dixie Cirillo, Physical Education Coordinator, Associate Athletic Director

Eric Stahl, 2014, Associate Athletic Director

Assistant Directors

Charles O'Dell, Assistant Athletic Director

Robert Thompson, Assistant Director of Athletics

Recreation Sports

Robert Thompson, Student Recreation Center Director

Ryan McCallum, Assistant Director of Recreation Center

John Howard, Director of Club and Intramural Sports

Nate Bondi, Director of Outdoor Recreation

Administrative Assistant

Carolyn Dennee, Administrative Assistant

Coaches

Austin DeVoe, Head Wrestling Coach

Kevin Fickes, Head Women's Soccer Coach

Leah Glasgow, Head Softball Coach

Jerod Goodale, Head Baseball Coach

Tyler Kimble, Head Golf Coach

Frank Kohlenstein, Head Men's Soccer Coach

Pryor Orser, Head Men's Basketball Coach

Nate Rothman, Head Swimming and Diving Coach

Chris Siemers, Head Cross Country Coach

Brittany Simpson, Head Women's Basketball Coach

Jamie Skadeland, Head Volleyball Coach

Matt Sparks, Head Track and Field Coach

Robert Stitt, Head Football Coach

Assistant Coaches

Tara Brooks, Assistant Track Coach

Clement Grinstead, Assistant Football Coach

Brian Hendricks, Assistant Football Coach

Scott Kaniecki, Assistant Football Coach

Shannon McDonnell, Assistant Women's Soccer Coach

Kellen Mitts, Assistant Baseball Coach

Greg Mulholland, Assistant Men's Soccer Coach

Matt Nicholson, Assistant Football Coach

Todd Porter, Assistant Wrestling Coach

Heather Roberts, Assistant Volleyball Coach

Brad Schick, Assistant Men's Basketball Coach

Jason Semore, Assistant Football Coach

Leslie Seymour, Assistant Women's Basketball Coach

Nolan Swett, Assistant Football Coach

Head Athletic Trainer

Jennifer McIntosh, Head Athletic Trainer

Assistant Athletics Trainers

Jacob Pope, Assistant Athletic Trainer

Andy Vanous, Assistant Athletic Trainer

Andrea Westhead, Assistant Athletic Trainer

Equipment Manager

Darren Townsend, Equipment Manager

Sports Information

Collin Bonnicksen, Sports Information Director

Bryan Desch, Assistant Sports Information Director

Courses

PAGN101. PHYSICAL EDUCATION. 0.5 Semester Hrs.

(I) (Required and not repeatable for credit) A general overview of life fitness basics which includes exposure to educational units of Nutrition, Stress Management, Drug and Alcohol Awareness. Instruction in Fitness units provides the student an opportunity for learning and the beginning basics for a healthy life style.

PAGN102. PHYSICAL EDUCATION. 0.5 Semester Hrs.

(II) (Required and not repeatable for credit) Sections in physical fitness and team sports, relating to personal health and wellness activities. Prerequisite: PAGN101.

PAGN151. VARSITY BASEBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of baseball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN153. VARSITY MEN'S BASKETBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of men's basketball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN154. VARSITY WOMEN'S BASKETBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of women's basketball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN157. VARSITY CROSS COUNTRY. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of cross country in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN159. VARSITY FOOTBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of football in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN161. VARSITY GOLF. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of golf in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN167. VARSITY MEN'S SOCCER. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of men's soccer in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN168. VARSITY WOMEN'S SOCCER. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of women's soccer in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN169. VARSITY SWIMMING. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of swimming and diving in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 1 semester hour.

PAGN173. VARSITY TRACK AND FIELD. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of track and field in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN175. VARSITY WRESTLING. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of wrestling in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN177. VARSITY VOLLEYBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of volleyball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN179. VARSITY SOFTBALL. 1.0 Semester Hr.

Instruction and practice in fundamentals and mechanics of softball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. Prerequisite: none. 1 semester hour.

PAGN198. SPECIAL TOPICS. 0.5-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PAGN201. PERSONAL WELLNESS. 1.0 Semester Hr.

Provides an overview of the 5 Dimensions of Wellness: Physical, Social, Emotional, Intellectual and Spiritual. Students will take a proactive approach to developing strategies for optimum wellness including goal setting and application of wellness principles through assignments and group in-class work. Prerequisites: PAGN101 and PAGN102. 2 hours lecturer; 1 semester hour. Repeatable for credit.

PAGN202. INDOOR SOCCER. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN203. TECHNIQUES OF RELAXATION. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN204. FLY FISHING. 0.5 Semester Hrs.

PAGN202 through PAGN280. (Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 and PAGN102. 2 hours activity; .5 semester hour. Repeatable. May be applied to free elective credits based on academic policy.

PAGN205. BEGINNING KARATE. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN206. INTERMEDIATE KARATE. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN207. TRAIL RUNNING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN208. KAYAKING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN209. AIKIDO. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN210. HIKING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN211. BEGINNING SWIMMING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN212. INTERMEDIATE SWIMMING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN221. BEGINNING WEIGHT TRAINING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN222. ADVANCED WEIGHT TRAINING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN223. DISTANCE RUNNING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN232. YOGA. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN235. WORKOUTS AND WELLNESS. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 and PAGN102. 2 hours activity; .5 semester hour. Repeatable. May be applied to free elective credits based on Registrar's Office policy.

PAGN241. WOMEN'S WEIGHT TRAINING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN242. WOMEN'S RAQUETBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN251. GOLF. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN255. MOUNTAIN BIKING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN257. INTRODUCTION TO ROCK CLIMBING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN258. WOMEN'S ROCK CLIMBING. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN271. BEGINNING BADMINTON. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN272. ADVANCED BADMINTON. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN273. BEGINNING BASKETBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN274. ADVANCED BASKETBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN275. VOLLEYBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN277. BEGINNING RACQUETBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN279. HANDBALL. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN280. CLUB SPORTS. 0.5 Semester Hrs.

(Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday or Thursday for 1.5 hours. Prerequisite: PAGN101 or PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN281. ADVANCED HANDBALL. 0.5 Semester Hrs.

(I, II) PAGN202 through PAGN280. (Students enrolling in these courses may be required to furnish their own equipment.) Classes will be offered on Monday and Wednesday for 50 minutes each day or on Tuesday, Thursday or Saturday for 1.5 hours. Prerequisite: PAGN101 and PAGN102. 2 hours activity; .5 semester hour. Repeatable for credit.

PAGN298. SPECIAL TOPICS. 0.5-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PAGN398. SPECIAL TOPICS. 0.5-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PAGN498. SPECIAL TOPICS. 0.5-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

Interdisciplinary Minors

Please select an item from the list on the right.

Energy

General CSM Minor/ASI requirements can be found here (p. 33).

<http://energyminor.mines.edu>

Programs Offered

- Minor in Energy
- Area of Special Interest in Energy

Program Educational Objectives

The discovery, production, and use of energy in modern societies has profound and far-reaching economic, political, and environmental effects. As energy is one of CSM's core statutory missions, several CSM departments have come together to offer Minor and Area of Special Interest (ASI) programs related to Energy. The 18-credit Energy Minor adds value to any CSM undergraduate degree program by not only addressing the scientific and technical aspects of energy production and use but its broader social impacts as well. Students pursuing the Energy Minor may choose from three curricular tracks: Fossil Energy, Renewable Energy, or General. The Energy Minor program is intended to provide engineering students with a deeper understanding of the complex role energy technology plays in modern societies by meeting the following learning objectives:

1. Students will gain a broad understanding of the scientific, engineering, environmental, economic and social aspects of the production, delivery, and utilization of energy as it relates to the support of current and future civilization both regional and worldwide.
2. Students will develop depth or breadth in their scientific and engineering understanding of energy technology.
3. Students will be able to apply their knowledge of energy science and technology to societal problems requiring economic, scientific, and technical analysis and innovation, while working in a multidisciplinary environment and be able to communicate effectively the outcomes of their analyses in written and oral form.

General CSM Minor/ASI requirements can be found here (p. 33).

Program Requirements

Minor in Energy:

The Minor in Energy requires a minimum of 18 credit hours of acceptable course work. All Energy Minors must take 9 credit hours:

ENGY200	INTRODUCTION TO ENERGY	3.0
EBGN/ ENGYnull330	ENERGY ECONOMICS	3.0
ENGY490 or LAIS424	ENERGY AND SOCIETY * RHETORIC, ENERGY AND PUBLIC POLICY	3.0

* Either ENGY490 or LAIS424 can serve as the policy capstone course.

Introductory Courses

ENGY200	INTRODUCTION TO ENERGY	3.0
EBGN/ ENGYnull330	ENERGY ECONOMICS	3.0
Total Semester Hrs		6.0

Energy-related Courses: Fossil Energy Track

PEGN102	INTRODUCTION TO PETROLEUM INDUSTRY	3.0
Select three of the following:		9.0

ENGY310	FOSSIL ENERGY	
CBEN408	NATURAL GAS PROCESSING	
CBEN409	PETROLEUM PROCESSES	
GEGN438	PETROLEUM GEOLOGY	
PEGN251	FLUID MECHANICS	
PEGN305	COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING	
PEGN308	RESERVOIR ROCK PROPERTIES	
PEGN311	DRILLING ENGINEERING	
PEGN361	COMPLETION ENGINEERING	
PEGN411	MECHANICS OF PETROLEUM PRODUCTION	
PEGN419	WELL LOG ANALYSIS AND FORMATION EVALUATION	
PEGN422	ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS	
PEGN/ MNGNnull438	PETROLEUM GEOSTATISTICS	

ENGY310	FOSSIL ENERGY	
ENGY320	RENEWABLE ENERGY	
ENGY340	NUCLEAR ENERGY	
ENGY350	INTRODUCTION TO GEOTHERMAL ENERGY	
CBEN472	INTRODUCTION TO ENERGY TECHNOLOGIES	
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY	
MEGN461	THERMODYNAMICS II	
EGGN589	DESIGN AND CONTROL OF WIND ENERGY SYSTEMS	
EBGN340	ENERGY AND ENVIRONMENTAL POLICY	
LAIS419	MEDIA AND THE ENVIRONMENT	
LAIS423	ADVANCED SCIENCE COMMUNICATION	
LAIS424	RHETORIC, ENERGY AND PUBLIC POLICY	
LAIS489	NUCLEAR POWER AND PUBLIC POLICY	
LAIS486	SCIENCE AND TECHNOLOGY POLICY	

Policy course (required for all Energy minors)

ENGY/ LAISnull490	ENERGY AND SOCIETY	3.0
Total Semester Hrs		3.0

The Area of Special Interest in Energy requires a minimum of 12 credit hours of acceptable course work:

ENGY200	INTRODUCTION TO ENERGY	3.0
EBGN/ ENGYnull330	ENERGY ECONOMICS	3.0

Two additional energy-related courses 6.0

Total Semester Hrs 12.0

ENGY200	INTRODUCTION TO ENERGY	3.0
ENGY310	FOSSIL ENERGY	3.0
ENGY320	RENEWABLE ENERGY	3.0
ENGY330	ENERGY ECONOMICS	3.0
ENGY340	NUCLEAR ENERGY	3.0
ENGY350	INTRODUCTION TO GEOTHERMAL ENERGY	3.0
ENGY490	ENERGY AND SOCIETY	3.0
ENGY497	SUMMER PROGRAMS	6.0

Professors

Murray W. Hitzman , Department of Geology and Geological Engineering,
Charles F. Fogarty Professor of Economics Geology

Reuben Collins, Department of Physics

John Curtis, Department of Geology and Geological Engineering

Carol Dahl, Division of Economics and Business

Roderick G. Eggert, Division of Economics and Business, Division
Director

Ramona M. Graves, Department of Petroleum Engineering, Interim
Department Head

Carl Mitcham, Division of Liberal Arts and International Studies

Masami Nakagawa, Department of Mining Engineering

P.K. Sen, Division of Engineering

Roel Snieder, Department of Geophysics, Keck Foundation Professor of
Basic Exploration Science

P. Craig Taylor, Department of Physics

Associate Professors

Linda Figueroa, Division of Environmental Science and Engineering

John Heilbrunn, Division of Liberal Arts and International Studies

Andrew M. Herring, Department of Chemical Engineering

Kathryn Johnson, Department of Mechanical Engineering

Joseph Beach Jr., Department of Physics, Research

Timothy R. Ohno, Minor and Area of Special Interest Only, Director

Marcelo Simoes, Division of Engineering

Neal Sullivan, Associate Professor

Assistant Professors

Eric Toberer , Department of Physics

Jason A. Delborne, Division of Liberal Arts and International Studies

Daniel Kaffine, Division of Economics and Business

Jeffrey C. King, Department of Metallurgical and Materials Engineering

Jennifer Schneider, Division of Liberal Arts and International Studies

Teaching Professor

Charles Stone, Department of Physics

Teaching Associate Professors

Linda Battalora, Department of Petroleum Engineering

John M. Persichetti, Department of Chemical Engineering

Humanitarian Engineering

General CSM Minor/ASI requirements can be found here (<http://bulletin.mines.edu/undergraduate/undergraduateinformation/minorasi>).

Program Mission

To teach students how engineering can contribute to co-creating just and sustainable solutions for communities.

Program Educational Objectives

To achieve its mission -- *teach students how engineering can contribute to co-creating just and sustainable solutions for communities* -- HE graduates will be able to

- *Reflect critically on the practices of engineering* to know why, how, when and whether to use engineering in the co-creation of just and sustainable solutions.
- *Serve communities effectively and responsibly* in collaboratively identifying problems and defining and providing solutions that are just and sustainable.
- *Design and build technologies* that promote just and sustainable solutions.
- *Map career trajectories* (corporate, public, NGOs, academic) that will enable them to work as engineers for just and sustainable solutions.

Programs Offered

- Minor in Humanitarian Engineering (18 credit hours)
- Area of Special Interest in Humanitarian Engineering (12 credit)

Program Requirements

1. Humanitarian Engineering Minor Program (18 credit hours)

Intro Course (3 cr)

LAIS377	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
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Area I Community, Culture & Social Justice (6 cr) Select two of the following:

LAIS325	CULTURAL ANTHROPOLOGY	3.0
LAIS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
LAIS475	ENGINEERING CULTURES IN THE DEVELOPING WORLD	3.0
LAIS478	ENGINEERING AND SOCIAL JUSTICE	3.0
LAIS490	ENERGY AND SOCIETY	3.0

Area II Engineering by Doing (EbD) (6 cr) Both courses below are required:

EGGN301	HUMAN-CENTERED PROBLEM DEFINITION (Required)	3.0
EGGN401	PROJECTS FOR PEOPLE (Required)	3.0

Capstone Course (3 cr)

EGGN492	SENIOR DESIGN II (for CECS students)	3.0
CEEN477	SUSTAINABLE ENGINEERING DESIGN (non CECS students)	3.0

3.

2. Area of Special Interest in Humanitarian Engineering (12 credit hours)

Intro Course (3 cr)

LAIS377	ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT	3.0
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Area I Community, Culture & Social Justice (6 cr) Select two of the following:

LAIS325	CULTURAL ANTHROPOLOGY	3.0
or HNRS305	EXPLORATIONS IN MODERN AMERICA	
LAIS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
LAIS475	ENGINEERING CULTURES IN THE DEVELOPING WORLD	3.0
LAIS478	ENGINEERING AND SOCIAL JUSTICE	3.0
LAIS490	ENERGY AND SOCIETY	3.0

Capstone Course (3 cr)

CEEN477	SUSTAINABLE ENGINEERING DESIGN	3.0
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Co-Curricular Activities

Students interested in the Humanitarian Engineering (HE) Program are strongly encouraged to join Engineers without Borders (EWB) in their first year at CSM to begin understanding the role of engineering in community development. HE students are also encouraged to attend the HE Lecture Series to gain new perspectives on the role of engineers in co-developing solutions to problems faced by communities in the US and abroad.

4. Senior Design Projects

During their senior year capstone experience, HE students must select HE projects in areas such as Community Development or Assistive Technologies for People with Disabilities. Projects which are approved for use towards the minor are indicated in the project list provided in EGGN491. HE students will be given priority on these projects and will be supported by a Social Context Consultant with whom they will interact regularly to make sure that their design addresses human- and/or community-centered needs as well as technical requirements.

CEEN477	SUSTAINABLE ENGINEERING DESIGN	3.0
LAIS325	CULTURAL ANTHROPOLOGY	3.0
LAIS430	CORPORATE SOCIAL RESPONSIBILITY	3.0
LAIS475	ENGINEERING CULTURES IN THE DEVELOPING WORLD	3.0
LAIS478	ENGINEERING AND SOCIAL JUSTICE	3.0
LAIS490	ENERGY AND SOCIETY	3.0
EGGN301	HUMAN-CENTERED PROBLEM DEFINITION	3.0
EGGN401	PROJECTS FOR PEOPLE	3.0

Professor

Juan Lucena, Humanitarian Engineering Program Director

Associate professor

Junko Munakata-Marr, Civil and Environmental Engineering Department

Assistant professor

Jessica Rolston, Division of Liberal Arts and International Studies

Professor emeritus

F. Edward Cecil, Department of Physics

Teaching Associate Professors

Jered Dean, Senior Design Director, College of Engineering and Computational Science

Courtney Holles, Division of Liberal Arts and International Studies

Leslie Light, Design EPICS Director

Adjunct Faculty

Mirna Mattjik, Program Coordinator & First Year Engineering Design Course Instructor

Nicole Smith, Energy and Society Course Instructor

Ben Teschner, Corporate Social Responsibility Project Manger & Project for People Course Instructor

Lecturer

David Frossard, Engineering for Sustainable Community Development Course Instructor

Guy T. McBride, Jr. Honors Program in Public Affairs

2015-2016

General CSM Minor/ASI requirements can be found here (p. 33).

Program Educational Objectives

The McBride Honors Program in Public Affairs offers an honors minor consisting of seminars, courses, and off-campus activities that has the primary goal of providing a select number of students the opportunity to cross the boundaries of their technical expertise into the ethical, cultural, socio-political, and environmental dimensions of human life. Students will develop their skills in communication, critical thinking, and leadership through seminar style classes that explore diverse aspects of the human experience. The seminars are designed to offer coherent perspectives across the curriculum, allowing for a maximum degree of discussion and debate on complex topics. Themes, approaches, and perspectives from the humanities and the social sciences are integrated with science and engineering perspectives to develop in students habits of thought necessary for a comprehensive understanding of societal and cultural issues that enhance critical thinking, social responsibility, and enlightened leadership.

Program Description

The McBride Honors Program is administered by the Division of Liberal Arts and International Studies.

As of fall 2013, the new 21 credit hour curriculum has been modified for all students.

The Program is delivered primarily in an interdisciplinary seminar format that maximizes discussion and debate. Seminars are taught by teams of faculty members from the humanities, social sciences, life sciences and physical sciences, and engineering. The curriculum of the McBride Honors Program includes the following features and educational experiences:

- Student-centered seminars guided by faculty moderators from various disciplines.
- An interdisciplinary approach that integrates domestic and global perspectives into the curriculum.
- One-to-one long-lasting intellectual relationships and camaraderie among students and between faculty and students.
- The Development and practice of oral/written communication, argumentation, and listening skills.
- The opportunity to develop an individualized educational experience involving study abroad, service learning, research, entrepreneurial projects, and/or professional internships.

An important experience in the Program is the opportunity to engage in a Practicum (an internship, overseas study, public service, undergraduate research experience, or thesis). Because engineers and scientists will continue to assume significant responsibilities as leaders in public and private sectors, it is essential that CSM students be prepared for more than their traditional "first jobs". Leadership and management demand an understanding of the accelerating pace of change that marks the social, political, economic, and environmental currents of society and a commitment to social and environmental responsibility. Regardless of their career goals, however, this same understanding is demanded of an educated person in the contemporary world. While the seminars in the Program are designed to nourish such an understanding, these Practicum experiences allow students to see firsthand the kinds of challenges that they will face in their professional and personal lives.

Foreign study is also possible either through CSM-sponsored trips or through individual plans arranged in consultation with the Director and the Office of International Programs. The program offers some competitive scholarships to selected students to facilitate study abroad or other exceptional educational experiences. Please contact the Director or see the Program website for more information.

Student Profile

The McBride Honors Program in Public Affairs seeks to enroll students who can benefit most from the learning experiences upon which the Program is based while significantly contributing to the broader learning objectives of the McBride community. Most honors programs admit students exclusively on the basis of academic record. Although the McBride Honors Program uses SAT and ACT test scores, and high school grade point average as important indicators of success in the McBride Program, they form only part of the criteria used in the admission process. The McBride Program also examines extracurricular activities, interest in human affairs, and the willingness to engage actively in discussion and debate. Applicants must demonstrate their commitment to public service, their leadership potential, willingness to understand

and respect perspectives other than their own, and writing, listening, and speaking abilities.

Once admitted into the Program, a McBride student commits to:

- completing the McBride curriculum as stated in the Bulletin;
- participating in the McBride seminars as an active and responsible member of the learning community, always completing reading and writing assignments on time in order to be ready to learn;
- engaging in the highest level of intellectual discourse in a civil and respectful manner with all members of the CSM community, particularly with those who hold different beliefs, values, and views;
- understanding that the McBride faculty are committed to provide the best education to help students become thoughtful and responsible persons, citizens, and professionals; and
- upholding the highest standards of ethical conduct and the CSM Honor Code, particularly those related to academic honesty and respect for peers, instructors, and Program administrators.

Although the educational experiences in the McBride Honors Program are rigorous and demand a high degree of dedication from the students, McBride graduates have gained positions of their choice in industry, business, government, and within non-governmental organizations, or in other professions more easily than others, and have been successful in winning admission to high-quality graduate, law, medicine and other professional schools.

Admission

Students typically begin the Program in the fall of their sophomore year, although in some cases transfer students and juniors may join the program. Students should apply to the McBride Program by the deadline set by the Program, by filling out an application, submitting an essay, and securing a letter of recommendation (see website for details: <http://mcbride.mines.edu/>), and participating in an interview.

Note: Students must complete LAIS100 Nature and Human Values prior to, or concurrently with, enrolling in the first course, HNRS305 Explorations in Modern America.

H & SS Core Curriculum Requirements

Students completing the McBride Honors Program are required to complete LAIS100, "Nature and Human Values," and EBG201, "Principles of Economics." McBride students are exempt from completing LAIS200, "Human Systems."

Transfer and Graduation Policies

The McBride Program accepts applications from transfer students as follows:

Transfer students must complete and submit an application and participate in the interview process like other applicants under the time frame set by the Program. Transfer students should expect to complete the entire McBride curriculum, but under some circumstances, transfer students may petition the Director for course substitutions.

Academic Standards

Students must perform to the highest levels of writing, reading, and discussion in preparation for and during McBride seminars. Participation in class projects and discussions is essential. Students who do not

maintain an appropriate level of participation and engagement may be asked to leave the Program.

Academic integrity and honesty are expected of all Mines students. Any infractions in these areas will be handled under the rules of CSM and the McBride Program and may result in dismissal from the Program. The Program demands a high level of achievement not only in Honors courses, but in all academic work attempted at CSM. To that end, a student must meet the following minimum requirements:

- A minimum cumulative GPA 2.9 is required for admission. Failure to meet the GPA requirement will result in voiding the invitation to join the McBride Program.
- A minimum cumulative GPA of 3.0 in Honors coursework is required to remain in good academic standing in the Program. Students who drop below the minimum in their McBride coursework will be placed on probation for one semester. If the required minimum GPA has not been met at the end of the probationary semester, or in any subsequent semester, the student may be withdrawn from the Program.
- A minimum *cumulative* GPA of 2.9 is required in all course work at CSM. Students who drop below a cumulative GPA of 2.9 will be placed on probation for one semester. If the required minimum GPA has not been met at the end of the probationary semester, or in any subsequent semester, the student will be withdrawn from the Program.
- The minimum *cumulative GPA* and the minimum *Honors GPA* at the time of graduation are required in order to receive the "Minor in the McBride Honors Program in Public Affairs." Graduating seniors who fall below these minima will receive a "Minor in Public Affairs" without the Honors designation if they choose to complete the Public Affairs minor instead of transferring their credits to the Division of Liberal Arts and International Studies.
- If students wish to appeal their withdrawal from the McBride Honors Program, they must write a letter of appeal to the Director, who will review the student's case in consultation with McBride faculty.

Curriculum

The Curriculum Effective for Students Beginning Fall 2013

Each elective will follow a specific theme that provides an in-depth look at a particular problem or case study relating to the overarching topic of the course. These specific themes will change frequently. Prior to registration each semester, the course theme and description will be announced to all McBride students via email and posted on the McBride website. Students may take a given course twice if and only if the course theme is different.

Honors Core Courses (6 credits):

HNRS305	EXPLORATIONS IN MODERN AMERICA	3.0
HNRS315	EXPLORATIONS IN THE MODERN WORLD	3.0

Honors Practicum Requirement (3 credits):

HNRS405	MCBRIDE PRACTICUM	1-3
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Honors Electives (12 credits):

HNRS425	EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP	3.0
HNRS430	EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION	3.0
HNRS435	EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS	3.0

HNRS440	EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS	3.0
HNRS445	EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY	3.0
HNRS450	EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT	3.0
Special Topics		
HNRS398	SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS	1-6
HNRS498	SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS	1-6
HNRS499	INDEPENDENT STUDY	1-6

Professor

Dr. Kenneth A. Osgood, Liberal Arts & International Studies, Program Director

Courses

HNRS198. SPECIAL TOPICS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS199. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS298. SPECIAL TOPICS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS299. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.

(I, II) (WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. Prerequisite: Admission to the Program and LAIS100: Nature & Human Values. 3 lecture hours, 3 credit hours.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.

(I, II) (WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. Prerequisite: Admission to the Program and LAIS100: Nature & Human Values. 3 lecture hours, 3 credit hours.

HNRS398. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS399. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.

(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.

(I, II) (WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student's learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS497. SUMMER COURSE. 6.0 Semester Hrs.**HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.**

A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.

Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

LAIS100. NATURE AND HUMAN VALUES. 4.0 Semester Hrs.

Equivalent with LIHU100, Nature and Human Values will focus on diverse views and critical questions concerning traditional and contemporary issues linking the quality of human life and Nature, and their interdependence. The course will examine various disciplinary and interdisciplinary approaches regarding two major questions: 1) How has Nature affected the quality of human life and the formulation of human values and ethics? (2) How have human actions, values, and ethics affected Nature? These issues will use cases and examples taken from across time and cultures. Themes will include but are not limited to population, natural resources, stewardship of the Earth, and the future of human society. This is a writing-intensive course that will provide instruction and practice in expository writing, using the disciplines and perspectives of the Humanities and Social Sciences. 4 hours lecture/seminar; 4 semester hours.

LAIS198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS200. HUMAN SYSTEMS. 3.0 Semester Hrs.

Equivalent with SYGN200, (I, II) Part of the CSM core curriculum, following the first-year requirement of LAIS 100 Nature and Human Values. This course examines political, economic, social, and cultural systems on a global scale during the modern era. Topics covered include development patterns in key regions of the world; the causes and outcomes of globalization; and the influence of energy, technology, and resources on development. Course material presented by instructors with social science and humanities disciplinary backgrounds, with weekly readings and evaluation through exams and written essays. Prerequisite: LAIS 100. 3 hours lecture; 3 semester hours.

LAIS220. INTRODUCTION TO PHILOSOPHY. 3.0 Semester Hrs.

A general introduction to philosophy that explores historical and analytic traditions. Historical exploration may compare and contrast ancient and modern, rationalist and empiricist, European and Asian approaches to philosophy. Analytic exploration may consider such basic problems as the distinction between illusion and reality, the one and the many, the structure of knowledge, the existence of God, the nature of mind or self. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 credit hours.

LAIS221. INTRODUCTION TO RELIGIONS. 3.0 Semester Hrs.

This course has two focuses. We will look at selected religions emphasizing their popular, institutional, and contemplative forms; these will be four or five of the most common religions: Hinduism, Buddhism, Judaism, Christianity, and/or Islam. The second point of the course focuses on how the Humanities and Social Sciences work. We will use methods from various disciplines to study religion-history of religions and religious thought, sociology, anthropology and ethnography, art history, study of myth, philosophy, analysis of religious texts and artifacts (both contemporary and historical), analysis of material culture and the role it plays in religion, and other disciplines and methodologies. We will look at the question of objectivity; is it possible to be objective? We will approach this methodological question using the concept ?standpoint.? For selected readings, films, and your own writings, we will analyze what the ?standpoint? is. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS286. INTRODUCTION TO GOVERNMENT AND POLITICS. 3.0 Semester Hrs.

Introduction to Government and Politics is a beginning- level course intended to familiarize students with the study of politics across societies. The method is comparative in that it approaches the task of studying the world's different political systems by contrasting and comparing them along different dimensions, and by seeking generalizations about them. The class focuses on cases, topics, and methodologies in American and comparative politics. No background in political science is required or expected. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS300. CREATIVE WRITING: FICTION. 3.0 Semester Hrs.

Students will write weekly exercises and read their work for the pleasure and edification of the class. The midterm in this course will be the production of a short story. The final will consist of a completed, revised short story. The best of these works may be printed in a future collection. Prerequisite: LAIS 100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS301. CREATIVE WRITING: POETRY I. 3.0 Semester Hrs.

This course focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and stimulate the development of the student?s craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students ?try on? various styles and contexts in order to develop their own voice. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS305. AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT. 3.0 Semester Hrs.

This course offers an overview of American literature from the colonial period to the present. The texts of the class provide a context for examining the traditions that shape the American nation as a physical, cultural and historical space. As we read, we will focus on the relationships between community, landscape, history, and language in the American imagination. We will concentrate specifically on conceptions of the nation and national identity in relation to race, gender, and class difference. Authors may include: Rowlandson, Brown, Apess, Hawthorne, Douglass, Melville, Whitman, James, Stein, Eliot, Hemingway, Silko, and Auster. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS307. EXPLORATIONS IN COMPARATIVE LITERATURE. 3.0 Semester Hrs.

This course examines major figures and themes in the modern literatures of Africa, the Caribbean, and Latin America. Reading, discussion and writing will focus on fiction and poetry representing Francophone, Arabic, and Hispanophone traditions within these world regions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic debates that have informed cultural practices in diverse colonial territories and nation-states. Thematic and stylistic concerns will include imperialism, nationalism, existentialism, Orientalism, negritude, and social and magical realisms. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS309. LITERATURE AND SOCIETY. 3.0 Semester Hrs.

Before the emergence of sociology as a distinct field of study, literary artists had long been investigating the seemingly infinite complexity of human societies, seeking to comprehend the forces shaping collective identities, socio-cultural transformations, technological innovations, and political conflicts. Designed to enrich recognition and understanding of the complex interplay of artistic creativity and social inquiry over time, this course compares influential literary and social-scientific responses to the Enlightenment, the Industrial Revolution, and other dynamic junctures integral to the forging of "modernity" and the volatile world we inhabit today. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS310. MODERN EUROPEAN LITERATURE. 1-3 Semester Hr.

This course will introduce students to some of the major figures and generative themes of post-Enlightenment European and British literature. Reading, discussion, and writing will focus on fiction, poetry, drama, and critical essays representing British, French, Germanic, Italian, Czech, and Russian cultural traditions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic movements and debates that have shaped modern European society and culture. Thematic concerns will include the French Enlightenment and its legacies, imperialism within and beyond Europe, comparative totalitarianisms, the rise of psychoanalytic theory and existentialism, and modernist and postmodern perspectives on the arts. Prerequisite: LAIS100, prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS311. BRITISH LITERATURE: MEDIEVAL TO MODERN. 3.0 Semester Hrs.

This course surveys British literature from the Middle Ages to early modernists in light of major developments in scientific thought. It considers topics such as medieval medicine and astrology in *The Canterbury Tales*, reflections of Copernicus' new astronomy in Shakespearean tragedy and John Donne's poetry, the tumultuous career of Newtonian physics across the Enlightenment and Romanticism, the struggle with Darwinian evolution in Victorian literature, and early 20th century reactions to anthropology and psychoanalysis. Pre-requisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS315. MUSICAL TRADITIONS OF THE WESTERN WORLD. 3.0 Semester Hrs.

An introduction to music of the Western world from its beginnings to the present. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS320. ETHICS. 3.0 Semester Hrs.

Equivalent with BELS320,
A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS322. LOGIC. 3.0 Semester Hrs.

A general introduction to logic that explores its analytic and historical traditions. Coverage will commonly consider informal and formal fallacies, syllogistic logic, sentential logic, and elementary quantification theory. Reference will commonly be made to the work of such logical theorists as Aristotle, Frege, Russell and Whitehead, Quine, and others. Prerequisite: LAIS100. Co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS323. INTRODUCTION TO SCIENCE COMMUNICATION. 3.0**Semester Hrs.**

This course will explore the relationship between science and the public through an examination of science writing and communication on current events. Students will study various forms of science communication, including essays, blogs, news segments, media clips, and radio programs in order to understand the ways in which science is communicated beyond the lab or university and into the public consciousness. Science writing often explores the human condition, reflects on hopes and worries about technology, and informs our collective knowledge about the world. Students will discuss the implications of this kind of communication, analyze breakdowns in communication through case studies, and write for peer and popular audiences, including turning a lab report into a short feature article and writing a science essay. Prerequisites: LAIS100, and pre- or co-requisite of LAIS200 hours lecture; 3 semester hours.

LAIS324. AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE. 3.0**Semester Hrs.**

(I) Audio/acoustical engineering and science teaches concepts surrounding the production, transmission, manipulation and reception of audible sound. These factors play a role in many diverse areas such as the design of modern music technology products, recording studios and loudspeakers, civil engineering and building design, and industrial safety. This course will explore and concepts of this field and the physics/mechanics that are involved, as well as aesthetic impacts related to the subject matter. Discussion of human anatomy and psycho acoustic phenomena are also presented. 3 hours lecture; 3 credit hours. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200.

LAIS325. CULTURAL ANTHROPOLOGY. 3.0 Semester Hrs.

A study of the social behavior and cultural development of humans. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS326. MUSIC THEORY. 3.0 Semester Hrs.

(I) The course begins with the fundamentals of music theory and moves into more complex applications. Music of the common practice period (18th century) and beyond is considered. Aural and visual recognition of harmonic material is emphasized. 3 hours lecture; 3 credit hours. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200.

LAIS327. MUSIC TECHNOLOGY. 3.0 Semester Hrs.

(I, II) An introduction to the physics of music and sound. The history of music technology from wax tubes to synthesizers. Construction of instruments and studio. 3 hours lecture. 3 semester hours. Prerequisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS328. BASIC MUSIC COMPOSITION AND ARRANGING. 1.0**Semester Hr.**

(I) This course begins with the fundamentals of music composition and works towards basic vocal and instrumental arrangement skills. Upon completion of this course the student should: 1) Demonstrate basic knowledge of (music) compositional techniques; 2) Demonstrate primary concepts of vocal and instrumental ensemble arrangement; 3) Demonstrate an ability to use notational software and Midi station hardware. 1 semester hour; repeatable for credit. Pre-requisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS330. MUSIC TECHNOLOGY CAPSTONE. 3.0 Semester Hrs.

(II) Project-based course designed to develop practical technological and communication skills for direct application to the music recording. 3 credit hours. Prerequisites: LAIS100, LAIS324, LAIS326, and LAIS327. Prerequisite or corequisite: LAIS200.

LAIS335. INTERNATIONAL POLITICAL ECONOMY OF LATIN AMERICA. 3.0 Semester Hrs.

A broad survey of the interrelationship between the state and economy in Latin America as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS337. INTERNATIONAL POLITICAL ECONOMY OF ASIA. 3.0 Semester Hrs.

A broad survey of the interrelationship between the state and economy in East and Southeast Asia as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS339. INTERNATIONAL POLITICAL ECONOMY OF THE MIDDLE EAST. 3.0 Semester Hrs.

A broad survey of the interrelationships between the state and market in the Middle East as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS341. INTERNATIONAL POLITICAL ECONOMY OF AFRICA. 3.0 Semester Hrs.

A broad survey of the interrelationships between the state and market in Africa as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS344. INTERNATIONAL RELATIONS. 3.0 Semester Hrs.

This course surveys major topics and theories of international relations. Students will evaluate diverse perspectives and examine a variety of topics including war and peace, economic globalization, human rights and international law, international environmental issues, and the role of the US as the current superpower. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS345. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.

International Political Economy is a study of contentious and harmonious relationships between the state and the market on the nation-state level, between individual states and their markets on the regional level, and between region-states and region-markets on the global level. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS365. HISTORY OF WAR. 3.0 Semester Hrs.

History of War looks at war primarily as a significant human activity in the history of the Western World since the times of Greece and Rome to the present. The causes, strategies, results, and costs of various wars will be covered, with considerable focus on important military and political leaders as well as on noted historians and theoreticians. The course is primarily a lecture course with possible group and individual presentations as class size permits. Tests will be both objective and essay types. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS370. HISTORY OF SCIENCE. 3.0 Semester Hrs.

An introduction to the social history of science, exploring significant people, theories, and social practices in science, with special attention to the histories of physics, chemistry, earth sciences, ecology, and biology. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours lecture; 3 semester hours.

LAIS371. HISTORY OF TECHNOLOGY. 3.0 Semester Hrs.

A survey of the history of technology in the modern period (from roughly 1700 to the present), exploring the role technology has played in the political and social history of countries around the world. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours lecture; 3 semester hours.

LAIS375. ENGINEERING CULTURES. 3.0 Semester Hrs.

This course seeks to improve students' abilities to understand and assess engineering problem solving from different cultural, political, and historical perspectives. An exploration, by comparison and contrast, of engineering cultures in such settings as 20th century United States, Japan, former Soviet Union and presentday Russia, Europe, Southeast Asia, and Latin America. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS376. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.

(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student's learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

LAIS377. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.

(I) This course is an introduction to the relationship between engineering and sustainable community development (SCD) from historical, political, ideological, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of community and sustainable development and the role that engineering might play in them. Also students will critically explore strengths and limitations of dominant methods in engineering problem solving, design, and research for working in SCD. Students will learn to research, describe, analyze and evaluate case studies in SCD and develop criteria for their evaluation. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LAIS401. CREATIVE WRITING: POETRY II. 3.0 Semester Hrs.

This course is a continuation of LAIS301 for those interested in developing their poetry writing further. It focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and simulate the development of the student's craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students try on various styles and contexts in order to develop their own voice. Prerequisite: LAIS100 and LAIS301. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS404. WOMEN, LITERATURE, AND SOCIETY. 3.0 Semester Hrs.

This reading and writing intensive course examines the role that women writers have played in a range of literary traditions. Far from residing in the margins of key national debates, women writers have actively contributed their voices to demands for social, racial, economic, and artistic equality. We will examine the writing produced by women from a diversity of racial, ethnic, and social backgrounds, as we examine the ways in which women writers respond to the various pressures placed on them as artists and activists. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours seminar; 3 semester hours.

LAIS406. THE LITERATURE OF WAR AND REMEMBRANCE. 3.0 Semester Hrs.

In "The Literature of War and Remembrance," students survey poetry, prose, and film ranging from classical to contemporary war literature. The course considers literary depictions of the individual and society in war and its aftermath. Critical reading and writing skills are demonstrated in creative presentations and analytical essays. Students will investigate war literature and commemorative art inspired by recent world conflicts, and place a contemporary work into the thematic structure of the course. Prerequisite: LAIS100. Co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS407. SCIENCE IN LITERATURE. 3.0 Semester Hrs.

Science fiction often serves as a cautionary tale that deals with the darker side of humanity's desires in order to find a better understanding of who we are and what we hope to become. This class examines scientific and social progress as it is imagined by some of the greatest authors of the genre. We will examine the current events that may have influenced the writing and position our lens to the scientific and technological breakthroughs, as well as the social, cultural, and political state of the world at the time of our readings. This course focuses on classic science fiction from the late 1800's to the present which may include: Jules Verne, H.G. Wells, Sir Arthur Conan Doyle, Jack Williamson, Isaac Asimov, Robert Heinlein, Alfred Bester, Philip Jose Farmer, Marion Zimmer Bradley, Ray Bradbury, Philip K. Dick, William Gibson, Arthur C. Clarke, Ursula K. LeGuin and Mary Doria Russell, among others. Prerequisite: LAIS100, Co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS408. LIFE STORIES. 3.0 Semester Hrs.

Using texts by published authors and members of the class, we will explore the pleasures and challenges of creating and interpreting narratives based on "real life." The class will consider critical theories about the relationship between the self and the stories we tell. Prerequisite: LAIS100. Pre-requisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS409. SHAKESPEAREAN DRAMA. 3.0 Semester Hrs.

Shakespeare, the most well known writer in English and perhaps the world, deals with universal themes and the ultimate nature of what it is to be a human being. His plays are staged, filmed, and read around the globe, even after 400 years. This seminar will explore why Shakespeare's plays and characters have such lasting power and meaning to humanity. The seminar will combine class discussion, lecture, and video. Grades will be based on participation, response essays, and a final essay. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS410. CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE. 3.0 Semester Hrs.

This course introduces students to texts and cultural productions of the 20th Century literature. We will examine a diverse collection of materials, including novels and short stories, poems, plays, films, painting, and sculpture. Science, technology, violence, history, identity, language all come under the careful scrutiny of the authors we will discuss in this course, which may include Conrad, Fanon, Achebe, Eliot, Kafka, Barnes, Camus, Borges, and Marquez, among others. We will also screen films that comment upon the fragility of individual identity in the face of modern technology. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS411. LITERATURES OF THE AFRICAN WORLD. 3.0 Semester Hrs.

This course examines wide-ranging writers' depictions of collective transformations and conflicts integral to the making and remaking of African and Afro-diasporic communities worldwide. Fiction, poetry, and essays representing diverse linguistic, aesthetic, and philosophical traditions will constitute the bulk of the reading. Alongside their intrinsic expressive values, these texts illuminate religious and popular cultural practices important to social groups throughout much of sub-Saharan Africa, the Caribbean, Latin America, and the United States. Primary socio-historical themes may include the slave trade, plantation cultures, generational consciousness, ethnicity, gender relations, urbanization, and collective violence. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS412. LITERATURE AND THE ENVIRONMENT. 3.0 Semester Hrs.

This reading and writing intensive course investigates the human connection to the environment in a broad range of literary materials. Discussions focus on the role of place - of landscape as physical, cultural, moral, historical space - and on the relationship between landscape and community, history, and language in the environmental imagination. Readings include texts that celebrate the natural world, those that indict the careless use of land and resources, and those that predict and depict the consequences of that carelessness. Additionally, we investigate philosophical, legal, and policy frameworks that shape approaches to environmental issues. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS415. MASS MEDIA STUDIES. 3.0 Semester Hrs.

This introduction to mass media studies is designed to help students become more active interpreters of mass media messages, primarily those that emanate from television, radio, the Internet, sound recordings (music), and motion pictures (film, documentary, etc.). Taking a broad rhetorical and sociological perspective, the course examines a range of mass media topics and issues. Students should complete this course with enhanced rhetorical and sociological understandings of how media shapes individuals, societies, and cultures as well as how those groups shape the media. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS416. FILM STUDIES. 3.0 Semester Hrs.

This course introduces students to the basics of film history, form, and criticism. Students will be exposed to a variety of film forms, including documentary, narrative, and formalist films, and will be encouraged to discuss and write about these forms using critical film language. Students will have an opportunity to work on their own film projects and to conduct research into the relationship between films and their historical, cultural, and ideological origins. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS418. NARRATING THE NATION. 3.0 Semester Hrs.

The novel, nationalism, and the modern nation-state share the same eighteenth and nineteenth-century roots. Relationships between the works of novelists, local nationalisms, and state politics have, however, always been volatile. These tensions have assumed particularly dramatic expressive and political forms in Latin America and postcolonial South Asia and Africa. This course examines the inspirations, stakes, and ramifications of celebrated novelists' explorations of the conflicted and fragmentary character their own and/or neighboring nationstates. Beyond their intrinsic literary values, these texts illuminate distinctive religious, ritual, and popular cultural practices that have shaped collective imaginings of the nation, as well as oscillations in nationalist sentiment across specific regions and historical junctures. Studies in relevant visual media -films, paintings, and telenovelas - will further our comparative inquiry into the relationships between artistic narrative and critical perspectives on "the nation." Alongside the focal literary and visual texts, the course will address major historians' and social theorists' accounts of the origins, spread, and varied careers of nationalist thought and practice across our modern world. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS419. MEDIA AND THE ENVIRONMENT. 3.0 Semester Hrs.

This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in environmental communication, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of environmentalism and the natural world are constructed. Students will analyze their role as science communicators and will participate in the creation of communication projects related to environmental research on campus or beyond. Prerequisite: LAIS100. Prerequisite or co-requisite LAIS200. 3 hours seminar; 3 semester hours.

LAIS421. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.

A critical examination of environmental ethics and the philosophical theories on which they depend. Topics may include preservation/conservation, animal welfare, deep ecology, the land ethic, eco-feminism, environmental justice, sustainability, or non-western approaches. This class may also include analyses of select, contemporary environmental issues. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS423. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.

This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS424. RHETORIC, ENERGY AND PUBLIC POLICY. 3.0 Semester Hrs.

(I) This course will examine the ways in which rhetoric shapes public policy debates on energy. Students will learn how contemporary rhetorical and public policy theory illuminates debates that can affect environmental, economic and/or socio-cultural aspects of energy use, transportation and production. 3 hour seminar; 3 credit hours. Prerequisite: LAIS 100; Pre-or Co-requisite: LAIS200.

LAIS426. SCIENTIFIC CONTROVERSIES. 3.0 Semester Hrs.

(I, II) Examines national and international, historical and contemporary scientific and engineering controversies. In particular, the course provides students with a window into how scientific controversies arise, evolve, and are resolved both within scientific circles and in the public arena. By exploring case studies of such controversies, students gain a better understanding about how scientific controversies shape and are shaped by communication as well as by public policy. Prerequisite: LAIS100. Corequisite: LAIS200. 3 hours lecture, 3 semester hours.

LAIS429. REAL WORLD RECORDING/RESEARCH. 3.0 Semester Hrs.

(WI) This reading and writing-intensive course explores the acoustical, musical, and technical aspects of recording a variety of live ethnomusicological music genres and/or performances, towards the purpose of learning how to research, document and capture the most accurate and authentic recording. Historical research, non-traditional recording techniques; archival documentation, and editing will all be a part of this course. Prerequisites: LAIS100 and either LAIS315 or LAIS327. Co-requisites: LAIS200. 3 semester hours.

LAIS430. CORPORATE SOCIAL RESPONSIBILITY. 3.0 Semester Hrs.

Businesses are largely responsible for creating the wealth upon which the well-being of society depends. As they create that wealth, their actions impact society, which is composed of a wide variety of stakeholders. In turn, society shapes the rules and expectations by which businesses must navigate their internal and external environments. This interaction between corporations and society (in its broadest sense) is the concern of Corporate Social Responsibility (CSR). This course explores the dimensions of that interaction from a multi-stakeholder perspective using case studies, guest speakers and field work. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS431. RELIGION & SECURITY. 3.0 Semester Hrs.

This course introduces students to the central topics in religion and society. It defines civil society in 21st century contexts and connects this definition with leading debates about the relationship of religion and security. It creates an understanding of diverse religious traditions from the perspective of how they view security. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours lecture and discussion; 3 semester hours.

LAIS435. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.

A seminar designed to explore the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization, institution-building, corporate-community-state interfaces, neoliberalism, privatization, democracy, and public policy formulation as it relates to development goals. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS437. ASIAN DEVELOPMENT. 3.0 Semester Hrs.

This international political economy seminar deals with the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS439. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.

This international political economy seminar analyzes economic, political and social dynamics that affect the progress and direction of states, markets, and peoples of the region. It examines the development of the Middle East from agrarian to post-industrial societies; economic, political and cultural transformations since World War II; contemporary security issues that both divide and unite the region; and the effects of globalization processes on economies and societies in the Middle East. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS440. WAR AND PEACE IN THE MIDDLE EAST. 3.0 Semester Hrs.

This course introduces students to theories of war and then discusses a select number of historical wars and contemporary ones. It also analyzes efforts at peace-making efforts and why some fail and others succeed. The global consequences of war and peace in the Middle East will be explored in terms of oil supply and of other geostrategic interests that America has in that region. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS441. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.

This course provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS442. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.

Africa possesses abundant natural resources yet suffers civil wars and international conflicts based on access to resource revenues. The course examines the distinctive history of Africa, the impact of the resource curse, mismanagement of government and corruption, and specific cases of unrest and war in Africa. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS446. GLOBALIZATION. 3.0 Semester Hrs.

This international political economy seminar is an historical and contemporary analysis of globalization processes examined through selected issues of world affairs of political, economic, military, and diplomatic significance. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS448. GLOBAL ENVIRONMENTAL ISSUES. 3.0 Semester Hrs.

Critical examination of interactions between development and the environment and the human dimensions of global change; social, political, economic, and cultural responses to the management and preservation of natural resources and ecosystems on a global scale. Exploration of the meaning and implications of "Stewardship of the Earth" and "Sustainable Development." Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS450. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.

This course will review the existing methodologies and techniques of risk assessment in both country-specific and global environments. It will also seek to design better ways of assessing and evaluating risk factors for business and public diplomacy in the increasingly globalized context of economy and politics wherein the role of the state is being challenged and redefined. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. Prerequisite: At least one IPE 300- or 400-level course. 3 hours seminar; 3 semester hours.

LAIS451. POLITICAL RISK ASSESSMENT RESEARCH SEMINAR. 1.0 Semester Hr.

This international political economy seminar must be taken concurrently with LAIS450, Political Risk Assessment. Its purpose is to acquaint the student with empirical research methods and sources appropriate to conducting a political risk assessment study, and to hone the students' analytical abilities. Prerequisite: LAIS100. Prerequisite or corequisite: LAIS200. Concurrent enrollment in LAIS450. 1 hour seminar; 1 semester hour.

LAIS452. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.

This course addresses the problem of corruption and its impact on development. Readings are multi disciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or bribe taking might occur. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS453. ETHNIC CONFLICT IN GLOBAL PERSPECTIVE. 3.0 Semester Hrs.

Many scholars used to believe that with modernization, racial, religious, and cultural antagonisms would weaken as individuals developed more rational outlooks and gave primacy to their economic concerns. Yet, with the waning of global ideological conflict of the left-right nature, conflict based on cultural and "civilization" differences have come to the fore in both developing and developed countries. This course will examine ethnic conflict, broadly conceived, in a variety of contexts. Case studies will include the civil war in Yugoslavia, the LA riots, the antagonism between the Chinese and "indigenous" groups in Southeast, the so-called war between the West and Islam, and ethnic relations in the U.S. We will consider ethnic contention in both institutionalized, political processes, such as the politics of affirmative action, as well as in non-institutionalized, extra-legal settings, such as ethnic riots, pogroms, and genocide. We will end by asking what can be done to mitigate ethnic conflict and what might be the future of ethnic group identification. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS456. POWER AND POLITICS IN EURASIA. 3.0 Semester Hrs.

This seminar covers the major internal and international issues confronting the fifteen states that once comprised the Soviet Union. After an overview of the USSR and its collapse in 1991, the course explores subsequent economic and security dilemmas facing the "new" nations of Eurasia. Special attention will be paid to oil, natural gas, and other energy sectors in the region. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS457. INTRODUCTION TO CONFLICT MANAGEMENT. 3.0 Semester Hrs.

This course introduces students to central topics in conflict management. It assesses the causes of contemporary conflicts with an initial focus on weak states, armed insurgencies, and ethnic conflict. It then examines a range of peace-building efforts, and strategies for reconstructing post-conflict states. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS460. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.

This seminar examines geopolitical competition between great and aspiring powers for influence, control over land and natural resources, critical geo-strategic trade routes, or even infrastructure. Using empirical evidence from case studies, students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of foreign policies, as well as issues of war and peace. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 credit hours.

LAIS464. HISTORY OF ENERGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

(II) This course examines the major patterns of human energy use and interaction with the natural environment on a global scale from the origins of civilization to the present day. Topics analyzed include the dynamics of historical change in energy and resource use, the ways in which energy and the environment have shaped the development of past societies, cultural perceptions of energy and the environment during different historical eras, and the impact of past human activities on natural systems. Analysis of historical trends will also serve as a basis for discussions related to current issues in energy and the environment. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture/seminar; 3 semester hours.

LAIS467. HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES. 3.0 Semester Hrs.

This course provides an overview of the history of some of the key sciences that help us understand the world we inhabit: geology, climatology, evolutionary biology, and ecology. As we investigate key scientific discoveries of the modern era, we will also consider the philosophical and cultural impacts of those scientific discoveries. Thus, our reading will include not only original texts by scientists, but also key literary, historical and other texts inspired by those discoveries. Prerequisites: LAIS100. Co-requisites: LAIS200. 3 hours lecture; 3 semester hours.

LAIS475. ENGINEERING CULTURES IN THE DEVELOPING WORLD. 3.0 Semester Hrs.

An investigation and assessment of engineering problem-solving in the developing world using historical and cultural cases. Countries to be included range across Africa, Asia, and Latin America. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS478. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.

(II) This course offers students the opportunity to explore the relationships between engineering and social justice. The course begins with students' exploration of their own social locations, alliances and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Then the course helps students to understand what constitutes social justice in different areas of social life and the role that engineers and engineering might play in these. Finally, the course gives students an understanding of why and how engineering has been aligned and/or divergent from social justice issues and causes. 3 hours lecture and discussion; 3 semester hours. Prerequisite: LAIS100; pre- or co-requisite: LAIS200.

LAIS485. CONSTITUTIONAL LAW AND POLITICS. 3.0 Semester Hrs.

This course presents a comprehensive survey of the U.S. Constitution with special attention devoted to the first ten Amendments, also known as the Bill of Rights. Since the Constitution is primarily a legal document, the class will adopt a legal approach to constitutional interpretation. However, as the historical and political context of constitutional interpretation is inseparable from the legal analysis, these areas will also be covered. Significant current developments in constitutional jurisprudence will also be examined. The first part of the course deals with Articles I through III of the Constitution, which specify the division of national governmental power among the executive, legislative, and judicial branches of government. Additionally, the federal nature of the American governmental system, in which governmental authority is apportioned between the national government and the state governments, will be studied. The second part of the course examines the individual rights specifically protected by the amendments to the Constitution, principally the First, Fourth, Fifth, Sixth, Eighth, and Fourteenth Amendments. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS486. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.

An examination of current issues relating to science and technology policy in the United States and, as appropriate, in other countries. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS487. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.

Seminar on environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS488. WATER POLITICS AND POLICY. 3.0 Semester Hrs.

Seminar on water policies and the political and governmental processes that produce them, as an exemplar of natural resource politics and policy in general. Group discussion and independent research on specific politics and policy issues. Primary but not exclusive focus on the U.S. Pre requisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS489. NUCLEAR POWER AND PUBLIC POLICY. 3.0 Semester Hrs.

A general introduction to research and practice concerning policies and practices relevant to the development and management of nuclear power. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours seminar; 3 semester hours.

LAIS490. ENERGY AND SOCIETY. 3.0 Semester Hrs.

Equivalent with ENGY490, MNGN490, (I,II) An interdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development as these affect particular communities and societies. Prerequisite: LAIS100. Prerequisite or co-requisite: LAIS200. 3 hours lecture; 3 semester hours.

LAIS498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LAIS499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL113. SPANISH I. 3.0 Semester Hrs.

Fundamentals of spoken and written Spanish with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Spanish American culture. 3 semester hours.

LIFL114. ARABIC I. 3.0 Semester Hrs.

Fundamentals of spoken and written Arabic with an emphasis on vocabulary, idiomatic expressions of daily conversation, and culture of Arabic-speaking societies. 3 semester hours.

LIFL115. GERMAN I. 3.0 Semester Hrs.

Fundamentals of spoken and written German with an emphasis on vocabulary, idiomatic expressions of daily conversation, and German culture. 3 semester hours.

LIFL119. FRENCH I. 3.0 Semester Hrs.

(I) French I provides basic instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Successful completion of French I will allow students to further their french studies in level 2. 3 hours lecture, 3 semester hours.

LIFL123. SPANISH II. 3.0 Semester Hrs.

Continuation of Spanish I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL124. ARABIC II. 3.0 Semester Hrs.

Continuation of Arabic I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and culture of Arabic speaking societies. 3 semester hours.

LIFL125. GERMAN II. 3.0 Semester Hrs.

Continuation of German I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL129. FRENCH II. 3.0 Semester Hrs.

(II) French 2 provides continued instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Prerequisites: LIFL119. 3 hours lecture.

LIFL198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL213. SPANISH III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL214. ARABIC III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and culture of Arabic-speaking societies. 3 semester hours.

LIFL215. GERMAN III. 3.0 Semester Hrs.

Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL299. INDEPENDENT STUDY. 6.0 Semester Hrs.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU101. BAND - FRESHMAN. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU102. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU111. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU112. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU189. INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION. 1.0 Semester Hr.

(I, II) The course affords the student an opportunity to study privately with CSM music faculty on a wide range of instruments including guitar, piano, bass guitar, voice, saxophone, flute, drums and world instruments. Students will be required to practice regularly and demonstrate proficiency on their instrument/voice. Topics of this class will include performance etiquette, musicianship, musical styles, stylistic vocabulary, foreign language and basic music theory. 1 credit hour.

LIMU198. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU201. BAND - SOPHOMORE. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU202. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU211. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU212. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU301. BAND - JUNIOR. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU302. BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU311. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU312. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU401. BAND - SENIOR. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU402. JAZZ ENSEMBLE/PEP BAND. 1.0 Semester Hr.

Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU411. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU412. CHORUS. 1.0 Semester Hr.

Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU421. JAZZ ENSEMBLE/PEP BAND - FALL. 1.0 Semester Hr.

FALL The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance (s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU422. JAZZ ENSEMBLE/PEP BAND - SPRING. 1.0 Semester Hr.

SPRING The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU423. JAZZ LAB. 1.0 Semester Hr.

The Jazz Lab provides an opportunity for students to participate in a musical ensemble in the jazz combo format. Jazz music is a unique American art form. The jazz combo format is an exciting way for students to experience the joy and sense of achievement of performing this great American music form. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU450. MUSIC TECHNOLOGY CAPSTONE COURSE. 3.0 Semester Hrs.

Project-based course designed to develop practical technological and communication skills for direct application to the music recording. Prerequisite: LIMU340 and LIMU350. 3 hours seminar; 3 semester hours.

LIMU498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Operations Research

2015-2016

Minor Program in Operations Research (OR)

The Operations Research minor consists of a minimum of 18 credit hours of a logical sequence of courses. Only three of these hours may be taken in the student's degree-granting department. Three of these hours must consist of a deterministic modeling course, three must consist of a stochastic modeling course, and no more than three must draw from a survey course (combining both stochastic and deterministic modeling).

The objectives of the minor are to supplement an engineering or applied science background with a formal approach to mathematical modeling that includes assessing and/or improving the performance of a system. Such a system could be naturally occurring or man-made. Examples of such systems are manufacturing lines, mines, wind farms, mechanical systems such as turbines and generators (or a collection of such objects), waste water treatment facilities, and chemical processes. The formal approach includes optimization, (e.g., linear programming, nonlinear programming, integer programming), decision analysis, stochastic modeling, and simulation.

Deterministic Modeling (minimum of one)

CSCI262	DATA STRUCTURES	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI406	ALGORITHMS	3.0
MATH406	ALGORITHMS	3.0
MATH332	LINEAR ALGEBRA	3.0
EBGN455	LINEAR PROGRAMMING	3.0
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS	3.0
EENG417	MODERN CONTROL DESIGN	3.0
MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN588	INTEGER OPTIMIZATION	3.0

Stochastic Modeling (minimum of one)

EBGN459	SUPPLY CHAIN MANAGEMENT	3.0
EBGN461	STOCHASTIC MODELS IN MANAGEMENT SCIENCE	3.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	3.0
EBGN560	DECISION ANALYSIS	3.0
MATH424	INTRODUCTION TO APPLIED STATISTICS	3.0
MATH438	STOCHASTIC MODELS	3.0
MNGN438	GEOSTATISTICS	3.0
PEGN438	PETROLEUM GEOSTATISTICS	3.0
MTGN450	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0

Survey Course (Maximum of one)

EBGN325	OPERATIONS RESEARCH	3.0
MNGN433	MINE SYSTEMS ANALYSIS I	3.0

Space and Planetary Science and Engineering

General CSM Minor/ASI requirements can be found here (p. 33).

Programs Offered

Area of Special Interest in Space and Planetary Science and Engineering

Program Description

The Space and Planetary Science and Engineering Program offers an Area of Special Interest for students interested in the science and exploration of space. This program brings together courses from five CSM departments and programs covering a diverse array of topics, including planetary science, astronomy, space exploration, and the engineering and design of instrumentation for space exploration. The curriculum can be chosen from a list of approved courses, in consultation with an SPSE program advisor. Interested students should contact Dr. Jeff Andrews-Hanna, Director of SPSE. (jcahanna@mines.edu)

Since the advent of the space age in the middle of the last century, the pace of human and robotic exploration of space has been ever increasing. This exploration is made possible by feats of engineering to allow long-term operation of robotic and human explorers in the harsh environment of space. The product of this exploration is a large and

growing body of knowledge about our neighbors in the Solar System and our place in the universe. The mission of the Space and Planetary Science and Engineering (SPSE) program is to provide students with a pathway for studying extraterrestrial applications of science, engineering, and resource utilization through an Area of Special Interest.

General CSM Minor/ASI requirements can be found here (p. 33).

Program Requirements

Area of Special Interest in Space and Planetary Science and Engineering:

Enrollment in the Area of Special Interest is approved by the Director or Associate Director. Students will then be assigned to an SPSE ASI advisor from among the faculty listed above, who will monitor and advise their progress. The Area of Special Interest requires a total of 12 credits, up to 3 of which may be at the 200 level or below, up to 3 of which may overlap with the requirements of the degree-granting program. Students may choose their ASI courses from the list of approved courses below or from any additional courses approved by the students' ASI advisor. Application of EPICS or Senior Design credits towards the ASI requires choice of a space or planetary related project and approval by the students' SPSE ASI advisor.

SPSE-approved Courses

EPIC251	DESIGN (EPICS) II	3.0
EGGN408	INTRODUCTION TO SPACE EXPLORATION	1.0
EGGNnull491/492	SENIOR DESIGN I	3.0
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0
GEOL410	PLANETARY GEOLOGY	2.0
GPGN438	GEOPHYSICS PROJECT DESIGN	1-3
GPGN/ GEOLnull470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
GPGN475	PLANETARY GEOPHYSICS	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
PHGN424	ASTROPHYSICS	3.0
PHGNnull471/481	SENIOR DESIGN PRINCIPLES I	0.5
PHGNnull472/482	SENIOR DESIGN PRINCIPLES II	0.5

Professors

Uwe Greife , Department of Physics

Thomas Furtack , Department of Physics, Department Head

Thomas Furtak, Minors and Areas of Special Interest Only, SPSE Program Advisor

Gary R. Olhoeft, Department of Geophysics and Geophysical Engineering

Assistant professors

Jeffrey C. Andrews-Hanna, Minors and Areas of Special Interest Only, SPSE Director

Jeffrey C. Andrews-Hanna, Department of Geophysics and Geophysical Engineering

John R. Spear, Department of Environmental Science and Engineering

Professor emeritus

F. Edward Cecil, Department of Physics

Teaching professor

Joel G. Duncan , Department of Geology and Geological Engineering

Teaching associate professor

Cynthia Norrgran , Department of Chemical Engineering

Research professor

Robert D. Knecht, Department of Chemical Engineering, Teaching Professor in EPICS

Associate research professor

Angel Abbud-Madrid, Minors and Areas of Special Interest Only, SPSE Associate Director

Assistant research professor

Christopher Dryer, Department of Engineering

Distinguished senior scientist

Warren Hamilton, Department of Geophysics and Geophysical Engineering

Underground Construction & Tunneling

General CSM Minor/ASI requirements can be found here (p. 33).

Programs Offered

Minor in Underground Construction and Tunneling (18.0 credit hours) and an Area of Special Interest (ASI) (12.0 credit hours).

Program Educational Objectives

Underground Construction and Tunneling is a growing discipline involving knowledge in the disciplines of mining engineering, geological engineering and civil engineering, among others. The Departments of Mining Engineering, Geology & Geological Engineering and Civil and Environmental Engineering offer an interdisciplinary Minor or Area of Special Interest (ASI) course of study that allows students from these departments to take a suite of courses providing them with a basis for work and further study in this field.

The objectives of the minor and ASI are to supplement an engineering background with a formal approach to subsurface engineering that includes site characterization, design and construction of underground infrastructure, including water, storm water, highway or subway tunnels and subsurface facilities.

General CSM Minor/ASI requirements can be found here (p. 33).

Curriculum

The Underground Construction & Tunneling minor consists of a minimum of 18 credit hours of coursework from the list below. An Area of Special Interest (ASI) in Underground Construction & Tunneling requires 12

credit hours of coursework from the list below. A student's advisor may authorize a student's Minor or Area of Special Interest (ASI) application. For questions about the minor and to request consideration of additional courses including independent study, students should meet with a UC&T faculty member. The petition process requires one month to complete.

Program Requirements:

Required Courses (Minor)

CEEN312	SOIL MECHANICS	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0
MNGN404	TUNNELING	3.0
GEGN466 or GEGN467	GROUNDWATER ENGINEERING	3.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0

Electives (Minor)

CEEN314	STRUCTURAL THEORY	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN415	FOUNDATION ENGINEERING	3.0
CEEN499	INDEPENDENT STUDY	1-6
CEEN520	EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS	3.0
CEEN523	ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND	3.0
GEOL308	INTRODUCTORY APPLIED STRUCTURAL GEOLOGY	3.0
or GEOL309 or GEOL311	STRUCTURAL GEOLOGY AND TECTONICS STRUCTURAL GEOLOGY FOR MINING ENGINEERS	
GEGN473	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN499	INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY	1-6
MNGN406	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0
MNGN407	ROCK FRAGMENTATION	3.0
MNGN408	UNDERGROUND DESIGN AND CONSTRUCTION	2.0
MNGN410	EXCAVATION PROJECT MANAGEMENT	2.0
MNGN418	ADVANCED ROCK MECHANICS	3.0
MNGN424	MINE VENTILATION	3.0
MNGN499	INDEPENDENT STUDY	1-6

Required Courses (Area of Special Interest - ASI)

CEEN312	SOIL MECHANICS	3.0
MNGN321	INTRODUCTION TO ROCK MECHANICS	3.0
MNGN404	TUNNELING	3.0

Electives (Area of Special Interest - ASI)

Students may choose one course from the required Minor courses or elective courses listed above.

Department of Civil & Environmental Engineering

Marte Gutierrez, Professor

Michael Mooney, Professor

Department of Geology & Geological Engineering

Jerry Higgins, Associate Professor

Wendy Zhou, Associate Professor

Department of Mining Engineering

Hugh Miller, Associate Professor

Ray Henn, Adjunct Professor

Priscilla Nelson, Professor & Department Head

Special Programs

Please select from the list of links on the right for more information about the various special programs offered to undergraduate students at the Colorado School of Mines.

Division of Liberal Arts and International Studies (LAIS) Writing Center

Located in room 309 Stratton Hall (phone: 303-273-3085), the LAIS Writing Center is a teaching facility providing all CSM students with an opportunity to enhance their writing proficiency. The LAIS Writing Center faculty are experienced technical and professional writing instructors. The Center assists writers with all their writing needs, from course assignments to scholarship applications, proposals, letters and resumes. This service is free to CSM students and includes one-to-one tutoring and online resources. <http://inside.mines.edu/LAIS-Writing-Center->

Skills Building Courses

The following courses are offered by various Administrative departments on campus to give students the opportunity to build valuable skills to assist with their academic and professional development.

The Freshman Seminar course, CSM101, is a required course and is part of the undergraduate degree requirements. All incoming Freshman will be registered for this course during their first semester at Mines. Incoming Transfer students may be eligible to receive transfer credit for this course to meet their degree requirements, based on previously completed coursework at the college level.

Transfer students who have successfully completed fewer than 30.0 transcribed semester hours at an institution of higher education after high school graduation will automatically be enrolled in CSM101.

CSM101	FRESHMAN SUCCESS SEMINAR	0.5
CSM151	SPATIAL VISUALIZATION AND MODELING FOR ENGINEERING AND APPLIED SCIENCE STUDENTS	1.0
CSM250	ENGINEERING YOUR CAREER PATH	1.0

CSM275	CASA BOUNCE BACK PROGRAM	1.0
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For more information about CSM101 and CSM151, contact the Center for Academic Services and Advising (CASA) (<http://inside.mines.edu/CASAhome>).

For more information about CSM250, contact the Career Center (<http://careers.mines.edu>).

Study Abroad

2015-2016

Students wishing to pursue study abroad opportunities, either coursework, internships or research should contact the Office of International Programs (OIP), listed under the Services Section (p. 364) of this Bulletin. Colorado School of Mines encourages students to include an international study/work experience in their undergraduate education. CSM maintains student exchange programs with engineering universities in South America, Europe, Australia, Africa, and Asia. Courses pre-approved, taken and successfully passed with a grade of "C" or better at a partner university abroad can be substituted for their equivalent course at CSM. Overall GPA is not affected by courses taken abroad. In addition, study abroad can be arranged on an individual basis at universities throughout the world.

Financial aid and selected scholarships and grants can be used to finance approved study abroad programs. International University partners may have additional scholarship funding for study abroad or internship programs. The OIP has developed a resource center for study abroad information in its office, 1706 Illinois Street, phone 303-384-2121. Students are invited to use the resource materials and meet with staff to discuss overseas study opportunities.

Writing Across the Curriculum (WAC)

To support the institutional goal of developing professional communication skills, required writing and communication-intensive courses are designated in both the core and in the degree-granting programs. According to guidelines approved by the Undergraduate Council, degree-granting programs are to identify four courses, often two junior and two senior-level courses, as writing-intensive. The (generally four) writing-intensive courses within the various degree-granting programs are designated with (WI) in their course descriptions. Course descriptions can be found on the Undergraduate Programs and Departments page, under the Courses tab for each department.

In addition to disciplinary writing experience, students also obtain writing experience outside their disciplines as courses in LAIS are virtually all writing intensive. The Campus Writing Program, housed in the Division of Liberal Arts and International Studies (LAIS), supports the WAC program.

Graduate

2015-2016

To Mines Graduate Students:

This Bulletin is for your use as a source of continuing reference. Please save it.

Published by:

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Golden, CO 80401

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<http://gradschool.mines.edu/GS-Graduate-Office-Staff>

General Information

2015-2016

Institutional Values and Principles

Graduate Education

The Colorado School of Mines is dedicated to serving the people of Colorado, the nation and the global community by providing high quality educational and research experiences to students in science, engineering and related areas that support the institutional mission. Recognizing the importance of responsible earth stewardship, Mines places particular emphasis on those fields related to the discovery, production and utilization of resources needed to improve the quality of life of the world's inhabitants and to sustain the earth system upon which all life and development depend. To this end, Mines is devoted to creating a learning community that provides students with perspectives informed by the humanities and social sciences, perspectives that also enhance students' understanding of themselves and their role in contemporary society. Mines therefore seeks to instill in all graduate students a broad class of developmental and educational attributes that are guided by a set of institutionally vetted educational objectives and student learning outcomes. For doctoral and masters degree programs, these are summarized below.

Doctoral Programs

Institutional Educational Objectives:

1. PhD graduates will advance the state of the art of their discipline (integrating existing knowledge and creating new knowledge) by conducting independent research that addresses relevant disciplinary issues and by disseminating their research results to appropriate target audiences.
2. PhD graduates will be scholars and international leaders who exhibit the highest standards of integrity.
3. PhD graduates will advance in their professions and assume leadership positions in industry, government and academia.

Institutional Student Outcomes:

1. Demonstration of exemplary disciplinary expertise.
2. Demonstration of a set of skills and attitudes usually associated with our understanding of what it is to be an academic scholar (e.g., intellectual curiosity, intellectual integrity, ability to think critically and argue persuasively, the exercise of intellectual independence, a passion for life-long learning, etc.).
3. Demonstration of a set of professional skills (e.g., oral and written communication, time-management, project planning, teaching, teamwork and team leadership, cross-cultural and diversity awareness, etc.) necessary to succeed in a student's chosen career path.

Masters Programs

The Colorado School of Mines offers a wide variety of Masters-level degree programs that include thesis and non-thesis Master of Science programs, Master of Engineering programs, Professional Master's programs and a Master of International Political Economy of Resources. While the objectives and outcomes provided below document expectations of all Masters-level programs, it is expected that given the diversity of program types, different programs will emphasize some objectives and outcomes more than others.

Institutional Educational Objectives:

1. Masters graduates will contribute to the advancement of their chosen fields through adopting, applying and evaluating state-of-the-art practices.
2. Masters graduates will be viewed within their organizations as technologically advanced and abreast of the latest scholarship.
3. Masters graduates will exhibit the highest standards of integrity in applying scholarship.
4. Masters graduates will advance in their professions.

Institutional Student Outcomes:

1. Graduates will demonstrate exemplary disciplinary expertise.
2. Graduates will demonstrate the ability to conduct direct research; the ability to assimilate and assess scholarship; and the ability to apply scholarship in new, creative and productive ways.
3. Graduates will demonstrate professional skills (e.g., oral and written communication, time-management, project planning, teamwork and team leadership, cross-cultural and diversity awareness, ethics, etc.) necessary to succeed in a student's chosen career path.

Research

The creation and dissemination of new knowledge are primary responsibilities of all members of the university community and fundamental to the educational and societal missions of the institution. Public institutions have an additional responsibility to use that knowledge to contribute to the economic growth and public welfare of the society from which they receive their charter and support. As a public institution of higher education, a fundamental responsibility of Mines is to provide an environment that enables contribution to the public good by encouraging creative research and ensuring the free exchange of ideas, information, and results. To this end, the institution acknowledges the following responsibilities:

- To insure that these activities are conducted in an environment of minimum influence and bias, it is essential that Mines protect the academic freedom of all members of its community.
- To provide the mechanisms for creation and dissemination of knowledge, the institution recognizes that access to information and information technology (e.g. library, computing and internet resources) are part of the basic infrastructure support to which every member of the community is entitled.
- To promote the utilization and application of knowledge, it is incumbent upon Mines to define and protect the intellectual-property rights and responsibilities of faculty members, students, as well as the institution.
- To insure integration of research activities into its basic educational mission, its research policies and practices conform to the state non-competition law requiring all research projects have an educational component through the involvement of students and/or post-doctoral fellows.

Intellectual Property

The creation and dissemination of knowledge are primary responsibilities of all members of the university community. As an institution of higher education, a fundamental mission of Mines is to provide an environment that motivates the faculty and promotes the creation, dissemination, and application of knowledge through the timely and free exchange of ideas, information, and research results for the public good. To insure that these activities are conducted in an environment of minimum influence and bias, so as to benefit society and the people of Colorado, it is essential that Mines protect the academic freedom of all members of its community. It is incumbent upon Mines to help promote the utilization and application of knowledge by defining and protecting the rights and responsibilities of faculty members, students and the institution, with respect to intellectual property which may be created while an individual is employed as a faculty member or enrolled as a student.

History of Colorado School of Mines

In 1865, only six years after gold and silver were discovered in the Colorado Territory, the fledgling mining industry was in trouble. The nuggets had been picked out of streams and the rich veins had been worked, and new methods of exploration, mining, and recovery were needed.

Early pioneers like W.A.H. Loveland, E.L. Berthoud, Arthur Lakes, George West and Episcopal Bishop George M. Randall proposed a school of mines. In 1874 the Territorial Legislature appropriated \$5,000 and commissioned Loveland and a Board of Trustees to found the Territorial School of Mines in or near Golden. Governor Routt signed the Bill on February 9, 1874, and when Colorado became a state in 1876, the Colorado School of Mines was constitutionally established. The first diploma was awarded in 1883.

As Mines grew, its mission expanded from the rather narrow initial focus on nonfuel minerals to programs in petroleum production and refining as well. Recently it has added programs in materials science and engineering, energy and environmental engineering, and a broad range of other engineering and applied science disciplines. Mines sees its mission as education and research in engineering and applied science with a special focus on the earth science disciplines in the context of responsible stewardship of the earth and its resources.

Mines long has had an international reputation. Students have come from nearly every nation, and alumni can be found in every corner of the globe.

Location

Golden, Colorado, has always been the home of Mines. Located in the foothills of the Rocky Mountains 20 minutes west of Denver, this community of 15,000 also serves as home to the Coors Brewing Company, the National Renewable Energy Laboratory, and a major U.S. Geological Survey facility that also contains the National Earthquake Center. The seat of government for Jefferson County, Golden once served as the territorial capital of Colorado. Skiing is an hour away to the west.

Administration

By State statute, the school is managed by a seven-member board of trustees appointed by the governor, and the student and faculty bodies elect one nonvoting board member each. The school is supported financially by student tuition and fees and by the State through annual appropriations. These funds are augmented by government and privately sponsored research, and private gift support from alumni, corporations, foundations and other friends.

Colorado School of Mines Non-Discrimination Statement

In compliance with federal law, including the provisions of Titles VI and VII of the Civil Rights Act of 1964, Title IX of the Education Amendment of 1972, Sections 503 and 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA) of 1990, the ADA Amendments Act of 2008, Executive Order 11246, the Uniformed Services Employment and Reemployment Rights Act, as amended, the Genetic Information Nondiscrimination Act of 2008, and Board of Trustees Policy 10.6, the Colorado School of Mines does not discriminate against individuals on the basis of age, sex, sexual orientation, gender identity, gender expression, race, religion, ethnicity, national origin, disability, military service, or genetic information in its administration of educational policies, programs, or activities; admissions policies; scholarship and loan programs; athletic or other school-administered programs; or employment.

Inquiries, concerns, or complaints should be directed by subject content as follows:

The Employment-related EEO and discrimination contact is:
Mike Dougherty, Associate Vice President for Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for employment is:

Ann Hix, Benefits Manager, Human Resources
Guggenheim Hall, Room 110
Golden, Colorado 80401
(Telephone: 303.273.3250)

The ADA Coordinator and the Section 504 Coordinator for students and academic educational programs is:

Kristen Wieger, Coordinator of Student Disability Services
Student Wellness Center, 1770 Elm Street
Golden, Colorado 80401

(Telephone: 303.273.3377)

The Title IX Coordinator is:
Karin Ranta-Curran, Assistant Director of HR for EEO and Equity
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.384.2558)
(E-Mail: krcurran@mines.edu)

The ADA Facilities Access Coordinator is:
Gary Bowersock, Director of Facilities Management
1318 Maple Street
Golden, Colorado 80401
(Telephone: 303.273.3330)

The Graduate School

2015-2016

<http://gradschool.mines.edu>

Unique Programs

Because of its special focus, Colorado School of Mines has unique programs in many fields. For example, Mines is the only institution in the world that offers doctoral programs in all five of the major earth science disciplines: Geology and Geological Engineering, Geophysics, Geochemistry, Mining Engineering, and Petroleum Engineering. It also has one of the few Metallurgical and Materials Engineering programs in the country that still focuses on the complete materials cycle from mineral processing to finished advanced materials.

In addition to the traditional programs defining the institutional focus, Mines is pioneering both undergraduate and graduate interdisciplinary programs. The School understands that solutions to the complex problems involving global processes and quality of life issues require cooperation among scientists, engineers, economists, and the humanities.

Mines offers interdisciplinary programs in areas such as materials science, hydrology, nuclear engineering and geochemistry. These programs make interdisciplinary connections between traditional fields of engineering, physical science and social science, emphasizing a broad exposure to fundamental principles while cross-linking information from traditional disciplines to create the insight needed for breakthroughs in the solution of modern problems. Additional interdisciplinary degree programs may be created by Mines' faculty as need arises and offered with the degree title "Interdisciplinary". Currently, one additional interdisciplinary degree is offered through this program. It is a specialty offering in operations research with engineering.

Lastly, Mines offers a variety of non-thesis Professional Master's degrees to meet the career needs of working professionals in Mines' focus areas.

Graduate Degrees Offered

Mines offers professional master's, master of science (M.S.), master of engineering (M.E.) and doctor of philosophy (Ph.D.) degrees in the disciplines listed in the chart at right.

In addition to masters and Ph.D. degrees, departments and divisions can also offer graduate certificates. Graduate certificates are designed to have selective focus, short time to completion and consist of course work only.

Accreditation

Mines is accredited through the doctoral degree by:
the Higher Learning Commission (HLC) of the North Central Association
230 South LaSalle Street, Suite 7-500
Chicago, Illinois 60604-1413
telephone (312) 263-0456

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology
111 Market Place, Suite 1050
Baltimore, MD 21202-4012
telephone (410) 347-7700

accredits undergraduate degree programs in chemical engineering, engineering, engineering physics, geological engineering, geophysical engineering, metallurgical and materials engineering, mining engineering and petroleum engineering. The American Chemical Society has approved the degree program in the Department of Chemistry and Geochemistry.

Degree Programs	Prof.	M.S.	M.E.	Ph.D.
Applied Mathematics and Statistics		x		x
Applied Physics		x		x
Chemical Engineering		x		x
Chemistry		x		
Applied Chemistry				x
Civil & Environmental Engineering		x		x
Computer Sciences		x		x
Electrical Engineering		x		x
Engineering Systems		x		x
Engineering & Technology Management		x		
Environmental Geochemistry	x			
Environmental Engineering & Science		x		x
Geochemistry		x		x
Geological Engineering		x	x	x
Geology		x		x
Geophysical Engineering		x		x
Geophysics		x		x
Hydrology		x		x
International Political Economy & Resources		x*		
Materials Science		x		x
Mechanical Engineering		x		x
Metallurgical & Materials Engineering		x	x	x
Mineral & Energy Economics		x		x
Mineral Exploration	x			
Mining & Earth Systems Engineering		x	x	x
Nuclear Engineering		x	x	x
Operations Research with Engineering**				x
Petroleum Engineering		x	x	x
Petroleum Reservoir Systems	x			
Underground Construction and Tunneling		x		x

* Master of International Political Economy of Resources

** Interdisciplinary degree with specialty in Operations Research with Engineering

Admission to the Graduate School

2015-2016

Admission Requirements

The Graduate School of Colorado School of Mines is open to graduates from four-year programs at recognized colleges or universities. Admission to all graduate programs is competitive, based on an evaluation of prior academic performance, test scores and references. The academic background of each applicant is evaluated according to the requirements of each department outlined later in this section of the Bulletin.

To be a candidate for a graduate degree, students must have completed an appropriate undergraduate degree program. Colorado School of Mines undergraduate students in the Combined Degree Program may, however, work toward completion of graduate degree requirements prior to completing undergraduate degree requirements. See the Combined Undergraduate/Graduate Degree section of the Graduate Bulletin for details of this program.

Categories of Admission

There are four categories of admission to graduate studies at Colorado School of Mines: regular, provisional, graduate non-degree, and foreign exchange.

Regular Degree Students

Applicants who meet all the necessary qualifications as determined by the program to which they have applied are admitted as regular graduate students.

Provisional Degree Students

Applicants who are not qualified to enter the regular degree program directly may be admitted as provisional degree students for a trial period not longer than 12 months. During this period students must demonstrate their ability to work for an advanced degree as specified by the admitting degree program. After the first semester, the student may request that the department review his or her progress and make a decision concerning full degree status. With department approval, the credits earned under the provisional status can be applied towards the advanced degree.

Non-degree Students

Practicing professionals may wish to update their professional knowledge or broaden their areas of competence without committing themselves to a degree program. They may enroll for regular courses as non-degree students. Inquiries and applications should be made to:

The Graduate Office, CSM
Golden, CO 80401-0028
Phone: 303-273-3247

A person admitted as a nondegree student who subsequently decides to pursue a regular degree program must apply and gain admission to the Graduate School. All graduate-level credits earned as a non-degree student may be transferred into the regular degree program if the

student's graduate committee and department head approve. Transfer credits must not have been used as credit toward a Bachelor's degree.

Foreign Exchange Students

Graduate level students living outside of the U.S. may wish to take courses at Colorado School of Mines as exchange students. They may enroll for regular courses as foreign exchange students. Inquiries and applications should be made to:

The Office of International Programs, CSM
Golden, CO 80401-0028
Phone: 303-384-2121

A person admitted as a foreign exchange student who subsequently decides to pursue a regular degree program must apply and gain admission to the Graduate School. All graduate-level credits earned as a foreign exchange student and not used toward a bachelor's degree may be transferred into the regular degree program if the student's graduate committee and department head approve.

Combined Undergraduate/Graduate Programs

Several degree programs offer Mines undergraduate students the opportunity to begin work on a Graduate Degree while completing the requirements of their Bachelor Degree. These programs can give students a head start on graduate education. An overview of these combined programs and description of the admission process and requirements are found in the Graduate Degrees and Requirements (<http://bulletin.mines.edu/graduate/programs>) section of this Bulletin.

Admission into a Combined Undergraduate/Graduate degree program is available only to current Mines undergraduate students. Mines alumni are not eligible for Combined degree program enrollment.

Admission Procedure

Applying for Admission

Both US resident and international students may apply electronically for admission. Our Web address is: <http://www.mines.edu/gradschoolapp/onlineapp.html>

To apply follow the procedure outlined below.

1. Application: Go to the online application form at <http://www.mines.edu/gradschoolapp/onlineapp.html>. Students wishing to apply for graduate school should submit completed applications by the following dates:

for Fall admission*

December 15 - Priority consideration for financial support

June 1 - International student deadline

July 1 - Domestic student deadline

for Spring Admission*

September 1

* Some programs have different application deadlines. Please refer to http://www.mines.edu/Deadlines_GS for current deadline information for specific programs.

Students wishing to submit applications beyond the final deadline should contact the Graduate Office.

2. Transcripts: The Graduate Office recommends uploading electronic copies of transcripts (in .pdf format) within the online application system from each school previously attended.

Electronic copies of transcripts can also be sent, via email, to grad.credentials@mines.edu. International students' transcripts must be in English or have an official English translation attached. Transcripts are not considered official unless they are sent directly by the institution attended and are complete, with no courses in progress.

3. Letters of Recommendation: Three (3) letters of recommendation are required. Individuals who know your personal qualities and scholastic or professional abilities can use the online application system to submit letters of recommendation on your behalf. Letters can also be mailed directly to the Graduate Office.
4. Graduate Record Examination (GRE): Most departments require the General test of the Graduate Record Examination for applicants seeking admission to their programs. Refer to the section Graduate Degree Programs and Courses by Department or the Graduate School application packet to find out if you must take the GRE examination. For information about the test, write to:
Graduate Record Examinations
Educational Testing Service
PO Box 6000
Princeton, NJ 08541- 6000
(Telephone 609-771-7670)
or visit online at www.gre.org (<http://www.gre.org>)
5. English Language Requirements: Applicants whose native language is not English must prove proficiency. Language examination results must be sent to the Graduate School as part of the admission process. The institution has minimum English proficiency requirements - learn more at: http://www.mines.edu/Intl_GS. English proficiency may be proven by achieving one of the following:
 - a. A TOEFL (Test of English as a Foreign Language) minimum score of 550 on the paper-based test or a score of 79 on the internet Based TOEFL (iBT).
 - b. At IELTS (International English Language Testing System) Score of 6.5, with no band below a 6.0.
 - c. A PTE A (Pearson test of English) score of 70 or higher.
 - d. Independent evaluation and approval by the admission-granting department.
6. Additional instructions for admission to graduate school specific to individual departments are contained in the application for admission.

Financial Assistance

To apply for Mines financial assistance, check the box in the Financial Information section of the online graduate application or complete the Financial Assistance section on the paper application.

Application Review Process

When application materials are received by the Graduate School, they are processed and sent to the desired degree program for review. The review is conducted according to the process developed and approved by the faculty of that degree program. The degree program transmits its decision to the Dean of the Graduate School, who then notifies the applicant. The decision of the degree program is final and may not be appealed.

Health Record and Additional Steps

When students first enroll at Mines, they must complete the student health record form which is sent to them when they are accepted for enrollment. Students must submit the student health record, including

health history, medical examination, and record of immunization, in order to complete registration.

Questions can be addressed to:
The Coulter Student Health Center
1225 17th Street
Golden, CO 80401-1869

The Health Center telephone numbers are 303-273-3381 and 303-279-3155.

Veterans

Colorado School of Mines is approved by the Colorado State Approving Agency for Veteran Benefits under chapters 30, 31, 32, 33, 35, 1606, and 1607. Undergraduate students must register for and maintain 12.0 credit hours, and graduate students must register for and maintain 9.0 credit hours of graduate work in any semester to be certified as a full-time student for full-time benefits. Any hours taken under the full-time category will decrease the benefits to 3/4 time, 1/2 time, or tuition payment only.

All changes in hours, program, addresses, marital status, or dependents are to be reported to the Veterans Certifying Officer as soon as possible so that overpayment or underpayment may be avoided. Veterans must see the Veteran's Certifying Officer each semester to be certified for any benefits for which they may be eligible. In order for veterans to continue to receive benefits, they must make satisfactory progress as defined by Colorado School of Mines.

An honorably or generally discharged military veteran providing a copy of his/her DD214 is awarded two credit hours to meet the physical education undergraduate degree requirement at CSM. Additionally, veterans may request substitution of a technical elective for the institution's core EPICS course requirement in all undergraduate degree programs.

For more information, please visit the Veterans Services (<http://inside.mines.edu/Veterans-Services>) webpage.

Student Life at CSM

2015-2016

Housing

Graduate students may choose to reside in campus-owned apartment housing areas on a space-available basis. The Mines Park apartment complex is located west of the 6th Avenue and 19th Street intersection on 55 acres owned by Mines. The complex houses upperclass undergraduate students, graduate students, and families. Residents must be full-time students.

Units are complete with refrigerators, stoves, dishwashers, cable television, wired and wireless internet connections, and an optional campus phone line for an additional fee. There are two community centers which contain the laundry facilities, recreational and study space, and meeting rooms. For more information or to apply for apartment housing, go to the [Apartment Housing website](#).

For all Housing & Dining rates, go to Tuition, Fees, Financial Assistance, Housing (p. 12)

Facilities

Student Center

The Ben H. Parker Student Center contains the offices for the Vice President of Student Life and Dean of Students, Associate Dean of Students, Student Activities, Student Government (USG and GSG), Financial Aid, Cashier, Bursar, Career Center, Registrar, Conference Services, and student organizations. The Student Center also contains The Period Table food court, bookstore, student lounges, meeting rooms, and banquet facilities.

Student Recreation Center

Completed in May 2007, the 108,000 square foot Student Recreation Center, located at the corner of 16th and Maple Streets in the heart of campus, provides a wide array of facilities and programs designed to meet student's recreational and leisure needs while providing for a healthy lifestyle. The Center contains a state-of-the-art climbing wall, an eight-lane, 25 meter swimming and diving pool, a cardiovascular and weight room, two multi-purpose rooms designed and equipped for aerobics, dance, martial arts programs and other similar activities, a competition gymnasium containing three full-size basketball courts as well as seating for 2500 people, a separate recreation gymnasium designed specifically for a wide variety of recreational programs, extensive locker room and shower facilities, and a large lounge intended for relaxing, playing games or watching television. In addition to housing the Outdoor Recreation Program as well as the Intramurals and Club Sports Programs, the Center serves as the competition venue for the Intercollegiate Men and Women's Basketball Programs, the Intercollegiate Volleyball Program and the Men and Women's Intercollegiate Swimming and Diving Program.

W. Lloyd Wright Student Wellness Center

The W. Lloyd Wright Student Wellness Center, 1770 Elm Street, houses several health and wellness programs for Mines students: the Coulter Student Health Center, the Student Health Benefits Plan, the Counseling Center, the Dental Clinic and Student Disability Services. The wellness center is open from 8:00 am to 5:00 pm, Monday through Friday, during the fall and spring semesters.

Coulter Student Health Center: Services are provided to all students who have paid the student health center fee. The Coulter Student Health Center (303) 273-3381, FAX (303) 273-3623 is located on the first floor of the W. Lloyd Wright Student Wellness Center at the corner of 18th and Elm Streets (1770 Elm Street). Nurse practitioners and registered nurses provide services Monday through Friday 8:00 am to 12:00 pm and 1:00 pm to 4:45 pm and family medicine physicians provide services by appointment several days a week. After hours students can call New West Physicians at (303) 278-4600 to speak to the physician on call (identify yourself as a CSM student). The Health Center offers primary health and dental care. For X-rays, specialists or hospital care, students are referred to appropriate providers in the community. More information is available at <http://healthcenter.mines.edu>.

Dental Clinic: The Dental Clinic is located on the second floor of the W. Lloyd Wright Wellness Center. Services include cleanings, restoratives, and x-rays. Students who have paid the student health fee are eligible for this service. The dental clinic is open Tuesdays, Wednesdays, and Fridays during the academic year with fewer hours in the summer. Services are by appointment only and can be made by calling the Dental Clinic. Dental care is on a fee-for-service basis, and students enrolled in

the CSM Student Health Benefits Plan pay lower rates for dental care. The Dental Clinic takes cash or checks, no credit/debit cards

Fees: Students are charged a mandatory Health Services fee each semester, which allows them access to services at the Health Center. Spouses of enrolled CSM students can choose to pay the health center fee and are eligible for services. Dental services are not available to spouses.

Immunization Requirement: The State of Colorado requires that all students enrolled have proof of two MMR's (measles, mumps and rubella). A blood test showing immunity to all three diseases is acceptable. History of disease is not acceptable.

Student Health Benefits Plan: The SHBP office is located on the second floor of the W. Lloyd Wright Student Wellness Center.

Adequate Health Insurance Requirement: All degree seeking U.S. citizen and permanent resident students, and all international students regardless of degree status, are required to have health insurance. Students are automatically enrolled in the Student Health Benefits Plan and may waive coverage if they have comparable coverage under a personal or employer plan. International students must purchase the SHBP, unless they meet specific requirements. Information about the CSM Student Health Benefits Plan, as well as the criteria for waiving, is available online at <http://studentinsurance.mines.edu> or by calling 303.273.3388. Enrollment confirmation or waiver of the CSM Student Health Benefits Plan is done online for U.S. Citizens and Permanent Residents. International students must complete a paper enrollment/waiver form. The deadline is Census Day.

Counseling Center: Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Services are available for students who have paid the Student Services fee. Individual personal, academic, and career counseling is offered on a short-term basis to all enrolled CSM students. In cases where a student requires longer-term counseling, referrals are made to providers in the local community. The Counseling Center also provides education and assessment on alcohol and other drug use. More information is available at <http://counseling.mines.edu/>.

Student Disability Services: Located on the second floor of the W. Lloyd Wright Student Wellness Center, phone 303-273-3377. Student Disability Services provides students with disabilities an equal opportunity to access the institution's courses, programs and activities. Services are available to students with a variety of disabilities, including but not limited to attention deficit hyperactivity disorders, learning disorders, psychological disorders, vision impairment, hearing impairment, and other disabilities. A student requesting disability accommodations at the Colorado School of Mines must comply with the Documentation Guidelines and submit required documents, along with a completed Request for Reasonable Accommodations form to Student Disability Services.

Documentation Guidelines and the Request form are available at <http://disabilities.mines.edu/>.

Services

Academic Advising & Support Services

Center for Academic Services and Advising (CASA)

Academic Advising: All students entering CSM are assigned an Academic Advising Coordinator. This assignment is made by last name. This Coordinator serves as the student's academic advisor until they formally declare their major or intended degree. This declaration occurs in their sophomore year. Incoming students have only noted an interest and are not declared.

The Coordinators will host individual, walk-in, and group advising sessions throughout the semester. Every student is required to meet with their Coordinator at least once per semester. The Coordinator will administer a PIN for course registration, each semester. Students unsure of their academic path (which major to choose) should work with their Coordinator to explore all different options.

CASA also hosts Peer 2 Peer advising. Students may walk-in and speak with a fellow student on various issues pertaining to course, such as course registration).

CSM101: The First-Year Symposium, is a required, credit-bearing class. CSM101 aims to facilitate the transition from high school to college; create community among peers and upper-class students; assess and monitor academic progress; and provide referrals to appropriate campus resources. CSM101 is taught by 38 professional staff members (including faculty) and 76 Peer Mentor students.

Tutoring Services: CASA offers weekly tutoring services for all core-curriculum courses. Our services run Sunday through Thursday and are hosted in CASA, the Student Center, and the Library. Students may also request to meet with a private tutor at a time, location, and date of their mutual choosing. All tutoring services are free to students.

Academic Support Services: Routinely, CASA offers great support workshops and events. CASA hosts pre-finals workshops as well as mid-term exam prep session. As well, students can work with our staff to develop the skills and technique of studying well in college – such as test-prep and cognitive learning development. CASA hosts late-night programs in the residence halls and Greek houses.

Core Supplemental Instruction (CSI): First-Year students are encouraged to attend our CSI workshops. These workshops run concurrent to many of the first-year classes (Calc, Chem, Physics, etc.) and reiterate/strengthen material taught in class. They are offered in the evening and are free to all students.

Faculty in CASA: Faculty from various departments host their regular office hours in CASA. Students are encouraged to utilize these professors for assistance with material and/or questions on course planning.

Website: CASA maintains an extensive website with resources, helpful tips, and guides. Check out CASA at <http://casa.mines.edu>.

Motor Vehicles Parking

All motor vehicles on campus must be registered with the campus Parking Services Division of Facilities Management, 1318 Maple Street, and must display a CSM parking permit. Vehicles must be registered at

the beginning of each semester or upon bringing your vehicle on campus, and updated whenever you change your address.

Public Safety

The Colorado School of Mines Department of Public Safety is a full service, community oriented law enforcement agency, providing 24/7 service to the campus. It is the mission of the Colorado School of Mines Police Department to make the Mines campus the safest campus in Colorado.

The department is responsible for providing services such as:

- Proactive patrol of the campus and its facilities
- Investigation and reporting of crimes and incidents
- Motor vehicle traffic and parking enforcement
- Crime and security awareness programs
- Alcohol / Drug abuse awareness / education
- Self defense classes
- Consultation with campus departments for safety and security matters
- Additional services to the campus community such as: vehicle unlocks and jumpstarts, community safe walks (escorts), authorized after-hours building and office access, and assistance in any medical, fire, or other emergency situation.

The police officers employed by the Department of Public Safety are fully trained police officers in accordance with the Peace Officer Standards and Training (P.O.S.T.) Board and the Colorado Revised Statute.

Career Center

The Mines Career Center mission is to assist students in developing, evaluating, and/or implementing career, education, and employment decisions and plans. Career development is integral to the success of Mines graduates and to the mission of Mines. All Colorado School of Mines graduates will be able to acquire the necessary job search and professional development skills to enable them to successfully take personal responsibility for the management of their own careers.

Services are provided to all students and for all recent graduates, up to 24 months after graduation. Students must adhere to the ethical and professional business and job searching practices as stated in the Career Center Student Policy, which can be found in its entirety on the Student's Homepage of DiggerNet.

In order to accomplish our mission, we provide a comprehensive array of career services:

Career, Planning, Advice, and Counseling

- "The Mines Strategy" a practical, user-friendly career manual with interview strategies, resume and cover letter examples, career exploration ideas, and job search tips;
- Online resources for exploring careers and employers at <http://careers.mines.edu>;
- Individual resume and cover letter critiques;
- Individual job search advice;
- Practice video-taped interviews;
- Job Search Workshops - successful company research, interviewing, resumes, business etiquette, networking skills;
- Salary and overall outcomes data;
- Information on applying to grad school;

- Career resource library.

Job Resources and Events

- Career Day (Fall and Spring);
- Online and in-person job search assistance for internships, CO-OPs, and full-time entry-level job postings;
- Virtual Career Fairs and special recruiting events;
- On-campus interviewing - industry and government representatives visit the campus to interview students and explain employment opportunities;
- General employment board;
- Company research resource;
- Cooperative Education Program - available to students who have completed three semesters at Mines (two for transfer students). It is an academic program which offers 3 semester hours of credit in the major for engineering work experience, awarded on the basis of a term paper written following the CO-OP term. The type of credit awarded depends on the decision of the department, but in most cases is additive credit. CO-OP terms usually extend from May to December, or from January to August, and usually take a student off campus full time. Students must apply for CO-OP before beginning the job (a no credit, no fee class), and must write learning objectives and sign formal contracts with their company's representative to ensure the educational component of the work experience.

Identification Cards (Blaster Card Office)

All new students must have a Blaster Card made as soon as possible after they enroll. The Blaster Card office also issues RTD College Passes, which allows students to ride RTD buses and light rail free of charge (or for a reduced fee for airport bus service). Students can replace lost, stolen, or damaged Blaster Cards for a small fee.

The Blaster Card can be used for student meal plans, to check material out of the CSM Library, to access certain electronic doors, and may be required to attend various CSM campus activities.

Standards, Codes of Conduct

Students can access campus rules and regulations, including the student code of conduct, student honor code, alcohol policy, sexual misconduct policy, the unlawful discrimination policy and complaint procedure, public safety and parking policies, and the distribution of literature and free speech policy, by visiting the Policy and Governance website at <http://inside.mines.edu/POGO-Policies-Governance>. We encourage all students to review the electronic document and expect that students know and understand the campus policies, rules and regulations as well as their rights as a student. Questions and comments regarding the above mentioned policies can be directed to the Associate Dean of Students located in the Student Center, Suite 218.

Student Publications

Two student publications are published at CSM by the Associated Students of CSM. Opportunities abound for students wishing to participate on the staffs. A Board of Student Publications acts in an advisory capacity to the publications staffs and makes recommendations on matters of policy.

The *Oredigger* is the student newspaper, published weekly during the school year. It contains news, features, sports, letters and editorials of interest to students, faculty, and the Golden community.

The literary magazine, *High Grade*, is published each semester. Contributions of poetry, short stories, drawings, and photographs are encouraged from students, faculty and staff.

Veterans Services

The Registrar's Office provides veterans services for students attending the School and using educational benefits from the Veterans Administration.

Activities

Student Activities Office

The Office of Student Activities coordinates the various activities and student organizations on the Mines campus. Student government, professional societies, living groups, honor societies, interest groups and special events add a balance to the academic side of the CSM community. Participants take part in management training, event planning, and leadership development. To obtain an up-to-date listing of the recognized campus organizations or more information about any of these organizations, contact the Student Activities office.

Student Government

Associated Students of CSM (ASCSM) is sanctioned by the Board of Trustees of the School. The purpose of ASCSM is, in part, to advance the interest and promote the welfare of CSM and all of the students and to foster and maintain harmony among those connected with or interested in the School, including students, alumni, faculty, trustees and friends.

Through funds collected as student fees, ASCSM strives to ensure a full social and academic life for all students with its organizations, publications, and special events. As the representative governing body of the students ASCSM provides leadership and a strong voice for the student body, enforces policies enacted by the student body, works to integrate the various campus organizations, and promotes the ideals and traditions of the School.

The Graduate Student Association was formed in 1991 and is recognized by CSM through the student government as the representative voice of the graduate student body. GSA's primary goal is to improve the quality of graduate education and offer academic support for graduate students.

The Mines Activity Council (MAC) serves as the campus special events board. The majority of all-student campus events are planned by MAC. Events planned by MAC include comedy shows to the campus on most Fridays throughout the academic year, events such as concerts, hypnotists, and one time specialty entertainment; discount tickets to local sporting events, theater performances, and concerts, movie nights bringing blockbuster movies to the Mines campus; and E-Days and Homecoming.

Special Events

Engineers' Days festivities are held each spring. The three day affair is organized entirely by students. Contests are held in drilling, hand-spiking, mucking, and oil-field olympics to name a few. Additional events include a huge fireworks display, the Ore-Cart Pull to the Colorado State Capitol, the awarding of scholarships to outstanding Colorado high school seniors and an Engineers' Day concert.

Homecoming weekend is one of the high points of the year. Events include a football rally and game, campus decorations, election of Homecoming Queen and Beast, parade, burro race, and other contests.

International Day is planned and conducted by the International Council. It includes exhibits and programs designed to further the cause of understanding among the countries of the world. The international dinner and entertainment have come to be one of the campus social events of the year.

Winter Carnival, sponsored by Blue Key, is an all-school ski day held each year at one of the nearby ski areas. In addition to skiing, there are also fun competitions (snowman contest, sled races, etc.) throughout the day.

Outdoor Recreation Program

The Outdoor Recreation Program is housed at the Mines Park Community Center. The Program teaches classes in outdoor activities; rents mountain bikes, climbing gear, backpacking and other equipment; and sponsors day and weekend activities such as camping, snowshoeing, rock climbing, and mountaineering.

Residence Hall Association (RHA)

Residence Hall Association (RHA) is a student-run organization developed to coordinate and plan activities for students living in the Residence Halls. Its membership is represented by students from each hall floor. Officers are elected each fall for that academic year. For more information, go to RHA (<http://inside.mines.edu/RSL-Residence-Hall-Association>).

Student Organizations

Social Fraternities and Sororities - There are seven national fraternities and three national sororities active on the CSM campus. Fraternities and Sororities offer the unique opportunity of leadership, service to one's community, and fellowship. Greeks are proud of the number of campus leaders, athletes and scholars that come from their ranks. Colorado School of Mines chapters are:

- Alpha Phi
- Alpha Tau Omega
- Beta Theta Pi
- Kappa Sigma
- Phi Gamma Delta
- Pi Beta Phi
- Sigma Alpha Epsilon
- Sigma Kappa
- Sigma Nu
- Sigma Phi Epsilon

Honor Societies - Honor societies recognize the outstanding achievements of their members in the areas of scholarship, leadership, and service. Each of the CSM honor societies recognizes different achievements in our students.

Special Interest Groups - Special interest organizations meet the special and unique needs of the CSM student body by providing co-curricular activities in specific areas.

International Student Organizations - The International Student Organizations provide the opportunity to experience a little piece of a

different culture while here at Mines, in addition to assisting the students from that culture adjust to the Mines campus.

Professional Societies - Professional Societies are generally student chapters of the national professional societies. As a student chapter, the professional societies offer a chance for additional professional development outside the classroom through guest speakers, trips, and interactive discussions about the current activities in the profession. Additionally, many of the organizations offer internship, fellowship and scholarship opportunities.

Recreational Organizations - The recreation organizations provide the opportunity for students with similar interests to participate as a group in these recreational activities. Most of the recreational organizations compete on both the local and regional levels at tournaments throughout the year.

For a complete list of all currently registered student organizations, please visit the Student Activities office or website at <http://studentactivities.mines.edu/>.

Registration and Tuition Classification

2015-2016

General Registration Requirements

The normal full load for graduate students is 9 credit hours per term.

Full-time graduate students may register for an overload of up to 6 credit hours (up to 15 credit hours total) per term at no increase in tuition. Subject to written approval by their advisor and department head or division director, students may register for more than 15 credit hours per term by paying additional tuition at the regular part-time rate for all hours over 15. The maximum number of credits for which a student can register during the summer is 12.

Except for students meeting any of the following conditions, students may register at less than the required full-time registration.

- International students subject to immigration requirements. This applies to international students holding J-1 and F-1 visas.
- Students receiving financial assistance in the form of graduate teaching assistantships, research assistantships, fellowships or hourly contracts.
- Students enrolled in academic programs that require full-time registration. Refer to the degree program sections of this bulletin to see if this applies to a particular program.

Students for whom any one of these conditions apply must register at the appropriate full-time credit hour requirement. Special cases to the full-time registration requirement for students listed above are under Full Time Status-Required Course load and include first-year international students who must receive special instruction to improve their language skills, and students who have completed their credit-hour requirements and are working full time on their thesis.

To remain active in their degree program, students must register continuously each fall and spring semester. If not required to register full-time, part-time students may register for any number of credit hours less than the full-time credit hour load.

Summer registration is not required to maintain an active program. Students who continue to work on their degree program and utilize Mines facilities during the summer, however, must register. Students registered during the summer are assessed regular tuition and fees.

New graduate students entering during the fall semester will be expected to pay full student fees for any courses taken in the summer sessions prior to the fall term of entry.

Research Registration

In addition to completing prescribed course work and defending a thesis, students in thesis-based degree programs must complete a research experience under the direct supervision of their faculty advisor. Master students must complete a minimum of 6 hours of research credit, and doctoral students must complete a minimum of 24 hours of research credit at Mines. While completing this experience, students register for research credit under course numbers 707. Faculty assign grades indicating satisfactory or unsatisfactory progress based on their evaluation of the student's work. Students registered for research during the summer semester and working on campus must pay regular tuition and thesis research fees for summer semester.

Eligibility for Reduced Registration

Students enrolled in thesis-based degree programs who have completed a minimum number of course and research credit hours in their degree programs are eligible to continue to pursue their graduate program as full-time students at a reduced registration level. In order to be considered for this reduced, full-time registration category, students must satisfy the following requirements:

1. For M.S. students, completion of 36 hours of eligible course, research and transfer credits combined
2. For Ph.D. students, completion of 72 hours of eligible course, research, and transfer credits combined
3. For all students, an approved Degree Audit form must be on file in the Graduate Office the semester prior to one for which you are applying for reduced registration.
4. Candidates may not count more than 12 credit hours per semester in determining eligibility for reduced, full-time registration.

Students who are eligible for reduced, full-time registration are considered full time if they register for 4 credit hours of research under course number 707.

Full-time Status - Required Course Load

To be deemed full-time during the fall and spring semesters, students must register for at least 9 credit hours. However, international students need only register for 6 credit hours during their first year, if they are required to take special language instruction or are accepted in Provisional Status. In the event a thesis-based student has completed his or her required course work and research credits and is eligible for reduced, full-time registration, the student will be deemed full-time if he or she is registered for at least 4 credit hours of research credit.

To be deemed full-time during the summer semester, students must register for a minimum of 3 credit hours.

Internships and Academic-Year Registration Requirements

Thesis-based graduate students may participate in corporate-sponsored internship opportunities during the academic year. The intent of graduate internships is to allow students to continue to advance toward degree while pursuing research activities off campus, that are of interest to both the student and a corporate sponsor. To qualify for an internship during the academic year, the work done while in residency at the corporate sponsor must be directly related to a student's thesis/dissertation, the internship shall last for no longer than one regular academic-year semester, and the scope of the activities completed during the internship must be agreed upon by the student, the student's advisor and the corporate sponsor prior to the start of the internship. Students not meeting these requirements are not eligible for the internship registration defined below.

Graduate students completing a one semester of corporate-sponsored internship, either domestic or international, during the academic year should register for zero credit hours of off-campus work experience under the course number 597. This registration will maintain a student's full-time academic standing for the internship semester. Students registered for an internship experience under course number 597 are not assessed tuition nor regular academic fees and as such do not have access to Mines facilities, services or staff. The Mines Health Insurance requirement applies to all students participating in an academic program (such as, but not limited to, undergraduate cooperative education, study abroad, and graduate internships) regardless of the domestic or international location of the academic program. As such, students enrolled in the Mines Health Insurance program are charged health insurance fees during their internship semester. Students participating in an international internship are required to complete the Office of International Programs paperwork in fulfillment of security and safety requirements.

Late Registration Fee

Students must complete their registration by the date specified in the Academic Calendar. Students who fail to complete their registration during this time will be assessed a \$100 late registration fee and will not receive any tuition fellowships for which they might otherwise be eligible.

Reciprocal Registration

Under the Exchange Agreement Between the State Supported Institutions in Northern Colorado, Mines graduate students who are paying full-time tuition may take courses at Colorado State University, University of Northern Colorado, and University of Colorado (Boulder, Denver, Colorado Springs, and the Health Sciences Center) at no charge by completing the request form and meeting the required conditions on registration and tuition, course load, and course and space availability. Request forms are available from the Registrar's office.

Courses completed under the reciprocal agreement may be applied to a student's degree program. These are, however, applied as transfer credit into the degree program. In doing so, they are subject to all the limitations, approvals and requirements of any regularly transferred course.

Dropping and Adding Courses

Students may drop or add courses through web registration without paying a fee during the first 11 school days of a regular semester, the first

four school days of a six-week field course, or the first six school days of an eight-week summer term.

After the 11th day of classes through the 12th week, continuing students may drop any course for any reason with a grade of "W". Graduate students in their first or second semesters at Mines have through the 14th week of that semester to drop a course. A student must process a drop-add form and pay a \$5.00 fee for any change in class schedule after the first 11 days of class, except in cases of withdrawal from school. Forms are available in the Registrar's Office.

After the 12th (or 14th) week, no drops are permitted except in case of withdrawal from school or for extenuating circumstances. To request consideration of extenuating circumstances, a student must submit a written request to the Graduate Dean, which includes the following:

1. A list of the courses from which they wish to withdraw. This must include all courses for which they are registered.
2. Documentation of the problem which is the basis for the request.
3. If the problem involves a medical condition, the documentation must be signed by a licensed medical doctor or a representative of the Mines Counseling Office.
4. Signatures indicating approval by the student's advisor and department head or division director.

A student who is allowed to withdraw from courses under this policy will receive a grade of "W" for each course and will be placed on automatic leave of absence. In order to resume their graduate program, they must submit a written application that includes documentation that the problems which caused the withdrawal have been corrected. The student will be reinstated to active status upon approval of their application by their advisor and their department head or division director.

The financial impact of a withdrawal is covered in the section on "Payments and Refunds."

Auditing Courses

As part of the maximum of 15 semester hours of graduate work, students may enroll for no credit (NC) in a course with the permission of the instructor. Tuition charges are the same for no credit as for credit enrollment.

Students must enroll for no credit before census day, the last day of registration. The form to enroll for a course for no credit is available in the Registrar's Office. NC designation is awarded only if all conditions stipulated by course instructors are met.

Mines requires that all U.S. students who are being supported by the institution register full time, and federal financial aid regulations prohibit us from counting NC registration in determining financial aid eligibility. In addition, the INS requires that international students register full time, and we are discouraged from counting NC registration toward that requirement. Furthermore, there are no consistent standards for expectations of students who register for NC in a course. Therefore, in order to treat all Mines students consistently, NC registration will not count toward the minimum number of hours for which students are required to register. This includes the minimum continuous registration requirement of part-time students and the 9 credit-hour requirement for students who must register full time.

The reduced registration policy is based on the principle that the minimum degree requirement (36 or 72 hours) would include only the credits applied toward that degree. Deficiency and extra courses are

above and beyond that minimum. NC courses fall into the latter category and may not be applied toward the degree. Therefore, NC registration will not count toward the number of hours required to be eligible for reduced thesis registration.

NC registration may involve additional effort on the part of faculty to give and/or grade assignments or exams, so it is the institution's policy to charge tuition for NC courses. Therefore, NC registration will count toward the maximum number of credits for which a graduate student may be allowed to register. This includes a tuition surcharge for credits taken over 15.

Off-Campus Study

A student must enroll in an official Mines course for any period of off-campus, course-related study, whether U.S. or foreign, including faculty-led short courses, study abroad, or any off-campus trip sponsored by Mines or led by a Mines faculty member. The registration must occur in the same term that the off-campus study takes place. In addition, the student must complete the necessary release, waiver, and emergency contact forms, transfer credit pre-approvals, and FERPA release, and provide adequate proof of current health insurance prior to departure. For additional information concerning study abroad requirements, contact the Office of International Programs at (303) 384-2121; for other information, contact the Registrar's Office.

Graduation Requirements

Graduation Requirements

To graduate, students must be registered during the term in which they complete their program. An exception to this registration policy allows students to complete an early checkout by census day of the graduation semester. Early checkout is accepted by the Graduate School and allows students to graduate in a term, without registering;

- checkout by Summer I census to graduate in Fall and avoid summer & fall registration,
- checkout by Fall census to graduate in Fall and avoid fall registration, and
- checkout by Spring census to graduate in the Spring and avoid spring registration.

Students not meeting this checkout deadline are required to register for an additional semester before the Graduate School will process their checkout request. For additional information, refer to <http://gradschool.mines.edu/GS-Graduation-Information-and-Deadlines>.

Leave of Absence & Parental Leave

Leave of Absence

Leaves of absence are granted when it is temporarily impossible for students to continue to work toward a degree. Leave of absence requests for the current semester must be received by the Dean of Graduate Studies prior to census. Leave of absence requests for prior semesters will not be considered.

Any request for a leave of absence must have the prior approval of the student's faculty advisor, the department head or division or program

director and the Dean of Graduate Studies. The request for a leave of absence must be in writing and must include:

1. the reasons why the student must interrupt his or her studies and,
2. a plan (including a timeline and deadlines) for resuming and completing the work toward the degree in a timely fashion.

Students on leave remain in good standing even though they are not registered for any course or research credits. While on leave, however, students will not have access to Mines resources. This includes, but is not limited to, office space, computational facilities, library and faculty.

Students are limited to two, not necessarily consecutive, regular semesters of leave while in a graduate degree program at Mines. Beyond these two semesters, students needing to suspend their degree programs further are required to formally withdraw from the degree program. To continue in the degree program at a later date, candidates would need to apply, and be readmitted, into the degree program. As with all degree program applications, applications from candidates returning from a leave are reviewed by the program and considered for readmission at the sole discretion of the program.

Students who fail to register and who are not on approved leaves of absence have their degree programs terminated. Students who wish to return to graduate school after an unauthorized leave of absence must apply for readmission and pay a \$200 readmission fee.

The financial impact of requesting a leave of absence for the current semester is covered in the section on "Payments and Refunds (p. 187)"

Parental Leave

Graduate students in thesis-based degree programs, who have full-time student status, may be eligible to request up to eight (8) weeks of parental leave. The Parental Leave Policy is designed to assist students who are primary child-care providers immediately following the birth or adoption of a child. The Policy is designed to make it possible for students to maintain full-time status in research-based degree programs while taking a leave from that program to care for their new child, and facilitate planning for continuance of their degree program.

Nothing in the Parental Leave policy can, or is intended to replace communication and cooperation between the student and his or her advisor, and the good-faith efforts of both to accommodate the birth or adoption of a child within the confines and expectations of participating in a research-active graduate degree program. It is the intent of this Policy to reinforce the importance of this cooperation, and to provide a framework of support and guidance.

Eligibility

In order to be eligible for Parental Leave, a graduate student must:

- be the primary child care provider;
- have been a full-time graduate student in his/her degree program during at least the two (2), prior consecutive semesters;
- be enrolled in a thesis-based degree program (i.e., Doctoral or thesis-based Masters);
- be in good academic standing as defined in the Unsatisfactory Academic Performance section of this Bulletin;
- provide a letter from a physician or other health care professional stating the anticipated due date of the child, or provide appropriate documentation specifying an expected date of adoption of the child;

- notify advisor of intent to apply for Parental Leave at least four (4) months prior to the anticipated due date or adoption date; and
- at least two (2) months prior to the expected leave date complete, and have approved, the Request for Parental Leave Form that includes an academic Program Plan for program continuance.

Exceptions and Limitations

This Policy has been explicitly constructed with the following limitations:

- part-time and non-thesis students are not eligible for Parental Leave. These students may, however, apply for a Leave of Absence through the regular procedure defined above;
- if both parents are Mines graduate students who would otherwise qualify for leave under this Policy, each is entitled to a Parental Leave period immediately following the birth or adoption of a child during which he or she is the primary care provider, but the leaves may not be taken simultaneously; and
- leaves extending beyond eight (8) weeks are not covered by this Policy. The regular Leave of Absence policy defined in the Graduate Bulletin applies to these cases.

Benefits

Under this Policy students will receive the following benefits and protections:

- a one-semester extension of all academic requirements (e.g., qualifying examinations, time to degree limitations, etc.);
- maintenance of full-time status in degree program while on Parental Leave;
- documentation of an academic plan that specifies both how a student will continue work toward his or her degree prior to the leave period and how a student will reintegrate into a degree program after returning from leave; and
- continuance of assistantship support during the semester in which the leave is taken.

Planning and Approval

It is the student's responsibility to initiate discussions with his/her advisor(s) at least four (4) months prior to the anticipated birth or adoption. This notice provides the lead time necessary to rearrange teaching duties (for those students supported by teaching assistantships), to adjust laboratory and research responsibilities and schedules, to identify and develop plans for addressing any new health and safety issues, and to develop an academic Program Plan that promotes seamless reintegration back into a degree program.

While faculty will make every reasonable effort to meet the needs of students requesting Parental Leave, students must recognize that faculty are ultimately responsible for ensuring the rigor of academic degree programs and may have a direct requirement to meet specific milestones defined in externally funded research contracts. Within this context, faculty may need to reassess and reassign specific work assignments, modify laboratory schedules, etc. Without good communication, such efforts may lead to significant misunderstandings between faculty and students. As such, there must be good-faith, and open communication by each party to meet the needs and expectations of each during this potentially stressful period.

The results of these discussions are to be formalized into an academic Program Plan that is agreed to by both the student and the advisor(s). This Plan, to be accepted, must also receive approval by the appropriate

Department Head, Division or Program Director and the Graduate Dean. Approval of the Dean should be sought by submitting to the Office of Graduate Studies a formal Parental Leave request, with all necessary signatures along with the following documentation;

- letter from a physician or other health care professional stating the anticipated due date of the child or other appropriate documentation specifying an expected date of adoption of the child; and
- the advisor(s) and Department Head, Division or Program Director approved academic Program Plan.

These materials should be delivered to the Office of Graduate Studies no less than two (2) months prior to the anticipated date of leave.

If a student and faculty member cannot reach agreement on a Program Plan, they should consult with the appropriate Department Head, Division or Program Director to help mediate and resolve the outstanding issues. As appropriate, the Department Head, Division or Program Director may request the Dean of Graduate Studies and the Director of the Women in Science, Engineering and Mathematics program provide additional assistance in finalizing the Program Plan.

Graduate Students with Appointments as Graduate Research and Teaching Assistants

A graduate student who is eligible for Parental Leave and has a continuing appointment as a research or teaching assistant is eligible for continued stipend and tuition support during the semester(s) in which the leave is taken. For consideration of this support, however, the timing of a leave with continued stipend and tuition support must be consistent with the academic unit's prior funding commitment to the student. No financial support will be provided during Leave in a semester in which the student would have otherwise not been funded.

Tuition and Fee Reimbursement: If the assistantship, either teaching or research, would have normally paid a student's tuition and mandatory fees, it will continue to do so for the semester(s) in which the Leave is taken. Costs for tuition will be shared proportionally between the normal source of funding for the research or teaching assistantship and the Office of Graduate Studies.

Stipend Support: Stipends associated with the assistantship will be provided at their full rate for that portion of the semester(s) during which the student is not on Parental Leave. No stipend support need be provided during the time period over which the Parental Leave is taken. The student may, however, choose to have the stipend he or she would receive during the semester(s) in which the Leave is taken delivered in equal increments over the entire semester(s).

While on Leave, students may elect to continue to work in some modified capacity and Faculty, Departments and Programs may elect to provide additional stipend support in recognition of these efforts. Students, however, are under no obligation to do so, and if they choose to not work during their Leave period this will not be held against them when they return from Leave. Upon return, students on Research Assistantships are expected to continue their normal research activities as defined in their Academic Plans. Students on Teaching Assistantships will be directed by the Department, Division or Program as to specific activities in which they will engage upon return from Parental Leave.

Registration

Students on Parental Leave should register at the full-time level for research credit hours under the direction of their Thesis Advisor. The

advisor will evaluate student progress toward degree for the semester in which Parental Leave is taken only on those activities undertaken by the student while he or she is not on Leave.

In-State Tuition Classification Status

In-State Tuition Classification Status

General Information

The State of Colorado partially subsidizes the cost of tuition for all students whose domicile, or permanent legal residence, is in Colorado. Each Mines student is classified as either an "in-state resident" or a "non-resident" at the time of matriculation. These classifications, which are governed by Colorado law, are based upon information furnished by each student on his or her application for admission to Mines. A student who willfully furnishes incorrect information to Mines to evade payment of non-resident tuition shall be subject to serious disciplinary action.

It is in the interest of each graduate student who is a U.S. citizen and who is supported on an assistantship or fellowship to become a legal resident of Colorado at the earliest opportunity. Typically, tuition at the non-resident rate will be paid by Mines for these students during their first year of study only. After the first year of study, these students may be responsible for paying the difference between resident and non-resident tuition.

Requirements for Establishing In-State Residency

The specific requirements for establishing residency for tuition classification purposes are prescribed by state law (Colorado Revised Statutes, Title 23, Article 7). Because Colorado residency status is governed solely by Colorado law, the fact that a student might not qualify for in-state status in any other state does not guarantee in-state status in Colorado. The tuition classification statute places the burden of proof on the student to provide clear and convincing evidence of eligibility.

In-state or resident status generally requires domicile in Colorado for the year immediately preceding the beginning of the semester in which in-state status is sought. "Domicile" is "a person's true, fixed and permanent home and place of habitation." An unemancipated minor is eligible for in-state status if at least one parent (or his or her court-appointed guardian) has been domiciled in Colorado for at least one year. If neither of the student's parents are domiciliaries of Colorado, the student must be a qualified person to begin the one-year domiciliary period. A "qualified person" is someone who is at least twenty-two years old, married, or emancipated. A student may prove emancipation if:

1. The student's parents have entirely surrendered the right to the student's custody and earnings;
2. The student's parents are no longer under any duty to financially support the student; and
3. The student's parents have made no provision for the continuing support of the student.

To begin the one-year domiciliary period, a qualified person must be living in Colorado with the present intention to reside permanently in Colorado. Although none of the following indicia are determinative, voter registration, driver's license, vehicle registration, state income tax filings, real property interests, and permanent employment (or acceptance of future employment) in Colorado will be considered in determining whether

a student has the requisite intention to permanently reside in Colorado. Once a student's legal residence has been permanently established in Colorado, he or she may continue to be classified as a resident student so long as such residence is maintained, even though circumstances may require extended temporary absences from Colorado.

For more information about the requirements for establishing in-state residency, please contact the Registrar's Office.

Petitioning for In-State Tuition Classification

A continuing, non-resident student who believes that he or she has become eligible for in-state resident tuition due to events that have occurred subsequent to his or her initial enrollment may file a Petition for In-State Tuition Classification with the Registrar's Office. This petition is due in the Registrar's Office no later than the first day of the semester for which the student is requesting in-state resident status. Upon receipt of the petition, the Registrar will initially decide whether the student should be granted in-state residency status. The Registrar's decision may be appealed by petition to the Tuition Classification Review Committee. For more information about this process, please contact the Registrar's Office (<http://inside.mines.edu/Petitioning-for-In-State-Tuition-Classification>).

In-State Tuition Classification for WICHE Program Participants

WICHE, the Western Interstate Commission for Higher Education, promotes the sharing of higher education resources among the participating western states. Under this program, residents of Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming who are enrolled in qualifying graduate programs may be eligible for in-state tuition classification. Current qualifying programs include:

- Applied Chemistry
- Environmental Engineering Science
- Geochemistry
- Geological Engineering
- Hydrology
- Mineral and Energy Economics
- Mining and Earth Systems Engineering
- Petroleum Engineering

Contact the Office of Graduate Studies (http://inside.mines.edu/Graduate_School) for more information about WICHE.

Academic Regulations

2015-2016

Graduate School Bulletin

It is the responsibility of the graduate student to become informed and to observe all regulations and procedures required by the program the student is pursuing. Ignorance of a rule does not constitute a basis for waiving that rule. The current Graduate Bulletin when a graduate student first enrolls, gives the academic requirements the student must meet to graduate. However, with department consent, a student can change to the requirements in a later catalog published while the student is enrolled in the graduate school. Changes to administrative policies and procedures become effective for all students as soon as the campus community is notified of the changes.

The Graduate Bulletin is available to students in both print and electronic forms. Print bulletins are updated annually. Electronic versions of the Graduate Bulletin may be updated more frequently to reflect changes approved by the campus community. As such, students are encouraged to refer to the most recently available electronic version of the Graduate Bulletin. This version is available at the CSM website. The electronic version of the Graduate Bulletin is considered the official version of this document. In case of disagreement between the electronic and print versions, the electronic version takes precedence.

Resolution of Conflicting Bulletin Provisions

If a conflict or inconsistency is found to exist between these policies and any other provision of the Mines Graduate Bulletin, the provisions of these policies shall govern the resolution of such conflict or inconsistency.

Curriculum Changes

The Mines Board of Trustees reserves the right to change any course of study or any part of the curriculum to respond to educational and scientific developments. No statement in this Bulletin or in the registration of any student shall be considered as a contract between Colorado School of Mines and the student.

Making up Undergraduate Deficiencies

If the department or division decides that new students do not have the necessary background to complete an advanced degree, they will be required to enroll in courses for which they will receive no credit toward their graduate degree, or complete supervised readings, or both. Students are notified of their apparent deficiency areas in their acceptance letter from the Graduate School or in their first interview with their department advisor.

Graduate students must attain a B average in deficiency courses, and any student receiving a grade of D in a deficiency course will be required to repeat the course. Grades for these deficiency courses are recorded on the student's transcript, become part of the student's permanent record, and are calculated into the overall GPA. Students whose undergraduate records are deficient should remove all deficiencies as soon as possible after they enroll for graduate studies.

Graduate Students in Undergraduate Courses

Students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work not taken to remove deficiencies and not taken as a degree requirement for a bachelor's degree upon the recommendation of the graduate committee and the approval of the Graduate Dean.

Students may apply toward graduate degree requirements 300-level courses only in those programs which have been recommended by the department and have been approved by the Graduate Council before the student enrolls in the course. In that case a maximum of nine (9.0) total hours of 300- and 400-level courses will be accepted for graduate credit.

Withdrawing from School

To officially withdraw from Mines, a graduate student must communicate directly with the Graduate Dean or process a withdrawal form through the Graduate Office. When the form is completed, the student will receive grades of W in courses in progress. If the student does not

officially withdraw the course grades are recorded as F's. Leaving school without having paid tuition and fees will result in the encumbrance of the transcript. Federal aid recipients should check with the financial aid office to determine what impact a withdrawal may have on current or future aid.

Graduate Grading System

Grades

When a student registers in a graduate (500- and 600-level) course, one of the following grades will appear on the academic record. Grades are based on the level of performance and represent the extent of the student's demonstrated mastery of the material listed in the course outline and achievement of the stated course objectives. These are CSM's grade symbols and their qualitative interpretations:

Symbol	Interpretation
A	Acceptable for Graduate Credit
A-	Acceptable for Graduate Credit
B+	Acceptable for Graduate Credit
B	Acceptable for Graduate Credit
B-	May be Acceptable for Graduate Credit
C+	May be Acceptable for Graduate Credit
C	May be Acceptable for Graduate Credit
C-	May be Acceptable for Graduate Credit
D+	Not Acceptable for Graduate Credit
D	Not Acceptable for Graduate Credit
D-	Not Acceptable for Graduate Credit
F	Failed
S	Satisfactory (C- or better, used as a mid-term grade)
U	Unsatisfactory (below C-, used as a mid-term grade)
INC	Incomplete
PRG	Satisfactory Progress
PRU	Unsatisfactory Progress

Graduate students enrolled in undergraduate-level courses (400-level and below) are graded using the undergraduate grading system. See the Mines Undergraduate Bulletin (p. 5) for a description of this system.

In addition to these performance symbols, the following is a list of additional registration symbols that may appear on a CSM transcript:

Symbol	Interpretation
WI	Involuntarily Withdrawn
W	Withdrew, No Penalty
T	Transfer Credit
NC	Not for Credit
Z	Grade not yet Submitted

Incomplete Grade

If a graduate student fails to complete a course because of illness or other reasonable excuse, the student receives a grade of Incomplete (INC), a temporary grade which indicates a deficiency in the quantity of work done.

A grade of INC must be removed not later than the end of the fourth week of the first major term of attendance following that in which it was received. A grade of INC will be converted to an F grade by the Registrar in the fifth week if it has not been updated by the professor by the end of the fourth week.

Graduating students must have all incomplete grades changed within 10 business days after graduation.

Satisfactory Progress Grades

A graduate student may receive a grade of Satisfactory Progress, PRG, in either one of three possible situations:

1. As a passing grade given in a course that is graded pass-fail,
2. As a grade for a course extending more than one semester or
3. As a grade indicating completion of research credit hours.

When applied to pass-fail courses, the Satisfactory Progress grade, PRG, indicates successful completion of the requirements of the course. A grade of Unsatisfactory Progress, PRU, as applied to pass-fail courses, indicates the student failed to meet the requirements for successful completion of the course. The PRG and PRU grades have no point value toward a student's GPA. As described in the Unsatisfactory Academic Performance (p. 190) portion of this Bulletin programs may determine that a PRU received in a course indicates unsatisfactory progress toward degree completion and trigger academic disciplinary proceedings.

For students completing independent study or seminar courses extending over multiple semesters, the progress grade has no point value. In such cases, the student receives a grade of PRG, which indicates that the work is not yet completed. For multi-semester independent study courses, upon completion of course requirements, final grades are assigned to all semesters in which the student enrolled in the course, replacing previous PRG grades as appropriate. In seminar courses which may not be repeated for credit, even if continuous enrollment is required by the degree program, the PRG grade remains with a final grade being assigned to last semester of attendance only.

For all multi-semester courses, independent study and seminar, students must register for the same course in each regular (Fall or Spring) semester of attendance until such time as a final grade is assigned.

When applied to research credits, the Satisfactory Progress grade, PRG, also has no point value toward a student's GPA, but indicates satisfactory progress toward completion of the research component of a student's thesis-based degree program. In this situation, a grade of PRU, Unsatisfactory Progress, may be given, and if given, indicates that a student has not made satisfactory progress toward the research component of a thesis-based degree program. In this case, receipt of a grade of PRU may trigger academic disciplinary proceedings as described in the Unsatisfactory Academic Performance (p. 190) portion of this Bulletin.

Unless faculty submit change of grade forms to the Registrar, grades of PRU delivered for unsatisfactory research performance, are not changed to PRG upon the successful completion of a student's degree program.

NC Grade

For special reasons and with the instructor's permission, a student may register in a course for no credit (NC). To have the grade NC appear on the transcript, the student must enroll at registration time as a NC student in the course and comply with all conditions stipulated by the course

instructor. If a student registered as NC fails to satisfy all conditions, no record of this registration in the course will be made.

Quality Hours and Quality Points

For graduation a student must successfully complete a certain number of required semester hours and must maintain grades at a satisfactory level. Numerical values assigned to each letter grade are given in the table below:

Grade	Numerical Value
A	4.000
A-	3.700
B+	3.300
B	3.000
B-	2.700
C+	2.300
C	2.000
C-	1.700
D+	1.300
D	1.000
D-	0.700
F	0.000

The number of quality points earned in any course is the number of semester hours assigned to that course multiplied by the numerical value of the grade received. The quality hours earned are the number of semester hours in which grades are awarded. To compute a grade-point average, the number of cumulative quality hours is divided into the cumulative quality points earned. Grades of W, WI, INC, PRG, PRU, or NC are not counted in quality hours.

Semester Hours

The number of times a class meets during a week (for lecture, recitation, or laboratory) determines the number of semester hours assigned to that course. Class sessions are normally 50 minutes long and represent one hour of credit for each hour meeting. Two to four hours of laboratory work per week are equivalent to 1-semester hour of credit. For the average student, each hour of lecture and recitation requires at least two hours of preparation.

Grade-Point Averages

Grade-Point Averages shall be specified, recorded, reported, and used to three figures following the decimal point for any and all purposes to which said averages may apply.

All graduate degree programs require students have a minimum overall grade point average of 3.000 in order to be eligible to receive the degree. All courses (including deficiency courses) taken at the Colorado School of Mines after first enrolling in a graduate degree program are included in the calculation of the overall grade point average for that program. Grades for courses applied to a degree program as transfer credit are not included in any grade point average calculation. Specifics in calculating the overall, and other grade point averages are defined below.

Overall Grade-Point Average

The overall grade-point average includes all attempts at courses taken at Colorado School of Mines with the exception of courses completed when the repeat policy was in effect: Fall 2007 through Summer 2011.

If a course completed during the Fall 2007 term through Summer 2011 was a repeat of a course completed in any previous term and the course was not repeatable for credit, the grade and credit hours earned for the most recent occurrence of the course will count toward the student's grade-point average and the student's degree requirements. The most recent course occurrence must be an exact match to the previous course completed (subject and number). The most recent grade is applied to the overall grade-point average even if the previous grade is higher.

Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average, and cannot be used under this repeat policy. Only courses originally completed and subsequently repeated at Colorado School of Mines during Fall 2007 through Summer 2011 with the same subject code and number apply to this repeat policy.

All occurrences of every course taken at Colorado School of Mines will appear on the official transcript along with the associated grade. Courses from other institutions transferred to Colorado School of Mines are not counted in any grade-point average.

Course and Research Grades

All candidates for graduate degrees must maintain a cumulative grade point average of at least 3.0 in all courses taken after acceptance into a degree program. This includes both graduate and undergraduate courses. Any grade lower than "C-" is not acceptable for credit toward graduate degree requirements or graduate deficiencies.

For research credits, students receive either an "In Progress-Satisfactory" or an "In Progress-Unsatisfactory" grade based on their faculty advisor's evaluation of their work. Research grades do not enter into the calculation of the student's grade point average.

Students who fail to maintain a grade point average of at least 3.0, or who receive an In Progress-Unsatisfactory research grade are placed on academic probation by the Graduate Dean and may be subject to discretionary dismissal as defined by the Unsatisfactory Academic Performance (p. 190) section of this Bulletin.

Grade Appeal Process

Mines faculty have the responsibility, and sole authority for, assigning grades. As instructors, this responsibility includes clearly stating the instructional objectives of a course, defining how grades will be assigned in a way that is consistent with these objectives, and then assigning grades. It is the student's responsibility to understand the grading criteria and then maintain the standards of academic performance established for each course in which he or she is enrolled.

If a student believes he or she has been unfairly graded, the student may appeal the grade to the Faculty Affairs Committee of the Faculty Senate. The Faculty Affairs Committee is the faculty body authorized to review and modify course grades, in appropriate circumstances. Any decision made by the Faculty Affairs Committee is final. In evaluating a grade appeal, the Faculty Affairs Committee will place the burden of proof on the student. For a grade to be revised by the Faculty Affairs Committee, the student must demonstrate that the grading decision was unfair by documenting that one or more of the following conditions applied:

1. The grading decision was based on something other than course performance; unless the grade was a result of penalty for academic dishonesty or the grade was WI (withdrawn involuntarily).
2. The grading decision was based on standards that were unreasonably different from those applied to other students in the same section of that course.
3. The grading decision was based on standards that differed substantially and unreasonably from those previously articulated by the instructor.

To appeal a grade, the student must proceed as follows:

1. The student must prepare a written appeal of the grade received in the course. This appeal must clearly define the basis for the appeal and must present all relevant evidence supporting the student's case.
2. After preparing the written appeal, the student must deliver this appeal to the course instructor and attempt to resolve the issue directly with the instructor. Written grade appeals must be delivered to the instructor no later than 10 business days after the start of the regular (fall or spring) semester immediately following the semester in which the contested grade was received. In the event that the course instructor is unavailable, the course coordinator (first) or the Department Head/Division Director (second) will represent the instructor.
3. If after discussion with the instructor, the student is still dissatisfied, he or she can proceed with the appeal by submitting three copies of the written appeal plus three copies of a summary of the instructor/student meetings held in connection with the previous step to the President of the Faculty Senate. These must be submitted to the President of the Faculty Senate no later than 25 business days after the start of the regular semester immediately following the semester in which the contested grade was received. The President of the Faculty Senate will forward the student's appeal and supporting documents to the Faculty Affairs Committee, the course instructor's Department Head/Division Director, and the instructor.
4. The Faculty Affairs Committee will request a response to the appeal from the instructor and begin an investigation of the student's allegations and basis for appealing the grade. During the course of performing its investigation, the Committee may:
 - a. Interview the student, the student's advisor, the course instructor and other witnesses deemed relevant to the investigation;
 - b. Review all documentation related to the appeal under consideration;
 - c. Secure the assistance of outside expertise, if needed; and
 - d. Obtain any other information deemed necessary to consider and resolve the appeal.

Upon request, the Faculty Affairs Committee may share summaries of testimony and other information examined by the Committee with both the student and the instructor. Certain information, however, may be redacted from materials forwarded to the student and instructor to maintain other students' rights subject to protection under the Family Educational Rights and Privacy Act (FERPA), or other state and federal law. Based on its investigation, the Faculty Affairs Committee will determine whether the grade should be revised. The decision rendered will be either:

 - i The original grading decision is upheld, or
 - ii Sufficient evidence exists to indicate a grade has been assigned unfairly.

In this latter case, the Faculty Affairs Committee will assign the student a new grade for the course. The Committee's

written decision and supporting documentation will be delivered to the President of the Faculty Senate, the office of the EVPAA, the student, the instructor, and the instructor's Department Head/Division Director no later than 25 business days following the Senate's receipt of the grade appeal. The Faculty Affairs Committee's decision shall constitute the final decision of the grade appeal. There is no further internal appeal available to the parties.

The schedule, but not the process, outlined above may be modified upon mutual agreement of the student, the instructor, and the Faculty Affairs Committee.

Graduation

All students expecting to graduate must apply to graduate in Trailhead.

Graduation application deadlines are scheduled well in advance of the date of Commencement to allow time for ordering diploma covers and for printing graduation invitations and programs. Students who submit applications after the stated deadline cannot be guaranteed a diploma dated for that graduation, and cannot be assured inclusion in the graduation program or ceremony. Graduation applications are accepted only for students who have previously submitted to, and had approved by the Office of Graduate Studies, the appropriate Advisor/Thesis Committee, Degree Audit form, and Admission to Candidacy form (PhD candidates only) as applicable to the degree sought.

All graduating students must officially check out of their degree program. Checkout cards may be obtained from the Graduate Office and must be completed and returned, along with all other appropriate checkout forms by the established deadline. Students must register for the graduation term, unless the checkout process is completed by census day of the graduation term.

The awarding of a degree is contingent upon the student's successful completion of all program requirements with at least a 3.000 GPA before the date of graduation. Students who fail to graduate at the time originally anticipated must reapply for the next graduation before the appropriate deadline date stated in the Graduate Handbook.

Students who have completed all of their degree requirements before the specific graduation date, but who have not applied for graduation can, if necessary, request a letter from the Graduate Office certifying the completion of their programs. The student should apply for the next graduation, and the diploma will show the date of that graduation.

Graduation exercises are held in December and May. Students eligible to graduate at these times are expected to attend their respective graduation exercises. Students in thesis-based degree programs may not under any circumstances, attend graduation exercises before completing all degree requirements.

Diplomas, transcripts, and letters of completion will not be released by the School for any student or graduate who has an unsettled obligation of any kind to the School.

Independent Studies

To register for independent study course, a student should get from the Registrar's Office (<http://inside.mines.edu/Independent-Study-Registration>) the form provided for that purpose, have it completed by

the instructor involved and appropriate department/division head, and return it to the Registrar's Office. The form must be submitted no later than the Census Day (last day of registration) for the term in which the independent study is to be completed.

For each semester credit hour awarded for independent study (x99 course), a student is expected to invest approximately 25.0 contact hours plus 30.0 hours of independent work. Additionally, the faculty certifies that an appropriate course syllabus has been developed for the course, reviewed by the Department/Division and the student, and is available upon request from the department.

Credit Hours	Instructor Contact Hours	Independent Work Hours	Total Hours	Hours Per Week
1.0	25.0	30.0	55.0	3.7
2.0	50.0	60.0	110.0	7.3
3.0	75.0	90.0	165.0	11.0
4.0	100.0	120.0	220.0	14.7
5.0	125.0	150.0	275.0	18.3
6.0	150.0	180.0	330.0	22.0

Non-Degree Students

A non-degree student is one who has not applied to pursue a degree program at Mines but wishes to take courses regularly offered on campus. Non-degree students register for courses through the Registrar's Office after degree-seeking students have registered. Such students may take any course for which they have the prerequisites as listed in the Mines Bulletin or have the permission of the instructor. Transcripts or evidence of the prerequisites are required. Non-degree students pay all applicable tuition and student fees.

Courses completed while the student is a non-degree graduate student count toward the overall graduate-level grade point average on the CSM transcript.

For more information, please visit the Non-Degree Graduate (http://www.mines.edu/NonDegree_GS) website.

Public Access to Graduate Thesis

The award of a thesis-based graduate degree is conditioned on the student's deposit of his or her completed thesis in the Mines library to ensure its availability to the public. Although the student retains the copyright in the thesis, by depositing the thesis with the library, the student assigns a perpetual, non-exclusive, royalty-free license to Mines to permit Mines to copy the thesis and allow the public reasonable access to it.

Under special circumstances, Mines may agree to include proprietary research in a graduate student's thesis. The nature and extent of the proprietary research reported in the thesis must be agreed upon in writing by the principal investigator, student and Dean of Graduate Studies. In some cases, the proprietary nature of the underlying research may require the school to delay public access to the completed thesis for a limited period of time. In no case will public access to the thesis be denied for more than 12 months from the date the Statement of Work Completion form is submitted to the Graduate School.

Unsatisfactory Academic Performance

2015/2016

Unsatisfactory Academic Progress Resulting in Probation or Discretionary Dismissal

A student's progress toward successful completion of a graduate degree shall be deemed unsatisfactory if any of the following conditions occur:

- Failure to maintain a cumulative grade point average of 3.0 or greater (see Grading System section);
- Receipt of an "Unsatisfactory Progress" grade for research; or
- Receipt of an "Unsatisfactory Progress" recommendation from:
 - the head or director of the student's home department or division,
 - the student's thesis committee, or
 - a departmental committee charged with the responsibility of monitoring the student's progress.

Unsatisfactory academic progress on the part of a graduate student shall be reported to the Dean of Graduate Studies in a timely manner. Students making unsatisfactory progress by any of the measures listed above shall be placed on academic probation upon the first occurrence of such indication. Upon the second occurrence of an unsatisfactory progress indication, the Dean shall notify the student that he or she is subject to discretionary dismissal according to the procedure outlined below.

In addition, students in thesis-based degree programs who are not admitted to candidacy within the time limits specified in this Bulletin may be subject to immediate mandatory dismissal according to the procedure outlined below. Failure to fulfill this requirement must be reported to the Dean of Graduate Studies in a timely manner by the department head or division/program director.

Probation and Discretionary Dismissal Procedures

If a student is subject to academic probation as a result of an initial indication of unsatisfactory academic progress, the Dean of Graduate Studies shall notify the student of his or her probationary status in a timely manner.

If a student is subject to discretionary dismissal by one of the mechanisms defined above, the Dean shall notify the student and invite him or her to submit a written remedial plan, including performance milestones and deadlines, to correct the deficiencies that caused or contributed to the student's unsatisfactory academic progress. The remedial plan, which must be approved by the student's faculty advisor and the department head, division or program director, shall be submitted to the Dean no later than 10 business days from the date of official notification to the student of the potential discretionary dismissal. If the Dean concludes that the remedial plan is likely to lead to successful completion of all degree requirements within an acceptable time frame, the Dean may halt the discretionary dismissal process and allow the student to continue working toward his or her degree. If the Dean concludes that the remedial plan is inadequate, or that it is unlikely to lead to successful completion of all degree requirements within an acceptable time frame, the Dean shall notify the student of his or her

discretionary dismissal and inform the student of his or her right to appeal the dismissal as outlined below.

Unsatisfactory Academic Performance Resulting in Mandatory Dismissal

Unsatisfactory performance as gauged by any of the following measures shall result in immediate, mandatory dismissal of a graduate student:

1. Failure to successfully defend the thesis after two attempts;
2. Failure to be admitted to candidacy; or
3. Failure by a student subject to discretionary dismissal to achieve a performance milestone or meet a deadline contained in his or her remedial plan.

The Dean of Graduate Studies shall be notified promptly of any situation that may subject a student to mandatory dismissal. In this event, the Dean shall notify the student of his or her dismissal and inform the student of his or her right to appeal the dismissal as outlined below.

Students who have been notified of mandatory dismissal will be placed in non-degree status. They may request re-admission to either the same or a different degree program by submitting a full application for admission to the Graduate Office. The application will be reviewed through the normal admission process.

If a student who has been reinstated or readmitted to his or her former degree program and is subsequently found to be making unsatisfactory progress, the student will immediately be subject to mandatory dismissal.

Appeal Procedures

Both mandatory and discretionary dismissals may be appealed by a graduate student pursuant to this procedure. To trigger review hereunder, an appeal must:

1. Be in writing;
2. Contain a succinct description of the matter being appealed; and
3. Be filed with the Office of the Dean of Graduate Studies no later than 10 business days from the date upon which the student received official notification from the Dean regarding his or her dismissal.

Upon receipt of a timely appeal of a discretionary or mandatory dismissal, the Faculty Senate shall appoint a review committee composed of three tenured faculty members who are not members of the student's home or minor department or division. The review committee shall review the student's appeal and issue a written recommendation thereon to the Dean within 10 business days. During the course of performing this function, the committee may:

1. Interview the student, the student's advisor, and, if appropriate, the student's thesis committee;
2. Review all documentation related to the appeal under consideration;
3. Secure the assistance of outside expertise, if needed; and
4. Obtain any other relevant information necessary to properly consider the appeal.

The authority to render a final decision regarding all graduate student appeals filed hereunder shall rest with the Dean of Graduate Studies.

Exceptions and Appeals

Academic Policies and Requirements

Academic policies and requirements are included in the Bulletin on the authority of the Mines Board of Trustees as delegated to the Faculty Senate. These include matters such as degree requirements, grading systems, thesis and dissertation standards, admission standards and new and modified degree programs, certificates, minors and courses. No Mines administrator, faculty or staff member may change, waive or grant exceptions to such academic policies and requirements without approval of the Graduate Council, the Senate and/or the Board of Trustees as appropriate.

Administrative Policies and Procedures

Administrative Policies and Procedures are included in this Bulletin on the authority of the Mines Board of Trustees as delegated to the appropriate administrative office. These include (but are not limited to) matters such as student record keeping, thesis and dissertation formats and deadlines, registration requirements and procedures, assessment of tuition and fees, and allocation of financial aid. The Dean of Graduate Studies may waive or grant exceptions to such administrative policies and procedures as warranted by the circumstances of individual cases.

Any graduate student may request a waiver or exception by the following process:

1. Contact the Graduate Office to determine whether a standard form exists. If so, complete the form. If a standard form does not exist, prepare a memo with a statement of the request and a discussion of the reasons why a waiver or exception would be justified.
2. Have the memo or the form approved by the student's advisor and department head or division director, then submit it to the Dean of Graduate Studies.
3. If the request involves academic policies or requirements, the Dean of Graduate Studies will request Graduate Council approval at the Council's next regularly scheduled meeting.
4. The Dean of Graduate Studies will notify the student of the decision. The student may file a written appeal with the Provost within 10 business days of being notified of the decision. The Provost will investigate as appropriate to the issue under consideration and render a decision. The decision of the Provost is final.
5. At the next graduate Council meeting, the Dean will notify the Graduate Council of the request, the decision and the reasons for the decision. If the Graduate Council endorses the decision, then any other student in the same situation having the same justification can expect the same decision.

Tuition, Fees, Financial Assistance

2015-2016

Tuition and fees are established by the Board of Trustees of the Colorado School of Mines following the annual budget process and action by the Colorado General Assembly and Governor.

Graduate Tuition

The official tuition and approved charges for the 2015-2016 academic year will be available prior to the start of the 2015-2016 academic year

located at: <https://inside.mines.edu/UserFiles/File/finance/budget/FY16/FY16%20Tuition%20Schedule.pdf>

Fees

The official fees, approved charges, and fee descriptions for the 2014-2015 academic year will be available prior to the start of the 2014-2015 academic year and can be found at: <https://inside.mines.edu/UserFiles/File/finance/budget/FY16/FY16%20Fees%20and%20Charges-FINAL.pdf>

Please note that graduate students who register for undergraduate courses to satisfy deficiencies may be assessed the same fee that an undergraduate student would pay.

Payments and Refunds

Payment Information

A student is expected to complete the registration process, including the payment of tuition and fees, before attending class. Students should mail their payments to:

Cashier Colorado School of Mines
1500 Illinois St.
Golden, CO 80401-1869 or

pay at the Cashier's Office in The Ben Parker Student Center. Please write your student ID on payment.

Late Payment Penalties

A penalty will be assessed against a student if payment is not received in full by the official day of registration. The penalty is described in the schedule of courses for each semester. If payment is not completed by the sixth week of class, the student may be officially withdrawn from classes.

Financial Responsibility

Registration for classes at CSM implies an obligation by the student to meet all related financial responsibilities in a timely manner. Students who do not fulfill their financial obligations according to published deadlines are subject to the following: late payment penalties accrued on any outstanding balance, and the withholding of transcripts. Past due accounts will be turned over to Colorado Central Collection Services in accordance with Colorado law. Collection costs will be added to the student's account, and delinquencies may be reported to national credit bureaus.

Encumbrances

A student will not be permitted to register for future classes, to graduate, or to get an official transcript of his academic record while indebted in any way to CSM.

Refunds

Refunds for tuition and fees are made according to the following policy:

The amount of tuition and fee assessment is based primarily on each student's enrolled courses. In the event a student withdraws from a course or courses, assessments will be adjusted as follows:

- If the withdrawal is made prior to the end of the add/drop period for the term of enrollment, as determined by the Registrar, tuition and fees will be adjusted to the new course level without penalty.

- If the withdrawal from a course or courses is made after the add/drop period, and the student does not officially withdraw from school, no adjustment in charges will be made.
- If the withdrawal from courses is made after the add/drop period, and the student withdraws from school, tuition and fee assessments will be reduced according to the following schedule:
 - Within the 7 calendar days following the end of the add/drop period, 60 percent reduction in charges.
 - Within the next following 7 calendar days, a 40 percent reduction in charges.
 - Within the next following 7 calendar days, a 20 percent reduction in charges.
 - After that period, no reduction of charges will be made.

The schedule above applies to the Fall and Spring semesters. The time periods for the Summer sessions - Field and Summer - will be adjusted in proportion to the reduced number of days in these semesters.

Room and board refunds are prorated to the date of checkout from the Residence Hall. Arrangements must be made with the Housing Office. Student health insurance charges are not refundable. The insurance remains in effect for the entire semester.

PLEASE NOTE: Students receiving federal financial aid under the Title IV programs may have a different refund determined as required by federal law or regulations.

Financial Assistance for Graduate Studies

Graduate study is a considerable investment of time, energy, and money by serious students who expect a substantial return not only in satisfaction but also in future earnings. Applicants are expected to weigh carefully the investment they are willing to make against expected benefits before applying for admission.

Students are also expected to make full use of any resources available, including personal and loan funds, to cover expenses, and the School can offer some students financial aid through graduate research and teaching assistantships and through industry, state, and federal fellowships.

Purpose of Financial Aid

The Graduate School's limited financial aid is used

1. To give equal access to graduate study by assisting students with limited personal resources;
2. To compensate graduate students who teach and do research;
3. To give an incentive to exceptional students who can provide academic leadership for continually improving graduate programs.

Employment Restrictions and Agreements

Students who are employed full time or who are enrolled part time are not eligible for financial aid through the Graduate School.

Students who are awarded assistant-ships must sign an appointment agreement, which gives the terms of appointment and specifies the amount and type of work required. Graduate assistants who hold regular appointments are expected to devote all of their efforts to their educational program and may not be otherwise employed without the written permission of their supervisor and the Graduate Dean. Students with assistant-ships during the academic year must be registered as full time. During the summer session they must be registered for a

minimum of three credit hours, unless they qualify for the summer research registration exception. Please see http://www.mines.edu/graduate_admissions for details on summer registration exception eligibility.

Aid Application Forms

New students interested in applying for financial aid are encouraged to apply early. Financial aid forms are included in Graduate School application packets and may be filled out and returned with the other application papers.

Graduate Fellowships

The departments and divisions may award fellowships based on the student's academic performance.

Graduate Student Loans

Federal student loans are available for graduate students who need additional funding beyond their own resources and any assistant-ships or fellowships they may receive. The Free Application for Federal Student Aid (FAFSA) must be completed to apply for these loan funds. Students must be degree seeking, taking courses towards their degree and attending at least part-time (4.5 hrs) per semester (including summer) to be eligible. Degree seeking students who are approved for reduced registration (4 hrs/semester fall and spring and 3 hrs summer) are also eligible.

Specific information and procedures for filing the FAFSA can be found on the Financial Aid Office web site at <http://finaid.mines.edu>. The Financial Aid Office telephone number is 303-273-3301, and the email address is finaid@mines.edu.

Satisfactory Academic Progress for Federal Student Loans and Colorado Grad Grant

Students receiving assistance from federal or Colorado funds must make satisfactory academic progress toward their degree. Satisfactory progress is defined by maintaining adequate pace towards graduation and maintaining a 3.0 cumulative GPA at all times. Pace is measured by dividing the overall credit hours attempted by the overall credit hours completed. Students will be required to maintain a 75% completion rate at all times. Satisfactory standing is determined after each semester, including summer. If students are deficient in either the pace or grade average measure, they will receive a one semester warning period during which they must return to satisfactory standing.

If this is not done, their eligibility will be terminated until such time as they return to satisfactory standing. In addition, if students receive grades of F or INC in all of their courses, their future financial aid eligibility will be terminated without a warning period. Financial aid eligibility termination may be appealed to the Financial Aid Office on the basis of extenuating or special circumstances having negatively affected the student's academic performance. If approved, the student will receive a probationary period of one semester to regain satisfactory standing.

Late Fee for Application to Graduate after Stated Deadlines - \$250 Beginning Fall 2014

Graduate Students:

The deadline to apply to graduate and participate in commencement is Census Day of the term in which the student intends to graduate/participate.

Any request to be added to the graduation list and/or commencement ceremony after Census Day (and before Graduation Salute for the appropriate semester) may be made in writing and will be considered by the Office of Graduate Studies. If the request is denied, the student will be required to apply for the next available graduation/ceremony. If the request is approved and all other conditions are met (i.e. degree requirements can be met, required forms are turned in, and outstanding hour limitations are not exceeded), a mandatory \$250 fee will be applied to the student's account. This fee cannot be waived and cannot be refunded if the student does not meet the graduation check-out deadlines.

For late requests that are approved, tickets to the commencement ceremony for family and friends of the graduate are not guaranteed, as they may have already been distributed or assigned. Additionally, the student's name may not appear in the commencement program due to publishing deadlines.

No graduate student will be added to a graduation or commencement when the request is made after Graduation Salute.

Graduate Departments and Programs

2015-2016

Colorado School of Mines offers post-baccalaureate programs leading to the awarding of Graduate Certificates, Professional Masters degrees, thesis and non-thesis Master of Science and Master of Engineering degrees, and Doctor of Philosophy degrees. This section describes these degrees and explains the minimum institutional requirements for each. Students may apply to, and be admitted in, multiple graduate degrees simultaneously. In this case, a student may use the same graduate course credits to satisfy the degree requirements for each degree.

Students enrolled simultaneously in two Masters degree programs may double count up to half of the course credits required for the Masters degree program with the smallest course credit hour requirement toward both degree programs. Students simultaneously enrolled in a Masters degree and Doctoral degree may double count course credits toward each degree without limit. Course credits, however, may never be applied (i.e., double counted in the case of concurrent degree enrollment or used as transfer credit in the case of sequential degree enrollment) toward more than two graduate degrees.

Before the Graduate School will count these credits toward each degree requirement, the student must obtain written permission to do so from each department, division or program granting degree. This permission should be submitted with the student's Degree Audit form and should clearly indicate that each degree program is aware that credits are being counted toward the requirements of multiple degrees. For thesis-based students this permission should be provided by the student's thesis committee. For non-thesis and certificate programs, permission should be obtained from program coordinators or department/division chairs.

I. Responsible Conduct of Research Requirement

All students supported at any time in their graduate career through the National Science Foundation (NSF), as research assistants, hourly employees or fellowship awardees, must complete training in the responsible conduct of research (RCR). This requirement is in addition to all other institutional and program requirements described below and in the appropriate program sections of this Bulletin.

To satisfy the RCR requirement students must complete one of the following options:

- LAIS565 - Option available to all students
- SYGN502 - Option available to all students
- Chemistry Program Option - Option available only to students in the Chemistry program
- Physics program option: option available only to students with physics faculty advisors or co-advisors

For additional information on program-specific options, contact the program.

By whatever means chosen, the NSF-RCR requirement must be completed prior to a candidate submitting the Degree Audit form. Students and advisors certify successful completion of the RCR requirement on the Degree Audit form.

II. Professional Programs

A. Graduate Certificate Program

Graduate Certificate Programs at CSM are designed to have selective focus, short time to completion and consist of course work only. For more information about specific professional programs, please refer to the "Graduate Degree Programs and Description of Courses" portion of this Bulletin.

1. Academic Requirements

Each Graduate Certificate requires a minimum of 12 total credit hours. No more than 3 credit hours at the 400 level may be applied toward the minimum credit-hours requirement. All other credits must be at or above the 500 level. Students may not, on an individual basis, request credit hours be transferred from other institutions as part of the Certificate requirements. Some Graduate Certificates, however, may allow the application of specific, pre-approved transfer credits, or credits from other institutions with whom CSM has formal agreements for this purpose toward fulfilling the requirements of the Certificate. All courses applied to a Graduate Certificate are subject to approval by the program offering the certificate.

If a student has earned a Graduate Certificate and subsequently applies, and is accepted into a Master's or PhD program at Mines, credits earned in the Certificate Program may, with the approval of the advanced degree program, be applied to the advanced degree subject to all the applicable restrictions on credit hours that may be applied toward fulfilling the requirements of the advanced degree.

2. Graduation Requirements

Full-time students must complete the following requirement within the first semester after enrolling into a Graduate Certificate degree program.

- complete all prerequisites and core curriculum course requirements of their program.

A list of prerequisites and core curriculum requirements for Graduate Certificate degrees is published by each program. When a student is admitted with deficiencies, the appropriate department head, division director or program director will provide the student with a written list of courses required to remove these deficiencies. This list will be given to the student no later than one week after the start of classes of his/her first semester in order to allow for adding/dropping courses as necessary.

Upon completion of the above-defined requirements, a student must submit a Degree Audit form and a completed Statement of Work Completion forms documenting satisfactory completion of the prerequisites and core curriculum requirements. The form must have the written approval of the program offering the Graduate Certificate.

B. Professional Master's Program

CSM awards specialized, career-oriented non-thesis Master degrees with the title of "Professional Master (descriptive title)." These are custom-designed, interdisciplinary degrees, each with a curriculum meeting the career advancement needs of a particular group of professionals in a field that is part of CSM's role and mission. For more information about these programs, please refer to the "Graduate Degree Programs and Description of Courses" portion of this Bulletin.

1. Academic Requirements

Each Professional Master's degree consists of a minimum of 30 total credit hours. Students must complete at least 21 credit hours at CSM in the degree program. The remaining hours may be transferred into the program. Requests for transfer credit must be approved by the faculty according to a process defined by the student's home department or division. Transfer credits must not have been used as credit toward a Bachelor degree. The transfer limit includes CSM distance learning courses. Up to six credit hours of Special Topic or Independent Study may be in the form of project credits done on the job as an employee or as a graduate intern. If project credits are to be used, the project proposal and final report must be approved by a CSM faculty advisor, although direct supervision may be provided by the employer. Students must maintain a cumulative grade point average of 3.0 or better in CSM course work.

2. Graduation Requirements

Full-time students must complete the following requirement within the first calendar year after enrolling into a Professional Master's degree program.

- complete all prerequisite and core curriculum course requirements of their program.

Each program publishes a list of prerequisites and core curriculum requirements for Professional Master's degrees. When a student is admitted with deficiencies, the appropriate department head, division director or program director will provide the student with a written list of courses required to remove these deficiencies. This list will be given to the student no later than one week after the start of classes of his/her first semester in order to allow for adding/dropping courses as necessary.

Upon completion of the above-defined requirements, a student must submit a Degree Audit form documenting satisfactory completion of the prerequisites and core curriculum requirements. The form must have the written approval of the program offering the Professional Master's degree.

To graduate, all Professional Master's students must apply to graduate, submit a completed checkout card and a completed Statement of Work Completion from by the posted deadlines.

III. Master of Science and Engineering Programs

A. General Requirements

Graduate study at CSM can lead to one of a number of thesis and non-thesis based Master's degrees, depending on the interests of the student. All Master's degree programs share the same academic requirements for grades, definition of minor programs, and the need to apply for admission to candidacy.

1. Academic Requirements

A Master's degree at Mines requires a minimum of 30 total credit hours. As part of this 30 hours, departments and divisions are required to include a research or design experience supervised by Mines faculty. For more information about the specific research/design requirements, please refer to the appropriate department/division section of the "Graduate Degree Programs and Description of Courses" portion of this Bulletin.

For non-thesis Master's degrees, students must complete at least 21 credit hours at Mines in the degree program. All other credits may be completed as transfer credits into the degree program. For thesis Master's degrees, no more than 9 credits may transfer. The transfer credit limit includes Mines distance learning courses. Transfer credits must not have been used as credit toward a Bachelor degree. Requests for transfer credit must be approved by the faculty according to the process defined by a student's home department or division. All credits applied toward degree, except transfer credits, must be earned on campus. Students must maintain a cumulative grade point average of 3.0 or better in Mines course work.

2. Minor Programs

Students may choose to have a minor program or programs at the Master's level. A minor program may not be taken in the student's major area of study. A designated minor requires a minimum of 9 semester hours of course work and must be approved by the student's advisor, home department head, and a faculty representative of the minor area of study. Less than half of the credit hours applied toward the minor degree program may be in the form of transfer credit hours. Transfer credit hours applied toward the minor are included as part of the overall transfer limitation applied to the degree as defined above.

3. Graduation Requirements

Full-time students must complete the following requirements within one calendar year of enrolling into the Master's degree program.

- have a thesis committee appointment form on file in the Graduate Office, and
- complete all prerequisite and core curriculum course requirements of their department, division or program.

Each degree program publishes a list of prerequisite and core curriculum requirements for that degree. If students are admitted with deficiencies, the appropriate department heads, division directors or program directors will provide the students written lists of courses required to remove the deficiencies. These lists will be given to the students no later than one

week after the start of classes of their first semester in order to allow them to add/drop courses as necessary.

Upon completion of the above defined requirements, students must submit Degree Audit form documenting satisfactory completion of the prerequisite and core curriculum requirements and granting permission to begin Master's level research. The form must have the written approval of all members of the advisor and thesis committee, if appropriate.

To graduate, all Master of Science and Engineering students must apply to graduate, submit a completed checkout card, a Statement of Work Completion form, and all thesis-based students must submit a completed Regulated Materials form by the posted deadlines.

B. Non-thesis Option

Non-thesis Master's degrees (both non-thesis Master of Science and Master of Engineering) are offered by a number of departments, divisions and programs. In lieu of preparing a thesis, non-thesis master's program students are required to complete a research or design experience taken as a special problem or as an independent study course. See the department/division section of the "Graduate Degree Programs and Description of Courses" portion of this Bulletin for more information. Although non-thesis master's students are not assigned a Thesis Committee, students in this program do select a faculty advisor, subject to the approval of the student's home department.

C. Thesis Option

Thesis-based Master of Science degrees require completion of a satisfactory thesis and successful oral defense of this thesis. Academic credit toward completion of the thesis must include successful completion of no fewer than 6 credit hours of masters-level research credit. The thesis is expected to report on original research that results in new knowledge and/or techniques or on creative engineering design that applies state-of-the-art knowledge and techniques to solve an important problem. In either case, the thesis should be an exemplary product that meets the rigorous scholarship standards of the Colorado School of Mines. The student's faculty advisor and the Master's Thesis Committee must approve the program of study and the topic for the thesis. The format of the thesis must comply with the appropriate guidelines promulgated by the Graduate School.

1. Faculty Advisor Appointment

Each thesis-based Master's student must select a faculty advisor to provide advice regarding the student's thesis direction, research and selection of courses. Master's students must select faculty advisors by the end of the second semester at CSM. Advisors must be full-time permanent members of the CSM faculty. In this context, full-time permanent members of the CSM faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors.

The Director of the degree program, often times the head of the student's home department or division, and the Graduate Dean must approve all faculty advisor appointments.

2. Thesis Committee

The Graduate Dean appoints a Thesis Committee whose members have been recommended by the student, the student's faculty advisor, and the

student's department head. Students should have a thesis committee appointed by the end of their second semester. This Committee will have a minimum of three voting members, including the student's advisor, who are familiar with the student's area of study. Of these Committee members, two must be from the home department or, in the case of interdisciplinary degree programs, an allied department. Off-campus members can be assigned to the Committee to serve either with full voting status or in a non-voting capacity. Off-campus members with voting status assume all of the responsibilities of on-campus Committee members with respect to attendance of Committee meetings, review of thesis drafts and participation in oral examinations and thesis defense sessions. If a thesis co-advisor is assigned, an additional faculty member from the home or allied department must be added to the committee. Students who choose to have a minor program at the Master's level must select a representative from their minor area of study to serve on the Thesis Committee. Minor representatives must be full-time members of the CSM faculty.

A Thesis Committee Chairperson is designated by the student at the time he/she requests the formation of his/her thesis committee. The chairperson is responsible for leading all meetings of the thesis committee and for directing the student's thesis defense. In selecting a Thesis Committee chairperson, the following guidelines must be met:

1. The chairperson cannot be the student's advisor or co-advisor and
2. The chairperson must be a full-time CSM faculty member.

Shortly after its appointment, the Committee will meet with the student to hear a presentation of the proposed course of study and thesis topic. The Committee and the student must agree on a satisfactory program and the student must obtain the Committee approval of the written thesis proposal at least one semester prior to the thesis defense. The student's faculty advisor assumes the primary responsibility for monitoring the program and directing the thesis work. The award of the thesis-based Master's degree is contingent upon the student's researching and writing a thesis acceptable to the student's faculty advisor and Thesis Committee.

3. Thesis Defense

The student submits an initial draft of his or her thesis to the faculty advisor, who will work with the student on necessary revisions. Upon approval of the student's advisor, the revised thesis is circulated to the Thesis Committee members at least one week prior to the oral defense of the thesis. The oral defense of the thesis is scheduled during the student's final semester of study. Students must be registered to defend. This defense session, which may include an examination of material covered in the student's course work, will be open to the public.

Following the defense, the Thesis Committee will meet privately to vote on whether the student has successfully defended the thesis. Three outcomes are possible: the student may pass the oral defense; the student may fail the defense; or the Committee may vote to adjourn the defense to allow the student more time to address and remove weaknesses or inadequacies in the thesis or underlying research. Two negative votes will constitute a failure regardless of the number of Committee members present at the thesis defense. In the event of either failure or adjournment, the Chair of the Thesis Committee will prepare a written statement indicating the reasons for this action and will distribute copies to the student, the Thesis Committee members, the student's department head and the Graduate Dean. In the case of failure or adjournment, the student may request a re-examination, which must be scheduled no less than one week after the original defense. A second

failure to defend the thesis satisfactorily will result in the termination of the student's graduate program.

Upon passing the oral defense of thesis or report, the student must make any corrections in the thesis required by the Thesis Committee. The final, corrected copy and an executed signature page indicating approval by the student's advisor and department head must be submitted to the Office of Graduate Studies for format approval. (Format instructions are available in the Office of Graduate Studies and should be obtained before beginning work on the thesis.)

4. Time Limitations

A candidate for a thesis-based Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. Time spent on approved leaves of absence is included in the five-year time limit. Candidates not meeting the time limitation will be notified and withdrawn from their degree programs.

Candidates may apply for a one-time extension of this time limitation. This application must be made in writing and approved by the candidate's advisor, thesis committee, department and Dean of Graduate Studies. The application must include specific timelines and milestones for degree completion. If an extension is approved, failure to meet any timeline or milestone will trigger immediate withdrawal from the degree program.

If the Dean of Graduate Studies denies an extension request, the candidate may appeal this decision to the Provost. The appeal must be made in writing, must specifically state how the candidate believes the request submitted to the Dean met the requirements of the policy, and must be received no later than 10 business days from the date of notification of the Dean's denial of the original request.

If a candidate is withdrawn from a degree program through this process (i.e., either by denial of an extension request or failure to meet a timeline or milestone) and wishes to reenter the degree program, that candidate must formally reapply for readmission. The program has full authority to determine if readmission is to be granted and, if granted to fully re-evaluate the Candidate's work to date and determine its applicability to the new degree program.

IV. Doctor of Philosophy

A. Credits, Hour and Academic Requirements

The Doctor of Philosophy degree requires completion of a minimum of 72 semester hours beyond the Bachelor degree. At least 24 semester hours must be research credits earned under the supervision of a Mines faculty advisor and at least 18 credit hours of course work must be applied to the degree program. Course requirements for each department or division are contained in the "Graduate Degree Programs and Description of Courses" section of this Bulletin.

The degree also requires completion of a satisfactory doctoral thesis and successful oral defense of this thesis. The Doctoral Thesis is expected to report on original research that results in a significant contribution of new knowledge and/or techniques. The student's faculty advisor and the Doctoral Thesis Committee must approve the program of study and the topic for the thesis.

B. Residency Requirements

Doctoral students must complete a residency requirement during the course of their graduate studies. The purpose of this requirement is to:

- require students to become engaged in extended and focused research activities under the direct supervision of Mines faculty;
- allow students to become immersed in the culture of an academic environment;
- allow students to engage in the professional activities associated with their research discipline;
- ensure students have access to the research tools and expertise needed for their chosen research activity;
- ensure the conduct of cutting-edge research with the expectation that this research will be completed in a timely fashion so that it is still relevant to the larger research community;
- provide Mines faculty with the ability to directly evaluate the research and academic credentials of a student and as such protect the integrity of the degree, department and the institution;
- ensure the research produced by students claiming a Mines degree is actually the product of Mines' intellectual environment; and
- make it clear that the intellectual property developed while in the degree program is the property of Mines as defined in the Faculty Handbook.

The residency requirement may be met by completing two semesters of full-time registration at Mines. The semesters need not be consecutive. Students may request an exception to the full-time registration requirement from the Dean of Graduate Studies. Requests for exception must be in writing, must clearly address how the student's learning experience has met the goals of the residency requirement, as articulated above, and must be submitted by both the student and the student's thesis advisor and be approved by the student's Department Head/ Division Director.

C. Transfer of Credits

Up to 24 semester hours of graduate-level course work may be transferred from other institutions toward the PhD degree subject to the restriction that those courses must not have been used as credit toward a Bachelor degree. Requests for transfer credit must be approved by the faculty according to a process defined by the student's home department or division. Transfer credits are not included in calculating the student's grade point average at CSM.

In lieu of transfer credit for individual courses defined above, students who enter the PhD program with a thesis-based Master's degree from another institution may transfer up to 36 semester hours in recognition of the course work and research completed for that degree. The request must be approved by the faculty according to a process defined by the student's home department or division.

D. Faculty Advisor Appointments

Each doctoral student must select a faculty advisor to advise with respect to the student's thesis direction and research and selection of courses. Doctoral students must select faculty advisors by the end of the second semester at CSM. Advisors must be full-time permanent members of the CSM faculty. In this context, full-time permanent members of the CSM faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors.

The Director of the doctoral degree program, often times the head of the student's home department or division, and the Graduate Dean must approve all faculty advisor appointments.

E. Minor Programs

Students may choose a minor program or programs at the PhD level consisting of 12 course credits in the minor program. The student's faculty advisor and Doctoral Thesis Committee, including an appropriate minor committee member as described below, approve the course selection and sequence in the selected minor program. Students may choose to complete multiple minor programs. Each program must consist of at least 12 credit hours approved by the faculty advisor and Doctoral Thesis Committee, including the appropriate minor committee members. Less than half of the credit hours applied toward the minor degree program may be in the form of transfer credit hours. Transfer credit hours applied toward a minor are included as part of the overall transfer limitation applied to the degree as defined above.

F. Doctoral Thesis Committees

The Graduate Dean appoints a Doctoral Thesis Committee whose members have been recommended by the student's doctoral degree program. Students should have a thesis committee appointed by the end of their second semester. This Committee must have a minimum of four voting members that fulfill the following criteria:

1. The Committee must include an advisor who meets the qualifications defined above. If two advisors are appointed, both shall be voting members of the Committee.
2. The Committee must have at least two voting members knowledgeable in the technical areas of the thesis in addition to the advisor(s) and who are full-time permanent CSM faculty members.
3. The fourth, required member of the Committee must be a full-time permanent CSM faculty member, may not be an advisor, and must be from outside of the student's doctoral degree program, home department and minor program area(s) – if appropriate. This committee member acts as Thesis Committee Chairperson.
4. If a minor field is designated, an additional committee member must be included who is an expert in that field. Minor representatives must be full-time permanent members of the CSM faculty who are participating members of the minor program area. If multiple minor programs are pursued, each must have a committee representative as defined above.
5. Off-campus representatives may serve as additional committee members. If off-campus members are nominated for voting status, the committee request form must include a brief resume of their education and/or experience that demonstrates their competence to judge the quality and validity of the thesis. Such members also must agree to assume the same responsibilities expected of on-campus shy;Committee members including, but not limited to, attenshy;dance at Committee meetings, review of thesis proposals and drafts, and participation in oral examinations and defense.

Shortly after its appointment, the Doctoral Thesis Committee meets with the student to hear a presentation of the proposed course of study and thesis topic. The Committee and student must agree on a satisfactory program. The student's faculty advisor then assumes the primary responsibility for monitoring the program, directing the thesis work, arranging qualifying examinations, and scheduling the thesis defense.

G. Admission to Candidacy

Full-time students must complete the following requirements within the first two calendar years after enrolling into the PhD program.

- have a thesis committee appointment form on file in the Graduate Office;
- complete all prerequisite and core curriculum course requirements of their department, division or program;
- demonstrate adequate preparation for, and satisfactory ability to conduct, doctoral research; and
- be admitted into full candidacy for the degree.

Each degree program publishes a list of prerequisite and core curriculum requirements for that degree. If students are admitted with deficiencies, the appropriate department heads, division directors or program directors will provide the students written lists of courses required to remove the deficiencies. These lists will be given to the students no later than one week after the start of classes of their first semester in order to allow them to add/drop courses as necessary. Each program also defines the process for determining whether its students have demonstrated adequate preparation for, and have satisfactory ability to do, high-quality, independent doctoral research in their specialties. These requirements and processes are described under the appropriate program headings in the section of this Bulletin on Graduate Degree Programs and Description of Courses.

Upon completion of these requirements, students must submit a Degree Audit form and an Admission to Candidacy form documenting satisfactory completion of the prerequisite and core curriculum requirements and granting permission to begin doctoral research. The form must have the written approval of all members of the Ph.D. Committee.

To graduate, all PhD students must apply to graduate, submit a completed checkout card, submit a completed Statement of Work Completion form, submit a completed Regulated Materials form and complete the Survey of Earned Doctorate by the posted deadlines.

H. Thesis Defense

The doctoral thesis must be based on original research of excellent quality in a suitable technical field, and it must exhibit satisfactory literary merit. In addition, the format of the thesis must comply with guidelines promulgated by the Office of Graduate Studies. (Students should obtain a copy of these guidelines from the Office of Graduate Studies before beginning work on the thesis.)

The thesis topic must be submitted in the form of a written proposal to the student's faculty advisor and the Committee. The Committee must approve the proposal at least one year before the thesis defense.

The student's faculty advisor is responsible for supervising the student's research work and consulting with other Doctoral Thesis Committee members on the progress of the work. The advisor must consult with the Committee on any significant change in the nature of the work. The student submits an initial draft of his or her thesis to the advisor, who will work with the student on necessary revisions. Upon approval of the student's advisor, the revised thesis is distributed to the other members of the Committee at least one week prior to the oral defense of the thesis.

The student must pass an oral defense of his or her thesis during the final semester of studies. Students must be registered to defend. This oral

defense may include an examination of material covered in the student's course work. The defense will be open to the public.

Following the defense, the Doctoral Thesis Committee will meet privately to vote on whether the student has successfully defended the thesis. Three outcomes are possible: the student may pass the oral defense; the student may fail the defense; or the Committee may vote to adjourn the defense to allow the student more time to address and remove weaknesses or inadequacies in the thesis or underlying research. Two negative votes will constitute a failure regardless of the number of Committee members present at the thesis defense. In the event of either failure or adjournment, the Chair of the Doctoral Thesis Committee will prepare a written statement indicating the reasons for this action and will distribute copies to the student, the Thesis Committee members, the student's department head and the Graduate Dean. In the case of failure, the student may request a re-examination, which must be scheduled no less than one week after the original defense. A second failure to defend the thesis satisfactorily will result in the termination of the student's graduate program.

Upon passing the oral defense of thesis, the student must make any corrections in the thesis required by the Doctoral Thesis Committee. The final, corrected copy and an executed signature page indicating approval by the student's advisor and department head must be submitted to the Office of Graduate Studies for format approval.

I. Time Limitations

A candidate for a thesis-based Doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program. Time spent on approved leaves of absence is included in the nine-year time limit. Candidates not meeting the time limitation will be notified and withdrawn from their degree programs.

Candidates may apply for a one-time extension of this time limitation. This application must be made in writing and approved by the candidate's advisor, thesis committee, department and Dean of Graduate Studies. The application must include specific timelines and milestones for degree completion. If an extension is approved, failure to meet any timeline or milestone will trigger immediate withdrawal from the degree program.

If the Dean of Graduate Studies denies an extension request, the candidate may appeal this decision to the Provost. The appeal must be made in writing, must specifically state how the candidate believes the request submitted to the Dean met the requirements of the policy, and must be received no later than 10 business days from the date of notification of the Dean's denial of the original request. The Provost's decision is final.

If a candidate is withdrawn from a degree program through this process (i.e., either by denial of an extension request or failure to meet a timeline or milestone) and wishes to reenter the degree program, that candidate must formally reapply for readmission. The program has full authority to determine if readmission is to be granted and, if granted to fully re-evaluate the Candidate's work to date and determine its applicability to the new degree program.

V. Roles and Responsibilities of Committee Members and Students

Below, are the roles and expectations Mines has of faculty as members of Thesis Committees and of students engaged in research-based degree programs.

Thesis Advisor(s)

The Thesis Advisor has the overall responsibility for guiding the student through the process of the successful completion of a thesis that fulfills the expectations of scholarly work at the appropriate level as well as meets the requirements of the Department/Division and the School. The Advisor shall:

- be able and willing to assume principal responsibility for advising the student;
- have adequate time for this work and be accessible to the student;
- provide adequate and timely feedback to both the student and the Committee regarding student progress toward degree completion;
- guide and provide continuing feedback on the student's development of a research project by providing input on the intellectual appropriateness of the proposed activities, the reasonableness of project scope, acquisition of necessary resources and expertise, necessary laboratory or computer facilities, etc.;
- establish key academic milestones and communicate these to the student and appropriately evaluate the student on meeting these milestones.

Regular Committee Member

With the exception of the student's advisor, all voting members of the Thesis Committee are considered Regular Committee Members. The Regular Committee Member shall:

- have adequate time to assume the responsibilities associated with serving on a student's Thesis Committee;
- be accessible to the student (at a minimum this implies availability for Committee meetings and availability to participate in a student's qualifying/comprehensive examinations – as dictated by the practices employed by the degree program – and the thesis defense);
- ensure that the student's work conforms to the highest standards of scholarly performance within the discipline, within the expertise provided by the Committee member;
- provide advice to both the student and the student's advisor(s) on the quality, suitability and timeliness of the work being undertaken;
- approve the student's degree plan (e.g., courses of study, compliance with program's qualifying process, thesis proposal, etc.), assuring that the plan not only meets the intellectual needs of the student, but also all institutional and program requirements;
- review dissertation drafts as provided by the student and the advisor and provide feedback in a timely fashion; and
- participate in, and independently evaluate student performance in the final thesis defense.

Minor Field Committee Representative

In addition to the responsibilities of a Regular Committee Member, the Minor Field Committee Representative has the following added responsibilities:

- provide advice for, and approval of coursework required as part of a student's minor degree program in a manner that is consistent with institutional and minor program requirements;
- participate in, as appropriate, the student's qualifying and comprehensive examination process to certify completion of minor degree requirements; and

- work individually with the student on the thesis aspects for which the Minor Committee member has expertise.

Thesis Committee Chairperson

In addition to the responsibilities of a Regular Committee Member, the Chairperson of Committee has the following added responsibilities:

- chair all meetings of the Thesis Committee including the thesis defense;
- represent the broad interests of the Institution with respect to high standards of scholarly performance;
- represent the Office of Graduate Studies by ensuring that all procedures are carried out fairly and in accordance with institutional guidelines and policies; and
- ensure there are no potential conflicts of interest between student, advisor or any other committee member are effectively identified and managed.

Student Responsibilities

While it is expected that students receive guidance and support from their advisor and all members of the Thesis Committee, the student is responsible for actually defining and carrying out the program approved by the Thesis Committee and completing the thesis/dissertation. As such, it is expected that the student assumes a leadership role in defining and carrying out all aspects of his/her degree program and thesis/dissertation project. Within this context, students have the following responsibilities:

- to formally establish a Thesis Advisor and Committee by the end of their first year of residence in their degree program;
- to call meetings of the Thesis Committee as needed;
- to actively inform and solicit feedback from the student's Advisor and Committee on progress made toward degree;
- to respond to, and act on feedback from the student's Advisor and Committee in a timely and constructive manner;
- to understand and then apply the institutional and programmatic standards related to the ethical conduct of research in the completion of the student's thesis/dissertation; and
- to know, understand and follow deadlines defined by the institution and the degree program related to all aspects of the student's degree program.

VI. Combined Undergraduate/Graduate Degree Programs

A. Overview

Many degree programs offer CSM undergraduate students the opportunity to begin work on a Graduate Certificate, Professional Master's Degree, Master's Degree or Doctoral Degree while completing the requirements for their Bachelor's Degree. These combined Bachelors-Masters/Doctoral programs have been created by Mines faculty in those situations where they have deemed it academically advantageous to treat undergraduate and graduate degree programs as a continuous and integrated process. These are accelerated programs that can be valuable in fields of engineering and applied science where advanced education in technology and/or management provides the opportunity to be on a fast track for advancement to leadership positions. These programs also can be valuable for students who want to get a head start on graduate education.

The combined programs at Mines offer several advantages to students who choose to enroll in them:

1. Students can earn a graduate degree in their undergraduate major or in a field that complements their undergraduate major.
2. Students who plan to go directly into industry leave Mines with additional specialized knowledge and skills which may allow them to enter their career path at a higher level and advance more rapidly. Alternatively, students planning on attending graduate school can get a head start on their graduate education.
3. Students can plan their undergraduate electives to satisfy prerequisites, thus ensuring adequate preparation for their graduate program.
4. Early assignment of graduate advisors permits students to plan optimum course selection and scheduling in order to complete their graduate program quickly.
5. Early acceptance into a Combined Degree Program leading to a Graduate Degree assures students of automatic acceptance into full graduate status if they maintain good standing while in early-acceptance status.
6. In many cases, students will be able to complete both a Bachelor's and a Master's Degrees in five years of total enrollment at Mines.

Certain graduate programs may allow Combined Degree Program students to fulfill part of the requirements of their graduate degree by including up to six hours of specified course credits which also were used in fulfilling the requirements of their undergraduate degree. These courses may only be applied toward fulfilling Doctoral degree or, Master's degree requirements beyond the institutional minimum Master's degree requirement of 30 credit hours. Courses must meet all requirements for graduate credit, but their grades are not included in calculating the graduate GPA. Check the departmental section of the Bulletin to determine which programs provide this opportunity.

B. Admission Process

A student interested in applying into a graduate degree program as a Combined Degree Program student should first contact the department or division hosting the graduate degree program into which he/she wishes to apply. Initial inquiries may be made at any time, but initial contacts made soon after completion of the first semester, Sophomore year are recommended. Following this initial inquiry, departments/ divisions will provide initial counseling on degree application procedures, admissions standards and degree completion requirements.

Admission into a graduate degree program as a Combined Degree Program student can occur as early as the first semester, Junior year, and must be granted no later than the end of registration, last semester Senior year. Once admitted into a graduate degree program, students may enroll in 500-level courses and apply these directly to their graduate degree. To apply, students must submit the standard graduate application package for the graduate portion of their Combined Degree Program. Upon admission into a graduate degree program, students are assigned graduate advisors. Prior to registration for the next semester, students and their graduate advisors should meet and plan a strategy for completing both the undergraduate and graduate programs as efficiently as possible. Until their undergraduate degree requirements are completed, students continue to have undergraduate advisors in the home department or division of their Bachelor's Degrees.

C. Requirements

Combined Degree Program students are considered undergraduate students until such time as they complete their undergraduate degree requirements. Combined Degree Program students who are still considered undergraduates by this definition have all of the privileges and are subject to all expectations of both their undergraduate and graduate programs. These students may enroll in both undergraduate and graduate courses (see section D below), may have access to departmental assistance available through both programs, and may be eligible for undergraduate financial aid as determined by the Office of Financial Aid. Upon completion of their undergraduate degree requirements, a Combined Degree Program student is considered enrolled full-time in his/her graduate program. Once having done so, the student is no longer eligible for undergraduate financial aid, but may now be eligible for graduate financial aid. To complete their graduate degree, each Combined Degree Program student must register as a graduate student for at least one semester.

Once admitted into a graduate program, undergraduate Combined Degree Program students must maintain good standing in the Combined Program by maintaining a minimum semester GPA of 3.0 in all courses taken. Students not meeting this requirement are deemed to be making unsatisfactory academic progress in the Combined Degree Program. Students for whom this is the case are subject to probation and, if occurring over two semesters, subject to discretionary dismissal from the graduate portion of their program as defined in the Unsatisfactory Academic Performance section of this Bulletin.

Upon completion of the undergraduate degree requirements, Combined Degree Program students are subject to all requirements (e.g., course requirements, departmental approval of transfer credits, research credits, minimum GPA, etc.) appropriate to the graduate program in which they are enrolled.

D. Enrolling in Graduate Courses as a Senior in a Combined Program

As described in the Undergraduate Bulletin, seniors may enroll in 500-level courses. In addition, undergraduate seniors who have been granted admission through the Combined Degree Program into thesis-based degree programs (Masters or Doctoral) may, with graduate advisor approval, register for 700-level research credits appropriate to Masters-level degree programs. With this single exception, while a Combined Degree Program student is still completing his/her undergraduate degree, all of the conditions described in the Undergraduate Bulletin for undergraduate enrollment in graduate-level courses apply. 700-level research credits are always applied to a student's graduate degree program.

If an undergraduate Combined Degree Program student would like to enroll in a 500-level course and apply this course directly to his/her graduate degree, he/she must notify the Registrar of the intent to do so at the time of enrollment in the course. The Registrar will forward this information to Financial Aid for appropriate action. Be aware that courses taken as an undergraduate student but not used toward a bachelor's degree are not eligible for undergraduate financial aid or the Colorado Opportunity Fund. If an undergraduate student has not been admitted into a graduate program, all 500-level graduate courses taken as an undergraduate Combined Degree Program student will be applied to the student's undergraduate degree transcript. If these are not used toward an undergraduate degree requirement, they may, with program consent, be applied to a graduate degree program as transfer credit. All

regular regulations and limitations regarding the use of transfer credit to a graduate degree program apply to these credits.

College of Engineering & Computational Sciences

Please choose from the list of links on the left to access more information.

Applied Mathematics & Statistics

2015-2016

Degrees Offered

- Master of Science (Applied Mathematics and Statistics)
- Doctor of Philosophy (Applied Mathematics and Statistics)

Program Description

The Department of Applied Mathematics and Statistics (AMS) offers two graduate degrees: A Master of Science in Applied Mathematics and Statistics and a Doctor of Philosophy in Applied Mathematics and Statistics. The master's program is designed to prepare candidates for careers in industry or government or for further study at the PhD level. The PhD program is sufficiently flexible to prepare candidates for careers in industry, government and academia. A course of study leading to the PhD degree can be designed either for students who have completed a Master of Science degree or for students with a Bachelor of Science degree.

Research within AMS is conducted in the following areas:

Computational and Applied Mathematics

Study of Wave Phenomena and Inverse Problems

Numerical Methods for PDEs

Study of Differential and Integral Equations

Computational Radiation Transport

Computational Acoustics and Electromagnetics

Multi-scale Analysis and Simulation

High Performance Scientific Computing

Dynamical Systems

Mathematical Biology

Statistics

Inverse Problems in Statistics

Multivariate Statistics

Spatial Statistics

Stochastic Models for Environmental Science

Survival Analysis

Uncertainty Quantification

Master of Science Program Requirements

The Master of Science degree (thesis option) requires 30 credit hours of acceptable coursework and research, completion of a satisfactory thesis, and successful oral defense of this thesis. At least six of the 30 credit hours must be designated for supervised research. The coursework includes the following core curriculum.

Specialty in Computational & Applied Mathematics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH502	REAL AND ABSTRACT ANALYSIS	3.0
MATH503	FUNCTIONAL ANALYSIS	3.0
MATH506	COMPLEX ANALYSIS II	3.0
MATH510	ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS	3.0
MATH540	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH556	MODELING WITH SYMBOLIC SOFTWARE	3.0
MATH557	INTEGRAL EQUATIONS	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Specialty in Statistics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH532	SPATIAL STATISTICS	3.0
MATH536	ADVANCED STATISTICAL MODELING	3.0
MATH537	MULTIVARIATE ANALYSIS	3.0
MATH538	STOCHASTIC MODELS	3.0
MATH539	SURVIVAL ANALYSIS	3.0

MATH582	STATISTICS PRACTICUM	3.0
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*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

For both specialties, elective courses may be selected from any other graduate courses offered by the Department of Applied Mathematics and Statistics, except for specially designated service courses. In addition, up to 6 credits of elective courses may be taken in other departments on campus.

The Master of Science degree (non-thesis option) requires 30 credit hours of coursework. The coursework includes the required core curriculum for the chosen specialty.

Combined BS/MS Program

The Department of Applied Mathematics and Statistics offers a combined Bachelor of Science/Master of Science program that enables students to work on a Bachelor of Science and a Master of Science in either specialty simultaneously. Students take 30 credit hours of coursework at the graduate level in addition to the undergraduate requirements, and work on both degrees at the same time. Students may apply for the program once they have completed five classes with a MATH prefix numbered 225 or higher.

Doctor of Philosophy Program Requirements:

The Doctor of Philosophy requires 72 credit hours beyond the bachelor's degree. At least 24 of these hours must be thesis hours. Doctoral students must pass the comprehensive examination (a qualifying examination and thesis proposal), complete a satisfactory thesis, and successfully defend their thesis. The coursework includes the following core curriculum.

Specialty in Computational & Applied Mathematics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following;

MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0

MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0
MATH502	REAL AND ABSTRACT ANALYSIS	3.0
MATH503	FUNCTIONAL ANALYSIS	3.0
MATH506	COMPLEX ANALYSIS II	3.0
MATH510	ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS	3.0
MATH540	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH556	MODELING WITH SYMBOLIC SOFTWARE	3.0
MATH557	INTEGRAL EQUATIONS	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Specialty in Statistics

Required Courses

MATH500	LINEAR VECTOR SPACES	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS *	1.0
MATH589	APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR **	1.0

plus two courses chosen from the following:

MATH532	SPATIAL STATISTICS	3.0
MATH536	ADVANCED STATISTICAL MODELING	3.0
MATH537	MULTIVARIATE ANALYSIS	3.0
MATH538	STOCHASTIC MODELS	3.0
MATH539	SURVIVAL ANALYSIS	3.0
MATH582	STATISTICS PRACTICUM	3.0

*Required for students receiving federal support.

** Required only for students employed by the department as graduate teaching assistants or student instructor/lecturers.

Further information can be found on the Web at ams.mines.edu. This website provides an overview of the programs, requirements and policies of the department.

Fields of Research

Computational and Applied Mathematics:

Study of Wave Phenomena and Inverse Problems

Numerical Methods for PDEs

Study of Differential and Integral Equations

Computational Radiation Transport

Computational Acoustics and Electromagnetics

Multi-scale Analysis and Simulation

High Performance Scientific Computing

Dynamical Systems

Mathematical Biology

Statistics:

Inverse Problems in Statistics

Multivariate Statistics

Spatial Statistics

Stochastic Models for Environmental Science

Survival Analysis

Uncertainty Quantification

Department Head

Willy Hereman, Professor

Professors

Bernard Bialecki

Mahadevan Ganesh

Paul A. Martin

Barbara M. Moskal

William Navidi

Associate Professor

Luis Tenorio

Assistant Professors

Paul Constantine

Cecilia Diniz Behn

Amanda Hering

Stephen Pankavich

Aaron Porter

Teaching Professors

G. Gustave Greivel

Scott Strong

Teaching Associate Professors

Terry Bridgman

Debra Carney

Holly Eklund

Mike Mikucki

Mike Nicholas

Jennifer Strong

Rebecca Swanson

Emeriti Professors

William R. Astle

Norman Bleistein

Ardel J. Boes

Austin R. Brown

John A. DeSanto

Graeme Fairweather

Raymond R. Gutzman

Frank G. Hagin

Donald C.B. Marsh

Steven Pruess

Emeriti Associate Professors

Barbara B. Bath

Ruth Maurer

Robert G. Underwood

Courses

MATH500. LINEAR VECTOR SPACES. 3.0 Semester Hrs.

(I) Finite dimensional vector spaces and subspaces: dimension, dual bases, annihilators. Linear transformations, matrices, projections, change of basis, similarity. Determinants, eigenvalues, multiplicity. Jordan form. Inner products and inner product spaces with orthogonality and completeness. Prerequisite: MATH301. 3 hours lecture; 3 semester hours.

MATH501. APPLIED ANALYSIS. 3.0 Semester Hrs.

(I) Fundamental theory and tools of applied analysis. Students in this course will be introduced to Banach, Hilbert, and Sobolev spaces; bounded and unbounded operators defined on such infinite dimensional spaces; and associated properties. These concepts will be applied to understand the properties of differential and integral operators occurring in mathematical models that govern various biological, physical and engineering processes. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH502. REAL AND ABSTRACT ANALYSIS. 3.0 Semester Hrs.

(I) Normed space \mathbb{R} , open and closed sets. Lebesgue measure, measurable sets and functions. Lebesgue integral and convergence theorems. Repeated integration and integration by substitution. L_p spaces, Banach and Hilbert spaces. Weak derivatives and Sobolev spaces. Weak solutions of two-point boundary value problems. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH503. FUNCTIONAL ANALYSIS. 3.0 Semester Hrs.

Equivalent with MACS503,

(II) Properties of metric spaces, normed spaces and Banach spaces, inner product and Hilbert spaces. Fundamental theorems for normed and Banach spaces with applications. Orthogonality and orthonormal systems on Hilbert spaces with applications to approximation theory. Compact, bounded and unbounded operators. Duality, adjoint, self-adjoint, Hilbert-adjoint operators. Spectral analysis of linear operators. Applications to differential and integral equations. Prerequisites: MATH502. 3 hours lecture; 3 semester hours.

MATH506. COMPLEX ANALYSIS II. 3.0 Semester Hrs.

(II) Analytic functions. Conformal mapping and applications. Analytic continuation. Schlicht functions. Approximation theorems in the complex domain. Prerequisite: MATH454. 3 hours lecture; 3 semester hours.

MATH510. ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with MACS510,

(I) Topics to be covered: basic existence and uniqueness theory, systems of equations, stability, differential inequalities, Poincare-Bendixon theory, linearization. Other topics from: Hamiltonian systems, periodic and almost periodic systems, integral manifolds, Lyapunov functions, bifurcations, homoclinic points and chaos theory. Prerequisite: MATH225 or MATH235 and MATH332 or MATH 342 or equivalent courses. 3 hours lecture; 3 semester hours.

MATH514. APPLIED MATHEMATICS I. 3.0 Semester Hrs.

(I) The major theme in this course is various non-numerical techniques for dealing with partial differential equations which arise in science and engineering problems. Topics include transform techniques, Green's functions and partial differential equations. Stress is on applications to boundary value problems and wave theory. Prerequisite: MATH455 or equivalent. 3 hours lecture; 3 semester hours.

MATH515. APPLIED MATHEMATICS II. 3.0 Semester Hrs.

(II) Topics include integral equations, applied complex variables, an introduction to asymptotics, linear spaces and the calculus of variations. Stress is on applications to boundary value problems and wave theory, with additional applications to engineering and physical problems. Prerequisite: MATH514. 3 hours lecture; 3 semester hours.

MATH530. STATISTICAL METHODS I. 3.0 Semester Hrs.

(I) Introduction to probability, random variables, and discrete and continuous probability models. Elementary simulation. Data summarization and analysis. Confidence intervals and hypothesis testing for means and variances. Chi square tests. Distribution-free techniques and regression analysis. Prerequisite: MATH213 or equivalent. 3 hours lecture; 3 semester hours.

MATH531. STATISTICAL METHODS II. 3.0 Semester Hrs.

Equivalent with MACS531,

(II) Continuation of MATH530. Multiple regression and trend surface analysis. Analysis of variance. Experimental design (Latin squares, factorial designs, confounding, fractional replication, etc.) Nonparametric analysis of variance. Topics selected from multivariate analysis, sequential analysis or time series analysis. Prerequisite: MATH201 or MATH530 or MATH535. 3 hours lecture; 3 semester hours.

MATH532. SPATIAL STATISTICS. 3.0 Semester Hrs.

(I) Modeling and analysis of data observed on a 2 or 3-dimensional surface. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes, spatio-temporal modeling. MATH424 or MATH531.

MATH534. MATHEMATICAL STATISTICS I. 3.0 Semester Hrs.

(I) The basics of probability, discrete and continuous probability distributions, sampling distributions, order statistics, convergence in probability and in distribution, and basic limit theorems, including the central limit theorem, are covered. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH535. MATHEMATICAL STATISTICS II. 3.0 Semester Hrs.

Equivalent with MACS535,

(II) The basics of hypothesis testing using likelihood ratios, point and interval estimation, consistency, efficiency, sufficient statistics, and some nonparametric methods are presented. Prerequisite: MATH534 or equivalent. 3 hours lecture; 3 semester hours.

MATH536. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.

(I) Modern extensions of the standard linear model for analyzing data. Topics include generalized linear models, generalized additive models, mixed effects models, and resampling methods. Prerequisite: MATH 335 and MATH 424. 3 hours lecture; 3.0 semester hours.

MATH537. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.

(II) Introduction to applied multivariate representations of data for use in data analysis. Topics include introduction to multivariate distributions; methods for data reduction, such as principal components; hierarchical and model-based clustering methods; factor analysis; canonical correlation analysis; multidimensional scaling; and multivariate hypothesis testing. Prerequisites: MATH 530 and MATH 332 or MATH 500. 3 hours lecture; 3.0 semester hours.

MATH538. STOCHASTIC MODELS. 3.0 Semester Hrs.

(II) An introduction to the mathematical principles of stochastic processes. Discrete- and continuous-time Markov processes, Poisson processes, Brownian motion. Prerequisites: MATH 534. 3 hours lecture and discussion; 3 semester hours.

MATH539. SURVIVAL ANALYSIS. 3.0 Semester Hrs.

(I) Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, the proportional hazards model, model diagnostics. Prerequisite: MATH335 or MATH535.

MATH540. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.

(I) This course is designed to facilitate students' learning of parallel programming techniques to efficiently simulate various complex processes modeled by mathematical equations using multiple and multi-core processors. Emphasis will be placed on the implementation of various scientific computing algorithms in FORTRAN/C/C++ using MPI and OpenMP. Prerequisite: MATH407, CSCI407. 3 hours lecture, 3 semester hours.

MATH542. SIMULATION. 3.0 Semester Hrs.

Equivalent with MACS542,

(I) Advanced study of simulation techniques, random number, and variate generation. Monte Carlo techniques, simulation languages, simulation experimental design, variance reduction, and other methods of increasing efficiency, practice on actual problems. Prerequisite: CSCI262 (or equivalent), MATH323 (or MATH530 or equivalent). 3 hours lecture; 3 semester hours.

MATH544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with CSCI544,

This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

MATH547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.

Equivalent with CSCI547,

Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

MATH550. NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

Equivalent with MACS550,

(II) Numerical methods for solving partial differential equations. Explicit and implicit finite difference methods; stability, convergence, and consistency. Alternating direction implicit (ADI) methods. Weighted residual and finite element methods. Prerequisite: MATH225 or MATH235, and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH551. COMPUTATIONAL LINEAR ALGEBRA. 3.0 Semester Hrs.

Equivalent with MACS551,

(II) Numerical analysis of algorithms for solving linear systems of equations, least squares methods, the symmetric eigenproblem, singular value decomposition, conjugate gradient iteration. Modification of algorithms to fit the architecture. Error analysis, existing software packages. Prerequisites: MATH332, CSCI407/MATH407. 3 hours lecture; 3 semester hours.

MATH556. MODELING WITH SYMBOLIC SOFTWARE. 3.0 Semester Hrs.

(I) Case studies of various models from mathematics, the sciences and engineering through the use of the symbolic software package MATHEMATICA. Based on hands-on projects dealing with contemporary topics such as number theory, discrete mathematics, complex analysis, special functions, classical and quantum mechanics, relativity, dynamical systems, chaos and fractals, solitons, wavelets, chemical reactions, population dynamics, pollution models, electrical circuits, signal processing, optimization, control theory, and industrial mathematics. The course is designed for graduate students and scientists interested in modeling and using symbolic software as a programming language and a research tool. It is taught in a computer laboratory. Prerequisites: none. 3 hours lecture; 3 semester hours.

MATH557. INTEGRAL EQUATIONS. 3.0 Semester Hrs.

(I) This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Prerequisite: MATH332 or MATH342, and MATH455.

MATH574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.

Equivalent with CSCI574,

Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

MATH582. STATISTICS PRACTICUM. 3.0 Semester Hrs.

(II) This is the capstone course in the Statistics Option. The main objective is to apply statistical knowledge and skills to a data analysis problem, which will vary by semester. Students will gain experience in problem-solving; working in a team; presentation skills (both orally and written); and thinking independently. Prerequisites: MATH 201 or 530 and MATH 424 or 531. 3 hours lecture and discussion; 3 semester hours.

MATH589. APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR. 1.0 Semester Hr.

(I) An introduction to teaching issues and techniques within the AMS department. Weekly, discussion-based seminars will cover practical issues such as lesson planning, grading, and test writing. Issues specific to the AMS core courses will be included. 1 hour lecture; 1.0 semester hour.

MATH598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH610. ADVANCED TOPICS IN DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

(II) Topics from current research in ordinary and/or partial differential equations; for example, dynamical systems, advanced asymptotic analysis, nonlinear wave propagation, solitons. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH614. ADVANCED TOPICS IN APPLIED MATHEMATICS. 3.0 Semester Hrs.

(I) Topics from current literature in applied mathematics; for example, wavelets and their applications, calculus of variations, advanced applied functional analysis, control theory. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH616. INTRODUCTION TO MULTI-DIMENSIONAL SEISMIC INVERSION. 3.0 Semester Hrs.

(II) Introduction to high frequency inversion techniques. Emphasis on the application of this theory to produce a reflector map of the earth's interior and estimates of changes in earth parameters across those reflectors from data gathered in response to sources at the surface or in the interior of the earth. Extensions to elastic media are discussed, as well. Includes high frequency modeling of the propagation of acoustic and elastic waves. Prerequisites: partial differential equations, wave equation in the time or frequency domain, complex function theory, contour integration. Some knowledge of wave propagation: reflection, refraction, diffraction. 3 hours lecture; 3 semester hours.

MATH650. ADVANCED TOPICS IN NUMERICAL ANALYSIS. 3.0 Semester Hrs.

(II) Topics from the current literature in numerical analysis and/or computational mathematics; for example, advanced finite element method, sparse matrix algorithms, applications of approximation theory, software for initial value ODE's, numerical methods for integral equations. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH691. GRADUATE SEMINAR. 1.0 Semester Hr.

(I) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH692. GRADUATE SEMINAR. 1.0 Semester Hr.

Equivalent with CSCI692, MACS692,
(II) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.

(I, II) Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on underlying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

MATH698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT
Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Civil and Environmental Engineering

Department Website - cee.mines.edu

2015-2016

Degrees Offered

- Master of Science (Civil and Environmental Engineering)
- Doctor of Philosophy (Civil and Environmental Engineering)
- Master of Science (Environmental Engineering Science)
- Doctor of Philosophy (Environmental Engineering Science)

Program Description

The Civil and Environmental Engineering Department offers two M.S. and Ph.D. graduate degrees - Civil & Environmental Engineering (CEE) and Environmental Engineering Science (EES). The Civil and Environmental Engineering (CEE) degree is designed for students who wish to earn a degree to continue the path towards professional engineering registration. Students entering this degree program should have a B.S. degree in engineering, or will generally need to take engineering prerequisite courses. Within the CEE degree, students complete specified requirements in one of four different emphasis areas: Engineering Mechanics (EM), Environmental and Water Engineering, Geotechnical Engineering (GT), and Structural Engineering (SE).

The Environmental Engineering Science (EES) degree does not require engineering credentials and has a flexible curriculum that enables students with a baccalaureate degree in biology, chemistry, math, physics, geology, engineering, and other technical fields, to tailor a course-work program that best fits their career goals.

The specific requirements for the EES & CEE degrees, as well as for the four emphasis areas within the CEE degree, are described in detail under the Major tab.

The M.S. and Ph.D. degrees in Environmental Engineering Science (EES) has been admitted to the Western Regional Graduate Program (WRGP/WICHE), a recognition that designates this curriculum as unique within the Western United States. An important benefit of this designation is that students who are residents from Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming are given the tuition status of Colorado residents.

To achieve the Master of Science (M.S.) degree, students may elect the Non-Thesis option, based exclusively upon coursework and project activities, or the Thesis option, which requires coursework and rigorous research conducted under the guidance of a faculty advisor and M.S. thesis committee, that is described in a final written thesis that is defended in an oral presentation.

The Doctor of Philosophy (Ph.D.) degree requires students to complete a combination of coursework and original research, under the guidance of a faculty advisor and doctoral committee, that culminates in a significant scholarly contribution (e.g., in the form of published journal articles) to a specialized field in Civil and Environmental Engineering or Environmental Engineering Science. The written dissertation must be defended in an public oral presentation before the advisor and dissertation committee.

The Ph.D. program may build upon one of the CEE or EES M.S. programs or a comparable M.S. program at another university. Full-time PhD enrollment is expected and leads to the greatest success, although part-time enrollment may be allowed under special circumstances.

Faculty Expertise and General Emphasis Areas:

Civil and Environmental Engineering faculty have expertise in engineering mechanics, environmental science and engineering, geotechnical engineering, hydrology, water-resources engineering, structural engineering, and underground construction and tunneling. These areas also serve as topic areas for coursework and for M.S. thesis or PhD dissertation research, and are the basis for degree requirements.

Engineering Mechanics: Engineering Mechanics is an interdisciplinary emphasis area offered with the Department of Mechanical Engineering. Engineering mechanics is concerned with the development and implementation of numerical and analytical procedures to simulate materials' expected behaviors. This emphasis area draws upon synergistic teaching and research strengths in the Departments of Civil and Environmental Engineering and Mechanical Engineering and offers options to take courses in Materials Science, Mathematics, and Computer Science. The skills developed in this emphasis area may be used for a wide range of applications in multiple engineering and science disciplines, including (but not limited to) structural mechanics, geomechanics, fluid mechanics, solid mechanics, hydrology, and physics. Students who pursue this discipline typically complete the requirements of the Engineering Mechanics (EM) emphasis area in the CEE degree.

Environmental Engineering and Science: Is the application of environmental processes in natural and engineered systems. CEE faculty have expertise in water resource engineering, biosystems engineering, environmental chemistry, environmental microbiology, microbial genomics, wastewater treatment, water treatment, bioremediation, mining treatment processes and systems, remediation processes, biogeochemical reactions in soils, geobiology, membrane processes, humanitarian engineering, social aspects of engineering, and energy recovery from fluids.

Geotechnical Engineering: Geotechnical Engineering is concerned with the engineering properties and behavior of natural and engineered geomaterials (soils and rocks), as well as the design and construction of foundations, earth dams and levees, retaining walls, embankments, underground structures and tunnels. Almost all constructed projects require input from geotechnical engineers as most structures are built on, in or of geomaterials. Additionally, mitigation of the impact of natural hazards such as earthquakes and landslides, sustainable use of energy and resources, and reduction of the environmental impacts of human activities require geotechnical engineers who have in-depth understanding of how geomaterials respond to loads, and environmental changes. Students who pursue this discipline complete the requirements of the Geotechnical Engineering emphasis area within the Civil & Environmental Engineering degree program.

Structural Engineering: Is a multidisciplinary subject spanning the disciplines of civil engineering, aerospace engineering, mechanical

engineering, and marine engineering. In all these disciplines, structural engineers use engineered materials and conduct analyses using general principles of structural mechanics, to design structures for civil systems. Designed systems may include bridges, dams, buildings, tunnels, sustainable infrastructure, highways, biomechanical apparatus, sustainable civil engineering materials and numerous other structures and devices. Students who pursue this discipline complete the requirements of the Structural Engineering (SE) emphasis area within the Civil & Environmental Engineering Degree program.

Hydrology and Water Resources Engineering: Students interested in this area have two options. Students interested in natural-systems hydrology, ground-water resources, contaminant transport, and hydrochemical processes often choose to earn a degree in "Hydrology" in the interdisciplinary Hydrologic Science and Engineering (HSE) program (see HSE section of this graduate bulletin). Students interested in engineered water systems or water-resources engineering, such as water infrastructure, water reclamation and reuse, ground-water remediation, contaminated water bodies, urban hydrology, water-resources management, and fluid mechanics typically choose the CEE degree - Environmental and Water Engineering Emphasis area. Students who are interested in the chemical, biological and fundamental water science that serves as the foundation for hydrology and water resources engineering may also elect the EES degree.

Underground Construction & Tunneling (UC&T): UC&T involves the planning, design, construction and rehabilitation of underground space (caverns, shafts, tunnels) in soil and rock. The main domains for UC&T include civil infrastructure, e.g., water and wastewater conveyance and storage, construction, transportation, and utilities, as well as underground facilities for civil, commercial and military use. UC&T is an interdisciplinary field involving civil, geological and mining engineering programs. Students interested in interdisciplinary studies including soil & rock mechanics, engineering geology and excavation methods can pursue the M.S. and/or Ph.D. in UC&T (see UC&T section of this graduate bulletin, and the website uct.mines.edu). CEE students may also take elective courses and pursue research in UC&T yet emphasize geotechnical and/or structural engineering within the CEE graduate degrees.

Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.S. degree in Civil & Environmental Engineering or Environmental Engineering Science while completing their Bachelor's degree. The CSM Combined Degree Program provides the vehicle for students to use undergraduate coursework as part of their Graduate Degree curriculum. For more information please contact the CEE Office or visit cee.mines.edu

Program Requirements

General Degree Requirements for CEE and EES degrees:

M.S. Non-Thesis Option: 30 total credit hours, consisting of coursework (27 h) and either a three credit hour research based Independent Study (CEEN 599) or a designated design course (3 h) and seminar.

M.S. Thesis Option: 30 total credit hours, consisting of coursework (24 h), seminar, and research (6 h). Students must also write and orally defend a research thesis.

Ph.D.: 72 total credit hours, consisting coursework (at least 24 h), seminar, and research (at least 24 h). Students must also successfully

complete written and oral qualifying examinations, prepare and present a dissertation proposal, and write and defend a doctoral dissertation. Ph.D. students are also expected to submit the dissertation work for publication in scholarly journals.

Prerequisites for CEE and EES degrees:

- Baccalaureate degree: required, preferably in a science or engineering discipline
- College calculus I & II: two semesters required
- College physics: one semester required, two semesters highly recommended
- College chemistry I & II: two semesters required
- College probability & statistics: one semester required
- All CEE degree emphasis areas require completion of the general science pre-requisites listed above, and also requires statics, dynamics, and differential equations. In addition, the CEE degree emphasis areas may require specific additional pre-requisites as listed below.

Required Curriculum for Environmental Engineering Science (EES) Degree:

The EES curriculum consists of common core and elective courses that may be focused toward specialized areas of emphasis. The common core includes:

- CEEN550 (p. 220): Principles of Environmental Chemistry
- CEEN592: Environmental Law or approved policy / law course
- CEEN580: Environmental Fate and Transport
- CEEN560 Molecular Microbial Ecology or CEEN562 Applied Geomicrobiology or CEEN564 Environmental Toxicology
- 3-credit Independent Study (CEEN 599) or a 3 credit hour design course

Students earning an EES degree work with their academic advisor to establish plans of study that best fit their individual interests and goals. Each student will develop and submit a plan of study during the first semester of enrollment; this plan must be submitted with the admission to candidacy form. Electives may be chosen freely from courses offered at CSM and other local universities. Please visit the CEE website for a complete outline of curriculum requirements and options (www.cee.mines.edu).

Required Curriculum for Civil and Environmental Engineering (CEE) Degree:

The CEE curriculum contains four emphasis areas: Environmental and Water Engineering, Engineering, Engineering Mechanics, Geotechnical Engineering, and Structural Engineering. CEE students must complete the requirements for at least one emphasis area.

Core Courses: Each emphasis area has required core courses that apply to MS and PhD degrees. These core courses are listed below.

Electives: CEE degree emphasis areas require additional engineering-course electives: 12 credits for M.S. thesis option, 15 credits for M.S. non-thesis option and 18 credits for Ph.D. A variety of engineering courses may be taken for electives in the CEE emphasis areas, including additional CEEN courses, as well as courses from other departments on campus. The student's advisor and committee must approve elective courses.

Non thesis students must take at least 21 elective credits within the CEEN prefix.

CEE Degree Emphasis Areas

GEOTECHNICAL ENGINEERING

Additional Prerequisites Courses: soil mechanics, structural theory/ structural analysis

Geotechnical Core Courses: Students are required to successfully complete four courses (12 credit hours) from the following core course list plus CEEN 590 Civil Engineering seminar.

CEEN510	ADVANCED SOIL MECHANICS	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN514	SOIL DYNAMICS	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN520	EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS (*)	3.0
CEEN523	ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND (*)	3.0

* Design Course

ENVIRONMENTAL AND WATER ENGINEERING

Additional Prerequisites Courses: fluid mechanics.

Environmental & Water Engineering Core Courses: Students are required to successfully complete one course as specified in each of the following areas plus CEEN 596 Environmental Seminar:

Chemistry: CEEN550 Principles of Env Chemistry

Physical Transport: CEEN580 Env Pollution

Bio Processes: CEEN560 Molecular Microbial Ecology or CEEN562 Geomicrobial Systems or CEEN564 Env Toxicology

Systems Design: CEEN570 Treatment of Waters & Waste * or CEEN471 Water & Wastewater Treatment Systems*

*Design Course

STRUCTURAL ENGINEERING

Additional Prerequisites Courses: soil mechanics, structural theory / structural analysis.

Structural Engineering Core Courses: Three courses from the following, 9 credits total including at least 3 credits of design course, plus CEEN 590 Civil Engineering seminar.

CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN530	ADVANCED STRUCTURAL ANALYSIS	3.0
CEEN531	STRUCTURAL DYNAMICS	3.0
CEEN540	ADVANCED DESIGN OF STEEL STRUCTURES (*)	3.0
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II (*)	3.0
CEEN542	TIMBER AND MASONRY DESIGN (*)	3.0

CEEN543 CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS (*) 3.0

* Design Course

ENGINEERING MECHANICS

Additional Prerequisites Courses: Mechanics of materials, fluid mechanics

EM Core Courses: Four core courses (12 credits), each one selected from each one of the following four topical areas, plus CEEN 590 Civil Engineering seminar:

1. Mechanics of Solid Materials
2. Mechanics of Fluid or Multiphase Materials
3. Numerical and Computational Methods
4. Analytical Applied Mathematical Methods

Topical Area: Mechanics of Solid Materials

MLGN501	STRUCTURE OF MATERIALS	3.0
MLGN505	MECHANICAL PROPERTIES OF MATERIALS	3.0
MEGN510	SOLID MECHANICS OF MATERIALS (*)	3.0
MEGN511	FATIGUE AND FRACTURE	3.0
MEGN512	ADVANCED ENGINEERING VIBRATION	3.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN530	ADVANCED STRUCTURAL ANALYSIS (*)	3.0
CEEN541	DESIGN OF REINFORCED CONCRETE STRUCTURES II (*)	3.0
CEEN542	TIMBER AND MASONRY DESIGN (*)	3.0
CEEN543	CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS (*)	3.0

*Design Course

Topical Area: Mechanics of Fluids and Multiphase Materials

MEGN520	BOUNDARY ELEMENT METHODS	3.0
MEGN521	INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS)	3.0
MEGN593	ENGINEERING DESIGN OPTIMIZATION (*)	3.0
CEEN505	NUMERICAL METHODS FOR ENGINEERS	3.0
CEEN506	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN582	MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS (*)	3.0

*Design Course

Topical Area: Numerical and Computational Methods

MEGN552	VISCOUS FLOW AND BOUNDARY LAYERS	3.0
MEGN553	INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA	3.0
CEEN481	HYDROLOGIC AND WATER RESOURCES ENGINEERING	3.0
CEEN510	ADVANCED SOIL MECHANICS (*)	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0
CEEN514	SOIL DYNAMICS (*)	3.0

CEEN515	HILLSLOPE HYDROLOGY AND STABILITY (*)	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0
CEEN611	MULTIPHASE CONTAMINANT TRANSPORT	3.0

*Design Course

Topical Area: Analytical Applied Mathematical Methods

MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0

Department Head

John E. McCray

Professors

D.V. Griffiths

Marte Gutierrez, James R. Paden Distinguished Chair

Terri Hogue

Tissa Illangasekare, AMAX Distinguished Chair

Ning Lu

John E. McCray

Michael Mooney, Grewcock Distinguished Chair

Robert L. Siegrist, University Emeritus Professor

John R. Spear

Timothy Strathmann

Associate Professors

Tzahi Y. Cath

Ronald R.H. Cohen

Linda A. Figueroa

Christopher Higgins

Panos Kiousis

Terri Hogue

Junko Munakata Marr

Jonathan O. Sharp

Kamini Singha, (Joint appointment with Geology & Geological Engineering)

Assistant Professors

Christopher Bellona

Reza Hedayat

Shiling Pei

Kathleen Smits

Teaching Professors

Joseph Crocker

Candace Sulzbach, Emeritus Teaching Professor

Teaching Associate Professors

Andres Guerra

Hongyan Liu

Susan Reynolds

Alexandra Wayllace

Teaching Assistant Professor

Jeffery Holley

Adjunct Faculty

Sidney Innerebner

Paul B. Queneau

Tanja Rauch

Patrick Ryan

Research Assistant Professors

Mengistu Geza

Lee Landkamer

Dong Li

Courses

CEEN505. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN560,

(S) Introduction to the use of numerical methods in the solution of commonly encountered problems of engineering analysis. Structural/solid analysis of elastic materials (linear simultaneous equations); vibrations (roots of nonlinear equations, initial value problems); natural frequency and beam buckling (eigenvalue problems); interpretation of experimental data (curve fitting and differentiation); summation of pressure distributions (integration); beam deflections (boundary value problems). All course participants will receive source code of all the numerical methods programs published in the course textbook which is coauthored by the instructor. Prerequisite: MATH225. 3 hours lecture; 3 semester hours.

CEEN506. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.

Equivalent with EGGN542,

(II) A course combining finite element theory with practical programming experience in which the multidisciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple structural elements, beams on elastic foundations, solid elasticity, steady state analysis and transient analysis. Some of the applications will lie in the general area of geomechanics, reflecting the research interests of the instructor. Students get a copy of all the source code published in the course textbook. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN510. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN548,

Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength, failure criteria and constitutive models for soil. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisites: A first course in soil mechanics. 3 Lecture Hours, 3 semester hours. Fall even years.

CEEN511. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.

Equivalent with EGES533,EGGN533,

The focus of this course is on soil mechanics for unsaturated soils. It provides an introduction to thermodynamic potentials in partially saturated soils, chemical potentials of adsorbed water in partially saturated soils, phase properties and relations, stress state variables, measurements of soil water suction, unsaturated flow laws, measurement of unsaturated permeability, volume change theory, effective stress principle, and measurement of volume changes in partially saturated soils. The course is designed for seniors and graduate students in various branches of engineering and geology that are concerned with unsaturated soil's hydrologic and mechanics behavior. When this course is cross-listed and concurrent with CEEN412, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 hours lecture; 3 semester hours. Spring even years.

CEEN512. SOIL BEHAVIOR. 3.0 Semester Hrs.

Equivalent with EGES534,EGGN534,

(I) The focus of this course is on interrelationships among the composition, fabric, and geotechnical and hydrologic properties of soils that consist partly or wholly of clay. The course will be divided into two parts. The first part provides an introduction to the composition and fabric of natural soils, their surface and pore-fluid chemistry, and the physico-chemical factors that govern soil behavior. The second part examines what is known about how these fundamental characteristics and factors affect geotechnical properties, including the hydrologic properties that govern the conduction of pore fluid and pore fluid constituents, and the geomechanical properties that govern volume change, shear deformation, and shear strength. The course is designed for graduate students in various branches of engineering and geology that are concerned with the engineering and hydrologic behavior of earth systems, including geotechnical engineering, geological engineering, environmental engineering, mining engineering, and petroleum engineering. When this course is cross-listed and concurrent with CEEN411, students that enroll in CEEN512 will complete additional and/or more complex assignments. Prerequisites: CEEN361 Soil Mechanics. 3 hours lecture; 3 semester hours.

CEEN514. SOIL DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN531,

(II) Dynamic phenomena in geotechnical engineering, e.g., earthquakes, pile and foundation vibrations, traffic, construction vibrations; behavior of soils under dynamic loading, e.g., small, medium and large strain behavior, soil liquefaction; wave propagation through soil and rock; laboratory and field techniques to assess dynamic soil properties; analysis and design of shallow and deep foundations subjected to dynamic loading; analysis of construction vibrations. Prerequisites: CEEN312, MEGN315, CEEN415. 3 hours lecture; 3 semester hours.

CEEN515. HILLSLOPE HYDROLOGY AND STABILITY. 3.0 Semester Hrs.

Equivalent with EGGN536,

(I) Introduction of shallow landslide occurrence and socio-economic dynamics. Roles of unsaturated flow and stress in shallow landslides. Slope stability analysis based on unsaturated effective stress conceptualization. Computer modeling of unsaturated flow and stress distributions in hillslope. Prediction of precipitation induced shallow landslides. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN520. EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS. 3.0 Semester Hrs.

(II) Analysis, design, construction and monitoring of earth retaining structures and support of excavations used for permanent and temporary support of transportation facilities, bridges, underground structures and tunnels, shafts, waterfront structures, earth slopes and embankments. Includes gravity, semi-gravity, cantilevered, anchored, geosynthetic and ground improvement walls. Addresses fundamental geomechanics required for analysis and design, ASD (allowable stress design) and LRFD (load resistance factor design) design techniques, and construction techniques. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 semester hours.

CEEN523. ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND. 3.0 Semester Hrs.

(I) Analysis and design of new and existing water, wastewater, transportation and utility tunnels in soft ground conditions (soil). Addresses geotechnical site characterization, selection of design parameters, and stability and deformation analysis of ground, utilities and overlying structures. Includes design of lining and ground support systems according to ASD (allowable stress design) and LRFD (load resistance factor design) approaches, and design of ground improvement schemes and instrumentation/monitoring approaches to mitigate risk. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 semester hours.

CEEN530. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN541,

(I) Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. Prerequisite: CEEN314. 3 hour lectures, 3 semester hours.

CEEN531. STRUCTURAL DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN557,

An introduction to the dynamics and earthquake engineering of structures is provided. Subjects include the analysis of linear and nonlinear single-degree and multi-degree of freedom structural dynamics. The link between structural dynamics and code-based analysis and designs of structures under earthquake loads is presented. The focus applications of the course include single story and multi-story buildings, and other types of structures that under major earthquake may respond in the inelastic range. Prerequisites: CEEN314 Structural Theory. 3 semester hours.

CEEN533. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.

(II) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN433, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisites: CEEN314 Elementary Structural Theory. 3 lecture hours, 3 semester hours.

CEEN540. ADVANCED DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.

Equivalent with EGGN549,

The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. Prerequisite: CEEN443 or equivalent. 3 hours lecture; 3 semester hours. Spring even years.

CEEN541. DESIGN OF REINFORCED CONCRETE STRUCTURES II. 3.0 Semester Hrs.

Equivalent with EGGN556,

Advanced problems in the analysis and design of concrete structures, design of slender columns; biaxial bending; two-way slabs; strut and tie models; lateral and vertical load analysis of multistory buildings; introduction to design for seismic forces; use of structural computer programs. Prerequisite: CEEN445. 3 hour lectures, 3 semester hours. Delivered in the spring of even numbered years.

CEEN542. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.

Equivalent with EGGN547,

The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Connection design and advanced seismic analysis principles are introduced. Prerequisite: CEEN314 or equivalent. 3 hours lecture; 3 semester hours. Spring odd years.

CEEN543. CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS. 3.0 Semester Hrs.

Equivalent with EGGN558,

This course presents the fundamentals of concrete bridge analysis and design including conceptual design, superstructure analysis, AASHTO-LRFD bridge specifications, flat slab bridge design, and pre-stressed concrete bridge design. The course is presented through the complete design of the superstructure of an example bridges. At the conclusion of the course, students will be able to analyze and design simple, but complete concrete bridge superstructures. Prerequisites: CEEN445, Design of Reinforced Concrete Structure. 3 hours lecture; 3 semester hours.

CEEN544. STRUCTURAL PRESERVATION OF EXISTING AND HISTORIC BUILDINGS. 3.0 Semester Hrs.

(I, II) A broad discussion of historic structural systems in the United States, including stone and brick masonry, terra cotta, timber, cast and wrought iron, early steel, and early concrete. Combines research of historic manuals with contemporary analysis. Introduces nondestructive tests for historic structures. Enables prediction of deterioration mechanisms and structural deficiencies. Synthesizes structural retrofit solutions with preservation philosophy and current building codes. Emphasizes the engineer's role in stewardship of historic buildings. Prerequisites: CEEN443 and CEEN445. 3 hours lecture and discussion; 3 semester hours.

CEEN550. PRINCIPLES OF ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN500,
This course provides an introduction to chemical equilibria in natural waters and engineered systems. Topics covered include chemical thermodynamics and kinetics, acid/base chemistry, open and closed carbonate systems, precipitation reactions, coordination chemistry, adsorption and redox reactions. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN551. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN555,
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CEEN552. CHEMISTRY OF THE SOIL / WATER INTERFACE. 3.0 Semester Hrs.

Equivalent with ESGN525,
The fate of many elements in the soil/water environment is regulated by sorption reactions. The content of this course focuses on the physical chemistry of reactions occurring at the soil-particle/water interface. The emphasis is on the use of surface complexation models to interpret solute sorption at the particle/water interface. Prerequisites: CEEN550. 3 hours lecture; 3 semester hours.

CEEN553. ENVIRONMENTAL RADIOCHEMISTRY. 3.0 Semester Hrs.

Equivalent with ESGN510,
This course covers the phenomena of radioactivity (e.g., modes of decay, methods of detection and biological effects) and the use of naturally occurring and artificial radionuclides as tracers for environmental processes. Discussions of tracer applications will range from oceanic trace element scavenging to contaminant transport through groundwater aquifers. Prerequisites: CEEN 550. 3 hours lecture; 3 semester hours.

CEEN555. LIMNOLOGY. 3.0 Semester Hrs.

Equivalent with ESGN513,
This course covers the natural chemistry, physics, and biology of lakes as well as some basic principles concerning contamination of such water bodies. Topics include heat budgets, water circulation and dispersal, sedimentation processes, organic compounds and their transformations, radionuclide limnology, redox reactions, metals and other major ions, the carbon dioxide system, oxygen, nutrients; planktonic, benthic and other communities, light in water and lake modeling. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN556. MINING AND THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN556,
The course will cover many of the environmental problems and solutions associated with each aspect of mining and ore dressing processes. Mining is a complicated process that differs according to the type of mineral sought. The mining process can be divided into four categories: Site Development; Extraction; Processing; Site Closure. Procedures for hard rock metals mining; coal mining; underground and surface mining; and in situ mining will be covered in relation to environmental impacts. Beneficiation, or purification of metals will be discussed, with cyanide and gold topics emphasized. Site closure will be focused on; stabilization of slopes; process area cleanup; and protection of surface and ground water. After discussions of the mining and beneficiation processes themselves, we will look at conventional and innovative measures to mitigate or reduce environmental impact.

CEEN558. ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES. 3.0 Semester Hrs.

Equivalent with ESGN511,
The stewardship of nuclear resources spans the entire nuclear fuel cycle, which includes mining and milling through chemical processing on the front end of the materials life cycle. On the back end, stewardship continues from materials removal from the power plant during re-fueling or facility decommissioning, through storage, recycling and disposal, as well as the management of activated or contaminated materials generated during facility decommissioning. Each stage in the fuel cycle has a different risk of public exposure through different pathways and the presence of different isotopes. These risks are an integral part in considering the long-term efficacy of nuclear as an energy alternative. Furthermore, nuclear energy has long been vilified in public opinion forums via emotional responses. Stewardship extends beyond quantification of risks to the incorporation and communication of these risks and the associated facts regarding nuclear power to the public at large. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

CEEN560. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

Equivalent with ESGN586,
This course explores the diversity of microbiota in a few of the countless environments of our planet. Topics include microbial ecology (from a molecular perspective), microbial metabolism, pathogens, extreme environments, engineered systems, oxidation / reduction of metals, bioremediation of both organics and inorganics, microbial diversity, phylogenetics, analytical tools and bioinformatics. The course has an integrated laboratory component for applied molecular microbial ecology to learn microscopy, DNA extraction, PCR, gel electrophoresis, cloning, sequencing, data analysis and bioinformatic applications. Prerequisite: College Biology and/or CHGC562, CHGC563 or equivalent and enrollment in the ESE graduate program. 3 hours lecture, some field trips; 3 semester hours.

CEEN562. ENVIRONMENTAL GEOMICROBIOLOGY. 3.0 Semester Hrs.

Equivalent with BELS596,ESGN596,

(II) This course explores the functional activities and biological significance of microorganisms in geological and engineered systems with a focus on implications to water resources. Topics include: microorganisms as geochemical agents of change, mechanisms and thermodynamics of microbial respiration, applications of analytical, material science and molecular biology tools to the field, and the impact of microbes on the fate and transport of problematic water pollutants. Emphasis will be placed on critical analysis and communication of peer-reviewed literature on these topics. 3 hours lecture and discussion; 3 semester hours.

CEEN564. ENVIRONMENTAL TOXICOLOGY. 3.0 Semester Hrs.

Equivalent with BELS545,ESGN545,

This course provides an introduction to general concepts of ecology, biochemistry, and toxicology. The introductory material will provide a foundation for understanding why, and to what extent, a variety of products and by-products of advanced industrialized societies are toxic. Classes of substances to be examined include metals, coal, petroleum products, organic compounds, pesticides, radioactive materials, and others. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN565. AQUATIC TOXICOLOGY. 3.0 Semester Hrs.

Equivalent with BELS544,ESGN544,

This course provides an introduction to assessment of the effects of toxic substances on aquatic organisms, communities, and ecosystems. Topics include general toxicological principles, water quality standards, sediment quality guidelines, quantitative structure-activity relationships, single species and community-level toxicity measures, regulatory issues, and career opportunities. The course includes hands-on experience with toxicity testing and subsequent data reduction. Prerequisite: none. 2.5 hours lecture; 1 hour laboratory; 3 semester hours.

CEEN566. MICROBIAL PROCESSES, ANALYSIS AND MODELING. 3.0 Semester Hrs.

Equivalent with BELS541,ESGN541,

Microorganisms facilitate the transformation of many organic and inorganic constituents. Tools for the quantitative analysis of microbial processes in natural and engineered systems will be presented. Stoichiometries, energetics, mass balances and kinetic descriptions of relevant microbial processes allow the development of models for specific microbial systems. Simple analytical models and complex models that require computational solutions will be presented. Systems analyzed include suspended growth and attached growth reactors for municipal and industrial wastewater treatment as well as in-stu bioremediation and bioenergy systems. 3 hours lecture; 3 semester hours.

CEEN570. WATER AND WASTEWATER TREATMENT. 3.0 Semester Hrs.

Equivalent with ESGN504,

Unit operations and processes in environmental engineering are discussed in this course, including physical, chemical, and biological treatment processes for water and wastewater. Treatment objectives, process theory, and practice are considered in detail. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN571. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE. 3.0 Semester Hrs.

Equivalent with ESGN506,

This course presents issues relating to theory, design, and operation of advanced water and wastewater treatment unit processes and water reuse systems. Topics include granular activated carbon (GAC), advanced oxidation processes (O₃/H₂O₂), UV disinfection, pressure-driven, current-driven, and osmotic-driven membranes (MF, UF, NF, RO, electrodialysis, and forward osmosis), and natural systems such as riverbank filtration (RBF) and soil-aquifer treatment (SAT). The course is augmented by CEEN571L offering hands-on experience using bench- and pilot-scale unit operations. Prerequisite: CEEN470 or CEEN471 or CEEN570 or CEEN572. 3 hours lecture; 3 semester hours.

CEEN571L. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE - LABORATORY. 1.0 Semester Hr.

Equivalent with ESGN506L,

This course provides hands-on experience using bench- and pilotscale unit operations and computer exercises using state-of-the-art software packages to design advanced water treatment unit processes. Topics include adsorption processes onto powdered and granular activated carbon, low-pressure membrane processes (microfiltration, ultrafiltration), and highpressure and current-driven membrane processes (nanofiltration, reverse osmosis, and electrodialysis). The course is a highly recommended component of CEEN571 and meets 5 - 6 times during the semester to support the work in CEEN571. Co- or Pre-requisite: CEEN571. 1 semester hour.

CEEN572. ENVIRONMENTAL ENGINEERING PILOT PLANT LABORATORY. 4.0 Semester Hrs.

Equivalent with ESGN530,

This course provides an introduction to bench and pilot-scale experimental methods used in environmental engineering. Unit operations associated with water and wastewater treatment for real-world treatment problems are emphasized, including multi-media filtration, oxidation processes, membrane treatment, and disinfection processes. Investigations typically include: process assessment, design and completion of bench- and pilot-scale experiments, establishment of analytical methods for process control, data assessment, upscaling and cost estimation, and project report writing. Projects are conducted both at CSM and at the City of Golden Water Treatment Pilot Plant Laboratory. Prerequisites: CEEN550 and CEEN570. 6 hours laboratory; 4 semester hours.

CEEN573. RECLAMATION OF DISTURBED LANDS. 3.0 Semester Hrs.

Equivalent with ESGN552,

Basic principles and practices in reclaiming disturbed lands are considered in this course, which includes an overview of present legal requirements for reclamation and basic elements of the reclamation planning process. Reclamation methods, including recontouring, erosion control, soil preparation, plant establishment, seed mixtures, nursery stock, and wildlife habitat rehabilitation, will be examined. Practitioners in the field will discuss their experiences. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN574. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.

Equivalent with ESGN562,

This course will examine, using case studies, ways in which industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisite: CEEN550. 3 hours lecture; 3 semester hours.

CEEN575. HAZARDOUS WASTE SITE REMEDIATION. 3.0 Semester Hrs.

Equivalent with ESGN575,

This course covers remediation technologies for hazardous waste contaminated sites, including site characteristics and conceptual model development, remedial action screening processes, and technology principles and conceptual design. Institutional control, source isolation and containment, subsurface manipulation, and in situ and ex situ treatment processes will be covered, including unit operations, coupled processes, and complete systems. Case studies will be used and computerized tools for process selection and design will be employed. Prerequisite: CEEN550 and CEEN580. 3 hours lecture; 3 semester hours.

CEEN575L. HAZARDOUS WASTE SITE REMEDIATION: TREATABILITY TESTING. 1.0 Semester Hr.

Equivalent with ESGN575L,

This laboratory module is designed to provide hands-on experience with treatability testing to aid selection and design of remediation technologies for a contaminated site. The course will be comprised of laboratory exercises in Coolbaugh Hall and possibly some field site work near CSM. Pre-requisite: CEEN575. 2 hours laboratory; 1 semester hour.

CEEN576. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.

Equivalent with ESGN563,

The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. 3 hours lecture; 3 semester hours.

CEEN580. ENVIRONMENTAL POLLUTION: SOURCES, CHARACTERISTICS, TRANSPORT AND FATE. 3.0 Semester Hrs.

Equivalent with ESGN503,

This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater, and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN581. WATERSHED SYSTEMS MODELING. 3.0 Semester Hrs.

Equivalent with ESGN527,

Introduction to surface water modeling, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis. Course is heavy on application of models across a range of diverse watersheds for streamflow and snowmelt predictions. In general, theoretical topics are covered in the first meeting each week, followed by hands-on application of concepts and models in the second meeting. Laptops and student Matlab licenses will be required for in-class activities. Prerequisite: none. 3 hours lecture per week; 3 semester hours.

CEEN582. MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with ESGN528,

This is an advanced graduate-level course designed to provide students with hands-on experience in developing, implementing, testing, and using mathematical models of environmental systems. The course will examine why models are needed and how they are developed, tested, and used as decision-making or policy-making tools. Typical problems associated with environmental systems, such as spatial and temporal scale effects, dimensionality, variability, uncertainty, and data insufficiency, will be addressed. The development and application of mathematical models will be illustrated using a theme topic such as Global Climate Change, In Situ Bioremediation, or Hydrologic Systems Analysis. Prerequisites: CEEN580 and knowledge of basic statistics and computer programming. 3 hours lecture; 3 semester hours.

CEEN583. SURFACE WATER QUALITY MODELING. 3.0 Semester Hrs.

Equivalent with ESGN520,

This course will cover modeling of water flow and quality in rivers, lakes, and reservoirs. Topics will include introduction to common analytical and numerical methods used in modeling surface water flow, water quality, modeling of kinetics, discharge of waste water into surface systems, sedimentation, growth kinetics, dispersion, and biological changes in lakes and rivers. Prerequisites: CEEN480 or CEEN580 recommended. 3 hours lecture; 3 semester hours.

CEEN584. SUBSURFACE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.

Equivalent with ESGN522,

This course will investigate physical, chemical, and biological processes governing the transport and fate of contaminants in the saturated and unsaturated zones of the subsurface. Basic concepts in fluid flow, groundwater hydraulics, and transport will be introduced and studied. The theory and development of models to describe these phenomena, based on analytical and simple numerical methods, will also be discussed. Applications will include prediction of extents of contaminant migration and assessment and design of remediation schemes. Prerequisites: CEEN580. 3 hours lecture; 3 semester hours.

CEEN590. CIVIL ENGINEERING SEMINAR. 1.0 Semester Hr.

(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

CEEN591. ENVIRONMENTAL PROJECT MANAGEMENT. 3.0 Semester Hrs.

Equivalent with ESGN571,

This course investigates environmental project management and decision making from government, industry, and contractor perspectives. Emphasis is on (1) economics of project evaluation; (2) cost estimation methods; (3) project planning and performance monitoring; (4) and creation of project teams and organizational/communications structures. Extensive use of case studies. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN592. ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with ESGN502, PEGN530,

This is a comprehensive introduction to U.S. Environmental Law, Policy, and Practice, especially designed for the professional engineer, scientist, planner, manager, consultant, government regulator, and citizen. It will prepare the student to deal with the complex system of laws, regulations, court rulings, policies, and programs governing the environment in the USA. Course coverage includes how our legal system works, sources of environmental law, the major USEPA enforcement programs, state/local matching programs, the National Environmental Policy Act (NEPA), air and water pollution (CAA, CWA), EPA risk assessment training, toxic/hazardous substances laws (RCRA, CERCLA, EPCRA, TSCA, LUST, etc.), and a brief introduction to international environmental law. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN593. ENVIRONMENTAL PERMITTING AND REGULATORY COMPLIANCE. 3.0 Semester Hrs.

Equivalent with ESGN593,

The purpose of this course is to acquaint students with the permit writing process, developing information requirements for permit applications, working with ambiguous regulations, negotiating with permit writers, and dealing with public comment. In addition, students will develop an understanding of the process of developing an economic and legally defensible regulatory compliance program. Prerequisite: CEEN592. 3 hours lecture; 3 semester hours.

CEEN594. RISK ASSESSMENT. 3.0 Semester Hrs.

Equivalent with ESGN501,

This course evaluates the basic principles, methods, uses, and limitations of risk assessment in public and private sector decision making. Emphasis is on how risk assessments are made and how they are used in policy formation, including discussion of how risk assessments can be objectively and effectively communicated to decision makers and the public. Prerequisite: CEEN592 and one semester of statistics. 3 hours lecture; 3 semester hours.

CEEN595. ANALYSIS OF ENVIRONMENTAL IMPACT. 3.0 Semester Hrs.

Equivalent with ESGN591,

Techniques for assessing the impact of mining and other activities on various components of the ecosystem. Training in the procedures of preparing Environmental Impact Statements. Course will include a review of pertinent laws and acts (i.e. Endangered Species Act, Coordination Act, Clean Air Act, etc.) that deal with environmental impacts. Prerequisite: none. 3 hours lecture, some field trips; 3 semester hours.

CEEN596. ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR. 0.0 Semester Hrs.

Equivalent with ESGN590,

Research presentations covering current research in a variety of environmental topics.

CEEN597. SPECIAL SUMMER COURSE. 6.0 Semester Hrs.**CEEN598. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN599AA. INDEPENDENT STUDY. 0.5-6 Semester Hr.**CEEN599AB. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AC. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AD. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AE. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AF. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AG. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AH. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AI. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AJ. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AK. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AL. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AM. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AN. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AO. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN599AP. INDEPENDENT STUDY. 0.5-6 Semester Hr.****CEEN610. INTERNATIONAL ENVIRONMENTAL LAW. 3.0 Semester Hrs.**

Equivalent with ESGN602,

The course covers an introductory survey of International Environmental Law, including multi-nation treaties, regulations, policies, practices, and politics governing the global environment. It surveys the key issues of sustainable development, natural resources projects, transboundary pollution, international trade, hazardous waste, climate change, and protection of ecosystems, wildlife, and human life. New international laws are changing the rules for engineers, project managers, scientists, teachers, businesspersons, and others both in the US and abroad, and this course is especially designed to keep professionals fully, globally informed and add to their credentials for international work. Prerequisites: CEEN592. 3 hours lecture; 3 semester hours.

CEEN611. MULTIPHASE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.

Equivalent with ESGN622,
Principles of multiphase and multicomponent flow and transport are applied to contaminant transport in the unsaturated and saturated zones. Focus is on immiscible phase, dissolved phase, and vapor phase transport of low solubility organic contaminants in soils and aquifer materials. Topics discussed include: capillarity, interphase mass transfer, modeling, and remediation technologies. Prerequisites: CEEN550 or equivalent, CEEN580 or CEEN584 or equivalent. 3 hours lecture; 3 semester hours.

CEEN698. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN699. ADVANCED INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707C,ESGN707,
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Electrical Engineering & Computer Science

2015-2016

Degrees Offered

- Master of Science (Computer Science)
- Master of Science (Electrical Engineering)
- Doctor of Philosophy (Computer Science)
- Doctor of Philosophy (Electrical Engineering)

Program Overview

The Electrical Engineering and Computer Science Department (EECS) offers the degrees Master of Science and Doctor of Philosophy in Computer Science and the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. These degree programs demand academic rigor and depth yet also address real-world problems.

The Department also supports graduate degrees in Mathematical and Computer Sciences (computer science option) and Engineering (electrical specialty), but these degrees have been retired. For details on these programs, please see the 2011-2012 CSM Graduate Bulletin. Students admitted to the Mathematical and Computer Sciences (computer science

option) or Engineering (electrical specialty) graduate programs for the 2012-2013 academic year may opt to change their program of study to EE or CS as appropriate with their background and complete the degree requirements for the selected degree.

The EECS department has nine areas of research activity that stem from the core fields of Electrical Engineering and Computer Science: (1) Antennas and Wireless Communications, (2) Applied Algorithms and Data Structures, (3) Education (4) Energy Systems and Power Electronics, (5) High Performance Computing, (6) Human-Centered Robotics, (7) Information and Systems Sciences, (8) Machine Learning, and (9) Networking. Additionally, students may study areas such as Embedded Systems and/or Robotics, which include elements from both Computer Science and Electrical Engineering disciplines. In many cases, individual research projects encompass more than one research area.

Antennas and Wireless Communications research areas include electromagnetics, antennas, microwave, and wireless communications. Applications address current academic, industry, and society needs. Examples include the design of antennas, antenna arrays, and microwave RF devices for communication and sensing applications.

Applied Algorithms and Data Structures is an interdisciplinary research area that is applied to areas such as VLSI design automation, cheminformatics, computational materials, and cyber-physical systems.

Education research includes areas within STEM education and K-12 education.

Energy Systems and Power Electronics is focused on both fundamental and applied research in the interrelated fields of conventional electric power systems and electric machinery, renewable energy and distributed generation, energy economics and policy issues, power quality, power electronics and drives. The overall scope of research encompasses a broad spectrum of electrical energy applications including investor-owned utilities, rural electric associations, manufacturing facilities, regulatory agencies, and consulting engineering firms.

High Performance Computing research is focused on compiler-based code and data transformation, memory optimization for both multi-core and many-core processors, speculative parallelization, approximate computation and GPU-based acceleration of Big Data applications (such as graph processing and machine learning algorithms).

Human-Centered Robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making.

Information and Systems Sciences is an interdisciplinary research area that encompasses the fields of control systems, communications, signal and image processing, compressive sensing, robotics, and mechatronics. Focus areas include intelligent and learning control systems, fault detection and system identification, computer vision and pattern recognition, sensor development, mobile manipulation and autonomous systems. Applications can be found in renewable energy and power systems, materials processing, sensor and control networks, bio-engineering, intelligent structures, and geosystems.

Machine Learning includes research in developing mathematical foundations and algorithm design needed for computers to learn. Focus areas include fundamental research in machine learning and numerical methods, as well as developing novel algorithms for bioinformatics, data mining, computer vision, biomedical image analysis, parallel computing, natural language processing, and data privacy.

Networking research includes mobile networks, sensor networks, pervasive computing, and wireless networking. Focus areas include credible network simulation, cyber-physical systems, game theoretic algorithm design, middleware, and mobile social applications. Interdisciplinary research also exists, mainly in the use of wireless sensor networks for environmental monitoring and development of energy efficient buildings.

Program Details

The EECS Department offers the degrees Master of Science and Doctor of Philosophy in Computer Science and the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these four degrees.

Combined Program: The EECS Department also offers combined BS/MS degree programs. These programs offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements. This program is described in the undergraduate catalog and is in place for both Computer Science and Electrical Engineering students. The Physics combined program also offers a track in Electrical Engineering. Details on this program can be found in the CSM Undergraduate Bulletin, and course schedules for this program can be obtained in the Physics Department.

Prerequisites

Requirements for Admission to CS: The minimum requirements for admission to the M.S. and Ph.D degrees in Computer Science are:

- Applicants must have a Bachelor's degree, or equivalent, from an accredited institution with a grade-point average of 3.0 or better on a 4.0 scale.
- Students are expected to have completed two semesters of calculus, along with courses in object-oriented programming and data structures, and upper level courses in at least three of the following areas: software engineering, numerical analysis, computer architecture, principles of programming languages, analysis of algorithms, and operating systems.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Requirements for Admission to EE: The minimum requirements for admission to the M.S. and Ph.D. degrees in Electrical Engineering are:

- A baccalaureate degree in engineering, computer science, a physical science, or math with a grade-point average of 3.0 or better on a 4.0 scale.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Admitted Students: The EECS Department Graduate Committee may require that an admitted student take undergraduate remedial coursework to overcome technical deficiencies. The committee will decide whether to recommend regular or provisional admission.

Transfer Courses: Graduate level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and EECS Department Head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the CSM Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the EECS faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of EECS faculty by rank is available in the faculty section (p.) of the bulletin.

Master of Science (thesis option) students in both EE and CS must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the EECS Department. Both EE and CS Ph.D. Thesis Committees must have at least four members; the Advisor/co-advisor and two additional members must be permanent faculty in the EECS Department, and one member must be outside the departmental faculty and serving as chair of the committee. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (<http://gradschool.mines.edu/Degree-Audit>) by the posted deadline. Ph.D. students need to submit the Degree

Audit form (<http://gradschool.mines.edu/Degree-Audit>) by the posted deadline and need to submit the Admission to Candidacy form (<https://inside.mines.edu/GS-Candidacy-Addendum>) two weeks prior to census day of the semester in which they want to be considered eligible for reduced registration.

Time Limit: As stipulated by the CSM Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

Program Requirements

Master of Science - Computer Science

The M.S. degree in Computer Science (Thesis or Non-Thesis option) requires 36 credit hours. Requirements for the thesis M.S. are 24 hours of coursework plus 12 hours of thesis credit leading to an acceptable Master's thesis; thesis students are encouraged to find a thesis advisor and form a Thesis Committee by the end of the first year. The non-thesis option consists of two tracks: a Project Track and a Coursework Track.

Requirements for the Project Track are 30 hours of coursework plus 6 hours of project credit; requirements for the Coursework Track are 36 hours of coursework. The following four core courses are required of all students. Students may choose elective courses from any CSCI graduate course offered by the Department. In addition, up to six credits of elective courses may be taken outside of CSCI. Lastly, a maximum of six Independent Study course units can be used to fulfill degree requirements.

CSCI406	ALGORITHMS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CSCI561	THEORY OF COMPUTATION	3.0
CSCI564	ADVANCED COMPUTER ARCHITECTURE	3.0

M.S. Project Track: Students are required to take six credits of CSCI700 to fulfill the MS project requirement. (It is recommended that the six credits consist of two consecutive semesters of three credits each.) At most six credits of CSCI700 will be counted toward the Masters non-thesis degree. Deliverables include a report and a presentation to a committee of two CS faculty including the Advisor. Deliverables must be successfully completed in the last semester in which the student registers for CSCI700. A student must receive two "pass" votes (i.e., a unanimous vote) to satisfy the project option.

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research. A student must "pass" this defense to earn an M.S. degree

Doctor of Philosophy - Computer Science

The Ph.D. degree in Computer Science requires 72 credit hours of course work and research credits. Required course work provides a strong background in computer science. A course of study leading to the Ph.D. degree can be designed either for the student who has completed the master's degree or for the student who has completed the bachelor's degree. The following five courses are required of all students. Students who have taken equivalent courses at another institution may satisfy these requirements by transfer.

CSCI406	ALGORITHMS	3.0
CSCI442	OPERATING SYSTEMS	3.0

CSCI561	THEORY OF COMPUTATION	3.0
CSCI564	ADVANCED COMPUTER ARCHITECTURE	3.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS	1.0

Ph.D. Qualifying Examination: Students desiring to take the Ph.D. Qualifying Exam must have:

- (if required by your advisor) taken SYGN 501 The Art of Science (previously or concurrently),
- taken at least four CSCI 500-level courses at CSM (only one CSCI599 is allowed), and
- maintained a GPA of 3.5 or higher in all CSCI 500-level courses taken.

The Ph.D. Qualifying Exam is offered once a semester. Each Ph.D. Qualifying Exam comprises of two research areas, chosen by the student. The exam consists of the following steps:

Step 1. A student indicates intention to take the CS Ph.D. Qualifying Exam by choosing two research interest areas from the following list: algorithms, education, high-performance computing, human-centered robotics, image processing, machine learning, and networks. This list is subject to change, depending on the current faculty research profile. Students must inform the EECS Graduate Committee Chair of their intention to take the exam no later than the first class day of the semester.

Step 2. The Graduate Committee Chair creates an exam committee of (at least) four appropriate faculty. The exam committee assigns the student deliverables for both research areas chosen. The deliverables will be some combination from the following list:

- read a set of technical papers, make a presentation, and answer questions;
- complete a hands-on activity (e.g., develop research software) and write a report;
- complete a set of take-home problems;
- write a literature survey (i.e., track down references, separate relevant from irrelevant papers); and
- read a set of papers on research skills (e.g., ethics, reviewing) and answer questions.

Step 3. The student must complete all deliverables no later than the Monday of Dead Week.

Step 4. Each member of the exam committee makes a recommendation on the deliverables from the following list: strongly support, support, and do not support. To pass the Ph.D. Qualifying Exam, the student must have at least two "strongly supports" and no more than one "do not support". The student is informed of the decision no later than the Monday after finals week. A student can only fail the exam one time. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student's Thesis Committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time Ph.D. students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student’s Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn a Ph.D. degree.

Master of Science – Electrical Engineering

The M.S. degree in Electrical Engineering (Thesis or Non-Thesis Option) requires 30 credit hours. Requirements for the thesis M.S. are 24 hours of coursework and six credit hours of thesis research. The non-thesis option requires 30 credit hours of coursework. A maximum of six credit hours of Independent Study can be used to fulfill degree requirements. There are three tracks in Electrical Engineering: (1) Antennas and Wireless Communications (AWC), (2) Energy Systems and Power Electronics (EPSE), and (3) Information and Systems Sciences (ISS). Students are encouraged to decide between tracks before pursuing an advanced degree. Students are also encouraged to speak to their Advisor and/or a member of the EE faculty before registering for classes and to select a permanent Advisor as soon as possible. The following set of courses is required of all students.

M.S. Thesis - Electrical Engineering

EENG707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
EE CORE: EE Core Courses (AWC track)		12.0
EE CORE: EE Core Courses (ESPE track)		6.0
EE CORE: EE Core Courses (ISS track)		12.0
TECHNICAL ELECTIVES	Technical Electives must be approved by Thesis Committee	
EE TECH: EE Technical Electives (AWC track)		12.0
EE TECH: EE Technical Electives (ESPE track)		18.0
EE TECH: EE Technical Electives (ISS track)		12.0

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research.

M.S. Non-Thesis - Electrical Engineering

EE CORE: EE Core Courses (AWC track)	12.0
EE CORE: EE Core Courses (ESPE track)	6.0
EE CORE: EE Core Courses (ISS track)	12.0
TECHNICAL ELECTIVES	Technical Electives must be approved by Advisor
EE TECH: EE Technical Electives (AWC track)	12.0
EE TECH: EE Technical Electives (ESPE track)	18.0
EE TECH: EE Technical Electives (ISS track)	12.0
EE Electives (all tracks)	6.0

Must be taught by an approved faculty member in EE

Doctor of Philosophy – Electrical Engineering

The Ph.D. degree in Electrical Engineering requires 72 credit hours of course work and research credits. A minimum of 36 credit hours of course work and a minimum of 24 credit hours of research is required.

The remaining 12 credit hours required can be earned through research or coursework and students should consult with their Advisor and/or Thesis Committee. There are three tracks in Electrical Engineering: (1) Antennas and Wireless Communications (AWC), (2) Energy Systems and Power Electronics (ESPE), and (3) Information and Systems Sciences (ISS). Students are encouraged to decide between tracks before pursuing an advanced degree. Students are also encouraged to speak to their Advisor and/or a member of the EE faculty before registering for classes and to select a permanent Advisor as soon as possible. The following set of courses is required of all students.

EENG707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0
EE CORE: EE Core Courses (AWC track)		12.0
EE CORE: EE Core Courses (ESPE track)		6.0
EE CORE: EE Core Courses (ISS track)		12.0
EE Technical Electives	Technical Electives must be approved by Thesis Committee	
EE TECH: EE Technical Electives (AWC track)		24.0
EE TECH: EE Technical Electives (ESPE track)		30.0
EE TECH: EE Technical Electives (ISS track)		24.0

Ph.D. Qualifying Examination: Students wishing to enroll in the Electrical Engineering Ph.D. program will be required to pass a Qualifying Exam.

Normally, full-time Ph.D. candidates will take the Qualifying Exam in their first year, but it must be taken within four semesters of entering the program. Part-time candidates will normally be expected to take the Qualifying Exam within no more than six semesters of entering the program.

The purpose of the Qualifying Exam is to assess some of the attributes expected of a successful Ph.D. student, including:

- To determine the student's ability to review, synthesize and apply fundamental concepts.
- To determine the creative and technical potential of the student to solve open-ended and challenging problems.
- To determine the student's technical communication skills.

The Qualifying Examination includes both written and oral sections. The written section is based on material from the EECS Department's undergraduate Electrical Engineering degree. The oral part of the exam covers one or more papers from the literature chosen by the student and the student's Advisor. The student's Advisor and two additional Electrical Engineering faculty members (typically from the student's Thesis Committee representing their track) administer the oral exam.

Ph.D. Qualifying exams will be held each spring semester. In the event of a student failing the Qualifying exam, she/he will be given one further opportunity to pass the exam in the following spring semester. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student’s graduate committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student's Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research.

Electrical Engineering Courses

Required Core: Antennas and Wireless Communications Track

All students must take 3 the following courses.

Advanced Engineering Electromagnetics

Computational Electromagnetics

Antennas

and choose at least one of the following:

EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0
EENG527	WIRELESS COMMUNICATIONS	3.0
EENG535	RF AND MICROWAVE ENGINEERING	3.0
Radar Systems (to be approved for 2015-16 academic year)		

Required Core: Energy Systems and Power Electronics Track

Choose at least 2 of the following:

EENG570	ADVANCED HIGH POWER ELECTRONICS	3.0
EENG580	POWER DISTRIBUTION SYSTEMS ENGINEERING	3.0
EENG581	POWER SYSTEM OPERATION AND MANAGEMENT	3.0

Required Core: Information and Systems Sciences Track

All students must take:

EENG515	MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS	3.0
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and choose at least 3 of the following:

EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG510	IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING	3.0
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS	3.0
EENG519	ESTIMATION THEORY AND KALMAN FILTERING	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL	3.0

Other EE Courses:

EENG512	COMPUTER VISION	3.0
EENG535	RF AND MICROWAVE ENGINEERING	3.0
MEGN540	MECHATRONICS	3.0

MEGN545	ADVANCED ROBOT CONTROL	3.0
EENGN589	DESIGN AND CONTROL OF WIND ENERGY SYSTEMS	3.0
EENG617	INTELLIGENT CONTROL SYSTEMS	3.0
EENG618	NONLINEAR AND ADAPTIVE CONTROL	3.0
EENG683	COMPUTER METHODS IN ELECTRIC POWER SYSTEMS	3.0

Interium Department Head and Professor

Atef Elsherbeni, Dobelman Chair

Professors

Kevin Moore, College Dean

Tracy Camp

Randy Haupt

Dinesh Mehta

P.K. Sen

Tyrone Vincent

Associate Professors

Qi Han

William Hoff

Kathryn Johnson

Marcelo Simoes

Michael Wakin

Assistant Professors

Salman Mohagheghi

Payam Nayeri

Gongguo Tang

Hua Wang

Bo Wu

Dejun Yang

Chuan Yue

Hao Zhang

Teaching Professors

Ravel Ammerman

Vibhuti Dave

Cyndi Rader

Jeff Schowalter

Teaching Associate Professors

Stephanie Claussen

Keith Hellman

Christopher Painter-Wakefield

Jeffrey Paone

Emeritus Associate Professor

Catherine Skokan

Courses

CSCI510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.

Equivalent with EGGN510,

(I) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 3 hours lecture; 3 semester hours.

CSCI512. COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with EGGN512,

(II) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 3 hours lecture; 3 semester hours.

CSCI522. INTRODUCTION TO USABILITY RESEARCH. 3.0 Semester Hrs.

(I) An introduction to the field of Human-Computer Interaction (HCI). Students will review current literature from prominent researchers in HCI and will discuss how the researchers' results may be applied to the students' own software design efforts. Topics include usability testing, ubiquitous computing user experience design, cognitive walkthrough and talk-aloud testing methodologies. Students will work in small teams to develop and evaluate an innovative product or to conduct an extensive usability analysis of an existing product. Project results will be reported in a paper formatted for submission to an appropriate conference (UbiComp, SIGCSE, CHI, etc.). Prerequisite: CSCI 261 or equivalent. 3 hours lecture, 3 semester hours.

CSCI542. SIMULATION. 3.0 Semester Hrs.

Equivalent with MACS542,

(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. Prerequisite: CSCI 262 (or equivalent) and MATH 323 (or MATH 530 or equivalent). 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH544,

This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

CSCI546. WEB PROGRAMMING II. 3.0 Semester Hrs.

(I) This course covers methods for creating effective and dynamic web pages, and using those sites as part of a research agenda related to Humanitarian Engineering. Students will review current literature from the International Symposium on Technology and Society (ISTAS), American Society for Engineering Education (ASEE), and other sources to develop a research agenda for the semester. Following a brief survey of web programming languages, including HTML, CSS, JavaScript and Flash, students will design and implement a website to meet their research agenda. The final product will be a research paper which documents the students' efforts and research results. Prerequisite: CSCI 262. 3 hours lecture, 3 semester hours.

CSCI547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.

Equivalent with MATH547,

Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

CSCI555. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.

(II) An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI406 Algorithms. 3 hours lecture; 3 semester hours.

CSCI561. THEORY OF COMPUTATION. 3.0 Semester Hrs.

(I) An introduction to abstract models of computation and computability theory; including finite automata (finite state machines), pushdown automata, and Turing machines. Language models, including formal languages, regular expressions, and grammars. Decidability and undecidability of computational problems. Prerequisite: CSCI/MATH358. 3 hours lecture; 3 semester hours.

CSCI562. APPLIED ALGORITHMS AND DATA STRUCTURES. 3.0 Semester Hrs.

(II) Industry competitiveness in certain areas is often based on the use of better algorithms and data structures. The objective of this class is to survey some interesting application areas and to understand the core algorithms and data structures that support these applications. Application areas could change with each offering of the class, but would include some of the following: VLSI design automation, computational biology, mobile computing, computer security, data compression, web search engines, geographical information systems. Prerequisite: MATH/CSCI406. 3 hours lecture; 3 semester hours.

CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.

(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.

The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI341. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED COMPUTING SYSTEMS. 3.0 Semester Hrs.

(II) This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems. Prerequisites: CSCI 442 or equivalent. 3 hours of lecture; 3 semester hours.

CSCI568. DATA MINING. 3.0 Semester Hrs.

Equivalent with MACS568,

(II) This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several applications specific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.

(I) Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.

Equivalent with MACS572,

(II) This course covers the network layer, data link layer, and physical layer of communication protocols in depth. Detailed topics include routing (unicast, multicast, and broadcast), one hop error detection and correction, and physical topologies. Other topics include state-of-the-art communications protocols for emerging networks (e.g., ad hoc networks and sensor networks). Prerequisite: CSCI 471 or equivalent. 3 hours lecture; 3 semester hours.

CSCI573. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.

Equivalent with CSCI473,

(I) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Students in CSCI 473 will be able to model and analyze human behaviors geared toward human-robot interaction applications. They will also be able to implement a working system using algorithms learnt to solve a given problem in human-centered robotics application. Students in CSCI 573 will get a more in-depth study into the theory of the algorithms. They will be able to compare the different algorithms to select the most appropriate one that can solve a specific problem. Prerequisites: CSCI262 and MATH201 (or equivalent). 3 hours lecture; 3 semester hours.

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.

Equivalent with MATH574,

Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI 262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

CSCI575. MACHINE LEARNING. 3.0 Semester Hrs.

Equivalent with MACS575,

(II) The goal of machine learning research is to build computer systems that learn from experience and that adapt to their environments.

Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course will focus on the methods that have proven valuable and successful in practical applications. The course will also contrast the various methods, with the aim of explaining the situations in which each is most appropriate. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI576. WIRELESS SENSOR SYSTEMS. 3.0 Semester Hrs.

With the advances in computational, communication, and sensing capabilities, large scale sensor-based distributed environments are becoming a reality. Sensor enriched communication and information infrastructures have the potential to revolutionize almost every aspect of human life benefitting application domains such as transportation, medicine, surveillance, security, defense, science and engineering. Such a distributed infrastructure must integrate networking, embedded systems, distributed computing and data management technologies to ensure seamless access to data dispersed across a hierarchy of storage, communication, and processing units, from sensor devices where data originates to large databases where the data generated is stored and/or analyzed. Prerequisite: CSCI406, CSCI446, CSCI471. 3 hours lecture; 3 semester hours.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.

This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

CSCI586. FAULT TOLERANT COMPUTING. 3.0 Semester Hrs.

This course provides a comprehensive overview of fault tolerant computing including uniprocessor fault tolerance, distributed fault tolerance, failure model, fault detection, checkpoint, message log, algorithm-based fault tolerance, error correction codes, and fault tolerance in large storage systems. 3 hours lecture; 3 semester hours.

CSCI597. SUMMER PROGRAMS. 6.0 Semester Hrs.**CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI691. GRADUATE SEMINAR. 1.0 Semester Hr.

Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI692. GRADUATE SEMINAR. 1.0 Semester Hr.

Equivalent with MACS692, MATH692,

Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.

Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on underlying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

CSCI698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.

(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

EENG504. ENGINEERING SYSTEMS SEMINAR - ELECTRICAL. 1.0 Semester Hr.

Equivalent with EGGN504E,

(I, II) This is a seminar forum for graduate students to present their research projects, critique others' presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today's competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Engineering graduate program. Prerequisite: Graduate standing. 1 hour seminar, 1 semester hour. Repeatable; maximum 1 hour granted toward degree requirements.

EENG509. SPARSE SIGNAL PROCESSING. 3.0 Semester Hrs.

Equivalent with EGGN509,

(II) This course presents a mathematical tour of sparse signal representations and their applications in modern signal processing. The classical Fourier transform and traditional digital signal processing techniques are extended to enable various types of computational harmonic analysis. Topics covered include time-frequency and wavelet analysis, filter banks, nonlinear approximation of functions, compression, signal restoration, and compressive sensing. Prerequisites: EENG411 and EENG515. 3 hours lecture; 3 semester hours.

EENG510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.

Equivalent with CSCI510, EGGN510,

(I) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 3 hours lecture; 3 semester hours.

EENG511. CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS. 3.0 Semester Hrs.

(II) The course focuses on recognizing and solving convex optimization problems that arise in applications in various engineering fields. Covered topics include basic convex analysis, conic programming, duality theory, unconstrained optimization, and constrained optimization. The application part covers problems in signal processing, power and energy, machine learning, control and mechanical engineering, and other fields, with an emphasis on modeling and solving these problems using the CVX package. Prerequisites: EENG311 and EENG511. 3 hours lecture; 3 semester hours.

EENG512. COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with CSCI512, EGGN512,

(II) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 3 hours lecture; 3 semester hours.

EENG515. MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN515,

(I) An introduction to mathematical methods for modern signal processing using vector space methods. Topics include signal representation in Hilbert and Banach spaces; linear operators and the geometry of linear equations; LU, Cholesky, QR, eigen- and singular value decompositions. Applications to signal processing and linear systems are included throughout, such as Fourier analysis, wavelets, adaptive filtering, signal detection, and feedback control.

EENG517. THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN517,

(II) This course will introduce and study the theory and design of multivariable and nonlinear control systems. Students will learn to design multivariable controllers that are both optimal and robust, using tools such as state space and transfer matrix models, nonlinear analysis, optimal estimator and controller design, and multi-loop controller synthesis. Prerequisite: EENG417. 3 hours lecture; 3 semester hours.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.

Equivalent with EGGN519,

Estimation theory considers the extraction of useful information from raw sensor measurements in the presence of signal uncertainty. Common applications include navigation, localization and mapping, but applications can be found in all fields where measurements are used. Mathematic descriptions of random signals and the response of linear systems are presented. The discrete-time Kalman Filter is introduced, and conditions for optimality are described. Implementation issues, performance prediction, and filter divergence are discussed. Adaptive estimation and nonlinear estimation are also covered. Contemporary applications will be utilized throughout the course. Pre-requisite: EENG515 and MATH534 or equivalent. Spring semester of odd years. 3 Lecture Hours; 3 Semester Hours.

EENG525. ANTENNAS. 3.0 Semester Hrs.

(I, II) This course provides an in depth introduction to the analysis and synthesis of antennas and antenna arrays. Students are expected to use MATLAB to model antennas and their performance. An extensive final project that involves experimental or computer demonstrations is required. EENG525 has more depth and required work than EENG425. EENG525 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on antenna and direction finding projects. Prerequisites: EGGN386 or GPGN302 or PHGN384. 3 hours lecture; 3 semester hours.

EENG527. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.

Equivalent with EENG513,EGGN513,

(I, II) This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. EENG527 has more depth and required work than EENG427. EENG527 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on final project. Prerequisites: EENG386, EENG311, and EENG388. 3 hours lecture, 3 semester hours.

EENG535. RF AND MICROWAVE ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN516,

This course teaches the basics of RF/microwave design including circuit concepts, modeling techniques, and test and measurement techniques, as applied to wireless communication systems. RF/microwave concepts that will be discussed are: scattering parameters, impedance matching, microstrip and coplanar transmission lines, power dividers and couplers, filters, amplifiers, oscillators, and diode mixers and detectors. Students will learn how to design and model RF/microwave components such as impedance matching networks, amplifiers and oscillators on Ansoft Designer software, and will build and measure these circuits in the laboratory. Prerequisites: EENG385, EENG386, EENG413. 3 hours lecture, 3 semester hours. Taught on demand.

EENG570. ADVANCED HIGH POWER ELECTRONICS. 3.0 Semester Hrs.

Equivalent with EGGN585,

(I) Basic principles of analysis and design of circuits utilizing high power electronics. AC/DC, DC/AC, AC/AC, and DC/DC conversion techniques. Laboratory project comprising simulation and construction of a power electronics circuit. Prerequisites: EENG385; EENG389 or equivalent. 3 hours lecture; 3 semester hours. Fall semester even years.

EENG571. MODERN ADJUSTABLE SPEED ELECTRIC DRIVES. 3.0 Semester Hrs.

Equivalent with EGGN581,

An introduction to electric drive systems for advanced applications. The course introduces the treatment of vector control of induction and synchronous motor drives using the concepts of general flux orientation and the feedforward (indirect) and feedback (direct) voltage and current vector control. AC models in space vector complex algebra are also developed. Other types of drives are also covered, such as reluctance, stepper-motor and switched-reluctance drives. Digital computer simulations are used to evaluate such implementations. Pre-requisite: Familiarity with power electronics and power systems, such as covered in EENG480 and EENG470. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG572. RENEWABLE ENERGY AND DISTRIBUTED GENERATION. 3.0 Semester Hrs.

Equivalent with EGGN582,

A comprehensive electrical engineering approach on the integration of alternative sources of energy. One of the main objectives of this course is to focus on the inter-disciplinary aspects of integration of the alternative sources of energy which will include most common and also promising types of alternative primary energy: hydropower, wind power, photovoltaic, fuel cells and energy storage with the integration to the electric grid. Pre-requisite: It is assumed that students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, power electronics, direct energy conversion, and fundamentals of electric power systems such as covered in basic engineering courses plus EENG480 and EENG470. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG573. ELECTRIC POWER QUALITY. 3.0 Semester Hrs.

Equivalent with EGGN580,

(II) Electric power quality (PQ) deals with problems exhibited by voltage, current and frequency that typically impact end-users (customers) of an electric power system. This course is designed to familiarize the concepts of voltage sags, harmonics, momentary disruptions, and waveform distortions arising from various sources in the system. A theoretical and mathematical basis for various indices, standards, models, analyses techniques, and good design procedures will be presented. Additionally, sources of power quality problems and some remedies for improvement will be discussed. The course bridges topics between power systems and power electronics. Prerequisite: EENG480 and EENG470. 3 lecture hours; 3 semester hours.

EENG580. POWER DISTRIBUTION SYSTEMS ENGINEERING. 3.0 Semester Hrs.

Equivalent with EGGN584,

This course deals with the theory and applications of problems and solutions as related to electric power distribution systems engineering from both ends: end-users like large industrial plants and electric utility companies. The primary focus of this course is on the medium voltage (4.16 kV ? 69 kV) power systems. Some references will be made to the LV power system. The course includes per-unit methods of calculations; voltage drop and voltage regulation; power factor improvement and shunt compensation; short circuit calculations; theory and fundamentals of symmetrical components; unsymmetrical faults; overhead distribution lines and power cables; basics and fundamentals of distribution protection. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG581. POWER SYSTEM OPERATION AND MANAGEMENT. 3.0 Semester Hrs.

Equivalent with EGGN587,

(I) This course presents a comprehensive exposition of the theory, methods, and algorithms for Energy Management Systems (EMS) in the power grid. It will focus on (1) modeling of power systems and generation units, (2) methods for dispatching generating resources, (3) methods for accurately estimating the state of the system, (4) methods for assessing the security of the power system, and (5) an overview of the market operations in the grid. Prerequisite: EENG480. 3 lecture hours; 3 semester hours.

EENG582. HIGH VOLTAGE AC AND DC POWER TRANSMISSION. 3.0 Semester Hrs.

Equivalent with EGGN586,

This course deals with the theory, modeling and applications of HV and EHV power transmission systems engineering. The primary focus is on overhead AC transmission line and voltage ranges between 115 kV ? 500 kV. HVDC and underground transmission will also be discussed. The details include the calculations of line parameters (RLC); steady-state performance evaluation (voltage drop and regulation, losses and efficiency) of short, medium and long lines; reactive power compensation; FACTS devices; insulation coordination; corona; insulators; sag-tension calculations; EMTF, traveling wave and transients; fundamentals of transmission line design; HV and EHV power cables: solid dielectric, oil-filled and gas-filled; Fundamentals of DC transmission systems including converter and filter. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of even years.

EENG583. ADVANCED ELECTRICAL MACHINE DYNAMICS. 3.0 Semester Hrs.

Equivalent with EGGN583,

This course deals primarily with the two rotating AC machines currently utilized in the electric power industry, namely induction and synchronous machines. The course is divided in two halves: the first half is dedicated to induction and synchronous machines are taught in the second half. The details include the development of the theory of operation, equivalent circuit models for both steady-state and transient operations, all aspects of performance evaluation, IEEE methods of testing, and guidelines for industry applications including design and procurement. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG584. POWER SYSTEM STABILITY. 3.0 Semester Hrs.

Advanced topics on stability of power and energy systems, including dynamic modeling of generators and motors, small signal stability of power system, transient stability during and in the aftermath of disturbances, voltage stability and voltage collapse, blackouts and brownouts in the bulk power grid, subsynchronous resonance, and impacts of distributed and renewable energy resources on grid stability. Prerequisites: EENG480, EENG481. 3 hours of lecture; 3 credit hours. Spring, even years.

EENG586. COMMUNICATION NETWORKS FOR POWER SYSTEMS. 3.0 Semester Hrs.

Advanced topics on communication networks for power systems including the fundamentals of communication engineering and signal modulation/transfer, physical layer for data transfer (e.g., wireline, wireless, fiber optics), different communication topologies for power networks (e.g., client-server, peer-to-peer), fundamentals of SCADA system, data modeling and communication services for power system applications, common protocols for utility and substation automation, and cyber-security in power networks. Prerequisites: EENG480. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG587. POWER SYSTEMS PROTECTION AND RELAYING. 3.0 Semester Hrs.

Theory and practice of power system protection and relaying; Study of power system faults and symmetrical components; Fundamental principles and tools for system modeling and analysis pertaining to relaying, and industry practices in the protection of lines, transformers, generators, motors, and industrial power systems; Introduction to microprocessor based relaying, control, and SCADA. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Spring, odd years.

EENG588. ENERGY POLICY, RESTRUCTURING AND DEREGULATION OF ELECTRICITY MARKET. 3.0 Semester Hrs.

The big picture of electric power, electricity and energy industry; Restructuring and Deregulation of electricity market; Energy Policy Acts and its impact on electricity market and pricing; Energy economics and pricing strategy; Public policy issues, reliability and security; Regulation. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG597. SUMMER PROGRAMS. 6.0 Semester Hrs.**EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG617. INTELLIGENT CONTROL SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN617,

Fundamental issues related to the design on intelligent control systems are described. Neural networks analysis for engineering systems are presented. Neural-based learning, estimation, and identification of dynamical systems are described. Qualitative control system analysis using fuzzy logic is presented. Fuzzy mathematics design of rule-based control, and integrated human-machine intelligent control systems are covered. Real-life problems from different engineering systems are analyzed. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Taught on demand.

EENG618. NONLINEAR AND ADAPTIVE CONTROL. 3.0 Semester Hrs.

Equivalent with EGGN618,

This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and the applications of this theory to adaptive control. It will focus on (1) methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations, (2) methods for designing controllers for such systems, (3) an introduction to the topic of system identification, and (4) study of the primary techniques in adaptive control, including model-reference adaptive control and model predictive control. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Spring, even numbered years.

EENG683. COMPUTER METHODS IN ELECTRIC POWER SYSTEMS.**3.0 Semester Hrs.**

Equivalent with EGGN583,

This course deals with the computer methods and numerical solution techniques applied to large scale power systems. Primary focus includes load flow, short circuit, voltage stability and transient stability studies and contingency analysis. The details include the modeling of various devices like transformer, transmission lines, FACTS devices, and synchronous machines. Numerical techniques include solving a large set of linear or non-linear algebraic equations, and solving a large set of differential equations. A number of simple case studies (as per IEEE standard models) will be performed. Prerequisites: EENG583, EENG580 and EENG582 or equivalent; a strong knowledge of digital simulation techniques. 3 lecture hours; 3 semester hours. Taught on demand.

EENG698. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0**Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707E,

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN555. SMARTGEO SEMINAR. 1.0 Semester Hr.

Geosystems are natural or engineered earth structures, e.g. earth dams or levees, groundwater systems, underground construction sites, and contaminated aquifers. An intelligent geosystem is one that can sense its environment, diagnose its condition/state, and provide decision support to improve the management, operation, or objective of the geosystem. The goal of this course is to introduce students to topics that are needed for them to be successful working in a multi-disciplinary field. The course will include training in leadership, multidisciplinary teams, policy and ethical issues, and a monthly technical seminar. Prerequisite/Corequisite: SYGN550. 1 hour lecture; 1 semester hour credit.

Mechanical Engineering

2015-2016**Degrees Offered**

- Master of Science (Mechanical Engineering)
- Doctor of Philosophy (Mechanical Engineering)

Program Overview

The Mechanical Engineering Department offers the Master of Science and Doctor of Philosophy degrees in Mechanical Engineering. The

program demands academic rigor and depth yet also addresses real-world engineering problems. The department has four broad divisions of research activity that stem from core fields in Mechanical Engineering: (1) Biomechanics, (2) Thermal-Fluid Systems, (3) Solid Mechanics and Materials, and (4) Robotics, Automation, and Design. In many cases, individual research projects encompass more than one research area and elements from other disciplines.

Biomechanics focuses on the application of engineering principles to the musculoskeletal system and other connective tissues. Research activities include experimental, computational, and theoretical approaches with applications in the areas of rehabilitation engineering, computer-assisted surgery and medical robotics, patient-specific biomechanical modeling, intelligent prosthetics and implants, and bioinstrumentation. The Biomechanics group has strong research ties with other campus departments, the local medical community, and industry partners.

Robotics, Automation, and Design merges research from multiple areas of science and engineering. Topics include the design of robotic and automation system hardware and software, particularly for tasks that require some level of autonomy, intelligence, self-prognostics and decision making. Such capabilities are built upon integrated mechatronic systems that enable pro-active system responses to its environment and current state. These capabilities are applied in applications such as advanced robotics and manufacturing systems. Research in this division explores the science underlying the design process, implementation of mechanical and control systems to enable autonomy, and innovative computational analysis for automation, intelligence, and systems optimization.

Solid Mechanics and Materials develops novel computational and experimental solutions for problems in the mechanical behavior of advanced materials. Research in the division spans length scales from nanometer to kilometer, and includes investigations of microstructural effects on mechanical behavior, nanomechanics, granular mechanics, and continuum mechanics. Material-behavior models span length scales from the nano- and micro-scale, to the meso- and macro-scale. Much of the research is computational in nature using advanced computational methods such as molecular dynamics, finite-element, boundary-element and discrete-element methods. Strong ties exist between this group and the campus communities of applied mathematics, chemical engineering, materials science, metallurgy, and physics.

Thermal-Fluid Systems incorporates a wide array of multidisciplinary applications such as advanced energy conversion and storage, multi-phase fluid flows, materials processing, combustion, alternative fuels, and renewable energy. Research in thermal-fluid systems integrates the disciplines of thermodynamics, heat transfer, fluid mechanics, transport phenomena, chemical engineering, and materials science towards solving problems and making advances through experiments and computational modeling in the broad areas of energy conversion, fluid mechanics, and thermal transport. Research projects in this area specialize in some aspect of mechanical engineering but often have a strong interdisciplinary component in related fields such as Materials Science and Chemical Engineering.

Program Details

The Mechanical Engineering Department offers the degrees Master of Science and Doctor of Philosophy in Mechanical Engineering. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both

thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these degrees.

Combined Program:

The ME Department also offers combined BS/MS degree programs. These programs enable students to begin graduate coursework while still finishing their undergraduate degree requirements. This program is described in the undergraduate catalog. In addition, the combined degree program is offered in collaboration with the Physics Department and allows students to obtain specific engineering skills that complement their physics background. Details on the combined programs can be found in the CSM Undergraduate Bulletin, and course schedules for the programs can be obtained in the Mechanical Engineering, and Physics Departments.

Prerequisites

Requirements for Admissions: The minimum requirements for admission into the M.S. and Ph.D. degrees in Mechanical Engineering are:

- a baccalaureate degree in engineering, computer science, a physical science, or mathematics with a minimum grade-point average of 3.0;
- Graduate Record Examination (Quantitative Reasoning) section score of 160 or higher. Applicants from an engineering program at CSM are not required to submit GRE scores;
- TOEFL score of 79 or higher (or 550 paper-based or 213 computer-based) for applicants whose native language is not English.

Program Requirements

Admitted Students: The Mechanical Engineering graduate admissions committee may require that an admitted student complete undergraduate remedial coursework to overcome technical deficiencies. Such coursework may not count toward the graduate degree. The committee will decide whether to recommend regular or provisional admission, and may ask the applicant to come to campus for an interview.

Transfer Courses: Graduate-level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit into the Mechanical Engineering Department. Approval from the Advisor and/or Thesis Committee and ME Department Head will be required as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the CSM Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the Mechanical Engineering Department Faculty to direct and monitor their academic plan, research, and independent studies. The M.S. graduate Thesis Committee must have at least three members, two of whom must be permanent faculty in the Mechanical Engineering Department. The Ph.D. graduate Thesis Committee must have at least four members; at least two members must be permanent faculty in the

Mechanical Engineering Department, and at least one member must be from outside the department. This outside member must chair the committee. Students who choose to have a minor program must select a representative from the minor areas of study to serve on the Thesis Committee.

Ph.D. Qualifying Exam:

Students enrolled in the Mechanical Engineering Ph.D. program will be required to pass a Qualifying Exam. The Ph.D. qualifying exam will be administered at a specific date during every semester by each research division independently. Each research division will appoint a Qualifying Exam chair, who oversees the process and ensures that the exam is administered fairly. Students must take the exam by no later than the end of their third semester in the Mechanical Engineering Ph.D. program. If the student fails the exam on their first attempt, they must retake the exam in the following semester with a maximum of two attempts to pass. One-semester extensions may be granted upon request to students who are enrolled as part-time or with non-ME backgrounds.

The purpose of the Qualifying Exam is to assess some of the attributes expected of a successful Ph.D. student, including:

- to determine the student's ability to review, synthesize and apply fundamental concepts;
- to determine the creative and technical potential of the student to solve open-ended and challenging problems;
- to determine the student's technical communication skills.

A written exam not to exceed 4.5 hours will be administered which will be divided into no more than five topical areas related to the research division, with topics announced in advance of the exam. The students will choose three topical areas to answer. Research divisions are encouraged to choose topical areas that relate to foundational undergraduate material linked to material in the core graduate courses required by that research division. Upon completion of the written exam, students will choose one paper out of a list of papers established by the research division faculty. Students will be given two weeks to write a two-page critical review of the paper which discusses possible extensions of the research.

Students, with a satisfactory performance on the written exam, will participate in an oral exam not to exceed two hours. The oral exam will be conducted by the qualifying exam committee and the student's advisor. The research division will specify the format of the exam in advance of the exam.

Exam results of Pass, Conditional Pass or Fail will be provided to the student in a timely manner by the exam committee. A Conditional Pass will require the student to take a remedial plan.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (<http://gradschool.mines.edu/Degree-Audit>) by the posted deadlines. Ph.D. students must complete the Degree Audit form (<http://gradschool.mines.edu/Degree-Audit>) by the posted deadlines and the Admission to Candidacy form (<http://gradschool.mines.edu/Admission-to-Candidacy-form>) two weeks prior to census day of the semester in which they want to be considered eligible for reduced registration.

Additionally, full-time Ph.D. students must complete the following requirements within the first two calendar years after enrolling into the Ph.D. program:

- have a Thesis Committee appointment form on file in the Graduate Office;
- complete all prerequisite and core curriculum course requirements;
- demonstrate adequate preparation for, and satisfactory ability to conduct doctoral research; and
- be admitted into full candidacy for the degree.

Time Limit: As stipulated by the CSM Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

Degree Requirements

The Master of Science degree in Mechanical Engineering (thesis or non-thesis option) requires 30 credit hours. Requirements for the M.S. are 24 credit hours of coursework and 6 credit hours of thesis research. The M.S. non-thesis option requires 30 credit hours of coursework.

The Ph.D. in Mechanical Engineering degree requires 72 credit hours of course work and research credits. A minimum of 36 credit hours of course work and 30 credit hours of research credits must be completed. A minimum of 12 of the 36 credit hours of required coursework must be taken at Colorado School of Mines.

All students must complete nine credit hours of course work within one research area by selecting 3 courses listed under the Research Division Courses.

M.S. Thesis Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN503	GRADUATE SEMINAR <small>Enrollment required every fall and spring semester</small>	0.0
RESEARCH CORE	Courses from one Research Division List	9.0
ME TECH	Technical Electives <small>Courses approved by Thesis Committee.</small>	9.0
ME CORE	Courses from ME Course List	3.0
MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
Total Semester Hrs		30.0

M.S. Non-Thesis Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
RESEARCH CORE	Course from one Research Division List	9.0
ME TECH	Technical Electives <small>Courses must be approved by Advisor.</small>	9.0
ME CORE	Courses from ME Course List	9.0
Total Semester Hrs		30.0

Ph.D. Degree

MEGN502	ADVANCED ENGINEERING ANALYSIS	3.0
MEGN503	GRADUATE SEMINAR <small>Enrollment required every fall and spring semester</small>	0.0
RESEARCH CORE	Courses from one Research Division List	9.0
ME TECH	Technical Electives <small>Must be approved by the Thesis Committee.</small>	24.0

MEGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	30.0
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RESEARCH DIVISION COURSES

BIOMECHANIC COURSES

MEGN531	PROSTHETIC AND IMPLANT ENGINEERING
MEGN532	EXPERIMENTAL METHODS IN BIOMECHANICS
MEGN535	MODELING AND SIMULATION OF HUMAN MOVEMENT
MEGN536	COMPUTATIONAL BIOMECHANICS

ROBOTICS, AUTOMATION AND DESIGN

MEGN540	MECHATRONICS
MEGN544	ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL
MEGN545	ADVANCED ROBOT CONTROL
MEGN591	ADVANCED ENGINEERING DESIGN METHODS
MEGN593	ENGINEERING DESIGN OPTIMIZATION
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN

SOLID MECHANICS AND MATERIALS

MEGN512	ADVANCED ENGINEERING VIBRATION
MEGN514	CONTINUUM MECHANICS
MEGN598	MICROMECHANICS/HOMOGENIZATION
MEGN598	NONLINEAR MECHANICS
MEGN598	COMPUTATIONAL MECHANICS

THERMAL-FLUID SYSTEMS

MEGN501	ADVANCED ENGINEERING MEASUREMENTS
MEGN552	VISCOUS FLOW AND BOUNDARY LAYERS
MEGN553	INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA
MEGN566	COMBUSTION
MEGN571	ADVANCED HEAT TRANSFER

ME COURSE LIST

Any graduate level course taught by a member of the CSM Mechanical Engineering faculty is considered a part of the list of acceptable Mechanical Engineering courses.

Professor and Department Head

Gregory S. Jackson

George R. Brown Distinguished Professor

Robert J. Kee

Professors

John R. Berger

Cristian V. Ciobanu

Graham G.W. Mustoe

Alexandra Newman

Associate Professor

Joel M. Bach

Robert Braun

Anthony J. Petrella

John P.H. Steele

Neal Sullivan

Cameron Turner

Ruichong "Ray" Zhang

Assistant Professor

Gregory Bogin

Ozkan Celik

Steven DeCaluwe

Jason Porter

Anne Silverman

Aaron Stebner

Paulo Tabares-Velasco

Nils Tilton

Douglas Van Bossuyt

Xiaoli Zhang

Teaching Associate Professors

Robert Amaro

Jennifer Blacklock

Jered Dean

Ventzi Karaivanov

Leslie M. Light

Derrick Rodriguez

Emeriti Professor

Robert King

Michael B. McGrath

Emerita Professor

Joan P. Gosink

Emeritus Associate Professor

Dave Munoz

Research Professor

George Gilmer

Research Associate Professor

Huayang Zhu

Research Assistant Professors

Christopher B. Dreyer

Branden Kappes

Sandrine Ricote

Affiliate Professor of Mechanical Engineering

Michael Mooney

Courses**MEGN501. ADVANCED ENGINEERING MEASUREMENTS. 3.0****Semester Hrs.**

Equivalent with EGGN501,

(I) Introduction to the fundamentals of measurements within the context of engineering systems. Topics that are covered include: errors and error analysis, modeling of measurement systems, basic electronics, noise and noise reduction, and data acquisition systems. Prerequisite: EGGN250, EENG281 or equivalent, and MATH323 or equivalent; graduate student status. 3 hours lecture, 1 hour lab; 3 semester hours.

MEGN502. ADVANCED ENGINEERING ANALYSIS. 3.0 Semester Hrs.

Equivalent with EGGN502,

(I) Introduce advanced mathematical and numerical methods used to solve engineering problems. Analytic methods include series solutions, special functions, Sturm-Liouville theory, separation of variables, and integral transforms. Numerical methods for initial and boundary value problems include boundary, domain, and mixed methods, finite difference approaches for elliptic, parabolic, and hyperbolic equations, Crank-Nicolson methods, and strategies for nonlinear problems. The approaches are applied to solve typical engineering problems. Prerequisite: This is an introductory graduate class. The student must have a solid understanding of linear algebra, calculus, ordinary differential equations, and Fourier theory. 3 hours lecture.

MEGN503. GRADUATE SEMINAR. 0.0 Semester Hrs.

Equivalent with EGGN504M,

(I, II) This is a seminar forum for graduate students to present their research projects, critique others' presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today's competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Mechanical Engineering graduate program. Prerequisite: Graduate standing. 1 hour per week; 0 semester hours. Course is repeatable, but no coursework credit is awarded.

MEGN510. SOLID MECHANICS OF MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN543,

(II) Introduction to the algebra of vectors and tensors; coordinate transformations; general theories of stress and strain; principal stresses and strains; octahedral stresses; Hooke's Law introduction to the mathematical theory of elasticity and to energy methods; failure theories for yield and fracture. Prerequisite: CEEN311 or equivalent, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MEGN511. FATIGUE AND FRACTURE. 3.0 Semester Hrs.

Equivalent with EGGN532,MTGN545,

(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, odd numbered years.

MEGN512. ADVANCED ENGINEERING VIBRATION. 3.0 Semester Hrs.

Equivalent with EGGN546,

Vibration theory as applied to single- and multi-degree-of freedom systems. Free and forced vibrations to different types of loading-harmonic, impulse, periodic and general. Natural frequencies. Role of Damping. Importance of resonance. Modal superposition method. Prerequisite: MEGN315, 3 hours lecture; 3 semester hours.

MEGN513. KINETIC PHENOMENA IN MATERIALS. 3.0 Semester Hrs.

Equivalent with EGGN555,MLGN511,

(I) Linear irreversible thermodynamics, force-flux couplings, diffusion, crystalline materials, amorphous materials, defect kinetics in crystalline materials, interface kinetics, morphological evolution of interfaces, nucleation theory, crystal growth, coarsening phenomena and grain growth, solidification, spinodal decomposition. Prerequisites: MATH225: Differential equations (or equivalent), MLGN504/MTGN555/CBEN509: Thermodynamics (or its equivalent).

MEGN514. CONTINUUM MECHANICS. 3.0 Semester Hrs.

(I) This is a graduate course covering fundamentals of continuum mechanics and constitutive modeling. The goal of the course is to provide graduate students interested in fluid and solid mechanics with the foundation necessary to review and write papers in the field. Students will also gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws. The course explores six subjects: 1. Mathematical Preliminaries of Continuum Mechanics (Vectors, Tensors, Indicical Notation, Tensor Properties and Operations, Coordinate Transformations) 2. Stress (Traction, Invariants, Principal Values) 3. Motion and Deformation (Deformation Rates, Geometric Measures, Strain Tensors, Linearized Displacement Gradients) 4. Balance Laws (Conservation of Mass, Momentum, Energy) 5. Ideal Constitutive Relations (Frictionless & Linearly Viscous Fluids, Elasticity) 6. Constitutive Modeling (Formulation, Derivation, Implementation, Programming). 3 hours lecture, 3 semester hours.

MEGN517. INELASTIC CONSTITUTIVE RELATIONS. 3.0 Semester Hrs.

(II) This is a graduate course on inelastic constitutive relations of solid materials. The goal of the course is to provide students working in solid mechanics and metallurgy with a foundation in theory and models of inelastic material behaviors. The behaviors we cover include plasticity, thermoelasticity, nonlinear elasticity, and phase transformations. We dive in at several length scales - crystal mechanics and phenomenological thermodynamic internal variable theory. We also discuss ties between models and state of the art experimental mechanics, including in-situ diffraction. We will cover both theory and numerical implementation strategies for the topics. Thus, students will gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws and crystal mechanics models. We will introduce many topics rather than focusing on a few such that students have a foot-in to dive deeper on their own, as they will do in the project. Prerequisites: MEGN514. 3 hours lecture, 3 semester hours.

MEGN520. BOUNDARY ELEMENT METHODS. 3.0 Semester Hrs.

Equivalent with EGGN545,

(II) Development of the fundamental theory of the boundary element method with applications in elasticity, heat transfer, diffusion, and wave propagation. Derivation of indirect and direct boundary integral equations. Introduction to other Green's function based methods of analysis. Computational experiments in primarily two dimensions. Prerequisite: MEGN502. 3 hours lecture; 3 semester hours Spring Semester, odd numbered years.

MEGN521. INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS). 3.0 Semester Hrs.

Equivalent with EGGN535,

(I) Review of particle/rigid body dynamics, numerical DEM solution of equations of motion for a system of particles/rigid bodies, linear and nonlinear contact and impact laws dynamics, applications of DEM in mechanical engineering, materials processing and geo-mechanics. Prerequisites: CEEN311, MEGN315 and some scientific programming experience in C/C++ or Fortran. 3 hours lecture; 3 semester hours Spring semester of even numbered years.

MEGN530. BIOMEDICAL INSTRUMENTATION. 3.0 Semester Hrs.

Equivalent with BELS530,EGGN530,

The acquisition, processing, and interpretation of biological signals presents many unique challenges to the Biomedical Engineer. This course is intended to provide students with the knowledge to understand, appreciate, and address these challenges. At the end of the semester, students should have a working knowledge of the special considerations necessary to gathering and analyzing biological signal data. Prerequisites: EGGN250 MEL I, EENG281 Introduction to Electrical Circuits, Electronics, and Power, MEGN330 Introduction to Biomedical Engineering. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN531. PROSTHETIC AND IMPLANT ENGINEERING. 3.0 Semester Hrs.

Equivalent with BELS527,EGGN527,

Prosthetics and implants for the musculoskeletal and other systems of the human body are becoming increasingly sophisticated. From simple joint replacements to myoelectric limb replacements and functional electrical stimulation, the engineering opportunities continue to expand. This course builds on musculoskeletal biomechanics and other BELS courses to provide engineering students with an introduction to prosthetics and implants for the musculoskeletal system. At the end of the semester, students should have a working knowledge of the challenges and special considerations necessary to apply engineering principles to augmentation or replacement in the musculoskeletal system. Prerequisites: Musculoskeletal Biomechanics [MEGN430], 3 hours lecture; 3 semester hours. Fall even years.

MEGN532. EXPERIMENTAL METHODS IN BIOMECHANICS. 3.0 Semester Hrs.

(I) Introduction to experimental methods in biomechanical research. Topics include experimental design, hypothesis testing, motion capture, kinematic models, ground reaction force data collection, electromyography, inverse dynamics calculations, and applications. Strong emphasis on hands-on data collection and technical presentation of results. The course will culminate in individual projects combining multiple experimental measurement techniques. Prerequisite: Graduate Student Standing. 3 hours lecture; 3.0 semester hours.

MEGN535. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.

Equivalent with BELS526,EGGN526,
(II) Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties and interactions with the environment to construct detailed computer models and simulations. The course will culminate in individual class projects related to each student's individual interests. Prerequisites: MEGN315 and MEGN330. 3 hours lecture; 3 semester hours.

MEGN536. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.

Equivalent with BELS528,EGGN528,
Computational Biomechanics provides an introduction to the application of computer simulation to solve some fundamental problems in biomechanics and bioengineering. Musculoskeletal mechanics, medical image reconstruction, hard and soft tissue modeling, joint mechanics, and inter-subject variability will be considered. An emphasis will be placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of computational techniques. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is demonstrated. Prerequisite: MEGN424, MEGN330. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN537. PROBABILISTIC BIOMECHANICS. 3.0 Semester Hrs.

Equivalent with EGGN529,
(II) MEGN537. PROBABILISTIC BIOMECHANICS The course introduces the application of probabilistic analysis methods in biomechanical systems. All real engineering systems, and especially human systems, contain inherent uncertainty due to normal variations in dimensional parameters, material properties, motion profiles, and loading conditions. The purpose of this course is to examine methods for including these sources of variation in biomechanical computations. Concepts of basic probability will be reviewed and applied in the context of engineering reliability analysis. Probabilistic analysis methods will be introduced and examples specifically pertaining to musculoskeletal biomechanics will be studied. Prerequisites: MEGN436/BELS428 or MEGN536/BELS528. 3 hours lecture, 3 semester hours. Spring even years.

MEGN540. MECHATRONICS. 3.0 Semester Hrs.

Equivalent with EGGN521,
(II) A course focusing on implementation aspects of mechatronic and control systems. Significant lab component involving embedded C programming on a mechatronics teaching platform, called a "haptic paddle", a single degree-of-freedom force-feedback joystick. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

MEGN544. ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL. 3.0 Semester Hrs.

Equivalent with EGGN518,
(I) Mathematical representation of robot structures. Mechanical analysis including kinematics, dynamics, and design of robot manipulators. Representations for trajectories and path planning for robots. Fundamentals of robot control including, linear, nonlinear and force control methods. Introduction to off-line programming techniques and simulation. Prerequisite: EENG307 and MEGN441. 3 hours lecture; 3 semester hours.

MEGN545. ADVANCED ROBOT CONTROL. 3.0 Semester Hrs.

Equivalent with EGGN514,
The focus is on mobile robotic vehicles. Topics covered are: navigation, mining applications, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path planning real time obstacle avoidance. Prerequisite: EENG307. 3 hours lecture; 3 semester hours. Spring semester of odd years.

MEGN552. VISCOUS FLOW AND BOUNDARY LAYERS. 3.0 Semester Hrs.

Equivalent with EGGN552,
(I) This course establishes the theoretical underpinnings of fluid mechanics, including fluid kinematics, stress-strain relationships, and derivation of the fluid-mechanical conservation equations. These include the mass-continuity and Navier-Stokes equations as well as the multi-component energy and species-conservation equations. Fluid-mechanical boundary-layer theory is developed and applied to situations arising in chemically reacting flow applications including combustion, chemical processing, and thin-film materials processing. Prerequisite: MEGN451, or CBEN430. 3 hours lecture; 3 semester hours.

MEGN553. INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA. 3.0 Semester Hrs.

Equivalent with EGGN573,
(II) Introduction to Computational Fluid Dynamics (CFD) for graduate students with no prior knowledge of this topic. Basic techniques for the numerical analysis of fluid flows. Acquisition of hands-on experience in the development of numerical algorithms and codes for the numerical modeling and simulation of flows and transport phenomena of practical and fundamental interest. Capabilities and limitations of CFD. Prerequisite: MEGN451. 3 hours lecture; 3 semester hours.

MEGN560. DESIGN AND SIMULATION OF THERMAL SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN570,
In this course the principles of design, modeling, analysis, and optimization of processes, devices, and systems are introduced and applied to conventional and advanced energy conversion systems. It is intended to integrate conservation principles of thermodynamics (MEGN361) with the mechanism relations of fluid mechanics (MEGN351) and heat transfer (MEGN471). The course begins with general system design approaches and requirements and proceeds with mathematical modeling, simulation, analysis, and optimization methods. The design and simulation of energy systems is inherently computational and involves modeling of thermal equipment, system simulation using performance characteristics, thermodynamic properties, mechanistic relations, and optimization (typically with economic-based objective functions). Fundamental principles for steady-state and dynamic modeling are covered. Methods for system simulation which involves predicting performance with a given design (fixed geometry) are studied. Analysis methods that include Pinch Technology, Exergy Analysis, and Thermo-economics are examined and are considered complementary to achieving optimal designs. Optimization encompasses objective function formulation, systems analytical methods, and programming techniques. System optimization of the design and operating parameters of a configuration using various objective functions are explored through case studies and problem sets. Economics and optimization for analyses and design of advanced energy systems, such as Rankine and Brayton cycle power plants, combined heat and power, refrigeration and geothermal systems, fuel cells, turbomachinery, and heat transfer equipment are a focus. 3 lecture hours; 3 credit hours.

MEGN566. COMBUSTION. 3.0 Semester Hrs.

Equivalent with EGGN566,

(I) An introduction to combustion. Course subjects include: the development of the Chapman-Jouget solutions for deflagration and detonation, a brief review of the fundamentals of kinetics and thermochemistry, development of solutions for diffusion flames and premixed flames, discussion of flame structure, pollutant formation, and combustion in practical systems. Prerequisite: MEGN451 or CBEN430. 3 hours lecture; 3 semester hours.

MEGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CBEN569, CHEN569, EGGN569, MLGN569, MTGN569,

(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

MEGN571. ADVANCED HEAT TRANSFER. 3.0 Semester Hrs.

Equivalent with EGGN571,

(II) An advanced course in heat transfer that supplements topics covered in MEGN471. Derivation and solution of governing heat transfer equations from conservation laws. Development of analytical and numerical models for conduction, convection, and radiation heat transfer, including transient, multidimensional, and multimode problems. Introduction to turbulence, boiling and condensation, and radiative transfer in participating media. 3 lecture hours; 3 credit hours.

MEGN587. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.

(II) We address both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Prerequisite: MATH111. 3 hours lecture; 3 semester hours.

MEGN588. INTEGER OPTIMIZATION. 3.0 Semester Hrs.

(I) We address the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Prerequisite: none. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN591. ADVANCED ENGINEERING DESIGN METHODS. 3.0 Semester Hrs.

Equivalent with EGGN503,

(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

MEGN592. RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.

(I) The importance of understanding, assessing, communicating, and making decisions based in part upon risk, reliability, robustness, and uncertainty is rapidly increasing in a variety of industries (e.g.: petroleum, electric power production, etc.) and has been a focus of some industries for many decades (e.g.: nuclear power, aerospace, automotive, etc). This graduate class will provide the student with a technical understanding of and ability to use common risk assessment tools such as Reliability Block Diagrams (RBD), Failure Modes and Effects Analysis (FMEA), and Probabilistic Risk Assessment (PRA); and new tools being developed in universities including Function Failure Design Methods (FFDM), Function Failure Identification and Propagation (FFIP), and Uncoupled Failure Flow State Reasoning (UFFSR) among others. Students will also be provided with a high-level overview of what risk really means and how to contextualize risk information. Methods of communicating and making decisions based in part upon risk information will be discussed. 3 hours lecture, 3 semester hours.

MEGN593. ENGINEERING DESIGN OPTIMIZATION. 3.0 Semester Hrs.

Equivalent with EGGN593,

The application of gradient, stochastic and heuristic optimization algorithms to linear and nonlinear optimization problems in constrained and unconstrained design spaces. Students will consider problems in constrained and unconstrained design spaces. Students will consider problems with continuous, integer and mixed-integer variables, problems with single or multiple objectives and the task modeling design spaces and constraints. Design optimization methods are becoming of increasing importance in engineering design and offer the potential to reduce design cycle times while improving design quality by leveraging simulation and historical design data. Prerequisites: Experience with computer programming languages, graduate or senior standing. 3 hours lecture; 3 semester hours.

MEGN598. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN688. ADVANCED INTEGER OPTIMIZATION. 3.0 Semester Hrs.

(II) As an advanced course in optimization, we expand upon topics in integer programming: advanced formulation, strong integer programming formulations (e.g., symmetry elimination, variable elimination, persistence), in-depth mixed integer programming cuts, rounding heuristics, constraint programming, and decompositions. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Prerequisite: MEGN588. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707M,

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

College of Earth Resource Sciences and Engineering

Please choose from the list of links on the left to access more information.

Economics and Business

2015-16

Degrees Offered

- Master of Science (Mineral and Energy Economics)
- Doctor of Philosophy (Mineral and Energy Economics)
- Master of Science (Engineering and Technology Management)

Mineral and Energy Economics Program Description

In an increasingly global and technical world, government and industry leaders in the mineral and energy areas require a strong foundation in economic and business skills. The Division offers such skills in unique programs leading to M.S. and Ph.D. degrees in Mineral and Energy Economics. Course work and research emphasizes the use of models to aid in decision making. Beyond the core courses students in the Mineral and Energy Economics Program may select, in consultation with their advisor from a set of electives that fit their specialized needs and educational goals. This may include advanced courses in Applied Economics, Finance, and Operations Research.

Engineering and Technology Management Program Description

The Division also offers an M.S. degree in Engineering and Technology Management (ETM). The ETM degree program is designed to integrate the technical elements of engineering practice with the managerial perspective of modern engineering and technology management. A major focus is on the business and management principles related to this integration. The ETM Program provides the analytical tools and managerial perspective needed to effectively function in a highly competitive and technologically complex business economy.

Students in the ETM Program may select elective courses from two areas of focus: Engineering Management and Optimization or Technology Management and Innovation. The Optimization courses focus on developing knowledge of advanced operations research, optimization, and decision making techniques applicable to a wide array of business and engineering problems. The Engineering Management courses emphasize valuable techniques for managing large engineering and technical projects effectively and efficiently. The Strategy and Innovation courses teach the correct match between organizational strategies and structures to maximize the competitive power of technology with a particular emphasis on management issues associated with the modern business enterprise.

Combined Degree Program Option

Mines undergraduate students have the opportunity to begin work on a M.S. degree in Mineral and Energy Economics or Engineering & Technology Management while completing their Bachelor's degree at Mines. The Mineral and Energy Economics Combined Degree Program provides the vehicle for students to use undergraduate coursework as part of their Graduate Degree curriculum. For more information please contact the EB Office or visit econbus.mines.edu.

Mineral and Energy Economics Program Description

In an increasingly global and technical world, government and industry leaders in the mineral and energy areas require a strong foundation in economic and business skills. The Division offers such skills in unique programs leading to M.S. and Ph.D. degrees in Mineral and Energy Economics. Course work and research emphasizes the use of models to aid in decision making. Beyond the core courses students in the Mineral and Energy Economics Program select, in consultation with their advisor, from a set of electives that fit their specialized needs and educational goals. This may include advanced courses in Applied Economics, Finance, and Operations Research.

Mineral and Energy Economics Program Requirements

M.S. Degree Students choose from either the thesis or non-thesis option in the Master of Science (M.S.) Program and are required to complete a minimum total of 36 credits (a typical course has 3 credits). Initial admission is only to the non-thesis program. Admission to the thesis option requires subsequent application after at least one full-time equivalent semester in the program.

Non-thesis option

Core courses	18.0
Approved electives*	18.0
Total Semester Hrs	36.0

Thesis option

Core courses	18.0
Research credits	12.0
Approved electives*	6.0
Total Semester Hrs	36.0

* Non-thesis M.S. students may apply six elective credits toward a nine hour minor in another department. See below for details.

Further Degree Requirements

All thesis and non-thesis students in the Mineral and Energy Economics Program are required to attend the Distinguished Lecture Series sponsored by the Earth Resources Institute and the Division of Economics and Business. This series facilitates active involvement in the Mineral and Energy Economics Program by top researchers and influential leaders in the policy arena. The Program Director will outline attendance requirements at the beginning of each fall semester.

Ph.D. Degree Doctoral students develop a customized curriculum to fit their needs. The degree requires a minimum of 72 graduate credit hours that includes course work and a thesis.

Course work (requires advisor and committee approval)

First year Core courses	18.0
Extended Core plus Research Methods	12.0
Approved electives	18.0
Total Semester Hrs	48.0

Research credits

Research credits	24.0
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The student's faculty advisor and the doctoral thesis committee must approve the student's program of study and the topic for the thesis.

Qualifying Examination Process

Upon completion of the first-year core course work, Ph.D. students must pass a first set of qualifying written examinations (collectively Qualifier 1). Exams covering the Micro Economics (Micro) and Quantitative Methods (Quant) portions of the core will be offered between semesters, during the summer and winter breaks. The Micro examination will include topics covered in EBGN 511 and EBGN 521, and the Quant examination will include topics covered in EBGN 509 and EBGN 590.

A student will receive one of four possible grades on the Micro and Quant examinations: High Pass, Pass, Marginal Fail, or Fail. A student

receiving a marginal fail on one, or both of the examinations will have the opportunity to retake the relevant examination(s) within a year of the initial attempt. Students receiving a marginal fail should consult their adviser as to whether to retake exams during the winter or summer breaks. A student receiving a Fail, or consecutive Marginal Fails, will be dismissed from the program. Consistent with university policy, the faculty will grade and inform students of qualification examination results within two weeks of the examinations.

Upon completion of the extended core (typically in the second year), Ph.D. students must pass a second qualifying written examination (Qualifier II). The examination will include topics from EBGN 611, Advanced Microeconomics, and two other 600-level courses, which the student chooses as their extended core. A student will receive one of four possible grades on Qualifier II: High Pass, Pass, Marginal Fail, or Fail. A student receiving a Marginal Fail on Qualifier II will have the opportunity to retake the exam, or relevant portions of the exam as determined by the examination committee, within a year of the initial attempt. Students receiving a marginal fail should consult their advisor as to whether to retake exams during the winter or summer breaks. A student receiving a Fail or consecutive Marginal Fails, on Qualifier II will be dismissed from the program. Consistent with university policy, the faculty will grade and inform students of qualification examination results within two weeks of the examinations.

Following a successful thesis-proposal defense and prior to the final thesis defense, a student is required to present a completed research paper (or dissertation chapter) in a research seminar at CSM. The research presentation must be considered satisfactory by at least three CSM faculty members in attendance.

Minor from Another Department

Non-thesis M.S. students may apply six elective credits towards a nine hour minor in another department. A minor is ideal for those students who want to enhance or gain knowledge in another field while gaining the economic and business skills to help them move up the career ladder. For example, a petroleum, chemical, or mining engineer might want to learn more about environmental engineering, a geophysicist or geologist might want to learn the latest techniques in their profession, or an economic policy analyst might want to learn about political risk. Students should check with the minor department for the opportunities and requirements.

Transfer Credits

Non-thesis M.S. students may transfer up to 6 credits (9 credits for a thesis M.S.). The student must have achieved a grade of B or better in all graduate transfer courses and the transfer credit must be approved by the student's advisor and the Division Director. Students who enter the Ph.D. program may transfer up to 24 hours of graduate-level course work from other institutions toward the Ph.D. degree subject to the restriction that those courses must not have been used as credit toward a Bachelor degree. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer must be approved by the student's Doctoral Thesis Committee and the Division Director.

Unsatisfactory Progress

In addition to the institutional guidelines for unsatisfactory progress as described elsewhere in this bulletin. Unsatisfactory progress will be assigned to any full-time student who does not pass the first year core courses on time. EBGN509, EBGN510 and EBGN511 in the first fall semester of study; and EBGN 521 and EBGN590 in the first spring

semester of study. Unsatisfactory progress will also be assigned to any students who do not complete requirements as specified in their admission letter. Part-time students develop an approved course plan with their advisor.

Ph.D. Students are expected to take the first set of qualification examinations (Qualifier I) in the first summer following eligibility. Unsatisfactory progress may be assigned to any student who does not meet this expectation. Consistent with university policy, consideration will be given to students who have documented illness or other qualifying personal event that prevents them from taking Qualifier I. A marginal fail on a qualification examination does not trigger the assignment of unsatisfactory progress. Unsatisfactory progress will, however be assigned to a student who fails to retake a marginally failed examination in the next available summer offering.

Combined BS/MS Program

Students enrolled in CSM's Combined Undergraduate/ Graduate Program may double count 6 hours from their undergraduate course-work towards the non-thesis graduate program provided the courses satisfy the M.S. requirements.

Dual Degree

The M.S. degree may be combined with a second degree from the IFP School (Paris, France) in Petroleum Economics and Management (see <http://www.ifp.fr>). This dual-degree program is geared to meet the needs of industry and government. Our unique program trains the next generation of technical, analytical and managerial professionals vital to the future of the petroleum and energy industries

These two world-class institutions offer a rigorous and challenging program in an international setting. The program gives a small elite group of students a solid economics foundation combined with quantitative business skills, the historical and institutional background, and the interpersonal and intercultural abilities to in the fast paced, global world of oil and gas.

Degrees: After studying in English for only 16 months (8 months at CSM and 8 months at IFP) the successful student of Petroleum Economics and Management (PEM) receives not 1 but 2 degrees:

- Masters of Science in Mineral and Energy Economics from CSM and
- Diplôme D'Ingénieur or Mastère Spécialisé from IFP

Important: Applications for admission to the joint degree program should be submitted for consideration by March 1st to begin the program the following fall semester in August. A limited number of students are selected for the program each year.

Prerequisites for the Mineral and Energy Economics Programs

Students must have completed the following undergraduate prerequisite courses prior to beginning the program with a grade of B or better:

1. Principles of Microeconomics;
2. One semester of college-level Calculus;
3. Probability and Statistics

Students will only be allowed to enter in the spring semester if they have completed all three prerequisites courses previously, as well as

undergraduate courses in mathematical economics and natural resource economics.

Required Course Curriculum in Mineral and Energy Economics

All M.S. and Ph.D. students in Mineral and Energy Economics are required to take a set of core courses that provide basic tools for the more advanced and specialized courses in the program.

1. M.S. Curriculum

a. Core Courses

EBGN509	MATHEMATICAL ECONOMICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN511	MICROECONOMICS	3.0
EBGN521	MICROECONOMICS OF MINERAL AND ENERGY MARKETS	3.0
EBGN590	ECONOMETRICS I	3.0
EBGN690	ECONOMETRICS II * An alternative econometrics elective may be substituted for EBGN690 (for example, EBGN694 Time-series Econometrics)	3.0

Total Semester Hrs **18.0**

b. Approved Electives (18 credits for M.S. non-thesis option or 12 credits for M.S. thesis option)

The student, in consultation with their advisor, will choose six additional courses (four for thesis students). A minimum of two courses must be at the 600 level (one course for thesis students). The program of study can be customized to fit the individual student's educational goals, but must be approved by their advisor.

2. Ph.D. Curriculum

a. Common Core Courses

EBGN509	MATHEMATICAL ECONOMICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
EBGN511	MICROECONOMICS	3.0
EBGN521	MICROECONOMICS OF MINERAL AND ENERGY MARKETS	3.0
EBGN590	ECONOMETRICS I	3.0
EBGN690	ECONOMETRICS II * An alternative econometrics elective may be substituted for EBGN690 (for example, EBGN694 Time-series Econometrics)	3.0

Total Semester Hrs **18.0**

b. Extended Core Courses and Research Methods

EBGN611	ADVANCED MICROECONOMICS	3.0
EBGN600-level course		3.0
EBGN600-level course		3.0
EBGN695	RESEARCH METHODOLOGY	3.0

Total Semester Hrs **12.0**

Engineering and Technology Management Program (ETM) Requirements

Students choose either the thesis or non-thesis option and complete a minimum of 30 credit hours. Initial admission is only to the non-thesis program. Admission to the thesis option requires subsequent application after at least one full-time equivalent semester in the program.

Non-thesis option

Core courses	12.0
Credits from one or both specializations	18.0
Total Semester Hrs	30.0

Thesis option

Core courses	12.0
Research credits	6.0
Credits from one or both specializations	12.0
Total Semester Hrs	30.0

Students must receive approval from their advisor in order to apply non-EB Division courses towards their ETM degree. Thesis students are required to complete 6 credit hours of thesis credit and complete a Master's level thesis under the direct supervision of the student's faculty advisor.

Further Degree Requirements

All thesis and non-thesis ETM Program students have three additional degree requirements:

1. the "Executive-in-Residence" seminar series;
2. the ETM Communications Seminar;
3. the Leadership and Team Building Exercise.

All students are required to attend the ETM Program "Executive-in-Residence" seminar series during at least one semester of their attendance at CSM. The "Executive-in-Residence" series features executives from industry who pass on insight and knowledge to graduate students preparing for positions in industry. This series facilitates active involvement in the ETM program by industry executives through teaching, student advising activities and more. Every spring semester the "Executive-in-Residence" will present 5-7 one hour seminars on a variety of topics related to leadership and strategy in the engineering and technology sectors. In addition, all students are required to attend a two-day Communications Seminar in their first fall semester of study in the ETM Program. The seminar will provide students a comprehensive approach to good quality communication skills, including presentation proficiency, organizational skills, professional writing skills, meeting management, as well as other professional communication abilities. The Communications Seminar is designed to better prepare students for the ETM learning experience, as well as their careers in industry. Finally, all students are required to attend a one-day Leadership and Team Building Exercise in their first fall semester of study in the ETM Program. This course will consist of non-competitive games, trust exercises and problem solving challenges. This exercise will introduce students to one another and provide some opportunity to learn and practice leadership and team skills.

Transfer Credits

Students who enter the M.S. in Engineering and Technology Management program may transfer up to 6 graduate course credits into the degree program. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer credit must be approved by the student's advisor and the Chair of the ETM Program.

Required Curriculum M.S. Degree Engineering and Technology Management

Thesis and non-thesis students are required to complete the following 12 hours of core courses:

a. Core Courses

EBGN525	OPERATIONS RESEARCH: DETERMINISTIC OPTIMIZATION	3.0
EBGN540	ACCOUNTING AND FINANCE	3.0
EBGN563	MANAGEMENT OF TECHNOLOGY	3.0
EBGN585	ENGINEERING AND TECHNOLOGY MANAGEMENT CAPSTONE (to be taken during the final semester of coursework)	3.0
Total Semester Hrs		12.0

b. Areas of Focus (18 credits required for non-thesis option or 9 credits required for thesis option)

Engineering Management and Optimization Methods

EBGN526	OPERATIONS RESEARCH: STOCHASTIC MODELING	3.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	3.0
EBGN559	SUPPLY CHAIN MANAGEMENT	3.0
EBGN560	DECISION ANALYSIS	3.0
EBGN555	LINEAR PROGRAMMING	3.0

Technology Management and Innovation

EBGN515	ECONOMICS AND DECISION MAKING	3.0
EBGN553	PROJECT MANAGEMENT	3.0
EBGN564	MANAGING NEW PRODUCT DEVELOPMENT	3.0
EBGN565	MARKETING FOR TECHNOLOGY-BASED COMPANIES	3.0
EBGN566	TECHNOLOGY ENTREPRENEURSHIP	3.0
EBGN572	INTERNATIONAL BUSINESS STRATEGY	3.0
EBGN598	SPECIAL TOPICS IN ECONOMICS AND BUSINESS	3.0

Professors

John T. Cuddington, Research Professor

Graham A. Davis, William J. Coulter Professor

Roderick G. Eggert, Professor

Michael R. Walls, Division Director and Professor

Associate Professors

Edward J. Balistreri

Jared C. Carbone

Michael B. Heeley

Steffen Rebennack

Assistant Professors

Harrison Fell

Ian A. Lange

Peter Maniloff

Teaching Associate Professors

Scott Houser

Becky Lafrancois

Mark Mondry

John M. Stermole

Professors Emeriti

Carol A. Dahl

Franklin J. Stermole

John E. Tilton

Courses

EBGN504. ECONOMIC EVALUATION AND INVESTMENT DECISION METHODS. 3.0 Semester Hrs.

Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis are applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics emphasize proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, and (4) mutually exclusive alternative analysis and service producing alternatives. Case study analysis of a mineral or petroleum investment situation is required. Students may not take EBGN504 for credit if they have completed EBGN321.

EBGN509. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.

This course reviews and re-enforces the mathematical and computer tools that are necessary to earn a graduate degree in Mineral Economics. It includes topics from differential and integral calculus; probability and statistics; algebra and matrix algebra; difference equations; and linear, mathematical and dynamic programming. It shows how these tools are applied in an economic and business context with applications taken from the mineral and energy industries. It requires both analytical as well as computer solutions. At the end of the course you will be able to appreciate and apply mathematics for better personal, economic and business decision making. Prerequisites: Principles of Microeconomics, and MATH111.

EBGN510. NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.

The threat and theory of resource exhaustion; commodity analysis and the problem of mineral market instability; cartels and the nature of mineral pricing; the environment; government involvement; mineral policy issues; and international mineral trade. This course is designed for entering students in mineral economics. Prerequisite: Principles of Microeconomics.

EBGN511. MICROECONOMICS. 3.0 Semester Hrs.

(I) This is a first-semester graduate courses dealing with applied microeconomic theory. The course concentrates on the behavior of individual segments of the economy, the theory of consumer behavior and demand, duality, welfare measures, policy instruments, preferences over time and states of nature, and the fundamentals of game theory. Prerequisites: MATH111, EBGN509 (co-requisite). 3 hours lecture and discussion; 3 semester hours.

EBGN512. MACROECONOMICS. 3.0 Semester Hrs.

This course will provide an introduction to contemporary macroeconomic concepts and analysis. Macroeconomics is the study of the behavior of the economy as an aggregate. Topics include the equilibrium level of inflation, interest rates, unemployment and the growth in national income. The impact of government fiscal and monetary policy on these variables and the business cycle, with particular attention to the effects on the mineral industry. Prerequisites: Principles of Microeconomics, MATH111.

EBGN515. ECONOMICS AND DECISION MAKING. 3.0 Semester Hrs.

The application of microeconomic theory to business strategy. Understanding the horizontal, vertical, and product boundaries of the modern firm. A framework for analyzing the nature and extent of competition in a firm's dynamic business environment. Developing strategies for creating and sustaining competitive advantage.

EBGN521. MICROECONOMICS OF MINERAL AND ENERGY MARKETS. 3.0 Semester Hrs.

(II) The second of two courses dealing with applied microeconomic theory. This part concentrates on the behavior of the minerals and energy segment of the economy, the theory of production and cost, derived demand, price and output level determination by firms, and the competitive structure of product and input markets. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN509, EBGN510; EBGN511.

EBGN523. MINERAL AND ENERGY POLICY. 3.0 Semester Hrs.

(II) An analysis of current topics in the news in mineral and energy issues through the lens of economics. Since many of the topics involve government policy, the course provides instruction related to the economic foundations of mineral and energy policy analysis. 3 credit hours.

EBGN525. OPERATIONS RESEARCH: DETERMINISTIC OPTIMIZATION. 3.0 Semester Hrs.

This course provides a scientific approach to planning and decision making problems that arise in business. The course covers deterministic optimization models such as linear programming, non-linear programming, integer programming, and network modeling. Applications of the models are covered using spreadsheets. The intent of the course is to enhance logical modeling ability and to develop quantitative managerial and spreadsheet skills. The models cover applications in the areas of earth, energy, production, logistics, work force scheduling, marketing and finance. 3 lecture hours, 3 semester hours.

EBGN526. OPERATIONS RESEARCH: STOCHASTIC MODELING. 3.0 Semester Hrs.

As a survey course in stochastic modeling, this course covers a range of topics including an introduction and review of probability models (e.g., sample spaces, events, conditional probabilities, Bayes' formula), and of random variables; and, some subset of the following topics: (i) Markov chains, (ii) Queuing Theory, (iii) Reliability Theory, (iv) Brownian motion, and (v) Simulation. Applications from a wide range of fields will be introduced including marketing, finance, production, logistics and distribution, energy and service systems. In addition to an intuitive understanding of analytical techniques to model stochastic processes, the course emphasizes how to use related software packages for managerial decision-making. 3 hour lecture; 3 semester hours.

EBGN528. INDUSTRIAL SYSTEMS SIMULATION. 3.0 Semester Hrs.

The course focuses on creating computerized models of real or proposed complex systems for performance evaluation. Simulation provides a cost effective way of pre-testing proposed systems and answering "what-if?" questions before incurring the expense of actual implementations. The course is instructed in the state-of-the-art computer lab (CTLM), where each student is equipped with a personal computer and interacts with the instructor during the lecture. Professional version of a widely used commercial software package, "Arena", is used to build models, analyze and interpret the results. Other business analysis and productivity tools that enhance the analysis capabilities of the simulation software are introduced to show how to search for optimal solutions within the simulation models. Both discrete-event and continuous simulation models are covered through extensive use of applications including call centers, various manufacturing operations, production/inventory systems, bulk-material handling and mining, port operations, high-way traffic systems and computer networks. Prerequisites: MATH111, MATH530.

EBGN530. ECONOMICS OF INTERNATIONAL ENERGY MARKETS. 3.0 Semester Hrs.

Application of models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques, and issues included are supply and demand, market structure, transportation models, game theory, futures markets, environmental issues, energy policy, energy regulation, input/output models, energy conservation, and dynamic optimization. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG510, EBG511.

EBGN535. ECONOMICS OF METAL INDUSTRIES AND MARKETS. 3.0 Semester Hrs.

(I) Metal supply from main product, byproduct, and secondary production. Metal demand and intensity of use analysis. Market organization and price formation. Public policy, comparative advantage, and international metal trade. Metals and economic development in the developing countries and former centrally planned economies. Environmental policy and mining and mineral processing. Students prepare and present a major research paper. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG510, EBG511. 3 hours lecture; 3 semester hours.

EBGN536. MINERAL POLICIES AND INTERNATIONAL INVESTMENT. 3.0 Semester Hrs.

Identification and evaluation of international mineral investment policies and company responses using economic, business and legal concepts. Assessment of policy issues in light of stakeholder interests and needs. Theoretical issues are introduced and then applied to case studies, policy drafting, and negotiation exercises to assure both conceptual and practical understanding of the issues. Special attention is given to the formation of national policies and corporate decision making concerning fiscal regimes, project financing, environmental protection, land use and local community concerns and the content of exploration and extraction agreements. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG510, EBG511.

EBGN540. ACCOUNTING AND FINANCE. 3.0 Semester Hrs.

(I) Included are the relevant theories associated with capital budgeting, financing decisions, and dividend policy. This course provides an in-depth study of the theory and practice of corporate accounting and financial management including a study of the firm's objectives, investment decisions, long-term financing decisions, and working capital management. Preparation and interpretation of financial statements and the use of this financial information in evaluation and control of the organization. 3 hours lecture; 3 semester hours.

EBGN541. INTERNATIONAL TRADE. 3.0 Semester Hrs.

Theories and evidence on international trade and development. Determinants of static and dynamic comparative advantage. The arguments for and against free trade. Economic development in nonindustrialized countries. Sectoral development policies and industrialization. The special problems and opportunities created by extensive mineral resource endowments. The impact of value-added processing and export diversification on development. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG511.

EBGN542. ECONOMIC DEVELOPMENT. 3.0 Semester Hrs.

Role of energy and minerals in the development process. Sectoral policies and their links with macroeconomic policies. Special attention to issues of revenue stabilization, resource largesse effects, downstream processing, and diversification. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG511, EBG512.

EBGN546. INVESTMENT AND PORTFOLIO MANAGEMENT. 3.0 Semester Hrs.

This course covers institutional information, valuation theory and empirical analysis of alternative financial investments, including stocks, bonds, mutual funds, ETS, and (to a limited extent) derivative securities. Special attention is paid to the role of commodities (esp. metals and energy products) as an alternative investment class. After an overview of time value of money and arbitrage and their application to the valuation of stocks and bonds, there is extensive treatment of optimal portfolio selection for risk averse investors, mean-variance efficient portfolio theory, index models, and equilibrium theories of asset pricing including the capital asset pricing model (CAPM) and arbitrage pricing theory (APT). Market efficiency is discussed, as are its implications for passive and active approaches to investment management. Investment management functions and policies, and portfolio performance evaluation are also considered. Prerequisites: Principles of Microeconomics, MATH111, MATH530.

EBGN547. FINANCIAL RISK MANAGEMENT. 3.0 Semester Hrs.

Analysis of the sources, causes and effects of risks associated with holding, operating and managing assets by individuals and organizations; evaluation of the need and importance of managing these risks; and discussion of the methods employed and the instruments utilized to achieve risk shifting objectives. The course concentrates on the use of derivative assets in the risk management process. These derivatives include futures, options, swaps, swaptions, caps, collars and floors. Exposure to market and credit risks will be explored and ways of handling them will be reviewed and critiqued through analysis of case studies from the mineral and energy industries. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBG505; EBG545 or EBG546. Recommended: EBG509, EBG511.

EBGN553. PROJECT MANAGEMENT. 3.0 Semester Hrs.

(I, II) Project management has evolved into a business process broadly used in organizations to accomplish goals and objectives through teams. This course covers the essential principles of traditional project management consistent with professional certification requirements (the Project Management Institute's PMP certification) as well as an introduction to current agile project management methodologies. The traditional project management phases of project initiation, planning, execution, monitoring and control, and project closure are covered including related scheduling, estimating, risk assessment and other analytical tools. Students will gain experience using Microsoft Project. Organizational structure and culture issues are analyzed to understand how they can impact project management success, and the concepts of project portfolios and project programs are applied from the organizational perspective. Agile project management methodologies are introduced, including adaptive and iterative processes, scrum, lean and other agile tools and techniques. By the end of the course, students will understand how traditional and agile project. Prerequisites: Enrollment in the M.S. in Engineering and Technology Management (ETM) Program. 3 hours lecture; 3 semester hours.

EBGN555. LINEAR PROGRAMMING. 3.0 Semester Hrs.

This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming and stochastic programming are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisite: MATH111; MATH332 or EBG509. 3 hours lecture; 3 semester hours.

EBGN559. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.

The focus of the course is to show how a firm can achieve better supply-demand matching through the implementation of rigorous mathematical models and various operational/tactical strategies. We look at organizations as entities that must match the supply of what they produce with the demand for their products. A considerable portion of the course is devoted to mathematical models that treat uncertainty in the supply-chain. Topics include managing economies of scale for functional products, managing market-mediation costs for innovative products, make-to order versus make-to-stock systems, quick response strategies, risk pooling strategies, supply-chain contracts and revenue management. Additional special topics may be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies, as time permits Prerequisites: MATH111, MATH530.

EBGN560. DECISION ANALYSIS. 3.0 Semester Hrs.

Introduction to the science of decision making and risk theory. Application of decision analysis and utility theory to the analysis of strategic decision problems. Focuses on the application of quantitative methods to business problems characterized by risk and uncertainty. Choice problems such as decisions concerning major capital investments, corporate acquisitions, new product introductions, and choices among alternative technologies are conceptualized and structured using the concepts introduced in this course. Prerequisite: EBG504.

EBGN563. MANAGEMENT OF TECHNOLOGY. 3.0 Semester Hrs.

Case studies and reading assignments explore strategies for profiting from technology assets and technological innovation. The roles of strategy, core competencies, product and process development, manufacturing, R&D, marketing, strategic partnerships, alliances, intellectual property, organizational architectures, leadership and politics are explored in the context of technological innovation. The critical role of organizational knowledge and learning in a firm's ability to leverage technological innovation to gain competitive advantage is explored. The relationships between an innovation, the competencies of the innovating firm, the ease of duplication of the innovation by outsiders, the nature of complementary assets needed to successfully commercialize an innovation and the appropriate strategy for commercializing the innovation are developed. Students explore the role of network effects in commercialization strategies, particularly with respect to standards wars aimed at establishing new dominant designs. Prerequisite: EBG5043 recommended.

EBGN564. MANAGING NEW PRODUCT DEVELOPMENT. 3.0 Semester Hrs.

Develops interdisciplinary skills required for successful product development in today's competitive marketplace. Small product development teams step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. Each student brings his or her individual disciplinary perspective to the team effort, and must learn to synthesize that perspective with those of the other students in the group to develop a sound, marketable product. Prerequisite: EBG563 recommended.

EBGN565. MARKETING FOR TECHNOLOGY-BASED COMPANIES. 3.0 Semester Hrs.

This class explores concepts and practices related to marketing in this unique, fast-paced environment, including the defining characteristics of high-technology industries; different types and patterns of innovations and their marketing implications; the need for (and difficulties in) adopting a customer-orientation; tools used to gather marketing research/intelligence in technology-driven industries; use of strategic alliances and partnerships in marketing technology; adaptations to the PESTs; regulatory and ethical considerations in technological arenas. Prerequisite: None.

EBGN566. TECHNOLOGY ENTREPRENEURSHIP. 3.0 Semester Hrs.

Introduces concepts related to starting and expanding a technological-based corporation. Presents ideas such as developing a business and financing plan, role of intellectual property, and the importance of a good R&D program. Prerequisite: None.

EBGN567. BUSINESS LAW AND ETHICS. 3.0 Semester Hrs.

(I) This course incorporates a broad range of legal topics and ethical issues relevant to technology-based organizations, from start-ups to mature Fortune 100 international corporations. The topics encompass numerous aspects of U.S. business law, including but not limited to: the U.S. court system, contracts, e-commerce, managerial ethics, white collar crimes, early stage business formation, intellectual property, product liability, agency law, employment law, mergers and acquisitions, antitrust, and unfair competition law. The course is discussion based, with some lecture, and is 3 semester credit hours. There are no prerequisites required for this course. A significant portion of class time will be applied to exploring and discussing assigned topics through relevant abbreviated court case descriptions, ethics reader assignments and current and recent events in global business. The overall goal of this course is not to make students legal experts but to make them better managers and leaders by equipping them with relevant legal. 3 hours lecture; 3 semester hours.

EBGN568. ADVANCED PROJECT ANALYSIS. 3.0 Semester Hrs.

An advanced course in economic analysis that will look at more complex issues associated with valuing investments and projects. Discussion will focus on development and application of concepts in after-tax environments and look at other criteria and their impact in the decision-making and valuation process. Applications to engineering and technology aspects will be discussed. Effective presentation of results will be an important component of the course. Prerequisite: EBG504.

EBGN570. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.

The role of markets and other economic considerations in controlling pollution; the effect of environmental policy on resource allocation incentives; the use of benefit/cost analysis in environmental policy decisions and the associated problems with measuring benefits and costs. Prerequisites: Principles of Microeconomics, MATH111, EBG509, EBG510.

EBGN571. MARKETING RESEARCH. 3.0 Semester Hrs.

The purpose of this course is to gain a deep understanding of the marketing research decisions facing product managers in technology based companies. While the specific responsibilities of a product manager vary across industries and firms, three main activities common to the position are: (1) analysis of market information, (2) marketing strategy development, and (3) implementing strategy through marketing mix decisions. In this course students will develop an understanding of available marketing research methods and the ability to use marketing research information to make strategic and tactical decisions. Prerequisite: MATH530.

EBGN572. INTERNATIONAL BUSINESS STRATEGY. 3.0 Semester Hrs.

The purpose of this course is to gain understanding of the complexities presented by managing businesses in an international environment. International business has grown rapidly in recent decades due to technological expansion, liberalization of government policies on trade and resource movements, development of institutions needed to support and facilitate international transactions, and increased global competition. Due to these factors, foreign countries increasingly are a source of both production and sales for domestic companies. Prerequisite: None.

EBGN573. ENTREPRENEURIAL FINANCE. 3.0 Semester Hrs.

Entrepreneurial activity has been a potent source of innovation and job generation in the global economy. In the U.S., the majority of new jobs are generated by new entrepreneurial firms. The financial issues confronting entrepreneurial firms are drastically different from those of established companies. The focus in this course will be on analyzing the unique financial issues which face entrepreneurial firms and to develop a set of skills that has wide applications for such situations. Prerequisite: EBG505. Corequisite: EBG545.

EBGN574. INVENTING, PATENTING, AND LICENSING. 3.0 Semester Hrs.

The various forms of intellectual property, including patents, trademarks, copyrights, trade secrets and unfair competition are discussed; the terminology of inventing, patenting and licensing is reviewed, and an overview of the complete process is given; the statutes most frequently encountered in dealing with patents (35 USC ?101, ?102, ?103 and ? 112) are introduced and explained; the basics of searching the prior art are presented; participants 'walk through' case histories illustrating inventing, patenting, licensing, as well as patent infringement and litigation; the importance of proper documentation at all stages of the process is explained; the "do's" and "don't" of disclosing inventions are presented; various types of agreements are discussed including license agreements; methods for evaluating the market potential of new products are presented; the resources available for inventors are reviewed; inventing and patenting in the corporate environment are discussed; the economic impacts of patents are addressed. Prerequisite: None. Offered in Field session and Summer session only.

EBGN575. ADVANCED MINING AND ENERGY ASSET VALUATION. 3.0 Semester Hrs.

(I) The use of option pricing techniques in mineral and energy asset valuation. Mining and energy valuation standards and guidelines. Differentiation between static decision making, intertemporal decision making, and dynamic decision making under uncertainty. The comparison sales and cost approaches to valuation. Commodity price simulation and price forecasting. Risk-neutral valuation. Prerequisites: EBG504, EBG509, EBG510, EBG511, EBG521, EBG590. 3 hours lecture; 3 semester hours.

EBGN576. MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS. 3.0 Semester Hrs.

(II) This course provides a scientific approach to developing and marketing new products which are often critical to the success of firms competing in technology based industries. We will start with an overview of core marketing and then develop prototypes of a new product design. We will step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. New product prototypes will be used to gather data from prospective target markets and assess the viability of the design in the marketplace. 3 hours lecture; 3 semester hours.

EBGN580. EXPLORATION ECONOMICS. 3.0 Semester Hrs.

Exploration planning and decision making for oil and gas, and metallic minerals. Risk analysis. Historical trends in exploration activity and productivity. Prerequisites: Principles of Microeconomics, EBG510. Offered when student demand is sufficient.

EBGN585. ENGINEERING AND TECHNOLOGY MANAGEMENT CAPSTONE. 3.0 Semester Hrs.

This course represents the culmination of the ETM Program. This course is about the strategic management process ? how strategies are developed and implemented in organizations. It examines senior management?s role in formulating strategy and the role that all an organization?s managers play in implementing a well thought out strategy. Among the topics discussed in this course are (1) how different industry conditions support different types of strategies; (2) how industry conditions change and the implication of those changes for strategic management; and (3) how organizations develop and maintain capabilities that lead to sustained competitive advantage. This course consists of learning fundamental concepts associated with strategic management process and competing in a web-based strategic management simulation to support the knowledge that you have developed. Prerequisites: MATH530, EBG504.

EBGN590. ECONOMETRICS I. 3.0 Semester Hrs.

(II) This course covers the statistical methods used by economists to estimate economic relationships and empirically test economic theories. Topics covered include hypothesis testing, ordinary least squares, specification error, serial correlations, heteroskedasticity, qualitative and limited dependent variables, time series analysis and panel data. Prerequisites: MATH111, MATH530, EBG509. 3 hours lecture and discussion; 3 semester hours.

EBGN594. TIME-SERIES ECONOMETRICS. 3.0 Semester Hrs.

(II) This is a course in applied time-series econometrics. It covers contemporary approaches for interpreting and analyzing time-series economic data. Hypothesis testing and forecasting both receive attention. Topics include stochastic difference equations, applied forecasting, stationary univariate models, models with constant and time-varying variance, deterministic and stochastic trend models and associated unit root and structural break tests, as well as single-equation and multiple-equation time-series models that include error-correction techniques and cointegration tests. 3 hours lecture; 3 semester hours.

EBGN598. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN610. ADVANCED NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.

Optimal resource use in a dynamic context using mathematical programming, optimal control theory and game theory. Constrained optimization techniques are used to evaluate the impact of capital constraints, exploration activity and environmental regulations. Offered when student demand is sufficient. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBG509, EBG510, EBG511.

EBGN611. ADVANCED MICROECONOMICS. 3.0 Semester Hrs.

A second graduate course in microeconomics, emphasizing state-of-the-art theoretical and mathematical developments. Topics include consumer theory, production theory and the use of game theoretic and dynamic optimization tools. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBG509, EBG511.

EBGN632. PRIMARY FUELS. 3.0 Semester Hrs.

(II) Application of models to understand markets for oil, gas, coal exploration and extraction. Empirical, theoretical and quantitative models and modeling techniques are stressed. The issues included are identification of cause and effect, market structure, game theory, futures markets, environmental issues, energy policy, energy regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in primary fuel/upstream markets. Prerequisites: EBG590. 3 hours lecture; 3 semester hours.

EBGN635. SEE EBG535. 3.0 Semester Hrs.**EBGN645. COMPUTATIONAL ECONOMICS. 3.0 Semester Hrs.**

(II) This course is about learning the skills required to construct and manipulate numerical models as an instrument of economic research. In the first part of the course, students will learn about basic classes of optimization problems as ways to operationalize models of equilibrium behavior from economics and how to formulate and solve these problems on the computer. In the second part of the course, students will focus on the techniques used specifically in computable general equilibrium (CGE) analysis and developing applications of CGE models to topics in energy, environmental and natural resource economics. Prerequisites: MATH111, MATH530, Principles of Microeconomics, EBG509, EBG511. 3 hours lecture; 3 semester hours.

EBGN655. ADVANCED LINEAR PROGRAMMING. 3.0 Semester Hrs.

Equivalent with EBG650,

As an advanced course in optimization, this course will expand upon topics in linear programming. Specific topics to be covered include advanced formulation, column generation, interior point method, stochastic optimization, and numerical stability in linear programming. Applications of state-of-the-art hardware and software will emphasize solving real-world problems in areas such as mining, energy, transportation and the military. Prerequisites: EBG555. 3 hours lecture; 3 semester hours.

EBGN675. SEE EBG575. 3.0 Semester Hrs.**EBGN690. ECONOMETRICS II. 3.0 Semester Hrs.**

A second course in econometrics. Compared to EBG590, this course provides a more theoretical and mathematical understanding of econometrics. Matrix algebra is used and model construction and hypothesis testing are emphasized rather than forecasting. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBG509, EBG590. Recommended: EBG511.

EBGN694. SEE EBG694. 3.0 Semester Hrs.

EBGN695. RESEARCH METHODOLOGY. 3.0 Semester Hrs.

Lectures provide an overview of methods used in economic research relating to EPP and QBA/OR dissertations in Mineral Economics and information on how to carry out research and present research results. Students will be required to write and present a research paper that will be submitted for publication. It is expected that this paper will lead to a Ph.D. dissertation proposal. It is a good idea for students to start thinking about potential dissertation topic areas as they study for their qualifier. This course is also recommended for students writing Master's thesis or who want guidance in doing independent research relating to the economics and business aspects of energy, minerals and related environmental and technological topics. Prerequisites: MATH530, EBG509, EBG510, EBG511, EBG590.

EBGN698. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Geology and Geological Engineering

Degrees Offered

- Professional Master Degree (Petroleum Reservoir Systems) (Non-Thesis)
- Professional Master Degree (Mineral Exploration) (Non-Thesis)
- Master of Engineering (Geological Engineer) (Non-Thesis)
- Master of Science (Geology)
- Master of Science (Geological Engineering)
- Doctor of Philosophy (Geology)
- Doctor of Philosophy (Geological Engineering)

Program Description

The Department of Geology and Geological Engineering offers Master of Science and Doctor of Philosophy degrees in Geology; and Master of Engineering, and Master of Science and Doctor of Philosophy degrees in Geological Engineering. Professional Master Degrees are offered in Petroleum Reservoir Systems and Mineral Exploration.

Geological Engineering degrees require possession or acquisition of an undergraduate engineering degree or its equivalent.

Graduate students desiring to study ground water, engineering geology/geotechnics, mining engineering geology and some environmental applications are generally expected to pursue the Geological Engineering degree. Students desiring to study petroleum or minerals exploration or development sciences, and/or geology generally pursue Geology degrees. Students are initially admitted to either geoscience or geological engineering degree programs and must receive approval of the GE department Graduate Advisory Committee to switch degree category.

Program Requirements

Geology Degrees

The Master of Science (Geology) program will require 36 semester hours of course and research credit hours (a maximum of 9 credit hours may be 400-level course work). Twelve of the 36 credit hours must be research credits. To ensure breadth of background, the course of study for the Master of Science (Geology) degree must include at least one graduate course in each of the fields of stratigraphy/ sedimentology, structural geology/tectonics, and petrology. At the discretion of the student's Thesis Advisory Committee, an appropriate course may be substituted for one (and only one) of the fields above. All Master of Science (Geology) candidates must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's Thesis Advisory Committee before the candidate begins substantial work on the thesis research.

The requirement for **Doctor of Philosophy (Geology)** program will be established individually by a student's Doctoral Thesis Advisory Committee, but must meet the minimum requirements presented below. The Doctor of Philosophy (Geology) academic program will require a minimum of 72 hours of course and research credit hours (a maximum of 9 credit hours may be 400-level course work). All students must complete:

Course work	48.0
Research	24.0
Total Semester Hrs	72.0

Students who enter the PhD program with a thesis-based Master's degree may transfer up to 36 semester hours in recognition of the course work and research completed for that degree. At the discretion of the student's Doctoral Thesis Advisory Committee, up to 24 semester hours of previous graduate-level course work (at CSM or elsewhere) can be applied towards the course requirement of the Doctor of Philosophy (Geology)."

To ensure breadth of background, the course of study to the degree of Doctor of Philosophy (Geology) must include at least one graduate course in each of the fields of stratigraphy/sedimentology, structural geology/tectonics, and petrology (this breadth requirement may be satisfied by courses already taken as part of a Master of Science degree). At the discretion of the student's Doctoral Thesis Advisory Committee, an appropriate course may be substituted for one (and only one) of the fields above. All Doctor of Philosophy (Geology) students must pass a qualifying examination and must complete an appropriate thesis based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's Doctoral

Thesis Advisory Committee before the student begins substantial work on the thesis research.

Prospective students should submit the results of the Graduate Record Examination with their application for admission to graduate study. In the event that it is not possible, because of geographic and other restrictions, to take the Graduate Record Examination prior to enrolling at Colorado School of Mines, enrollment may be granted on a provisional basis subject to satisfactory completion of the examination within the first year of residence.

Prerequisites

Geology Program

The candidate for the degree of Master of Science (Geology) or Doctor of Philosophy (Geology) must have completed the following or equivalent subjects, for which credit toward an advanced degree will not be granted.

- General Geology
- Structural Geology
- Field Geology (6 weeks)
- Mineralogy
- Petrology
- Stratigraphy
- Chemistry (3 semesters, including at least 1 semester of physical or organic)
- Mathematics (2 semesters of calculus)
- An additional science course (other than geology) or advanced mathematics
- Physics (2 semesters)

Professional Master Degree Programs:

Candidates for the Professional Master Degree must possess an appropriate geosciences undergraduate degree or its equivalent. Prerequisites are the same as those required for the Master of Science (Geology) Degree.

Engineering Programs

The candidate for the degree of Master of Engineering (Geological Engineer), Master of Science (Geological Engineering) or Doctor of Philosophy (Geological Engineering) must have completed the following or equivalent subjects. Graduate credit may be granted for courses at or above the 400 level, if approved by the student's advisory committee.

Mathematics

Four semesters including: Calculus (2 semesters) and one semester of any two of: calculus III, differential equations, probability and statistics, numerical analysis, linear algebra, operations research, optimization.

Basic Science

- Chemistry (2 semesters)
- Mineralogy and Petrology
- Physics (2 semesters)
- Stratigraphy or Sedimentation
- Physical Geology
- Computer Programming or GIS

Engineering Science

- Structural Geology and one semester in four of the following subjects:
 - Physical Chemistry or Thermodynamics
 - Statics
 - Mechanics of Materials
 - Fluid Mechanics
 - Dynamics
 - Soil Mechanics
 - Rock Mechanics

Engineering Design

- Field Geology

As part of the graduate program each student must take one semester in two of the following subjects if such courses were not taken for a previous degree:

- Mineral Deposits/Economic Geology
- Hydrogeology
- Engineering Geology

and also as part of the graduate program one semester in three of the following subjects if such courses were not taken for a previous degree:

- Foundation Engineering
- Engineering Hydrology
- Geomorphology
- Airphoto Interpretation, Photogeology, or Remote Sensing
- Petroleum Geology
- Introduction to Mining
- Introductory Geophysics
- Engineering Geology Design
- Mineral Exploration Design
- Groundwater Engineering Design
- Other engineering design courses as approved by the program committee

Professional Master in Mineral Exploration

This non-thesis, master degree program is designed for working professionals who want to increase their knowledge and skills, while gaining a thorough up-date of advances across the spectrum of economic geology, mineral exploration techniques, and mining geosciences. Admission to the program is competitive. Preference will be given to applicants with a minimum of two years of industrial or equivalent experience.

The program requires a minimum of 30 credit hours. A minimum of 15 credit hours must be accumulated in five of the following core areas:

- mineral deposits,
- mineral exploration,
- applied geophysics,
- applied geochemistry,
- applied structural geology,
- petrology,
- field geology, and
- economic evaluation.

An additional 15 credit hours may be selected from the course offerings of the Department of Geology and Geological Engineering and allied departments including Mining Engineering, Economics and Business, Geophysics, Chemistry and Geochemistry, Metallurgy and Materials Science, and Environmental Sciences.

Selection of courses will be undertaken in consultation with the academic advisor. Up to 9 credit hours may be at the 400-level. All other credits towards the degree must be 500-level or above. A maximum of 9 credit hours may be independent study focusing on a topic relevant to the mineral exploration and mining industries.

Prerequisites: Admission to the program is generally restricted to individuals holding a four-year undergraduate degree in earth sciences. Candidates for the degree of Professional Master in Mineral Exploration must have completed the following or equivalent subjects, for which credit toward the advanced degree will not be granted. These are general geology, structural geology, field geology, mineralogy, petrology, chemistry (2 semesters), mathematics (2 semesters of calculus), physics (1 semester), and an additional science course other than geology.

Professional Master in Petroleum Reservoir Systems

This is a non-thesis, interdisciplinary master degree program jointly administered by the departments of Geology and Geological Engineering, Geophysics, and Petroleum Engineering. This program consists only of coursework in petroleum geoscience and engineering. No research is required.

General Administration

The three participating departments share oversight for this program through a committee consisting of one faculty member from each of the three departments. Students gain admission to the program by application to any of the three sponsoring departments. Students are administered by that department into which they first matriculate.

Requirements

The program requires a minimum of 36 credit hours. Up to 9 credit hours may be at the 400 level. All other credits toward the degree must be 500 level or above.

9 hours must consist of:

GPGN/ PEGNnull419 or GPGN/ PEGNnull519	WELL LOG ANALYSIS AND FORMATION EVALUATION ADVANCED FORMATION EVALUATION	3.0
Select two of the following:		6.0
GEGN439 or GPGN439 or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN MULTIDISCIPLINARY PETROLEUM DESIGN	
GEGN503 or GPGN503 or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT	
GEGN504 or GPGN504	INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT	

or PEGN504 INTEGRATED EXPLORATION AND DEVELOPMENT

Total Semester Hrs 9.0

9 additional hours must consist of one course each from the 3 participating departments.

The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Geological Engineering Degrees

The Master of Engineering (Non-Thesis) Program in Geological Engineering outlined below may be completed by individuals already holding undergraduate or advanced degrees or as a **combined degree program** (see Graduate Degrees and Requirements (p. 189) section of this bulletin) by individuals already matriculated as undergraduate students at The Colorado School of Mines. The program is comprised of:

CORE	Course Work	30.0
GEGN599	INDEPENDENT STUDY	6.0
Total Semester Hrs		36.0

Up to nine credit hours can be at the 400 level and the remainder will be 500 or 600 level. For the combined degree program, courses recommended as appropriate for double counting may be chosen from:

GEGN403	MINERAL EXPLORATION DESIGN	3.0
GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
GEGN469	ENGINEERING GEOLOGY DESIGN	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0

The typical program plan includes 15 course credit hours in both the fall and the spring terms followed by 6 independent study credit hours during the summer term. The non-thesis degree includes three areas of specialization (engineering geology/geotechnics, ground-water engineering, and mining geological engineering).

All Master of Engineering (Non-Thesis) program will include the following core requirements:

GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN599	INDEPENDENT STUDY	6.0

GEGN599 requires a project and report that demonstrate competence in the application of geological engineering principles that merits a grade of B or better. The project topic and content of the report is determined by the student's advisor, in consultation with the student, and is approved by the Geological Engineering Graduate Program Committee. The format of the report will follow the guidelines for a professional journal paper.

The student, in consultation with the advisor, must prepare a formal program of courses and independent study topic for approval by the Geological Engineering Graduate Program Committee. The program must be submitted to the committee on or before the end of the first week of classes of the first semester.

The most common difficulty in scheduling completion of the degree involves satisfaction of prerequisites. Common deficiency courses are Statics, Mechanics of Materials, and Fluid Mechanics. These are essential to the engineering underpinnings of the degree. An intense program at CSM involving 18 credit hours each semester including

Statics in the fall and Fluid Mechanics in the spring and 9 credits in the summer including Mechanics of Materials, allows these classes to be taken along with the standard program. Some students may choose to take these prerequisites elsewhere before arriving on the CSM campus.

Engineering Geology/Geotechnics Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Engineering Geology/ Geotechnics must meet the prerequisite course requirements listed later in this section. Required courses for the degree are:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN570	CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY	3.0
or GEGN571	ADVANCED ENGINEERING GEOLOGY	
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN599	INDEPENDENT STUDY	6.0
GEGN671	LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION	3.0
or GEGN672	ADVANCED GEOTECHNICS	
GE ELECT	Electives *	10.0
Total Semester Hrs		36.0

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. As part of their elective courses, students are required to have an advanced course in both soil and rock engineering. Possibilities for other electives include graduate-level rock mechanics and rock engineering, soil mechanics and foundations, ground water, site characterization, geographical information systems (GIS), project management and geophysics, for example.

Ground Water Engineering/Hydrogeology Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Ground Water Engineering and Hydrogeology must meet the prerequisite course requirements listed later in this section. Required courses for the degree (36 hours) are:

GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS (Fall)	3.0
GEGN681	VADOSE ZONE HYDROLOGY (Fall)	3.0
or GEGN581	ADVANCED GROUNDWATER ENGINEERING	
GEGN509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY (Fall or Spring)	3.0
or CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS (Spring)	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN (Spring)	3.0
or CEEN575	HAZARDOUS WASTE SITE REMEDIATION	

GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS (Fall/Spring)	3.0
GEGN599	INDEPENDENT STUDY ^{Summer}	6.0
GE ELECT	Electives *	9.0
Total Semester Hrs		36.0

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. As part of their elective courses, students are required to have at least one additional advanced course in hydrogeochemistry. Possibilities for other electives include courses in site characterization, environmental science and engineering, geographical information systems (GIS), geochemistry, and geophysics, for example.

Mining Geological Engineering Specialty (Non-Thesis)

Students working towards a Masters of Engineering (non-thesis) with specialization in Mining Geology must meet the prerequisite course requirements listed later in this section. Required courses for the degree are:

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
or GEGN467	GROUNDWATER ENGINEERING	
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEOL515	ADVANCED MINERAL DEPOSITS	3.0
Selected Topics		2-4
MNGN523	SELECTED TOPICS (Surface Mine Design OR)	
MNGN523	SELECTED TOPICS (Underground Mine Design)	
GE ELECT	Elective *	3.0
GEOL505	ADVANCED STRUCTURAL GEOLOGY	3.0
GEOL520	NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS	3.0
GE ELECT	Elective *	6.0
GEGN599	INDEPENDENT STUDY	6.0
Total Semester Hrs		33-35

* Electives and course substitutions are approved by the Geological Engineering Graduate Program Committee and must be consistent with the program specialization. Typically, the elective courses are selected from the following topical areas: mineral deposits geology, ore microscopy, applied geophysics, applied geochemistry, remote sensing, engineering geology, environmental geology, engineering economics / management, mineral processing, geostatistics, geographic information systems, environmental or exploration and mining law, and computers sciences.

The **Master of Science Degree Program in Geological Engineering** requires a minimum of 36 semester hours of course and project/ research credit hours (a maximum of 9 credit hours may be 400-level course work), plus a Graduate Thesis. The degree includes three areas of specialization (engineering geology/geotechnics, groundwater engineering, and mining geological engineering) with common requirements as follows:

GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN707	GRADUATE THESIS/DISSERTATION RESEARCH CREDIT (minimum)	12.0

GEGN	Course work, approved by the thesis committee	24.0
Total Semester Hrs		39.0

The content of the thesis is to be determined by the student's advisory committee in consultation with the student. The Masters thesis must demonstrate creative and comprehensive ability in the development or application of geological engineering principles. The format of the thesis will follow the guidelines described under the Thesis Writer's Guide.

In addition to the common course requirements, the Master of Science degree with **specialization in Engineering Geology/Geotechnics** requires:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN570	CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY	3.0
Select at least two of the following:		6.0
GEGN571	ADVANCED ENGINEERING GEOLOGY	
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	
GEGN671	LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION	
GEGN672	ADVANCED GEOTECHNICS	
Total Semester Hrs		17.0

Typically, the additional courses are selected from the following topical areas: engineering geology, groundwater engineering, groundwater modeling, soil mechanics and foundations, rock mechanics, underground construction, seismic hazards, geomorphology, geographic information systems, construction management, finite element modeling, waste management, environmental engineering, environmental law, engineering management, and computer programming.

In addition to the common course requirements, the Master of Science degree with specialization in Ground Water also requires the following courses:

GEGN467	GROUNDWATER ENGINEERING	4.0
GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
2 Courses Selected as Follows:		6.0
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	
CEEN580	ENVIRONMENTAL POLLUTION: SOURCES, CHARACTERISTICS, TRANSPORT AND FATE	
GEGN509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEGN581	ADVANCED GROUNDWATER ENGINEERING	
Total Semester Hrs		17.0

As nearly all ground water software is written in Fortran, if the student does not know Fortran, a Fortran course must be taken before graduation, knowledge of other computer languages is encouraged.

In addition to the common course requirements, the Master of Science degree with **specialization in Mining Geology** also requires:

Specialty Areas (minimum)	17.0
Total Semester Hrs	17.0

This will include about 5–6 courses (predominantly at 500 and 600 level) selected by the student in conjunction with the Masters program advisory committee. Specialty areas might include: mineral deposits geology, mineral exploration, mining geology, mineral processing, applied geophysics, applied geochemistry, engineering geology, environmental geology, geostatistics, geographic information systems, environmental or exploration and mining law, engineering economics/ management, and computer sciences.

The **Doctor of Philosophy (Geological Engineering)** degree requires a minimum of 72 hours course work and research combined. Requirements include the same courses as for the Master of Science (Geological Engineering) with the additions noted below. After completing all coursework and an admission to candidacy application, the Dissertation is completed under GEGN707 Graduate Research. The content of the dissertation is to be determined by the student's advisory committee in consultation with the student. The dissertation must make a new contribution to the geological engineering profession. The format of the dissertation will follow the guidelines described under the Thesis Writer's Guide. A minimum of 24 research credits must be taken. Up to 24 course credit hours may be awarded by the candidate's Doctoral Thesis Advisory Committee for completion of a Master of Science degree (at CSM or elsewhere).

In addition to the common course requirements, a PhD **specializing in Engineering Geology/Geotechnics** requires additional course work tailored to the student's specific interests and approved by the doctoral program committee. (Typically, the additional courses are selected from the following topical areas: engineering geology, groundwater engineering, groundwater modeling, soil mechanics and foundations, rock mechanics, underground construction, seismic hazards, geomorphology, geographic information systems, construction management, finite element modeling, waste management, environmental engineering, environmental law, engineering management, and computer programming.)

In addition to the common course requirements listed previously, a PhD **specializing in Ground Water** also requires:

GEGN581	ADVANCED GROUNDWATER ENGINEERING	3.0
GEGN669	ADVANCED TOPICS IN ENGINEERING HYDROGEOLOGY	1-2
GEGN681	VADOSE ZONE HYDROLOGY	3.0
GEGN683	ADVANCED GROUND WATER MODELING	3.0

and additional course work tailored to the student's specific interests, which are likely to include chemistry, engineering, environmental science, geophysics, math (particularly Partial Differential Equations), microbiology, organic chemistry, contaminant transport, soil physics, optimization, shallow resistivity or seismic methods. The student's advisory committee has the authority to approve elective courses and any substitutions for required courses.

In addition to the common course requirements, a PhD **specializing in Mining Geology** also requires:

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
or GEGN467	GROUNDWATER ENGINEERING	
GEOL505	ADVANCED STRUCTURAL GEOLOGY	3.0

GEOL515	ADVANCED MINERAL DEPOSITS	3.0
GEOL520	NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS	3.0
MNGN523	SELECTED TOPICS (Surface Mine Design or Underground Mine Design)	2.0
Total Semester Hrs		15.0

Additional course work suited to the student's specific interests and approved by the doctoral program committee. (Typically, the additional courses are selected from the following topical areas: mineral deposits geology, mineral exploration, mining geology, mineral processing, applied geophysics, applied geochemistry, engineering geology, environmental geology, geostatistics, geographic information systems, environmental or exploration and mining law, engineering economics/management, and computer sciences).

Geochemistry

The Geochemistry Program is an interdisciplinary graduate program administered by the departments of Geology and Geological Engineering and Chemistry and Geochemistry. The geochemistry faculty from each department are responsible for the operations of the program. Student reside in either Department. Please see the Geochemistry section of the Bulletin for detailed information on this degree program.

Hydrologic Science and Engineering

The Hydrologic Science and Engineering (HSE) Program is an interdisciplinary graduate program comprised of faculty from several different CSM departments. Please see the Hydrologic Science and Engineering section of the Bulletin for detailed information on this degree program.

Qualifying Examination

Ph.D. students in Geology, Geological Engineering, Geochemistry, and Hydrologic Science and Engineering must pass a qualifying examination by the end of the second year of their programs. This timing may be adjusted for part-time students. This examination will be administered by the student's Doctoral committee and will consist of an oral and a written examination, administered in a format to be determined by the Doctoral Committee. Two negative votes in the Doctoral Committee constitute failure of the examination. In case of failure of the qualifying examination, a re-examination may be given upon the recommendation of the Doctoral Committee and approval of the Graduate Dean. Only one re-examination may be given.

Professor and Department Head

Paul M. Santi

Professors

Wendy J. Harrison

Murray W. Hitzman, Charles F. Fogarty Professor of Economic Geology

Reed M. Maxwell

Stephen A. Sonnenberg, Charles Boettcher Distinguished Chair in Petroleum Geology

Richard F. Wendlandt

Lesli J. Wood, Weimer Distinguished Chair and Professor, Geology

Associate Professors

David A. Benson

Jerry D. Higgins

John D. Humphrey

Thomas Monecke

Piret Plink-Bjorklund

Kamini Singha, Joint appointment with Civil and Environmental Engineering

Bruce Trudgill

Wei Zhou

Assistant Professors

Alexander Gysi

Yvette Kuiper

Alexis Stichler

Gabriel Walton

Teaching Associate Professor

Christian V. Shorey

Research Professors

David Pyles

J. Frederick (Rick) Sarg

Research Associate Professors

Donna S. Anderson

Nicholas B. Harris

Karin Hoal

Research Assistant Professors

Jennifer L. Aschoff

Jeremy Boak

Maeve Boland

Mary Carr

Brian Ebel

Nigel Kelly

Professor Emerita

Eileen P. Poeter

Professors Emeriti

John B. Curtis

Thomas L.T. Grose

John D. Haun

Neil F. Hurley

Keenan Lee

Samuel B. Romberger

A. Keith Turner

John E. Warme

Robert J. Weimer

Associate Professors Emeriti

L. Graham Closs

Timothy A. Cross

Gregory S. Holden

Joint Appointment

Stephen M. Enders

John E. McCray

Courses

GEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GEGN509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.

(I) Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

GEGN520. INDUSTRIAL MINERALS AND ROCKS. 3.0 Semester Hrs. Introduction to the Industrial Minerals industry via appreciation of geologic occurrence, physical and chemical material properties, mining and processing considerations, and marketing of various commodities. Development of skills in preparation of commodity surveys, reserves and resources classifications, and project appraisals. Required field trips to operational sites and trip reports. Mid-term and final exams. Individual student commodity term project and presentation. Prerequisite: Senior or graduate status in earth resources field. 3 hours lecture/seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEGN527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.

(II) A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal, and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

GEGN530. CLAY CHARACTERIZATION. 1.0 Semester Hr.

(I) Clay mineral structure, chemistry and classification, physical properties (flocculation and swelling, cation exchange capacity, surface area and charge), geological occurrence, controls on their stabilities. Principles of X-ray diffraction, including sample preparation techniques, data collection and interpretation, and clay separation and treatment methods. The use of scanning electron microscopy to investigate clay distribution and morphology. Methods of measuring cation exchange capacity and surface area. Prerequisite: GEGN206 or equivalent. 1 hour lecture, 2 hours lab; 1 semester hour.

GEGN532. GEOLOGICAL DATA ANALYSIS. 3.0 Semester Hrs.

(I or II) Techniques and strategy of data analysis in geology and geological engineering: basic statistics review, analysis of data sequences, mapping, sampling and sample representativity, univariate and multivariate statistics, geostatistics, and geographic information systems (GIS). Practical experience with geological applications via supplied software and data sets from case histories. Prerequisites: Introductory statistics course (MATH323 or MATH530 equivalent). 2 hours lecture/discussion; 3 hours lab; 3 semester hours.

GEGN570. CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY. 3.0 Semester Hrs.

(I) Case histories in geological and geotechnical engineering, ground water, and waste management problems. Students are assigned problems and must recommend solutions and/or prepare defensible work plans. Discussions center on the role of the geological engineer in working with government regulators, private-sector clients, other consultants, and other special interest groups. Prerequisite: GEGN467, GEGN468, GEGN469, GEGN470. 3 hours lecture; 3 semester hours.

GEGN571. ADVANCED ENGINEERING GEOLOGY. 3.0 Semester Hrs.

(I) Emphasis will be on engineering geology mapping methods, and geologic hazards assessment applied to site selection and site assessment for a variety of human activities. Prerequisite: GEGN468 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEGN573. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.

(II) Methods of field investigation, testing, and monitoring for geotechnical and hazardous waste sites, including: drilling and sampling methods, sample logging, field testing methods, instrumentation, trench logging, foundation inspection, engineering stratigraphic column and engineering soils map construction. Projects will include technical writing for investigations (reports, memos, proposals, workplans). Class will culminate in practice conducting simulated investigations (using a computer simulator). 3 hours lecture; 3 semester hours.

GEGN575. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.

(II) An introduction to Geographic Information Systems (GIS) and their applications to all areas of geology and geological engineering. Lecture topics include: principles of GIS, data structures, digital elevation models, data input and verification, data analysis and spatial modeling, data quality and error propagation, methods of GIS evaluation and selection. Laboratories will use Macintosh and DOS-based personal computer systems for GIS projects, as well as video-presentations. Visits to local GIS laboratories, and field studies will be required. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN578. GIS PROJECT DESIGN. 1-3 Semester Hr.

(I, II) Project implementation of GIS analysis. Projects may be undertaken by individual students, or small student teams. Documentation of all project design stages, including user needs assessment, implementation procedures, hardware and software selection, data sources and acquisition, and project success assessment. Various GIS software may be used; projects may involve 2-dimensional GIS, 3-dimensional subsurface models, or multi-dimensional time-series analysis. Prerequisite: none. Variable credit, 1-3 semester hours, depending on project. Offered on demand.

GEGN580. APPLIED REMOTE SENSING FOR GEOENGINEERING AND GEOSCIENCES. 3.0 Semester Hrs.

(I) This course offers an introduction to remote sensing in general and radar remote sensing and optical remote sensing in specific as well as their applications to all areas of geoengineering and geosciences. Lecture topics include: principles SAR (Synthetic Aperture Radar) and InSAR (Interferometry of Synthetic Aperture Radar) and their applications, as well as basic concepts of optical remote sensing and its application in geoengineering and geosciences. Topics include various sensors and platforms of SAR data acquisition, SAR data access, SAR data processing, data acquisition and processing of optical remote sensing images. Prerequisites: Graduate standing. 2 hours lecture, 3 hours lab, 3 semester hours.

GEGN581. ANALYTICAL HYDROLOGY. 3.0 Semester Hrs.

(I) Lectures, assigned readings, and discussions concerning the theory, measurement, and estimation of ground water parameters, fractured-rock flow, new or specialized methods of well hydraulics and pump tests, tracer methods. Prerequisite: GEGN467. 3 hours lecture; 3 semester hours.

GEGN582. INTEGRATED SURFACE WATER HYDROLOGY. 3.0 Semester Hrs.

Equivalent with ESGN582,

(I) This course provides a quantitative, integrated view of the hydrologic cycle. The movement and behavior of water in the atmosphere (including boundary layer dynamics and precipitation mechanisms), fluxes of water between the atmosphere and land surface (including evaporation, transpiration, precipitation, interception and through fall) and connections between the water and energy balances (including radiation and temperature) are discussed at a range of spatial and temporal scales. Additionally, movement of water along the land surface (overland flow and snow dynamics) and in the subsurface (saturated and unsaturated flow) as well as surface-subsurface exchanges and runoff generation are also covered. Finally, integration and connections within the hydrologic cycle and scaling of river systems are discussed. Prerequisites: Groundwater Engineering (GEGN466/GEGN467), Fluid Mechanics (GEGN351/EGGN351), math up to differential equations, or equivalent classes. 3 hours lecture; 3 semester hours.

GEGN583. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.

(II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of finite-difference and finite-element numerical methods and analytical solutions to ground water flow and mass transport problems. Prerequisite: A knowledge of FORTRAN programming, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN584. FIELD METHODS IN HYDROLOGY. 3.0 Semester Hrs.

(I) Design and implementation of tests that characterize surface and subsurface hydrologic systems, including data logger programming, sensor calibration, pumping tests, slug tests, infiltration tests, stream gauging and dilution measurements, and geophysical (EM, resistivity, and/or SP) surveys. Prerequisites: Groundwater Engineering (GEGN466/GEGN467, Surface Water Hydrology (ESGN582) or equivalent classes. 2 hours lecture; 5 hours lab and field exercises one day of the week. Days TBD by instructor; 3 semester hours.

GEGN586. NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS. 3.0 Semester Hrs.

(II) This course provides quantitative methods for evaluating the geochemical characteristics of geological systems. The course is project based with lectures to provide information about the topic and use of geochemical modeling software. Student projects consist of chemical speciation of waters, activity diagrams, reaction progress models, water-rock interactions, sorption and surface complexation, and kinetic mineral reactions. Students complete an individual project on the geochemical system of their choice and present it to the class. Prerequisite: CEEN550 or CHGC509. 3 hours lecture, 3 semester hours. Offered spring semester, odd years.

GEGN598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN599. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN669. ADVANCED TOPICS IN ENGINEERING HYDROGEOLOGY. 1-2 Semester Hr.

(I, II) Review of current literature and research regarding selected topics in hydrogeology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 1 to 2 semester hours; may be repeated for credit.

GEGN670. ADVANCED TOPICS IN GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.

(I, II) Review of current literature and research regarding selected topics in engineering geology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 3 hours lecture; 3 semester hours. Repeatable for credit under different topics.

GEGN671. LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION. 3.0 Semester Hrs.

(I) Geological investigation, analysis, and design of natural rock and soil slopes and mitigation of unstable slopes. Topics include landslide types and processes, triggering mechanisms, mechanics of movements, landslide investigation and characterization, monitoring and instrumentation, soil slope stability analysis, rock slope stability analysis, rock fall analysis, stabilization and risk reduction measures. Prerequisites: GEGN468, EGGN361, MNGN321, (or equivalents). 3 hours lecture; 3 semester hours.

GEGN672. ADVANCED GEOTECHNICS. 3.0 Semester Hrs.

Practical analysis and application of techniques in weak rock engineering, ground-water control in construction, fluvial stabilization and control, earthquake hazard assessment, engineering geology in construction, engineering geology in dam investigation, and other current topics in geotechnics practice. Prerequisite: GEGN468, CEEN312, CEEN312L and MNGN321. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN673. ADVANCED GEOLOGICAL ENGINEERING DESIGN. 3.0 Semester Hrs.

(II) Application of geological principles and analytical techniques to solve complex engineering problems related to geology, such as mitigation of natural hazards, stabilization of earth materials, and optimization of construction options. Design tools to be covered will include problem solving techniques, optimization, reliability, maintainability, and economic analysis. Students will complete independent and group design projects, as well as a case analysis of a design failure. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN681. VADOSE ZONE HYDROLOGY. 3.0 Semester Hrs.

(II) Study of the physics of unsaturated groundwater flow and contaminant transport. Fundamental processes and data collection methods will be presented. The emphasis will be on analytic solutions to the unsaturated flow equations and analysis of field data. Application to non-miscible fluids, such as gasoline, will be made. The fate of leaks from underground tanks will be analyzed. Prerequisites: GEGN467 or equivalent; Math through Differential Equations. 3 hours lecture; 3 semester hours.

GEGN682. FLOW AND TRANSPORT IN FRACTURED ROCK. 3.0 Semester Hrs.

(I) Explores the application of hydrologic and engineering principles to flow and transport in fractured rock. Emphasis is on analysis of field data and the differences between flow and transport in porous media and fractured rock. Teams work together throughout the semester to solve problems using field data, collect and analyze field data, and do independent research in flow and transport in fractured rock. Prerequisites: GEGN581. 3 hours lecture; 3 credit hours. Offered alternate years.

GEGN683. ADVANCED GROUND WATER MODELING. 3.0 Semester Hrs.

(II) Flow and solute transport modeling including: 1) advanced analytical modeling methods; 2) finite elements, random-walk, and method of characteristics numerical methods; 3) discussion of alternative computer codes for modeling and presentation of the essential features of a number of codes; 4) study of selection of appropriate computer codes for specific modeling problems; 5) application of models to ground water problems; and 6) study of completed modeling projects through literature review, reading and discussion. Prerequisite: GEGN509/CHGC509 or GEGN583. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN699. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

GEGX571. GEOCHEMICAL EXPLORATION. 3.0 Semester Hrs.

(I) Dispersion of trace metals from mineral deposits and their discovery. Laboratory consists of analysis and statistical interpretation of data of soils, stream sediments, vegetation, and rock in connection with field problems. Term report required. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL501. APPLIED STRATIGRAPHY. 4.0 Semester Hrs.

(I) Review of basic concepts in siliciclastic and carbonate sedimentology and stratigraphy. Introduction to advanced concepts and their application to exploration and development of fossil fuels and stratiform mineral deposits. Modern facies models and sequence-stratigraphic concepts applied to solving stratigraphic problems in field and subsurface settings. Prerequisites: GEOL314 or equivalent. 3 hours lecture, 4 hours lab; 4 semester hours.

GEOL502. STRUCTURAL METHODS FOR SEISMIC INTERPRETATION. 3.0 Semester Hrs.

(I) A practical course that covers the wide variety of structural methods and techniques that are essential to produce a valid and coherent interpretation of 2D and 3D seismic reflection data in structurally complex areas. Topics covered include: Extensional tectonics, fold and thrust belts, salt tectonics, inversion tectonics and strike-slip fault systems. Laboratory exercises are based on seismic datasets from a wide variety of structural regimes from across the globe. The course includes a 4 day field trip to SE Utah. Prerequisite: GEOL309 and GEOL314 or GEOL315, or equivalents. 3 hours lecture/lab; 3 semester hours.

GEOL503. INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA. 3.0 Semester Hrs.

(II) INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA-A PRACTICAL COURSE IN SEISMIC INTERPRETATION OF GLOBAL DATASETS. A practical course in workstation based, integrated geological interpretation of 3D seismic reflection data. Course builds directly on the seismic interpretation skills learnt in the prerequisite GEOL502 Structural Methods for Seismic Interpretation. Key concepts developed in this course are: making internally consistent interpretations of complex 3D datasets and developing integrated geological (structural and stratigraphic) interpretations of 3D seismic data. Prerequisite: GEOL502. 3 hours lecture/lab; 3 semester hours.

GEOL505. ADVANCED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.

(I) Advanced Structural Geology builds on basic undergraduate Structural Geology. Structures such as folds, faults, foliations, lineations and shear zones will be considered in detail. The course focuses on microstructures, complex geometries and multiple generations of deformation. The laboratory consists of microscopy, in-class problems, and some field-based problems. Prerequisites: GEGN307, GEOL309, GEGN316, GEOL321, or equivalents. 2 hours lecture, 2 hours lab, and field exercise; 3 semester hours.

GEOL507. GRADUATE SEMINAR. 1.0 Semester Hr.

Equivalent with GEOL607,

(II) Recent geologic ideas and literature reviewed. Preparation and oral presentation of short papers. 1 hour seminar; 1 semester hour. Required of all geology candidates for advanced degrees during their enrollment on campus.

GEOL512. MINERALOGY AND CRYSTAL CHEMISTRY. 3.0 Semester Hrs.

(I) Relationships among mineral chemistry, structure, crystallography, and physical properties. Systematic treatments of structural representation, defects, mineral stability and phase transitions, solid solutions, substitution mechanisms, and advanced methods of mineral identification and characterization. Applications of principles using petrological and environmental examples. Prerequisites: GEOL321, DCGN209 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL513. HYDROTHERMAL GEOCHEMISTRY. 3.0 Semester Hrs.

Equivalent with CHGC513,

(II) Geochemistry of high-temperature aqueous systems. Examines fundamental phase relationships in model systems at elevated temperatures and pressures. Major and trace element behavior during fluid-rock interaction. Theory and application of stable isotopes as applied to hydrothermal mineral deposits. Review of the origin of hydrothermal fluids and mechanisms of transport and deposition of ore minerals. Includes the study of the geochemistry of magmatic aqueous systems, geothermal systems, and submarine hydrothermal vents. Prerequisites: GEGN401. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL514. BUSINESS OF ECONOMIC GEOLOGY. 3.0 Semester Hrs.

Examines the business side of mineral exploration including company structure, fundraising, stock market rules and regulations, and legal environment. Reviews the types of minerals exploration companies, differences between mineral sectors, rules and practices of listing a minerals company on a stock exchange, and legal requirements of listing and presenting data to stockholders. The course is centered on lectures by industry representatives from the Denver area. Includes participation in a technical conference in Vancouver or Toronto and meetings with lawyers, stockbrokers, and geoscientists working in the mineral industry. Prerequisites: GEGN401. 3 hours lecture and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL515. ADVANCED MINERAL DEPOSITS. 3.0 Semester Hrs.

(I) Geology of mineral systems at a deposit, district, and regional scale formed by magmatic-hydrothermal, sedimentary/basinal, and metamorphic processes. Emphasis will be placed on a systems approach to evaluating metal and sulfur sources, transportation paths, and traps. Systems examined will vary by year and interest of the class. Involves a team-oriented research project that includes review of current literature and laboratory research. Prerequisites: GEGN401. 1 hour lecture, 5 hours lab; 3 semester hours. Repeatable for credit.

GEOL517. FIELD METHODS FOR ECONOMIC GEOLOGY. 3.0 Semester Hrs.

(II) Methods of field practices related to mineral exploration and mining. Lithology, structural geology, alteration, and mineralization vein-type precious metal deposits. Mapping is conducted both underground at the Edgar Test Mine and above ground in the Idaho Springs area. Drill core and rock chips from different deposit types are utilized. Technical reports are prepared for each of four projects. Class is run on Saturday (9 am-4 pm) throughout the semester. Prerequisites: GEGN401. 6 hours lab and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL518. MINERAL EXPLORATION. 3.0 Semester Hrs.

(II) Mineral industry overview, deposit economics, target selection, deposit modeling, exploration technology, international exploration, environmental issues, program planning, proposal development. Team development and presentation of an exploration proposal. Prerequisite: GEOL515, GEOL520, or equivalent. 2 hours lecture/seminar, 3 hours lab; 3 semester hours. Offered when student demand is sufficient.

GEOL519. ABITIBI GEOLOGY AND EXPLORATION FIELD SCHOOL. 3.0 Semester Hrs.

(II, S) Methods of field practices related to mineral exploration and mining. Regional and deposit-scale geology of Archean mineral deposits, including lode gold deposits and volcanic-hosted massive sulfide deposits. Includes mineral prospect evaluation, structural geology, physical volcanology, deposit definition, alteration mapping, mining methods, ore processing, and metallurgy. Core logging, underground stope mapping, open pit mapping, lithogeochemical sampling, and field-analytical techniques. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 14-day field trip is run in the summer semester. Each day includes up to 4 hours of instruction in the field and 4 hours of team-oriented field exercises. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient.

GEOL520. NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS. 3.0 Semester Hrs.

(I, II) Each topic unique and focused on a specific mineral deposit type or timely aspects of economic geology. Review of the geological and geographic setting of a specific magmatic, hydrothermal, or sedimentary mineral deposit type. Detailed study of the physical and chemical characteristics of selected deposits and mining districts. Theory and application of geological field methods and geochemical investigations. Includes a discussion of genetic models, exploration strategies, and mining methods. Prerequisites: GEGN401. 2 hours lecture; 2 semester hours. Repeatable for credit.

GEOL521. FIELD AND ORE DEPOSIT GEOLOGY. 3.0 Semester Hrs.

(I, S) Field study of major mineral deposit districts inside and outside of the USA. Examines regional and deposit-scale geology. Underground and open pit mine visits and regional traverses. Topics addressed include deposit definition, structural geology, alteration mapping, mining methods, and ore processing. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 10-14 day field trip is run in the summer semester. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient. Repeatable for credit.

GEOL522. TECTONICS AND SEDIMENTATION. 3.0 Semester Hrs.

(II) Application and integration of advanced sedimentologic and stratigraphic concepts to understand crustal deformation at a wide range of spatial- and time-scales. Key concepts include: growth-strata analysis, interpretation of detrital composition (conglomerate unroofing sequences and sandstone provenance trends), paleocurrent deflection and thinning trends, tectonic control on facies distribution and basic detrital zircon and fission track analysis. Students will read a wide range of literature to explore the utility and limitation of traditional "tectonic signatures" in stratigraphy, and will work on outcrop and subsurface datasets to master these concepts. Special attention is paid to fold-thrust belt, extensional and salt-related deformation. The course has important applications in Petroleum Geology, Geologic Hazards, and Hydrogeology. Required: 2-3 fieldtrips, class presentations, and a final paper that is written in a peer-reviewed journal format. Prerequisites: GEOL314 or equivalent, and GEOL309 or equivalent. 3 hours lecture and seminar; 3 semester hours. Offered even years.

GEOL523. REFLECTED LIGHT AND ELECTRON MICROSCOPY. 3.0 Semester Hrs.

(I) Theoretical and practical aspects of reflected light and electron microscopy. Emphasis will be placed on applications to ore deposit exploration and research. Lecture and discussion topics will highlight both standard and new techniques and instrumentation including SEM and QEMSCAN, as well as key questions in mineral deposit genesis which can be addressed using reflected light and electron microscopy. Includes detailed study of a selected suite of samples, with emphasis on mineral identification, textural relationships, paragenetic sequences, and mineral chemistry. Course culminates in a project. Prerequisites: GEGN401. 2 hours lecture, 2 hours lab; 3 semester hours.

GEOL525. TECTONOTHERMAL EVOLUTION OF THE CONTINENTS. 3.0 Semester Hrs.

(I) Evolution of the continental crust with a specific focus on processes occurring at collisional margins. Emphasis will be on the application of metamorphic processes and concepts., including integration of major, trace, and isotopic geochemistry of rocks and minerals to interpreting and understanding the tectonic and thermal evolution of the crust through space and time. Laboratory emphasizes the interpretation of metamorphic textures and assemblages within the context of geochemistry and deformation, and the application of thermodynamic principles to the understanding of the thermal history of rocks and terrains. Prerequisite: Appropriate undergraduate optical mineralogy and petrology coursework (GEOL321 and GEGN307, or equivalent). 2 hours lecture and seminar, 3 hours lab: 3 semester hours. Offered alternate years.

GEOL530. CLAY CHARACTERIZATION. 1.0 Semester Hr.

(I) Clay mineral structure, chemistry and classification, physical properties (flocculation and swelling, cation exchange capacity, surface area and charge), geological occurrence, controls on their stabilities. Principles of X-ray diffraction, including sample preparation techniques, data collection and interpretation, and clay separation and treatment methods. The use of scanning electron microscopy to investigate clay distribution and morphology. Methods of measuring cation exchange capacity and surface area. Prerequisite: GEGN206 or equivalent. 1 hour lecture, 2 hours lab; 1 semester hour.

GEOL540. ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY. 3.0 Semester Hrs.

(II) A study of the principles of geochronology and stable isotope distributions with an emphasis on the application of these principles to important case studies in igneous petrology and the formation of ore deposits. U, Th, and Pb isotopes, K-Ar, Rb-Sr, oxygen isotopes, hydrogen isotopes, and carbon isotopes included. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL550. INTEGRATED BASIN MODELING. 3.0 Semester Hrs.

(I) This course introduces students to principal methods in computer-based basin modeling: structural modeling and tectonic restoration; thermal modeling and hydrocarbon generation; and stratigraphic modeling. Students apply techniques to real data set that includes seismic and well data and learn to integrate results from multiple approaches in interpreting a basin's history. The course is primarily a lab course. Prerequisite: none. A course background in structural geology, sedimentology/stratigraphy or organic geochemistry will be helpful. 1 hour lecture, 5 hours labs; 3 semester hours.

GEOL551. APPLIED PETROLEUM GEOLOGY. 3.0 Semester Hrs.

(II) Subjects to be covered include computer subsurface mapping and cross sections, petrophysical analysis of well data, digitizing well logs, analyzing production decline curves, creating hydrocarbon-porosity-thickness maps, volumetric calculations, seismic structural and stratigraphic mapping techniques, and basin modeling of hydrocarbon generation. Students are exposed to three software packages used extensively by the oil and gas industry. Prerequisite: GEGN438 or GEOL609. 3 hours lecture; 3 semester hours.

GEOL552. UNCONVENTIONAL PETROLEUM SYSTEMS. 3.0 Semester Hrs.

(II) Unconventional petroleum systems have emerged as a critical and indispensable part of current US production and potential future reserves. Each of the 5 unconventional oil and 4 unconventional gas systems will be discussed: what are they, world wide examples, required technology to evaluate and produce, environmental issues, and production/resource numbers. The oil part of the course will be followed by looking at cores from these systems. The gas part of the course will include a field trip to the Denver, Eagle, and Piceance Basins in Colorado to see outstanding outcrops of actual producing units. Prerequisites: GEGN438 or GEOL609, GEGN527. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL553. GEOLOGY AND SEISMIC SIGNATURES OF RESERVOIR SYSTEMS. 3.0 Semester Hrs.

(II) This course is a comprehensive look at the depositional models, log signatures, characteristics, and seismic signatures for all the main reservoirs we explore for and produce from in the subsurface. The first half is devoted to the clastic reservoirs (12 in all); the second part to the carbonate reservoirs (7 total). The course will utilize many hands-on exercises using actual seismic lines for the various reservoir types. Prerequisites: GEOL501 or GEOL314. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL555. STRUCTURAL FIELD RESEARCH. 4.0 Semester Hrs.

(I) This course focuses on geological field work along the Colorado Front Range through inquiry-based research and hypothesis-testing. The type of problems students will work on will vary from more applied problems (e.g. centered around the Edgar mine) or more academic/scientific orientated problems, depending on the student's interest. The class will be split up in groups of students with similar interests. In the first part of the course, we take an introductory two-day field trip, and students will review existing literature and maps and write a brief research proposal including hypotheses, tests and a work plan for the remainder of the course. The second part of the course will focus on field work. During the last part of the course, students prepare a geological map and appropriate cross sections, and a report presenting rock descriptions, structural analysis, a geological history, and interpretation of results in the context of the hypotheses posed. Prerequisites: (need previous field experience such as a field course, and a course in structural geology and one in earth materials). 2 hours lecture, 6 hours lab; 4 semester hours.

GEOL570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GEOL597. SPECIAL SUMMER COURSE. 15.0 Semester Hrs.**GEOL598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL598LA. SPECIAL TOPICS LAB. 6.0 Semester Hrs.**GEOL598LB. SPECIAL TOPICS LAB. 6.0 Semester Hrs.****GEOL599. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.**

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL601. FIELD STRATIGRAPHY. 1.0 Semester Hr.

(II) Keynote lectures and a seminar series on select topics in stratigraphy, linked to a field trip. Specific topics vary yearly depending on course participant's interests. Seminar discussions based on reading journal papers. Field trip consists of series of projects/exercises focused on making field observations and deducing interpretations, based on multiple hypotheses. Field trip includes specific observations and recognition criteria for depositional processes and environments, as well as for regional climatic and tectonic controls. Presentation required. Prerequisite: GEOL501. 3-4 seminars, 3 hours each, over the course of the semester, and a field trip; 1 semester hour.

GEOL608. HISTORY OF GEOLOGICAL CONCEPTS. 3.0 Semester Hrs.

(II) Lectures and seminars concerning the history and philosophy of the science of geology; emphasis on the historical development of basic geologic concepts. 3 hours lecture and seminar; 3 semester hours. Required of all doctoral candidates in department. Offered alternate years.

GEOL609. ADVANCED PETROLEUM GEOLOGY. 3.0 Semester Hrs.

(II) Subjects to be covered involve consideration of basic chemical, physical, biological and geological processes and their relation to modern concepts of oil/gas generation (including source rock deposition and maturation), and migration/accumulation (including that occurring under hydrodynamic conditions). Concepts will be applied to the historic and predictive occurrence of oil/gas to specific Rocky Mountain areas. In addition to lecture attendance, course work involves review of topical papers and solution of typical problems. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

GEOL610. ADVANCED SEDIMENTOLOGY. 3.0 Semester Hrs.

(I) Keynote lectures, mixed with discussions, in-class exercises, core and field observations in a seminar series on sedimentology. Introduction to current hot topics in sedimentology, and discussions on fundamental principles. Specific topics vary yearly depending on most recent advancements and course participant's interests. Quantitative sedimentology. Applications of sedimentology. All seminars are based on reading and discussing journal papers. Field trip to a modern environment. Essays and presentations required. Prerequisite: GEOL501. Acceptable to take GEOL610 at the same time, as GEOL501. 3 hours lecture and seminar; 3 semester hours. Offered alternate years.

GEOL611. SEQUENCE STRATIGRAPHY IN SEISMIC, WELL LOGS, AND OUTCROP. 3.0 Semester Hrs.

(I) Keynote lectures and a seminar series on the sequence stratigraphy of depositional systems, including both siliciclastics and carbonates and how they behave in changing sea-level, tectonic subsidence, and sediment supply conditions. Application of sequence stratigraphy concepts to reflection seismic, well-log, and outcrop datasets. Field trip and report required. Prerequisite: GEOL501. 3 hours lecture and seminar; 3 semester hours.

GEOL613. GEOLOGIC RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.

(I, II) Principles and practice of characterizing petroleum reservoirs using geologic and engineering data, including well logs, sample descriptions, routine and special core analysis and well tests. Emphasis is placed on practical analysis of such data sets from a variety of clastic petroleum reservoirs worldwide. These data sets are integrated into detailed characterizations, which then are used to solve practical oil and gas field problems. Prerequisites: GEGN438, GEOL501, GEOL505 or equivalents. 3 hours lecture; 3 semester hours.

GEOL617. THERMODYNAMICS AND MINERAL PHASE EQUILIBRIA. 3.0 Semester Hrs.

(I) Basic thermodynamics applied to natural geologic systems. Evaluation of mineral-vapor mineral solution, mineral-melt, and solid solution equilibria with special emphasis on oxide, sulfide, and silicate systems. Experimental and theoretical derivation, use, and application of phase diagrams relevant to natural rock systems. An emphasis will be placed on problem solving rather than basic theory. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL621. PETROLOGY OF DETRITAL ROCKS. 3.0 Semester Hrs.

(II) Compositions and textures of sandstones, siltstones, and mudrocks. Relationship of compositions and textures of provenance, environment of deposition, and burial history. Development of porosity and permeability. Laboratory exercises emphasize use of petrographic thin sections, x-ray diffraction analysis, and scanning electron microscopy to examine detrital rocks. A term project is required, involving petrographic analysis of samples selected by student. Pre-requisites: GEGN206, GEOL321 or equivalent. 2 hours lecture and seminar, 3 hours lab; 3 semester hours. Offered on demand.

GEOL624. CARBONATE SEDIMENTOLOGY AND PETROLOGY. 3.0 Semester Hrs.

(II) Processes involved in the deposition of carbonate sediments with an emphasis on Recent environments as analogs for ancient carbonate sequences. Carbonate facies recognition through bio- and lithofacies analysis, three-dimensional geometries, sedimentary dynamics, sedimentary structures, and facies associations. Laboratory stresses identification of Recent carbonate sediments and thin section analysis of carbonate classification, textures, non-skeletal and biogenic constituents, diagenesis, and porosity evolution. Prerequisite: GEOL321 and GEOL314. 2 hours lecture/seminar, 2 hours lab; 3 semester hours.

GEOL628. ADVANCED IGNEOUS PETROLOGY. 3.0 Semester Hrs.

(I) Igneous processes and concepts, emphasizing the genesis, evolution, and emplacement of tectonically and geochemically diverse volcanic and plutonic occurrences. Tectonic controls on igneous activity and petrochemistry. Petrographic study of igneous suites, mineralized and non-mineralized, from diverse tectonic settings. Prerequisites: GEOL321, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL642. FIELD GEOLOGY. 1-3 Semester Hr.

(S) Field program operated concurrently with GEGN316 field camp to familiarize the student with basic field technique, geologic principles, and regional geology of Rocky Mountains. Prerequisite: Undergraduate degree in geology and GEGN316 or equivalent. During summer field session; 1 to 3 semester hours.

GEOL643. GRADUATE FIELD SEMINARS. 1-3 Semester Hr.

(I, II, S) Special advanced field programs emphasizing detailed study of some aspects of geology. Normally conducted away from the Golden campus. Prerequisite: Restricted to Ph.D. or advanced M.S. candidates. Usually taken after at least one year of graduate residence. Background requirements vary according to nature of field study. Fees are assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL645. VOLCANOLOGY. 3.0 Semester Hrs.

(II) Assigned readings and seminar discussions on volcanic processes and products. Principal topics include pyroclastic rocks, craters and calderas, caldron subsidence, diatremes, volcanic domes, origin and evolution of volcanic magmas, and relation of volcanism to alteration and mineralization. Petrographic study of selected suites of lava and pyroclastic rocks in the laboratory. Prerequisite: none. 1 hour seminar, 6 hours lab; 3 semester hours.

GEOL653. CARBONATE DIAGENESIS AND GEOCHEMISTRY. 3.0 Semester Hrs.

(II) Petrologic, geochemical, and isotopic approaches to the study of diagenetic changes in carbonate sediments and rocks. Topics covered include major near-surface diagenetic environments, subaerial exposure, dolomitization, burial diagenesis, carbonate aqueous equilibria, and the carbonate geochemistry of trace elements and stable isotopes. Laboratory stresses thin section recognition of diagenetic textures and fabrics, x-ray diffraction, and geochemical/isotopic approaches to diagenetic problems. Prerequisite: GEOL624 or equivalent. 4 to 6 hours lecture/ seminar/lab; 3 semester hours.

GEOL660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION ENGINEERING. 3.0 Semester Hrs.

(II) An introduction to the reservoir characterization of carbonate rocks, including geologic description, petrophysics, and production engineering. Develops an understanding of the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises that include reflection seismic, well-log, and core data. Prerequisite: None. 3 hours lecture and seminar; 3 semester hours.

GEOL698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL699. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Geophysics

Degrees Offered

- Professional Masters in Petroleum Reservoir Systems
- Master of Science (Geophysics)
- Master of Science (Geophysical Engineering)
- Doctor of Philosophy (Geophysics)
- Doctor of Philosophy (Geophysical Engineering)

Program Description

Founded in 1926, the Department of Geophysics at Colorado School of Mines is recognized and respected around the world for its programs in applied geophysical research and education.

Geophysics is an interdisciplinary field -- a rich blend of disciplines such as geology, physics, mathematics, computer science, and electrical engineering. Professionals working in the field of geophysics come from programs in these allied disciplines, as well as from formal programs in geophysics.

Geophysicists study and explore the Earth's interior through physical measurements collected at the Earth's surface, in boreholes, from aircraft, and from satellites. Using a combination of mathematics, physics, geology, chemistry, hydrology, and computer science, a geophysicist analyzes these measurements to infer properties and processes within the Earth's complex interior. Noninvasive imaging beneath the surface of Earth and other planets by geophysicists is analogous to noninvasive imaging of the interior of the human body by medical specialists.

The Earth supplies all materials needed by our society, serves as the repository of used products, and provides a home to all its inhabitants. Therefore, geophysics and geophysical engineering have important roles to play in the solution of challenging problems facing the inhabitants of this planet, such as providing fresh water, food, and energy for Earth's growing population, evaluating sites for underground construction and containment of hazardous waste, monitoring noninvasively the aging infrastructures (natural gas pipelines, water supplies, telecommunication conduits, transportation networks) of developed nations, mitigating the threat of geohazards (earthquakes, volcanoes, landslides, avalanches) to populated areas, contributing to homeland security (including detection and removal of unexploded ordnance and land mines), evaluating changes in climate and managing humankind's response to them, and exploring other planets.

Energy companies and mining firms employ geophysicists to explore for hidden resources around the world. Engineering firms hire geophysical engineers to assess the Earth's near-surface properties when sites are chosen for large construction projects and waste-management operations. Environmental organizations use geophysics to conduct groundwater surveys and to track the flow of contaminants. On the global scale, geophysicists employed by universities and government agencies (such as the United States Geological Survey, NASA, and the National Oceanographic and Atmospheric Administration) try to understand such Earth processes as heat flow, gravitational, magnetic, electric, thermal, and stress fields within the Earth's interior. For the past decade, 100% of CSM's geophysics graduates have found employment in their chosen field.

With nearly 20 active faculty members and small class sizes, students receive individualized attention in a close-knit environment. Given the interdisciplinary nature of geophysics, the graduate curriculum requires

students to become thoroughly familiar with geological, mathematical, and physical theory, in addition to exploring the theoretical and practical aspects of the various geophysical methodologies.

Research Emphasis

The Department conducts research in a wide variety of areas that are mostly related, but not restricted, to applied geophysics. Candidates interested in the research activities of a specific faculty member are encouraged to visit the Department's website and to contact that faculty member directly. To give prospective candidates an idea of the types of research activities available in geophysics at CSM, a list of the recognized research groups operating within the Department of Geophysics is given below.

The Center for Wave Phenomena (CWP) is a research group with four faculty members from the Department of Geophysics. With research sponsored by some 30 companies worldwide in the petroleum exploration industry, plus U.S. government agencies, CWP emphasizes the development of theoretical and computational methods for imaging of the Earth's subsurface, primarily through use of the reflection seismic method. Researchers have been involved in forward and inverse problems of wave propagation as well as data processing for data obtained where the subsurface is complex, specifically where it is both heterogeneous and anisotropic. Further information about CWP can be obtained at <http://www.cwp.mines.edu>.

The Reservoir Characterization Project (RCP) integrates the acquisition and interpretation of 3D multicomponent time-lapse seismic reflection and downhole data with geology and petroleum engineering information of existing oil fields to solve complex reservoir challenges and gain improvements in reservoir performance prediction and development optimization. RCP's unique research model emphasizes a multidisciplinary, collaborative approach for practical research. It is an industry-funded research consortium with faculty and graduate-level students from Geophysics, Petroleum Engineering, and Geology disciplines. Read more about RCP at <http://rcp.mines.edu/>.

The Center for Gravity, Electrical & Magnetic Studies (CGEM) in the Department of Geophysics is an academic research center that focuses on the quantitative interpretation of gravity, magnetic, electrical and electromagnetic, and surface nuclear magnetic resonance (NMR) data in applied geophysics. The center brings together the diverse expertise of faculty and students in these different geophysical methods and works towards advancing the state of art in geophysical data interpretation for real-world problems. The emphases of CGEM research are processing and inversion of applied geophysical data. The primary areas of application include petroleum exploration and production, mineral exploration, geothermal, and geotechnical and engineering problems. In addition, environmental problems, infrastructure mapping, archaeology, hydrogeophysics, and crustal studies are also research areas within the Center. There are currently five major focus areas of research within CGEM: Gravity and Magnetism Research Consortium (GMRC), mineral exploration, geothermal exploration, surface NMR, and hydrogeophysics. Research funding is provided by petroleum and mining industries, ERDC, SERDP, and other agencies. More information about CGEM is available on the web at: <http://geophysics.mines.edu/cgem/>.

The Group for Hydrogeophysics and Porous Media focuses on combining geoelectrical (DC resistivity, complex conductivity, self-potential, and EM) and gravity methods with rock physics models at various scales and for various applications including the study of contaminant plumes, geothermal systems, leakage in earth dams and

embankments, and active volcanoes. Website: <http://www.andre-revil.com/research.html>

The Planetary Geophysics Group investigates the geophysical evolution of the terrestrial planets and moons of our solar system using a combination of numerical modeling and geophysical data analysis. Research areas include planetary geodynamics, tectonics, and hydrology. More information is available at <http://inside.mines.edu/~jcahanna/>.

The Earthquake and Active Tectonics Group investigates earthquakes and active faulting using a combination of remote sensing, field work, dating techniques, and seismology. More information, including descriptions of recent and ongoing research, is available at <http://inside.mines.edu/~enissen/>.

Another research strength of the Department is the rock-physics laboratory, which conducts research in rock and fluid properties for basic science as well as for exploration and industrial applications. The primary goal of exploration and production geophysics is to identify fluids, specifically hydrocarbons, in rocks. These applications are successful only with a fundamental understanding of the physical phenomena of transport and storage properties as well as the interactions between fluids and rocks. Rock physics projects center on polar and non-polar fluid storage, fluid distributions and storage in rocks and how these distributions affect characteristics such as wave attenuation, velocity dispersion and seismic signatures.

Program Requirements

The Department offers both traditional, research-oriented graduate programs and a non-thesis professional education program designed to meet specific career objectives. The program of study is selected by the student, in consultation with an advisor, and with thesis committee approval, according to the student's career needs and interests. Specific degrees have specific requirements as detailed below.

Geophysical Engineering Program Objectives

The principal objective for students pursuing the PhD degree in Geophysics or Geophysical Engineering is: Geophysics PhD graduates will be regarded by their employers as effective teachers and/or innovative researchers in their early-career peer group. In support of this objective, the PhD programs in the Department of Geophysics are aimed at achieving these student outcomes:

- Graduates will command superior knowledge of Geophysics and fundamental related disciplines.
- Graduates will independently be able to conduct research leading to significant new knowledge and Geophysical techniques.
- Graduates will be able to report their findings orally and in writing.

The chief objective for students pursuing the MS degree in Geophysics or Geophysical Engineering is: Geophysics MS graduates will be regarded by their employers as effective practitioners addressing earth, energy and environmental problems with geophysical techniques. In support of this objective, the MS programs in the Department of Geophysics aim to achieve these student outcomes:

- Graduates will command superior knowledge of Geophysics and fundamental related disciplines.
- Graduates will be able to conduct original research that results in new knowledge and Geophysical techniques.

- Graduates will be able to report their findings orally and in writing.

Professional Masters in Petroleum Reservoir Systems

This is a multi-disciplinary, non-thesis master's degree for students interested in working as geoscience professionals in the petroleum industry. The Departments of Geophysics, Petroleum Engineering, and Geology and Geological Engineering share oversight for the Professional Masters in Petroleum Reservoir Systems program through a committee consisting of one faculty member from each department. Students gain admission to the program by application to any of the three sponsoring departments. Students are administered by that department into which they first matriculate. A minimum of 36 hours of course credit is required to complete the Professional Masters in Petroleum Reservoir Systems program. Up to 9 credits may be earned in 400-level courses. All other credits toward the degree must be 500 level or above. At least 9 hours must consist of:

One course selected from the following:

GPGN/ PEGNnull419	WELL LOG ANALYSIS AND FORMATION EVALUATION	3.0
GPGN/ PEGNnull519	ADVANCED FORMATION EVALUATION	3.0

Two courses selected from the following:

GEGN439 or GPGN439	MULTIDISCIPLINARY PETROLEUM DESIGN GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
GEGN503 or GPGN503 or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT	3.0
GEGN504 or GPGN504 or PEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT INTEGRATED EXPLORATION AND DEVELOPMENT	3.0

Also, 9 additional hours must consist of one course, each, from the 3 participating departments. The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Master of Science Degrees: Geophysics and Geophysical Engineering

Students may obtain a Master of Science Degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below.

For either Master of Science degree, the minimum credits required include:

Course credits	26.0
Graduate research	12.0
Total Semester Hrs	38.0

While individual courses constituting the degree are determined by the student, and approved by the advisor and thesis committee, courses applied to all MS degrees must satisfy the following specific criteria:

- All course, research, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the Bulletin.
- Up to 9 credits may be satisfied through 400 (senior) level coursework. All remaining course credits applied to the degree must be at the 500 level or above.
- Students must include the following courses in their Master degree program:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
GPGN581	GRADUATE SEMINAR	1.0
GPGN707	GRADUATE RESEARCH CREDIT <small>beyond the required 26.0 course credits</small>	12.0

- Additional courses may also be required by the student's advisor and committee to fulfill background requirements as described below.

Students are admitted into the Master of Science in Geophysics program. If a student would like to obtain the Master of Science in Geophysical Engineering, the student must submit a request to the Department to change to the Master of Science in Geophysical Engineering. The coursework and thesis topic must meet the following specific requirements. Note that these requirements are in addition to those associated with the Master of Science in Geophysics.

- Students must complete, either prior to their arrival at CSM or while at CSM, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- In the opinion of the Geophysics faculty, the student's dissertation topic must be appropriate for inclusion as part of an Engineering degree.

As described in the Master of Science, Thesis and Thesis Defense section of this Bulletin, all MS candidates must successfully defend their MS thesis in an open oral Thesis Defense. The guidelines for the Thesis Defense enforced by the Department of Geophysics generally follow those outlined in the Graduate Departments and Programs section of the Bulletin, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee no later than three weeks prior to the thesis defense date.

Doctor of Philosophy Degrees: Geophysics and Geophysical Engineering

We invite applications to our PhD program not only from those individuals with a background in geophysics, but also from those whose background is in allied disciplines such as geology, physics, mathematics, computer science, and electrical engineering.

Students may obtain a Doctor of Philosophy Degree in either Geophysics or Geophysical Engineering, pursuant to the general and individual program requirements outlined below.

For either PhD degree, at least 72 credits beyond the Bachelors Degree are required. Of that total, at least 24 research credits are required. At least 12 course credits must be completed in a minor program of study, approved by the candidate's PhD thesis committee. Up to 36 course

credits may be awarded by the candidate's committee for completion of a thesis-based Master's Degree.

While individual courses constituting the degree are determined by the student and approved by the student's advisor and committee, courses applied to all PhD degrees must satisfy the following criteria:

- All course, research, minor degree programs, transfer, residence, and thesis requirements are as described in Registration and Tuition Classification and Graduate Degrees and Requirements sections of the Bulletin.
- Up to 9 credits may be satisfied through 400 (senior) level coursework. All remaining course credits applied to the degree must be at the 500 level or above.
- Students must include the following courses in their PhD program:

LICM501	PROFESSIONAL ORAL COMMUNICATION	1.0
SYGN502	INTRODUCTION TO RESEARCH ETHICS	1.0
GPGN681	GRADUATE SEMINAR ? PHD	1.0
GPGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	24.0

Choose two of the following:

SYGN501	THE ART OF SCIENCE	1.0
SYGN600	COLLEGE TEACHING	2.0
LAIS601	ACADEMIC PUBLISHING	2.0
		-
		3.0

- Additional courses may also be required by the student's advisor and committee to fulfill background requirements described below.

Students are admitted into the PhD in Geophysics program. If a student would like to obtain the PhD in Geophysical Engineering, the student must submit a request to the Department to change to the Doctor of Philosophy in Geophysical Engineering. The coursework and thesis topic must meet the following additional requirements:

- Students must complete, either prior to their arrival at CSM or while at CSM, no fewer than 16 credits of engineering coursework. What constitutes coursework considered as engineering is determined by the Geophysics faculty.
- In the opinion of the Geophysics faculty, the student's dissertation topic must be appropriate for inclusion as part of an Engineering degree.

Students in both PhD programs are also required to participate in a practical teaching experience. This must take place within a single semester and include:

- Planning and delivery of a minimum of 6 lecture hours, or 4 lecture hours and 2 labs;
- Creating and evaluating students' homework and laboratory reports, if appropriate; and
- Holding office hours if necessary.

In both PhD programs, students must demonstrate the potential for successful completion of independent research and enhance the breadth of their expertise by completing a Doctoral Research Qualifying Examination no later than two years from the date of enrollment in the program. An extension of one additional year may be petitioned by students through their thesis committees. In the Department of Geophysics, the Doctoral Research Qualifying Examination consists of

the preparation, presentation, and defense of one research project and a thesis proposal. The research project and thesis proposal used in this process must conform to the standards posted on the Department of Geophysics website. As described in the Doctor of Philosophy Thesis Defense section of this bulletin, all PhD candidates must successfully defend their PhD thesis in an open oral Thesis Defense. The guidelines for the Thesis Defense enforced by the Department of Geophysics follow those outlined in the Graduate Departments and Programs section of the Bulletin, with one exception. The Department of Geophysics requires students submit the final draft of their written thesis to their thesis committee not later than three weeks prior to the thesis defense date.

Acceptable Thesis Formats

In addition to traditional dissertations, the Department of Geophysics also accepts dissertations that are compendia of papers published or submitted to peer-reviewed journals. The following guidelines are applied by the Department in determining the suitability of a thesis submitted as a series of written papers.

- All papers included in the dissertation must have a common theme, as approved by a student's thesis committee.
- Papers should be submitted for inclusion in a dissertation in a uniform format and typeset.
- In addition to the individual papers, students must prepare abstract, introduction, discussion, and conclusions sections of the thesis that tie together the individual papers into a unified dissertation.
- A student's thesis committee might also require the preparation and inclusion of various appendices with the dissertation in support of the papers prepared explicitly for publication.

Graduate Program Background Requirements

All graduate programs in Geophysics require that applicants have a background that includes the equivalent of adequate undergraduate preparation in the following areas:

- Mathematics – Linear Algebra or Linear Systems, Differential Equations, and Computer Programming
- Physics – Classical Physics
- Geology – Structural Geology and Stratigraphy
- Geophysics – Courses that include theory and application in three of the following areas: gravity/magnetics, seismic, electrical/electromagnetics, borehole geophysics, remote sensing, and physics of the Earth
- Field experience in the hands-on application of several geophysical methods
- In addition, candidates in the Doctoral program are required to have no less than one year of college-level or two years of high-school-level courses in a single foreign language, or be able to demonstrate proficiency in at least one language other than English.

Professors

Terence K. Young, Professor and Department Head

Thomas L. Davis

Roelof K. Snieder, Keck Foundation Professor of Basic Exploration Science

Ilya D. Tsvankin

Associate Professors

Jeffrey Andrews-Hanna

Thomas M. Boyd, Associate Provost and Dean of Graduate Studies

Yaoguo Li

Andre Revil

Paul C. Sava, C.H. Green Chair of Exploration Geophysics

Assistant Professors

Edwin Nissen

Andrei Swidinsky

Whitney Trainor-Guitton

Professors Emeriti

Frank A. Hadsell

Alexander A. Kaufman

Gary R. Olhoeft

Phillip R. Romig, Jr.

Research Professors

Norman Bleistein, University Emeritus Professor

Dave Hale

Kenneth L. Larner, University Emeritus Professor

Research Associate Professor

Robert D. Benson

Research Assistant Professor

Richard Krahenbuhl

Adjunct Faculty

Timothy Collett

Gavin P. Hayes

Stephen J. Hill

Walter S. Lynn

Charles P. Oden

Bruce VerWest

David J. Wald

Distinguished Senior Scientists

Warren B. Hamilton

Misac N. Nabighian

Research Associate

John W. Stockwell, Jr.

Courses

GPGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GPGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GPGN507. NEAR-SURFACE FIELD METHODS. 3.0 Semester Hrs.

(I) Students design and implement data acquisition programs for all forms of near-surface geophysical surveys. The result of each survey is then modeled and discussed in the context of field design methods. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, even years.

GPGN509. PHYSICAL AND CHEMICAL PROPERTIES AND PROCESSES IN ROCK, SOILS, AND FLUIDS. 3.0 Semester Hrs.

(I) Physical and chemical properties and processes that are measurable with geophysical instruments are studied, including methods of measurement, interrelationships between properties, coupled processes, and processes which modify properties in pure phase minerals and fluids, and in mineral mixtures (rocks and soils). Investigation of implications for petroleum development, minerals extraction, groundwater exploration, and environmental remediation. Prerequisite: none. 3 hours lecture, 3 semester hours.

GPGN511. ADVANCED GRAVITY AND MAGNETIC EXPLORATION. 4.0 Semester Hrs.

(I) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing, and interpreting gravity and magnetic data, methods for the solution of two- and three-dimensional potential field problems, Fourier transforms as applied to gravity and magnetics, the geologic implications of filtering gravity and magnetic data, equivalent distributions, harmonic functions, inversions. Prerequisite: GPGN411. 3 hours lecture, 3 hours lab and field; 4 semester hours.

GPGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.

(II) A detailed review of well logging and other formation evaluation methods will be presented, with the emphasis on the imaging and characterization of hydrocarbon reservoirs. Advanced logging tools such as array induction, dipole sonic, and imaging tools will be discussed. The second half of the course will offer in parallel sessions: for geologists and petroleum engineers on subjects such as pulsed neutron logging, nuclear magnetic resonance, production logging, and formation testing; for geophysicists on vertical seismic profiling, cross well acoustics and electro-magnetic surveys. Prerequisite: GPGN419/PEGN419. 3 hours lecture; 3 semester hours.

GPGN520. ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.

(I) Electromagnetic theory. Instrumentation. Survey planning. Processing of data. Geologic interpretations. Methods and limitations of interpretation. Prerequisite: GPGN302 and GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours. Offered fall semester, odd years.

GPGN521. ADVANCED ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.

(II) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing and interpreting electrical and electromagnetic data, methods for the solution of two- and three-dimensional EM problems, physical modeling, integrated inversions. Prerequisite: GPGN420 or GPGN520. 3 hours lecture, 3 hours lab; 4 semester hours. Offered spring semester, even years.

GPGN530. APPLIED GEOPHYSICS. 3.0 Semester Hrs.

(II) Introduction to geophysical techniques used in a variety of industries (mining, petroleum, environmental and engineering) in exploring for new deposits, site design, etc. The methods studied include gravity, magnetic, electrical, seismic, radiometric and borehole techniques. Emphasis on techniques and their applications are tailored to student interests. The course, intended for non-geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique so that non-specialists can more effectively evaluate the results of geophysical investigations. Prerequisites: PHGN100, PHGN200, MATH111, GEGN401. 3 hours lecture; 3 semester hours.

GPGN535. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.

(I) A survey of computer programming skills most relevant to geophysical data processing, visualization and analysis. Skills enhanced include effective use of multiple programming languages, data structures, multicore systems, and computer memory hierarchies. Problems addressed include multidimensional geophysical image processing, geophysical data acquired at scattered locations, finite-difference approximations to partial differential equations, and other computational problems encountered in research by students. Prerequisites: Experience programming in Java, C, C++ or Fortran. 3 hours lecture, 3 credit hours.

GPGN540. MINING GEOPHYSICS. 3.0 Semester Hrs.

(I) Introduction to gravity, magnetic, electric, radiometric and borehole techniques used primarily by the mining industry in exploring for new deposits but also applied extensively to petroleum, environmental and engineering problems. The course, intended for graduate geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique. Prerequisites: GPGN221, GPGN322, MATH111, MATH112, MATH213. 3 hours lecture; 3 semester hours.

GPGN551. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.

(I, II) Students will probe a range of current methodologies and issues in seismic data processing, and discuss their ongoing and planned research projects. Topic areas include: Statics estimation and compensation, deconvolution, multiple suppression, wavelet estimation, imaging and inversion, anisotropic velocity and amplitude analysis, seismic interferometry, attenuation and dispersion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Every student registers for GPGN551 in only the first semester in residence and receives a grade of PRG. The grade is changed to a letter grade after the student's presentation of thesis research. Prerequisite: none. 1 hour seminar; 1 semester hour.

GPGN552. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.

(I) Introduction to basic principles of elasticity including Hooke's law, equation of motion, representation theorems, and reciprocity. Representation of seismic sources, seismic moment tensor, radiation from point sources in homogeneous isotropic media. Boundary conditions, reflection/transmission coefficients of plane waves, plane-wave propagation in stratified media. Basics of wave propagation in attenuative media, brief description of seismic modeling methods. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN553. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.

(II) This course is focused on the physics of wave phenomena and the importance of wave-theory results in exploration and earthquake seismology. Includes reflection and transmission problems for spherical waves, methods of steepest descent and stationary phase, point-source radiation in layered isotropic media, surface and non-geometrical waves. Discussion of seismic modeling methods, fundamentals of wave propagation in anisotropic and attenuative media. Prerequisite: GPGN552. 3 hours lecture; 3 semester hours. Offered spring semester, even years.

GPGN555. INTRODUCTION TO EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.

(II) Introductory course in observational, engineering, and theoretical earthquake seismology. Topics include: seismogram interpretation, elastic plane waves and surface waves, source kinematics and constraints from seismograms, seismicity and earthquake location, magnitude and intensity estimates, seismic hazard analysis, and earthquake induced ground motions. Students interpret digital data from globally distributed seismic stations. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN558. SEISMIC DATA INTERPRETATION. 3.0 Semester Hrs.

(II) Practical interpretation of seismic data used in exploration for hydrocarbons. Integration with other sources of geological and geophysical information. Prerequisite: GPGN461, GEOL501 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN561. SEISMIC DATA PROCESSING I. 3.0 Semester Hrs.

(I) Introduction to basic principles underlying the processing of seismic data for suppression of various types of noise. Includes the rationale for and methods for implementing different forms of gain to data, and the use of various forms of stacking for noise suppression, such as diversity stacking of Vibroseis data, normal-moveout correction and common-midpoint stacking, optimum-weight stacking, beam steering and the stack array. Also discussed are continuous and discrete one and two-dimensional data filtering, including Vibroseis correlation, spectral whitening, moveout filtering, data interpolation, slant stacking, and the continuous and discrete Radon transform for enhancing data resolution and suppression of multiples and other forms of coherent noise. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN562. SEISMIC DATA PROCESSING II. 3.0 Semester Hrs.

(II) The student will gain understanding of applications of deterministic and statistical deconvolution for wavelet shaping, wavelet compression, and multiple suppression. Both reflection-based and refraction-based statistics estimation and correction for 2-D and 3-D seismic data will be covered, with some attention to problems where subsurface structure is complex. Also for areas of complex subsurface structure, students will be introduced to analytic and interactive methods of velocity estimation. Where the near-surface is complex, poststack and prestack imaging methods, such as layer replacement are introduced to derive dynamic corrections to reflection data. Also discussed are special problems related to the processing of multi-component seismic data for enhancement of shearwave information, and those related to processing of vertical seismic profile data for separation of upgoing and downgoing P- and S-wave arrivals. Prerequisite: GPGN461 and GPGN561. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.

(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GPGN574. GROUNDWATER GEOPHYSICS. 4.0 Semester Hrs.

(II) Description of world groundwater aquifers. Effects of water saturation on the physical properties of rocks. Use of geophysical methods in the exploration, development and production of groundwater. Field demonstrations of the application of the geophysical methods in the solution of some groundwater problems. Prerequisite: none. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN575. PLANETARY GEOPHYSICS. 3.0 Semester Hrs.

Equivalent with GPGN475,

(I) Of the solid planets and moons in our Solar System, no two bodies are exactly alike. This class will provide an overview of the observed properties of the planets and moons, cover the basic physical processes that govern their evolution, and then investigate how the planets differ and why. The overarching goals are to develop a quantitative understanding of the processes that drive the evolution of planetary surfaces and interiors, and to develop a deeper understanding of the Earth by placing it in the broader context of the Solar System. Prerequisites: Graduate standing. 3 hours lecture; 3 semester hours.

GPGN576. SPECIAL TOPICS IN THE PLANETARY SCIENCES. 1.0 Semester Hr.

(I, II) Students will read and discuss papers on a particular topic in the planetary sciences. The choice of topic will change each semester. The emphasis is on key topics related to the current state and evolution of the solid planets and moons in our solar system. Readings will include both seminal papers and current research on the topic. Students will take turns presenting summaries of the papers and leading the ensuing discussion. Prerequisites: Graduate standing, or senior standing. 1 hour lecture; 1 semester hour. Repeatable for credit.

GPGN581. GRADUATE SEMINAR. 1.0 Semester Hr.

(I, II) Presentation describing results of MS thesis research. All students must present their research at an approved public venue before the degree is granted. Every MS student registers for GPGN581 only in his/her first semester in residence and receives a grade of PRG. Thereafter, students must attend the weekly Heiland Distinguished Lecture every semester in residence. The grade of PRG is changed to a letter grade after the student's public research presentation and thesis defense are both complete. 1 hour seminar, 1 semester hour.

GPGN597. SUMMER PROGRAMS. 12.0 Semester Hrs.**GPGN598. SPECIAL TOPICS IN GEOPHYSICS. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN599. GEOPHYSICAL INVESTIGATIONS MS. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN605. INVERSION THEORY. 3.0 Semester Hrs.

(II) Introductory course in inverting geophysical observations for inferring earth structure and processes. Techniques discussed include: Monte-Carlo procedures, Marquardt-Levenburg optimization, and generalized linear inversion. In addition, aspects of probability theory, data and model resolution, uniqueness considerations, and the use of a priori constraints are presented. Students are required to apply the inversion methods described to a problem of their choice and present the results as an oral and written report. Prerequisite: MATH225 and knowledge of a scientific programming language. 3 hours lecture; 3 semester hours.

GPGN651. ADVANCED SEISMOLOGY. 3.0 Semester Hrs.

(I) In-depth discussion of wave propagation and seismic processing for anisotropic, heterogeneous media. Topics include influence of anisotropy on plane-wave velocities and polarizations, traveltimes analysis for transversely isotropic models, anisotropic velocity-analysis and imaging methods, point-source radiation and Green's function in anisotropic media, inversion and processing of multicomponent seismic data, shear-wave splitting, and basics of seismic fracture characterization. Prerequisites: GPGN552 and GPGN553. 3 hours lecture; 3 semester hours.

GPGN658. SEISMIC WAVEFIELD IMAGING. 3.0 Semester Hrs.

(I) Seismic imaging is the process that converts seismograms, each recorded as a function of time, to an image of the earth's subsurface, which is a function of depth below the surface. The course emphasizes imaging applications developed from first principles (elastodynamics relations) to practical methods applicable to seismic wavefield data. Techniques discussed include reverse-time migration and migration by wavefield extrapolation, angle-domain imaging, migration velocity analysis and analysis of angle-dependent reflectivity. Students do independent term projects presented at the end of the term, under the supervision of a faculty member or guest lecturer. Prerequisite: none. 3 hours lecture; 3 semester hours.

GPGN660. MATHEMATICS OF SEISMIC IMAGING AND MIGRATION. 3.0 Semester Hrs.

(II) During the past 40 years geophysicists have developed many techniques (known collectively as ?migration?) for imaging geologic structures deep within the Earth's subsurface. Beyond merely imaging strata, migration can provide information about important physical properties of rocks, necessary for the subsequent drilling and development of oil- and gas-bearing formations within the Earth. In this course the student will be introduced to the mathematical theory underlying seismic migration, in the context of ?inverse scattering imaging theory.? The course is heavily oriented toward problem solving. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN681. GRADUATE SEMINAR ? PHD. 1.0 Semester Hr.

(I, II) Presentation describing results of PhD thesis research. All students must present their research at an approved public venue before the degree is granted. Every PhD student registers for GPGN681 only in his/her first semester in residence and receives a grade of PRG. Thereafter, students must attend the weekly Heiland Distinguished Lecture every semester in residence. The grade of PRG is changed to a letter grade after the student's public research presentation and thesis defense are both complete. 1 hour seminar, 1 semester hour.

GPGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN699. GEOPHYSICAL INVESTIGATION-PHD. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN501. THE ART OF SCIENCE. 1.0 Semester Hr.

This course consists of class sessions and practical exercises. The content of the course is aimed at helping students acquire the skills needed for a career in research. The class sessions cover topics such as the choice of a research topic, making a work plan and executing that plan effectively, what to do when you are stuck, how to write a publication and choose a journal for publication, how to write proposals, the ethics of research, the academic career versus a career in industry, time-management, and a variety of other topics. The course is open to students with very different backgrounds; this ensures a rich and diverse intellectual environment. Prerequisite: none. 1 hour lecture; 1 semester hour.

Liberal Arts and International Studies

2015-2016

Degree Offered

- Master of International Political Economy of Resources

Certificates Offered

- Graduate Certificate in International Political Economy
- Graduate Certificate in Science, Technology, Engineering, and Policy

Minors Offered

- International Political Economy of Resources
- Science, Technology, Engineering, and Policy

Program Description

As the 21st century unfolds, individuals, communities, and nations face major challenges in energy, natural resources, and the environment. While these challenges demand practical ingenuity from engineers and applied scientists, solutions must also take into account social, political, economic, cultural, ethical, and global contexts. CSM students, as citizens and future professionals, confront a rapidly changing society that demands core technical skills complemented by flexible intelligence, original thought, and cultural sensitivity.

Courses in Liberal Arts and International Studies (LAIS) expand students' professional capacities by providing opportunities to explore the humanities, social sciences, and fine arts. Our curricula encourage the development of critical thinking skills that will help students make more informed choices as national and world citizens - promoting more complex understandings of justice, equality, culture, history, development, and sustainability. Students study ethical reasoning, compare and contrast different economies and cultures, and develop arguments from data and analyze globalization. LAIS courses also foster creativity by offering opportunities for self-discovery. Students conduct literary analyses, improve communication skills, play music, learn media theory, and write poetry. These experiences foster intellectual agility, personal maturity, and respect for the complexity of our world.

The Division of Liberal Arts & International Studies offers a graduate degree, the Master of International Political Economy of Resources (MIPER); two graduate certificates in International Political Economy (IPE); a graduate certificate in Science, Technology, Engineering, and Policy (STEP); and a graduate individual minor.

Combined Undergraduate/Graduate Degree Programs

Some students may earn the master's degree as part of CSM's Combined Undergraduate/Graduate programs. Students participating in the combined degree program may double count up to 6 semester hours of 400-level course work from their undergraduate course work.

Please note that CSM students interested in pursuing a Combined Undergraduate/Graduate program are encouraged to make an initial contact with the MIPER Director after completion of the first semester of their sophomore year for counseling on degree application procedures, admissions standards, and degree completion requirements.

See "Combined Undergraduate/Graduate Degree Programs (<http://bulletin.mines.edu/graduate/programs>)" elsewhere in this bulletin for further details.

Admission Requirements

The requirements for admission into LAIS Graduate Programs are as follows:

1. An undergraduate degree with a cumulative grade point average (GPA) at or above 3.0 (4.0 scale) or be a CSM undergraduate with a minimum GPA of 3.0 in LAIS course work.
2. The GRE is required. Under certain circumstances, the GRE requirements can be waived. GMAT scores may be used in lieu of the GRE.
3. A TOEFL score of 580 (paper test), 237 (computer test), or 92-93 (Internet test) or higher is required for students who are non-native English speakers.

Degree Offered

- Master of International Political Economy of Resources

Requirements for a Master of International Political Economy of Resources (MIPER)

The interdisciplinary Master of International Political Economy of Resources (MIPER) aims to train the next generation of social scientists, physical scientists, and engineers so that they possess the critical skills to respond to the global challenges of natural resource management and energy policies in the 21st century. It trains them in quantitative and qualitative methodologies as well as enhancing their skills to understand, analyze, and implement complex solutions in diverse social and political settings around the world. The program is writing- and research-intensive, with a strong focus on verbal and written communication skills in critical issues facing the extractive industries, natural resource management, and national and global energy policies in the broader context of politics, economics, culture and religion.

The Master of International Political Economy of Resources (MIPER) provides students with either a thesis-based or non-thesis professional degree that requires 36 semester hours. Students in the MIPER program may choose to earn one or more minors in other departments. Please see the website <https://miper.mines.edu/> for more information on specific courses associated with the degree.

Non-Thesis Option

Core Courses	15.0
Elective Courses	21.0
Total Semester Hrs	36.0

Thesis Option

Core Courses	15.0
Elective Courses	15.0
Research	6.0
Total Semester Hrs	36.0

Minors Offered

- International Political Economy of Resources
- Science, Technology, Engineering and Policy

International Political Economy of Resources (IPER) Graduate Minor

The IPER minor requires a minimum of nine (9) semester hours for Master students and twelve (12) semester hour for PhD students. Students work with a full-time LAIS faculty member to create a minor that focuses on an area of interest to the student. Courses must be at the 500- or 600-level and may include independent studies and special topics. The minor must be approved by the student's graduate committee and by the LAIS Division.

Science, Technology, Engineering, and Policy (STEP) Graduate Minor

The STEP graduate minor for the MS degree requires a minimum 9 semester hours of course work. The STEP graduate minor for the PhD degree requires a minimum 12 semester hours of course work. In all cases, the required course work must include [LAIS586](#) Science and Technology Policy. Other courses may be selected from a list of recommended courses posted and regularly updated on the LAIS Science and Technology Policy Studies web site, a list which includes some courses from other academic units. Among non-LAIS courses, the MS minor is limited to one such course and the PhD minor and graduate certificate are limited to two such courses. With the approval of the LAIS STEP adviser, it is also possible to utilize a limited number of other courses from the CSM Bulletin as well as transfer courses from other institutions. For more information, please contact Dr. Jason Delborne.

Certificates Offered

- Graduate Certificate in International Political Economy
- Graduate Certificate in Science, Technology, Engineering and Policy

Graduate Certificates

The IPE Graduate Certificate program is 15 credit hour certificate and may focus on either IPE theories, methods, and models; or on specialization, such as regional development (Asia-Pacific, Latin America, Africa, Russia, Eurasia, and the Middle East), international or comparative political economy issues, and specific themes like trade, finance, the environment, gender and ethnicity. It must be approved by the MIPER Director.

The STEP graduate certificate requires a minimum 15 semester hours of course work and must include LAIS586 Science and Technology Policy. It must be approved by the STEP advisor.

Admissions requirements are the same as for the degree program. Please see the MIPER Director for more information.

Professors

Elizabeth Van Wie Davis

Juan C Lucena

Carl Mitcham

Kenneth Osgood, Director of the McBride Honors Program

Associate Professors

Hussein A. Amery

Tina L. Gianquitto, Interim Division Director

Kathleen J. Hancock

John R. Heilbrunn

Jon A. Leydens

James D. Straker

Assistant Professors

Sylvia Gaylord

Derrick Hudson, Director MIPER Program

Jessica Smith Rolston

Professors Emeriti

W. John Cieslewicz

Wilton Eckley

T. Graham Hereford

Barbara M. Olds

Eul-Soo Pang

Anton G. Pegis

Thomas Philipose, University Emeritus Professor

Arthur B. Sacks

Joseph D. Sneed

Robert E.D. Woolsey

Associate Professors Emeriti

Betty J. Cannon

Kathleen H. Ochs

Laura J. Pang

Karen B. Wiley

Teaching Professors

James V. Jesudason

Robert Klimek

Toni Lefton

Sandy Woodson, Undergraduate Advisor

Teaching Associate Professors

Jonathan H. Cullison

Paula A. Farca

Cortney E. Holles

Rose Pass

Teaching Assistant Professors

James Bishop

Olivia Burgess

Sara J. Hitt

Joseph Horan

Rachel Osgood

Seth Tucker

Courses

LAIS521. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0

Semester Hrs.

Analyzes environmental ethics and philosophy including the relation of philosophical perspectives to policy decision making. Critically examines often unstated ethical and/or philosophical assumptions about the environment and how these may complicate and occasionally undermine productive policies. Policies that may be considered include environmental protection, economic development, and energy production and use. 3 hours seminar; 3 semester hours.

LAIS523. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.

This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. 3 hours seminar; 3 semester hours.

LAIS524. RHETORIC, ENERGY & PUBLIC POLICY. 3.0 Semester Hrs.

An introduction to the ways in which rhetoric shapes public policy debates that have broad social impact, particularly debates surrounding resource/energy issues. Students study and evaluate some classical but mostly contemporary rhetorical theories, as well as apply them to resource/energy-related case studies, such as sources within fossil or renewable energy. Students write a research paper and make a policy-shaping contribution to an ongoing public policy debate in fossil or renewable energy.

LAIS525. MEDIA AND THE ENVIRONMENT. 3.0 Semester Hrs.

This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in communications, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of "nature" are constructed. Students will analyze their role as science or technology communicators and will participate in the creation of communications projects related to environmental research on campus. 3 hours seminar; 3 semester hours.

LAIS531. RELIGION AND SECURITY. 3.0 Semester Hrs.

An introduction to the central topics in religion and society. Develops an analysis of civil society in 21st century contexts and connects this analysis with leading debates about the relationship of religion and security. Creates an understanding of diverse religious traditions from the perspective of how they view security. 3 hours lecture and discussion; 3 semester hours.

LAIS535. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.

Explores the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization; institution-building; corporate-community-state interfaces; neoliberalism; privatization; democracy; and public policy formulation as it relates to development goals. 3 hours lecture and discussion; 3 semester hours.

LAIS537. ASIAN DEVELOPMENT. 3.0 Semester Hrs.

Explores the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. 3 hours lecture and discussion; 3 semester hours.

LAIS539. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.

Equivalent with LAIS439,

This course invokes economic, political, social and historical dynamics to help understand the development trajectories that the Middle East has been on in recent decades. This research-intensive graduate seminar discusses the development of Middle Eastern societies from their tribal and agrarian roots to post-industrial ones, and reflects on the pursuant contemporary security issues that both divide and unite the region, and analyzes the effects of globalization on economic development.

LAIS541. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.

Provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. 3 hours lecture and discussion; 3 semester hours.

LAIS542. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.

Examines the relationship between natural resources and wars in Africa. It begins by discussing the complexity of Africa with its several many languages, peoples, and geographic distinctions. Among the most vexing challenges for Africa is the fact that the continent possesses such wealth and yet still struggles with endemic warfare, which is hypothetically caused by greed and competition over resource rents. Readings are multidisciplinary and draw from policy studies, economics, and political science. Students will acquire an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and war in Africa. The course helps students apply the different theories to specific cases and productive sectors. 3 hours lecture and discussion; 3 semester hours.

LAIS545. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.

Introduces students to the field of International Political Economy (IPE). IPE scholars examine the intersection between economics and politics, with a focus on interactions between states, organizations, and individuals around the world. Students will become familiar with the three main schools of thought on IPE: Realism (mercantilism), Liberalism, and Historical Structuralism (including Marxism and feminism) and will evaluate substantive issues such as the role of international organizations (the World Trade Organization, the World Bank, and the International Monetary Fund), the monetary and trading systems, regional development, international development, foreign aid, debt crises, multinational corporations, and globalization. 3 hours seminar; 3 semester hours.

LAIS546. GLOBALIZATION. 3.0 Semester Hrs.

Assesses the historical development of international political economy as a discipline. Originally studied as the harbinger of today's political science, economics, sociology, anthropology, and history, International Political Economy is the multidisciplinary study of the relationship between states and markets. A fuller understanding will be achieved through research and data analysis as well as interpretation of case studies. Prerequisites: LAIS345 and any 400-level IPE course, or two equivalent courses. 3 hours lecture and discussion; 3 semester hours.

LAIS548. GLOBAL ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.

Examines the increasing importance of environmental policy and politics in international political economy and global international relations. Using historical analysis and interdisciplinary environmental studies perspectives, this course explores global environmental problems that have prompted an array of international and global regimes and other approaches to deal with them. It looks at the impact of environmental policy and politics on development, and the role that state and nonstate actors play, especially in North-South relations and in the pursuit of sustainability. Prerequisites: any two IPE courses at the 300-level; or one IPE course at the 400 level; or one IPE course at the 300 level and one environmental policy/issues course at the 400 level. 3 hours lecture and discussion; 3 semester hours.

LAIS550. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.

Uses social science analytical tools and readings as well as indices prepared by organizations, such as the World Bank and the International Monetary Fund, to create assessments of the political, social, economic, environmental and security risks that multinational corporations may face as they expand operations around the world. Students will develop detailed political risk reports for specific countries that teams collectively select. Prerequisite: LAIS 545 and IPE Minor. 3 hours seminar; 3 semester hours.

LAIS551. POL RISK ASSESS RESEARCH SEM. 1.0 Semester Hr.

When offered, this international political economy seminar must be taken concurrently with LAIS450/LAIS550, Political Risk Assessment. Its purpose is to acquaint the student with empirical research methods and sources appropriate to conducting a political risk assessment study, and to hone the students analytical abilities. Prerequisite: None. Concurrent enrollment in LAIS450/LAIS550. 1 hour seminar; 1 semester hour.

LAIS552. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.

Addresses the problem of corruption and its impact on development. Readings are multidisciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or taking might occur. 3 hours lecture and discussion; 3 semester hours.

LAIS553. ETHNIC CONFLICT IN THE GLOBAL PERSPECTIVE. 3.0 Semester Hrs.

Studies core economic, cultural, political, and psychological variables that pertain to ethnic identity and ethnic contention, and analyzes their operation in a wide spectrum of conflict situations around the globe. Considers ethnic contention in institutionalized contexts, such as the politics of affirmative action, as well as in non-institutionalized situations, such as ethnic riots and genocide. Concludes by asking what can be done to mitigate ethnic conflict and what might be the future of ethnic group identification. 3 hours seminar; 3 semester hours.

LAIS555. INTERNATIONAL ORGANIZATIONS. 3.0 Semester Hrs.

Familiarizes students with the study of international organizations: how they are created, how they are organized and what they try to accomplish. By the end of the semester, students will be familiar with the role of international organization in the world system as well as the analytical tools used to analyze them. 3 hours lecture and discussion; 3 semester hours.

LAIS556. POWER AND POLITICS IN EURASIA. 3.0 Semester Hrs.

This seminar covers the major international economic and security issues affecting the fifteen states that once comprised the Soviet Union. The class begins with an overview of the Soviet Union and its collapse in 1991, and then focuses on the major international economic and security dilemmas facing the former Soviet states and how the US, China, European Union and other countries, as well as international organizations affect politics in the former Soviet states. Special attention will be paid to oil, natural gas, and other energy sectors in the region. 3 hours seminar; 3 semester hours.

LAIS557. INTRODUCTION TO CONFLICT MANAGEMENT. 3.0 Semester Hrs.

Introduces graduate students to the issue of international conflict management with an emphasis on conflict in resource abundant countries. Its goal is to develop analytic tools to acquire a systematic means to think about conflict management in the international political economy and to assess and react to such events. The course addresses the causes of contemporary conflicts with an initial focus on weak states, armed insurgencies, and ethnic conflict. It then turns to intra-state war as a failure of conflict management before discussing state failure, intractable conflicts, and efforts to build peace and reconstruct failed, post-conflict states. 3 hours lecture and discussion; 3 semester hours.

LAIS558. NATURAL RESOURCES AND DEVELOPMENT. 3.0 Semester Hrs.

Examines the relationship between natural resources and development. It begins by discussing theories of development and how those theories account for specific choices among resource abundant countries. From the theoretical readings, students examine sector specific topics in particular cases. These subjects include oil and natural gas in African and Central Asian countries; hard rock mining in West Africa and East Asia; gemstone mining in Southern and West Africa; contracting in the extractive industries; and corporate social responsibility. Readings are multidisciplinary and draw from policy studies, economics, and political science to provide students an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and development. 3 hours lecture and discussion; 3 semester hours.

LAIS559. INTERNATIONAL INDUSTRIAL PSYCHOLOGY. 3.0**Semester Hrs.**

This course has, as its primary aim, the equipping of a future consultant to deal with the cultural, socioeconomic, behavioral, psychological, ethical, and political problems in the international workplace. Specific materials covered are: Early experimentation with small group dynamics relative to economic incentive; Hawthorne experiments; experiments of Asch on perception, Analysis of case studies of work productivity in service and technological industries. Review of work of F.W. Taylor, Douglas McGregor, Blake & Mouton, and others in terms of optimum working conditions relative to wage and fringe benefits. Review of Niccolò Machiavelli's *The Prince and the Discourses*, and *The Art of War* by Sun Tzu with application to present times and international cultural norms. The intent of this course is to teach the survival, report writing, and presentation skills, and cultural awareness needed for success in the real international business world. The students are organized into small groups and do a case each week requiring a presentation of their case study results, and a written report of the results as well. (Textbooks: *Human Side of Enterprise* by Douglas McGregor, *Principles of Scientific Management* by F.W. Taylor, *The Art of War* by Sun Tzu, *Up The Organization* by Robert Townsend, *The Prince and the Discourses* of Niccolò Machiavelli, and *The Managerial Grid* by Blake & Mouton.) 3 hours seminar; 3 semester hours.

LAIS560. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.

Examines geopolitical theories and how they help us explain and understand contemporary developments in the world. Empirical evidence from case studies help students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of governmental policies and corporate decisions. Prerequisites: any two IPE courses at the 300-level, or one IPE course at the 400 level. 3 hours lecture and discussion; 3 semester hours.

LAIS564. QUANTITATIVE METHODS FOR THE SOCIAL SCIENCES.**3.0 Semester Hrs.**

Teaches basic methods of quantitative empirical research in the social sciences. Places social science in the broader context of scientific inquiry by addressing the role of observation and hypothesis testing in the social sciences. The focus is on linear regression and group comparisons, with attention to questions of research design, internal validity, and reliability. 3 hours lecture and discussion; 3 semester hours.

LAIS565. SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.

Provides an introduction to foundational concepts, themes, and questions developed within the interdisciplinary field of science and technology studies (STS). Readings address anthropological understandings of laboratory practice, sociological perspectives on the settling of techno-scientific controversies, historical insights on the development of scientific institutions, philosophical stances on the interactions between technology and humans, and relationships between science and democracy. Students complete several writing assignments, present material from readings and research, and help to facilitate discussion. 3 hours lecture and discussion; 3 semester hours.

LAIS570. HISTORY OF SCIENTIFIC THOUGHT. 3.0 Semester Hrs.

This course offers a critical examination of the history of scientific thought, investigation, discovery, and controversy in a range of historical contexts. This course, which examines the transition from descriptive and speculative science to quantitative and predictive science, will help students understand the broad context of science, technology, and social relations, a key component of the MEPS program framework. 3 hours lecture and discussion; 3 semester hours.

LAIS577. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.

Analyzes the relationship between engineering and sustainable community development (SCD) from historical, political, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of sustainability, development, and "helping", and the role that engineering might play in each. Will include critical explorations of strengths and limitations of dominant methods in engineering problem solving, design and research for working in SCD. Through case-studies, students will analyze and evaluate projects in SCD and develop criteria for their evaluation. 3 hours lecture and discussion; 3 semester hours.

LAIS578. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.

(II) Explores the meaning of social justice in different areas of social life and the role that engineers and engineering can play in promoting or defending social justice. Begins with students' exploration of their own social locations, alliances, and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Offers understandings of why and how engineering has on occasion been aligned with or divergent from specific social justice issues and causes. 3 hours seminar; 3 semester hours.

LAIS586. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.

Examines current issues relating to science and technology policy in the United States and, as appropriate, in other countries. 3 hours lecture and discussion; 3 semester hours.

LAIS587. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.

Explores environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. 3 hours lecture and discussion; 3 semester hours.

LAIS588. WATER POLITICS AND POLICY. 3.0 Semester Hrs.

Examines water policies and the political and governmental processes that produce them, as an example of natural resource politics and policy in general. Group discussion and independent research on specific politics and policy issues. Primary but not exclusive focus on the U.S. 3 hours lecture and discussion; 3 semester hours.

LAIS589. NUCLEAR POWER AND PUBLIC POLICY. 3.0 Semester Hrs.

A general introduction to research and practice concerning policies and practices relevant to the development and management of nuclear power. Corequisite: PHGN590 Nuclear Reactor Physics. 3 hours lecture and seminar; 3 semester hours.

LAIS590. ENERGY AND SOCIETY. 3.0 Semester Hrs.

(II) The course begins with a brief introduction to global energy production and conservation, focusing on particular case studies that highlight the relationship among energy, society, and community in different contexts. The course examines energy successes and failures wherein communities, governments, and/or energy companies come together to promote socially just and economically viable forms of energy production/conservation. The course also explores conflicts driven by energy development. These case studies are supplemented by the expertise of guest speakers from industry, government, NGOs, and elsewhere. Areas of focus include questioning the forward momentum of energy production, its social and environmental impact, including how it distributes power, resources and risks across different social groups and communities. 3 hours seminar; 3 semester hours.

LAIS598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

LAIS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

LAIS601. ACADEMIC PUBLISHING. NaN Semester Hrs.

Students will finish this course with increased knowledge of general and discipline- specific writing conversations as well as the ability to use that knowledge in publishing portions of theses or dissertations. Beyond the research article, students will also have the opportunity to learn more about genres such as conference abstracts, conference presentations, literature reviews, and research funding proposals. Prerequisite: Must have completed one full year (or equivalent) of graduate school course work. Variable credit: 2 or 3 semester hours.

LAIS698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

LAIS699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

LAIS707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

LICM501. PROFESSIONAL ORAL COMMUNICATION. 1.0 Semester Hr.

A five-week course which teaches the fundamentals of effectively preparing and presenting messages. "Hands-on" course emphasizing short (5- and 10-minute) weekly presentations made in small groups to simulate professional and corporate communications. Students are encouraged to make formal presentations which relate to their academic or professional fields. Extensive instruction in the use of visuals. Presentations are rehearsed in class two days prior to the formal presentations, all of which are video-taped and carefully evaluated. 1 hour lecture/lab; 1 semester hour.

SYGN502. INTRODUCTION TO RESEARCH ETHICS. 1.0 Semester Hr.

A five-week course that introduces students to the various components of responsible and research practices. Topics covered move from issues related to the planning of research through the conducting of research to the dissemination of research results. The course culminates with students writing and defending their ethics statements. 1 hour lecture/lab; 1 semester hour.

Mining Engineering

Degrees Offered

- Master of Engineering (Engineer of Mines)
- Master of Science (Mining and Earth Systems Engineering)
- Doctor of Philosophy (Mining and Earth Systems Engineering)

Program Description

The program has two distinctive, but inherently interwoven specialties.

The **Mining Engineering** area or specialty is predominantly for mining engineers and it is directed towards the traditional mining engineering fields. Graduate work is normally centered around subject areas such as mine planning and development, computer aided mine design, rock mechanics, operations research applied to the mineral industry, environment and sustainability considerations, mine mechanization, mine evaluation, finance and management and similar mining engineering topics.

The **Earth Systems Engineering** area or specialty is designed to be distinctly interdisciplinary by merging the mining engineering fundamentals with civil, geotechnical, environmental or other engineering into advanced study tracks in earth systems, rock mechanics and earth structural systems, underground excavation, and construction systems. This specialty is open for engineers with different sub-disciplinary backgrounds, but interested in working and/or considering performing research in mining, tunneling, excavation and underground construction areas.

Graduate work is normally centered around subject areas such as site characterization, environmental aspects, underground construction and tunneling (including microtunneling), excavation methods and equipment, mechanization of mines and underground construction, environmental and management aspects, modeling and design in geoenvironmental engineering.

Program Requirements

The Master of Science degree in Mining and Earth Systems Engineering has two options available. Master of Science - Thesis and Master of Science - Non-Thesis.

Thesis Option

Course work (minimum)	21.0
Research, approved by the graduate committee	9.0
Master's Thesis	
Total Semester Hrs	30.0

Non-Thesis Option

Course work (minimum) *	30.0
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* Six (6) credit hours may be applied towards the analytical report writing, if required.

The Master of Engineering degree (Engineer of Mines) in Mining Engineering includes all the requirements for the M.S. degree, with the sole exception that an "engineering report" is required rather than a Master's Thesis.

The Doctor of Philosophy degree in Mining and Earth Systems Engineering requires a total of 72 credit hours, beyond the bachelor's degree.

Course work (maximum)	48.0
Research (minimum)	24.0
Total Semester Hrs	72.0

Those with an MSc in an appropriate field may transfer a maximum of 30 credit hours of course work towards the 48 credit hour requirement upon the approval of the advisor and thesis committee. The thesis must be successfully defended before a doctoral committee.

Prerequisites

Students entering a graduate program for the master's or doctor's degree are expected to have had much the same undergraduate training as that required at Colorado School of Mines in mining, if they are interested in the traditional mining specialty. Students interested in the Earth Systems engineering specialty with different engineering sub-disciplinary background may also require special mining engineering subjects depending upon their graduate program. Deficiencies if any, will be determined by the Department of Mining Engineering on the basis of students' education, experience, and graduate study.

For specific information on prerequisites, students are encouraged to refer to a copy of the Mining Engineering Department's Departmental Guidelines and Regulations (p. 207) for Graduate Students, available from the Mining Engineering Department.

Required Curriculum

Graduate students, depending upon their specialty and background may be required to complete two of the three core courses listed below during their program of study at CSM. These courses are:

MNGN508	ADVANCED ROCK MECHANICS	3.0
MNGN512	SURFACE MINE DESIGN	3.0
MNGN516	UNDERGROUND MINE DESIGN	3.0

In addition, all full-time graduate students are required to register for and attend MNGN625 - Graduate Mining Seminar each semester while in residence, except in the case of extreme circumstances. For these circumstances, consideration will be given on a case-by-case basis by the coordinator or the Department Head. It is expected that part time students participate in MNGN625 as determined by the course coordinator or the Department Head. Although it is mandatory to enroll in MNGN625 each semester, this course will only count as one credit hour for the total program.

Fields of Research

The Mining Engineering Department focuses on the following fundamental areas:

- Geomechanics, Rock Mechanics and Stability of Underground and Surface Excavations

- Computerized Mine Design and Related Applications (including Geostatistical Modeling)
- Advanced Integrated Mining Systems Incorporating Mine Mechanization and Mechanical Mining Systems
- Underground Excavation (Tunneling) and Construction
- Site Characterization and Geotechnical Investigations, Modeling and Design in Geoengineering.
- Rock Fragmentation
- Mineral Processing, Communitation, Separation Technology
- Bulk Material Handling

Department Head

Priscilla P. Nelson

Professors

Kadri Dagdelen

Priscilla P. Nelson

M. Ugur Ozbay

Associate Professors

Mark Kuchta

Hugh B. Miller

Masami Nakagawa

Assistant Professors

Elizabeth A. Holley

Rennie Kaunda

Research Professors

Jurgen F. Brune

M. Stephen Enders

Research Associate Professor

Vilem Petr

Adjunct Faculty

John W. Grubb

Wm. Mark Hart

Raymond Henn

Paul Jones

Andy Schissler

D. Erik Spiller

William R. Wilson

Courses

GOGN501. SITE INVESTIGATION AND CHARACTERIZATION. 3.0 Semester Hrs.

An applications oriented course covering: geological data collection, geophysical methods for site investigation; hydrological data collection; materials properties determination; and various engineering classification systems. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN502. SOLID MECHANICS APPLIED TO ROCKS. 3.0 Semester Hrs.

An introduction to the deformation and failure of rocks and rock masses and to the flow of groundwater. Principles of displacement, strain and stress, together with the equations of equilibrium are discussed. Elastic and plastic constitutive laws, with and without time dependence, are introduced. Concepts of strain hardening and softening are summarized. Energy principles, energy changes caused by underground excavations, stable and unstable equilibria are defined. Failure criteria for intact rock and rock masses are explained. Principles of numerical techniques are discussed and illustrated. Basic laws and modeling of groundwater flows are introduced. Prerequisite: Introductory Rock Mechanics. 3 hours lecture; 3 semester hours.

GOGN503. CHARACTERIZATION AND MODELING LABORATORY. 3.0 Semester Hrs.

An applications oriented course covering: Advanced rock testing procedures; dynamic rock properties determination; on-site measurements; and various rock mass modeling approaches. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN504. SURFACE STRUCTURES IN EARTH MATERIALS. 3.0 Semester Hrs.

Principles involved in the design and construction of surface structures involving earth materials. Slopes and cuts. Retaining walls. Tailing dams. Leach dumps. Foundations. Piles and piers. Extensive use of case examples. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN505. UNDERGROUND EXCAVATION IN ROCK. 3.0 Semester Hrs.

Components of stress, stress distributions, underground excavation failure mechanisms, optimum orientation and shape of excavations, excavation stability, excavation support design, ground treatment and rock pre-reinforcement, drill and blast excavations, mechanical excavation, material haulage, ventilation and power supply, labor requirements and training, scheduling and costing of underground excavations, and case histories. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN625. GEO-ENGINEERING SEMINAR. 1.0 Semester Hr.

Discussions presented by graduate students, staff, and visiting lectures on research and development topics of general interest. Required of all graduate students in Geo-Engineering every semester, during residence. Prerequisite: Enrollment in Geo-Engineering Program. 1 semester hour upon completion of thesis or residence.

MNGN501. REGULATORY MINING LAWS AND CONTRACTS. 3.0 Semester Hrs.

(I) Basic fundamentals of engineering law, regulations of federal and state laws pertaining to the mineral industry and environment control. Basic concepts of mining contracts. Offered in even numbered years. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN503. MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT. 3.0 Semester Hrs.

(I, II) The primary focus of this course is to provide students an understanding of the fundamental principles of sustainability and how they influence the technical components of a mine's life cycle, beginning during project feasibility and extending through operations to closure and site reclamation. Course discussions will address a wide range of traditional engineering topics that have specific relevance and impact to local and regional communities, such as mining methods and systems, mine plant design and layout, mine operations and supervision, resource utilization and cutoff grades, and labor. The course will emphasize the importance of integrating social, political, and economic considerations into technical decision-making and problem solving. 3 hours lecture; 3 semester hours.

MNGN504. TUNNELING. 3.0 Semester Hrs.

(II) Modern tunneling techniques. Emphasis on evaluation of ground conditions. Estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN505. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.

(I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN506. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.

Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of insitu and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN507. ADVANCED DRILLING AND BLASTING. 3.0 Semester Hrs.

(I) An advanced study of the theories of rock penetration including percussion, rotary, and rotary percussion drilling. Rock fragmentation including explosives and the theories of blasting rock. Application of theory to drilling and blasting practice at mines, pits, and quarries. Prerequisite: MNGN407. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN508. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.

Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. Insitu stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours.

MNGN509. EXCAVATION PROJECT MANAGEMENT. 2.0 Semester Hrs.

Equivalent with GOGN506,

(II) Successful implementation and management of surface and underground construction projects, preparation of contract documents, project bidding and estimating, contract awarding and notice to proceed, value engineering, risk management, construction management and dispute resolution, evaluation of differing site conditions claims. Prerequisite: MNGN210, 2 hour lecture, 2 semester hours.

MNGN510. FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT. 3.0 Semester Hrs.

Specifically designed for non-majors, the primary focus of this course is to provide students with a fundamental understanding of how mineral resources are found, developed, mined, and ultimately reclaimed. The course will present a wide range of traditional engineering and economic topics related to: exploration and resource characterization, project feasibility, mining methods and systems, mine plant design and layout, mine operations and scheduling, labor, and environmental and safety considerations. The course will emphasize the importance of integrating social (human), political, and environmental issues into technical decision-making and design. 3 hours lecture; 3 semester hours.

MNGN511. MINING INVESTIGATIONS. 2-4 Semester Hr.

(I, II) Investigational problems associated with any important aspect of mining. Choice of problem is arranged between student and instructor. Prerequisite: none. Lecture, consultation, lab, and assigned reading; 2 to 4 semester hours.

MNGN512. SURFACE MINE DESIGN. 3.0 Semester Hrs.

Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore estimates, unit operations, equipment selection, final pit determinations, short- and long-range planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210. 3 hours lecture; 3 semester hours.

MNGN514. MINING ROBOTICS. 3.0 Semester Hrs.

(I) Fundamentals of robotics as applied to the mining industry. The focus is on mobile robotic vehicles. Topics covered are mining applications, introduction and history of mobile robotics, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path finding. Prerequisite: CSCI404. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN515. MINE MECHANIZATION AND AUTOMATION. 3.0 Semester Hrs.

This course will provide an in-depth study of the current state of the art and future trends in mine mechanization and mine automation systems for both surface and underground mining, review the infrastructure required to support mine automation, and analyze the potential economic and health and safety benefits. Prerequisite: MNGN312, MNGN314, MNGN316. 2 hours lecture, 3 hours lab; 3 semester hours. Fall of odd years.

MNGN516. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.

Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost estimates. Prerequisite: MNGN210. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN517. ADVANCED UNDERGROUND MINING. 3.0 Semester Hrs.

(II) Review and evaluation of new developments in advanced underground mining systems to achieve improved productivity and reduced costs. The major topics covered include: mechanical excavation techniques for mine development and production, new haulage and vertical conveyance systems, advanced ground support and roof control methods, mine automation and monitoring, new mining systems and future trends in automated, high productivity mining schemes. Prerequisite: Underground Mine Design (e.g., MNGN314). 3 hours lecture; 3 semester hours.

MNGN518. ADVANCED BULK UNDERGROUND MINING TECHNIQUES. 3.0 Semester Hrs.

This course will provide advanced knowledge and understanding of the current state-of-the-art in design, development, and production in underground hard rock mining using bulk-mining methods. Design and layout of sublevel caving, block caving, open stoping and blasthole stoping systems. Equipment selection, production scheduling, ventilation design, and mining costs. Prerequisites: MNGN314, MNGN516. 2 hours lecture, 3 hours lab; 3 semester hours. Spring of odd years.

MNGN519. ADVANCED SURFACE COAL MINE DESIGN. 3.0 Semester Hrs.

(II) Review of current manual and computer methods of reserve estimation, mine design, equipment selection, and mine planning and scheduling. Course includes design of a surface coal mine for a given case study and comparison of manual and computer results. Prerequisite: MNGN312, 316, 427. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN520. ROCK MECHANICS IN UNDERGROUND COAL MINING. 3.0 Semester Hrs.

(I) Rock mechanics consideration in the design of room-and-pillar, longwall, and shortwall coal mining systems. Evaluation of bump and outburst conditions and remedial measures. Methane drainage systems. Surface subsidence evaluation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN522. FLOTATION. 3.0 Semester Hrs.

Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN523. SELECTED TOPICS. 2-4 Semester Hr.

(I, II) Special topics in mining engineering, incorporating lectures, laboratory work or independent study, depending on needs. This course may be repeated for additional credit only if subject material is different. Prerequisite: none. 2 to 4 semester hours. Repeatable for credit under different titles.

MNGN524. ADVANCED MINE VENTILATION. 3.0 Semester Hrs.

(I) Advanced topics of mine ventilation including specific ventilation designs for various mining methods, ventilation numerical modeling, mine atmosphere management, mine air cooling, prevention and ventilation response to mine fires and explosions, mine dust control. Prerequisites: MNGN424 Mine Ventilation. Lecture and Lab Contact Hours: 3 hours lecture; 3 semester credit hours.

MNGN525. INTRODUCTION TO NUMERICAL TECHNIQUES IN ROCK MECHANICS. 3.0 Semester Hrs.

(I) Principles of stress and infinitesimal strain analysis are summarized, linear constitutive laws and energy methods are reviewed. Continuous and laminated models of stratified rock masses are introduced. The general concepts of the boundary element and finite element methods are discussed. Emphasis is placed on the boundary element approach with displacement discontinuities, because of its relevance to the modeling of the extraction of tabular mineral bodies and to the mobilization of faults, joints, etc. Several practical problems, selected from rock mechanics and subsidence engineering practices, are treated to demonstrate applications of the techniques. Prerequisite: MNGN321, EGGN320, or equivalent courses, MATH455. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN526. MODELING AND MEASURING IN GEOMECHANICS. 3.0 Semester Hrs.

(II) Introduction to instruments and instrumentation systems used for making field measurements (stress, convergence, deformation, load, etc.) in geomechanics. Techniques for determining rock mass strength and deformability. Design of field measurement programs. Interpretation of field data. Development of predictive models using field data. Introduction to various numerical techniques (boundary element, finite element, FLAC, etc.) for modeling the behavior of rock structures. Demonstration of concepts using various case studies. Prerequisite: Graduate standing. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN527. THEORY OF PLATES AND SHELLS. 3.0 Semester Hrs.

Classical methods for the analysis of stresses in plate type structure are presented first. The stiffness matrices for plate element will be developed and used in the finite element method of analysis. Membrane and bending stresses in shells are derived. Application of the theory to tunnels, pipes, pressure vessels, and domes, etc., will be included. Prerequisites: EGGN320. 3 hours lecture; 3 credit hours.

MNGN528. MINING GEOLOGY. 3.0 Semester Hrs.

(I) Role of geology and the geologist in the development and production stages of a mining operation. Topics addressed: mining operation sequence, mine mapping, drilling, sampling, reserve estimation, economic evaluation, permitting, support functions. Field trips, mine mapping, data evaluation, exercises and term project. Prerequisite: GEGN401 or GEGN405. 2 hours lecture/seminar, 3 hours laboratory: 3 semester hours. Offered in even years.

MNGN529. URANIUM MINING. 2.0 Semester Hrs.

(I) Overview and introduction to the principles of uranium resource extraction and production. All aspects of the uranium fuel cycle are covered, including the geology of uranium, exploration for uranium deposits, mining, processing, environmental issues, and health and safety aspects. A lesser emphasis will be placed on nuclear fuel fabrication, nuclear power and waste disposal.

MNGN530. INTRODUCTION TO MICRO COMPUTERS IN MINING. 3.0 Semester Hrs.

(I) General overview of the use of PC based micro computers and software applications in the mining industry. Topics include the use of: database, CAD, spreadsheets, computer graphics, data acquisition, and remote communications as applied in the mining industry. Prerequisite: Any course in computer programming. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN536. OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY. 3.0 Semester Hrs.

Analysis of exploration, mining, and metallurgy systems using statistical analysis. Monte Carlo methods, simulation, linear programming, and computer methods. Prerequisite: MNGN433. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in even years.

MNGN538. GEOSTATISTICAL ORE RESERVE ESTIMATION. 3.0 Semester Hrs.

(I) Introduction to the application and theory of geostatistics in the mining industry. Review of elementary statistics and traditional ore reserve calculation techniques. Presentation of fundamental geostatistical concepts, including: variogram, estimation variance, block variance, kriging, geostatistical simulation. Emphasis on the practical aspects of geostatistical modeling in mining. Prerequisite: MATH323 or equivalent course in statistics; graduate or senior status. 3 hours lecture; 3 semester hours.

MNGN539. ADVANCED MINING GEOSTATISTICS. 3.0 Semester Hrs.

(II) Advanced study of the theory and application of geostatistics in mining engineering. Presentation of state-of-the-art geostatistical concepts, including: robust estimation, nonlinear geostatistics, disjunctive kriging, geostatistical simulation, computational aspects. This course includes presentations by many guest lecturers from the mining industry. Emphasis on the development and application of advanced geostatistical techniques to difficult problems in the mining industry today. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN540. CLEAN COAL TECHNOLOGY. 3.0 Semester Hrs.

(I, II) Clean Energy - Gasification of Carbonaceous Materials - including coal, oil, gas, plastics, rubber, municipal waste and other substances. This course also covers the process of feedstock preparation, gasification, cleaning systems, and the output energy blocks along with an educational segment on CO products. These output energy blocks include feedstock to electrical power, feedstock to petroleum liquids, feedstock to pipeline quality gas. The course covers co-product development including urea, fertilizers, CO₂ extraction/sequestration and chemical manufacturing.

MNGN545. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.

Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture. 3 semester hours.

MNGN549. MARINE MINING SYSTEMS. 3.0 Semester Hrs.

(I) Define interdisciplinary marine mining systems and operational requirements for the exploration survey, sea floor mining, hoisting, and transport. Describe and design components of deep-ocean, manganese-nodule mining systems and other marine mineral extraction methods. Analyze dynamics and remote control of the marine mining systems interactions and system components. Describe the current state-of-the-art technology, operational practice, trade-offs of the system design and risk. Prerequisite: EGGN351, EGGN320, GEOC408. 3 hours lecture; 3 semester hours. Offered alternate even years.

MNGN550. NEW TECHNIQUES IN MINING. 3.0 Semester Hrs.

(II) Review of various experimental mining procedures, including a critical evaluation of their potential applications. Mining methods covered include deep sea nodule mining, in situ gassification of coal, in situ retorting of oil shale, solution mining of soluble minerals, in situ leaching of metals, geothermal power generation, oil mining, nuclear fragmentation, slope caving, electro-thermal rock penetration and fragmentation. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN552. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.

(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status. 3 hours lecture, 3 semester hours. Offered in spring.

MNGN559. MECHANICS OF PARTICULATE MEDIA. 3.0 Semester Hrs.

(1) This course allows students to establish fundamental knowledge of quasi-static and dynamic particle behavior that is beneficial to interdisciplinary material handling processes in the chemical, civil, materials, metallurgy, geophysics, physics, and mining engineering. Issues of interest are the definition of particle size and size distribution, particle shape, nature of packing, quasi-static behavior under different external loading, particle collisions, kinetic theoretical modeling of particulate flows, molecular dynamic simulations, and a brief introduction of solid-fluid two-phase flows. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, every other year.

MNGN560. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.

(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregate industries. The course will cover resource definition, quarry planning and design, extraction, and processing of minerals for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth.

MNGN565. MINE RISK MANAGEMENT. 3.0 Semester Hrs.

(II) Fundamentals of identifying, analyzing, assessing and treating risks associated with the feasibility, development and operation of mines. Methodologies for identifying, assessing and treating risks will be presented and practiced in case studies and exercises. Concepts and principles for analyzing risks will be demonstrated and practiced utilizing deterministic and stochastic models, deductive models, decision trees and other applicable principles. Prerequisites: Graduate student or senior in Mining Engineering or graduate students or seniors in other curricula. 3 hours lecture; 3 semester hours.

MNGN570. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.

(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN575. HEAT MINING. 3.0 Semester Hrs.

(I) Heat Mining focuses on identifying available sub-surface heat sources. Heat trapped in crystalline rock deep underground is available by engineering an artificial geothermal system. Hot geothermal fluid, heat generated by underground coal fire and hot water trapped in abandoned underground mine are some of other examples. We will discuss how to find them, how to estimate them, and how to extract and convert them to a usable energy form. The concept of sustainable resource development will be taught as the foundation of heat mining. Prerequisites: None. 3 hours lecture; 3 semester hours.

MNGN585. MINING ECONOMICS. 3.0 Semester Hrs.

(I) Advanced study in mine valuation with emphasis on revenue and cost aspects. Topics include price and contract consideration in coal, metal and other commodities; mine capital and operating cost estimation and indexing; and other topics of current interest. Prerequisite: MNGN427 or EBGN504 or equivalent. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN590. MECHANICAL EXCAVATION IN MINING. 3.0 Semester Hrs.

(II) This course provides a comprehensive review of the existing and emerging mechanical excavation technologies for mine development and production in surface and underground mining. The major topics covered in the course include: history and development of mechanical excavators, theory and principles of mechanical rock fragmentation, design and performance of rock cutting tools, design and operational characteristics of mechanical excavators (e.g. continuous miners, roadheaders, tunnel boring machines, raise drills, shaft borers, impact miners, slotters), applications to mine development and production, performance prediction and geotechnical investigations, costs versus conventional methods, new mine designs for applying mechanical excavators, case histories, future trends and anticipated developments and novel rock fragmentation methods including water jets, lasers, microwaves, electron beams, penetrators, electrical discharge and sonic rock breakers. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN598. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN625. GRADUATE MINING SEMINAR. 1.0 Semester Hr.

(I, II) Discussions presented by graduate students, staff, and visiting lecturers on research and development topics of general interest. Required of all graduate students in mining engineering every semester during residence. 1 semester hour upon completion of thesis or residence.

MNGN698. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN700. GRADUATE ENGINEERING REPORTMASTER OF ENGINEERING. 1-6 Semester Hr.

(I, II) Laboratory, field, and library work for the Master of Engineering report under supervision of the student's advisory committee. Required of candidates for the degree of Master of Engineering. Variable 1 to 6 hours. Repeatable for credit to a maximum of 6 hours.

MNGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Petroleum Engineering

2015/2016

Degrees Offered

- Professional Masters in Petroleum Reservoir Systems
- Master of Engineering (Petroleum Engineering)
- Master of Science (Petroleum Engineering)
- Doctor of Philosophy (Petroleum Engineering)

Program Description

The Petroleum Engineering Department offers students a choice of a Master of Science (MS) degree or a Master of Engineering (ME) degree. For the MS degree, a thesis is required in addition to course work. For the ME degree, no thesis is required, but the course work requirement is greater than that for the MS degree. The Petroleum Engineering

Department also offers CSM undergraduate students the option of a Combined Undergraduate/Graduate Program. This is an accelerated program that provides the opportunity to CSM students to have a head start on their graduate education.

Applications from students having a MS in Petroleum Engineering, or in another complimentary discipline, will be considered for admission to the Doctor of Philosophy (Ph.D.) program. To obtain the Ph.D. degree, a student must demonstrate unusual competence, creativity, and dedication in the degree field. In addition to extensive course work, a dissertation is required for the Ph.D. degree.

Applying for Admission

All graduate applicants must have taken core engineering, math and science courses before applying to graduate school. For the Colorado School of Mines this would be 3 units of Calculus, 2 units of Chemistry with Quantitative Lab, 2 units of Physics, Differential Equations, Statics, Fluid Mechanics, Thermodynamics and Mechanics of Materials. To apply for admission, follow the procedure outlined in the general section of this bulletin. Three letters of recommendation must accompany the application. The Petroleum Engineering Department requires the general test of the Graduate Record Examination (GRE) for applicants to all degree levels.

Applicants for the Master of Science, Master of Engineering, and Professional Masters in Petroleum Reservoir Systems programs should have a minimum score of 155 or better and applicants for the Ph.D. program are expected to have 159 or better on the quantitative section of the GRE exam, in addition to acceptable scores in the verbal and analytical sections. The GPA of the applicant must be 3.0 or higher. The graduate application review committee determines minimum requirements accordingly, and these requirements may change depending on the application pool for the particular semester. The applicants whose native language is not English are also expected to provide satisfactory scores on the TOEFL (Test of English as a Foreign Language) exam as specified in the general section of this bulletin.

Required Curriculum

A student in the graduate program selects course work by consultation with the Faculty Advisor and with the approval of the graduate committee. Course work is tailored to the needs and interests of the student. Students who do not have a BS degree in petroleum engineering must take deficiency courses as required by the department as soon as possible in their graduate programs. Depending on the applicant's undergraduate degree, various basic undergraduate petroleum engineering and geology courses will be required. These deficiency courses are not counted towards the graduate degree; nonetheless, the student is expected to pass the required courses and the grades received in these courses are included in the GPA. Not passing these courses can jeopardize the student's continuance in the graduate program. It is desirable for students with deficiencies to complete the deficiencies or course work within the first two semesters of arrival to the program or as soon as possible with the approval of their advisor.

All PE graduate students are required to complete 3 credit hours of course work in writing, research, or presentation intensive classes, such as PEGN681, LICM501, SYGN501, and SYGN600, as agreed to by their graduate advisor.

Fields of Research

Current fields of research include:

- Rock and fluid properties, phase behavior, and rock mechanics
- Geomechanics
- Formation evaluation, well test analysis, and reservoir characterization
- Oil recovery processes
- IOR/EOR Methods
- Naturally fractured reservoirs
- Analytical and numerical modeling of fluid flow in porous media
- Pore-scale modeling and flow in nanopores
- Development of unconventional oil and gas plays
- Geothermal energy
- Gas Hydrates
- Completion and stimulation of wells
- Horizontal and multilateral wells
- Multi-stage fracturing of horizontal wells
- Drilling management and rig automation
- Fluid flow in wellbores and artificial lift
- Drilling mechanics, directional drilling,
- Extraterrestrial drilling
- Ice coring and drilling
- Bit vibration analysis, tubular buckling and stability, wave propagation in drilling tubulars
- Laser technology in penetrating rocks
- Environment, health, and safety in oil and gas industry

Research projects may involve professors and graduate students from other disciplines. Projects may include off-campus laboratories, institutes, and other resources.

The Petroleum Engineering Department houses a research institute, two research centers, and two consortia.

Research Institute

- Unconventional Natural Gas and Oil Institute (UNGI)

Research Centers

- Marathon Center of Excellence for Reservoir Studies (MCERS)
- Center for Earth Mechanics, Materials, and Characterization (CEMMC)

Research Consortia

- Fracturing, Acidizing, Stimulation Technology (FAST) Consortium.
- Unconventional Reservoir Engineering Project (UREP) Consortium.

Special Features

In the exchange programs with the Petroleum Engineering Departments of the Mining University of Leoben, Austria, Technical University in Delft, Holland, and the University of Adelaide, Australia, a student may spend one semester abroad during graduate studies and receive full transfer of credit back to CSM with prior approval of the Petroleum Engineering Department at CSM.

In the fall of 2012, the new Petroleum Engineering building, Marquez Hall, was opened. The new home for the Petroleum Engineering

Department is a prominent campus landmark, showcasing Mines' longstanding strengths in its core focus areas and our commitment to staying at the forefront of innovation. The new building is designed using aggressive energy saving strategies and will be LEED certified. Marquez Hall is the first building on the Colorado School of Mines Campus that is funded entirely by donations.

The Petroleum Engineering Department enjoys strong collaboration with the Geology and Geological Engineering Department and Geophysics Department at CSM. Courses that integrate the faculty and interests of the three departments are taught at the undergraduate and graduate levels.

The department is close to oil and gas field operations, oil companies and laboratories, and geologic outcrops of producing formations. There are many opportunities for summer and part-time employment in the oil and gas industry.

Each summer, several graduate students assist with the field sessions designed for undergraduate students. The field sessions in the past several years have included visits to oil and gas operations in Europe, Alaska, Canada, Southern California, the Gulf Coast, the Northeast US, the Rocky Mountain regions, and western Colorado.

The Petroleum Engineering Department encourages student involvement with the Society of Petroleum Engineers, the American Association of Drilling Engineers and the American Rock Mechanics Association. The department provides some financial support for students attending the annual technical conferences for these professional societies.

Program Requirements

Professional Masters in Petroleum Reservoir Systems

Minimum 36 hours of course credit

Master of Engineering

Minimum 36 hours of course credit

Master of Science

Minimum 36 hours, of which no less than 12 credit hours earned by research and 24 credit hours by course work

Combined Undergraduate/Graduate Program

The same requirements as Master of Engineering or Master of Science after the student is granted full graduate status. Students in the Combined Undergraduate/Graduate Program may fulfill part of the requirements of their graduate degree by including up to 6 credit hours of undergraduate course credits upon approval of the department.

Doctor of Philosophy

Minimum 90 credit hours beyond the bachelor's degree of which no less than 30 credit hours earned by research, or minimum 54 credit hours beyond the Master's degree of which no less than 30 credit hours earned by research.

The Petroleum Engineering, Geology and Geological Engineering, and the Geophysics Departments share oversight for the **Professional Masters in Petroleum Reservoir Systems** program through a committee consisting of one faculty member from each department. Students gain admission to the program by application to any of the three

sponsoring departments. Students are administered by that department into which they first matriculate. A minimum of 36 credit hours of course credit is required to complete the Professional Masters in Petroleum Reservoir Systems program. Up to 9 credits may be earned by 400 level courses. All other credits toward the degree must be 500 level or above. At least 9 hours must consist of:

GEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	3.0
or GPGN439	GEOPHYSICS PROJECT DESIGN / MULTIDISCIPLINARY PETROLEUM DESIGN	
or PEGN439	MULTIDISCIPLINARY PETROLEUM DESIGN	
Select one of the following:		3.0
GPGN/ PEGNnull419	WELL LOG ANALYSIS AND FORMATION EVALUATION	
GPGN/ PEGNnull519	ADVANCED FORMATION EVALUATION	
Select one of the following:		3.0
GEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or GPGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN503	INTEGRATED EXPLORATION AND DEVELOPMENT	
GEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or GPGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
or PEGN504	INTEGRATED EXPLORATION AND DEVELOPMENT	
Total Semester Hrs		9.0

Also 9 additional hours must consist of one course each from the 3 participating departments. The remaining 18 hours may consist of graduate courses from any of the 3 participating departments, or other courses approved by the committee. Up to 6 hours may consist of independent study, including an industry project.

Candidates for the non-thesis **Master of Engineering** degree must complete a minimum of 36 hours of graduate course credit. At least 18 of the credit hours must be from the Petroleum Engineering Department. Up to 12 graduate credit hours can be transferred from another institution, and up to 9 credit hours of senior-level courses may be applied to the degree. All courses must be approved by the student's advisor and the department head. No graduate committee is required. No more than six credit hours can be earned through independent study.

Candidates for the **Master of Science** degree must complete at least 24 graduate credit hours of course work, approved by the candidate's graduate committee, and a minimum of 12 hours of research credit. At least 12 of the course credit hours must be from the Petroleum Engineering Department. Up to 9 credit hours may be transferred from another institution. Up to 9 credit hours of senior-level courses may be applied to the degree. For the MS degree, the student must demonstrate ability to observe, analyze, and report original scientific research. For other requirements, refer to the general instructions of the Graduate School (p. 189) in this bulletin.

The requirements for the **Combined Undergraduate/Graduate Program** are defined in the section of this Bulletin titled "Graduate Degrees and Requirements—V. Combined Undergraduate/Graduate Programs." After the student is granted full graduate status, the requirements are the same as those for the non-thesis Master of Engineering or thesis-based Master of Science degree, depending to which program the student was accepted. The Combined Undergraduate/Graduate Program allows

students to fulfill part of the requirements of their graduate degree by including up to 6 credit hours of their undergraduate course credits upon approval of the department. The student must apply for the program by submitting an application through the Graduate School before the first semester of their Senior year. For other requirements, refer to the general directions of the Graduate School (p. 189) in this bulletin.

A candidate for the **Ph.D.** must complete at least 60 hours of course credit and a minimum of 30 credit hours of research beyond the Bachelor's degree or at least 24 hours of course credit and a minimum of 30 credit hours of research beyond the Master's degree. The credit hours to be counted toward a Ph.D. are dependent upon approval of the student's thesis committee. Students who enter the Ph.D. program with a Bachelor's degree may transfer up to 33 graduate credit hours from another institution with the approval of the graduate advisor. Students who enter the Ph.D. program with a master's degree may transfer up to 45 credit hours of course and research work from another institution upon approval by the graduate advisor. Ph.D. students must complete a minimum of 12 credit hours of their required course credit in a minor program of study. The student's faculty advisor, thesis committee, and the department head must approve the course selection. Full-time Ph.D. students must satisfy the following requirements for admission to candidacy within the first two calendar years after enrolling in the program:

1. have a thesis committee appointment form on file,
2. complete all prerequisite courses successfully,
3. demonstrate adequate preparation for and satisfactory ability to conduct doctoral research by successfully completing a series of written and/or oral examinations and fulfilling the other requirements of their graduate committees as outlined in the department's graduate handbook.

Failure to fulfill these requirements within the time limits specified above may result in immediate mandatory dismissal from the Ph.D. program according to the procedure outlined in the section of this Bulletin titled "General Regulations—Unsatisfactory Academic Performance—Unsatisfactory Academic Progress Resulting in Probation or Discretionary Dismissal." For other requirements, refer to the general directions of the Graduate School (p. 189) in this bulletin and/or the Department's Graduate Student Handbook.

Professors

Hazim Abass

Ramona M. Graves, Dean, College of Earth Resource Sciences and Engineering

Hossein Kazemi, Chesebro' Distinguished Chair

Erdal Ozkan, Interim Department Head

Azra N.Tutuncu, Harry D. Campbell Chair

Yu-Shu Wu, CMG Chair

Associate Professors

Alfred W. Eustes III

Jorge H. B. Sampaio Jr.

Manika Prasad

Xiaolong Yin

Assistant Professors

Rosmer Maria Brito

Luis Zerpa

Teaching Professor

Linda A. Battalora

Teaching Associate Professors

Mansur Ermila

Carrie J. McClelland

Mark G. Miller

Teaching Assistant Professor

Elio S. Dean

Research Associate Professor

Philip H. Winterfeld

Research Assistant Professor

Wendy Wempe

Adjunct Professor

William W. Fleckenstein

Professor Emeritus

Craig W. Van Kirk

Associate Professor Emeritus

Richard Christiansen

Courses

PEGN501. APPLICATIONS OF NUMERICAL METHODS TO PETROLEUM ENGINEERING. 3.0 Semester Hrs.

The course will solve problems of interest in Petroleum Engineering through the use of spreadsheets on personal computers and structured FORTRAN programming on PCs or mainframes. Numerical techniques will include methods for numerical quadrature, differentiation, interpolation, solution of linear and nonlinear ordinary differential equations, curve fitting and direct or iterative methods for solving simultaneous equations. Prerequisites: PEGN414 and PEGN424. 3 hours lecture; 3 semester hours.

PEGN502. ADVANCED DRILLING FLUIDS. 3.0 Semester Hrs.

The physical properties and purpose of drilling fluids are investigated. Emphasis is placed on drilling fluid design, clay chemistry, testing, and solids control. Prerequisite: PEGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

PEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.

(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

PEGN505. HORIZONTAL WELLS: RESERVOIR AND PRODUCTION ASPECTS. 3.0 Semester Hrs.

This course covers the fundamental concepts of horizontal well reservoir and production engineering with special emphasis on the new developments. Each topic covered highlights the concepts that are generic to horizontal wells and draws attention to the pitfalls of applying conventional concepts to horizontal wells without critical evaluation. There is no set prerequisite for the course but basic knowledge on general reservoir engineering concepts is useful. 3 hours lecture; 3 semester hours.

PEGN506. ENHANCED OIL RECOVERY METHODS. 3.0 Semester Hrs.

Enhanced oil recovery (EOR) methods are reviewed from both the qualitative and quantitative standpoint. Recovery mechanisms and design procedures for the various EOR processes are discussed. In addition to lectures, problems on actual field design procedures will be covered. Field case histories will be reviewed. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN507. INTEGRATED FIELD PROCESSING. 3.0 Semester Hrs.

Integrated design of production facilities covering multistage separation of oil, gas, and water, multiphase flow, oil skimmers, natural gas dehydration, compression, crude stabilization, petroleum fluid storage, and vapor recovery. Prerequisite: PEGN411. 3 hours lecture; 3 semester hours.

PEGN508. ADVANCED ROCK PROPERTIES. 3.0 Semester Hrs.

Application of rock mechanics and rock properties to reservoir engineering, well logging, well completion and well stimulation. Topics covered include: capillary pressure, relative permeability, velocity effects on Darcy's Law, elastic/mechanical rock properties, subsidence, reservoir compaction, and sand control. Prerequisites: PEGN423 and PEGN426. 3 hours lecture; 3 semester hours.

PEGN511. ADVANCED THERMODYNAMICS AND PETROLEUM FLUIDS PHASE BEHAVIOR. 3.0 Semester Hrs.

Essentials of thermodynamics for understanding the phase behavior of petroleum fluids such as natural gas and oil. Modeling of phase behavior of single and multi-component systems with equations of states with a brief introduction to PVT laboratory studies, commercial PVT software, asphaltenes, gas hydrates, mineral deposition, and statistical thermodynamics. Prerequisites: PEGN310 and PEGN305 or equivalent. 3 hours lecture; 3 semester hours.

PEGN512. ADVANCED GAS ENGINEERING. 3.0 Semester Hrs.

The physical properties and phase behavior of gas and gas condensates will be discussed. Flow through tubing and pipelines as well as through porous media is covered. Reserve calculations for normally pressured, abnormally pressured and water drive reservoirs are presented. Both stabilized and isochronal deliverability testing of gas wells will be illustrated. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN513. RESERVOIR SIMULATION I. 3.0 Semester Hrs.

The course provides the rudiments of reservoir simulation, which include flow equations, solution methods, and data requirement. Specifically, the course covers: equations of conservation of mass, conservation of momentum, and energy balance; numerical solution of flow in petroleum reservoirs by finite difference (FD) and control volume FD; permeability tensor and directional permeability; non-Darcy flow; convective flow and numerical dispersion; grid orientation problems; introduction to finite element and mixed finite-element methods; introduction to hybrid analytical/numerical solutions; introduction to multi-phase flow models; relative permeability, capillary pressure and wettability issues; linear equation solvers; streamline simulation; and multi-scale simulation concept. Prerequisite: PEGN424 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN514. PETROLEUM TESTING TECHNIQUES. 3.0 Semester Hrs.

Investigation of basic physical properties of petroleum reservoir rocks and fluids. Review of recommended practices for testing drilling fluids and oil well cements. Emphasis is placed on the accuracy and calibration of test equipment. Quality report writing is stressed. Prerequisite: Graduate status. 2 hours lecture, 1 hour lab; 3 semester hours. Required for students who do not have a BS in PE.

PEGN515. RESERVOIR ENGINEERING PRINCIPLES. 3.0 Semester Hrs.

Reservoir Engineering overview. Predicting hydrocarbon in place; volumetric method, deterministic and probabilistic approaches, material balance, water influx, graphical techniques. Fluid flow in porous media; continuity and diffusivity equations. Well performance; productivity index for vertical, perforated, fractured, restricted, slanted, and horizontal wells, inflow performance relationship under multiphase flow conditions. Combining material balance and well performance equations. Future reservoir performance prediction; Muskat, Tarner, Carter and Tracy methods. Fetkovich decline curves. Reservoir simulation; fundamentals and formulation, streamline simulation, integrated reservoir studies. 3 hours lecture, 3 semester hours.

PEGN516. PRODUCTION ENGINEERING PRINCIPLES. 3.0 Semester Hrs.

Production Engineering Overview. Course provides a broad introduction to the practice of production engineering. Covers petroleum system analysis, well stimulation (fracturing and acidizing), artificial lift (gas lift, sucker rod, ESP, and others), and surface facilities. 3 hours lecture, 3 semester hours.

PEGN517. DRILLING ENGINEERING PRINCIPLES. 3.0 Semester Hrs.

Drilling Engineering overview. Subjects to be covered include overall drilling organization, contracting, and reporting; basic drilling engineering principles and equipment; drilling fluids, hydraulics, and cuttings transport; drillstring design; drill bits; drilling optimization; fishing operations; well control; pore pressure and fracture gradients, casing points and design; cementing; directional drilling and horizontal drilling. 3 hours lecture, 3 semester hours.

PEGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.

A detailed review of wireline well logging and evaluation methods stressing the capability of the measurements to determine normal and special reservoir rock parameters related to reservoir and production problems. Computers for log processing of single and multiple wells. Utilization of well logs and geology in evaluating well performance before, during, and after production of hydrocarbons. The sensitivity of formation evaluation parameters in the volumetric determination of petroleum in reservoirs. Prerequisite: PEGN419. 3 hours lecture; 3 semester hours.

PEGN522. ADVANCED WELL STIMULATION. 3.0 Semester Hrs.

Basic applications of rock mechanics to petroleum engineering problems. Hydraulic fracturing; acid fracturing, fracturing simulators; fracturing diagnostics; sandstone acidizing; sand control, and well bore stability. Different theories of formation failure, measurement of mechanical properties. Review of recent advances and research areas. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN523. ADVANCED ECONOMIC ANALYSIS OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.

Determination of present value of oil properties. Determination of severance, ad valorem, windfall profit, and federal income taxes. Analysis of profitability indicators. Application of decision tree theory and Monte Carlo methods to oil and gas properties. Economic criteria for equipment selection. Prerequisite: PEGN422 or EBG504 or ChEN504 or MNGN427 or ChEN421. 3 hours lecture; 3 semester hours.

PEGN524. PETROLEUM ECONOMICS AND MANAGEMENT. 3.0 Semester Hrs.

Business applications in the petroleum industry are the central focus. Topics covered are: fundamentals of accounting, oil and gas accounting, strategic planning, oil and gas taxation, oil field deals, negotiations, and the formation of secondary units. The concepts are covered by forming companies that prepare proforma financial statements, make deals, drill for oil and gas, keep accounting records, and negotiate the participation formula for a secondary unit. Prerequisite: PEGN422. 3 hours lecture; 3 semester hours.

PEGN530. ENVIRONMENTAL LAW. 3.0 Semester Hrs.

Equivalent with ESGN502, Designed for engineers, geoscientists, managers, consultants and citizens, this course covers the basics of environmental, energy and natural resources law. Topics include: an introduction to U.S. Environmental Law, Policy and Practice; the administrative process; enforcement and liability; a survey of U.S. laws and compliance programs addressing pollution, toxic substances, endangered species, pesticides, minerals, oil & gas, land uses and others including the National Environmental Protection Act (NEPA), Resource Conservation and Recovery Act (RCRA), Underground Storage Tanks (UST), Clean Air Act (CAA), Clean Water Act (CWA), Oil Pollution Act (OPA); Safe Drinking Water Act (SDWA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Toxic Substances Control Act (TSCA) and others; an introduction to international environmental law; ethics; and case studies." 3 hours lecture; 3 semester hours.

PEGN541. APPLIED RESERVOIR SIMULATION. 3.0 Semester Hrs.

Concepts of reservoir simulation within the context of reservoir management will be discussed. Course participants will learn how to use available flow simulators to achieve reservoir management objectives. They will apply the concepts to an open-ended engineering design problem. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN542. INTEGRATED RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.

The course introduces integrated reservoir characterization from a petroleum engineering perspective. Reservoir characterization helps quantify properties that influence flow characteristics. Students will learn to assess and integrate data sources into a comprehensive reservoir model. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN550. MODERN RESERVOIR SIMULATORS. 3.0 Semester Hrs.

Students will learn to run reservoir simulation software using a variety of reservoir engineering examples. The course will focus on the capabilities and operational features of simulators. Students will learn to use pre- and post-processors, fluid property analysis software, black oil and gas reservoir models, and compositional models. 3 hours lecture; 3 semester hours.

PEGN577. WORKOVER DESIGN AND PRACTICE. 3.0 Semester Hrs.

Workover Engineering overview. Subjects to be covered include Workover Economics, Completion Types, Workover Design Considerations, Wellbore Cleanout (Fishing), Workover Well Control, Tubing and Workstring Design, Slickline Operations, Coiled Tubing Operations, Packer Selection, Remedial Cementing Design and Execution, Completion Fluids, Gravel Packing, and Acidizing. 3 hours lecture, 3 semester hours.

PEGN590. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.

The course provides an introduction to fundamental rock mechanics concepts and aims to emphasize their role in exploration, drilling, completion and production engineering operations. Basic stress and strain concepts, pore pressure, fracture gradient and in situ stress magnitude and orientation determination and how these properties are obtained from the field measurements, mechanisms of deformation in rock, integrated wellbore stability analysis, depletion induced compaction and associated changes in rock properties and formation strength, hydraulic fracturing and fracture stability are among the topics to be covered in this rock course. Naturally fractured formation properties and how they impact the characteristics measured in the laboratory and in field are also included in the curriculum. Several industry speakers are invited as part of the lecture series to bring practical aspects of the fundamentals of geomechanics covered in the classroom. In addition, Petrel, FLAC3D and FRACMAN software practices with associated assignments are offered to integrate field data on problems including in situ stress magnitude and orientations, pore pressure and fracture gradient prediction and rock property determination using laboratory core measurements, logs, seismic, geological data. Problems are assigned for students to use the field and laboratory data to obtain static and dynamic moduli, rock failure criteria, wellbore stress concentration and failure, production induced compaction/subsidence and hydraulic fracture mechanics.

PEGN591. SHALE RESERVOIR ENGINEERING. 3.0 Semester Hrs.

Equivalent with PEGN615,

Fundamentals of shale-reservoir engineering and special topics of production from shale reservoirs are covered. The question of what makes shale a producing reservoir is explored. An unconventional understanding of shale-reservoir characterization is emphasized and the pitfalls of conventional measurements and interpretations are discussed. Geological, geomechanical, and engineering aspects of shale reservoirs are explained. Well completions with emphasis on hydraulic fracturing and fractured horizontal wells are discussed from the viewpoint of reservoir engineering. Darcy flow, diffusive flow, and desorption in shale matrix are covered. Contributions of hydraulic and natural fractures are discussed and the stimulated reservoir volume concept is introduced. Interactions of flow between fractures and matrix are explained within the context of dual-porosity modeling. Applications of pressure-transient, rate-transient, decline-curve and transient-productivity analyses are covered. Field examples are studied. 3 hours lecture; 3 semester hours.

PEGN592. GEOMECHANICS FOR UNCONVENTIONAL RESOURCES. 3.0 Semester Hrs.

A wide spectrum of topics related to the challenges and solutions for the exploration, drilling, completion, production and hydraulic fracturing of unconventional resources including gas and oil shale, heavy oil sand and carbonate reservoirs, their seal formations is explored. The students acquire skills in integrating and visualizing multidiscipline data in Petrel (a short tutorial is offered) as well as assignments regarding case studies using field and core datasets. The role of integrating geomechanics data in execution of the exploration, drilling, completion, production, hydraulic fracturing and monitoring of pilots as well as commercial applications in unlocking the unconventional resources are pointed out using examples. Prerequisite: PEGN590. 3 hours lecture; 3 semester hours.

PEGN593. ADVANCED WELL INTEGRITY. 3.0 Semester Hrs.

Fundamentals of wellbore stability, sand production, how to keep wellbore intact is covered in this course. The stress alterations in near wellbore region and associated consequences in the form of well failures will be covered in detailed theoretically and with examples from deepwater conventional wells and onshore unconventional well operations. Assignments will be given to expose the students to the real field data to interpret and evaluate cases to determine practical solutions to drilling and production related challenges. Fluid pressure and composition sensitivity of various formations will be studied. 3 hours lecture; 3 semester hours.

PEGN594. ADVANCED DIRECTIONAL DRILLING. 3.0 Semester Hrs.

Application of directional control and planning to drilling. Major topics covered include: Review of procedures for the drilling of directional wells. Section and horizontal view preparation. Two and three dimensional directional planning. Collision diagrams. Surveying and trajectory calculations. Surface and down hole equipment. Common rig operating procedures, and horizontal drilling techniques. Prerequisite: PEGN311 or equivalent. 3 hours lecture; 3 semester hours.

PEGN595. DRILLING OPERATIONS. 3.0 Semester Hrs.

Lectures, seminars, and technical problems with emphasis on well planning, rotary rig supervision, and field practices for execution of the plan. This course makes extensive use of the drilling rig simulator. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN596. ADVANCED WELL CONTROL. 3.0 Semester Hrs.

Principles and procedures of pressure control are taught with the aid of a full-scale drilling simulator. Specifications and design of blowout control equipment for onshore and offshore drilling operations, gaining control of kicks, abnormal pressure detection, well planning for wells containing abnormal pressures, and kick circulation removal methods are taught. Students receive hands-on training with the simulator and its peripheral equipment. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN597. TUBULAR DESIGN. 3.0 Semester Hrs.

Fundamentals of tubulars (casing, tubing, and drill pipe) design applied to drilling. Major topics covered include: Dogleg running loads. Directional hole considerations. Design criteria development. Effects of formation pressures. Stability loads after cementing. Effects of temperature, pressure, mud weights, and cement. Helical bending of tubing. Fishing loads. Micro-annulus problem. Strengths of API tubulars. Abrasive wear while rotating drill pipe. How to design for hydrogen sulfide and fatigue corrosion. Connection selection. Common rig operating procedures. Prerequisites: PEGN311 and PEGN361 or equivalent. 3 hours lecture; 3 semester hours.

PEGN598. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN598LA. SPECIAL TOPICS LAB. 6.0 Semester Hrs.**PEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.**

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN601. APPLIED MATHEMATICS OF FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

This course is intended to expose petroleum-engineering students to the special mathematical techniques used to solve transient flow problems in porous media. Bessel's equation and functions, Laplace and Fourier transformations, the method of sources and sinks, Green's functions, and boundary integral techniques are covered. Numerical evaluation of various reservoir engineering solutions, numerical Laplace transformation and inverse transformation are also discussed. 3 hours lecture; 3 semester hours.

PEGN603. DRILLING MODELS. 3.0 Semester Hrs.

Analytical models of physical phenomena encountered in drilling. Casing and drilling failure from bending, fatigue, doglegs, temperature, stretch; mud filtration; corrosion; wellhead loads; and buoyancy of tubular goods. Bit weight and rotary speed optimization. Prerequisites: PEGN311 and PEGN361. 3 hours lecture; 3 semester hours.

PEGN604. INTEGRATED FLOW MODELING. 3.0 Semester Hrs.

Students will study the formulation, development and application of a reservoir flow simulator that includes traditional fluid flow equations and a petrophysical model. The course will discuss properties of porous media within the context of reservoir modeling, and present the mathematics needed to understand and apply the simulator. Simulator applications will be interspersed throughout the course. 3 hours lecture; 3 semester hours.

PEGN605. WELL TESTING AND EVALUATION. 3.0 Semester Hrs.

Various well testing procedures and interpretation techniques for individual wells or groups of wells. Application of these techniques to field development, analysis of well problems, secondary recovery, and reservoir studies. Productivity, gas well testing, pressure buildup and drawdown, well interference, fractured wells, type curve matching, and short-term testing. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN606. ADVANCED RESERVOIR ENGINEERING. 3.0 Semester Hrs.

A review of depletion type, gas-cap, and volatile oil reservoirs. Lectures and supervised studies on gravity segregation, moving gas-oil front, individual well performance analysis, history matching, performance prediction, and development planning. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN607. PARTIAL WATER DRIVE RESERVOIRS. 3.0 Semester Hrs.

The hydrodynamic factors which influence underground water movement, particularly with respect to petroleum reservoirs. Evaluation of oil and gas reservoirs in major water containing formations. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN608. MULTIPHASE FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

The factors involved in multiphase fluid flow in porous and fractured media. Physical processes and mathematical models for micro- and macroscopic movement of multiphase fluids in reservoirs. Performance evaluation of various displacement processes in the laboratory as well as in the petroleum field during the secondary and EOR/IOR operations. Prerequisite: PEGN 424, 3 hours lecture; 3 semester hours.

PEGN614. RESERVOIR SIMULATION II. 3.0 Semester Hrs.

The course reviews the rudiments of reservoir simulation and flow equations, solution methods, and data requirement. The course emphasizes multi-phase flow and solution techniques; teaches the difference between conventional reservoir simulation, compositional modeling and multi-porosity modeling; teaches how to construct three-phase relative permeability from water-oil and gas-oil relative permeability data set; the importance of capillary pressure measurements and wettability issues; discusses the significance of gas diffusion and interphase mass transfer. Finally, the course develops solution techniques to include time tested implicit-pressure-explicit saturation, sequential and fully implicit methods. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN619. GEOMECHANICALLY AND PHYSICOCHEMICALLY COUPLED FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.

The role of physico-chemistry and geomechanics on fluid flow in porous media will be included in addition to conventional fluid flow modeling and measurements in porous media. The conventional as well as unconventional reservoirs will be studied with the coupling of physicochemical effects and geomechanics stresses. Assignments will be given to expose the students to the real field data in interpretation and evaluation of filed cases to determine practical solutions to drilling and production related modeling challenges. 3 hours lecture; 3 semester hours.

PEGN620. NATURALLY FRACTURED RESERVOIRS -- ENGINEERING AND RESERVOIR SIMULATION. 3.0 Semester Hrs.

The course covers reservoir engineering, well testing, and simulation aspects of naturally fractured reservoirs. Specifics include: fracture description, connectivity and network; fracture properties; physical principles underlying reservoir engineering and modeling naturally fractured reservoirs; local and global effects of viscous, capillary, gravity and molecular diffusion flow; dual-porosity/dual-permeability models; multi-scale fracture model; dual-mesh model; streamlin model; transient testing with non-Darcy flow effects; tracer injection and breakthrough analysis; geomechanics and fractures; compositional model; coal-bed gas model; oil and gas from fractured shale; improved and enhanced oil recovery in naturally fracture reservoirs. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN624. COMPOSITIONAL MODELING - APPLICATION TO ENHANCED OIL RECOVERY. 3.0 Semester Hrs.

Efficient production of rich and volatile oils as well as enhanced oil recovery by gas injection (lean and rich natural gas, CO₂, N₂, air, and steam) is of great interest in the light of greater demand for hydrocarbons and the need for CO₂ sequestration. This course is intended to provide technical support for engineers dealing with such issues. The course begins with a review of the primary and secondary recovery methods, and will analyze the latest worldwide enhanced oil recovery production statistics. This will be followed by presenting a simple and practical solvent flooding model to introduce the student to data preparation and code writing. Next, fundamentals of phase behavior, ternary phase diagram, and the Peng-Robinson equation of state will be presented. Finally, a detailed set of flow and thermodynamic equations for a full-fledged compositional model, using molar balance, equation of motion and the afore-mentioned equation of state, will be developed and solution strategy will be presented. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN681. PETROLEUM ENGINEERING SEMINAR. 3.0 Semester Hrs.

Comprehensive reviews of current petroleum engineering literature, ethics, and selected topics as related to research and professionalism. 3 hours seminar; 3 semester hour.

PEGN698. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

College of Applied Science and Engineering

The College of Applied Science and Engineering (<http://case.mines.edu>) (CASE) comprises four academic departments and two interdisciplinary programs:

- Department of Chemical and Biological Engineering
- Department of Chemistry and Geochemistry
- Department of Metallurgical and Materials Engineering
- Department of Physics
- Materials Science Program
- Nuclear Science and Engineering Program

Through these departments and programs CASE is proud to offer rigorous and highly-regarded educational programs, featuring an emphasis on problem solving and critical thinking, that address professional and societal needs. CASE departments and programs are also leaders in the creation of knowledge, recognizing the critical role research plays both in building a dynamic and rigorous intellectual learning community and in the advancement of humankind. The college structure facilitates collaboration among our departments, allowing our faculty and students to tackle the most challenging problems, with a particular emphasis on analysis of relevant systems at the molecular level.

The students and faculty in CASE are working collaboratively toward a shared vision of academic excellence. To learn more about each department's extraordinary capabilities and accomplishments visit their websites and the College website.

Please select from the list of links on the right or above to locate more information.

Chemical and Biological Engineering

Degrees Offered

- Master of Science (Chemical Engineering)
- Doctor of Philosophy (Chemical Engineering)

Program Description

The Chemical and Biological Engineering Department of the Colorado School of Mines is a dynamic, exciting environment for research and higher education. Mines provides a rigorous educational experience where faculty and top-notch students work together on meaningful research with far-reaching societal applications. Departmental research areas include hydrates, renewable energy, soft materials, biomedical devices, thin-film materials, simulation and modeling. Visit our website for additional information about our graduate program. <http://chemeng.mines.edu/>

Program Requirements

See required curriculum below.

Prerequisites

The program outlined here assumes that the candidate for an advanced degree has a background in chemistry, mathematics, and physics equivalent to that required for the BS degree in Chemical Engineering at the Colorado School of Mines. Undergraduate course deficiencies must be removed prior to enrollment in graduate coursework.

The essential undergraduate courses include:

CBEN201	MATERIAL AND ENERGY BALANCES	3.0
CBEN307	FLUID MECHANICS	3.0
CBEN308	HEAT TRANSFER	3.0
CBEN357	CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN375	MASS TRANSFER	3.0
CBEN418	KINETICS AND REACTION ENGINEERING	3.0
Total Semester Hrs		18.0

Required Curriculum

Master of Science Program

Master of Science (with Thesis)

Students entering the Master of Science (with thesis) program with an acceptable undergraduate degree in chemical engineering are required to take a minimum of 18 semester hours of coursework. All students must complete:

Chemical Engineering core graduate courses

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
CBEN568	INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING	3.0
CBEN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	6.0
ELECT	Approved Coursework Electives	6.0
RESEARCH	Research Credits or Coursework	6.0
Total Semester Hrs		30.0

Students must take a minimum of 6 research credits, complete, and defend an acceptable Masters dissertation. Upon approval of the thesis committee, graduate credit may be earned for 400-level courses.

Between coursework and research credits a student must earn a minimum of 30 total semester hours. Full-time Masters students must enroll in graduate colloquium (CBEN605) each semester.

Master of Science (non-thesis)

Students entering the Master of Science (non-thesis) program with an acceptable undergraduate degree in chemical engineering are required to take a minimum of 30 semester hours of coursework. All students must complete:

Chemical Engineering core graduate courses

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0

ELECT	Approved Electives	21.0
Total Semester Hrs		30.0

Students may complete an acceptable engineering report for up to 6 hours of academic credit. Upon approval of the thesis committee, graduate credit may be earned for selected 400-level courses. Full-time Masters students must enroll in graduate colloquium (CBEN605) each semester.

CSM undergraduates enrolled in the combined BS/MS degree program must meet the requirements described above for the MS portion of their degree (both thesis and non-thesis). Students accepted into the combined program may take graduate coursework and/or research credits as an undergraduate and have them applied to their MS degree.

Doctor of Philosophy Program

The course of study for the PhD degree consists of a minimum of 30 semester hours of coursework. All PhD students must complete:

Core courses

CBEN509	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	3.0
CBEN516	TRANSPORT PHENOMENA	3.0
CBEN518	REACTION KINETICS AND CATALYSIS	3.0
CBEN568	INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING	3.0
CBEN6XX	600-Level Coursework Electives	6.0
CBEN707	Graduate Research Credit (up to 12 hours per semester)	42.0
ELECT	Approved Coursework Electives	12.0
Total Semester Hrs		72.0

In addition, students must complete and defend an acceptable Doctoral dissertation. Upon approval of the thesis committee, graduate credit may be earned for 400-level courses. Full-time PhD students must enroll in graduate colloquium (CBEN605) each semester.

Students in the PhD program are required to pass both a Qualifying Exam and the PhD Proposal Defense. After successful completion of 30 semester hours of coursework and completion of the PhD proposal defense, PhD candidates will be awarded a non-thesis Master of Science Degree. The additional requirements for the PhD program are described below.

PhD Qualifying Examination

The PhD qualifying examination will be offered twice each year, at the start and end of the Spring semester. All students who have entered the PhD program must take the qualifying examination at the first possible opportunity. However, a student must be in good academic standing (above 3.0 GPA) to take the qualifying exam. A student may retake the examination once if he/she fails the first time; however, the examination must be retaken at the next regularly scheduled examination time. Failure of the PhD qualifying examination does not disqualify a student for the MS degree, although failure may affect the student's financial aid status.

The qualifying examination will cover the traditional areas of Chemical Engineering, and will consist of two parts: GPA from core graduate classes (CBEN509, CBEN516, CBEN518 and CBEN568) and an oral examination. The oral examination will consist of a presentation by the student on a technical paper from chemical engineering literature. Students will choose a paper from a list determined by the faculty. Papers

for the oral examination will be distributed well in advance of the oral portion of the exam so students have sufficient time to prepare their presentations. The student is required to relate the paper to the core chemical engineering classes and present a research plan, followed by questions from the faculty. A 1-2 page paper on the research plan is due the Friday prior to the oral examination.

If a student fails the first attempt at the qualifying exam, his/her grade from a 600 level Chemical Engineering elective can replace the lowest grade from the core graduate classes for, and only for, the GPA calculation defined above.

PhD Proposal Defense

After passing the Qualifying Exam, all PhD candidates are required to prepare a detailed written proposal on the subject of their PhD research topic. An oral examination consisting of a defense of the thesis proposal must be completed within approximately one year of passing the Qualifying Examination. Written proposals must be submitted to the student's thesis committee no later than one week prior to the scheduled oral examination.

Two negative votes from the doctoral committee members are required for failure of the PhD Proposal Defense. In the case of failure, one re-examination will be allowed upon petition to the Department Head. Failure to complete the PhD Proposal Defense within the allotted time without an approved postponement will result in failure. Under extenuating circumstances a student may postpone the exam with approval of the Graduate Affairs committee, based on the recommendation of the student's thesis committee. In such cases, a student must submit a written request for postponement that describes the circumstances and proposes a new date. Requests for postponement must be presented to the thesis committee no later than 2 weeks before the end of the semester in which the exam would normally have been taken.

Dean of the College of Applied Sciences and Engineering

Michael J. Kaufman

Professors

John R. Dorgan

Andrew M. Herring

Carolyn A. Koh

David W.M. Marr, Department Head

J. Douglas Way

Colin A. Wolden, Weaver Distinguished Professor

David T.W. Wu, by courtesy

Associate Professors

Sumit Agarwal

Moises Carreon, Coors Developmental Chair

Keith B. Neeves

Amadeu K. Sum

Assistant Professors

Nanette Boyle, Coors Developmental Chair

Kevin J. Cash

Melissa D. Krebs

C. Mark Maupin

Ning Wu

Teaching Associate Professors

Jason C. Ganley, Assistant Department Head

Tracy Q. Gardner

Rachel M. Morrish

Cynthia L. Norrgran

Paul D. Ogg

John M. Persichetti

Judith N. Schoonmaker

Charles R. Vestal

Teaching Assistant Professor

C. Joshua Ramey

Research Associate Professor

Angel Abbud-Madrid

Research Assistant Professor

Stephanie Villano

Adjunct Faculty

John Jechura

Sarah M. Ryan

Professors Emeriti

Robert M. Baldwin

Annette L. Bunge

James F. Ely, University Professor Emeritus

John O. Golden

J. Thomas McKinnon

Ronald L. Miller

E. Dendy Sloan, Jr. , University Professor Emeritus

Victor F. Yesavage

Courses

CBEN504. ADVANCED PROCESS ENGINEERING ECONOMICS. 3.0 Semester Hrs.

Equivalent with CHEN504,

Advanced engineering economic principles applied to original and alternate investments. Analysis of chemical and petroleum processes relative to marketing and return on investments. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN505. NUMERICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN505,

Engineering applications of numerical methods. Numerical integration, solution of algebraic equations, matrix 54 Colorado School of Mines Graduate Bulletin 2011 2012 algebra, ordinary differential equations, and special emphasis on partial differential equations. Emphasis on application of numerical methods to chemical engineering problems which cannot be solved by analytical methods. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN507. APPLIED MATHEMATICS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.

Equivalent with CHEN507,

This course stresses the application of mathematics to problems drawn from chemical engineering fundamentals such as material and energy balances, transport phenomena and kinetics. Formulation and solution of ordinary and partial differential equations arising in chemical engineering or related processes or operations are discussed. Mathematical approaches are restricted to analytical solutions or techniques for producing problems amenable to analytical solutions. Prerequisite: Undergraduate differential equations course; undergraduate chemical engineering courses covering reaction kinetics, and heat, mass and momentum transfer. 3 hours lecture discussion; 3 semester hours.

CBEN509. ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with CHEN509,

Extension and amplification of under graduate chemical engineering thermodynamics. Topics will include the laws of thermodynamics, thermodynamic properties of pure fluids and fluid mixtures, phase equilibria, and chemical reaction equilibria. Prerequisite: CBEN357 or equivalent. 3 hours lecture; 3 semester hours.

CBEN511. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.

(II) This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. Successful students in the course should be able to read, understand, and critique current, scholarly literature on the topic of Neuroscience, Memory, and Learning. When this course is cross-listed and concurrent with CBEN411, students that enroll in CBEN511 will complete additional and/or more complex assignments. Pre-requisites: BIOL110, CBEN303, CHGN121, CHGN122, PHGN100, and PHGN200. 3 hours lecture, 3 semester hours.

CBEN513. SELECTED TOPICS IN CHEMICAL ENGINEERING. 1-3 Semester Hr.

Equivalent with CHEN513,

Selected topics chosen from special interests of instructor and students. Course may be repeated for credit on different topics. Prerequisite: none. 1 to 3 semester hours lecture/discussion; 1 to 3 semester hours.

CBEN516. TRANSPORT PHENOMENA. 3.0 Semester Hrs.

Equivalent with CHEN516,

Principles of momentum, heat, and mass transport with applications to chemical and biological processes. Analytical methods for solving ordinary and partial differential equations in chemical engineering with an emphasis on scaling and approximation techniques including singular and regular perturbation methods. Convective transport in the context of boundary layer theory and development of heat and mass transfer coefficients. Introduction to computational methods for solving coupled transport problems in irregular geometries. 3 hours lecture and discussion; 3 semester hours.

CBEN518. REACTION KINETICS AND CATALYSIS. 3.0 Semester Hrs.

Equivalent with CHEN518,

Homogeneous and heterogeneous rate expressions. Fundamental theories of reaction rates. Analysis of rate data and complex reaction networks. Properties of solid catalysts. Mass and heat transfer with chemical reaction. Heterogeneous non-catalytic reactions. Prerequisite: CBEN418 or equivalent. 3 hours lecture; 3 semester hours.

CBEN524. COMPUTER-AIDED PROCESS SIMULATION. 3.0 Semester Hrs.

Equivalent with CHEN524,

Advanced concepts in computer-aided process simulation are covered. Topics include optimization, heat exchanger networks, data regression analysis, and separations systems. Use of industry-standard process simulation software (Aspen Plus) is stressed. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN531. IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.

Equivalent with BELS531,

(II) This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies, immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry. Prerequisites: Biology BIOL110 or equivalent or graduate standing.

CBEN535. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.

Equivalent with CHEN435, CHEN535, MLGN535, PHGN435, PHGN535,

Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. 1 hour lecture, 4 hours lab; 3 semester hours.

CBEN550. MEMBRANE SEPARATION TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN550,

This course is an introduction to the fabrication, characterization, and application of synthetic membranes for gas and liquid separations. Industrial membrane processes such as reverse osmosis, filtration, pervaporation, and gas separations will be covered as well as new applications from the research literature. The course will include lecture, experimental, and computational (molecular simulation) laboratory components. Prerequisites: CBEN375, CBEN430. 3 hours lecture; 3 semester hours.

CBEN554. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.

Equivalent with BELS554,

(II) In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. General Biology BIOL110 or Graduate standing.

CBEN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.

Equivalent with BELS555, CHEN555, CHGN555, MLGN555,

The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN568. INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING. 3.0 Semester Hrs.

Equivalent with CHEN568,

(I) Students will be expected to apply chemical engineering principles to critically analyze theoretical and experimental research results in the chemical engineering literature, placing it in the context of the related literature, and interact effectively with students in classroom. literature. Skills to be developed and discussed include oral presentations, technical writing, critical reviews, ethics, research documentation (the laboratory notebook), research funding, types of research, developing research, and problem solving, pedagogical methods, and assessment tool. solving. Students will also use state-of-the-art tools to explore the literature and develop well-documented research proposals and presentations. Prerequisites: graduate student in Chemical and Biological Engineering in good standing. 3 semester hours.

CBEN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CHEN569, EGGN569, MEGN569, MLGN569, MTGN569,

(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

CBEN570. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.

Equivalent with CHEN570,

This course introduces the basic principles and applications of microfluidics systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Students will critically analyze the literature in this emerging field. Prerequisites: CBEN307 or equivalent. 3 hours lecture, 3 semester hours.

CBEN580. NATURAL GAS HYDRATES. 3.0 Semester Hrs.

Equivalent with CHEN580,

The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.

Equivalent with CHEN584,

The basic principles involved in the preparation, characterization, testing and theory of heterogeneous and homogeneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN604. TOPICAL RESEARCH SEMINARS. 1.0 Semester Hr.

Equivalent with CHEN604,

Lectures, reports, and discussions on current research in chemical engineering, usually related to the student's thesis topic. Sections are operated independently and are directed toward different research topics. Course may be repeated for credit. Prerequisite: none. 1 hour lecture-discussion; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN605. COLLOQUIUM. 1.0 Semester Hr.

Equivalent with CHEN605,

Students will attend a series of lectures by speakers from industry, academia, and government. Primary emphasis will be on current research in chemical engineering and related disciplines, with secondary emphasis on ethical, philosophical, and career-related issues of importance to the chemical engineering profession. Prerequisite: Graduate status. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 10 hours.

CBEN608. ADVANCED TOPICS IN FLUID MECHANICS. 1-3 Semester Hr.

Equivalent with CHEN608,
In-depth analysis of selected topics in fluid mechanics with special emphasis on chemical engineering applications. Prerequisite: CBEN508. 1 to 3 hours lecture discussion; 1 to 3 semester hours.

CBEN609. ADVANCED TOPICS IN THERMODYNAMICS. 1-3 Semester Hr.

Equivalent with CHEN609,
Advanced study of thermodynamic theory and application of thermodynamic principles. Possible topics include stability, critical phenomena, chemical thermodynamics, thermodynamics of polymer solutions and thermodynamics of aqueous and ionic solutions. Prerequisite: none. 1 to 3 semester hours.

CBEN610. APPLIED STATISTICAL THERMODYNAMICS. 3.0 Semester Hrs.

Equivalent with CHEN610,
Principles of relating behavior to microscopic properties. Topics include element of probability, ensemble theory, application to gases and solids, distribution theories of fluids, and transport properties. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN617. GRADUATE TRANSPORT PHENOMENA II. 3.0 Semester Hrs.

(II) Analysis of momentum, heat, and mass transfer problems using advanced analytical and numerical methods with an emphasis on coupled transport problems and irregular geometries. Advanced analytical techniques may include regular and singular perturbation analysis, eigenvalue problems, finite Fourier transforms, and Laplace transforms. Numerical methods for solving differential equations include finite differences, finite elements, Monte Carlo methods, and computational fluid dynamics. Prerequisite: CBEN516. 3 hours lecture; 3 semester hours.

CBEN620. ENGINEERING OF SOFT MATTER. 3.0 Semester Hrs.

(II) Soft matter is a field of inquiry involving physical systems having low moduli and which are structured on length scales ranging from about 10 nanometers up to 100 microns. This graduate level class provides a survey of relevant material systems including polymers, colloids, surfactants, liquid crystals, and biological materials. The course emphasis is on the chemical physics of soft materials and therefore requires a high level of mathematical sophistication; students should have the equivalent of one semester of graduate level applied mathematics as a prerequisite. A term paper in the form of a short publishable review of a relevant topic is a major component of the class. Prerequisites: the equivalent of one semester of graduate level applied mathematics. 3 hours lecture; 3 semester hours.

CBEN624. APPLIED STATISTICAL MECHANICS. 4.0 Semester Hrs.

(II) This course will introduce the both rigorous and approximate theories to estimate the macroscopic thermodynamic properties of systems based on laws that control the behavior of molecules. Course contents include classical dynamics and phase space, different types of ensembles, ideal and interacting gases, modern theory of liquids, ideal solids, as well as molecular simulation techniques. Prerequisite: undergraduate-level classical thermodynamics. 4 hours lecture; 4 semester hours.

CBEN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.

Equivalent with CHEN625,
Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: CBEN509 or equivalent, CBEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CBEN690. SUPERVISED TEACHING OF CHEMICAL ENGINEERING. 2.0 Semester Hrs.

Equivalent with CHEN690,
Individual participation in teaching activities. Discussion, problem review and development, guidance of laboratory experiments, course development, supervised practice teaching. Course may be repeated for credit. Prerequisite: Graduate standing, appointment as a graduate student instructor. 6 to 10 hours supervised teaching; 2 semester hours.

CBEN698. SPECIAL TOPICS IN CHEMICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with CHEN707,
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN600. COLLEGE TEACHING. 2.0 Semester Hrs.

This course is designed for graduate students planning careers in academia and focuses on principles of learning and teaching in a college setting; methods to foster and assess higher order thinking; and effective design, delivery and assessment of college courses. Prerequisite: None. 2 hours lecture; 2 semester hours.

Chemistry and Geochemistry

2015-2016

Degrees Offered

- Master of Science (Chemistry; thesis and non-thesis options)
- Doctor of Philosophy (Applied Chemistry)
- Master of Science (Geochemistry; thesis)
- Professional Masters in Environmental Geochemistry (non-thesis)
- Doctor of Philosophy (Geochemistry)

All graduate degree programs in the Department of Chemistry & Geochemistry have been admitted to the Western Regional Graduate

Program (WICHE). This program allows residents of Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming to register at Colorado resident tuition rates.

Program Description

The Department of Chemistry & Geochemistry offers graduate degrees in chemistry and in geochemistry. This section of the Bulletin only describes the chemistry degrees. For geochemistry degrees, please consult the Geochemistry section of the bulletin.

Prerequisites

A candidate for an advanced degree in the chemistry program should have completed an undergraduate program in chemistry which is essentially equivalent to that offered by the Department of Chemistry & Geochemistry at the Colorado School of Mines. Undergraduate deficiencies will be determined by faculty in the Department of Chemistry & Geochemistry through interviews and/or placement examinations at the beginning of the student's first semester of graduate work.

Required Curriculum

Chemistry

A student in the chemistry program, in consultation with the advisor and thesis committee, selects the program of study. Initially, before a thesis advisor and thesis committee have been chosen, the student is advised by a temporary advisor and by the Graduate Affairs Committee in the Department of Chemistry & Geochemistry.

M.S. Degree (chemistry, thesis option): The program of study includes coursework, research, and the preparation and oral defense of an MS thesis based on the student's research. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0

Students should enroll in CHGN560 in the first semester of their degree program. A minimum of 36 semester hours, including at least 24 semester hours of course work, are required. At least 15 of the required 24 semester hours of course work must be taken in the Department of Chemistry & Geochemistry at CSM. The student's thesis committee makes decisions on transfer credit. Up to 9 semester hours of graduate courses may be transferred from other institutions, provided that those courses have not been used as credit toward a Bachelor's degree.

Research-Intensive MS Degree: CSM undergraduates who enter the graduate program through the combined BS/MS program may use this option (thesis-based MS) to acquire a research-intensive MS degree by minimizing the time spent on coursework. This option requires a minimum of 12 hours of coursework up to six hours of which may be double counted from the student's undergraduate studies at CSM (see below).

M.S. Degree (chemistry, non-thesis option): The non-thesis M.S. degree requires 30 semester hours of course credit:

Course work 24.0

Independent study	6.0
Total Semester Hrs	30.0

The program of study includes coursework, independent study on a topic determined by the student and the student's faculty advisor, and the preparation of an oral presentation of a report based on the student's independent study topic. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0
Total Semester Hrs	14.0	

Students should enroll in CHGN560 in the first semester of their degree program. At least 21 of the required 30 semester hours of course work must be taken as a registered master's degree student at CSM. The student's committee makes decisions on courses to be taken, transfer credit, and examines the student's written report. Up to 15 semester hours of graduate courses may be transferred into the degree program, provided that those courses have not been used as credit toward a Bachelor's degree.

Ph.D. Degree (Applied Chemistry): The program of study for the Ph.D. degree in Applied Chemistry includes coursework, a comprehensive examination, a thesis proposal, research, and the preparation and oral defense of a Ph.D. thesis based on the student's research.

Coursework. The required courses are:

CHGN502	ADVANCED INORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
CHGN505	ADVANCED ORGANIC CHEMISTRY	3.0
CHGN507	ADVANCED ANALYTICAL CHEMISTRY	3.0
CHGN560	GRADUATE SEMINAR, M.S. (M.S.-level seminar)	1.0
CHGN660	GRADUATE SEMINAR, Ph.D. (Ph.D.-level seminar)	1.0
Total Semester Hrs	15.0	

The total hours of course work required for the Ph.D. degree is determined on an individual basis by the student's thesis committee. Up to 24 semester hours of graduate-level course work may be transferred from other institutions toward the Ph.D. degree provided that those courses have not been used by the student toward a Bachelor's degree. Up to 36 hours of credit may be transferred if the student has completed a Master's degree. The student's thesis committee may set additional course requirements and will make decisions on requests for transfer credit.

Seminar requirement. Students should enroll in CHGN560 in the first semester of their degree program. The CHGN560 seminar must be completed no later than the end of the student's second year of graduate studies at CSM. The semester after completion of the CHGN560 seminar, students must enroll in CHGN660. The CHGN660 seminar must include detailed research findings and interpretation of the student's Ph.D thesis research and must be presented close to, but before, the student's oral defense of the thesis.

Comprehensive examination. The comprehensive examination comprises a written literature review of the student's field of research, an oral

presentation and defense of the literature review before the student's thesis committee, and oral answers to questions posed by the thesis committee during the defense. The literature review must be completed prior to the end of the student's second year of graduate studies. A student's thesis committee may, at its discretion, require additional components to the comprehensive examination process.

Thesis proposal. The thesis proposal should include a statement of the hypotheses, goals and objectives of the proposed research, the significance and novelty of the research in the context of previously published studies, a description of methodology and results to date, a timeline with milestones, and a description of how the student has contributed to the creation or direction of the project. The thesis proposal must be orally defended before the student's thesis committee prior to completion of the student's third year of studies.

Geochemistry

Please see the Geochemistry (<http://bulletin.mines.edu/graduate/programs/interdisciplinaryprograms/geochemistry>) section of this bulletin for more information.

Fields of Research

Analytical and bioanalytical chemistry. Separation and characterization techniques for polymers, biopolymers, nano-particles and natural colloids. Biodetection of pathogens. Advanced separations for nuclear fuel cycle. Instrumental analysis.

Energy sciences. Alternative fuels. New materials and technologies for solar energy capture, conversion, and storage. Electrochemistry and Radiochemistry. Energy materials from chemical wastes.

Environmental chemistry. Detection and fate of anthropogenic contaminants in water, soil, and air. Acid mine drainage. Ecotoxicology. Environmental photochemistry. Cleaning of industrial pollutants.

Geochemistry and biogeochemistry. Microbial and chemical processes in global climate change, biomineralization, metal cycling, medical and archeological geochemistry, humic substances.

Inorganic Chemistry. Synthesis, characterization, and applications of metal, metal oxide, and semiconductor nanomaterials.

Nanoscale materials. Design, synthesis and characterization of new materials for catalysis, energy sciences, spectroscopic applications and drug delivery. Environmental fate of nanoparticles.

Organic Chemistry. Polymer design, synthesis and characterization. Catalysis. Alternative fuels.

Physical and Computational Chemistry. Computational chemistry for polymer design, clathrate hydrates, porous media, molecular simulation, energy sciences, biophysical chemistry, rational design of molecular materials, photochemical processes and excited state dynamics, and materials research. Surface-enhanced Raman spectroscopy. Laser Flash Photolysis.

Polymers. New techniques for controlling polymer architecture and composition. Theory and simulation. Separation and characterization.

Professors

Mark E. Eberhart

Mark P. Jensen, Grandey University Chair in Nuclear Science & Engineering

Daniel M. Knauss

James F. Ranville

Ryan M. Richards

Bettina M. Voelker

Kim R. Williams

David T. Wu, Department Head

Associate Professors

Stephen G. Boyes

Matthew C. Posewitz

Alan S. Sellinger

Assistant Professors

Jenifer C. Braley

Svitlana Pylypenko

Brian G. Trewyn

Shubham Vyas

Yongan Yang

Teaching Professors

Renee L. Falconer

Mark R. Seger

Teaching Associate Professor

Angela Sower

Teaching Assistant Professors

Allison G. Caster

Edward A. Dempsey

Research Professors

Donald L. Macalady

Kent J. Voorhees

Research Assistant Professors

Christopher Cox

Fiona Davies

Yuan Yang

Research Faculty

Jesse Hensley

Bryan Pivovar

Robert Rundberg

Affiliated Faculty

Joseph Meyer

Professor Emeriti

Scott W. Cowley

Stephen R. Daniel

Dean W. Dickerhoof

Kenneth W. Edwards

Ronald W. Klusman

Donald Langmuir

Patrick MacCarthy

Michael J. Pavelich

E. Craig Simmons

Thomas R. Wildeman

John T. Williams

Robert D. Witters

Courses

CHGC503. INTRODUCTION TO GEOCHEMISTRY. 4.0 Semester Hrs.

A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisite: Introductory chemistry, mineralogy and petrology. 4 hours lecture, 4 semester hours.

CHGC504. METHODS IN GEOCHEMISTRY. 2.0 Semester Hrs.

Sampling of natural earth materials including rocks, soils, sediments, and waters. Preparation of naturally heterogeneous materials, digestions, and partial chemical extractions. Principles of instrumental analysis including atomic spectroscopy, mass separations, and chromatography. Quality assurance and quality control. Interpretation and assessment of geochemical data using statistical methods. Prerequisite: Graduate standing in geochemistry or environmental science and engineering. 2 hours lecture; 2 semester hours.

CHGC505. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.

Equivalent with CHGN403, (II) Processes by which natural and anthropogenic chemicals interact, react, and are transformed and redistributed in various environmental compartments. Air, soil, and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized environments such as waste treatment facilities and the upper atmosphere. Meets with CHGN403. CHGN403 and CHGC505 may not both be taken for credit. Prerequisites: GEGN101, CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGC506. WATER ANALYSIS LABORATORY. 2.0 Semester Hrs.

Instrumental analysis of water samples using spectroscopy and chromatography. Methods for field collection of water samples and field measurements. The development of laboratory skills for the use of ICP-AES, HPLC, ion chromatography, and GC. Laboratory techniques focus on standard methods for the measurement of inorganic and organic constituents in water samples. Methods of data analysis are also presented. Prerequisite: Introductory chemistry, graduate standing. 3 hour laboratory, 1 hour lecture, 2 semester hours.

CHGC509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.

Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

CHGC511. GEOCHEMISTRY OF IGNEOUS ROCKS. 3.0 Semester Hrs.

A survey of the geochemical characteristics of the various types of igneous rock suites. Application of major element, trace element, and isotope geochemistry to problems of their origin and modification. Prerequisite: Undergraduate mineralogy and petrology. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGC514. GEOCHEMISTRY THERMODYNAMICS AND KINETICS. 3.0 Semester Hrs.

(II) Fundamental principles of classical thermodynamics and kinetics with specific application to the earth sciences. Volume-temperature ? pressure relationships for solids, liquids, gases and solutions. Energy and the First Law, Entropy and the Second and Third Laws. Gibbs Free Energy, chemical equilibria and the equilibrium constant. Solutions and activity-composition relationships for solids, fluids and gases. Phase equilibria and the graphical representation of equilibria. Application of the fundamentals of kinetics to geochemical examples. Prerequisite: Introductory chemistry, introductory thermodynamics, mineralogy and petrology. 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGC527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.

A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

CHGC555. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.

A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CHGC562. MICROBIOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.

This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of micro-organisms; microbial metabolism, energetics, genetics, growth and diversity; microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: ESGN301. 3 hours lecture, 3 semester hours. Offered alternate years.

CHGC563. ENVIRONMENTAL MICROBIOLOGY. 2.0 Semester Hrs.

An introduction to the microorganisms of major geochemical importance, as well as those of primary importance in water pollution and waste treatment. Microbes and sedimentation, microbial leaching of metals from ores, acid mine water pollution, and the microbial ecology of marine and freshwater habitats are covered. Prerequisite: none. 1 hour lecture, 3 hours lab; 2 semester hours. Offered alternate years.

CHGC564. BIOGEOCHEMISTRY AND GEOMICROBIOLOGY. 3.0 Semester Hrs.

Designed to give the student an understanding of the role of living things, particularly microorganisms, in the shaping of the earth. Among the subjects will be the aspects of living processes, chemical composition and characteristics of biological material, origin of life, role of microorganisms in weathering of rocks and the early diagenesis of sediments, and the origin of petroleum, oil shale, and coal. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGC598. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGC698. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN502. ADVANCED INORGANIC CHEMISTRY. 3.0 Semester Hrs.

(II) Detailed examination of topics such as ligand field theory, reaction mechanisms, chemical bonding, and structure of inorganic compounds. Emphasis is placed on the correlations of the chemical reactions of the elements with periodic trends and reactivities. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN503. ADV PHYSICAL CHEMISTRY I. 4.0 Semester Hrs.

(II) Quantum chemistry of classical systems. Principles of chemical thermodynamics. Statistical mechanics with statistical calculation of thermodynamic properties. Theories of chemical kinetics. Prerequisite: none. 4 hours lecture; 4 semester hours.

CHGN505. ADVANCED ORGANIC CHEMISTRY. 3.0 Semester Hrs.

Detailed discussion of the more important mechanisms of organic reaction. Structural effects and reactivity. The application of reaction mechanisms to synthesis and structure proof. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN507. ADVANCED ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.

(I) Review of fundamentals of analytical chemistry. Literature of analytical chemistry and statistical treatment of data. Manipulation of real substances; sampling, storage, decomposition or dissolution, and analysis. Detailed treatment of chemical equilibrium as related to precipitation, acid-base, complexation and redox titrations. Potentiometry and UV-visible absorption spectrophotometry. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN508. ANALYTICAL SPECTROSCOPY. 3.0 Semester Hrs.

(II) Detailed study of classical and modern spectroscopic methods; emphasis on instrumentation and application to analytical chemistry problems. Topics include: UV-visible spectroscopy, infrared spectroscopy, fluorescence and phosphorescence, Raman spectroscopy, arc and spark emission spectroscopy, flame methods, nephelometry and turbidimetry, reflectance methods, Fourier transform methods in spectroscopy, photoacoustic spectroscopy, rapid-scanning spectroscopy. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN510. CHEMICAL SEPARATIONS. 3.0 Semester Hrs.

(II) Survey of separation methods, thermodynamics of phase equilibria, thermodynamics of liquid-liquid partitioning, various types of chromatography, ion exchange, electrophoresis, zone refining, use of inclusion compounds for separation, application of separation technology for determining physical constants, e.g., stability constants of complexes. Prerequisite: CHGN507. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN511. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.

(II) The Applied Radiochemistry course is designed for those who have a budding interest radiochemistry and its applications. A brief overview of radioactivity and general chemistry will be provided in the first three weeks of the course. Follow-on weeks will feature segments focusing on the radiochemistry in the nuclear fuel cycle, radioisotope production, nuclear forensics and the environment. Prerequisites: CHGN121/ CHGN122. 3 hours lecture and discussion; 3 semester hours.

CHGN515. CHEMICAL BONDING IN MATERIALS. 3.0 Semester Hrs.

(I) Introduction to chemical bonding theories and calculations and their applications to solids of interest to materials science. The relationship between a material's properties and the bonding of its atoms will be examined for a variety of materials. Includes an introduction to organic polymers. Computer programs will be used for calculating bonding parameters. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN523. SOLID STATE CHEMISTRY. 3.0 Semester Hrs.

(I) Dependence of properties of solids on chemical bonding and structure; principles of crystal growth, crystal imperfections, reactions and diffusion in solids, and the theory of conductors and semiconductors. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN536. ADVANCED POLYMER SYNTHESIS. 3.0 Semester Hrs.

(II) An advanced course in the synthesis of macromolecules. Various methods of polymerization will be discussed with an emphasis on the specifics concerning the syntheses of different classes of organic and inorganic polymers. Prerequisite: CHGN430, ChEN415, MLGN530. 3 hours lecture, 3 semester hours.

CHGN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.

Equivalent with BELS555, CBEN555, CHEN555, MLGN555, The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CHGN560. GRADUATE SEMINAR, M.S.. 1.0 Semester Hr.

(I, II) Required for all candidates for the M.S. and Ph.D. degrees in chemistry and geochemistry. M.S. students must register for the course during each semester of residency. Ph.D. students must register each semester until a grade is received satisfying the prerequisites for CHGN660. Presentation of a graded non-thesis seminar and attendance at all departmental seminars are required. Prerequisite: Graduate student status. 1 semester hour.

CHGN580. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.

(II) Application of X-ray diffraction techniques for crystal and molecular structure determination of minerals, inorganic and organometallic compounds. Topics include the heavy atom method, data collection by moving film techniques and by diffractometers, Fourier methods, interpretation of Patterson maps, refinement methods, direct methods. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN581. ELECTROCHEMISTRY. 3.0 Semester Hrs.

(I) Introduction to theory and practice of electrochemistry. Electrode potentials, reversible and irreversible cells, activity concept. Interionic attraction theory, proton transfer theory of acids and bases, mechanisms and fates of electrode reactions. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN583. PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES. 3.0 Semester Hrs.

(II) Instrumental techniques for the characterization of surfaces of solid materials; Applications of such techniques to polymers, corrosion, metallurgy, adhesion science, microelectronics. Methods of analysis discussed: x-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), ion scattering spectroscopy (ISS), secondary ion mass spectrometry (SIMS), Rutherford backscattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive x-ray analysis; principles of these methods, quantification, instrumentation, sample preparation. Prerequisite: B.S. in Metallurgy, Chemistry, Chemical Engineering, Physics. 3 hours lecture; 3 semester hours.

CHGN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.

(II) The basic principles involved in the preparation, characterization, testing and theory of heterogeneous and homogeneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN585. CHEMICAL KINETICS. 3.0 Semester Hrs.

(II) Study of kinetic phenomena in chemical systems. Attention devoted to various theoretical approaches. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN597. SPECIAL RESEARCH. 15.0 Semester Hrs.**CHGN598. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.

Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: ChEN509 or equivalent, ChEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CHGN660. GRADUATE SEMINAR, Ph.D.. 1.0 Semester Hr.

(I, II) Required of all candidates for the doctoral degree in chemistry or geochemistry. Students must register for this course each semester after completing CHGN560. Presentation of a graded nonthesis seminar and attendance at all department seminars are required. Prerequisite: CHGN560 or equivalent. 1 semester hour.

CHGN698. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Metallurgical and Materials Engineering

2015-2016

Degrees Offered

- Master of Engineering (Metallurgical and Materials Engineering)
- Master of Science (Metallurgical and Materials Engineering)
- Doctor of Philosophy (Metallurgical and Materials Engineering)

Program Description

The program of study for the Master or Doctor of Philosophy degrees in Metallurgical and Materials Engineering is selected by the student in consultation with her or his advisor, and with the approval of the Thesis Committee. The program can be tailored within the framework of the regulations of the Graduate School to match the student's interests while maintaining the main theme of materials engineering and processing. There are three Areas of Specialization within the Department:

- Physical and Mechanical Metallurgy;
- Physicochemical Processing of Materials; and,
- Ceramic Engineering.

The Department is home to six research centers:

- Advanced Coatings and Surface Engineering Laboratory (ACSEL);
- Advanced Steel Processing and Products Research Center (ASPPRC);
- Center for Advanced Non Ferrous Structural Alloys (CANFSA)
- Center for Welding Joining, and Coatings Research (CWJCR);
- Colorado Center for Advanced Ceramics (CCAC); and,
- Kroll Institute for Extractive Metallurgy (KIEM).

The Nuclear Science and Engineering Center (NuSEC) also operates closely with the Department.

A Graduate Certificate is offered by each Department Center – the requirements for the Graduate Certificate are:

1. Be admitted to MME Graduate Certificate Program upon the recommendation of the MME Department.
2. Complete a total of 12 hours of course credits of which only 3 credit hours can be at the 400 level.

The specific courses to be taken are determined by the Graduate Advisor in the Department Center selected by the candidate. A cumulative grade point average of B or better must be maintained while completing these requirements.

Degree Program Requirements

The program requirements for the three graduate degrees offered by the Department are listed below:

Master of Engineering Degree

Requirements: A minimum total of 30.0 credit hours consisting of:

1. A minimum of 24.0 credit hours of approved course work and 6.0 hours of graduate research-credits listed under MTGN700.
2. Approval of all courses by the Engineering-Report Committee and the Department Head (Engineering-Report Committee consisting of 3 or more members, including the advisor and at least 2 additional members from the Metallurgical and Materials Engineering Department.)
3. Submittal and successful oral defense, before the Engineering-Report Committee, of an Engineering Report, which presents the results of a case study or an engineering development.

Restrictions:

1. Only three (3) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

The Master of Engineering Degree can be obtained as part of the combined undergraduate/graduate degree program. See "Combined Undergraduate/Graduate Degree Programs" section of the bulletin for more details.

Master of Science Degree

Requirements: A minimum total of 30.0 credit hours, consisting of:

1. A minimum of 18.0 credit hours of approved course work and a minimum of 6.0 hours of graduate research-credits listed under MTGN707.
2. Approval of all courses by the Thesis Committee and the Department Head. (Thesis Committee: consisting of 3 or more members, including the advisor and at least 1 additional member from the Metallurgical and Materials Engineering Department.)
3. Submittal and successful oral defense of a thesis before a Thesis Committee. The thesis must present the results of original scientific research or development.

Restrictions:

1. Only three (3) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

Doctor of Philosophy Degree

Requirements: A minimum total of 72.0 credit hours consisting of:

1. A minimum of 36.0 credit hours of approved course work and a minimum of 24.0 hours of research-credits (MTGN707). Credit hours previously earned for a Master's degree may be applied, subject to approval, toward the Doctoral degree provided that the Master's degree was in Metallurgical and Materials Engineering or a similar field. At least 21.0 credit hours of approved course work must be taken at the Colorado School of Mines.
2. All courses and any applicable Master's degree credit-hours must be approved by the Thesis Committee and the Department Head (Thesis Committee consisting of: 5 or more members, including the advisor, at least 2 additional members from the Metallurgical and Materials Engineering Department, and at least 1 member from outside the Department.)
3. Presentation of a Proposal on the Thesis-Research Project to the Thesis Committee.
4. Passing grade on the written and oral Qualifying-Process (Q.P.) Examinations.
5. Presentation of a Progress Report on their Research Project to the Thesis Committee; this presentation is usually 6 months after successfully completing the Q.P. Examinations and no fewer than 6 weeks before the Defense of Thesis.
6. Submittal and successful oral-defense of a thesis before the Thesis Committee. The thesis must present the results of original scientific research or development.

Restrictions:

1. Only six (6) credit hours of independent course work, e.g. MTGN599, may be applied toward the degree.
2. A maximum of nine (9) credit hours of approved 400-level course work may be applied toward the degree.
3. Courses taken to remove deficiencies may not be applied toward the degree.

Prerequisites

The entering graduate-student in the Department of Metallurgical and Materials Engineering must have completed an undergraduate program equivalent to that required for the B.S. degree in: Metallurgical and Materials Engineering, Materials Science or a related field. This undergraduate program should have included a background in science fundamentals and engineering principles. A student, who possesses this background but has not taken specific undergraduate courses in Metallurgical and Materials Engineering, will be allowed to rectify these course deficiencies at the beginning of their program of study.

Fields of Research

Ceramic Research

- Ceramic processing

- Ceramic-metal composites
- Functional materials
- Ion implantation
- Modeling of ceramic processing
- Solid oxide fuel cell materials and membranes
- Transparent conducting oxides

Coatings Research

- Chemical vapor deposition
- Coating materials, films and applications
- Epitaxial growth
- Interfacial science
- Physical vapor deposition
- Surface mechanics
- Surface physics
- Tribology of thin films and coatings

Extractive and Mineral Processing Research

- Chemical and physical processing of materials
- Electrometallurgy
- Hydrometallurgy
- Mineral processing
- Pyrometallurgy
- Recycling and recovery of materials
- Thermal plasma processing

Nonferrous Research

- Aluminum alloys
- High entropy alloys
- Magnesium alloys
- Nonferrous structural alloys
- Shape memory alloys
- Superalloys
- Titanium alloys

Polymers and Biomaterials Research

- Advanced polymer membranes and thin films
- Biopolymers
- Bio-mimetic and bio-inspired materials engineering
- Calcium phosphate based ceramics
- Drug delivery
- Failure of medical devices
- Interfaces between materials and tissue
- Living/controlled polymerization
- Organic-inorganic hybrid materials
- Porous structured materials
- Self- and directed-assembly
- Structural medical alloys
- Tissue as a composite material

Steel Research

- Advanced high strength steels
- Advanced steel coatings

- Carburized steels
- Deformation behavior of steels
- Fatigue behavior of steels
- Microalloyed steels
- Nickel-based steels
- Quench and partitioned steels
- Plate steels
- Sheet steels

Welding and Joining Research

- Brazing of ultra wide gaps
- Explosive processing of materials
- Laser welding and processing
- Levitation for kinetics and surface tension evaluation
- Materials joining processes
- Pyrochemical kinetics studies using levitation
- Underwater and under oil welding
- Welding and joining science
- Welding rod development
- Welding stress management
- Weld metallurgy
- Weld wire development

Nuclear Materials Research

- Nuclear materials characterization
- Nuclear materials processing
- Nuclear materials properties

Experimental Methods

- 3D atom probe tomography
- Atomic force microscopy
- Computer modeling and simulation
- Electron microscopy
- Mathematical modeling of material processes
- Nanoindentation
- Non-destructive evaluation
- X-ray diffraction

Other Research Areas

- Combustion synthesis
- Corrosion science and engineering
- Failure analysis
- Mechanical metallurgy
- Phase transformation and mechanism of microstructural change
- Physical metallurgy
- Reactive metals properties
- Strengthening mechanisms
- Structure-property relationships

MTGN505	CRYSTALLOGRAPHY AND DIFFRACTION	3.0
MTGN511	SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS	1-3

MTGN512	SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS	1-3
MTGN514	DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS	3.0
MTGN516	MICROSTRUCTURE OF CERAMIC SYSTEMS	3.0
MTGN517	REFRACTORIES	3.0
MTGN518	PHASE EQUILIBRIA IN CERAMIC SYSTEMS	3.0
MTGN523	APPLIED SURFACE AND SOLUTION CHEMISTRY	3.0
MTGN526	GEL SCIENCE AND TECHNOLOGY	3.0
MTGN527	SOLID WASTE MINIMIZATION AND RECYCLING	3.0
MTGN528	EXTRACTIVE METALLURGY OF COPPER, GOLD AND SILVER	3.0
MTGN529	METALLURGICAL ENVIRONMENT	3.0
MTGN530	ADVANCED IRON AND STEELMAKING	3.0
MTGN531	THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING	3.0
MTGN532	PARTICULATE MATERIAL PROCESSING I - COMMUNITION AND PHYSICAL SEPARATIONS	3.0
MTGN533	PARTICULATE MATERIAL PROCESSING II - APPLIED SEPARATIONS	3.0
MTGN534	CASE STUDIES IN PROCESS DEVELOPMENT	3.0
MTGN535	PYROMETALLURGICAL PROCESSES	3.0
MTGN536	OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS	3.0
MTGN537	ELECTROMETALLURGY	3.0
MTGN538	HYDROMETALLURGY	3.0
MTGN539	PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN	3.0
MTGN541	INTRODUCTORY PHYSICS OF METALS	3.0
MTGN542	ALLOYING THEORY, STRUCTURE, AND PHASE STABILITY	3.0
MTGN543	THEORY OF DISLOCATIONS	3.0
MTGN544	FORGING AND DEFORMATION MODELING	3.0
MTGN545	FATIGUE AND FRACTURE	3.0
MTGN546	CREEP AND HIGH TEMPERATURE MATERIALS	3.0
MTGN547	PHASE EQUILIBRIA IN MATERIALS SYSTEMS	3.0
MTGN548	TRANSFORMATIONS IN METALS	3.0
MTGN549	CURRENT DEVELOPMENTS IN FERROUS ALLOYS	3.0
MTGN551	ADVANCED CORROSION ENGINEERING	3.0
MTGN552	INORGANIC MATRIX COMPOSITES	3.0
MTGN553	STRENGTHENING MECHANISMS	3.0
MTGN554	OXIDATION OF METALS	3.0
MTGN555	SOLID STATE THERMODYNAMICS	3.0
MTGN556	TRANSPORT IN SOLIDS	3.0
MTGN557	SOLIDIFICATION	3.0
MTGN560	ANALYSIS OF METALLURGICAL FAILURES	3.0
MTGN561	PHYSICAL METALLURGY OF ALLOYS FOR AEROSPACE	3.0
MTGN564	ADVANCED FORGING AND FORMING	3.0
MTGN565	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES	3.0
MTGN569	FUEL CELL SCIENCE AND TECHNOLOGY	3.0

MTGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MTGN571	METALLURGICAL AND MATERIALS ENGINEERING LABORATORY	1-3
MTGN572	BIOMATERIALS	3.0
MTGN580	ADVANCED WELDING METALLURGY	3.0
MTGN581	WELDING HEAT SOURCES AND INTERACTIVE CONTROLS	3.0
MTGN582	MECHANICAL PROPERTIES OF WELDED JOINTS	3.0
MTGN583	PRINCIPLES OF NON-DESTRUCTIVE TESTING AND EVALUATION	3.0
MTGN584	NON-FUSION JOINING PROCESSES	3.0
MTGN586	DESIGN OF WELDED STRUCTURES AND ASSEMBLIES	3.0
MTGN587	PHYSICAL PHENOMENA OF WELDING AND JOINING PROCESSES	3.0
MTGN591	PHYSICAL PHENOMENA OF COATING PROCESSES	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN598	SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING	1-6
MTGN599	INDEPENDENT STUDY	1-3
MTGN605	ADVANCED TRANSMISSION ELECTRON MICROSCOPY	2.0
MTGN605L	ADVANCED TRANSMISSION ELECTRON MICROSCOPY LABORATORY	1.0
MTGN631	TRANSPORT PHENOMENA IN METALLURGICAL AND MATERIALS SYSTEMS	3.0
MTGN671	ADVANCED MATERIALS LABORATORY	1-3
MTGN672	ADVANCED MATERIALS LABORATORY	1-3
MTGN696	VAPOR DEPOSITION PROCESSES	3.0
MTGN697	MICROSTRUCTURAL EVOLUTION OF COATINGS AND THIN FILMS	3.0
MTGN698	SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING	1-3
MTGN699	INDEPENDENT STUDY	1-3
MTGN700	GRADUATE RESEARCH CREDIT: MASTER OF ENGINEERING	1-6
MTGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-15

Professors

Ivar E. Reimanis, Interim Department Head, Herman F. Coors Distinguished Professor of Ceramics

Corby G. Anderson, Harrison Western Professor

Michael J. Kaufman, Dean of CASE

Stephen Liu, American Bureau of Shipping Endowed Chair Professor of Metallurgical and Materials Engineering

Ryan O'Hayre

John G. Speer, John Henry Moore Distinguished Professor of Metallurgical and Materials Engineering

Patrick R. Taylor, George S. Ansell Distinguished Professor of Chemical Metallurgy

Chester J. Van Tyne, Associate Department Head, FIERF Professor

Associate Professors

Kip O. Findley

Brian Gorman

Jeffrey C. King

Steven W. Thompson

Assistant Professors

Geoff L. Brennecka

Emmanuel De Moor

Corinne E. Packard

Vladan Stevanovic

Zhenzhen Yu

Teaching Associate Professors

Gerald Bourne

John P. Chandler

Research Professors

Richard K. Ahrenkiel

Ivan Cornejo

Hongjun Liang

Stephen Midson

William Sproul

William (Grover) Coors

Robert Field

Terry Lowe

D. (Erik) Spiller

James C. Williams

Research Associate Professors

Robert Cryderman

Carole Graas

Jianhua Tong

Edgar Vidal

Research Assistant Professors

David Diercks

Judith C. Gomez

Jianliang Lin

Svitlana Pylypenko

Professors Emeriti

George S. Ansell, President Emeritus

W. Rex Bull, Professor Emeritus

Glen R. Edwards, University Professor Emeritus

John P. Hager, University Professor Emeritus

George Krauss, University Professor Emeritus

Gerard P. Martins, Professor Emeritus

David K. Matlock, University Professor Emeritus

Brajendra Mishra

John J. Moore, Professor Emeritus

David L. Olson, University Professor Emeritus

Dennis W. Readey, University Professor Emeritus

Associate Professors Emeriti

Gerald L. DePoorter

Robert H. Frost

Physics

2015-2016

Degrees Offered

- Master of Science (Applied Physics)
- Doctor of Philosophy (Applied Physics)

Program Description

The Physics Department at CSM offers a full program of instruction and research leading to the M.S. or Ph.D. in Applied Physics and is part of interdisciplinary programs in Materials Science and in Nuclear Engineering, through which students can obtain both the M.S. and the Ph.D. degrees. The research in these graduate programs is supported by external grants and contracts totaling \$6.5M/year. Research in the Department is organized under three primary themes: subatomic physics, condensed matter physics, and applied optics. With 23 faculty, 83 graduate students, and 262 undergraduate physics majors, the Physics Department at CSM is a vibrant intellectual community providing high-quality education in state-of-the-art facilities.

Graduate students are given a solid background in the fundamentals of classical and modern physics at an advanced level and are encouraged early in their studies to learn about the research interests of the faculty so that a thesis topic can be identified.

Program Requirements

Students entering graduate programs in Applied Physics will select an initial program in consultation with the departmental graduate student

advising committee until such time as a research field has been chosen and a thesis committee appointed.

Master of Science

Requirements: 20 semester hours of course work in an approved program, plus 16 semester hours of research credit, with a satisfactory thesis.

Doctorate of Philosophy

Requirements: 32 semester hours of course work in an approved program, plus 40 semester hours of research credit, with a satisfactory thesis. 12 semester hours of course work will be in a specialty topic area defined in consultation with the thesis advisor. Possible specialty topic areas within the Physics Department exist in Optical Science and Engineering, Condensed Matter Physics, Theoretical Physics, Renewable Energy Physics, and Nuclear/Particle Physics and Astrophysics.

To demonstrate adequate preparation for the Ph.D. degree in Applied Physics, each student must achieve a grade of 3.0 or better in each core course. Students not meeting this standard must pass oral examinations covering the relevant core courses or retake the courses with a grade of 3.0 or better within one year. This process is part of the requirement for admission to candidacy, which full time Ph.D. students must complete within two calendar years of admission, as described in the campus-wide graduate degree requirements (<http://bulletin.mines.edu/graduate/programs>) section of this bulletin. Other degree requirements, time limits, and procedural details can be found in the Physics Department Graduate Student Advising Brochure.

Physics Colloquium

All full-time physics graduate students must attend the Physics Colloquium, which is represented in the curriculum by the Graduate Seminar courses. Students must take one of these courses every semester that they are enrolled at CSM. Those students who are in the M.S. Program, sign up for PHGN501 (fall) and PHGN502 (spring). Students in the Ph.D. program sign up for PHGN601 (fall) and PHGN602 (spring). At the end of each semester students are assigned either a satisfactory or unsatisfactory progress grade, based on attendance, until the final semester of the student's degree program, when a letter grade is assigned based on all prior semesters' attendance grades. As a result, while these courses are taken each year, only 1 hour total of course credit is conferred for each of 501, 502, 601, or 602. Students who have official part-time status and who have already taken at least one semester of 501 and 502 for the M.S. degree, or 601 and 602 for the Ph.D. degree are not required to sign up for Graduate Seminar during subsequent semesters.

Prerequisites

The Graduate School of the Colorado School of Mines is open to graduates from four-year programs at accredited colleges or universities. Admission to the Physics Department M.S. and Ph.D. programs is competitive and is based on an evaluation of undergraduate performance, standardized test scores, and references. The undergraduate course of study of each applicant is evaluated according to the requirements of the Physics Department.

Required Curriculum

Master of Science, Applied Physics

Core Courses

PHGN511	MATHEMATICAL PHYSICS	3.0
PHGN520	QUANTUM MECHANICS I	3.0
	Select one of the following:	3.0
PHGN505	CLASSICAL MECHANICS I	
PHGN507	ELECTROMAGNETIC THEORY I	
PHGN521	QUANTUM MECHANICS II	
PHGN530	STATISTICAL MECHANICS	
PH ELECT	Electives	9.0
PHGN501 & PHGN502	GRADUATE SEMINAR and GRADUATE SEMINAR *	2.0
PHGN707	Master's Thesis	16.0
Total Semester Hrs		36.0

* Graduate Seminar: Each full-time M.S. graduate student will register for Graduate Seminar each semester for a total of 2 semester hours of credit cumulative over the degree.

Doctor of Philosophy, Applied Physics

Core Courses

PHGN505	CLASSICAL MECHANICS I	3.0
PHGN507	ELECTROMAGNETIC THEORY I	3.0
PHGN511	MATHEMATICAL PHYSICS	3.0
PHGN520	QUANTUM MECHANICS I	3.0
PHGN521	QUANTUM MECHANICS II	3.0
PHGN530	STATISTICAL MECHANICS	3.0
PHGN601 & PHGN602	ADVANCED GRADUATE SEMINAR and ADVANCED GRADUATE SEMINAR *	2.0
PH ELECT	Special topic area electives	12.0
PHGN707	Doctoral Thesis	40.0
Total Semester Hrs		72.0

* Graduate Seminar: Each full-time Ph.D. graduate student will register for Graduate Seminar each semester for a total of 2 semester hours of cumulative credit over the degree.

Fields of Research

Applied Optics: lasers, ultrafast optics and x-ray generation, spectroscopy, near-field and multiphoton microscopy, non-linear optics, quasi-optics and millimeter waves.

Ultrasonics: laser ultrasonics, resonant ultrasound spectroscopy, wave propagation in random media.

Subatomic: low energy nuclear physics, nuclear astrophysics, cosmic ray physics, nuclear theory, fusion plasma diagnostics.

Materials Physics: photovoltaics, nanostructures and quantum dots, thin film semiconductors, transparent conductors, amorphous materials, thermoelectric materials, plasmonics, first principles materials theory.

Condensed Matter: x-ray diffraction, Raman spectroscopy, self assembled systems, soft condensed matter, condensed matter theory, quantum chaos, quantum information and quantum many body theory.

Surface and Interfaces: x-ray photoelectron spectroscopy, Auger spectroscopy, scanning probe microscopies, second harmonic generation.

Professors

Lincoln D. Carr

Reuben T. Collins

Charles G. Durfee III

Uwe Greife

Frank V. Kowalski

Mark T. Lusk

Frederic Sarazin

John A. Scales

Jeff A. Squier, Department Head

P. Craig Taylor

Associate Professors

Timothy R. Ohno

Lawrence R. Wiencke

David M. Wood

Assistant Professors

Kyle G. Leach

Susanta K. Sarkar

Eric S. Toberer

Zhigang Wu

Jeremy D. Zimmerman

Teaching Professors

Alex T. Flournoy

Patrick B. Kohl

H. Vincent Kuo

Todd G. Ruskell

Charles A. Stone

Matt Young

Teaching Associate Professor

Kristine E. Callan

Research Professors

Mark W. Coffey

Jonathan L. Mace

Zeev Shayer

Research Associate Professors

Joseph D. Beach

James E. Bernard

Research Assistant Professor

P. David Flammer

Professors Emeriti

F. Edward Cecil

Thomas E. Furtak

James A. McNeil

Don L. Williamson

Associate Professors Emeriti

William B. Law

Arthur Y. Sakakura

Courses**PHGN501. GRADUATE SEMINAR. 1.0 Semester Hr.**

(I) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN502. GRADUATE SEMINAR. 1.0 Semester Hr.

(II) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN503. RESPONSIBLE CONDUCT OF RESEARCH. 1.0 Semester Hr.

(II) This course introduces students to the various components of responsible research practices. Subjects covered move from issues related to professional rights and obligations through those related to collaboration, communication and the management of grants, to issues dealing with intellectual property. The course culminates with students writing an ethics essay based on a series of topics proposed by the course instructor. 1 hour lecture; 1 semester hour.

PHGN504. RADIATION DETECTION AND MEASUREMENT. 3.0 Semester Hrs.

Physical principles and methodology of the instrumentation used in the detection and measurement of ionizing radiation. Prerequisite: none. 3 hours lecture; 3 semester hours.

PHGN505. CLASSICAL MECHANICS I. 3.0 Semester Hrs.

(I) Review of Lagrangian and Hamiltonian formulations in the dynamics of particles and rigid bodies; kinetic theory; coupled oscillations and continuum mechanics; fluid mechanics. Prerequisite: PHGN350 or equivalent. 3 hours lecture; 3 semester hours.

PHGN507. ELECTROMAGNETIC THEORY I. 3.0 Semester Hrs.

(II) To provide a strong background in electromagnetic theory. Electrostatics, magnetostatics, dynamical Maxwell equations, wave phenomena. Prerequisite: PHGN462 or equivalent and PHGN511. 3 hours lecture; 3 semester hours.

PHGN511. MATHEMATICAL PHYSICS. 3.0 Semester Hrs.

(I) Review of complex variable and finite and infinite-dimensional linear vector spaces. Sturm-Liouville problem, integral equations, computer algebra. Prerequisite: PHGN311 or equivalent. 3 hours lecture; 3 semester hours.

PHGN520. QUANTUM MECHANICS I. 3.0 Semester Hrs.

(II) Schroedinger equation, uncertainty, change of representation, one-dimensional problems, axioms for state vectors and operators, matrix mechanics, uncertainty relations, time-independent perturbation theory, time-dependent perturbations, harmonic oscillator, angular momentum; semiclassical methods, variational methods, two-level system, sudden and adiabatic changes, applications. Prerequisite: PHGN511 and PHGN320 or equivalent. 3 hours lecture; 3 semester hours.

PHGN521. QUANTUM MECHANICS II. 3.0 Semester Hrs.

(I) Review of angular momentum, central potentials and applications. Spin; rotations in quantum mechanics. Formal scattering theory, Born series, partial wave analysis. Addition of angular momenta, Wigner-Eckart theorem, selection rules, identical particles. Prerequisite: PHGN520. 3 hours lecture; 3 semester hours.

PHGN530. STATISTICAL MECHANICS. 3.0 Semester Hrs.

(I) Review of thermodynamics; equilibrium and stability; statistical operator and ensembles; ideal systems; phase transitions; non-equilibrium systems. Prerequisite: PHGN341 or equivalent and PHGN520. Co-requisite: PHGN521. 3 hours lecture; 3 semester hours.

PHGN535. INTERDISCIPLINARY SILICON PROCESSING LABORATORY. 3.0 Semester Hrs.

Equivalent with CBEN435, CBEN535, CHEN435, CHEN535, MLGN535, PHGN435, (II) Explores the application of science and engineering principles to the fabrication and testing of microelectronic devices with emphasis on specific unit operations and interrelation among processing steps. Teams work together to fabricate, test, and optimize simple devices. Prerequisite: none. 1 hour lecture, 4 hours lab; 3 semester hours.

PHGN542. SOLID STATE DEVICES AND PHOTOVOLTAIC APPLICATIONS. 3.0 Semester Hrs.

(II) An overview of the physical principles involved in the characterization, and operation of solid state devices. Topics will include: semiconductor physics, electronic transport, recombination and generation, intrinsic and extrinsic semiconductors, electrical contacts, p-n junction devices (e.g., LEDs, solar cells, lasers, particle detectors); other semiconductor devices (e.g., bipolar junction transistors and field effect transistors and capacitors). There will be emphasis on optical interactions and application to photovoltaic devices. Prerequisite: PHGN440 or equivalent. 3 hours lecture; 3 semester hours.

PHGN550. NANOSCALE PHYSICS AND TECHNOLOGY. 3.0 Semester Hrs.

An introduction to the basic physics concepts involved in nanoscale phenomena, processing methods resulting in engineered nanostructures, and the design and operation of novel structures and devices which take advantage of nanoscale effects. Students will become familiar with interdisciplinary aspects of nanotechnology, as well as with current nanoscience developments described in the literature. Prerequisites: PHGN320, PHGN341, co-requisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN566. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.

Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors, and optical system examples. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN570. FOURIER AND PHYSICAL OPTICS. 3.0 Semester Hrs.

This course addresses the propagation of light through optical systems. Diffraction theory is developed to show how 2D Fourier transforms and linear systems theory can be applied to imaging systems. Analytic and numerical Fourier and microscopes, spectrometers and holographic imaging. They are also applied to temporal propagation in ultrafast optics. Prerequisite: PHGN462 or equivalent. 3 hours lecture; 3 semester hours.

PHGN585. NONLINEAR OPTICS. 3.0 Semester Hrs.

An exploration of the nonlinear response of a medium (semiclassical and quantum descriptions) and nonlinear wave mixing and propagation. Analytic and numeric techniques to treat nonlinear dynamics are developed. Applications to devices and modern research areas are discussed, including harmonic and parametric wave modulation, phase conjugation, electro-optic modulation. Prerequisite: PHGN462 or equivalent, PHGN520. 3 hours lecture; 3 semester hours.

PHGN590. NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.

Bridges the gap between courses in fundamental nuclear physics and the practice of electrical power production using nuclear reactors. Review of nuclear constituents, forces, structure, energetics, decay and reactions; interaction of radiation with matter, detection of radiation; nuclear cross sections, neutron induced reactions including scattering, absorption, and fission; neutron diffusion, multiplication, criticality; simple reactor geometries and compositions; nuclear reactor kinetics and control; modeling and simulation of reactors. Prerequisite: PHGN422.

PHGN597. SUMMER PROGRAMS. 6.0 Semester Hrs.**PHGN598. SPECIAL TOPICS. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN601. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.

(I) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN602. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.

(II) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN608. ELECTROMAGNETIC THEORY II. 3.0 Semester Hrs.

Spherical, cylindrical, and guided waves; relativistic 4-dimensional formulation of electromagnetic theory. Prerequisite: PHGN507. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN612. MATHEMATICAL PHYSICS II. 3.0 Semester Hrs.

Continuation of PHGN511. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN623. NUCLEAR STRUCTURE AND REACTIONS. 3.0 Semester Hrs.

The fundamental physics principles and quantum mechanical models and methods underlying nuclear structure, transitions, and scattering reactions. Prerequisite: PHGN521. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN624. NUCLEAR ASTROPHYSICS. 3.0 Semester Hrs.

The physical principles and research methods used to understand nucleosynthesis and energy generation in the universe. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN641. ADVANCED CONDENSED MATTER PHYSICS. 3.0 Semester Hrs.

Provides working graduate-level knowledge of applications of solid state physics and important models to crystalline and non-crystalline systems in two and three dimensions. Review of transport by Bloch electrons; computation, interpretation of band structures. Interacting electron gas and overview of density functional theory. Quantum theory of optical properties of condensed systems; Kramers-Kronig analysis, sum rules, spectroscopies. Response and correlation functions. Theoretical models for metal-insulator and localization transitions in 1, 2, 3 dimensions (e.g., Mott, Hubbard, Anderson, Peierls distortion). Boltzmann equation. Introduction to magnetism; spin waves. Phenomenology of soft condensed matter: order parameters, free energies. Conventional superconductivity. Prerequisites: PHGN440 or equivalent, PHGN520, PHGN530. 3 hours lecture; 3 semester hours.

PHGN698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

Interdisciplinary Programs

Please choose from the list of links on the left to access more information.

Geochemistry

Degrees Offered

- Professional Masters in Environmental Geochemistry
- Master of Science (Geochemistry)
- Doctor of Philosophy (Geochemistry)

Program Description

The Graduate Program in Geochemistry is an interdisciplinary program with the mission to educate students whose interests lie at the intersection of the geological and chemical sciences. The Geochemistry Program consists of two subprograms, administering two M.S. and Ph.D. degree tracks and one Professional Master's (non-thesis) degree program. The Geochemistry (GC) degree track pertains to the history and evolution of the Earth and its features, including but not limited to the chemical evolution of the crust and mantle, geochemistry of energy and mineral resources, aqueous geochemistry and fluid-rock/fluid-mineral interactions and chemical mineralogy. The Environmental Biogeochemistry (EBGC) degree track pertains to the coupled chemical and biological processes of Earth's biosphere, and the changes in these processes caused by human activities.

Master of Science and Doctor of Philosophy

1. Geochemistry degree track

Prerequisites

Each entering student will have an entrance interview with members of the Geochemistry subprogram faculty. Since entering students may not be proficient in both areas, a placement examination in geology and/or chemistry may be required upon the discretion of the interviewing faculty. If a placement examination is given, the results may be used to establish deficiency requirements. Credit toward a graduate degree will not be granted for courses taken to fulfill deficiencies.

Requirements

The Master of Science (Geochemistry degree track) requires a minimum of 36 semester hours including:

Course work	24.0
Research credits	12.0
Total Semester Hrs	36.0

To ensure breadth of background, the course of study for the Master of Science (Geochemistry degree track) must include:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0

Master of Science (Geochemistry) students select two of the following:

CHGN503	ADV PHYSICAL CHEMISTRY I	
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	

GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	
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In addition, all students must complete a 1-2 hour laboratory course selected from several available. Master of Science (Geochemistry degree track) students must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's thesis committee before the student begins substantial work on the thesis research.

The requirement for the Doctor of Philosophy (Geochemistry degree track) program will be established individually by a student's thesis committee, but must meet the minimum requirements presented below. The Doctor of Philosophy (Geochemistry degree track) program will require a minimum of 72 credit hours. At least 24 hours must be research credit and at least 18 hours must be course work. Up to 24 hours of course credit may be transferred from previous graduate-level work upon approval of the thesis committee. Research credits may not be transferred. Students who enter the Doctor of Philosophy (Geochemistry degree track) program with a thesis-based Master of Science degree from another institution may transfer up to 36 semester hours, upon approval of the thesis committee, in recognition of the course work and research completed for that degree.

Doctor of Philosophy (Geochemistry degree track) students must take:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC514	GEOCHEMISTRY THERMODYNAMICS AND KINETICS	3.0
Laboratory course		1.0
Select two of the following:		3-4
CHGN503	ADV PHYSICAL CHEMISTRY I	
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	
GEOL512	MINERALOGY AND CRYSTAL CHEMISTRY	
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	

Doctor of Philosophy (Geochemistry degree track) students must also complete an appropriate thesis, based upon original research they have conducted. A thesis proposal and course of study must be approved by the student's thesis committee before the student begins substantial work on the thesis research.

Master of Science (Geochemistry degree track) and Doctor of Philosophy (Geochemistry degree track) students resident in the Department of Chemistry and Geochemistry or the Department of Geology and Geological Engineering shall adhere to the seminar rules and requirements of the department of residence.

2. Environmental Biogeochemistry (EBGC) degree track

Prerequisites

A candidate for an M.S. or Ph.D. in the EBGC degree track should have an undergraduate science or engineering degree with coursework including multivariable calculus, two semesters each of physics and chemistry, and one semester each of biology and earth science. Applicants who do not fulfill these requirements may still be admitted, but will need to undergo an entrance interview to establish deficiency

requirements. Credit toward a graduate degree will not be given for undergraduate courses taken to fulfill deficiencies.

Requirements

Required Curriculum: A thesis proposal and thesis are required for all M.S. and Ph.D. degrees in the EBGC degree track. M.S. thesis advisors (or at least one co-advisor) must be members of the EBGC subprogram.

Ph.D. thesis committees must have a total of at least four members.

Ph.D. advisors (or at least one of two co-advisors) and one additional committee member must be members of the EBGC subprogram. M.S. students will be expected to give one public seminar on their research; Ph.D. students are required to give at least one in addition to their thesis defense presentation.

In addition, both M.S. and Ph.D. students in the EBGC degree track must complete the following coursework:

1. Two required classes:

CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0

2. One chemistry-focused class, chosen from the following list:

CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0
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CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
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CEEN551	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
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3. One biology-focused class chosen from the following list:

CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
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CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0
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4. One earth science-focused class chosen from the following list

GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
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(New class) Earth Surface Geochemistry

5. One class focusing on analytical methods in environmental/biogeochemistry chosen from several available, including:

GEGN530	CLAY CHARACTERIZATION ((New class) Adv Geoenvironmental Anal)	3.0
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(New class) Adv Geoenvironmental Anal		3.0
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Total credits required for M.S.: 36

Total credits required for Ph.D.: 72 (at least 18 of coursework)

The student's thesis committee may specify additional course requirements and makes final decisions regarding transfer credits.

Comprehensive Examination

Doctor of Philosophy (Geochemistry) students in both degree tracks must take a comprehensive examination. It is expected that this exam will be completed within three years of matriculation or after the bulk of course work is finished, whichever occurs earlier. This examination will be administered by the student's thesis committee and will consist of an oral and a written examination, administered in a format to be determined by the thesis committee. Two negative votes in the thesis committee constitute failure of the examination.

In case of failure of the comprehensive examination, a re-examination may be given upon the recommendation of the thesis committee and

approval of the Dean of Graduate Studies. Only one re-examination may be given.

Tuition

The Master of Science (Geochemistry) and Doctor of Philosophy (Geochemistry) programs have been admitted to the Western Regional Graduate Program. This entity recognizes the Geochemistry Program as unique in the region. Designation of the Geochemistry Program by Western Regional Graduate program allows residents of western states to enroll in the program at Colorado resident tuition rates. Eligible states include Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, Washington and Wyoming.

Professional Masters in Environmental Geochemistry

Introduction

The Professional Masters in Environmental Geochemistry program is intended to provide:

1. an opportunity for CSM undergraduates to obtain, as part of a fifth year of study, a Master in addition to the Bachelor degree; and
2. additional education for working professionals in the area of geochemistry as it applies to problems relating to the environment.

This is a non-thesis Master degree program administered by the Environmental Biogeochemistry subprogram of the Geochemistry program, and may be completed as part of a combined degree program by individuals already matriculated as undergraduate students at CSM, or by individuals already holding undergraduate or advanced degrees and who are interested in a graduate program that does not have the traditional research requirement. The program consists primarily of coursework in geochemistry and allied fields with an emphasis on environmental applications. No research is required though the program does allow for independent study, professional development, internship, and cooperative experience.

Application

Undergraduate students at CSM must declare an interest during their third year to allow for planning of coursework that will apply towards the program. These students must have an overall GPA of at least 3.0. Students majoring in other departments besides the Department of Geology and Geological Engineering and the Department of Chemistry and Geochemistry may want to decide on the combined degree program option earlier to be sure prerequisites are satisfied. Applicants other than CSM undergraduates who are applying for this non-thesis Master degree program must follow the same procedures that all prospective graduate students follow. However, the requirement of the general GRE may be waived.

Prerequisites

Each entering student will have an entrance interview with members of the Geochemistry faculty. Each department recognizes that entering students may not be proficient in both areas. A placement examination in geology and/or chemistry may be required upon the discretion of the interviewing faculty. If a placement examination is given, the results may

be used to establish deficiency requirements. Credit toward a graduate degree will not be granted for courses taken to fulfill deficiencies.

Requirements

A minimum of 30 credit hours are required, with an overall GPA of at least 3.0. The overall course requirements will depend on the background of the individual, but may be tailored to professional objectives.

A 10 credit-hour core program consists of:

GEGN466	GROUNDWATER ENGINEERING *	3.0
CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
Total Semester Hrs		10.0

In addition, 14 credit hours must be selected from the list below, representing the following core areas: geochemical methods, geographic information system, geological data analysis, groundwater engineering or modeling, hydrothermal geochemistry, isotope geochemistry, physical chemistry, microbiology, mineralogy, organic geochemistry, and thermodynamics. This selection of courses must include at least one laboratory course.

CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC555	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
CHGN503	ADV PHYSICAL CHEMISTRY I	4.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN581	ADVANCED GROUNDWATER ENGINEERING	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL530	CLAY CHARACTERIZATION	1.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0

Laboratory courses:

(New course) Adv Geoenvironmental Anal	3.0	
GEOL530	CLAY CHARACTERIZATION	1.0

An additional 6 credit-hours of free electives may be selected to complete the 30 credit-hour requirement. Free electives may be selected from the course offerings of the Department of Geology and Geological Engineering, the Department of Chemistry and Geochemistry, or the Department of Civil and Environmental Engineering, and may also be independent study credits taken to fulfill a research cooperative, or other professional development experience. A course program will be designed in advanced through consultation between the student and an advisor from the Geochemistry Committee of the Whole.

CHGC503	INTRODUCTION TO GEOCHEMISTRY	4.0
CHGC504	METHODS IN GEOCHEMISTRY	2.0
CHGC505	INTRODUCTION TO ENVIRONMENTAL CHEMISTRY	3.0

CHGC506	WATER ANALYSIS LABORATORY	2.0
CHGC509	INTRODUCTION TO AQUEOUS GEOCHEMISTRY	3.0
CHGC511	GEOCHEMISTRY OF IGNEOUS ROCKS	3.0
CHGC527	ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
CHGC555	ENVIRONMENTAL ORGANIC CHEMISTRY	3.0
CHGC563	ENVIRONMENTAL MICROBIOLOGY	2.0
CHGC564	BIOGEOCHEMISTRY AND GEOMICROBIOLOGY	3.0
CHGC598	SPECIAL TOPICS	1-6
CHGC698	SPECIAL TOPICS	1-6

Professors

Wendy J. Harrison, Geology and Geological Engineering

Murray W. Hitzman, Charles F. Fogarty Professor of Economic Geology

John McCray, Civil and Environmental Engineering

James F. Ranville, Chemistry and Geochemistry

John R. Spear, Civil and Environmental Engineering

Bettina M. Voelker, Chemistry and Geochemistry

Richard F. Wendlandt, Geology and Geological Engineering

Associate Professors

Linda A. Figueroa, Civil and Environmental Engineering

John D. Humphrey, Geology and Geological Engineering

Thomas Monecke, Geology and Geological Engineering

Jonathan O. Sharp, Civil and Environmental Engineering

Assistant Professors

Alexander Gysi, Geology and Geological Engineering

Christopher P. Higgins, Civil and Environmental Engineering

Alexis Navarre-Sitchler, Geology and Geological Engineering

Professors Emeriti

John B. Curtis, Geology and Geological Engineering

Donald L. Macalady, Chemistry and Geochemistry

Patrick MacCarthy, Chemistry and Geochemistry

Samuel B. Romberger, Geology and Geological Engineering

Thomas R. Wildeman, Chemistry and Geochemistry

Associate Professors Emeriti

L. Graham Closs, Geology and Geological Engineering

E. Craig Simmons, Chemistry and Geochemistry

Hydrologic Science and Engineering

2015-2016

Degrees Offered

- Master of Science (Hydrology), Thesis option
- Master of Science (Hydrology), Non-thesis option
- Doctor of Philosophy (Hydrology)

Program Description

The Hydrologic Science and Engineering (HSE) Program is an interdisciplinary graduate program comprised of faculty from several different CSM departments.

The program offers programs of study in fundamental hydrologic science and applied hydrology with engineering applications. Our program encompasses groundwater hydrology, surface-water hydrology, vadose-zone hydrology, watershed hydrology, contaminant transport and fate, contaminant remediation, hydrogeophysics, and water policy/law. Students may elect to follow the Science or the Engineering Track.

HSE requires a core study of 4 formal graduate courses. Programs of study are interdisciplinary in nature, and coursework is obtained from multiple departments at CSM and is approved for each student by the student's advisor and thesis committee.

To achieve the Master of Science (M.S.) degree, students may elect the Non-Thesis option, based exclusively upon coursework and a project report, or the Thesis option. The thesis option is comprised of coursework in combination with individual laboratory, modeling and/or field research performed under the guidance of a faculty advisor and presented in a written thesis approved by the student's committee.

HSE also offers a combined baccalaureate/masters degree program in which CSM students obtain an undergraduate degree as well as a Thesis or Non-thesis M.S. in Hydrology. In the Combined Degree Program as many as six credit hours may be counted towards the B.S. and M.S. non-thesis degree requirements. Please see the Combined Undergraduate/Graduate Programs sections in the Graduate (<http://bulletin.mines.edu/graduate/programs>) and Undergraduate (<http://bulletin.mines.edu/undergraduate/undergraduateinformation/combinedundergraduategraduate>) Bulletins for additional information.

To achieve the Doctor of Philosophy (Ph.D.) degree, students are expected to complete a combination of coursework and novel, original research, under the guidance of a faculty advisor and Doctoral committee, which culminates in a significant scholarly contribution to a specialized field in hydrologic sciences or engineering. Full-time enrollment is expected and leads to the greatest success, although part-time enrollment may be allowed under special circumstances. All doctoral students must complete the full-time, on-campus residency requirements (p. 195).

Currently, students will apply to the hydrology program through the Graduate School and be assigned to the HSE participating department or division of the student's HSE advisor. Participating units include: Chemistry and Geochemistry, Civil & Environmental Engineering (CEE), Geology and Geological Engineering (GE), Geophysical Engineering, Mining Engineering (ME), and Petroleum Engineering (PE). HSE is part of the Western Regional Graduate Program (WICHE), a recognition

that designates these programs as unique within the Western United States. An important benefit of this designation is that students from several western states are given the tuition status of Colorado residents. These states include Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

For more information on HSE curriculum please refer to the HSE website at hydrology.mines.edu.

Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.S. degree in Hydrology while completing their Bachelor's degree. The CSM Combined Degree Program provides the vehicle for students to complete graduate coursework while still an undergraduate student. For more information please contact the HSE program faculty.

Program Requirements

MS Thesis: 30 credit hours total, consisting of 24 credit hours of coursework and 6 credit hours of thesis credit. Students must also write and orally defend a research thesis.

MS Non-Thesis: 30 credit hours total, consisting of 27 credit hours of coursework and 3 credit hours of independent study or completion of an approved 3 credit hour Design Course*.

Ph.D.: 72 total credit hours, consisting of coursework (at least 36 h post-baccalaureate), and research (at least 24 h). Students must also successfully complete qualifying examinations, write and defend a dissertation proposal, write and defend a doctoral dissertation, and are expected to submit the dissertation work for publication in scholarly journals.

Thesis & Dissertation Committee Requirements

Students must meet the general requirements listed in the graduate bulletin section *Graduate Degrees and Requirements*. In addition, the student's advisor or co-advisor must be an HSE faculty member. For M.S. thesis students, at least two committee members must be members of the HSE faculty. For doctoral students, at least 2 faculty on the committee must be a member of the HSE faculty. For all committees one at-large member must be from a department outside the student's home department and HSE.

Prerequisites

- baccalaureate degree in a science or engineering discipline
- college calculus: two semesters required
- differential equations: one semester required
- college physics: one semester required
- college chemistry: two semesters required
- fluid mechanics, one semester required
- college statistics: one semester required

Note that some prerequisites may be completed in the first few semesters of the graduate program if approved by the HSE Director.

Required Curriculum

Students will work with their academic advisors and graduate thesis committees to establish plans of study that best fit their individual

interests and goals. Each student will develop and submit a plan of study to their advisor during the first semester of enrollment. Doctoral students may transfer in credits from an earned M.S. graduate program according to requirements listed in the Graduate Degrees and Requirements (p. 207) section of the graduate bulletin, and after approval by the student's thesis committee.

Core Curriculum

Curriculum areas of emphasis consist of core courses, and electives. Core courses include the following:

GEGN466	GROUNDWATER ENGINEERING	3.0
GEGN582	INTEGRATED SURFACE WATER HYDROLOGY	3.0
CEEN550	PRINCIPLES OF ENVIRONMENTAL CHEMISTRY	3.0
CEEN584 or CEEN583	SUBSURFACE CONTAMINANT TRANSPORT SURFACE WATER QUALITY MODELING	3.0
Total Semester Hrs		12.0

Starting Fall 2015 a two credit hour Fluid Mechanics for Hydrology is required for the HSE graduate degrees. If a student has completed a Fluid Mechanics course this core requirement will be waived once an HSE Waiver Form is approved.

An HSE seminar is also required and will typically have a 598 course number. These are one-credit reading and discussion seminars. PhD students are required to complete at least two during their studies, and M.S. students must complete one seminar. The seminar courses are taught nearly every semester, with different topics depending on the instructor.

Students who plan to incorporate hydrochemistry into their research may elect to replace CEEN550 with a two-course combination that includes an aqueous inorganic chemistry course (CHGC509) and an environmental organic chemistry course (CEEN511).

A grade of B- or better is required in all core classes for graduation.

For Non Thesis MS students, the following is a list of **Design Courses*** that may be completed in lieu of an Independent Study:

CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN584	SUBSURFACE CONTAMINANT TRANSPORT	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN583	MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS	3.0
GEGN584	FIELD METHODS IN HYDROLOGY	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0

Elective courses may be chosen from the approved list below or as approved by your advisor or thesis committee.

CEEN471	WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN	3.0
CEEN511	UNSATURATED SOIL MECHANICS	3.0

CEEN512	SOIL BEHAVIOR	3.0
CEEN515	HILLSLOPE HYDROLOGY AND STABILITY	3.0
CEEN560	MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT	3.0
CEEN562	ENVIRONMENTAL GEOMICROBIOLOGY	3.0
CEEN570	WATER AND WASTEWATER TREATMENT	3.0
CEEN571	ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE	3.0
CEEN575	HAZARDOUS WASTE SITE REMEDIATION	3.0
CEEN581	WATERSHED SYSTEMS MODELING	3.0
CEEN582	MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS	3.0
CEEN611	MULTIPHASE CONTAMINANT TRANSPORT	3.0
GEGN470	GROUND-WATER ENGINEERING DESIGN	3.0
GEGN532	GEOLOGICAL DATA ANALYSIS	3.0
GEGN573	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN575	APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS	3.0
GEGN581	ADVANCED GROUNDWATER ENGINEERING	3.0
GEGN584	FIELD METHODS IN HYDROLOGY	3.0
GEGN586	NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS	3.0
GEOL540	ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY	3.0
GPGN470	APPLICATIONS OF SATELLITE REMOTE SENSING	3.0
MATH530	STATISTICAL METHODS I	3.0
MATH531	STATISTICAL METHODS II	3.0
MATH532	SPATIAL STATISTICS	3.0
EBGN510	NATURAL RESOURCE ECONOMICS	3.0
LAIS588	WATER POLITICS AND POLICY	3.0

Directors

Terri Hogue, HSE Director, Civil & Environmental Engineering

Kamini Singha, HSE Associate Director, Geology & Geological Engineering

Department of Chemistry and Geochemistry

James Ranville, Professor

Bettina Voelker, Professor

Department of Civil & Environmental Engineering

Tzahi Y. Cath, Associate Professor

Linda Figueroa, Associate Professor

Marte Gutierrez, Professor & James R. Paden Distinguished Professor

Christopher Higgins, Associate Professor

Terri Hogue, Professor

Tissa Illangasekare, Professor and AMAX Distinguished Chair

Ning Lu, Professor

Junko Munakata Marr, Associate Professor

John McCray, Professor & Department Head Civil & Environmental Engineering

Jonathan Sharp, Associate Professor

Kathleen Smits, Assistant Professor

John Spear, Professor

Department of Geology and Geological Engineering

David Benson, Associate Professor

John Humphrey, Associate Professor

Reed Maxwell, Professor

Eileen Poeter, Professor Emerita

Paul Santi, Professor & Department Head Geology & Geological Engineering

Kamini Singha, Associate Professor

Alexis Stichter, Assistant Professor

Department of Geophysics

Jeff Andrews-Hannah, Assistant Professor

David Hale, Professor

Yaoguo Li, Associate Professor

Division of Liberal Arts & International Studies

Hussein Amery, Professor

Department of Petroleum Engineering

Yu-Shu Wu, Professor

Interdisciplinary

Degrees Offered

- Master of Science (Interdisciplinary)
- Doctor of Philosophy (Interdisciplinary)

Program Description

In addition to its traditional degree programs, Mines offers innovative, interdisciplinary, research-based degree programs that fit the institutional role and mission, but cannot easily be addressed within a single discipline or degree program. Specialties offered under this option are provided for a limited time during which faculty from across campus come together to address relevant, timely, interdisciplinary issues. The Interdisciplinary Graduate Program is intended to:

1. Encourage faculty and students to participate in broadly interdisciplinary research,

2. Provide a mechanism by which a rigorous academic degree program may be tightly coupled to this interdisciplinary research, and
3. Provide a mechanism for faculty to develop and market test, timely and innovative interdisciplinary degree programs in the hope that, if successful, may become full-fledged, stand-alone degree programs in the future.

Program Requirements

Graduates of the Interdisciplinary Graduate Program must meet all institutional requirements for graduation and the requirements of the Specialty under which they are admitted.

Program Management

Overall management and oversight of the Interdisciplinary Degree Program is undertaken by a Program Oversight Committee consisting of the:

- Dean of Graduate Studies (Chair and Program Director),
- One Representative from the Faculty Senate,
- One Representative from Department Heads/Division Directors, and
- One Faculty Representative from each active Specialty Areas.

The role of the Oversight Committee is fourfold:

- *Specialty Oversight*: includes advising and assisting faculty in the creation of new Specialty areas, periodic Specialty review and termination of Specialties having exceeded the allowed time limits,
- *Specialty Mentoring*: includes providing assistance to, and support of existing Specialties as they move toward applying for full degree status,
- *Program Advocacy*: includes promotion of program at the institutional level, and promotion, development and support of new Specialty areas with individual groups of faculty, and
- *Council Representation*: upon the advise of the directors of the individual Specialties offered, the Oversight Committee appoints an Interdisciplinary Degree program representative to Graduate Council.

Specialty Requirements and Approval Processes

Specialties must meet the following minimum requirements:

- Specialty area must be, within the context of Mines, interdisciplinary in nature. That is, expertise that would be reasonably expected to be required to deliver the specialty must span multiple degree programs at Mines.
- Faculty participating in the Specialty must be derived from no fewer than two separate home units.
- There must be a minimum of six tenure/tenure-track core faculty participating in the Specialty.

The package of materials to be reviewed for Specialty approval must, at a minimum, include the following items:

- Descriptive overview of Specialty degree area,
- List of participating Faculty and the Departments/Divisions in which they are resident,
- Name of Specialty to be included on the transcript,
- Listing and summary description of all Specialty degree requirements,

- A description of how program quality is overseen by participating Specialty faculty including the Admission to Candidacy process to be used within the Specialty,
- A copy of Bylaws (i.e., operating parameters that define how the Specialty is managed, how faculty participate, how admissions is handled, etc.) under which the Specialty and its faculty operate,
- A listing and justification for any additional resources needed to offer the Specialty, and
- A draft of the Graduate Bulletin text that will be used to describe the Specialty in the Interdisciplinary Degree section of Bulletin.

Materials for Specialty approval must be approved by all of the following groups. Faculty advancing a Specialty should seek approval from each group in the order in which they are presented below:

- Faculty and Department Heads/Division Directors of each of the departments/divisions contributing staffing to the Specialty,
- Interdisciplinary Program Oversight Committee,
- Graduate Council,
- Faculty Senate, and
- Provost.

Failure to receive approval at any level constitutes an institutional decision to not offer the Specialty as described.

Full-Fledged Degree Creation and Specialty Time Limits

Documentation related to specific program Specialties, as published in the Graduate Bulletin, includes the inception semester of the Specialty. For Specialties garnering significant enrollment and support by participating academic faculty, the Program Oversight Committee encourages the participating faculty to seek approval – both on campus, and through the Board of Trustees and DHE – for a stand alone degree program. Upon approval, all students still in the Specialty will be moved to the full-fledged degree program.

Admissions to all doctoral-level Specialties will be allowed for a maximum of 7 years after the Specialty inception date. Specialties may apply to the Oversight Committee for a one-time extension to this time limit that shall not exceed 3 additional years. If successful, the Oversight Committee shall inform Graduate Council and the Faculty Senate of the extension.

Specialties

Operations Research with Engineering (ORwE) (initiated Fall, 2011)

Degrees Offered

- Doctor of Philosophy (Interdisciplinary); Specialty (Operations Research with Engineering)

Program Description

Operations Research (OR) involves mathematically modeling physical systems (both naturally occurring and man-made) with a view to determining a course of action for the system to either improve or optimize its functionality. Examples of such systems include, but are not limited to, manufacturing systems, chemical processes, socio-economic systems, mechanical systems (e.g., those that produce energy), and mining systems. The ORwE PhD Specialty allows students to complete an interdisciplinary doctoral degree in Operations Research with Engineering by taking courses and conducting research in eight

departments/divisions: Applied Mathematics and Statistics, Electrical Engineering and Computer Sciences, Engineering and Computational Sciences, Civil and Environmental Engineering, Economics & Business, Mining Engineering, Mechanical Engineering, and Metallurgical & Materials Engineering.

Specialty Requirements

Doctoral students develop a customized curriculum to fit their needs. The degree requires a minimum of 72 graduate credit hours that includes course work and a thesis. Coursework is valid for nine years towards a Ph.D. degree; any exceptions must be approved by the Director of the ORwE program and student advisor.

Course Work

Core Courses	25.0
Area of Specialization Courses	12.0
Total Semester Hrs	37.0

Research Credits

At least 24.0 research credits. The student's faculty advisor and the doctoral thesis committee must approve the student's program of study and the topic for the thesis.

Qualifying Examination Process and Thesis Proposal

Upon completion of the core coursework, students must pass qualifying written examinations to become a candidate for the Ph.D. ORwE specialty. The proposal defense should be done within ten months of passing the qualifying exam.

Transfer Credits

Students may transfer up to 24.0 hours of graduate-level coursework from other institutions toward the Ph.D. degree subject to the restriction that those courses must not have been used as credit toward a Bachelor's degree. The student must have achieved a grade of B or better in all graduate transfer courses and the transfer must be approved by the student's Doctoral Thesis Committee and the Director of the ORwE program.

Unsatisfactory Progress

In addition to the institutional guidelines for unsatisfactory progress as described elsewhere in this bulletin: Unsatisfactory progress will be assigned to any full-time student who does not pass the following prerequisite and core courses in the first fall semester of study:

CSCI262	DATA STRUCTURES	3.0
EBGN555	LINEAR PROGRAMMING	3.0
MATH530	STATISTICAL METHODS I	3.0

and the following in the first spring semester of study:

CSCI406	ALGORITHMS	3.0
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Unsatisfactory progress will also be assigned to any students who do not complete requirements as specified in their admission letter. Any exceptions to the stipulations for unsatisfactory progress must

be approved by the ORwE committee. Part-time students develop an approved course plan with their advisor.

Prerequisites

Students must have completed the following undergraduate prerequisite courses with a grade of B or better:

CSCI261	PROGRAMMING CONCEPTS	3.0
CSCI262	DATA STRUCTURES	3.0

Students entering in the fall semester must have completed the Programming (CSCI261) prerequisite or equivalent. Students will only be allowed to enter in the spring semester if they have developed a course program such that they are able to take the qualifying exam within 3 semesters.

Required Course Curriculum

All Ph.D. students are required to take a set of core courses that provides basic tools for the more advanced and specialized courses in the program.

Core Courses

CSCI/	ALGORITHMS	3.0
MATHnull406		
MEGN502	ADVANCED ENGINEERING ANALYSIS	4.0
MATH530	STATISTICAL METHODS I	3.0
EBGN555	LINEAR PROGRAMMING	3.0
Total Semester Hrs		13.0

Area of Specialization Courses

Select Four of the Following:		12.0
EBGN528	INDUSTRIAL SYSTEMS SIMULATION	
or MATH542	SIMULATION	
or CSCI542	SIMULATION	
MTGNnull450/	STATISTICAL PROCESS CONTROL AND	
MLGN550	DESIGN OF EXPERIMENTS	
EBGN560	DECISION ANALYSIS	
EENG517	THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS	
EBGN655	ADVANCED LINEAR PROGRAMMING	
CSCI562	APPLIED ALGORITHMS AND DATA STRUCTURES	
MNGN536	OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY	
MNGN538	GEOSTATISTICAL ORE RESERVE ESTIMATION	
EBGN509	MATHEMATICAL ECONOMICS	
EBGN575	ADVANCED MINING AND ENERGY VALUATION	
MATH531	STATISTICAL METHODS II	
xxxx598/698	Special Topics (Requires approval of the advisor and ORwE program director)	

Materials Science

Degrees Offered

- Master of Science (Materials Science; thesis option or non-thesis option)

- Doctor of Philosophy (Materials Science)

Program Description

The Departments of Chemistry and Geochemistry, Metallurgical and Materials Engineering, Physics, and Chemical and Biological Engineering jointly administer the interdisciplinary materials science program. This interdisciplinary degree program coexists along side strong disciplinary programs, in Chemistry, Chemical and Biochemical Engineering, Mechanical Engineering, Metallurgical and Materials Engineering, and Physics. For administrative purposes, the student will reside in the advisor's home academic department. The student's graduate committee will have final approval of the course of study.

The interdisciplinary graduate program in Materials Science exists to educate students, with at least a Bachelor of Science degree in engineering or science, in the diverse field of Materials Science. This diversity includes the four key foundational aspects of Materials Science – materials properties including characterization and modeling, materials structures, materials synthesis and processing and materials performance – as applied to materials of a variety of types (i.e., metals, ceramics, polymers, electronic materials and biomaterials). The Materials Science graduate program is responsible for administering MS (thesis and non-thesis) and PhD Degrees in Materials Science.

Fields of Research

- Advanced polymeric materials
- Alloy theory, concurrent design, theory-assisted materials engineering, and electronic structure theory
- Applications of artificial intelligence techniques to materials processing and manufacturing, neural networks for process modeling and sensor data processing, manufacturing process control
- Atomic scale characterization
- Atom Probe Tomography
- Biomaterials
- Ceramic processing, modeling of ceramic processing
- Characterization, thermal stability, and thermal degradation mechanisms of polymers
- Chemical and physical processing of materials, engineered materials, materials synthesis
- Chemical vapor deposition
- Coating materials and applications
- Computational condensed-matter physics, semiconductor alloys, first-principles phonon calculations
- Computer modeling and simulation
- Control systems engineering, artificial neural systems for sensor data processing, polymer cure monitoring sensors, process monitoring and control for composites manufacturing
- Crystal and molecular structure determination by X-ray crystallography
- Electrodeposition
- Electron and ion microscopy
- Experimental condensed-matter physics, thermal and electrical properties of materials, superconductivity, photovoltaics
- Fuel cell materials
- Fullerene synthesis, combustion chemistry
- Heterogeneous catalysis, reformulated and alcohol fuels, surface analysis, electrophotography

- High temperature ceramics
- Intelligent automated systems, intelligent process control, robotics, artificial neural systems
- Materials synthesis, interfaces, flocculation, fine particles
- Mathematical modeling of material processes
- Mechanical metallurgy, failure analysis, deformation of materials, advanced steel coatings
- Mechanical properties of ceramics and ceramic composites
- High entropy alloys
- Mössbauer spectroscopy, ion implantation, small-angle X-ray scattering, semiconductor defects
- Nano materials
- Non-destructive evaluation
- Non-ferrous structural alloys
- Novel separation processes: membranes, catalytic membrane reactors, biopolymer adsorbents for heavy metal remediation of ground surface water
- Numerical modeling of particulate media, thermomechanical analysis
- Optical properties of materials and interfaces
- Phase transformations and mechanisms of microstructural change
- Photovoltaic materials and device processing
- Physical metallurgy, ferrous and nonferrous alloy systems
- Physical vapor deposition, thin films, coatings
- Power electronics, plasma physics, pulsed power, plasma material processing
- Processing and characterization of electroceramics (ferro-electrics, piezoelectrics, pyroelectrics, and dielectrics)
- Semiconductor materials and device processing
- Soft materials
- Solidification and near net shape processing
- Surface physics, epitaxial growth, interfacial science, adsorption
- Transport phenomena and mathematical modeling
- Weld metallurgy, materials joining processes
- Welding and joining science

Program Requirements

Each of the three degree programs require the successful completion of three core courses for a total of 9 credit hours that will be applied to the degree program course requirements. Depending upon the individual student's background, waivers for these courses may be approved by the program director. In order to gain a truly interdisciplinary understanding of Materials Science, students in the program are encouraged to select elective courses from several different departments outside of the Materials Science program. Course selection should be completed in consultation with the student's advisor or program director as appropriate.

Listed below are the three required Materials Science core courses:

MLGN591	MATERIALS THERMODYNAMICS	3.0
MLGN592	ADVANCED MATERIALS KINETICS AND TRANSPORT	3.0
MLGN593	BONDING, STRUCTURE, AND CRYSTALLOGRAPHY	3.0
Total Semester Hrs		9.0

Master of Science (Thesis Option)

The Master of Science degree requires a minimum of 30.0 semester hours of acceptable coursework and thesis research credits (see table below). The student must also submit a thesis and pass the Defense of Thesis examination before the Thesis Committee.

COURSEWORK	Materials Science Courses *	18.0
MLGN707	Thesis Research Credits	12.0
Total Semester Hrs		30.0

* Must include 9.0 credit hours of core courses.

Master of Science (Non-Thesis Option with a case study)

The Master of Science degree requires a minimum of 30.0 semester hours of acceptable course work and case study credit including:

COURSEWORK	Materials Science Courses *	24.0
MLGN	Case Study	6.0
Total Semester Hrs		30.0

* Must include 9.0 credit hours of core courses.

Doctor of Philosophy

The Doctor of Philosophy degree requires a minimum of 72.0 hours of course and research credit including:

COURSEWORK	Materials Science Courses (minimum) *	24.0
MLGN707	Thesis Research Credits (minimum)	24.0

* Must include 9.0 credit hours of core courses.

Deficiency Courses

All doctoral candidates must complete at least 6 credit hours of background courses. This course requirement is individualized for each candidate, depending on previous experience and research activities to be pursued. Competitive candidates may already possess this background information. In these cases, the candidate's Thesis Committee may award credit for previous experience. In cases where additional coursework is required as part of a student's program, these courses are treated as fulfilling a deficiency requirement that is beyond the total institutional requirement of 72 credit hours.

PhD Qualifying Process

The following constitutes the qualifying processes by which doctoral students are admitted to candidacy in the Materials Science program.

Core Curriculum – The three required core classes must be completed in the first Fall semester for all doctoral candidates. Students must obtain a grade of B- or better in each class to be eligible to take the qualifying examination at the end of the succeeding spring semester. If a student receives a grade of less than B- in a class, the student may request an additional final examination be given during the mid-term break of the following spring semester. If the result of this examination is a B- or better, the student will be allowed to take the qualifying examination. The grade originally obtained in the course will not be changed as a result. If not allowed to complete the qualifying examination at the end of the

spring semester, students will be discouraged from the PhD program and encouraged, rather, to finish with a Masters degree

Qualifying Examination – A qualifying examination is given annually at the end of the spring semester under the direction of the Materials Science Graduate Affairs Committee. All first-year Materials Science students are expected to successfully complete the qualifying examination within three semesters to remain in good standing in the program. The examination covers material from the core curriculum plus a standard introductory text on Materials Science, such as "Materials Science and Engineering: An Introduction", by William Callister. If a student performs below the expectations of the Materials Science faculty on the written exam, they will be asked to complete a follow-up oral examination in the subsequent fall semester. The oral examination will be based on topics deemed to be deficient in the written examination. Satisfactorily completing the oral exam will allow the student to proceed with the PhD program. Students who perform below the expectations of the Materials Science faculty on the oral exam will not be allowed to continue with the PhD program.

Thesis Proposal – A student's thesis committee administers a Thesis Proposal defense. The proposal defense should occur no later than the student's fourth semester. While the proposal itself should focus on the central topic of a student's research efforts, during the proposal defense, candidates may expect to receive a wide range of questions from the Committee. This would include all manner of questions directly related to the proposal. Candidates, however, should also expect questions related to the major concept areas of Materials Science within the context of a candidate's research focus. The Committee formally reports results of the proposal defense to the Materials Science Program Director using the Committee Reporting form developed by the Office of Graduate Studies.

Upon completion of these steps and upon completion of all required coursework, candidates are admitted to candidacy.

Following successful completion of coursework and the PhD qualifying process, candidates must also submit a thesis and successfully complete the Defense of Thesis examination before the Thesis Committee.

MLGN500	PROCESSING, MICROSTRUCTURE, AND PROPERTIES OF MATERIALS	3.0
MLGN501	STRUCTURE OF MATERIALS	3.0
MLGN502	SOLID STATE PHYSICS	3.0
MLGN503	CHEMICAL BONDING IN MATERIALS	3.0
MLGN504	SOLID STATE THERMODYNAMICS	3.0
MLGN505	MECHANICAL PROPERTIES OF MATERIALS	3.0
MLGN506	TRANSPORT IN SOLIDS	3.0
MLGN509	SOLID STATE CHEMISTRY	3.0
MLGN510	SURFACE CHEMISTRY	3.0
MLGN511	KINETIC CONCERNS IN MATERIALS PROCESSING I	3.0
MLGN512	CERAMIC ENGINEERING	3.0
MLGN513	PROBLEM SOLVING IN MATERIALS SCIENCE	3.0
MLGN515	ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS	3.0
MLGN516	PROPERTIES OF CERAMICS	3.0
MLGN517	SOLID MECHANICS OF MATERIALS	3.0
MLGN518	PHASE EQUILIBRIA IN CERAMICS SYSTEMS	3.0
MLGN519	NON-CRYSTALLINE MATERIALS	3.0

MLGN521	KINETIC CONCERNS IN MATERIAL PROCESSING II	3.0
MLGN523	APPLIED SURFACE AND SOLUTION CHEMISTRY	3.0
MLGN526	GEL SCIENCE AND TECHNOLOGY	3.0
MLGN530	INTRODUCTION TO POLYMER SCIENCE	3.0
MLGN531	POLYMER ENGINEERING AND TECHNOLOGY	3.0
MLGN535	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
MLGN536	ADVANCED POLYMER SYNTHESIS	3.0
MLGN544	PROCESSING OF CERAMICS	3.0
MLGN550	STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS	3.0
MLGN552	INORGANIC MATRIX COMPOSITES	3.0
MLGN555	POLYMER AND COMPLEX FLUIDS COLLOQUIUM	1.0
MLGN561	TRANSPORT PHENOMENA IN MATERIALS PROCESSING	3.0
MLGN563	POLYMER ENGINEERING: STRUCTURE, PROPERTIES AND PROCESSING	3.0
MLGN565	MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES	3.0
MLGN569	FUEL CELL SCIENCE AND TECHNOLOGY	3.0
MLGN570	BIOCOMPATIBILITY OF MATERIALS	3.0
MLGN572	BIOMATERIALS	3.0
MLGN583	PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES	3.0
MLGN589	MATERIALS THERMODYNAMICS	3.0
MLGN591	MATERIALS THERMODYNAMICS	3.0
MLGN592	ADVANCED MATERIALS KINETICS AND TRANSPORT	3.0
MLGN593	BONDING, STRUCTURE, AND CRYSTALLOGRAPHY	3.0
MLGN607	CONDENSED MATTER	3.0
MLGN625	MOLECULAR SIMULATION METHODS	3.0
MLGN634	ADVANCED TOPICS IN THERMODYNAMICS	3.0
MLGN635	POLYMER REACTION ENGINEERING	3.0
MLGN648	CONDENSED MATTER II	3.0
MLGN673	STRUCTURE AND PROPERTIES OF POLYMERS	3.0
MLGN696	VAPOR DEPOSITION PROCESSES	3.0
MLGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-15

Professors

Colin Wolden , Department of Chemical Engineering, Weaver Distinguished Professor

Stephen Liu , Department of Metallurgical and Materials Engineering, American Bureau of Shipping Endowed Chair of Metallurgical and Materials Engineering

John R. Dorgan, Department of Chemical and Biological Engineering

Mark Eberhart, Department of Chemistry and Geochemistry

Thomas E. Furtak, Department of Physics

Michael J. Kaufman, Department of Metallurgical and Materials Engineering, Dean of CASE

Daniel M. Knauss, Department of Chemistry and Geochemistry

Ryan P. O'Hayre, Department of Metallurgical and Materials Engineering

Ivar E. Reimanis, Department of Metallurgical and Materials Engineering, Herman F. Coors Distinguished Professor of Ceramic Engineering

P. Craig Taylor, Department of Physics

Chester J. Van Tyne, Department of Metallurgical and Materials Engineering, FIERF Professor and Associate Department Head

Associate Professors

John R. Berger, Department of Mechanical Engineering

Stephen G. Boyes, Department of Chemistry and Geochemistry

Cristian V. Ciobanu, Department of Mechanical Engineering

Brian P. Gorman, Department of Metallurgical and Materials Engineering

Timothy R. Ohno, Department of Physics

Ryan Richards, Department of Chemistry and Geochemistry, Materials Science Program Interim Director

Neal Sullivan, Department of Mechanical Engineering

Assistant Professors

Geoff L. Brennecka, Department of Metallurgical and Materials Engineering

Honjun Liang, Department of Metallurgical and Materials Engineering

Corinne E. Packard, Department of Metallurgical and Materials Engineering

Eric Toberer, Department of Physics

Zhigang Wu, Department of Physics

Yongan Yang, Department of Chemistry and Geochemistry

Professors Emeriti

John Moore, Department of Metallurgical and Materials Engineering

Denis W. Readey, Department of Metallurgical and Materials Engineering, University Professor-Emeritus

Teaching Associate Professors

Gerald Bourne, Department of Metallurgical and Materials Engineering

John Chandler, Department of Metallurgical and Materials Engineering

Research Professors

Richard K. Ahrenkiel, Department of Metallurgical and Materials Engineering

William (Grover) Coors, Department of Metallurgical and Materials Engineering

Research Associate Professors

James E. Bernard, Department of Physics

Jianhua Tong, Department of Metallurgical and Materials Engineering

Research Assistant Professors

David Diercks, Department of Metallurgical and Materials Engineering

Jianliang Lin, Department of Metallurgical and Materials Engineering

Nuclear Engineering

2015-2016

Degrees Offered

- Master of Engineering (Nuclear Engineering)
- Master of Science (Nuclear Engineering)
- Doctor of Philosophy (Nuclear Engineering)

Program Description

The Nuclear Science and Engineering program at the Colorado School of Mines is interdisciplinary in nature and draws contributions from the Department of Applied Mathematics and Statistics, the Department of Chemistry and Geochemistry, the Department of Civil and Environmental Engineering, the Department of Liberal Arts and International Studies, the Department of Mechanical Engineering, the Department of Metallurgical and Materials Engineering, and the Department of Physics. While delivering a traditional Nuclear Engineering course core, the School of Mines program in Nuclear Science and Engineering emphasizes the nuclear fuel life cycle. Faculty bring to the program expertise in all aspects of the nuclear fuel life cycle; fuel exploration and processing, nuclear power systems production, design and operation, fuel recycling, storage and waste remediation, radiation detection and radiation damage as well as the policy issues surrounding each of these activities. Related research is conducted in CSM's Nuclear Science and Engineering Center.

Students in all three Nuclear Engineering degrees are exposed to a broad systems overview of the complete nuclear fuel cycle as well as having detailed expertise in a particular component of the cycle. Breadth is assured by requiring all students to complete a rigorous set of core courses. The core consists of a 21 credit-hour course sequence. The remainder of the course and research work is obtained from the multiple participating departments, as approved for each student by the student's advisor and the student's thesis committee (as appropriate).

The Master of Engineering degree is a non-thesis graduate degree intended to supplement the student's undergraduate degree by providing the core knowledge needed to prepare the student to pursue a career in the nuclear energy field. The Master of Science and Doctor of Philosophy degrees are thesis-based degrees that emphasize research.

In addition, students majoring in allied fields may complete a minor degree through the Nuclear Science and Engineering Program, consisting of 12 credit hours of coursework. The Nuclear Science and Engineering Minor programs are designed to allow students in allied fields to acquire and then indicate, in a formal way, specialization in a nuclear-related area of expertise.

Program Requirements

The Nuclear Science and Engineering Program offers programs of study leading to three graduate degrees:

Master of Engineering (M.E.)

Core courses	13.0
Elective core courses	12.0
Additional elective courses	9.0
Nuclear Science and Engineering Seminar	2.0
Total Semester Hrs	36.0

Master of Science (M.S.)

Core courses	13.0
Elective core courses	6.0
Nuclear Science and Engineering Seminar	2.0
Graduate research (minimum)	12.0
Graduate research or elective courses	3.0
Total Semester Hrs	36.0

M.S. students must complete and defend a research thesis in accordance with this Graduate Bulletin and the Nuclear Science and Engineering Thesis Procedures (<http://nuclear.mines.edu/Student-Information>).

The student must complete the preparation and defense of a Thesis Proposal as described by the Nuclear Science and Engineering Proposal Procedures (<http://nuclear.mines.edu/Student-Information>) at least one semester before the student defends his or her M.S. thesis.

Doctor of Philosophy (Ph.D.)

Core courses	13.0
Elective core courses	9.0
Additional elective courses	12.0
Nuclear Science and Engineering Seminar	4.0
Graduate research (minimum)	24.0
Graduate research or elective courses	10.0
Total Semester Hrs	72.0

Ph.D. students must successfully complete the program's quality control process.

The Ph.D. quality control process includes the following:

- Prior to admission to candidacy, the student must complete all seven of the Nuclear Engineering required and elective core classes;
- Prior to admission to candidacy, the student must pass a qualifying examination in accordance with the Nuclear Science and Engineering Qualifying Exam Procedures (<http://nuclear.mines.edu/Student-Information>) for any of his or her seven core classes in which he or she did not receive a grade of B or better;
- Prior to admission to candidacy, a Ph.D. thesis proposal must be presented to, and accepted by, the student's thesis committee in accordance with the Nuclear Science and Engineering Proposal Procedures (<http://nuclear.mines.edu/Student-Information>); and
- The student must complete and defend a Ph.D. thesis in accordance with this Graduate Bulletin and the Nuclear Science and Engineering Thesis Procedures (<http://nuclear.mines.edu/Student-Information>).

Students seeking a Ph.D. in Nuclear Engineering are also generally expected to complete a thesis-based Master's degree in Nuclear Engineering or a related field prior to their admission to Ph.D. candidacy.

Thesis Committee Requirements

The student's thesis committee must meet the general requirements listed in the Graduate Bulletin section on Graduate Degrees and Requirements (<http://bulletin.mines.edu/graduate/programs>). In addition, the student's advisor or co-advisor must be an active faculty member of CSM's Nuclear Science and Engineering Program. For M.S. students, at least two, and for Ph.D. students, at least three, committee members must be faculty members of the Nuclear Science and Engineering Program and must come from at least two different departments. At least one member of the Ph.D. committee must be a faculty member from outside the Nuclear Science and Engineering Program.

Required Curriculum

In order to be admitted to the Nuclear Science and Engineering Graduate Degree Program, students must meet the following minimum requirements:

- baccalaureate degree in a science or engineering discipline from an accredited program
- mathematics coursework up to and including differential equations
- physics coursework up to and including courses in modern physics and introductory nuclear physics (or equivalent)
- coursework in thermodynamics, heat transfer, and fluid flow (or equivalent)

Students who do not meet these minimum requirements may be admitted with specified coursework to be completed in the first semesters of the graduate program. Entering students without an appropriate nuclear engineering background will be advised to take introductory nuclear engineering coursework prior to starting the nuclear engineering core course sequence. These introductory courses will be selected in consultation with the student's graduate advisor.

All degree offerings within the Nuclear Science and Engineering program are based on a set of required and elective core courses. The required core classes are:

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY (taught in collaboration with the USGS)	3.0
NUGN585 & NUGN586	NUCLEAR REACTOR DESIGN I and NUCLEAR REACTOR DESIGN II	4.0
Total Semester Hrs		13.0

Additionally, students pursuing a Nuclear Engineering graduate degree must take a certain number of courses from the elective core (four for a M.E., two for a M.S. and three for a Ph.D.). The core electives consist of the following:

CEEN558	ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
LAIS589	NUCLEAR POWER AND PUBLIC POLICY	3.0

MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
CHGN511	APPLIED RADIOCHEMISTRY	3.0
MEGN592	RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN	3.0
NUGN598	NUCLEAR FUEL CYCLE	

Students will select additional coursework in consultation with their graduate advisor and their thesis committee (where applicable). This additional coursework may include offerings from all of the academic units participating in the degree program: Applied Math and Statistics, Chemistry and Geochemistry, Civil and Environmental Engineering, Liberal Arts and International Studies, Mechanical Engineering, Metallurgical and Materials Engineering, and Physics. Through these additional courses, students gain breadth and depth in their knowledge of the Nuclear Engineering industry.

Students seeking M.S. and Ph.D. degrees are required to complete the minimum research credit hour requirements ultimately leading to the completion and defense of a thesis. Research is conducted under the direction of a member of CSM's Nuclear Science and Engineering faculty and could be tied to a research opportunity provided by industry partners.

Graduate Seminar

Full-time graduate students in the Nuclear Science and Engineering Program are expected to maintain continuous enrollment in Nuclear Science and Engineering Seminar. Students who are concurrently enrolled in a different degree program that also requires seminar attendance may have this requirement waived at the discretion of the Program Director.

Nuclear Engineering Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.E. or M.S. degree in Nuclear Engineering while completing their Bachelor's degree. The Nuclear Engineering Combined Degree Program provides the vehicle for students to use up to 6 credit hours of undergraduate coursework as part of their Nuclear Engineering Graduate Degree curriculum, as well as the opportunity to take additional graduate courses while completing their undergraduate degree. Students in the Nuclear Engineering Combined Degree Program are expected to apply for admission to the graduate program by the beginning of their Senior Year. For more information please contact the Nuclear Science and Engineering Program Director.

Minor Degree Programs

Students majoring in allied fields may choose to complete minor degree programs through the Nuclear Science and Engineering Program indicating specialization in a nuclear-related area of expertise. Minor programs require completion of 12 credit hours of approved coursework. Existing minors and their requirements are as follows:

Nuclear Engineering

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0

LAIS589 or CEEN558	NUCLEAR POWER AND PUBLIC POLICY ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
Total Semester Hrs		12.0

Nuclear Materials Processing

NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
MTGN593	NUCLEAR MATERIALS SCIENCE AND ENGINEERING	3.0
MTGN591	PHYSICAL PHENOMENA OF COATING PROCESSES	3.0
CEEN558	ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES	3.0
Total Semester Hrs		12.0

Nuclear Detection

PHGN422	NUCLEAR PHYSICS	3.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
PHGN504	RADIATION DETECTION AND MEASUREMENT	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
Total Semester Hrs		12.0

Nuclear Geoscience and Geoengineering

PHGN422	NUCLEAR PHYSICS	3.0
Select three of the following:		9.0
Nuclear and Isotope Geochemistry		
In-situ Mining		
Uranium Mining		
Total Semester Hrs		12.0

NUGN505	NUCLEAR SCIENCE AND ENGINEERING SEMINAR	1.0
NUGN510	INTRODUCTION TO NUCLEAR REACTOR PHYSICS	3.0
NUGN520	INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS	3.0
NUGN535	INTRODUCTION TO HEALTH PHYSICS	3.0
NUGN580	NUCLEAR REACTOR LABORATORY	3.0
NUGN585	NUCLEAR REACTOR DESIGN I	2.0
NUGN586	NUCLEAR REACTOR DESIGN II	2.0
NUGN598	SPECIAL TOPICS	1-6
NUGN698	SPECIAL TOPICS	6.0
NUGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	1-12

Program Director

Mark Jensen, Jerry and Tina Grandey University Chair in Nuclear Science and Engineering, Department of Chemistry and Geochemistry

College of Engineering and Computational Sciences

Kevin Moore, Professor and Dean

Department of Applied Math and Statistics

Cory Ahrens, Assistant Professor

Department of Chemistry

James Ranville, Associate Professor

Jenifer Braley, Assistant Professor

Department of Civil and Environmental Engineering

Linda Figueroa, Associate Professor, Nuclear Science and Engineering Center Management Team Co-Chair

Department of Mechanical Engineering

Robert Kee, Professor

Douglas Van Bossuyt, Assistant Professor

Department of Metallurgical and Materials Engineering

Corby Anderson, Professor

Gerard Martins, Professor

Brajendra Mishra, Professor

David Olson, Professor

Ivar Reimanis, Professor

Patrick Taylor, Professor

Brian Gorman, Associate Professor

Jeffrey King, Associate Professor

Edgar Vidal, Research Associate Professor

Haitao Dong, Radiation Safety Officer

Timothy Debey, Research Associate, Geologic Survey TRIGA Reactor Manager

Department of Physics

Uwe Greife, Professor, Nuclear Science and Engineering Center Management Team Chair

Frederic Sarazin, Professor

Jim McNeil, Professor Emeritus

Edward Cecil, University Professor Emeritus

Zeev Shayer, Research Professor

Underground Construction & Tunneling

2015-2016

Degrees Offered

- Master of Science (Underground Construction & Tunneling), Thesis
- Master of Science (Underground Construction & Tunneling), Non-Thesis
- Doctor of Philosophy (Underground Construction & Tunneling)

Program Description

Underground Construction and Tunneling (UC&T) is an interdisciplinary field primarily involving civil engineering, geological engineering and mining engineering, and secondarily involving mechanical engineering, electrical engineering, geophysics, geology and others. UC&T deals with the design, construction, rehabilitation and management of underground space including caverns, shafts and tunnels for commercial, transportation, water and wastewater use. UC&T is a challenging field involving complex soil and rock behavior, groundwater conditions, excavation methods, construction materials, structural design flow, heterogeneity, and very low tolerance for deformation due to existing infrastructure in urban environments. Students pursuing a graduate degree in UC&T will gain a strong and interdisciplinary foundation in these topics.

The graduate degree program in UC&T is offered jointly by the Departments of Civil & Environmental Engineering (CEE), Geology & Geological Engineering (GEGN), and Mining Engineering (MN). UC&T faculty from each department are collectively responsible for the operations of the program. Participating students reside in one of these departments, typically the home department of their advisor.

Program coursework is selected from multiple departments at CSM (primarily CEE, GEGN, MN) and is approved for each student by the student's advisor and graduate committee. To achieve the M.S. degree, students may elect the non-thesis option based upon coursework and an independent study report tied to a required internship. Students may alternatively select the thesis option comprised of coursework and a research project performed under the guidance of a UC&T faculty advisor and presented in a written thesis approved by the student's thesis committee.

Ph.D. students are expected to complete a combination of coursework and novel, original research under the guidance of a UC&T faculty advisor and doctoral committee, which culminates in a significant scholarly contribution to a specialized field in UC&T. Full-time enrollment is encouraged and leads to the greatest success, although part-time enrollment is permissible for working professionals. All graduate students must complete the full-time, on-campus residency requirements described in the general section of the Graduate Bulletin.

Program Requirements

M.S. Non-Thesis Option:

Coursework - 27.0 credit hours

Independent Study* - 3.0 credit hours

UC&T Seminar - 0.0 credit hours

Total Hours - 30.0

*M.S. non-thesis students are expected to complete an internship of approximately 3 months in duration (with a design firm, contractor, owner, equipment manufacturer, etc., and preferably on a UC&T job site). During the internship, each student completes a project-focused independent study related to an aspect of the internship. This is determined in consultation with the faculty advisor and internship sponsor. The independent study culminates with a project report and presentation. If an internship is not available or if the student has sufficient industry experience (determined by advisor and committee), the student may complete an industry-focused research project with a UC&T faculty member and industry partner. The research project culminates with a written report and final presentation.

M.S. Thesis Option:

Coursework - 24.0 credit hours

Research (minimum) - 6.0 credit hours

UC&T Seminar - 0.0 credit hours

Total Hours - 30.0

M.S. Thesis students must write and successfully defend a thesis report of their research. Ideally, M.S. thesis research should be industry focused and should provide value to industry UC&T practice.

Ph.D. Option

Coursework (beyond B.S. degree) - 42.0 credit hours

Independent Study* - 3.0 credit hours

Research (minimum) - 24.0 credit hours

UC&T Seminar - 0.0 credit hours

Total Hours - 72.0

Students must also successfully complete qualifying examinations, write and defend a dissertation proposal, and write and defend a doctoral dissertation. Ph.D. research is aimed at fundamentally advancing the state of the art in UC&T. Ph.D. students are expected to submit the dissertation work for publication in scholarly journals and disseminate findings throughout industry periodicals.

*Ph.D. students are expected to complete an internship of approximately 3 months in duration (with a design firm, contractor, owner, equipment manufacturer, etc., and preferably on a UC&T job site). If an internship is not available or if the student has sufficient industry experience (determined by advisor and committee), the student may complete an industry-focused research project via independent study with a UC&T faculty member and industry partner culminating with a written report and presentation.

Required Coursework

The following 21 credit hours are required for the M.S. (thesis and non-thesis) and Ph.D. degrees.

GEGN468	ENGINEERING GEOLOGY AND GEOTECHNICS	4.0
MNGN504	TUNNELING	3.0
MNGN508	ADVANCED ROCK MECHANICS	3.0
MNGN509	EXCAVATION PROJECT MANAGEMENT	2.0
CEEN512	SOIL BEHAVIOR	3.0
CEEN520	EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS	3.0
CEEN523	ANALYSIS AND DESIGN OF TUNNELS IN SOFT GROUND	3.0

All M.S. and Ph.D. students are required to attend the UC&T seminar series (0 h); no registration is required.

M.S. non-thesis and Ph.D. students must complete an internship-related project, registering as an independent study in the home department of the faculty advisor (CEEN 599, GEGN 599, or MNGN 599). This requirement may be waived for students with sufficient UC&T industry experience.

Elective Coursework

The following courses may be taken as electives to complete the M.S. and Ph.D. course requirements. Students may petition for other courses not listed below to count towards the elective requirement. In addition, M.S. or Ph.D. students may petition one of the following courses to substitute for a required course if one of the required courses is not offered during the student's course of study or if a student has sufficient background in one of the required course topics. All petitions must be made to the student's advisor and thesis committee.

Course List

CEEN415 (p. 327)	FOUNDATIONS	3.0
CEEN506 (p. 327)	FINITE ELEMENT METHODS FOR ENGINEERS	3.0
CEEN510 (p. 327)	ADVANCED SOIL MECHANICS	3.0
CEEN541 (p. 327)	DESIGN OF REINFORCED CONCRETE STRUCTURES	3.0
CEEN599 (p. 327)	INDEPENDENT STUDY	1-6
GEGN466 (p. 327)	GROUNDWATER ENGINEERING	3.0
GEGN573 (p. 327)	GEOLOGICAL ENGINEERING SITE INVESTIGATION	3.0
GEGN581 (p. 327)	ANALYTICAL HYDROLOGY	3.0
GEGN672 (p. 327)	ADVANCED GEOTECHNICS	3.0
GEGN673 (p. 327)	ADVANCED GEOLOGICAL ENGINEERING DESIGN	3.0
GEGN599 (p. 327)	INDEPENDENT STUDY	1-6
MNGN424 (p. 327)	MINE VENTILATION	3.0
MNGN506 (p. 327)	DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS	3.0
MNGN507 (p. 327)	ADVANCED DRILLING AND BLASTING	3.0
MNGN524 (p. 327)	ADVANCED MINE VENTILATION	3.0
MNGN590 (p. 327)	MECHANICAL EXCAVATION IN MINING	3.0
MNGN599 (p. 327)	INDEPENDENT STUDY	1-6

Thesis Committee Requirements

Students must meet the general committee requirements listed in the graduate bulletin. In addition, the student's advisor or co-advisor must

be a UC&T faculty member. For Ph.D. students, at least two committee members must be members of the UC&T faculty.

Prerequisites

Students will enter the UC&T programs with a variety of backgrounds. Because the UC&T degrees are engineering degrees, the required prerequisite courses for the UC&T programs include basic engineering coursework, and specifically: (1) Strength of Materials or Mechanics of Materials, and (2) Fluid Mechanics. These prerequisite courses may be completed during the first semester of the graduate program if approved by the UC&T program faculty. The required coursework includes graduate level soil and rock mechanics as well as aspects of structural analysis and groundwater engineering. It is permissible for students to take these courses without having completed undergraduate courses in soil mechanics, rock mechanics, structural analysis and groundwater engineering. However, students may choose to complete undergraduate courses in these topics prior to or concurrently during enrollment in the required graduate program courses. The prerequisite courses do not count towards the requirements of the M.S. or Ph.D. degrees. Students should consult with UC&T faculty for guidance in this matter.

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Academic Calendar

Fall Semester 2015

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Aug. 24	Monday
Faculty Conference	Aug. 24	Monday
Classes Start (1)	Aug. 25	Tuesday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Aug. 28	Friday
Labor Day - Classes in Session	Sep. 7	Monday
Census Day	Sep. 9	Wednesday
Fall Break (not always Columbus Day)	Oct. 19 & 20	Monday & Tuesday
Midterm Grades Due	Oct. 19	Monday
Last Withdrawal - Continuing Students (12 wks)	Nov. 13	Friday
Priority Registration for Spring Term	Nov. 16-20	Monday - Friday
Non-Class Day prior to Thanksgiving Break	Nov. 25	Wednesday
Thanksgiving Break - Campus Closed	Nov. 26-27	Thursday & Friday
Last Withdrawal - New Freshmen & Transfers	Dec. 4	Monday
Classes End	Dec. 10	Thursday
Dead Week - no exams	Dec. 7-11	Monday - Friday
Dead Day - no academic activities	Dec. 11	Friday
Final Exams	Dec. 12, 14-17	Saturday, Monday - Thursday
Semester Ends	Dec. 18	Friday
Commencement	Dec. 18	Friday
Final Grades Due	Dec. 21	Monday
Winter Break	Dec. 21 - Jan 12	

Spring Semester 2016

Description	Date(s)	Day(s) of Week
Confirmation Deadline	Jan. 12	Tuesday
Classes Start (1)	Jan. 13	Wednesday
Graduate Student Registration Deadline - Late Fee Applied After this Date	Jan. 15	Friday
Census Day	Jan. 28	Thursday
Non-Class Day - President's Day	Feb. 15	Monday
Midterm Grades Due	Mar. 7	Monday
Spring Break - 9th full week of Spring Term	Mar. 14-18	Saturday - Sunday
Last Withdrawal - Continuing & Grad (13 weeks)	April 7	Thursday
E-Days	Mar. 31 - April 2	Thursday - Saturday

Priority Registration Summer/Fall	April 11-15	Monday - Friday
Last Withdrawal - New Freshmen & Transfers	April 29	Friday
Classes End	May 5	Thursday
Dead Week - No Exams	May 2-6	Monday - Friday
Dead Day - No Academic Activities	May 6	Friday
Final Exams	May 7, 9-12	Saturday, Monday - Thursday
Semester Ends	May 13	Friday
Commencement	May 13	Friday
Final Grades Due	May 16	Monday

Summer Sessions 2016

Description	Date(s)	Day(s) of Week
Summer I Starts (6-week session) (1)	May 16	Monday
Summer I Census	May 20	Friday
Memorial Day - No Classes, Campus Closed	May 30	Monday
Summer I Last Withdrawal - All Students	June 10	Friday
Summer I Ends	June 24	Friday
Summer I Grades Due	June 27	Monday
Summer II Starts (6-week session) (1)	June 27	Monday
Summer II Census	July 1	Friday
Independence Day - No Classes, Campus Closed	July 4	Friday
Summer II Last Withdrawal - All Students	July 22	Friday
Summer II Ends (2)	Aug. 5	Friday
Summer II Grades Due	Aug. 8	Monday
Summer Grades Available on Transcript	Aug. 24	Wednesday

¹ Petitions for changes in tuition classification due in the Registrar's Office for this term.

² PHGN courses end two weeks later on Friday, August 19th.

Directory of the School

2015-2016

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SCOTT HOUSER, 2007-B.S., Colorado State University; B.S., University of Southern Colorado; M.S., Ph.D, University of Wisconsin-Madison; Teaching Associate Professor of Economics and Business

PATRICK B. KOHL, 2007-B.S., Western Washington University; Ph. D. University of Colorado; Teaching Associate Professor of Physics

H. VINCENT KUO, 2006-B.S., M.S., Ph.D., University of Minnesota; Teaching Associate Professor of Physics

BECKY A. LAFRANCOIS, 2013-B.S., Bryant University; M.A., Ph.D., Syracuse University; Teaching Associate Professor of Economics and Business

LESLIE LIGHT, 2014-B.S., Stanford University; M.B.A., Wharton School of Business, University of Pennsylvania; Teaching Associate Professor of Mechanical Engineering

CARRIE J. MCCLELLAND, 2012-B.S., Colorado School of Mines; M.S., Ph.D., University of Colorado; Teaching Associate Professor of Petroleum Engineering

MICHAEL A. MIKUCKI, 2015-B.S., M.S., Ph.D., Colorado State University; Teaching Associate Professor of Applied Math and Statistics

DAN MILLER, 2009-B.A., University of Colorado, Boulder; Ph.D., University of Iowa; Teaching Associate Professor and Assistant Division Director of Liberal Arts and International Studies

MARK MILLER, 1996-B.S., Ph.D., Colorado School of Mines; Teaching Associate Professor of Petroleum Engineering

MARK B. MONDRY, 2014-B.S., Miami University; M.A.S., Johns Hopkins University; J.D. University of Maryland; Teaching Associate Professor of Economics and Business

RACHEL MORRISH, 2010-B.S.c., Colorado School of Mines, Ph.D. University of Arizona; Teaching Associate Professor of Chemical and Biological Engineering

MIKE NICHOLAS, 2012-B.A., B.S., University of Utah; M.S., Ph.D., Duke University; Teaching Associate Professor of Applied Mathematics and Statistics

CYNTHIA NORRGRAN, 2008-B.S., University of Minnesota; M.D., University of Nevada, Reno; Teaching Associate Professor of Chemical and Biological Engineering/BELS

PAUL OGG, 2007-B.A., Albion College; Ph.D., University of Iowa; Teaching Associate Professor of Chemical and Biological Engineering/BELS

CHRISTOPHER R. PAINTER-WAKEFIELD, 2013-B.S., Wake Forest University; Ph.D., Duke University; Teaching Associate Professor of Electrical Engineering and Computer Science

JEFFREY R. PAONE, 2015-M.S., University of Colorado; B.S., Ph.D., University of Notre Dame; Teaching Associate Professor of Electrical Engineering and Computer Science

ROSE A. PASS, 2006-A.B, M.A. Boston College; Teaching Associate Professor of Liberal Arts and International Studies

JOHN PERSICHETTI, 1997-B.S., University of Colorado; M.S., Colorado School of Mines; Teaching Associate Professor of Chemical and Biological Engineering

CHRISTIAN SHOREY, 2005-B.S., University of Texas at Austin; Ph.D., University of Iowa; Teaching Associate Professor of Geology and Geological Engineering

ANGELA SOWER, 2014-B.S., Northern Arizona University; Ph.D., University of New Mexico; Teaching Associate Professor of Chemistry and Geochemistry

JOHN STERMOLE, 1988-B.S., University of Denver; M.S., Colorado School of Mines; Teaching Associate Professor of Economics and Business

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CANDACE S. SULZBACH, 1983-B.S., Colorado School of Mines; Teaching Associate Professor of Civil and Environmental Engineering

REBECCA SWANSON, 2012-B.A., Dakota Wesleyan University; M.A., Ph.D., Indiana University; Teaching Associate Professor of Applied Mathematics and Statistics

ROMAN TANKELEVICH, 2003-B.S., M.S., Moscow Physics Engineering Institute; Ph.D., Moscow Energy Institute; Teaching Associate Professor of Electrical Engineering and Computer Science

NATALIE VAN TYNE, 2008-B.S., Rutgers University, M.S., M.B.A., Lehigh University; M.S., Colorado School of Mines; Program Director and Teaching Associate Professor of EPICS

ALEXANDRA WAYLLACE, 2008-B.S., M.S., Colorado School of Mines; Ph.D., University of Missouri-Columbia; Teaching Associate Professor of Civil and Environmental Engineering

Teaching Assistant Professors

YONG J. BAKOS, 2012-B.A., Northwestern University; M.S., Regis University; Teaching Assistant Professor of Electrical Engineering and Computer Science

OLIVIA BURGESS, 2014-B.A., Texas State University; M.A., Texas A&M University; Ph.D., Texas A&M University; Teaching Assistant Professor of Liberal Arts and International Studies

JAMES BISHOP, 2014-B.A., Bowdoin College; M.A., Middlebury College; Ph.D., University of Nevada; Teaching Assistant Professor of Liberal Arts and International Studies

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ELIO S. DEAN, 2015-B.S., M.S., Colorado School of Mines; Teaching Assistant Professor of Petroleum Engineering

ED A. DEMPSEY, 2007-Electronics Technician Diploma, DeVry Technical Institute; Teaching Assistant Professor of Chemistry and Geochemistry

ANN DOZORETZ, 2004-B.S., University of Denver; M.S., Colorado School of Mines; Teaching Assistant Professor of Economics and Business

SARAH J. HITT, 2012-Ph.D., University of Denver; M.A., DePaul University; B.A., MacMurray College; Teaching Assistant Professor of Liberal Arts and International Studies

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MARTIN SPANN, 2006-B.S., National University; Teaching Assistant Professor of EPICS

SETH B. TUCKER, 2014-B.A., San Francisco State University; M.A. Northern Arizona University; Ph.D., Florida State University; Teaching Assistant Professor of Liberal Arts and International Studies

Library Faculty

PATRICIA E. ANDERSEN, 2002-Associate Diploma of the Library Association of Australia, Sydney, Australia; Assistant Librarian

CHRISTINE BAKER, 2006-B.A., University of Massachusetts, Amherst; M.L.S., Emporia State University; Assistant Librarian

PAMELA M. BLOME, 2002-B.A., University of Nebraska; M.A.L.S., University of Arizona, Tucson; Assistant Librarian

LISA DUNN, 1991-B.S., University of Wisconsin-Superior; M.A., Washington University; M.L.S., Indiana University; shy; Librarian

LAURA A. GUY, 2000-B.A., University of Minnesota; M.L.S., University of Wisconsin; Librarian

JOANNE V. LERUD-HECK, 1989-B.S.G.E., M.S., University of North Dakota; M.A., University of Denver; Librarian and Director of Library

LISA S. NICKUM, 1994-B.A., University of New Mexico; M.S.L.S., University of North Carolina; Associate Librarian

CHRISTOPHER J. J. THIRY, 1995-B.A., M.I.L.S., University of Michigan; Associate Librarian

LIA VELLA, 2011-B.A., University of Rochester; Ph.D., University of Buffalo; M.L.I.S., University of Washington; Assistant Librarian

HEATHER WHITEHEAD, 2001-B.S., University of Alberta; M.L.I.S., University of Western Ontario; Associate Librarian

Coaches/Athletics Faculty

SATYEN BHAKTA, 2011-B.A., Temple University; Instructor and Assistant Football Coach

STEPHANIE BEGLAY, 2007-B.S., Loras College, M.A., Minnesota State University at Mankato; Assistant Athletics Trainer

BOB BENSON, 2008-B.A., University of Vermont, M.Ed, University of Albany; Instructor and Associate Head Football Coach

ARDEL J. BOES, B.A., St. Ambrose College; M.S., Ph.D., Purdue University; Emeritus Professor of Mathematical and Computer Sciences and Co-Head Cross Country Coach

W. SCOTT CAREY, 2011-B.S., Tarleton State University; M.S., Northeastern State University; Instructor and Assistant Football Coach

CLEMENT GRINSTEAD, 2001-B.A., B.S. Coe College; Instructor and Assistant Football Coach

KRISTIE HAWKINS, 2010-B.S., University of Maine; Instructor and Head Softball Coach

JOHN HOWARD, 2005-B.S., M.S., Western Illinois University; Director of Intramural and Club Sports

JOSHUA HUTCHENS, 2007-B.S. Purdue, M.S. James Madison; Instructor and Co-Head Wrestling Coach

GREGORY JENSEN, 2000-B.S., M.S., Colorado State University; Instructor and Assistant Trainer

TYLER KIMBLE, 2007-B.S., Colorado State University; Instructor and Head Golf Coach

FRANK KOHLENSTEIN, 1998-B.S., Florida State University; M.S., Montana State University; Instructor and Head Soccer Coach

PAULA KRUEGER, 2003-B.S, M.S., Northern State University Head Women's Basketball Coach

ADAM LONG, 2010-B.S., M.S., Northwest Missouri State University; Instructor and Assistant Football Coach

JENNIFER MCINTOSH, 1996-B.S., Russell Sage College, M.S., Chapman University; Head Athletic Trainer

GREG MULHOLLAND, 2007-B.S., Millersville University, M.S., University of Colorado at Denver; Instructor and Assistant Men's Soccer Coach

JERRID OATES, 2004-B.S., Nebraska Wesleyan University, M.S., Fort Hayes State University; Instructor and Head Baseball Coach

PRYOR ORSER, 2002- B.S., M.A., Montana State University; Instructor and Head Men's Basketball Coach

HEATHER ROBERTS, 2008- B.S., William Woods University, M.S., Bemidji State University; Instructor and Assistant Volleyball Coach

NATHAN ROTHMAN, 2008-B.A., University of Colorado; Instructor and Head Swimming and Diving Coach

BRAD J. SCHICK, 2007-B.A., University of Northern Colorado; M.S. University of Nebraska at Omaha; Instructor and Assistant Men's Basketball Coach

ARTHUR SIEMERS, 2004-B.S., Illinois State University-Normal, M.S., University of Colorado-Boulder, Instructor and Head Track and Field and Cross Country Coach

BRITTNEY SIMPSON, 2008-B.S., Mesa State College, M.B.A., University of Colorado at Colorado Springs; Instructor and Assistant Women's Basketball Coach

JAMIE L. SKADELAND, 2007-B.S., University of North Dakota, M.A., Minnesota State University at Mankato; Head Volleyball Coach

ROBERT A. STITT, 2000- B.A., Doane College; M.A., University of Northern Colorado; Head Football Coach

NOLAN SWETT, 2010-B.A., Colorado College, Instructor and Assistant Football Coach

ROB THOMPSON, 2004-B.A., Bowling Green State University, M.A., Bowling Green State University; Instructor and Director of the Outdoor Recreation Center

Policies & Procedures

2015-2016

Standards, Codes of Conduct

Students can access campus rules and regulations, including the student code of conduct, alcohol policy, public safety and parking policies, the distribution of literature and free speech policy, and a variety of others by visiting the School's policy website (<https://inside.mines.edu/POGO-Policies-Governance>). We encourage all students to review the website and expect that students know and understand the campus policies, rules and regulations as well as their rights as a student. Questions and comments regarding the above mentioned policies can be directed to the Associate Dean of Students located in the Student Center, Suite 172.

For emphasis, the following policies are included in this section:

- Student Honor Code
- Policy on Academic Integrity/Misconduct
- Policy Prohibiting Sexual Harassment (includes sexual assault and sexual violence)
- Unlawful Discrimination Policy and Complaint Procedure (currently under revision)
- Electronic Communications (E-mail) Policy
- Student Complaint Process
- Access to Student Records
- Posthumous Degree Awards
- Equal Opportunity, Equal Access, and Affirmative Action

Student Honor Code

1.0 PREAMBLE

The students of Colorado School of Mines have adopted the following Student Honor Code in order to establish a high standard of student behavior at Mines. The Code may only be amended through a student referendum supported by a majority vote of the Mines student body. Mines students shall be involved in the enforcement of the Code through their participation in the Student Conduct Appeals Board.

2.0 CODE

Mines students believe it is our responsibility to promote and maintain high ethical standards in order to ensure our safety, welfare, and enjoyment of a successful learning environment. Each of us, under this Code, shall assume responsibility for our behavior in the area of academic integrity. As a Mines student, I am expected to adhere to the highest standards of academic excellence and personal integrity regarding my schoolwork, exams, academic projects, and research endeavors. I will act honestly, responsibly, and above all, with honor and integrity in all aspects of my academic endeavors at Mines. I will not misrepresent the work of others as my own, nor will I give or receive unauthorized assistance in the performance of academic coursework. I will conduct myself in an ethical manner in my use of the library, computing center, and all other school facilities and resources. By practicing these principles, I will strive to uphold the principles of integrity and academic excellence at Mines. I will not participate in or tolerate any form of discrimination or mistreatment of another individual.

Policy on Academic Integrity/Misconduct

1.0 ACADEMIC INTEGRITY

The Colorado School of Mines affirms the principle that all individuals associated with the Mines academic community have a responsibility for establishing, maintaining and fostering an understanding and appreciation for academic integrity. In broad terms, this implies protecting the environment of mutual trust within which scholarly exchange occurs, supporting the ability of the faculty to fairly and effectively evaluate every student's academic achievements, and giving credence to the university's educational mission, its scholarly objectives and the substance of the degrees it awards. The protection of academic integrity requires there to be clear and consistent standards, as well as confrontation and sanctions when individuals violate those standards. The Colorado School of Mines desires an environment free of any and all forms of academic misconduct and expects students to act with integrity at all times.

2.0 POLICY ON ACADEMIC MISCONDUCT

Academic misconduct is the intentional act of fraud, in which an individual seeks to claim credit for the work and efforts of another without authorization, or uses unauthorized materials or fabricated information in any academic exercise. Student Academic Misconduct arises when a student violates the principle of academic integrity. Such behavior erodes mutual trust, distorts the fair evaluation of academic achievements, violates the ethical code of behavior upon which education and scholarship rest, and undermines the credibility of the university. Because of the serious institutional and individual ramifications, student misconduct arising from violations of academic integrity is not tolerated at Mines. If a student is found to have engaged in such misconduct sanctions such as change of a grade, loss of institutional privileges, or academic suspension or dismissal may be imposed. As a guide, some of the more common forms of academic misconduct are noted below. This list is not intended to be all inclusive, but rather to be illustrative of practices the Mines faculty have deemed inappropriate:

1. **Dishonest Conduct** - general conduct unbecoming a scholar. Examples include issuing misleading statements; withholding pertinent information; not fulfilling, in a timely fashion, previously agreed to projects or activities; and verifying as true, things that are known to the student not to be true or verifiable.
2. **Plagiarism** - presenting the work of another as one's own. This is usually accomplished through the failure to acknowledge the borrowing of ideas, data, or the words of others. Examples include submitting as one's own work the work of another student, a ghost writer, or a commercial writing service; quoting, either directly or paraphrased, a source without appropriate acknowledgment; and using figures, charts, graphs or facts without appropriate acknowledgment. Inadvertent or unintentional misuse or appropriation of another's work is nevertheless plagiarism.
3. **Falsification/Fabrication** - inventing or altering information. Examples include inventing or manipulating data or research procedures to report, suggest, or imply that particular results were achieved from procedures when such procedures were not actually undertaken or when such results were not actually supported by the pertinent data; false citation of source materials; reporting false information about practical, laboratory, or clinical experiences; submitting false excuses for absence, tardiness, or missed deadlines; and, altering previously submitted examinations.
4. **Tampering** - interfering with, forging, altering or attempting to alter university records, grades, assignments, or other documents without authorization. Examples include using a computer or a false-

written document to change a recorded grade; altering, deleting, or manufacturing any academic record; and, gaining unauthorized access to a university record by any means.

5. **Cheating** - using or attempting to use unauthorized materials or aid with the intent of demonstrating academic performance through fraudulent means. Examples include copying from another student's paper or receiving unauthorized assistance on a homework assignment, quiz, test or examination; using books, notes or other devices such as calculators, PDAs and cell phones, unless explicitly authorized; acquiring without authorization a copy of the examination before the scheduled examination; and copying reports, laboratory work or computer files from other students. Authorized materials are those generally regarded as being appropriate in an academic setting, unless specific exceptions have been articulated by the instructor.
6. **Impeding** - negatively impacting the ability of other students to successfully complete course or degree requirements. Examples include removing pages from books and removing materials that are placed on reserve in the Library for general use; failing to provide team members necessary materials or assistance; and, knowingly disseminating false information about the nature of a test or examination.
7. **Sharing Work** - giving or attempting to give unauthorized materials or aid to another student. Examples include allowing another student to copy your work; giving unauthorized assistance on a homework assignment, quiz, test or examination; providing, without authorization, copies of examinations before the scheduled examination; posting work on a website for others to see; and sharing reports, laboratory work or computer files with other students.

3.0 PROCEDURES FOR ADDRESSING ACADEMIC MISCONDUCT

Faculty members and thesis committees have discretion to address and resolve misconduct matters in a manner that is commensurate with the infraction and consistent with the values of the Institution. This includes imposition of appropriate academic sanctions for students involved in academic misconduct. However, there needs to be a certain amount of consistency when handling such issues, so if a member of the Mines community has grounds for suspecting that a student or students have engaged in academic misconduct, they have an obligation to act on this suspicion in an appropriate fashion. The following procedure will be followed:

- The faculty member or thesis committee informs the student(s) of the allegations and charge of academic misconduct within 10 business days. This involves verbal communication with the student(s). The faculty member/thesis committee must have a meeting with the student(s) regarding the incident. This meeting allows the student the opportunity to give his/her perspective prior to an official decision being made. It also allows the faculty member to have a conversation with the student(s) to educate him/her on appropriate behavior.
- The circumstances of the academic misconduct dictate the process to be followed:
 - In the case of an allegation of academic misconduct associated with **regular coursework**, if after talking with the student(s), the faculty member feels the student is responsible for academic misconduct the faculty member should:
 - Assign a grade of "F" in the course to the student(s) that committed academic misconduct. A faculty member may impose a lesser penalty if the circumstances warrant, however the typical sanction is a grade of "F".

- Contact the Associate Dean of Students and his/her Department Head/Division Director to officially report the violation in writing within 5 business days of the charge of academic misconduct. The Associate Dean of Students will communicate the final resolution in writing to the student, the faculty member, the Office of Academic Affairs, the Office of Graduate Studies and the student's advisor. The Associate Dean of Students will also keep official records on all students with academic misconduct violations.
- Prescribed disciplinary action for misconduct associated with regular coursework:
 - 1st Offense: A grade of "F" in the course.
 - 2nd Offense: A grade of "F" in the course, one-year academic suspension, and permanent notation of Academic Misconduct on the student's transcript.
- In the case of an allegation of academic misconduct associated with **activities not a part of regular coursework** (e.g. an allegation of cheating on a comprehensive examination), if after talking with the student, faculty member(s) feel the student is responsible for misconduct, the faculty should:
 - Assign an outcome to the activity that constitutes failure. If appropriate, the student's advisor may also assign a grade of "PRU" (unsatisfactory progress) for research credits in which the student is enrolled. Regular institutional procedures resulting from either of these outcomes are then followed. Faculty members may impose a lesser penalty if the circumstances warrant, however, the typical sanction is failure.
 - Contact the Associate Dean of Students, Graduate Dean and the student's Department Head/Division Director to officially report the violation in writing within 5 business days of the charge of misconduct. The Associate Dean of Students will communicate the final resolution in writing to the student, the faculty member, the Office of Graduate Studies, and the student's advisor. The Associate Dean of Students will also keep official records on all students with academic misconduct violations.
- In the case of an allegation of academic misconduct associated with **research activities**, investigation and resolution of the misconduct is governed by the Institution's Research Integrity Policy. The Research Integrity Policy is available as section 10.3 of the Faculty Handbook. If, after talking with the student, the faculty member feels the student is responsible for misconduct of this type, the faculty member should proceed as indicated in the Research Integrity Policy. If appropriate, the student's advisor may also assign a grade of "PRU" for research credits in which the student is enrolled. Regular institutional procedures resulting from this grade assignment are then followed.
- Students who suspect other students of academic misconduct should report the matter to the appropriate faculty member, the appropriate Department Head/Division/Program Director, the Dean of Undergraduate Students, the Dean of Graduate Students, or the Associate Dean of Students. The information is then provided to the faculty member concerned.

4.0 APPEAL PROCESS FOR STUDENT ACADEMIC MISCONDUCT

The academic misconduct appeal process is under revision. For the most up-to-date version of this procedure, please see the student section of the policy website (<https://inside.mines.edu/POGO-Policies-Governance>).

Policy Prohibiting Sexual Harassment*

***Note:** This policy is inclusive of all forms of sexual harassment, including sexual assault and sexual violence.

1.0 STATEMENT OF AUTHORITY AND PURPOSE

This policy is promulgated pursuant to the authority conferred by §23-41-104(1), C.R.S., and Title IX of the Education Amendments of 1972 (Title IX), 20 U.S.C. §§ 1681 *et seq.*, and its implementing regulations, 34 C.F.R. Part 106; Title IV of the Civil Rights Act of 1964 (42 U.S.C. § 2000c). Its purpose is to set forth a policy statement from the Board of Trustees concerning sexual harassment at the Colorado School of Mines ("Mines" or "the School"). This policy shall supersede any Mines' policy that is in conflict herewith.

2.0 SEXUAL HARASSMENT POLICY

2.1 Policy Statement

The Mines Board of Trustees wishes to foster an environment for the Mines' campus community that is free from all forms of sexual harassment. Accordingly, the School will not tolerate any forms of sexual harassment and will take all necessary measures to deter such misconduct, including but not limited to preventive educational programs, thorough investigation of sexual harassment complaints, and discipline of policy violators with appropriate sanctions. Retaliation in any form against an individual for reporting sexual harassment or cooperating in a sexual harassment investigation is strictly prohibited. Such retaliation shall be dealt with as a separate instance of sexual harassment. Complaints of sexual harassment will be handled in accordance with the administrative procedures that accompany this policy.

2.2 Definition of Sexual Harassment

Sexual harassment shall, without regard to the gender of the Complainant or Respondent, consist of unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature when: (1) either explicitly or implicitly, submission to such conduct is made a term or condition of an individual's employment or educational endeavors; (2) submission to or rejection of such conduct by an individual is used as the basis for employment or educational decisions affecting the individual; or (3) such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance, or creating an intimidating, hostile, or offensive working or educational environment.

Sexual violence and sexual assault are forms of sexual harassment. Sexual harassment shall also be defined to include retaliation against an individual for reporting sexual harassment or cooperating in a sexual harassment investigation.

2.3 Sanctions for Sexual Harassment

Appropriate sanctions may be imposed upon an employee or student who has sexually harassed another. The sanctions may include, but are not limited to one or more of the following: oral reprimand and warning; written reprimand and warning; student probation; suspension or expulsion; monetary fine; attendance at a sexual harassment prevention seminar; suspension without pay; or termination of employment or appointment.

3.0 IMPLEMENTATION

The Mines Board of Trustees authorizes and directs the President or President's delegates to develop, administer, and maintain the appropriate administrative policies, procedures, and guidelines to implement this policy.

Title IX Coordinator:

Karin Ranta-Curran, Assistant Director of HR for EEO and Equity
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.384.2558)
(E-Mail: krcurran@mines.edu)

Contact for Complaints about Employee or Third-Party Behavior:

Mike Dougherty, Associate Vice President for Human Resources
Guggenheim Hall, Room 110
Golden, CO 80401
(Telephone: 303.273.3250)

Contact for Complaints about Student Behavior:

Derek Morgan, Associate Dean of Students
Student Center, Room 175
1200 6th Street
Golden, CO 80401
(Telephone: 303.273.3288)

Related Administrative Policies, Procedures, Resources:

For Complaints about Employee or Third-Party Behavior:

- Sexual Harassment Complaint, Investigation and Resolution Procedure for Complaints Involving Employees or Third Parties
- Sexual Harassment Complaint Investigation Authorization Form

For Complaints about Student Behavior:

- Sexual Harassment Complaint, Investigation, Resolution and Adjudication Procedure for Complaints about Student Behavior
- Procedures/Resources for Survivors of Sexual Assault or Other Sexual Violence
- Anonymous Sexual Violence Reporting Form

This policy was promulgated by the Colorado School of Mines Board of Trustees on March 13, 1992. Amended by the Colorado School of Mines Board of Trustees on March 26, 1998. Amended by the Colorado School of Mines Board of Trustees on June 10, 1999. Amended by the Colorado School of Mines Board of Trustees on June 22, 2000. Amended by the Colorado School of Mines Board of Trustees on June 7, 2003. Amended by the Colorado School of Mines Board of Trustees on December 15, 2011.

Unlawful Discrimination Policy and Complaint Procedure

I. STATEMENT OF AUTHORITY AND PURPOSE

This policy is promulgated by the Board of Trustees pursuant to the authority conferred upon it by §23-41-104(1), C.R.S. (1999) in order to set forth a policy concerning unlawful discrimination at CSM. This policy shall supersede any previously promulgated CSM policy that is in conflict herewith.

II. UNLAWFUL DISCRIMINATION POLICY

Attendance and employment at CSM are based solely on merit and fairness. Discrimination on the basis of age, gender, race, ethnicity, religion, national origin, disability, sexual orientation, and military veteran status is prohibited. No discrimination in admission, application of academic standards, financial aid, scholastic awards, promotion, compensation, transfers, reductions in force, terminations, re-employment, professional development, or conditions of employment shall be permitted. The remainder of this policy shall contain a complaint procedure outlining a method for reporting alleged violations of this policy and a review mechanism for the impartial determination of the merits of complaints alleging unlawful discrimination.

As of June 2011, this policy is under revision. For a complete policy statement please see the policy website (<https://inside.mines.edu/POGO-Policies-Governance>). Promulgated by the CSM Board of Trustees on March 13, 1992. Amended by the CSM Board of Trustees on June 10, 1999. Amended by the CSM Board of Trustees on June 22, 2000.

Electronic Communications (E-mail) Policy

1.0 BACKGROUND AND PURPOSE

Communication to students at the Colorado School of Mines (Mines) is an important element of the official business of the university. It is vital that Mines have an efficient and workable means of getting important and timely information to students. Examples of communications that require timely distribution include information from Fiscal Services, the Registrar's Office, or other offices on campus that need to deliver official and time-sensitive information to students. (Please note that emergency communications may occur in various forms based on the specific circumstances).

Electronic communication through email and Trailhead Portal announcements provides a rapid, efficient, and effective form of communication. Reliance on electronic communication has become the accepted norm within the Mines community. Additionally, utilizing electronic communications is consistent with encouraging a more environmentally-conscious means of doing business and encouraging continued stewardship of scarce resources. Because of the wide-spread use and acceptance of electronic communication, Mines is adopting the following policy regarding electronic communications with students.

2.0 POLICY

It is the policy of the Colorado School of Mines that official university-related communications with students will be sent via Mines' internal email system or via campus or targeted Trailhead announcements. All students will be assigned a Mines email address and are expected to periodically check their Mines assigned email as well as their Trailhead portal page. It is also expected that email sent to students will be read in a timely manner. Communications sent via email to students will be considered to have been received and read by the intended recipients.

3.0 PROCEDURES

1. All students will be given an EKey, which is an activation code that offers access to electronic resources at Mines. With their EKey, students must activate their assigned Mines email address.
2. Once their email address is activated, students are expected to check their Mines email inbox on a frequent and consistent basis and have the responsibility to recognize that certain communications from the university may be timecritical. As such, students also are responsible

for responding in a timely manner to official communications from the university when a response is requested.

3. The policy does not prevent students from using a personal email address for university-related communications and purposes. If a student chooses to use a personal email address as his or her address of choice for receiving university-related communications, he or she must forward email from the Mines assigned email address to the personal email address. However, if a student chooses to forward communications to a personal email address, she or he must be aware that Mines personnel may not be able to assist in resolving technical difficulties with personal email accounts. Furthermore, forwarding communications to a personal email address does not absolve a student from the responsibilities associated with communication sent to his or her official Mines email address. Please note: If a student changes his or her official Mines email address to a personal address, it will be changed back to the Mines assigned email address. Students have the option to forward their Mines email to a personal address to avoid this problem. Should a student choose the forwarding option, he or she must ensure that SPAM filters will not block email coming from the mines.edu address.
4. Nothing in these procedures should be construed as prohibiting university-related communications being sent via traditional means. Use of paper-based communication may be necessary under certain circumstances or may be more appropriate to certain circumstances. Examples of such communications could include, but not be limited to disciplinary notices, fiscal services communications, graduation information and so forth.

Responsible Parties

Questions about this policy may be directed as follows:

Registrar's Office Phone: 303-273-3200 or
E-mail: registrar@mines.edu

Computing, Communications & Information Technologies (CCIT)
Phone: 303-273-3431 or
Complete a request form at the Mines Help Center (<http://helpdesk.mines.edu/>)

Student Complaint Process

Students are consumers of services offered as part of their academic and co-curricular experience at the Colorado School of Mines. If a student needs to make a complaint, specific or general, about their experience at Mines, he or she should contact the Office of the Dean of Students at 303-273-3231. If the issue is related to discrimination or sexual harassment, there are specific procedures that will be followed (these are noted and linked in this section). Regardless, the student should begin with the Dean's Office if interested in making any complaint. All complaints, as well as the interests of all involved parties, will be considered with fairness, impartiality, and promptness while a complaint is being researched and/or investigated by the School.

Access to Student Records

Students at the Colorado School of Mines are protected by the Family Educational Rights and Privacy Act of 1974, as amended. This Act was designed to protect the privacy of education records, to establish the right of students to inspect and review their education records, and to provide guidelines for the correction of inaccurate or misleading data through informal and formal hearings. Students also have the right to file complaints with The Family Educational Rights and Privacy Act Office

(FERPA) concerning alleged failures by the institution to comply with the Act. Copies of local policy can be found in the Registrar's Office. Contact information for FERPA complaints is

Family Policy Compliance Office
U.S. Department of Education
400 Maryland Avenue, SW
Washington, D. C. 20202-4605

Directory Information. The School maintains lists of information which may be considered directory information as defined by the regulations. This information includes name, current and permanent addresses and phone numbers, date of birth, major field of study, dates of attendance, part or full-time status, degrees awarded, last school attended, participation in officially recognized activities and sports, class, and academic honors. Students who desire that this information not be printed or released must so inform the Registrar before the end of the first two weeks of the fall semester for which the student is registered. Information will be withheld for the entire academic year unless the student changes this request. The student's signature is required to make any changes for the current academic year. The request must be renewed each fall term for the upcoming year. The following student records are maintained by Colorado School of Mines at the various offices listed below:

1. General Records: Registrar and Graduate Dean
2. Transcript of Grades: Registrar
3. Computer Grade Lists: Registrar
4. Encumbrance List: Controller and Registrar
5. Academic Probation/Suspension List: Graduate Dean
6. Advisor File: Academic Advisor
7. Option/Advisor/Enrolled/ Minority/Foreign List: Registrar, Dean of Students, and Graduate Dean
8. Externally Generated SAT/GRE Score Lists: Graduate Dean
9. Financial Aid File: Financial Aid (closed records)
10. Medical History File: School Physician (closed records)

Student Access to Records. The graduate student wishing access to his or her educational records will make a written request to the Graduate Dean. This request will include the student's name, date of request and type of record to be reviewed. It will be the responsibility of the Dean to arrange a mutually satisfactory time for review. This time will be as soon as practical but is not to be later than 30 business days from receipt of the request. The record will be reviewed in the presence of the Dean or designated representative. If the record involves a list including other students, steps will be taken to preclude the viewing of the other student name and information.

Challenge of the Record. If the student wishes to challenge any part of the record, the Dean will be so notified in writing. The Dean may then

1. remove and destroy the disputed document, or
2. inform the student that it is his decision that the document represents a necessary part of the record; and, if the student wishes to appeal,
3. convene a meeting of the student and the document originator (if reasonably available) in the presence of the Executive Vice President for Academic Affairs as mediator, whose decision will be final.

Destruction of Records. Records may be destroyed at any time by the responsible official if not otherwise precluded by law except that no record may be destroyed between the dates of access request and the

viewing of the record. If during the viewing of the record any item is in dispute, it may not be destroyed.

Access to Records by Other Parties. Colorado School of Mines will not permit access to student records by persons outside the School except as follows:

1. In the case of open record information as specified in the section under Directory Information.
2. To those people specifically designated by the student. Examples would include request for transcript to be sent to graduate school or prospective employer.
3. Information required by a state or federal agency for the purpose of establishing eligibility for financial aid.
4. Accreditation agencies during their on-campus review.
5. In compliance with a judicial order or lawfully issued subpoena after the student has been notified of the intended compliance.
6. Any institutional information for statistical purposes which is not identifiable with a particular student.
7. In compliance with any applicable statute now in effect or later enacted. Each individual record (general, transcript, advisor, and medical) will include a log of those persons not employed by Colorado School of Mines who have requested or obtained access to the student record and the legitimate interest that the person has in making the request.

The School discloses education records without a student's prior written consent under the FERPA exception for disclosure to school officials with legitimate educational interests. A school official is a person employed by the School in an administrative, supervisory, academic or research, or support staff position (including law enforcement unit personnel and health staff); a person or company with whom the School has contracted as its agent to provide a service instead of using School employees or officials (such as an attorney, auditor, or collection agent); a person serving on the Board of Trustees; or a student serving on an official committee, such as a disciplinary or grievance committee, or assisting another school official in performing his or her tasks.

A school official has a legitimate educational interest if the official needs to review an education record in order to fulfill his or her professional responsibilities for the School.

Posthumous Degree Awards

The faculty may recognize the accomplishments of students who have died while pursuing their educational goals. If it is reasonable to expect that the student would have completed his or her degree requirements, the faculty may award a Baccalaureate or Graduate Degree that is in all ways identical to the degree the student was pursuing. Alternatively, the faculty may award a Posthumous BS, MS, or Ph.D. to commemorate students who distinguished themselves while at Mines by bringing honor to the School and its traditions.

Consideration for either of these degrees begins with a petition to the Faculty Senate from an academic department or degree granting unit. The petition should identify the degree sought. In the event that the degree-granting unit is seeking a conventional degree award, the petition should include evidence of the reasonable expectations that the student would have completed his or her degree requirements. For a Baccalaureate, such evidence could consist of, but is not limited to:

- The student was a senior in the final semester of coursework,

- The student was enrolled in courses that would have completed the degree requirements at the time of death
- The student would have passed the courses with an acceptable grade, and would likely have fulfilled the requirements of the degree.

For a Graduate Degree:

- For graduate degrees not requiring a research product, the student was enrolled in courses that would have completed the degree requirements at the time of death, would have passed the courses with an acceptable grade, and would likely have fulfilled the requirements of the degree.
- For graduate degrees requiring a research product, the student had completed all course and mastery requirements pursuant to the degree and was near completion of the dissertation or thesis, and the student's committee found the work to be substantial and worthy of the degree.

The requirement that there be a reasonable expectation of degree completion should be interpreted liberally and weight should be given to the judgment of the departmental representative(s) supporting the petition.

In the event that the degree being sought is a Posthumous BS, MS, or Ph.D., the petition should include evidence that the student conducted himself or herself in the best tradition of a Mines' graduate and is therefore deserving of that honor.

Equal Opportunity, Equal Access, and Affirmative Action

The institution's Statement of Equal Opportunity and Equal Access to Educational Programs, and associated staff contacts, can be found in the Welcome Section of this Bulletin as well as on the policy website (<https://inside.mines.edu/POGO-Policies-Governance>). Colorado School of Mines has instituted an affirmative action plan, which is available for perusal in numerous CSM offices including the Library, the Dean of Students' Office, and the Office of Human Resources.

Research Centers & Institutes

Please select from the list of links on the left to locate more information on the various Research Centers & Institutes at the Colorado School of Mines.

Institutional Centers

2015-2016

Please select from the list of links on the right for more information.

Please contact Jean Yeager, Executive Assistant for Research and Technology Transfer, jyeager@mines.edu or 303-273-3077, for questions.

Center for Research on Hydrates and Other Solids

Since 1975, the Center for Research on Hydrates and Other Solids has performed both fundamental and applied research on natural gas hydrates, curious ice-like compounds composed of water and hydrocarbon gases. Gas hydrates, which generally form at cold temperatures and high pressures, present both a major challenge and major opportunity in energy production. Gas hydrates can plug deep sea and arctic gas and oil pipelines, and preventing hydrate formation is a major design and operational challenge. On the other hand, naturally occurring gas hydrates could potentially provide the world's largest resource of natural gas. Recently, researchers at the center have also found that hydrates can be used as an energy storage material for potential use in fuel cell applications.

With active participation of faculty, graduate, and undergraduate students, the center provides a unique combination of expertise that has enabled CSM to achieve international prominence in gas hydrate research. CSM participants interact on an on-going basis with sponsors and other collaborators, including frequent visits to their facilities both in the US and abroad. For students, this interaction often continues beyond graduation, with opportunities for employment at sponsoring industries.

More information can be found at the center website, <http://hydrates.mines.edu/>.

Professors

Carolyn Koh, Director

David Wu, Associate Director

Associate professor

Amadeu Sum

Professor emeritus

E. Dendy Sloan

Colorado Energy Research Institute

Originally established in 1974 and re-authorized in 2004, the Colorado Energy Research Institute (CERI) promotes research and educational activities across the spectrum of sustainable energy technologies. For the past 10 years, much of the focus has been on sustainable pathways for fossil energy development, including research and education on water that is co-produced with energy, reduction in emissions of such greenhouse gasses as CO₂ and methane, and geothermal energy. The research is funded by the US Department of Energy, related Federal agencies, and also by long-term consortia of energy industry companies. CERI itself operates more as a research funding "program" within the Colorado School of Mines, rather than an entity with its own technical faculty, staff and students. CERI also supports research in a number of individual Mines departments. Funding and collaboration includes other Colorado research universities and the National Laboratories in the Front Range communities. CERI has developed a close synergy with the Colorado Energy Research Collaboratory, which offers a specific funded relationship to the State of Colorado, and to the National Renewable Energy Laboratory through formal joint institutes and programs.

Director

Dag Nummedal

Critical Materials Institute

<http://cmi.mines.edu/>

CMI is an Energy Innovation Hub of the U.S. Department of Energy. Its focus is innovation to reduce supply risks for materials critical to clean energy technologies. The goal of this innovation is to remove supply risk as an impediment to the development and deployment of emerging energy technologies. CMI is a multi-institutional, multi-disciplinary consortium led by the Ames Laboratory (<http://cmi.ameslab.gov>). It carries out scientific and engineering research that facilitates more-diverse primary supply chains; more-efficient manufacturing, re-use, and recycling; and development of new materials. CMI also conducts complementary and supporting research on basic science, environmental sustainability, and supply chain and economic analysis. CMI research at Mines, in partnership with the Kroll Institute for Extractive Metallurgy, focuses especially on: process engineering to improve primary mineral processing and recovery, as well as secondary recovery through recycling of manufacturing wastes and end-of-life products; material characterization; environmental sustainability; and economic analysis of material supply chains. In addition, Mines spearheads CMI efforts in education, training, and outreach and is part of CMI senior leadership.

The Nuclear Science and Engineering Center

The Nuclear Science and Engineering Center (NuSEC) is an interdisciplinary research center whose objectives range from basic subatomic science through applied nuclear physics to research across all aspects of the nuclear fuel life cycle that includes: mineral exploration, extraction and processing; synthesis and processing of metal, oxide and ceramic fuels; nuclear power systems production, design and operation; fuel recycling, storage and waste remediation; and radiation damage, and the policy issues surrounding each of these activities.

Contact: Uwe Greife, Department of Physics, e-mail: ugreife@mines.edu

Website: nusec.mines.edu

Renewable Energy Materials Research Science and Engineering Center

New energy technologies are in demand and meeting energy needs is one of the most significant challenges we will face in the coming century. The National Science Foundation, beginning in 2008, sponsored Renewable Energy Materials Research Science and Engineering Center (REMRSEC) which focuses on bringing transformative material advances and educational directions that greatly impact emerging renewable energy technologies. The Center has made substantial progress in its research mission of identifying, launching and advancing an innovative research direction. Currently, the Center has two primary areas of research focus. Photovoltaic materials of potential use in the next generation of PV devices with research focused on the excitation, scattering and relaxation mechanisms that govern electronic transport in semiconducting materials. The second major thrust is advanced membranes for renewable energy applications with research on polymers, ionic solids, and hybrid systems with processes in the conversion, utilization, and storage of energy. Additionally, the Center's Seed Program explores high-risk, high-payoff innovative research that can be integrated within the Center's two main thrusts, or attract independent funding. The Center also has a human resource mission for educating the next generation of renewable energy professionals.

The REMRSEC Research Experiences for Undergraduates (REU) attracts students of diverse backgrounds interested in renewable energy from other universities across the United States. Undergraduates that are selected for the program are paired with a professor and take on a research project over a 10 week period during the summer. A K-12 outreach program for teachers is designed to address renewable energy concepts and renewable energy curriculum development that empowers them to directly expose students to renewable energy concepts at a young age and prepare them, throughout their K-12 education and into college, for potential careers in the renewable energy field. A diversity initiative seeks to increase the participation of underrepresented groups in science, technology, engineering and mathematics. The REMRSEC has a strong component of collaboration with other Centers on campus including the Center for Solar and Electronic Materials (CSEM), the Colorado Fuel Cell Center (CFCC), the Colorado Energy Research Collaboratory (CERC) and the Golden Energy Computing Organization (GECO). A strategic partnership with the National Energy Research Laboratory (NREL) and the REMRSEC allows scientists and engineers to share students, research associates, equipment and facilities between the two organizations. More information about the Center's activities is available on the [REMRSEC Website](http://remrsec.mines.edu) (<http://remrsec.mines.edu>).

Director

P. Craig Taylor

Associate Director

Reuben Collins

Principle Investigators

Reuben Collins

Andrew Herring

Ryan O'Hayre

Faculty

Sumit Agarwal

Annette Bunge

Cristian Ciobanu

Chip Durfee

Thomas Furtak

Brian Gorman

Dan Knauss

Carolyn Koh

Matthew Liberatore

Mark Lusk

C. Mark Maupin

Will Medlin

Barbara Moskal

Timothy Ohno

Ryan Richards

Kerry Shaklee

Venkata Somiseti

Jeff Squier

Adele Tamboli

Eric Toberer

Jianhua Tong

Kim Williams

Colin Wolden

David Wood

Zhigang Wu

Yongan Yang

ReNUWIt: The Urban Water Center

An Engineering Research Center (ERC), funded by the National Science Foundation for Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt). ReNUWIt is an interdisciplinary, multi-institution research center whose goal is to change the ways in which we manage urban water. Our vision is safe, sustainable urban water infrastructures enabled by technological advances in natural and engineered systems, and informed by a deeper understanding of institutional frameworks.

Collaboratory Centers

2015-2016

Please select from the list of links on the right for more information.

For additional information contact Jean Yeager, Executive Assistant for Research and Technology Transfer, at jyeager@mines.edu or 303-273-3077.

Colorado Renewable Energy Collaboratory

The Colorado Renewable Energy Collaboratory was created by the State of Colorado to advance multidisciplinary science, technology development and technology transfer on challenges related to renewable, reliable, secure, clean, and economically viable energy resources and technologies ("renewable energy"). Currently five centers have been created to explore initiatives in renewable energy:

- Colorado Center for Biorefining and Biofuels (C2B2)
- Center for Revolutionary Solar Photoconversion (CRSP)
- Collaborative Research and Education in Wind (CREW)
- Solar Technology Acceleration Center - Research Partnership (SolarTAC)
- Carbon Management Center (CMC)

Centers of Excellence & Research Institutes

2015-2016

Please select from the list of links on the right for more information.

Please contact Jean Yeager, Executive Assistant for Research and Technology Transfer, at jyeager@mines.edu or 303-273-3077, for additional information.

Advanced Coatings and Surface Engineering Laboratory

The Advanced Coating and Surface Engineering Laboratory (ACSEL) is a multi-disciplinary laboratory that serves as a focal point for industry-driven research and education in advanced thin films and coating systems, surface engineering, tribology, electronic, optical and magnetic thin films and devices. The laboratory is supported by a combination of government funding agencies (NSF, DOE, DOD) and an industrial consortium that holds annual workshops designed to maximize interaction between participants, evaluate the research conducted by graduate students and faculty, and provide direction and guidance for future activities. ACSEL provides opportunities for CSM faculty and graduate students to visit and work in sponsor facilities, participate in technical meetings with sponsors, and for CSM graduates to gain employment with sponsors.

Advanced Steel Processing and Products Research Center

2015-2016

The Advanced Steel Processing and Products Research Center (<http://aspprc.mines.edu>) (ASPPRC) at Colorado School of Mines was established in 1984. The Center is a unique partnership between industry, the National Science Foundation (NSF), and Colorado School of Mines, and is devoted to building excellence in research and education in the ferrous metallurgy branch of materials science and engineering. Objectives of ASPPRC are to perform research of direct benefit to the users and producers of steels, to educate graduate students within the context of research programs of major theoretical and practical interest to the steel-using and steel-producing industries, to stimulate undergraduate education in ferrous metallurgy, and to develop a forum to stimulate advances in the processing, quality and application of steel.

Research programs consist of several projects, each of which is a graduate student thesis. Small groups of students and faculty are involved in each of the research programs. Sponsor representatives are encouraged to participate on the graduate student committees.

The Center was established with a five-year grant of \$575,000 from the National Science Foundation, and is now self-sufficient, primarily as a result of industry support.

Advanced Water Technology Center

2015/2016

Advanced Water Technology Center

The Advanced Water Technology Center (AQWATEC) was established in 2006 to support the advancement of the campus's thrust areas of water and energy. Research activities at AQWATEC focus on advancing research and development of novel water treatment technologies and hybrid systems to enable sustainable and energy efficient utilization of impaired water sources, transforming them into new sources of potable and non-potable water supplies. Our focus areas include:

- Traditional and novel membrane separation processes for water purification, reuse, and desalination; including zero-liquid discharge systems
- Development of multiple-barrier hybrid processes to improve the efficiency of water treatment systems
- Advanced natural systems for elimination of emerging contaminants from the environment
- Predictive tools for process performance/reliability and water quality assessments
- Advanced concepts in decentralized water treatment facilities
- Development of more efficient water treatment systems for the industrial and renewable energy sectors
- Treatment and management strategies for produced and fracturing water from conventional and unconventional oil & gas resources

AQWATEC operates three major on-campus facilities, a state-of-the-art water quality analysis laboratory, a high-bay facility for laboratory and pilot-scale research, and a 7,000 gal/day advanced wastewater treatment research facility. The center also jointly operates a state-of-the-art surface water pilot plant at Golden's Water Treatment Plant. AQWATEC faculty currently sustain a research funding base of over \$6.6M via active grants and contracts from WaterRF, WERF, WRF, NSF, Cal DWR, U.S. Bureau of Reclamation, U.S. Department of Energy, NREL, and private industry.

Center for Assessment in Science, Technology, Engineering and Mathematics (CA:STEM)

The mission of the Center for Assessment (CA) in Science, Technology, Engineering and Mathematics (STEM) at the Colorado School of Mines (CSM) is to improve the methodologies used in the assessment of educational interventions in the STEM disciplines. CA:STEM's role is to bring together experts in quantitative research, qualitative research, and STEM content with the purpose of improving the evaluation of educational research projects and the validity of the interpretations made based on the results of those projects. CA:STEM also provides a training ground for undergraduate students, graduate students and researchers who are interested in assessment and evaluation. The primary goals of CA:STEM are:

- To conduct research in the assessment of STEM disciplines at all levels, kindergarten through graduate education.
- To provide evaluation experts for educational research projects (kindergarten through graduate education) conducted both in CSM and across the nation.
- To train undergraduate and graduate students in both qualitative and quantitative research techniques for the evaluation of educational research projects in the STEM disciplines.

Center for Automation, Robotics and Distributed Intelligence

The mission of the Center for Automation, Robotics and Distributed Intelligence (CARDI) is to engage in interdisciplinary research encompassing the fields of control systems, robotics and automation, and distributed systems and networking. Focus areas include the theory of adaptive and non-linear control, intelligent and learning control systems, system identification and fault detection, computer vision and image processing, wireless communication networks, intelligent autonomous robotic systems, machine learning and artificial intelligence, network communication protocols and simulation and modeling of computer networks. Applications of CARDI research can be found in renewable energy and power systems, materials processing, sensor and control networks, bio-engineering and medicine, data mining and activity recognition, defense and homeland security, smart structures, intelligent geo-systems, and environmental monitoring. CARDI research concentrates on problems which are not amenable to traditional solutions within a single discipline, but rather require a multi-disciplinary systems approach to integrate technologies.

Established in 1994, CARDI includes faculty from the Department of Electrical Engineering and Computer Science, the Department of Mechanical Engineering, the Department of Civil and Environmental Engineering, and the Department of Applied Mathematics and Statistics. Research is sponsored by industry, federal agencies, state agencies,

and joint government-industry initiatives. Interaction with industry enables CARDI to identify technical needs that require research, to cooperatively develop solutions, and to generate innovative mechanisms for the technology transfer. Enthusiastic and motivated students are encouraged to join CARDI for education and research in the area of automation, robotics, and distributed systems.

Center for Biomechanics and Rehabilitation Research

<http://biomechanics.mines.edu>

The Biomechanics and Rehabilitation Research group at Mines develops innovative solutions for accommodating musculoskeletal disabilities. Our research spans the range from implantable medical devices to assistive technologies including prosthetics and robotics. We seek to apply computational and experimental methods that relate phenomena across length scales from tissue to organ to whole body.

The Center for Biomechanics and Rehabilitation Research (CBRR, formerly IBDMS) was established in 1998 as a National Science Foundation (NSF) Industry/University Cooperative Research Center (I/UCRC) that focuses on research and education in bioengineering. The center integrates programs and expertise from the Colorado School of Mines, University of Colorado at Denver and the Colorado VA Research Center across a range of disciplines including engineering, materials and medicine.

CBRR has become an international center for the development of mathematical modeling of the musculoskeletal system, in vivo implant and normal joint imaging and measurement, bionic orthopaedics, sports medicine, human sensory augmentation, human amplifiers (exoskeletons), and smart orthoses. Additionally, through the efforts of this center, major and minor programs in bioengineering and biotechnology are being established at both the CSM graduate and undergraduate levels.

Associate professors

Joel M. Bach, Ph.D.

Anthony J. Petrella, Ph.D.

Assistant professor

Anne Silverman, Ph.D.

Center for Earth Materials, Mechanics, and Characterization

CEMMC is a multidisciplinary research center intended to promote research in a variety of areas including rock mechanics, earth systems, and nontraditional characterization. The Center does not limit its focus to either "hard" or "soft" rock applications but instead fosters research in both arenas and encourages interdisciplinary communication between the associated disciplines. The Colorado School of Mines is a world leader in multidisciplinary integration and therefore presents a unique atmosphere to promote the success of such research. Faculty and students from the Departments of Petroleum Engineering, Geophysical Engineering, Physics, Geology and Geological Engineering, Engineering, and Mining Engineering are involved in CEMMC. In addition to traditional topics in these disciplines, the center cultivates research in nontraditional characterization such as arctic ice coring, extraterrestrial space boring,

and laser/rock destruction for multiple applications. CEMMC was established in 2003.

Center for Environmental Risk Assessment

The mission of the Center for Environmental Risk Assessment (CERA) at CSM is to unify and enhance environmental risk assessment research and educational activities at CSM. By bringing diverse, inter-disciplinary expertise to bear on problems in environmental risk assessment, CERA facilitates the development of significantly improved, scientifically based approaches for estimating human and ecological risks and for using the results of such assessments. Education and research programs within CERA currently integrate faculty and students from the departments of Chemical & Biological Engineering, Civil & Environmental Engineering and Chemistry & Geochemistry.

Center for Experimental Study of Subsurface Environmental Processes

The Center for Experimental Study of Subsurface Environmental Processes (CESEP) emphasizes the multidisciplinary nature of subsurface hydrological and environmental sciences by integrating the fundamental sciences of chemistry, biology, geology, hydrology and physics with applied geotechnical, civil and environmental engineering. With this emphasis, the focus for CESEP is to conduct experimental investigations of subsurface and coupled land/atmospheric processes leading to improved modeling and decision tools to address critical problems in environment, water and climate

Summarized in terms of three broad goals:

1. Utilize the knowledge from diverse disciplines to provide a broad and thorough understanding of flow, transport and thermal processes in complex subsurface and land/atmospheric systems.
2. Integrate both fundamental and applied sciences to include efforts to join academic research to current socially important questions related to environment, water and climate change.
3. Produce researchers and students with a greater appreciation and understanding of the multi-disciplinary nature of critical environmental and water problems.

Center for Gravity, Electrical and Magnetic Studies

The Center for Gravity, Electrical & Magnetic Studies (CGEM) in the Department of Geophysics is an academic research center that focuses on the quantitative interpretation of gravity, magnetic, electrical and electromagnetic, and surface nuclear magnetic resonance (NMR) data in applied geophysics. The center brings together the diverse expertise of faculty and students in these different geophysical methods and works towards advancing the state of art in geophysical data interpretation for real-world problems. The emphases of CGEM research are processing and inversion of applied geophysical data. The primary areas of application include petroleum exploration and production, mineral exploration, geothermal, and geotechnical and engineering problems. In addition, environmental problems, infrastructure mapping, archaeology, hydrogeophysics, and crustal studies are also research areas within the

Center. There are currently five major focus areas of research within CGEM: Gravity and Magnetics Research Consortium (GMRC), mineral exploration, geothermal exploration, surface NMR, and hydrogeophysics. Research funding is provided by petroleum and mining industries, ERDC, SERDP, and other agencies. More information about CGEM is available on the web at: <http://geophysics.mines.edu/cgem/>.

Center for Rock Abuse

The Center for Rock Abuse is a rock-physics laboratory focused on research in rock and fluid properties for basic science, as well as exploration and industrial applications. The primary goal of exploration and production geophysics is to identify fluids, specifically hydrocarbons, in rocks. These applications are successful only with a fundamental understanding of the physical phenomena of transport and storage properties as well as the interactions between fluids and rocks. Current projects center on polar and non-polar fluid storage, fluid distributions and storage in rocks and how these distributions affect characteristics such as wave attenuation, velocity dispersion and seismic signatures. <http://crusher.mines.edu>

Center for Solar and Electronic Materials

The Center for Solar and Electronic Materials (CSEM) operates as a subcomponent of the National Science Foundation sponsored Renewable Energy Materials Research Science and Engineering Center (REMRSEC). CSEM's mission is to focus, support, and extend activity in electronic materials for solar applications, in electronic and microelectronic technologies, and in related optical technologies. In addition to photovoltaics, CSEM supports research into advanced optics, novel optical devices, thin film materials, polymeric devices, nanoscale science and nanofabrication, novel characterization, electronic materials processing, process simulation, and systems issues associated with electronic materials and devices. Alternative energy technologies and sustainability are also areas of interest. Working with REMRSEC, CSEM facilitates interdisciplinary collaborations across the CSM campus, fosters interactions with national laboratories, industries, public utilities, local state and federal government, and other universities. The Center coordinates grant applications by its members to collective funding opportunities, helps REMRSEC maintain joint-use laboratories with a broad range of characterization and processing tools, and purchases joint-use tools based on member needs. In fulfilling its research and educational mission, CSEM draws from expertise in the departments of Physics, Chemical Engineering, Metallurgical and Materials Engineering, Chemistry and Geochemistry, and from the Division of Engineering.

CSEM also serves to guide and strengthen the curriculum in electronic materials and related areas. CSEM members develop and teach relevant courses. CSEM also emphasizes training through research experiences for both graduate and undergraduate students. Graduate students in the above-mentioned departments as well as the materials science program can pursue research on center-related projects. Undergraduates are involved through engineering design courses and summer research experiences. Close proximity to the National Renewable Energy Lab and several local companies specializing in electronic materials provides a unique opportunity for students to work with industry and government labs as they solve real world problems. External contacts also provide guidance in targeting the educational curriculum toward the needs of the electronic materials industry.

Center for Space Resources (CSR)

The Center for Space Resources is dedicated to the human and robotic exploration of space and to the utilization of what we learn to the improvement of our society. These objectives are pursued by developing technologies for space resource prospecting, drilling, excavation, extraction, materials processing and manufacturing in space, and life-support systems on spacecraft and planetary habitats. While there are several practical applications of space exploration on Earth, the greatest achievement bringing benefits to humankind would be to develop commercial applications of space technology, including space and planetary resources, in space.

These applications will one day form the basis for new space industries that include the harvesting of solar energy outside Earth's atmosphere, the development of an in-space reusable transportation infrastructure carrying payloads from Earth to geostationary orbits, the Moon or Mars and back, servicing of satellites to extend their useful lifetimes and reduce the costs of space operations, processing of value-added materials in Earth orbit based on lunar material resources, and utilization of resources for in-situ planetary applications, such as energy, propellants, manufacturing, and habitat development.

These goals are pursued by a Consortium involving faculty and students from several departments, NASA and other government agencies, and industrial partners working together on space-related projects.

Center for Wave Phenomena

The Center for Wave Phenomena (CWP) is a research group with a total of four faculty members from the Department of Geophysics. With research sponsored by some 30 companies worldwide in the petroleum-exploration industry, plus U.S. government agencies, CWP emphasizes the development of theoretical and computational methods for imaging of the Earth's subsurface, primarily through use of the reflection seismic method. Researchers have been involved in forward and inverse problems of wave propagation as well as data processing for data obtained where the subsurface is complex, specifically where it is both heterogeneous and anisotropic. Further information about CWP can be obtained at <http://cwp.mines.edu>.

Center for Welding, Joining and Coatings Research

The Center for Welding, Joining and Coatings Research (CWJCR) is an interdisciplinary organization with researchers and faculty from the Metallurgical and Materials Engineering Department, the Mechanical Engineering Department, the Electrical Engineering and Computer Science Department, and the Mining Engineering Department. The goal of CWJCR is to promote graduate and undergraduate level education and research, and to advance understanding of the metallurgical, processing and modeling aspects of welding, joining and coating of ferrous and non-ferrous alloys, ceramic and composite materials. Current center activities include: education, research, conferences, short courses, seminars, information source and transfer, and industrial consortia. The Center receives significant support from industry, national laboratories and government entities. Additionally, the Center also houses the activities of the NSF Center for Integrative Materials Joining Science for Energy Applications. Finally, CWJCR also co-sponsors the Advanced

Explosive Processing and Research Group (AXPRO) in the Mining Engineering Department.

The Center for Welding, Joining and Coatings Research strives to provide numerous opportunities that directly contribute to the student's professional growth. Some of the opportunities include:

- Direct involvement of graduate students in projects that constitute the Center's research program portfolio. Several undergraduate students are also selected per year to participate in ongoing CWJCR research projects.
- Interaction with internationally renowned visiting scholars.
- Industrial collaborations that provide equipment, materials and services.
- Research experience at industrial plants or national laboratories.
- Professional experience and exposure before nationally recognized organizations through student presentations of university research.
- Direct involvement in national welding, materials, and engineering professional societies.

Chevron Center of Research Excellence

The Chevron Center of Research Excellence (CoRE) is an innovative industry-academic partnership between the Colorado School of Mines and Chevron that promotes world-class research and education. Each year, CoRE supports 4-6 graduate Research Assistants (RAs) -- students pursuing MS or PhD degrees.

The CoRE research team focuses on addressing challenges faced by the Chevron Energy Technology Company (ETC) in exploration, production, and development of deepwater, fluvial, and shallow marine reservoirs. Using a quantitative outcrop characterization research approach, the Center develops databases and empirically based rules and workflows.

Colorado Center for Advanced Ceramics

The Colorado Center for Advanced Ceramics (CCAC) is developing the fundamental knowledge that is leading to important technological developments in advanced ceramics and composite materials. Established at CSM in April 1988 as a joint effort between CSM and the Coors Ceramics Company (now CoorsTek); the Center is dedicated to excellence in research and graduate education in high technology ceramic and composite materials. The goal of the Center is to translate advances in materials science into new and improved ceramic fabrication processes and ceramic and composite materials. Current research projects cover a broad spectrum of materials and phenomena including fuel cell, solar cell and battery materials; nano-scale powder preparation and mechanics; ceramic-metal composites; layered materials for ballistic applications; and mechanical behavior. Current projects are supported by both industry and government and several students are performing their research through collaboration with the National Renewable Energy Laboratory located in Golden. Each project involves research leading to a graduate thesis of a student. Significant international collaboration exists leading to student experiences abroad.

Colorado Fuel Cell Center

<http://www.coloradofuelcellcenter.org>

The Colorado Fuel Cell Center (CFCC) seeks to advance fuel-cell research, development, and commercialization and to promote business opportunities in Colorado. The CFCC was created in 2005 with funding from the Governor's Energy Office and co-funding from four partnering organizations. In July 2006 the CFCC was granted status as a Colorado School of Mines research center. The CFCC is managed by a faculty panel consisting of CSM faculty members using the facilities to perform research. The various scopes of the center are solid-oxide fuel cell (SOFC) development and testing, polymer-electrolyte membrane (PEM) development, fuel processing, modeling and simulation, advanced materials processing and evaluation, manufacturing technology development, and systems integration.

Colorado Institute for Energy, Materials and Computational Science

The Colorado Institute for Energy, Materials and Computational Science (CIEMACS) is an interdisciplinary research institute involving research active faculty and students from several academic departments at the Colorado School of Mines. These faculty and students have expertise in the chemistry, physics and engineering of energy conversion processes, including solid oxide and PEMS fuel cells, clean fuels, combustion experimentation and modeling, materials synthesis in flames, atomistic materials modeling and the development of optical measurement techniques for combustion systems and reactive flows.

Colorado Institute for Macromolecular Science and Engineering

The Colorado Institute for Macromolecular Science and Engineering (CIMSE) was established in 1999 by an interdisciplinary team of faculty from several CSM departments. It is sponsored by the National Science Foundation, the Environmental Protection Agency, and the Department of Energy.

The mission of the Institute is to enhance the training and research capabilities of CSM in the area of polymeric and other complex materials as well as to promote education in the areas of materials, energy, and the environment.

Fourteen CSM faculty members from eight departments are involved with the Institute's research. The research volume is more than \$1 million and supports around 15 full-time graduate students in polymers, colloids and complex fluids. Current research projects include plastics from renewable resources, computer simulation of polymers, novel synthetic methods, and the development of new processing strategies from polymer materials.

CIMSE works to improve the educational experience of undergraduate and graduate students in polymers and complex fluids as well as maintain state-of-the-art lab facilities. Currently CSM has the largest polymeric materials effort in the State of Colorado. Materials are a dominant theme

at CSM, and CIMSE will play an important role in ensuring that our students remain competitive in the workforce.

Energy and Minerals Field Institute

The Energy and Minerals Field Institute is an educational activity serving Colorado School of Mines students and external audiences. The goal of the Institute is to provide better understanding of complex regional issues surrounding development of western energy and mineral resources by providing firsthand experience that cannot be duplicated in the classroom. The Institute conducts field programs for educators, the media, government officials, industry, and the financial community. The Institute also hosts conferences and seminars throughout the year dealing with issues specific to western resources development. Students involved in Institute programs are afforded a unique opportunity to learn about the technological, economic, environmental, and policy aspects of resource development.

The Energy Modeling Group

EMG's mission is to develop state-of-the-art reservoir modeling technology and advanced simulation tools for research, teaching, and field applications in the areas of subsurface energy and natural resources, and environmental science and engineering. Research members consists of faculty members, graduate students, visiting scholars, and post-doctoral.

Excavation Engineering and Earth Mechanics Institute

The Excavation Engineering and Earth Mechanics Institute (EMI), established in 1974, combines education and research for the development of improved excavation technology. By emphasizing a joint effort among research, academic, and industrial concerns, EMI contributes to the research, development and testing of new methods and equipment, thus facilitating the rapid application of economically feasible new technologies.

Current research projects are being conducted throughout the world in the areas of tunnel, raise and shaft boring, rock mechanics, micro-seismic detection, machine instrumentation and robotics, rock fragmentation and drilling, materials handling systems, innovative mining methods, and mine design and economics analysis relating to energy and non-fuel minerals development and production. EMI has been a pioneer in the development of special applications software and hardware systems and has amassed extensive databases and specialized computer programs. Outreach activities for the Institute include the offering of short courses to the industry, and sponsorship and participation in major international conferences in tunneling, shaft drilling, raise boring and mine mechanization.

The full-time team at EMI consists of scientists, engineers, and support staff. Graduate students pursue their thesis work on Institute projects, while undergraduate students are employed in research.

Golden Energy Computing Organization

The Golden Energy Computing Organization (GECO) is a partnership between Mines, the National Renewable Energy Laboratory, the National Center for Atmospheric Research and the National Science Foundation. It is dedicated to the use of high performance computing to advance research in the energy sciences. GECO has four main priority areas: pursuing renewable sources, locating and developing existing resources, advancing environmental stewardship, and designing new energy related materials. The center has acquired and maintains a Linux supercomputer, named Ra, which has 2144 computing cores and a peak performance of 23 teraflops. This is one of the most powerful computer resources in academe. It can do three-thousand calculations per second for each of the 6.6 billion people on the planet. A staff of full-time specialists works with researchers to install and optimize computing codes. The facility is open to all CSM faculty and students pursuing energy-related research.

Integrated Ground-Water Modeling Center

The Integrated Ground Water Modeling Center (IGWMC) is an internationally oriented information, education and research center for groundwater modeling. IGWMC advises on groundwater modeling problems, distributes groundwater modeling software, organizes short courses, workshops and conferences, conducts research in practical, applied areas of groundwater hydrology and modeling, and provides technical assistance on problems related to groundwater modeling. As a focal point for groundwater professionals, the Center supports and advances the appropriate use of quality-assured models in groundwater resources protection and management.

Kroll Institute for Extractive Metallurgy

The Kroll Institute for Extractive Metallurgy (KIEM), a Center for Excellence in Extractive Metallurgy, was established at the Colorado School of Mines in 1974 using a bequest from William J. Kroll. Over the years, the Kroll Institute has provided support for a significant number of undergraduate and graduate students who have gone on to make important contributions to the mining, minerals and metals industries. The initial endowment has provided a great foundation for the development of a more comprehensive program to support industry needs.

The primary objectives of the Kroll Institute are to provide research expertise, well-trained engineers to industry, and research and educational opportunities to students, in the areas of minerals, metals and materials processing; extractive and chemical metallurgy; chemical processing of materials; and recycling and waste treatment and minimization.

Marathon Center of Excellence for Reservoir Studies

Marathon Center of Excellence for Reservoir Studies conducts collaborative research on timely topics of interest to the upstream segment of the petroleum industry and provides relevant technical service support, technology transfer, and training to the Center's sponsors. Research includes sponsorship of M.S. and Ph.D. graduate students,

while technology transfer and training involve one-on-one training of practicing engineers and students from the sponsoring companies. The Center is a multidisciplinary organization housed in the Petroleum Engineering Department. The Center activities call for the collaboration of the CSM faculty and graduate students in various engineering and earth sciences disciplines together with local world-class experts. The Center was initiated with a grant from Marathon Oil Company, in 2003 and has been serving the oil industry around the world. The current research topics include: modeling and evaluation of unconventional oil and gas resources, reservoir engineering aspects of horizontal and deviated wells, Non-Darcy flow effects in hydraulic fractures and naturally fractured reservoirs, streamline modeling in dual-porosity reservoirs, multi-scale simulation methods to capture the fine-scale heterogeneity effects in displacement processes, modeling of transient flow in hydraulically fractured horizontal wells, naturally fractured reservoirs containing multiple sets of intersecting fractures, numerical modeling of reservoirs containing sparse naturally fractured regions, improved modeling of matrix vertical flow in dual-porosity reservoirs, steam assisted gravity drainage (SAGD) for medium gravity foamy oil reservoirs.

Microintegrated Optics for Advanced Bioimaging and Control

Microintegrated Optics for Advanced Bioimaging and Control (MOABC) focuses on the integration of optics into microscale and microfluidics systems by reducing macro-scale optics and electronics to an "optical lab-on-a-chip" compatible with the fluidics lab-on-a-chip paradigm. The center develops new fabrication techniques and new methods of biological measurement and manipulation based on microintegrated optics. Technology at the center is organized around three cores that tie strongly together with one another: spectroscopy, microscopy and manipulation. Our unique facilities enable the center to work closely with both academic and industrial collaborators to employ the developed technologies in useful and relevant applications.

Petroleum Exploration and Production Center

The Petroleum Exploration and Production Center (PEPC) is an interdisciplinary educational and research organization specializing in applied studies of petroleum reservoirs. The center integrates disciplines from within the Departments of Geology and Geological Engineering, Geophysics and Petroleum Engineering.

PEPC offers students and faculty the opportunity to participate in research areas including: improved techniques for exploration, drilling, completion, stimulation and reservoir evaluation techniques; characterization of stratigraphic architecture and flow behavior of petroleum reservoirs at multiple scales; evaluation of petroleum reserves and resources on a national and worldwide basis; and development and application of educational techniques to integrate the petroleum disciplines.

Reservoir Characterization Project

The Reservoir Characterization Project (RCP) integrates the acquisition and interpretation of 3D multicomponent time-lapse seismic

reflection and downhole data with geology and petroleum engineering information of existing oil fields to solve complex reservoir challenges and gain improvements in reservoir performance prediction and development optimization. RCP's unique research model emphasizes a multidisciplinary, collaborative approach for practical research. It is an industry-funded research consortium with faculty and graduate-level students from Geophysics, Petroleum Engineering, and Geology disciplines. Read more about RCP at <http://rcp.mines.edu/>.

Unconventional Natural Gas and Oil Institute (UNGI)

<http://ungi.mines.edu>

Unconventional Natural Gas and Oil Institute (UNGI) The main focus for the Unconventional Natural Gas and Oil Institute is to provide multidisciplinary, multiscale advance oil and gas research opportunities on unconventional resources in partnership with industry and government organizations for enhancing the existing Mines in-house expertise and improving the research integration between various departments in Colorado School of Mines. Fourteen current CSM research centers, along with faculty from nine of the thirteen degree-granting departments are affiliated with UNGI.

UNGI aids as:

- Offering an umbrella structure for enhanced coordination of large, multidisciplinary integrated projects
- Providing impartial information to public and government organizations on Unconventional Resources
- Helping to train undergraduate and graduate students for specializing in unconventional resources in addition to post-graduate research opportunities
- Providing custom designed training programs for the non-petroleum engineering professionals, non-technical management personnel, regulators and policy makers bringing technical fundamentals for effective teamwork on design and operations across the upstream oil and gas industry
- K-12 educational training programs for teachers
- Bringing opportunities for enhanced infrastructure

Western Mining Resource Center

WMRC addresses the research and training needs of western mining constituencies. The center complements the research and outreach activities of the Office for Mine Safety and Health of NIOSH, as well as the training programs of the Department of Labor, Mine Safety and Health Administration.

Services

2015-2016

Please select from the list of links on the left for more information on the various services at the Colorado School of Mines.

Arthur Lakes Library

Arthur Lakes Library

2015-2016

Arthur Lakes Library is a regional information center for engineering, energy, minerals, materials, and associated fields. The Library supports university education and research. We're committed to meeting the information needs of the Mines community and all library users.

The Library has over 170,000 visitors a year and is a campus center for learning, study and research. Facilities include meeting space, a campus computer lab, and individual and group study space. We host many cultural events during the year, including concerts and art shows.

The librarians provide personalized help and instruction (<http://library.mines.edu/LIB-Library-Instruction>), and assist with research. The Library's collections (electronic and print) include books, journals, databases, one of the largest map collections in the West; an archive on Colorado School of Mines and western mining history; and several special collections. The Library is a selective U.S. and Colorado state depository.

The Library Catalog (<http://primotc1.hosted.exlibrisgroup.com:1701/primolibweb/action/search.do?dscnt=1&fromLogin=true&dstmp=1337889381059&vid=CSM&fromLogin=true>) provides access to our collections and your user account. Our databases help you discover publications for classroom assignments, research or personal interest. Students and faculty can use most of the Library's electronic databases and publications from any computer on the campus network, including those in networked Mines residential facilities. Connect from off campus (<http://library.mines.edu/LIB-Connect>) via VPN (https://secure.mines.edu/dana-na/auth/url_2/welcome.cgi).

Arthur Lakes Library is a member of the Colorado Alliance. Students and faculty can use their library cards at other Alliance libraries. Materials can also be requested from anywhere in the world through interlibrary loan (<http://library.mines.edu/LIB-Interlibrary-Loan>).

Director

Joanne Lerud-Heck, Library Director

Librarian

Patricia Andersen, Public Services Librarian

Lisa Dunn, Head of Reference

Lia Vella, Reference Librarian

Lisa Nickum, Government Publications Librarian

Christopher J. J. Thiry, Map Librarian

Christine Baker, Special Formats Cataloging Librarian

Pam Blome, Monograph Cataloging Librarian

Heather Whitehead, Acquisitions Librarian

Laura Guy, Systems Librarian

Staff

Christine Monroe, Executive Assistant to the Director

Michelle Bontrager, Circulation Coordinator

Tim Ramstetter, Circulation

Nick Bennett, Circulation

Wendy Shortridge, Interlibrary Loan, Borrowing

Beth Zecca, Interlibrary Loan, Lending

Karen Pfiffner, Government Publications

Stephen Katz, Head of Serials

Craig Robbins, Monograph Cataloging

Sherry Muniz, Binding & Preservation

Assessment of Student Learning Outcomes

2015/2016

The mission of assessment is to promote excellence in student learning and educational practices by fostering a campus culture of continuous improvement. These efforts support CSM's mission in educating students related to:

1. The discovery and recovery of the Earth's resources,
2. Their conversion to materials and energy,
3. Their utilization in advanced processes and products, and
4. The economic and social systems necessary to ensure their prudent and provident use in a sustainable global society.

As an institution that highly values student learning, we routinely assess our courses and programs by conducting surveys of employers, alumni, and current students. We measure student learning by analyzing assignments (lab reports, exams, oral performances, etc.) to determine areas of strength and opportunities for improvement. We are committed to using assessment information when making decisions about our educational programs.

You may contact the assessment director at 303-273-3087 if you would like additional information about assessment processes at the Colorado School of Mines. In addition, the assessment website at <http://inside.mines.edu/assessment> is a resource for the Mines community.

Undergraduate

Assessment of student learning outcomes will enable us to demonstrate how effectively we are achieving the goals articulated in the Profile of the Colorado School of Mines Graduate (<http://inside.mines.edu/UserFiles/File/Assessment/Profile%20of%20the%20Colorado%20School%20of%20Mines%20Graduate.pdf>).

Graduate

Assessment of student learning outcomes will enable us to demonstrate how effectively we are achieving the institutional values and principles for graduate education that are articulated in the Graduate Bulletin (p. 187).

Cecil H. and Ida Green Graduate and Professional Center

Completed in 1971, the Cecil H. and Ida Green Graduate and Professional Center is named in honor of Dr. and Mrs. Green, who were major contributors to the funding of the building. Dr. Green was a co-founder and Vice President for Texas Instruments.

Bunker Auditorium can accommodate 1,100 patrons in theater style seating. Bunker also is home to an orchestra pit with an orchestra lift, a digital pipe organ, and a 9' concert grand piano. Bunker Auditorium is a common host to weekly campus movie nights, and other large events for students.

The Green Center Lobby is a multi-use space that functions as a place where students can study in a quiet environment during the day. The Lobby can also transform into a large exhibit space for poster sessions, receptions and conventions throughout the year.

Friedhoff Hall 1 is one of the premier lecture and event venues on campus, seating up to 320 persons for banquets, or 400 for lectures with theater style seating. Friedhoff 1 can also be setup for receptions, dances, and small performances by utilizing hardwood floors, a built in stage, grand staircase entrance, and 26 foot high ceilings. For technical events, Friedhoff 1 has three LCD projectors and a concert grade sound system.

Friedhoff 2 is one of the campus's largest activity and exhibit spaces, and is used for Engineering Days and International Days events. Friedhoff Hall 2 seats up to 288 persons for banquets. Friedhoff 2 has carpeted floors, indirect architectural lighting and 12 foot high ceilings. A 6' baby grand piano is also available for a minimal charge.

Friedhoff Hall 3 is the smallest portion of Friedhoff hall, accommodating 48 persons. Friedhoff 3 has carpeted flooring and can lighting also with 12 foot high ceilings. Friedhoff Hall 3 is often used as the buffet line location for larger Friedhoff Hall 1 & 2 events.

Green Center banquet furnishings consist of 5-foot round tables with 8 chairs per table, and several sizes of long rectangular tables that may be placed in almost any event venue within the building.

Petroleum Hall seats 122 persons and is not used for academic classes. With wheeled office chairs and large tables arranged in a stadium seating fashion, Petroleum Hall is perfectly catered to business meetings, seminars, and professional functions. Equipped with an LCD projector and a wireless lavalier microphone, speakers can be heard and seen from any seat in the room.

Metals Hall is our largest lecture hall, and is used primarily for academic classes. Seating is comprised of 45 cushioned office chairs and 270 fixed folding-tablet armchairs with a total capacity of 315. Despite its limited availability, Metals Hall can be used for any lecture event.

For more information and to schedule an event, please visit <http://greencenter.mines.edu/>.

Computing, Communications, & Information Technologies

Campus Computing, Communications, & Information Technologies (CCIT) provides computing and networking services to meet the instructional, research, administrative, and networking infrastructure needs of the campus. CCIT manages and operates campus networks along with central academic and administrative computing systems, telecommunication systems, a high performance computing system (see <http://geco.mines.edu>), and computer classrooms and workrooms in several locations on campus. CCIT's customer services and support group also provides technical support for most electronic classrooms, departmental laboratories and desktops throughout the campus.

Central computing accounts and services are available to registered students and current faculty and staff members. Information about hours, services, and the activation of new accounts is available on the website at <http://ccit.mines.edu/>, in person at the Help Desk in the Computer Commons (in CTLM 156), or by calling (303) 273-3431.

Workrooms in several locations on campus contain networked PCs and workstations. Printers, scanners, digitizers, and other specialized resources are available for use in some of the locations.

In addition to central server and facilities operations, services supported for the campus community include e-mail, wired and wireless network operation and support, access to the commodity Internet, Internet 2, system and network security, volume and site licensing of software, videoconferencing, student registration, billing, and other administrative applications, campus web sites and central systems administration and support. CCIT also manages and supports the central learning management system (Blackboard), printing, short-term equipment loan, and room scheduling for some general computer teaching classrooms.

All major campus buildings are connected to the network operated by CCIT and most areas of the campus are covered by the wireless network. All residence hall rooms and Mines Park housing units are directly connected to the campus network along with most fraternity and sorority houses.

All users of Colorado School of Mines computing and networking resources are expected to comply with all policies related to the use of these resources. Policies are updated periodically and are available via the web pages at <http://ccit.mines.edu>.

Copy Center

Located on the first floor of Guggenheim Hall, the Copy Center offers on-line binding, printed tabs, transparencies and halftones. Printing can be done on 8 ½" x11", 11"x14" and 11x17" paper sizes from odd-sized originals. Some of the other services offered are GBC and Velo Binding, folding, sorting and machine collating, reduction and enlargement, two sided copying, and color copying. We have a variety of paper colors, special resume paper and CSM watermark for thesis copying. These services are available to students, faculty, and staff. The Copy Center campus extension is 3202.

CSM Alumni Association

The Colorado School of Mines Alumni Association (CSMAA), established in 1895, serves the Colorado School of Mines and more than 24,000 proud members of the powerful and successful alumni community. While

all alumni are included in the reach of the CSMAA, it is a membership-based, independent organization reliant upon membership funds for much of its budget. Other sources of funding include the School, Foundation, merchandise sales and revenue-sharing partnerships. For example, CSMAA administers the Colorado School of Mines license plate program for cars registered in Colorado.

General services and programs include:

- Mines magazine, a quarterly publication covering campus and alumni news
- An online directory of all Mines alumni for networking purposes
- Online job listings for alumni two years out of school
- Access to the alumni network on LinkedIn*
- Section activities that provide social and networking connections to the campus and Mines alumni around the world
- Alumni gatherings (meetings, reunions, golf tournaments, educational programs and other special events) on and off campus
- Alumni recognition awards
- On-campus CSM library privileges for Colorado residents
- Insurance discounts through Liberty Mutual; access to group health insurance, membership in the Credit Union of Colorado, and a Mines credit card from Bank of America

Benefits for current Colorado School of Mines students include:

- Legacy Grants for children or grandchildren of alumni when parent or grandparent has been a consistent member of CSMAA for previous five years
- The Student Financial Assistance Program
- Celebration of Alumni banquet for graduating students
- The CSMAA Mentorship program, pairing students with alumni for professional development*
- Invitations to social and networking events, i.e. Dinner and Dialogue, Leadership Development events, Holiday Party, sporting events
- Access to the alumni network on LinkedIn*
- Access to the CSMAA social networking website, www.minesalumni.com (<http://www.minesonline.net>)
- Early notice, information and reminders about alumni-based scholarships
- Exclusive opportunities to enter drawings for a CSMAA book scholarship*
- CSM Bookstore discounts (excluding textbooks and Apple products)*
- Renter's insurance discount from Liberty Mutual
- Access to group health insurance, membership in the Credit Union of Colorado, and a Mines credit card from Bank of America
- "Blaster Pack" – Mines marbles, an "M"-ulator t-shirt, membership card and more*

* Students can join the CSMAA at the student membership ("M"-ulator) level for exclusive benefits.

For further information:

call 303-273-3295

Fax 303-273-3583

e-mail csmaa@mines.edu, or

write Mines Alumni Association
Coolbaugh House

P.O. Box 1410
Golden, CO 80402-1410

Environmental Health and Safety

The Environmental Health and Safety (EHS) Department is located in Chauvenet Hall 194. The Department provides a variety of services to students, staff and faculty members. Services include: laboratory safety; EHS training; environmental and hazardous waste management; chemical procurement and distribution; chemical spill response; radiation safety; and biosafety.

EHS Staff are available to consult on Environmental Health and Safety topics, questions or concerns. Stop by our office or call 303-273-3316. The EHS telephone is monitored 24/7 to respond to chemical spills and other emergencies.

LAIS Writing Center

Located on the third floor of Stratton Hall (phone: 303-273-3085), the LAIS Writing Center is a teaching facility providing all CSM students, faculty, and staff with an opportunity to enhance their writing abilities. The LAIS Writing Center faculty are experienced technical and professional writing instructors who are prepared to assist writers with everything from course assignments to scholarship and job applications. This service is free to CSM students, faculty, and staff and entails one-to-one tutoring and online resources. <http://inside.mines.edu/LAIS-Writing-Center>

Off-Campus Study

A student must enroll in an official CSM course for any period of off-campus, course-related study, whether U.S. or foreign, including faculty-led short courses, study abroad, or any off-campus trip sponsored by CSM or led by a CSM faculty member. The registration must occur in the same term that the off-campus study takes place. In addition, the student must complete the necessary release, waiver, and emergency contact forms, transfer credit pre-approvals, and FERPA release, and provide adequate proof of current health insurance prior to departure. For additional information concerning study abroad requirements, contact the Office of International Programs (<http://oip.mines.edu>) at (303) 384-2121; for other information, contact the Registrar's Office.

Office of International Programs

2015-2016

The Office of International Programs (OIP) fosters and facilitates international education, research and outreach at CSM. OIP is administered by the Office of Academic Affairs.

OIP also advises students interested in applying for one or more of the nationally competitive scholarships, such as Rhodes, Marshall, Churchill, Fulbright, or Mitchell and will work with individual students to prepare competitive application packages.

OIP is located at 1706 Illinois Street. For more specific information about study abroad and other international programs, contact OIP at 384-2121 or visit the OIP web page (<http://OIP.mines.edu>).

The office works with the departments and divisions of the School to:

1. help develop and facilitate study abroad opportunities for CSM students while serving as an informational and advising resource for them;
2. assist in attracting new international students to CSM;
3. serve as a resource for faculty and scholars of the CSM community, promoting faculty exchanges, faculty-developed overseas learning opportunities, and the pursuit of collaborative international research activities;
4. foster international outreach and technology transfer programs;
5. facilitate arrangements for official international visitors to CSM; and
6. in general, helps promote the internationalization of CSM's curricular programs and activities.

Office of Research

2015 - 2016

Mines is a global leader in research and the advancement of technology. Led by our world-class faculty, the research conducted at Mines enhances the educational experience of our graduates. Students have the opportunity to actively participate in research at every level of their education.

Our research spans many highly relevant areas with a specific focus on **energy and environmental stewardship**. Our first-rate facilities and partnerships with industry, national laboratories, other universities, funding agencies and international institutions enable us to maintain our cutting edge research and have a significant impact on real world problems. Research is a cooperative effort in the Mines community.

For more information about the Office of Research please contact: Jean Yeager, Executive Assistant for Research, jyeager@mines.edu or (303) 273-3077.

Office of Technology Transfer

2015 - 2016

The purpose of the Office of Technology Transfer (OTT) is to reward innovation and entrepreneurial activity by students, faculty and staff, recognize the value, preserve ownership of CSM's intellectual property, and contribute to local and national the economic growth. OTT reports directly to the Vice President of Research and Technology Transfer and works closely with the school's offices of Legal Services and Research Administration to coordinate activities. With support from its external Advisory Board, OTT strives to:

1. Initiate and stimulate entrepreneurship and development of mechanisms for effective investment of CSM's intellectual capital;
2. Secure CSM's intellectual properties generated by faculty, students, and staff;
3. Contribute to the economic growth of the community, state, and nation through facilitating technology transfer to the commercial sector;
4. Retain and motivate faculty by rewarding entrepreneurship;
5. Utilize OTT opportunities to advance high-quality faculty and students;
6. Provide a return on investment on CSM inventions which is used to expand the school's research and education missions.

For Information about the schools technology transfer office contact: Dr. Will Vaughan, Director of Technology Transfer, wvaughan@mines.edu or (303) 384-2555.

Public Relations

<http://newsroom.mines.edu>

Public Relations & Marketing

The Colorado School of Mines public relations team is dedicated to telling Mines' extraordinary story, increasing worldwide awareness of the school's excellence and leadership in education, discovery, research and application.

Send news story ideas to pr@mines.edu.

For information about the school's publication guidelines, including the use of Mines logos and media-related requests, see the public relations resources page (http://inside.mines.edu/Public_Relations_Resources).

For Mines news, visit the newsroom (<http://minesnewsroom.com>). For events and lectures, visit the campus calendar on inside.mines.edu.

Find Mines on Facebook (<https://www.facebook.com/ColoradoSchoolofMines>) | Twitter (<http://twitter.com/coschoolofmines>) | Instagram (<http://instagram.com/coloradoschoolofmines>) | Flickr (<http://www.flickr.com/photos/coloradoschoolofmines>) | LinkedIn (<http://www.linkedin.com/edu/school?id=17994&trk=edu-cp-logo>) | Pinterest (<http://www.pinterest.com/coschoolofmines>) | YouTube (<https://www.youtube.com/user/ColoSchooolofMines>)

Registrar

2015-2016

The Office of the Registrar supports the academic mission of the Colorado School of Mines by providing service to our current and former students, faculty, staff, and administration. These services include maintaining and protecting the integrity and security of the official academic record, registration, degree verification, scheduling and reporting. Our office routinely reviews policy, makes recommendations for change, and coordinates the implementation of approved policy revisions.

The Office of the Registrar seeks to fulfill this mission through a commitment to high quality service provided in a professional, efficient and courteous manner. Our specific services include but are not limited to:

- Enrollment and degree verifications
- Transcripts
- Degree auditing and diplomas (undergraduate)
- Transfer credit evaluation, entry, and verification
- Department of Veteran's Affairs Certifying Official services
- Registration setup and execution
- Course and room scheduling
- Academic and enrollment reporting
- Residency for current students
- Grade collection, reporting and changes

Management of the Registrar's Office adheres to the guidelines of professional practices and ethical standards developed by the American Association of Collegiate Registrars and Admissions Officers (AACRAO). Our office also complies with the Family Educational Rights and Privacy Act of 1974 (FERPA), Colorado Department of Higher Education rules and policies, and the Colorado School of Mines policies on confidentiality and directory information.

The Registrar's Office is located in the Student Center, Room 018.

Hours of operation are:
Monday/Tuesday/Thursday/Friday, 9am-5pm
Wednesday 10am-5pm

The office phone number is (303) 273-3200.
The fax number is (303) 384-2253.
The office e-mail address is registrar@mines.edu.

Lara Medley represents Colorado School of Mines as the Registrar. She is normally available on a walk-in basis (when not in meetings) if a student or other client has an issue that needs special attention. Appointments are also welcomed.

Registrar

Lara Medley

Staff

Tabatha Brawand, Assistant Registrar

Dahl Grayckowski, Associate Registrar of Operations

Kara Hodgson, Transfer Specialist

Margaret Kenney, Reporting Specialist

Nolan Oltjenbruns, Registration Specialist

Corey Wahl, Associate Registrar of Systems

Judy Westley, Records Specialist

Research Administration

The Office of Research Administration (ORA), under the Vice President for Finance and Administration, provides administrative support in proposal preparation and contract and grant administration, which includes negotiation, account set-up, and close out of expired agreements. Information on any of these areas of research and specific forms can be accessed on our web site at <http://inside.mines.edu/ORA-Home>.

Office of Strategic Enterprises

The mission of the Office of Strategic Enterprises (OSE) is to bring Mines' educational and intellectual resources to the world and enable professionals, corporate entities, and universities from around the globe to interact with Mines. The goal is a distinctive "anywhere, anytime" approach to learning in a fast-paced, changing world. Initiatives include executive and corporate training, non-degree courses, and summer intensives. Professionals needing continuing education can find short-term and part-time offerings, targeted training, off-campus programs and certificate courses. OSE also reaches out to prospective universities on different continents to initiate partnerships that could benefit from Mines'

academic capabilities in resource or energy development. Advancing Mines' global mission in other countries, OSE increases opportunities for international researchers to study at Mines, and for Mines researchers to work at international facilities. The Office of Special Programs and Continuing Education (SPACE) reports to OSE and administers most of the programmatic offerings. For further information about OSE, visit inside.mines.edu/Educational_Outreach.

Special Programs and Continuing Education (SPACE)

2015-2016

The SPACE Office extends CSM's academic mission and thought leadership via professional outreach programs for practicing engineers, managers and scientists. Short courses and corporate training programs, offered both on the CSM campus and throughout the world, provide focused instruction in specialized technical areas and are taught by CSM faculty members and other experienced professionals. The Office offers a broad array of STEM programs for K-12 teachers and students through its Teacher Enhancement Program. The SPACE Office provides a customized Executive Academy designed for innovative, high-performance organizations wanting to hone strategic leadership, talent management and best practices for competitive advantage. SPACE also coordinates educational programs for international corporations and governments through the International Institute for Professional Advancement. A separate bulletin lists the educational programs offered by:

The SPACE Office, CSM
1600 Jackson Street, Suite 160A
Golden, CO 80401
Phone: 303-279-5563
FAX: 303-277-8683
email: space@mines.edu
website: www.csmspace.com (http://www.mines.edu/Educational_Outreach)

Telecommunications

The Telecommunications Office is located in the CTLM building 2nd floor east end room 256 and provides telephone services to the campus.

The office is open 8:00am to 4:00pm Monday through Friday, and can be reached by calling (303) 273-3355 or via the web at <http://inside.mines.edu/Telecommunications>.

Courtesy phones are provided on each floor of the traditional residence halls and Weaver Towers as well as school owned fraternities and sororities. In-room phones are available to students living in Mines Park for \$18.50 per month. Students wishing to take advantage of in-room phones in Mines Park should contact the Telecommunications Office to arrange for service. Telephone sets are not provided by the Telecommunications Office.

Students may make long distance calls from any CSM provided phone by using a third party calling card. Access to third party carriers is available through toll-free (800, 888, 877, 866 and 855) numbers provided by the third party carrier along with the appropriate instructions.

Women in Science, Engineering and Mathematics Program (WISEM)

The mission of WISEM is to enhance opportunities for women in science and engineering careers, to increase retention of women at CSM, and to promote equity and diversity in higher education. The office sponsors programs and services for the CSM community regarding gender and equity issues. For further information, contact:

Stephanie Berry, Director of the Women in Science, Engineering and Mathematics Program
Colorado School of Mines
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