



MATH 500

Fall 2021

## Linear Vector Spaces

**Instructor:** Prof. Stephen Pankavich

• **Contact Information:**

Office: Stratton Hall (SH) 223

Phone: 303.273.3584

Email: [pankavic@mines.edu](mailto:pankavic@mines.edu)

• Office Hours: 11:30am - 12:30pm, 3:15 - 4:00pm TR

• Class Day/Time: 2:00pm - 3:15pm TR, Class Location: Coorstek 150

• Web Page/Canvas link: [elearning.mines.edu/login/saml](http://elearning.mines.edu/login/saml)

**Instructional Activity:** 3 Hours Lecture 0 Hours Lab 3 Semester Hours

**Course Designation:** X Graduate Course (Required)

**Course Description:**

Vector spaces and subspaces: bases, dimension, duality, normed and Banach spaces. Linear operators, matrices, projections, change of basis, similarity. Eigenvalues, multiplicity, and spectral theory. Inner products and Hilbert spaces with orthogonality and completeness. Additional topics may include QR Factorization, the Gram-Schmidt process, least squares problems, Jordan form, diagonal decompositions, Schur form, orthogonal, unitary, Hermitian, and normal operators, real symmetric matrices, Spectral Theorem, Singular Value Decomposition (SVD), pseudoinverses, and applications to ranking systems, Markov Chains, and image compression. Prerequisite: MATH332 or consent of instructor.

**Text:** Lecture Notes distributed by Prof. Pankavich (Required)

*Applied Linear Algebra*, 3rd Ed., by Noble and Daniel, Pearson (Reference)

*Linear Algebra Done Right*, 2nd Ed., by Axler, Springer (Reference)

*Linear Algebra Done Wrong*, by Treil (Reference), <https://www.math.brown.edu/~treil>

**Student Learning Outcomes:**

At the conclusion of the class students will:

1. Perform basic matrix and vector operations. (For example, row-reduce matrices, add/multiply matrices, and determine eigenvalues/eigenvectors, perform suitable decompositions.)
2. Combine interpretation of abstract linear algebra and analytic definitions and theorems to establish properties of linear operators and subsets of vector spaces through precise mathematical proof.
3. Utilize matrix and vector operations, decompositions, and forms to solve applied problems.
4. Recall/restate definitions and theorems of advanced linear algebra and/or prove properties of linear vector spaces and subspaces, linear operators, and sets of vectors.

**Grading Procedures:**

Midterm Exam:	25%	90 - 100%	A
Final Exam:	35%	80 - 89%	B
Homework:	40%	70 - 79%	C
Total:	100%	60 - 69%	D
		Below 60%	F

**Coursework Return Policy:**

Barring any unforeseen circumstances, coursework (homework and exams) will be graded and returned to students within **two weeks**. Feedback will be provided on all coursework or solutions will be posted.

**Homework:**

Assignments will generally be made on a bi-weekly basis. Due dates will be announced in class. Late homework will not be accepted. One score will be dropped in determining the final homework grade.

**Exams:**

There will be one “take-home” midterm exam and one “take-home” final exam. Exam dates will be discussed and announced in class. Make-ups will only be issued in the event of excused absences (see the absence policy). It is the student’s responsibility to contact the instructor as soon as possible regarding the need for a make-up due to an excused absence.

**Expectations for Participation:**

You are expected to engage in all course activities, tasks, and assignment as an emerging professional. You are expected to spend between 6-8 hours on this course each week during out-of-class time, in addition to actively participating during our class time each week.

**Oredigger Promise: We Climb Together.** Orediggers climb together. Orediggers look out for each other. It will take a shared commitment from each and every one of us to stop the spread of [COVID-19](#), open campus and be together at Mines this year. We take great pride in being a top engineering and applied sciences university and we will strive to be the exemplar in preventing the spread of COVID-19 in a university setting. Therefore, as a member of the Oredigger community, I promise to protect classmates and colleagues, our families and neighbors, and myself by adopting the practices and attitudes summarized below; I will:

- Complete training sessions to learn required safety practices and expectations for learning, working, and living on campus.
- Monitor my health daily. I will report to a medical professional if I experience any of the COVID-19 symptoms: fever of 100.4F or higher, dry cough, difficulty breathing or shortness of breath, chills, unusual muscle aches, sore throat, or new loss of taste or smell.
- Stay home if I have COVID-19-related symptoms, even if I feel well enough to come to campus.
- Isolate and self-quarantine for the prescribed period of time after exposure to someone who is ill or has tested positive for COVID-19.
- Maintain appropriate social distancing in all settings, both on- and off-campus.
- Wear an appropriate face covering over my mouth and nose when indoors and in any other setting where it is difficult to maintain social distancing, and use any other protective gear prescribed by the university.
- Wash my hands frequently using soap and water or hand sanitizer. Contribute to the cleaning of classroom surfaces as requested.
- Carefully observe and follow campus and building instructional signs and directions.
- Participate in COVID-19 testing and contact tracing to preserve the wellness of the community.
- Be positive and gracious when others provide safety reminders and suggestions.
- Be attentive and helpful to anyone around who may be in need of support.

**Diversity and Inclusion:** At Mines, we understand that a diverse and inclusive learning environment inspires creativity and innovation, which are essential to the engineering process. We also know that in order to address current and emerging national and global challenges, it is important to learn with and from people who have different backgrounds, thoughts, and experiences.

Our students represent every state in the nation and more than 90 countries around the world, and we continue to make progress in the areas of diversity and inclusion by providing [Diversity and Inclusion programs and services](#) to support these efforts.

**Disability Support Services:** Mines is committed to ensuring the full participation of all students in its programs, including students with disabilities. If you anticipate or experience any barriers to learning in this course, please feel welcome to discuss your concerns with me. Students with disabilities may also wish to contact [Disability Support Services \(DSS\)](#) to discuss options to removing barriers in this course, including

how to register and request official accommodations. If you have already been approved for accommodations through DSS, please contact me at your earliest convenience so we can discuss your needs in this course.

**Accessibility within Canvas:** Read the [Accessibility Statement](#) from Canvas to see how the learning management system at Mines is committed to providing a system that is usable by everyone. The Canvas platform was built using the most modern HTML and CSS technologies, and is committed to W3C's Web Accessibility Initiative and Section 508 guidelines.

**Office of Institutional Equity and Title IX:** All learning opportunities at Mines, including this course, require an environment that allows each student to be able to learn without fear of discrimination or harassment based on any protected class. Discrimination and harassment of any type, including sexual harassment, sexual assault, dating violence, domestic violence, and stalking, are prohibited under the Policy Prohibiting Unlawful Discrimination and the Policy Prohibiting Sexual Harassment, Sexual Assault, and Interpersonal Violence. To report discrimination or harassment, please utilize one of the following options:

- Katie Schmalzel (Title IX Coordinator and Director): 303-273-3260; [titleix@mines.edu](mailto:titleix@mines.edu)
- Any of the confidential and non-confidential reporting options listed [here](#).
- [Online Reporting Form](#) (with an option to be anonymous).

Note: Course rosters are provided to the instructor with the student's legal name. I will honor your request to address you by a preferred name and I will use your identified pronouns. Please advise me of any adjustments early in the semester so I may make appropriate changes to my records.

**CARE @ Mines:** If you feel overwhelmed, anxious, depressed, distressed, mentally or physically unhealthy, or concerned about your wellbeing overall, there are resources both on- and off-campus available to you. If you need assistance, please ask for help from a trusted faculty or staff member, fellow student, or any of the resources below. As a community of care, we can help one another get through difficult times. If you need help, reach out. If you are concerned for another student, offer assistance and/or ask for help on their behalf. Students seeking resources for themselves or others should visit [care.mines.edu](http://care.mines.edu). Additional suggestions for referrals for support, depending on comfort level and needs include:

- [CARE at Mines](#) for various resources and options, or to submit an online "CARE report" about someone you're concerned about, or email [care@mines.edu](mailto:care@mines.edu).
- [CASA](#) for academic advising, tutoring, academic support, and academic workshops
- [Counseling Center](#). Students may call 303-273-3377 to make an appointment or use the website, where online resources for students can also be found. Located in the Wellness Center, 2nd floor, 1770 Elm St.
- [Health Center](#). Students may call 303-273-3381 to make an appointment or use the website. Located in the Wellness Center, 1st floor, 1770 Elm St.
- [Colorado Crisis Services](#). For crisis support 24 hrs/7 days, either by phone, text, or in person. This is a great confidential resource, available to anyone: 1-844-493-8255, or text "TALK" to 38255. Walk-in location addresses are posted on the website.
- Food and/or Housing. Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. Furthermore, please notify your professor if you are comfortable in doing so. This will enable your professor to provide resources that may be available.

All of these options are available for free for students. The Counseling Center, Health Center, and Colorado Crisis Services are confidential resources. The Counseling Center will also make referrals to off-campus counselors, if preferred.

In an emergency, call 911: they will dispatch a Mines or Golden Police Department officer to assist.

**Course Issues and Concerns:** As part of good professional practice, students are encouraged to speak with the faculty directly to raise issues and concerns with regards to the course professionally in compliance with the student code of conduct. Students can also contact the current head of the AMS Department, Dr. Greg Fasshauser; he can investigate and work with the faculty member to resolve course-related concerns. Students' final point of contact is the dean, Dr. Terri Hogue.

**The Writing Center:** This is a free academic support service available to all members of the campus community including undergraduate and graduate students. They can assist you at any stage of the writing process, from brainstorming to final revisions. You do not need a complete draft to make an appointment. Their consultants are experts in a variety of composition and communication fields, providing support as you work on projects such as lab reports, essays, collaborative papers, scholarly publications, thesis chapters, and oral presentations. Whether you are focusing on organization or sentence structure, the [Writing Center](#) can evaluate your individual needs and tailor each appointment so that you become a more effective and efficient communicator. The Writing Center is open Sunday–Friday for in-person and online appointments. To learn more or to make an appointment, visit [writing.mines.edu](http://writing.mines.edu). For questions, email [writing@mines.edu](mailto:writing@mines.edu).

The [Student Absences](#) webpage outlines Mines’ policy regarding student absences. It contains information and documents to obtain excused 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, 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.

In the case of an absence, the student is responsible for determining what work was missed and for putting forth a good faith effort to review the material on their own.

**Policy on Academic Integrity/Misconduct:** 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. Mines desires an environment free of any and all forms of academic misconduct and expects students to act with integrity at all times.

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, academic suspension or dismissal may be imposed.

The complete policy can be found in the [Mines Policy Library](#).

# Tentative Course Schedule

## MATH 500: Linear Vector Spaces

### Fall 2021

Week of	Section Topics	Week of	Section Topics
<b>Aug 23</b>	Linear Algebra Review (Defs, Solvability, Eigs & IMT)	<b>Oct 18</b>	Linear Transformations (Fundamental Thm & Subspaces )
<b>Aug 30</b>	Application: Stochastic Matrices & PageRank	<b>Oct 25</b>	Linear Transformations (Adjoint, duality, operator norm)
<b>Sep 6</b>	Vector Spaces (Subspace, span, linear independence)	<b>Nov 1</b>	Application: Least Squares, Linear Regression & Ranking Systems
<b>Sep 13</b>	Vector Spaces (Basis, dim, Schauder basis)	<b>Nov 8</b>	Eigenspaces (Multiplicity & orthogonality)
<b>Sep 20</b>	Vector Spaces (Metric & normed spaces)	<b>Nov 15</b>	Unitary, Orthogonal & Hermitian Operators
<b>Sep 27</b>	Vector Spaces (Inner product spaces)	<b>Nov 22</b>	Diagonalization & Decompositions (Spectral Thm, Jordan & Schur form)
<b>Oct 4</b>	Vector Spaces (Orthogonality, $V_0^\perp$ , GS & QR)	<b>Nov 29</b>	Singular Value Decomposition (Properties - rank, LS, $\sigma_1 = \ A\ _2$ )
<b>Oct 11</b>	Linear Transformations (Kernel & Image, Rank-Nullity Thm) <b>Midterm Exam</b>	<b>Dec 6</b>	Application: Principal Components Analysis <b>Final Exam</b>