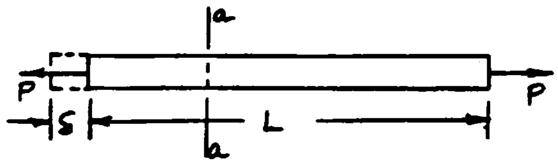
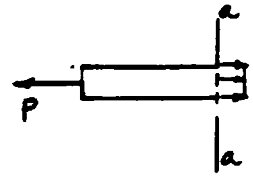
EG 320 - MECHANICS OF MATERIALS

REVIEW FOR EIT EXAM

I AXIAL LOADING





$\sigma = \frac{P}{A}$

CONDITIONS: (1) LINEAR ELASTIC RANGE
(2) PRISMATIC (CONSTANT) X-SECTION
(3) AXIAL LOAD, P, ACTS THROUGH CENTROID OF X-SECTION

$\sigma_{axial} = \frac{P}{A}$ $\quad \epsilon = \frac{\delta}{L}$ $\quad \delta = \frac{PL}{AE}$ $\quad E = \frac{\sigma}{\epsilon}$ $\quad \nu = -\frac{\epsilon_{lat}}{\epsilon_{long}}$

A. DIRECT SHEAR

$\tau = \frac{V}{A_s}$

B. STRESS- STRAIN DIAGRAM (MATERIAL PROPERTIES)

$E = \frac{\sigma}{\epsilon}$ (linear elastic range), σ_y, σ_{ult}, etc

C. FACTOR OF SAFETY

WITH RESPECT TO FAILURE BY YIELD: F.S. = $\frac{\sigma_y}{\sigma_{allow}}$

2. WITH RESPECT TO FAILURE BY FRACTURE F.S. = $\frac{\sigma_{ult}}{\sigma_{allow}}$

D. STATICALLY INDETERMINATE STRUCTURE

1. FBD - Statics Equation
2. Supplement Statics Equation with DEFORMATION COMPATIBILITY EQUATION.

E. STRESSES ON INCLINED PLANE - BY WEDGE METHOD

Stress Diagram
2. Area Diagram } 3 Force Diagram = Stress x Area
[$\Sigma F_n = 0$ $\quad \Sigma F_t = 0$ on Force Diagram]

NOTE: Stress Diagrams and Force Diagrams are required.

F. MAX. NORMAL AND SHEAR STRESSES

$\sigma_{max} = \sigma_{axial} = \frac{P}{A}$ ON Transverse Planes (i.e $\theta = 0°$)

Associated Shear Stress $\tau_{0°} = 0$

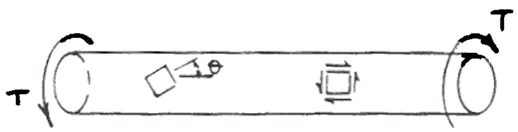
2. $\tau_{max} = \frac{\sigma_{axial}}{2}$ $\quad \frac{P}{2A}$ ON 45° Planes

Associated normal stress: $\sigma_{45°} = \frac{P}{2A}$

G. SHEAR STRAIN - γ - Angular deformation associated with shear stress.

$\gamma = \frac{\tau}{G}$

II. TORSIONAL LOADING



CONDITIONS: (1) LINEAR ELASTIC RANGE
(2) PRISMATIC X-SECTION
(3) CIRCULAR X-SECTION

$\frac{T\rho}{J}$ – SHEAR STRESS AT A DIST. ρ FROM CENTER OF SHAFT.

$\tau_{max} = \frac{Tc}{J}$ – SHEAR STRESS VARIES LINEARLY FROM ZERO AT CENTER OF SHAFT TO MAX. AT OUTER FIBERS.

$\theta = \frac{TL}{JG}$ (radians) where $J = \frac{\pi}{32} d^4$ FOR SOLID X-SECTION

A. STATICALLY INDETERMINATE

– Same approach as solution for axially loaded members

B. MAXIMUM NORMAL AND SHEAR STRESSES

1. $\tau_{max} = \tau = \frac{Tc}{J}$ on transverse and longitudinal planes

   Associated normal stress $\sigma_{0°} = \sigma_{90°} = 0$

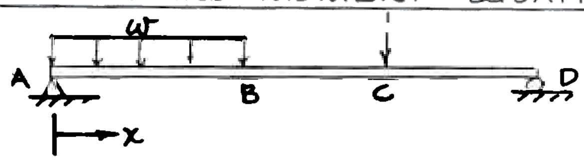
2. $\sigma_{max} = \tau$ when $\theta = 45°$

   $\sigma_{min} = -\tau$ when $\theta = -45°$

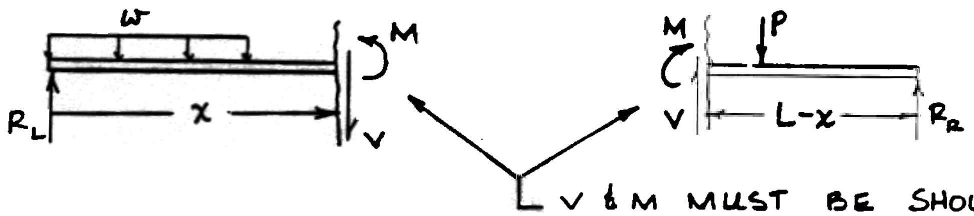
   Associated shear stress: $\tau_{45°} = 0$

III. BEAMS

A. SHEAR AND MOMENT EQUATIONS



REQUIRED TO WRITE EQUATIONS FOR V AND M IN SEC BC:

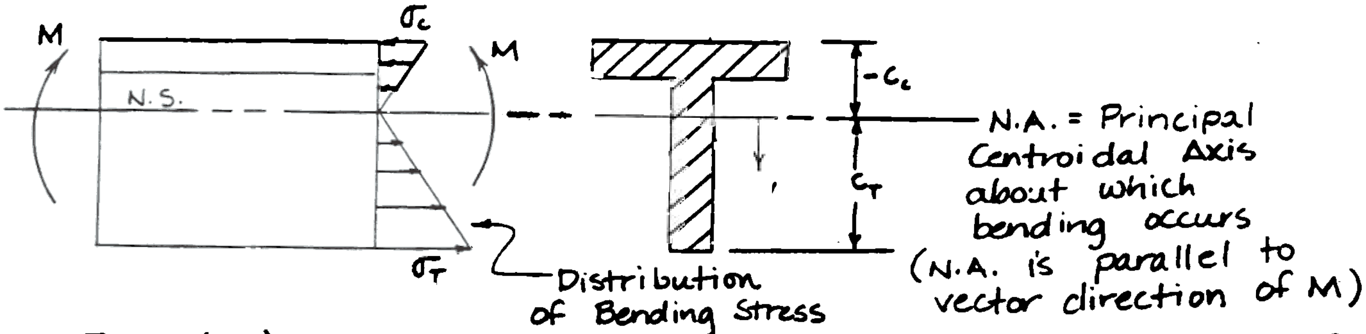


V & M MUST BE SHOWN IN (+) DIRECTIONS ACCORDING TO DEFORMATION SIGN CONVENTION

B. SHEAR AND MOMENT DIAGRAMS

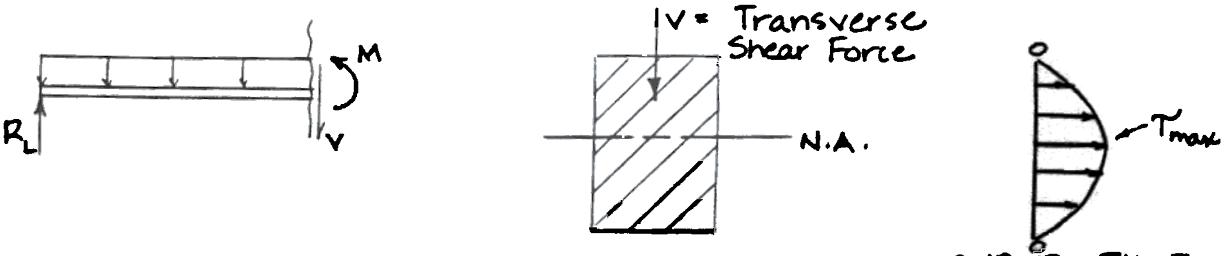
LOAD = $\frac{dV}{dx}$ AND SHEAR = $\frac{dM}{dx}$

C. BENDING STRESS (σ)



$\sigma_c = \dfrac{M(-c_c)}{I}$ AND $\sigma_T = \dfrac{Mc_T}{I}$ where I = Moment of Inertia of X-Section about N.A.

D. TRANSVERSE SHEAR STRESS



TRANSVERSE X-SECTION

CURVE THAT REPRESENTS THE MAGNITUDE OF τ DUE TO V.

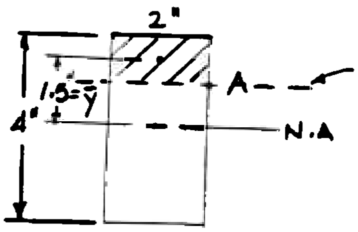
$\tau = \dfrac{VQ}{It}$

I = Moment of Inertia of X-section about N.A. (Note: N.A. is perpendicular to direction of V.)

t = thickness or width of X-section at point of interest

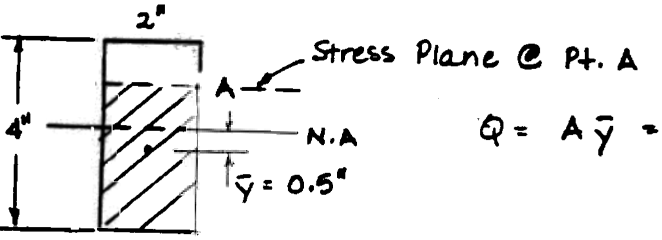
Q = moment of area above or below stress plane about N.A

EX.



$Q = A\bar{y} = \underbrace{2(1)}_{A}\underbrace{(1.5)}_{\bar{y}} = 3\,in^3$

OR



$Q = A\bar{y} = \underbrace{3(2)}_{A}\underbrace{(.5)}_{\bar{y}} =$

IV. ELASTIC DEFLECTIONS OF BEAMS

A. BY INTEGRATION:

Use boundary conditions from deflected shape of loaded beam to evaluate constants of integration

$EI\dfrac{d^2y}{dx^2} = EIy'' = M$ ← internal bending moment

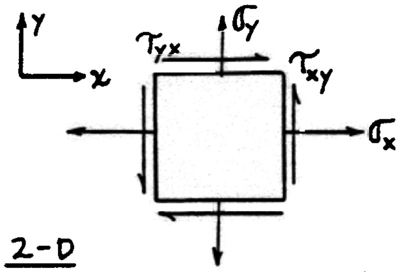
EIy' where $y' = \theta$ = slope

EIy where y = deflection

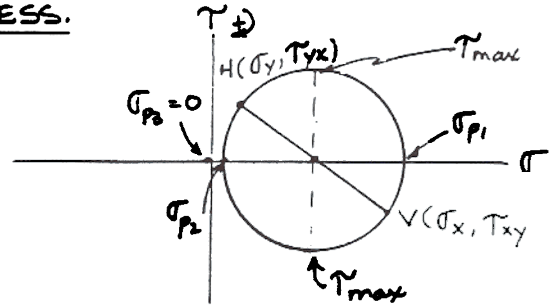
B. BY SUPERPOSITION USE MODELS -

C. STATICALLY INDETERMINATE BEAMS - by Superposition

V MOHR'S CIRCLE FOR PRINCIPAL NORMAL STRESSES AND MAX. SHEAR STRESS.



2-D
STATE OF STRESS AT A POINT
(NOTE: ALL STRESSES SHOWN ARE POSITIVE)



VI. THIN-WALLED PRESSURE VESSELS (i.e. $\frac{\text{radius}}{\text{wall thickness}} > 10$)

A. SPHERICAL $\sigma_a = \dfrac{pr}{2t}$

B. CYLINDRICAL $\sigma_a = \dfrac{pr}{2t}$

$\sigma_h = \dfrac{pr}{t} = 2\sigma_a$

p = internal pressure
r = inner radius
t = wall thickness

VII. COMBINED LOADING

FIND STATE OF STRESS AT A PT. IN A LOADED STRUCTURE

$$\sigma = \pm \frac{P}{A} \pm \frac{Mc}{I}$$

$$\tau = \pm \frac{Tc}{J} \pm \frac{VQ}{It}$$

— USE MOHRS CIRCLE TO FIND σ_{p_1}, σ_{p_2}, τ_{max} AT THE POINT

VIII. STRESS·CONCENTRATION FACTORS $\sigma_{max} = K_t\, \sigma_{nomina}$

$\sigma_{max} = \dfrac{k_t P}{A_t}$ FOR AXIAL LOADING $\sigma_{max} = \dfrac{k_t M c_t}{I_t}$ FOR BENDING

IX. COLUMN BUCKLING MUST MEMORIZE EFFECTIVE LENGTHS

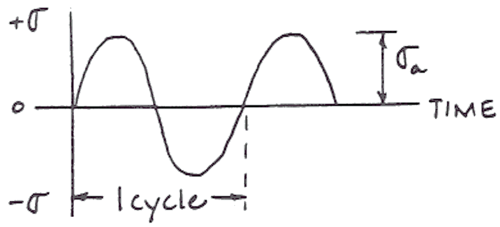
A EULER'S EQUATION $P_{cr} = \dfrac{\pi^2 EA}{(L'/r)^2}$ For Slender Range Columns

B. EMPIRICAL COLUMN FORMULAS - (CODES)

NOTE: A column always buckles first about axis with maximum L'/r ratio.

X. FATIGUE FAILURE DUE TO REPEATED LOADING

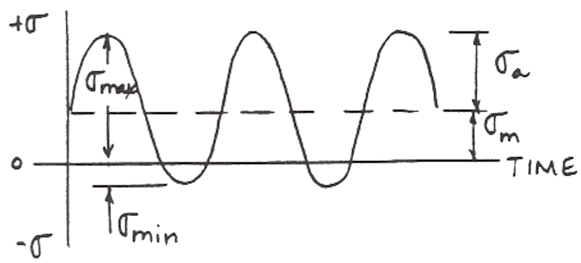
A. FULLY REVERSED LOADS (i.e $\sigma_m = 0$)



STRESS CYCLE DUE TO $P = P_a \sin \omega t$

USE S-N DIAGRAM TO GET DESIGN STRESS FOR A CERTAIN LIFE

B. FLUCTUATING LOADING

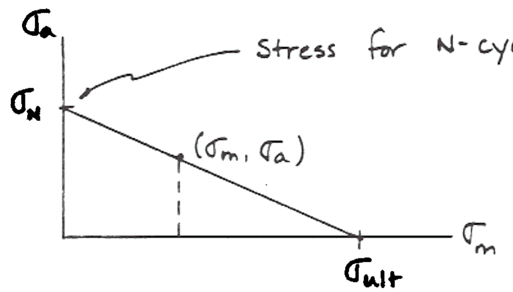


STRESS CYCLE DUE TO $P = P_m + P_a \sin \omega t$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

USE GOODMAN DIAGRAM TO GET DESIGN STRESS:

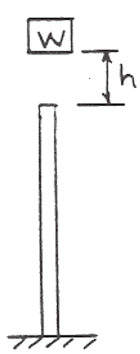


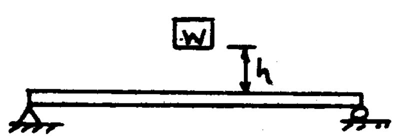
SOLVE BY SIMILAR TRIANGLES

$$\frac{\sigma_N}{\sigma_{ult}} = \frac{\sigma_a}{\sigma_{ult} - \sigma_m}$$

XI. IMPACT LOADING (For Axial and Bending Loads)

$$\eta W (h + \delta) = \frac{1}{2} k \delta^2$$





W = wt. of impacting object
h = free fall distance from release pt. of wt. to contact with structure
k = spring rate of structure
$$\left[k = \frac{\text{Static load}}{\text{deformation}} \right]$$
η = efficiency of impact
δ = max. deflection due to impact (at the pt. of impact)