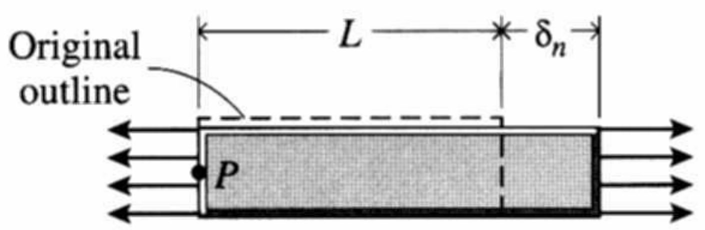
FORMULA SHEET FOR ENGINEERING 3016
PART 4 – MECHANICS OF MATERIALS

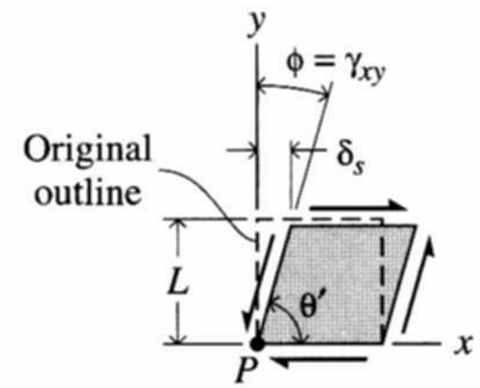
Chapter 4 Stress, Strain, and Deformation: Axial Loading

Normal stress is normal to the plane $\sigma = \frac{F}{A}$, F is the normal force, A is the cross-sectional area.

Shear stress is in the plane $\tau = \frac{V}{A}$, V is the shear force, A is the cross-sectional area.



Average normal strain $\varepsilon = \frac{\delta_n}{L}$



Average shear strain $\gamma = \frac{\delta_s}{L} = \tan\phi$

Hooke's Law:
for normal stress $\sigma = E\varepsilon$
for shear stress $\tau = G\gamma$
E is the Young's modulus
G is the shear modulus

$G = \frac{E}{2(1+\nu)}$, $\nu = -\frac{\varepsilon_{lat}}{\varepsilon_{long}}$ is Poisson's ratio where ε_{lat} is strain in lateral direction and ε_{long} is strain in longitudinal direction.

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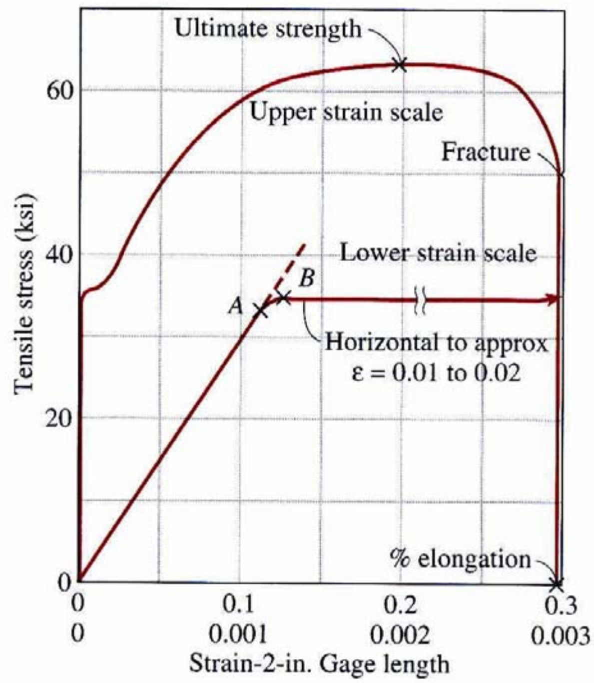
Deformation of Axially Loaded Members

Member with uniform cross section $\delta = \frac{PL}{EA}$

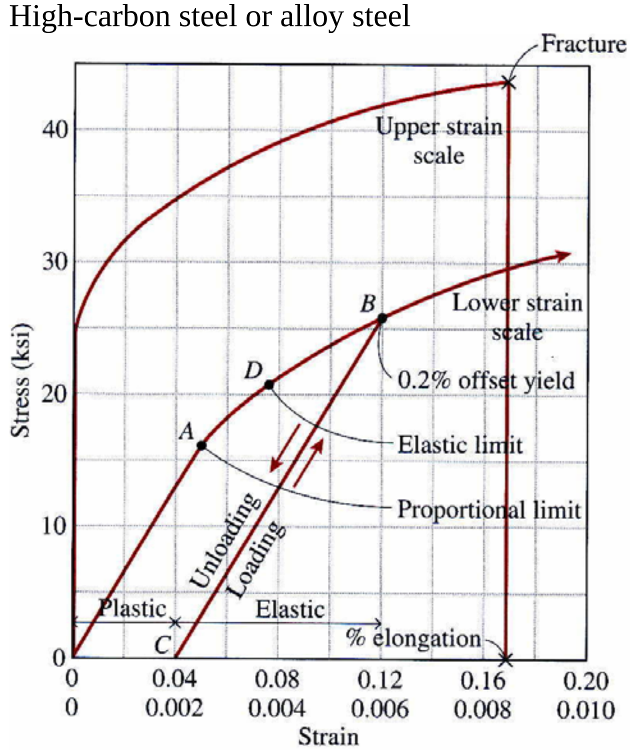
Members with multiple loads/sizes $\delta = \sum_{i=1}^{n} \frac{P_i L_i}{E_i A_i}$

Stress-Strain Relationships
Low-carbon steel or ductile materials



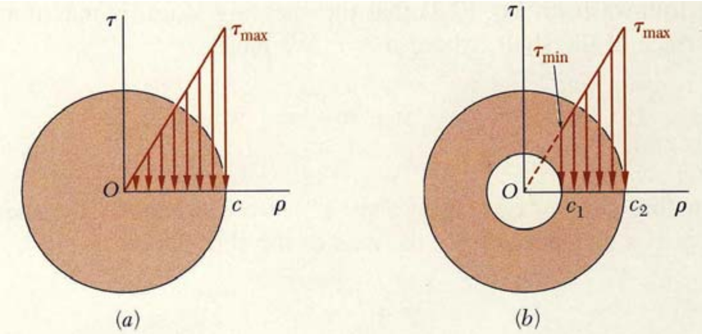
(*a*) Structural steel

High-carbon steel or alloy steel



(*b*) Magnesium alloy

Chapter 7 Torsional Loading: Shafts



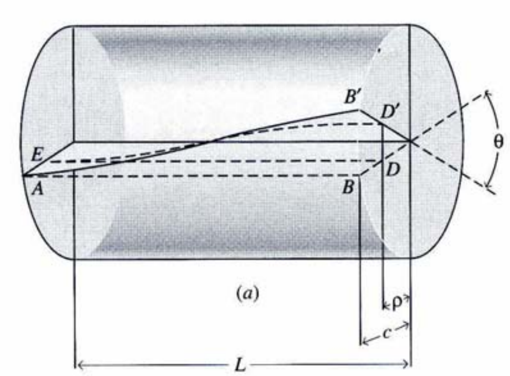
Shear stress at c, $\tau = \frac{Tc}{J}$,

J is polar second moment of area

For solid cross section $J = \frac{\pi}{2} c^4$

For hollow cross section $J = \frac{\pi}{2}(c_2^4 - c_1^4)$

Torsional displacement or angle of twist



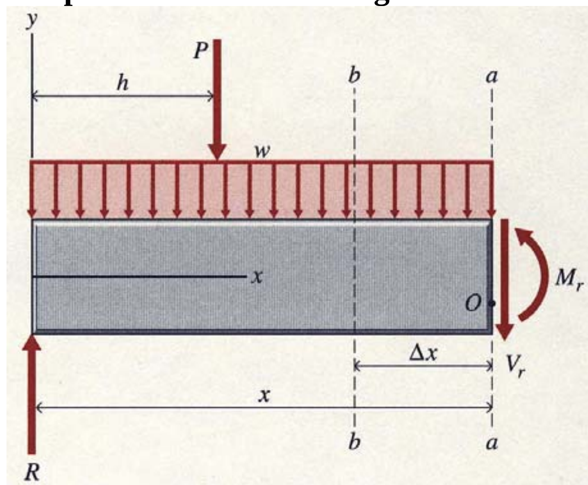
For uniform shaft $\theta = \frac{TL}{GJ}$

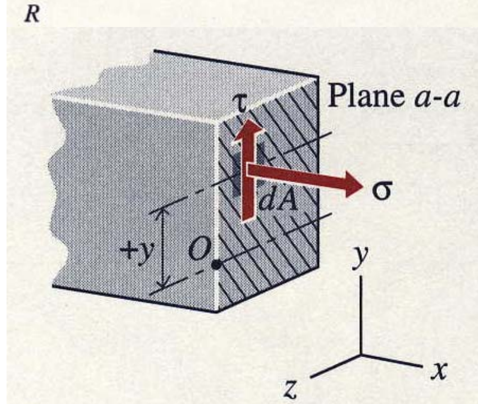
For shaft with multi-step $\theta = \sum_{i=1}^{n} \frac{T_i L_i}{G_i J_i}$

Work of a couple
$u = C\theta$, C is couple, θ is angle of twist

Power Transmission by Torsional Shafts
$Power = T\omega$, ω is angular velocity

Chapter 8 Flexural Loading: Stress in Beams





M_r is the resultant of normal stress

V_r is the resultant of shear stress

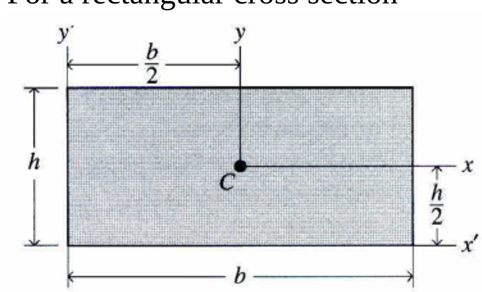
The Elastic Flexural Formula

Normal stress at y: $\sigma = -\frac{My}{I}$

Max. normal stress at upper surface $y = c : \sigma = -\frac{M_r c}{I}$

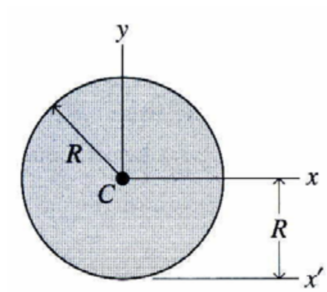
I is the second moment of area

For a rectangular cross section



$I_x = \frac{bh^3}{12}$

For a circular cross section



$I_x = \frac{\pi R^4}{4}$

Shear Forces and Bending Moments in Beams

the max. bending stress $\sigma_{\max} = \dfrac{M_{r\max}}{S}$ where $S = \dfrac{I}{c}$ is the section modulus of the beam. If the beam is uniform cross section, S is constant.

$M_{r\max}$ is the max. bending moment in the beam as M_r varies along the beam, to find $M_{r\max}$, need to draw the bending moment diagram.

Shear force diagram shows the variation of the shear force V_r along beam

Bending moment diagram shows the variation of the bending moment M_r along beam

Sign convention

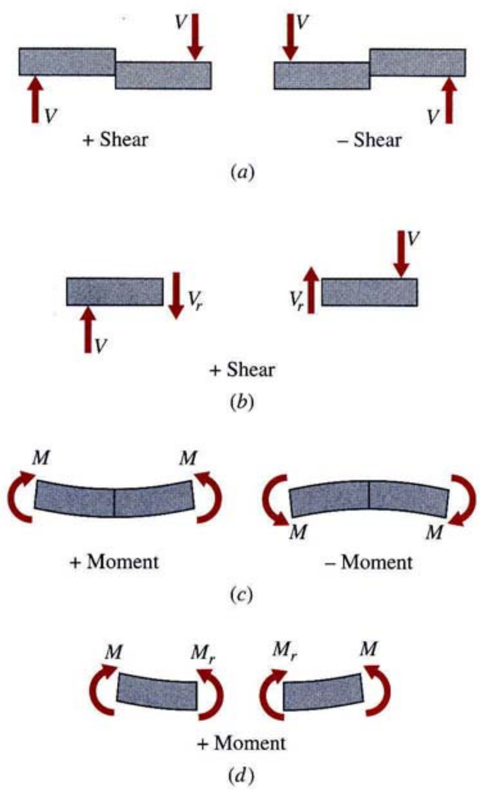


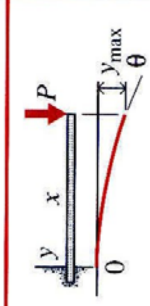
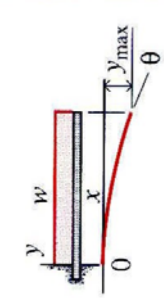
Figure 8-19

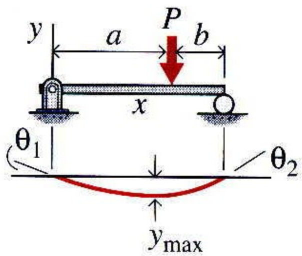
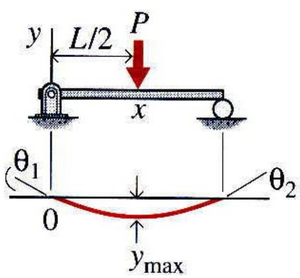
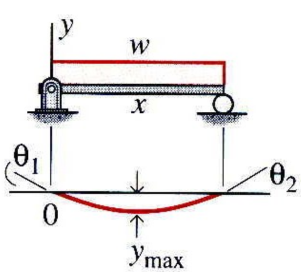
Procedure

1. Find the reactions at supports.
2. Determine how to divide the beam into different segments.
3. Starting from the far left end, section the beam at an arbitrary location x within the chosen segment.
4. Draw FBD for the portion of the beam to the left.
5. Apply equilibrium equations.
6. Repeat the process for each different segment of the beam.

Chapter 9 Flexural Loading: Beam Deflections

TABLE A-19 Beam Deflections and Slopes

Case	Load and Support (Length L)	Slope at End $(+\Delta)$	Maximum Deflection (+ upward)	Equation of Elastic Curve (+ upward)
1		$\theta = -\dfrac{PL^2}{2EI}$ at $x = L$	$y_{\max} = -\dfrac{PL^3}{3EI}$ at $x = L$	$y = -\dfrac{Px^2}{6EI}(3L - x)$
2		$\theta = -\dfrac{wL^3}{6EI}$ at $x = L$	$y_{\max} = -\dfrac{wL^4}{8EI}$ at $x = L$	$y = -\dfrac{wx^2}{24EI}(x^2 - 4Lx + 6L^2)$

5	 $b < a$	$\theta_1 = -\frac{Pb(L^2 - b^2)}{6LEI}$ at $x = 0$ $\theta_2 = +\frac{Pa(L^2 - a^2)}{6LEI}$ at $x = L$	$y_{max} = -\frac{Pb(L^2 - b^2)^{3/2}}{9\sqrt{3}\,LEI}$ at $x = \sqrt{(L^2 - b^2)/3}$ $y_{\substack{center \\ not\ max}} = -\frac{Pb(3L^2 - 4b^2)}{48EI}$	$y = -\frac{Pbx}{6EIL}(L^2 - b^2 - x^2)$ $0 \le x \le a$
6		$\theta_1 = -\frac{PL^2}{16EI}$ at $x = 0$ $\theta_2 = +\frac{PL^2}{16EI}$ at $x = L$	$y_{max} = -\frac{PL^3}{48EI}$ at $x = L/2$	$y = -\frac{Px}{48EI}(3L^2 - 4x^2)$ $0 \le x \le \frac{L}{2}$
7		$\theta_1 = -\frac{wL^3}{24EI}$ at $x = 0$ $\theta_2 = +\frac{wL^3}{24EI}$ at $x = L$	$y_{max} = -\frac{5wL^4}{384EI}$ at $x = L/2$	$y = -\frac{wx}{24EI}(x^3 - 2Lx^2 + L^3)$