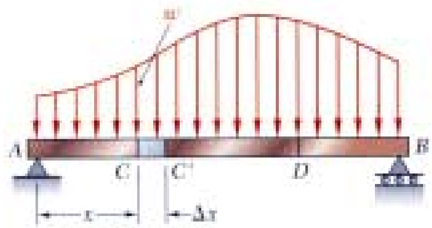
Clarkson University
ES 222, Strength of Materials
Spring 2003, Exam III
Formula Sheet

<u>Shear and Bending Moment Diagrams</u>

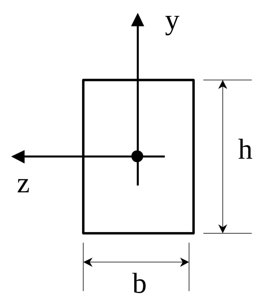
(a) Internal forces
(positive shear and positive bending moment)



$$\frac{dV}{dx} = -w \quad \rightarrow \quad V_D - V_C = -\int_{x_c}^{x_d} w\,dx = -(\text{area under load curve between } C \text{ and } D)$$

$$\frac{dM}{dx} = V \quad \rightarrow \quad M_D - M_C = \int_{x_c}^{x_d} V\,dx = +(\text{area under shear curve between } C \text{ and } D)$$

<u>Bending Stress</u>



$$\sigma_x = -\frac{My}{I} \qquad \sigma_{\max} = \frac{Mc}{I} = \frac{M}{S}$$

$$I_z = \frac{1}{12}bh^3 \qquad I_y = \frac{1}{12}hb^3$$

<u>Coordinates of the Centroid</u>: $\bar{x} = \frac{\sum_i x_i A_i}{\sum_i A_i}$ $\quad \bar{y} = \frac{\sum_i y_i A_i}{\sum_i A_i}$

<u>Parallel Axis Theorem</u>: $I_{x'} = I_x + Ad^2$, where d is the distance from the x–axis to the x'–axis

<u>Shear Stress in Beams</u>

$$\tau_{ave} = \frac{VQ}{It} \qquad q = \frac{VQ}{I} = \text{shear per unit length} \qquad Q = A\bar{y}$$

Stress Transformation

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos 2\theta - \tau_{xy}\sin 2\theta$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$$

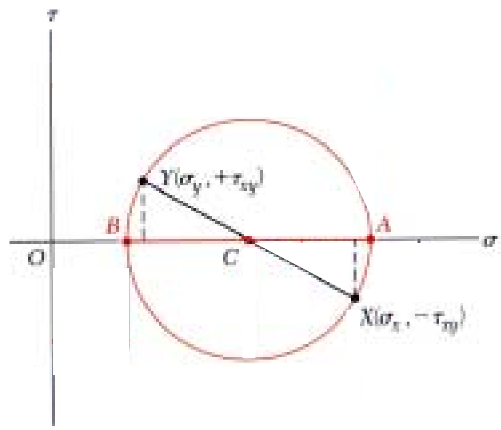
Principal stresses: $\sigma_{\max,\min} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \left(\tau_{xy}\right)^2}$

Principal planes: $\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$

Planes of maximum in-plane shear stress: $\tan 2\theta_s = -\frac{\sigma_x - \sigma_y}{2\tau_{xy}}$

Maximum in-plane shear stress: $\tau_{\max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \left(\tau_{xy}\right)^2} = R$

Corresponding normal stress: $\sigma' = \sigma_{ave} = \frac{\sigma_x + \sigma_y}{2}$



Thin Walled Pressure Vessels

Cylindrical: Hoop stress = $\sigma_1 = \frac{pr}{t}$ Longitudinal stress = $\sigma_2 = \frac{pr}{2t}$

Maximum shear stress (out of plane) = $\tau_{\max} = \sigma_2 = \frac{pr}{2t}$

Spherical: Principal stresses = $\sigma_1 = \sigma_2 = \frac{pr}{2t}$

Maximum shear stress (out of plane) = $\tau_{\max} = \frac{\sigma_2}{2} = \frac{pr}{4t}$