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Relationships between w, V, M

$$\frac{dV}{dx} = -w(x), \qquad \frac{dM}{dx} = V$$

Centroid

$$\bar{x} = \frac{Q_y}{A} = \frac{\sum \bar{x}_i A_i}{\sum A_i}, \quad \bar{y} = \frac{Q_x}{A} = \frac{\sum \bar{y}_i A_i}{\sum A_i}$$

Moments of inertia

$$I_x = \int y^2 dA, \quad I_y = \int x^2 dA$$

Polar moment of inertia

$$J_o = \int r^2 dA = I_x + I_y$$

Product of moment of inertia

$$I_{xy} = \int xy dA$$

Parallel axis theorem

$$I_x = I_{x_c} + Ad_1^2 \quad I_y = I_{y_c} + Ad_2^2$$

$$J_o = J_c + Ad^2 \quad I_{xy} = I_{x_c y_c} + Ad_1 d_2$$

Principal moments of inertia (max/min)

$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} = \frac{I_x + I_y}{2} \pm \sqrt{\left(\frac{I_x - I_y}{2}\right)^2 + I_{xy}^2}$$

$$\tan(2\theta) = \frac{-2I_{xy}}{(I_x - I_y)}$$

Note: the geometric properties table for simple shapes (rectangle, circle and triangle) will be provided with the exam.

Axial members

Normal stress & strain

$$\sigma = \frac{P}{A}, \quad \varepsilon = \frac{\delta}{L}$$

Axial deformation

$$\delta = \frac{PL}{AE}, \quad \delta = \sum \frac{N_i L_i}{A_i E_i}, \quad \delta = \int_0^L \frac{N}{AE} dx$$

Space for notes

- You may include notes in this **BOXED** area **ONLY**
- The notes must be **hand written** (no photocopies or computer print)
- You may include explanations/ diagrams
- You are **not permitted** to include **sample problems**

TO BE RETURNED WITH THE EXAM

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Torsion

Shear stress (circular section)

$$\tau = \frac{T\rho}{J}$$

Angle of twist

$$\phi = \frac{TL}{JG}\ , \quad \phi = \sum \frac{T_i L_i}{J_i G_i}, \quad \phi = \int_0^L \frac{T}{JG}\, dx$$

Flexure

Normal stress

$$\sigma = -\left(\frac{My}{I}\right) \qquad \left|\sigma_{\max}\right| = \left|\frac{My_{\max}}{I}\right|$$

Shear stress

$$\tau = \frac{VQ}{I\,b} \qquad \tau_{\max} = \frac{VQ_{\max}}{I\,b} \qquad Q = \sum (A_i')(\bar{y}_i')$$

Deflections

$$\frac{d^2v}{dx^2} = \frac{M}{EI}$$

Discontinuity functions for $n \geq 0$

$$\langle x-a \rangle^n = \begin{cases} 0 & \text{for } x < a \\ (x-a)^n & \text{for } x \geq a \end{cases}$$

$$\int_{-\infty}^{x} \langle x-a \rangle^n\, dx = \frac{\langle x-a \rangle^{n+1}}{n+1}$$

Note: the table with the $M\langle x \rangle$ functions is provided on page 4.

Buckling

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

B.C.'s	*K*
Pinned-pinned	1
Fixed-free	2
Fixed-fixed	0.5
Fixed-pinned	0.7

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Stress transformation equations

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

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

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

Principal stresses

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

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}\ , \quad \tau_{12} = 0$$

Maximum in-plane shear stress

$$\tan 2\theta_s = -\frac{\sigma_x - \sigma_y}{2\tau_{xy}}, \quad \theta_s = \theta_p \pm 45^\circ$$

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2}$$

Mohr's circle

$$C = \frac{\sigma_x + \sigma_y}{2}$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \left(\tau_{xy}\right)^2}$$

$$\sigma_{1,2} = C \pm R$$

$$\tau_{\max} = R\ , \quad \sigma_{avg} = C$$

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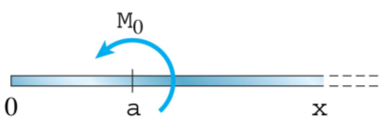
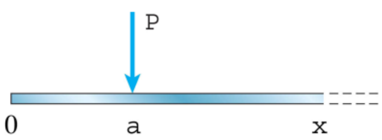
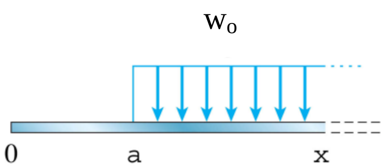
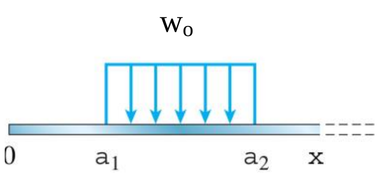
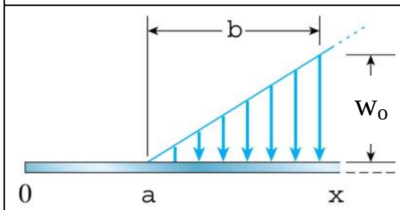
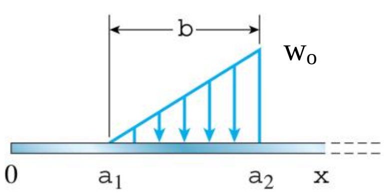
DISCONTINUITY FUNCTIONS

	$w(x)=M_o\langle x-a\rangle^{-2}$ $V(x)=-M_o\langle x-a\rangle^{-1}$ $M(x)=-M_o\langle x-a\rangle^{0}$
	$w(x)=P\langle x-a\rangle^{-1}$ $V(x)=-P\langle x-a\rangle^{0}$ $M(x)=-P\langle x-a\rangle$
	$w(x)=w_o\langle x-a\rangle^{0}$ $V(x)=-w_o\langle x-a\rangle$ $M(x)=-\frac{1}{2}w_o\langle x-a\rangle^{2}$
	$w(x)=w_o\langle x-a_1\rangle^{0}-w_o\langle x-a_2\rangle^{0}$ $V(x)=-w_o\langle x-a_1\rangle+w_o\langle x-a_2\rangle$ $M(x)=-\frac{1}{2}w_o\langle x-a_1\rangle^{2}+\frac{1}{2}w_o\langle x-a_2\rangle^{2}$
	$w(x)=\frac{w_o}{b}\langle x-a\rangle$ $V(x)=-\frac{1}{2}\frac{w_o}{b}\langle x-a\rangle^{2}$ $M(x)=-\frac{1}{6}\frac{w_o}{b}\langle x-a\rangle^{3}$
	$w(x)=\frac{w_o}{b}\langle x-a_1\rangle-\frac{w_o}{b}\langle x-a_2\rangle-w_o\langle x-a_2\rangle^{0}$ $V(x)=-\frac{1}{2}\frac{w_o}{b}\langle x-a_1\rangle^{2}+\frac{1}{2}\frac{w_o}{b}\langle x-a_2\rangle^{2}+w_o\langle x-a_2\rangle$ $M(x)=-\frac{1}{6}\frac{w_o}{b}\langle x-a_1\rangle^{3}+\frac{1}{6}\frac{w_o}{b}\langle x-a_2\rangle^{3}+\frac{1}{2}w_o\langle x-a_2\rangle^{2}$