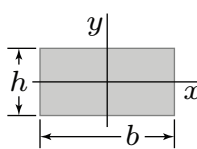
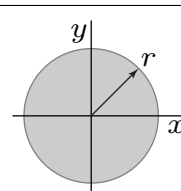
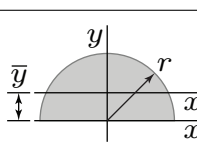


TAM 251 EQUATION SHEET

Main Equations	
Stress	$\sigma_{avg} = \frac{F}{A}$ $\tau_{avg} = \frac{V}{A}$
Strain	$\epsilon_{eng} = \frac{\delta}{L_0}$ $\epsilon_{true} = \ln \frac{L_f}{L_0}$ $\gamma = \frac{\delta_x}{L_y} + \frac{\delta_y}{L_x}$
Constitutive Relations	$\sigma = E\epsilon$ $\tau = G\gamma$
Material Properties (Isotropic)	$\nu = -\frac{\epsilon_{lat}}{\epsilon_{long}}$ $G = \frac{E}{2(1+\nu)}$
Thermal Expansion	$\epsilon_{th} = \alpha \Delta T$ $\delta_{th} = \alpha L_0 \Delta T$
Axial Loading	$\delta = \frac{FL_0}{EA}$ $\sigma = \frac{F}{A}$
Torsion	$\phi = \frac{TL_0}{GJ}$ $\tau = \frac{T\rho}{J}$ $\gamma = \frac{\phi\rho}{L_0}$
Stiffness and Flexibility	$k_{axial} = \frac{EA}{L_0} = \frac{1}{f_{axial}}$ $k_{torsion} = \frac{GJ}{L_0} = \frac{1}{f_{torsion}}$
Bending	$\sigma = \frac{Mc}{I}$
Thin-Walled Pressure Vessels	$\sigma_h = \frac{pr}{t}$ $\sigma_a = \frac{pr}{2t}$
Transverse Shear	$\tau = \frac{VQ}{It}$ $q = \frac{VQ}{I}$

Miscellaneous	
Distributed Loads, Shear, & Bending Moments	$\frac{dV}{dx} = -w$ $\frac{dM}{dx} = V$
Inclined Plane: Normal Stress	$\sigma_n = \sigma_x \cos^2 \theta + 2\tau_{xy} \sin \theta \cos \theta + \sigma_y \sin^2 \theta$
Inclined Plane: Shear Stress	$\tau_{n,s} = (\sigma_y - \sigma_x) \sin \theta \cos \theta + \tau_{xy} (\cos^2 \theta - \sin^2 \theta)$
Tresca Criterion	$ \sigma_1 = \sigma_{yield}, \sigma_2 = \sigma_{yield}$ when σ_1, σ_2 have the same sign
Tresca Criterion	$ \sigma_1 - \sigma_2 = \sigma_{yield}$ when σ_1, σ_2 have the opposite sign
Von-Mises Criterion	$\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2 = \sigma_{yield}^2$

Stress Transformations	
Plane Stress	$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos(2\theta) + \tau_{xy} \sin(2\theta)$
	$\sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2} \cos(2\theta) - \tau_{xy} \sin(2\theta)$
	$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2} \sin(2\theta) + \tau_{xy} \cos(2\theta)$
Mohr's Circle	$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2}$ $R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$
Principal Stresses	$\sigma_1 = \sigma_{avg} + R$ $\sigma_2 = \sigma_{avg} - R$ $\tau_{max} = R$
Plane Orientations	$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$ $\tan 2\theta_s = -\frac{\sigma_x - \sigma_y}{2\tau_{xy}}$

Moments and Geometric Centroids	
	$Q = \bar{y}A$ $I_x = \int_A y^2 dA$ $J_o = \int_A \rho^2 dA$ $\bar{y} = \frac{1}{A} \int_A y dA$
Rectangle	 $I_x = \frac{1}{12} bh^3$
Circle	 $I_x = \frac{\pi}{4} r^4$ $J_z = \frac{\pi}{2} r^4$
Semicircle	 $I_x = \frac{\pi}{8} r^4$ $I_{x'} = \left(\frac{\pi}{8} - \frac{8}{9\pi}\right) r^4$ $\bar{y} = \frac{4r}{3\pi}$
Parallel Axis Theorem	$I_c = I_{c'} + Ad_{cc'}^2$

Buckling			
Critical Load	$P_{cr} = \frac{\pi^2 EI}{(L_e)^2}$	pinned-pinned	$L_e = L$
		pinned-fixed	$L_e = 0.7L$
		fixed-fixed	$L_e = 0.5L$
		fixed-free	$L_e = 2L$

Beam Deflection

Diagram	Max. Deflection	Slope at End	Elastic Curve
	y_{max}	θ	$y(x)$
	$-\frac{PL^3}{3EI}$	$-\frac{PL^2}{2EI}$	$y(x) = \frac{P}{6EI} (x^3 - 3Lx^2)$
	$-\frac{wL^4}{8EI}$	$-\frac{wL^3}{6EI}$	$y(x) = -\frac{w}{24EI} (x^4 - 4Lx^3 + 6L^2x^2)$
	$-\frac{ML^2}{2EI}$	$-\frac{ML}{EI}$	$y(x) = -\frac{M}{2EI} x^2$
	$-\frac{5wL^4}{384EI}$	$\pm \frac{wL^3}{24EI}$	$y(x) = -\frac{w}{24EI} (x^4 - 2Lx^3 + L^3x)$
	$-\frac{PL^3}{48EI}$	$\pm \frac{PL^2}{16EI}$	For $0 \leq x \leq \frac{L}{2}$ $y(x) = \frac{P}{48EI} (4x^3 - 3L^2x)$
	For $a > b$ $-\frac{Pb(L^2 - b^2)^{3/2}}{9\sqrt{3}EIL}$ at $x_m = \sqrt{\frac{L^2 - b^2}{3}}$	$\theta_A = -\frac{Pb(L^2 - b^2)}{6EIL}$ $\theta_B = +\frac{Pa(L^2 - a^2)}{6EIL}$	For $x < a$: $y(x) = \frac{Pb}{6EIL} [x^3 - x(L^2 - b^2)]$ For $x = a$: $y = -\frac{Pa^2b^2}{3EIL}$
	$-\frac{ML^2}{9\sqrt{3}EI}$ at $x_m = \frac{L}{\sqrt{3}}$	$\theta_A = -\frac{ML}{6EI}$ $\theta_B = +\frac{ML}{3EI}$	$y(x) = \frac{M}{6EIL} (x^3 - L^2x)$