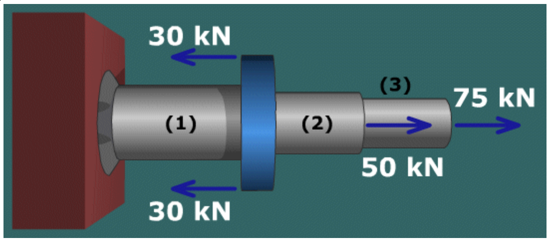
Name: ___________________________

1. Determine the internal axial forces in segments (1), (2) and (3).

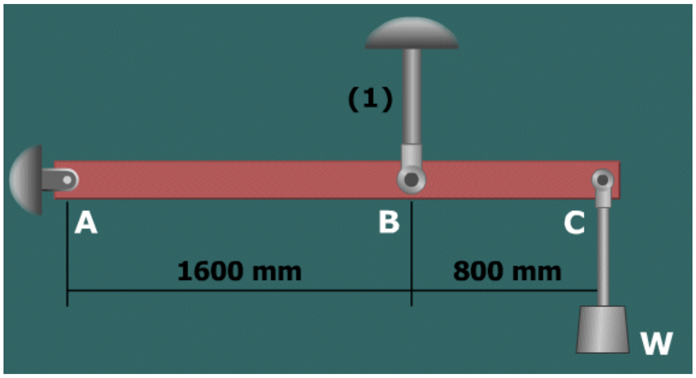


(a) N_1 = ___________ kN

(b) N_2 = ___________ kN

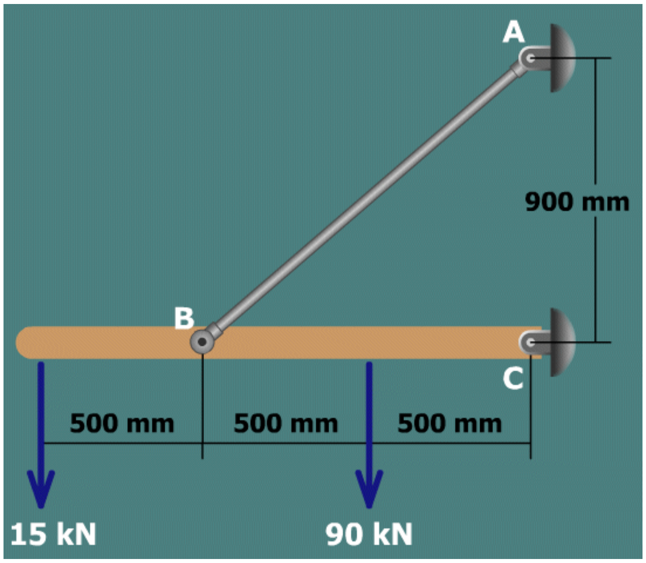
(c) N_3 = ___________ kN

2. Rigid bar ABC supports a weight of W = 50 kN. Bar *ABC* is pinned at *A* and supported at *B* by rod (1). What is the axial force in rod (1)?



N_1 = ___________ kN

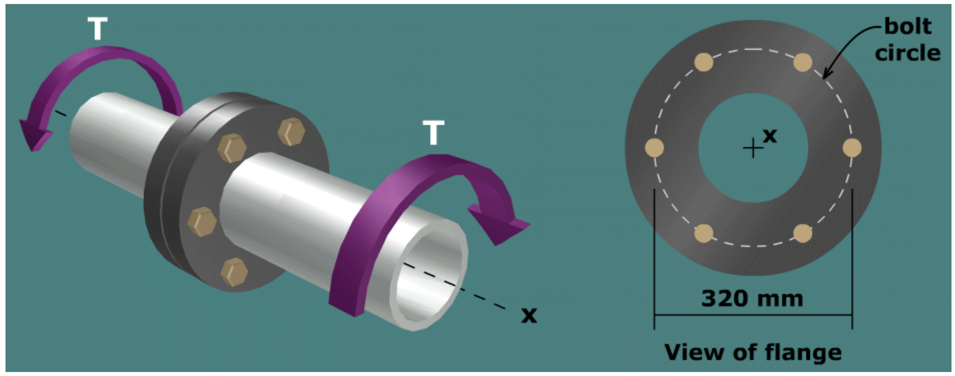
3. Determine the axial force in bar *AB*.



N_{AB} = ___________ kN

4. A torque of $T = 32$ kN-m is transmitted between two flanged shafts by means of six bolts. Determine the shear force in each bolt.

V_{bolt} = __________ kN



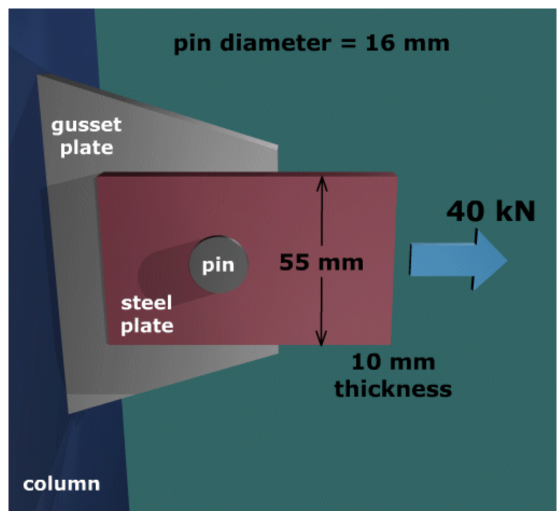
5. For the pin connection shown, determine the normal stress acting on the gross area, the normal stress acting on the net area, the shear stress in the pin, and the bearing stress in the steel plate at the pin.

(a) σ_{gross} = __________ MPa

(b) σ_{net} = __________ MPa

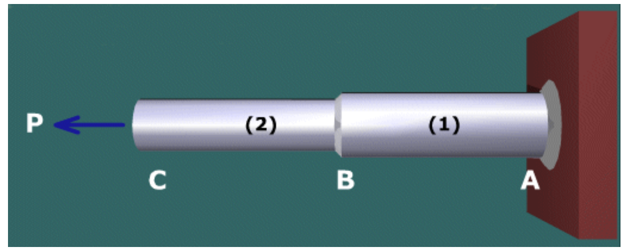
(c) τ_{pin} = __________ MPa

(d) σ_b = __________ MPa



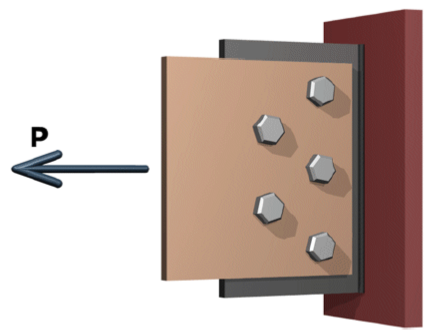
6. A metal rod having two different diameters is loaded by an axial force P. Segments (1) and (2) are circular in cross section with diameters of 40 mm and 25 mm, respectively. If the normal stress in (1) is 65 MPa, what is the normal stress in segment (2)?

σ_2 = __________ MPa



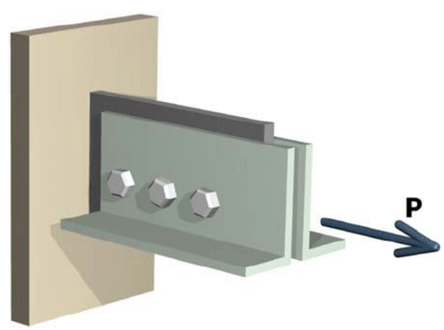
7. The five-bolt connection must support an applied load of P = 600 kN. If the diameter of each bolt is 35 mm, determine the average shear stress in each bolt.

τ = __________ MPa

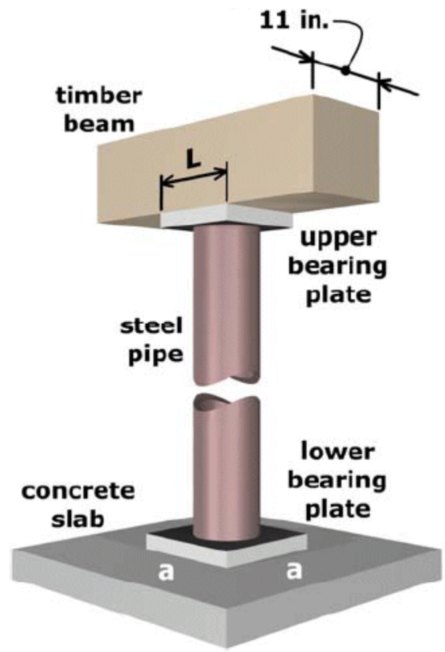


8. The three-bolt connection must support an applied load of P = 600 kN. If the average shear stress in each bolt must be limited to 210 MPa, determine the minimum bolt diameter that may be used in the connection.

d = __________ mm

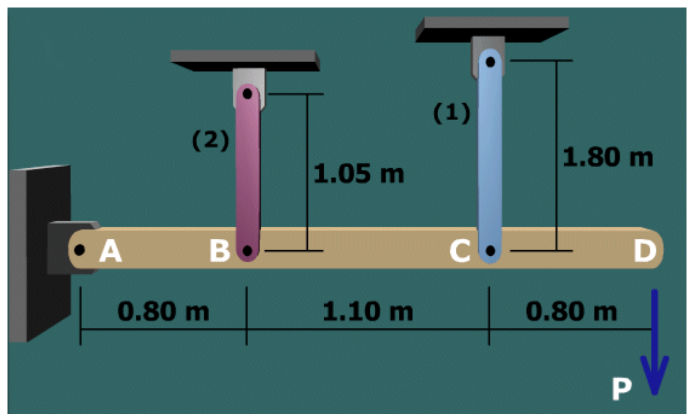


9. The steel pipe column has an outside diameter of 8 in. and wall thickness of 0.5 in. The timber beam is 11 in. wide, and the upper plate has the same width. The load imposed on the column by the timber beam is 80 kips. Determine the length L of the rectangular upper bearing plate if the average bearing stress between the steel plate and the wood beam is not to exceed 500 psi.



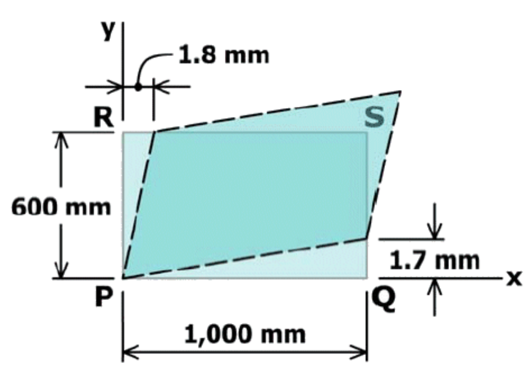
L = __________ in.

10. Rigid bar $ABCD$ is supported by two vertical bars. There is no strain in the vertical bars before load P is applied. After load P is applied, the axial strain in bar (2) is 700 μm/m. Determine the axial strain in bar (1).



ε_1 = __________ μm/m

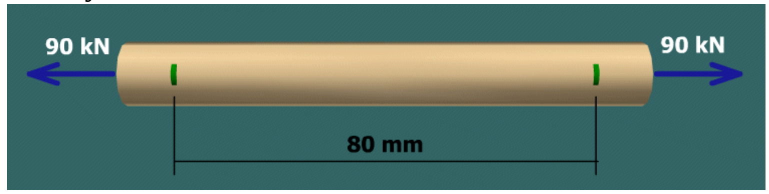
11. A thin rectangular plate is uniformly deformed as shown. Determine the shear strain γ_{xy} at P.



γ_{xy} = __________ με

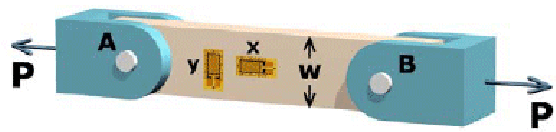
12. Two gage marks are placed exactly 80 mm apart on a 18-mm-diameter solid metal rod. When an axial tension force of 90 kN is applied to the rod, the distance between the gage marks in precisely measured as 80.1800 mm. Determine the modulus of elasticity of the metal.

E = __________ GPa



13. A 1.0-in. thick rectangular alloy bar is subjected to a tensile load *P* by pins at *A* and *B*. The width of the bar is *w* = 4.0 in. Strain gages bonded to the specimen measure the following strains in the longitudinal (*x*) and transverse (*y*) directions: $\varepsilon_x = 2100\ \mu\varepsilon$ and $\varepsilon_y = -650\ \mu\varepsilon$. Determine Poisson's ratio for this specimen.

ν = __________



14. A tension-test specimen with a diameter of 0.500 in. and an 8.0-in gage length was tested to fracture. Two graphs of the collected data are given on the next page. Determine the following.

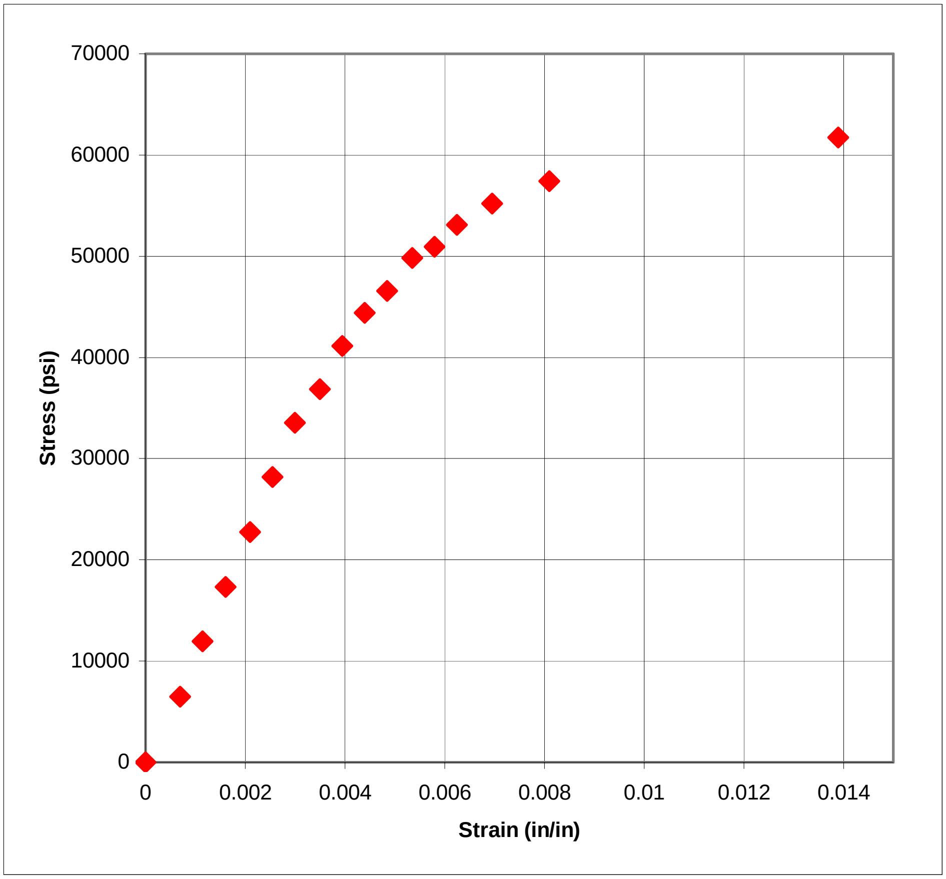
(a) the modulus of elasticity = __________ Msi

(b) the proportional limit = __________ ksi

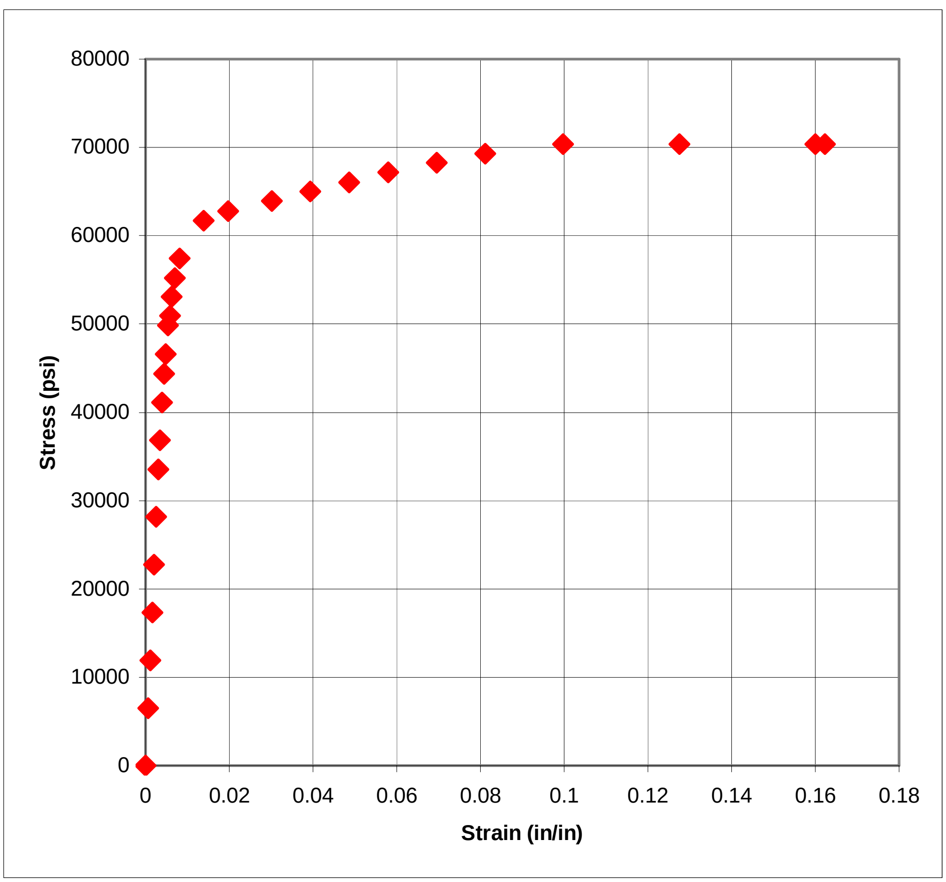
(c) the ultimate strength = __________ ksi

(d) the yield strength (0.20% offset) = __________ ksi

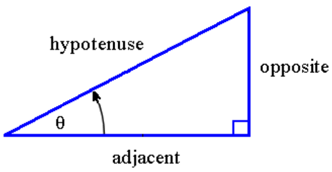
This graph is zoomed to show initial data.



This graph shows all of the collected data.



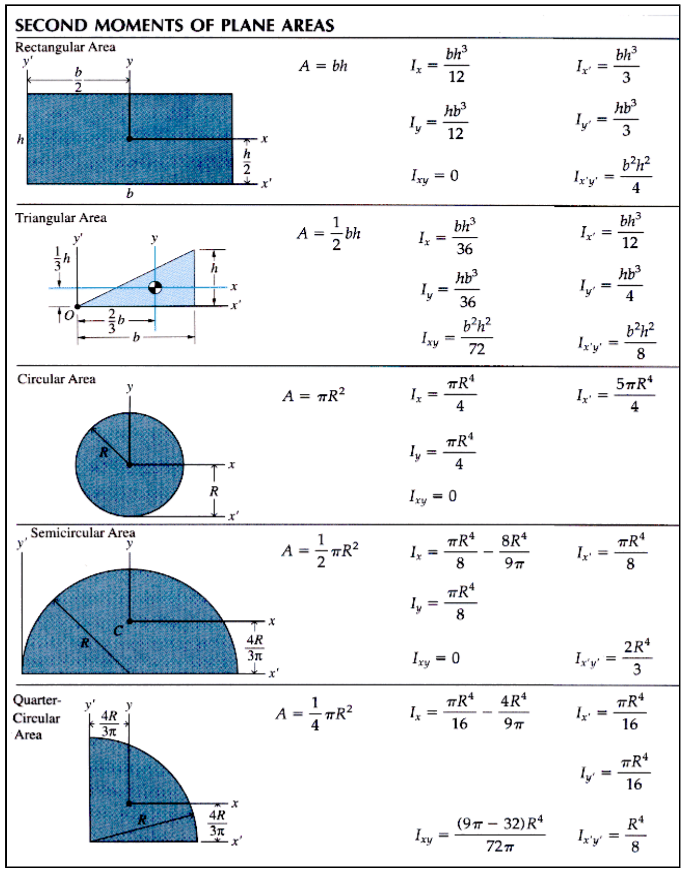
TRIGONOMETRY



$\sin\theta$ = opp / hyp
$\cos\theta$ = adj / hyp
$\tan\theta$ = opp / adj

STATICS

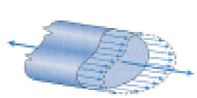
Symbol	Meaning	Equation	Units
$\bar{x}, \bar{y}, \bar{z}$	centroid position	$\bar{y} = \Sigma \bar{y}_i A_i / \Sigma A_i$	in, m
I	moment of inertia	$I = \Sigma(I_i + d_i^2 A_i)$	in^4, m^4
J	polar moment of inertia	$J_{\text{solid circular shaft}} = \pi d^4/32$ $J_{\text{hollow circular shaft}} = \pi(d_o^4 - d_i^4)/32$	in^4, m^4
N	normal force		lb, N
V	shear force	$V = \int -w(x)\,dx$	lb, N
M	bending moment	$M = \int V(x)\,dx$	in-lb, Nm
equilibrium		$\Sigma\mathbf{F} = \mathbf{0}$ $\Sigma\mathbf{M}_{(\text{any point})} = \mathbf{0}$	lb, N in-lb, Nm

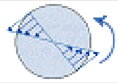
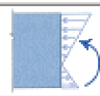
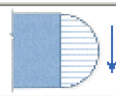


SECOND MOMENTS OF PLANE AREAS

Area	A		
Rectangular Area	$A = bh$	$I_x = \frac{bh^3}{12}$ $I_y = \frac{hb^3}{12}$ $I_{xy} = 0$	$I_{x'} = \frac{bh^3}{3}$ $I_{y'} = \frac{hb^3}{3}$ $I_{x'y'} = \frac{b^2h^2}{4}$
Triangular Area	$A = \frac{1}{2}bh$	$I_x = \frac{bh^3}{36}$ $I_y = \frac{hb^3}{36}$ $I_{xy} = \frac{b^2h^2}{72}$	$I_{x'} = \frac{bh^3}{12}$ $I_{y'} = \frac{hb^3}{4}$ $I_{x'y'} = \frac{b^2h^2}{8}$
Circular Area	$A = \pi R^2$	$I_x = \frac{\pi R^4}{4}$ $I_y = \frac{\pi R^4}{4}$ $I_{xy} = 0$	$I_{x'} = \frac{5\pi R^4}{4}$
Semicircular Area	$A = \frac{1}{2}\pi R^2$	$I_x = \frac{\pi R^4}{8} - \frac{8R^4}{9\pi}$ $I_y = \frac{\pi R^4}{8}$ $I_{xy} = 0$	$I_{x'} = \frac{\pi R^4}{8}$ $I_{x'y'} = \frac{2R^4}{3}$
Quarter-Circular Area	$A = \frac{1}{4}\pi R^2$	$I_x = \frac{\pi R^4}{16} - \frac{4R^4}{9\pi}$ $I_{xy} = \frac{(9\pi - 32)R^4}{72\pi}$	$I_{x'} = \frac{\pi R^4}{16}$ $I_{y'} = \frac{\pi R^4}{16}$ $I_{x'y'} = \frac{R^4}{8}$

MECHANICS OF MATERIALS

Topic	Symbol	Meaning	Equation	Units
axial	σ, sigma	normal stress 	$\sigma_{axial} = N/A$ $\tau_{cutting} = V/A$ $\sigma_{bearing} = F_b/A_b$	psi, Pa
	ε, epsilon	normal strain	$\varepsilon_{axial} = \Delta L/L_o = \delta/L_o$ $\varepsilon_{transverse} = \Delta d/d$	in/in, m/m
	γ, gamma	shear strain	γ = change in angle, $\gamma = c\theta$	rad
	E	Young's modulus, modulus of elasticity	$\sigma = E\varepsilon$ (one-dimensional only)	psi, Pa
	G	shear modulus, modulus of rigidity	$G = \tau/\gamma = E / 2(1+\nu)$	psi, Pa
	ν, nu	Poisson's ratio	$\nu = -\varepsilon'/\varepsilon$	
	δ, delta	deformation, elongation, deflection	$\delta = NL_o/EA + \alpha\Delta TL_o$	in, m
	α, alpha	coefficient of thermal expansion (CTE)		in/inF, m/mC
	F.S.	factor of safety	F.S. = actual strength / design strength	

Topic	Symbol	Meaning	Equation		Units
torsion	τ, tau	shear stress 	$\tau_{torsion} = Tc/J$		psi, Pa
	ϕ, phi	angle of twist	$\phi = TL/GJ$		rad, degrees
	θ, theta	angle of twist per unit length, rate of twist	$\theta = \phi / L$		rad/in, rad/m
	P	power	$P = T\omega$	$r_2T_1 = r_1T_2$ $r_1\omega_1 = r_2\omega_2$	watts = Nm/s hp=6600 in-lb/s
	ω, omega	angular speed, speed of rotation			rad/s
	f	frequency	$\omega = 2\pi f$		Hz = rev/s
	K	stress concentration factor	$\tau_{max} = KTc/J$		psi, Pa
flexure	σ, sigma	normal stress 	$\sigma_{beam} = -My/I$		psi, Pa
	σ, sigma	composite beams, $n = E_B/E_A$	$\sigma_A = -My / I^T$	$\sigma_B = -nMy / I^T$	psi, Pa
	τ, tau	shear stress 	$\tau_{beam} = VQ/Ib$ where $Q = \Sigma(y_{bar\ i} A_i)$		psi, Pa
	q	shear flow	$q = V_{beam}Q/I = nV_{fastener}/s$		
	v or y	beam deflection	$v = \iint M(x)\, dx^2 / EI$		in, m

Topic	Equations		Units
stress trans-formation	*planar rotations* $\sigma_u = (\sigma_x+\sigma_y)/2 + (\sigma_x-\sigma_y)/2 \cos(2\theta) + \tau_{xy}\sin(2\theta)$ $\sigma_v = (\sigma_x+\sigma_y)/2 - (\sigma_x-\sigma_y)/2 \cos(2\theta) - \tau_{xy}\sin(2\theta)$ $\tau_{uv} = -(\sigma_x-\sigma_y)/2 \sin(2\theta) + \tau_{xy}\cos(2\theta)$	*principals and max in-plane shear* $\tan(2\theta_p) = 2\tau_{xy} / (\sigma_x-\sigma_y)$, $\theta_s = \theta_p \pm 45^o$ $\sigma_{1,2} = (\sigma_x+\sigma_y)/2 \pm \text{sqrt}\{ [(\sigma_x-\sigma_y)/2]^2 + \tau_{xy}{}^2 \}$ $\tau_{max} = \text{sqrt}\{ [(\sigma_x-\sigma_y)/2]^2 + \tau_{xy}{}^2 \} = (\sigma_1-\sigma_2)/2$ $\sigma_{avg} = (\sigma_x+\sigma_y)/2 = (\sigma_1+\sigma_2)/2$	psi, Pa
strain trans-formation	*planar rotations* $\varepsilon_u = (\varepsilon_x+\varepsilon_y)/2 + (\varepsilon_x-\varepsilon_y)/2 \cos(2\theta) + \gamma_{xy}/2 \sin(2\theta)$ $\varepsilon_v = (\varepsilon_x+\varepsilon_y)/2 - (\varepsilon_x-\varepsilon_y)/2 \cos(2\theta) - \gamma_{xy}/2 \sin(2\theta)$ $\gamma_{uv}/2 = -(\varepsilon_x-\varepsilon_y)/2 \sin(2\theta) + \gamma_{xy}/2 \cos(2\theta)$ $\varepsilon_z = -\nu\, (\varepsilon_x + \varepsilon_y) / (1-\nu)$	*principals and max in-plane shear* $\tan(2\theta_p) = \gamma_{xy} / (\varepsilon_x-\varepsilon_y)$, $\theta_s = \theta_p \pm 45^o$ $\varepsilon_{1,2} = (\varepsilon_x+\varepsilon_y)/2 \pm \text{sqrt}\{ [(\varepsilon_x-\varepsilon_y)/2]^2 + (\gamma_{xy}/2)^2 \}$ $\gamma_{max}/2 = \text{sqrt}\{ [(\varepsilon_x-\varepsilon_y)/2]^2 + (\gamma_{xy}/2)^2 \}$ $\varepsilon_{avg} = (\varepsilon_x+\varepsilon_y)/2$	psi, Pa in/in, m/m
Hooke's law	*1D strain to stress* $\sigma = E\varepsilon$ *2D strain to stress* $\sigma_x = E(\varepsilon_x+\nu\varepsilon_y) / (1-\nu^2)$ $\sigma_y = E(\varepsilon_y+\nu\varepsilon_x) / (1-\nu^2)$ $\tau_{xy} = G\gamma_{xy} = E\gamma_{xy} / 2(1+\nu)$	*2D stress to strain* $\varepsilon_x = (\sigma_x-\nu\sigma_y) / E$ $\varepsilon_y = (\sigma_y-\nu\sigma_x) / E$ $\varepsilon_z = -\nu(\varepsilon_x+\varepsilon_y) / (1-\nu)$ $\gamma_{xy} = \tau_{xy}/G = 2(1+\nu)\tau_{xy} / E$	psi, Pa in/in, m/m
pressure	$\sigma_{spherical} = pr/2t$ $\sigma_{cylindrical,\ hoop} = pr/t$ $\sigma_{cylindrical,\ axial} = pr/2t$	$\sigma_{radial,\ outside} = 0$ $\sigma_{radial,\ inside} = -p$	psi, Pa
failure theories	*maximum principal stress theory* $\sigma_{1,2} < \sigma_{yp}$	*maximum shear stress theory* $\tau_{max} < 0.5\ \sigma_{yp}$	psi, Pa