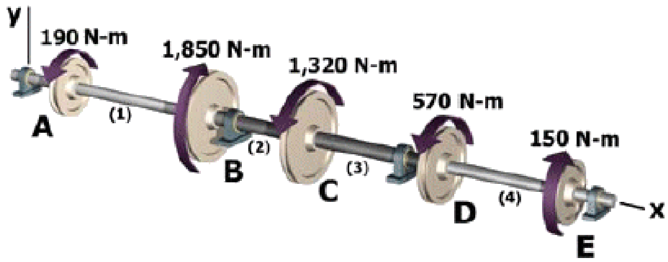
 Name: ______________________

1. A compound shaft supports several pulleys. The bearings allow the shaft to turn freely. Using the sign convention shown in the text and MecMovies, determine the internal torque in each segment of the shaft.



T_1 = __________ N-m

T_2 = __________ N-m

T_3 = __________ N-m

T_4 = __________ N-m

2. If T_E = 600 N-m in *Image 2*, determine the magnitude of the internal torque in shaft (1). The bearings permit free rotation of the shafts.

T_1 = __________ N-m

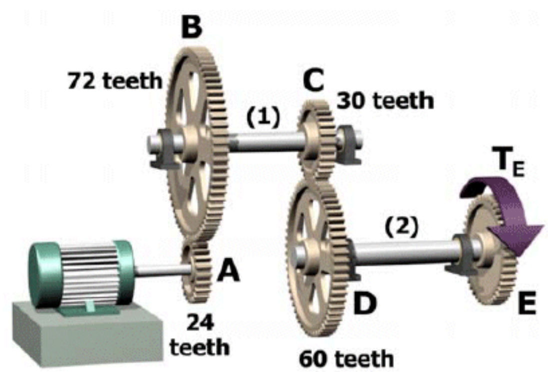


Image 2

3. If the motor in *Image 2* rotates at 4 Hz, determine the rotational speed of shaft (1) in radians per second.

ω_1 = __________ rad/s

4. If the motor in *Image 2* supplies 12 hp at 4 rpm to gear *A*, determine the power in shaft (1) in inch-pounds per second.

P_1 = __________ in-lb/s

5. If gear *D* in *Image 2* rotates 15 degrees, how much does gear C rotate in radians?

ϕ_C = __________ radians

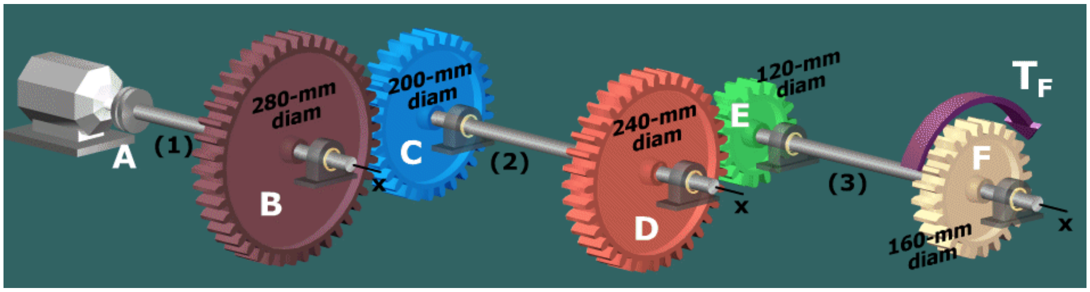
6. In *Image 2*, if T_E = 600 N-m and the allowable shear stress in shaft (2) must be limited to 50 MPa, determine the minimum permissible diameter for solid shaft (2).

d_2 = __________ mm

7. In *Image 2*, if T_E = 600 N-m, G = 80 GPa for both shafts, the length of shaft (2) is 1 m, and the rotation of gear *D* relative to gear *E* must be limited to 3 degrees, determine the minimum permissible diameter for solid shaft (2).

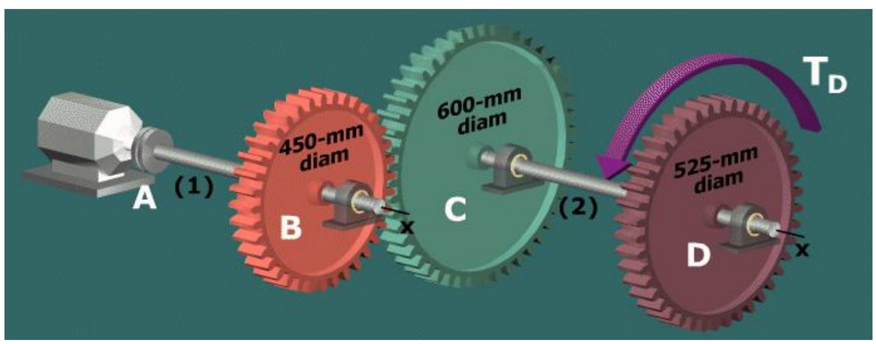
d_2 = __________ mm

8. If the motor at *A* produces a torque of 2,030 N-m, what is the maximum shear stress in shaft (3), which is hollow with an outside diameter of 50 mm and a wall thickess of 5 mm.



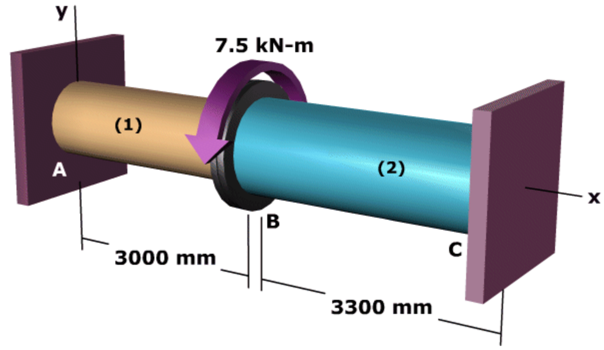
τ_3 = __________ MPa

9. A 4,200 N-m torque is applied at *D*. Shafts (1) and (2) are both 52-mm-diameter solid steel shafts 800-mm-long (G = 80 GPa). Determine the rotation angle of gear *D* relative to motor *A*.



ϕ = __________ radians

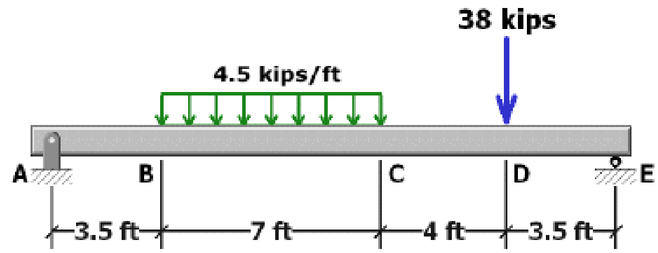
10. A composite torsion member consists of two solid shafts joined at flange *B*. Shafts (1) and (2) are attached to rigid supports at *A* and *C*, respectively. A concentrated torque *T* is applied to flange *B* in the direction shown. Determine the internal torque in shaft (1).



$J_1 = I_{p1} = 1.27\text{x}10^6$ mm^4
$G_1 = 25$ GPa
$J_2 = I_{p2} = 2.36\text{x}10^6$ mm^4
$G_2 = 70$ GPa

T_1 = __________ kN-m

11. Determine the ground reactions at A and E.

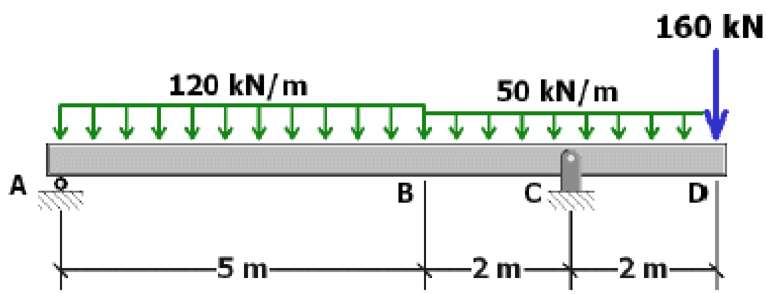


A_x = __________ kips

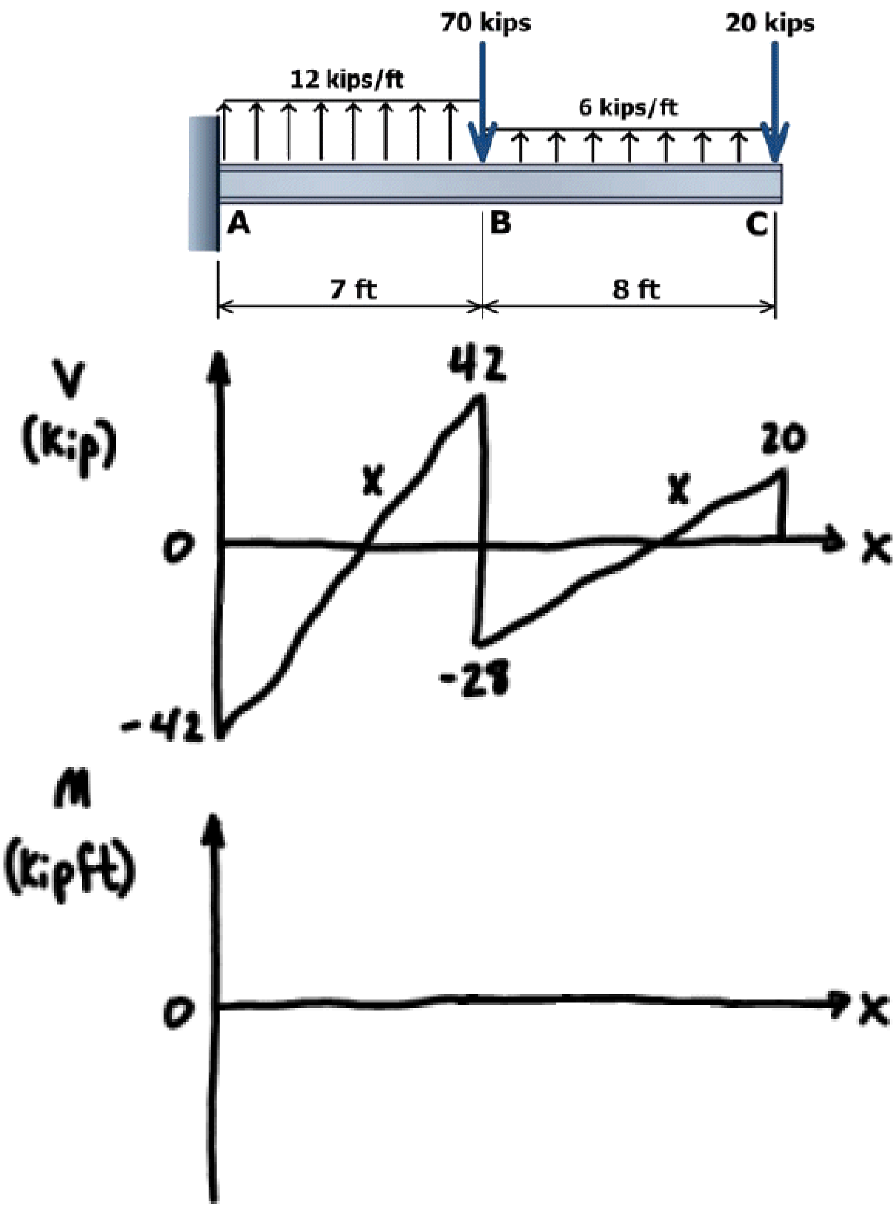
A_y = __________ kips

E_y = __________ kips

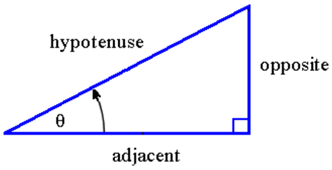
12. Draw the shear-force diagram for the beam shown. Label all significant points on the diagram, and clearly distinguish straight-line and curved portions of the diagram. The ground reactions are A_y = 340 kN upward, C_x = 0, and C_y = 620 kN upward.



13. Draw the bending-moment diagram for the beam shown. Label all significant points on the diagram, and clearly distinguish straight-line and curved portions of the diagram. The ground reactions are $A_x = 0$, $A_y = 42$ kips downward, and $M_A = 32$ kip-ft clockwise.



TRIGONOMETRY



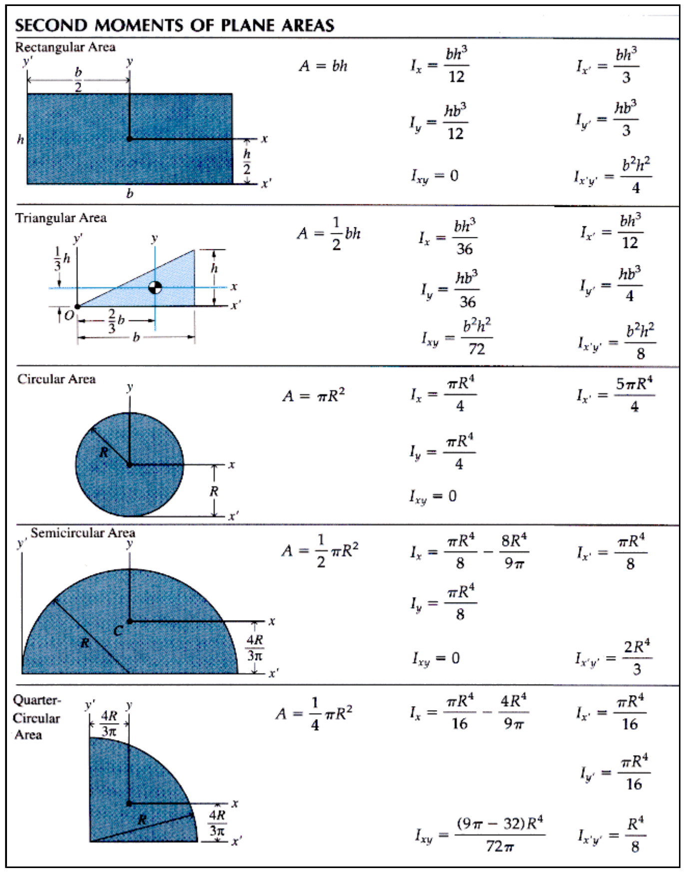
$\sin\theta = \text{opp} / \text{hyp}$

$\cos\theta = \text{adj} / \text{hyp}$

$\tan\theta = \text{opp} / \text{adj}$

STATICS

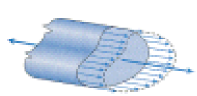
Symbol	Meaning	Equation	Units
$\bar{x}, \bar{y}, \bar{z}$	centroid position	$\bar{y} = \Sigma \bar{y}_i A_i / \Sigma A_i$	in, m
I	moment of inertia	$I = \Sigma(I_i + d_i^2 A_i)$	in^4, m^4
J	polar moment of inertia	$J_{\text{solid circular shaft}} = \pi d^4/32$ $J_{\text{hollow circular shaft}} = \pi(d_o^4 - d_i^4)/32$	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

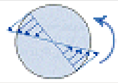
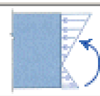
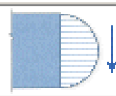


SECOND MOMENTS OF PLANE AREAS

Area	A	Centroidal	About x', y'
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 	$\sigma_{\text{axial}} = N/A$ $\tau_{\text{cutting}} = V/A$ $\sigma_{\text{bearing}} = F_b/A_b$	psi, Pa
	ε, epsilon	normal strain	$\varepsilon_{\text{axial}} = \Delta L/L_o = \delta/L_o$ $\varepsilon_{\text{transverse}} = \Delta d/d$	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	$\delta = NL_o/EA + \alpha\Delta T L_o$	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