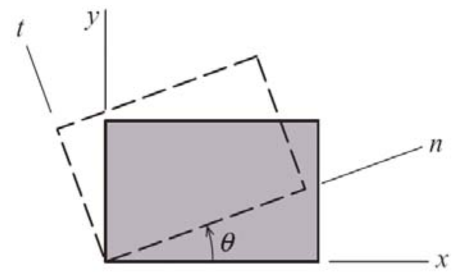
1. The strain components ε_x = 946 με, ε_y = -294 με and γ_{xy} = -362 με are given for a point in a body subjected to plane strain. Determine the strain components ε_n, ε_t, and γ_{nt} at the point if the n–t axes are rotated with respect to the x–y axes by the amount and in the direction indicated by the angle θ = 12°. *(9 points)*



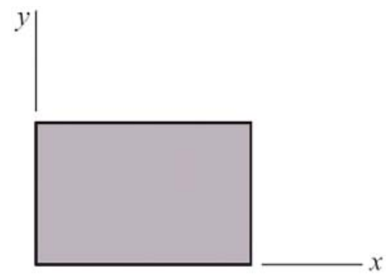
ε_n = ___________ με

ε_t = ___________ με

γ_{nt} = ___________ μrad

Sketch the deformed shape of the element. *(3 points)*

2. The strain components ε_x = -800 με, ε_y = 400 με and γ_{xy} = -1350 με are given for a point in a body subjected to plane strain. Determine θ_p and the normal and shear strains at the θ_p orientation (i.e. the "principals"). *(12 points)*



θ_p = ___________ deg

ε_n = ___________ με

ε_t = ___________ με

γ_{nt} = ___________ μrad

Determine θ_s and the normal and shear strains at the θ_s orientation (i.e. the "average normal strain" and "in-plane maximum shear strain"). *(12 points)*

θ_s = ___________ deg

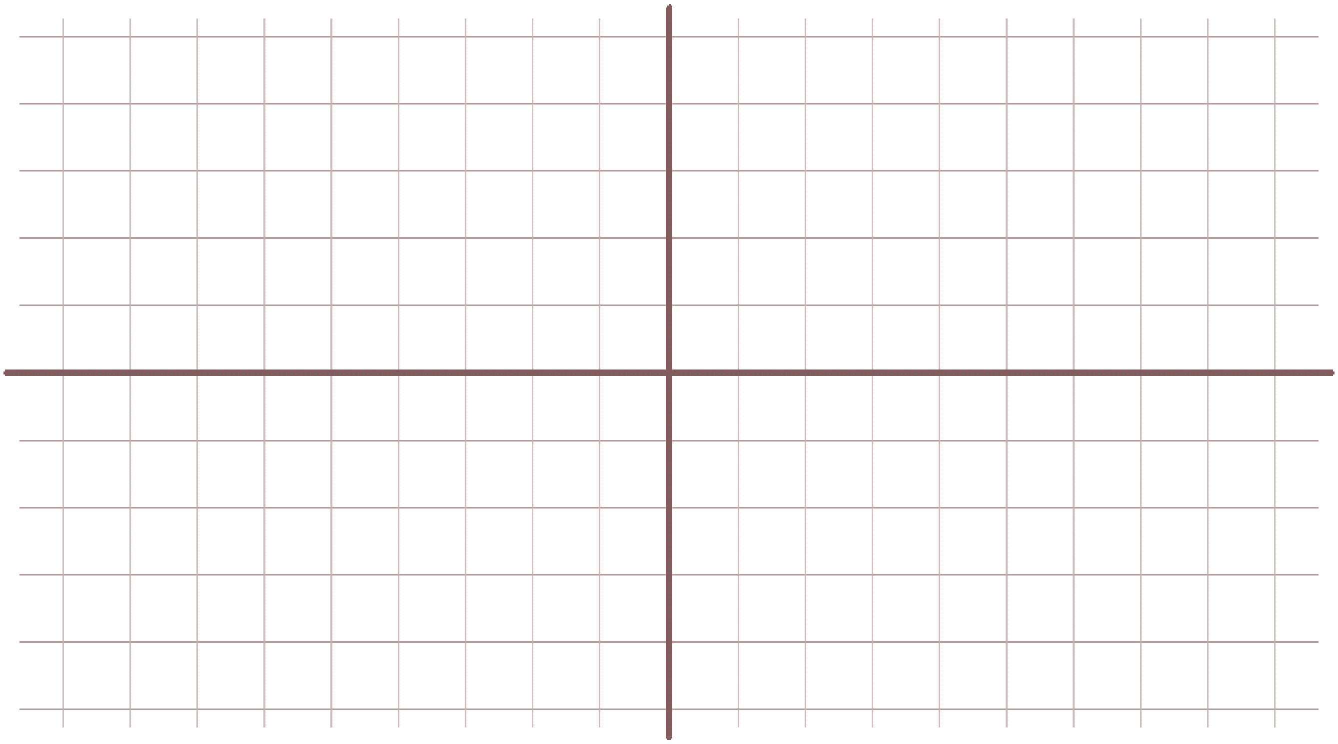
ε_n = ___________ με

ε_t = ___________ με

γ_{nt} = ___________ μrad

Show the angle θ_p, the principal strain deformations, and the maximum in-plane shear strain distortion on a sketch. *(4 points)*

3. The strain components ε_x = -200 με, ε_y = -700 με and γ_{xy} = 600 με are given for a point in a body subjected to plane strain. Draw Mohr's circle. *(5 points)*



Using the circle, determine the principal strains, the maximum in-plane shear strain, and the absolute maximum shear strain at the point. *(18 points)*

ε_{center} = ___________ με

radius = ___________ με

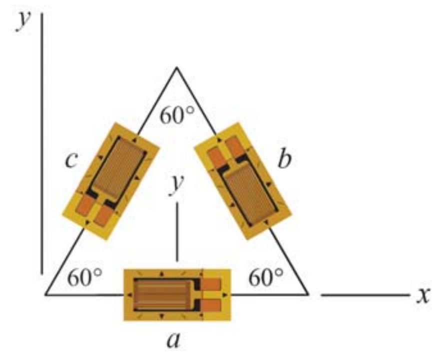
ε_1 = ___________ με

ε_2 = ___________ με

$\gamma_{in\text{-}plane\ max}$ = ___________ μrad

$\gamma_{absolute\ max}$ = ___________ μrad

4. The strain rosette shown in the figures was used to obtain normal strain data at a point on the free surface of a machine part. Determine the strain components ε_x, ε_y at the point. To save time, γ_{xy} is not needed. *(15 points)*



ε_a = -600 $\mu\varepsilon$
ε_b = 250 $\mu\varepsilon$
ε_c = 800 $\mu\varepsilon$

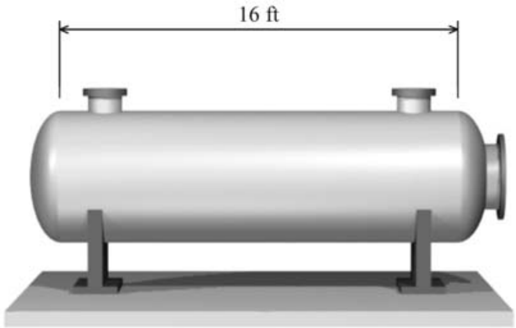
ε_x = ___________ $\mu\varepsilon$

ε_y = ___________ $\mu\varepsilon$

5. A strain gage is used to monitor the strain in a spherical steel tank ($E = 210$ GPa; $\nu = 0.32$), which contains a fluid under pressure. The tank has an inside diameter of 2.50 m and a wall thickness of 100 mm. Determine the internal pressure in the tank when the strain gage reads 120 $\mu\varepsilon$. *(10 points)*

p = __________ MPa

6. A closed cylindrical vessel contains a fluid at a pressure of 640 psi. The cylinder, which has an outside diameter of 72 in. and a wall thickness of 1.000 in., is fabricated from stainless steel [$E = 28{,}000$ ksi; $\nu = 0.32$]. Determine the axial and hoop stresses and principal strains. *(12 points)*



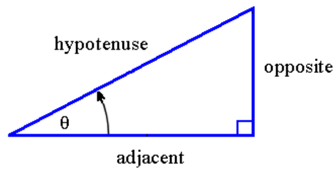
σ_{axial} = __________ psi

σ_{hoop} = __________ psi

ε_1 = __________ $\mu\varepsilon$

ε_2 = __________ $\mu\varepsilon$

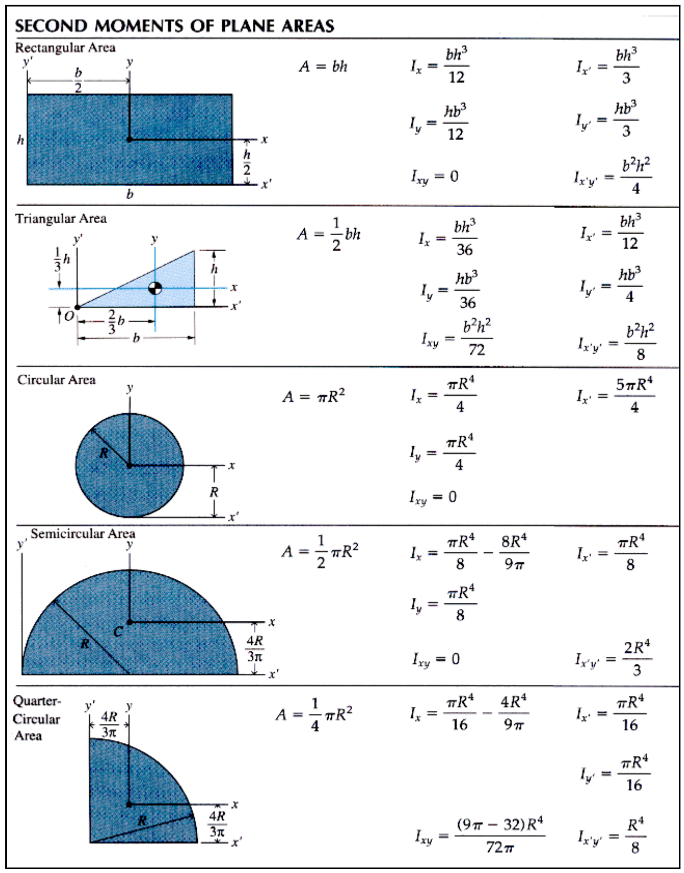
TRIGONOMETRY



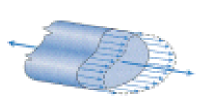
$\sin\theta = \text{opp} / \text{hyp}$
$\cos\theta = \text{adj} / \text{hyp}$
$\tan\theta = \text{opp} / \text{adj}$

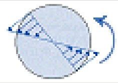
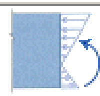
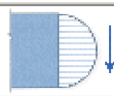
STATICS

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



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	$\delta = NL_o/EA + \alpha\Delta T L_o$	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