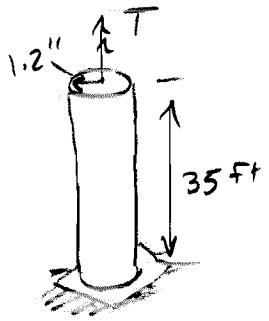
Prob. 3.111



$\tau_Y = 22$ ksi

G 11200 ksi

$T = 75$ k-in

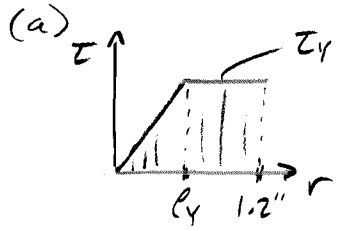
(a) What is shear stress?

(b) What is ϕ?

For given cross-section, $T_Y = \frac{\tau_Y \cdot J}{c} = \frac{22 \text{ ksi} \times \frac{\pi}{2} \times 1.2''^4}{1.2''} = 59.7$ k-in

Since $T = 75 > T_Y = 59.7$, some of cross-section has yielded

(a)



$\rho_Y = ?$ $\quad T = \frac{4}{3} T_Y \left(1 - \frac{1}{4} \times \frac{\rho_Y^3}{c^3}\right)$

Plug in $T = 75$, $T_Y = 59.7$, $c = 1.2''$

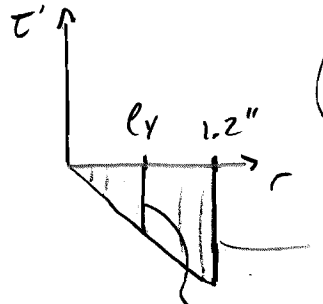
$\rho_Y = 0.736''$

(b) ϕ at end $= ?$

$$\phi_Y = \frac{T_Y \cdot L}{GJ} = \frac{(59.7 \text{ k-in})(35 \times 12 \text{ in})}{(11200 \text{ ksi})(\frac{\pi}{2} \times 1.2^4 \text{ in}^4)} = 0.687 \text{ rad}$$

$\phi / \phi_Y = c / \rho_Y$, $\quad \phi = \phi_Y \cdot \frac{c}{\rho_Y} = 1.12$ rad

(c) What is max residual stress after T is removed?

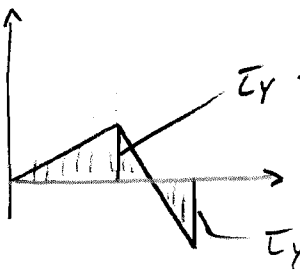


(NOTE: τ' represents the change in stress during unloading.)

$$\tau'_{max} = -\frac{T \cdot J}{c} = \frac{(-75 \text{ k-in})(\frac{\pi}{2} \times 1.2'' \text{ in}^4)}{1.2''} = 27.64 \text{ ksi}$$

$$\tau' @ \rho_Y = \tau'_{max} \times \frac{\rho_Y}{c} = 27.64 \text{ ksi} \times \frac{0.736}{1.2} = 16.95 \text{ ksi}$$

τ_{res} → residual stress after T is removed



$\tau_Y - \tau'@\rho_Y = 5.04$ ksi

$\tau_Y - \tau'_{max} = -5.64$ ksi ← maximum residual shear stress

(d) Permanent (Residual) angle of twist $\phi_p = ?$

$\phi = 1.12$ rad

$$\phi' = \frac{-T \cdot L}{GJ} = \frac{(-75)(35\times12)}{11200 \times \frac{\pi}{2} \times 1.2^4} = -0.863 \text{ rad}$$

$$\phi_p = \phi + \phi' = 0.257 \text{ rad}$$