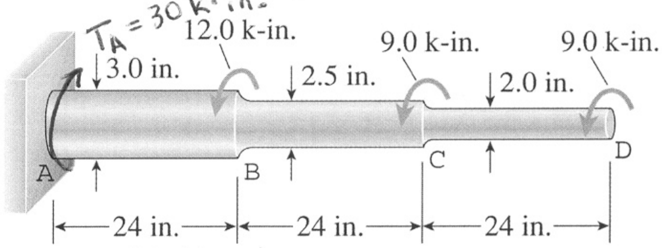
MULTIPLE CHOICE PROBLEMS (10 Points each)

1. A stepped shaft *ABCD* consisting of solid circular segments is subjected to three torques as shown in the Figure. The maximum shear stress, τ_{max}, in the shaft is most nearly:

(a) 5.66 ksi
(b) 5.87 ksi
(c) 733 psi
(d) 5.73 ksi
(e) 2.93 ksi



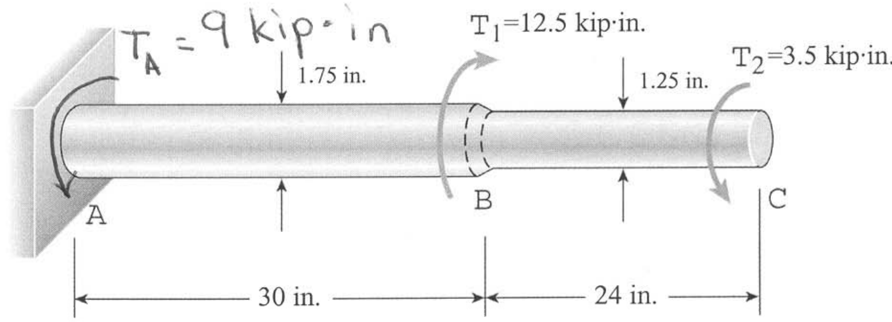
$$\tau_{AB} = \frac{T_{AB}\, r_{AB}}{J_{AB}} = \frac{T_{AB}\, r_{AB}}{\frac{\pi}{2} r_{AB}^4} = \frac{T_{AB}}{\frac{\pi}{2} r_{AB}^3} = \frac{30 \text{ kip}\cdot\text{in}}{\frac{\pi}{2}(1.5\text{ in})^3} = 5.66 \text{ ksi}$$

$$\tau_{BC} = \frac{18 \text{ kip}\cdot\text{in}}{\frac{\pi}{2}(1.25\text{in})^3} = \underline{\underline{5.87 \text{ ksi}}}$$

$$\tau_{CD} = \frac{9 \text{ kip}\cdot\text{in}}{\frac{\pi}{2}(1\text{in})^3} = 5.73 \text{ ksi}$$

2. For the solid brass shaft shown, $G = 17\text{x}10^3$ ksi. The angle of rotation at section B is most nearly:

(a) 1.079×10^{-3} radians
(b) 20.6×10^{-3} radians
(c) 17.25×10^{-3} radians
(d) 24.0×10^{-3} radians
(e) 73.7×10^{-3} radians



$$\phi_B = \phi_{B/A} = \frac{T_{AB} L_{AB}}{J_{AB}\, G}$$

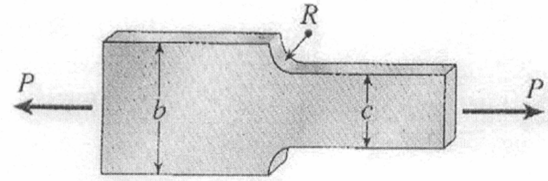
$$= \frac{(9 \text{ kip}\cdot\text{in})(30\text{ in})}{\frac{\pi}{2}(0.875\text{in})^4 (17\times10^3 \text{ kip/in}^2)}$$

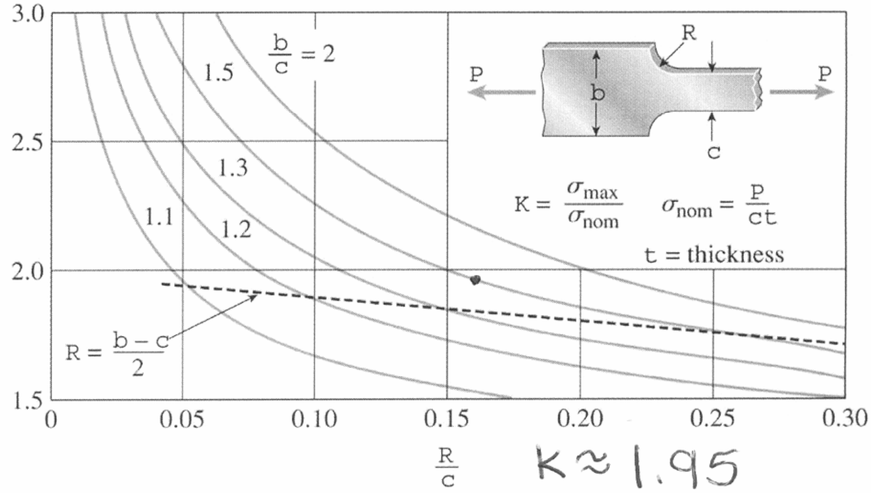
$$= 0.01725 \text{ rad}$$

$$= \underline{\underline{17.25 \times 10^{-3} \text{ rad}}}$$

3. The flat bar shown has thickness 3.0 cm and fillets of radius R = 0.25 cm. The larger width is b = 2.4 cm and the smaller width is c = 1.6 cm. It is subjected to a tensile load P. Determine the largest permissible load P if the maximum allowable normal stress in the bar is 20 MPa.

(a) 4.92 kN
(b) 18.72 kN
(c) 6.27 kN
(d) 7.38 kN
(e) 17.47 kN





$K \approx 1.95$

FIG. 2-64 **Stress-concentration factor *K* for flat bars with shoulder fillets. The dashed line is for a full quarter-circular fillet.**

$$\frac{b}{c} = \frac{2.4\text{ cm}}{1.6\text{ cm}} = 1.5$$

$$\frac{R}{c} = \frac{0.25\text{cm}}{1.6\text{ cm}} = 0.15625$$

$$\sigma_{max} = K\,\sigma_{\cancel{ave}\ nom} = \sigma_{all}$$

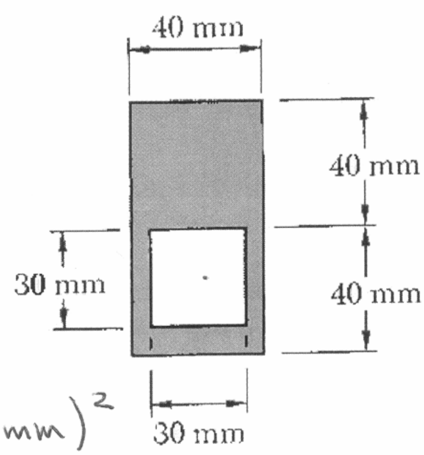
$$\sigma_{\cancel{ave}\ nom} = \frac{\sigma_{all}}{K} = \frac{P_{all}}{ct}$$

$$P_{all} = \frac{\sigma_{all}}{K}\,ct$$

$$= \frac{20\text{ N/mm}^2}{1.95}(16\text{mm})(30\text{ mm}) = \underline{4.92\text{ kN}}$$

4. The centroid of the section shown below is located 45.870 mm from the bottom of the area. The second moment of area (the area moment of inertia) about a horizontal axis that passes through the centroid of the area is most nearly:

(a) $4.27\text{x}10^6$ mm^4
(b) $3.59\text{x}10^6$ mm^4
(c) $1.357\text{x}10^6$ mm^4
(d) $1.639\text{x}10^6$ mm^4
(e) $1.707\text{x}10^6$ mm^4



$$I = \frac{1}{12}(80\text{mm})^3(40\text{mm})$$

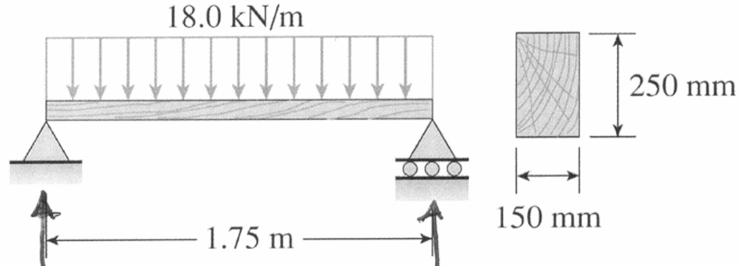
$$+ (80\text{mm})(40\text{mm})(40\text{mm} - 45.87\text{mm})^2$$

$$- \Big[\frac{1}{12}(30\text{mm})^3(30\text{mm}) + (30\text{mm})(30\text{mm})\big(25\text{mm} - 45.87\text{mm}$$

$$= \underline{\underline{1.357\times10^6\text{ mm}^4}}$$

5. The maximum bending stress in the simply supported wood beam loaded as shown below is most nearly:

(a) 4.41 MPa
(b) 9.21 MPa
(c) 4.80 MPa
(d) 4.20 MPa
(e) 3.61 MPa



15.75 kN ~~15.75 kN~~ 15.75 kN

$$\sigma_m = \frac{M_{max}\, c}{I}$$

$$= \frac{(6.89 \times 10^3\, N \cdot m)(0.125\, m)}{\frac{1}{12}(0.15 m)(0.25 m)^3}$$

$$M_{max} = \frac{1}{2}(15.75 kN)(0.875 m)$$

$$= 6.89\ kN \cdot m$$

$$= 4.41 \times 10^6\, N/m^2 = \underline{4.41\ MPa}$$

6. Point A is deflected downward by a very small increment, δ, in response to the load, P. The corresponding shear stress in rod *BC* which has a diameter *d* is given by:

(a) $\tau_{max} = \frac{G\delta a}{Ld}$

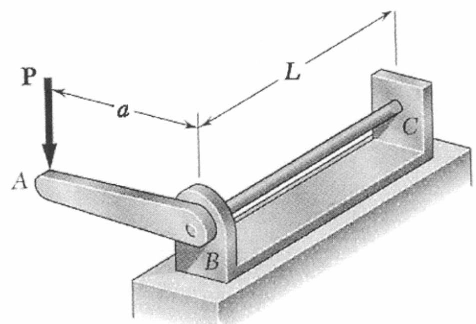
(b) $\tau_{max} = \frac{Gd\delta}{La}$

(c) $\tau_{max} = \frac{Gd\delta}{2La}$

(d) $\tau_{max} = \frac{G\delta a}{6Ld}$

(e) $\tau_{max} = \frac{d\delta a}{2GL}$

$$T = Pa$$



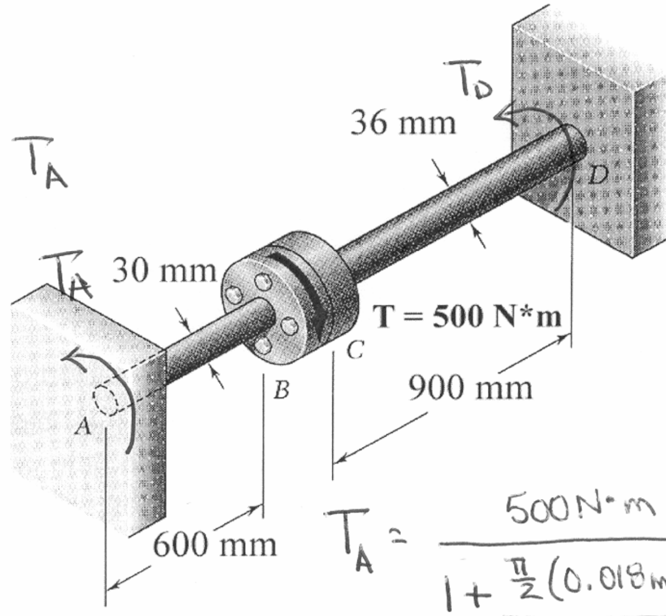
$$\phi_B = \phi_{B/C} = \frac{\delta}{a} = \frac{TL}{JG}$$

$$\frac{\delta}{a}\frac{JG}{L} = T$$

$$\tau_{max} = \frac{Tc}{J} = \frac{\frac{\delta}{a}\frac{\cancel{J}G}{L}\left(\frac{d}{2}\right)}{\cancel{J}} = \frac{G\delta d}{2aL}$$

7. **WORK OUT PROBLEM (40 Points)**

Two solid steel shafts are fitted with rigid flanges which are then connected by fitted bolts so that there is no relative rotation between the flanges. Knowing that $G = 77$ GPa, determine the maximum shearing stress in shaft AB when a torque of magnitude $T = 500$ N·m is applied to flange B.



Equilibrium:

$$T_A + T_D = T \Rightarrow T_D = T - T_A$$

Kinematics:

$$\phi_{B/A} = \phi_B = \phi_C = \phi_{C/D}$$

Torque - Angle of twist:

$$\phi_{B/A} = \frac{T_{AB} L_{AB}}{J_{AB} G} = \frac{T_A L_{AB}}{J_{AB} G}$$

$$\phi_{C/D} = \frac{T_{CD} L_{CD}}{J_{CD} G} = \frac{T_D L_{CD}}{J_{CD} G}$$

$$\phi_{B/A} = \phi_{C/D} \Rightarrow \frac{T_D L_{CD}}{J_{CD} G} = \frac{T_A L_{AB}}{J_{AB} G}$$

$$\frac{(T - T_A) L_{CD}}{J_{CD} G} = \frac{T_A L_{AB}}{J_{AB} G}$$

$$\frac{T L_{CD}}{J_{CD} G} = T_A \left(\frac{L_{CD}}{J_{CD} G} + \frac{L_{AB}}{J_{AB} G} \right)$$

$$T_A = \frac{T L_{CD}}{J_{CD} G} \Big/ \left(\frac{L_{CD}}{J_{CD} G} + \frac{L_{AB}}{J_{AB} G} \right) = \frac{T}{\left(1 + \frac{J_{CD}}{J_{AB}} \frac{L_{AB}}{L_{CD}}\right)}$$

$$T_A = \frac{500\,\text{N}\cdot\text{m}}{1 + \frac{\frac{\pi}{2}(0.018\,\text{m})^4}{\frac{\pi}{2}(0.015\,\text{m})^4} \frac{600\,\text{mm}}{900\,\text{mm}}}$$

$$= \underline{210\,\text{N}\cdot\text{m}}$$

$$\tau_{AB} = \frac{T_A c_{AB}}{J_{AB}} = \frac{(210\,\text{N}\cdot\text{m})(0.015\,\text{m})}{\frac{\pi}{2}(0.015\,\text{m})^4}$$

$$= \underline{\underline{39.6\,\text{MPa}}}$$