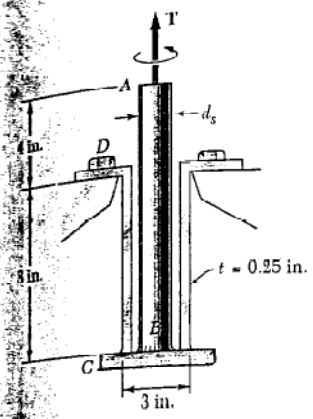
Problem 3.7



3.7 The solid spindle AB is made of a steel with an **allowable shearing stress of** 12 ksi, and sleeve *CD* is made of a brass with an **allowable shearing stress of 7** ksi. Determine (a) the largest torque T that can be **applied at A if the allowable** shearing stress is not to be exceeded in sleeve *CD*, (b) **the corresponding required** value of the diameter d_s of spindle *AB*.

(a) Sleeve CD: $c_2 = \frac{1}{2} d_2 = \frac{1}{2}(3.0) = 1.5$ in.

$c_1 = c_2 - t = 1.5 - 0.25 = 1.25$ in.

$J = \frac{\pi}{2}(c_2^4 - c_1^4) = \frac{\pi}{2}(1.5^4 - 1.25^4) = 4.1172$ in^4

$\tau_{max} = \frac{T c_2}{J}$

$T_{CD} = \frac{J \tau_{CD}}{c_2} = \frac{(4.1172)(7)}{1.5} = 19.213$ kip·in

For equilibrium, $T = 19.21$ kip·in

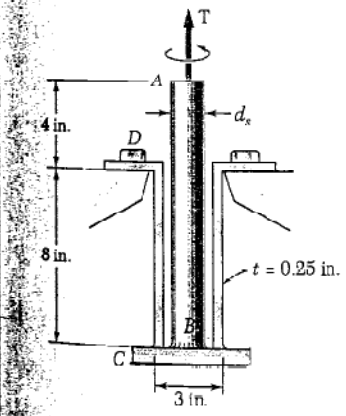
(b) Solid spindle AB: $T = 19.213$ kip·in

$\tau = \frac{Tc}{J} = \frac{2T}{\pi c^3}$

$c = \sqrt[3]{\frac{2T}{\pi \tau}} = \sqrt[3]{\frac{(2)(19.213)}{\pi (12)}} = 1.0064$ in.

$d_s = 2c = (2)(1.0064)$ $\quad d_s = 2.01$ in.

Problem 3.8



3.8 The solid spindle *AB* has a diameter $d_s = 1.5$ in. and is made of a steel with an allowable shearing stress of 12 ksi, while sleeve *CD* is made of a brass with an allowable shearing stress of 7 ksi. Determine the largest torque T that can be applied at *A*.

Solid spindle AB: $c = \frac{1}{2} d_s = \frac{1}{2}(1.5) = 0.75$ in.

$J = \frac{\pi}{2} c^4 = \frac{\pi}{2}(0.75)^4 = 0.49701$ in^4

$\tau_{max} = \frac{Tc}{J}$

$T_{AB} = \frac{J \tau_{all}}{c} = \frac{(0.49701)(12)}{0.75} = 7.952$ kip·in

Sleeve CD: $c_2 = \frac{1}{2} d_2 = \frac{1}{2}(3.0) = 1.5$ in.

$c_1 = c_2 - t = 1.5 - 0.25 = 1.25$ in.

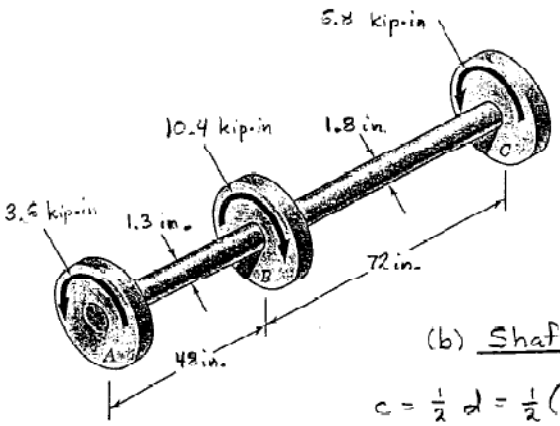
$J = \frac{\pi}{2}(c_2^4 - c_1^4) = \frac{\pi}{2}(1.5^4 - 1.25^4) = 4.1172$ in^4

$T_{CD} = \frac{J \tau_{all}}{c_2} = \frac{(4.1172)(7)}{1.5} = 19.213$ kip·in

Allowable value of torque T is the smaller. $T = 7.95$ kip·in

Problem 3.13

3.13 The torques shown are exerted on pulleys *A*, *B*, and *C*. Knowing that both shafts are solid, determine the maximum shearing stress in (a) shaft *AB*, (b) shaft *BC*.



(a) Shaft AB: $T_{AB} = 3.6 \times 10^3$ lb-in

$c = \frac{1}{2}d = \frac{1}{2}(1.3) = 0.65$ in.

$J = \frac{\pi}{2}c^4 \qquad \tau_{max} = \frac{Tc}{J} = \frac{2T}{\pi c^3}$

$\tau_{max} = \frac{(2)(3.6\times10^3)}{\pi(0.65)^3} = 8.35\times10^3$ psi

$\tau_{max} = 8.35$ ksi

(b) Shaft BC: $T_{BC} = 6.8\times10^3$ lb-in

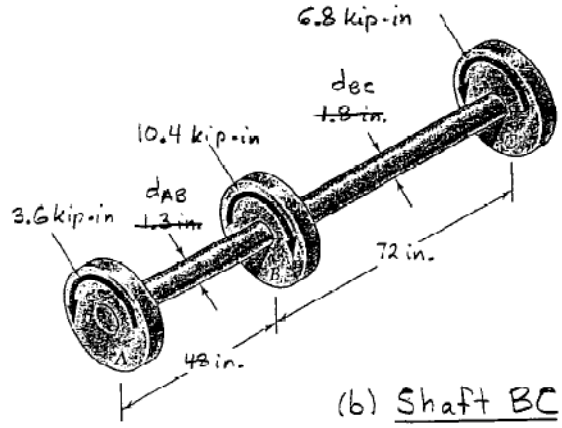
$c = \frac{1}{2}d = \frac{1}{2}(1.8) = 0.9$ in. $\qquad J = \frac{\pi}{2}c^4$

$\tau_{max} = \frac{2T_{BC}}{\pi c^3} = \frac{(2)(6.8\times10^3)}{\pi(0.9)^3} = 5.94\times10^3$ psi

$\tau_{max} = 5.94$ ksi

Problem 3.14

3.14 The shafts of the pulley assembly shown are to be redesigned. Knowing that the allowable shearing stress in each shaft is 8.5 ksi, determine the smallest allowable diameter of (a) shaft *AB*, (b) shaft *BC*.



(a) Shaft AB: $T_{AB} = 3.6\times10^3$ lb-in

$\tau_{max} = 8.5$ ksi $= 8.5\times10^3$ psi

$J = \frac{\pi}{2}c^4 \qquad \tau_{max} = \frac{Tc}{J} = \frac{2T}{\pi c^3}$

$c = \sqrt[3]{\frac{2T_{AB}}{\pi\tau_{max}}} = \sqrt[3]{\frac{(2)(3.6\times10^3)}{\pi(8.5\times10^3)}} = 0.646$ in.

$d_{AB} = 2c = 1.292$ in.

(b) Shaft BC: $T_{BC} = 6.8\times10^3$ lb-in $\qquad \tau_{max} = 8.5\times10^3$ psi

$c = \sqrt[3]{\frac{2T_{BC}}{\pi\tau_{max}}} = \sqrt[3]{\frac{(2)(6.8\times10^3)}{\pi(8.5\times10^3)}} = 0.7985$ in.

$d_{BC} = 2c = 1.597$ in.

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Problem 3.34

3.34 Determine the largest allowable diameter of a 10-ft-long steel rod ($G = 11.2 \times 10^6$ psi) if the rod is to be twisted through 30° without exceeding a shearing stress of 12 ksi.

$L = 10 \text{ ft} = 120 \text{ in.}$ $\quad \varphi = 30^\circ = \frac{30\pi}{180} = 0.52360 \text{ rad}$

$\tau = 12 \text{ ksi} = 12 \times 10^3 \text{ psi}$

$\varphi = \frac{TL}{GJ}, \quad T = \frac{GJ\varphi}{L}, \quad \tau = \frac{Tc}{J} = \frac{GJ\varphi c}{JL} = \frac{G\varphi c}{L}, \quad c = \frac{\tau L}{G\varphi}$

$c = \frac{(12\times10^3)(120)}{(11.2\times10^6)(0.52360)} = 0.24555 \text{ in.} \quad d = 2c = 0.491 \text{ in.}$

Problem 3.64

3.64 Determine the maximum shearing stress in a solid shaft of 1.5-in. diameter as it transmits 75 hp at a speed of (*a*) 750 rpm, (*b*) 1500 rpm.

$c = \frac{1}{2}d = 0.75 \text{ in.} \quad P = 75 \text{ hp} = (75)(6600) = 495 \times 10^3 \text{ lb·in/s}$

(a) $f = \frac{750}{60} = 12.5 \text{ Hz}$

$T = \frac{P}{2\pi f} = \frac{495\times10^3}{2\pi(12.5)} = 6.3025\times10^3 \text{ lb·in}$

$\tau = \frac{Tc}{J} = \frac{2T}{\pi c^3} = \frac{(2)(6.3025\times10^3)}{\pi(0.75)^3} = 9.51\times10^3 \text{ psi} \quad \tau = 9.51 \text{ ksi}$

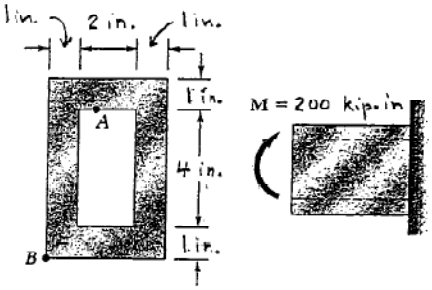
(b) $f = \frac{1500}{60} = 25 \text{ Hz}$

$T = \frac{495\times10^3}{2\pi(25)} = 3.1513\times10^3 \text{ lb·in}$

$\tau = \frac{(2)(3.1513\times10^3)}{\pi(0.75)^3} = 4.76\times10^3 \text{ psi} \quad \tau = 4.76 \text{ ksi}$

Problem 4.1

4.1 and 4.2 Knowing that the couple shown acts in a vertical plane, determine the stress at (*a*) point *A*, (*b*) point *B*.



For a rectangle $I = \frac{1}{12} b h^3$

Outside rectangle: $I_1 = \frac{1}{12}(4)(6)^3$

$I_1 = 72 \text{ in}^4$

Cutout: $I_2 = \frac{1}{12}(2)(4)^3 = 10.667 \text{ in}^4$

Section: $I = I_1 - I_2 = 61.333 \text{ in}^4$

(a) $y_A = 2 \text{ in.}$ $\quad \sigma_A = -\frac{M y_A}{I} = -\frac{(200)(2)}{61.333} = -6.5217 \text{ ksi}$

$\sigma_A = -6.52 \text{ ksi}$

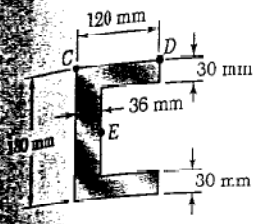
(b) $y_B = -3 \text{ in.}$ $\quad \sigma_B = -\frac{M y_B}{I} = -\frac{(200)(-3)}{61.333} = 9.7826 \text{ ksi}$

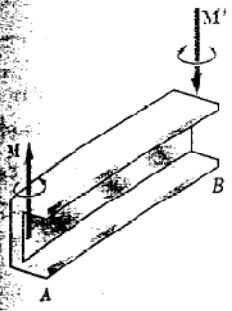
$\sigma_B = 9.78 \text{ ksi}$

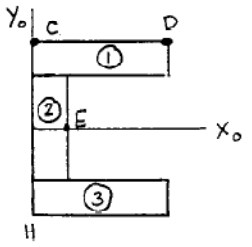
Problem 4.2

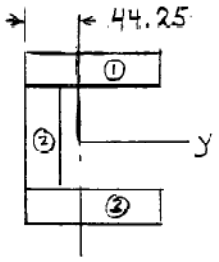
Problem 4.10

4.10 Two equal and opposite couples of magnitude $M = 25$ kN · m are applied to the channel-shaped beam AB. Observing that the couples cause the beam to bend in a horizontal plane, determine the stress at (*a*) point *C*, (*b*) point *D*, (*c*) point *E*.









	A, mm^2	$\bar{x}_o$, mm	$A\bar{x}_o$, mm^3
①	3600	60	216×10^3
②	4320	18	77.76×10^3
③	3600	60	216×10^3
Σ	11520		509.76×10^3

$$\bar{X} = \frac{509.76 \times 10^3}{11520} = 44.25 \text{ mm}$$

$y_C = -44.25 \text{ mm} = -0.04425 \text{ m}$

$y_D = 120 - 44.25 = 75.75 \text{ mm} = 0.07575 \text{ m}$

$y_E = 36 - 44.25 = -8.25 \text{ mm} = -0.00825 \text{ m}$

$d_1 = 60 - 44.25 = 15.75 \text{ mm}$

$d_2 = 44.25 - 18 = 26.25 \text{ mm}$

$d_3 = d_1$

$I_1 = I_3 = \frac{1}{12} b_1 h_1^3 + A_1 d_1^2 = \frac{1}{12}(30)(120)^3 + (3600)(15.75)^2 = 5.2130 \times 10^6 \text{ mm}^4$

$I_2 = \frac{1}{12} b_2 h_2^3 + A_2 d_2^2 = \frac{1}{12}(120)(36)^3 + (4320)(26.25)^2 = 3.4433 \times 10^6 \text{ mm}^4$

$I = I_1 + I_2 + I_3 = 6.5187 \times 10^6 \text{ mm}^4 = 13.8694 \times 10^{-6} \text{ m}^4$

$M = 15 \times 10^3 \text{ N-m}$

(a) Point C: $\sigma_C = -\frac{My_C}{I} = -\frac{(25 \times 10^3)(-0.04425)}{13.8694 \times 10^{-6}} = 79.8 \times 10^6 \text{ Pa}$

$\sigma_C = 79.8 \text{ MPa}$

(b) Point D: $\sigma_D = -\frac{My_D}{I} = -\frac{(25 \times 10^3)(0.07575)}{13.8694 \times 10^{-6}} = -136.5 \times 10^6 \text{ Pa}$

$\sigma_D = -136.5 \text{ MPa}$

(c) Point E: $\sigma_E = -\frac{My_E}{I} = -\frac{(25 \times 10^3)(-0.00825)}{13.8694 \times 10^{-6}} = 14.87 \times 10^6 \text{ Pa}$

$\sigma_E = 14.87 \text{ MPa}$