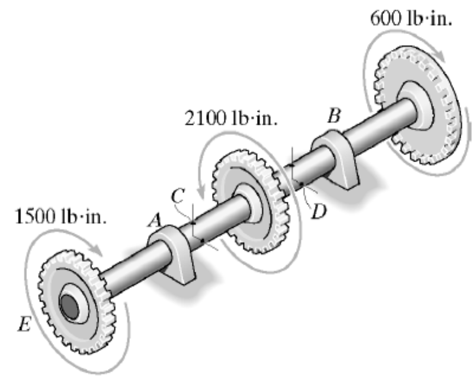
# HW 18 SOLUTIONS

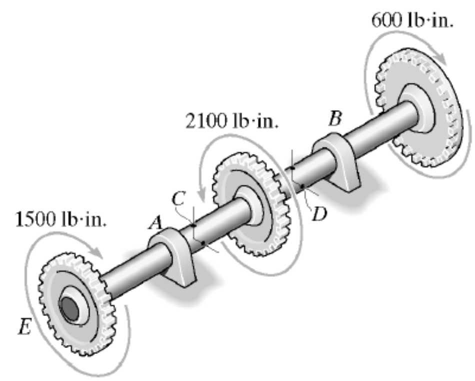
**5–7.** The shaft has an outer diameter of 1.25 in. and an inner diameter of 1 in. If it is subjected to the applied torques as shown, determine the absolute maximum shear stress developed in the shaft. The smooth bearings at *A* and *B* do not resist torque.




$T_{max} = 1500 \text{ lb} \cdot \text{in.}$

$$\tau_{\substack{abs \\ max}} = \frac{Tc}{J} = \frac{1500(0.625)}{\frac{\pi}{2}\left[(0.625)^4 - (0.5)^4\right]} = 6.62 \text{ ksi} \qquad \textbf{Ans}$$

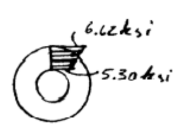
***5–8.** The shaft has an outer diameter of 1.25 in. and an inner diameter of 1 in. If it is subjected to the applied torques as shown, plot the shear-stress distribution acting along a radial line lying within region *EA* of the shaft. The smooth bearings at *A* and *B* do not resist torque.



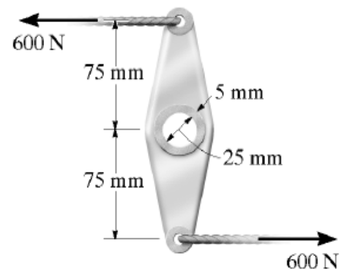

$T = 1500 \text{ lb} \cdot \text{in.}$

$$\tau_{max} = \frac{Tc}{J} = \frac{1500(0.625)}{\frac{\pi}{2}\left[(0.625)^4 - (0.5)^4\right]} = 6.62 \text{ ksi}$$

$$\tau_2 = \frac{T\rho}{J} = \frac{1500(0.5)}{\frac{\pi}{2}\left[(0.625)^4 - (0.5)^4\right]} = 5.30 \text{ ksi}$$



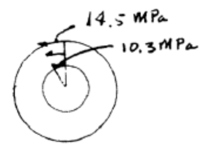
**5–10.** The link acts as part of the elevator control for a small airplane. If the attached aluminum tube has an inner diameter of 25 mm and a wall thickness of 5 mm, determine the maximum shear stress in the tube when the cable force of 600 N is applied to the cables. Also, sketch the shear-stress distribution over the cross section.



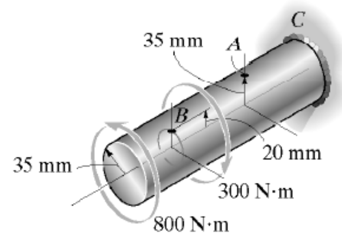

$$T = 600(0.15) = 90\ \text{N}\cdot\text{m}$$

$$\tau_{max} = \frac{Tc}{J} = \frac{90(0.0175)}{\frac{\pi}{2}[(0.0175)^4 - (0.0125)^4]} = 14.5\ \text{MPa} \qquad \textbf{Ans}$$

$$\tau_i = \frac{T\rho}{J} = \frac{90(0.0125)}{\frac{\pi}{2}[(0.0175)^4 - (0.0125)^4]} = 10.3\ \text{MPa}$$

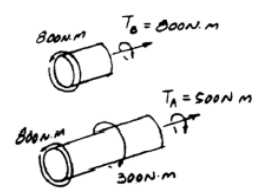


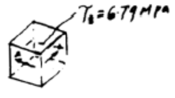

***5–12.** The solid shaft is fixed to the support at *C* and subjected to the torsional loadings shown. Determine the shear stress at points *A* and *B* and sketch the shear stress on volume elements located at these points.

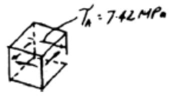



$$\tau_B = \frac{T_B\rho}{J} = \frac{800(0.02)}{\frac{\pi}{2}(0.035^4)} = 6.79\ \text{MPa} \qquad \textbf{Ans}$$

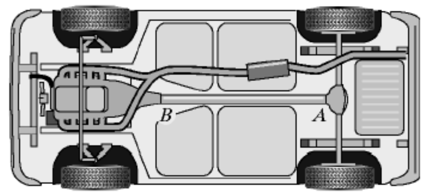
$$\tau_A = \frac{T_A\,c}{J} = \frac{500(0.035)}{\frac{\pi}{2}(0.035^4)} = 7.42\ \text{MPa} \qquad \textbf{Ans}$$



*5–32. The drive shaft $AB$ of an automobile is made of a steel having an allowable shear stress of $\tau_{allow} = 8$ ksi. If the outer diameter of the shaft is 2.5 in. and the engine delivers 200 hp to the shaft when it is turning at 1140 rev/min, determine the minimum required thickness of the shaft's wall.




$$\omega = \frac{1140(2\pi)}{60} = 119.38 \text{ rad/s}$$

$$P = T\omega$$

$$200(550) = T(119.38)$$

$$T = 921.42 \text{ lb} \cdot \text{ft}$$

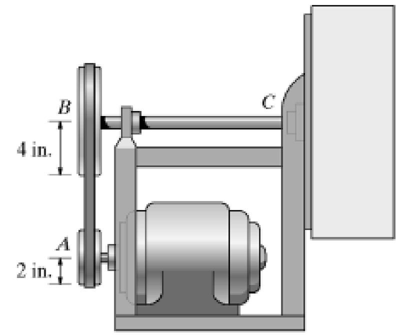
$$\tau_{allow} = \frac{Tc}{J}$$

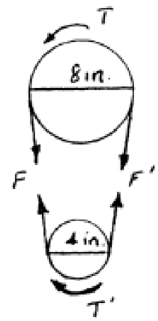
$$8(10^3) = \frac{921.42(12)(1.25)}{\frac{\pi}{2}(1.25^4 - r_i^4)}, \qquad r_i = 1.0762 \text{ in.}$$

$$t = r_o - r_i = 1.25 - 1.0762$$

$$t = 0.174 \text{ in.} \qquad \textbf{Ans}$$

**5–43.** The motor delivers 50 hp while turning at a constant rate of 1350 rpm at $A$. Using the belt and pulley system this loading is delivered to the steel blower shaft $BC$. Determine to the nearest $\frac{1}{8}$ in. the smallest diameter of this shaft if the allowable shear stress for steel if $\tau_{\text{allow}} = 12$ ksi.




$P = T\omega$

$$50(550) = T'(1350 \text{ rev/min})\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$T' = 194.52$ lb · ft

$4(F' - F) = T'$

$4(F' - F) = (194.52)(12)$

$(F' - F) = 583.57$ lb

$T = 8(F' - F)$

$= 8(583.57) = 4668.5$ lb · in

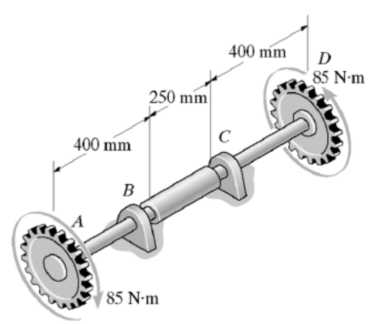
$$\tau_{\text{allow}} = \frac{Tc}{J}; \qquad 12(10^3) = \frac{4668.5c}{\frac{\pi}{2}(c)^4}$$

$c = 0.628$ in.

$d = 1.26$ in. **Ans**

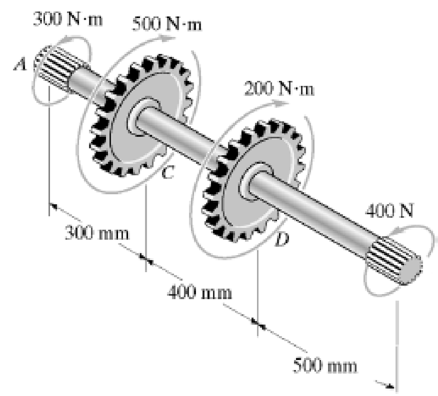
Use $1\frac{3}{8}$ in. – diameter shaft. **Ans**

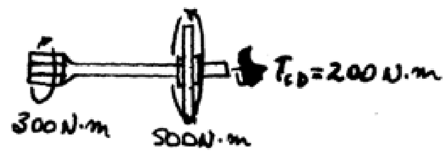
***5–48.** The A-36 steel axle is made from tubes $AB$ and $CD$ and a solid section $BC$. It is supported on smooth bearings that allow it to rotate freely. If the gears, fixed to its ends, are subjected to 85-N · m torques, determine the angle of twist of the end $B$ of the solid section relative to end $C$. The tubes have an outer diameter of 30 mm and an inner diameter of 20 mm. The solid section has a diameter of 40 mm.




$$\phi_{B/C} = \frac{TL}{JG} = \frac{85(0.250)}{\frac{\pi}{2}(0.020)^4(75)(10^9)} = 0.00113 \text{ rad} = 0.0646° \qquad \textbf{Ans}$$

**5–50.** The splined ends and gears attached to the A-36 steel shaft are subjected to the torques shown. Determine the angle of twist of gear $C$ with respect to gear $D$. The shaft has a diameter of 40 mm.

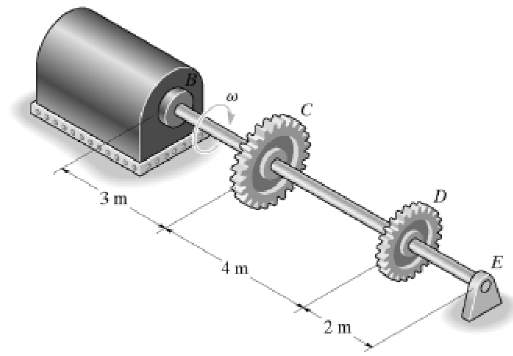


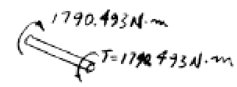

$$\phi_{C/D} = \frac{200(0.4)}{\frac{\pi}{2}(0.02^4)(75)(10^9)}$$

$$= 0.004244 \text{ rad} = 0.243^\circ \qquad \textbf{Ans}$$

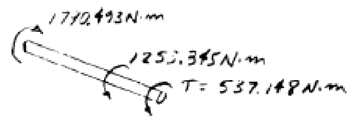
**5–53.** The turbine develops 150 kW of power, which is transmitted to the gears such that $C$ receives 70% and $D$ receives 30%. If the rotation of the 100-mm-diameter A-36 steel shaft is $\omega = 800$ rev/min., determine the absolute maximum shear stress in the shaft and the angle of twist of end $E$ of the shaft relative to $B$. The journal bearing at $E$ allows the shaft to turn freely about its axis.




$P = T\omega;$ $\quad 150(10^3)W = T(800\frac{\text{rev}}{\text{min}})(\frac{1 \text{ min}}{60 \text{ sec}})(\frac{2\pi \text{ rad}}{1 \text{ rev}})$




$$T = 1790.493 \text{ N}\cdot\text{m}$$




$T_C = 1790.493(0.7) = 1253.345 \text{ N}\cdot\text{m}$

$T_D = 1790.493(0.3) = 537.148 \text{ N}\cdot\text{m}$

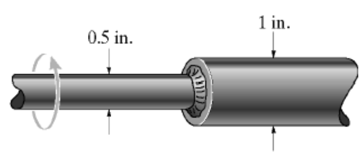
Maximum torque is in region $BC$.

$$\tau_{max} = \frac{Tc}{J} = \frac{1790.493(0.05)}{\frac{\pi}{2}(0.05)^4} = 9.12 \text{ MPa} \qquad \textbf{Ans}$$

$$\phi_{E/B} = \Sigma(\frac{TL}{JG}) = \frac{1}{JG}[1790.493(3) + 537.148(4) + 0]$$

$$= \frac{7520.171}{\frac{\pi}{2}(0.05)^4(75)(10^9)} = 0.0102 \text{ rad} = 0.585° \qquad \textbf{Ans}$$

***5–112.** The shaft is used to transmit 0.8 hp while turning at 450 rpm. Determine the maximum shear stress in the shaft. The segments are connected together using a fillet weld having a radius of 0.075 in.




$$\frac{D}{d} = \frac{1}{0.5} = 2 \qquad \frac{r}{d} = \frac{0.075}{0.5} = 0.15$$

From Fig. 5 - 36, $K = 1.30$.

$$\omega = \frac{450(2\,\pi)}{60} = 47.124 \text{ rad/s}$$

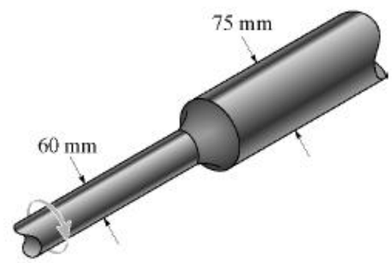
$P = T\omega$

$0.8(550) = T(47.124)$

$T = 9.337 \text{ lb}\cdot\text{ft}$

$$\tau_{max} = K\frac{Tc}{J} = \frac{1.30(9.337)(12)(0.25)}{\frac{\pi}{2}(0.25^4)} = 5.93 \text{ ksi} \qquad \textbf{Ans}$$

**5–115.** The built-up shaft is designed to rotate at 540 rpm. If the radius of the fillet weld connecting the shafts is $r = 7.20$ mm, and the allowable shear stress for the material is $\tau_{allow} = 55$ MPa, determine the maximum power the shaft can transmit.




$$\frac{D}{d} = \frac{75}{60} = 1.25; \qquad \frac{r}{d} = \frac{7.2}{60} = 0.12$$

From Fig. 5 – 36, $K = 1.30$

$$\tau_{max} = K\frac{Tc}{J}; \qquad 55(10^6) = 1.30\left[\frac{T(0.03)}{\frac{\pi}{2}(0.03^4)}\right]; \qquad T = 1794.33 \text{ N}\cdot\text{m}$$

$$\omega = 540\,\frac{\text{rev}}{\text{min}}\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right)\frac{1 \text{ min}}{60 \text{ s}} = 18\,\pi \text{ rad/s}$$

$$P = T\omega = 1794.33(18\pi) = 101466 \text{ W} = 101 \text{ kW}$$ **Ans**