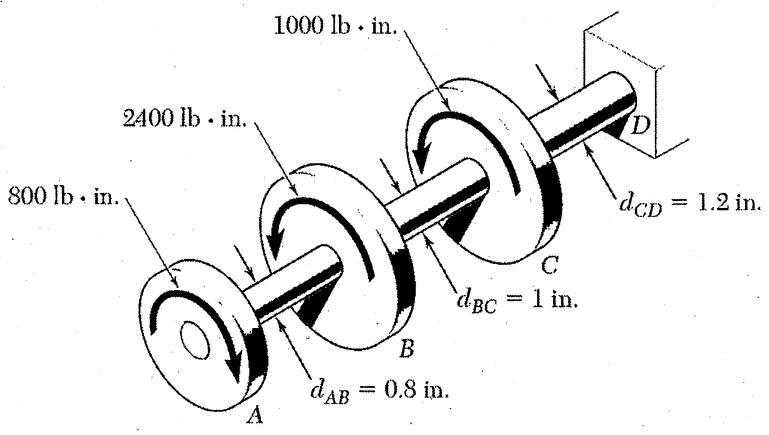
1) GIVEN: Solid steel shaft with pulleys spaced every 6 in and torques as shown.
$G_{steel} = 11.2 \times 10^6$ psi (B10.9)



REQ'D: (a) Torque in each segment

$T_{AB} = -800$ in.lb

$T_{BC} = -800$ in.lb $+ 2400$ in.lb $= 1600$ in.lb

$T_{CD} = 1600$ in.lb $+ 1000$ in.lb $= 2600$ in.lb

(b) Maximum shear stress in shaft. In which segment does it occur?

$$\tau_{AB} = \frac{T_{AB} c_{AB}}{J_{AB}} = \frac{800 \text{ in.lb}(.4 \text{ in})}{\frac{\pi}{32}(.8 \text{ in})^4 = 40.21 \times 10^{-3} \text{ in}^4} = 7.958 \text{ ksi}$$

$$\tau_{BC} = \frac{T_{BC} c_{BC}}{J_{BC}} = \frac{1600 \text{ in.lb}(.5 \text{ in})}{\frac{\pi}{32}(1.0 \text{ in})^4 = 98.17 \times 10^{-3} \text{ in}^4} = 8.148 \text{ ksi}$$

$$\tau_{CD} = \frac{T_{CD} c_{CD}}{J_{CD}} = \frac{2600 \text{ in.lb}(.6 \text{ in})}{\frac{\pi}{32}(1.2 \text{ in})^4 = 203.6 \times 10^{-3} \text{ in}^4} = 7.663 \text{ ksi}$$

$\tau_{max} = 8.15$ ksi IN SEGMENT BC

(c) The angle of twist at end A of the shaft. Indicate direction of twist.

$$\phi_{TOTAL} = \phi_{AB} + \phi_{BC} + \phi_{CD} \quad \text{WHERE} \quad \phi = \frac{TL}{JG}$$

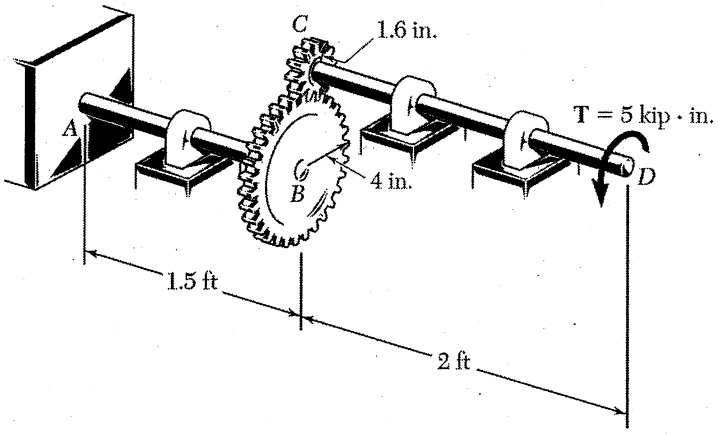
$$= \frac{T_{AB} L_{AB}}{J_{AB} G} + \frac{T_{BC} L_{BC}}{J_{BC} G} + \frac{T_{CD} L_{CD}}{J_{CD} G}$$

$$= \frac{-800 \text{ in.lb}(6 \text{ in})}{40.21 \times 10^{-3} \text{ in}^4 (11.2 \times 10^6 \text{ psi})} + \frac{1600 \text{ in.lb}(6 \text{ in})}{98.17 \times 10^{-3} \text{ in}^4 (11.2 \times 10^6 \text{ psi})} + \frac{2600 \text{ in.lb}(6 \text{ in})}{203.6 \times 10^{-3} (11.2 \times 10^6 \text{ psi})}$$

$$= -0.010658 \text{ rad} + 0.008731 \text{ rad} + 0.006841 \text{ rad}$$

$$= 0.004914 \text{ rad} \quad \text{DEFLECTION AT A}$$

2) GIVEN: ∅2.0in solid steel shafts and gears as shown.
$G_{steel} = 11.2 \times 10^6$ psi



REQ'D: (a) Torque in each segment.

$T_{CD} = \underline{5 \text{ kip·in}}$

$T_{AB} = T_{CD} \times \text{GEAR RATIO}$

$= 5 \text{ kip·in}\left(\frac{4 \text{ in}}{1.6 \text{ in}}\right) = \underline{12.5 \text{ kip·in}}$

(c) Max shear stress in shafts.

$$\tau_{AB} = \frac{T_{AB} c_{AB}}{J_{AB}} = \frac{12.5 \text{ kip·in}(1 \text{in})}{\frac{\pi}{2}(1 \text{in})^4} = \underline{7.96 \text{ ksi}}$$

$$\tau_{CD} = \frac{T_{CD} c_{CD}}{J_{CD}} = \frac{5 \text{ kip·in}(1 \text{in})}{\frac{\pi}{2}(1 \text{in})^4} = \underline{3.183 \text{ ksi}}$$

(b) Angle and direction of twist at points B and D.

$$\phi_B = \frac{T_{AB} L_{AB}}{J_{AB} G} = \frac{(12.5 \text{ kip·in})(1.5 \text{ ft})(12 \text{in/ft})}{\frac{\pi}{2}(1 \text{in})^4 (11.2 \times 10^6 \text{ psi})} = \underline{.012790 \text{ rad}}$$

$$\phi_{CD} = \frac{T_{CD} L_{CD}}{J_{CD} G} = \frac{(5 \text{ kip·in})(2 \text{ft})(12 \text{in/ft})}{\frac{\pi}{2}(1 \text{in})^4 (11.2 \times 10^6 \text{ psi})} = \underline{.006821 \text{ rad}}$$

$$\phi_D = .012790 \text{ rad}\left(\frac{4 \text{in}}{1.6 \text{in}}\right) + .006821 \text{ rad}$$

$$= .031973 + .006821 \text{ rad}$$

$$= \underline{.03879 \text{ rad}} \Rightarrow \underline{2.22°}$$

ALLOW TORSIONAL DEFLECTION

GENERAL – .001 - .01 °/in
MED PREC. – .00002 - .0004 °/in
PRECISION – .000001 - .00002 °/in