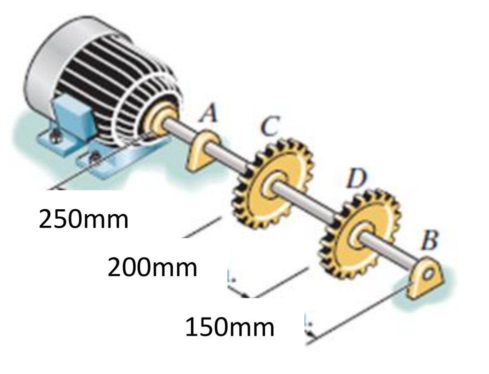
5-58. The motor delivers 33 kW to the 304 stainless steel solid shaft while it rotates at 20 Hz. The shaft has a diameter of 37.5 mm. and is supported on smooth bearings at *A* and *B*, which allow free rotation of the shaft. The gears *C* and *D* fixed to the shaft remove 20 kW and 12 kW, respectively. Determine the absolute maximum stress in the shaft and the angle of twist of gear *C* with respect to gear *D.*



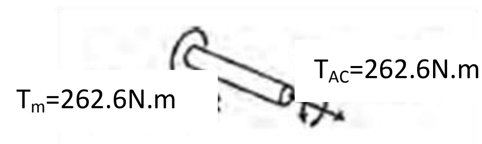
$$T_m = \frac{33*1000}{2\pi*20} = 262.61\ N.m, \quad T_C = \frac{20*1000}{2\pi*20} = 159.15\ N.m,$$

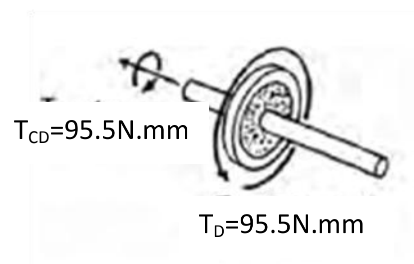
$$T_D = \frac{12*1000}{2\pi*20} = 95.5\ N.m,$$

$$T_{max} = T_{AC} = 262.61\ N.m,$$

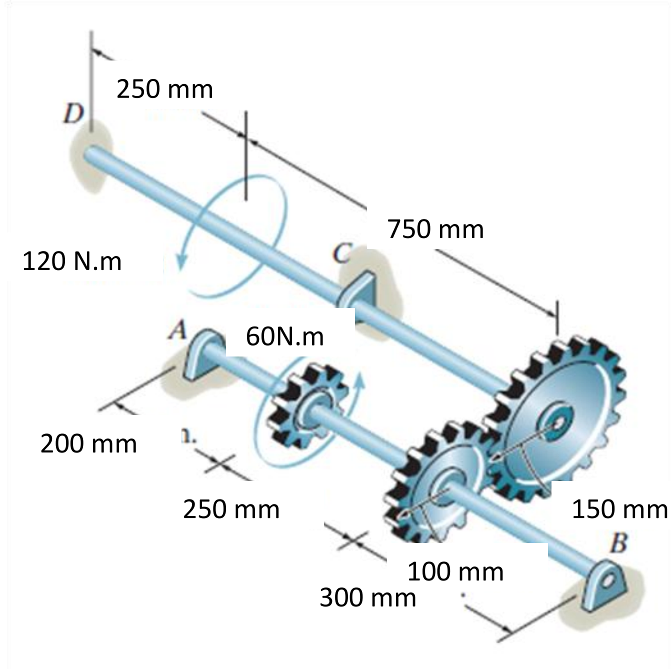
$$\tau_{max} = \frac{T_{max}*C}{J} = \frac{262.61*1000*\frac{37.5}{2}}{\frac{\pi}{2}*(\frac{37.5}{2})^4} = \mathbf{25.36\ MPa} \quad \textbf{Ans.}$$

$$\varphi_{C/D} = \frac{T_{CD}*L_{CD}}{JG} = \frac{95.5*1000*200}{\frac{\pi}{2}*(\frac{37.5}{2})^4*75*1000} = \mathbf{0.001311\ Rad.} \quad \textbf{Ans}$$





5.62 The two shafts are made of A-36 steel. Each has a diameter of 25 mm., and they are supported by bearings at *A*, *B*, and *C*, which allow free rotation. If the support at *D* is fixed, determine the angle of twist of end *A* when the torques is applied to the assembly as shown.



Internal Torque: As shown on FBD.

Angle of Twist:

$$\phi_E = \sum \frac{TL}{JG}$$

$$= \frac{1}{\frac{\pi}{2}(12.5)^4 * 75 * 1000}[-90 * 1000 * 750 + 30 * 1000 * 250] =$$

$$-0.02086 = \mathbf{0.02086} \quad \boldsymbol{Rad},$$

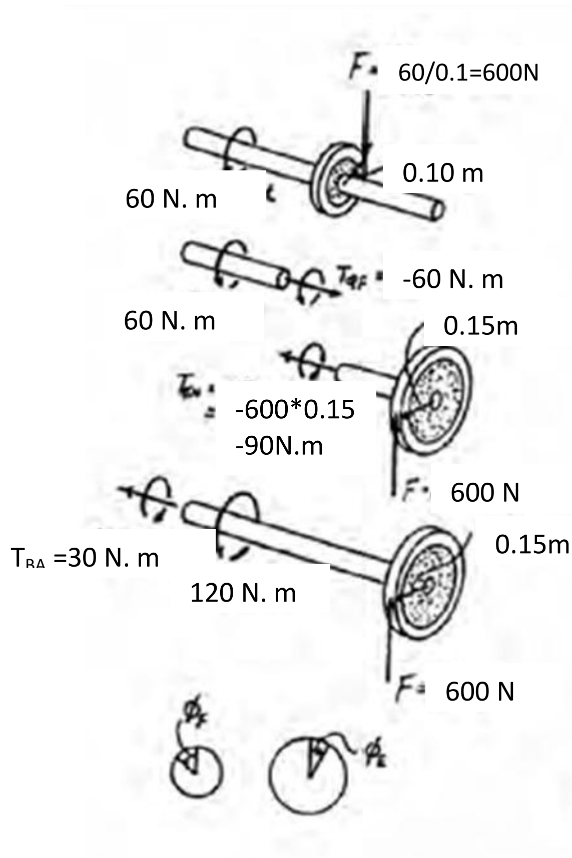
$$\varphi_F = \frac{6}{4}\varphi_E = \frac{6}{4} * 0.02086 = \mathbf{0.03129} \quad \boldsymbol{Rad}.$$

$$\varphi_{A/F} = \frac{-60 * 1000 * 250}{\frac{\pi}{2}(12.5)^4 * 75 * 1000} = -0.0052$$

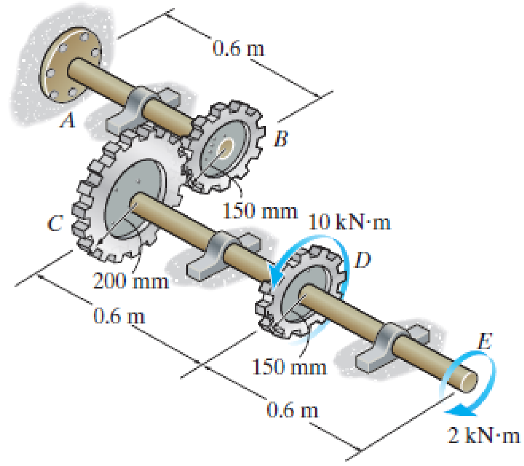
$$= \mathbf{0.0052} \; \boldsymbol{Rad}.$$

$$\varphi_A = \varphi_F + \varphi_{A/F} = 0.03129 + 0.0052$$

$$= \mathbf{0.03651} \; \boldsymbol{Rad}. \qquad \boldsymbol{Ans}$$



5–70. The shafts are made of A-36 steel and each has a diameter of 80 mm. Determine the angle of twist of gear D.



Equilibrium: Referring to the free-body diagram of shaft CDE shown in Fig. a,

$$\Sigma M_x = 0; \quad 10(10^3) - 2(10^3) - F(0.2) = 0 \qquad F = 40(10^3)\text{ N}$$

Internal Loading: Referring to the free - body diagram of gear B, Fig. b,

$$\Sigma M_x = 0; \quad -T_{AB} - 40(10^3)(0.15) = 0 \qquad T_{AB} = -6(10^3)\text{ N}\cdot\text{m}$$

Referring to the free - body diagram of gear D, Fig. c,

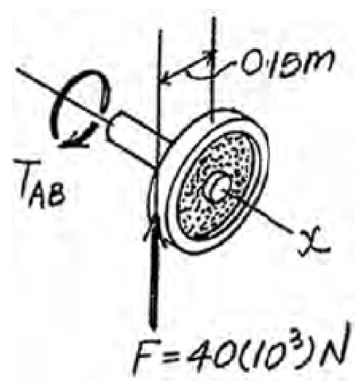
$$\Sigma M_x = 0; \quad 10(10^3) - 2(10^3) - T_{CD} = 0 \qquad T_{CD} = 8(10^3)\text{ N}\cdot\text{m}$$

Angle of Twist: The polar moment of inertia of the shafts are $J = \frac{\pi}{2}\left(0.04^4\right) = 1.28(10^{-6})\pi\text{ m}^4$. We have

$$\phi_B = \frac{T_{AB}L_{AB}}{JG_{st}} = \frac{-6(10^3)(0.6)}{1.28(10^{-6})\pi(75)(10^9)} = -0.01194\text{ rad} = 0.01194\text{ rad}$$

Using the gear ratio,

$$\phi_C = \phi_B\left(\frac{r_B}{r_C}\right) = 0.01194\left(\frac{150}{200}\right) = 0.008952\text{ rad}$$



(b)

Also,

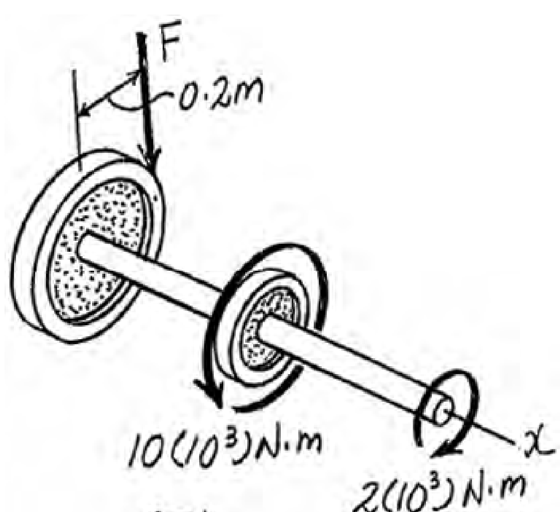
$$\phi_{D/C} = \frac{T_{CD}L_{CD}}{JG_{st}} = \frac{8(10^3)(0.6)}{1.28(10^{-6})\pi(75)(10^9)} = 0.01592\text{ rad}$$

Thus,

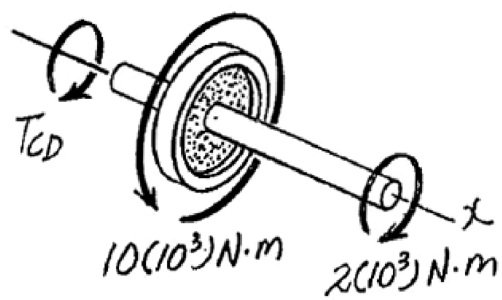
$$\phi_D = \phi_C + \phi_{D/C}$$

$$\phi_D = 0.008952 + 0.01592$$

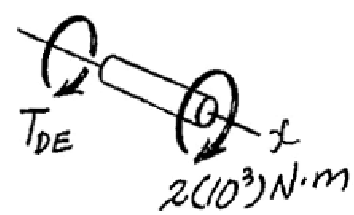
$$= 0.02487\text{ rad} = 1.42^\circ \qquad \textbf{Ans.}$$



(a)

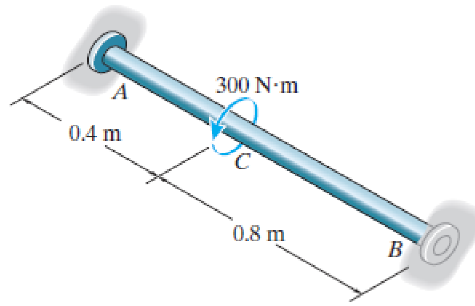


(c)



(d)

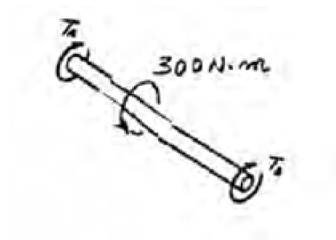
•**5–77.** The A-36 steel shaft has a diameter of 50 mm and is fixed at its ends A and B. If it is subjected to the torque, determine the maximum shear stress in regions AC and CB of the shaft.



Equilibrium:

$$T_A + T_B - 300 = 0 \qquad [1]$$

Compatibility:



$$\phi_{C/A} = \phi_{C/B}$$

$$\frac{T_A(0.4)}{JG} = \frac{T_B(0.8)}{JG}$$

$$T_A = 2.00T_B \qquad [2]$$

Solving Eqs. [1] and [2] yields:

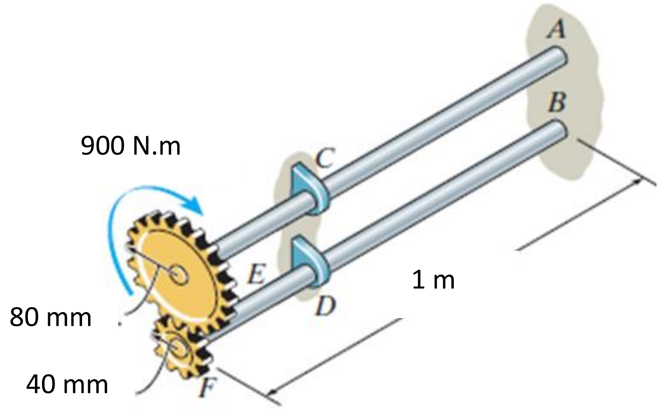
$$T_A = 200 \text{ N}\cdot\text{m} \qquad T_B = 100 \text{ N}\cdot\text{m}$$

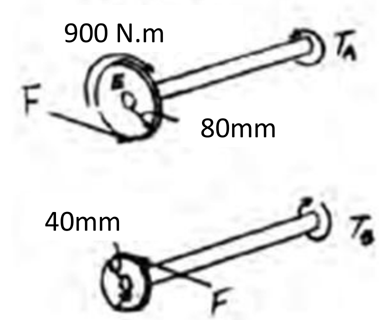
Maximum Shear stress:

$$(\tau_{AC})_{max} = \frac{T_A c}{J} = \frac{200(0.025)}{\frac{\pi}{2}(0.025^4)} = 8.15 \text{ MPa} \qquad \textbf{Ans.}$$

$$(\tau_{CB})_{max} = \frac{T_B c}{J} = \frac{100(0.025)}{\frac{\pi}{2}(0.025^4)} = 4.07 \text{ MPa} \qquad \textbf{Ans.}$$

5–90. The two 1-m-long shafts are made of 2014-T6 aluminum. Each has a diameter of 30 mm. and they are connected using the gears fixed to their ends. Their other ends are attached to fixed supports at *A* and *B*. They are also supported by bearings at *C* and *D*, which allow free rotation of the shafts along their axes. If a torque of 900 N.m is applied to the top gear as shown, determine the maximum shear stress in each shaft.





$T_A +$ F(80) - 900* 1000 = 0 (1)

$T_B -$ F(40) = 0 (2)

From Eqs. (1) and (2)

$T_A + 2T_B$ - 900* 1000 = 0 (3)

$4(\phi_E) = 2(\phi_F); \qquad \phi_E = 0.5\phi_F$

$\frac{T_A L}{JG} = 0.5\left(\frac{T_B L}{JG}\right); \qquad T_A = 0.5T_B$ (4)

Solving Eqs. (3) and (4) yields:

T_A = 180000 N.mm ; T_B = 360000 N.mm

$$(\tau_{BD})_{max} = \frac{T_B c}{J} = \frac{360000 * 15}{\frac{\pi}{2}(15)^4} = 67.9\ MPa. \qquad Ans.$$

$$(\tau_{AC})_{max} = \frac{T_A c}{J} = \frac{180000 * 15}{\frac{\pi}{2}(15)^4} = 33.95\ MPa. \qquad Ans.$$