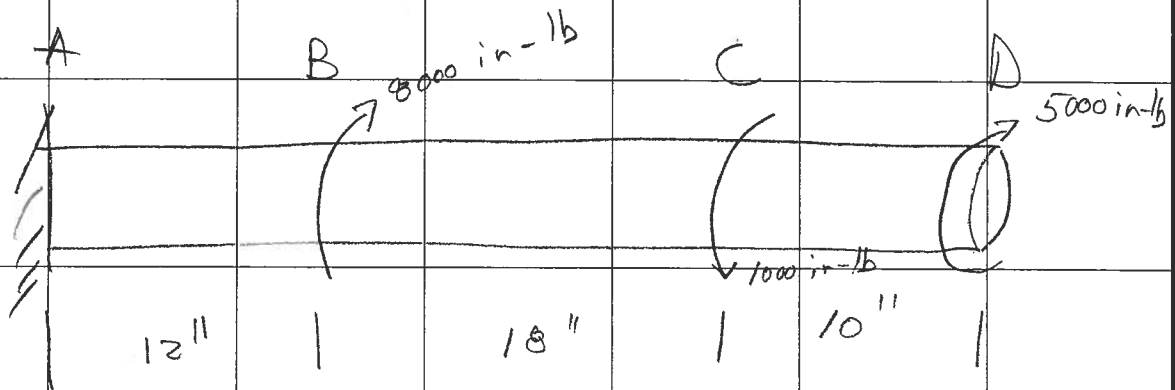
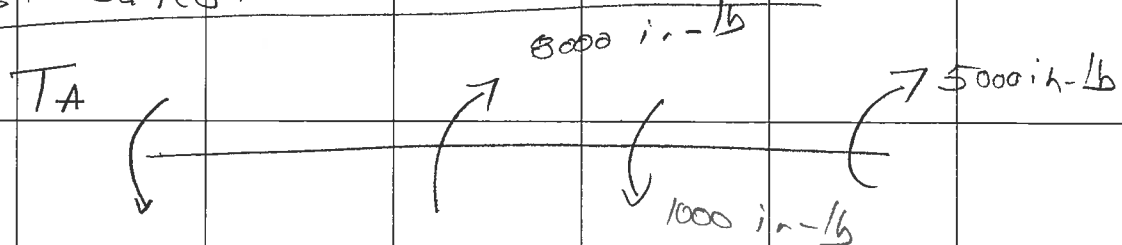


A solid steel shaft is subjected to the torques shown. The constant diameter of the shaft is 2 in. Calculate the maximum shearing stress in the shaft and the angle of twist between A and D. Assume $G_{stl} = 11 \times 10^6 \frac{lb}{in^2}$.



First Calculate Reaction at A



$$\sum T = 0$$

$$T_A - 8000 + 1000 - 5000 = 0$$

$$\underline{T_A = 12000 \text{ in-lb}}$$

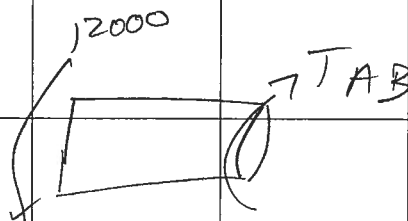
Calculate I_P

$$I_P = \frac{\pi}{2} (r_o^4 - r_i^4) \quad (3)$$

$$I_P = \frac{\pi}{2} \left(\frac{2}{2}^4 \right) \quad (4)$$

$$I_P = 1.571 \text{ in}^4 \quad (5)$$

Section AB



$$\sum T = 0$$

$$12000 - T_{AB} = 0 \quad (6)$$

$$T_{AB} = 12000 \text{ in-lb} \quad (7)$$

$$\tau_{AB} = \frac{T_{AB} r_{AB}}{I_{PAB}} \quad (8)$$

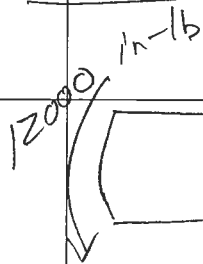
$$\tau_{AB} = \frac{12000 \text{ in-lb} (1 \text{ in})}{1.571 \text{ in}^4} \quad (9)$$

$$\tau_{AB} = 7,638 \frac{\text{lb}}{\text{in}^2} \quad (10)$$

$$(11) \quad \phi_{AB} = \frac{T_{AB} L_{AB}}{I_{PAB} G_{AB}} = \frac{(12000 \text{ in-lb}) (12 \text{ in})}{(1.571 \text{ in}^4) (11 \times 10^6 \frac{\text{lb}}{\text{in}^2})}$$

$$(12) \quad \phi_{AB} = 8.33 \times 10^{-3} \text{ radians}$$

Section BC



$$\sum T = 0$$

$$12000 - 8000 - T_{BC} = 0 \quad (13)$$

$$T_{BC} = 4000 \text{ in-lb} \quad (14)$$

$$\tau_{BC} = \frac{T_{BC} r_{BC}}{J_{PBC}} \quad (15)$$

$$\tau_{BC} = \frac{(4000 \text{ in-lb})(1 \text{ in})}{1.571 \text{ in}^4} \quad (16)$$

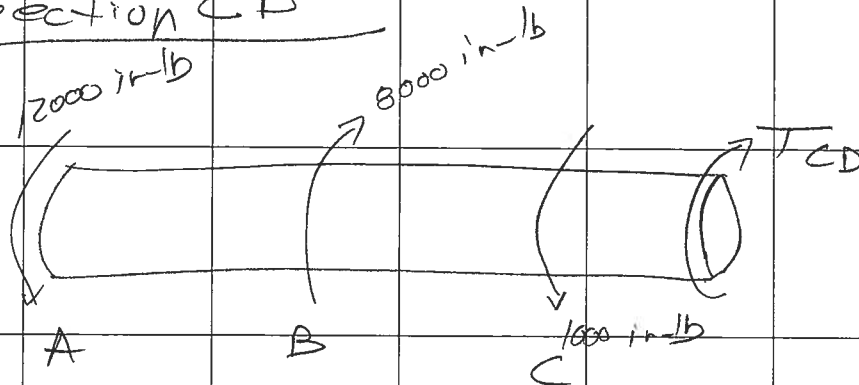
$$\tau_{BC} = 2,546 \frac{\text{lb}}{\text{in}^2} \quad (17)$$

$$\phi_{BC} = \frac{T_{BC} L_{BC}}{J_{PBC} G_{BC}} \quad (18)$$

$$\phi_{BC} = \frac{(4000 \text{ in-lb})(18 \text{ in})}{(1.571 \text{ in}^4)(11 \times 10^6 \frac{\text{lb}}{\text{in}^2})} \quad (19)$$

$$\phi_{BC} = 4.17 \times 10^{-3} \text{ radians} \quad (20)$$

Section CD



$$\sum T = 0$$

$$12,000 - 8,000 + 1,000 - T_{CD} = 0 \quad (21)$$

$$T_{CD} = 5,000 \text{ in-lb} \quad (22)$$

$$\tau_{CD} = \frac{T_{CD} r_{CD}}{I_{PCD}} \quad (23)$$

$$\tau_{CD} = \frac{(5,000 \text{ in-lb})(1 \text{ in})}{1.571 \text{ in}^4} \quad (24)$$

$$\tau_{CD} = 3,183 \frac{\text{lb}}{\text{in}^2} \quad (25)$$

$$(26) \quad \phi_{CD} = \frac{T_{CD} L_{CD}}{I_{PCD} G_{CD}} = \frac{(5,000 \text{ in-lb})(10 \text{ in})}{(1.571 \text{ in}^4)(11 \times 10^6 \frac{\text{lb}}{\text{in}^2})}$$

$$(27) \quad \phi_{CD} = 2.89 \times 10^{-3} \text{ radians}$$

The maximum shearing stress in the shaft occurs in section AB

$$\tau_{max} = \tau_{AB} = 7,638 \frac{\text{lb}}{\text{in}^2} \quad (28)$$

The total angle of twist is given as follows.

$$\phi_{AD} = \phi_{AB} + \phi_{BC} + \phi_{CD} \quad (29)$$

$$\phi_{AD} = 8.33 \times 10^{-3} + 1.17 \times 10^{-3} + 2.89 \times 10^{-3} \quad (30)$$

$$\phi_{AD} = 1.54 \times 10^{-2} \text{ rad} \quad (31)$$

$$\left(1.54 \times 10^{-2} \right) \left(\frac{180}{\pi} \right) = .882 \text{ deg} \quad (32)$$