8–1 A spherical gas tank has an inner radius of $r = 1.5$ m. If it is subjected to an internal pressure of $p = 300$ kPa, determine its required thickness if the maximum normal stress is not to exceed 12 MPa.

$$\sigma_{allow} = \frac{p\,r}{2\,t}; \qquad 12(10^6) = \frac{300(10^3)(1.5)}{2\,t}$$

$t = 0.0188$ m $= 18.8$ mm **Ans**

8–2 A pressurized spherical tank is to be made of 0.5-in.-thick steel. If it is subjected to an internal pressure of p = 200 psi, determine its outer radius if the maximum normal stress is not to exceed 15 ksi.

$$\sigma_{\text{allow}} = \frac{p\,r}{2\,t}; \qquad 15(10^3) = \frac{200\,r_i}{2(0.5)}$$

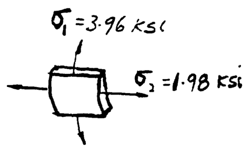
$$r_i = 75 \text{ in.}$$

$$r_o = 75 \text{ in.} + 0.5 \text{ in.} = 75.5 \text{ in.}$$ **Ans**

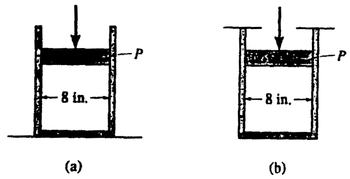
8-3. The tank of a cylindrical air compressor is subjected to an internal pressure of 90 psi. If the internal diameter of the tank is 22 in., and the wall thickness is 0.25 in., determine the stress components acting at a point. Draw a volume element of the material at this point, and show the results on the element.

$$\sigma_1 = \frac{p\,r}{t} = \frac{90\,(11)}{0.25} = 3960 \text{ psi} = 3.96 \text{ ksi} \qquad \textbf{Ans}$$

$$\sigma_2 = \frac{p\,r}{2\,t} = \frac{90(11)}{2(0.25)} = 1980 \text{ psi} = 1.98 \text{ ksi} \qquad \textbf{Ans}$$



•8–4 The thin-walled cylinder can be supported in one or two ways as shown. Determine the state of stress in the wall of the cylinder for both cases if the piston P causes the internal pressure to be 65 psi. The wall has a thickness of 0.25 in. and the inner diameter of the cylinder is 8 in.



Case (a) :

$\sigma_1 = \frac{pr}{t};$ $\sigma_1 = \frac{65(4)}{0.25} = 1.04 \text{ ksi}$ **Ans**

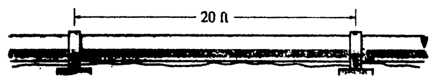
$\sigma_2 = 0$ **Ans**

Case (b) :

$\sigma_1 = \frac{pr}{t};$ $\sigma_1 = \frac{65(4)}{0.25} = 1.04 \text{ ksi}$ **Ans**

$\sigma_2 = \frac{pr}{2t};$ $\sigma_2 = \frac{65(4)}{2(0.25)} = 520 \text{ psi}$ **Ans**

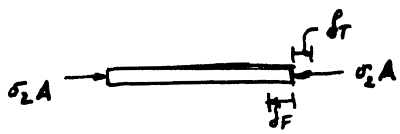
8–5 The gas pipe line is supported every 20 ft by concrete piers and also lays on the ground. If there are rigid retainers at the piers that hold the pipe fixed, determine the longitudinal and hoop stress in the pipe if the temperature rises 60°F from the temperature at which it was installed. The gas within the pipe is at a pressure of 600 lb/in². The pipe has an inner diameter of 20 in. and thickness of 0.25 in. The material is A-36 steel.



Require,

$$\delta_F = \delta_T; \qquad \delta_F = \frac{PL}{AE} = \frac{\sigma L}{E}, \qquad \delta_T = \alpha \Delta T L$$

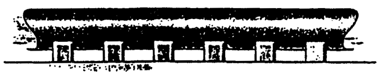
$$\frac{\sigma_2 (20)(12)}{29(10^6)} = (6.60)(10^{-6})(60)(20)(12)$$



$\sigma_2 = 11.5$ ksi **Ans**

$$\sigma_1 = \frac{pr}{t} = \frac{600(10)}{0.25} = 24 \text{ ksi}$$ **Ans**

8-6. The open-ended polyvinyl chloride pipe has an inner diameter of 4 in. and thickness of 0.2 in. If it carries flowing water at 60 psi pressure, determine the state of stress in the walls of the pipe.

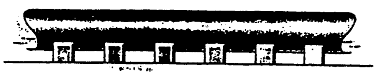


$$\sigma_1 = \frac{p\,r}{t} = \frac{60(2)}{0.2} = 600 \text{ psi} \qquad \textbf{Ans}$$

$$\sigma_2 = 0 \qquad \textbf{Ans}$$

There is no stress component in the longitudinal direction since the pipe has open ends.

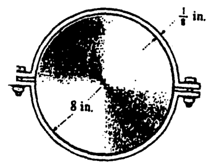
8-7. If the flow of water within the pipe in Prob. 8–6 is stopped due to the closing of a valve, determine the state of stress in the walls of the pipe. Neglect the weight of the water. Assume the supports only exert vertical forces on the pipe.



$$\sigma_1 = \frac{p\,r}{t} = \frac{60(2)}{0.2} = 600\text{ psi} \qquad \textbf{Ans}$$

$$\sigma_2 = \frac{p\,r}{2\,t} = \frac{60(2)}{2(0.2)} = 300\text{ psi} \qquad \textbf{Ans}$$

***8-8.** The A-36-steel band is 2 in. wide and is secured around the smooth rigid cylinder. If the bolts are tightened so that the tension in them is 400 lb, determine the normal stress in the band, the pressure exerted on the cylinder, and the distance half the band stretches.



$$\sigma_1 = \frac{400}{2(1/8)(1)} = 1600 \text{ psi}$$

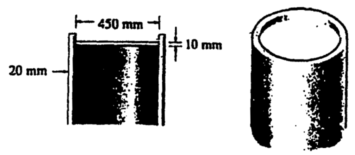
$$\sigma_1 = \frac{pr}{t}; \qquad 1600 = \frac{p(8)}{(1/8)}$$

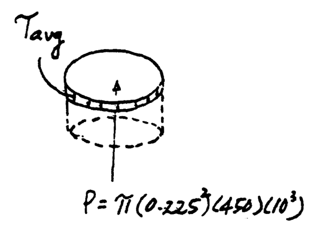
$$p = 25 \text{ psi} \qquad \textbf{Ans}$$

$$\varepsilon_1 = \frac{\sigma_1}{E} = \frac{1600}{29(10^6)} = 55.1724(10^{-6})$$

$$\delta = \varepsilon_1 L = 55.1724(10^{-6})(\pi)(8 + \frac{1}{16}) = 0.00140 \text{ in.} \qquad \textbf{Ans}$$

8-9. A pressure-vessel head is fabricated by gluing the circular plate to the end of the vessel as shown. If the vessel sustains an internal pressure of 450 kPa, determine the average shear stress in the glue and the state of stress in the wall of the vessel.





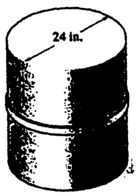
$+\uparrow \Sigma F_y = 0; \quad \pi(0.225)^2 450(10^3) - \tau_{avg}(2\pi)(0.225)(0.01) = 0;$

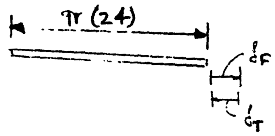
$\tau_{avg} = 5.06 \text{ MPa}$ **Ans**

$$\sigma_1 = \frac{p\,r}{t} = \frac{450(10^3)(0.225)}{0.02} = 5.06 \text{ MPa} \quad \textbf{Ans}$$

$$\sigma_2 = \frac{p\,r}{2\,t} = \frac{450(10^3)(0.225)}{2(0.02)}\ 2.53 \text{ MPa} \quad \textbf{Ans}$$

8–10. An A-36-steel hoop has an inner diameter of 23.99 in., thickness of 0.25 in., and width of 1 in. If it and the 24-in.-diameter rigid cylinder have a temperature of 65° F, determine the temperature to which the hoop should be heated in order for it to just slip over the cylinder. What is the pressure the hoop exerts on the cylinder, and the tensile stress in the ring when it cools back down to 65° F?





$$\delta_T = \alpha \Delta T L$$

$$\pi(24) - \pi(23.99) = 6.60(10^{-6})(T_1 - 65)(\pi)(23.99)$$

$$T_1 = 128.16^\circ F = 128^\circ \quad \textbf{Ans}$$

Cool down :

$$\delta_F = \delta_T$$

$$\frac{FL}{AE} = \alpha \Delta T L$$

$$\frac{F(\pi)(24)}{(1)(0.25)(29)(10^6)} = 6.60(10^{-6})(128.16 - 65)(\pi)(24)$$

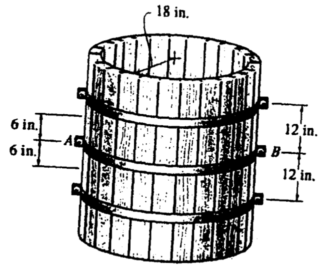
$$F = 3022.21 \text{ lb}$$

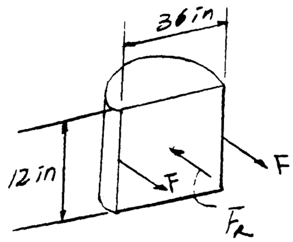
$$\sigma_1 = \frac{F}{A}; \qquad \sigma_1 = \frac{3022.21}{(1)(0.25)} = 12\,088 \text{ psi} = 12.1 \text{ ksi} \quad \textbf{Ans}$$

$$\sigma_1 = \frac{pr}{t}; \qquad 12\,088 = \frac{p(12)}{(0.25)}$$

$$p = 252 \text{ psi} \quad \textbf{Ans}$$

8–11 The staves or vertical members of the wooden tank are held together using semicircular hoops having a thickness of 0.5 in. and a width of 2 in. Determine the normal stress in hoop AB if the tank is subjected to an internal gauge pressure of 2 psi and this loading is transmitted directly to the hoops. Also, if 0.25-in.-diameter bolts are used to connect each hoop together, determine the tensile stress in each bolt at A and B. Assume hoop AB supports the pressure loading within a 12-in. length of the tank as shown.





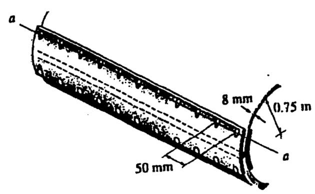
$F_R = 2(36)(12) = 864$ lb

$\Sigma F = 0;\quad 864 - 2F = 0;\ F = 432$ lb

$$\sigma_h = \frac{F}{A_h} = \frac{432}{0.5(2)} = 432 \text{ psi}$$ **Ans.**

$$\sigma_b = \frac{F}{A_b} = \frac{432}{\frac{\pi}{4}(0.25)} = 8801 \text{ psi} = 8.80 \text{ ksi}$$ **Ans.**

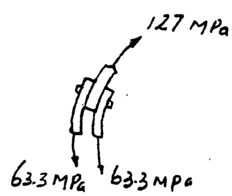
***8-12.** A boiler is constructed of 8-mm steel plates that are fastened together at their ends using a butt joint consisting of two 8-mm cover plates and rivets having a diameter of 10 mm and spaced 50 mm apart as shown. If the steam pressure in the boiler is 1.35 MPa, determine (a) the circumferential stress in the boiler's plate apart from the seam, (b) the circumferential stress in the outer cover plate along the rivet line *a–a*, and (c) the shear stress in the rivets.



a) $\sigma_1 = \frac{p\,r}{t} = \frac{1.35(10^6)(0.75)}{0.008} = 126.56\,(10^6) = 127\text{ MPa}$ **Ans**

b) $126.56\,(10^6)(0.05)(0.008) = \sigma_1'(2)(0.04)(0.008)$

$\sigma_1' = 79.1\text{MPa}$ **Ans**

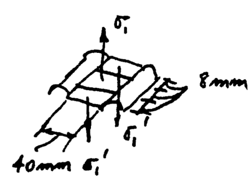


c) From FBD (a)

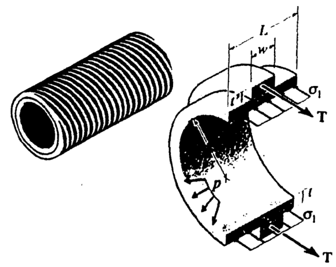
$+\uparrow \Sigma F_y = 0;\quad F_b - 79.1(10^6)[(0.008)(0.04)] = 0$

$F_b = 25.3\text{ kN}$

$(\tau_{avg})_b = \frac{F_b}{A} = \frac{25312.5}{\frac{\pi}{4}(0.01)^2} = 322\text{ MPa}$ **Ans**



8–13 In order to increase the strength of the pressure vessel, filament winding of the same material is wrapped around the circumference of the vessel as shown. If the pretension in the filament is T, and the vessel is subjected to an internal pressure p, determine the hoop stresses in the filament and in the wall of the vessel. Use the free-body diagram shown, and assume the filament winding has a thickness t' and width w for every length L of the vessel.



$$\sigma_{fil} = \frac{T}{t'w}$$

Equilibrium over entire length of the cylinder without internal pressure p.

$$-2\sigma_1'(L)(t) + 2T\left(\frac{L}{w}\right) = 0$$

$$\sigma_1' = \frac{T}{w\,t}$$

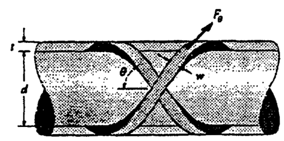
After applying the internal pressure p, the stress in the filament is

$$\sigma_{fil} = \frac{p\,r}{(t + t')} + \frac{T}{w\,t} \qquad \textbf{Ans}$$

And for the cylinder ,

$$\sigma_1 = \frac{p\,r}{(t + t')} - \frac{T}{w\,t} \qquad \textbf{Ans}$$

8–14. A closed-ended pressure vessel is fabricated by cross winding glass filaments over a mandrel, so that the wall thickness t of the vessel is composed entirely of filament and an epoxy binder as shown. Consider a segment of the vessel of width w and wrapped at an angle θ. If the vessel is subjected to an internal pressure p, show that the force in the segment is $F_\theta = \sigma_0 wt$, where σ_0 is the stress in the filaments. Also, show that the stresses in the hoop and longitudinal directions are $\sigma_h = \sigma_0 \sin^2\theta$ and $\sigma_l = \sigma_0 \cos^2\theta$, respectively. At what angle θ (optimum winding angle) would the filaments have to be wound so that the hoop and longitudinal stresses are equivalent?



The Hoop and Longitudinal Stresses : Applying Eq.8 – 1 and Eq.8 – 2

$$\sigma_1 = \frac{pr}{t} = \frac{p\left(\frac{d}{2}\right)}{t} = \frac{pd}{2t}$$

$$\sigma_2 = \frac{pr}{2t} = \frac{p\left(\frac{d}{2}\right)}{2t} = \frac{pd}{4t}$$

The Hoop and Longitudinal Force for Filament :

$$F_h = \sigma_1 A = \frac{pd}{2t}\left(\frac{w}{\sin\theta}t\right) = \frac{pdw}{2\sin\theta}$$

$$F_l = \sigma_2 A = \frac{pd}{4t}\left(\frac{w}{\cos\theta}t\right) = \frac{pdw}{4\cos\theta}$$

Hence,

$$F_\theta = \sqrt{F_h^2 + F_l^2}$$
$$= \sqrt{\left(\frac{pdw}{2\sin\theta}\right)^2 + \left(\frac{pdw}{4\cos\theta}\right)^2}$$
$$= \frac{pdw}{4}\sqrt{\frac{4}{\sin^2\theta} + \frac{1}{\cos^2\theta}}$$
$$= \frac{pdw}{4}\sqrt{\frac{4\cos^2\theta + \sin^2\theta}{\sin^2\theta\cos^2\theta}}$$
$$= \frac{pdw}{2\sqrt{2}\sin 2\theta}\sqrt{3\cos 2\theta + 5}$$

$$\sigma_\theta = \frac{F_\theta}{A} = \frac{\frac{pdw}{2\sqrt{2}\sin 2\theta}\sqrt{3\cos 2\theta + 5}}{wt}$$
$$= \frac{pd}{2\sqrt{2}t}\left(\frac{\sqrt{3\cos 2\theta + 5}}{\sin 2\theta}\right) \qquad (Q.E.D.)$$

$\frac{d\sigma_\theta}{d\theta} = 0$ when σ_θ is minimum.

$$\frac{d\sigma_\theta}{d\theta} = \frac{pd}{2\sqrt{2}t}\left[-\frac{2\cos 2\theta}{\sin^2 2\theta}\left(\sqrt{3\cos 2\theta + 5}\right) - \frac{3}{\sqrt{3\cos 2\theta + 5}}\right] = 0$$

$$\frac{2\cos 2\theta}{\sin^2 2\theta}\left(\sqrt{3\cos 2\theta + 5}\right) + \frac{3}{\sqrt{3\cos 2\theta + 5}} = 0$$

$$\left(\sqrt{3\cos 2\theta + 5}\right)\left(\frac{2\cos\theta}{\sin^2 2\theta} + \frac{3}{3\cos 2\theta + 5}\right) = 0$$

$$\left(\sqrt{3\cos 2\theta + 5}\right)\left[\frac{3\cos^2 2\theta + 10\cos 2\theta + 3}{\sin^2 2\theta(3\cos 2\theta + 5)}\right] = 0$$

However, $\sqrt{3\cos 2\theta + 5} \neq 0$. Therefore,

$$\frac{3\cos^2 2\theta + 10\cos 2\theta + 3}{\sin^2 2\theta(3\cos 2\theta + 5)} = 0$$

$$3\cos^2 2\theta + 10\cos 2\theta + 3 = 0$$

$$\cos 2\theta = \frac{-10 \pm \sqrt{10^2 - 4(3)(3)}}{2(3)}$$

$$\cos 2\theta = -0.3333$$

$$\theta = 54.7^\circ \qquad \textbf{Ans}$$

Force in θ Direction : Consider a portion of the cylinder. For a filament wire the cross - sectional area is $A = wt$, then

$$F_\theta = \sigma_0 w t \qquad (Q.E.D.)$$

Hoop Stress : The force in hoop direction is $F_h = F_\theta \sin\theta = \sigma_0 wt\sin\theta$ and the area is $A = \frac{wt}{\sin\theta}$. Then due to the internal pressure p,

$$\sigma_h = \frac{F_h}{A} = \frac{\sigma_0 wt\sin\theta}{wt/\sin\theta}$$
$$= \sigma_0 \sin^2\theta \qquad (Q.E.D.)$$

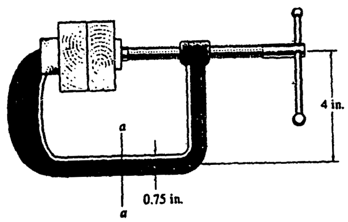
Longitudinal Stress : The force in the longitudinal direction is $F_l = F_\theta\cos\theta = \sigma_0 wt\cos\theta$ and the area is $A = \frac{wt}{\cos\theta}$. Then due to the internal pressure p,

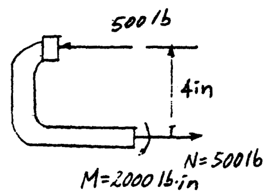
$$\sigma_l = \frac{F_h}{A} = \frac{\sigma_0 wt\cos\theta}{wt/\cos\theta}$$
$$= \sigma_0 \cos^2\theta \qquad (Q.E.D.)$$

Optimum Wrap Angle : This require $\frac{\sigma_h}{\sigma_l} = \frac{pd/2t}{pd/4t} = 2$. Then

$$\frac{\sigma_h}{\sigma_l} = \frac{\sigma_0\sin^2\theta}{\sigma_0\cos^2\theta} = 2$$
$$\tan^2\theta = 2$$
$$\theta = 54.7^\circ \qquad \textbf{Ans}$$

8–15. The screw of the clamp exerts a compressive force of 500 lb on the wood blocks. Determine the maximum normal stress developed along section *a–a*. The cross section there is rectangular, 0.75 in. by 0.50 in.





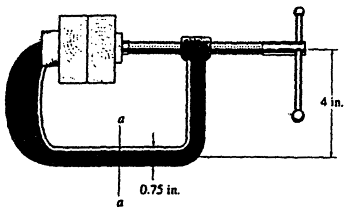
$A = 0.75(0.5) = 0.375\ \text{in}^2$

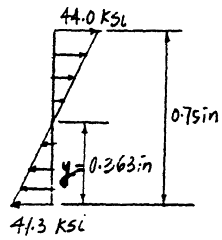
$I = \frac{1}{12}(0.5)(0.75^3) = 0.017578\ \text{in}^4$

$$\sigma_{max} = \frac{P}{A} + \frac{Mc}{I}$$

$$= \frac{500}{0.375} + \frac{2000(0.375)}{0.017578} = 44.0\ \text{ksi (T)} \qquad \textbf{Ans}$$

***8-16.** The screw of the clamp exerts a compressive force of 500 lb on the wood blocks. Sketch the stress distribution along section *a–a* of the clamp. The cross section there is rectangular, 0.75 in. by 0.50 in.





$$A = 0.75(0.5) = 0.375\ \text{in}^2$$

$$I = \frac{1}{12}(0.5)(0.75^3) = 0.017578\ \text{in}^4$$

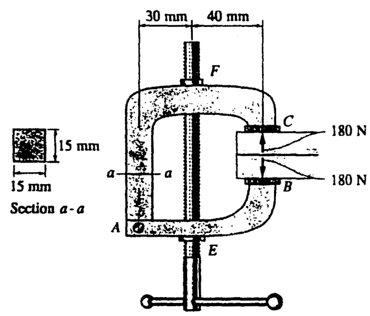
$$\sigma_{max} = \frac{P}{A} + \frac{Mc}{I} = \frac{500}{0.375} + \frac{2000(0.375)}{0.017578} = 44.0\ \text{ksi (T)}$$

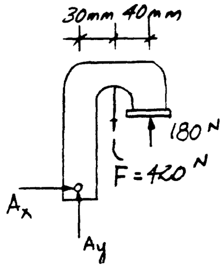
$$\sigma_{min} = \frac{P}{A} - \frac{Mc}{I} = \frac{500}{0.375} - \frac{2000(0.375)}{0.017578} = -41.3\ \text{ksi (C)}$$

$$\frac{y}{41.33} = \frac{(0.75 - y)}{44.0}$$

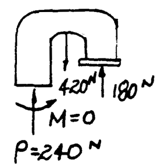
$$y = 0.363\ \text{in.}$$

8–17 The clamp is made from members AB and AC, which are pin connected at A. If it exerts a compressive force at C and B of 180 N, determine the maximum compressive stress in the clamp at section a–a. The screw EF is subjected only to a tensile force along its axis.



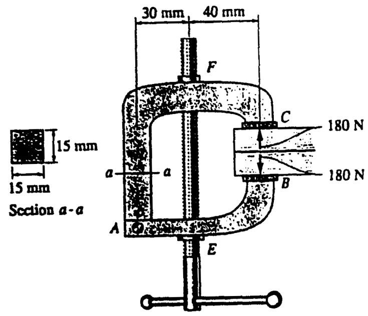


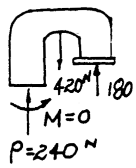
There is no moment in this problem .Therefore, the compressive stress is produced by axial force only.



$$\sigma_{max} = \frac{P}{A} = \frac{240}{(0.015)(0.015)} = 1.07 \text{ MPa} \qquad \textbf{Ans}$$

8–18 The clamp is made from members AB and AC, which are pin connected at A. If it exerts a compressive force at C and B of 180 N, sketch the stress distribution acting over section a–a. The screw EF is subjected only to a tensile force along its axis.

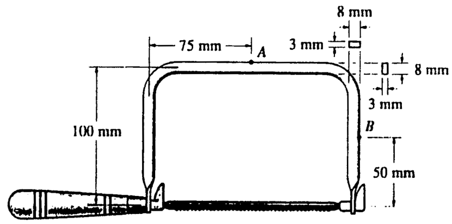


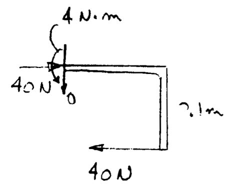


There is no moment in this problem .Therefore, the compressive stress is produced by axial force only.

$$\sigma_{max} = \frac{P}{A} = \frac{240}{(0.015)(0.015)} = 1.07 \text{ MPa}$$

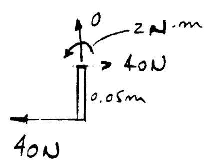
8–19 The coping saw has an adjustable blade that is tightened with a tension of 40 N. Determine the state of stress in the frame at points A and B.

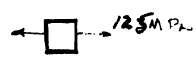


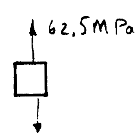


$$\sigma_A = -\frac{P}{A} + \frac{Mc}{I} = -\frac{40}{(0.008)(0.003)} + \frac{4(0.004)}{\frac{1}{12}(0.003)(0.008)^3} = 123 \text{ MPa} \qquad \textbf{Ans.}$$

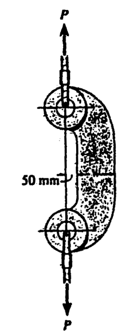
$$\sigma_B = \frac{Mc}{I} = \frac{2(0.004)}{\frac{1}{12}(0.003)(0.008)^3} = 62.5 \text{ MPa} \qquad \textbf{Ans}$$

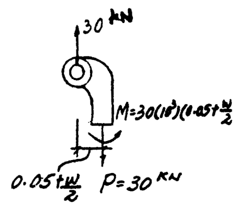






***8-20.** The offset link supports the loading of $P = 30$ kN. Determine its required width w if the allowable normal stress is $\sigma_{allow} = 73$ MPa. The link has a thickness of 40 mm.





σ due to axial force :

$$\sigma_a = \frac{P}{A} = \frac{30\,(10^3)}{(w)(0.04)} = \frac{750\,(10^3)}{w}$$

σ due to bending :

$$\sigma_b = \frac{Mc}{I} = \frac{30\,(10^3)(0.05 + \frac{w}{2})(\frac{w}{2})}{\frac{1}{12}(0.04)(w)^3}$$

$$= \frac{4500\,(10^3)(0.05 + \frac{w}{2})}{w^2}$$

$$\sigma_{max} = \sigma_{allow} = \sigma_a + \sigma_b$$

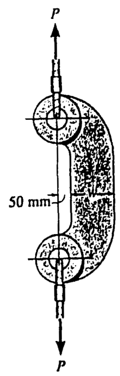
$$73\,(10^6) = \frac{750\,(10^3)}{w} + \frac{4500\,(10^3)(0.05 + \frac{w}{2})}{w^2}$$

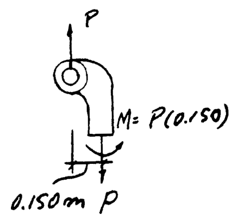
$$73\,w^2 = 0.75\,w + 0.225 + 2.25\,w$$

$$73\,w^2 - 3\,w - 0.225 = 0$$

$w = 0.0797$ m $= 79.7$ mm **Ans**

8–21 The offset link has a width of w = 200 mm and a thickness of 40 mm. If the allowable normal stress is σ_{allow} = 75 MPa, determine the maximum load P that can be applied to the cables.





$$A = 0.2(0.04) = 0.008\ \text{m}^2$$

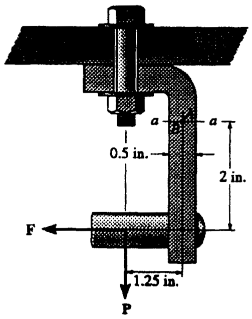
$$I = \frac{1}{12}(0.04)(0.2)^3 = 26.6667(10^{-6})\ \text{m}^4$$

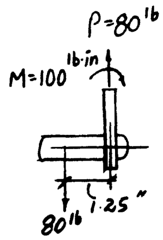
$$\sigma = \frac{P}{A} + \frac{Mc}{I}$$

$$75(10^6) = \frac{P}{0.008} + \frac{0.150\,P(0.1)}{26.6667(10^{-6})}$$

P = 109 kN **Ans**

8–22 The joint is subjected to a force of $P = 80$ lb and $F = 0$. Sketch the normal-stress distribution acting over section a–a if the member has a rectangular cross-sectional area of width 2 in. and thickness 0.5 in.





σ due to axial force :

$$\sigma = \frac{P}{A} = \frac{80}{(0.5)(2)} = 80 \text{ psi}$$

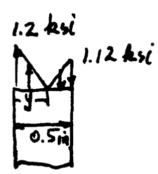
σ due to bending :

$$\sigma = \frac{M\,c}{I} = \frac{100\,(0.25)}{\frac{1}{12}(2)(0.5)^3} = 1200 \text{ psi}$$

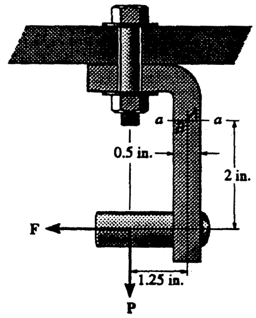
$$(\sigma_{max})_t = 80 + 1200 = 1280\text{psi} = 1.28 \text{ ksi} \quad \textbf{Ans}$$
$$(\sigma_{max})_c = 1200 - 80 = 1120 \text{ psi} = 1.12 \text{ ksi} \quad \textbf{Ans}$$

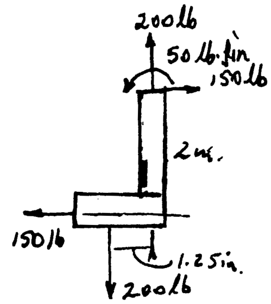
$$\frac{y}{1.25} = \frac{(0.5 - y)}{1.12}$$

$y = 0.264$ in.



8–23 The joint is subjected to a force of P = 200 lb and F = 150 lb. Determine the state of stress at points A and B and sketch the results on differential elements located at these points. The member has a rectangular cross-sectional area of width 0.75 in. and thickness 0.5 in.

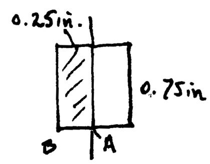




$$A = 0.5(0.75) = 0.375 \text{ in}^2$$

$$Q_A = \bar{y}'_A A' = 0.125(0.75)(0.25) = 0.0234375 \text{ in}^3 ; \qquad Q_B = 0$$

$$I = \frac{1}{12}(0.75)(0.5^3) = 0.0078125 \text{ in}^4$$



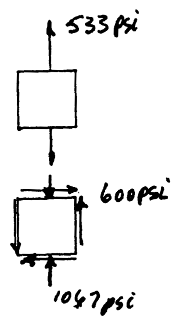
Normal Stress :

$$\sigma = \frac{N}{A} \pm \frac{My}{I}$$

$$\sigma_A = \frac{200}{0.375} + 0 = 533 \text{ psi (T)} \qquad \textbf{Ans}$$

$$\sigma_B = \frac{200}{0.375} - \frac{50(0.25)}{0.0078125} = -1067 \text{ psi} = 1067 \text{ psi (C)}$$

Ans



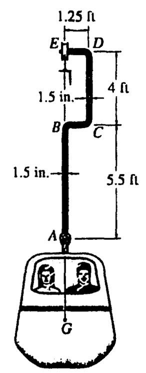
Shear stress :

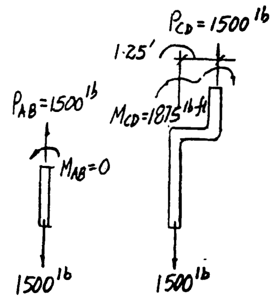
$$\tau = \frac{VQ}{It},$$

$$\tau_A = \frac{150(0.0234375)}{(0.0078125)(0.75)} = 600 \text{ psi} \qquad \textbf{Ans}$$

$$\tau_B = 0 \qquad \textbf{Ans}$$

•8–24 The gondola and passengers have a weight of 1500 lb and center of gravity at G. The suspender arm AE has a square cross-sectional area of 1.5 in. by 1.5 in., and is pin connected at its ends A and E. Determine the largest tensile stress developed in regions AB and DC of the arm.





Segment AB :

$$(\sigma_{max})_{AB} = \frac{P_{AB}}{A} = \frac{1500}{(1.5)(1.5)} = 667 \text{ psi} \qquad \textbf{Ans}$$

Segment CD :

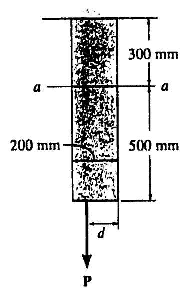
$$\sigma_a = \frac{P_{CD}}{A} = \frac{1500}{(1.5)(1.5)} = 666.67 \text{ psi}$$

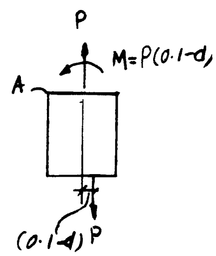
$$\sigma_b = \frac{Mc}{I} = \frac{1875(12)(0.75)}{\frac{1}{12}(1.5)(1.5^3)} = 40\,000 \text{ psi}$$

$$(\sigma_{max})_{CD} = \sigma_a + \sigma_b = 666.67 + 40\,000$$

$$= 40\,666.67 \text{ psi} = 40.7 \text{ ksi} \qquad \textbf{Ans}$$

8–25 The vertical force **P** acts on the bottom of the plate having a negligible weight. Determine the shortest distance d to the edge of the plate at which it can be applied so that it produces no compressive stresses on the plate at section a–a. The plate has a thickness of 10 mm and **P** acts along the center line of this thickness.





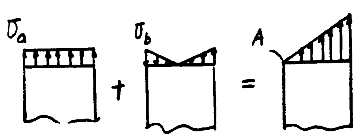
$$\sigma_A = 0 = \sigma_a - \sigma_b$$

$$0 = \frac{P}{A} - \frac{Mc}{I}$$

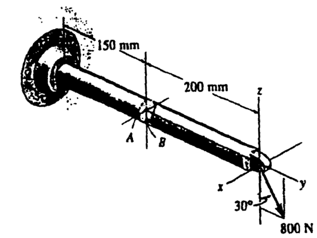
$$0 = \frac{P}{(0.2)(0.01)} - \frac{P\,(0.1 - d)(0.1)}{\frac{1}{12}(0.01)(0.2^3)}$$

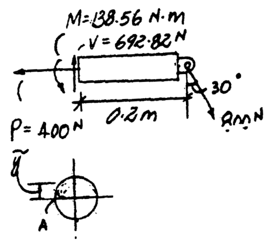
$$P\,(-1000 + 15000\,d) = 0$$

$$d = 0.0667\text{m} = 66.7\text{ mm} \qquad \textbf{Ans}$$



8-26. The bar has a diameter of 40 mm. If it is subjected to a force of 800 N as shown, determine the stress components that act at point A and show the results on a volume element located at this point.





$$I = \frac{1}{4}\pi r^4 = \frac{1}{4}(\pi)(0.02^4) = 0.1256637\,(10^{-6})\ \text{m}^4$$

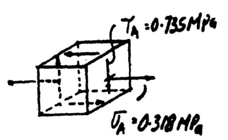
$$A = \pi r^2 = \pi(0.02^2) = 1.256637\,(10^{-3})\ \text{m}^2$$

$$Q_A = \bar{y}'A' = \left(\frac{4\,(0.02)}{3\pi}\right)\left(\frac{\pi\,(0.02)^2}{2}\right) = 5.3333\,(10^{-6})\ \text{m}^3$$

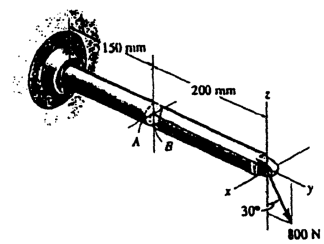
$$\sigma_A = \frac{P}{A} + \frac{M z}{I}$$

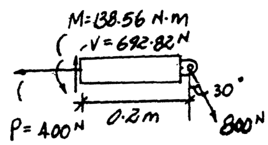
$$= \frac{400}{1.256637\,(10^{-3})} + 0 = 0.318\ \text{MPa} \qquad \textbf{Ans}$$

$$\tau_A = \frac{V Q_A}{I t} = \frac{692.82\,(5.3333)\,(10^{-6})}{0.1256637\,(10^{-6})(0.04)} = 0.735\ \text{MPa} \qquad \textbf{Ans}$$



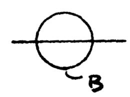
8-27. Solve Prob. 8–26 for point *B*.





$$I = \frac{1}{4}\pi r^4 = \frac{1}{4}(\pi)(0.02^4) = 0.1256637\,(10^{-6})\ \text{m}^4$$

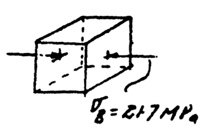
$$A = \pi r^2 = \pi(0.02^2) = 1.256637\,(10^{-3})\ \text{m}^2$$



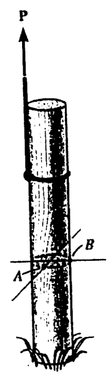
$Q_B = 0$

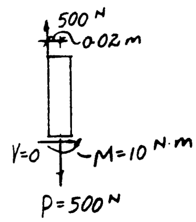
$$\sigma_B = \frac{P}{A} - \frac{Mc}{I} = \frac{400}{1.256637\,(10^{-3})} - \frac{138.56\,(0.02)}{0.1256637\,(10^{-6})} = -21.7\ \text{MPa} \qquad \textbf{Ans}$$

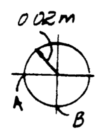
$\tau_B = 0$ **Ans**



***8–28** The cylindrical post, having a diameter of 40 mm, is being pulled from the ground using a sling of negligible thickness. If the rope is subjected to a vertical force of $P = 500$ N, determine the stress at points A and B. Show the results on a volume element located at each of these points.







$$I = \frac{1}{4}\pi r^4 = \frac{1}{4}(\pi)(0.02^4) = 0.1256637\,(10^{-6})\ \text{m}^4$$

$$A = \pi r^2 = \pi\,(0.02^2) = 1.256637\,(10^{-3})\ \text{m}^2$$

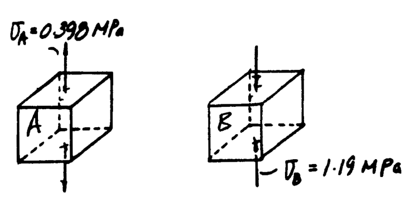
$$\sigma_A = \frac{P}{A} + \frac{Mx}{I}$$

$$= \frac{500}{1.256637\,(10^{-3})} + 0 = 0.398\ \text{MPa} \qquad \textbf{Ans}$$

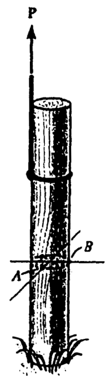
$$\sigma_B = \frac{P}{A} - \frac{Mc}{I}$$

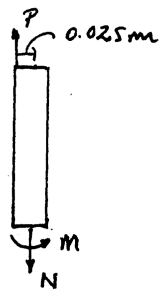
$$= \frac{500}{1.256637\,(10^{-3})} - \frac{10\,(0.02)}{0.1256637\,(10^{-6})}$$

$$= -\ 1.19\ \text{MPa} \qquad \textbf{Ans}$$



8–29 Determine the maximum load P that can be applied to the sling having a negligible thickness so that the normal stress in the post does not exceed $\sigma_{allow} = 30$ MPa. The post has a diameter of 50 mm.





$+\downarrow \Sigma F = 0; \quad N - P = 0; \quad N = P$

$\circlearrowleft + \Sigma M = 0; \quad M - P(0.025) = 0; \quad M = 0.025P$

$$A = \frac{\pi}{4} d^2 = \pi(0.025^2) = 0.625\,(10^{-3})\pi \text{ m}^2$$

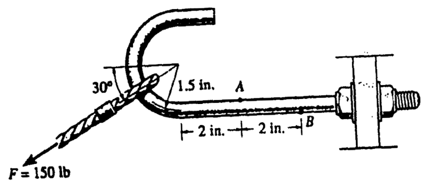
$$I = \frac{\pi}{4} r^4 = \frac{\pi}{4}(0.025^4) = 97.65625\,(10^{-9})\pi \text{ m}^4$$

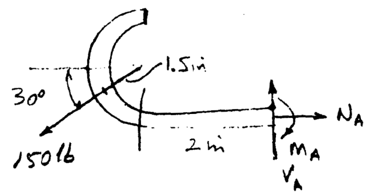
$$\sigma = \frac{N}{A} + \frac{My}{I}$$

$$\sigma = 30(10^6) = \frac{P}{0.625\,(10^{-3})\pi} + \frac{P(0.025)(0.025)}{97.65625\,(10^{-9})\pi}$$

$P = 11.8$ kN **Ans**

8-30 The $\frac{1}{2}$-in.-diameter bolt hook is subjected to the load of $F = 150$ lb. Determine the stress components at point A on the shank. Show the results on a volume element located at this point.





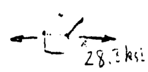
$\xrightarrow{+} \Sigma F_x = 0; \quad N_A - 150\cos 30° = 0$

$N_A = 129.9038$ lb

$+\uparrow \Sigma F_y = 0; \quad V_A - 150\sin 30° = 0$

$V_A = 75$ lb

$\circlearrowleft + \Sigma M_A = 0; \quad 150\cos 30°(1.5) + 150\sin 30°(2) - M_A = 0$

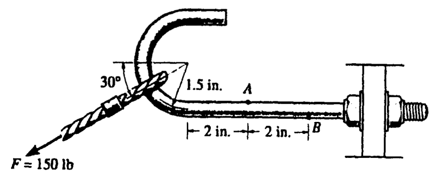


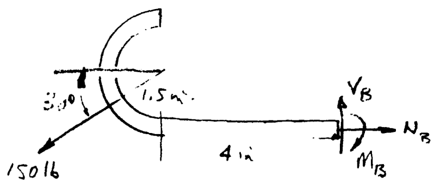
$M_A = 344.8557$ lb · in.

$$\sigma_A = \frac{P}{A} + \frac{Mc}{I} = \frac{129.9038}{\pi(\frac{1}{4})^2} + \frac{344.8557(\frac{1}{4})}{\frac{\pi}{4}(\frac{1}{4})^4} = 28.8 \text{ ksi} \qquad \textbf{Ans}$$

$\tau_A = 0$ (since $Q_A = 0$) **Ans**

8–31 The $\frac{1}{2}$-in.-diameter bolt hook is subjected to the load of $F = 150$ lb. Determine the stress components at point B on the shank. Show the results on a volume element located at this point.





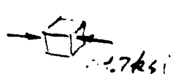
$$\xrightarrow{+} \Sigma F_x = 0; \qquad N_B - 150 \cos 30° = 0; \qquad N_B = 129.9038$$

$$+\uparrow \Sigma F_y = 0; \qquad V_B - 150 \sin 30° = 0; \qquad V_B = 75 \text{ lb}$$

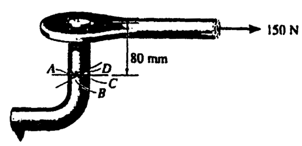
$$\circlearrowleft + \Sigma M_B = 0; \qquad 150 \cos 30°(1.5) + 150 \sin 30°(4) - M_B = 0$$

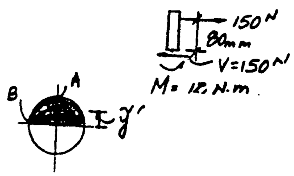
$$M_B = 494.8557 \text{ lb} \cdot \text{in.}$$

$$\sigma_B = \frac{P}{A} - \frac{Mc}{I} = \frac{129.9038}{\pi(\frac{1}{4})^2} - \frac{494.8557(\frac{1}{4})}{\frac{\pi}{4}(\frac{1}{4})^4} = -39.7 \text{ ksi} \qquad \textbf{Ans}$$



***8-32.** The pin support is made from a steel rod and has a diameter of 20 mm. Determine the stress components at points *A* and *B* and represent the results on a volume element located at each of these points.





$$I = \frac{1}{4}(\pi)(0.01^4) = 7.85398\,(10^{-9})\ \text{m}^4$$

$$Q_B = \bar{y}'A' = \frac{4\,(0.01)}{3\pi}\left(\frac{1}{2}\right)(\pi)(0.01^2) = 0.66667\,(10^{-6})\ \text{m}^3$$

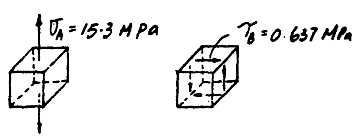
$$Q_A = 0$$

$$\sigma_A = \frac{M\,c}{I} = \frac{12(0.01)}{7.85398\,(10^{-9})} = 15.3\ \text{MPa} \qquad \textbf{Ans}$$

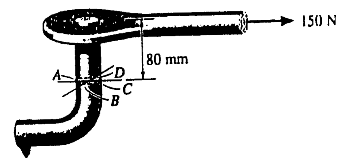
$$\tau_A = 0 \qquad \textbf{Ans}$$

$$\sigma_B = 0 \qquad \textbf{Ans}$$

$$\tau_B = \frac{V\,Q_B}{I\,t} = \frac{150\,(0.6667)(10^{-6})}{7.85398\,(10^{-9})(0.02)} = 0.637\ \text{MPa} \qquad \textbf{Ans}$$



8–33 Solve Prob. 8-32 for points *C* and *D*.

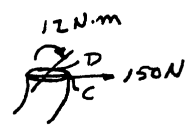


$$I = \frac{1}{4}(\pi)(0.01^4) = 7.85398\,(10^{-9})\text{ m}^4$$

$$Q_D = \bar{y}'A' = \frac{4\,(0.01)}{3\pi}\left(\frac{1}{2}\right)(\pi)(0.01^2) = 0.66667\,(10^{-6})\text{ m}^3$$

$$Q_C = 0$$

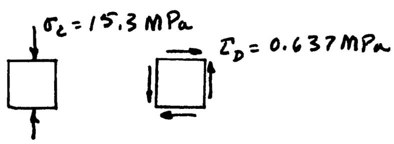
$$\sigma_C = \frac{Mc}{I} = \frac{12(0.01)}{7.85398(10^{-9})} = 15.3\text{ MPa} \qquad \textbf{Ans}$$



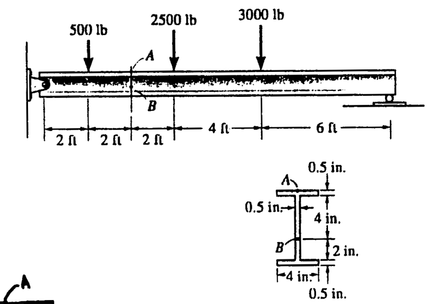
$$\tau_C = 0 \qquad \textbf{Ans}$$

$$\sigma_D = 0 \qquad \textbf{Ans}$$

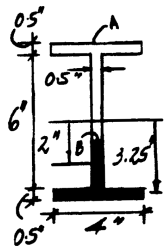
$$\tau_D = \frac{VQ_D}{It} = \frac{150(0.6667)(10^{-6})}{7.8539(10^{-9})(0.02)} = 0.637\text{ MPa} \qquad \textbf{Ans}$$



8–34 The wide-flange beam is subjected to the loading shown. Determine the stress components at points *A* and *B* and show the results on a volume element at each of these points. Use the shear formula to compute the shear stress.



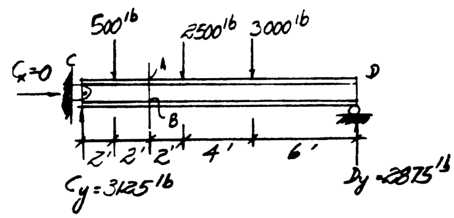
$$I = \frac{1}{12}(4)(7^3) - \frac{1}{12}(3.5)(6^3) = 51.33 \text{ in}^4$$



$$A = 2(0.5)(4) + 6(0.5) = 7 \text{ in}^2$$

$$Q_B = \Sigma\bar{y}'A' = 3.25(4)(0.5) + 2(2)(0.5) = 8.5 \text{ in}^3$$

$$Q_A = 0$$

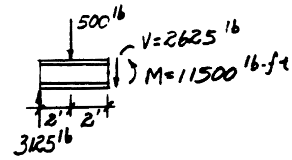


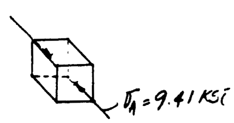
$$\sigma_A = \frac{-Mc}{I} = \frac{-11500\,(12)(3.5)}{51.33} = -9.41 \text{ ksi} \qquad \textbf{Ans}$$

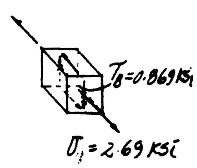
$$\tau_A = 0 \qquad \textbf{Ans}$$

$$\sigma_B = \frac{My}{I} = \frac{11500(12)(1)}{51.33} = 2.69 \text{ ksi} \qquad \textbf{Ans}$$

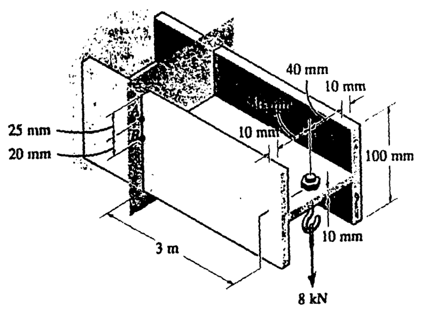
$$\tau_B = \frac{VQ_B}{It} = \frac{2625(8.5)}{51.33(0.5)} = 0.869 \text{ ksi} \qquad \textbf{Ans}$$

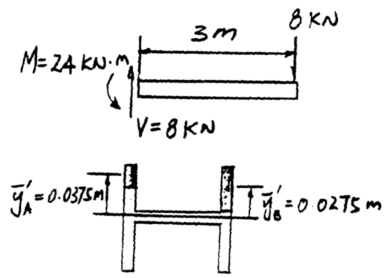






8–35 The cantilevered beam is used to support the load of 8 kN. Determine the state of stress at points A and B, and sketch the results on differential elements located at each of these points.





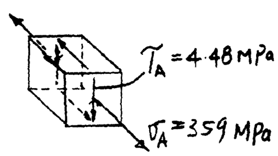
$$I = 2[\frac{1}{12}(0.01)(0.1^3)] + \frac{1}{12}(0.08)(0.01^3) = 1.6733(10^{-6})\ \text{m}^4$$

$$A = 2[0.01(0.1)] + 0.08(0.01) = 0.0028\ \text{m}^2$$

$$Q_A = \bar{y}'_A A = 0.0375(0.025)(0.01) = 9.375(10^{-6})\ \text{m}^3$$

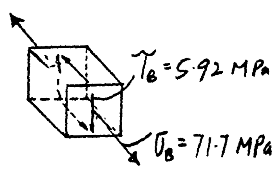
$$Q_B = \bar{y}'_B A = 0.0275(0.045)(0.01) = 12.375(10^{-6})\ \text{m}^3$$

$$\sigma = \frac{M y}{I}$$



$$\sigma_A = \frac{24(10^3)(0.025)}{1.6733(10^{-6})} = 359\ \text{MPa (T)}$$ **Ans**

$$\sigma_B = \frac{24(10^3)(0.005)}{1.6733(10^{-6})} = 71.7\ \text{MPa(T)}$$ **Ans**

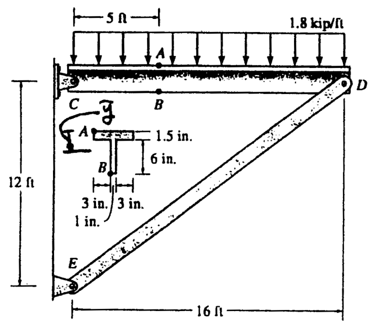


$$\tau = \frac{VQ}{I t}$$

$$\tau_A = \frac{8(10^3)(9.375)(10^{-6})}{1.6733(10^{-6})(0.01)} = 4.48\ \text{MPa}$$ **Ans**

$$\tau_B = \frac{8(10^3)(12.375)(10^{-6})}{1.6733(10^{-6})(0.01)} = 5.92\ \text{MPa}$$ **Ans**

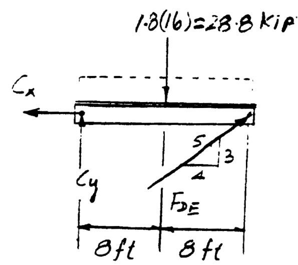
***8-36** The frame supports a centrally applied distributed load of 1.8 kip/ft. Determine the state of stress at points A and B on member CD and indicate the results on a volume element located at each of these points. The pins at C and D are at the same location as the neutral axis for the cross section.



Member CD :

$\curvearrowleft + \Sigma M_C = 0;\quad \frac{3}{5}F_{DE}(16) - 28.8(8) = 0;$

$F_{DE} = 24.0\text{ kip}$



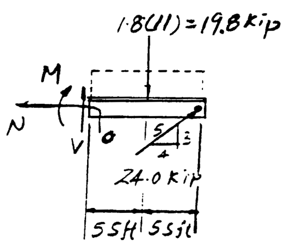
Segment :

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N - \frac{4}{5}(24.0) = 0;\quad N = 19.2\text{ kip}$

$+\uparrow \Sigma F_y = 0;\quad V + \frac{3}{5}(24.0) - 19.8 = 0;\quad V = 5.40\text{ kip}$

$\curvearrowleft + \Sigma M_O = 0;\quad -M - 19.8(5.5) + \frac{3}{5}(24.0)(11) = 0;$

$M = 49.5\text{ kip}\cdot\text{ft}$



$A = 7(1.5) + 6(1) = 16.5\text{ in}^2$

$$\bar{y} = \frac{\Sigma \tilde{y}A}{\Sigma A} = \frac{0.75(1.5)(7) + 4.5(6)(1)}{16.5} = 2.1136\text{ in.}$$

$$I = \frac{1}{12}(7)(1.5^3) + 7(1.5)(2.1136-0.75)^2 + \frac{1}{12}(1)(6^3) + 1(6)(4.5-2.1136)^2 = 73.662\text{ in}^4$$

$Q_A = Q_B = 0$

Normal Stress :

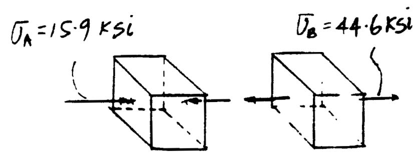
$$\sigma = \frac{N}{A} + \frac{My}{I}$$

$$\sigma_A = \frac{19.2}{16.5} - \frac{49.5(12)(7.5-2.1136)}{73.662} = -15.9\text{ ksi} = 15.9\text{ ksi(C)}\qquad \textbf{Ans}$$

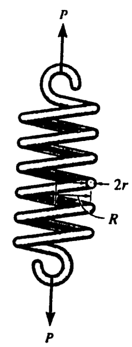
$$\sigma_B = \frac{19.2}{16.5} + \frac{49.5(12)(5.3864)}{73.662} = 44.6\text{ ksi(T)}\qquad \textbf{Ans}$$

Shear Stress : Since $Q_A = Q_B = 0$,

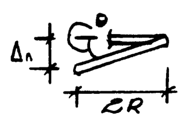
$\tau_A = \tau_B = 0$ **Ans**



8–37 The coiled spring is subjected to a force P. If we assume the shear stress caused by the shear force at any vertical section of the coil wire to be uniform, show that the maximum shear stress in the coil is $\tau_{max} = P/A + PRr/J$, where J is the polar moment of inertia of the coil wire and A is its cross-sectional area.



$$\tau_{max} = \frac{V}{A} + \frac{Tc}{J} = \frac{P}{A} + \frac{PRr}{J}$$ **QED**



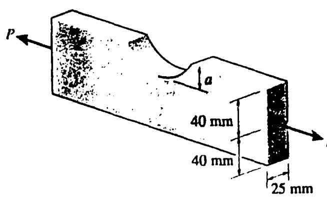
$\Delta_n = 2R\theta$

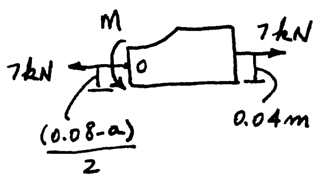
$$\tau_{max} = \frac{Vq_{max}}{It} + \frac{Tc}{J}$$

$$\frac{VQ}{It} = \frac{4}{3}\frac{V}{A}$$

$$\frac{Tc}{J} = \text{max on perimeter} = \frac{PRr}{J}$$

8-38 The metal link is subjected to the axial force of $P = 7$ kN. Its original cross section is to be altered by cutting a circular groove into one side. Determine the distance a the groove can penetrate into the cross section so that the tensile stress does not exceed $\sigma_{allow} = 175$ MPa. Offer a better way to remove this depth of material from the cross section and calculate the tensile stress for this case. Neglect the effects of stress concentration.





$$\curvearrowleft + \Sigma M_O = 0; \qquad M - 7(10^3)(0.04 - (\frac{0.08-a}{2})) = 0$$

$$M = 3.5(10^3)a$$

$$\sigma_{max} = \frac{P}{A} + \frac{Mc}{I}$$

$$175(10^6) = \frac{7(10^3)}{(0.025)(0.08-a)} + \frac{3.5\,(10^3)a(0.08-a)/2}{\frac{1}{12}(0.025)(0.08-a)^3}$$

Set $x = 0.08 - a$

$$4375 = \frac{7}{x} + \frac{21(0.08-x)}{x^2}$$

$$4375x^2 + 14x - 1.68 = 0$$

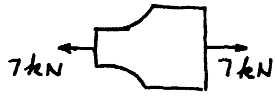
Choose positive root:

$$x = 0.01806$$

$$a = 0.08 - 0.01806 = 0.0619 \text{ m}$$

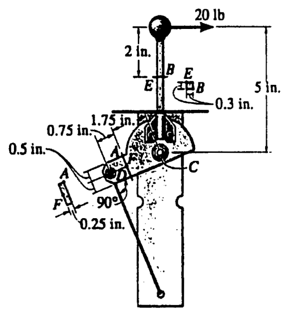
$a = 61.9$ mm **Ans**

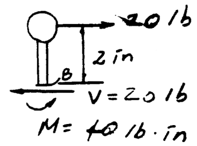
Remove material equally from both sides.

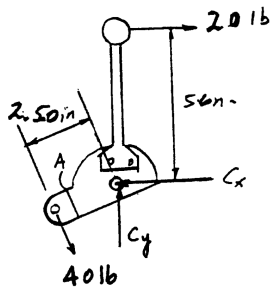


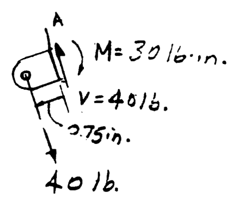
$$\sigma = \frac{7(10^3)}{(0.025)(0.01806)} = 15.5 \text{ MPa}$$ **Ans**

8–39 The control lever is subjected to a horizontal force of 20 lb on the handle. Determine the state of stress at points A and B. Sketch the results on differential elements located at each of these points. The assembly is pin-connected at C and attached to a cable at D.





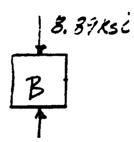




For point B :

$$I = \frac{1}{12}(0.3)(0.3^3) = 0.675(10^{-3})\ \text{in}^4$$

$$\sigma_B = \frac{Mc}{I} = \frac{40(0.15)}{0.675(10^{-3})} = 8.89\ \text{ksi (C)}$$ **Ans**

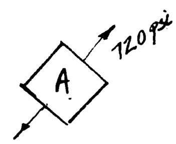


$\tau_B = 0 \qquad (\text{since } Q_B = 0)$ **Ans**

For point A :

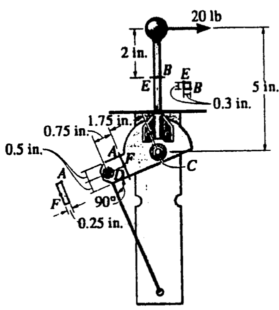
$$I = \frac{1}{12}(0.25)(1^3) = 0.020833\ \text{in}^4$$

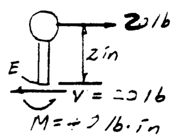
$$\sigma_A = \frac{Mc}{I} = \frac{30(0.5)}{0.020833} = 720\ \text{psi (T)}$$ **Ans**

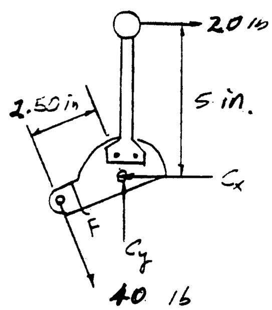


$\tau_A = 0 \qquad (\text{since } Q_A = 0)$ **Ans**

•8–40 The control lever is subjected to a horizontal force of 20 lb on the handle. Determine the state of stress at points *E* and *F*. Sketch the results on differential elements located at each of these points. The assembly is pin-connected at *C* and attached to a cable at *D*.

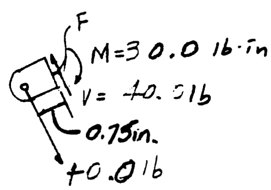






For point *E* :

$$I = \frac{1}{12}(0.3)(0.3^3) = 0.675(10^{-3})\ \text{in}^4$$

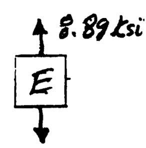


$$\sigma_E = \frac{Mc}{I} = \frac{40(0.15)}{0.675(10^{-3})} = 8.89\ \text{ksi (T)}$$ **Ans**

$$\tau_E = 0 \qquad (\text{since } Q_E = 0)$$ **Ans**

For point *F* :

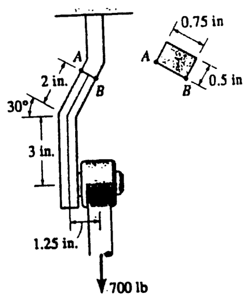
$$I = \frac{1}{12}(0.25)(1^3) = 0.020833\ \text{in}^4$$

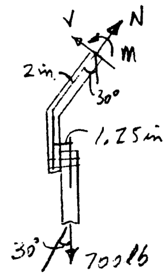


$$\sigma_F = 0$$ **Ans**

$$\tau_F = \frac{VQ}{It} = \frac{40(0.25)(0.5)(0.25)}{\frac{1}{12}(0.25)(1)^3(0.25)} = 240\ \text{psi}$$ **Ans**

8-41 The bearing pin supports the load of 700 lb. Determine the stress components in the support member at point *A*. The support is 0.5 in. thick.





$\Sigma F_x = 0; \quad N - 700\cos 30° = 0; \quad N = 606.218 \text{ lb}$

$\Sigma F_y = 0; \quad V - 700\sin 30° = 0; \quad V = 350 \text{ lb}$

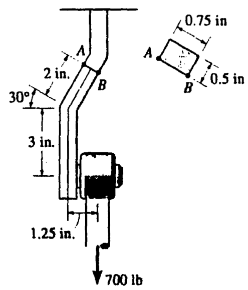
$\curvearrowleft + \Sigma M = 0; \quad M - 700(1.25 - 2\sin 30°) = 0; \quad M = 175 \text{ lb}\cdot\text{in.}$

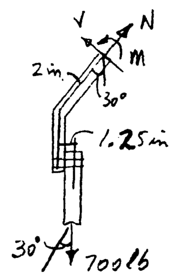
$$\sigma_A = \frac{N}{A} - \frac{Mc}{I} = \frac{606.218}{(0.75)(0.5)} - \frac{(175)(0.375)}{\frac{1}{12}(0.5)(0.75)^3}$$

$\sigma_A = -2.12$ ksi **Ans**

$\tau_A = 0$ (since $Q_A = 0$) **Ans**

8–42 The bearing pin supports the load of 700 lb. Determine the stress components in the support member at point *B*. The support is 0.5 in. thick.





$\Sigma F_x = 0; \quad N - 700\cos 30° = 0; \quad N = 606.218\text{ lb}$

$\Sigma F_y = 0; \quad V - 700\sin 30° = 0; \quad V = 350\text{ lb}$

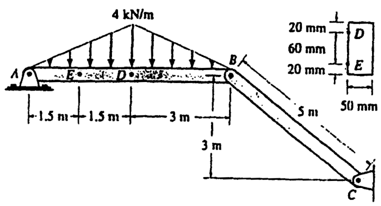
$\curvearrowleft + \Sigma M = 0; \quad M - 700(1.25 - 2\sin 30°) = 0; \quad M = 175\text{ lb}\cdot\text{in.}$

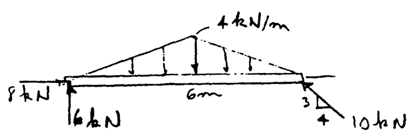
$$\sigma_B = \frac{N}{A} + \frac{Mc}{I} = \frac{606.218}{(0.75)(0.5)} + \frac{175(0.375)}{\frac{1}{12}(0.5)(0.75)^3}$$

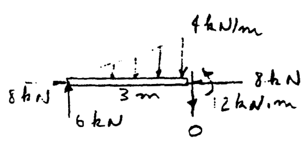
$\sigma_B = 5.35\text{ ksi}$ **Ans**

$\tau_B = 0 \quad (\text{since } Q_B = 0)$ **Ans**

8-43. The frame supports the distributed load shown. Determine the state of stress acting at point D. Show the results on a differential element located at this point.





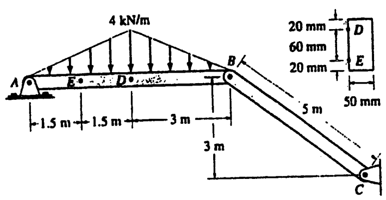


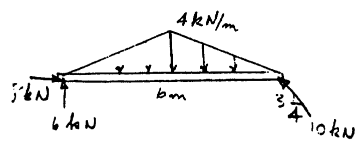
$$\sigma_D = -\frac{P}{A} - \frac{My}{I} = -\frac{8(10^3)}{(0.1)(0.05)} - \frac{12(10^3)(0.03)}{\frac{1}{12}(0.05)(0.1)^3}$$

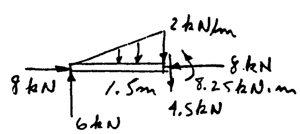
$\sigma_D = -88.0\text{ MPa}$ **Ans**

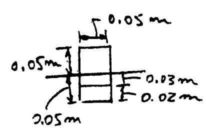
$\tau_D = 0$ **Ans**

***8-44.** The frame supports the distributed load shown. Determine the state of stress acting at point E. Show the results on a differential element located at this point.



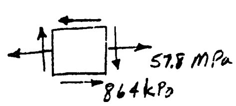




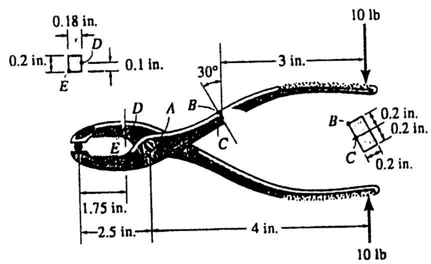


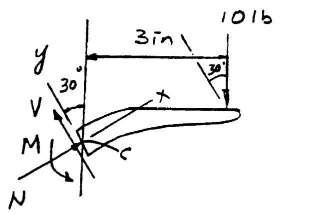
$$\sigma_E = -\frac{P}{A} - \frac{My}{I} = -\frac{8(10^3)}{(0.1)(0.05)} + \frac{8.25(10^3)(0.03)}{\frac{1}{12}(0.05)(0.1)^3} = 57.8 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_E = \frac{VQ}{It} = \frac{4.5(10^3)(0.04)(0.02)(0.05)}{\frac{1}{12}(0.05)(0.1)^3(0.05)} = 864 \text{ kPa} \qquad \textbf{Ans}$$



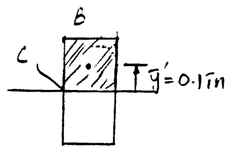
8–45 The pliers are made from two steel parts pinned together at A. If a smooth bolt is held in the jaws and a gripping force of 10 lb is applied at the handles, determine the state of stress developed in the pliers at points B and C. Here the cross section is rectangular, having the dimensions shown in the figure.





$$+\Sigma F_x = 0; \quad N - 10\sin 30° = 0; \quad N = 5.0 \text{ lb}$$

$$+\Sigma F_y = 0; \quad V - 10\cos 30° = 0; \quad V = 8.660 \text{ lb}$$



$$\circlearrowleft + \Sigma M_C = 0; \quad M - 10(3) = 0; \quad M = 30 \text{ lb} \cdot \text{in.}$$

$$A = 0.2(0.4) = 0.08 \text{ in}^2$$

$$I = \frac{1}{12}(0.2)(0.4^3) = 1.0667(10^{-3}) \text{ in}^4$$

$$Q_B = 0$$
$$Q_C = \bar{y}'A' = 0.1(0.2)(0.2) = 4(10^{-3}) \text{ in}^3$$

Point B :

$$\sigma_B = \frac{N}{A} + \frac{My}{I} = \frac{-5.0}{0.08} + \frac{30(0.2)}{1.0667(10^{-3})} = 5.56 \text{ ksi(T)} \qquad \textbf{Ans}$$

$$\tau_B = \frac{VQ}{It} = 0 \qquad \textbf{Ans}$$

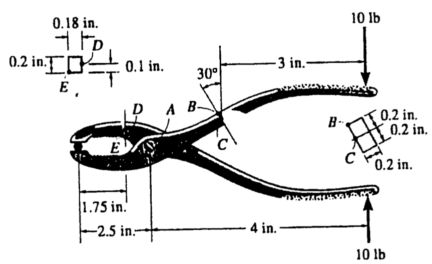
Point C :

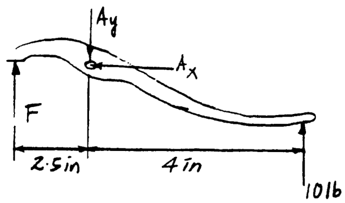
$$\sigma_C = \frac{N}{A} + \frac{My}{I} = \frac{-5.0}{0.08} + 0 = -62.5 \text{ psi} = 62.5 \text{ psi(C)} \qquad \textbf{Ans}$$

Shear Stress :

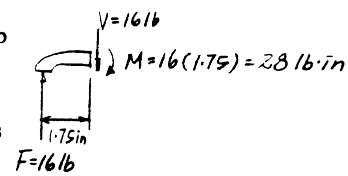
$$\tau_C = \frac{VQ}{It} = \frac{8.660(4)(10^{-3})}{1.0667(10^{-3})(0.2)} = 162 \text{ psi} \qquad \textbf{Ans}$$

8–46 Solve Prob. 8–45 for points D and E.





$\circlearrowleft + \Sigma M_A = 0; \quad -F(2.5) + 4(10) = 0; \quad F = 16 \text{ lb}$



Point D :

$\sigma_D = 0$ **Ans**

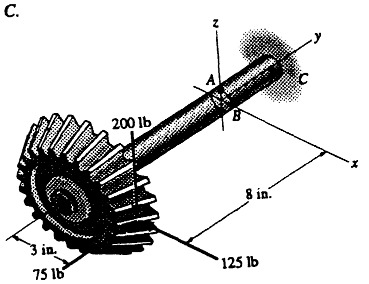
$$\tau_D = \frac{VQ}{It} = \frac{16(0.05)(0.1)(0.18)}{[\frac{1}{12}(0.18)(0.2)^3](0.18)} = 667 \text{ psi}$$ **Ans**

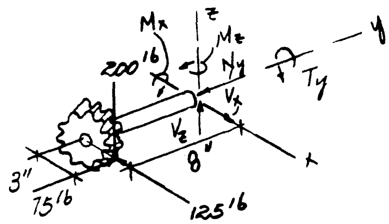
Point E :

$$\sigma_E = \frac{My}{I} = \frac{28(0.1)}{\frac{1}{12}(0.18)(0.2)^3} = 23.3 \text{ ksi (C)}$$ **Ans**

$\tau_E = 0$ **Ans**

8–47 The beveled gear is subjected to the loads shown. Determine the stress components acting on the shaft at point *A*, and show the results on a volume element located at this point. The shaft has a diameter of 1 in. and is fixed to the wall at *C*.





$\Sigma F_x = 0; \quad V_x - 125 = 0; \quad V_x = 125\text{ lb}$

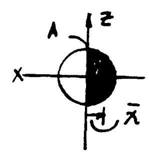
$\Sigma F_y = 0; \quad 75 - N_y = 0; \quad N_y = 75\text{ lb}$

$\Sigma F_z = 0; \quad V_z - 200 = 0; \quad V_z = 200\text{ lb}$

$\Sigma M_x = 0; \quad 200(8) - M_x = 0; \quad M_x = 1600\text{ lb}\cdot\text{in.}$

$\Sigma M_y = 0; \quad 200(3) - T_y = 0; \quad T_y = 600\text{ lb}\cdot\text{in.}$

$\Sigma M_z = 0; \quad M_z + 75(3) - 125(8) = 0; \quad M_z = 775\text{ lb}\cdot\text{in.}$



$$A = \pi(0.5^2) = 0.7854\text{ in}^2$$

$$J = \frac{\pi}{2}(0.5^4) = 0.098175\text{ in}^4$$

$$I = \frac{\pi}{4}(0.5^4) = 0.049087\text{ in}^4$$

$$(Q_A)_x = 0$$

$$(Q_A)_z = \frac{4(0.5)}{3\pi}\left(\frac{1}{2}\right)(\pi)(0.5^2) = 0.08333\text{ in}^3$$

$$(\sigma_A)_y = -\frac{N_y}{A} + \frac{M_x c}{I}$$

$$= -\frac{75}{0.7854} + \frac{1600(0.5)}{0.049087}$$

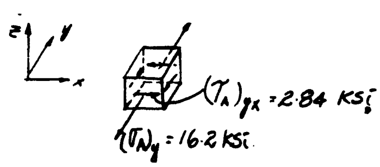
$$= 16202\text{ psi} = 16.2\text{ ksi (T)} \qquad \textbf{Ans}$$

$$(\tau_A)_{yx} = (\tau_A)_V - (\tau_A)_{\text{twist}}$$

$$= \frac{V_x(Q_A)_z}{I\,t} - \frac{T_y c}{J}$$

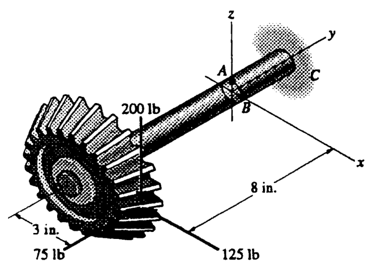
$$= \frac{125(0.08333)}{0.049087\,(1)} - \frac{600(0.5)}{0.098175}$$

$$= -2843\text{ psi} = -2.84\text{ ksi} \qquad \textbf{Ans}$$



$$(\tau_A)_{yz} = \frac{V_z(Q_A)_x}{I\,t} = 0 \qquad \textbf{Ans}$$

*8–48 The beveled gear is subjected to the loads shown. Determine the stress components acting on the shaft at point B, and show the results on a volume element located at this point. The shaft has a diameter of 1 in. and is fixed to the wall at C.



$\Sigma F_x = 0; \quad V_x - 125 = 0; \quad V_x = 125 \text{ lb}$

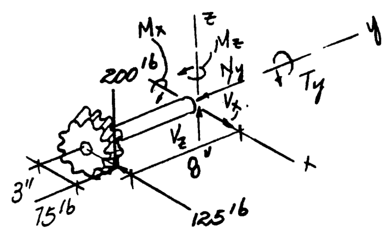
$\Sigma F_y = 0; \quad 75 - N_y = 0; \quad N_y = 75 \text{ lb}$

$\Sigma F_z = 0; \quad V_z - 200 = 0; \quad V_z = 200 \text{ lb}$

$\Sigma M_x = 0; \quad 200(8) - M_x = 0; \quad M_x = 1600 \text{ lb} \cdot \text{in.}$

$\Sigma M_y = 0; \quad 200(3) - T_y = 0; \quad T_y = 600 \text{ lb} \cdot \text{in.}$

$\Sigma M_z = 0; \quad M_z + 75(3) - 125(8) = 0; \quad M_z = 775 \text{ lb} \cdot \text{in.}$



$A = \pi(0.5^2) = 0.7854 \text{ in}^2$

$J = \frac{\pi}{2}(0.5^4) = 0.098175 \text{ in}^4$

$I = \frac{\pi}{4}(0.5^4) = 0.049087 \text{ in}^4$

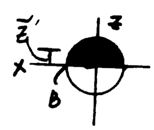
$(Q_B)_z = 0$

$(Q_B)_x = \frac{4(0.5)}{3\pi}\left(\frac{1}{2}\right)(\pi)(0.5^2) = 0.08333 \text{ in}^3$

$$(\sigma_B)_y = -\frac{P_y}{A} + \frac{M_z c}{I}$$

$$= -\frac{75}{0.7854} + \frac{775(0.5)}{0.049087}$$

$$= 7.80 \text{ ksi (T)} \qquad \textbf{Ans}$$

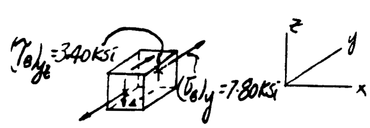


$$(\tau_B)_{yz} = (\tau_B)_V + (\tau_B)_{\text{twist}}$$

$$= \frac{V_z (Q_B)_x}{I\,t} + \frac{T_y\,c}{J}$$

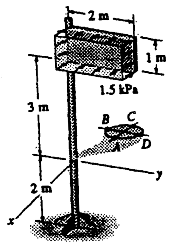
$$= \frac{200(0.08333)}{0.049087\,(1)} + \frac{600(0.5)}{0.098175}$$

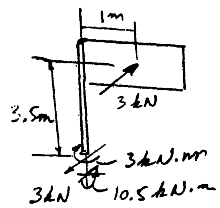
$$= 3395 \text{psi} = 3.40 \text{ ksi} \qquad \textbf{Ans}$$



$$(\tau_B)_{yx} = \frac{V_x (Q_B)_z}{I\,t} = 0 \qquad \textbf{Ans}$$

8-49. The sign is subjected to the uniform wind loading. Determine the stress components at points A and B on the 100-mm-diameter supporting post. Show the results on a volume element located at each of these points.

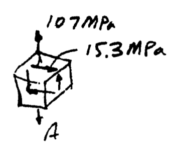




Point A :

$$\sigma_A = \frac{Mc}{I} = \frac{10.5(10^3)(0.05)}{\frac{\pi}{4}(0.05)^4} = 107 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_A = \frac{Tc}{J} = \frac{3(10^3)(0.05)}{\frac{\pi}{2}(0.05)^4} = 15.279(10^6) = 15.3 \text{ MPa} \qquad \textbf{Ans}$$

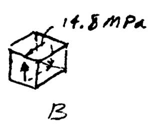


Point B :

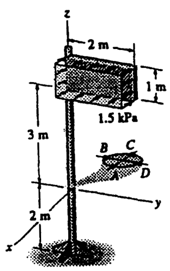
$\sigma_B = 0$ **Ans**

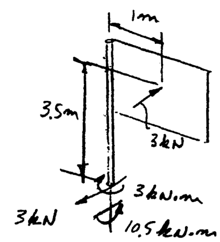
$$\tau_B = \frac{Tc}{J} - \frac{VQ}{It} = 15.279(10^6) - \frac{3000(4(0.05)/3\pi))(\frac{1}{2})(\pi)(0.05)^2}{\frac{\pi}{4}(0.05)^4(0.1)}$$

$\tau_B = 14.8$ MPa **Ans**



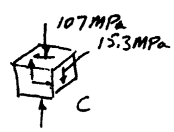
8-50. The sign is subjected to the uniform wind loading. Determine the stress components at points C and D on the 100-mm-diameter supporting post. Show the results on a volume element located at each of these points.





Point C:

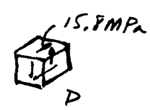
$$\sigma_C = \frac{Mc}{I} = \frac{10.5(10^3)(0.05)}{\frac{\pi}{4}(0.05)^4} = 107 \text{ MPa (C)} \qquad \textbf{Ans}$$



$$\tau_C = \frac{Tc}{J} = \frac{3(10^3)(0.05)}{\frac{\pi}{2}(0.05)^4} = 15.279(10^6) = 15.3 \text{ MPa} \qquad \textbf{Ans}$$

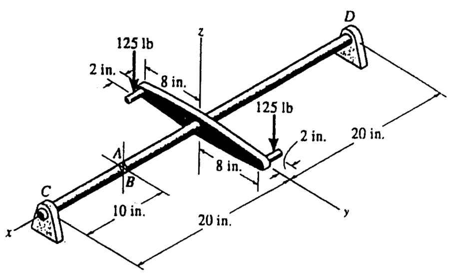
Point D:

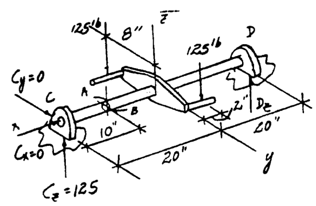
$\sigma_D = 0$ **Ans**



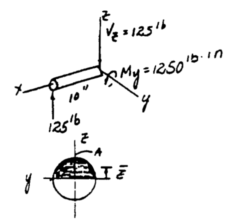
$$\tau_D = \frac{Tc}{J} + \frac{VQ}{It} = 15.279(10^6) + \frac{3(10^3)(4(0.05)/3\pi)(\frac{1}{2})(\pi)(0.05)^2}{\frac{\pi}{4}(0.05)^4(0.1)} = 15.8 \text{ MPa} \qquad \textbf{Ans}$$

8–51 The $\frac{3}{4}$-in.-diameter shaft is subjected to the loading shown. Determine the stress components at point A. Sketch the results on a volume element located at this point. The journal bearing at C can exert only force components $\mathbf{C}_y$ and $\mathbf{C}_z$ on the shaft, and the thrust bearing at D can exert force components $\mathbf{D}_x$, $\mathbf{D}_y$, and $\mathbf{D}_z$ on the shaft.





$$A = \frac{\pi}{4}(0.75^2) = 0.44179 \text{ in}^2$$

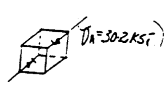


$$I = \frac{\pi}{4}(0.375^4) = 0.015531 \text{ in}^4$$

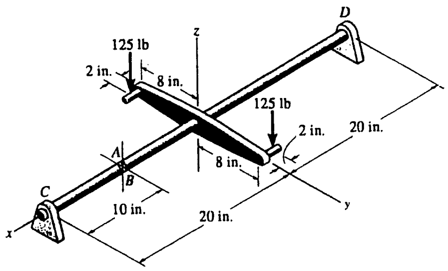
$$Q_A = 0$$

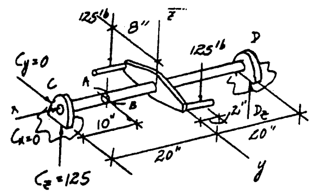
$$\tau_A = 0 \qquad \textbf{Ans}$$

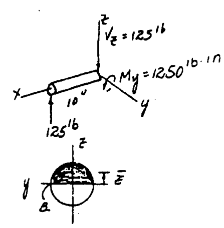
$$\sigma_A = \frac{M_y c}{I} = \frac{-1250(0.375)}{0.015531} = -30.2 \text{ ksi} = 30.2 \text{ ksi (C)} \qquad \textbf{Ans}$$



***8-52** Solve Prob. 8-51 for the stress components at point *B*.







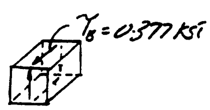
$$A = \frac{\pi}{4}(0.75^2) = 0.44179 \text{ in}^2$$

$$I = \frac{\pi}{4}(0.375^4) = 0.015531 \text{ in}^4$$

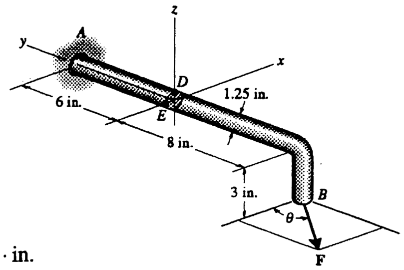
$$Q_B = y'A' = \frac{4(0.375)}{3\pi}(\frac{1}{2})(\pi)(0.375^2) = 0.035156 \text{ in}^3$$

$$\sigma_B = 0$$ **Ans**

$$\tau_B = \frac{V_z Q_B}{I\,t} = \frac{125(0.035156)}{0.015531(0.75)} = 0.377 \text{ ksi}$$ **Ans**



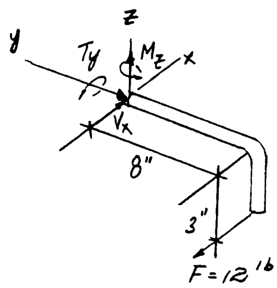
8–53 The bent shaft is fixed in the wall at A. If a force **F** is applied at B, determine the stress components at points D and E. Show the results on a differential element located at each of these points. Take $F = 12$ lb and $\theta = 0°$.



$$\Sigma F_x = 0; \quad V_x - 12 = 0; \quad V_x = 12 \text{ lb}$$

$$\Sigma M_y = 0; \quad -T_y + 12(3) = 0; \quad T_y = 36 \text{ lb}\cdot\text{in.}$$

$$\Sigma M_z = 0; \quad M_z - 12(8) = 0; \quad M_z = 96 \text{ lb}\cdot\text{in.}$$



$$A = \pi(0.625^2) = 1.2272 \text{ in}^2$$

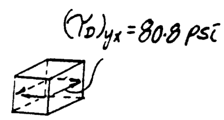
$$I = \frac{1}{4}\pi(0.625^4) = 0.1198 \text{ in}^4$$

$$J = \frac{1}{2}\pi(0.625^4) = 0.2397 \text{ in}^4$$

Point D :

$$(Q_D)_z = \frac{4(0.625)}{3\pi}\,\frac{1}{2}(\pi)(0.625^2) = 0.1628 \text{ in}^3$$

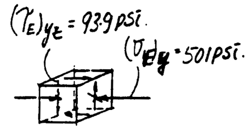
$$\sigma_D = \frac{M_z\,x}{I} = 0 \qquad \textbf{Ans}$$



$$\begin{aligned}(\tau_D)_{yx} &= (\tau_D)_V - (\tau_D)_{\text{twist}} \\ &= \frac{V_x(Q_D)_z}{I\,t} - \frac{T_y\,c}{J} \\ &= \frac{12(0.1628)}{0.1198(1.25)} - \frac{36(0.625)}{0.2397} = -\,80.8 \text{ psi}\end{aligned} \qquad \textbf{Ans}$$

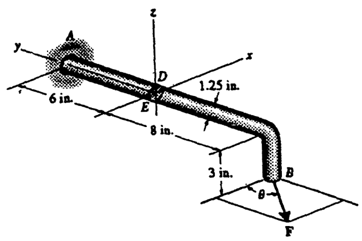
Point E :

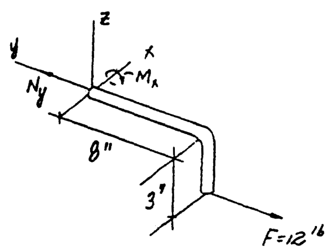
$$(\sigma_E)_y = \frac{M_z x}{I} = \frac{-96(0.625)}{0.1198} = -501 \text{ psi} \qquad \textbf{Ans}$$



$$\begin{aligned}(\tau_E)_{yz} &= (\tau_E)_V - (\tau_E)_{\text{twist}} \\ &= 0 - \frac{T_y\,c}{J} = \frac{-36(0.625)}{0.2397} \\ &= -\,93.9 \text{ psi}\end{aligned} \qquad \textbf{Ans}$$

8-54. The bent shaft is fixed in the wall at A. If a force **F** is applied at B, determine the stress components at points D and E. Show the results on a differential element located at each of these points. Take $F = 12$ lb and $\theta = 90°$.





$\Sigma F_y = 0; \quad N_y - 12 = 0; \quad N_y = 12$ lb

$\Sigma M_x = 0; \quad M_x - 12(3) = 0; \quad M_x = 36$ lb·in.

$A = \pi(0.625^2) = 1.2272$ in^2

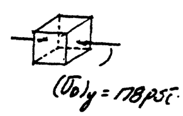
$I = \frac{1}{4}\pi(0.625^4) = 0.1198$ in^4

Point D :

$(\sigma_D)_y = \frac{N_y}{A} - \frac{M_x z}{I} = \frac{12}{1.2272} - \frac{36(0.625)}{0.1198}$

$= -178$ psi **Ans**

$(\tau_D)_{yx} = (\tau_D)_{yz} = 0$ **Ans**

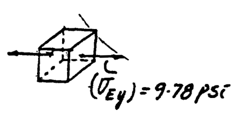


Point E :

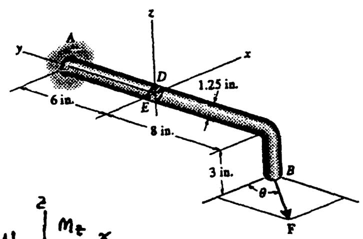
$(\sigma_E)_y = \frac{N_y}{A} + \frac{M_x z}{I} = \frac{12}{1.2272}$

$= 9.78$ psi **Ans**

$(\tau_E)_{yx} = (\tau_E)_{yz} = 0$ **Ans**



8-55. The bent shaft is fixed in the wall at A. If a force $\mathbf{F}$ is applied at B, determine the stress components at points D and E. Show the results on a volume element located at each of these points. Take $F = 12$ lb and $\theta = 45°$.



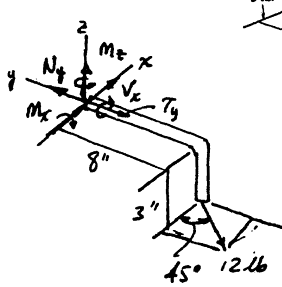
$\Sigma F_x = 0; \quad V_x - 12\cos 45° = 0; \quad V_x = 8.485 \text{ lb}$

$\Sigma F_y = 0; \quad N_y - 12\sin 45° = 0; \quad N_y = 8.485 \text{ lb}$

$\Sigma M_x = 0; \quad M_x - 12\sin 45°(3) = 0;$
$M_x = 25.456 \text{ lb}\cdot\text{in.}$

$\Sigma M_y = 0; \quad -T_y + 12\cos 45°(3) = 0; \quad T_y = 25.456 \text{ lb}\cdot\text{in.}$

$\Sigma M_z = 0; \quad M_z - 12\cos 45°(8) = 0; \quad M_z = 67.882 \text{ lb}\cdot\text{in.}$



$A = \pi(0.625^2) = 1.2272 \text{ in}^2$

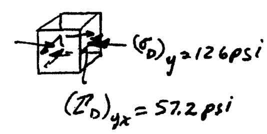
$I = \frac{1}{4}\pi(0.625^4) = 0.1198 \text{ in}^4$

$J = \frac{1}{2}\pi(0.625^4) = 0.2397 \text{ in}^4$

Point D :

$(Q_D)_z = \frac{4(0.625)}{3\pi}\,\frac{1}{2}(\pi)(0.625^2) = 0.1628 \text{ in}^3$

$(\sigma_D)_y = \frac{N_y}{A} - \frac{M_x z}{I} = \frac{8.485}{1.2272} - \frac{25.456(0.625)}{0.1198}$
$= -126 \text{ psi}$ **Ans**

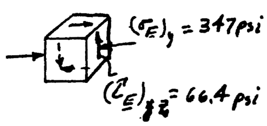


$(\tau_D)_{yx} = \frac{V_x (Q_D)_z}{I\,t} - \frac{T_y\,c}{J}$
$= \frac{8.485(0.1628)}{0.1198(1.25)} - \frac{(25.456)(0.625)}{0.2397}$
$= -57.2 \text{ psi}$ **Ans**

Point E :

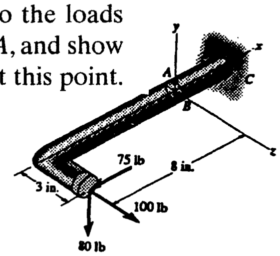
$(\sigma_E)_z = 0$

$(\sigma_E)_y = \frac{N_y}{A} - \frac{M_z x}{I} = \frac{8.485}{1.2272} - \frac{(67.882)(0.625)}{0.1198}$
$= -347 \text{ psi}$ **Ans**



$(\tau_E)_{yz} = \frac{V_x Q_E}{I\,t} - \frac{T\,c}{J}$
$= 0 - \frac{(25.456)(0.625)}{0.2397}$
$= -66.4 \text{ psi}$ **Ans**

***8-56.** The 1-in.-diameter rod is subjected to the loads shown. Determine the state of stress at point A, and show the results on a differential element located at this point.



$\Sigma F_z = 0; \quad V_z + 100 = 0; \quad V_z = -100 \text{ lb}$

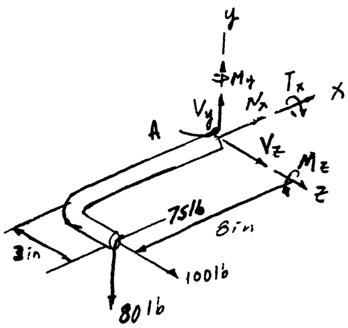
$\Sigma F_x = 0; \quad N_x - 75 = 0; \quad N_x = 75 \text{ lb}$

$\Sigma F_y = 0; \quad V_y - 80 = 0; \quad V_y = 80 \text{ lb}$

$\Sigma M_z = 0; \quad M_z + 80(8) = 0; \quad M_z = -640 \text{ lb}\cdot\text{in.}$

$\Sigma M_x = 0; \quad T_x + 80(3) = 0; \quad T_x = -240 \text{ lb}\cdot\text{in.}$

$\Sigma M_y = 0; \quad M_y + 100(8) - 75(3) = 0; \quad M_y = -575 \text{ lb}\cdot\text{in.}$



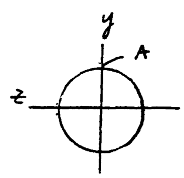
$A = \frac{\pi}{4} d^2 = \frac{\pi}{4}(1^2) = \frac{1}{4}\pi \text{ in}^2$

$J = \frac{\pi}{2} c^4 = \frac{\pi}{2}(0.5^4) = 0.03125\pi \text{ in}^4$

$(Q_y)_A = 0$

$(Q_z)_A = \bar{y}'A' = \frac{4(0.5)}{3\pi}\,\frac{1}{2}(\pi)(0.5^2) = 0.08333 \text{ in}^3$

$I_y = I_z = \frac{\pi}{4} r^4 = \frac{\pi}{4}(0.5^4) = 0.015625\pi \text{ in}^4$



Normal stress: $\sigma = \frac{P}{A} + \frac{M_z y}{I_z} + \frac{M_y z}{I_y}$

$\sigma_A = \frac{75}{\frac{1}{4}\pi} + \frac{640\,(0.5)}{0.0156\pi} + 0 = 6.61 \text{ ksi (T)}$ **Ans**

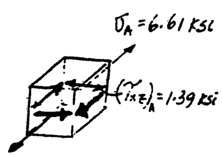
Shear stress:

$\tau = \frac{VQ}{It} + \frac{Tc}{J}$

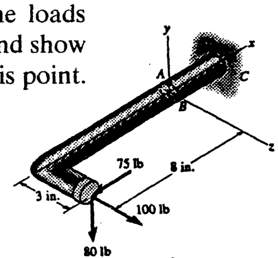
$(\tau_{xz})_A = \frac{100(0.08333)}{0.0156\pi(1)} + \frac{240(0.5)}{0.0312\pi}$

$= 1.39 \text{ ksi}$ **Ans**

$(\tau_{xy})_A = 0$ **Ans**



8-57. The 1-in.-diameter rod is subjected to the loads shown. Determine the state of stress at point B, and show the results on a differential element located at this point.



$\Sigma F_z = 0;\quad V_z + 100 = 0;\quad V_z = -100 \text{ lb}$

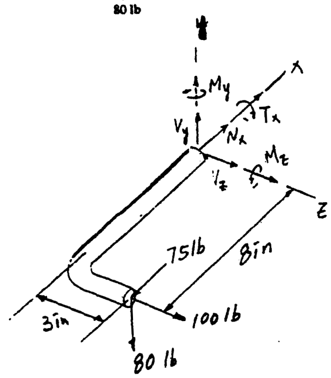
$\Sigma F_x = 0;\quad N_x - 75 = 0;\quad N_x = 75.0 \text{ lb}$

$\Sigma F_y = 0;\quad V_y - 80 = 0;\quad V_y = 80 \text{ lb}$

$\Sigma M_z = 0;\quad M_z + 80(8) = 0;\quad M_z = -640 \text{ lb}\cdot\text{in.}$

$\Sigma M_x = 0;\quad T_x + 80(3) = 0;\quad T_x = -240 \text{ lb}\cdot\text{in.}$

$\Sigma M_y = 0;\quad M_y + 100(8) - 75(3) = 0;\quad M_y = -575 \text{ lb}\cdot\text{in.}$



$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(1^2) = \frac{\pi}{4} \text{ in}^2$

$J = \frac{\pi}{2}c^4 = \frac{\pi}{2}(0.5^4) = 0.03125\,\pi \text{ in}^4$

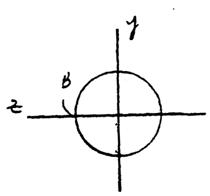
$(Q_y)_B = \frac{4(0.5)}{3\pi}\,\frac{1}{2}\left(\frac{\pi}{4}\right)(1^2) = 0.08333 \text{ in}^3$

$I_y = I_z = \frac{\pi}{4}r^4 = \frac{\pi}{4}(0.5^4) = 0.015625\pi \text{ in}^4$

Normal stress :

$\sigma = \frac{P}{A} + \frac{M_z y}{I_z} + \frac{M_y z}{I_y}$

$\sigma_B = \frac{75}{\frac{\pi}{4}} + 0 - \frac{575(0.5)}{0.015625\pi} = -5.76 \text{ ksi} = 5.76 \text{ ksi (C)}$ **Ans**

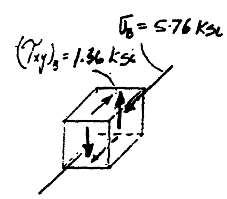


Shear stress :

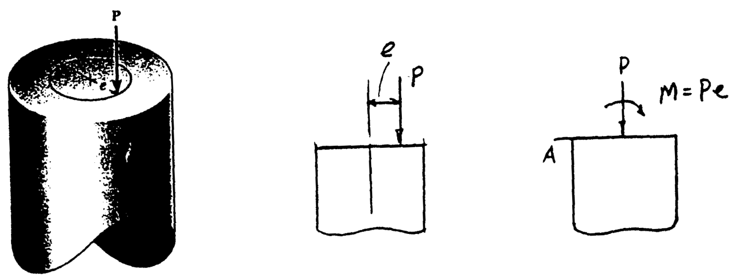
$\tau = \frac{VQ}{It}$ and $\tau = \frac{Tc}{J}$

$(\tau_{xy})_B = \frac{Tc}{J} - \frac{VQ}{It} = \frac{240(0.5)}{0.03125\,\pi} + \frac{80(0.0833)}{0.015625\pi(1)} = 1.36 \text{ ksi}$ **Ans**

$(\tau_{xz})_B = 0$ **Ans**



8–58 The post has a circular cross section of radius c. Determine the maximum radius e at which the load can be applied so that no part of the post experiences a tensile stress. Neglect the weight of the post.

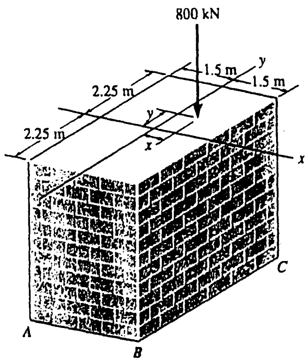


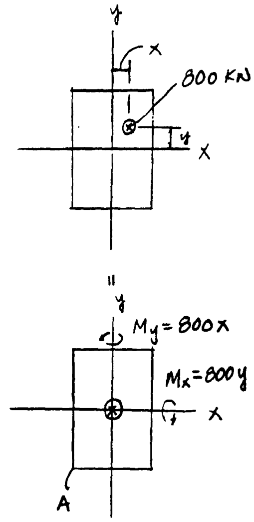
Require $\sigma_A = 0$

$$\sigma_A = 0 = \frac{P}{A} + \frac{Mc}{I}; \qquad 0 = \frac{-P}{\pi c^2} + \frac{(Pe)c}{\frac{\pi}{4}c^4}$$

$$e = \frac{c}{4}$$ **Ans**

8–59 The masonry pier is subjected to the 800-kN load. For the range y>0, x>0, determine the equation of the line $y = f(x)$ along which the load can be placed without causing a tensile stress in the pier. Neglect the weight of the pier.





$A = 3(4.5) = 13.5 \text{ m}^2$

$I_x = \frac{1}{12}(3)(4.5^3) = 22.78125 \text{ m}^4$

$I_y = \frac{1}{12}(4.5)(3^3) = 10.125 \text{ m}^4$

Normal stress : Require $\sigma_A = 0$

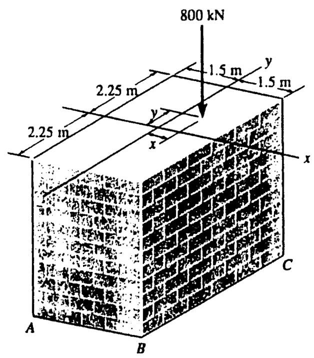
$$\sigma_A = \frac{P}{A} + \frac{M_x y}{I_x} + \frac{M_y x}{I_y}$$

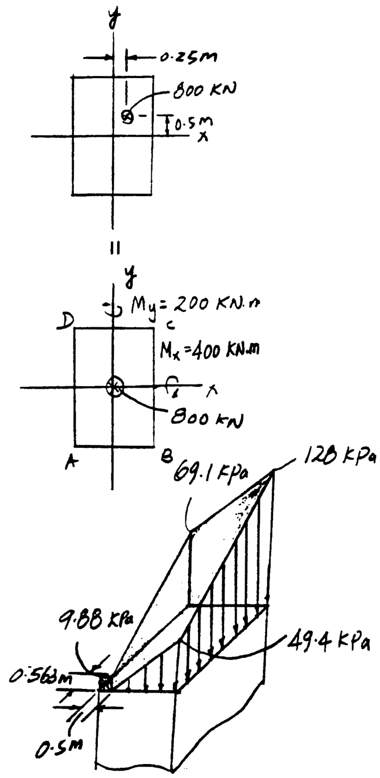
$$0 = \frac{-800(10^3)}{13.5} + \frac{800(10^3)y(2.25)}{22.78125} + \frac{800(10^3)x(1.5)}{10.125}$$

$0 = 0.148x + 0.0988y - 0.0741$

$y = 0.75 - 1.5x$ **Ans**

***8–60** The masonry pier is subjected to the 800-kN load. If $x = 0.25$ m and $y = 0.5$ m, determine the normal stress at each corner A, B, C, D (not shown) and plot the stress distribution over the cross section. Neglect the weight of the pier.





$$A = 3(4.5) = 13.5\ \text{m}^2$$

$$I_x = \frac{1}{12}(3)(4.5^3) = 22.78125\ \text{m}^4$$

$$I_y = \frac{1}{12}(4.5)(3^3) = 10.125\ \text{m}^4$$

$$\sigma = \frac{P}{A} + \frac{M_x y}{I_x} + \frac{M_y x}{I_y}$$

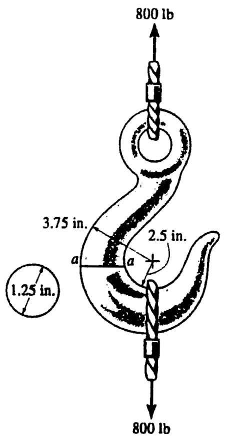
$$\sigma_A = \frac{-800(10^3)}{13.5} + \frac{400(10^3)(2.25)}{22.78125} + \frac{200(10^3)(1.5)}{10.125}$$
$$= 9.88\ \text{kPa (T)}$$ **Ans**

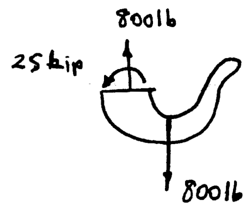
$$\sigma_B = \frac{-800(10^3)}{13.5} + \frac{400(10^3)(2.25)}{22.78125} - \frac{200(10^3)(1.5)}{10.125}$$
$$= -49.4\ \text{kPa} = 49.4\ \text{kPa (C)}$$ **Ans**

$$\sigma_C = \frac{-800(10^3)}{13.5} - \frac{400(10^3)(2.25)}{22.78125} - \frac{200(10^3)(1.5)}{10.125}$$
$$= -128\ \text{kPa} = 128\ \text{kPa (C)}$$ **Ans**

$$\sigma_D = \frac{-800(10^3)}{13.5} - \frac{400(10^3)(2.25)}{22.78125} + \frac{200(10^3)(1.5)}{10.125}$$
$$= -69.1\ \text{kPa} = 69.1\ \text{kPa (C)}$$ **Ans**

8–61 The eye hook has the dimensions shown. If it supports a cable loading of 80 kN, determine the maximum normal stress at section *a–a* and sketch the stress distribution acting over the cross section.

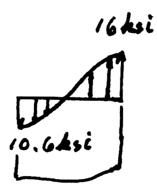




$$\int \frac{dA}{r} = 2\pi\,(3.125 - \sqrt{(3.125)^2 - (0.625)^2}\,) = 0.395707$$

$$R = \frac{A}{\int \frac{dA}{r}} = \frac{\pi\,(0.625)^2}{0.396707} = 3.09343 \text{ in.}$$

$$M = 800(3.125) = 2.5(10^3)$$

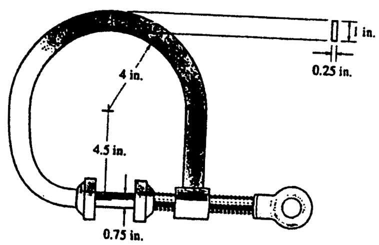


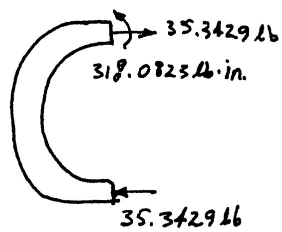
$$\sigma = \frac{M(R-r)}{Ar(\bar{r}-R)} + \frac{P}{A}$$

$$(\sigma_t)_{max} = \frac{2.5(10^3)(3.09343 - 2.5)}{\pi\,(0.625)^2(2.5)(3.125 - 3.09343)} + \frac{800}{\pi\,(0.625)^2} = 16.0 \text{ ksi} \qquad \textbf{Ans}$$

$$(\sigma_c)_{max} = \frac{2.5(10^3)(3.09343 - 3.75)}{\pi\,(0.625)^2(3.75)(3.125 - 3.09343)} + \frac{800}{\pi\,(0.625)^2} = -10.6 \text{ ksi} \qquad \textbf{Ans}$$

8-62. The C-clamp applies a compressive stress on the cylindrical block of 80 psi. Determine the maximum normal stress developed in the clamp.





$$\int_A \frac{dA}{r} = 0.25 \ln \frac{5}{4} = 0.055786$$

$$R = \frac{A}{\int \frac{dA}{r}} = \frac{1(0.25)}{0.055786} = 4.48142$$

$$P = \sigma_b A = 80\pi (0.375)^2 = 35.3429 \text{ lb}$$

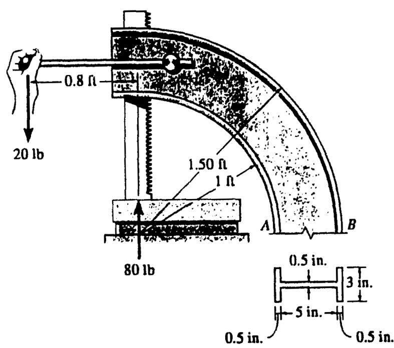
$$M = 35.3429(9) = 318.0863 \text{ kip} \cdot \text{in.}$$

$$\sigma = \frac{M(R-r)}{Ar(\bar{r}-R)} + \frac{P}{A}$$

$$(\sigma_t)_{max} = \frac{318.0863(4.48142-4)}{(1)(0.25)(4)(4.5-4.48142)} + \frac{35.3429}{(1)(0.25)} = 8.38 \text{ ksi}$$ **Ans**

$$(\sigma_c)_{max} = \frac{318.0863(4.48142-5)}{1(0.25)(5)(4.5-4.48142)} + \frac{35.3429}{(1)(0.25)} = -6.96 \text{ ksi}$$

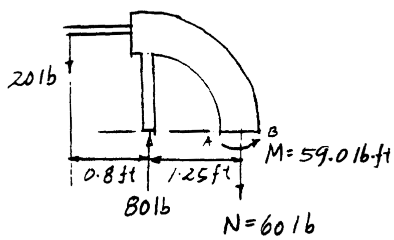
8-63 The handle of the press is subjected to a force of 20 lb. Due to internal gearing, this causes the block to be subjected to a compressive force of 80 lb. Determine the normal stress acting in the frame at points along the outside flanges A and B. Use the curved-beam formula to compute the bending stress.



Normal stress due to axial force :

$A = 2[0.5(3)] + 5(0.5) = 5.5\ \text{in}^2$

$\sigma_A = \frac{P}{A} = \frac{60}{5.5} = 10.9090\ \text{psi} \quad \text{(T)}$



Normal stress due to bending :

$\bar{r} = 15\ \text{in.} \quad r_A = 12\ \text{in.} \quad r_B = 18\ \text{in.}$

$$\Sigma\int \frac{dA}{r} = \Sigma\, b \ln\frac{r_2}{r_1} = 3\ln\frac{12.5}{12} + 0.5\ln\frac{17.5}{12.5} + 3\ln\frac{18}{17.5} = 0.3752\ \text{in.}$$

$$R = \frac{A}{\int\frac{dA}{r}} = \frac{5.5}{0.3752} = 14.6583\ \text{in.}$$

$\bar{r} - R = 0.3417\ \text{in.}$

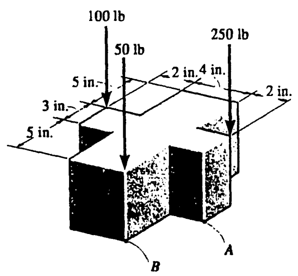
$$(\sigma_A)_b = \frac{M(R - r_A)}{Ar_A(\bar{r} - R)} = \frac{59.0(12)(14.6583 - 12)}{5.5(12)(0.3417)} = 83.4468\ \text{psi (T)}$$

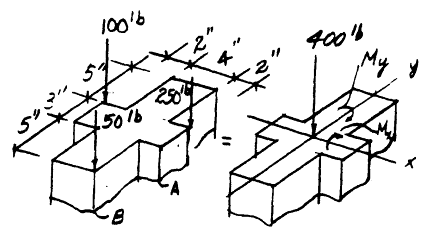
$$(\sigma_B)_b = \frac{M(R - r_B)}{Ar_B(\bar{r} - R)} = \frac{59.0(12)(14.6583 - 18)}{5.5(18)(0.3417)} = -69.9342\ \text{psi} = 69.9342\ \text{psi (C)}$$

$\sigma_A = 83.4468 + 10.9090 = 94.4\ \text{psi (T)}$ **Ans**

$\sigma_B = 69.9342 - 10.9090 = 59.0\ \text{psi (C)}$ **Ans**

*8–64 The block is subjected to the three axial loads shown. Determine the normal stress developed at points A and B. Neglect the weight of the block.





$$M_x = -250(1.5) - 100(1.5) + 50(6.5) = -200 \text{ lb}\cdot\text{in.}$$

$$M_y = 250(4) + 50(2) - 100(4) = 700 \text{ lb}\cdot\text{in.}$$

$$I_x = \frac{1}{12}(4)(13^3) + 2(\frac{1}{12})(2)(3^3) = 741.33 \text{ in}^4$$

$$I_y = \frac{1}{12}(3)(8^3) + 2(\frac{1}{12})(5)(4^3) = 181.33 \text{ in}^4$$

$$A = 4(13) + 2(2)(3) = 64 \text{ in}^2$$

$$\sigma = \frac{P}{A} - \frac{M_y\, x}{I_y} + \frac{M_x\, y}{I_x}$$

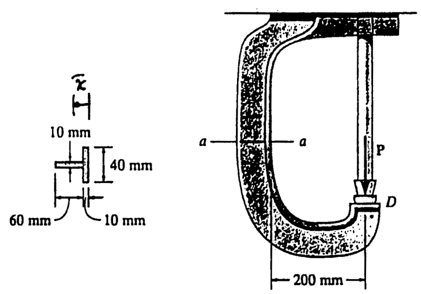
$$\sigma_A = -\frac{400}{64} - \frac{700(4)}{181.33} + \frac{-200\ (-1.5)}{741.33}$$

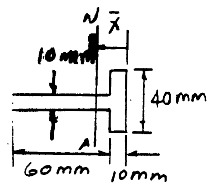
$$= -21.3 \text{ psi} \qquad \textbf{Ans}$$

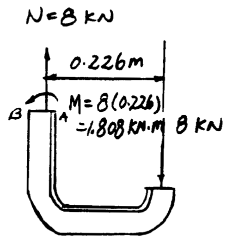
$$\sigma_B = -\frac{400}{64} - \frac{700(2)}{181.33} + \frac{-200\ (-6.5)}{741.33}$$

$$= -12.2 \text{ psi} \qquad \textbf{Ans}$$

8-65 **The C-frame is used in a riveting machine. If the force at the ram on the clamp at D is $P = 8$ kN, sketch the stress distribution acting over the section a–a.**







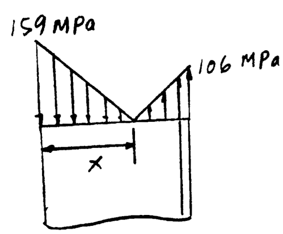
$$\bar{x} = \frac{\Sigma \bar{x} A}{\Sigma A} = \frac{(0.005)(0.04)(0.01) + 0.04(0.06)(0.01)}{0.04(0.01) + 0.06(0.01)} = 0.026\text{ m}$$

$$A = 0.04(0.01) + 0.06(0.01) = 0.001\text{ m}^2$$

$$I = \frac{1}{12}(0.04)(0.01^3) + (0.04)(0.01)(0.026 - 0.005)^2 + \frac{1}{12}(0.01)(0.06^3) + 0.01(0.06)(0.040 - 0.026)^2 = 0.4773(10^{-6})\text{ m}^4$$

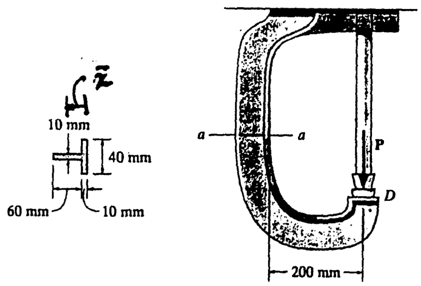
$$(\sigma_{max})_t = \frac{P}{A} + \frac{Mx}{I} = \frac{8(10^3)}{0.001} + \frac{1.808(10^3)(0.07 - 0.26)}{0.4773(10^{-6})} = 106.48\text{ MPa} = 106\text{ MPa}$$

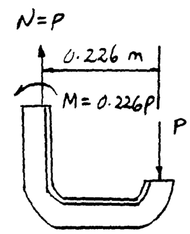
$$(\sigma_{max})_c = \frac{P}{A} - \frac{Mc}{I} = \frac{8(10^3)}{0.001} - \frac{1.808(10^3)(0.070 - 0.026)}{0.4773(10^{-6})} = -158.66\text{ MPa} = -159\text{ MPa}$$



$$\frac{x}{158.66} = \frac{70 - x}{106.48}; \qquad x = 41.9\text{ mm}$$

8-66 Determine the maximum ram force P that can be applied to the clamp at D if the allowable normal stress for the material is $\sigma_{allow} = 180$ MPa.





$$\bar{x} = \frac{\Sigma \bar{x} A}{\Sigma A} = \frac{(0.005)(0.04)(0.01) + 0.04(0.06)(0.01)}{0.04(0.01) + 0.06(0.01)} = 0.026 \text{ m}$$

$$A = 0.04(0.01) + 0.06(0.01) = 0.001 \text{ m}^2$$

$$I = \frac{1}{12}(0.04)(0.01^3) + (0.04)(0.01)(0.026 - 0.005)^2 + \frac{1}{12}(0.01)(0.06^3) + 0.01(0.06)(0.040 - 0.026)^2 = 0.4773(10^{-6}) \text{ m}^4$$

$$\sigma = \frac{P}{A} \pm \frac{Mx}{I}$$

Assume tension failure,

$$180(10^6) = \frac{P}{0.001} + \frac{0.226\,P(0.026)}{0.4773(10^{-6})}$$

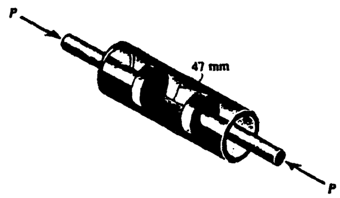
$$P = 13524 \text{ N} = 13.5 \text{ kN}$$

Assume compression failure,

$$-180(10^6) = \frac{P}{0.001} - \frac{0.226\,P(0.070 - 0.026)}{0.4773(10^{-6})}$$

$P = 9076 \text{ N} = 9.08 \text{ kN}$ (controls) **Ans**

8-67. Air pressure in the cylinder is increased by exerting forces $P = 2$ kN on the two pistons, each having a radius of 45 mm. If the cylinder has a wall thickness of 2 mm, determine the state of stress in the wall of the cylinder.



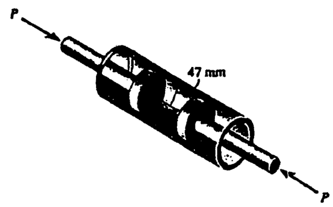
$$p = \frac{P}{A} = \frac{2(10^3)}{\pi(0.045^2)} = 314\,380.13 \text{ Pa}$$

$$\sigma_1 = \frac{p\,r}{t} = \frac{314\,380.13(0.045)}{0.002} = 7.07 \text{ MPa} \qquad \textbf{Ans}$$

$$\sigma_2 = 0 \qquad \textbf{Ans}$$

The pressure p is supported by the surface of the pistons in the longitudinal direction.

***8-68.** Determine the maximum force P that can be exerted on each of the two pistons so that the circumferential stress component in the cylinder does not exceed 3 MPa. Each piston has a radius of 45 mm and the cylinder has a wall thickness of 2 mm.

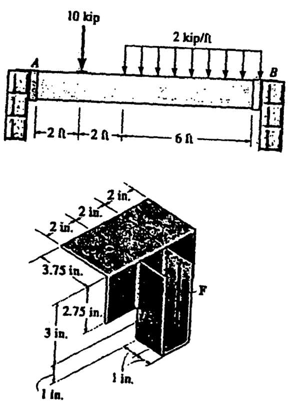


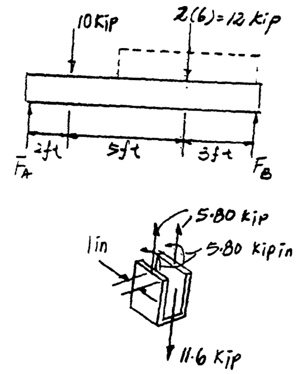
$$\sigma = \frac{p\,r}{t}; \qquad 3(10^6) = \frac{p(0.045)}{0.002}$$

$$p = 133.3 \text{ kPa} \qquad \textbf{Ans}$$

$$P = pA = 133.3\left(10^3\right)(\pi)(0.045)^2 = 848 \text{ N} \qquad \textbf{Ans}$$

8-69. The wall hanger has a thickness of 0.25 in. and is used to support the vertical reactions of the beam that is loaded as shown. If the load is transferred uniformly to each strap of the hanger, determine the state of stress at points C and D on the strap at A. Assume the vertical reaction **F** at this end acts in the center and on the edge of the bracket as shown.





$\curvearrowleft + \Sigma M_B = 0; \qquad 12(3) + 10(8) - F_A(10) = 0$

$$F_A = 11.60 \text{ kip}$$

$$I = 2[\frac{1}{12}(0.25)(2)^3] = 0.333 \text{ in}^4$$

$$A = 2(0.25)(2) = 1 \text{ in}^2$$

At point C,

$$\sigma_C = \frac{P}{A} = \frac{2(5.80)}{1} = 11.6 \text{ ksi} \qquad \textbf{Ans}$$

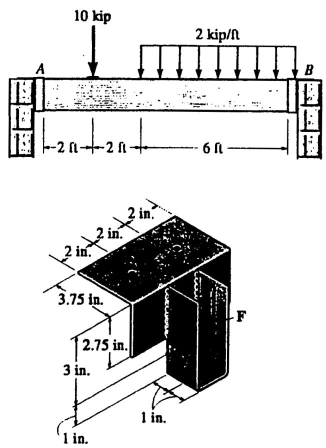
$$\tau_C = 0 \qquad \textbf{Ans}$$

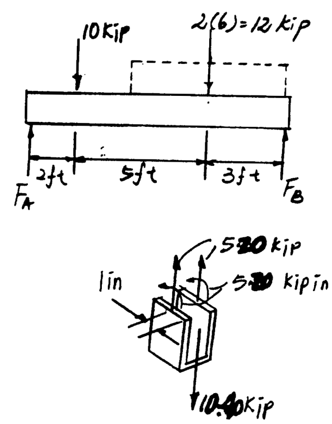
At point D,

$$\sigma_D = \frac{P}{A} - \frac{Mc}{I} = \frac{2(5.80)}{1} - \frac{[2(5.80)](1)}{0.333} = -23.2 \text{ ksi} \qquad \textbf{Ans}$$

$$\tau_D = 0 \qquad \textbf{Ans}$$

8–70 The wall hanger has a thickness of 0.25 in. and is used to support the vertical reactions of the beam that is loaded as shown. If the load is transferred uniformly to each strap of the hanger, determine the state of stress at points *C* and *D* of the strap at *B*. Assume the vertical reaction *F* at this end acts in the center and on the edge of the bracket as shown.





$$\circlearrowleft + \Sigma M_A = 0; \qquad F_B(10) - 10(2) - 12(7) = 0; \qquad F_B = 10.40 \text{ kip}$$

$$I = 2\left[\frac{1}{12}(0.25)(2)^3\right] = 0.333 \text{ in}^4 ; \qquad A = 2(0.25)(2) = 1 \text{ in}^2$$

At point C :

$$\sigma_C = \frac{P}{A} = \frac{2(5.20)}{1} = 10.4 \text{ ksi}$$ **Ans**

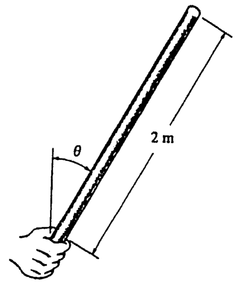
$$\tau_C = 0$$ **Ans**

At point D :

$$\sigma_D = \frac{P}{A} - \frac{Mc}{I} = \frac{2(5.20)}{1} - \frac{[2(5.20)](1)}{0.333} = -20.8 \text{ ksi}$$ **Ans**

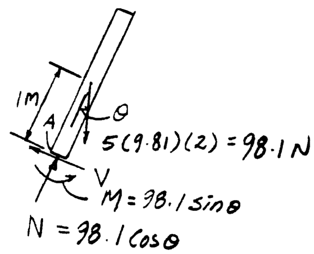
$$\tau_D = 0$$ **Ans**

8–71 A bar having a square cross section of 30 mm by 30 mm is 2 m long and is held upward. If it has a mass of 5 kg/m, determine the largest angle θ, measured from the vertical, at which it can be supported before it is subjected to a tensile stress along its axis near the grip.



$$A = 0.03(0.03) = 0.9(10^{-3})\ \text{m}^2$$

$$I = \frac{1}{12}(0.03)(0.03^3) = 67.5(10^{-9})\ \text{m}^4$$



Require $\sigma_A = 0$

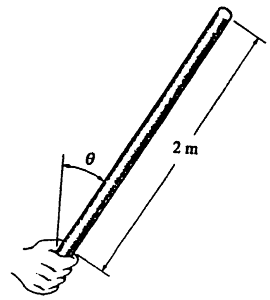
$$\sigma_A = 0 = \frac{P}{A} + \frac{Mc}{I}$$

$$0 = \frac{-98.1\cos\theta}{0.9(10^{-3})} + \frac{98.1\sin\theta(0.015)}{67.5(10^{-9})}$$

$$0 = -1111.11\cos\theta + 222222.22\sin\theta$$

$\tan\theta = 0.005;\qquad \theta = 0.286°\qquad$ **Ans**

***8–72** Solve Prob. 8–71 if the bar has a circular cross section of 30-mm diameter.

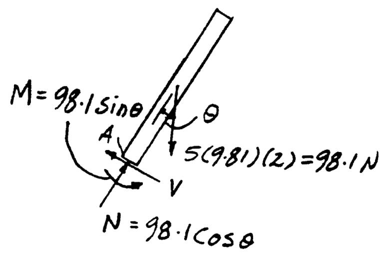


$$A = \frac{\pi}{4}(0.03^2) = 0.225\pi(10^{-3})\ \text{m}^2$$

$$I = \frac{\pi}{4}(0.015^4) = 12.65625\pi\,(10^{-9})\ \text{m}^4$$

Require $\sigma_A = 0$

$$\sigma_A = 0 = \frac{P}{A} + \frac{Mc}{I}$$



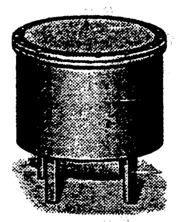
$$0 = \frac{-98.1\cos\theta}{0.225\pi(10^{-3})} + \frac{98.1\sin\theta(0.015)}{12.65625\,\pi(10^{-9})}$$

$$0 = -\,4444.44\cos\theta + 1185185.185\sin\theta$$

$$\tan\theta = 0.00375$$

$$\theta = 0.215° \qquad \textbf{Ans}$$

8-73. The cap on the cylindrical tank is bolted to the tank along the flanges. The tank has an inner diameter of 1.5 m and a wall thickness of 18 mm. If the largest normal stress is not to exceed 150 MPa, determine the maximum pressure the tank can sustain. Also, compute the number of bolts required to attach the cap to the tank if each bolt has a diameter of 20 mm. The allowable stress for the bolts is $(\sigma_{\text{allow}})_b = 180$ MPa.

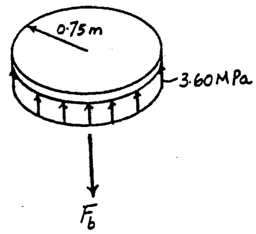


Hoop Stress for Cylindrical Tank : Since $\frac{r}{t} = \frac{750}{18} = 41.6 > 10$, then *thin wall* analysis can be used. Applying Eq. 8 – 1

$$\sigma_1 = \sigma_{\text{allow}} = \frac{pr}{t}$$

$$150(10^6) = \frac{p(750)}{18}$$

$$p = 3.60 \text{ MPa} \qquad \textbf{Ans}$$



Force Equilibrium for the Cap :

$$+\uparrow \Sigma F_y = 0; \quad 3.60(10^6)\left[\pi(0.75^2)\right] - F_b = 0$$

$$F_b = 6.3617(10^6) \text{ N}$$

Allowable Normal Stress for Bolts :

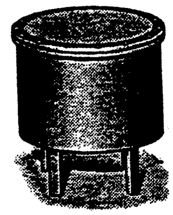
$$(\sigma_{\text{allow}})_b = \frac{P}{A}$$

$$180(10^6) = \frac{6.3617(10^6)}{n\left[\frac{\pi}{4}(0.02^2)\right]}$$

$$n = 112.5$$

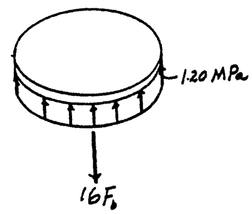
Use $n = 113$ bolts $\qquad$ **Ans**

8-74. The cap on the cylindrical tank is bolted to the tank along the flanges. The tank has an inner diameter of 1.5 m and a wall thickness of 18 mm. If the pressure in the tank is $p = 1.20$ MPa, determine the force in the 16 bolts that are used to attach the cap to the tank. Also, specify the state of stress in the wall of the tank.



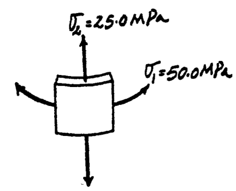
Hoop Stress for Cylindrical Tank : Since $\frac{r}{t} = \frac{750}{18}$ $= 41.6 > 10$, then *thin wall* analysis can be used. Applying Eq. 8 – 1

$$\sigma_1 = \frac{pr}{t} = \frac{1.20(10^6)(750)}{18} = 50.0 \text{ MPa} \qquad \textbf{Ans}$$



Longitudinal Stress for Cylindrical Tank :

$$\sigma_2 = \frac{pr}{2t} = \frac{1.20(10^6)(750)}{2(18)} = 25.0 \text{ MPa} \qquad \textbf{Ans}$$

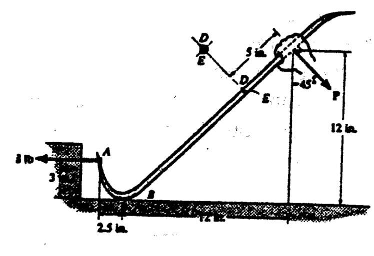


Force Equilibrium for the Cap :

$$+\uparrow \Sigma F_y = 0; \quad 1.20(10^6)\left[\pi(0.75^2)\right] - 16F_b = 0$$

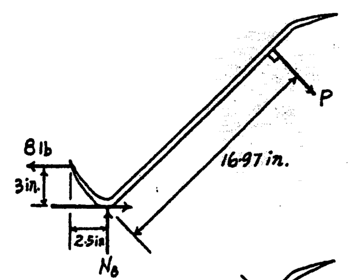
$$F_b = 132536 \text{ N} = 133 \text{ kN} \qquad \textbf{Ans}$$

8-75. The crowbar is used to pull out the nail at A. If a force of 8 lb is required, determine the stress components in the bar at points D and E. Show the results on a differential volume element located at each of these points. The bar has a circular cross section with a diameter of 0.5 in. No slipping occurs at B.



Support Reactions :

$\circlearrowleft + \Sigma M_B = 0;\quad 8(3) - P(16.97) = 0 \quad P = 1.414 \text{ lb}$

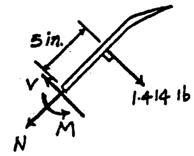


Internal Forces and Moment :

$\nearrow + \Sigma F_{x'} = 0;\quad N = 0$

$\nwarrow + \Sigma F_{y'} = 0;\quad V - 1.414 = 0 \quad V = 1.414 \text{ lb}$

$\circlearrowleft + \Sigma M_O = 0;\quad M - 1.414(5) = 0 \quad M = 7.071 \text{ lb}\cdot\text{in.}$



Section Properties :

$$A = \pi\left(0.25^2\right) = 0.0625\pi \text{ in}^2$$

$$I = \frac{\pi}{4}\left(0.25^4\right) = 0.9765625\pi\left(10^{-3}\right) \text{ in}^4$$

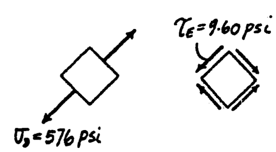
$$Q_D = 0$$

$$Q_E = \bar{y}'A' = \frac{4(0.25)}{3\pi}\left[\frac{1}{2}(\pi)\left(0.25^2\right)\right] = 0.0104167 \text{ m}^3$$

Normal Stress : Since $N = 0$, the normal stress is caused by bending stress only.

$$\sigma_D = \frac{Mc}{I} = \frac{7.071(0.25)}{0.9765625\pi(10^{-3})} = 576 \text{ psi (T)} \qquad \textbf{Ans}$$

$$\sigma_E = \frac{My}{I} = \frac{7.071(0)}{0.9765625\pi(10^{-3})} = 0 \qquad \textbf{Ans}$$

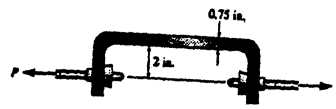


Shear Stress : Applying the shear formul.

$$\tau_D = \frac{VQ_D}{It} = 0 \qquad \textbf{Ans}$$

$$\tau_E = \frac{VQ_E}{It} = \frac{1.414(0.0104167)}{0.9765625\pi(10^{-3})(0.5)} = 9.60 \text{ psi} \qquad \textbf{Ans}$$

*8-76. The steel bracket is used to connect the ends of two cables. If the applied force $P = 500$ lb, determine the maximum normal stress in the bracket. The bracket has a thickness of 0.5 in. and a width of 0.75 in.



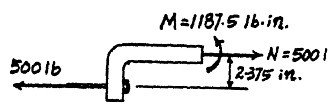
Internal Force and Moment : As shown on FBD.

Section Properties :

$$A = 0.5(0.75) = 0.375 \text{ in}^2$$

$$I = \frac{1}{12}(0.5)\left(0.75^3\right) = 0.01758 \text{ in}^4$$

Maximum Normal Stress : The maximum normal stress occurs at the bottom of the steel bracket.

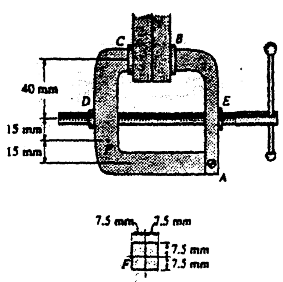


$$\sigma_{max} = \frac{N}{A} + \frac{Mc}{I}$$

$$= \frac{500}{0.375} + \frac{1187.5(0.375)}{0.01758}$$

$$= 26.7 \text{ ksi} \qquad \textbf{Ans}$$

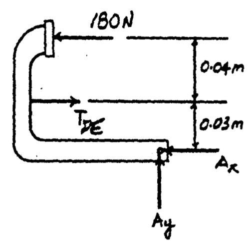
8-77. The clamp is made from members AB and AC, which are pin connected at A. If the compressive force at C and B is 180 N, determine the state of stress at point F, and indicate the results on a differential volume element. The screw DE is subjected only to a tensile force along its axis.



Support Reactions :

$\curvearrowleft + \Sigma M_A = 0; \quad 180(0.07) - T_{DE}(0.03) = 0$

$T_{DE} = 420 \text{ N}$



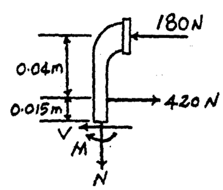
Internal Forces and Moment :

$\xrightarrow{+} \Sigma F_x = 0; \quad 420 - 180 - V = 0 \quad V = 240 \text{ N}$

$+\uparrow \Sigma F_y = 0; \quad N = 0$

$+\Sigma M_O = 0; \quad 180(0.055) - 420(0.015) - M = 0$

$M = 3.60 \text{ N} \cdot \text{m}$



Section Properties :

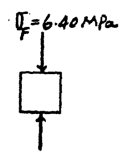
$A = 0.015(0.015) = 0.225\left(10^{-3}\right) \text{ m}^2$

$I = \frac{1}{12}(0.015)\left(0.015^3\right) = 4.21875\left(10^{-9}\right) \text{ m}^4$

$Q_F = 0$

Normal Stress : Since $N = 0$, the normal stress is caused by bending stress only.

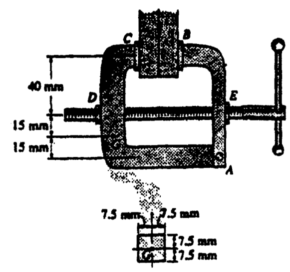
$$\sigma_F = \frac{Mc}{I} = \frac{3.60(0.0075)}{4.21875(10^{-9})} = 6.40 \text{ MPa (C)} \qquad \textbf{Ans}$$



Shear Stress : Applying shear formula, we have

$$\tau_F = \frac{VQ_F}{It} = 0 \qquad \textbf{Ans}$$

8-78. The clamp is made from members AB and AC, which are pin-connected at A. If the compressive force at C and B is 180 N, determine the state of stress at point G, and indicate the results on a differential volume element. The screw DE is subjected only to a tensile force along its axis.

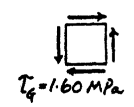


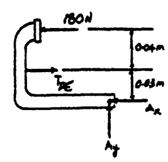
Support Reactions :

$$\circlearrowleft + \Sigma M_A = 0; \quad 180(0.07) - T_{DE}(0.03) = 0$$
$$T_{DE} = 420\text{ N}$$

Internal Forces and Moment :

$$\xrightarrow{+} \Sigma F_x = 0; \quad 420 - 180 - V = 0 \quad V = 240\text{ N}$$
$$+\uparrow \Sigma F_y = 0; \quad N = 0$$
$$\circlearrowleft + \Sigma M_O = 0; \quad 180(0.055) - 420(0.015) - M = 0$$
$$M = 3.60\text{ N}\cdot\text{m}$$





Section Properties :

$$A = 0.015(0.015) = 0.225\left(10^{-3}\right)\text{ m}^2$$
$$I = \frac{1}{12}(0.015)\left(0.015^3\right) = 4.21875\left(10^{-9}\right)\text{ m}^4$$
$$Q_G = \bar{y}'A' = 0.00375(0.0075)(0.015) = 0.421875\left(10^{-6}\right)\text{ m}^3$$

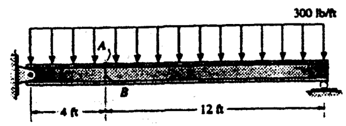
Normal Stress : Since $N = 0$, the normal stress is caused by bending stress only.

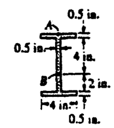
$$\sigma_G = \frac{My}{I} = \frac{3.60(0)}{4.21875(10^{-9})} = 0 \qquad \textbf{Ans}$$

Shear Stress : Applying shear formula, we have

$$\tau_G = \frac{VQ_G}{It} = \frac{240\left[0.421875(10^{-6})\right]}{4.21875(10^{-9})(0.015)} = 1.60\text{ MPa} \qquad \textbf{Ans}$$

8-79. The wide-flange beam is subjected to the loading shown. Determine the state of stress at points A and B, and show the results on a differential volume element located at each of these points.





Support Reactions : As shown on FBD.

Internal Forces and Moment : As shown on FBD.

Section Properties :

$$A = 4(7) - 3.5(6) = 7.00 \text{ in}^2$$

$$I = \frac{1}{12}(4)(7^3) - \frac{1}{12}(3.5)(6^3) = 51.333 \text{ in}^4$$

$$Q_A = 0$$

$$Q_B = \Sigma \bar{y}' A' = 3.25(0.5)(4) + 2.00(0.5)(2) = 8.50 \text{ in}^3$$

Normal Stress : Since $N = 0$, the normal stress is contributed by bending stress only.

$$\sigma_A = \frac{Mc}{I} = \frac{7.20(12)(3.5)}{51.333} = 5.89 \text{ ksi (C)} \qquad \textbf{Ans}$$

$$\sigma_B = \frac{My}{I} = \frac{7.20(12)(1)}{51.333} = 1.68 \text{ ksi (T)} \qquad \textbf{Ans}$$

Shear Stress : Applying the shear formula.

$$\tau_A = \frac{VQ_A}{It} = 0 \qquad \textbf{Ans}$$

$$\tau_B = \frac{VQ_B}{It} = \frac{1.20(8.50)}{51.333(0.5)} = 0.397 \text{ ksi} \qquad \textbf{Ans}$$