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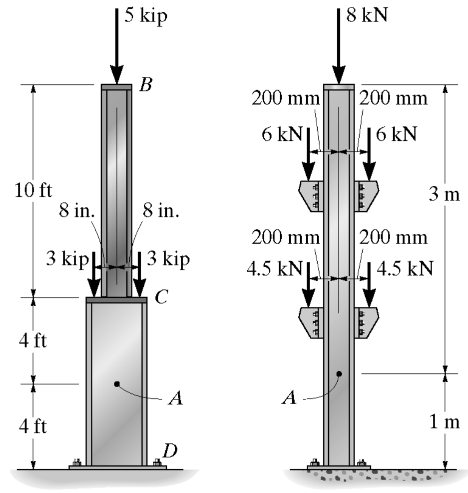
1–1. Determine the resultant internal normal force acting on the cross section through point A in each column. In (a), segment BC weighs 180 lb/ft and segment CD weighs 250 lb/ft. In (b), the column has a mass of 200 kg/m.

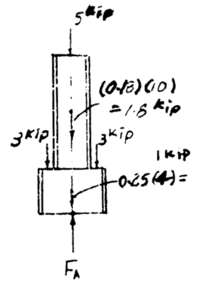


(a) (b)

(a)

$$+\uparrow \Sigma F_y = 0; \quad F_A - 1.0 - 3 - 3 - 1.8 - 5 = 0$$

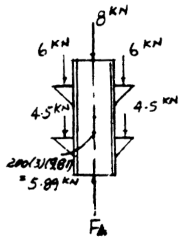
$$F_A = 13.8 \text{ kip} \quad \textbf{Ans}$$



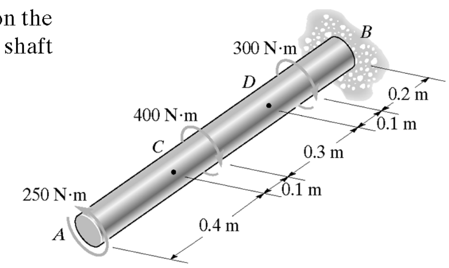
(b)

$$+\uparrow \Sigma F_y = 0; \quad F_A - 4.5 - 4.5 - 5.89 - 6 - 6 - 8 = 0$$

$$F_A = 34.9 \text{ kN} \quad \textbf{Ans}$$



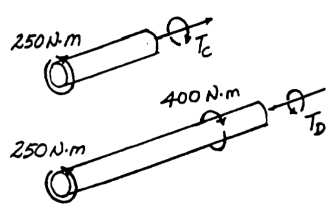
1–2. Determine the resultant internal torque acting on the cross sections through points C and D of the shaft. The shaft is fixed at B.



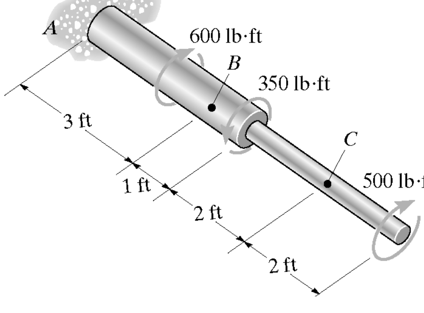
Equations of Equilibrium :

$$\circlearrowleft + \quad 250 - T_C = 0 \qquad T_C = 250 \text{ N}\cdot\text{m} \quad \textbf{Ans}$$

$$\circlearrowleft + \quad 250 - 400 + T_D = 0 \qquad T_D = 150 \text{ N}\cdot\text{m} \quad \textbf{Ans}$$

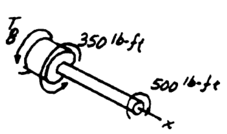


1–3. Determine the resultant internal torque acting on the cross sections through points B and C.



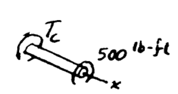
$$\Sigma M_x = 0; \quad T_B + 350 - 500 = 0$$

$$T_B = 150 \text{ lb}\cdot\text{ft} \quad \textbf{Ans}$$



$$\Sigma M_x = 0; \quad T_C - 500 = 0$$

$$T_C = 500 \text{ lb}\cdot\text{ft} \quad \textbf{Ans}$$



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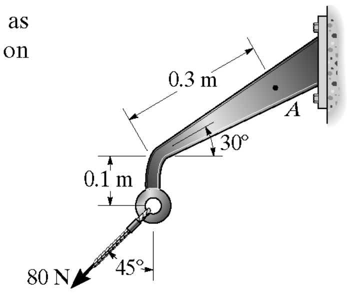
***1–4.** A force of 80 N is supported by the bracket as shown. Determine the resultant internal loadings acting on the section through point A.



Equations of Equilibrium :

$+\nearrow \Sigma F_{x'} = 0; \quad N_A - 80 \cos 15° = 0$

$N_A = 77.3 \text{ N}$ **Ans**

$\nwarrow + \; \Sigma F_{y'} = 0; \quad V_A - 8\;0\sin 15° = 0$

$V_A = 20.7 \text{ N}$ **Ans**

$\circlearrowleft + \; \Sigma M_A = 0; \quad M_A + 80 \cos 45°(0.3\cos 30°) - 80\sin 45°(0.1 + 0.3\sin 30°) = 0$

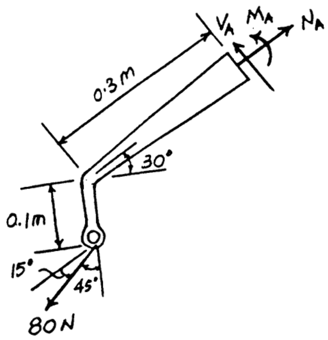
$M_A = -0.555 \text{ N} \cdot \text{m}$ **Ans**

or

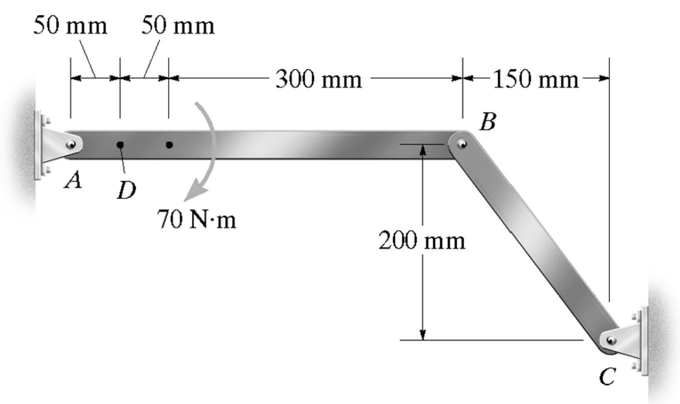
$\circlearrowleft + \; \Sigma M_A = 0; \quad M_A + 80 \sin 15°(0.3 + 0.1\sin 30°) - 80 \cos 15°(0.1\cos 30°) = 0$

$M_A = -0.555 \text{ N} \cdot \text{m}$ **Ans**

Negative sign indicates that $\mathbf{M}_A$ acts in the opposite direction to that shown on FBD.



1–5. Determine the resultant internal loadings acting on the cross section through point D of member AB.

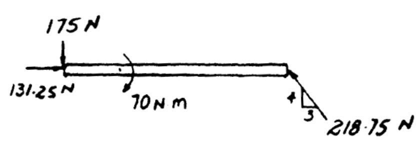


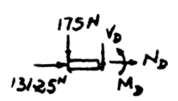
Segment ***AD*** **:**

$\xrightarrow{+} \Sigma F_x = 0; \quad N_D + 131.25 = 0; \quad N_D = -131 \text{ N}$ **Ans**

$+\downarrow \Sigma F_y = 0; \quad V_D + 175 = 0; \quad V_D = -175 \text{ N}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0; \quad M_D + 175(0.05) = 0; \quad M_D = -8.75 \text{ N} \cdot \text{m}$ **Ans**





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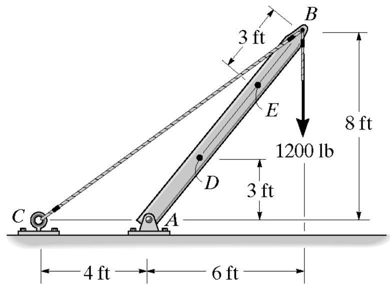
1–6. The beam AB is pin supported at A and supported by a cable BC. Determine the resultant internal loadings acting on the cross section at point D.



$$\theta = \tan^{-1}\left(\frac{6}{8}\right) = 36.87°$$

$$\phi = \tan^{-1}\left(\frac{10}{8}\right) - 36.87° = 14.47°$$

Member AB :

$\circlearrowleft + \Sigma M_A = 0;\quad F_{BC} \sin 14.47°(10) - 1200(6) = 0$

$F_{BC} = 2881.46$ lb

Segment BD :

$+\nearrow \Sigma F_x = 0;\quad -N_D - 2881.46 \cos 14.47° - 1200 \cos 36.87° = 0$

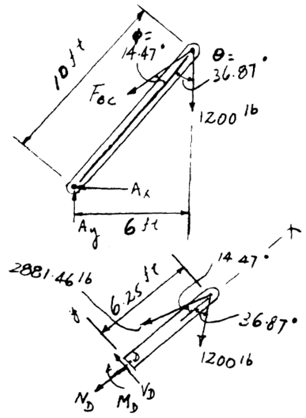
$N_D = -3750$ lb $= -3.75$ kip **Ans**

$+\nwarrow \Sigma F_y = 0;\quad V_D + 2881.46 \sin 14.47° - 1200 \sin 36.87° = 0$

$V_D = 0$ **Ans**

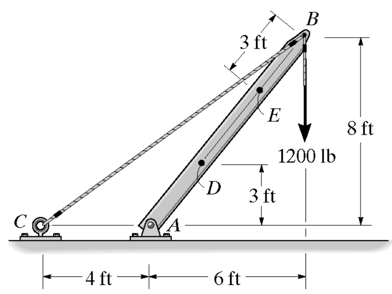
$\circlearrowleft + \Sigma M_D = 0;\quad 2881.46 \sin 14.47°(6.25) - 1200 \sin 36.87°(6.25) - M_D = 0$

$M_D = 0$ **Ans**



Notice that member AB is the two-force member; therefore the shear force and moment are zero.

1–7. Solve Prob. 1–6 for the resultant internal loadings acting at point E.



$$\theta = \tan^{-1}\left(\frac{6}{8}\right) = 36.87°$$

$$\phi = \tan^{-1}\left(\frac{10}{8}\right) - 36.87° = 14.47°$$

Member AB :

$\circlearrowleft + \Sigma M_A = 0;\quad F_{BC} \sin 14.47°(10) - 1200(6) = 0$

$F_{BC} = 2881.46$ lb

Segment BE :

$+\nearrow \Sigma F_x = 0;\quad -N_E - 2881.46 \cos 14.47° - 1200 \cos 36.87° = 0$

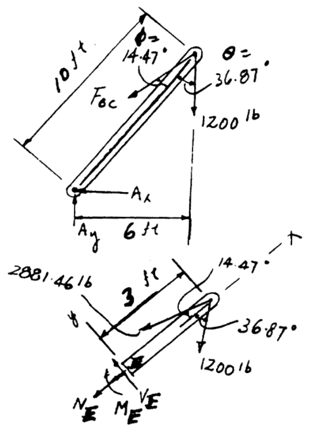
$N_E = -3750$ lb $= -3.75$ kip **Ans**

$\nwarrow + \Sigma F_y = 0;\quad V_E + 2881.46 \sin 14.47° - 1200 \sin 36.87° = 0$

$V_E = 0$ **Ans**

$\circlearrowleft + \Sigma M_E = 0;\quad 2881.46 \sin 14.47°(3) - 1200 \sin 36.87°(3) - M_E = 0$

$M_E = 0$ **Ans**



Notice that member AB is the two-force member; therefore the shear force and moment are zero.

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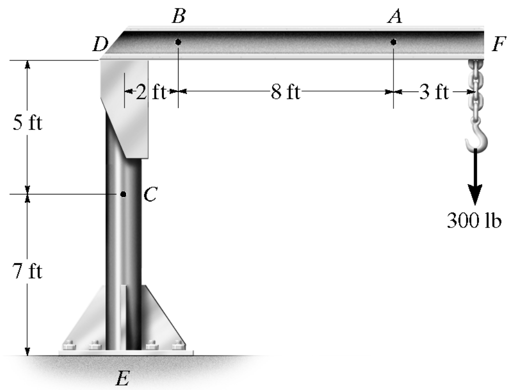
***1–8.** The boom DF of the jib crane and the column DE have a uniform weight of 50 lb/ft. If the hoist and load weigh 300 lb, determine the resultant internal loadings in the crane on cross sections through points A, B, and C.



Equations of Equilibrium : For point A

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_A = 0$ **Ans**

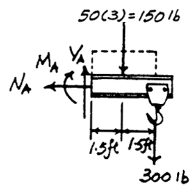
$+\uparrow \Sigma F_y = 0;\quad V_A - 150 - 300 = 0$

$V_A = 450\ \text{lb}$ **Ans**

$\circlearrowleft + \Sigma M_A = 0;\quad -M_A - 150(1.5) - 300(3) = 0$

$M_A = -1125\ \text{lb}\cdot\text{ft} = -1.125\ \text{kip}\cdot\text{ft}$ **Ans**

Negative sign indicates that $\mathbf{M}_A$ acts in the opposite direction to that shown on FBD.



Equations of Equilibrium : For point B

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_B = 0$ **Ans**

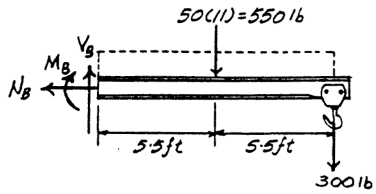
$+\uparrow \Sigma F_y = 0;\quad V_B - 550 - 300 = 0$

$V_B = 850\ \text{lb}$ **Ans**

$\circlearrowleft + \Sigma M_B = 0;\quad -M_B - 550(5.5) - 300(11) = 0$

$M_B = -6325\ \text{lb}\cdot\text{ft} = -6.325\ \text{kip}\cdot\text{ft}$ **Ans**

Negative sign indicates that $\mathbf{M}_B$ acts in the opposite direction to that shown on FBD.



Equations of Equilibrium : For point C

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad V_C = 0$ **Ans**

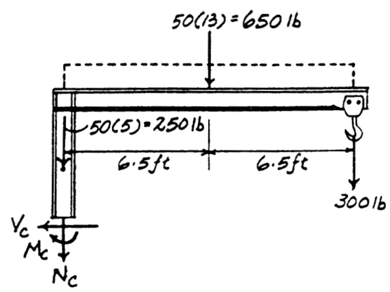
$+\uparrow \Sigma F_y = 0;\quad -N_C - 250 - 650 - 300 = 0$

$N_C = -1200\ \text{lb} = -1.20\ \text{kip}$ **Ans**

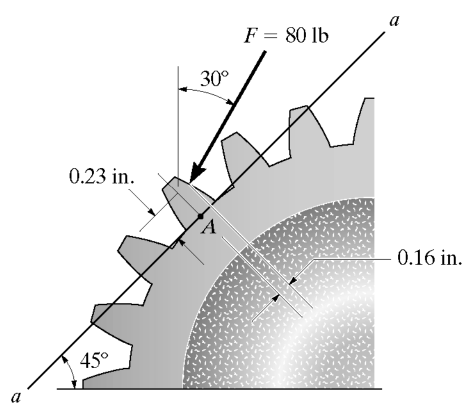
$\circlearrowleft + \Sigma M_C = 0;\quad -M_C - 650(6.5) - 300(13) = 0$

$M_C = -8125\ \text{lb}\cdot\text{ft} = -8.125\ \text{kip}\cdot\text{ft}$ **Ans**

Negative signs indicate that $\mathbf{N}_C$ and $\mathbf{M}_C$ act in the opposite direction to that shown on FBD.



1–9. The force $F = 80$ lb acts on the gear tooth. Determine the resultant internal loadings on the root of the tooth, i.e., at the centroid point A of section a–a.



Equations of Equilibrium : For section $a-a$

$+\nearrow \Sigma F_{x'} = 0;\quad V_A - 80\cos 15° = 0$

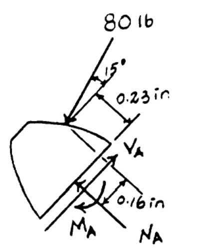
$V_A = 77.3\ \text{lb}$ **Ans**

$\nwarrow + \Sigma F_{y'} = 0;\quad N_A - 80\sin 15° = 0$

$N_A = 20.7\ \text{lb}$ **Ans**

$\circlearrowleft + \Sigma M_A = 0;\quad -M_A - 80\sin 15°(0.16) + 80\cos 15°(0.23) = 0$

$M_A = 14.5\ \text{lb}\cdot\text{in.}$ **Ans**



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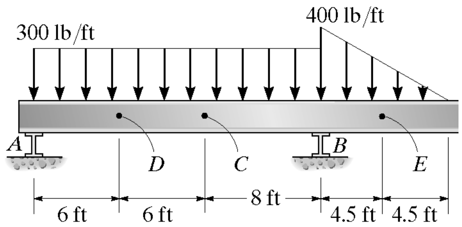
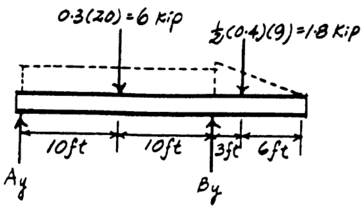
1–10. The beam supports the distributed load shown. Determine the resultant internal loadings on the cross section through point C. Assume the reactions at the supports A and B are vertical.



Support Reactions :

$\circlearrowleft + \Sigma M_A = 0;\quad B_y(20) - 6(10) - 1.8(23) = 0$

$B_y = 5.07 \text{ kip}$

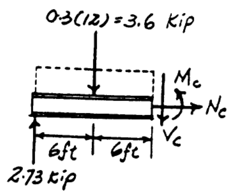


$+\uparrow \Sigma F_y = 0;\quad A_y + 5.07 - 6 - 1.8 = 0$

$A_y = 2.73 \text{ kip}$

Equations of Equilibrium : For point C

$\xrightarrow{+} \Sigma F_x = 0;\quad N_C = 0$ **Ans**



$+\uparrow \Sigma F_y = 0;\quad 2.73 - 3.60 - V_C = 0$

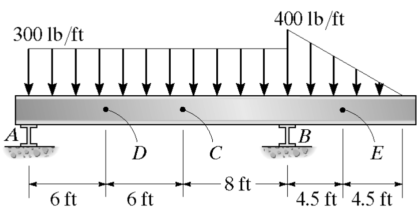
$V_C = -0.870 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0;\quad M_C + 3.60(6) - 2.73(12) = 0$

$M_C = 11.2 \text{ kip} \cdot \text{ft}$ **Ans**

Negative sign indicates that $\mathbf{V}_C$ acts in the opposite direction to that shown on FBD.

1–11. The beam supports the distributed load shown. Determine the resultant internal loadings on the cross sections through points D and E. Assume the reactions at the supports A and B are vertical.



Equations of Equilibrium : For point D

$\xrightarrow{+} \Sigma F_x = 0;\quad N_D = 0$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad 2.73 - 1.8 - V_D = 0$

$V_D = 0.930 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad M_D + 1.8(3) - 2.73(6) = 0$

$M_D = 11.0 \text{ kip} \cdot \text{ft}$ **Ans**

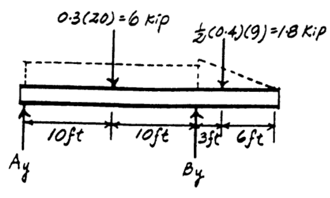
Support Reactions :

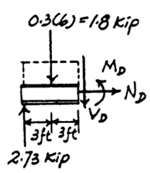
$\circlearrowleft + \Sigma M_A = 0;\quad B_y(20) - 6(10) - 1.8(23) = 0$

$B_y = 5.07 \text{ kip}$

$+\uparrow \Sigma F_y = 0;\quad A_y + 5.07 - 6 - 1.8 = 0$

$A_y = 2.73 \text{ kip}$





Equations of Equilibrium : For point E

$\xleftarrow{+} \Sigma F_x = 0;\quad N_E = 0$ **Ans**

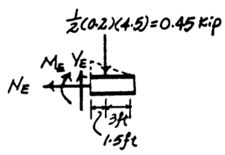
$+\uparrow \Sigma F_y = 0;\quad V_E - 0.45 = 0$

$V_E = 0.450 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_E = 0;\quad -M_E - 0.45(1.5) = 0$

$M_E = -0.675 \text{ kip} \cdot \text{ft}$ **Ans**

Negative sign indicates that $\mathbf{M}_E$ acts in the opposite direction to that shown on FBD.



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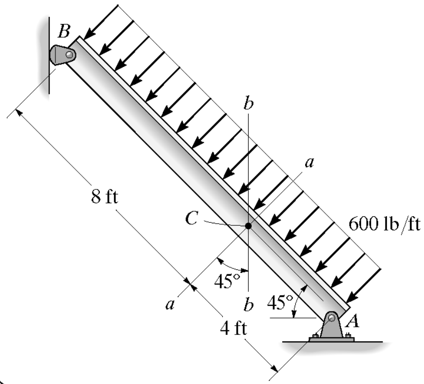
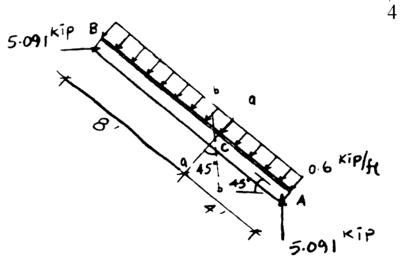
***1–12.** Determine the resultant internal loadings acting on (a) section *a–a* and (b) section *b–b*. Each section is located through the centroid, point *C*.





(a)

$\nwarrow + \Sigma F_x = 0; \quad N_C + 5.091 \sin 45° = 0$

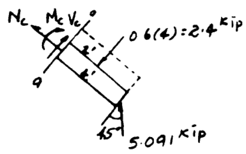
$N_C = -3.60 \text{ kip}$ **Ans**

$\nearrow + \Sigma F_y = 0; \quad V_C + 5.091 \cos 45° - 2.4 = 0$

$V_C = -1.20 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0; \quad -M_C - 2.4(2) + 5.091 \cos 45°(4) = 0$

$M_C = 9.60 \text{ kip} \cdot \text{ft}$ **Ans**



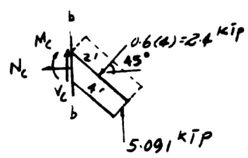
(b)

$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad N_C + 2.4 \cos 45° = 0$

$N_C = -1.70 \text{ kip}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad V_C + 5.091 - 2.4 \sin 45° = 0$

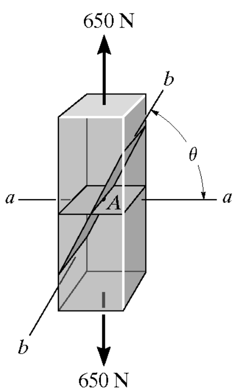
$V_C = -3.39 \text{ kip}$ **Ans**

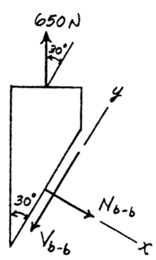


$\circlearrowleft + \Sigma M_C = 0; \quad -M_C - 2.4(2) + 5.091 \cos 45°(4) = 0$

$M_C = 9.60 \text{ kip} \cdot \text{ft}$ **Ans**

1–13. Determine the resultant internal normal and shear forces in the member at (a) section *a–a* and (b) section *b–b*, each of which passes through point *A*. Take $\theta = 60°$. The 650-N load is applied along the centroidal axis of the member.



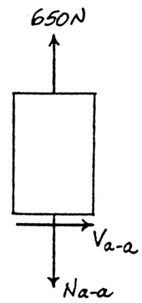


Equations of Equilibrium : For section *a–a*

$+\uparrow \Sigma F_y = 0; \quad 650 - N_{a-a} = 0$

$N_{a-a} = 650 \text{ N}$ **Ans**

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad V_{a-a} = 0$ **Ans**



Equations of Equilibrium : For section *b–b*

$\nearrow + \Sigma F_y = 0; \quad 650 \cos 30° - V_{b-b} = 0$

$V_{b-b} = 563 \text{ N}$ **Ans**

$\searrow + \Sigma F_x = 0; \quad N_{b-b} - 650 \sin 30° = 0$

$N_{b-b} = 325 \text{ N}$ **Ans**

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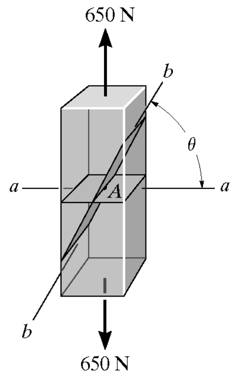
1–14. Determine the resultant internal normal and shear forces in the member at section b–b, each as a function of θ. Plot these results for $0° \le \theta \le 90°$. The 650-N load is applied along the centroidal axis of the member.



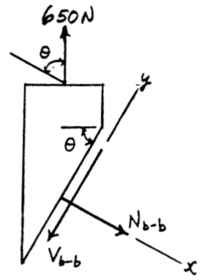
Equations of Equilibrium : **For section $b-b$**

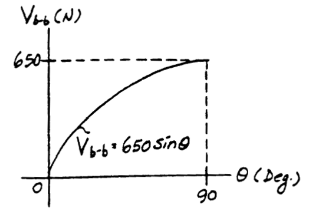
$\nwarrow + \Sigma F_x = 0;\quad N_{b-b} - 650\cos\theta = 0$

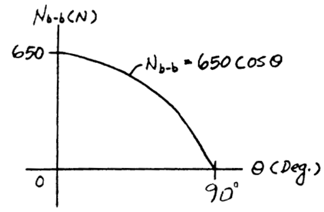
$N_{b-b} = 650\cos\theta$ **Ans**

$+\nearrow \Sigma F_y = 0;\quad -V_{b-b} + 650\sin\theta = 0$

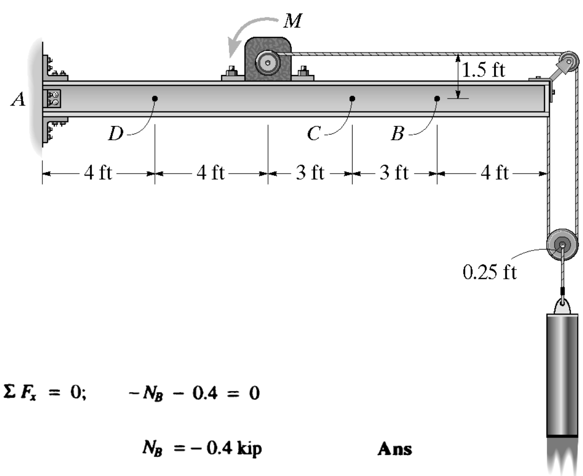
$V_{b-b} = 650\sin\theta$ **Ans**







1–15. The 800-lb load is being hoisted at a constant speed using the motor M, which has a weight of 90 lb. Determine the resultant internal loadings acting on the cross section through point B in the beam. The beam has a weight of 40 lb/ft and is fixed to the wall at A.



$\xrightarrow{+} \Sigma F_x = 0;\quad -N_B - 0.4 = 0$

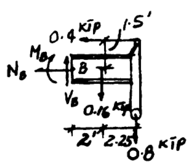
$N_B = -0.4$ kip **Ans**

$+\uparrow \Sigma F_y = 0;\quad V_B - 0.8 - 0.16 = 0$

$V_B = 0.960$ kip **Ans**

$\circlearrowleft + \Sigma M_B = 0;\quad -M_B - 0.16(2) - 0.8(4.25) + 0.4(1.5) = 0$

$M_B = -3.12$ kip · ft **Ans**



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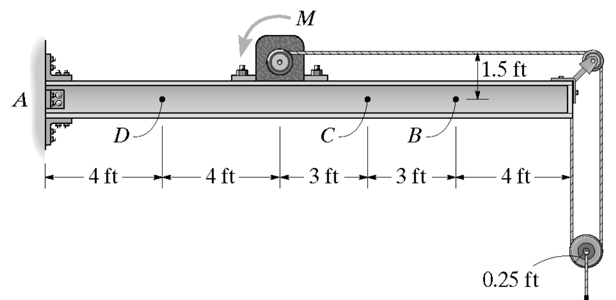
***1–16.** Determine the resultant internal loadings acting on the cross section through points C and D of the beam in Prob. 1–15.



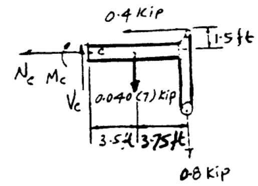
For point C :

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_C + 0.4 = 0;\quad N_C = -0.4\text{ kip}$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad V_C - 0.8 - 0.04(7) = 0;\quad V_C = 1.08\text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0;\quad -M_C - 0.8(7.25) - 0.04(7)(3.5) + 0.4(1.5) = 0$

$M_C = -6.18\text{ kip}\cdot\text{ft}$ **Ans**



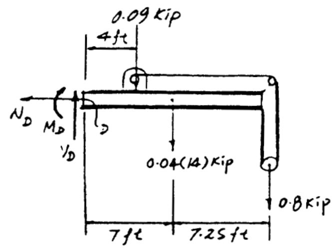
For point D :

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_D = 0$ **Ans**

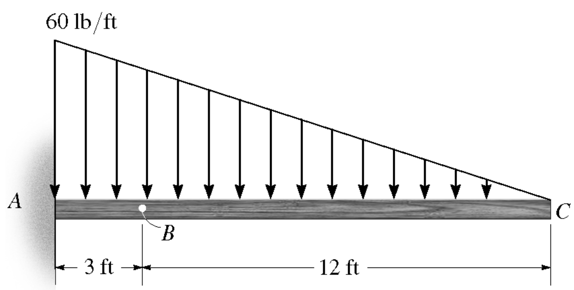
$+\uparrow \Sigma F_y = 0;\quad V_D - 0.09 - 0.04(14) - 0.8 = 0;\quad V_D = 1.45\text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad -M_D - 0.09(4) - 0.04(14)(7) - 0.8(14.25) = 0$

$M_D = -15.7\text{ kip}\cdot\text{ ft}$ **Ans**



1–17. Determine the resultant internal loadings acting on the cross section at point B.



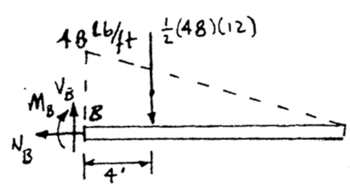
$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad N_B = 0$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad V_B - \frac{1}{2}(48)(12) = 0$

$V_B = 288\text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_B = 0;\quad -M_B - \frac{1}{2}(48)(12)(4) = 0$

$M_B = -1152\text{ lb}\cdot\text{ft} = -1.15\text{ kip}\cdot\text{ft}$ **Ans**



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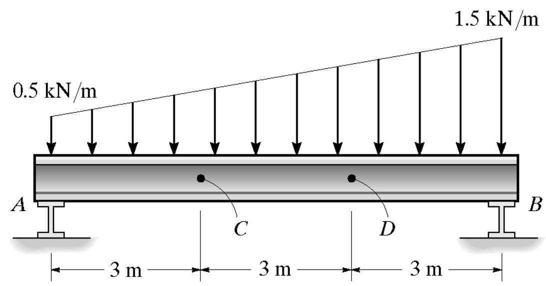
1–18. The beam supports the distributed load shown. Determine the resultant internal loadings acting on the cross section through point C. Assume the reactions at the supports A and B are vertical.



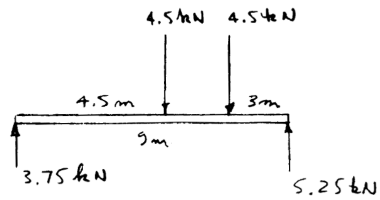
$\xrightarrow{+} \Sigma F_x = 0;$ $N_C = 0$ **Ans**

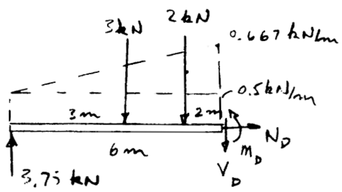
$+\downarrow \Sigma F_y = 0;$ $V_C + 0.5 + 1.5 - 3.75 = 0$

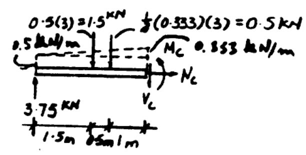
$V_C = 1.75 \text{ kN}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0;$ $M_C + 0.5(1) + 1.5(1.5) - 3.75(3) = 0$

$M_C = 8.50 \text{ kN}\cdot\text{m}$ **Ans**







1–19. Determine the resultant internal loadings acting on the cross section through point D in Prob. 1–18.

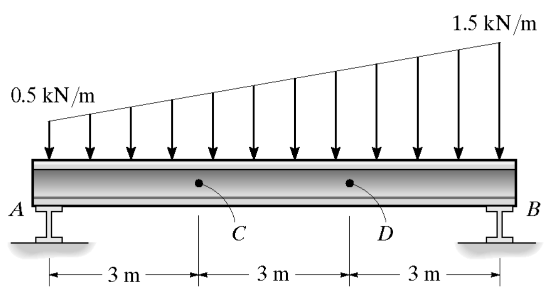
$\xrightarrow{+} \Sigma F_x = 0;$ $N_D = 0$ **Ans**

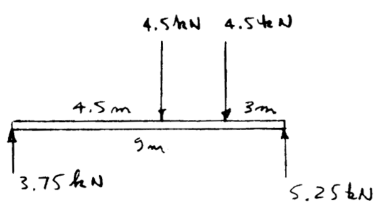
$+\uparrow \Sigma F_y = 0;$ $3.75 - 3 - 2 - V_D = 0$

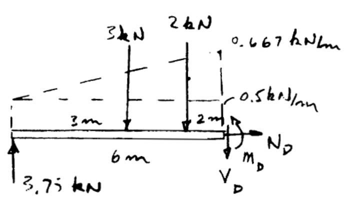
$V_D = -1.25 \text{ kN}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;$ $M_D + 2(2) + 3(3) - 3.75(6) = 0$

$M_D = 9.50 \text{ kN}\cdot\text{m}$ **Ans**







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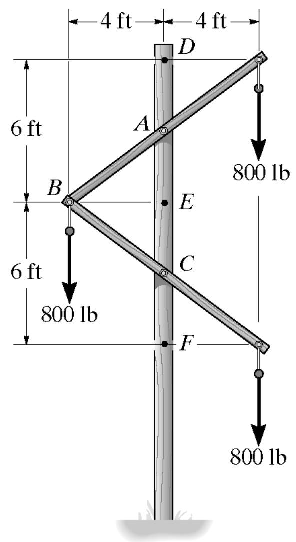
***1–20.** The wishbone construction of the power pole supports the three lines, each exerting a force of 800 lb on the bracing struts. If the struts are pin connected at A, B, and C, determine the resultant internal loadings at cross sections through points D, E, and F.



Support Reaction : FBD(a) and (b).

$\circlearrowleft + \Sigma M_A = 0;\quad B_y(4) + B_x(3) - 800(4) = 0 \qquad [1]$

$\circlearrowleft + \Sigma M_C = 0;\quad B_x(3) + 800(4) - B_y(4) - 800(4) = 0 \qquad [2]$

Solving Eq. [1] and [2] yields

$B_y = 400.0 \text{ lb} \qquad B_x = 533.33 \text{ lb}$

From FBD (a)

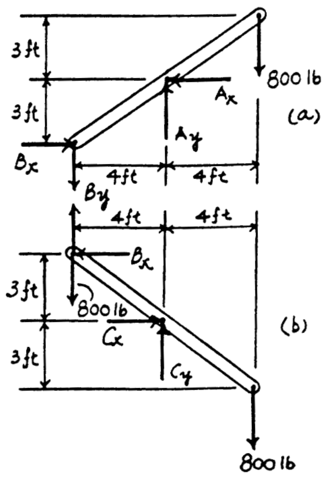
$\xrightarrow{+} \Sigma F_x = 0;\quad 533.33 - A_x = 0 \qquad A_x = 533.33 \text{ lb}$

$+\uparrow \Sigma F_y = 0;\quad A_y - 800 - 400.0 = 0 \qquad A_y = 1200 \text{ lb}$

From FBD (b)

$\xrightarrow{+} \Sigma F_x = 0;\quad C_x - 533.33 = 0 \qquad C_x = 533.33 \text{ lb}$

$+\uparrow \Sigma F_y = 0;\quad C_y + 400.0 - 800 - 800 = 0 \qquad C_y = 1200 \text{ lb}$



Equations of Equilibrium : For point D [FBD(c)].

$\xrightarrow{+} \Sigma F_x = 0;\quad V_D = 0 \qquad$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad N_D = 0 \qquad$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad M_D = 0 \qquad$ **Ans**

For point E [FBD(d)].

$\xrightarrow{+} \Sigma F_x = 0;\quad 533.33 - V_E = 0 \qquad V_E = 533 \text{ lb} \qquad$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad N_E - 1200 = 0 \qquad N_E = 1200 \text{ lb} \qquad$ **Ans**

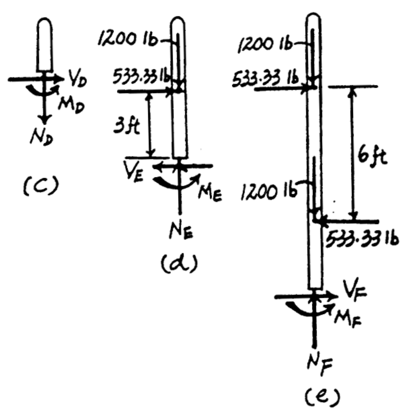
$\circlearrowleft + \Sigma M_E = 0;\quad M_E - 533.33(3) = 0 \qquad M_E = 1600 \text{ lb} \cdot \text{ft} \qquad$ **Ans**

For point F [FBD(e)].

$\xrightarrow{+} \Sigma F_x = 0;\quad V_F + 533.33 - 533.33 = 0 \qquad V_F = 0 \qquad$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad N_F - 1200 - 1200 = 0 \qquad N_F = 2400 \text{ lb} \qquad$ **Ans**

$\circlearrowleft + \Sigma M_F = 0;\quad M_F - 533.33(6) = 0 \qquad M_F = 3200 \text{ lb} \cdot \text{ft} \qquad$ **Ans**



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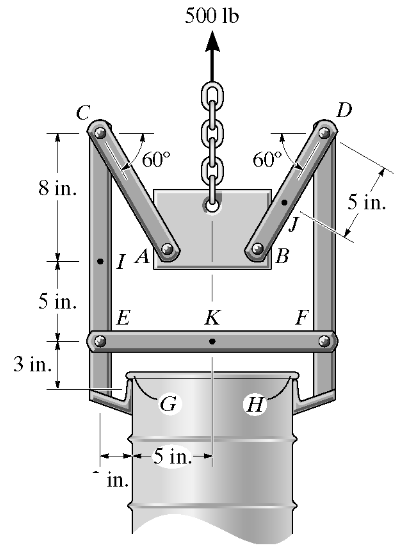
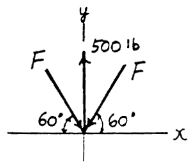
1–21. The drum lifter suspends the 500-lb drum. The linkage is pin connected to the plate at A and B. The gripping action on the drum chime is such that only horizontal and vertical forces are exerted on the drum at G and H. Determine the resultant internal loadings on the cross section through point I.



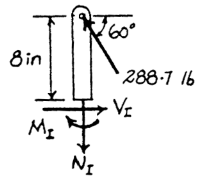
Equations of Equilibrium : Members AC and BD are two-force members.



$+\uparrow \Sigma F_y = 0; \quad 500 - 2F\sin 60° = 0$

$F = 288.7 \text{ lb}$

Equations of Equilibrium : For point I



$\xrightarrow{+} \Sigma F_x = 0; \quad V_I - 288.7\cos 60° = 0$

$V_I = 144 \text{ lb}$ **Ans**

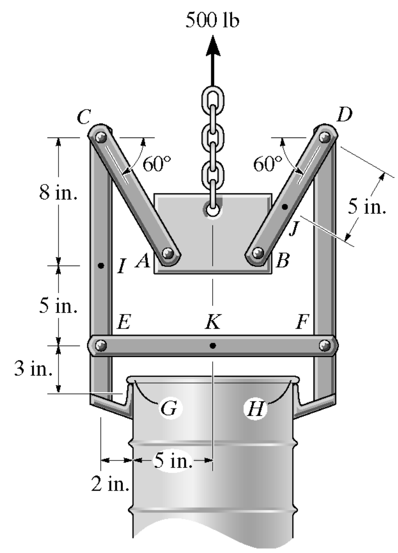
$+\uparrow \Sigma F_y = 0; \quad 288.7\sin 60° - N_I = 0$

$N_I = 250 \text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_I = 0; \quad 288.7\cos 60°(8) - M_I = 0$

$M_I = 1154.7 \text{ lb}\cdot\text{in.} = 1.15 \text{ kip}\cdot\text{in.}$ **Ans**

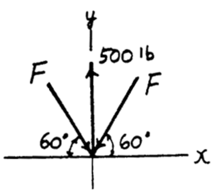
1–22. Determine the resultant internal loadings on the cross sections through points K and J on the drum lifter in Prob. 1–21.



Equations of Equilibrium : Members AC and BD are two force members.

$+\uparrow \Sigma F_y = 0; \quad 500 - 2F\sin 60° = 0$

$F = 288.7 \text{ lb}$



Equations of Equilibrium : For point J

$\nwarrow + \Sigma F_{y'} = 0; \qquad V_J = 0$ **Ans**

$\nearrow + \Sigma F_{x'} = 0; \quad 288.7 + N_J = 0 \qquad N_J = -289 \text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_J = 0; \qquad M_J = 0$ **Ans**

Negative sign indicates that $\mathbf{N}_J$ acts in the opposite direction to that shown on FBD.

Support Reactions : For member DFH

$\circlearrowleft + \Sigma M_H = 0; \quad F_{EF}(3) - 288.7\cos 60°(16) + 288.7\sin 60°(2) = 0$

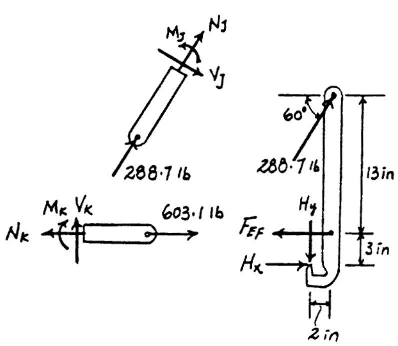
$F_{EF} = 603.1 \text{ lb}$

Equations of Equilibrium : For point K

$\xleftarrow{+} \Sigma F_x = 0; \quad N_K - 603. = 0 \qquad N_K = 603 \text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = 0; \qquad V_K = 0$ **Ans**

$\circlearrowleft + \Sigma M_K = 0; \qquad M_K = 0$ **Ans**



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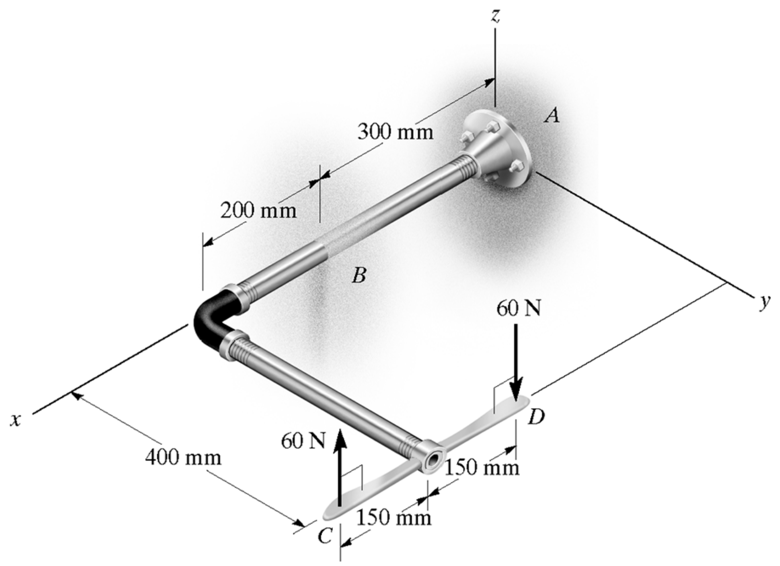
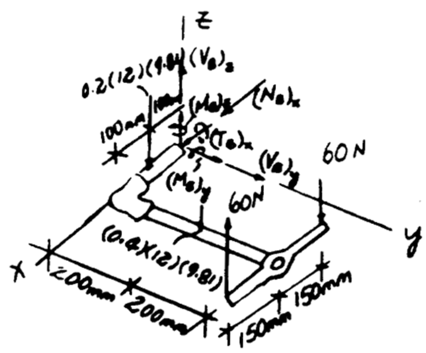
1–23. The pipe has a mass of 12 kg/m. If it is fixed to the wall at A, determine the resultant internal loadings acting on the cross section at B. Neglect the weight of the wrench CD.





$\Sigma F_x = 0;\quad (N_B)_x = 0$ **Ans**

$\Sigma F_y = 0;\quad (V_B)_y = 0$ **Ans**

$\Sigma F_z = 0;\quad (V_B)_z - 60 + 60 - (0.2)(12)(9.81) - (0.4)(12)(9.81) = 0$

$(V_B)_z = 70.6\text{ N}$ **Ans**

$\Sigma M_x = 0;\quad (T_B)_x + 60(0.4) - 60(0.4) - (0.4)(12)(9.81)(0.2) = 0$

$(T_B)_x = 9.42\text{ N}\cdot\text{m}$ **Ans**

$\Sigma M_y = 0;\quad (M_B)_y + (0.2)(12)(9.81)(0.1) + (0.4)(12)(9.81)(0.2) - 60(0.3) = 0$

$(M_B)_y = 6.23\text{ N}\cdot\text{m}$ **Ans**

$\Sigma M_z = 0;\quad (M_B)_z = 0$ **Ans**

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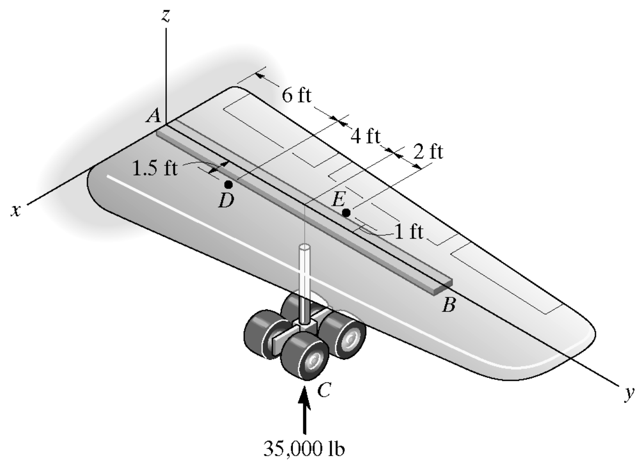
***1–24.** The main beam AB supports the load on the wing of the airplane. The loads consist of the wheel reaction of 35,000 lb at C, the 1200-lb weight of fuel in the tank of the wing, having a center of gravity at D, and the 400-lb weight of the wing, having a center of gravity at E. If it is fixed to the fuselage at A, determine the resultant internal loadings on the beam at this point. Assume that the wing does not transfer any of the loads to the fuselage, except through the beam.



$\Sigma F_x = 0;\quad (V_A)_x = 0$ **Ans**

$\Sigma F_y = 0;\quad (N_A)_y = 0$ **Ans**

$\Sigma F_z = 0;\quad (V_A)_z - 1200 - 400 + 35000 = 0$

$(V_A)_z = -33.4\ \text{kip}$ **Ans**

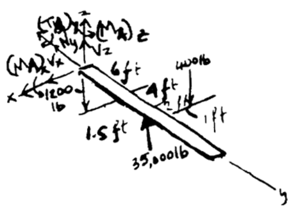
$\Sigma M_x = 0;\quad (M_A)_x - 1200(6) + 35000(10) - 400(12) = 0$

$(M_A)_x = 338\ \text{kip}\cdot\text{ft}$ **Ans**

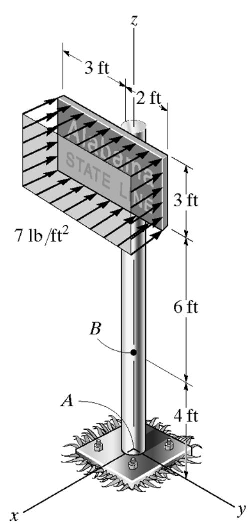
$\Sigma M_y = 0;\quad (T_A)_y + 1200(1.5) - 400(1) = 0$

$(T_A)_y = -1.40\ \text{kip}\cdot\text{ft}$ **Ans**

$\Sigma M_z = 0;\quad (M_A)_z = 0$ **Ans**



1–25. Determine the resultant internal loadings acting on the cross section through point B of the signpost. The post is fixed to the ground and a uniform pressure of 7 lb/ft^2 acts perpendicular to the face of the sign.



$\Sigma F_x = 0;\quad (V_B)_x - 105 = 0;\quad (V_B)_x = 105\ \text{lb}$ **Ans**

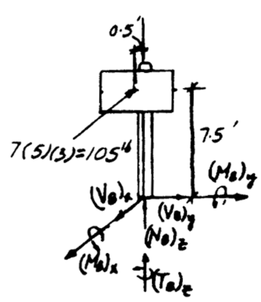
$\Sigma F_y = 0;\quad (V_B)_y = 0$ **Ans**

$\Sigma F_z = 0;\quad (N_B)_z = 0$ **Ans**

$\Sigma M_x = 0;\quad (M_B)_x = 0$ **Ans**

$\Sigma M_y = 0;\quad (M_B)_y - 105(7.5) = 0;\quad (M_B)_y = 788\ \text{lb}\cdot\text{ft}$ **Ans**

$\Sigma M_z = 0;\quad (T_B)_z - 105(0.5) = 0;\quad (T_B)_z = 52.5\ \text{lb}\cdot\text{ft}$ **Ans**



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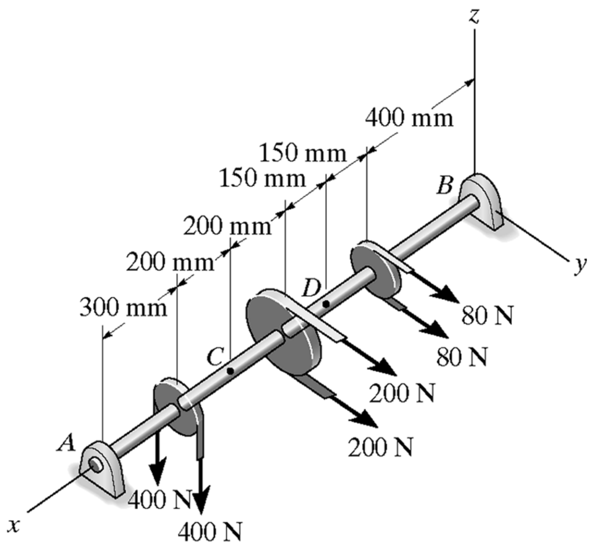
1–26. The shaft is supported at its ends by two bearings A and B and is subjected to the forces applied to the pulleys fixed to the shaft. Determine the resultant internal loadings acting on the cross section through point D. The 400-N forces act in the $-z$ direction and the 200-N and 80-N forces act in the $+y$ direction. The journal bearings at A and B exert only y and z components of force on the shaft.



Support Reactions :

$\Sigma M_z = 0;\quad 160(0.4) + 400(0.7) - A_y(1.4) = 0$

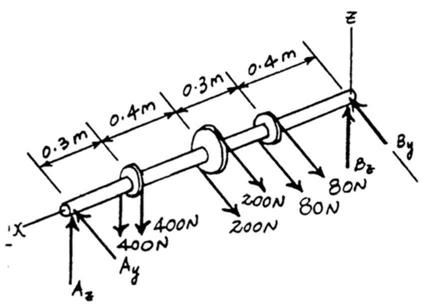
$A_y = 245.71 \text{ N}$

$\Sigma F_y = 0;\quad -245.71 - B_y + 400 + 160 = 0$

$B_y = 314.29 \text{ N}$

$\Sigma M_y = 0;\quad 800(1.1) - A_z(1.4) = 0 \qquad A_z = 628.57 \text{ N}$

$\Sigma F_z = 0;\quad B_z + 628.57 - 800 = 0 \qquad B_z = 171.43 \text{ N}$



Equations of Equilibrium : For point D

$\Sigma F_x = 0;\quad (N_D)_x = 0$ **Ans**

$\Sigma F_y = 0;\quad (V_D)_y - 314.29 + 160 = 0$

$(V_D)_y = 154 \text{ N}$ **Ans**

$\Sigma F_z = 0;\quad 171.43 + (V_D)_z = 0$

$(V_D)_z = -171 \text{ N}$ **Ans**

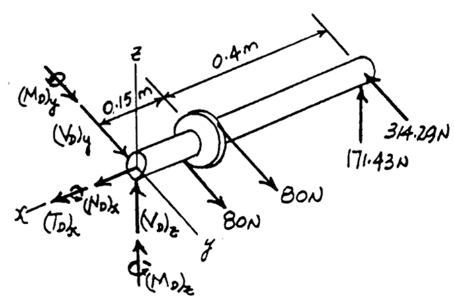
$\Sigma M_x = 0;\quad (T_D)_x = 0$ **Ans**

$\Sigma M_y = 0;\quad 171.43\,(0.55) + (M_D)_y = 0$

$(M_D)_y = -94.3 \text{ N}\cdot\text{m}$ **Ans**

$\Sigma M_z = 0;\quad 314.29(0.55) - 160(0.15) + (M_D)_z = 0$

$(M_D)_z = -149 \text{ N}\cdot\text{m}$ **Ans**



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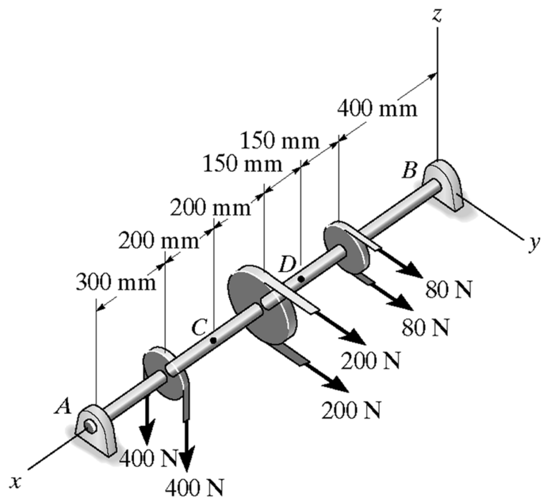
1–27. The shaft is supported at its ends by two bearings A and B and is subjected to the forces applied to the pulleys fixed to the shaft. Determine the resultant internal loadings acting on the cross section through point C. The 400-N forces act in the $-z$ direction and the 200-N and 80-N forces act in the $+y$ direction. The journal bearings at A and B exert only y and z components of force on the shaft.



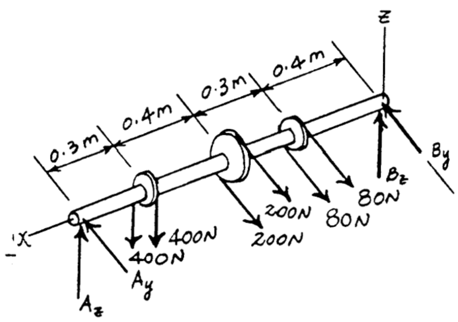
Support Reactions :

$\Sigma M_z = 0;\quad 160(0.4) + 400(0.7) - A_y(1.4) = 0$
$A_y = 245.71 \text{ N}$

$\Sigma F_y = 0;\quad -245.71 - B_y + 400 + 160 = 0$
$B_y = 314.29 \text{ N}$

$\Sigma M_y = 0;\quad 800(1.1) - A_z(1.4) = 0 \qquad A_z = 628.57 \text{ N}$

$\Sigma F_z = 0;\quad B_z + 628.57 - 800 = 0 \qquad B_z = 171.43 \text{ N}$



Equations of Equilibrium : For point C

$\Sigma F_x = 0;\quad (N_C)_x = 0$ **Ans**

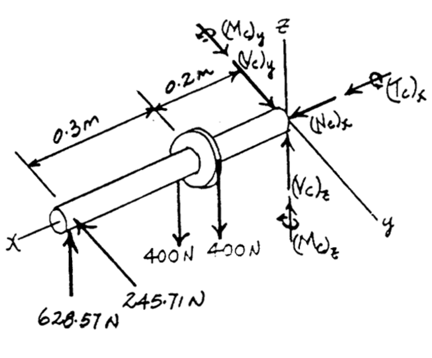
$\Sigma F_y = 0;\quad -245.71 + (V_C)_y = 0$
$(V_C)_y = -246 \text{ N}$ **Ans**

$\Sigma F_z = 0;\quad 628.57 - 800 + (V_C)_z = 0$
$(V_C)_z = -171 \text{ N}$ **Ans**

$\Sigma M_x = 0;\quad (T_C)_x = 0$ **Ans**

$\Sigma M_y = 0;\quad (M_C)_y - 628.57(0.5) + 800(0.2) = 0$
$(M_C)_y = -154 \text{ N}\cdot\text{m}$ **Ans**

$\Sigma M_z = 0;\quad (M_C)_z - 245.71(0.5) = 0$
$(M_C)_z = -123 \text{ N}\cdot\text{m}$ **Ans**



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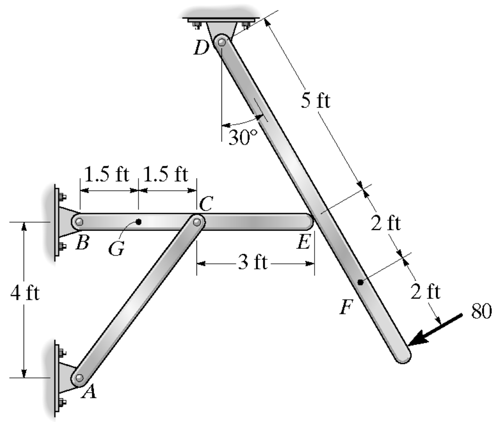
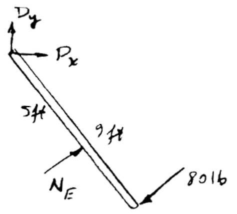
***1–28.** Determine the resultant internal loadings acting on the cross section of the frame at points F and G. The contact at E is smooth.



Member DEF :

$\circlearrowleft + \Sigma M_D = 0; \quad N_E\,(5) - 80\,(9) = 0$

$N_E = 144\text{ lb}$



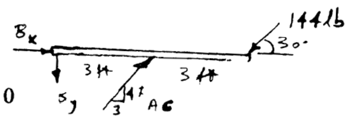
Member BCE :

$\circlearrowleft + \Sigma M_B = 0; \quad F_{AC}\,(\frac{4}{5})(3) - 144\sin 30°\,(6) = 0$

$F_{AC} = 180\text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0; \quad B_x + 180\,(\frac{3}{5}) - 144\cos 30° = 0$

$B_x = 16.708\text{ lb}$



$+\uparrow \Sigma F_y = 0; \quad -B_y + 180(\frac{4}{5}) - 144\sin 30° = 0$

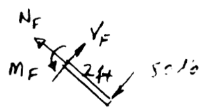
$B_y = 72.0\text{ lb}$

For point F :

$+\nwarrow \Sigma F_x = 0; \quad N_F = 0$ **Ans**

$+\nearrow \Sigma F_y = 0; \quad V_F - 80 = 0; \quad V_F = 80\text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_F = 0; \quad M_F - 80\,(2) = 0; \quad M_F = 160\text{ lb}\cdot\text{ft}$ **Ans**

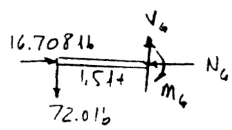


For point G :

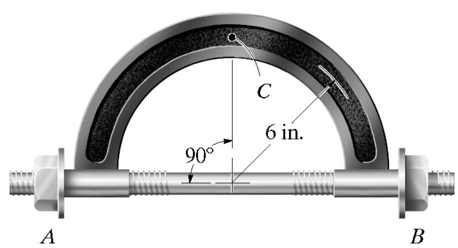
$\xrightarrow{+} \Sigma F_x = 0; \quad 16.708 - N_G = 0; \quad N_G = 16.7\text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad V_G - 72.0 = 0; \quad V_G = 72.0\text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_G = 0; \quad 72\,(1.5) - M_G = 0; \quad M_G = 108\text{ lb}\cdot\text{ft}$ **Ans**



1–29. The bolt shank is subjected to a tension of 80 lb. Determine the resultant internal loadings acting on the cross section at point C.

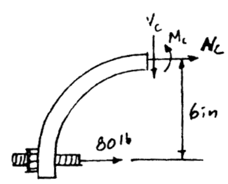


Segment AC :

$\xrightarrow{+} \Sigma F_x = 0; \quad N_C + 80 = 0; \quad N_C = -80\text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad V_C = 0$ **Ans**

$\circlearrowleft + \Sigma M_C = 0; \quad M_C + 80(6) = 0; \quad M_C = -480\text{ lb}\cdot\text{in.}$ **Ans**



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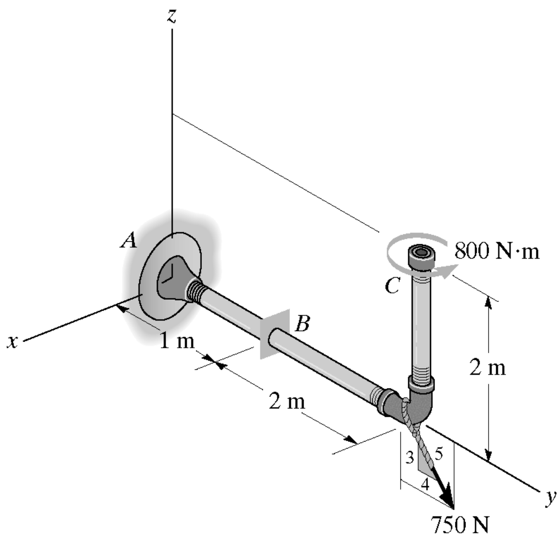
1–30. The pipe has a mass of 12 kg/m. If it is fixed to the wall at A, determine the resultant internal loadings acting on the cross section through B.



Equations of Equilibrium : For point *B*

$\Sigma F_x = 0;\quad (V_B)_x = 0$ **Ans**

$\Sigma F_y = 0;\quad (N_B)_y + \frac{4}{5}(750) = 0$

$(N_B)_y = -600\text{ N}$ **Ans**

$\Sigma F_z = 0;\quad (V_B)_z - 235.44 - 235.44 - \frac{3}{5}(750) = 0$

$(V_B)_z = 921\text{ N}$ **Ans**

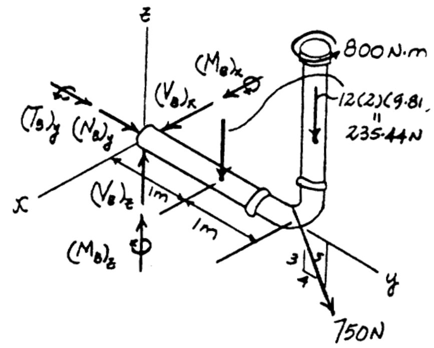
$\Sigma M_x = 0;\quad (M_B)_x - 235.44(1) - 235.44(2) - \frac{3}{5}(750)(2) = 0$

$(M_B)_x = 1606\text{ N}\cdot\text{m}$ **Ans**

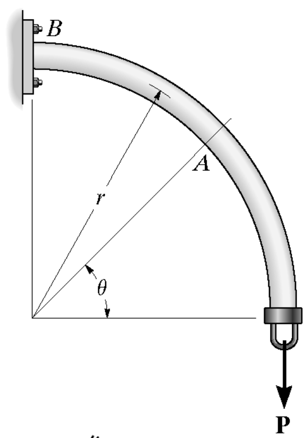
$\Sigma M_y = 0;\quad (T_B)_y = 0$ **Ans**

$\Sigma M_z = 0;\quad (M_B)_z + 800 = 0$

$(M_B)_z = -800\text{ N}\cdot\text{m}$ **Ans**



1–31. The curved rod has a radius r and is fixed to the wall at B. Determine the resultant internal loadings acting on the cross section through A which is located at an angle θ from the horizontal.



Equations of Equilibrium : For point *A*

$\searrow + \Sigma F_x = 0;\quad P\cos\theta - N_A = 0$

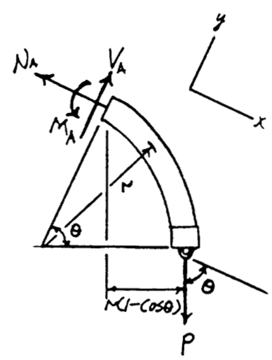
$N_A = P\cos\theta$ **Ans**

$\nearrow + \Sigma F_y = 0;\quad V_A - P\sin\theta = 0$

$V_A = P\sin\theta$ **Ans**

$\circlearrowleft + \Sigma M_A = 0;\quad M_A - P[r(1-\cos\theta)] = 0$

$M_A = Pr(1-\cos\theta)$ **Ans**



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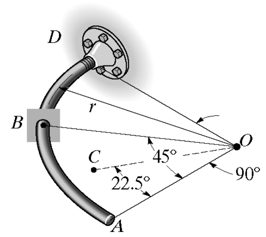
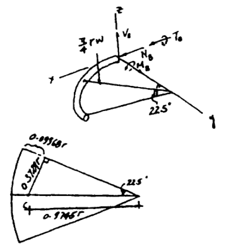
***1–32.** The curved rod AD of radius r has a weight per length of w. If it lies in the horizontal plane, determine the resultant internal loadings acting on the cross section through point B. *Hint*: The distance from the centroid C of segment AB to point O is $CO = 0.9745r$.





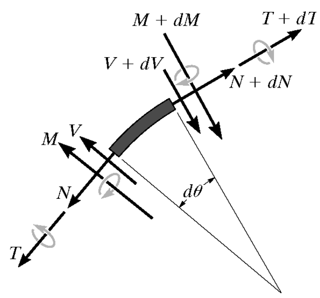
$\Sigma F_z = 0; \quad V_B - \frac{\pi}{4} rw = 0; \quad V_B = 0.785\, w\, r$ **Ans**

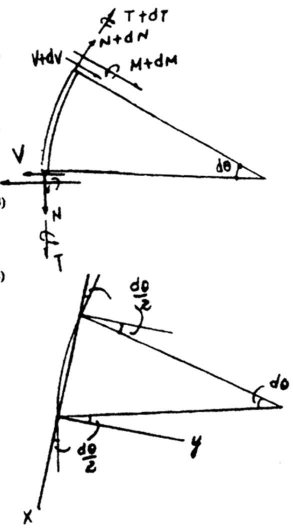
$\Sigma F_x = 0; \quad N_B = 0$ **Ans**

$\Sigma M_x = 0; \quad T_B - \frac{\pi}{4} rw(0.09968r) = 0; \quad T_B = 0.0783\, w\, r^2$ **Ans**

$\Sigma M_y = 0; \quad M_B + \frac{\pi}{4} rw(0.3729\, r) = 0; \quad M_B = -\,0.293\, w\, r^2$ **Ans**

1–33. A differential element taken from a curved bar is shown in the figure. Show that $dN/d\theta = V$, $dV/d\theta = -N$, $dM/d\theta = -T$, and $dT/d\theta = M$.





$\Sigma F_x = 0;$

$$N \cos\frac{d\theta}{2} + V \sin\frac{d\theta}{2} - (N + dN)\cos\frac{d\theta}{2} + (V + dV)\sin\frac{d\theta}{2} = 0 \quad (1)$$

$\Sigma F_y = 0;$

$$N \sin\frac{d\theta}{2} - V \cos\frac{d\theta}{2} + (N + dN)\sin\frac{d\theta}{2} + (V + dV)\cos\frac{d\theta}{2} = 0 \quad (2)$$

$\Sigma M_x = 0;$

$$T \cos\frac{d\theta}{2} + M \sin\frac{d\theta}{2} - (T + dT)\cos\frac{d\theta}{2} + (M + dM)\sin\frac{d\theta}{2} = 0 \quad (3)$$

$\Sigma M_y = 0;$

$$T \sin\frac{d\theta}{2} - M \cos\frac{d\theta}{2} + (T + dT)\sin\frac{d\theta}{2} + (M + dM)\cos\frac{d\theta}{2} = 0 \quad (4)$$

Since $\frac{d\theta}{2}$ is small, then $\sin\frac{d\theta}{2} = \frac{d\theta}{2}, \cos\frac{d\theta}{2} = 1$

Eq. (1) becomes $V d\theta - dN + \frac{dV d\theta}{2} = 0$

Neglecting the second order term, $V d\theta - dN = 0$

$\frac{dN}{d\theta} = V$ **QED**

Eq.(2) becomes $N d\theta + dV + \frac{dN d\theta}{2} = 0$

Neglecting the second order term, $N d\theta + dV = 0$

$\frac{dV}{d\theta} = -N$ **QED**

Eq.(3) becomes $M d\theta - dT + \frac{dM d\theta}{2} = 0$

Neglecting the second order term, $M d\theta - dT = 0$

$\frac{dT}{d\theta} = M$ **QED**

Eq. (4) becomes $T d\theta + dM + \frac{dT d\theta}{2} = 0$

Neglecting the second order term, $T d\theta + dM = 0$

$\frac{dM}{d\theta} = -T$ **QED**

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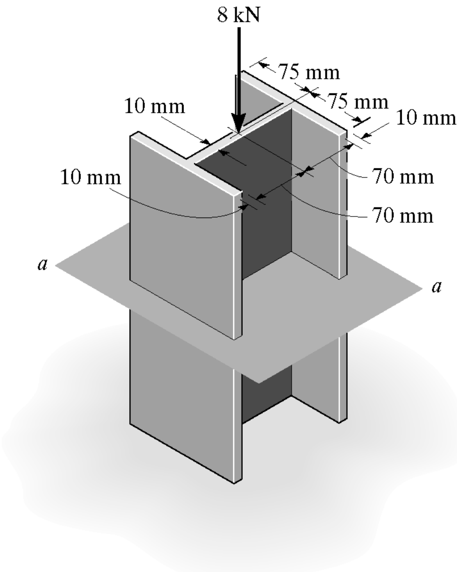
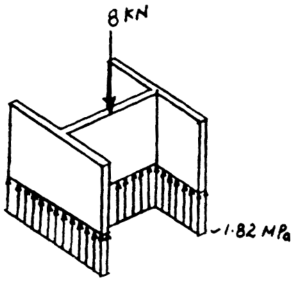
1-34. The column is subjected to an axial force of 8 kN at its top. If the cross-sectional area has the dimensions shown in the figure, determine the average normal stress acting at section *a–a*. Show this distribution of stress acting over the area's cross section.

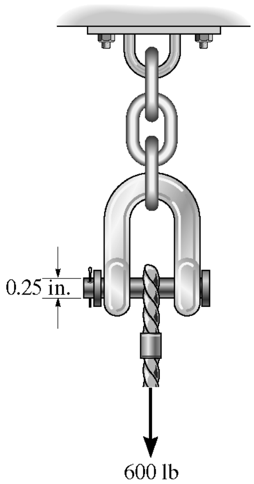




$$A = (2)(150)(10) + (140)(10)$$
$$= 4400\ \text{mm}^2 = 4.4\,(10^{-3})\ \text{m}^2$$

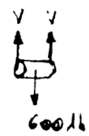
$$\sigma = \frac{P}{A} = \frac{8\,(10^3)}{4.4\,(10^{-3})} = 1.82\ \text{MPa} \qquad \textbf{Ans}$$

1–35. The anchor shackle supports a cable force of 600 lb. If the pin has a diameter of 0.25 in., determine the average shear stress in the pin.



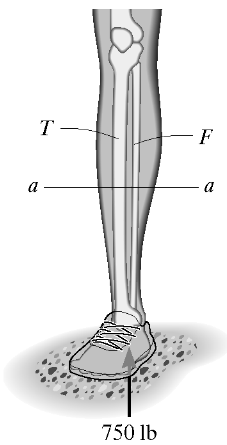
$$+\uparrow \Sigma F_y = 0; \qquad 2V - 600 = 0$$

$$V = 300\ \text{lb}$$



$$\tau_{avg} = \frac{V}{A} = \frac{300}{\frac{\pi}{4}(0.25)^2} = 6.11\ \text{ksi} \qquad \textbf{Ans}$$

***1–36.** While running the foot of a 150-lb man is momentarily subjected to a force which is 5 times his weight. Determine the average normal stress developed in the tibia *T* of his leg at the mid section *a–a*. The cross section can be assumed circular, having an outer diameter of 1.75 in. and an inner diameter of 1 in. Assume the fibula *F* does not support a load.



$$P = 5(150\ \text{lb}) = 750\ \text{lb}$$

$$\sigma = \frac{P}{A} = \frac{750}{\frac{\pi}{4}((1.75)^2 - (1)^2)} = 463\ \text{psi} \qquad \textbf{Ans}$$

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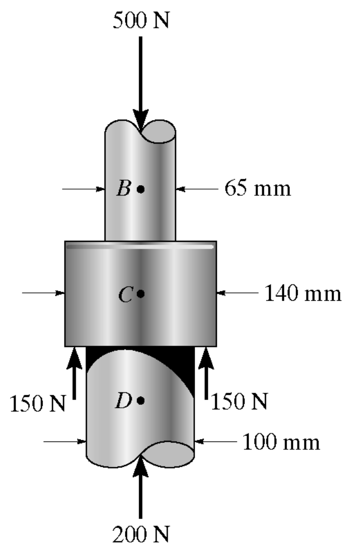
1–37. The thrust bearing is subjected to the loads shown. Determine the average normal stress developed on cross sections through points B, C, and D. Sketch the results on a differential volume element located at each section.

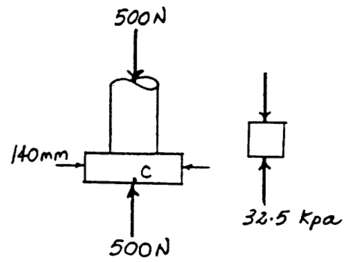


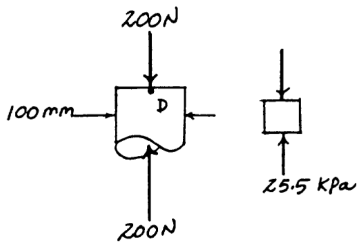
Average Normal Stress :

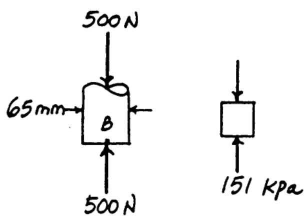
$$\sigma_B = \frac{500}{\frac{\pi}{4}(\frac{65}{1000})^2} = 151 \text{ kPa} \qquad \textbf{Ans}$$

$$\sigma_C = \frac{500}{\frac{\pi}{4}(\frac{140}{1000})^2} = 32.5 \text{ kPa} \qquad \textbf{Ans}$$

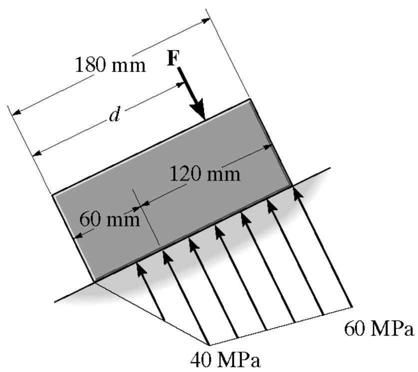
$$\sigma_D = \frac{200}{\frac{\pi}{4}(\frac{100}{1000})^2} = 25.5 \text{ kPa} \qquad \textbf{Ans}$$







1–38. The small block has a thickness of 5 mm. If the stress distribution at the support developed by the load varies as shown, determine the force **F** applied to the block, and the distance d to where it is applied.



$F = \int \sigma \, dA$ = volume under stress diagram

$$F = \frac{1}{2}(0.06)(40)(10^6)(0.005) + (0.120)(40)(10^6)(0.005) + \frac{1}{2}(0.120)(20)(10^6)(0.005)$$

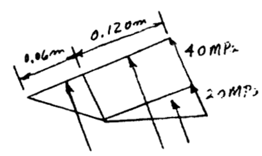
$F = 36$ kN **Ans**

Require

$F\,d = \int x(\sigma \, dA)$

$$36.0(10^3)d = \frac{2}{3}(0.06)(\frac{1}{2})(0.06)(40)(10^6)(0.005) + (0.06 + \frac{1}{2}(0.120))(0.120)(40)(10^6)(0.005) +$$

$$(0.06 + \frac{2}{3}(0.120))(\frac{1}{2})(0.120)(20)(10^6)(0.005)$$



$36.0(10^3)d = 3960$

$d = 0.110 = 110$ mm **Ans**

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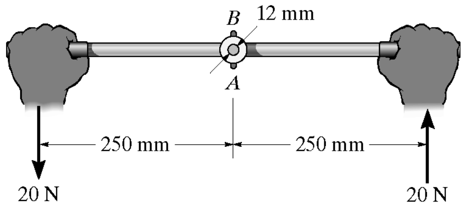
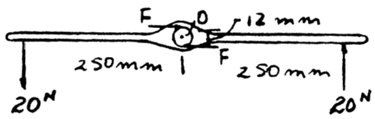
1–39. The lever is held to the fixed shaft using a tapered pin AB, which has a mean diameter of 6 mm. If a couple is applied to the lever, determine the average shear stress in the pin between the pin and lever.

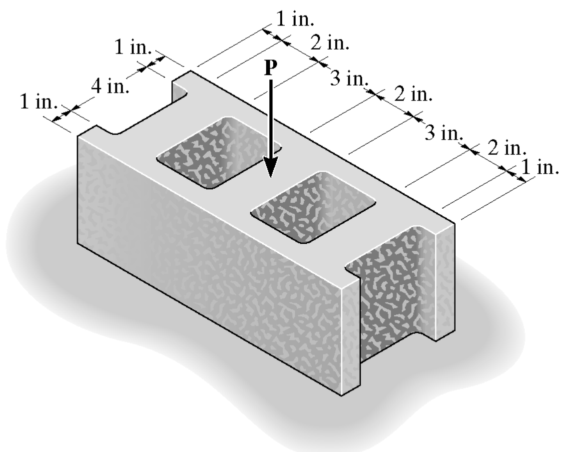


$\circlearrowleft + \Sigma M_O = 0; \quad F(12) - 20(500) = 0; \quad F = 833.33\text{ N}$

$\tau_{avg} = \frac{V}{A} = \frac{833.33}{\frac{\pi}{4}(\frac{6}{1000})^2} = 29.5\text{ MPa}$ **Ans**



***1–40.** The cinder block has the dimensions shown. If the material fails when the average normal stress reaches 120 psi, determine the largest centrally applied vertical load **P** it can support.



Cross section Area :

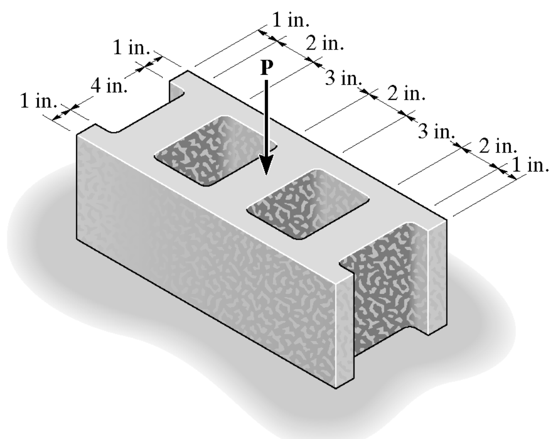
$A = 6(14) - 2[4(1) + 3(4)] = 52\text{ in}^2$

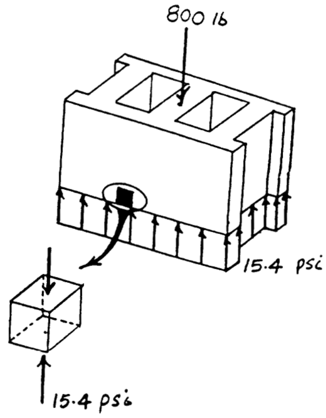
Average Normal Stress :

$\sigma_{allow} = \frac{P_{allow}}{A}; \quad 120 = \frac{P_{allow}}{52}$

$P_{allow} = 6240\text{ lb} = 6.24\text{ kip}$ **Ans**

1–41. The cinder block has the dimensions shown. If it is subjected to a centrally applied force of $\mathbf{P} = 800$ lb, determine the average normal stress in the material. Show the result acting on a differential volume element of the material.





Cross section Area :

$A = 14(6) - 4(8) = 52\text{ in}^2$

Average Normal Stress :

$\sigma = \frac{P}{A} = \frac{800}{52} = 15.4\text{ psi}$ **Ans**

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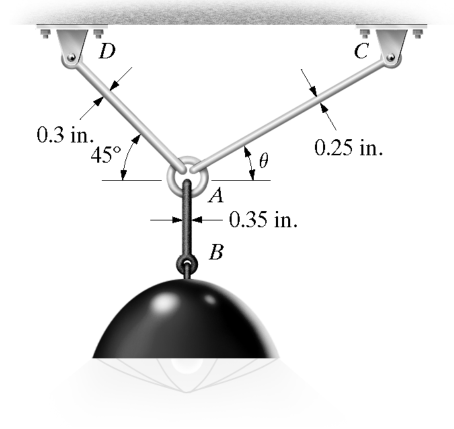
1–42. The 50-lb lamp is supported by three steel rods connected by a ring at A. Determine which rod is subjected to the greater average normal stress and compute its value. Take $\theta = 30°$. The diameter of each rod is given in the figure.



$\xrightarrow{+} \Sigma F_x = 0;\quad F_{AC}\cos 30° - F_{AD}\cos 45° = 0$

$+\uparrow \Sigma F_y = 0;\quad F_{AC}\sin 30° + F_{AD}\sin 45° - 50 = 0$

$F_{AC} = 36.60\text{ lb},\qquad F_{AD} = 44.83\text{ lb}$

Rod *AB* :

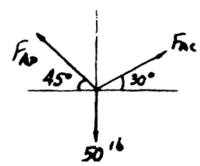
$$\sigma_{AB} = \frac{50}{\frac{\pi}{4}(0.35)^2} = 520\text{ psi}$$

Rod *AD* :

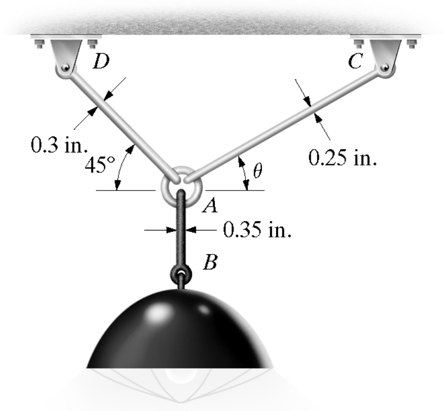
$$\sigma_{AD} = \frac{44.83}{\frac{\pi}{4}(0.3)^2} = 634\text{ psi}$$

Rod *AC* :

$$\sigma_{AC} = \frac{36.60}{\frac{\pi}{4}(0.25)^2} = 746\text{ psi} \qquad \textbf{Ans}$$



1–43. Solve Prob. 1–42 for $\theta = 45°$.



$\xrightarrow{+} \Sigma F_x = 0;\quad F_{AC}\cos 45° - F_{AD}\cos 45° = 0$

$+\uparrow \Sigma F_y = 0;\quad F_{AC}\sin 45° + F_{AD}\sin 45° - 50 = 0$

$F_{AC} = F_{AD} = 35.36\text{ lb}$

Rod *AB* :

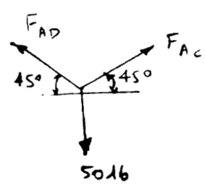
$$\sigma_{AB} = \frac{50}{\frac{\pi}{4}(0.35)^2} = 520\text{ psi}$$

Rod *AC* :

$$\sigma_{AC} = \frac{35.36}{\frac{\pi}{4}(0.25)^2} = 720\text{ psi} \qquad \textbf{Ans}$$

Rod *AD* :

$$\sigma_{AD} = \frac{35.36}{\frac{\pi}{4}(0.3)^2} = 500\text{ psi}$$



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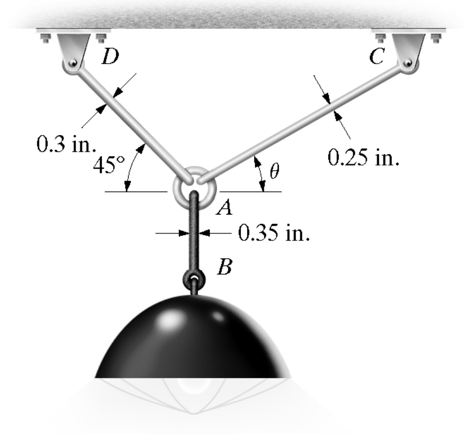
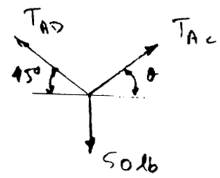
***1–44.** The 50-lb lamp is supported by three steel rods connected by a ring at A. Determine the angle of orientation θ of AC such that the average normal stress in rod AC is twice the average normal stress in rod AD. What is the magnitude of stress in each rod? The diameter of each rod is given in the figure.



$$\sigma_{AD} = \frac{T_{AD}}{\frac{\pi}{4}(0.3)^2}; \qquad T_{AD} = (0.070686)\sigma_{AD}$$



$$\sigma_{AC} = 2\sigma_{AD} = \frac{T_{AC}}{\frac{\pi}{4}(0.25)^2}; \qquad T_{AC} = (0.098175)\sigma_{AD}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad -T_{AD}\cos 45° + T_{AC}\cos\theta = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad T_{AC}\sin\theta + T_{AD}\sin 45° - 50 = 0 \qquad (2)$$

Thus

$$-(0.070686)\sigma_{AD}(\cos 45°) + (0.098175)\sigma_{AD}(\cos\theta) = 0$$

$$\theta = 59.39° = 59.4° \qquad \textbf{Ans}$$

From Eq. (2) :

$$(0.098175)\sigma_{AD}\sin 59.39° + (0.070686)\sigma_{AD}\sin 45° - 50 = 0$$

$$\sigma_{AD} = 371.8 \text{ psi} = 372 \text{ psi} \qquad \textbf{Ans}$$

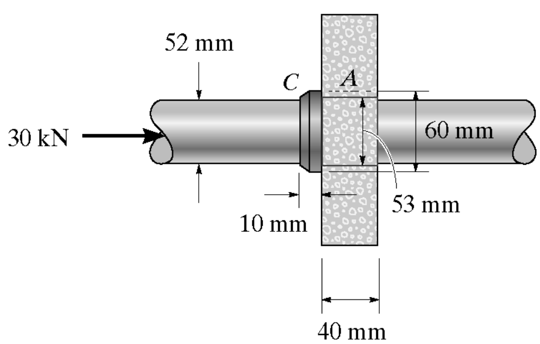
Hence,

$$\sigma_{AC} = 2(371.8) = 744 \text{ psi} \qquad \textbf{Ans}$$

And,

$$\sigma_{AB} = \frac{T_{AB}}{\frac{\pi}{4}(0.35)^2} = \frac{50}{\frac{\pi}{4}(0.35)^2} = 520 \text{ psi} \qquad \textbf{Ans}$$

1–45. The shaft is subjected to the axial force of 30 kN. If the shaft passes through the 53-mm diameter hole in the fixed support A, determine the bearing stress acting on the collar C. Also, what is the average shear stress acting along the inside surface of the collar where it is fixed connected to the 52-mm diameter shaft?



Bearing Stress :

$$\sigma_b = \frac{P}{A} = \frac{30(10^3)}{\frac{\pi}{4}(0.06^2 - 0.053^2)} = 48.3 \text{ MPa} \qquad \textbf{Ans}$$

Average Shear Stress :

$$\tau_{avg} = \frac{V}{A} = \frac{30(10^3)}{\pi(0.052)(0.01)} = 18.4 \text{ MPa} \qquad \textbf{Ans}$$

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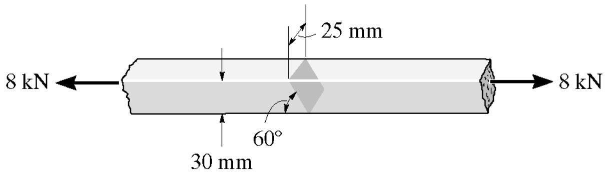
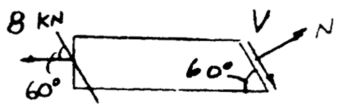
1–46. The two steel members are joined together using a 60° scarf weld. Determine the average normal and average shear stress resisted in the plane of the weld.



$+\nearrow \Sigma F_x = 0; \quad N - 8 \sin 60° = 0$

$N = 6.928 \text{ kN}$



$+\nwarrow \Sigma F_y = 0; \quad V - 8 \cos 60° = 0$

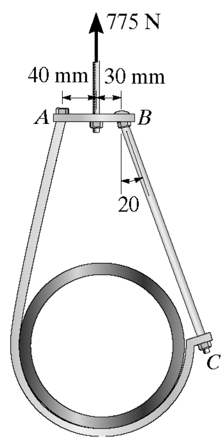
$V = 4 \text{ kN}$

$$A = (25)\left(\frac{30}{\sin 60°}\right) = 866.03 \text{ mm}^2$$

$$\sigma = \frac{N}{A} = \frac{6.928\,(10^3)}{0.8660\,(10^{-3})} = 8 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_{avg} = \frac{V}{A} = \frac{4\,(10^3)}{0.8660\,(10^{-3})} = 4.62 \text{ MPa} \qquad \textbf{Ans}$$

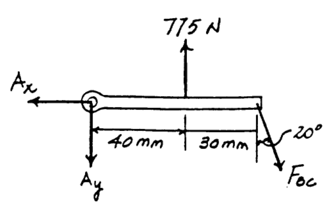
1–47. The J hanger is used to support the pipe such that the force on the vertical bolt is 775 N. Determine the average normal stress developed in the bolt BC if the bolt has a diameter of 8 mm. Assume A is a pin.



Support Reaction :

$\curvearrowleft + \Sigma M_A = 0; \quad 775(40) - F_{BC} \cos 20°(70) = 0$

$F_{BC} = 471.28 \text{ N}$



Average Normal Stress :

$$\sigma_{BC} = \frac{F_{BC}}{A_{BC}} = \frac{471.28}{\frac{\pi}{4}(0.008^2)} = 9.38 \text{ MPa} \qquad \textbf{Ans}$$

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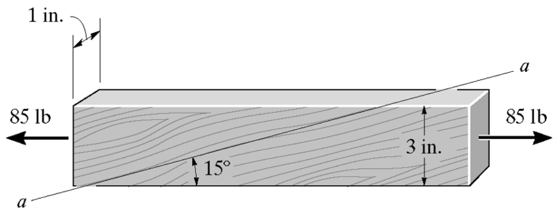
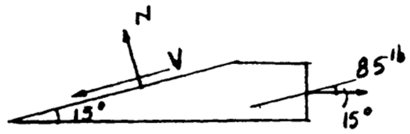
***1–48.** The board is subjected to a tensile force of 85 lb. Determine the average normal and average shear stress developed in the wood fibers that are oriented along section *a–a* at 15° with the axis of the board.



$\nearrow + \Sigma F_x = 0; \quad V - 85\cos 15^\circ = 0$

$V = 82.10\text{ lb}$



$\nwarrow + \Sigma F_y = 0; \quad N - 85\sin 15^\circ = 0$

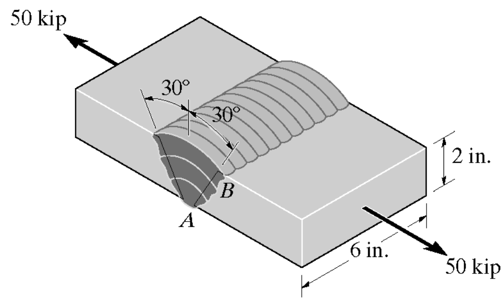
$N = 22.00\text{ lb}$

$A = (1)\left(\dfrac{3}{\sin 15^\circ}\right) = 11.591\text{ in}^2$

$\sigma = \dfrac{N}{A} = \dfrac{22.0}{11.591} = 1.90\text{ psi}$ **Ans**

$\tau_{avg} = \dfrac{V}{A} = \dfrac{82.10}{11.591} = 7.08\text{ psi}$ **Ans**

1–49. The open square butt joint is used to transmit a force of 50 kip from one plate to the other. Determine the average normal and average shear stress components that this loading creates on the face of the weld, section *AB*.



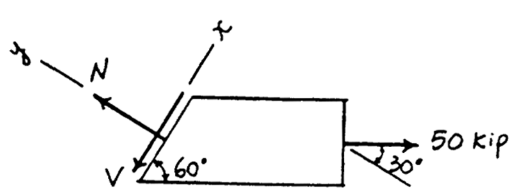
Equations of Equilibrium :

$\nwarrow + \Sigma F_y = 0; \quad N - 50\cos 30^\circ = 0 \qquad N = 43.30\text{ kip}$

$\nearrow + \Sigma F_x = 0; \quad -V + 50\sin 30^\circ = 0 \qquad V = 25.0\text{ kip}$

Average Normal and Shear Stress :

$$A' = \left(\frac{2}{\sin 60^\circ}\right)(6) = 13.86\text{ in}^2$$



$\sigma = \dfrac{N}{A'} = \dfrac{43.30}{13.86} = 3.125\text{ ksi}$ **Ans**

$\tau_{avg} = \dfrac{V}{A'} = \dfrac{25.0}{13.86} = 1.80\text{ ksi}$ **Ans**

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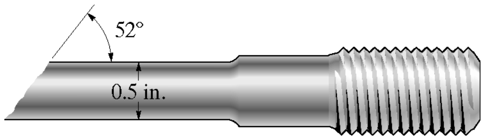
1–50. The specimen failed in a tension test at an angle of 52° when the axial load was 19.80 kip. If the diameter of the specimen is 0.5 in., determine the average normal and average shear stress acting on the area of the inclined failure plane. Also, what is the average normal stress acting on the *cross section* when failure occurs?

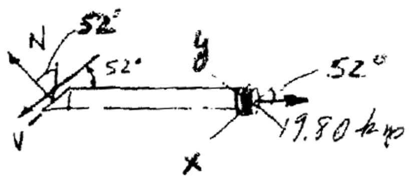


$+\swarrow \Sigma F_x = 0;\quad V - 19.80\cos 52° = 0$

$V = 12.19$ kip

$+\nwarrow \Sigma F_y = 0;\quad N - 19.80\sin 52° = 0$

$N = 15.603$ kip



Inclined plane :

$$\sigma' = \frac{P}{A};\qquad \sigma' = \frac{15.603}{\frac{\pi(0.25)^2}{\sin 52°}} = 62.6 \text{ ksi}\qquad \textbf{Ans}$$

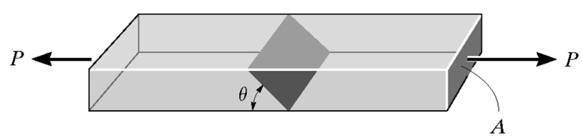
$$\tau'_{avg} = \frac{V}{A};\qquad \tau'_{avg} = \frac{12.19}{\frac{\pi(0.25)^2}{\sin 52°}} = 48.9 \text{ ksi}\qquad \textbf{Ans}$$

Cross section :

$$\sigma = \frac{P}{A};\qquad \sigma = \frac{19.80}{\pi(0.25)^2} = 101 \text{ ksi}\qquad \textbf{Ans}$$

$$\tau_{avg} = \frac{V}{A};\qquad \tau_{avg} = 0\qquad \textbf{Ans}$$

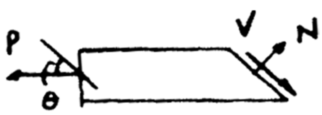
1–51. A tension specimen having a cross-sectional area A is subjected to an axial force **P**. Determine the maximum average shear stress in the specimen and indicate the orientation θ of a section on which it occurs.



$+\nwarrow \Sigma F_y = 0;\quad V - P\cos\theta = 0;\quad V = P\cos\theta$

$$\tau = \frac{P\cos\theta}{A/\sin\theta} = \frac{P\cos\theta\sin\theta}{A} = \frac{P\sin 2\theta}{2A}$$

$$\frac{d\tau}{d\theta} = \frac{P\cos 2\theta}{A} = 0$$



$$\cos 2\theta = 0$$

$$2\theta = 90°$$

$$\theta = 45°\qquad \textbf{Ans}$$

$$\tau_{max} = \frac{P}{2A}\sin 90° = \frac{P}{2A}\qquad \textbf{Ans}$$

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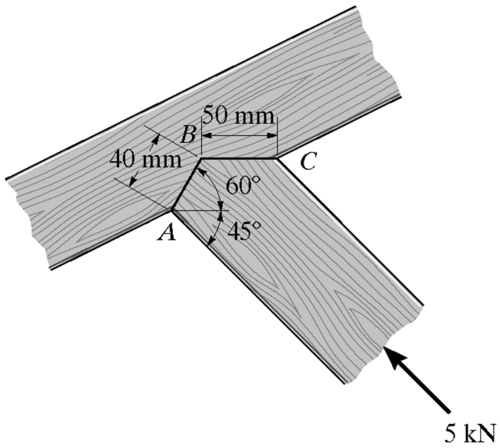
***1–52.** The joint is subjected to the axial member force of 5 kN. Determine the average normal stress acting on sections AB and BC. Assume the member is smooth and is 50-mm thick.

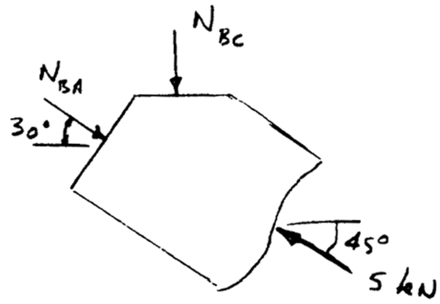


$\xrightarrow{+} \Sigma F_x = 0;\qquad N_{BA}\cos 30° - 5\cos 45° = 0$

$N_{BA} = 4.082\text{ kN}$

$+\uparrow \Sigma F_y = 0;\qquad -N_{BC} - 4.082\sin 30° + 5\sin 45° = 0$

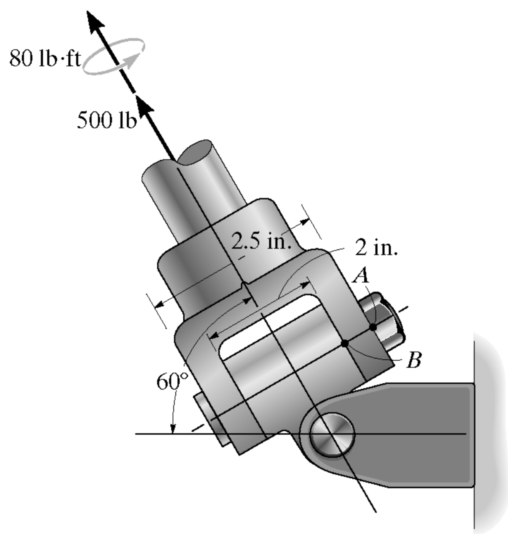
$N_{BC} = 1.494\text{ kN}$



$$\sigma_{BA} = \frac{N_{BA}}{A_{BA}} = \frac{4.082(10^3)}{(0.04)(0.05)} = 2.04\text{ MPa}\qquad \textbf{Ans}$$

$$\sigma_{BC} = \frac{N_{BC}}{A_{BC}} = \frac{1.494(10^3)}{(0.05)(0.05)} = 0.598\text{ MPa}\qquad \textbf{Ans}$$

1–53. The yoke is subjected to the force and couple moment. Determine the average shear stress in the bolt acting on the cross sections through A and B. The bolt has a diameter of 0.25 in. *Hint:* The couple moment is resisted by a set of couple forces developed in the shank of the bolt.



At A force on bolt shank is zero, then

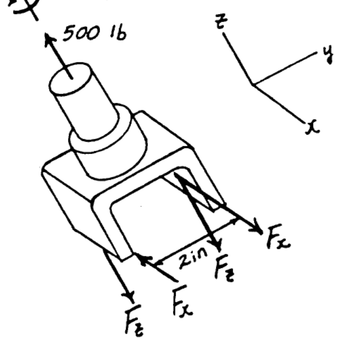
$\tau_A = 0$ **Ans**

Equations of Equilibrium : Force on bolt shank at B.

$\Sigma F_z = 0;\qquad 500 - 2F_z = 0\qquad F_z = 250\text{ lb}$

$\Sigma M_z = 0;\qquad 80\text{ lb}\cdot\text{ft}\left(\frac{12\text{ in}}{\text{ft}}\right) - F_x(2\text{ in.}) = 0$

$F_x = 480\text{ lb}$



Average Shear Stress : The bolt shank subjected to a shear force of $V_B = F_B = \sqrt{250^2 + 480^2} = 541.2$ lb.

$$(\tau_B)_{avg} = \frac{541.2}{\frac{\pi}{4}(0.25)^2} = 11.0\text{ ksi}\qquad \textbf{Ans}$$

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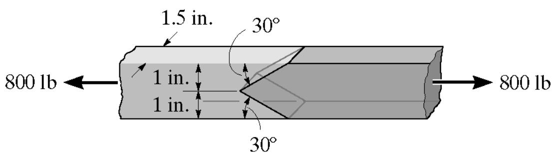
1–54. The two members used in the construction of an aircraft fuselage are joined together using a 30° fish-mouth weld. Determine the average normal and average shear stress on the plane of each weld. Assume each inclined plane supports a horizontal force of 400 lb.



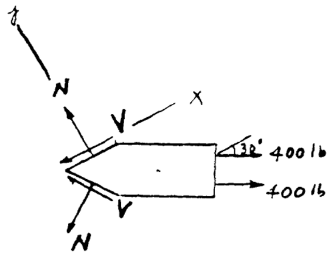
$N - 400 \sin 30° = 0; \quad N = 200 \text{ lb}$

$400 \cos 30° - V = 0; \quad V = 346.41 \text{ lb}$

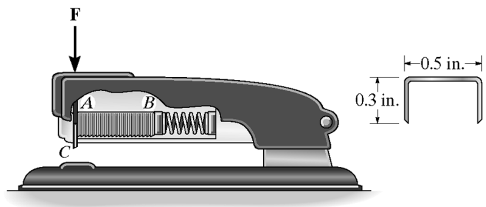
$A' = \frac{1.5(1)}{\sin 30°} = 3 \text{ in}^2$

$\sigma = \frac{N}{A'} = \frac{200}{3} = 66.7 \text{ psi}$ **Ans**

$\tau = \frac{V}{A'} = \frac{346.41}{3} = 115 \text{ psi}$ **Ans**



1–55. The row of staples AB contained in the stapler is glued together so that the maximum shear stress the glue can withstand is $\tau_{max} = 12$ psi. Determine the minimum force **F** that must be placed on the plunger in order to shear off a staple from its row and allow it to exit undeformed through the groove at C. The outer dimensions of the staple are shown in the figure. It has a thickness of 0.05 in. Assume all the other parts are rigid and neglect friction.



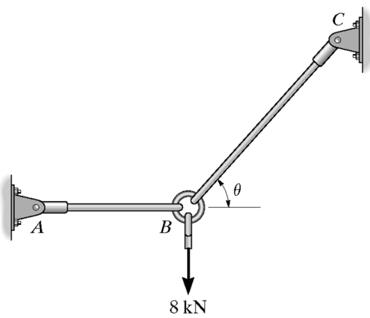
Average Shear Stress :

$A = 0.5(0.3) - 0.4(0.25) = 0.05 \text{ in}^2$

$\tau_{max} = \frac{V}{A}; \quad 12 = \frac{V}{0.05}$

$F_{min} = V = 0.60 \text{ lb}$ **Ans**

***1–56.** Rods AB and BC have diameters of 4 mm and 6 mm, respectively. If the load of 8 kN is applied to the ring at B, determine the average normal stress in each rod if $\theta = 60°$.



$+\uparrow \Sigma F_y = 0; \quad T_{BC} \sin 60° - 8 = 0$

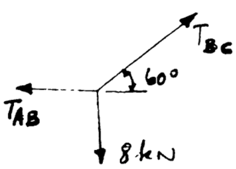
$T_{BC} = 9.2376 \text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0; \quad 9.2376 \cos 60° - T_{AB} = 0$

$T_{AB} = 4.6188 \text{ kN}$

$\sigma_{AB} = \frac{T_{AB}}{A_{AB}} = \frac{4.6188(10^3)}{\frac{\pi}{4}(0.004)^2} = 368 \text{ MPa}$ **Ans**

$\sigma_{BC} = \frac{T_{BC}}{A_{BC}} = \frac{9.2376(10^3)}{\frac{\pi}{4}(0.006)^2} = 327 \text{ MPa}$ **Ans**



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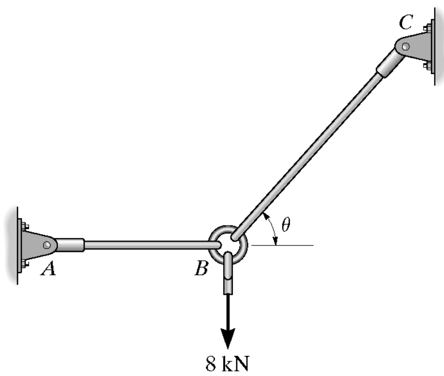
1–57. Rods *AB* and *BC* have diameters of 4 mm and 6 mm, respectively. If the vertical load of 8 kN is applied to the ring at *B*, determine the angle θ of rod *BC* so that the average normal stress in each rod is equivalent. What is this stress?



$F_{AB} = \sigma A_{AB} = \sigma(\pi)(0.002)^2$

$F_{BC} = \sigma A_{BC} = \sigma(\pi)(0.003)^2$

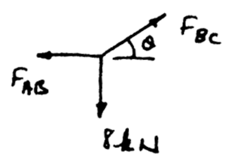
$\xrightarrow{+} \Sigma F_x = 0; \quad \sigma(\pi)(0.003^2)\cos\theta - \sigma\pi(0.002^2) = 0 \quad (1)$

$+\uparrow \Sigma F_y = 0; \quad \sigma\pi(0.003^2)\sin\theta - 8(10^3) = 0 \quad (2)$

From Eq. (1) :

$$\cos\theta = \left(\frac{0.002}{0.003}\right)^2$$

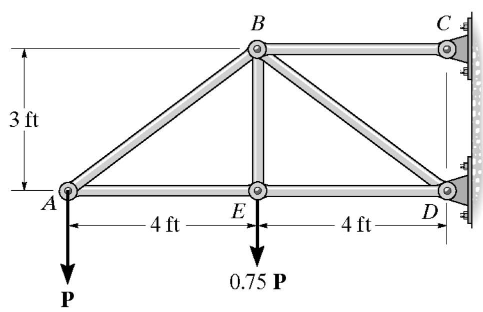
$\theta = 63.6°$ **Ans**



From Eq. (2) :

$$\sigma = \frac{8(10^3)}{\pi(0.003)^2 \sin 63.6°} = 316 \text{ MPa}$$ **Ans**

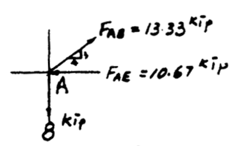
1–58. The bars of the truss each have a cross-sectional area of 1.25 in². Determine the average normal stress in each member due to the loading $P = 8$ kip. State whether the stress is tensile or compressive.



Joint *A* :

$\sigma_{AB} = \frac{F_{AB}}{A_{AB}} = \frac{13.33}{1.25} = 10.7 \text{ ksi}$ (T) **Ans**

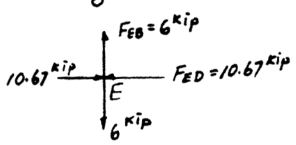
$\sigma_{AE} = \frac{F_{AE}}{A_{AE}} = \frac{10.67}{1.25} = 8.53 \text{ ksi}$ (C) **Ans**



Joint *E* :

$\sigma_{ED} = \frac{F_{ED}}{A_{ED}} = \frac{10.67}{1.25} = 8.53 \text{ ksi}$ (C) **Ans**

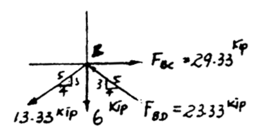
$\sigma_{EB} = \frac{F_{EB}}{A_{EB}} = \frac{6.0}{1.25} = 4.80 \text{ ksi}$ (T) **Ans**



Joint *B* :

$\sigma_{BC} = \frac{F_{BC}}{A_{BC}} = \frac{29.33}{1.25} = 23.5 \text{ ksi}$ (T) **Ans**

$\sigma_{BD} = \frac{F_{BD}}{A_{BD}} = \frac{23.33}{1.25} = 18.7 \text{ ksi}$ (C) **Ans**



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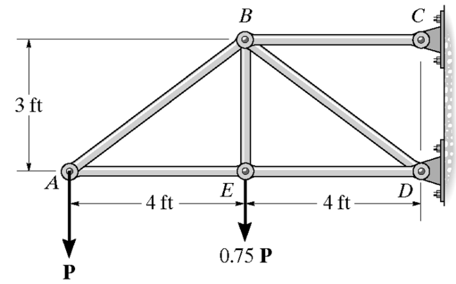
1–59. The bars of the truss each have a cross-sectional area of 1.25 in^2. If the maximum average normal stress in any bar is not to exceed 20 ksi, determine the maximum magnitude P of the loads that can be applied to the truss.



Joint A :

$+\uparrow \Sigma F_y = 0; \quad -P + (\frac{3}{5})F_{AB} = 0$

$F_{AB} = (1.667)P$

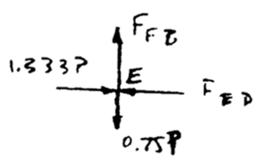
$\xrightarrow{+} \Sigma F_x = 0; \quad -F_{AE} + (1.667)P(\frac{4}{5}) = 0$

$F_{AE} = (1.333)P$

Joint E :

$+\uparrow \Sigma F_y = 0; \quad F_{EB} - (0.75)P = 0$

$F_{EB} = (0.75)P$



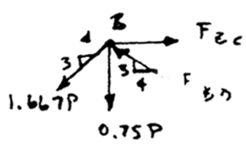
$\xrightarrow{+} \Sigma F_x = 0; \quad (1.333)P - F_{ED} = 0$

$F_{ED} = (1.333)P$

Joint B :

$+\uparrow \Sigma F_y = 0; \quad (\frac{3}{5})F_{BD} - (0.75)P - (1.667)P(\frac{3}{5}) = 0$

$F_{BD} = (2.9167)P$



$\xrightarrow{+} \Sigma F_x = 0; \quad F_{BC} - (2.9167)P(\frac{4}{5}) - (1.667)P(\frac{4}{5}) = 0$

$F_{BC} = (3.67)P$

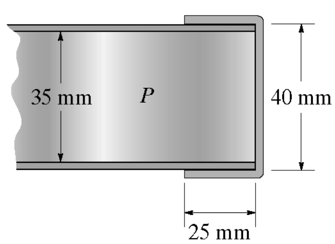
The highest stressed member is BC :

$$\sigma_{BC} = \frac{(3.67)P}{1.25} = 20$$

$P = 6.82$ kip **Ans**

***1–60.** The plug is used to close the end of the cylindrical tube that is subjected to an internal pressure of $p = 650$ Pa. Determine the average shear stress which the glue exerts on the sides of the tube needed to hold the cap in place.

Average Shear Stress :



$$V = 650\left[\frac{\pi}{4}\left(0.035^2\right)\right] = 0.6254 \text{ N}$$

$$\tau_{avg} = \frac{V}{A} = \frac{0.6254}{\pi(0.04)(0.025)} = 199 \text{ Pa} \qquad \textbf{Ans}$$

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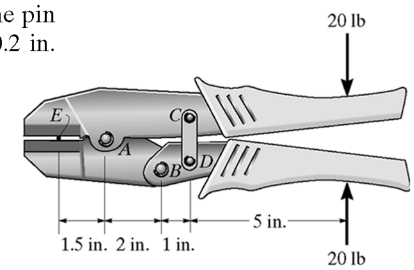
1–61. The crimping tool is used to crimp the end of the wire E. If a force of 20 lb is applied to the handles, determine the average shear stress in the pin at A. The pin is subjected to double shear and has a diameter of 0.2 in. Only a vertical force is exerted on the wire.



Support Reactions :

From FBD (a)

$\circlearrowleft + \Sigma M_D = 0;\quad 20(5) - B_y(1) = 0 \quad B_y = 100 \text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0;\quad B_x = 0$

From FBD (b)

$\xrightarrow{+} \Sigma F_x = 0;\quad A_x = 0$

$\circlearrowleft + \Sigma M_E = 0;\quad A_y(1.5) - 100(3.5) = 0$

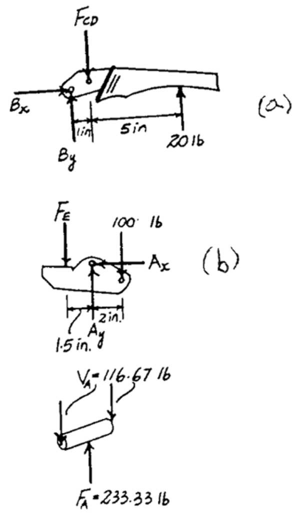
$A_y = 233.33 \text{ lb}$

Average Shear Stress : Pin A is subjected to double shear. Hence,

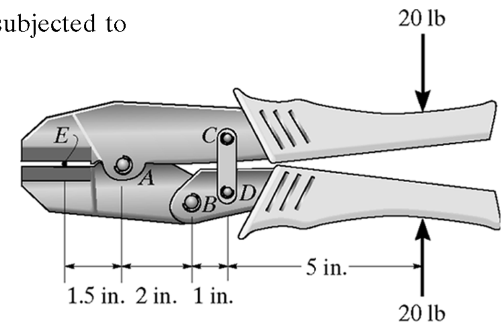
$$V_A = \frac{F_A}{2} = \frac{A_y}{2} = 116.67 \text{ lb}$$

$$(\tau_A)_{avg} = \frac{V_A}{A_A} = \frac{116.67}{\frac{\pi}{4}(0.2^2)}$$

$= 3714 \text{ psi} = 3.71 \text{ ksi}$ **Ans**



1–62. Solve Prob. 1–61 for pin B. The pin is subjected to double shear and has a diameter of 0.2 in.



Support Reactions :

From FBD (a)

$\circlearrowleft + \Sigma M_D = 0;\quad 20(5) - B_y(1) = 0 \quad B_y = 100 \text{ lb}$

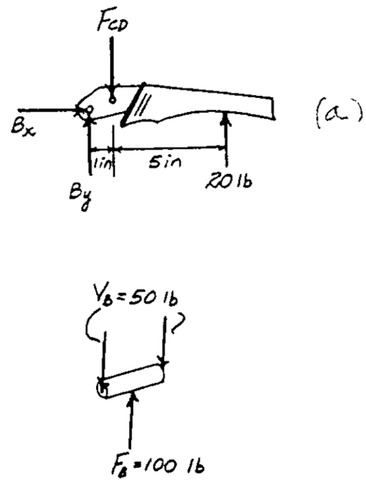
$\xrightarrow{+} \Sigma F_x = 0;\quad B_x = 0$

Average Shear Stress : Pin B is subjected to double shear. Hence,

$$V_B = \frac{F_B}{2} = \frac{B_y}{2} = 50.0 \text{ lb}$$

$$(\tau_B)_{avg} = \frac{V_B}{A_B} = \frac{50.0}{\frac{\pi}{4}(0.2^2)}$$

$= 1592 \text{ psi} = 1.59 \text{ ksi}$ **Ans**



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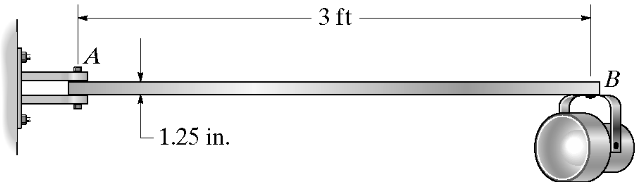
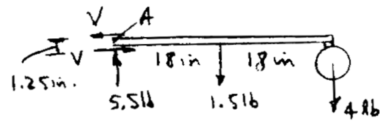
1–63. The railcar docklight is supported by the $\frac{1}{8}$-in.-diameter pin at A. If the lamp weighs 4 lb, and the extension arm AB has a weight of 0.5 lb/ft, determine the average shear stress in the pin needed to support the lamp. *Hint:* The shear force in the pin is caused by the couple moment required for equilibrium at A.



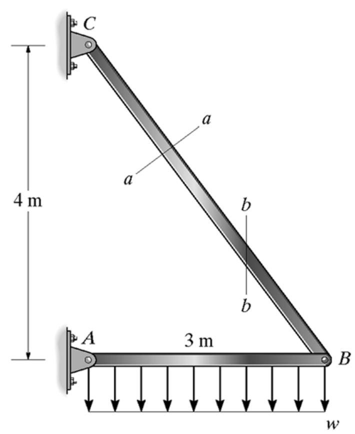
$\curvearrowleft + \Sigma M_A = 0;\quad V(1.25) - 1.5(18) - 4(36) = 0$

$V = 136.8 \text{ lb}$

$\tau_{avg} = \frac{V}{A} = \frac{136.8}{\frac{\pi}{4}(\frac{1}{8})^2} = 11.1 \text{ ksi}$ **Ans**



***1–64.** The two-member frame is subjected to the distributed loading shown. Determine the average normal stress and average shear stress acting at sections a–a and b–b. Member CB has a square cross section of 35 mm on each side. Take $w = 8$ kN/m.



At setion a - a :

$\sigma_{a-a} = \frac{15(10^3)}{(0.035)^2} = 12.2 \text{ MPa}$ **Ans**

$\tau_{a-a} = 0$ **Ans**

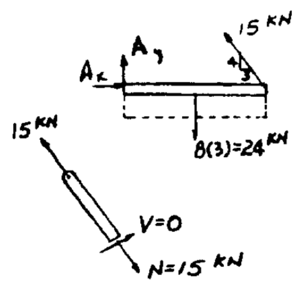
At section b - b :

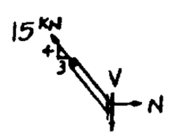
$\xrightarrow{+} \Sigma F_x = 0;\quad N - 15(3/5) = 0;\quad N = 9 \text{ kN}$

$+\downarrow \Sigma F_y = 0;\quad V - 15(4/5) = 0;\quad V = 12 \text{ kN}$

$\sigma_{b-b} = \frac{9(10^3)}{(0.035)(0.035/0.6)} = 4.41 \text{ MPa}$ **Ans**

$\tau_{b-b} = \frac{12(10^3)}{(0.035)(0.035/0.6)} = 5.88 \text{ MPa}$ **Ans**





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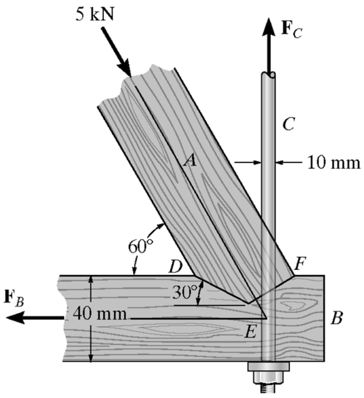
1–65. Member A of the timber step joint for a truss is subjected to a compressive force of 5 kN. Determine the average normal stress acting in the hanger rod C which has a diameter of 10 mm and in member B which has a thickness of 30 mm.



Equations of Equilibrium :

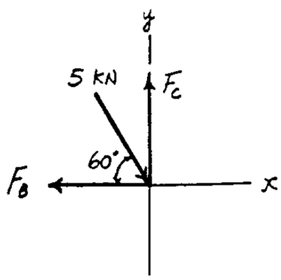
$\xrightarrow{+} \Sigma F_x = 0; \quad 5\cos 60° - F_B = 0 \qquad F_B = 2.50 \text{ kN}$

$+\uparrow \Sigma F_y = 0; \quad F_c - 5\sin 60° = 0 \qquad F_c = 4.330 \text{ kN}$

Average Normal Stress :

$$\sigma_B = \frac{F_B}{A_B} = \frac{2.50(10^3)}{(0.04)(0.03)} = 2.08 \text{ MPa} \qquad \textbf{Ans}$$

$$\sigma_C = \frac{F_C}{A_C} = \frac{4.330(10^3)}{\frac{\pi}{4}(0.01^2)} = 55.1 \text{ MPa} \qquad \textbf{Ans}$$



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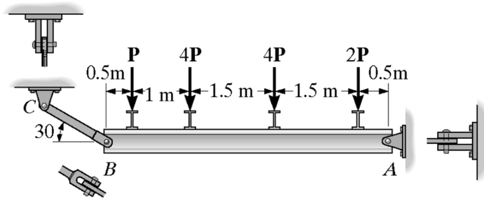
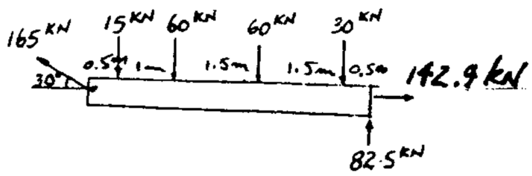
1–67. The beam is supported by a pin at A and a short link BC. If $P = 15$ kN, determine the average shear stress developed in the pins at A, B, and C. All pins are in double shear as shown, and each has a diameter of 18 mm.





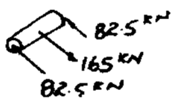
For pins B and C:

$$\tau_B = \tau_C = \frac{V}{A} = \frac{82.5\,(10^3)}{\frac{\pi}{4}\left(\frac{18}{1000}\right)^2} = 324 \text{ MPa} \qquad \textbf{Ans}$$

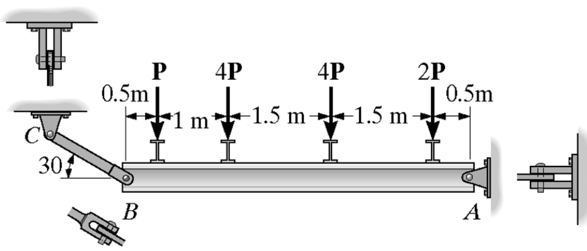
For pin A:

$$F_A = \sqrt{(82.5)^2 + (142.9)^2} = 165 \text{ kN}$$

$$\tau_A = \frac{V}{A} = \frac{82.5\,(10^3)}{\frac{\pi}{4}\left(\frac{18}{1000}\right)^2} = 324 \text{ MPa} \qquad \textbf{Ans}$$



***1–68.** The beam is supported by a pin at A and a short link BC. Determine the maximum magnitude P of the loads the beam will support if the average shear stress in each pin is not to exceed 80 MPa. All pins are in double shear as shown, and each has a diameter of 18 mm.



$\circlearrowleft + \Sigma M_A = 0;\quad 2P(0.5) + 4P(2) + 4P(3.5) + P(4.5) - (T_{CB}\sin 30°)(5) = 0$

$T_{CB} = 11P$

$\xrightarrow{+} \Sigma F_x = 0;\quad A_x - 11P\cos 30° = 0$

$A_x = 9.5263P$

$+\uparrow \Sigma F_y = 0;\quad A_y - 11P + 11P\sin 30° = 0$

$A_y = 5.5P$

$$F_A = \sqrt{(9.5263P)^2 + (5.5P)^2} = 11P$$

Require;

$$\tau = \frac{V}{A};\qquad 80(10^6) = \frac{11P/2}{\frac{\pi}{4}(0.018)^2}$$

$P = 3.70$ kN **Ans**

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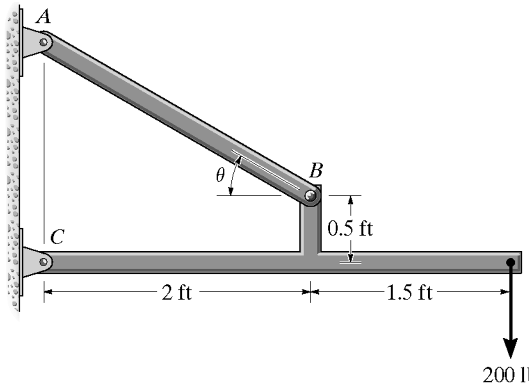
1–69. The frame is subjected to the load of 200 lb. Determine the average shear stress in the bolt at A as a function of the bar angle θ. Plot this function, $0 \le \theta \le 90°$, and indicate the values of θ for which this stress is a minimum. The bolt has a diameter of 0.25 in. and is subjected to single shear.

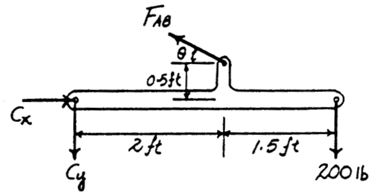


Support Reactions :

$\curvearrowleft + \Sigma M_C = 0; \quad F_{AB}\cos\theta\,(0.5) + F_{AB}\sin\theta\,(2) - 200(3.5) = 0$

$$F_{AB}(0.5\cos\theta + 2\sin\theta) = 700$$

$$F_{AB} = \frac{700}{0.5\cos\theta + 2\sin\theta}$$

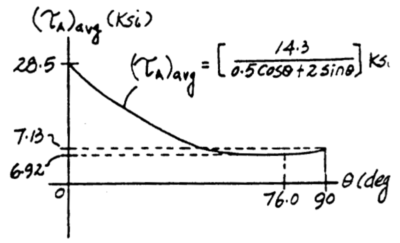


Average Shear Stress : Pin A is subjected to single shear. Hence, $V_A = F_{AB}$

$$(\tau_A)_{avg} = \frac{V_A}{A_A} = \frac{\left(\frac{700}{0.5\cos\theta + 2\sin\theta}\right)}{\frac{\pi}{4}(0.25^2)}$$

$$= \left\{\frac{14260}{0.5\cos\theta + 2\sin\theta}\right\}\text{ psi}$$

$$= \left\{\frac{14.3}{0.5\cos\theta + 2\sin\theta}\right\}\text{ ksi} \qquad \textbf{Ans}$$



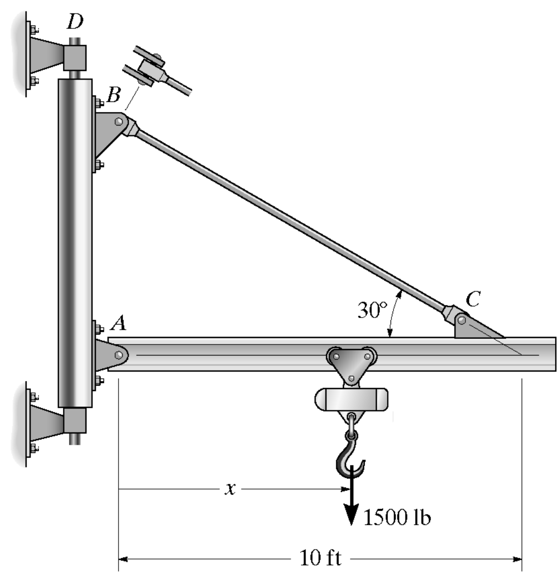
$$\frac{d\tau}{d\theta} = 0$$

$$\frac{(0.5\cos\theta + 2\sin\theta)(0) - (-0.5\sin\theta + 2\cos\theta)(14260)}{(0.5\cos\theta + 2\sin\theta)^2} = 0$$

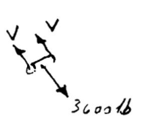
$$0.5\sin\theta - 2\cos\theta = 0$$

$$\tan\theta = 4; \quad \theta_{min} = 76.0° \qquad \textbf{Ans}$$

1–70. The jib crane is pinned at A and supports a chain hoist that can travel along the bottom flange of the beam, $1 \text{ ft} \le x \le 12 \text{ ft}$. If the hoist is rated to support a maximum of 1500 lb, determine the maximum average normal stress in the $\frac{3}{4}$-in.-diameter tie rod BC and the maximum average shear stress in the $\frac{5}{8}$-in.-diameter pin at B.



$\curvearrowleft + \Sigma M_A = 0; \quad T_{BC}\sin 30°(10) - 1500(x) = 0$

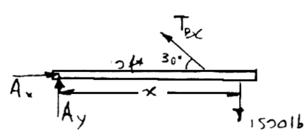


Maximum T_{BC} occurs when $x = 12$ ft

$$T_{BC} = 3600 \text{ lb}$$

$$\sigma = \frac{P}{A} = \frac{3600}{\frac{\pi}{4}(0.75)^2} = 8.15 \text{ ksi} \qquad \textbf{Ans}$$

$$\tau = \frac{V}{A} = \frac{3600/2}{\frac{\pi}{4}(5/8)^2} = 5.87 \text{ ksi} \qquad \textbf{Ans}$$



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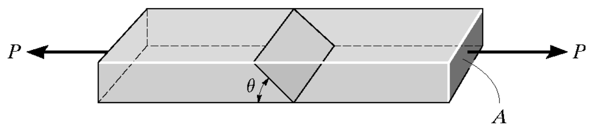
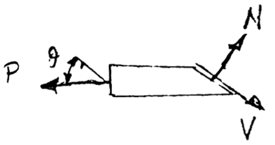
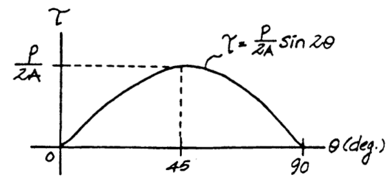
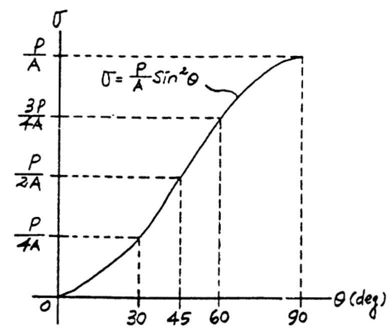
1–71. The bar has a cross-sectional area A and is subjected to the axial load P. Determine the average normal and average shear stresses acting over the shaded section, which is oriented at θ from the horizontal. Plot the variation of these stresses as a function of θ $(0 \leq \theta \leq 90°)$.









Equations of Equilibrium :

$+\Sigma F_x = 0;\quad V - P\cos\theta = 0 \qquad V = P\cos\theta$

$+\Sigma F_y = 0;\quad N - P\sin\theta = 0 \qquad N = P\sin\theta$

Average Normal Stress and Shear Stress :

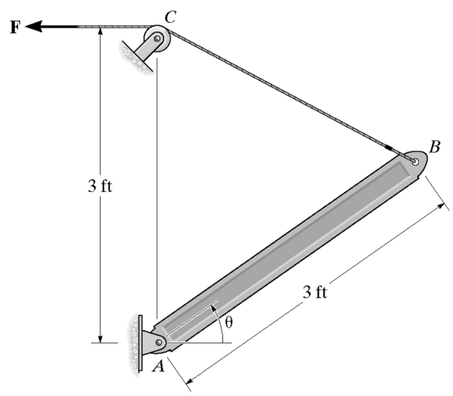
Area at θ plane, $A' = \dfrac{A}{\sin\theta}$.

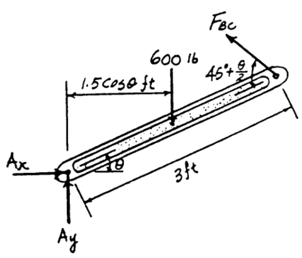
$$\sigma = \frac{N}{A'} = \frac{P\sin\theta}{\frac{A}{\sin\theta}} = \frac{P}{A}\sin^2\theta \qquad \textbf{Ans}$$

$$\tau_{avg} = \frac{V}{A'} = \frac{P\cos\theta}{\frac{A}{\sin\theta}}$$

$$= \frac{P}{A}\sin\theta\cos\theta = \frac{P}{2A}\sin 2\theta \qquad \textbf{Ans}$$

***1–72.** The boom has a uniform weight of 600 lb and is hoisted into position using the cable BC. If the cable has a diameter of 0.5 in., plot the average normal stress in the cable as a function of the boom position θ for $0° \leq \theta \leq 90°$.





Support Reactions :

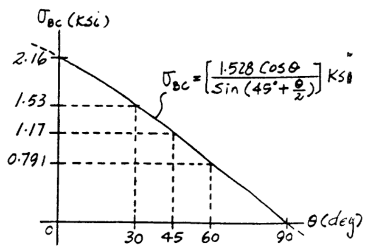
$$+\Sigma M_A = 0;\quad F_{BC}\sin\left(45° + \frac{\theta}{2}\right)(3) - 600(1.5\cos\theta) = 0$$

$$F_{BC} = \frac{300\cos\theta}{\sin\left(45° + \frac{\theta}{2}\right)}$$

Average Normal Stress :

$$\sigma_{BC} = \frac{F_{BC}}{A_{BC}} = \frac{\frac{300\cos\theta}{\sin\left(45° + \frac{\theta}{2}\right)}}{\frac{\pi}{4}(0.5^2)}$$

$$= \left\{\frac{1.528\cos\theta}{\sin\left(45° + \frac{\theta}{2}\right)}\right\}\ \text{ksi} \qquad \textbf{Ans}$$



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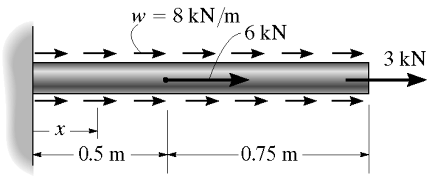
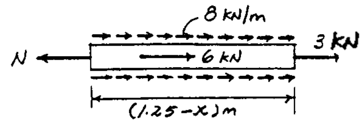
1–73. The bar has a cross-sectional area of $400\,(10^{-6})\ \text{m}^2$. If it is subjected to a uniform axial distributed loading along its length and to two concentrated loads as shown, determine the average normal stress in the bar as a function of x for $0 < x \le 0.5$ m.



Equation of Equilibrium :

$\xrightarrow{+} \Sigma F_x = 0; \qquad -N + 3 + 6 + 8(1.25 - x) = 0$

$N = (19.0 - 8.00x)\ \text{kN}$

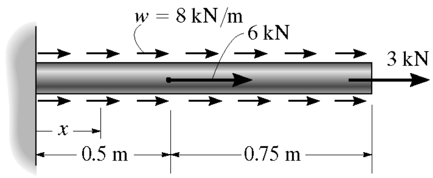


Average Normal Stress :

$$\sigma = \frac{N}{A} = \frac{(19.0 - 8.00x)(10^3)}{400(10^{-6})}$$

$= (47.5 - 20.0x)\ \text{MPa}$ **Ans**

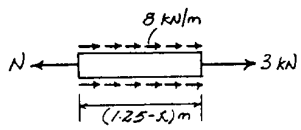
1–74. The bar has a cross-sectional area of $400(10^{-6})\ \text{m}^2$. If it is subjected to a uniform axial distributed loading along its length and to two concentrated loads as shown, determine the average normal stress in the bar as a function of x for $0.5\ \text{m} < x \le 1.25$ m.



Equation of Equilibrium :

$\xrightarrow{+} \Sigma F_x = 0; \qquad -N + 3 + 8(1.25 - x) = 0$

$N = (13.0 - 8.00x)\ \text{kN}$

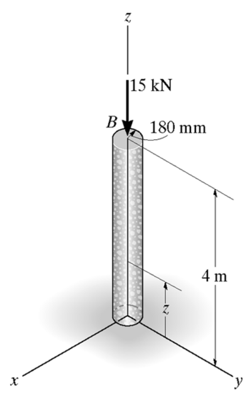


Average Normal Stress :

$$\sigma = \frac{N}{A} = \frac{(13.0 - 8.00x)(10^3)}{400(10^{-6})}$$

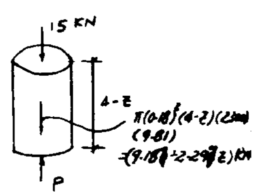
$= (32.5 - 20.0x)\ \text{MPa}$ **Ans**

1–75. The column is made of concrete having a density of $2.30\ \text{Mg/m}^3$. At its top B it is subjected to an axial compressive force of 15 kN. Determine the average normal stress in the column as a function of the distance z measured from its base. *Note:* The result will be useful only for finding the average normal stress at a section removed from the ends of the column, because of localized deformation at the ends.



$+\uparrow \Sigma F_y = 0 \qquad P - 15 - 9.187 + 2.297z = 0$

$P = 24.187 - 2.297z$



$$\sigma = \frac{P}{A} = \frac{24.187 - 2.297z}{\pi(0.18)^2} = (238 - 22.6z)\ \text{kPa}$$ **Ans**

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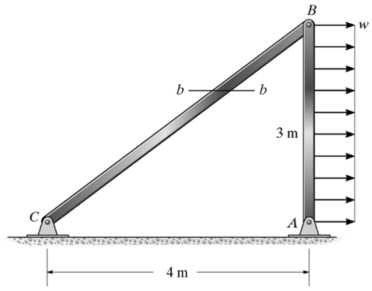
***1–76.** The two-member frame is subjected to the distributed loading shown. Determine the largest intensity w of the uniform loading that can be applied to the frame without causing either the average normal stress or the average shear stress at section b–b to exceed $\sigma = 15$ MPa and $\tau = 16$ MPa, respectively. Member CB has a square cross-section of 30 mm on each side.



Support Reactions : FBD (a)

$\circlearrowleft + \Sigma M_A = 0; \quad \frac{4}{5}F_{BC}(3) - 3w(1.5) = 0 \qquad F_{BC} = 1.875w$

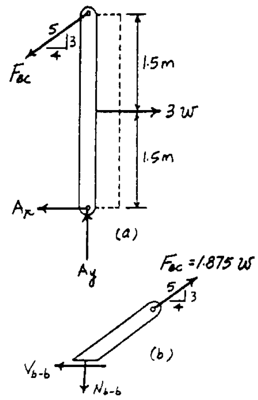
Equations of Equilibrium : For section b-b, FBD (b)

$\xrightarrow{+} \Sigma F_x = 0; \quad \frac{4}{5}(1.875w) - V_{b-b} = 0 \qquad V_{b-b} = 1.50w$

$+\uparrow \Sigma F_y = 0; \quad \frac{3}{5}(1.875w) - N_{b-b} = 0 \qquad N_{b-b} = 1.125w$

Average Normal Stress And Shear Sress : The cross - sectional area of section b-b, $A' = \frac{5A}{3}$; where $A = (0.03)(0.03) = 0.90(10^{-3})\ \text{m}^2$.

Then $A' = \frac{5}{3}(0.90)(10^{-3}) = 1.50(10^{-3})\ \text{m}^2$.



Assume failure due to normal stress.

$(\sigma_{b-b})_{\text{Allow}} = \frac{N_{b-b}}{A'}; \quad 15(10^6) = \frac{1.125w}{1.50(10^{-3})}$

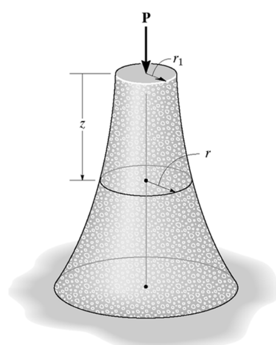
$w = 20000\ \text{N/m} = 20.0\ \text{kN/m}$

Assume failure due to shear stress.

$(\tau_{b-b})_{\text{Allow}} = \frac{V_{b-b}}{A'}; \quad 16(10^6) = \frac{1.50w}{1.50(10^{-3})}$

$w = 16000\ \text{N/m} = 16.0\ \text{kN/m}$ (***Controls !***) **Ans**

1–77. The pedestal supports a load **P** at its center. If the material has a mass density ρ, determine the radial dimension r as a function of z so that the average normal stress in the pedestal remains constant. The cross section is circular.



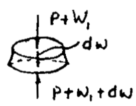
Require :

$$\sigma = \frac{P + W_1}{A} = \frac{P + W_1 + dW}{A + dA}$$

$$P\,dA + W_1\,dA = A\,dW$$

$$\frac{dW}{dA} = \frac{P + W_1}{A} = \sigma \qquad (1)$$

$$dA = \pi(r + dr)^2 - \pi r^2 = 2\pi r\,dr$$

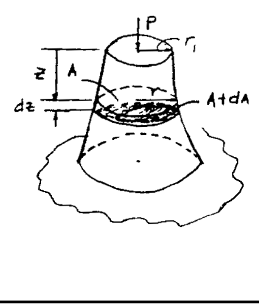


$$dW = \pi r^2(\rho g)\,dz$$

From Eq. (1),

$$\frac{\pi r^2(\rho g)\,dz}{2\pi r\,dr} = \sigma$$

$$\frac{r\rho g\,dz}{2\,dr} = \sigma$$



$$\frac{\rho g}{2\sigma}\int_0^z dz = \int_{r_1}^{r} \frac{dr}{r}$$

$$\frac{\rho g z}{2\sigma} = \ln\frac{r}{r_1}; \qquad r = r_1\, e^{\left(\frac{\rho g}{2\sigma}\right)z}$$

However, $\sigma = \dfrac{P}{\pi r_1^2}$

$$r = r_1\, e^{\left(\frac{\pi r_1^2 \rho g}{2P}\right)z}$$ **Ans**

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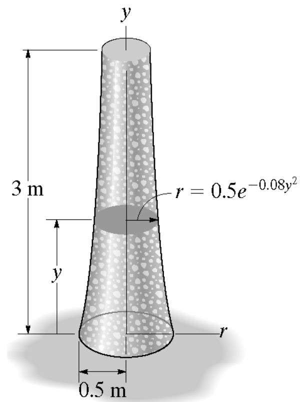
1–78. The radius of the pedestal is defined by $r = (0.5e^{-0.08y^2})$ m, where y is given in meters. If the material has a density of 2.5 Mg/m^3, determine the average normal stress at the support.



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

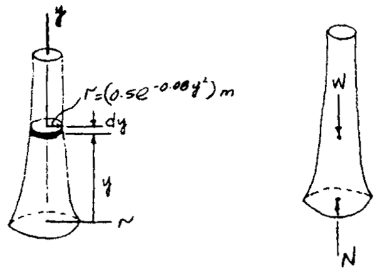
$$dV = \pi(r^2)\,dy = \pi(0.5)^2\,(e^{-0.08y^2})^2$$

$$V = \int_0^3 \pi(0.5)^2\,(e^{-0.08y^2})^2 dy = 0.7854\int_0^3 (e^{-0.08y^2})^2\,dy$$

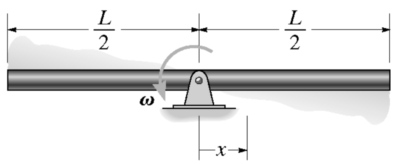
$$W = \rho g\,V = (2500)(9.81)(0.7854)\int_0^3 (e^{-0.08y^2})^2\,dy$$

$$W = 19.262(10^3)\int_0^3 (e^{-0.08y^2})^2\,dy = 38.849 \text{ kN}$$

$$\sigma = \frac{W}{A} = \frac{38.849}{0.7854} = 49.5 \text{ kPa} \qquad \textbf{Ans}$$



1–79. The uniform bar, having a cross-sectional area of A and mass per unit length of m, is pinned at its center. If it is rotating in the horizontal plane at a constant angular rate of ω, determine the average normal stress in the bar as a function of x.



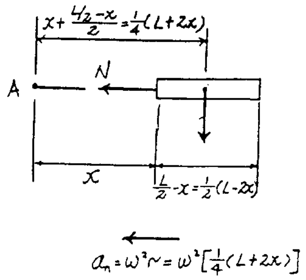
Equation of Motion :

$$\overset{+}{\leftarrow} \Sigma F_x = ma_N; \quad N = m\left[\frac{1}{2}(L-2x)\right]\omega^2\left[\frac{1}{4}(L+2x)\right]$$

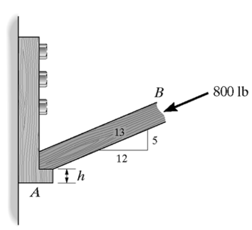
$$= \frac{m\omega^2}{8}\left(L^2 - 4x^2\right)$$

Average Normal Stress :

$$\sigma = \frac{N}{A} = \frac{m\omega^2}{8A}\left(L^2 - 4x^2\right) \qquad \textbf{Ans}$$



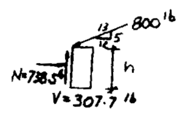
***1–80.** Member B is subjected to a compressive force of 800 lb. If A and B are both made of wood and are $\frac{3}{8}$ in. thick, determine to the nearest $\frac{1}{4}$ in. the smallest dimension h of the support so that the average shear stress does not exceed $\tau_{allow} = 300$ psi.



$$\tau_{allow} = 300 = \frac{307.7}{(\frac{3}{8})h}$$

$$h = 2.74 \text{ in.}$$

$$\text{Use } h = 2\frac{3}{4} \text{ in.} \qquad \textbf{Ans}$$



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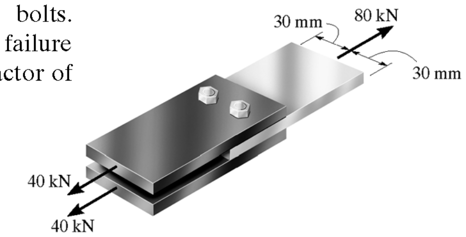
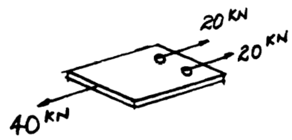
1–81. The joint is fastened together using two bolts. Determine the required diameter of the bolts if the failure shear stress for the bolts is $\tau_{fail} = 350$ MPa. Use a factor of safety for shear of F.S. = 2.5.



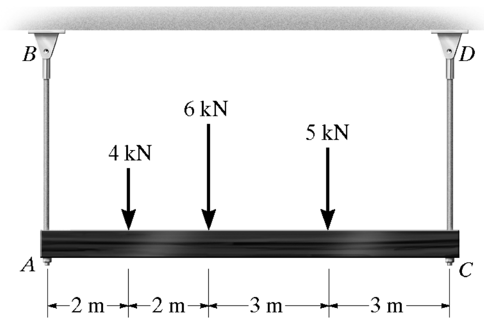
$$\frac{350(10^6)}{2.5} = 140(10^6)$$

$$\tau_{allow} = 140(10^6) = \frac{20(10^3)}{\frac{\pi}{4}d^2}$$

$d = 0.0135$ m $= 13.5$ mm **Ans**



1–82. The rods AB and CD are made of steel having a failure tensile stress of $\sigma_{fail} = 510$ MPa. Using a factor of safety of F.S. = 1.75 for tension, determine their smallest diameter so that they can support the load shown. The beam is assumed to be pin connected at A and C.



Support Reactions :

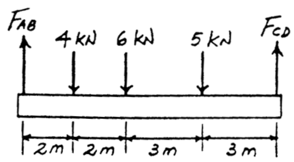
$+\Sigma M_A = 0;\quad F_{CD}(10) - 5(7) - 6(4) - 4(2) = 0$

$F_{CD} = 6.70$ kN

$+\Sigma M_C = 0;\quad 4(8) + 6(6) + 5(3) - F_{AB}(10) = 0$

$F_{AB} = 8.30$ kN

Allowable Normal Stress : Design of rod sizes



For rod AB

$$\sigma_{allow} = \frac{\sigma_{fail}}{\text{F.S}} = \frac{F_{AB}}{A_{AB}};\qquad \frac{510(10^6)}{1.75} = \frac{8.30(10^3)}{\frac{\pi}{4}d_{AB}^2}$$

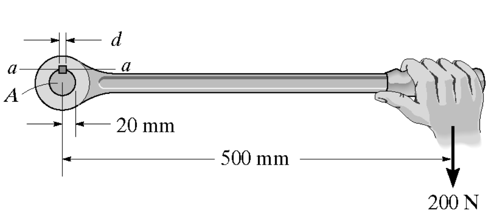
$d_{AB} = 0.006022$ m $= 6.02$ mm **Ans**

For rod CD

$$\sigma_{allow} = \frac{\sigma_{fail}}{\text{F.S}} = \frac{F_{CD}}{A_{CD}};\qquad \frac{510(10^6)}{1.75} = \frac{6.70(10^3)}{\frac{\pi}{4}d_{CD}^2}$$

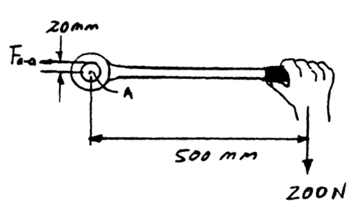
$d_{CD} = 0.005410$ m $= 5.41$ mm **Ans**

1–83. The lever is attached to the shaft A using a key that has a width d and length of 25 mm. If the shaft is fixed and a vertical force of 200 N is applied perpendicular to the handle, determine the dimension d if the allowable shear stress for the key is $\tau_{allow} = 35$ MPa.



$\curvearrowleft + \Sigma M_A = 0;\quad F_{a\text{-}a}(20) - 200(500) = 0$

$F_{a\text{-}a} = 5000$ N



$$\tau_{allow} = \frac{F_{a\text{-}a}}{A_{a\text{-}a}};\qquad 35(10^6) = \frac{5000}{d(0.025)}$$

$d = 0.00571$ m $= 5.71$ mm **Ans**

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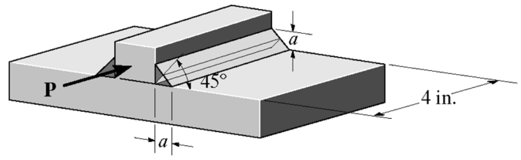
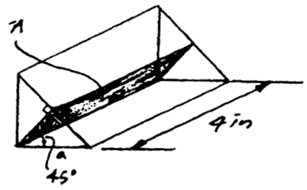
***1–84.** The fillet weld size a is determined by computing the average shear stress along the shaded plane, which has the smallest cross section. Determine the smallest size a of the two welds if the force applied to the plate is $P = 20$ kip. The allowable shear stress for the weld material is $\tau_{allow} = 14$ ksi.



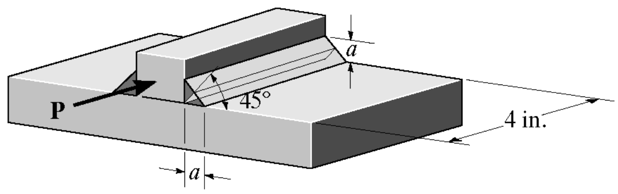
Shear plane $A = a \sin 45°(4) = 2.8284\,a$

$$\tau_{allow} = \frac{V}{A}; \qquad 14(10^3) = \frac{\frac{20(10^3)}{2}}{2.8284\,a}$$

$$a = 0.253 \text{ in.} \qquad \textbf{Ans}$$

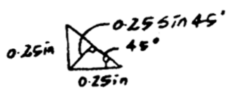


1–85. The fillet weld size $a = 0.25$ in. If the joint is assumed to fail by shear on both sides of the block along the shaded plane, which is the smallest cross section, determine the largest force P that can be applied to the plate. The allowable shear stress for the weld material is $\tau_{allow} = 14$ ksi.



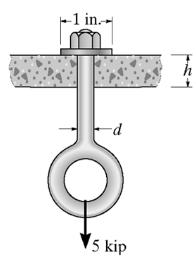
Area $= (2)[(4)(0.707)(0.25)] = 1.414 \text{ in}^2$

$$\tau_{allow} = \frac{V}{A}; \qquad 14 = \frac{P}{1.414}$$



$$P = 19.8 \text{ kip} \qquad \textbf{Ans}$$

1–86. The eye bolt is used to support the load of 5 kip. Determine its diameter d to the nearest $\frac{1}{8}$ in. and the required thickness h to the nearest $\frac{1}{8}$ in. of the support so that the washer will not penetrate or shear through it. The allowable normal stress for the bolt is $\sigma_{allow} = 21$ ksi and the allowable shear stress for the supporting material is $\tau_{allow} = 5$ ksi.



Allowable Normal Stress : Design of bolt size

$$\sigma_{allow} = \frac{P}{A_b}; \qquad 21.0(10^3) = \frac{5(10^3)}{\frac{\pi}{4}d^2}$$

$$d = 0.5506 \text{ in.}$$

$$\text{Use } d = \frac{5}{8} \text{ in.} \qquad \textbf{Ans}$$

Allowable Shear Stress : Design of support thickness

$$\tau_{allow} = \frac{V}{A}; \qquad 5(10^3) = \frac{5(10^3)}{\pi(1)(h)}$$

$$h = 0.3183 \text{ in.}$$

$$\text{Use } h = \frac{3}{8} \text{ in.} \qquad \textbf{Ans}$$

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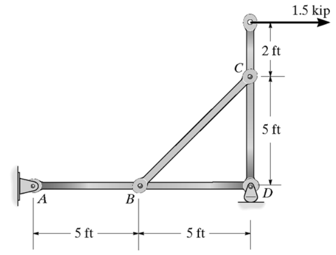
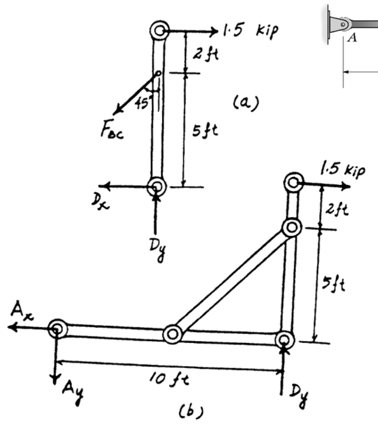
1–87. The frame is subjected to the load of 1.5 kip. Determine the required diameter of the pins at A and B if the allowable shear stress for the material is $\tau_{allow} = 6$ ksi. Pin A is subjected to double shear, whereas pin B is subjected to single shear.





Support Reactions : From FBD (a),

$\circlearrowleft + \Sigma M_D = 0; \quad F_{BC}(\sin 45°)(5) - 1.5(7) = 0$

$F_{BC} = 2.970$ kip

From FBD (b),

$\circlearrowleft + \Sigma M_A = 0; \quad D_y(10) - 1.5(7) = 0 \quad D_y = 1.05$ kip

$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad A_x - 1.5 = 0 \quad A_x = 1.50$ kip

$+\uparrow \Sigma F_y = 0; \quad 1.05 - A_y = 0 \quad A_y = 1.05$ kip

Allowable Shear Stress : Design of pin sizes

For pin A

Pin A is subjected to double shear and

$F_A = \sqrt{1.50^2 + 1.05^2} = 1.831$ kip.

Therefore, $V_A = \dfrac{F_A}{2} = 0.9155$ kip

$$\tau_{allow} = \frac{V_A}{A_A}; \quad 6 = \frac{0.9155}{\frac{\pi}{4}d_A^2}$$

$d_A = 0.441$ in. **Ans**

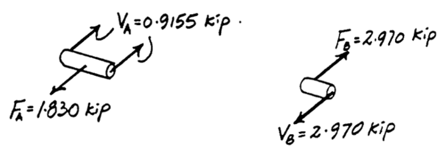
For pin B

Pin B is subjected to single shear. Therefore,

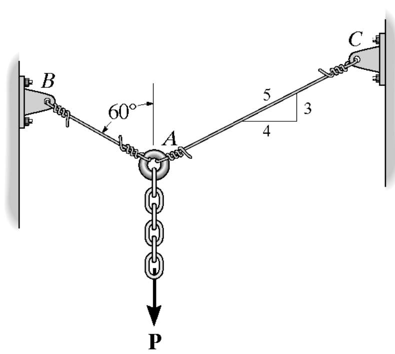
$V_B = F_B = F_{BC} = 2.970$ kip

$$\tau_{allow} = \frac{V_B}{A_B}; \quad 6 = \frac{2.970}{\frac{\pi}{4}d_B^2}$$

$d_B = 0.794$ in. **Ans**



***1–88.** The two steel wires AB and AC are used to support the load. If both wires have an allowable tensile stress of $\sigma_{allow} = 200$ MPa, determine the required diameter of each wire if the applied load is $P = 5$ kN.



$$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad \frac{4}{5}F_{AC} - F_{AB}\sin 60° = 0 \quad (1)$$

$$+\uparrow \Sigma F_y = 0; \quad \frac{3}{5}F_{AC} + F_{AB}\cos 60° - 5 = 0 \quad (2)$$

Solving Eqs. (1) and (2) yields :

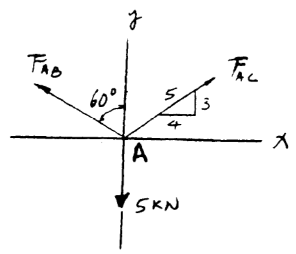
$F_{AB} = 4.3496$ kN; $\quad F_{AC} = 4.7086$ kN

Applying $\sigma_{allow} = \dfrac{P}{A}$

For wire AB,

$$200(10^6) = \frac{4.3496(10^3)}{\frac{\pi}{4}(d_{AB})^2}$$

$d_{AB} = 0.00526$ m $= 5.26$ mm **Ans**



For wire AC,

$$200(10^6) = \frac{4.7086(10^3)}{\frac{\pi}{4}(d_{AC})^2}$$

$d_{AC} = 0.00548$ m $= 5.48$ mm **Ans**

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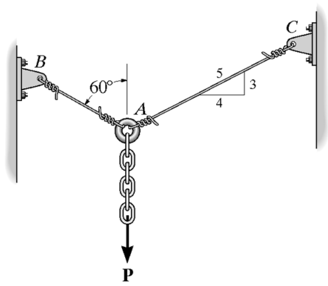
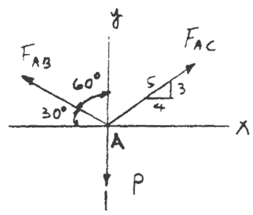
1–89. The two steel wires AB and AC are used to support the load. If both wires have an allowable tensile stress of $\sigma_{allow} = 180$ MPa, and wire AB has a diameter of 6 mm and AC has a diameter of 4 mm, determine the greatest force P that can be applied to the chain before one of the wires fails.



$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad \frac{4}{5}F_{AC} - F_{AB}\sin 60° = 0 \qquad (1)$

$+\uparrow \Sigma F_y = 0; \quad \frac{3}{5}F_{AC} + F_{AB}\cos 60° - P = 0 \qquad (2)$



Assume failure of AB :

$\sigma_{allow} = \frac{F_{AB}}{A_{AB}}; \quad 180(10^6) = \frac{F_{AB}}{\frac{\pi}{4}(0.006)^2}$

$F_{AB} = 5089.38 \text{ N} = 5.089 \text{ kN}$

Solving Eqs.(1) and (2) yields :

$F_{AC} = 5.509 \text{ kN}; \quad P = 5.85 \text{ kN}$

Assume failure of AC :

$\sigma_{allow} = \frac{F_{AC}}{A_{AC}}; \quad 180(10^6) = \frac{F_{AC}}{\frac{\pi}{4}(0.004)^2}$

$F_{AC} = 2261.94 \text{ N} = 2.262 \text{ kN}$

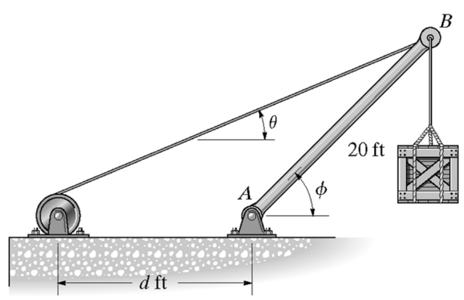
Solving Eqs. (1) and (2) yields :

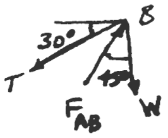
$F_{AB} = 2.089 \text{ kN}; \quad P = 2.40 \text{ kN}$

Choose the smallest value

$P = 2.40 \text{ kN}$ **Ans**

1–90. The boom is supported by the winch cable that has a diameter of 0.25 in. and an allowable normal stress of $\sigma_{allow} = 24$ ksi. Determine the greatest load that can be supported without causing the cable to fail when $\theta = 30°$ and $\phi = 45°$. Neglect the size of the winch.





$\sigma = \frac{P}{A}; \quad 24(10^3) = \frac{T}{\frac{\pi}{4}(0.25)^2};$

$T = 1178.10 \text{ lb}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad -1178.10\cos 30° + F_{AB}\sin 45° = 0$

$+\uparrow \Sigma F_y = 0; \quad -W + F_{AB}\cos 45° - 1178.10\sin 30° = 0$

$W = 431 \text{ lb}$ **Ans**

$F_{AB} = 1442.9 \text{ lb}$

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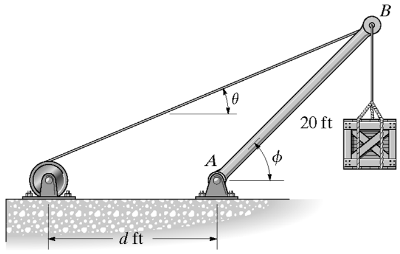
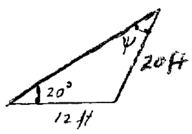
1–91. The boom is supported by the winch cable that has an allowable normal stress of $\sigma_{allow} = 24$ ksi. If it is required that it be able to slowly lift 5000 lb, from $\theta = 20°$ to $\theta = 50°$, determine the smallest diameter of the cable to the nearest $\frac{1}{16}$ in. The boom AB has a length of 20 ft. Neglect the size of the winch. Set $d = 12$ ft.

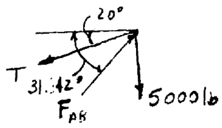


Maximum tension in cable occurs when $\theta = 20°$,



$$\frac{\sin 20°}{20} = \frac{\sin \psi}{12}$$

$$\psi = 11.842°$$



$\xrightarrow{+} \Sigma F_x = 0;\quad -T\cos 20° + F_{AB}\cos 31.842° = 0$

$+\uparrow \Sigma F_y = 0;\quad F_{AB}\sin 31.842° - T\sin 20° - 5000 = 0$

$$T = 20\,698.3 \text{ lb}$$

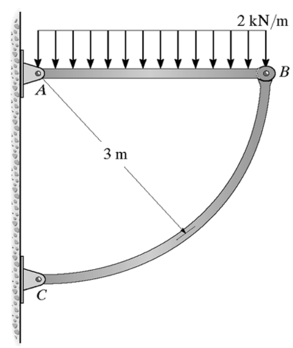
$$F_{AB} = 22\,896 \text{ lb}$$

$\sigma = \frac{P}{A};\quad 24(10^3) = \frac{20\,698.3}{\frac{\pi}{4}(d)^2}$

$$d = 1.048 \text{ in.}$$

Use $\quad d = 1\frac{1}{16}$ in. **Ans**

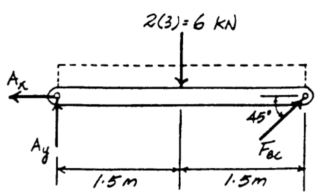
***1–92.** The frame is subjected to the distributed loading of 2 kN/m. Determine the required diameter of the pins at A and B if the allowable shear stress for the material is $\tau_{allow} = 100$ MPa. Both pins are subjected to double shear.



Support Reactions : Member BC is a two force member.

$\circlearrowleft + \Sigma M_A = 0;\quad F_{BC}\sin 45°(3) - 6(1.5) = 0$

$$F_{BC} = 4.243 \text{ kN}$$



$+\uparrow \Sigma F_y = 0;\quad A_y + 4.243\sin 45° - 6 = 0$

$$A_y = 3.00 \text{ kN}$$

$\xleftarrow{+} \Sigma F_x = 0;\quad A_x - 4.243\cos 45° = 0$

$$A_x = 3.00 \text{ kN}$$

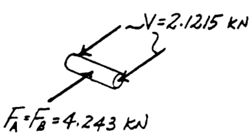
Allowable Shear Stress : Pin A and pin B are subjected to double shear.

$F_A = \sqrt{3.00^2 + 3.00^2} = 4.243$ kN and

$F_B = F_{BC} = 4.243$ kN.

Therefore,

$V_A = V_B = \frac{4.243}{2} = 2.1215$ kN



$\tau_{allow} = \frac{V}{A};\quad 100(10^6) = \frac{2.1215(10^3)}{\frac{\pi}{4}d^2}$

$$d = 0.005197 \text{ m} = 5.20 \text{ mm}$$

$d_A = d_B = d = 5.20$ mm **Ans**

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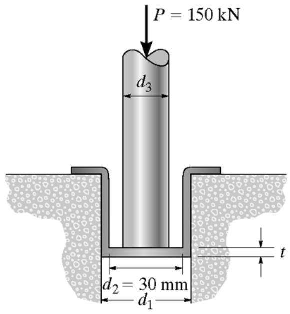
1–93. Determine the smallest dimensions of the circular shaft and circular end cap if the load it is required to support is $P = 150$ kN. The allowable tensile stress, bearing stress, and shear stress is $(\sigma_t)_{\text{allow}} = 175$ MPa, $(\sigma_b)_{\text{allow}} = 275$ MPa, and $\tau_{\text{allow}} = 115$ MPa.



Allowable Normal Stress : Design of end cap outer diameter

$$(\sigma_t)_{\text{allow}} = \frac{P}{A}; \qquad 175(10^6) = \frac{150(10^3)}{\frac{\pi}{4}(d_1^2 - 0.03^2)}$$

$$d_1 = 0.04462 \text{ m} = 44.6 \text{ mm} \qquad \textbf{Ans}$$

Allowable Bearing Stress : Design of circular shaft diameter

$$(\sigma_b)_{\text{allow}} = \frac{P}{A}; \qquad 275(10^6) = \frac{150(10^3)}{\frac{\pi}{4}d_3^2}$$

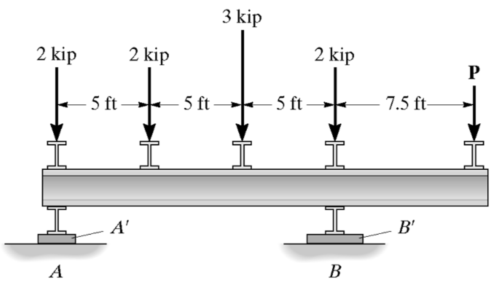
$$d_3 = 0.02635 \text{ m} = 26.4 \text{ mm} \qquad \textbf{Ans}$$

Allowable Shear Stress : Design of end cap thickness

$$\tau_{\text{allow}} = \frac{V}{A}; \qquad 115(10^6) = \frac{150(10^3)}{\pi(0.02635)\,t}$$

$$t = 0.01575 \text{ m} = 15.8 \text{ mm} \qquad \textbf{Ans}$$

1–94. If the allowable bearing stress for the material under the supports at A and B is $(\sigma_b)_{\text{allow}} = 400$ psi, determine the size of *square* bearing plates A' and B' required to support the loading. Take $P = 1.5$ kip. Dimension the plates to the nearest $\frac{1}{2}$ in. The reactions at the supports are vertical.



For Plate A' :

$$\sigma_{\text{allow}} = 400 = \frac{3.583\,(10^3)}{a_{A'}^2}$$

$a_{A'} = 2.99$ in.

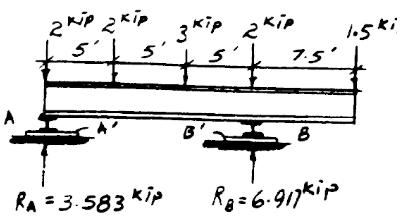
Use a 3 in. x 3 in. plate **Ans**

For Plate B' :

$$\sigma_{\text{allow}} = 400 = \frac{6.917\,(10^3)}{a_{B'}^2}$$

$a_{B'} = 4.16$ in.

Use a $4\frac{1}{2}$ in. x $4\frac{1}{2}$ in. plate **Ans**



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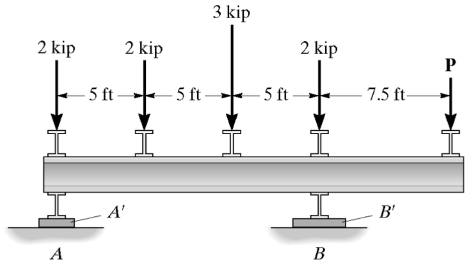
1–95. If the allowable bearing stress for the material under the supports at A and B is $(\sigma_b)_{\text{allow}} = 400$ psi, determine the maximum load **P** that can be applied to the beam. The bearing plates A' and B' have square cross sections of 2 in. × 2 in. and 4 in. × 4 in., respectively.

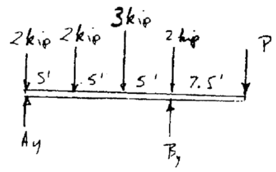


$\circlearrowleft + \Sigma M_A = 0; \quad B_y(15) - 2(5) - 3(10) - 2(15) - P(22.5) = 0$

$B_y = 1.5P + 4.667$

$+\uparrow \Sigma F_y = 0; \quad A_y + 1.5P + 4.667 - 9 - P = 0$

$A_y = 4.333 - 0.5P$



At A:

$$0.400 = \frac{4.333 - 0.5P}{2(2)}$$

$P = 5.47$ kip

At B:

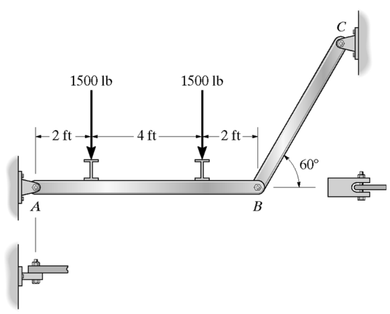
$$0.400 = \frac{1.5P + 4.667}{4(4)}$$

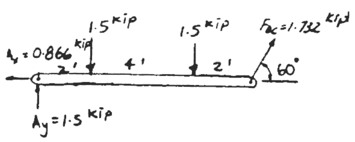
$P = 1.16$ kip

Thus,

$P_{\text{allow}} = 1.16$ kip **Ans**

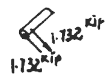
***1–96.** Determine the required cross-sectional area of member BC and the diameter of the pins at A and B if the allowable normal stress is $\sigma_{\text{allow}} = 3$ ksi and the allowable shear stress is $\tau_{\text{allow}} = 4$ ksi.





Member BC:

$$\sigma_{\text{allow}} = 3(10^3) = \frac{1.732(10^3)}{A_{BC}}$$

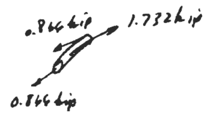


$A_{BC} = 0.577 \text{ in}^2$ **Ans**

Pin A:

$F_A = \sqrt{(0.866)^2 + (1.5)^2} = 1.732$ kip

$$\tau_{\text{allow}} = 4(10^3) = \frac{1.732(10^3)}{\frac{\pi}{4}(d_A)^2}$$



$d_A = 0.743$ in. **Ans**

Pin B:

$$\tau_{\text{allow}} = 4(10^3) = \frac{0.866(10^3)}{\frac{\pi}{4}(d_B)^2}$$

$d_B = 0.525$ in. **Ans**

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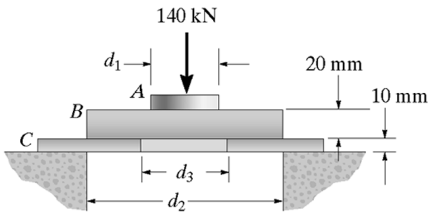
1–97. The assembly consists of three disks A, B, and C that are used to support the load of 140 kN. Determine the smallest diameter d_1 of the top disk, the diameter d_2 within the support space, and the diameter d_3 of the hole in the bottom disk. The allowable bearing stress for the material is $(\sigma_{\text{allow}})_b = 350\text{ MPa}$ and allowable shear stress is $\tau_{\text{allow}} = 125\text{ MPa}$.



Solution

Allowable Shear Stress : Assume shear failure for disk C.

$$\tau_{\text{allow}} = \frac{V}{A}; \qquad 125(10^6) = \frac{140(10^3)}{\pi d_2\,(0.01)}$$

$$d_2 = 0.03565 \text{ m} = 35.7 \text{ mm} \qquad \textbf{Ans}$$

Allowable Bearing Stress : Assume bearing failure for disk C.

$$(\sigma_b)_{\text{allow}} = \frac{P}{A}; \qquad 350(10^6) = \frac{140(10^3)}{\frac{\pi}{4}\left(0.03565^2 - d_3^2\right)}$$

$$d_3 = 0.02760 \text{ m} = 27.6 \text{ mm} \qquad \textbf{Ans}$$

Allowable Bearing Stress : Assume bearing failure for disk B.

$$(\sigma_b)_{\text{allow}} = \frac{P}{A}; \qquad 350(10^6) = \frac{140(10^3)}{\frac{\pi}{4} d_1^2}$$

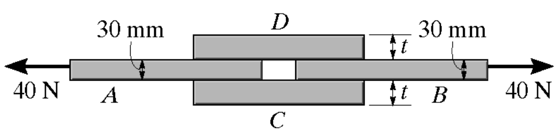
$$d_1 = 0.02257 \text{ m} = 22.6 \text{ mm}$$

Since $d_3 = 27.6 \text{ mm} > d_1 = 22.6 \text{ mm}$, disk B might fail due to shear.

$$\tau = \frac{V}{A} = \frac{140(10^3)}{\pi(0.02257)(0.02)} = 98.7 \text{ MPa} < \tau_{\text{allow}} = 125 \text{ MPa } (\boldsymbol{O.K!})$$

Therefore, $\qquad d_1 = 22.6 \text{ mm} \qquad$ **Ans**

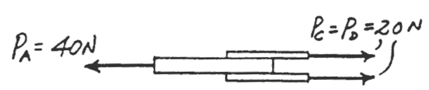
1–98. Strips A and B are to be glued together using the two strips C and D. Determine the required thickness t of C and D so that all strips will fail simultaneously. The width of strips A and B is 1.5 times that of strips C and D.



Average Normal Stress : Requires,

$$\sigma_A = \sigma_B = \sigma_C; \qquad \frac{40}{(0.03)(1.5w)} = \frac{20}{wt}$$

$$t = 0.0225 \text{ m} = 22.5 \text{ mm} \qquad \textbf{Ans}$$



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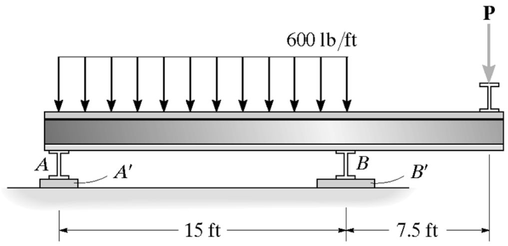
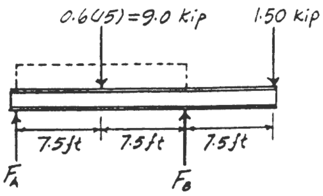
1–99. If the allowable bearing stress for the material under the supports at A and B is $(\sigma_b)_{allow} = 400$ psi, determine the size of *square* bearing plates A' and B' required to support the load. Dimension the plates to the nearest $\frac{1}{2}$ in. The reactions at the supports are vertical. Take $P = 1500$ lb.



Support Reactions :

$$\curvearrowleft +\Sigma M_A = 0; \quad F_B(15) - 9.00(7.5) - 1.50(22.5) = 0$$
$$F_B = 6.75 \text{ kip}$$

$$+\uparrow \Sigma F_y = 0; \quad F_A + 6.75 - 9.00 - 1.50 = 0$$
$$F_A = 3.75 \text{ kip}$$



Allowable Bearing Stress : Design of bearing plates

For plate A′

$$(\sigma_b)_{allow} = \frac{F_A}{A_{A'}}; \quad 400 = \frac{3.75(10^3)}{L_{A'}^2} \quad L_{A'} = 3.06 \text{ in.}$$

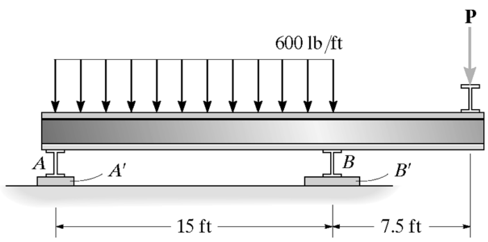
Use $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in. plate **Ans**

For plate B′

$$(\sigma_b)_{allow} = \frac{F_B}{A_{B'}}; \quad 400 = \frac{6.75(10^3)}{L_{B'}^2} \quad L_{B'} = 4.11 \text{ in.}$$

Use $4\frac{1}{2}$ in. × $4\frac{1}{2}$ in. plate **Ans**

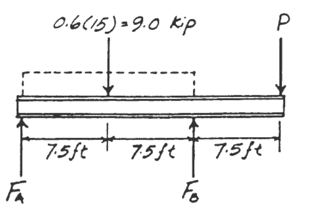
***1–100.** If the allowable bearing stress for the material under the support at A and B is $(\sigma_b)_{allow} = 400$ psi, determine the maximum load **P** that can be applied to the beam. The bearing plates A' and B' have square cross sections of 2 in. × 2 in. and 4 in. × 4 in., respectively.



Support Reactions :

$$\curvearrowleft +\Sigma M_A = 0; \quad F_B(15) - 9.00(7.5) - P(22.5) = 0$$
$$15F_B - 22.5P = 67.5 \qquad [1]$$

$$\curvearrowleft +\Sigma M_B = 0; \quad 9.00(7.5) - P(7.5) - F_A(15) = 0$$
$$15F_A + 7.5P = 67.5 \qquad [2]$$



Allowable Bearing Stress : Assume failure of material occurs under plate A'

$$(\sigma_b)_{allow} = \frac{F_A}{A_{A'}}; \quad 400 = \frac{F_A}{2(2)}$$
$$F_A = 1600 \text{ lb} = 1.60 \text{ kip}$$

From Eq. [2]

$$P = 5.80 \text{ kip}$$

Assume failure of material occurs under B'

$$(\sigma_b)_{allow} = \frac{F_B}{A_{B'}}; \quad 400 = \frac{F_B}{4(4)}$$
$$F_B = 6400 \text{ lb} = 6.40 \text{ kip}$$

From Eq. [1]

$$P = 1.27 \text{ kip}$$

Choose the ***smallest*** value $P = 1.27$ kip **Ans**

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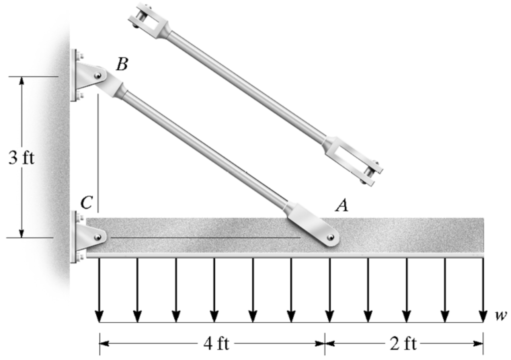
1–101. The hanger assembly is used to support a distributed loading of $w = 0.8$ kip/ft. Determine the average shear stress in the 0.40-in.-diameter bolt at A and the average tensile stress in rod AB, which has a diameter of 0.5 in. If the yield shear stress for the bolt is $\tau_y = 25$ ksi, and the yield tensile stress for the rod is $\sigma_y = 38$ ksi, determine the factor of safety with respect to yielding in each case.



For bolt A:

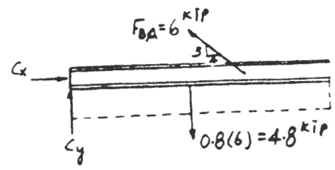
$$\tau = \frac{V}{A} = \frac{3}{\frac{\pi}{4}(0.4^2)} = 23.9 \text{ ksi} \qquad \textbf{Ans}$$

$$\text{F. S.} = \frac{\tau_y}{\tau} = \frac{25}{23.9} = 1.05 \qquad \textbf{Ans}$$

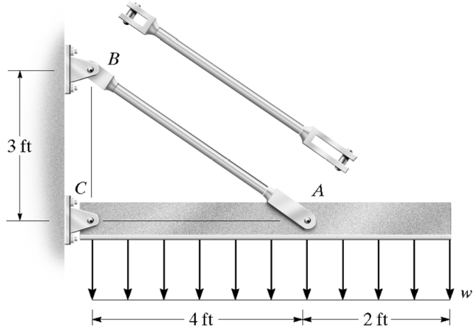
For rod AB:

$$\sigma = \frac{P}{A} = \frac{6}{\frac{\pi}{4}(0.5^2)} = 30.6 \text{ ksi} \qquad \textbf{Ans}$$

$$\text{F. S.} = \frac{\sigma_y}{\sigma} = \frac{38}{30.6} = 1.24 \qquad \textbf{Ans}$$



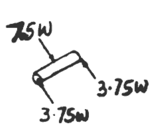
1–102. Determine the intensity w of the maximum distributed load that can be supported by the hanger assembly so that an allowable shear stress of $\tau_{\text{allow}} = 13.5$ ksi is not exceeded in the 0.40-in.-diameter bolts at A and B, and an allowable tensile stress of $\sigma_{\text{allow}} = 22$ ksi is not exceeded in the 0.5-in.-diameter rod AB.

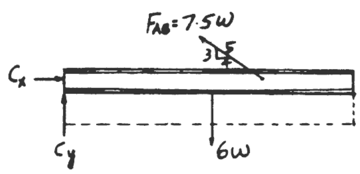


Assume failure of pin A or B:

$$\tau_{\text{allow}} = 13.5 = \frac{3.75w}{\frac{\pi}{4}(0.4^2)}$$

$$w = 0.452 \text{ kip/ft (controls)} \qquad \textbf{Ans}$$





Assuming failure of rod AB:

$$\sigma_{\text{allow}} = 22 = \frac{7.5w}{\frac{\pi}{4}(0.5^2)}$$

$$w = 0.576 \text{ kip/ft}$$

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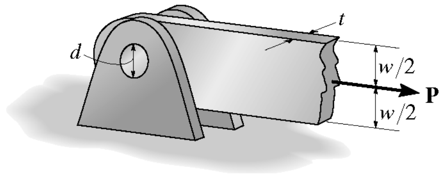
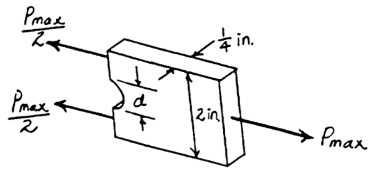
1–103. The bar is supported by the pin. If the allowable tensile stress for the bar is $(\sigma_t)_{\text{allow}} = 21$ ksi, and the allowable shear stress for the pin is $\tau_{\text{allow}} = 12$ ksi, determine the diameter of the pin for which the load P will be a maximum. What is this maximum load? Assume the hole in the bar has the same diameter d as the pin. Take $t = \frac{1}{4}$ in. and $w = 2$ in.



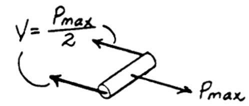
Allowable Normal Stress : The effective cross - sectional area A' for the bar must be considered here by taking into account the reduction in cross sectional area introduced by the hole. Here $A' = (2-d)(\frac{1}{4})$.



$$(\sigma_t)_{\text{allow}} = \frac{P}{A'}; \quad 21(10^3) = \frac{P_{\max}}{(2-d)(\frac{1}{4})} \qquad [1]$$

Allowable Shear Stress : The pin is subjected to double shear and therefore, $V = \frac{P_{\max}}{2}$

$$\tau_{\text{allow}} = \frac{V}{A}; \quad 12(10^3) = \frac{P_{\max}/2}{\frac{\pi}{4}d^2} \qquad [2]$$

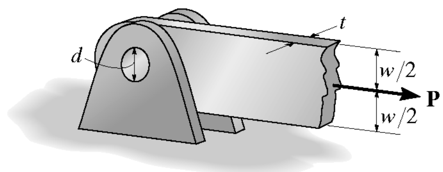


Solving Eq.[1] and[2] yields :

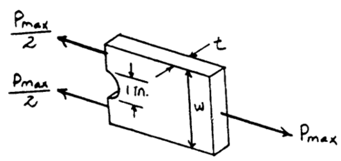
$d = 0.620$ in. **Ans**

$P_{\max} = 7.25$ kip **Ans**

***1–104.** The bar is connected to the support using a pin having a diameter of $d = 1$ in. If the allowable tensile stress for the bar is $(\sigma_t)_{\text{allow}} = 20$ ksi, and the allowable bearing stress between the pin and the bar is $(\sigma_b)_{\text{allow}} = 30$ ksi, determine the dimensions w and t such that the gross area of the cross section is $wt = 2\text{ in}^2$ and the load P is a maximum. What is this maximum load? Assume the hole in the bar has the same diameter as the pin.

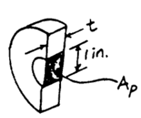


Allowable Normal Stress : The effective cross - sectional area A' for the bar must be considered here by taking into account the reduction in cross - sectional area introduced by the hole. Here $A' = (w-1)t = wt - t = (2-t)\text{ in}^2$ where $wt = 2\text{ in}^2$.



$$(\sigma_t)_{\text{allow}} = \frac{P}{A'}; \quad 20(10^3) = \frac{P_{\max}}{2-t} \qquad [1]$$

Allowable Bearing Stress : The projected area $A_p = (1)t = t\text{ in}^2$.



$$(\sigma_b)_{\text{allow}} = \frac{P}{A_p}; \quad 30(10^3) = \frac{P_{\max}}{t} \qquad [2]$$

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

$t = 0.800$ in. **Ans**

$P_{\max} = 24.0$ kip **Ans**

And $w = 2.50$ in. **Ans**

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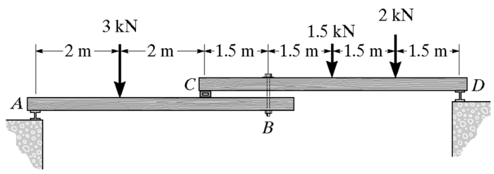
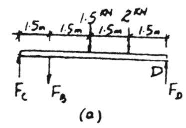
1–105. The compound wooden beam is connected together by a bolt at B. Assuming that the connections at A, B, C, and D exert only vertical forces on the beam, determine the required diameter of the bolt at B and the required outer diameter of its washers if the allowable tensile stress for the bolt is $(\sigma_t)_{allow} = 150$ MPa and the allowable bearing stress for the wood is $(\sigma_b)_{allow} = 28$ MPa. Assume that the hole in the washers has the same diameter as the bolt.



From FBD (a) :

$$\circlearrowleft + \Sigma M_D = 0; \quad F_B(4.5) + 1.5(3) + 2(1.5) - F_C(6) = 0$$

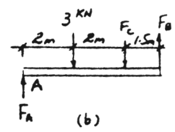
$$4.5\,F_B - 6\,F_C = -7.5 \qquad (1)$$



From FBD (b) :

$$\circlearrowleft + \Sigma M_A = 0; \quad F_B(5.5) - F_C(4) - 3(2) = 0$$

$$5.5\,F_B - 4\,F_C = 6 \qquad (2)$$



Solving Eqs. (1) and (2) yields

$$F_B = 4.40\text{ kN}; \quad F_C = 4.55\text{ kN}$$

For bolt :

$$\sigma_{allow} = 150\,(10^6) = \frac{4.40(10^3)}{\frac{\pi}{4}(d_B)^2}$$

$$d_B = 0.00611\text{ m}$$

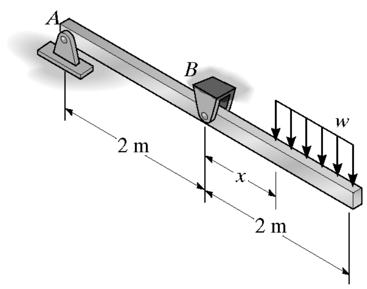
$$= 6.11\text{ mm} \qquad \textbf{Ans}$$

For washer :

$$\sigma_{allow} = 28\,(10^6) = \frac{4.40(10^3)}{\frac{\pi}{4}(d_w^2 - 0.00611^2)}$$

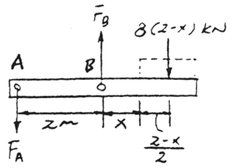
$$d_w = 0.0154\text{ m} = 15.4\text{ mm} \qquad \textbf{Ans}$$

1–106. The bar is held in equilibrium by the pin supports at A and B. Note that the support at A has a single leaf and therefore it involves single shear in the pin, and the support at B has a double leaf and therefore it involves double shear. The allowable shear stress for both pins is $\tau_{allow} = 150$ MPa. If a uniform distributed load of $w = 8$ kN/m is placed on the bar, determine its minimum allowable position x from B. Pins A and B each have a diameter of 8 mm. Neglect any axial force in the bar.



$$\circlearrowleft + \Sigma M_A = 0; \quad F_B(2) - 8(2 - x)(3 + \frac{x}{2}) = 0$$

$$2F_B - 48 + 16x + 4x^2 = 0 \qquad (1)$$

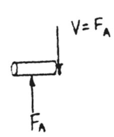


$$\circlearrowleft + \Sigma M_B = 0; \quad F_A(2) - 8(2 - x)(\frac{x}{2} + 1) = 0$$

$$2F_A - 16 + 4x^2 = 0 \qquad (2)$$

Assume failure of pin A

$$\tau_{allow} = \frac{F_A}{A_A}; \quad 150(10^6) = \frac{F_A}{\frac{\pi}{4}(0.008)^2}$$

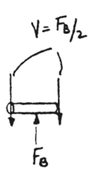


$$F_A = 7539.8\text{ N} = 7.5398\text{ kN}$$

Substitute $F_A = 7.5398$ kN into Eq. (2), $x = 0.480$ m

Assume failure of pin B

$$\tau_{allow} = \frac{\frac{F_B}{2}}{A_B}; \quad 150(10^6) = \frac{\frac{F_B}{2}}{\frac{\pi}{4}(0.008)^2}$$



$$F_B = 15079.6\text{ N} = 15.0796\text{ kN}$$

Substitute $F_B = 15.0796$ kN into Eq. (1), $x = 0.909$ m

Choose the larger $x = 0.909$ m **Ans**

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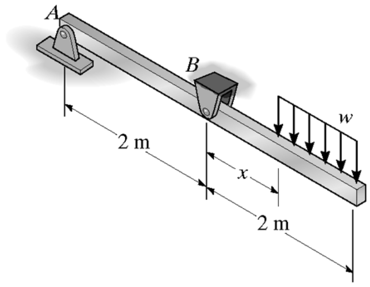
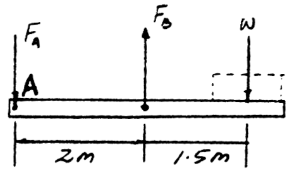
1–107. The bar is held in equilibrium by the pin supports at A and B. Note that the support at A has a single leaf and therefore it involves single shear in the pin, and the support at B has a double leaf and therefore it involves double shear. The allowable shear stress for both pins is $\tau_{allow} = 125$ MPa. If $x = 1$ m, determine the maximum distributed load w the bar will support. Pins A and B each have a diameter of 8 mm. Neglect any axial force in the bar.



$\curvearrowleft + \Sigma M_A = 0; \quad F_B(2) - w(3.5) = 0; \quad F_B = 1.75w$

$+\uparrow \Sigma F_y = 0; \quad 1.75w - w - F_A = 0; \quad F_A = 0.75w$



For pin A,

$$\tau_{allow} = \frac{F_A}{A_A}; \qquad 125(10^6) = \frac{0.75w}{\frac{\pi}{4}(0.008)^2}$$

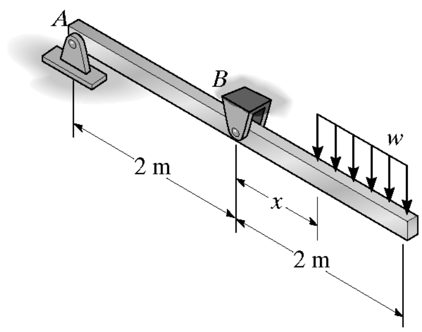
$w = 8377$ N/m $= 8.38$ kN/m

For pin B,

$$\tau_{allow} = \frac{\frac{F_B}{2}}{A_B}; \qquad 125(10^6) = \frac{\frac{1.75w}{2}}{\frac{\pi}{4}(0.008)^2}$$

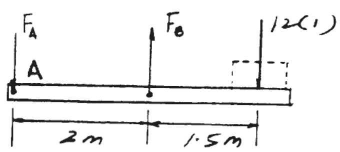
$w = 7181$ N/m $= 7.18$ kN/m (controls) **Ans**

***1–108.** The bar is held in equilibrium by the pin supports at A and B. Note that the support at A has a single leaf and therefore it involves single shear in the pin, and the support at B has a double leaf and therefore it involves double shear. The allowable shear stress for both pins is $\tau_{allow} = 125$ MPa. If $x = 1$ m and $w = 12$ kN/m, determine the smallest required diameter of pins A and B. Neglect any axial force in the bar.



$\curvearrowleft + \Sigma M_A = 0; \quad F_B(2) - 12(3.5) = 0; \quad F_B = 21$ kN

$+\uparrow \Sigma F_y = 0; \quad 21 - 12 - F_A = 0; \quad F_A = 9$ kN



For pin A,

$$\tau_{allow} = \frac{F_A}{A_A}; \qquad 125(10^6) = \frac{9(10^3)}{\frac{\pi}{4}(d_A)^2}$$

$d_A = 0.00957$ m $= 9.57$ mm **Ans**

For pin B,

$$\tau_{allow} = \frac{\frac{F_B}{2}}{A_B}; \qquad 125(10^6) = \frac{\frac{21(10^3)}{2}}{\frac{\pi}{4}(d_B)^2}$$

$d_B = 0.0103$ m $= 10.3$ mm **Ans**

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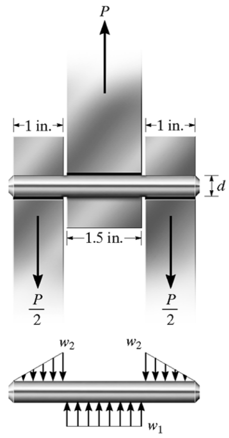
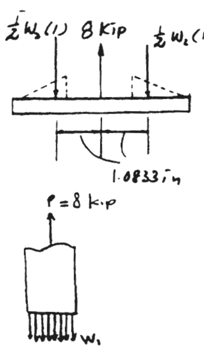
1–109. The pin is subjected to double shear since it is used to connect the three links together. Due to wear, the load is distributed over the top and bottom of the pin as shown on the free-body diagram. Determine the diameter d of the pin if the allowable shear stress is $\tau_{allow} = 10$ ksi and the load $P = 8$ kip. Also, determine the load intensities w_1 and w_2.





Pin :

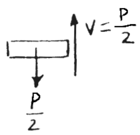
$+\uparrow \Sigma F_y = 0;\quad 8 - 1.5\, w_1 = 0$

$w_1 = 5.33$ kip/in. **Ans**

Link :

$+\uparrow \Sigma F_y = 0;\quad -2(\frac{1}{2} w_2)(1) + 8 = 0$

$w_2 = 8$ kip/in. **Ans**

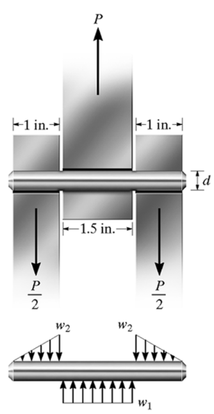


Shear stress

$\tau_{allow} = \frac{\frac{P}{2}}{\frac{\pi}{4}(d)^2};\quad 10 = \frac{\frac{8}{2}}{\frac{\pi}{4}(d)^2}$

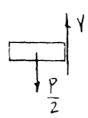
$d = 0.714$ in. **Ans**

1–110. The pin is subjected to double shear since it is used to connect the three links together. Due to wear, the load is distributed over the top and bottom of the pin as shown on the free-body diagram. Determine the maximum load P the connection can support if the allowable shear stress for the material is $\tau_{allow} = 8$ ksi and the diameter of the pin is 0.5 in. Also, determine the load intensities w_1 and w_2.



$V = \frac{P}{2}$

$\tau_{allow} = \frac{\frac{P}{2}}{A};\quad 8(10^3) = \frac{\frac{P}{2}}{\frac{\pi}{4}(0.5)^2}$



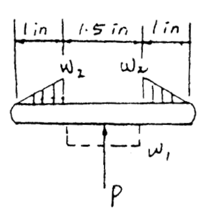
$P = 3.1416 = 3.14$ kip **Ans**

$3.1416 \text{ kip} = w_1\,(1.5)$

$w_1 = 2.09$ kip/in. **Ans**

$\frac{3.1416}{2} = \frac{1}{2} w_2\,(1)$

$w_2 = 3.14$ kip/in. **Ans**



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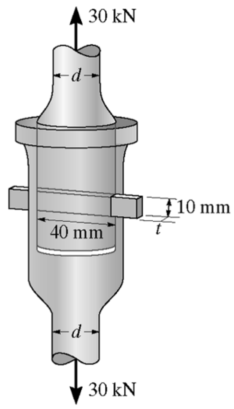
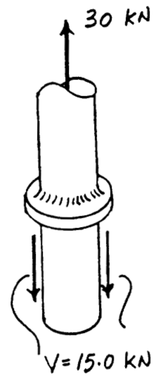
1–111. The cotter is used to hold the two rods together. Determine the smallest thickness t of the cotter and the smallest diameter d of the rods. All parts are made of steel for which the failure tensile stress is $\sigma_{\text{fail}} = 500$ MPa and the failure shear stress is $\tau_{\text{fail}} = 375$ MPa. Use a factor of safety of $(\text{F.S.})_t = 2.50$ in tension and $(\text{F.S.})_s = 1.75$ in shear.



Allowable Normal Stress : Design of rod size

$$\sigma_{\text{allow}} = \frac{\sigma_{\text{fail}}}{\text{F.S}} = \frac{P}{A}; \qquad \frac{500(10^6)}{2.5} = \frac{30(10^3)}{\frac{\pi}{4}d^2}$$

$d = 0.01382$ m $= 13.8$ mm **Ans**

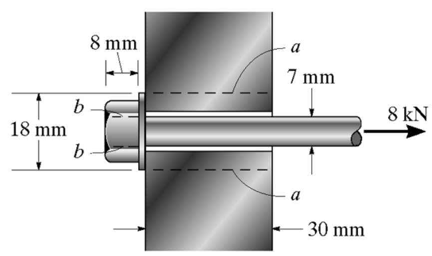


Allowable Shear Stress : Design of cotter size.

$$\tau_{\text{allow}} = \frac{\tau_{\text{fail}}}{\text{F.S}} = \frac{V}{A}; \qquad \frac{375(10^6)}{1.75} = \frac{15.0(10^3)}{(0.01)t}$$

$t = 0.0070$ m $= 7.00$ mm **Ans**

***1–112.** The long bolt passes through the 30-mm-thick plate. If the force in the bolt shank is 8 kN, determine the average normal stress in the shank, the average shear stress along the cylindrical area of the plate defined by the section lines a–a, and the average shear stress in the bolt head along the cylindrical area defined by the section lines b–b.



$$\sigma_s = \frac{P}{A} = \frac{8\,(10^3)}{\frac{\pi}{4}\,(0.007)^2} = 208 \text{ MPa} \qquad \textbf{Ans}$$

$$(\tau_{avg})_a = \frac{V}{A} = \frac{8\,(10^3)}{\pi\,(0.018)(0.030)} = 4.72 \text{ MPa} \qquad \textbf{Ans}$$

$$(\tau_{avg})_b = \frac{V}{A} = \frac{8\,(10^3)}{\pi\,(0.007)(0.008)} = 45.5 \text{ MPa} \qquad \textbf{Ans}$$

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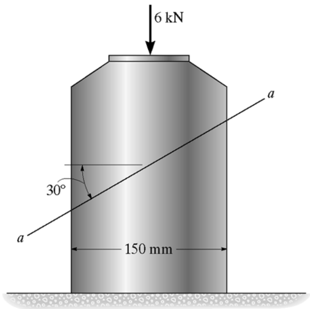
1–113. The bearing pad consists of a 150 mm by 150 mm block of aluminum that supports a compressive load of 6 kN. Determine the average normal and shear stress acting on the plane through section *a–a*. Show the results on a differential volume element located on the plane.



Equations of Equilibrium :

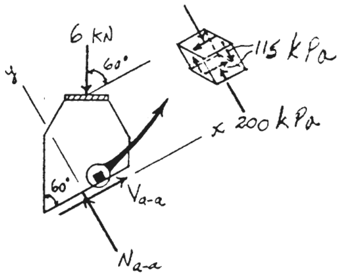
$\nearrow + \Sigma F_x = 0;\quad V_{a-a} - 6\cos 60° = 0 \qquad V_{a-a} = 3.00 \text{ kN}$

$\nwarrow + \Sigma F_y = 0;\quad N_{a-a} - 6\sin 60° = 0 \qquad N_{a-a} = 5.196 \text{ kN}$

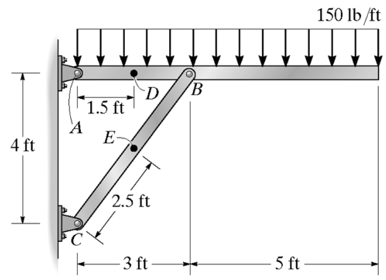
Average Normal Stress And Shear Stress : The cross sectional Area at section a-a is $A = \left(\dfrac{0.15}{\sin 60°}\right)(0.15) = 0.02598 \text{ m}^2$.

$$\sigma_{a-a} = \frac{N_{a-a}}{A} = \frac{5.196(10^3)}{0.02598} = 200 \text{ kPa} \qquad \textbf{Ans}$$

$$\tau_{a-a} = \frac{V_{a-a}}{A} = \frac{3.00(10^3)}{0.02598} = 115 \text{ kPa} \qquad \textbf{Ans}$$



1–114. Determine the resultant internal loadings acting on the cross sections located through points *D* and *E* of the frame.



Segment *AD* :

$\xrightarrow{+} \Sigma F_x = 0;\quad N_D - 1.2 = 0;\quad N_D = 1.20 \text{ kip} \qquad \textbf{Ans}$

$+\downarrow \Sigma F_y = 0;\quad V_D + 0.225 + 0.4 = 0;\quad V_D = -0.625 \text{ kip} \qquad \textbf{Ans}$

$\circlearrowleft + \Sigma M_D = 0;\quad M_D + 0.225(0.75) + 0.4(1.5) = 0$

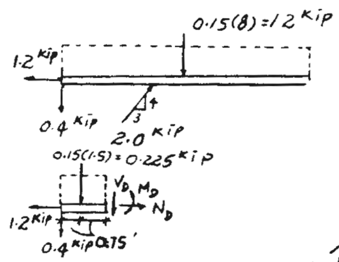
$M_D = -0.769 \text{ kip}\cdot\text{ft} \qquad \textbf{Ans}$

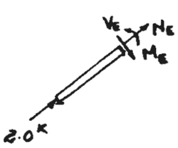
Segment *CE* :

$\nearrow + \Sigma F_x = 0;\quad N_E + 2.0 = 0;\quad N_E = -2.00 \text{ kip} \qquad \textbf{Ans}$

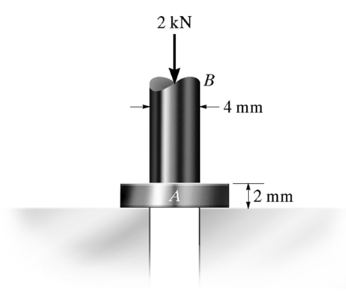
$\nwarrow + \Sigma F_y = 0;\quad V_E = 0 \qquad \textbf{Ans}$

$\circlearrowleft + \Sigma M_E = 0;\quad M_E = 0 \qquad \textbf{Ans}$





1–115. The circular punch *B* exerts a force of 2 kN on the top of the plate *A*. Determine the average shear stress in the plate due to this loading.



Average Shear Stress : The shear area $A = \pi(0.004)(0.002) = 8.00(10^{-6})\pi \text{ m}^2$

$$\tau_{avg} = \frac{V}{A} = \frac{2(10^3)}{8.00(10^{-6})\pi} = 79.6 \text{ MPa} \qquad \textbf{Ans}$$

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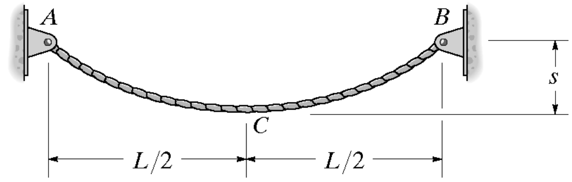
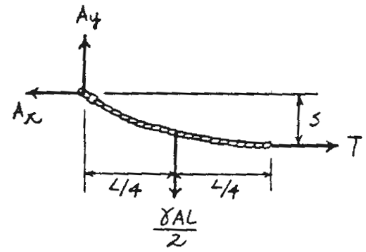
***1–116.** The cable has a specific weight γ (weight/volume) and cross-sectional area A. If the sag s is small, so that its length is approximately L and its weight can be distributed uniformly along the horizontal axis, determine the average normal stress in the cable at its lowest point C.



Equation of Equilibrium :

$\circlearrowleft + \Sigma M_A = 0;\quad T\,s - \dfrac{\gamma A L}{2}\left(\dfrac{L}{4}\right) = 0$

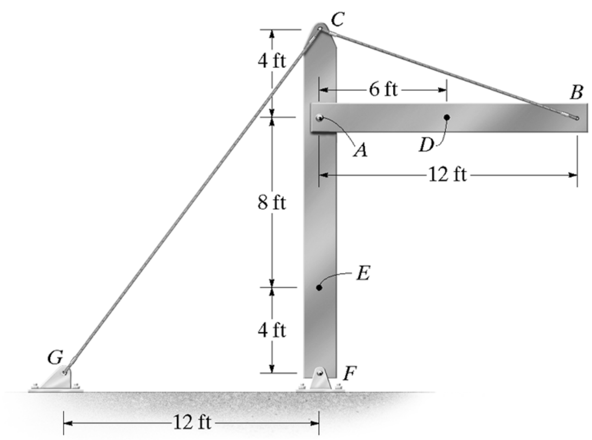
$$T = \frac{\gamma A L^2}{8\,s}$$

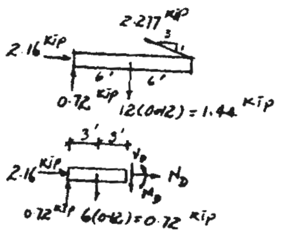


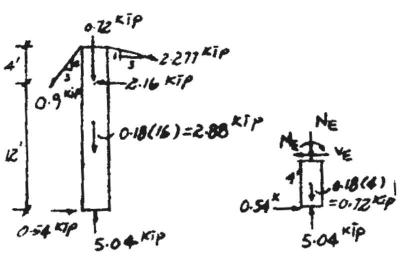
Average Normal Stress :

$$\sigma = \frac{T}{A} = \frac{\frac{\gamma A L^2}{8\,s}}{A} = \frac{\gamma L^2}{8\,s} \qquad \textbf{Ans}$$

1–117. The beam AB is pin supported at A and supported by a cable BC. A *separate* cable CG is used to hold up the frame. If AB weighs 120 lb/ft and the column FC has a weight of 180 lb/ft, determine the resultant internal loadings acting on cross sections located at points D and E. Neglect the thickness of both the beam and column in the calculation.







Segment *BD* :

$\xrightarrow{+} \Sigma F_x = 0;\quad N_D + 2.16 = 0;\quad N_D = -2.16 \text{ kip} \qquad$ **Ans**

$+\downarrow \Sigma F_y = 0;\quad V_D + 0.72 - 0.72 = 0;\quad V_D = 0 \qquad$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad M_D - 0.72(3) = 0;\quad M_D = 2.16 \text{ kip}\cdot\text{ft} \qquad$ **Ans**

Segment *FE* :

$\xleftarrow{+} \Sigma F_x = 0;\quad V_E - 0.54 = 0;\quad V_E = 0.540 \text{ kip} \qquad$ **Ans**

$+\downarrow \Sigma F_y = 0;\quad N_E + 0.72 - 5.04 = 0;\quad N_E = 4.32 \text{ kip} \qquad$ **Ans**

$\circlearrowleft + \Sigma M_E = 0;\quad -M_E + 0.54(4) = 0;\quad M_E = 2.16 \text{ kip}\cdot\text{ft} \qquad$ **Ans**

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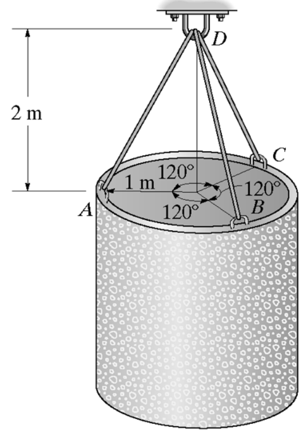
1–118. The 3-Mg concrete pipe is suspended by the three wires. If BD and CD have a diameter of 10 mm and AD has a diameter of 7 mm, determine the average normal stress in each wire.



Equations of Equilibrium :

$\Sigma M_x = 0;\quad F_{BD}(1\sin 60°) - F_{CD}(1\sin 60°) = 0$

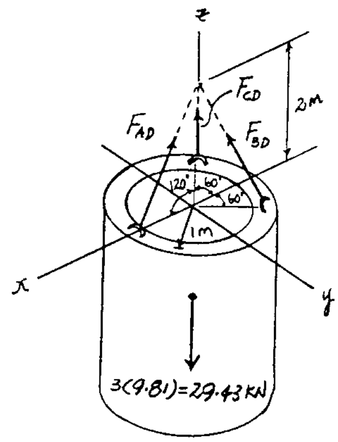
$F_{BD} = F_{CD} = F$

$\Sigma M_y = 0;\quad 2F(1\cos 60°) - F_{AD}(1) = 0$

$F_{AD} = F$

$\Sigma F_z = 0;\quad 3\left[F\left(\frac{2}{\sqrt{5}}\right)\right] - 29.43 = 0$

$F = 10.97\text{ kN}$

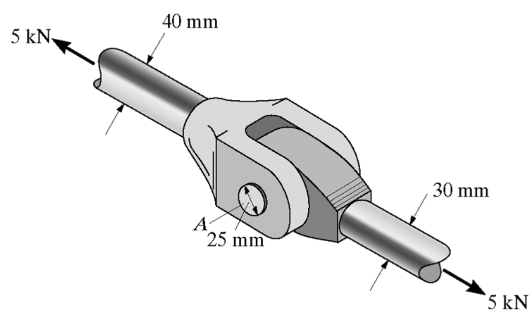


Average Normal Stress :

$$\sigma_{BD} = \sigma_{CD} = \frac{F}{A_{BD}} = \frac{10.97(10^3)}{\frac{\pi}{4}(0.01^2)} = 140\text{ MPa}\qquad \textbf{Ans}$$

$$\sigma_{AD} = \frac{F}{A_{AD}} = \frac{10.97(10^3)}{\frac{\pi}{4}(0.007^2)} = 285\text{ MPa}\qquad \textbf{Ans}$$

1–119. The yoke-and-rod connection is subjected to a tensile force of 5 kN. Determine the average normal stress in each rod and the average shear stress in the pin A between the members.

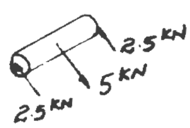


For the 40 – mm – dia. rod :

$$\sigma_{40} = \frac{P}{A} = \frac{5\,(10^3)}{\frac{\pi}{4}\,(0.04)^2} = 3.98\text{ MPa}\qquad \textbf{Ans}$$

For the 30 – mm – dia. rod :

$$\sigma_{30} = \frac{V}{A} = \frac{5\,(10^3)}{\frac{\pi}{4}\,(0.03)^2} = 7.07\text{ MPa}\qquad \textbf{Ans}$$



Average shear stress for pin A :

$$\tau_{avg} = \frac{P}{A} = \frac{2.5\,(10^3)}{\frac{\pi}{4}\,(0.025)^2} = 5.09\text{ MPa}\qquad \textbf{Ans}$$