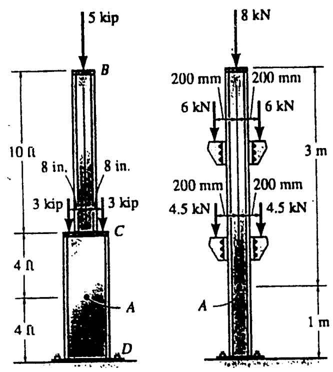
1–1 Determine the resultant internal normal force acting on the cross section through point A in each column. In (a), segment BC weighs 180 lb/ft and segment CD weighs 250 lb/ft. In (b), the column has a mass of 200 kg/m.

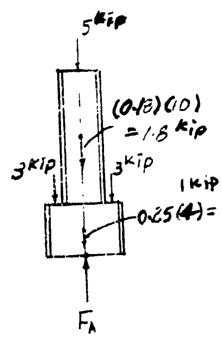


(a) (b)

(a)

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

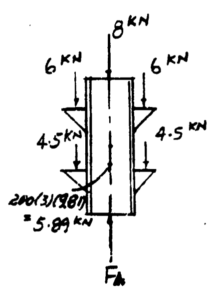
$$F_A = 13.8 \text{ kip} \qquad \textbf{Ans}$$



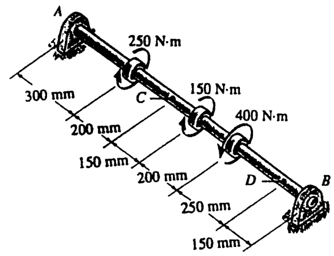
(b)

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

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

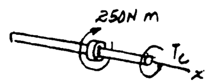


1–2 Determine the resultant internal torque acting on the cross sections through points *C* and *D*. The support bearings at *A* and *B* allow free turning of the shaft.

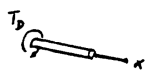


$\Sigma M_x = 0; \qquad T_C - 250 = 0$

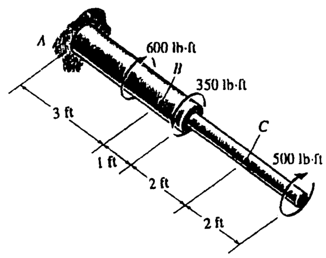
$T_C = 250 \text{ N} \cdot \text{m}$ **Ans**



$\Sigma M_x = 0; \quad T_D = 0$ **Ans**

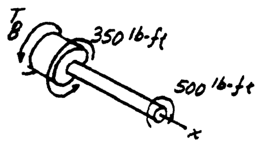


1–3 Determine the resultant internal torque acting on the cross sections through points B and C.



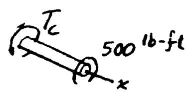
$\Sigma M_x = 0;\quad T_B + 350 - 500 = 0$

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

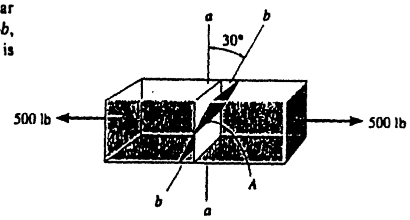


$\Sigma M_x = 0;\quad T_C - 500 = 0$

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



•1–4 Determine the resultant internal normal and shear force in the member at (*a*) section *a–a* and (*b*) section *b–b*, each of which passes through point *A*. The 500-lb load is applied along the centroidal axis of the member.

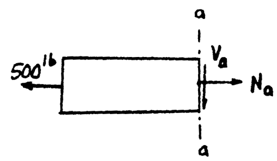


(a)

$\xrightarrow{+}\Sigma F_x = 0;\qquad N_a - 500 = 0$

$N_a = 500\text{ lb}$ **Ans**

$+\downarrow \Sigma F_y = 0;\qquad V_a = 0$ **Ans**



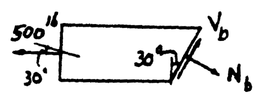
(b)

$\searrow^{+}\Sigma F_x = 0;\qquad N_b - 500\cos 30° = 0$

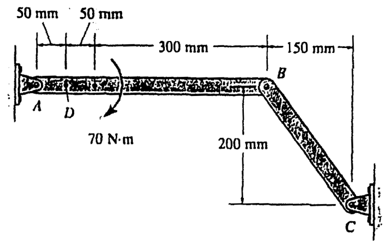
$N_b = 433\text{ lb}$ **Ans**

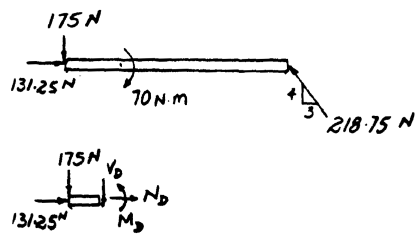
$+\nearrow \Sigma F_y = 0;\qquad V_b - 500\sin 30° = 0$

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



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





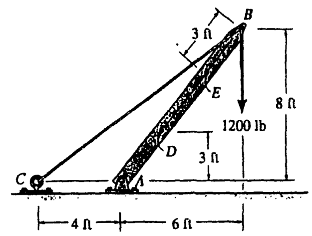
Segment AD **:**

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

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* :

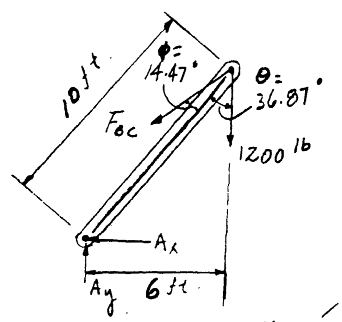
$\circlearrowleft + \Sigma M_A = 0; \quad F_{BC} \sin 14.47°(10) - 1200(6) = 0$

$F_{BC} = 2881.46 \text{ lb}$

Segment *BD* :

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

$N_D = -3750 \text{ lb} = -3.75 \text{ kip}$ **Ans**

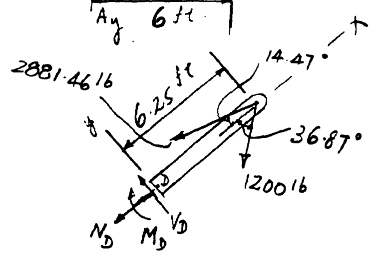


$+\nwarrow \Sigma F_y = 0; \quad V_D + 2881.46 \sin 14.47° - 1200 \sin 36.87° = 0$

$V_D = 0$ **Ans**

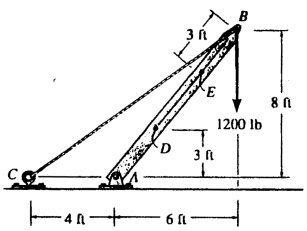
$\circlearrowleft + \Sigma M_D = 0; \quad 2881.46 \sin 14.47°(6.25) - 1200 \sin 36.87°(6.25) - M_D = 0$

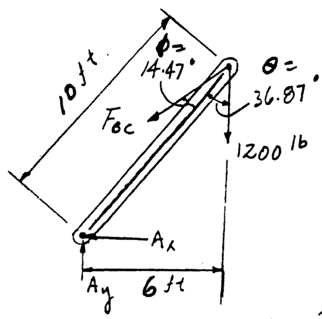
$M_D = 0$ **Ans**



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

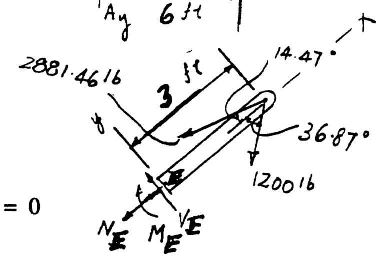
1–7 Solve Prob. 1–6 for the resultant internal loadings acting at point *E*.





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

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



Member *AB* :

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

$F_{BC} = 2881.46 \text{ lb}$

Segment *BE* :

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

$N_E = -3750 \text{ lb} = -3.75 \text{ kip}$ **Ans**

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

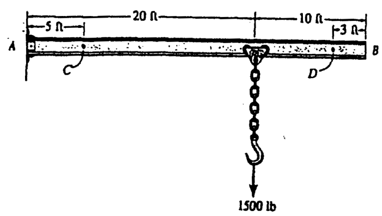
$V_E = 0$ **Ans**

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

$M_E = 0$ **Ans**

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

***1-8.** The beam AB is fixed to the wall and has a uniform weight of 80 lb/ft. If the trolley supports a load of 1500 lb, determine the resultant internal loadings acting on the cross sections through points C and D.



Segment BC:

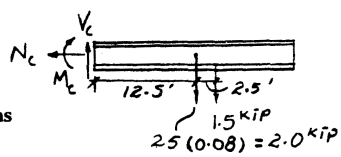
$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_C = 0$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad V_C - 2.0 - 1.5 = 0$

$V_C = 3.50 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0;\quad -M_C - 2(12.5) - 1.5(15) = 0$

$M_C = -47.5 \text{ kip}\cdot\text{ft}$ **Ans**



Segment BD:

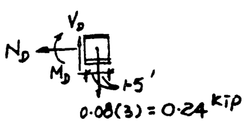
$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad N_D = 0$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad V_D - 0.24 = 0$

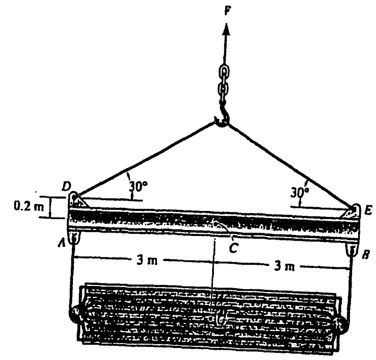
$V_D = 0.240 \text{ kip}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad -M_D - 0.24(1.5) = 0$

$M_D = -0.360 \text{ kip}\cdot\text{ft}$ **Ans**



1-9. Determine the resultant internal loadings acting on the cross section at point C. The cooling unit has a total weight of 52 kip and a center of gravity at G.



From FBD (a)

$\circlearrowleft + \Sigma M_A = 0; \quad T_B(6) - 52(3) = 0; \quad T_B = 26 \text{ kip}$

From FBD (b)

$\circlearrowleft + \Sigma M_D = 0; \quad T_E \sin 30°(6) - 26(6) = 0; \quad T_E = 52 \text{ kip}$

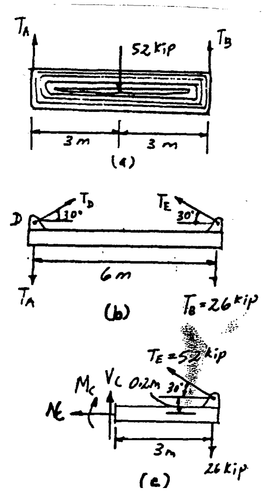
From FBD (c)

$\xrightarrow{+} \Sigma F_x = 0; \quad -N_C - 52 \cos 30° = 0; \quad N_C = -45.0 \text{ kip}$ **Ans**

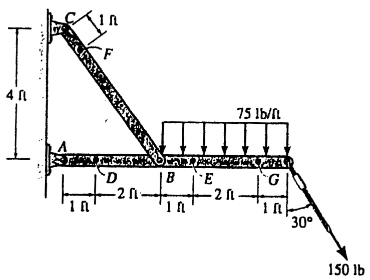
$+\uparrow \Sigma F_y = 0; \quad V_C + 52 \sin 30° - 26 = 0; \quad V_C = 0$ **Ans**

$\circlearrowleft + \Sigma M_C = 0; \quad 52 \cos 30°(0.2) + 52 \sin 30°(3) - 26(3) - M_C = 0$

$M_C = 9.00 \text{ kip} \cdot \text{ft}$ **Ans**



1–10 Determine the resultant internal loadings acting on the cross sections through points D and E of the frame.

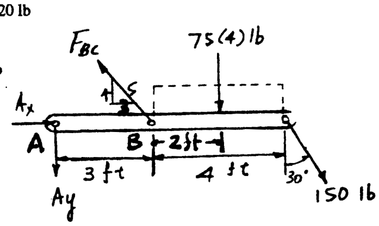


Member AG :

$\circlearrowleft + \Sigma M_A = 0;\quad \frac{4}{5}F_{BC}(3) - 75(4)(5) - 150\cos 30^\circ(7) = 0;\quad F_{BC} = 1003.89\text{ lb}$

$\circlearrowleft + \Sigma M_B = 0;\quad A_y(3) - 75(4)(2) - 150\cos 30^\circ(4) = 0;\quad A_y = 373.20\text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0;\quad A_x - \frac{3}{5}(1003.89) + 150\sin 30^\circ = 0;\quad A_x = 527.33\text{ lb}$



For point D :

$\xrightarrow{+} \Sigma F_x = 0;\quad N_D + 527.33 = 0$

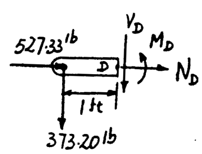
$N_D = -527\text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad -373.20 - V_D = 0$

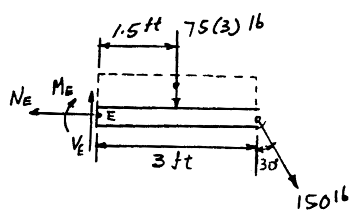
$V_D = -373\text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_D = 0;\quad M_D + 373.20(1) = 0$

$M_D = -373\text{ lb}\cdot\text{ft}$ **Ans**



For point E :



$\xrightarrow{+} \Sigma F_x = 0;\quad 150\sin 30^\circ - N_E = 0$

$N_E = 75.0\text{ lb}$ **Ans**

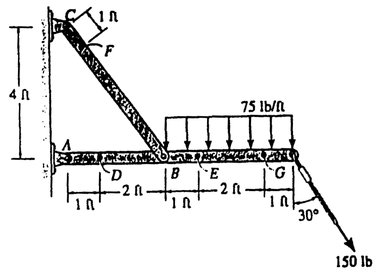
$+\uparrow \Sigma F_y = 0;\quad V_E - 75(3) - 150\cos 30^\circ = 0$

$V_E = 355\text{ lb}$ **Ans**

$\circlearrowleft + \Sigma M_E = 0;\quad -M_E - 75(3)(1.5) - 150\cos 30^\circ(3) = 0;$

$M_E = -727\text{ lb}\cdot\text{ft}$ **Ans**

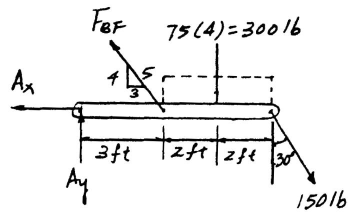
1–11 Determine the resultant internal loadings acting on the cross sections through points F and G of the frame.



Member AG :

$\circlearrowleft + \Sigma M_A = 0; \quad \frac{4}{5}F_{BF}(3) - 300(5) - 150\cos 30^\circ(7) = 0$

$F_{BF} = 1003.9 \text{ lb}$

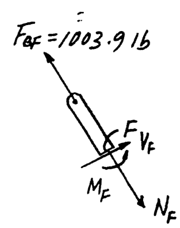


For point F :

$\nearrow + \Sigma F_{x'} = 0; \quad V_F = 0$ **Ans**

$\nwarrow + \Sigma F_{y'} = 0; \quad N_F - 1003.9 = 0$

$N_F = 1004 \text{ lb}$ **Ans**



$\circlearrowleft + \Sigma M_F = 0; \quad M_F = 0$ **Ans**

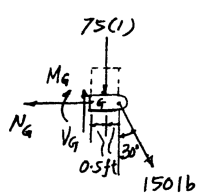
For point G :

$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad N_G - 150\sin 30^\circ = 0$

$N_G = 75.0 \text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad V_G - 75(1) - 150\cos 30^\circ = 0$

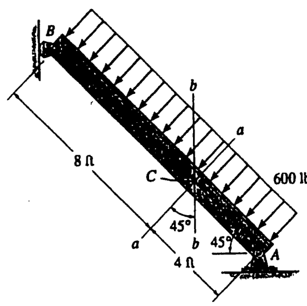
$V_G = 205 \text{ lb}$ **Ans**

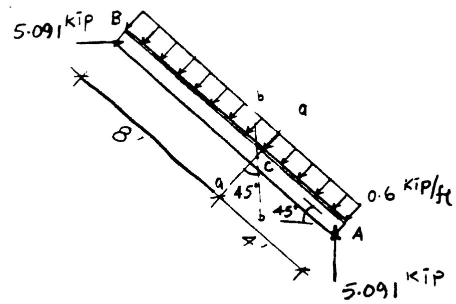


$\circlearrowleft + \Sigma M_G = 0; \quad -M_G - 75(1)(0.5) - 150\cos 30^\circ(1) = 0$

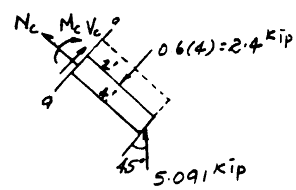
$M_G = -167 \text{ lb}\cdot\text{ft}$ **Ans**

•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)



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

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

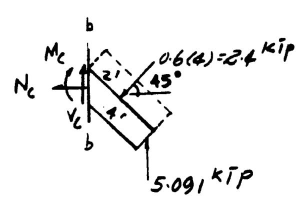
$\nearrow + \Sigma F_y = 0;\quad V_C + 5.091 \cos 45° - 2.4 = 0$

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

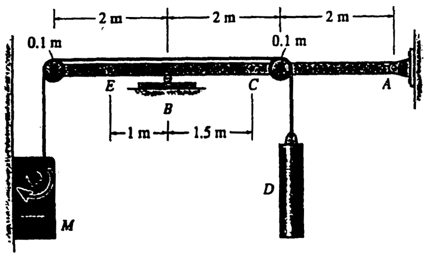
$+\uparrow \Sigma F_y = 0;\quad V_C + 5.091 - 2.4 \sin 45° = 0$

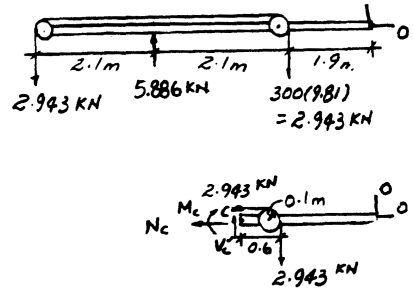
$V_C = -3.39\text{ kip}$ **Ans**

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

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

1–13 **Determine the resultant internal loadings acting on the cross section through point *C* in the beam. The load *D* has a mass of 300 kg and is being hoisted by the motor *M* with constant velocity.**





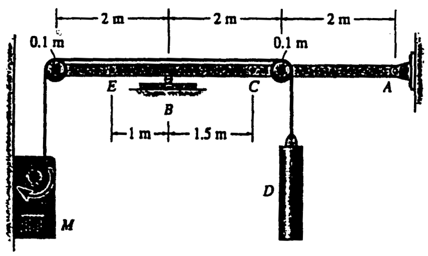
$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad N_C + 2.943 = 0; \quad N_C = -2.94 \text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad V_C - 2.943 = 0; \quad V_C = 2.94 \text{ kN}$ **Ans**

$\circlearrowleft + \Sigma M_C = 0; \quad -M_C - 2.943(0.6) + 2.943(0.1) = 0$

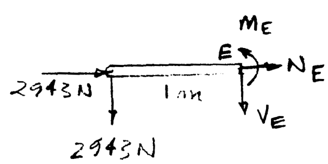
$M_C = -1.47 \text{ kN} \cdot \text{m}$ **Ans**

1–14 Determine the resultant internal loadings acting on the cross section through point E of the beam in Prob. 1–13.



$\xrightarrow{+} \Sigma F_x = 0;\qquad N_E + 2943 = 0$

$N_E = -2.94\text{ kN}$ **Ans**



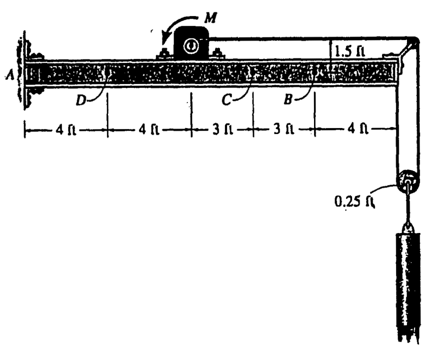
$+\uparrow \Sigma F_y = 0;\qquad -2943 - V_E = 0$

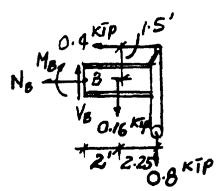
$V_E = -2.94\text{ kN}$ **Ans**

$\circlearrowleft + \Sigma M_E = 0;\qquad M_E + 2943\,(1) = 0$

$M_E = -2.94\text{ kN}\cdot\text{m}$ **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*.





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

$N_B = -0.4 \text{ kip}$ **Ans**

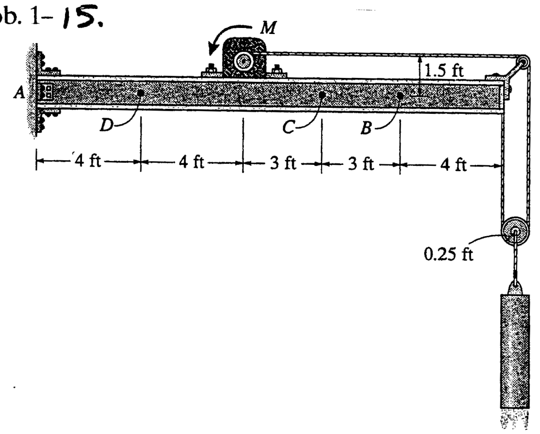
$+\uparrow \Sigma F_y = 0; \quad V_B - 0.8 - 0.16 = 0$

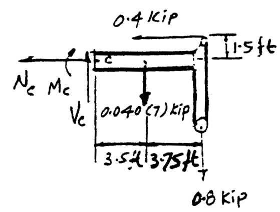
$V_B = 0.960 \text{ kip}$ **Ans**

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

$M_B = -3.12 \text{ kip} \cdot \text{ft}$ **Ans**

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





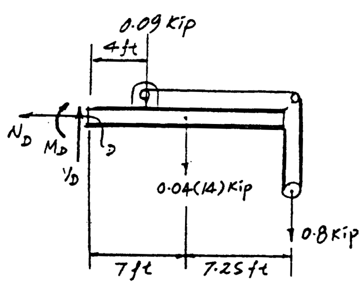
For point C:

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

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

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

$M_C = -6.18$ kip·ft **Ans**



For point D:

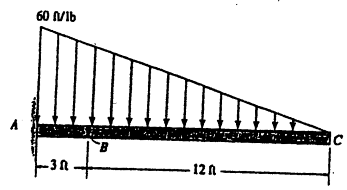
$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad N_D = 0$ **Ans**

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

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

$M_D = -15.7$ kip·ft **Ans**

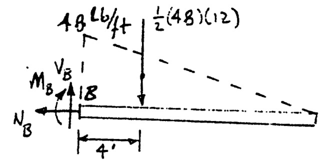
1-17. Determine the resultant internal loadings acting on the cross section at point *B*.



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

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

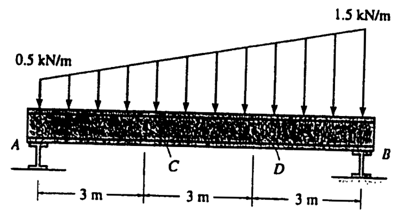
$V_B = 288 \text{ lb}$ **Ans**



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

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

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.



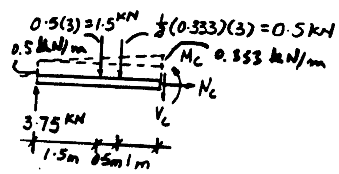
$\xrightarrow{+} \Sigma F_x = 0;$ $N_C = 0$ **Ans**

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

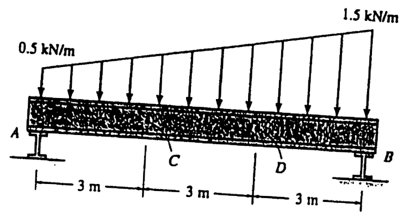
$V_C = 1.75 \text{ kN}$ **Ans**

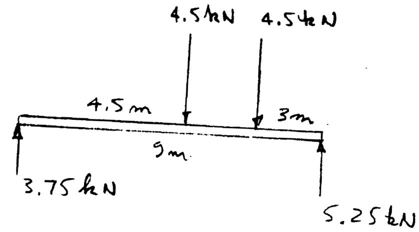
$\circlearrowleft + \Sigma M_C = 0;$ $M_C + 0.5(1) + 1.5(1.5) - 3.75(3) = 0$

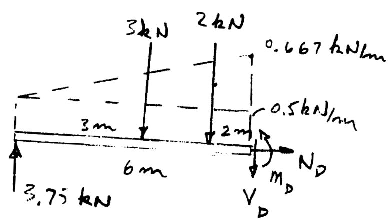
$M_C = 8.50 \text{ kN} \cdot \text{m}$ **Ans**



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







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

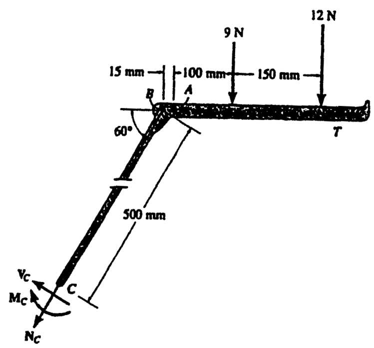
$+\uparrow \Sigma F_y = 0; \quad 3.75 - 3 - 2 - V_D = 0$

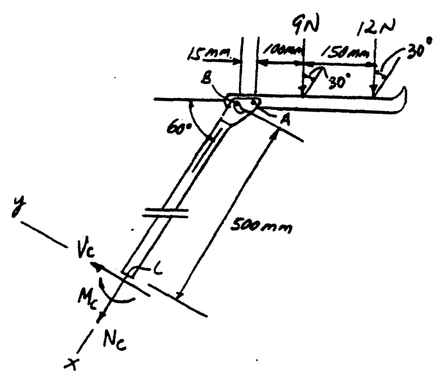
$V_D = -1.25 \text{ kN}$ **Ans**

$\curvearrowleft + \Sigma M_D = 0; \quad M_D + 2\,(2) + 3\,(3) - 3.75\,(6) = 0$

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

***1-20.** The serving tray T used on an airplane is supported on *each side* by an arm. The tray is pin connected to the arm at A, and at B there is a smooth pin. (The pin can move within the slot in the arms to permit folding the tray against the front passenger seat when not in use.) Determine the resultant internal loadings acting on the cross section of the arm through point C when the tray arm supports the loads shown.





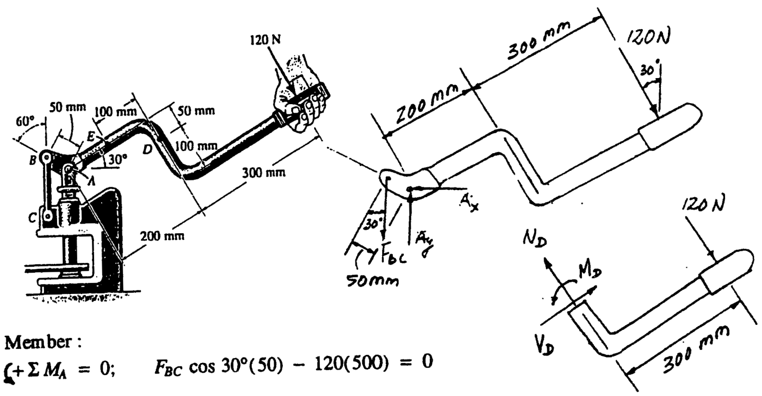
$\nearrow\!+ \Sigma F_x = 0;\quad N_C + 9\cos 30° + 12\cos 30° = 0;\quad N_C = -18.2\text{ N}$ **Ans**

$\nwarrow\!+ \Sigma F_y = 0;\quad V_C - 9\sin 30° - 12\sin 30° = 0;\quad V_C = 10.5\text{ N}$ **Ans**

$\circlearrowleft\!+ \Sigma M_C = 0;\quad -M_C - 9(0.5\cos 60° + 0.115) - 12(0.5\cos 60° + 0.265) = 0$

$M_C = -9.46\text{ N}\cdot\text{m}$ **Ans**

1-21. The metal stud punch is subjected to a force of 120 N on the handle. Determine the magnitude of the reactive force at the pin *A* and in the short link *BC*. Also, determine the internal resultant loadings acting on the cross section passing through the handle arm at *D*.



Member:

$\circlearrowleft + \Sigma M_A = 0;\quad F_{BC}\cos 30°(50) - 120(500) = 0$

$F_{BC} = 1385.6\text{ N} = 1.39\text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = 0;\quad A_y - 1385.6 - 120\cos 30° = 0$

$A_y = 1489.56\text{ N}$

$\overset{+}{\leftarrow} \Sigma F_x = 0;\quad A_x - 120\sin 30° = 0;\quad A_x = 60\text{ N}$

$F_A = \sqrt{1489.56^2 + 60^2}$
$= 1490\text{ N} = 1.49\text{ kN}$ **Ans**

Segment:

$\nwarrow + \Sigma F_{x'} = 0;\quad N_D - 120 = 0$

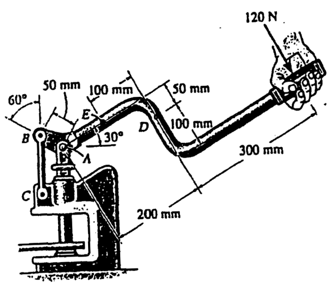
$N_D = 120\text{ N} = 0.12\text{ kN}$ **Ans**

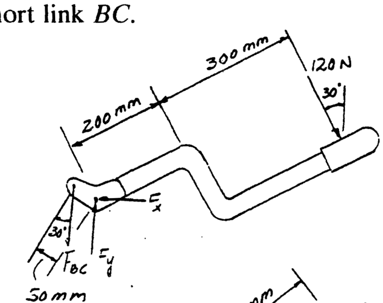
$+\nearrow \Sigma F_{y'} = 0;\quad V_D = 0$ **Ans**

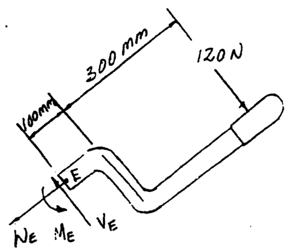
$\circlearrowleft + \Sigma M_D = 0;\quad M_D - 120(0.3) = 0$

$M_D = 36.0\text{ N}\cdot\text{m}$ **Ans**

1-22. Solve Prob. 1–21 for the resultant internal loadings acting on the cross section passing through the handle arm at E and at a cross section of the short link BC.







Member :

$\circlearrowleft + \Sigma M_A = 0; \quad F_{BC}\cos 30°(50) - 120(500) = 0$

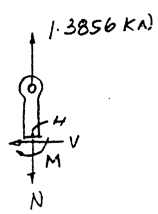
$F_{BC} = 1385.6\text{ N} = 1.3856\text{ kN}$

Segment :

$\nearrow + \Sigma F_{x'} = 0; \quad N_E = 0$ **Ans**

$\nwarrow + \Sigma F_{y'} = 0; \quad V_E - 120 = 0; \quad V_E = 120\text{ N}$ **Ans**

$\circlearrowleft + \Sigma M_E = 0; \quad M_E - 120(0.4) = 0; \quad M_E = 48.0\text{ N}\cdot\text{m}$ **Ans**



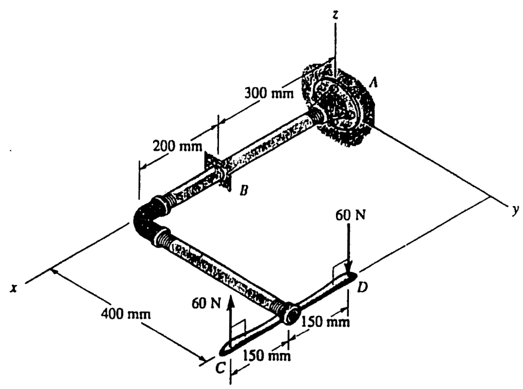
Short link :

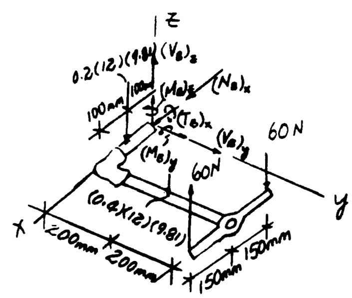
$\overset{+}{\leftarrow} \Sigma F_x = 0; \quad V = 0$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad 1.3856 - N = 0; \quad N = 1.39\text{ kN}$ **Ans**

$\circlearrowleft + \Sigma M_H = 0; \quad M = 0$ **Ans**

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**

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

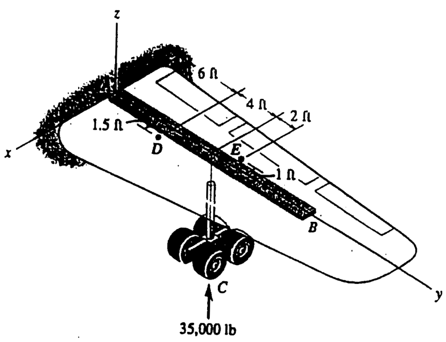
$(T_B)_x = 9.42\text{ N}\cdot\text{m}$ **Ans**

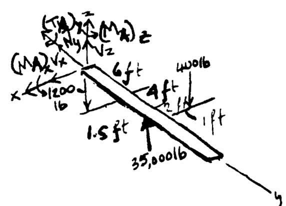
$\Sigma M_y = 0;\quad (M_B)_y + (0.2)(12)(9.81)(0.1) + (0.4)(12)(9.81)(0.2) - 60(0.3) = 0$

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

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

•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**

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

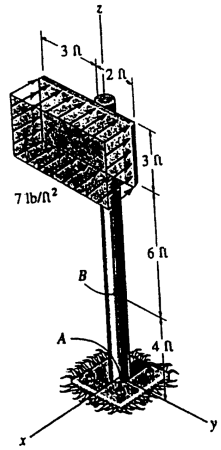
$(M_A)_x = 338 \text{ kip} \cdot \text{ft}$ **Ans**

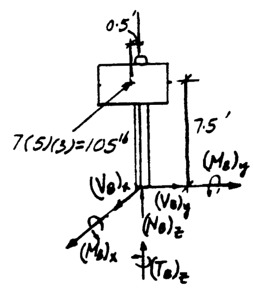
$\Sigma M_y = 0; \quad (T_A)_y + 1200(1.5) - 400(1) = 0$

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

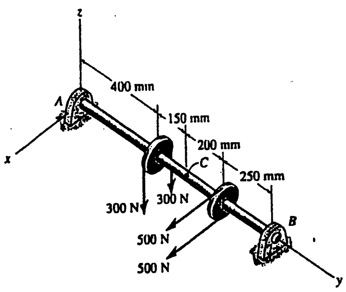
$\Sigma F_z = 0;\quad (N_B)_z = 0$ **Ans**

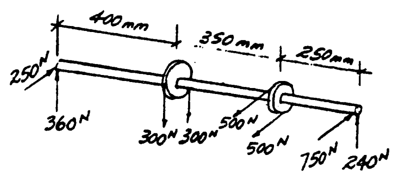
$\Sigma M_x = 0;\quad (M_B)_x = 0$ **Ans**

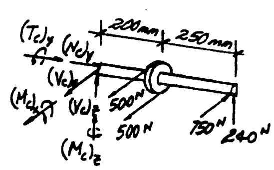
$\Sigma M_y = 0;\quad (M_B)_y - 105(7.5) = 0;\quad (M_B)_y = 788 \text{ lb}\cdot\text{ft}$ **Ans**

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

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 located at point C. The 300-N forces act in the $-z$ direction and the 500-N forces act in the $+x$ direction. The journal bearings at A and B exert only x and z components of force on the shaft.







$\Sigma F_x = 0;\quad (V_C)_x + 1000 - 750 = 0;\quad (V_C)_x = -250\text{ N}$ **Ans**

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

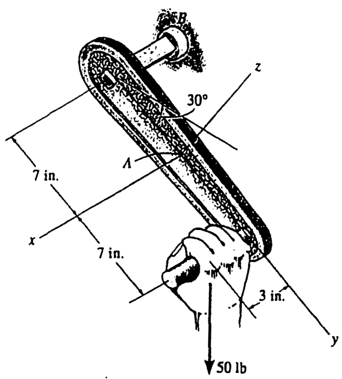
$\Sigma F_z = 0;\quad (V_C)_z + 240 = 0;\quad (V_C)_z = -240\text{ N}$ **Ans**

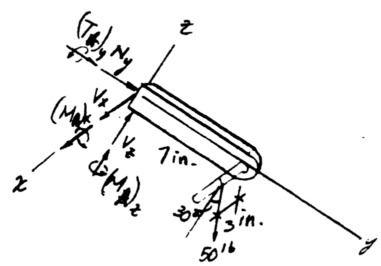
$\Sigma M_x = 0;\quad (M_C)_x + 240(0.45) = 0;\quad (M_C)_x = -108\text{ N}\cdot\text{m}$ **Ans**

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

$\Sigma M_z = 0;\quad (M_C)_z - 1000(0.2) + 750(0.45) = 0;\quad (M_C)_z = -138\text{ N}\cdot\text{m}$ **Ans**

1–27 A hand crank that is used in a press has the dimensions shown. Determine the resultant internal loadings acting on the cross section at A if a vertical force of 50 lb is applied to the handle as shown. Assume the crank is fixed to the shaft at B.





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

$\Sigma F_y = 0;\quad (N_A)_y + 50 \sin 30° = 0;\quad (N_A)_y = -25\text{ lb}$ **Ans**

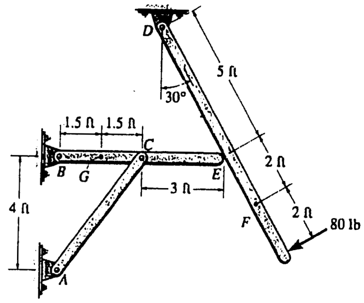
$\Sigma F_z = 0;\quad (V_A)_z - 50 \cos 30° = 0;\quad (V_A)_z = 43.3\text{ lb}$ **Ans**

$\Sigma M_x = 0;\quad (M_A)_x - 50 \cos 30°(7) = 0;\quad (M_A)_x = 303\text{ lb}\cdot\text{in.}$ **Ans**

$\Sigma M_y = 0;\quad (T_A)_y + 50 \cos 30°(3) = 0;\quad (T_A)_y = -130\text{ lb}\cdot\text{in.}$ **Ans**

$\Sigma M_z = 0;\quad (M_A)_z + 50 \sin 30°(3) = 0;\quad (M_A)_z = -75\text{ lb}\cdot\text{in.}$ **Ans**

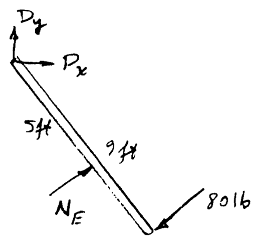
•1–28 Determine the resultant internal loadings acting on the cross section of the frame at points F and G. The contact at E is smooth.



Member DEF :

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

$N_E = 144 \text{ lb}$



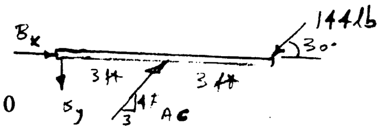
Member BCE :

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

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

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

$B_x = 16.708 \text{ lb}$

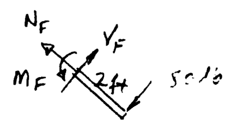


$+\uparrow \Sigma F_y = 0; \qquad -B_y + 180(\frac{4}{5}) - 144 \sin 30° = 0$

$B_y = 72.0 \text{ lb}$

For point F :

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

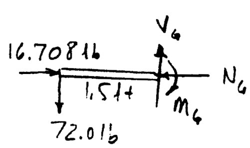


$+\nearrow \Sigma F_y = 0; \qquad V_F - 80 = 0; \qquad V_F = 80 \text{ lb}$ **Ans**

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

For point G :

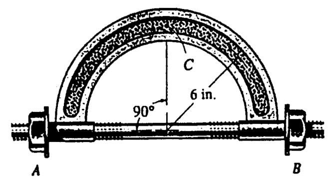
$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 16.708 - N_G = 0; \qquad N_G = 16.7 \text{ lb}$ **Ans**



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

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

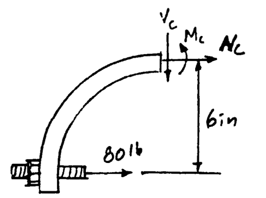


Segment *AC* :

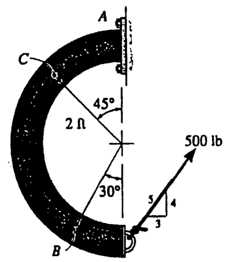
$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad N_C + 80 = 0; \qquad N_C = -80 \text{ lb}$ **Ans**

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

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



1–30 Determine the resultant internal loadings acting on the cross section at points B and C of the curved member.



From FBD (a)

$\nearrow + \Sigma F_{x'} = 0;\quad 400\cos 30° + 300\cos 60° - V_B = 0$

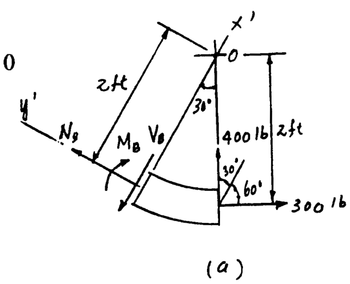
$V_B = 496 \text{ lb}$ **Ans**

$\nwarrow + \Sigma F_{y'} = 0;\quad N_B + 400\sin 30° - 300\sin 60° = 0$

$N_B = 59.80 = 59.8 \text{ lb}$ **Ans**

$\curvearrowleft + \Sigma M_O = 0;\quad 300(2) - 59.80(2) - M_B = 0$

$M_B = 480 \text{ lb}\cdot\text{ft}$ **Ans**



From FBD (b)

$\nearrow + \Sigma F_{x'} = 0;\quad 400\cos 45° + 300\cos 45° - N_C = 0$

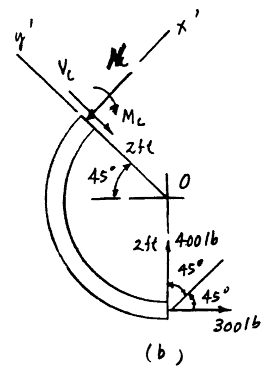
$N_C = 495 \text{ lb}$ **Ans**

$\nwarrow + \Sigma F_{y'} = 0;\quad -V_C + 400\sin 45° - 300\sin 45° = 0$

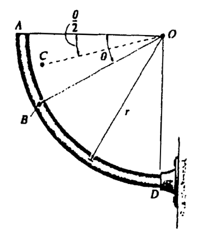
$V_C = 70.7 \text{ lb}$ **Ans**

$\curvearrowleft + \Sigma M_O = 0;\quad 300(2) + 495(2) - M_C = 0$

$M_C = 1590 \text{ lb}\cdot\text{ft} = 1.59 \text{ kip}\cdot\text{ft}$ **Ans**



1–31 The curved rod AD of radius r has a weight per length of w. If it lies in the vertical 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 $OC = [2r \sin(\theta/2)]/\theta$.



$\searrow + \Sigma F_x = 0; \quad N_B + wr\theta\cos\theta = 0$

$N_B = -wr\theta\cos\theta$ **Ans**

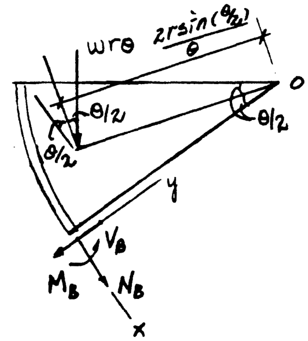
$\nearrow + \Sigma F_y = 0; \quad -V_B - wr\theta\sin\theta = 0$

$V_B = -wr\theta\sin\theta$ **Ans**

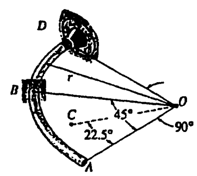
$\circlearrowleft + \Sigma M_O = 0; \quad wr\theta\left(\cos\frac{\theta}{2}\right)\left(\frac{2r\sin(\theta/2)}{\theta}\right) + (N_B)r + M_B = 0$

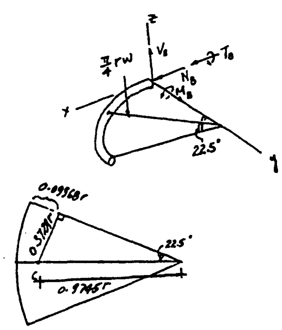
$M_B = -N_B r - wr^2\, 2\sin(\theta/2)\cos(\theta/2)$

$M_B = wr^2(\theta\cos\theta - \sin\theta)$ **Ans**



*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 $CO = 0.9745r$.





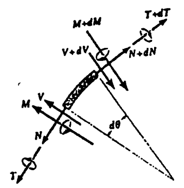
$$\Sigma F_z = 0; \quad V_B - \frac{\pi}{4} rw = 0; \quad V_B = 0.785\, w\, r \qquad \textbf{Ans}$$

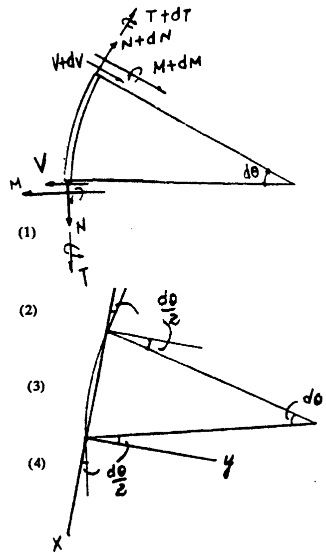
$$\Sigma F_x = 0; \quad N_B = 0 \qquad \textbf{Ans}$$

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

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

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, $M d\theta - dT = 0$

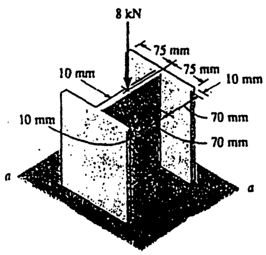
$\frac{dT}{d\theta} = M$ **QED**

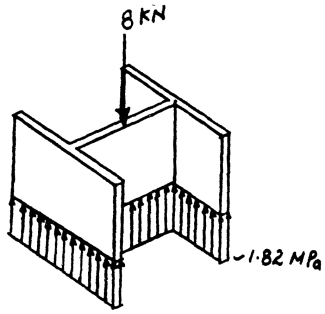
Eq. (4) becomes $T d\theta + dM + \frac{dT d\theta}{2} = 0$

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

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

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.

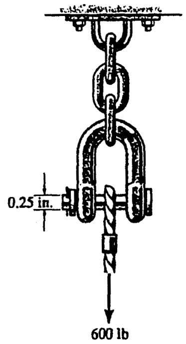


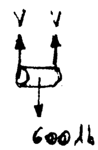


$$A = (2)(150)(10) + (140)(10)$$
$$= 4400 \text{ mm}^2 = 4.4\,(10^{-3})\text{ m}^2$$

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

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.



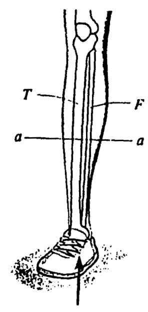


$$+\uparrow \Sigma F_y = 0; \qquad 2V - 600 = 0$$

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

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

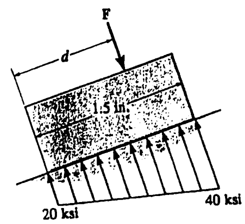
*1–36 While running the foot of a 150-lb man is momentarily subjected to a force which is 5 times his weight. Determine the average normal stress developed in the tibia T of his leg at the mid section a–a. The cross section can be assumed circular, having an outer diameter of 1.75 in. and an inner diameter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



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

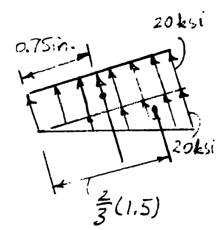
$$\sigma = \frac{P}{A} = \frac{750}{\frac{\pi}{4}((1.75)^2 - (1)^2)} = 463 \text{ psi} \qquad \textbf{Ans}$$

1–37 The small block has a thickness of 0.5 in. 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 load diagram

$F = 20(1.5)(0.5) + \frac{1}{2}(20)(1.5)(0.5) = 22.5$ kip **Ans**



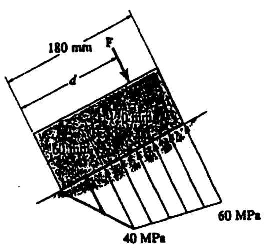
$Fd = \int x(\sigma\, dA)$

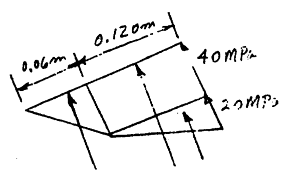
$(22.5)\, d = (0.75)(20)(1.5)(0.5) + \frac{2}{3}(1.5)(\frac{1}{2})(20)(1.5)(0.5)$

$(22.5)\, d = 18.75$

$d = 0.833$ in. **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

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

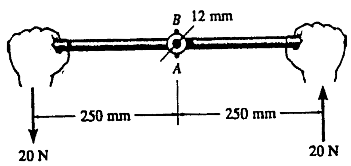
$$36.0(10^3)d = \frac{2}{3}(0.06)(\frac{1}{2})(0.06)(40)(10^6)(0.005) + (0.06 + \frac{1}{2}(0.120))(0.120)(40)(10^6)(0.005) +$$

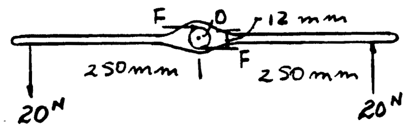
$$(0.06 + \frac{2}{3}(0.120))(\frac{1}{2})(0.120)(20)(10^6)(0.005)$$

$36.0(10^3)d = 3960$

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

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.**





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

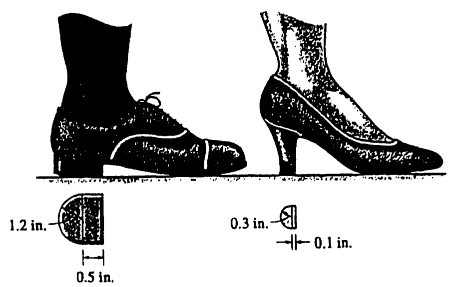
$\tau_{avg} = \frac{V}{A} = \frac{833.33}{\frac{\pi}{4}(\frac{6}{1000})^2} = 29.5\text{ MPa}$ **Ans**

***1-40.** The supporting wheel on a scaffold is held in place on the leg using a 4-mm-diameter pin as shown. If the wheel is subjected to a normal force of 3 kN, determine the average shear stress developed in the pin. Neglect friction between the inner scaffold puller leg and the tube used on the wheel.

$+\uparrow \Sigma F_y = 0; \quad 3\text{ kN} - 2V = 0; \quad V = 1.5\text{ kN}$

$$\tau_{avg} = \frac{V}{A} = \frac{1.5(10^3)}{\frac{\pi}{4}(0.004)^2} = 119\text{ MPa} \quad \textbf{Ans}$$

1–41 A 175-lb woman stands on a vinyl floor wearing stiletto high-heel shoes. If the heel has the dimensions shown, determine the average normal stress she exerts on the floor and compare it with the average normal stress developed when a man having the same weight is wearing flat-heeled shoes. Assume the load is applied slowly, so that dynamic effects can be ignored. Also, assume the entire weight is supported only by the heel of one shoe.



Stiletto shoes :

$$A = \frac{1}{2}(\pi)(0.3)^2 + (0.6)(0.1) = 0.2014 \text{ in}^2$$

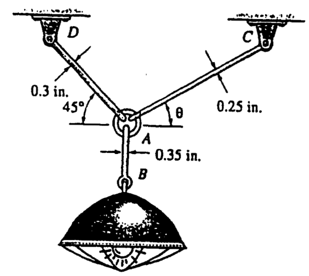
$$\sigma = \frac{P}{A} = \frac{175 \text{ lb}}{0.2014 \text{ in}^2} = 869 \text{ psi} \qquad \textbf{Ans}$$

Flat - heeled shoes :

$$A = \frac{1}{2}(\pi)(1.2)^2 + 2.4(0.5) = 3.462 \text{ in}^2$$

$$\sigma = \frac{P}{A} = \frac{175 \text{ lb}}{3.462 \text{ in}^2} = 50.5 \text{ psi} \qquad \textbf{Ans}$$

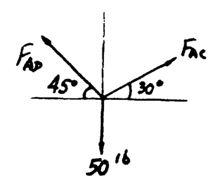
1–42 The 50-lb lamp is supported by three steel rods connected by a ring at A. Determine which rod is subjected to the greater average normal stress and compute its value. Take $\theta = 30°$. The diameter of each rod is given in the figure.



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

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

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



Rod AB :

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

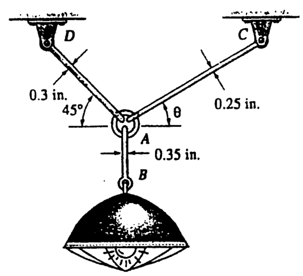
Rod AD :

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

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 $\theta = 45°$.



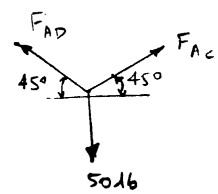
$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AC} \cos 45° - F_{AD} \cos 45° = 0$$

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

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

Rod *AB* :

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



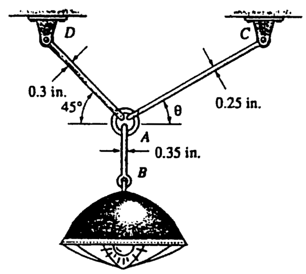
Rod *AC* :

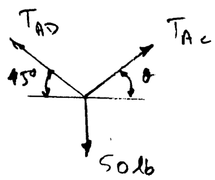
$$\sigma_{AC} = \frac{35.36}{\frac{\pi}{4}(0.25)^2} = 720 \text{ psi} \qquad \textbf{Ans}$$

Rod *AD* :

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

•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) :

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

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

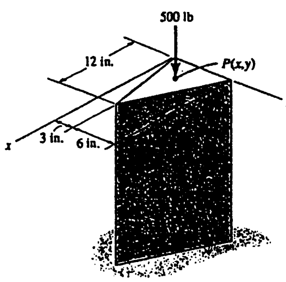
Hence,

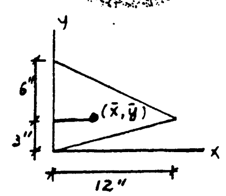
$$\sigma_{AC} = 2(371.8) = 744 \text{ psi} \qquad \textbf{Ans}$$

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 pedestal has a triangular cross section as shown. If it is subjected to a compressive force of 500 lb, specify the x and y coordinates for the location of point $P(x, y)$, where the load must be applied on the cross section, so that the average normal stress is uniform. Compute the stress and sketch its distribution acting on the cross section at a location removed from the point of load application.

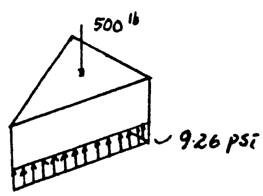




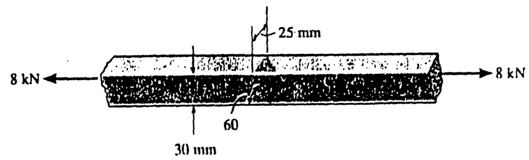
$$\bar{x} = \frac{\frac{1}{2}(3)(12)(\frac{12}{3}) + \frac{1}{2}(6)(12)(\frac{12}{3})}{\frac{1}{2}(9)(12)} = 4 \text{ in.} \qquad \textbf{Ans}$$

$$\bar{y} = \frac{\frac{1}{2}(3)(12)(3)(\frac{2}{3}) + \frac{1}{2}(6)(12)(3 + \frac{6}{3})}{\frac{1}{2}(9)(12)} = 4 \text{ in.} \qquad \textbf{Ans}$$

$$\sigma = \frac{P}{A} = \frac{500}{\frac{1}{2}(9)(12)} = 9.26 \text{ psi} \qquad \textbf{Ans}$$



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.

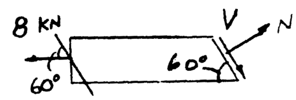


$+\nearrow \Sigma F_x = 0; \qquad N - 8 \sin 60° = 0$

$N = 6.928 \text{ kN}$

$+\searrow \Sigma F_y = 0; \qquad V - 8 \cos 60° = 0$

$V = 4 \text{ kN}$

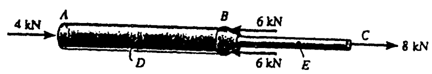


$$A = (25)\left(\frac{30}{\sin 60°}\right) = 866.03 \text{ mm}^2$$

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

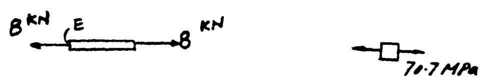
$$\tau_{avg} = \frac{V}{A} = \frac{4\,(10^3)}{0.8660\,(10^{-3})} = 4.62 \text{ MPa} \qquad \textbf{Ans}$$

1-47. The built-up shaft consists of a pipe AB and solid rod BC. The pipe has an inner diameter of 20 mm and outer diameter of 28 mm. The rod has a diameter of 12 mm. Determine the average normal stress at points D and E and represent the stress on a volume element located at each of these points.



At D:

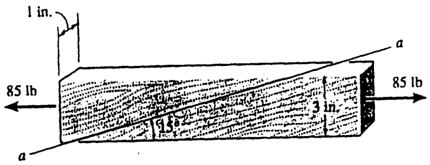
$$\sigma_D = \frac{P}{A} = \frac{4(10^3)}{\frac{\pi}{4}(0.028^2 - 0.02^2)} = 13.3 \text{ MPa (C)} \quad \textbf{Ans}$$

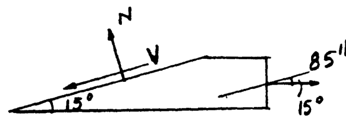


At E:

$$\sigma_E = \frac{P}{A} = \frac{8(10^3)}{\frac{\pi}{4}(0.012^2)} = 70.7 \text{ MPa (T)} \quad \textbf{Ans}$$

*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.





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

$V = 82.10\text{ lb}$

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

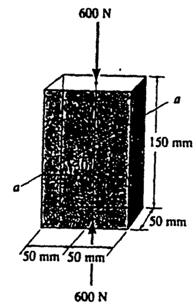
$N = 22.00\text{ lb}$

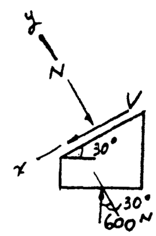
$$A = (1)\left(\frac{3}{\sin 15^\circ}\right) = 11.591\text{ in}^2$$

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

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

1-49. The plastic block is subjected to an axial compressive force of 600 N. Assuming that the caps at the top and bottom distribute the load uniformly throughout the block, determine the average normal and average shear stress acting along section $a-a$.





Along a - a :

$+\nearrow \Sigma F_x = 0; \quad V - 600 \sin 30^\circ = 0$

$V = 300\text{ N}$

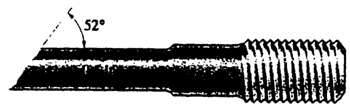
$+\nwarrow \Sigma F_y = 0; \quad -N + 600 \cos 30^\circ = 0$

$N = 519.6\text{ N}$

$$\sigma_{a-a} = \frac{519.6}{(0.05)(\frac{0.1}{\cos 30^\circ})} = 90.0\text{ kPa} \quad \textbf{Ans}$$

$$\tau_{a-a} = \frac{300}{(0.05)(\frac{0.1}{\cos 30^\circ})} = 52.0\text{ kPa} \quad \textbf{Ans}$$

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?

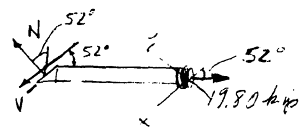


$+\nearrow \Sigma F_x = 0;\quad V - 19.80\cos 52° = 0$

$V = 12.19$ kip

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

$N = 15.603$ kip



Inclined plane :

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

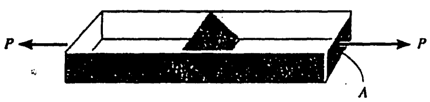
$\tau'_{avg} = \frac{V}{A};\quad \tau'_{avg} = \frac{12.19}{\frac{\pi(0.25)^2}{\sin 52°}} = 48.9\text{ ksi}$ **Ans**

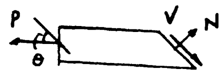
Cross section :

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

$\tau_{avg} = \frac{V}{A};\quad \tau_{avg} = 0$ **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.





$+\searrow \Sigma F_y = 0;\qquad V - P\cos\theta = 0;\qquad V = P\cos\theta$

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

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

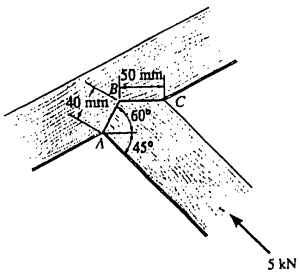
$$\cos 2\theta = 0$$

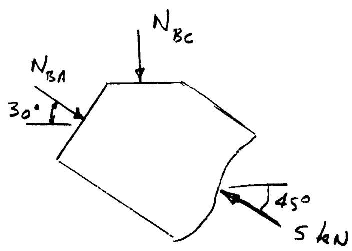
$$2\theta = 90^\circ$$

$$\theta = 45^\circ \qquad \textbf{Ans}$$

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

*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.





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

$N_{BA} = 4.082$ kN

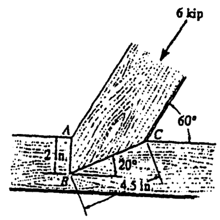
$+\uparrow \Sigma F_y = 0; \qquad -N_{BC} - 4.082 \sin 30° + 5 \sin 45° = 0$

$N_{BC} = 1.494$ 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 joint in subjected to the axial member force of 6 kip. Determine the average normal stress acting on sections AB and BC. Assume the member is smooth and is 1.5 in. thick.

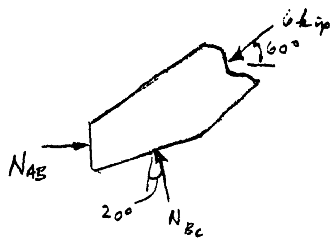


$+\uparrow \Sigma F_y = 0; \quad -6 \sin 60° + N_{BC} \cos 20° = 0$

$N_{BC} = 5.530 \text{ kip}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad N_{AB} - 6 \cos 60° - 5.530 \sin 20° = 0$

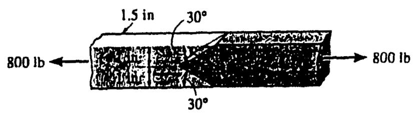
$N_{AB} = 4.891 \text{ kip}$

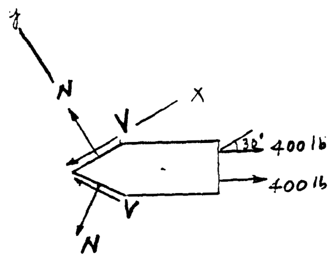


$\sigma_{AB} = \frac{N_{AB}}{A_{AB}} = \frac{4.891}{(1.5)(2)} = 1.63 \text{ ksi}$ **Ans**

$\sigma_{BC} = \frac{N_{BC}}{A_{BC}} = \frac{5.530}{(1.5)(4.5)} = 0.819 \text{ ksi}$ **Ans**

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.





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

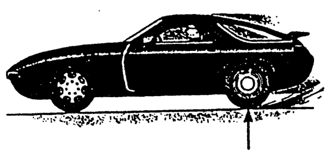
$400 \cos 30° - V = 0; \qquad V = 346.41 \text{ lb}$

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

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

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

1-55. The driver of the sports car applies his rear brakes and causes the tires to slip. If the normal force on each rear tire is 400 lb and the coefficient of kinetic friction between the tires and the pavement is $\mu_k = 0.5$, determine the average shear stress developed by the friction force on the tires. Assume the rubber of the tires is flexible and each tire is filled with an air pressure of 32 psi.

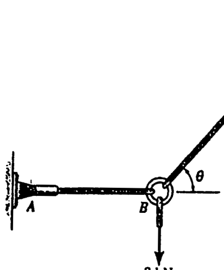


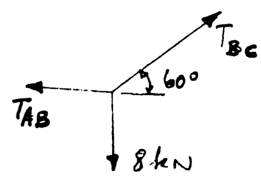
$$F = \mu_k N = 0.5\,(400) = 200 \text{ lb}$$

$$p = \frac{N}{A}; \qquad A = \frac{400}{32} = 12.5 \text{ in}^2$$

$$\tau_{avg} = \frac{F}{A} = \frac{200}{12.5} = 16 \text{ psi} \qquad \textbf{Ans}$$

•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 $\theta = 60°$.





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

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

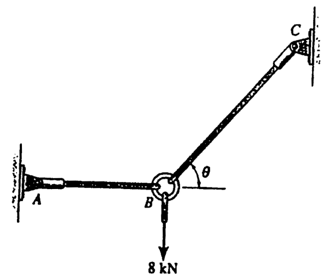
$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 9.2376 \cos 60° - T_{AB} = 0$

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

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

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

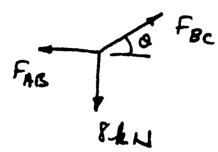
1-57 Rods *AB* and *BC* have diameters of 4 mm and 6 mm, respectively. If the vertical load of 8 kN is applied to the ring at *B*, determine the angle θ of rod *BC* so that the average normal stress in each rod is equivalent. What is this stress?



$$F_{AB} = \sigma A_{AB} = \sigma(\pi)(0.002)^2$$
$$F_{BC} = \sigma A_{BC} = \sigma(\pi)(0.003)^2$$

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

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



From Eq. (1) :

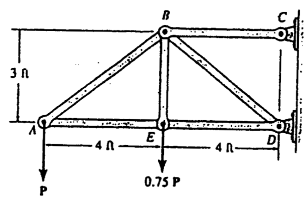
$$\cos\theta = \left(\frac{0.002}{0.003}\right)^2$$

$$\theta = 63.6^\circ \qquad \textbf{Ans}$$

From Eq. (2) :

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

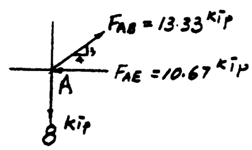
1-58. The bars of the truss each have a cross-sectional area of 1.25 in^2. Determine the average normal stress in each member due to the loading $P = 8$ kip. State whether the stress is tensile or compressive.



Joint A :

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

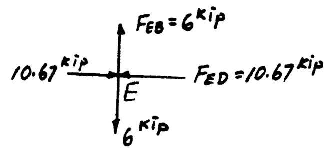
$$\sigma_{AE} = \frac{F_{AE}}{A_{AE}} = \frac{10.67}{1.25} = 8.53 \text{ ksi} \quad \text{(C)} \quad \textbf{Ans}$$



Joint E :

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

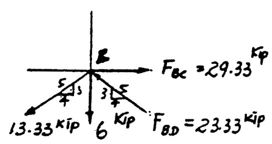
$$\sigma_{EB} = \frac{F_{EB}}{A_{EB}} = \frac{6.0}{1.25} = 4.80 \text{ ksi} \quad \text{(T)} \quad \textbf{Ans}$$



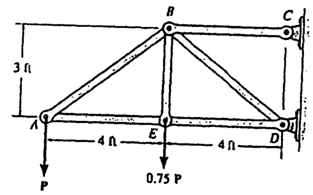
Joint B :

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

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



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.



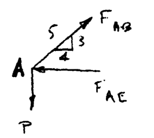
Joint A:

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

$F_{AB} = (1.667)P$

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

$F_{AE} = (1.333)P$



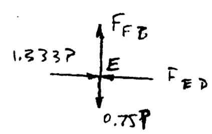
Joint E:

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

$F_{EB} = (0.75)P$

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

$F_{ED} = (1.333)P$



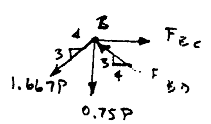
Joint B:

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

$F_{BD} = (2.9167)P$

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

$F_{BC} = (3.67)P$

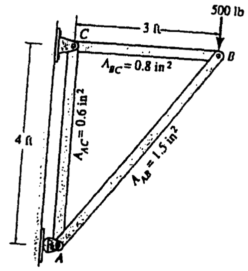


The highest stressed member is BC:

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

$P = 6.82$ kip **Ans**

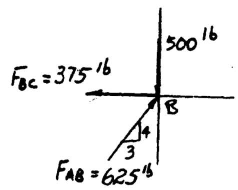
***1-60.** The truss is made from three pin-connected members having the cross-sectional areas shown in the figure. Determine the average normal stress developed in each member when the truss is subjected to the load shown. State whether the stress is tensile or compressive.



Joint B :

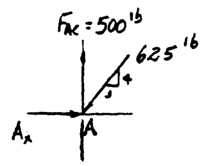
$\sigma_{AB} = \frac{F_{AB}}{A_{AB}} = \frac{625}{1.5} = 417$ psi (C) **Ans**

$\sigma_{BC} = \frac{F_{BC}}{A_{BC}} = \frac{375}{0.8} = 469$ psi (T) **Ans**

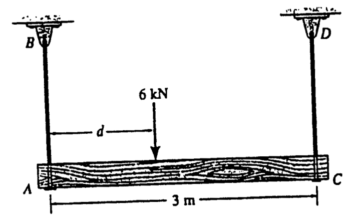


Joint A :

$\sigma_{AC} = \frac{F_{AC}}{A_{AC}} = \frac{500}{0.6} = 833$ psi (T) **Ans**

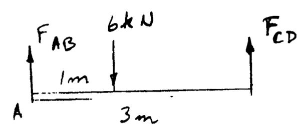


1-61 The uniform beam is supported by two rods AB and CD that have cross-sectional areas of 12 mm² and 8 mm², respectively. If d = 1 m, determine the average normal stress in each rod.



$$\circlearrowleft + \Sigma M_A = 0; \qquad F_{CD}(3) - 6(1) = 0$$

$$F_{CD} = 2 \text{ kN}$$



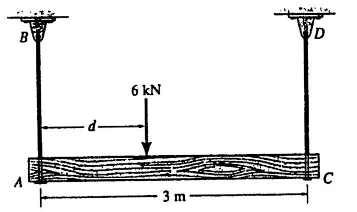
$$+\uparrow \Sigma F_y = 0; \qquad F_{AB} - 6 + 2 = 0$$

$$F_{AB} = 4 \text{ kN}$$

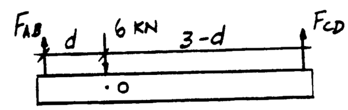
$$\sigma_{AB} = \frac{F_{AB}}{A_{AB}} = \frac{4(10^3)}{12(10^{-6})} = 333 \text{ MPa} \qquad \textbf{Ans}$$

$$\sigma_{CD} = \frac{F_{CD}}{A_{CD}} = \frac{2(10^3)}{8(10^{-6})} = 250 \text{ MPa} \qquad \textbf{Ans}$$

1–62 The uniform beam is supported by two rods *AB* and *CD* that have cross-sectional areas of 12 mm^2 and 8 mm^2, respectively. Determine the position *d* of the 6-kN load so that the average normal stress in each rod is the same.



$$\curvearrowleft + \Sigma M_O = 0; \qquad F_{CD}\,(3 - d) - F_{AB}\,(d) = 0 \qquad (1)$$



$$\sigma = \frac{F_{AB}}{12} = \frac{F_{CD}}{8}$$

$$F_{AB} = 1.5\,F_{CD} \qquad (2)$$

From Eqs. (1) and (2),

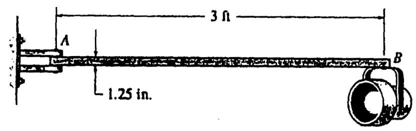
$$F_{CD}\,(3 - d) - 1.5\,F_{CD}(d) = 0$$

$$F_{CD}\,(3 - d - 1.5\,d) = 0$$

$$3 - 2.5\,d = 0$$

$$d = 1.20\text{ m} \qquad \textbf{Ans}$$

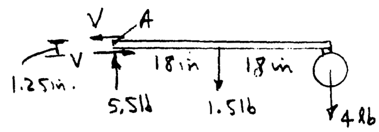
1–63 The railcar docklight is supported by the $\frac{1}{8}$-in.-diameter pin at *A*. If the lamp weighs 4 lb, and the extension arm *AB* has a weight of 0.5 lb/ft, determine the average shear stress in the pin needed to support the lamp. *Hint:* The shear force in the pin is caused by the couple moment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



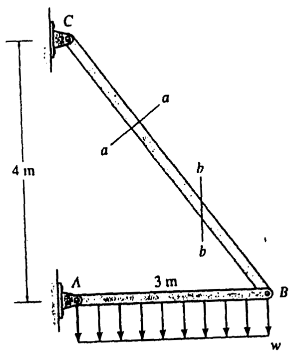
$$\curvearrowleft + \Sigma M_A = 0; \qquad V(1.25) - 1.5(18) - 4(36) = 0$$

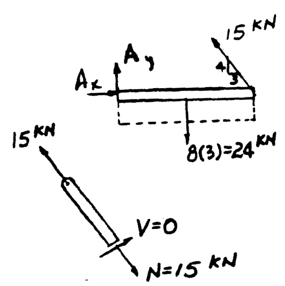
$$V = 136.8 \text{ lb}$$

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



•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 :

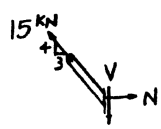
$$\sigma_{a\text{-}a} = \frac{15(10^3)}{(0.035)^2} = 12.2 \text{ MPa} \qquad \textbf{Ans}$$

$$\tau_{a\text{-}a} = 0 \qquad \textbf{Ans}$$

At section b - b :

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

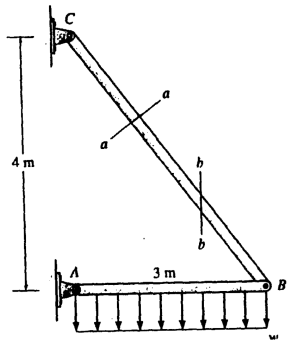
$$+\downarrow \Sigma F_y = 0; \qquad V - 15(4/5) = 0; \qquad V = 12 \text{ kN}$$



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

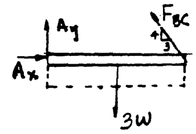
$$\tau_{b\text{-}b} = \frac{12(10^3)}{(0.035)(0.035/0.6)} = 5.88 \text{ MPa} \qquad \textbf{Ans}$$

1–65 The two-member frame is subjected to the distributed loading shown. Determine the intensity w of the largest 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 35 mm on each side.



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

$2.4\,F_{BC} - 4.5w = 0 \qquad (1)$

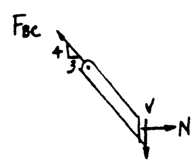


$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad N - (3/5)F_{BC} = 0; \quad N = 0.6F_{BC}$

$+\downarrow \Sigma F_y = 0; \quad V - (4/5)F_{BC} = 0; \quad V = 0.8F_{BC}$

$$\sigma = 15(10^6) = \frac{0.6F_{BC}}{(0.035)(0.035/0.6)}$$

$F_{BC} = 51.04$ kN



$$\tau = 16(10^6) = \frac{0.8F_{BC}}{(0.035)(0.035/0.6)}$$

$F_{BC} = 40.83$ kN (controls)

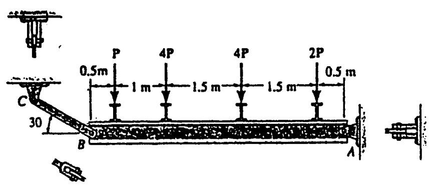
From Eq. (1),

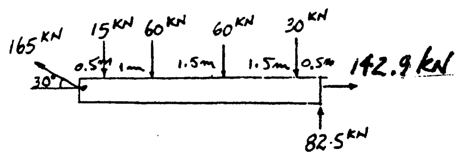
$2.4(40.83) - 4.5w = 0$

$w = 21.8$ kN/m **Ans**

Because of the number and variety of potential correct solutions to this problem, no solution is being given.

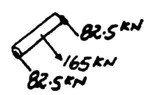
1-67. The beam is supported by a pin at A and a short link BC. If $P = 15$ kN, determine the average shear stress developed in the pins at A, B, and C. All pins are in double shear as shown, and each has a diameter of 18 mm.





For pins B and C :

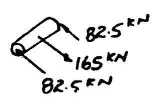
$$\tau_B = \tau_C = \frac{V}{A} = \frac{82.5\,(10^3)}{\frac{\pi}{4}\,(\frac{18}{1000})^2} = 324 \text{ MPa} \qquad \textbf{Ans}$$



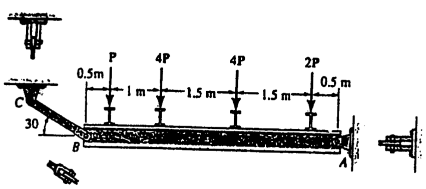
For pin A :

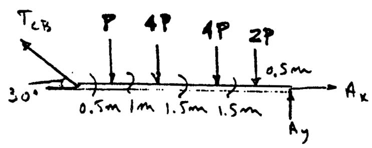
$$F_A = \sqrt{(82.5)^2 + (142.9)^2} = 165 \text{ kN}$$

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



***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.





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

$T_{CB} = 11P$

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

$A_x = 9.5263P$

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

$A_y = 5.5P$

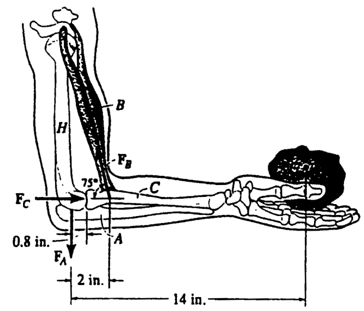
$$F_A = \sqrt{(9.5263P)^2 + (5.5P)^2} = 11P$$

Require;

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

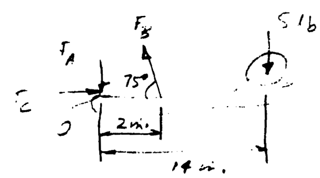
$P = 3.70$ kN **Ans**

1–69 When the hand is holding the 5-lb stone, the humerus H, assumed to be smooth, exerts normal forces F_C and F_A on the radius C and ulna A, respectively, as shown. If the smallest cross-sectional area of the ligament at B is 0.30 in^2, determine the greatest average tensile stress to which it is subjected.



$$\circlearrowleft + \Sigma M_O = 0; \qquad F_B \sin 75°(2) - 5(14) = 0$$

$$F_B = 36.235 \text{ lb}$$



$$\sigma = \frac{P}{A} = \frac{36.235}{0.30} = 121 \text{ psi} \qquad \textbf{Ans}$$