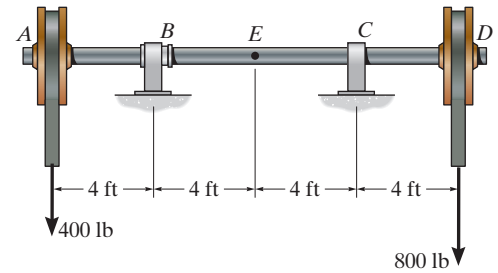


1-1.

The shaft is supported by a smooth thrust bearing at  $B$  and a journal bearing at  $C$ . Determine the resultant internal loadings acting on the cross section at  $E$ .



## SOLUTION

**Support Reactions:** We will only need to compute  $C_y$  by writing the moment equation of equilibrium about  $B$  with reference to the free-body diagram of the entire shaft, Fig.  $a$ .

$$\zeta + \sum M_B = 0; \quad C_y(8) + 400(4) - 800(12) = 0 \quad C_y = 1000 \text{ lb}$$

**Internal Loadings:** Using the result for  $C_y$ , section  $DE$  of the shaft will be considered. Referring to the free-body diagram, Fig.  $b$ ,

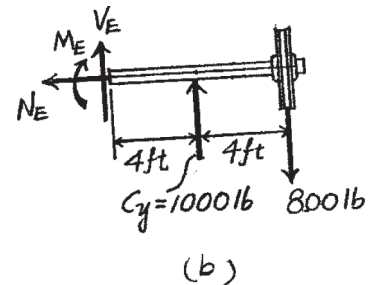
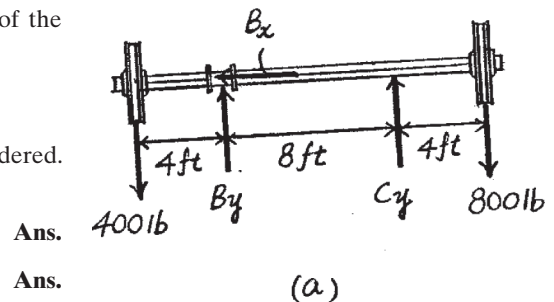
$$\pm \sum F_x = 0; \quad N_E = 0$$

$$+\uparrow \sum F_y = 0; \quad V_E + 1000 - 800 = 0 \quad V_E = -200 \text{ lb}$$

$$\zeta + \sum M_E = 0; \quad 1000(4) - 800(8) - M_E = 0$$

$$M_E = -2400 \text{ lb} \cdot \text{ft} = -2.40 \text{ kip} \cdot \text{ft} \quad \text{Ans.}$$

The negative signs indicates that  $V_E$  and  $M_E$  act in the opposite sense to that shown on the free-body diagram.

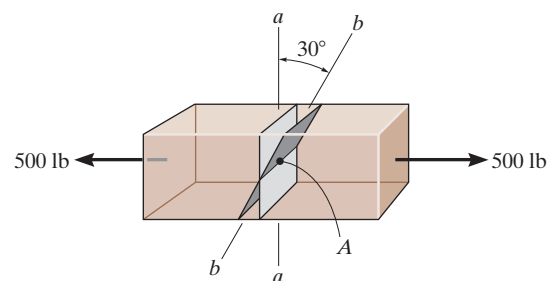


**Ans:**

$$N_E = 0, V_E = -200 \text{ lb}, M_E = -2.40 \text{ kip} \cdot \text{ft}$$

1-2.

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 the centroid  $A$ . The 500-lb load is applied along the centroidal axis of the member.



## SOLUTION

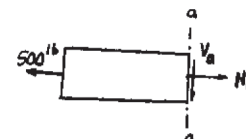
(a)

$$\pm \Sigma F_x = 0; \quad N_a - 500 = 0$$

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

$$+\downarrow \Sigma F_y = 0; \quad V_a = 0$$

Ans.



Ans.

(b)

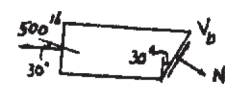
$$\searrow^+ \Sigma F_x = 0; \quad N_b - 500 \cos 30^\circ = 0$$

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

$$+\nearrow \Sigma F_y = 0; \quad V_b - 500 \sin 30^\circ = 0$$

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

Ans.



Ans.

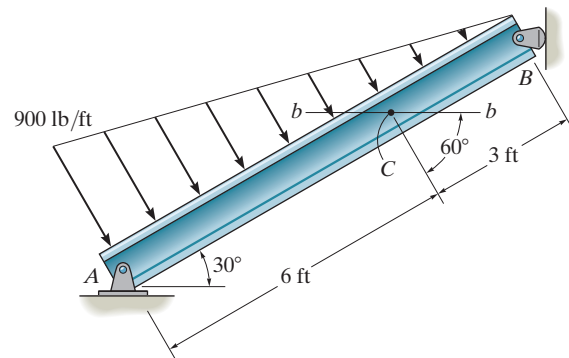
**Ans:**

(a)  $N_a = 500 \text{ lb}$ ,  $V_a = 0$ ,

(b)  $N_b = 433 \text{ lb}$ ,  $V_b = 250 \text{ lb}$

1-3.

Determine the resultant internal loadings acting on section  $b-b$  through the centroid  $C$  on the beam.



## SOLUTION

**Support Reaction:**

$$\zeta + \sum M_A = 0; \quad N_B(9 \sin 30^\circ) - \frac{1}{2}(900)(9)(3) = 0$$

$$N_B = 2700 \text{ lb}$$

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

$$\pm \rightarrow \sum F_x = 0; \quad V_{b-b} + \frac{1}{2}(300)(3) \sin 30^\circ - 2700 = 0$$

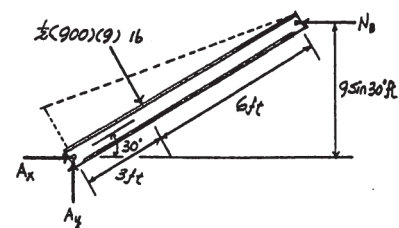
$$V_{b-b} = 2475 \text{ lb} = 2.475 \text{ kip}$$

$$+\uparrow \sum F_y = 0; \quad N_{b-b} - \frac{1}{2}(300)(3) \cos 30^\circ = 0$$

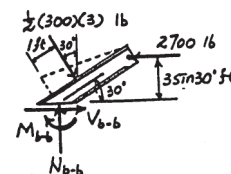
$$N_{b-b} = 389.7 \text{ lb} = 0.390 \text{ kip}$$

$$\zeta + \sum M_C = 0; \quad 2700(3 \sin 30^\circ) - \frac{1}{2}(300)(3)(1) - M_{b-b} = 0$$

$$M_{b-b} = 3600 \text{ lb} \cdot \text{ft} = 3.60 \text{ kip} \cdot \text{ft}$$



Ans.



Ans.

Ans.

**Ans:**

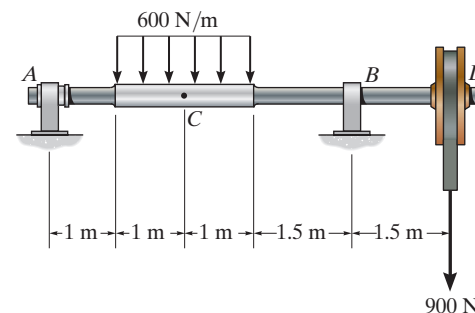
$$V_{b-b} = 2.475 \text{ kip},$$

$$N_{b-b} = 0.390 \text{ kip},$$

$$M_{b-b} = 3.60 \text{ kip} \cdot \text{ft}$$

\*1-4.

The shaft is supported by a smooth thrust bearing at  $A$  and a smooth journal bearing at  $B$ . Determine the resultant internal loadings acting on the cross section at  $C$ .



## SOLUTION

**Support Reactions:** We will only need to compute  $B_y$  by writing the moment equation of equilibrium about  $A$  with reference to the free-body diagram of the entire shaft, Fig.  $a$ .

$$\zeta + \Sigma M_A = 0; \quad B_y(4.5) - 600(2)(2) - 900(6) = 0 \quad B_y = 1733.33 \text{ N}$$

**Internal Loadings:** Using the result of  $B_y$ , section  $CD$  of the shaft will be considered. Referring to the free-body diagram of this part, Fig.  $b$ ,

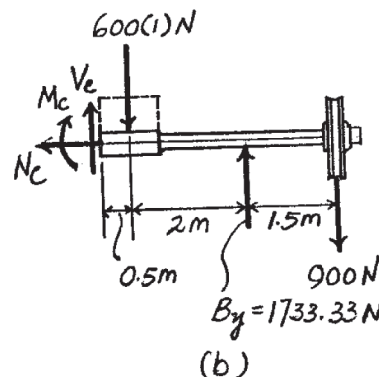
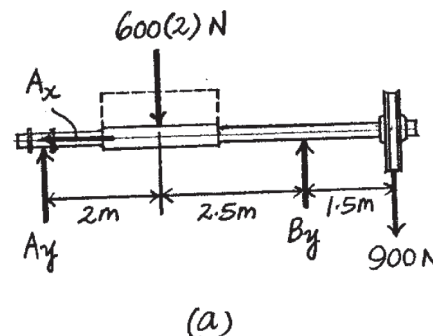
$$\rightarrow \Sigma F_x = 0; \quad N_C = 0 \quad \text{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \quad V_C - 600(1) + 1733.33 - 900 = 0 \quad V_C = -233 \text{ N} \quad \text{Ans.}$$

$$\zeta + \Sigma M_C = 0; \quad 1733.33(2.5) - 600(1)(0.5) - 900(4) - M_C = 0$$

$$M_C = 433 \text{ N} \cdot \text{m} \quad \text{Ans.}$$

The negative sign indicates that  $V_C$  acts in the opposite sense to that shown on the free-body diagram.



**Ans:**

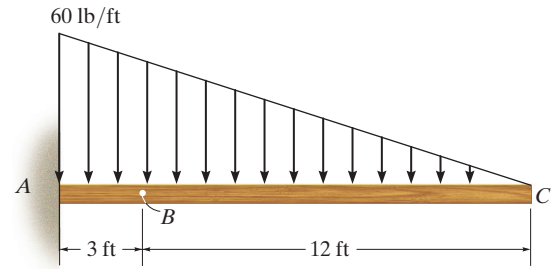
$$N_C = 0,$$

$$V_C = -233 \text{ N},$$

$$M_C = 433 \text{ N} \cdot \text{m}$$

1-5.

Determine the resultant internal loadings acting on the cross section at point  $B$ .



### SOLUTION

$$\pm \rightarrow \Sigma F_x = 0; \quad N_B = 0$$

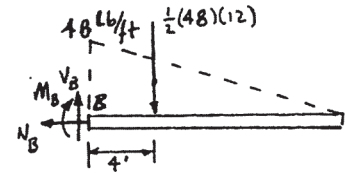
$$+\uparrow \Sigma F_y = 0; \quad V_B - \frac{1}{2}(48)(12) = 0$$

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

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

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

Ans.



Ans.

Ans.

**Ans:**

$$N_B = 0,$$

$$V_B = 288 \text{ lb},$$

$$M_B = -1.15 \text{ kip} \cdot \text{ft}$$

1-6.

Determine the resultant internal loadings on the cross section at point  $D$ .

## SOLUTION

**Support Reactions:** Member  $BC$  is the two force member.

$$\zeta + \Sigma M_A = 0; \quad \frac{4}{5}F_{BC}(1.5) - 1.875(0.75) = 0$$

$$F_{BC} = 1.1719 \text{ kN}$$

$$+\uparrow \Sigma F_y = 0; \quad A_y + \frac{4}{5}(1.1719) - 1.875 = 0$$

$$A_y = 0.9375 \text{ kN}$$

$$\pm \Sigma F_x = 0; \quad \frac{3}{5}(1.1719) - A_x = 0$$

$$A_x = 0.7031 \text{ kN}$$

**Equations of Equilibrium:** For point  $D$

$$\pm \Sigma F_x = 0; \quad N_D - 0.7031 = 0$$

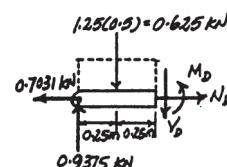
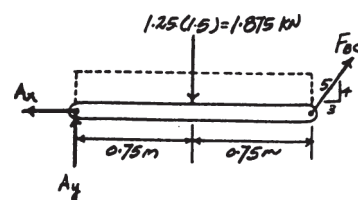
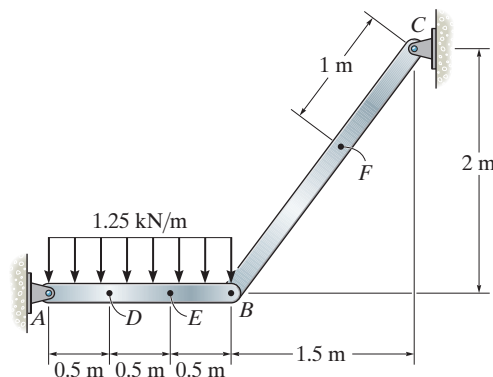
$$N_D = 0.703 \text{ kN}$$

$$+\uparrow \Sigma F_y = 0; \quad 0.9375 - 0.625 - V_D = 0$$

$$V_D = 0.3125 \text{ kN}$$

$$\zeta + \Sigma M_D = 0; \quad M_D + 0.625(0.25) - 0.9375(0.5) = 0$$

$$M_D = 0.3125 \text{ kN} \cdot \text{m}$$



Ans.

Ans.

Ans.

**Ans:**

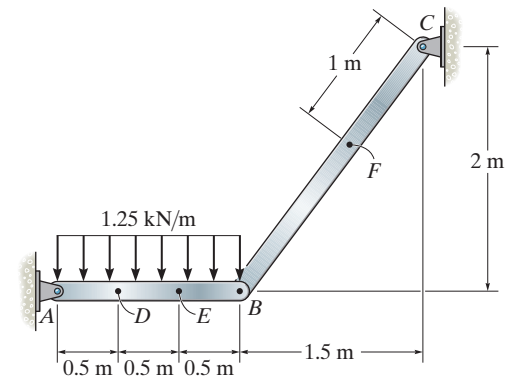
$$N_D = 0.703 \text{ kN},$$

$$V_D = 0.3125 \text{ kN},$$

$$M_D = 0.3125 \text{ kN} \cdot \text{m}$$

1-7.

Determine the resultant internal loadings at cross sections at points  $E$  and  $F$  on the assembly.



## SOLUTION

**Support Reactions:** Member  $BC$  is the two-force member.

$$\zeta + \Sigma M_A = 0; \quad \frac{4}{5} F_{BC}(1.5) - 1.875(0.75) = 0$$

$$F_{BC} = 1.1719 \text{ kN}$$

$$+\uparrow \Sigma F_y = 0; \quad A_y + \frac{4}{5}(1.1719) - 1.875 = 0$$

$$A_y = 0.9375 \text{ kN}$$

$$\pm \Sigma F_x = 0; \quad \frac{3}{5}(1.1719) - A_x = 0$$

$$A_x = 0.7031 \text{ kN}$$

**Equations of Equilibrium:** For point  $F$

$$+\swarrow \Sigma F_{x'} = 0; \quad N_F - 1.1719 = 0$$

$$N_F = 1.17 \text{ kN}$$

$$\nwarrow + \Sigma F_{y'} = 0; \quad V_F = 0$$

$$\zeta + \Sigma M_F = 0; \quad M_F = 0$$

**Equations of Equilibrium:** For point  $E$

$$\leftarrow \Sigma F_x = 0; \quad N_E - \frac{3}{5}(1.1719) = 0$$

$$N_E = 0.703 \text{ kN}$$

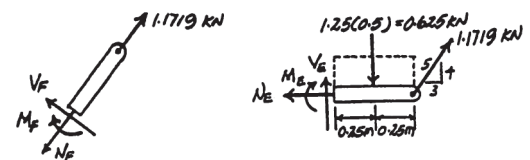
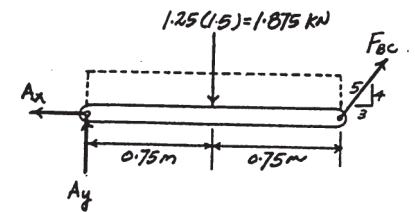
$$+\uparrow \Sigma F_y = 0; \quad V_E - 0.625 + \frac{4}{5}(1.1719) = 0$$

$$V_E = -0.3125 \text{ kN}$$

$$\zeta + \Sigma M_E = 0; \quad -M_E - 0.625(0.25) + \frac{4}{5}(1.1719)(0.5) = 0$$

$$M_E = 0.3125 \text{ kN} \cdot \text{m}$$

Negative sign indicates that  $V_E$  acts in the opposite direction to that shown on FBD.



Ans.

Ans.

Ans.

Ans.

Ans.

Ans.

**Ans:**

$$N_F = 1.17 \text{ kN},$$

$$V_F = 0,$$

$$M_F = 0,$$

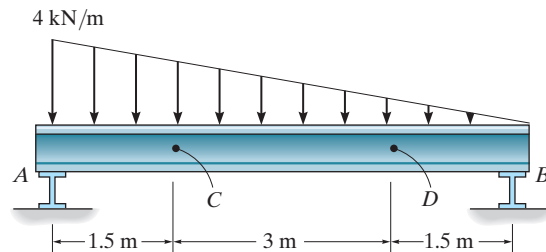
$$N_E = 0.703 \text{ kN},$$

$$V_E = -0.3125 \text{ kN},$$

$$M_E = 0.3125 \text{ kN} \cdot \text{m}$$

\*1-8.

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



## SOLUTION

**Support Reactions:** Referring to the FBD of the entire beam, Fig. *a*,

$$\zeta + \Sigma M_A = 0; \quad B_y(6) - \frac{1}{2}(4)(6)(2) = 0 \quad B_y = 4.00 \text{ kN}$$

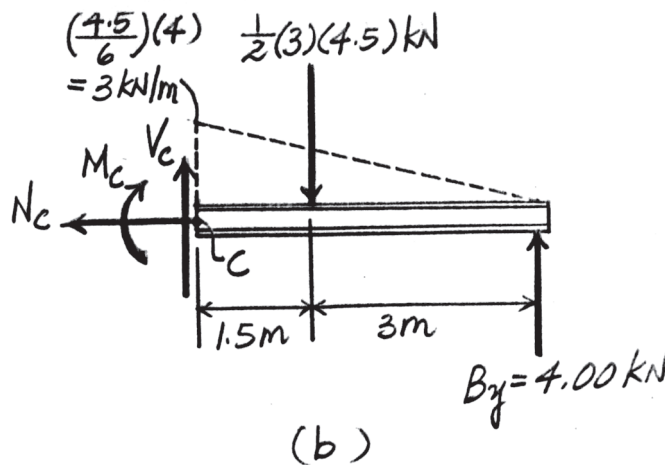
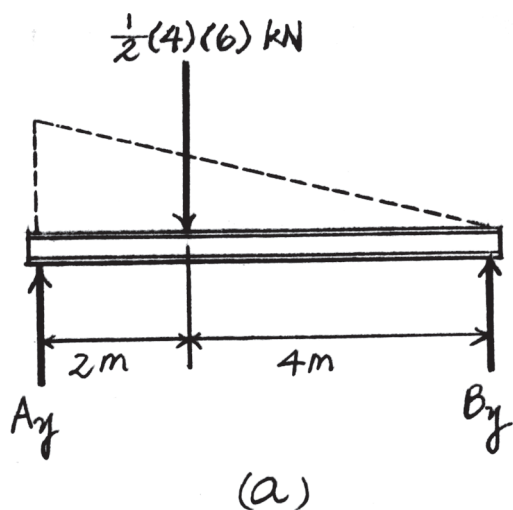
**Internal Loadings:** Referring to the FBD of the right segment of the beam sectioned through C, Fig. *b*,

$$\pm \Sigma F_x = 0; \quad N_C = 0 \quad \text{Ans.}$$

$$+ \uparrow \Sigma F_y = 0; \quad V_C + 4.00 - \frac{1}{2}(3)(4.5) = 0 \quad V_C = 2.75 \text{ kN} \quad \text{Ans.}$$

$$\zeta + \Sigma M_C = 0; \quad 4.00(4.5) - \frac{1}{2}(3)(4.5)(1.5) - M_C = 0$$

$$M_C = 7.875 \text{ kN} \cdot \text{m} \quad \text{Ans.}$$



**Ans:**

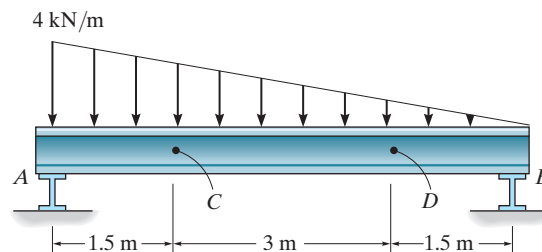
$$N_C = 0,$$

$$V_C = 2.75 \text{ kN},$$

$$M_C = 7.875 \text{ kN} \cdot \text{m}$$

1-9.

The beam supports the distributed load shown. Determine the resultant internal loadings acting on the cross section at point  $D$ . Assume the reactions at the supports  $A$  and  $B$  are vertical.



## SOLUTION

**Support Reactions:** Referring to the FBD of the entire beam, Fig.  $a$ ,

$$\zeta + \Sigma M_A = 0; \quad B_y(6) - \frac{1}{2}(4)(6)(2) = 0 \quad B_y = 4.00 \text{ kN}$$

**Internal Loadings:** Referring to the FBD of the right segment of the beam sectioned through  $D$ , Fig.  $b$ ,

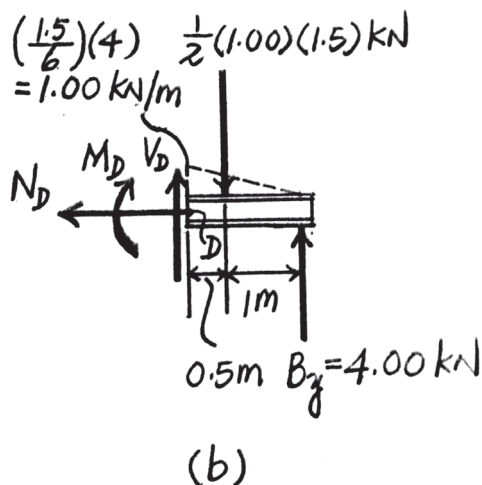
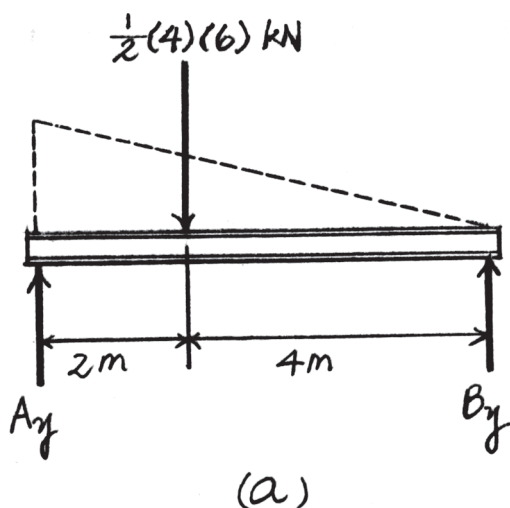
$$\rightarrow \Sigma F_x = 0; \quad N_D = 0 \quad \text{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \quad V_D + 4.00 - \frac{1}{2}(1.00)(1.5) = 0 \quad V_D = -3.25 \text{ kN} \quad \text{Ans.}$$

$$\zeta + \Sigma M_D = 0; \quad 4.00(1.5) - \frac{1}{2}(1.00)(1.5)(0.5) - M_D = 0$$

$$M_D = 5.625 \text{ kN} \cdot \text{m} \quad \text{Ans.}$$

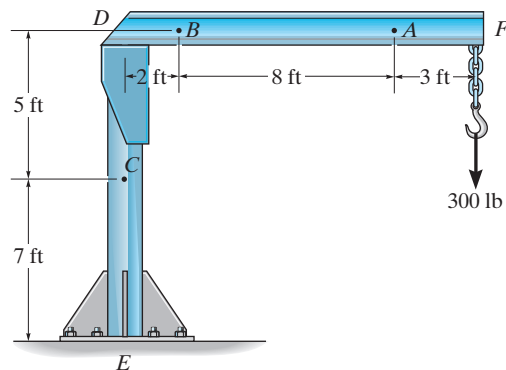
The negative sign indicates that  $V_D$  acts in the sense opposite to that shown on the FBD.



**Ans:**  
 $N_D = 0$ ,  
 $V_D = -3.25 \text{ kN}$ ,  
 $M_D = 5.625 \text{ kN} \cdot \text{m}$

1-10.

The boom  $DF$  of the jib crane and the column  $DE$  have a uniform weight of 50 lb/ft. If the supported load is 300 lb, determine the resultant internal loadings in the crane on cross sections at points  $A$ ,  $B$ , and  $C$ .



## SOLUTION

**Equations of Equilibrium:** For point  $A$

$$\leftarrow \Sigma F_x = 0; \quad N_A = 0$$

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

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

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

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

Negative sign indicates that  $M_A$  acts in the opposite direction to that shown on FBD.

**Equations of Equilibrium:** For point  $B$

$$\leftarrow \Sigma F_x = 0; \quad N_B = 0$$

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

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

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

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

Negative sign indicates that  $M_B$  acts in the opposite direction to that shown on FBD.

**Equations of Equilibrium:** For point  $C$

$$\leftarrow \Sigma F_x = 0; \quad V_C = 0$$

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

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

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

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

Negative signs indicate that  $N_C$  and  $M_C$  act in the opposite direction to that shown on FBD.

Ans.

Ans.

Ans.

Ans.

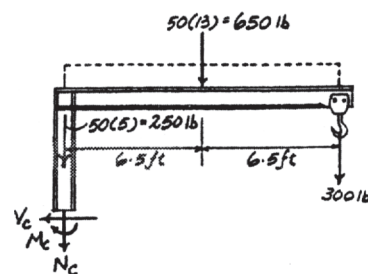
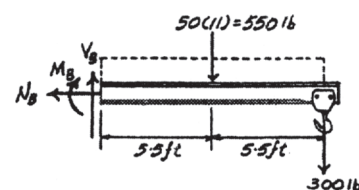
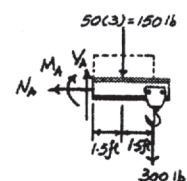
Ans.

Ans.

Ans.

Ans.

Ans.



**Ans:**

$$N_A = 0, V_A = 450 \text{ lb}, M_A = -1.125 \text{ kip} \cdot \text{ft}, \\ N_B = 0, V_B = 850 \text{ lb}, M_B = -6.325 \text{ kip} \cdot \text{ft}, \\ V_C = 0, N_C = -1.20 \text{ kip}, M_C = -8.125 \text{ kip} \cdot \text{ft}$$

**1-11.**

Determine the resultant internal loadings acting on the cross sections at points *D* and *E* of the frame.

**SOLUTION**

Member *AG*:

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

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

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

For point *D*:

$$\rightarrow \Sigma F_x = 0; \quad N_D + 527.33 = 0$$

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

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

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

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

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

For point *E*:

$$\rightarrow \Sigma F_x = 0; \quad 150 \sin 30^\circ - N_E = 0$$

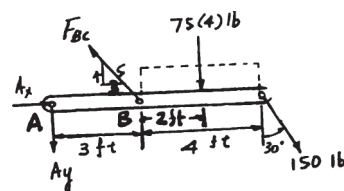
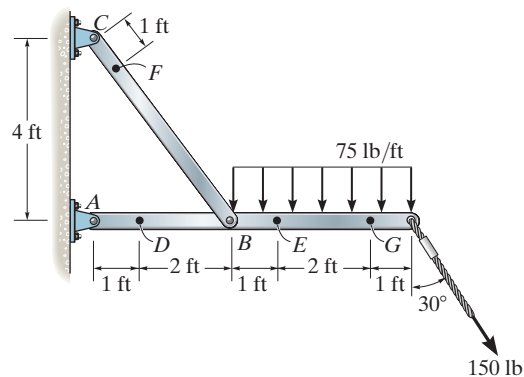
$$N_E = 75.0 \text{ lb}$$

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

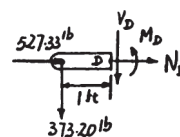
$$V_E = 355 \text{ lb}$$

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

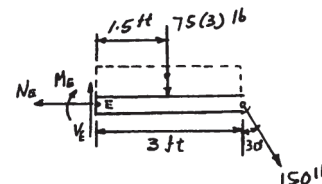
$$M_E = -727 \text{ lb} \cdot \text{ft}$$



Ans.



Ans.



Ans.

Ans.

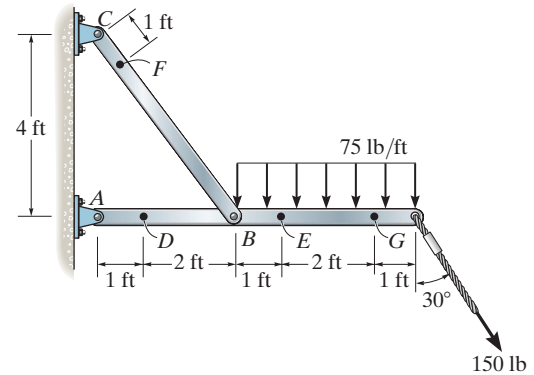
Ans.

**Ans:**

$$\begin{aligned} N_D &= -527 \text{ lb}, \\ V_D &= -373 \text{ lb}, \\ M_D &= -373 \text{ lb} \cdot \text{ft}, \\ N_E &= 75.0 \text{ lb}, \\ V_E &= 355 \text{ lb}, \\ M_E &= -727 \text{ lb} \cdot \text{ft} \end{aligned}$$

\*1-12.

Determine the resultant internal loadings acting on the cross sections at points  $F$  and  $G$  of the frame.



## SOLUTION

Member  $AG$ :

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

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

For point  $F$ :

$$+\nearrow \sum F_{x'} = 0; \quad V_F = 0$$

$$\nearrow + \sum F_{y'} = 0; \quad N_F - 1003.9 = 0$$

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

$$\zeta + \sum M_F = 0; \quad M_F = 0$$

For point  $G$ :

$$\leftarrow \sum F_x = 0; \quad N_G - 150 \sin 30^\circ = 0$$

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

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

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

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

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

Ans.

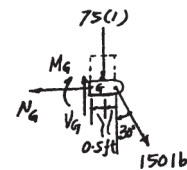
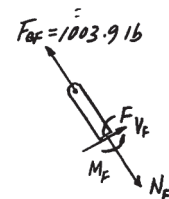
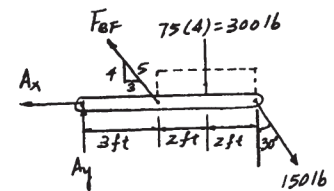
Ans.

Ans.

Ans.

Ans.

Ans.



Ans:

$$V_F = 0,$$

$$N_F = 1004 \text{ lb},$$

$$M_F = 0,$$

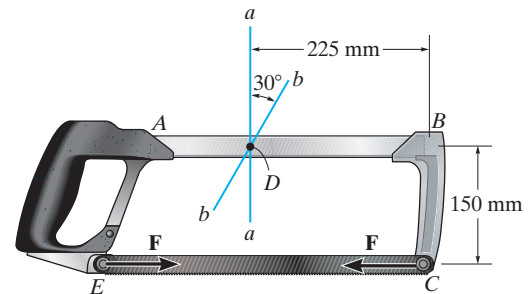
$$N_G = 75.0 \text{ lb},$$

$$V_G = 205 \text{ lb},$$

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

1-13.

The blade of the hacksaw is subjected to a pretension force of  $F = 100$  N. Determine the resultant internal loadings acting on section  $a-a$  that passes through point  $D$ .



## SOLUTION

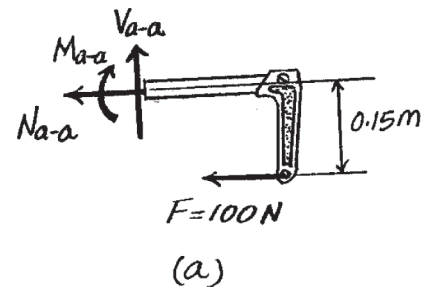
**Internal Loadings:** Referring to the free-body diagram of the section of the hacksaw shown in Fig.  $a$ ,

$$\leftarrow \sum F_x = 0; \quad N_{a-a} + 100 = 0 \quad N_{a-a} = -100 \text{ N} \quad \text{Ans.}$$

$$+\uparrow \sum F_y = 0; \quad V_{a-a} = 0 \quad \text{Ans.}$$

$$\zeta + \sum M_D = 0; \quad -M_{a-a} - 100(0.15) = 0 \quad M_{a-a} = -15 \text{ N} \cdot \text{m} \quad \text{Ans.}$$

The negative sign indicates that  $\mathbf{N}_{a-a}$  and  $\mathbf{M}_{a-a}$  act in the opposite sense to that shown on the free-body diagram.

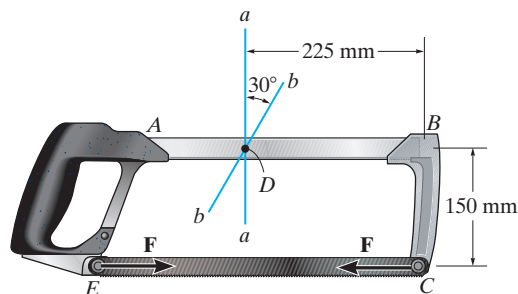


**Ans:**

$$N_{a-a} = -100 \text{ N}, V_{a-a} = 0, M_{a-a} = -15 \text{ N} \cdot \text{m}$$

1-14.

The blade of the hacksaw is subjected to a pretension force of  $F = 100$  N. Determine the resultant internal loadings acting on section  $b-b$  that passes through point  $D$ .



## SOLUTION

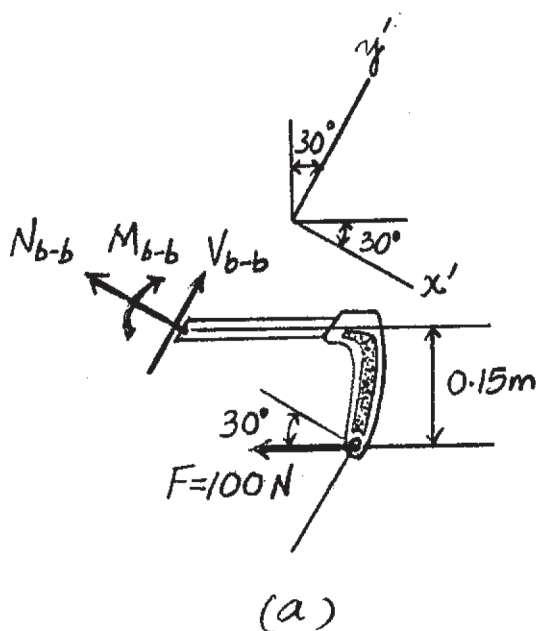
**Internal Loadings:** Referring to the free-body diagram of the section of the hacksaw shown in Fig.  $a$ ,

$$\Sigma F_{x'} = 0; \quad N_{b-b} + 100 \cos 30^\circ = 0 \quad N_{b-b} = -86.6 \text{ N} \quad \text{Ans.}$$

$$\Sigma F_{y'} = 0; \quad V_{b-b} - 100 \sin 30^\circ = 0 \quad V_{b-b} = 50 \text{ N} \quad \text{Ans.}$$

$$\Sigma M_D = 0; \quad -M_{b-b} - 100(0.15) = 0 \quad M_{b-b} = -15 \text{ N} \cdot \text{m} \quad \text{Ans.}$$

The negative sign indicates that  $N_{b-b}$  and  $M_{b-b}$  act in the opposite sense to that shown on the free-body diagram.

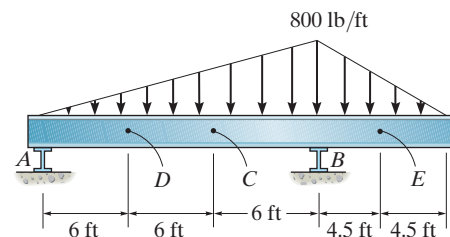


**Ans:**

$$N_{b-b} = -86.6 \text{ N}, \quad V_{b-b} = 50 \text{ N}, \quad M_{b-b} = -15 \text{ N} \cdot \text{m}$$

1-15.

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



## SOLUTION

**Support Reactions:** Referring to the FBD of the entire beam, Fig. a,

$$\zeta + \Sigma M_B = 0; \quad \frac{1}{2}(0.8)(18)(6) - \frac{1}{2}(0.8)(9)(3) - A_y(18) = 0 \quad A_y = 1.80 \text{ kip}$$

**Internal Loadings:** Referring to the FBD of the left beam segment sectioned through point C, Fig. b,

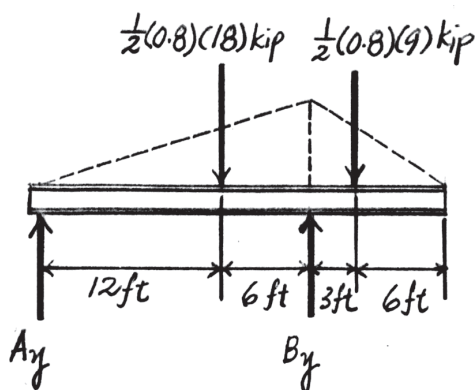
$$\pm \Sigma F_x = 0; \quad N_C = 0 \quad \text{Ans.}$$

$$+ \uparrow \Sigma F_y = 0; \quad 1.80 - \frac{1}{2}(0.5333)(12) - V_C = 0 \quad V_C = -1.40 \text{ kip} \quad \text{Ans.}$$

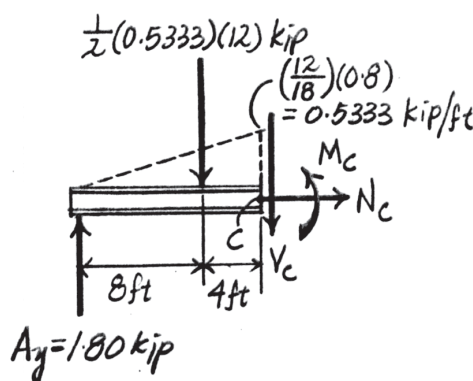
$$\zeta + \Sigma M_C = 0; \quad M_C + \frac{1}{2}(0.5333)(12)(4) - 1.80(12) = 0$$

$$M_C = 8.80 \text{ kip} \cdot \text{ft} \quad \text{Ans.}$$

The negative sign indicates that  $V_C$  acts in the sense opposite to that shown on the FBD.



(a)



(b)

**Ans:**

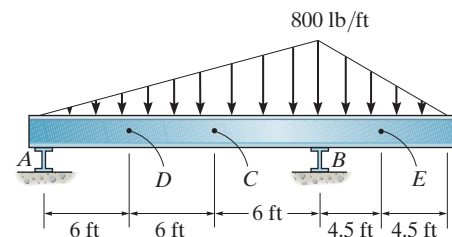
$$N_C = 0,$$

$$V_C = -1.40 \text{ kip},$$

$$M_C = 8.80 \text{ kip} \cdot \text{ft}$$

\*1-16.

The beam supports the distributed load shown. Determine the resultant internal loadings on the cross section at points  $D$  and  $E$ . Assume the reactions at the supports  $A$  and  $B$  are vertical.



## SOLUTION

**Support Reactions:** Referring to the FBD of the entire beam, Fig.  $a$ ,

$$\zeta + \Sigma M_B = 0; \quad \frac{1}{2}(0.8)(18)(6) - \frac{1}{2}(0.8)(9)(3) - A_y(18) = 0 \quad A_y = 1.80 \text{ kip}$$

**Internal Loadings:** Referring to the FBD of the left segment of the beam section through  $D$ , Fig.  $b$ ,

$$\pm \Sigma F_x = 0; \quad N_D = 0$$

$$+\uparrow \Sigma F_y = 0; \quad 1.80 - \frac{1}{2}(0.2667)(6) - V_D = 0 \quad V_D = 1.00 \text{ kip}$$

$$\zeta + \Sigma M_D = 0; \quad M_D + \frac{1}{2}(0.2667)(6)(2) - 1.80(6) = 0$$

$$M_D = 9.20 \text{ kip} \cdot \text{ft} \quad \text{Ans.}$$

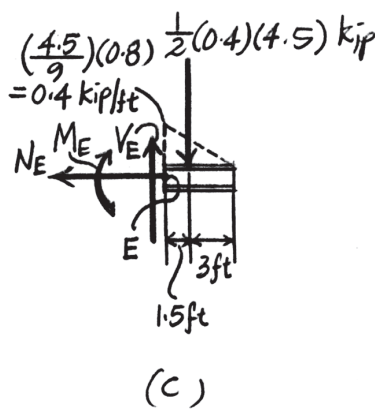
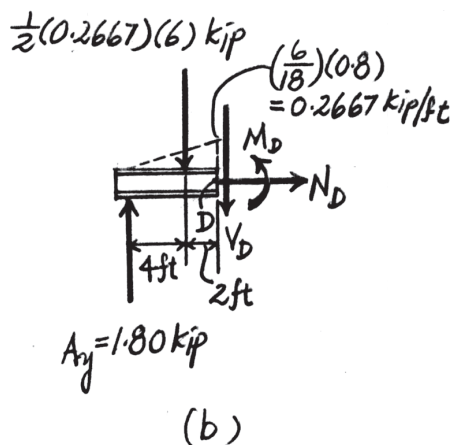
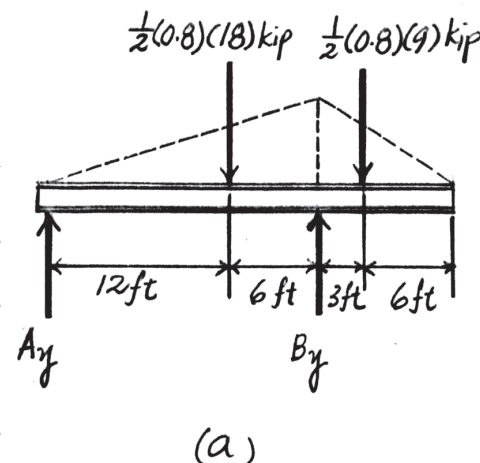
Referring to the FBD of the right segment of the beam sectioned through  $E$ , Fig.  $c$ ,

$$\pm \Sigma F_x = 0; \quad N_E = 0 \quad \text{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \quad V_E - \frac{1}{2}(0.4)(4.5) = 0 \quad V_E = 0.900 \text{ kip} \quad \text{Ans.}$$

$$\zeta + \Sigma M_E = 0; \quad -M_E - \frac{1}{2}(0.4)(4.5)(1.5) = 0 \quad M_E = -1.35 \text{ kip} \cdot \text{ft} \quad \text{Ans.}$$

The negative sign indicates that  $M_E$  act in the sense opposite to that shown in Fig.  $c$ .



**Ans:**

$$\begin{aligned} N_D &= 0, \\ V_D &= 1.00 \text{ kip}, \\ M_D &= 9.20 \text{ kip} \cdot \text{ft}, \\ N_E &= 0, \\ V_E &= 0.900 \text{ kip}, \\ M_E &= -1.35 \text{ kip} \cdot \text{ft} \end{aligned}$$

1-17.

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 at 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.

## SOLUTION

### Support Reactions:

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

$$A_y = 245.71 \text{ N}$$

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

$$B_y = 314.29 \text{ N}$$

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

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

### Equations of Equilibrium: For point $D$

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

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

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

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

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

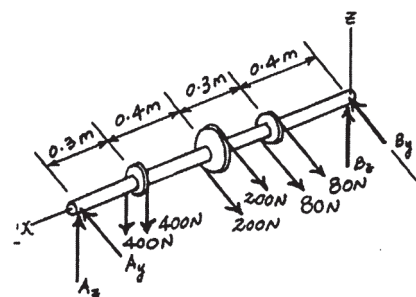
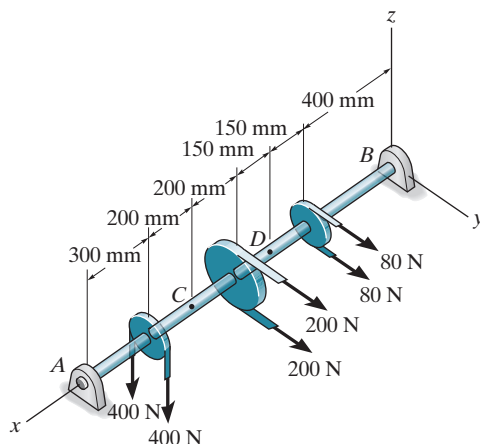
$$\Sigma M_x = 0; \quad (T_D)_x = 0$$

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

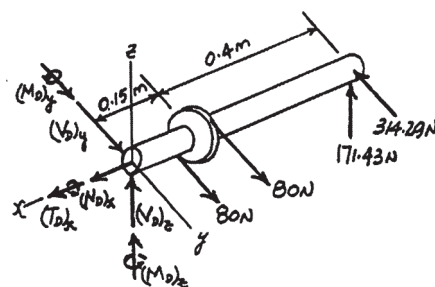
$$(M_D)_y = -94.3 \text{ N} \cdot \text{m}$$

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

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



Ans.



Ans.

Ans.

Ans.

Ans.

Ans.

Ans:

$$\begin{aligned} (N_D)_x &= 0, \\ (V_D)_y &= 154 \text{ N}, \\ (V_D)_z &= -171 \text{ N}, \\ (T_D)_x &= 0, \\ (M_D)_y &= -94.3 \text{ N} \cdot \text{m}, \\ (M_D)_z &= -149 \text{ N} \cdot \text{m} \end{aligned}$$

1-18.

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 at 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.

## SOLUTION

### Support Reactions:

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

$$A_y = 245.71 \text{ N}$$

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

$$B_y = 314.29 \text{ N}$$

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

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

### Equations of Equilibrium: For point *C*

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

$$\Sigma F_y = 0; \quad -245.71 + (V_C)_y = 0$$

$$(V_C)_y = -246 \text{ N}$$

$$\Sigma F_z = 0; \quad 628.57 - 800 + (V_C)_z = 0$$

$$(V_C)_z = -171 \text{ N}$$

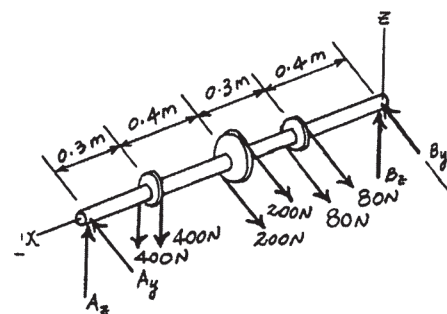
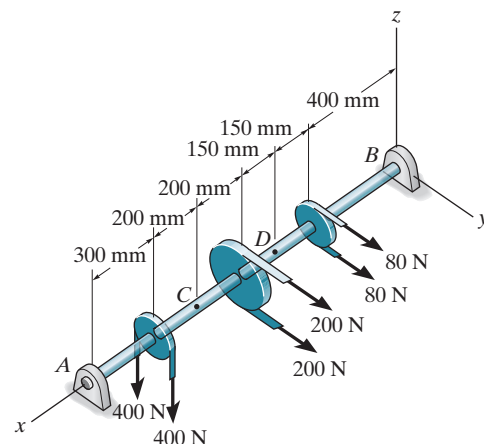
$$\Sigma M_x = 0; \quad (T_C)_x = 0$$

$$\Sigma M_y = 0; \quad (M_C)_y - 628.57(0.5) + 800(0.2) = 0$$

$$(M_C)_y = -154 \text{ N} \cdot \text{m}$$

$$\Sigma M_z = 0; \quad (M_C)_z - 245.71(0.5) = 0$$

$$(M_C)_z = -123 \text{ N} \cdot \text{m}$$



Ans.

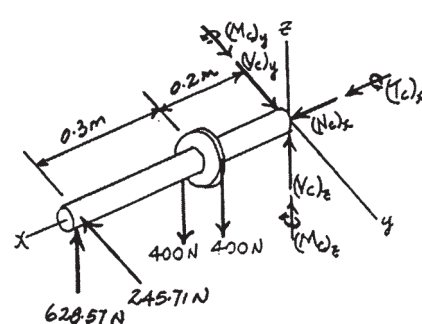
Ans.

Ans.

Ans.

Ans.

Ans.



Ans:

$$(N_C)_x = 0,$$

$$(V_C)_y = -246 \text{ N},$$

$$(V_C)_z = -171 \text{ N},$$

$$(T_C)_x = 0,$$

$$(M_C)_y = -154 \text{ N} \cdot \text{m},$$

$$(M_C)_z = -123 \text{ N} \cdot \text{m}$$

1-19.

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

### SOLUTION

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

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

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

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

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

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

Ans.

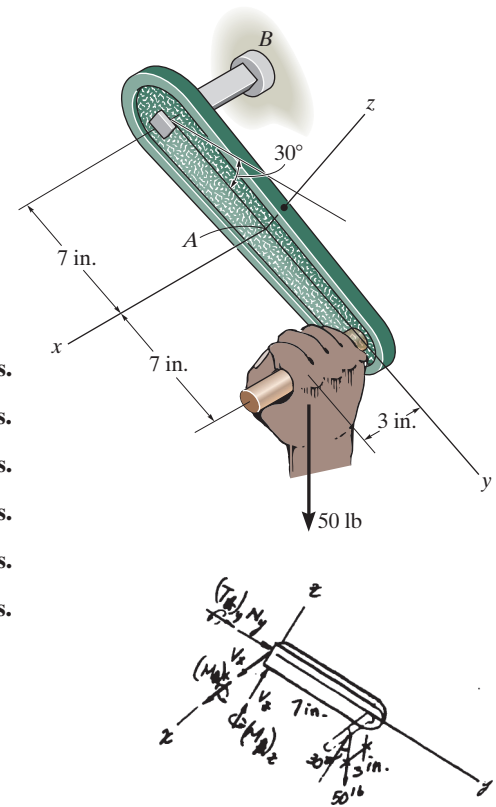
Ans.

Ans.

Ans.

Ans.

Ans.



Ans:

$$\begin{aligned} (V_A)_x &= 0, \\ (N_A)_y &= -25 \text{ lb}, \\ (V_A)_z &= 43.3 \text{ lb}, \\ (M_A)_x &= 303 \text{ lb} \cdot \text{in.}, \\ (T_A)_y &= -130 \text{ lb} \cdot \text{in.}, \\ (M_A)_z &= -75 \text{ lb} \cdot \text{in.} \end{aligned}$$

\*1-20.

Determine the resultant internal loadings acting on the cross section at 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.

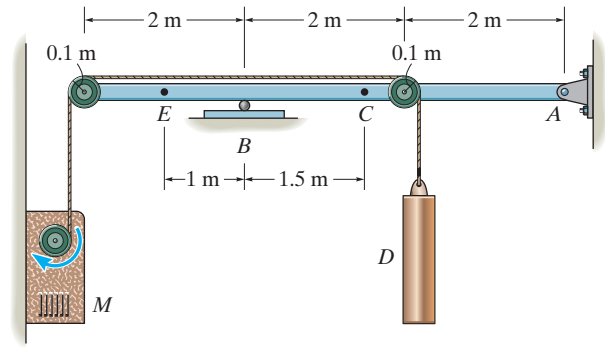
### SOLUTION

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

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

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

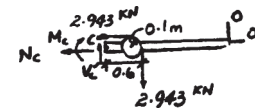
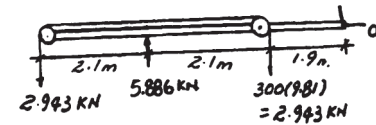
$$M_C = -1.47 \text{ kN} \cdot \text{m}$$



Ans.

Ans.

Ans.



Ans:

$$N_C = -2.94 \text{ kN},$$

$$V_C = 2.94 \text{ kN},$$

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

1-21.

Determine the resultant internal loadings acting on the cross section at point  $E$ . The load  $D$  has a mass of 300 kg and is being hoisted by the motor  $M$  with constant velocity.

### SOLUTION

$$\pm \rightarrow \Sigma F_x = 0; \quad N_E + 2943 = 0$$

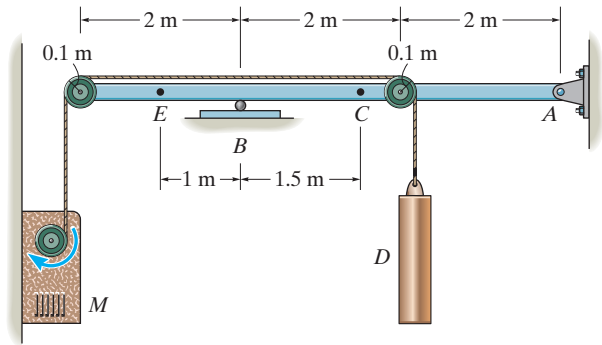
$$N_E = -2.94 \text{ kN}$$

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

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

$$\zeta + \Sigma M_E = 0; \quad M_E + 2943(1) = 0$$

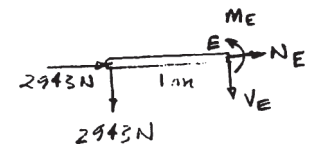
$$M_E = -2.94 \text{ kN} \cdot \text{m}$$



Ans.

Ans.

Ans.



Ans:

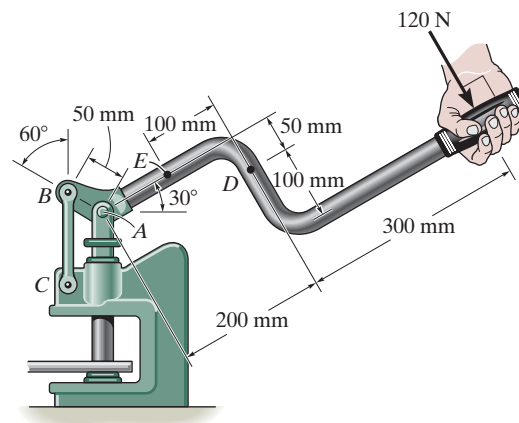
$$N_E = -2.94 \text{ kN},$$

$$V_E = -2.94 \text{ kN},$$

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

1-22.

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 resultant internal loadings acting on the cross section at point  $D$ .



## SOLUTION

Member:

$$\zeta + \sum M_A = 0; \quad F_{BC} \cos 30^\circ (50) - 120(500) = 0$$

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

$$+\uparrow \sum F_y = 0; \quad A_y - 1385.6 - 120 \cos 30^\circ = 0$$

$$A_y = 1489.56 \text{ N}$$

$$\leftarrow \sum F_x = 0; \quad A_x - 120 \sin 30^\circ = 0; \quad A_x = 60 \text{ N}$$

$$F_A = \sqrt{1489.56^2 + 60^2}$$

$$= 1491 \text{ N} = 1.49 \text{ kN}$$

Segment:

$$\nearrow \sum F_x' = 0; \quad N_D - 120 = 0$$

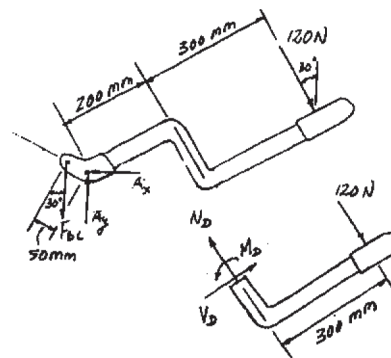
$$N_D = 120 \text{ N}$$

$$+\nearrow \sum F_y' = 0; \quad V_D = 0$$

$$\zeta + \sum M_D = 0; \quad M_D - 120(0.3) = 0$$

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

Ans.



Ans.

Ans.

Ans.

Ans.

Ans:

$$F_{BC} = 1.39 \text{ kN}, F_A = 1.49 \text{ kN}, N_D = 120 \text{ N},$$

$$V_D = 0, M_D = 36.0 \text{ N} \cdot \text{m}$$

**1-23.**

Determine the resultant internal loadings acting on the cross section at point *E* of the handle arm, and on the cross section of the short link *BC*.

**SOLUTION**

Member:

$$\zeta + \sum M_A = 0; \quad F_{BC} \cos 30^\circ (50) - 120(500) = 0$$

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

Segment:

$$\uparrow \sum F_{x'} = 0; \quad N_E = 0$$

$$\curvearrowleft + \sum F_{y'} = 0; \quad V_E - 120 = 0; \quad V_E = 120 \text{ N}$$

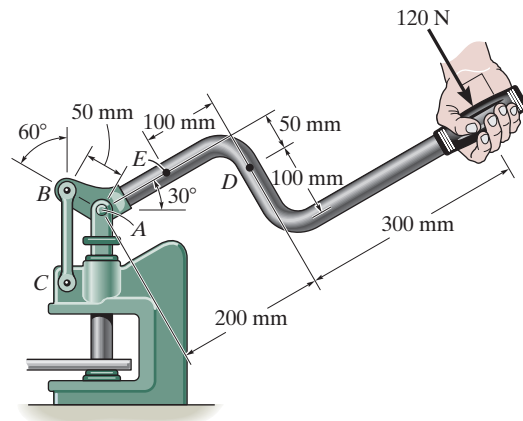
$$\zeta + \sum M_E = 0; \quad M_E - 120(0.4) = 0; \quad M_E = 48.0 \text{ N} \cdot \text{m}$$

Short link:

$$\leftarrow \sum F_x = 0; \quad V = 0$$

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

$$\zeta + \sum M_H = 0; \quad M = 0$$



**Ans.**

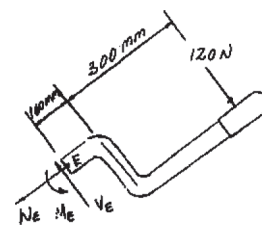
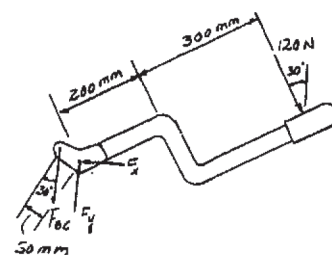
**Ans.**

**Ans.**

**Ans.**

**Ans.**

**Ans.**



**Ans:**

$N_E = 0, V_E = 120 \text{ N}, M_E = 48.0 \text{ N} \cdot \text{m},$   
 Short link:  $V = 0, N = 1.39 \text{ kN}, M = 0$

\*1-24.

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.

## SOLUTION

From FBD (a)

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

From FBD (b)

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

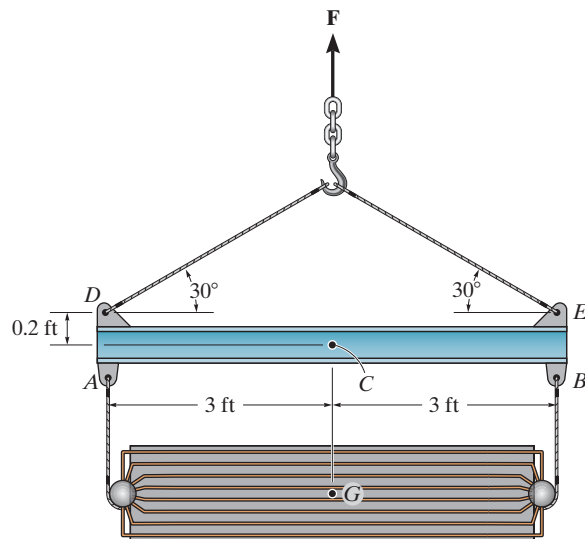
From FBD (c)

$$\pm \Sigma F_x = 0; \quad -N_C - 52 \cos 30^\circ = 0; \quad N_C = -45.0 \text{ kip}$$

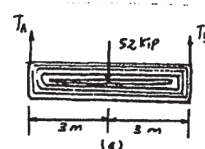
$$+\uparrow \Sigma F_y = 0; \quad V_C + 52 \sin 30^\circ - 26 = 0; \quad V_C = 0$$

$$\zeta + \Sigma M_C = 0; \quad 52 \cos 30^\circ(0.2) + 52 \sin 30^\circ(3) - 26(3) - M_C = 0$$

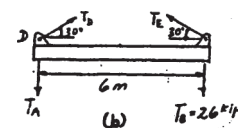
$$M_C = 9.00 \text{ kip} \cdot \text{ft}$$



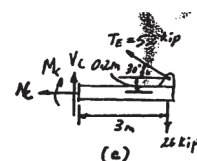
Ans.



Ans.



Ans.



Ans:

$$N_C = -45.0 \text{ kip},$$

$$V_C = 0,$$

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

1-25.

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

## SOLUTION

From FBD (a)

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

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

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

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

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

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

From FBD (b)

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

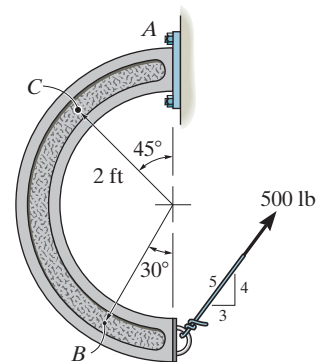
$$N_C = 495 \text{ lb}$$

$$\searrow + \Sigma F_{y'} = 0; \quad -V_C + 400 \sin 45^\circ - 300 \sin 45^\circ = 0$$

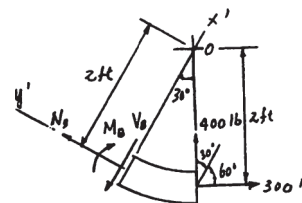
$$V_C = 70.7 \text{ lb}$$

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

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



Ans.

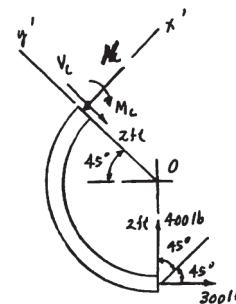


Ans.

Ans.

(a)

Ans.



Ans.

Ans.

(b)

**Ans:**

$$\begin{aligned} V_B &= 496 \text{ lb}, \\ N_B &= 59.8 \text{ lb}, \\ M_B &= 480 \text{ lb} \cdot \text{ft}, \\ N_C &= 495 \text{ lb}, \\ V_C &= 70.7 \text{ lb}, \\ M_C &= 1.59 \text{ kip} \cdot \text{ft} \end{aligned}$$