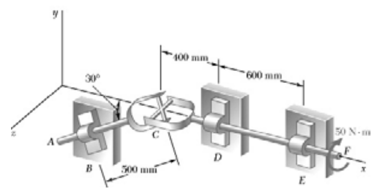


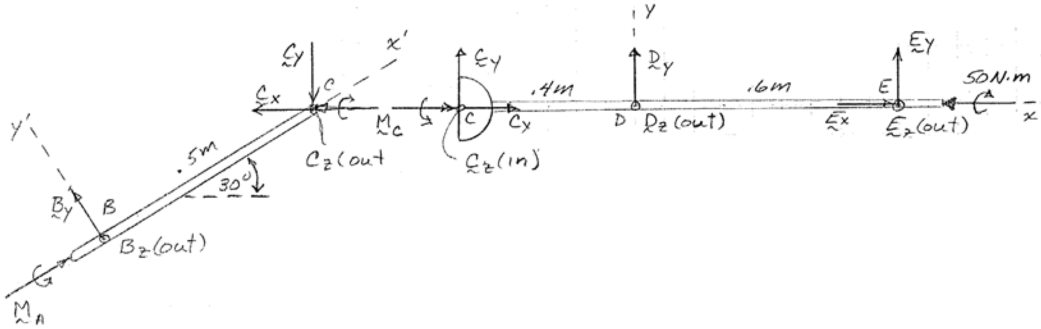
PROBLEM 6.154

Solve Prob. 6.153 assuming that the arm of the crosspiece attached to shaft *CF* is vertical.

SOLUTION

Note: The couples exerted by the two yokes on the crosspiece must be equal and opposite. Since neither yoke can exert a couple along the arm of the crosspiece it contacts, these equal and opposite couples must be normal to the plane of the crosspiece.

If the crosspiece arm attached to *CF* is vertical, the plane of the crosspiece is normal to *CF*, so the couple $\mathbf{M}_C$ is along *CF*.



(*a*) FBD *CDE*: $\Sigma M_x = 0\text{: } M_C - 50\text{ N}\cdot\text{m} = 0 \qquad M_C = 50\text{ N}\cdot\text{m}$

FBD *BC*: $\Sigma M_{x'} = 0\text{: } M_A - M_C\cos 30° = 0 \qquad M_A = (50\text{ N}\cdot\text{m})\cos 30°$

$M_A = 43.3\text{ N}\cdot\text{m}$ ◀

(*b*) $\Sigma M_{Cy'} = 0\text{: } M_C\sin 30° + (0.5\text{ m})B_z = 0 \qquad B_z = -\dfrac{(50\text{ N}\cdot\text{m})(0.5)}{0.5\text{ m}} = -50\text{ N}$

$\Sigma M_{Cz} = 0\text{: } -(0.5\text{ m})B_y = 0 \qquad B_y = 0 \qquad$ so $\mathbf{B} = -(50.0\text{ N})\mathbf{k}$ ◀

$\Sigma\mathbf{F} = 0\text{: } \mathbf{B} + \mathbf{C} = 0 \qquad \mathbf{C} = -\mathbf{B} \qquad$ so $\qquad \text{C} = (50\text{ N})\mathbf{k}$ on BC

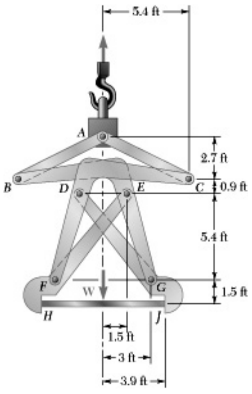
FBD *CDE*: $\Sigma M_{Dy} = 0\text{: } -(0.4\text{ m})C_z - (0.6\text{ m})E_z = 0 \qquad E_z = -(50\text{ N})\left(\dfrac{4}{6}\right) = -33.3\text{ N}$

$\Sigma M_{Dz} = 0\text{: } E_y = 0$

$\Sigma F_x = 0\text{: } E_x = 0 \qquad$ so $\mathbf{E} = -(33.3\text{ N})\ \mathbf{k}$ ◀

$\Sigma\mathbf{F} = 0\text{: } \mathbf{C} + \mathbf{D} + \mathbf{E} = 0 \qquad -(50\text{ N})\ \mathbf{k} + \mathbf{D} - (33.3\text{ N})\ \mathbf{k} = 0$

$\mathbf{D} = (83.3\text{ N})\ \mathbf{k}$ ◀

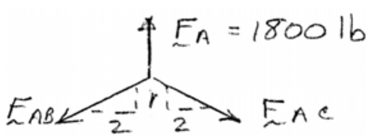


PROBLEM 6.155

The large mechanical tongs shown are used to grab and lift a thick 1800-lb steel slab *HJ*. Knowing that slipping does not occur between the tong grips and the slab at *H* and *J*, determine the components of all forces acting on member *EFH*. (*Hint:* Consider the symmetry of the tongs to establish relationships between the components of the force acting at *E* on *EFH* and the components of the force acting at *D* on *CDF*.)

SOLUTION

FBD A:

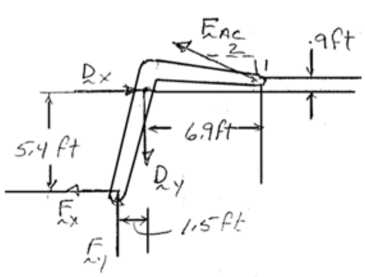


By inspection of FBD whole: $F_A = W = 1800$ lb

By symmetry: $F_{AB} = F_{AC} = T$ (say)

$$\uparrow \Sigma F_y = 0: 1800 \text{ lb} - 2\frac{1}{\sqrt{5}}T = 0 \qquad T = 900\sqrt{5} \text{ lb} = F_{AC} = F_{AB}$$

FBD CDF:



$$\longrightarrow \Sigma F_x = 0: D_x - F_x - \frac{2}{\sqrt{5}}\left(900\sqrt{5} \text{ lb}\right) = 0$$

$$D_x - F_x = 1800 \text{ lb} \qquad (1)$$

$$\uparrow \Sigma F_y = 0: -D_y + F_y + \frac{1}{\sqrt{5}}\left(900\sqrt{5} \text{ lb}\right) = 0$$

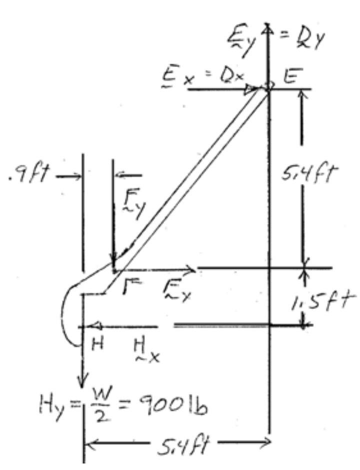
$$D_y - F_y = 900 \text{ lb} \qquad (2)$$

$$\circlearrowleft \Sigma M_D = 0: (6.9 \text{ ft})\left[\frac{1}{\sqrt{5}}\left(900\sqrt{5}\right) \text{ lb}\right] + (0.9 \text{ ft})\left[\frac{2}{\sqrt{5}}\left(900\sqrt{5}\right) \text{ lb}\right]$$

$$-(1.5 \text{ ft})F_y - (5.4 \text{ ft})F_x = 0$$

$$5.4F_x + 1.5F_y = 7830 \text{ lb} \qquad (3)$$

FBD EFH:



Note: By symmetry $E_x = D_x$; $E_y = D_y$

$$\circlearrowleft \Sigma M_F = 0: (4.5 \text{ ft})D_y - (5.4 \text{ ft})D_y - (1.5 \text{ ft})H_x$$

$$+ (0.9 \text{ ft})900 \text{ lb} = 0$$

$$5.4D_x - 4.5D_y + 1.5H_x = 810 \text{ lb} \qquad (4)$$

$$\longrightarrow \Sigma F_x = 0: D_x + F_x - H_x = 0 \qquad (5)$$

$\mathbf{F}_x = 648$ lb $\longrightarrow$ ◀

PROBLEM 6.155 CONTINUED

Solving equations (1) through (5):

$\mathbf{F}_x = 648 \text{ lb} \longrightarrow$ ◀

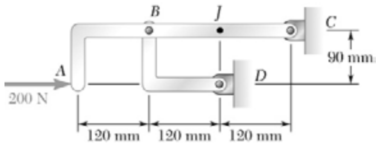
$\mathbf{F}_y = 2.89 \text{ kips} \downarrow$ ◀

$\mathbf{E}_x = \mathbf{D}_x = 2.45 \text{ kips} \longrightarrow$ ◀

$\mathbf{E}_y = \mathbf{D}_y = 3.79 \text{ kips} \uparrow$ ◀

$\mathbf{H}_x = 3.10 \text{ kip} \longleftarrow$ ◀

and, as noted $\mathbf{H}_y = 900 \text{ lb} \downarrow$ ◀

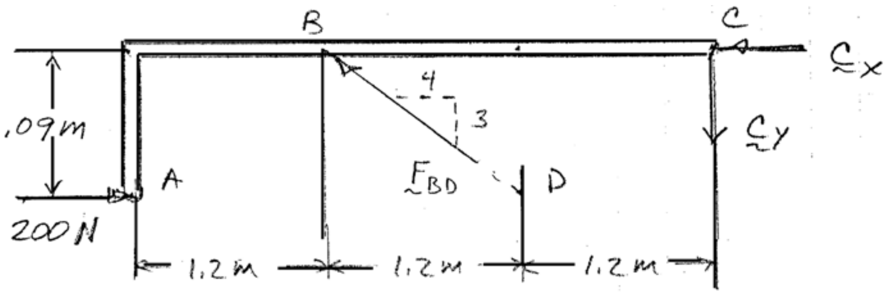


PROBLEM 6.156

For the frame and loading shown, determine the force acting on member *ABC* (*a*) at *B*, (*b*) at *C*.

SOLUTION

FBD ABC:



Note: *BD* is two-force member

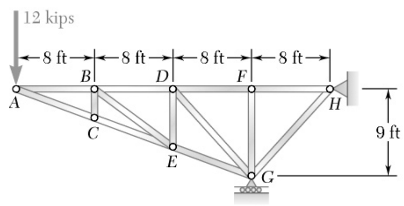
(*a*) $$\circlearrowleft \Sigma M_C = 0: (0.09 \text{ m})(200 \text{ N}) - (2.4 \text{ m})\left(\frac{3}{5}F_{BD}\right) = 0$$

$$\mathbf{F}_{BD} = 125.0 \text{ N} \searrow 36.9° \blacktriangleleft$$

(*b*) $$\rightarrow \Sigma F_x = 0: 200 \text{ N} - \frac{4}{5}(125 \text{ N}) - C_x = 0 \qquad \mathbf{C}_x = 100 \text{ N} \leftarrow$$

$$\uparrow \Sigma F_y = 0: \frac{3}{5}F_{BD} - C_y = 0 \qquad \mathbf{C}_y = \frac{3}{5}(125 \text{ N}) = 75 \text{ N} \downarrow$$

$$\mathbf{C} = 125.0 \text{ N} \swarrow 36.9° \blacktriangleleft$$



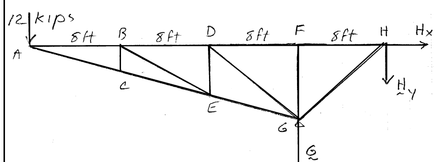
PROBLEM 6.157

Determine the force in each member of the truss shown. State whether each member is in tension or compression.

SOLUTION

$$\xrightarrow{} \Sigma F_x = 0: H_x = 0$$

FBD Truss:



$$\circlearrowleft \Sigma M_H = 0: (32 \text{ ft})(12 \text{ kips}) - (8 \text{ ft})G = 0 \qquad \mathbf{G} = 48 \text{ kips} \uparrow$$

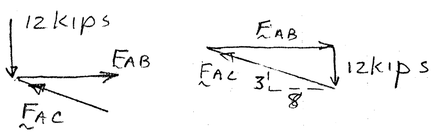
$$\uparrow \Sigma F_y = 0: \ -12 \text{ kips} + G - H_y = 0$$

$$H_y = 48 \text{ kips} - 12 \text{ kips} = 36 \text{ kips} \qquad \mathbf{H}_y = 36 \text{ kips} \downarrow$$

FBD joint A:

$$\frac{12 \text{ kips}}{3} = \frac{F_{AB}}{8} = \frac{F_{AC}}{\sqrt{73}}$$

so $F_{AB} = 32.0 \text{ kips T}$ ◀



$F_{AC} = 4\sqrt{73}$ kips; $F_{AC} = 34.2 \text{ kips C}$ ◀

By inspection of joint C: $F_{BC} = 0$ ◀

$F_{CE} = 34.2 \text{ kips C}$ ◀

Then by inspection of joint B: $F_{BE} = 0$ ◀

$F_{BD} = 32.0 \text{ kips T}$ ◀

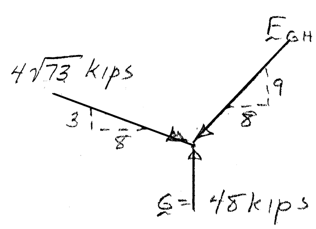
Then by inspection of joint E: $F_{DE} = 0$ ◀

$F_{EG} = 34.2 \text{ kips C}$ ◀

Then by inspection of joint D: $F_{DG} = 0$ ◀

FBD joint G:

$F_{DF} = 32.0 \text{ kips T}$ ◀



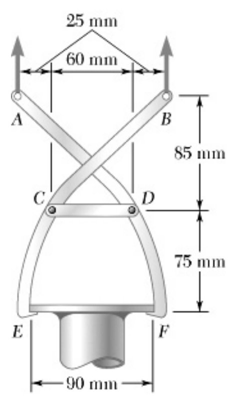
By inspection of joint F: $F_{FG} = 0$ ◀

$F_{FH} = 32.0 \text{ kips T}$ ◀

$$\xrightarrow{} \Sigma F_x = 0: \ \frac{8}{\sqrt{73}}\left(4\sqrt{73} \text{ kips}\right) - \frac{8}{\sqrt{145}} F_{GH} = 0$$

$F_{GH} = 4\sqrt{145}$ kips $\qquad F_{GH} = 48.2 \text{ kips C}$ ◀

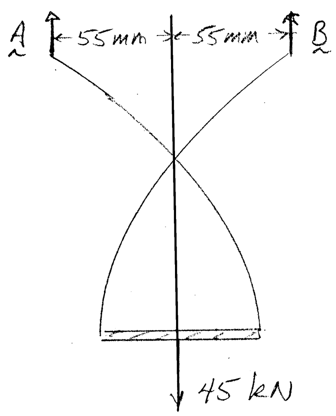
PROBLEM 6.158



The tongs shown are used to apply a total upward force of 45 kN on a pipe cap. Determine the forces exerted at *D* and *F* on tong *ADF*.

SOLUTION

FBD whole:

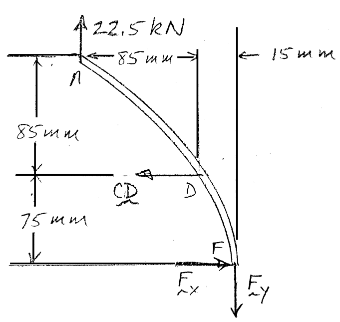


By symmetry $\mathbf{A} = \mathbf{B} = 22.5 \text{ kN} \uparrow$

$$\circlearrowleft \Sigma M_F = 0: (75 \text{ mm})CD - (100 \text{ mm})(22.5 \text{ kN}) = 0$$

$$\mathbf{CD} = 30 \text{ kN} \longleftarrow \blacktriangleleft$$

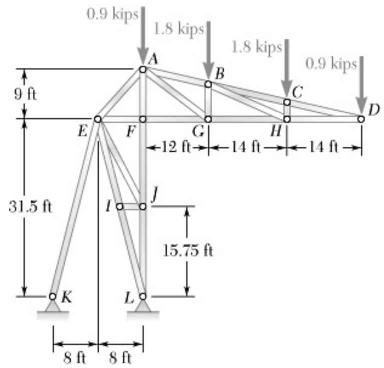
FBD ADF:



$$\longrightarrow \Sigma F_x = 0: F_x - CD = 0 \qquad F_x = CD = 30 \text{ kN}$$

$$\uparrow \Sigma F_y = 0: 22.5 \text{ kN} - F_y = 0 \qquad F_y = 22.5 \text{ kN}$$

$$\text{so } \mathbf{F} = 37.5 \text{ kN} \searrow 36.9° \blacktriangleleft$$

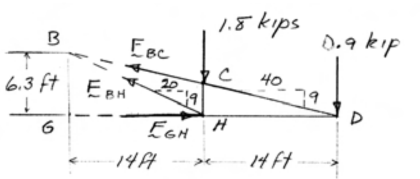


PROBLEM 6.159

A stadium roof truss is loaded as shown. Determine the force in members *BC*, *BH*, and *GH*.

SOLUTION

FBD Section:



$$\circlearrowleft \Sigma M_B = 0: (6.3 \text{ ft})F_{GH} - (14 \text{ ft})(1.8 \text{ kips}) - (28 \text{ ft})(0.9 \text{ kip}) = 0$$

$$F_{GH} = 8.00 \text{ kips C} \blacktriangleleft$$

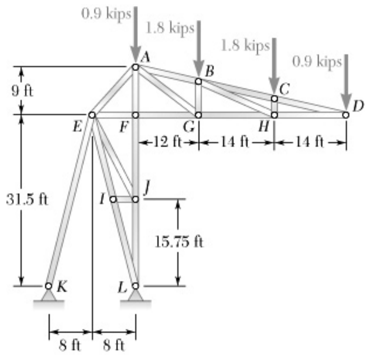
$$\circlearrowleft \Sigma M_H = 0: (3.15 \text{ ft})\left(\frac{40}{41}F_{BC}\right) - (14 \text{ ft})(0.9 \text{ kip}) = 0$$

$$F_{BC} = 4.10 \text{ kips T} \blacktriangleleft$$

$$\uparrow \Sigma F_Y = 0: \frac{9}{41}F_{BC} - 1.8 \text{ kips} - 0.9 \text{ kip} + \frac{9}{21.93}F_{BH} = 0$$

$$F_{BH} = \frac{21.93}{9}\left[2.7 \text{ kips} - \frac{9}{41}(4.10 \text{ kips})\right] = 4.386 \text{ kips}$$

$$F_{BH} = 4.39 \text{ kips T} \blacktriangleleft$$

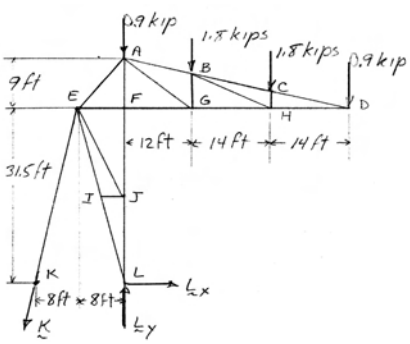


PROBLEM 6.160

A stadium roof truss is loaded as shown. Determine the force in members *EJ*, *FJ*, and *EI*.

SOLUTION

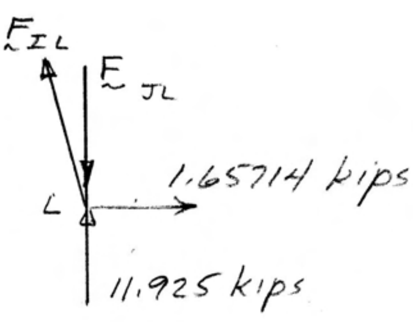
FBD Truss:



$$\Sigma M_K = 0:\ (16\text{ ft})(L_y - 0.9\text{ kip})$$
$$-(28\text{ ft})(1.8\text{ kips})$$
$$-(42\text{ ft})(1.8\text{ kips})$$
$$-(56\text{ ft})(0.9\text{ kip}) = 0$$
$$L_y = 11.925\text{ kips}$$

$$\Sigma M_E = 0:\ (8\text{ ft})(11.925\text{ kips} - 0.9\text{ kip})$$
$$-(20\text{ ft})(1.8\text{ kips}) - (34\text{ ft})(1.8\text{ kips})$$
$$-(48\text{ ft})(0.9\text{ kip}) + (31.5\text{ ft})L_x = 0$$
$$L_x = 1.65714\text{ kips}$$

Joint L:



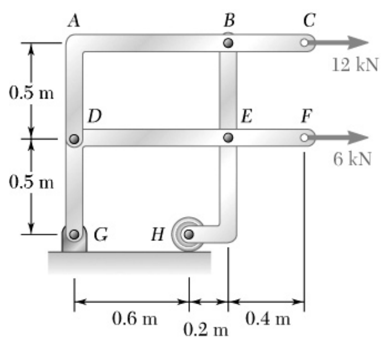
$$\rightarrow \Sigma F_x = 0:\ -\frac{8}{32.5}F_{IL} + 1.65714\text{ kips} = 0$$
$$F_{IL} = 6.7321\text{ kips}$$

$$\uparrow \Sigma F_y = 0:\ \frac{31.5}{32.5}(6.7321\text{ kips}) + 11.925\text{ kips}$$
$$-F_{JL} = 0$$
$$F_{JL} = 18.4500\text{ kips}$$

By inspection of joint I, $F_{IJ} = 0$ *and* $F_{EI} = F_{IL} = 6.73\text{ kips}$ T ◀

Then by inspection of joint J, $F_{EJ} = 0$ ◀

and $F_{FJ} = F_{JL} = 18.45\text{ kips}$ C ◀

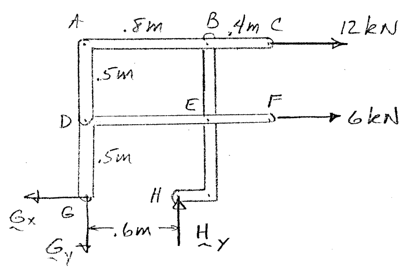


PROBLEM 6.161

For the frame and loading shown, determine the components of the forces acting on member *DABC* at *B* and at *D*.

SOLUTION

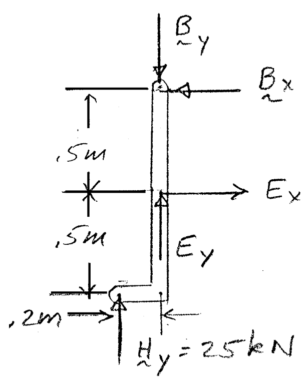
FBD Frame:



$$\circlearrowleft \Sigma M_G = 0: (0.6 \text{ m})H_y - (0.5 \text{ m})6 \text{ kN} - (1.0 \text{ m})(12 \text{ kN}) = 0$$

$$\mathbf{H}_y = 25 \text{ kN} \uparrow$$

FBD BEH:



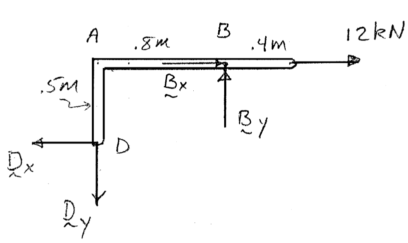
$$\circlearrowleft \Sigma M_E = 0: (0.5 \text{ m})B_x - (0.2 \text{ m})(25 \text{ kN}) = 0$$

$$B_x = 10 \text{ kN}$$

$$\text{on } DABC \quad \mathbf{B}_x = 10.00 \text{ kN} \longrightarrow \blacktriangleleft$$

$$\rightarrow \Sigma F_x = 0: \ -D_x + B_x + 12 \text{ kN} = 0$$

FBD DABC:



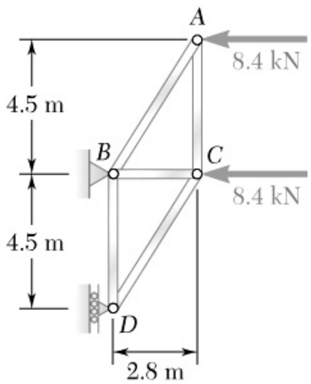
$$D_x = (10 \text{ kN} + 12 \text{ kN}) = 22 \text{ kN} \qquad \mathbf{D}_x = 22.0 \text{ kN} \longleftarrow \blacktriangleleft$$

$$\circlearrowleft \Sigma M_B = 0: (0.8 \text{ m})D_y - (0.5 \text{ m})D_x = 0$$

$$D_y = 13.75 \text{ kN} \qquad \mathbf{D}_y = 13.75 \text{ kN} \downarrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: B_y - D_y = 0$$

$$B_y = 13.75 \text{ kN} \qquad \mathbf{B}_y = 13.75 \text{ kN} \uparrow \blacktriangleleft$$



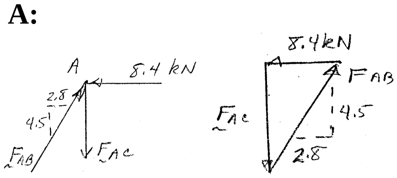
PROBLEM 6.162

Using the method of joints, determine the force in each member of the truss shown. State whether each member is in tension or compression.

SOLUTION

Joint FBDs:

A:

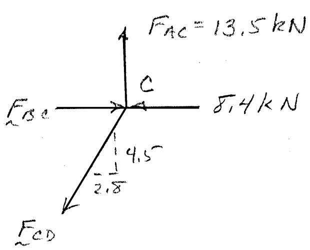


$$\frac{8.4 \text{ kN}}{2.8} = \frac{F_{AC}}{4.5} = \frac{F_{AB}}{5.3}$$

$F_{AB} = 15.90 \text{ kN C}$ ◀

$F_{AC} = 13.50 \text{ kN T}$ ◀

C:



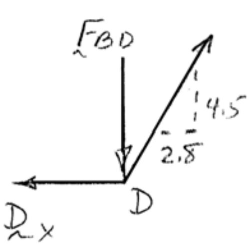
$$\uparrow \Sigma F_y = 0: 13.5 \text{ kN} - \frac{4.5}{5.3} F_{CD} = 0$$

$F_{CD} = 15.90 \text{ kN T}$ ◀

$$\longrightarrow \Sigma F_y = 0: F_{BC} - \frac{2.8}{5.3}(15.9 \text{ kN}) - 8.4 \text{ kN} = 0$$

$F_{BC} = 16.80 \text{ kN C}$ ◀

D:



$$\uparrow \Sigma F_y = 0: \frac{4.5}{5.3}(15.9 \text{ kN}) - F_{BD} = 0$$

$F_{BD} = 13.50 \text{ kN C}$ ◀