Solution Manual for Engineering Mechanics Statics and Dynamics 14th Edition by Hibbeler ISBN 0133915425 9780133915426

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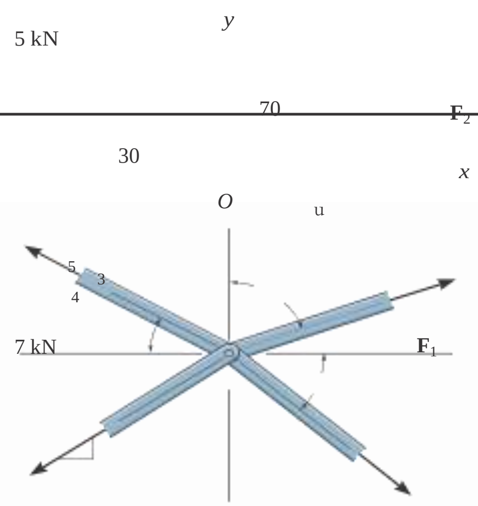
3–1.

The members of a truss are pin connected at joint *O*. Determine the magnitudes of $\mathbf{F}_1$ and $\mathbf{F}_2$ for equilibrium. Set $u = 60°$.



SOLUTION

$\xrightarrow{+} \Sigma F_x = 0; \quad F_2 \sin 70° + F_1 \cos 60° - 5 \cos 30° - \frac{4}{5}(7) = 0$

$0.9397F_2 + 0.5F_1 = 9.930$

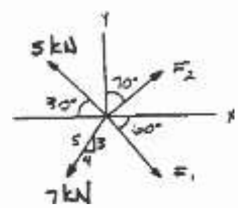
$+\uparrow \Sigma F_y = 0; \quad F_2 \cos 70° + 5 \sin 30° - F_1 \sin 60° - \frac{3}{5}(7) = 0$

$0.3420F_2 - 0.8660F_1 = 1.7$

Solving:

$F_2 = 9.60 \text{ kN}$ **Ans.**

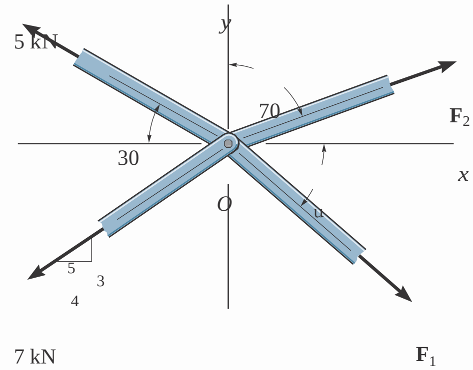
$F_1 = 1.83 \text{ kN}$ **Ans.**



Ans:
$F_2 = 9.60$ kN
$F_1 = 1.83$ kN

3–2.

The members of a truss are pin connected at joint *O*. Determine the magnitude of $\mathbf{F}_1$ and its angle θ for equilibrium. Set $F_2 = 6$ kN.



SOLUTION

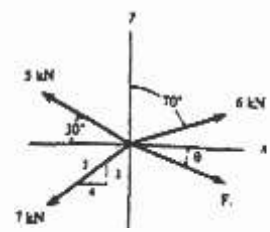
$\stackrel{+}{\rightarrow} \Sigma F_x = 0;$ $\quad 6 \sin 70° + F_1 \cos\theta - 5 \cos 30° - \frac{4}{5}(7) = 0$

$F_1 \cos\theta = 4.2920$

$+\uparrow \Sigma F_y = 0;$ $\quad 6 \cos 70° + 5 \sin 30° - F_1 \sin\theta - \frac{3}{5}(7) = 0$

$F_1 \sin\theta = 0.3521$

Solving:



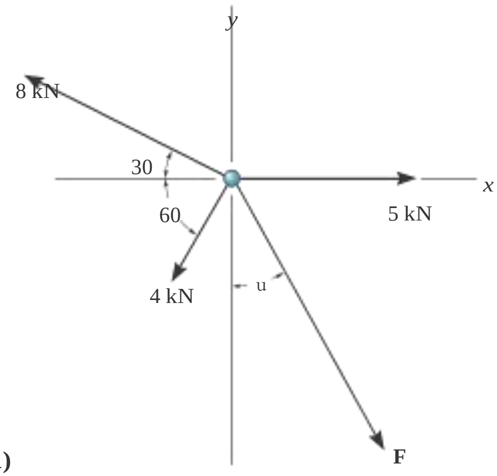
$\theta = 4.69°$ **Ans.**

$F_1 = 4.31$ kN **Ans.**

Ans:
u = 4.69°
F_1 = 4.31 kN

3–3.

Determine the magnitude and direction θ of **F** so that the particle is in equilibrium.



Solution

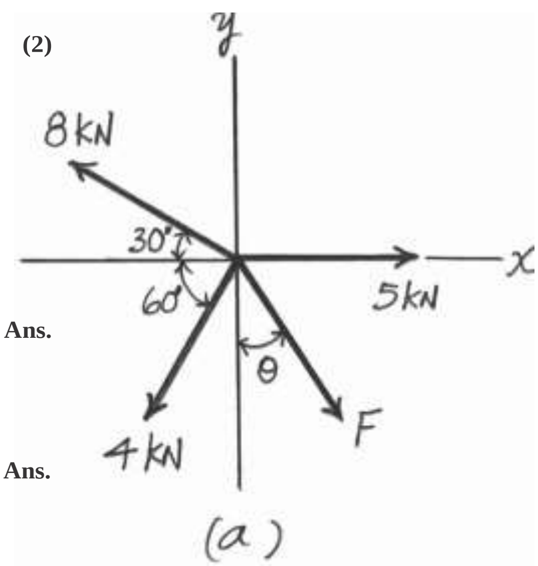
Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$\xrightarrow{+} \Sigma F_x = 0; \quad F \sin\theta + 5 - 4\cos 60° - 8\cos 30° = 0$

$$F \sin\theta = 3.9282 \quad (1)$$

$+\uparrow \Sigma F_y = 0; \quad 8\sin 30° - 4\sin 60° - F\cos\theta = 0$

$$F\cos\theta = 0.5359 \quad (2)$$



Divide Eq (1) by (2),

$$\frac{\sin\theta}{\cos\theta} = 7.3301$$

Realizing that $\tan\theta = \frac{\sin\theta}{\cos\theta}$, then

$$\tan\theta = 7.3301$$

$$\theta = 82.23° = 82.2° \quad \textbf{Ans.}$$

Substitute this result into Eq. (1),

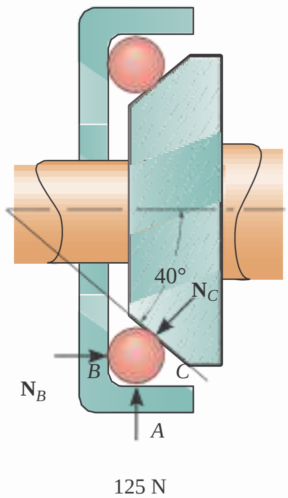
$$F \sin 82.23° = 3.9282$$

$$F = 3.9646\text{ kN} = 3.96\text{ kN} \quad \textbf{Ans.}$$

Ans:
$\theta = 82.2°$

$F = 3.96\text{ kN}$

***3–4.**



The bearing consists of rollers, symmetrically confined within the housing. The bottom one is subjected to a 125-N force at its contact A due to the load on the shaft. Determine the normal reactions N_B and N_C on the bearing at its contact points B and C for equilibrium.

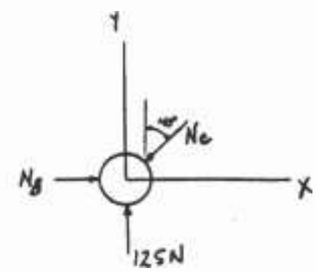
SOLUTION

$+\uparrow \Sigma F_y = 0; \quad 125 - N_C \cos 40° = 0$

$N_C = 163.176 = 163 \text{ N}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad N_B - 163.176 \sin 40° = 0$

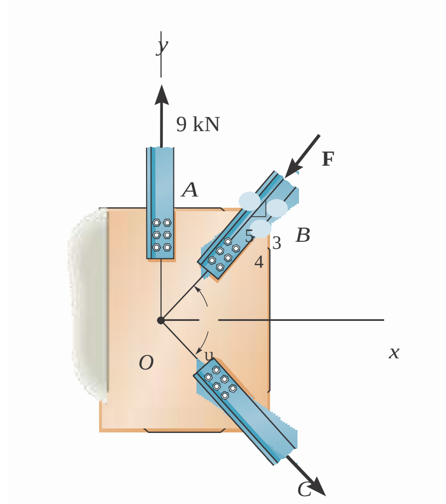
$N_B = 105 \text{ N}$ **Ans.**



Ans:
$N_C = 163$ N
$N_B = 105$ N

3–5.

The members of a truss are connected to the gusset plate. If the forces are concurrent at point O, determine the magnitudes of **F** and **T** for equilibrium. Take $\theta = 90°$.



SOLUTION

$$\phi = 90° - \tan^{-1}\left(\frac{3}{4}\right) = 53.13°$$

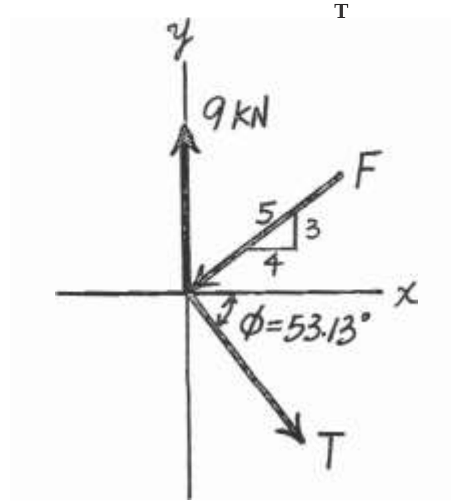
$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad T \cos 53.13° - F\left(\frac{4}{5}\right) = 0$$

$$+\uparrow \Sigma F_y = 0; \qquad 9 - T \sin 53.13° - F\left(\frac{3}{5}\right) = 0$$

Solving,

$$T = 7.20 \text{ kN} \qquad \textbf{Ans.}$$

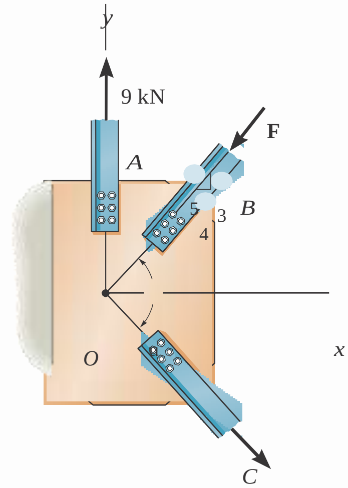
$$F = 5.40 \text{ kN} \qquad \textbf{Ans.}$$



Ans:
$T = 7.20$ kN
$F = 5.40$ kN

3–6.

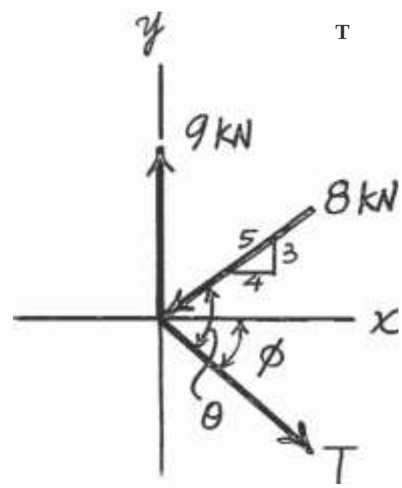
The gusset plate is subjected to the forces of three members. Determine the tension force in member *C* and its angle θ for equilibrium. The forces are concurrent at point *O*. Take $F = 8$ kN.



SOLUTION

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad T\cos\phi - 8\left(\frac{4}{5}\right) = 0 \qquad \textbf{(1)}$$

$$+\uparrow \Sigma F_y = 0; \qquad 9 - 8\left(\frac{3}{5}\right) - T\sin\phi = 0 \qquad \textbf{(2)}$$



Rearrange then divide Eq. (1) into Eq. (2):

$$\tan\phi = 0.656, \quad \phi = 33.27°$$

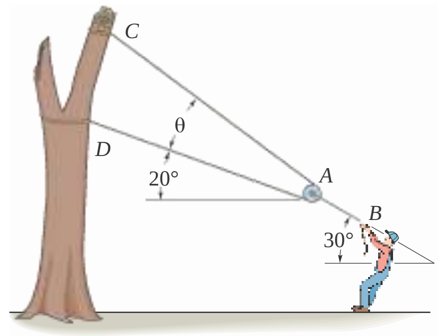
$$T = 7.66 \text{ kN} \qquad \textbf{Ans.}$$

$$\theta = \phi + \tan^{-1}\left(\frac{3}{4}\right) = 70.1° \qquad \textbf{Ans.}$$

Ans:
$T = 7.66$ kN
u = 70.1°

3–7.

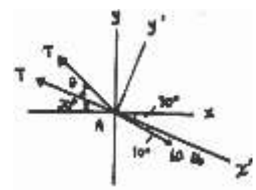
The man attempts to pull down the tree using the cable and *small* pulley arrangement shown. If the tension in *AB* is 60 lb, determine the tension in cable *CAD* and the angle θ which the cable makes at the pulley.



SOLUTION

$+\searrow \Sigma F_{x'} = 0; \qquad 60 \cos 10° - T - T\cos\theta = 0$

$+\nearrow \Sigma F_{y'} = 0; \qquad T \sin\theta - 60 \sin 10° = 0$



Thus,

$$T(1 + \cos\theta) = 60 \cos 10°$$

$$T\left(2\cos^2 \frac{\theta}{2}\right) = 60 \cos 10° \qquad \textbf{(1)}$$

$$2T \sin\frac{\theta}{2} \cos\frac{\theta}{2} = 60 \sin 10° \qquad \textbf{(2)}$$

Divide Eq.(2) by Eq.(1)

$$\tan\frac{\theta}{2} = \tan 10°$$

$\theta = 20°$ **Ans.**

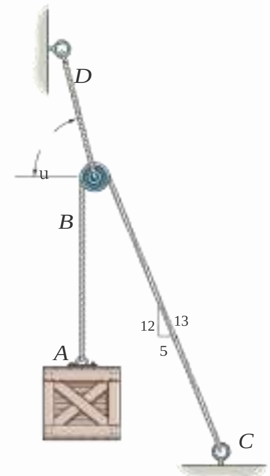
$T = 30.5$ lb **Ans.**

Ans:

u = 20°
T = 30.5 lb

***3–8.**

The cords ABC and BD can each support a maximum load of 100 lb. Determine the maximum weight of the crate, and the angle θ for equilibrium.



Solution

Equations of Equilibrium. Assume that for equilibrium, the tension along the length of rope ABC is constant. Assuming that the tension in cable BD reaches the limit first. Then, $T_{BD} = 100$ lb. Referring to the FBD shown in Fig. a,

$$\xrightarrow{+} \Sigma F_x = 0; \qquad W\left(\frac{5}{13}\right) - 100\cos\theta = 0$$

$$100\cos\theta = \frac{5W}{13} \qquad \textbf{(1)}$$

$$+\uparrow \Sigma F_y = 0; \qquad 100\sin\theta - W - W\left(\frac{12}{13}\right) = 0$$

$$100\sin\theta = \frac{25}{13}W \qquad \textbf{(2)}$$

Divide Eq. (2) by (1),

$$\frac{\sin\theta}{\cos\theta} = 5$$

Realizing that $\tan\theta = \dfrac{\sin\theta}{\cos\theta}$,

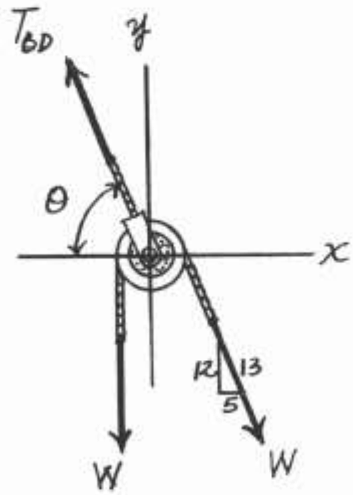
$$\tan\theta = 5$$

$$\theta = 78.69° = 78.7° \qquad \textbf{Ans.}$$

Substitute this result into Eq. (1),

$$100\cos 78.69° = \frac{5}{13}W$$

$$W = 50.99 \text{ lb} = 51.0 \text{ lb} < 100 \text{ lb} \quad \textbf{(O.K)} \qquad \textbf{Ans.}$$



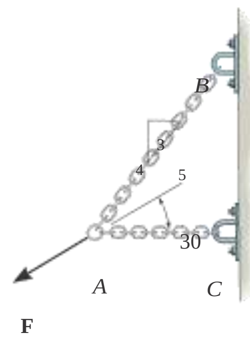
(a)

Ans:
$\theta = 78.7°$

$W = 51.0$ lb

3–9.

Determine the maximum force **F** that can be supported in the position shown if each chain can support a maximum tension of 600 lb before it fails.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

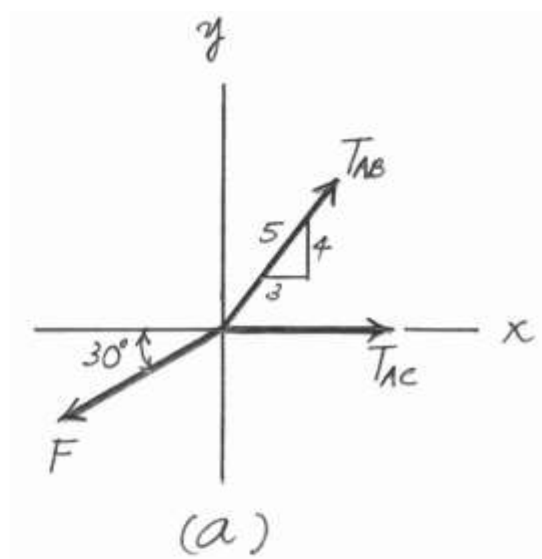
$$+\uparrow\Sigma F_y = 0; \qquad T_{AB}\left(\frac{4}{5}\right) - F\sin 30° = 0 \qquad T_{AB} = 0.625\,F$$

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad T_{AC} + 0.625\,F\left(\frac{3}{5}\right) - F\cos 30° = 0 \qquad T_{AC} = 0.4910\,F$$

Since chain *AB* is subjected to a higher tension, its tension will reach the limit first. Thus,

$$T_{AB} = 600; \qquad 0.625\,F = 600$$

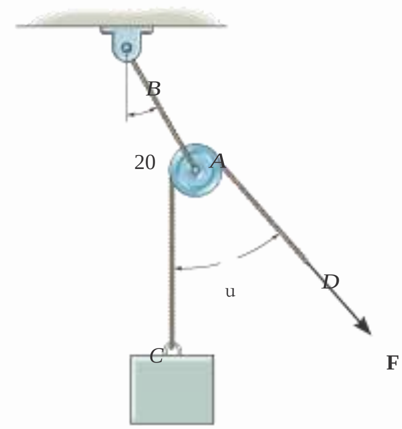
$$F = 960\text{ lb}$$ **Ans.**



Ans:
$F = 960$ lb

3–10.

The block has a weight of 20 lb and is being hoisted at uniform velocity. Determine the angle u for equilibrium and the force in cord *AB*.



Solution

Equations of Equilibrium. Assume that for equilibrium, the tension along the length of cord *CAD* is constant. Thus, $F = 20$ lb. Referring to the *FBD* shown in Fig. *a*,

$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 20 \sin u - T_{AB} \sin 20° = 0$

$$T_{AB} = \frac{20 \sin u}{\sin 20°} \qquad \textbf{(1)}$$

$+c\Sigma F_y = 0; \qquad T_{AB} \cos 20° - 20 \cos u - 20 = 0 \qquad \textbf{(2)}$

Substitute Eq (1) into (2),

$$\frac{20 \sin u}{\sin 20°} \cos 20° - 20 \cos u = 20$$

$$\sin u \cos 20° - \cos u \sin 20° = \sin 20°$$

Realizing that $\sin (u - 20°) = \sin u \cos 20° - \cos u \sin 20°$, then

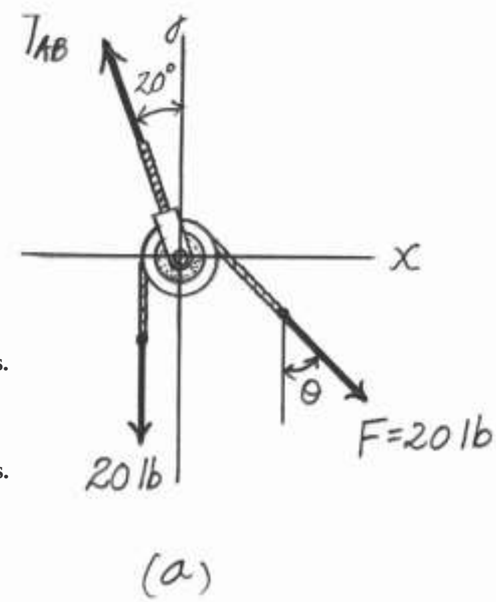
$$\sin (u - 20°) = \sin 20°$$

$$u - 20° = 20°$$

$$u = 40° \qquad \textbf{Ans.}$$

Substitute this result into Eq (1)

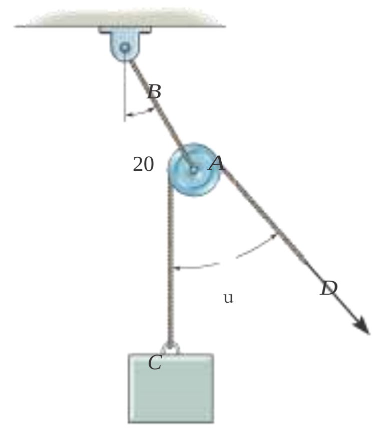
$$T_{AB} = \frac{20 \sin 40°}{\sin 20°} = 37.59 \text{ lb} = 37.6 \text{ lb} \qquad \textbf{Ans.}$$



Ans:
u = 40°
T_{AB} = 37.6 lb

3–11.

Determine the maximum weight W of the block that can be suspended in the position shown if cords AB and CAD can each support a maximum tension of 80 lb. Also, what is the angle θ for equilibrium?



Solution

Equations of Equilibrium. Assume that for equilibrium, the tension along the length of cord CAD is constant. Thus, $F = W$. Assuming that the tension in cord AB reaches the limit first, then $T_{AB} = 80$ lb. Referring to the FBD shown in Fig. a,

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad W \sin \theta - 80 \sin 20° = 0$

$$W = \frac{80 \sin 20°}{\sin \theta} \qquad \textbf{(1)}$$

$+\uparrow \Sigma F_y = 0; \quad 80 \cos 20° - W - W \cos \theta = 0$

$$W = \frac{80 \cos 20°}{1 + \cos \theta} \qquad \textbf{(2)}$$

Equating Eqs (1) and (2),

$$\frac{80 \sin 20°}{\sin \theta} = \frac{80 \cos 20°}{1 + \cos \theta}$$

$$\sin \theta \cos 20° - \cos \theta \sin 20° = \sin 20°$$

Realizing then $\sin(\theta - 20°) = \sin \theta \cos 20° - \cos \theta \sin 20°$, then

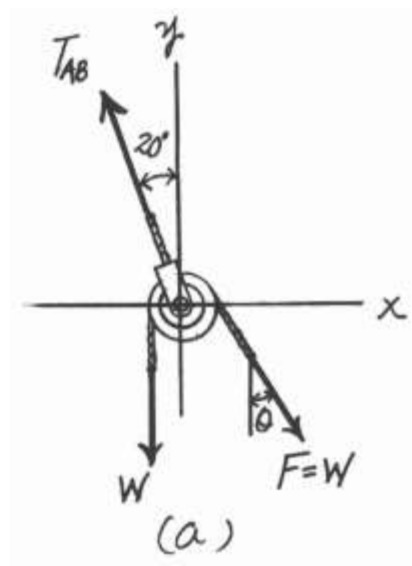
$$\sin(\theta - 20°) = \sin 20°$$

$$\theta - 20° = 20°$$

$$\theta = 40° \qquad \textbf{Ans.}$$

Substitute this result into Eq (1)

$$W = \frac{80 \sin 20°}{\sin 40°} = 42.56 \text{ lb} = 42.6 \text{ lb} < 80 \text{ lb} \quad \textbf{(O.K)} \qquad \textbf{Ans.}$$

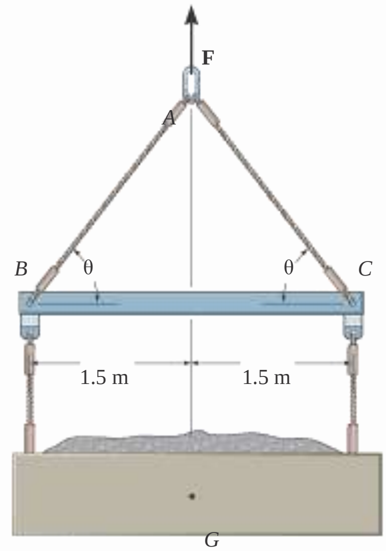


Ans:

u = 40°
W = 42.6 lb

***3–12.**

The lift sling is used to hoist a container having a mass of 500 kg. Determine the force in each of the cables *AB* and *AC* as a function of θ. If the maximum tension allowed in each cable is 5 kN, determine the shortest lengths of cables *AB* and *AC* that can be used for the lift. The center of gravity of the container is located at *G*.



SOLUTION

Free-Body Diagram: By observation, the force $\mathbf{F}_1$ has to support the entire weight

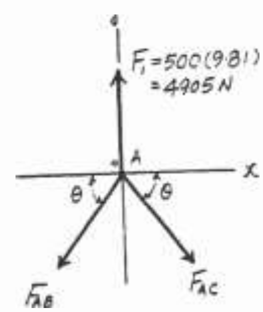
Equations of Equilibrium:

$\xrightarrow{+} \Sigma F_x = 0; \quad F_{AC} \cos\theta - F_{AB} \cos\theta = 0 \quad F_{AC} = F_{AB} = F$

$+\uparrow \Sigma F_y = 0; \quad 4905 - 2F \sin\theta = 0 \quad F = \{2452.5 \cos\theta\}\ \text{N}$

Thus,

$$F_{AC} = F_{AB} = F = \{52.45 \cos\theta\}\ \text{kN}$$ **Ans.**



If the maximum allowable tension in the cable is 5 kN, then

$$2452.5 \cos\theta = 5000$$

$$\theta = 29.37°$$

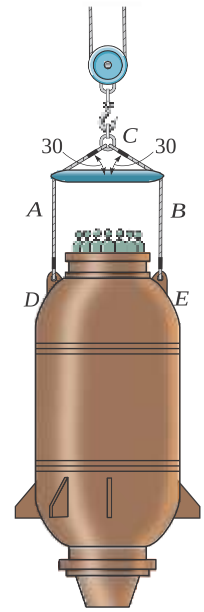
From the geometry, $l = \dfrac{1.5}{\cos\theta}$ and $\theta = 29.37°$. Therefore

$$l = \frac{1.5}{\cos 29.37°} = 1.72\ \text{m}$$ **Ans.**

Ans:
$F_{AC} = \{2.45 \cos \theta\}$ kN
$l = 1.72$ m

3–13.

A nuclear-reactor vessel has a weight of $500(10^3)$ lb. Determine the horizontal compressive force that the spreader bar AB exerts on point A and the force that each cable segment CA and AD exert on this point while the vessel is hoisted upward at constant velocity.



Solution

At point C:

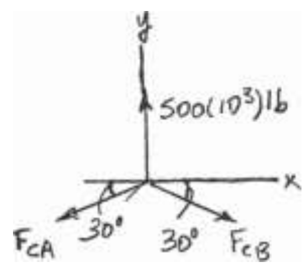
$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{CB} \cos 30° - F_{CA} \cos 30° = 0$

$F_{CB} = F_{CA}$

$+\uparrow \Sigma F_y = 0;$ $\quad 500(10^3) - F_{CA} \sin 30° - F_{CB} \sin 30° = 0$

$500(10^3) - 2F_{CA} \sin 30° = 0$

$F_{CA} = 500(10^3)$ lb **Ans.**



At point A:

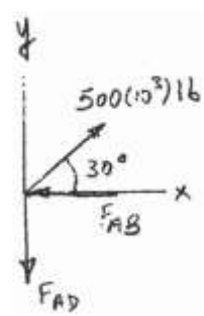
$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 500(10^3) \cos 30° - F_{AB} = 0$

$F_{AB} = 433(10^3)$ lb **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 500(10^3) \sin 30° - F_{AD} = 0$

$F_{AD} = 500(10^3) \sin 30°$

$F_{AD} = 250(10^3)$ lb **Ans.**

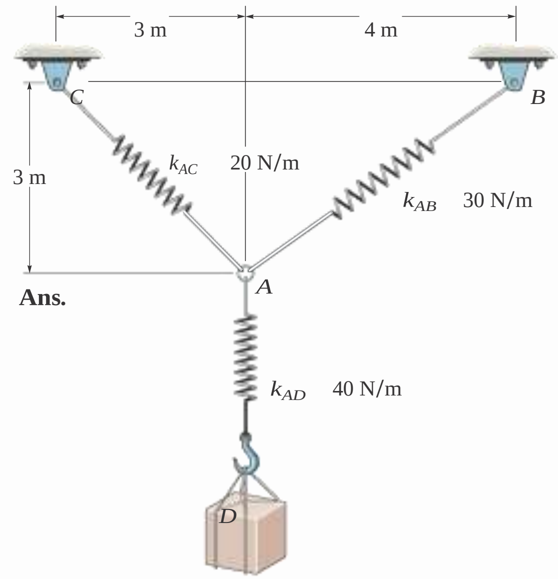


Ans:
$F_{CA} = 500(10^3)$ lb

$F_{AB} = 433(10^3)$ lb
$F_{AD} = 250(10^3)$ lb

3–14.

Determine the stretch in each spring for equlibrium of the 2-kg block. The springs are shown in the equilibrium position.



SOLUTION

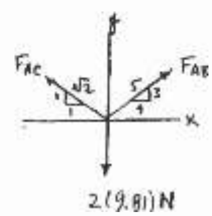
$F_{AD} = 2(9.81) = x_{AD}(40) \quad x_{AD} = 0.4905 \text{ m}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AB}\left(\frac{4}{5}\right) - F_{AC}\left(\frac{1}{\sqrt{2}}\right) = 0$

$+\uparrow \Sigma F_y = 0; \qquad F_{AC}\left(\frac{1}{\sqrt{2}}\right) + F_{AB}\left(\frac{3}{5}\right) - 2(9.81) = 0$

$F_{AC} = 15.86 \text{ N}$

$x_{AC} = \frac{15.86}{20} = 0.793 \text{ m}$ **Ans.**



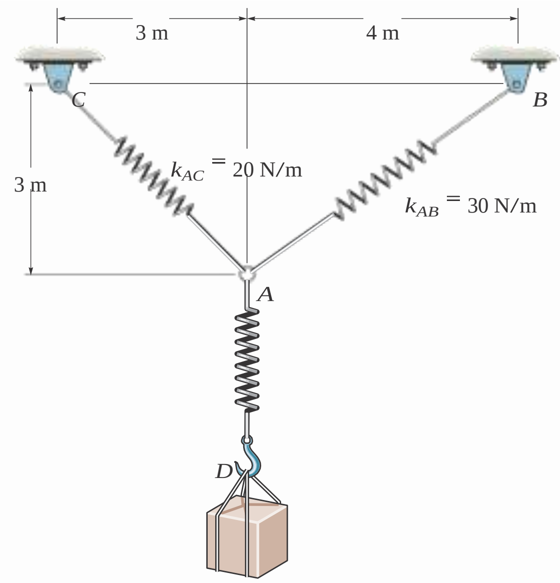
$F_{AB} = 14.01 \text{ N}$

$x_{AB} = \frac{14.01}{30} = 0.467 \text{ m}$ **Ans.**

Ans:
x_{AD} = 0.4905 m
x_{AC} = 0.793 m
x_{AB} = 0.467 m

3–15.

The unstretched length of spring AB is 3 m. If the block is held in the equilibrium position shown, determine the mass of the block at D.



SOLUTION

$F = kx = 30(5 - 3) = 60\text{ N}$

$\stackrel{+}{\rightarrow} \Sigma F_x = 0; \qquad T\cos 45° - 60\left(\frac{4}{5}\right) = 0$

$T = 67.88\text{ N}$

$+\uparrow \Sigma F_y = 0; \qquad -W + 67.88\sin 45° + 60\left(\frac{3}{5}\right) = 0$

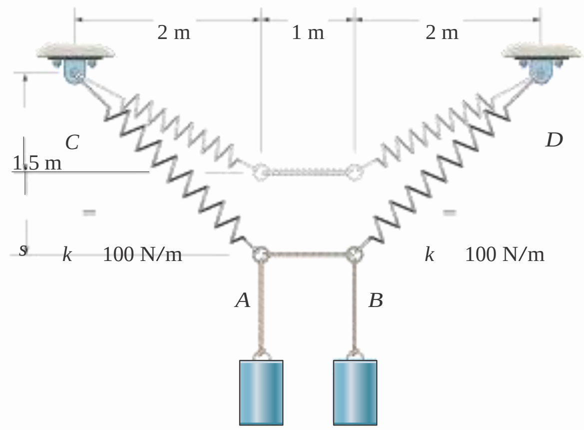
$W = 84\text{ N}$

$m = \frac{84}{9.81} = 8.56\text{ kg}$ **Ans.**

Ans:
$m = 8.56$ kg

***3–16.**

Determine the mass of each of the two cylinders if they cause a sag of $s = 0.5$ m when suspended from the rings at A and B. Note that $s = 0$ when the cylinders are removed.

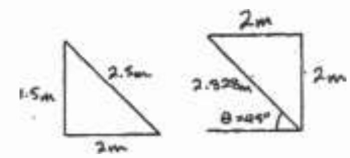


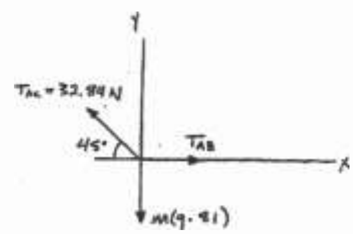
SOLUTION

$T_{AC} = 100 \text{ N/m } (2.828 - 2.5) = 32.84 \text{ N}$

$+\uparrow \Sigma F_y = 0; \quad 32.84 \sin 45° - m(9.81) = 0$

$m = 2.37 \text{ kg}$ **Ans.**

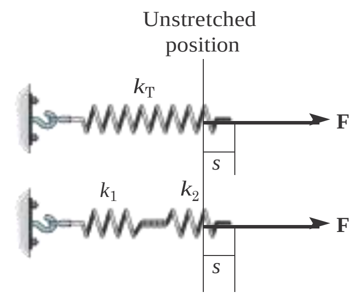




Ans:
$m = 2.37$ kg

3–17.

Determine the stiffness k_T of the single spring such that the force **F** will stretch it by the same amount s as the force **F** stretches the two springs. Express k_T in terms of stiffness k_1 and k_2 of the two springs.



Solution

$$F = ks$$

$$s = s_1 + s_2$$

$$s = \frac{F}{k_T} = \frac{F}{k_1} + \frac{F}{k_2}$$

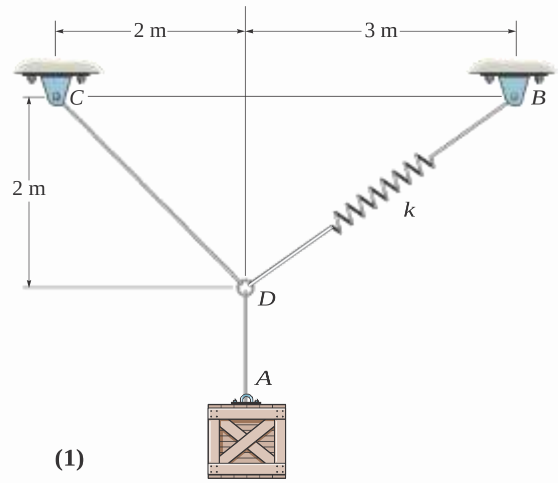
$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2}$$ **Ans.**

Ans:

$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2}$$

3–18.

If the spring DB has an unstretched length of 2 m, determine the stiffness of the spring to hold the 40-kg crate in the position shown.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad T_{BD}\left(\frac{3}{\sqrt{13}}\right) - T_{CD}\left(\frac{1}{\sqrt{2}}\right) = 0 \qquad \textbf{(1)}$$

$$+\uparrow\Sigma F_y = 0; \qquad T_{BD}\left(\frac{2}{\sqrt{13}}\right) + T_{CD}\left(\frac{1}{\sqrt{2}}\right) - 40(9.81) = 0 \qquad \textbf{(2)}$$

Solving Eqs (1) and (2)

$$T_{BD} = 282.96 \text{ N} \qquad T_{CD} = 332.96 \text{ N}$$

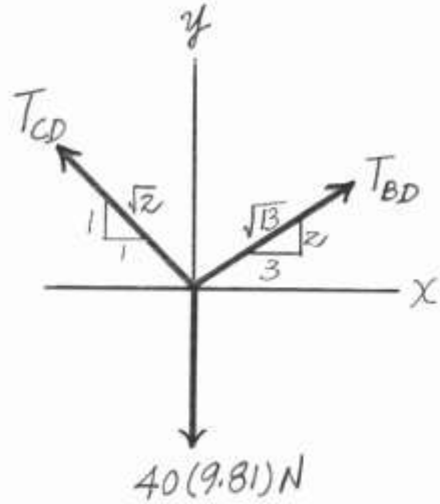
The stretched length of the spring is

$$l = \sqrt{3^2 + 2^2} = \sqrt{13} \text{ m}$$

Then, $x = l - l_0 = \left(\sqrt{13} - 2\right)$ m. Thus,

$$F_{sp} = kx; \qquad 282.96 = k\left(\sqrt{13} - 2\right)$$

$$k = 176.24 \text{ N/m} = 176 \text{ N/m} \qquad \textbf{Ans.}$$

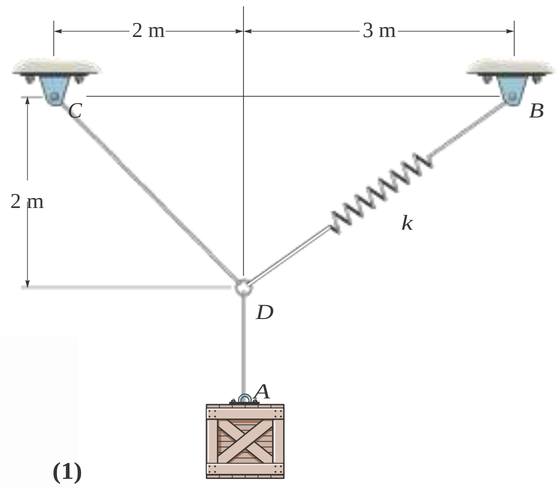


(a)

Ans:
$k = 176$ N/m

3–19.

Determine the unstretched length of *DB* to hold the 40-kg crate in the position shown. Take $k = 180$ N/m.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\xrightarrow{+} \Sigma F_x = 0; \qquad T_{BD}\left(\frac{3}{\sqrt{13}}\right) - T_{CD}\left(\frac{1}{\sqrt{2}}\right) = 0 \qquad \textbf{(1)}$$

$$+\uparrow \Sigma F_y = 0; \qquad T_{BD}\left(\frac{2}{\sqrt{13}}\right) + T_{CD}\left(\frac{1}{\sqrt{2}}\right) - 40(9.81) = 0 \qquad \textbf{(2)}$$

Solving Eqs (1) and (2)

$$T_{BD} = 282.96 \text{ N} \qquad T_{CD} = 332.96 \text{ N}$$

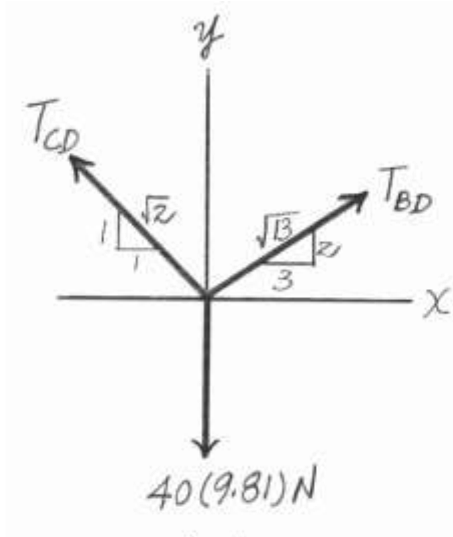
The stretched length of the spring is

$$l = \sqrt{3^2 + 2^2} = \sqrt{13} \text{ m}$$

Then, $x = l - l_0 = \sqrt{13} - l_0$. Thus

$$F_{sp} = kx; \qquad 282.96 = 180\left(\sqrt{13} - l_0\right)$$

$$l_0 = 2.034 \text{ m} = 2.03 \text{ m} \qquad \textbf{Ans.}$$



(a)

Ans:

$l_0 = 2.03 \text{ m}$

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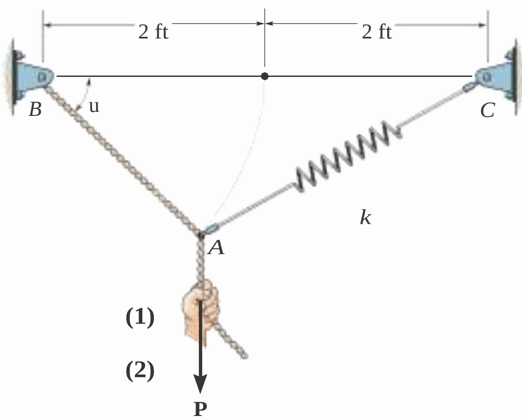
***3–20.**

A vertical force $P = 10$ lb is applied to the ends of the 2-ft cord AB and spring AC. If the spring has an unstretched length of 2 ft, determine the angle θ for equilibrium. Take $k = 15$ lb/ft.



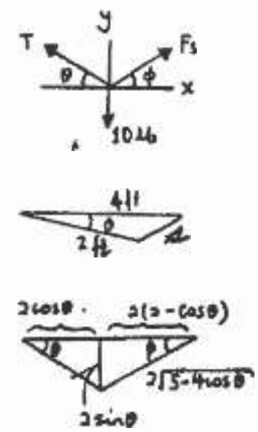
SOLUTION

$\stackrel{+}{\rightarrow}\Sigma F_x = 0; \qquad F_s \cos\phi - T\cos\theta = 0$ **(1)**

$+\uparrow\Sigma F_y = 0; \qquad T\sin\theta + F_s\sin\phi - 10 = 0$ **(2)**

$s = \sqrt{(4)^2 + (2)^2 - 2(4)(2)\cos\theta} - 2 = 2\sqrt{5 - 4\cos\theta} - 2$

$F_s = ks = 2k\left(\sqrt{5 - 4\cos\theta} - 1\right)$



From Eq. (1): $T = F_s\left(\dfrac{\cos\phi}{\cos\theta}\right)$

$$T = 2k\left(\sqrt{5 - 4\cos\theta} - 1\right)\left(\frac{2 - \cos\theta}{\sqrt{5 - 4\cos\theta}}\right)\left(\frac{1}{\cos\theta}\right)$$

From Eq. (2):

$$\frac{2k\left(\sqrt{5-4\cos\theta} - 1\right)(2 - \cos\theta)}{\sqrt{5 - 4\cos\theta}}\tan\theta + \frac{2k\left(\sqrt{5 - 4\cos\theta} - 1\right)2\sin\theta}{2\sqrt{5-4\cos\theta}} = 10$$

$$\frac{\left(\sqrt{5-4\cos\theta} - 1\right)}{\sqrt{5-4\cos\theta}}(2\tan\theta - \sin\theta + \sin\theta) = \frac{10}{2k}$$

$$\frac{\tan\theta\left(\sqrt{5-4\cos\theta} - 1\right)}{\sqrt{5-4\cos\theta}} = \frac{10}{4k}$$

Set $k = 15$ lb/ft

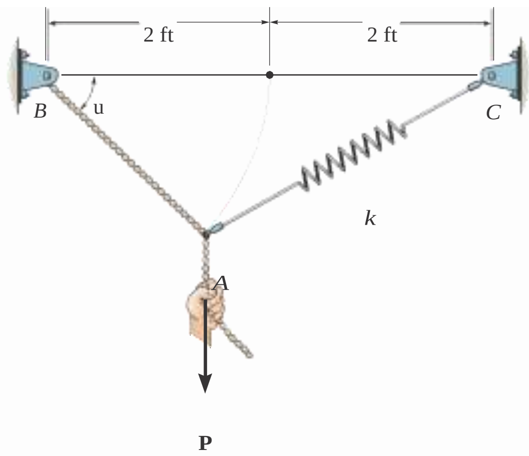
Solving for θ by trial and error,

$\theta = 35.0°$ **Ans.**

Ans:
$u = 35.0°$

3–21.

Determine the unstretched length of spring AC if a force $P = 80$ lb causes the angle $\theta = 60°$ for equilibrium. Cord AB is 2 ft long. Take $k = 50$ lb/ft.



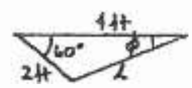
SOLUTION

$$l = \sqrt{4^2 + 2^2 - 2(2)(4)\cos 60°}$$

$$l = \sqrt{12}$$

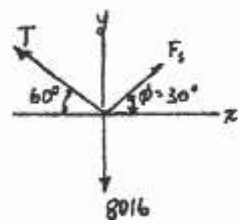
$$\frac{\sqrt{12}}{\sin 60°} = \frac{2}{\sin \phi}$$

$$\phi = \sin^{-1}\left(\frac{2\sin 60°}{\sqrt{12}}\right) = 30°$$



$+\uparrow \Sigma F_y = 0; \quad T\sin 60° + F_s \sin 30° - 80 = 0$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad -T\cos 60° + F_s \cos 30° = 0$



Solving for F_s,

$F_s = 40$ lb

$F_s = kx$

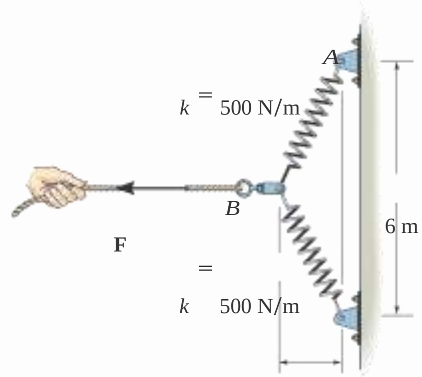
$40 = 50(\sqrt{12} - l')$

$$l' = \sqrt{12} - \frac{40}{50} = 2.66 \text{ ft}$$ **Ans.**

Ans:
$l = 2.66$ ft

3–22.

The springs BA and BC each have a stiffness of 500 N/m and an unstretched length of 3 m. Determine the horizontal force **F** applied to the cord which is attached to the small ring *B* so that the displacement of the ring from the wall is d = 1.5 m.

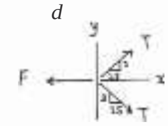


SOLUTION

$$\overset{+}{\leftarrow}\Sigma F_x = 0; \qquad \frac{1.5}{\sqrt{11.25}}(T)(2) - F = 0$$

$$T = ks = 500\left(\sqrt{3^2 + (1.5)^2} - 3\right) = 177.05\text{ N}$$

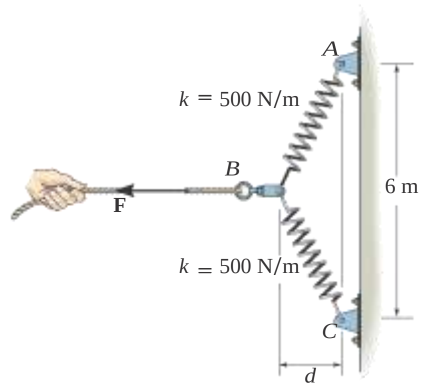
$$F = 158\text{ N}$$ **Ans.**



Ans:
$F = 158 \text{ N}$

3–23.

The springs *BA* and *BC* each have a stiffness of 500 N/m and an unstretched length of 3 m. Determine the displacement *d* of the cord from the wall when a force F = 175 N is applied to the cord.

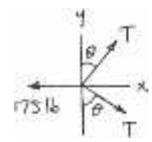


SOLUTION

$\overset{+}{\leftarrow} \Sigma F_x = 0; \qquad 175 = 2T\sin\theta$

$T\sin\theta = 87.5$

$T\left[\dfrac{d}{\sqrt{3^2 + d^2}}\right] = 87.5$



$T = ks = 500(\sqrt{3^2 + d^2} - 3)$

$d\left(1 - \dfrac{3}{\sqrt{9 + d^2}}\right) = 0.175$

By trial and error:

$d = 1.56 \text{ m}$ **Ans.**

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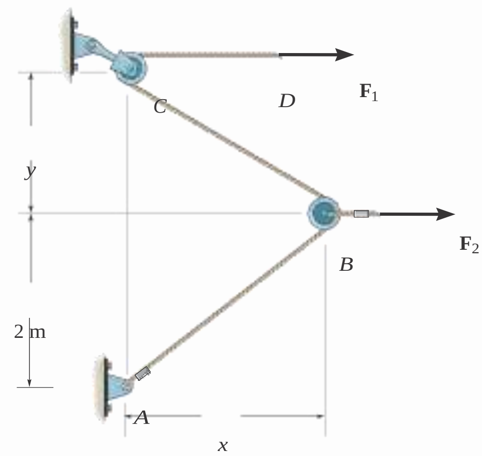
Ans:
$d = 1.56$ m

***3–24.**

Determine the distances x and y for equilibrium if $F_1 = 800$ N and $F_2 = 1000$ N.



Solution

Equations of Equilibrium. The tension throughout rope $ABCD$ is constant, that is $F_1 = 800$ N. Referring to the FBD shown in Fig. a,

$+\uparrow \Sigma F_y = 0;$ $\quad 800 \sin \phi - 800 \sin \theta = 0 \quad$ $\phi = 0$

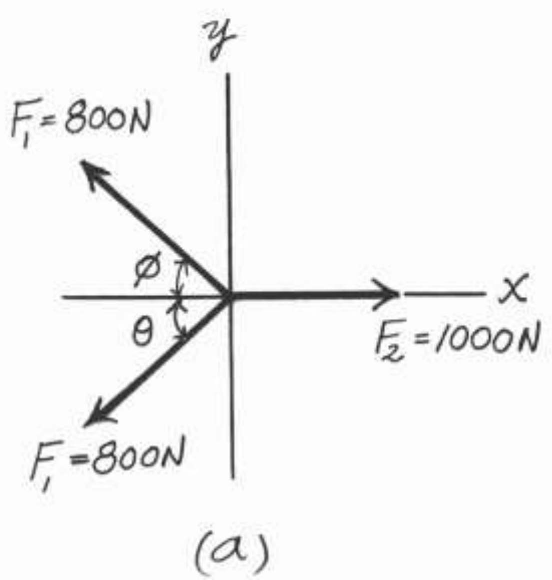
$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 1000 - 2[800 \cos \theta] = 0 \quad$ $\theta = 51.32°$

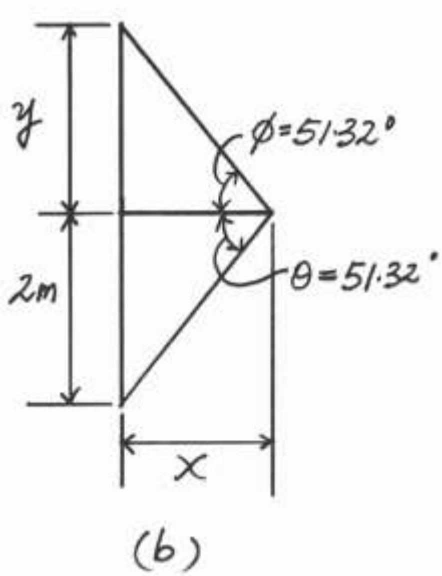
Referring to the geometry shown in Fig. b,

$$y = 2 \text{ m}$$ **Ans.**

and

$$\frac{2}{x} = \tan 51.32°; \quad x = 1.601 \text{ m} = 1.60 \text{ m}$$ **Ans.**



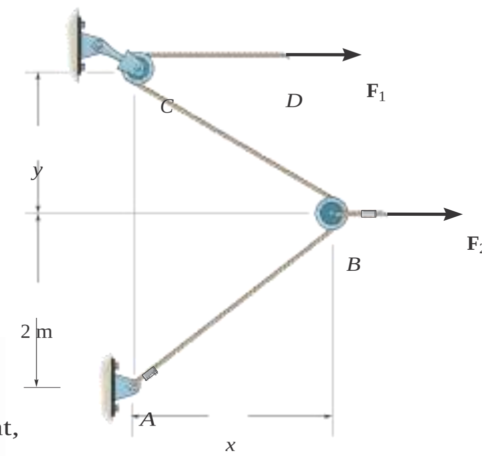


Ans:
$y = 2$ m

$x = 1.60$ m

3–25.

Determine the magnitude of F_1 and the distance y if $x = 1.5$ m and $F_2 = 1000$ N.



Solution

Equations of Equilibrium. The tension throughout rope *ABCD* is constant, that is $\mathbf{F}_1$. Referring to the *FBD* shown in Fig. *a*,

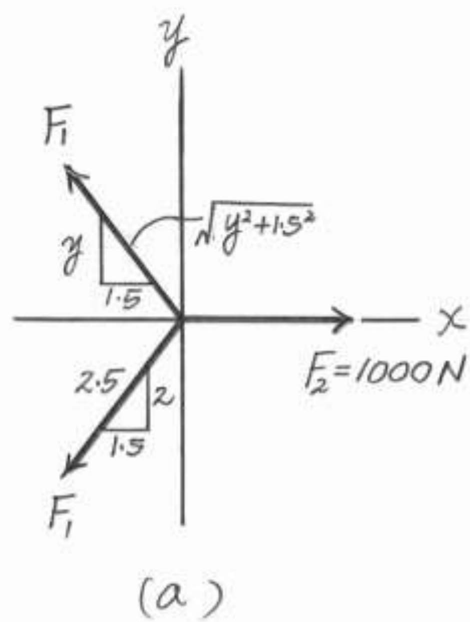
$$+\uparrow \Sigma F_y = 0; \quad F_1\left(\frac{y}{\sqrt{y^2 + 1.5^2}}\right) - F_1\left(\frac{2}{2.5}\right) = 0$$

$$\frac{y}{\sqrt{y^2 + 1.5^2}} = \frac{2}{2.5}$$

$$y = 2 \text{ m}$$ **Ans.**

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 1000 - 2\left[F_1\left(\frac{1.5}{2.5}\right)\right] = 0$$

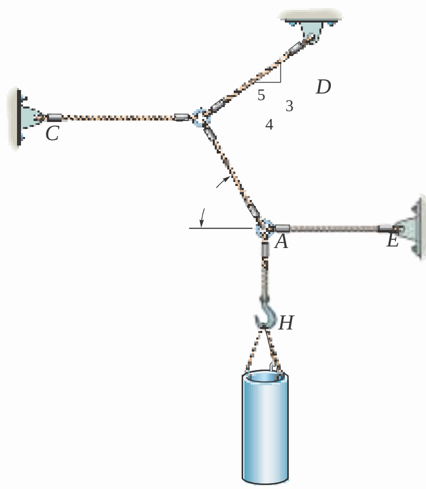
$$F_1 = 833.33 \text{ N} = 833 \text{ N}$$ **Ans.**



Ans:
$y = 2$ m
$F_1 = 833$ N

3–26.

The 30-kg pipe is supported at *A* by a system of ve cords. Determine the force in each cord for equilibrium.



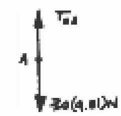
SOLUTION

At *H*:

$+\uparrow \Sigma F_y = 0; \qquad T_{HA} - 30(9.81) = 0$

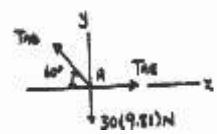
$T_{HA} = 294 \text{ N}$ **Ans.**

At *A*:



$+\uparrow \Sigma F_y = 0; \qquad T_{AB} \sin 60° - 30(9.81) = 0$

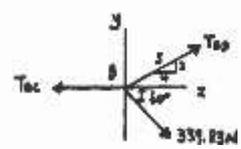
$T_{AB} = 339.83 = 340 \text{ N}$ **Ans.**



$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad T_{AE} - 339.83 \cos 60° = 0$

$T_{AE} = 170 \text{ N}$ **Ans.**

At *B*:



$+\uparrow \Sigma F_y = 0; \qquad T_{BD}\left(\frac{3}{5}\right) - 339.83 \sin 60° = 0$

$T_{BD} = 490.50 = 490 \text{ N}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 490.50\left(\frac{4}{5}\right) + 339.83 \cos 60° - T_{BC} = 0$

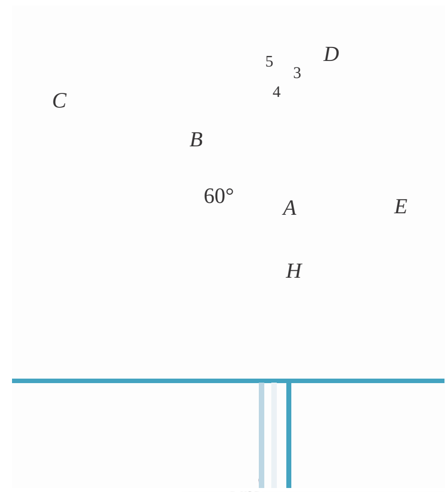
$T_{BC} = 562 \text{ N}$ **Ans.**

Ans:
$T_{HA} = 294 \text{ N}$
$T_{AB} = 340 \text{ N}$
$T_{AE} = 170 \text{ N}$

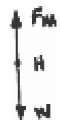
$T_{BD} = 490$ N
$T_{BC} = 562$ N

3–27.

Each cord can sustain a maximum tension of 500 N. Determine the largest mass of pipe that can be supported.

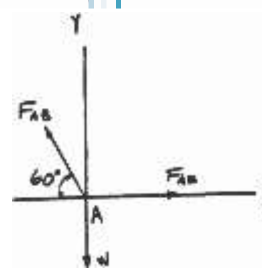


SOLUTION



At *H*:

$+\uparrow \Sigma F_y = 0; \qquad F_{HA} = W$



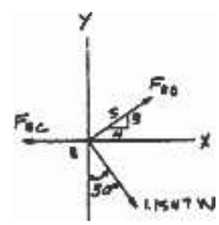
At *A*:

$+\uparrow \Sigma F_y = 0; \qquad F_{AB} \sin 60° - W = 0$

$F_{AB} = 1.1547\, W$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad F_{AE} - (1.1547\, W) \cos 60° = 0$

$F_{AE} = 0.5774\, W$



At *B*:

$+\uparrow \Sigma F_y = 0; \qquad F_{BD} \left(\frac{3}{5}\right) - (1.1547 \cos 30°)W = 0$

$F_{BD} = 1.667\, W$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad -F_{BC} + 1.667\, W \left(\frac{4}{5}\right) + 1.1547 \sin 30° = 0$

$F_{BC} = 1.9107\, W$

By comparison, cord *BC* carries the largest load. Thus

$$500 = 1.9107\, W$$

$$W = 261.69 \text{ N}$$

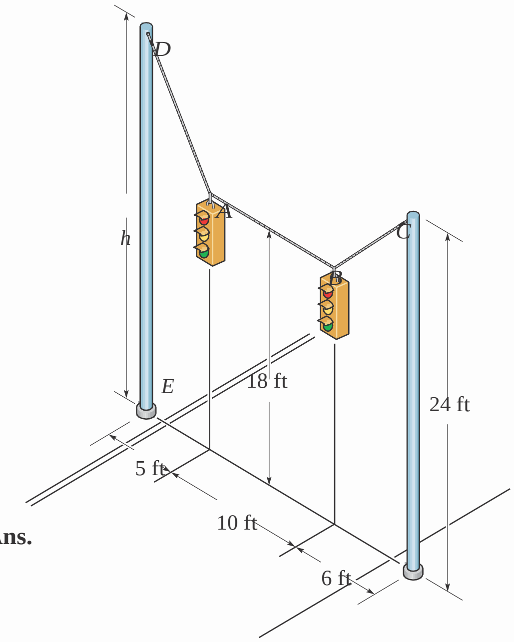
$$m = \frac{261.69}{9.81} = 26.7 \text{ kg}$$ **Ans.**

Ans:

$m = 26.7$ kg

***3–28.**

The street-lights at A and B are suspended from the two poles as shown. If each light has a weight of 50 lb, determine the tension in each of the three supporting cables and the required height h of the pole DE so that cable AB is horizontal.



Solution

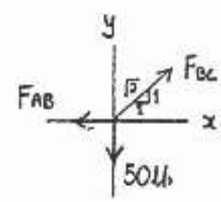
At point B:

$+\uparrow \Sigma F_y = 0; \quad \frac{1}{\sqrt{2}} F_{BC} - 50 = 0$

$F_{BC} = 70.71 = 70.7 \text{ lb}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \quad \frac{1}{\sqrt{2}}(70.71) - F_{AB} = 0$

$F_{AB} = 50 \text{ lb}$ **Ans.**



At point A:

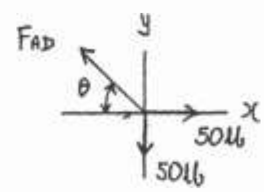
$\xrightarrow{+} \Sigma F_x = 0; \quad 50 - F_{AD} \cos\theta = 0$ **Ans.**

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

$\theta = 45°$

$F_{AD} = 70.7 \text{ lb}$ **Ans.**

$h = 18 + 5 = 23 \text{ ft}$ **Ans.**

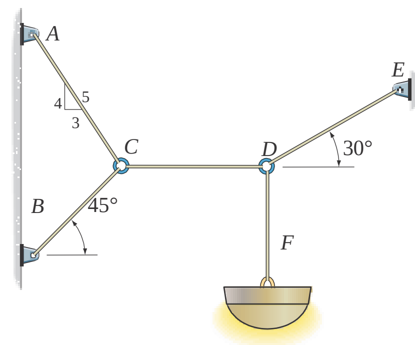


Ans:

$F_{AB} = 50$ lb
$F_{AD} = 70.7$ lb
$h = 23$ ft

3–29.

Determine the tension developed in each cord required for equilibrium of the 20-kg lamp.

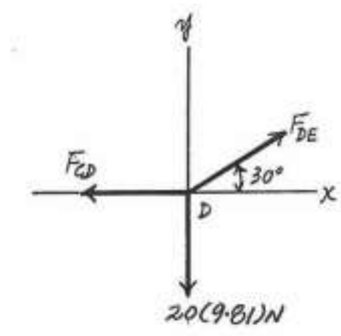


SOLUTION

Equations of Equilibrium: Applying the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. *a*, we have

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $F_{DE} \sin 30° - 20(9.81) = 0$ $F_{DE} = 392.4 \text{ N} = 392 \text{ N}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $392.4 \cos 30° - F_{CD} = 0$ $F_{CD} = 339.83 \text{ N} = 340 \text{ N}$ **Ans.**



(a)

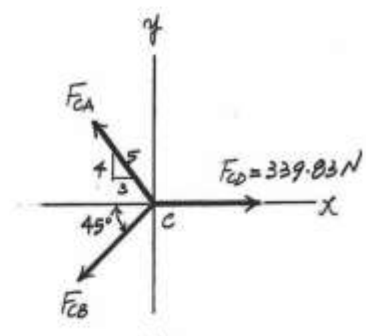
Using the result $F_{CD} = 339.83$ N and applying the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. *b*, we have

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $339.83 - F_{CA}\left(\frac{3}{5}\right) - F_{CD} \cos 45° = 0$ **(1)**

$+\uparrow \Sigma F_y = 0;$ $F_{CA}\left(\frac{4}{5}\right) - F_{CB} \sin 45° = 0$ **(2)**

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

$F_{CB} = 275 \text{ N}$ $F_{CA} = 243 \text{ N}$ **Ans.**

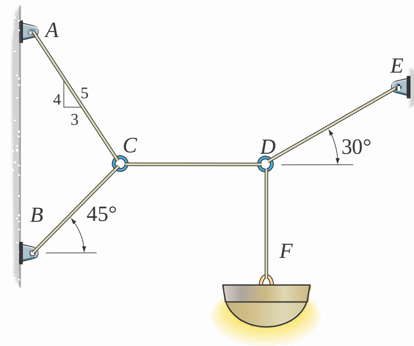


(b)

Ans:

$F_{DE} = 392\text{ N}$
$F_{CD} = 340\text{ N}$
$F_{CB} = 275\text{ N}$
$F_{CA} = 243\text{ N}$

3–30.



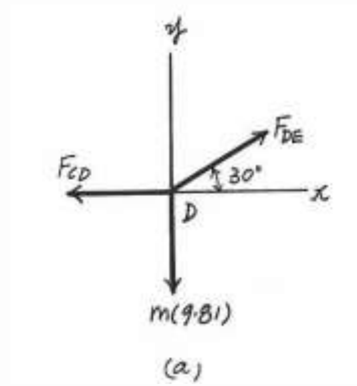
Determine the maximum mass of the lamp that the cord system can support so that no single cord develops a tension exceeding 400 N.

SOLUTION

Equations of Equilibrium: Applying the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. *a*, we have

$+\uparrow\Sigma F_y = 0;\quad F_{DE}\sin 30^\circ - m(9.81) = 0 \qquad F_{DE} = 19.62m$

$\xrightarrow{+}\Sigma F_x = 0;\quad 19.62m\cos 30^\circ - F_{CD} = 0 \qquad F_{CD} = 16.99m$



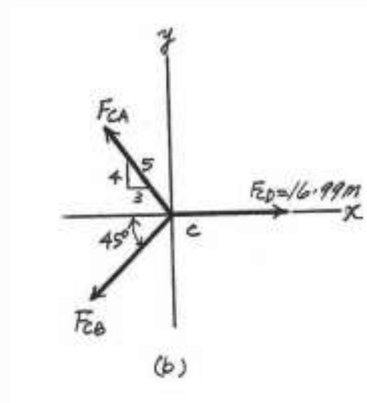
Using the result $F_{CD} = 16.99m$ and applying the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. *b*, we have

$\xrightarrow{+}\Sigma F_x = 0;\quad 16.99m - F_{CA}\left(\frac{3}{5}\right) - F_{CD}\cos 45^\circ = 0$ **(1)**

$+\uparrow\Sigma F_y = 0;\quad F_{CA}\left(\frac{4}{5}\right) - F_{CB}\sin 45^\circ = 0$ **(2)**

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

$F_{CB} = 13.73m \qquad F_{CA} = 12.14m$



Notice that cord *DE* is subjected to the greatest tensile force, and so it will achieve the maximum allowable tensile force first. Thus

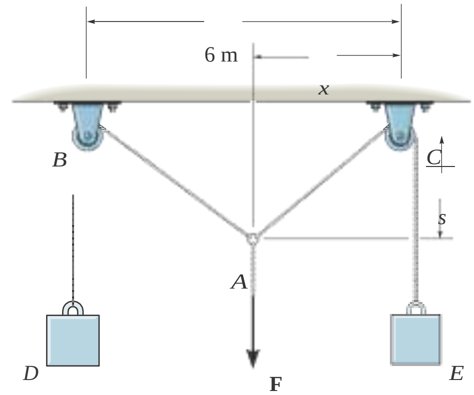
$F_{DE} = 400 = 19.62m$

$m = 20.4\text{ kg}$ **Ans.**

Ans:
$m = 20.4$ kg

3–31.

Blocks D and E have a mass of 4 kg and 6 kg, respectively. If $x = 2$ m determine the force **F** and the sag s for equilibrium.



Solution

Equations of Equilibrium. Referring to the geometry shown in Fig. a,

$$\cos\phi = \frac{s}{\sqrt{s^2+2^2}} \qquad \sin\phi = \frac{2}{\sqrt{s^2+2^2}}$$

$$\cos\theta = \frac{s}{\sqrt{s^2+4^2}} \qquad \sin\theta = \frac{4}{\sqrt{s^2+4^2}}$$

Referring to the FBD shown in Fig. b,

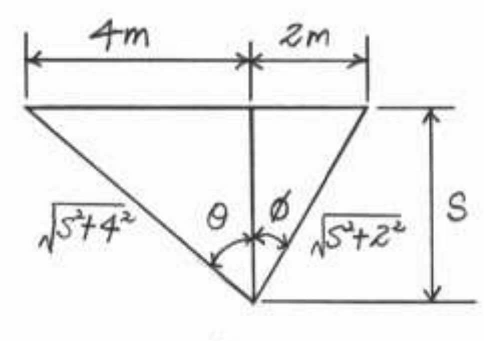
$$\xrightarrow{+} \Sigma F_x = 0; \qquad 6(9.81)\left(\frac{2}{\sqrt{s^2+2^2}}\right) - 4(9.81)\left(\frac{4}{\sqrt{s^2+4^2}}\right) = 0$$

$$\frac{3}{\sqrt{s^2+2^2}} = \frac{4}{\sqrt{s^2+4^2}}$$

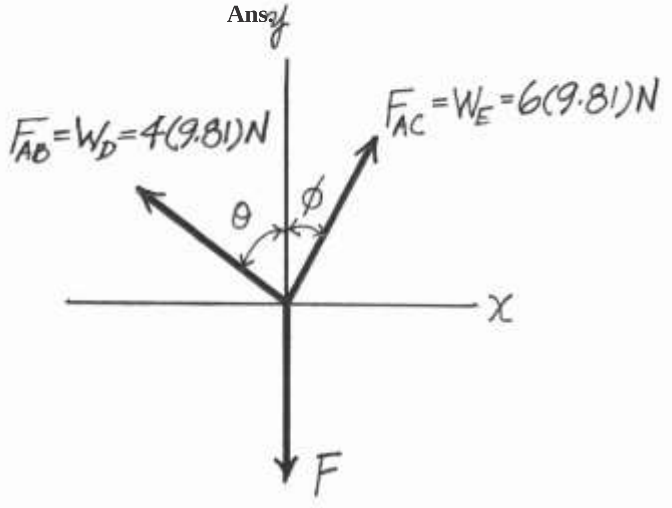
$$s = 3.381 \text{ m} = 3.38 \text{ m} \qquad \textbf{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad 6(9.81)\left(\frac{3.381}{\sqrt{3.381^2+2^2}}\right) + 4(9.81)\left(\frac{3.381}{\sqrt{3.381^2+4^2}}\right) - F = 0$$

$$F = 75.99 \text{ N} = 76.0 \text{ N} \qquad \textbf{Ans.}$$



(a)



(b)

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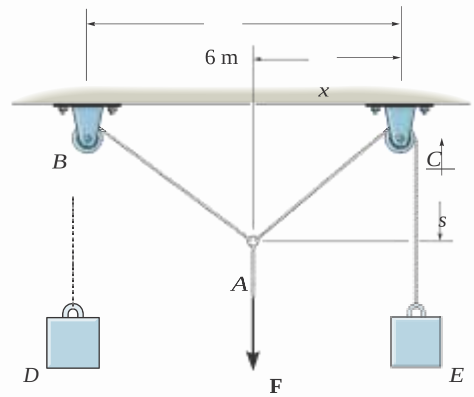
Ans:
$s = 3.38$ m
$F = 76.0$ N

193

***3–32.**

Blocks D and E have a mass of 4 kg and 6 kg, respectively. If $F = 80$ N, determine the sag s and distance x for equilibrium.



Solution

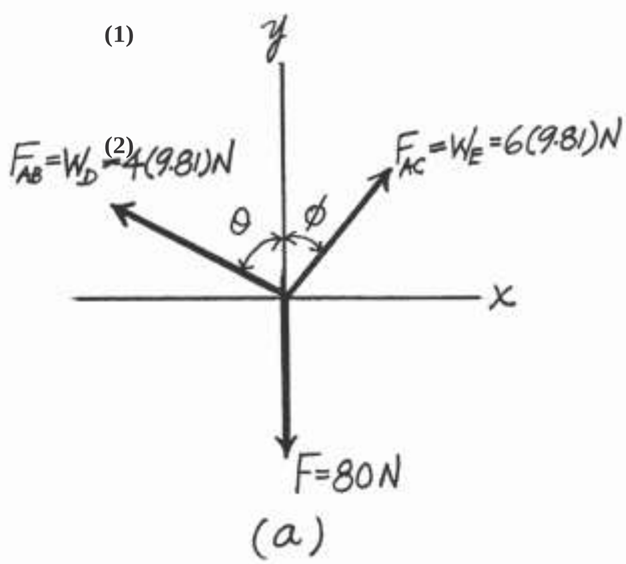
Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\xrightarrow{+} \Sigma F_x = 0; \qquad 6(9.81)\sin\phi - 4(9.81)\sin\theta = 0$$

$$\sin\phi = \frac{2}{3}\sin\theta \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad 6(9.81)\cos\phi + 4(9.81)\cos\theta - 80 = 0$$

$$3\cos\phi + 2\cos\theta = 4.0775 \qquad (2)$$



Using Eq (1), the geometry shown in Fig. *b* can be constructed. Thus

$$\cos\phi = \frac{\sqrt{9 - 4\sin^2\theta}}{3}$$

Substitute this result into Eq. (2),

$$3\left(\frac{\sqrt{9 - 4\sin^2\theta}}{3}\right) + 2\cos\theta = 4.0775$$

$$\sqrt{9 - 4\sin^2\theta} = 4.0775 - 2\cos\theta$$

$$9 - 4\sin^2\theta = 4\cos^2\theta - 16.310\cos\theta + 16.6258$$

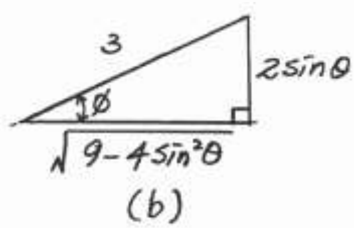
$$16.310\cos\theta = 4\left(\cos^2\theta + \sin^2\theta\right) + 7.6258$$

Here, $\cos^2\theta + \sin^2\theta = 1$. Then

$$\cos\theta = 0.7128 \qquad \theta = 44.54°$$

Substitute this result into Eq (1)

$$\sin\phi = \frac{2}{3}\sin 44.54° \qquad \phi = 27.88°$$



From Fig. *c*, $\frac{6 - x}{s} = \tan 44.54°$ and $\frac{x}{s} = \tan 27.88°$.

So then,

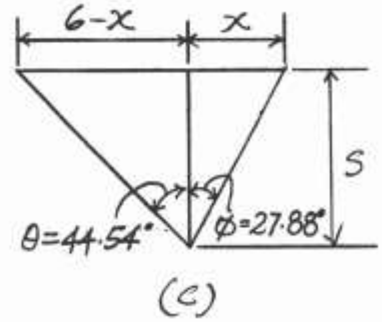
$$\frac{6 - x}{s} + \frac{x}{s} = \tan 44.54° + \tan 27.88°$$

$$\frac{6}{s} = 1.5129$$

$$s = 3.9659 \text{ m} = 3.97 \text{ m} \qquad \textbf{Ans.}$$

$$x = 3.9659 \tan 27.88°$$

$$= 2.0978 \text{ m} = 2.10 \text{ m} \qquad \textbf{Ans.}$$



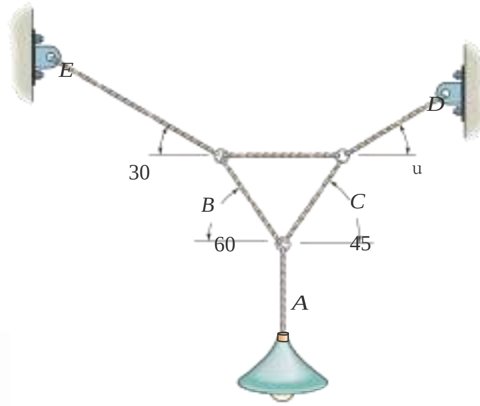
Ans:

$s = 3.97$ m

$x = 2.10$ m

3–33.

The lamp has a weight of 15 lb and is supported by the six cords connected together as shown. Determine the tension in each cord and the angle u for equilibrium. Cord BC is horizontal.



Solution

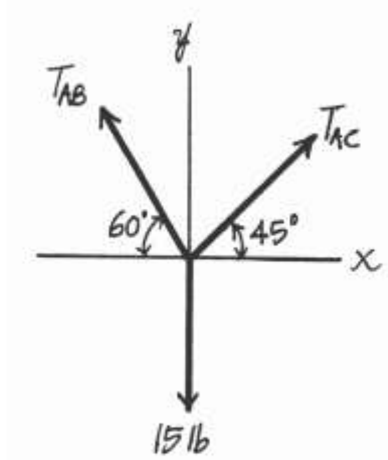
Equations of Equilibrium. Considering the equilibrium of Joint A by referring to its *FBD* shown in Fig. *a*,

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{AC}\cos 45° - T_{AB}\cos 60° = 0$ **(1)**

$+c\Sigma F_y = 0;\quad T_{AC}\sin 45° + T_{AB}\sin 60° - 15 = 0$ **(2)**

Solving Eqs (1) and (2) yield

$T_{AB} = 10.98 = 11.0\text{ lb} \qquad T_{AC} = 7.764\text{ lb} = 7.76\text{ lb}$ **Ans.**



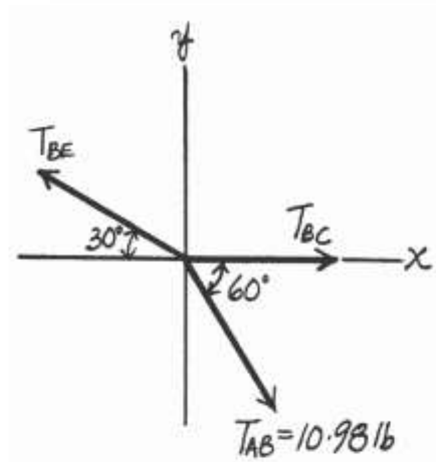
(a)

Then, joint B by referring to its *FBD* shown in Fig. *b*

$+c\Sigma F_y = 0;\quad T_{BE}\sin 30° - 10.98\sin 60° = 0 \quad T_{BE} = 19.02\text{ lb} = 19.0\text{ lb}$ **Ans.**

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{BC} + 10.98\cos 60° - 19.02\cos 30° = 0$

$T_{BC} = 10.98\text{ lb} = 11.0\text{ lb}$ **Ans.**



(b)

Finally joint C by referring to its *FBD* shown in Fig. *c*

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{CD}\cos u - 10.98 - 7.764\cos 45° = 0$

$T_{CD}\cos u = 16.4711$ **(3)**

$+c\Sigma F_y = 0;\quad T_{CD}\sin u - 7.764\sin 45° = 0$

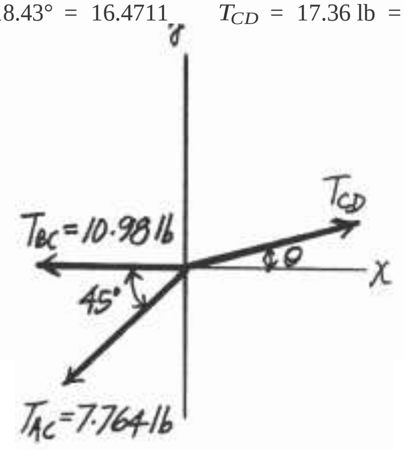
$T_{CD}\sin u = 5.4904$ **(4)**

Divided Eq (4) by (3)

$\tan u = 0.3333 \qquad u = 18.43° = 18.4°$ **Ans.**

Substitute this result into Eq (3)

$T_{CD}\cos 18.43° = 16.4711 \qquad T_{CD} = 17.36\text{ lb} = 17.4\text{ lb}$ **Ans.**



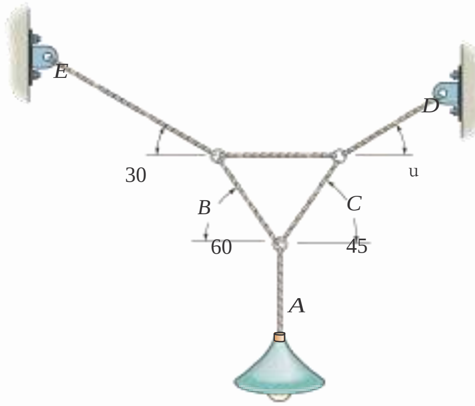
(c)

Ans:
$T_{AB} = 11.0$ lb
$T_{AC} = 7.76$ lb
$T_{BC} = 11.0$ lb
$T_{BE} = 19.0$ lb

$T_{CD} = 17.4$ lb
u = 18.4°

3–34.

Each cord can sustain a maximum tension of 20 lb. Determine the largest weight of the lamp that can be supported. Also, determine u of cord *DC* for equilibrium.



Solution

Equations of Equilibrium. Considering the equilibrium of Joint *A* by referring to its *FBD* shown in Fig. *a*,

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{AC}\cos 45° - T_{AB}\cos 60° = 0$ **(1)**

$+c\Sigma F_y = 0;\quad T_{AC}\sin 45° - T_{AB}\sin 60° - W = 0$ **(2)**

Solving Eqs (1) and (2) yield

$T_{AB} = 0.7321\ W \qquad T_{AC} = 0.5176\ W$

Then, joint *B* by referring to its *FBD* shown in Fig. *b*,

$+c\Sigma F_y = 0;\quad T_{BE}\sin 30° - 0.7321W\sin 60° = 0 \quad T_{BE} = 1.2679\ W$

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{BC} + 0.7321\ W\cos 60° - 1.2679\ W\cos 30° = 0$

$T_{BC} = 0.7321\ W$

Finally, joint *C* by referring to its *FBD* shown in Fig. *c*,

$\overset{+}{S}\ \Sigma F_x = 0;\quad T_{CD}\cos u - 0.7321\ W - 0.5176\ W\cos 45° = 0$

$T_{CD}\cos u = 1.0981\ W$ **(3)**

$+c\Sigma F_y = 0;\quad T_{CD}\sin u - 0.5176\ W\sin 45° = 0$

$T_{CD}\sin u = 0.3660\ W$ **(4)**

Divided Eq (4) by (3)

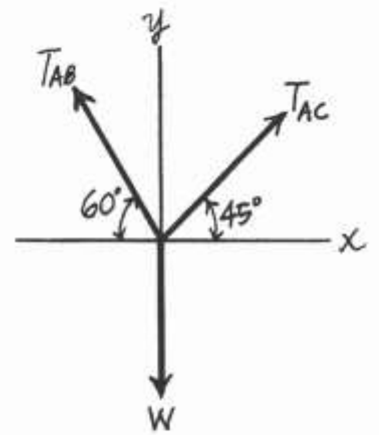
$\tan u = 0.3333 \qquad u = 18.43° = 18.4°$ **Ans.**

Substitute this result into Eq (3),

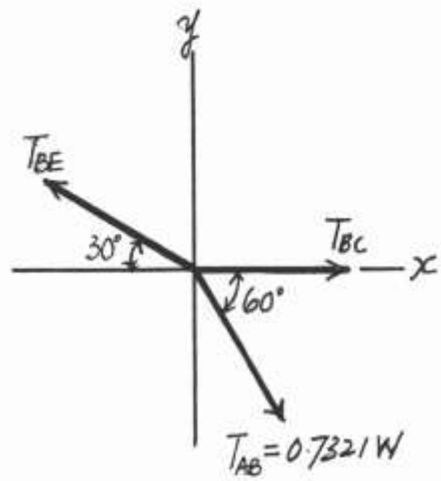
$T_{CD}\cos 18.43° = 1.0981\ W \qquad T_{CD} = 1.1575\ W$

Here cord *BE* is subjected to the largest tension. Therefore, its tension will reach the limit first, that is $T_{BE} = 20$ lb. Then

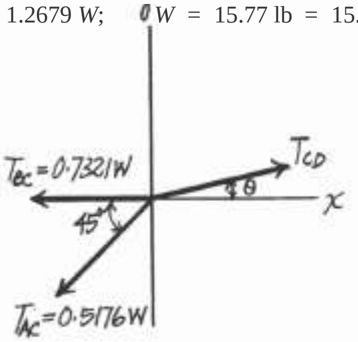
$20 = 1.2679\ W;\quad W = 15.77\text{ lb} = 15.8\text{ lb}$ **Ans.**



(a)



(b)



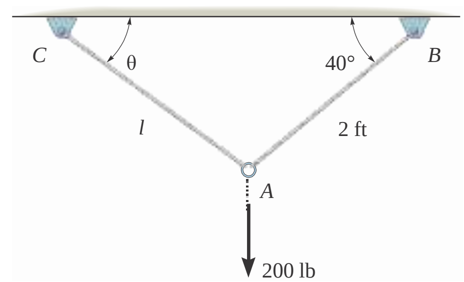
(c)

Ans:

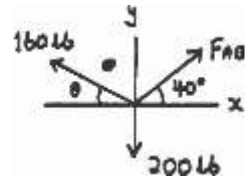
u = 18.4°
W = 15.8 lb

3–35.

The ring of negligible size is subjected to a vertical force of 200 lb. Determine the required length l of cord AC such that the tension acting in AC is 160 lb. Also, what is the force in cord AB? *Hint:* Use the equilibrium condition to determine the required angle θ for attachment, then determine l using trigonometry applied to triangle ABC.



SOLUTION



$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad F_{AB}\cos 40° - 160\cos\theta = 0$

$+\uparrow \Sigma F_y = 0; \qquad 160\sin\theta + F_{AB}\sin 40° - 200 = 0$

Thus,

$$\sin\theta + 0.8391\cos\theta = 1.25$$

Solving by trial and error,

$$\theta = 33.25°$$

$$F_{AB} = 175 \text{ lb}$$ **Ans.**

$$\frac{2}{\sin 33.25°} = \frac{l}{\sin 40°}$$

$$l = 2.34 \text{ ft}$$ **Ans.**

Also,

$$\theta = 66.75°$$

$$F_{AB} = 82.4 \text{ lb}$$ **Ans.**

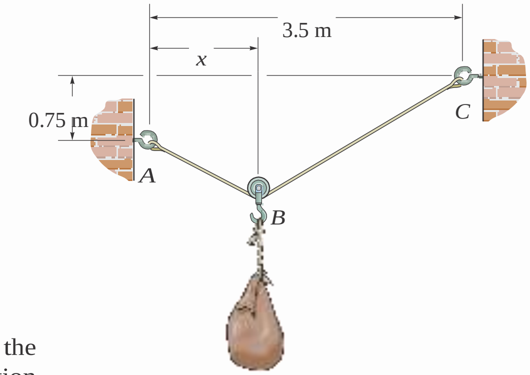
$$\frac{2}{\sin 66.75°} = \frac{l}{\sin 40°}$$

$$l = 1.40 \text{ ft}$$ **Ans.**

Ans:
$F_{AB} = 175$ lb
$l = 2.34$ ft

$F_{AB} = 82.4$ lb
$l = 1.40$ ft

***3–36.**



Cable ABC has a length of 5 m. Determine the position x and the tension developed in ABC required for equilibrium of the 100-kg sack. Neglect the size of the pulley at B.

SOLUTION

Equations of Equilibrium: Since cable ABC passes over the smooth pulley at B, the tension in the cable is constant throughout its entire length. Applying the equation of equilibrium along the y axis to the free-body diagram in Fig. a, we have

$$+\uparrow \Sigma F_y = 0; \qquad 2T\sin\phi - 100(9.81) = 0 \qquad (1)$$

Geometry: Referring to Fig. b, we can write

$$\frac{3.5 - x}{\cos\phi} + \frac{x}{\cos\phi} = 5$$

$$\phi = \cos^{-1}\left(\frac{3.5}{5}\right) = 45.57^\circ$$

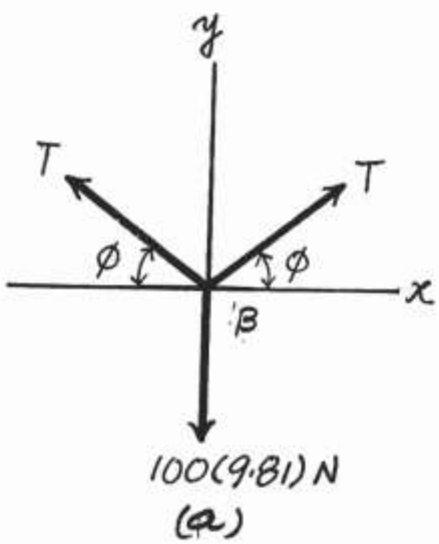
Also,

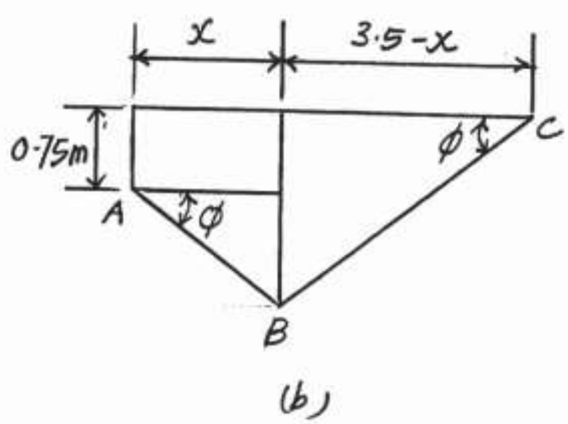
$$x\tan 45.57^\circ + 0.75 = (3.5 - x)\tan 45.57^\circ$$

$$x = 1.38\text{ m}$$ **Ans.**

Substituting $\phi = 45.57^\circ$ into Eq. (1), yields

$$T = 687\text{ N}$$ **Ans.**

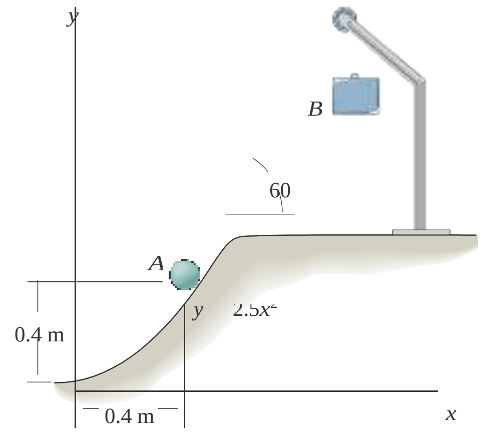




Ans:
$x = 1.38$ m
$T = 687$ N

3–37.

A 4-kg sphere rests on the smooth parabolic surface. Determine the normal force it exerts on the surface and the mass m_B of block *B* needed to hold it in the equilibrium position shown.

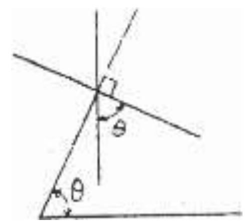


SOLUTION

Geometry: The angle θ which the surface make with the horizontal is to be determined first.

$$\tan\theta\Big|_{x=0.4\text{ m}} = \frac{dy}{dx}\Big|_{x=0.4\text{m}} = 5.0x\Big|_{x=0.4\text{ m}} = 2.00$$

$$\theta = 63.43°$$



Free Body Diagram: The tension in the cord is the same throughout the cord and is equal to the weight of block *B*, $W_B = m_B(9.81)$.

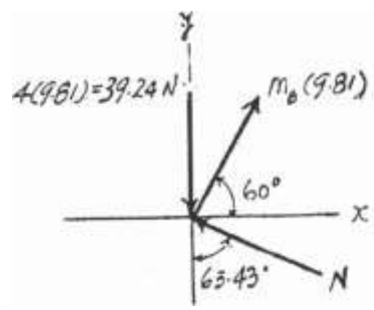
Equations of Equilibrium:

$\overset{+}{\rightarrow}\Sigma F_x = 0;\quad m_B(9.81)\cos 60° - N\sin 63.43° = 0$

$$N = 5.4840m_B \qquad \textbf{[1]}$$

$+\uparrow\Sigma F_y = 0;\quad m_B(9.81)\sin 60° + N\cos 63.43° - 39.24 = 0$

$$8.4957m_B + 0.4472N = 39.24 \qquad \textbf{[2]}$$



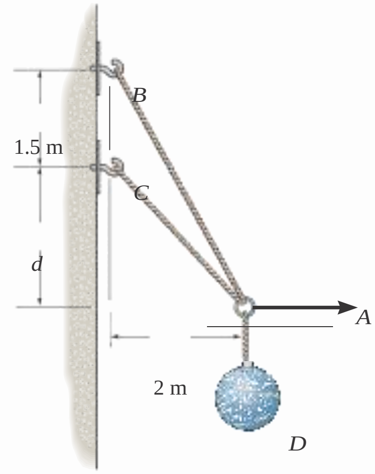
Solving Eqs. [1] and [2] yields

$$m_B = 3.58\text{ kg} \qquad N = 19.7\text{ N}$$ **Ans.**

Ans:
$m_B = 3.58$ kg
$N = 19.7$ N

3–38.

Determine the forces in cables *AC* and *AB* needed to hold the 20-kg ball *D* in equilibrium. Take $F = 300$ N and $d = 1$ m.



SOLUTION

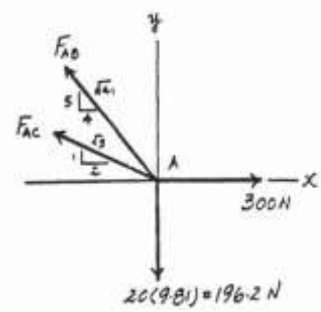
Equations of Equilibrium:

$$\xrightarrow{+} \Sigma F_x = 0; \quad 300 - F_{AB}\left(\frac{4}{\sqrt{41}}\right) - F_{AC}\left(\frac{2}{\sqrt{5}}\right) = 0$$

$$0.6247F_{AB} + 0.8944F_{AC} = 300 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \quad F_{AB}\left(\frac{5}{\sqrt{41}}\right) + F_{AC}\left(\frac{1}{\sqrt{5}}\right) - 196.2 = 0$$

$$0.7809F_{AB} + 0.4472F_{AC} = 196.2 \qquad (2)$$



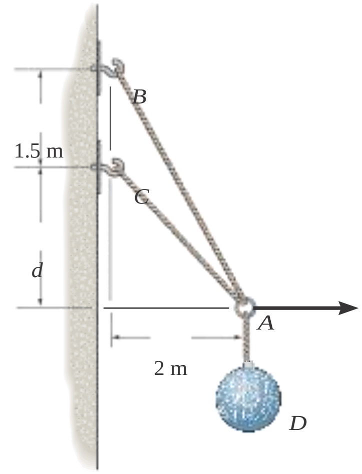
Solving Eqs. (1) and (2) yields

$F_{AB} = 98.6$ N $\qquad F_{AC} = 267$ N **Ans.**

Ans:
F_{AB} = 98.6 N
F_{AC} = 267 N

3–39.

The ball D has a mass of 20 kg. If a force of $F = 100$ N is applied horizontally to the ring at A, determine the largest dimension d so that the force in cable AC is zero.



SOLUTION

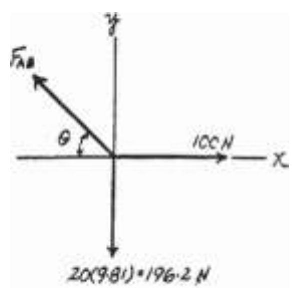
Equations of Equilibrium:

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 100 - F_{AB} \cos\theta = 0 \quad F_{AB} \cos\theta = 100$ **(1)**

$+\uparrow \Sigma F_y = 0; \quad F_{AB} \sin\theta - 196.2 = 0 \quad F_{AB} \sin\theta = 196.2$ **(2)**

Solving Eqs. (1) and (2) yields

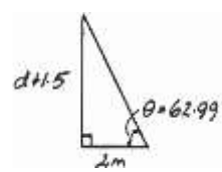
$$\theta = 62.99^\circ \qquad F_{AB} = 220.21 \text{ N}$$



From the geometry,

$$d + 1.5 = 2 \tan 62.99^\circ$$

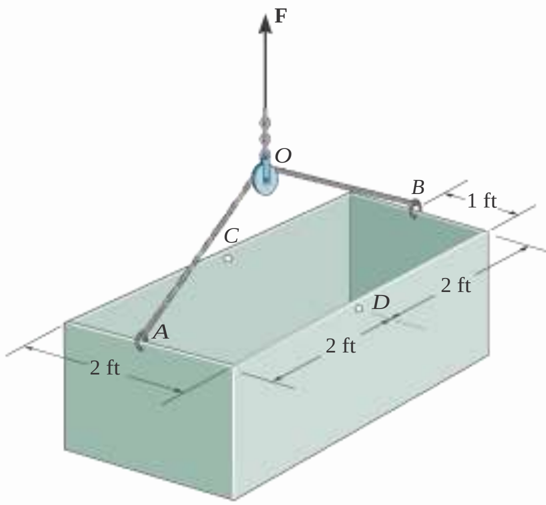
$$d = 2.42 \text{ m}$$ **Ans.**



Ans:
$d = 2.42$ m

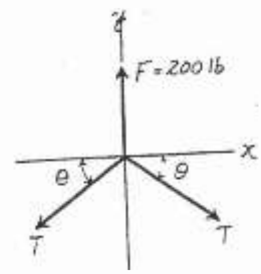
***3–40.**

The 200-lb uniform tank is suspended by means of a 6-ft-long cable, which is attached to the sides of the tank and passes over the small pulley located at *O*. If the cable can be attached at either points *A* and *B*, or *C* and *D*, determine which attachment produces the least amount of tension in the cable. What is this tension?



SOLUTION

Free-Body Diagram: By observation, the force **F** has to support the entire weight of the tank. Thus, $F = 200$ lb. The tension in cable *AOB* or *COD* is the same throughout the cable.

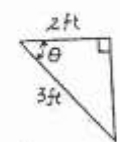


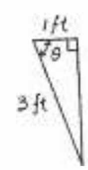
Equations of Equilibrium:

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad T\cos\theta - T\cos\theta = 0 \qquad$ ***(Satisfied!)***

$+\uparrow \Sigma F_y = 0; \quad 200 - 2T\sin\theta = 0 \qquad T = \dfrac{100}{\sin\theta}$ **(1)**

From the function obtained above, one realizes that in order to produce the least amount of tension in the cable, $\sin\theta$ hence θ must be as great as possible. Since the attachment of the cable to point *C* and *D* produces a greater $\theta\left(\theta = \cos^{-1}\frac{1}{3} = 70.53^\circ\right)$ as compared to the attachment of the cable to points *A* and B $\left(\theta = \cos^{-1}\frac{2}{3} = 48.19^\circ\right)$,





the attachment of the cable to point *C* and *D* will produce the least amount of tension in the cable. **Ans.**

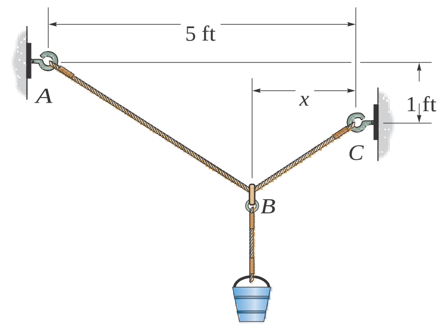
Thus,

$$T = \frac{100}{\sin 70.53^\circ} = 106 \text{ lb}$$ **Ans.**

Ans:
$T = 106$ lb

3–41.

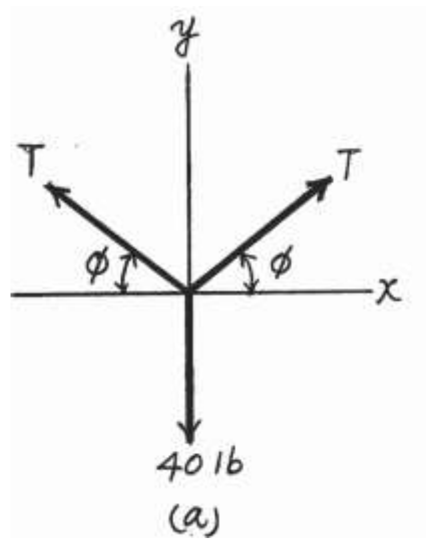
The single elastic cord *ABC* is used to support the 40-lb load. Determine the position *x* and the tension in the cord that is required for equilibrium. The cord passes through the smooth ring at *B* and has an unstretched length of 6 ft and stiffness of $k = 50$ lb/ft.



SOLUTION

Equations of Equilibrium: Since elastic cord *ABC* passes over the smooth ring at *B*, the tension in the cord is constant throughout its entire length. Applying the equation of equilibrium along the *y* axis to the free-body diagram in Fig. *a*, we have

$$+\uparrow \Sigma F_y = 0; \qquad 2T \sin \phi - 40 = 0 \qquad \textbf{(1)}$$



Geometry: Referring to Fig. (*b*), the stretched length of cord *ABC* is

$$l_{ABC} = \frac{x}{\cos \phi} + \frac{5 - x}{\cos \phi} = \frac{5}{\cos \phi} \qquad \textbf{(2)}$$

Also,

$$x \tan \phi + 1 = (5 - x) \tan \phi$$

$$x = \frac{5 \tan \phi - 1}{2 \tan \phi} \qquad \textbf{(3)}$$

Spring Force Formula: Applying the spring force formula using Eq. (2), we obtain

$$F_{sp} = k(l_{ABC} - l_0)$$

$$T = 50\left[\frac{5}{\cos \phi} - 6\right] \qquad \textbf{(4)}$$

Substituting Eq. (4) into Eq. (1) yields

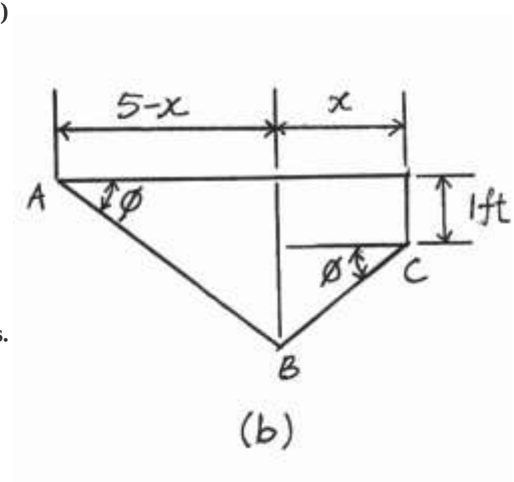
$$5 \tan \phi - 6 \sin \phi = 0.4$$

Solving the above equation by trial and error

$$\phi = 40.86°$$

Substituting $\phi = 40.86°$ into Eqs. (1) and (3) yields

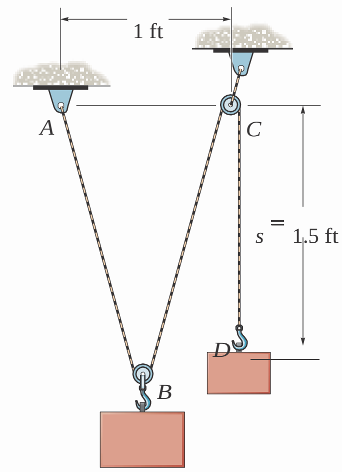
$T = 30.6$ lb $\qquad x = 1.92$ ft **Ans.**



Ans:
$T = 30.6$ lb
$x = 1.92$ ft

3–42.

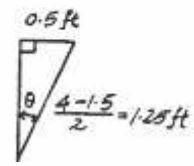
A "scale" is constructed with a 4-ft-long cord and the 10-lb block *D*. The cord is fixed to a pin at *A* and passes over two *small* pulleys at *B* and *C*. Determine the weight of the suspended block at *B* if the system is in equilibrium when $s = 1.5$ ft.



SOLUTION

Free-Body Diagram: The tension force in the cord is the same throughout the cord, that is, 10 lb. From the geometry,

$$\theta = \sin^{-1}\left(\frac{0.5}{1.25}\right) = 23.58°$$

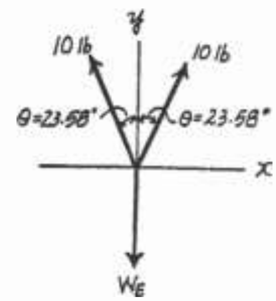


Equations of Equilibrium:

$\xrightarrow{+} \Sigma F_x = 0; \quad 10 \sin 23.58° - 10 \sin 23.58° = 0$ **(*Satisfied!*)**

$+\uparrow \Sigma F_y = 0; \quad 2(10) \cos 23.58° - W_B = 0$

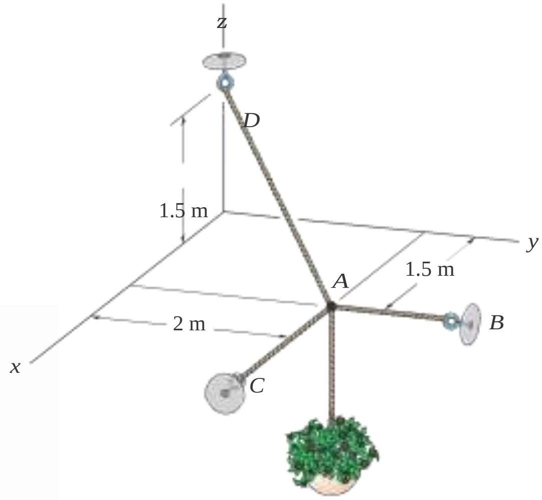
$W_B = 18.3 \text{ lb}$ **Ans.**



Ans:
W_B = 18.3 lb

3–43.

The three cables are used to support the 40-kg flowerpot. Determine the force developed in each cable for equilibrium.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_z = 0; \quad F_{AD}\left(\frac{1.5}{\sqrt{1.5^2 + 2^2 + 1.5^2}}\right) - 40(9.81) = 0$$

$$F_{AD} = 762.69 \text{ N} = 763 \text{ N} \qquad \textbf{Ans.}$$

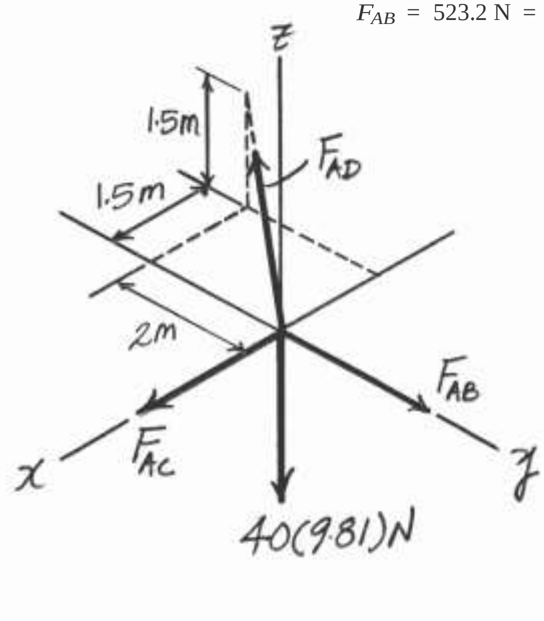
Using this result,

$$\Sigma F_x = 0; \quad F_{AC} - 762.69\left(\frac{1.5}{\sqrt{1.5^2 + 2^2 + 1.5^2}}\right) = 0$$

$$F_{AC} = 392.4 \text{ N} = 392 \text{ N} \qquad \textbf{Ans.}$$

$$\Sigma F_y = 0; \quad F_{AB} - 762.69\left(\frac{2}{\sqrt{1.5^2 + 2^2 + 1.5^2}}\right) = 0$$

$$F_{AB} = 523.2 \text{ N} = 523 \text{ N} \qquad \textbf{Ans.}$$



(a)

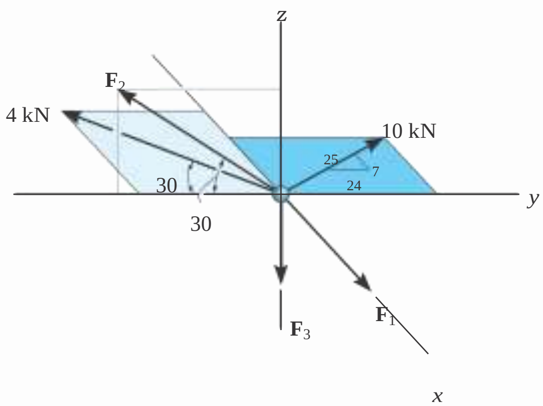
Ans:

206

F_{AD} = 763 N
F_{AC} = 392 N
F_{AB} = 523 N

***3–44.**

Determine the magnitudes of $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ for equilibrium of the particle.



Solution

Equations of Equilibrium. Referring to the *FBD* shown,

$\Sigma F_y = 0;\quad 10\left(\frac{24}{25}\right) - 4\cos 30^\circ - F_2 \cos 30^\circ = 0 \quad F_2 = 7.085 \text{ kN} = 7.09 \text{ kN}$ **Ans.**

$\Sigma F_x = 0;\quad F_1 - 4\sin 30^\circ - 10\left(\frac{7}{25}\right) = 0 \quad F_1 = 4.80 \text{ kN}$ **Ans.**

Using the result of $F_2 = 7.085$ kN,

$\Sigma F_z = 0;\quad 7.085 \sin 30^\circ - F_3 = 0 \quad F_3 = 3.543 \text{ kN} = 3.54 \text{ kN}$ **Ans.**

Ans:

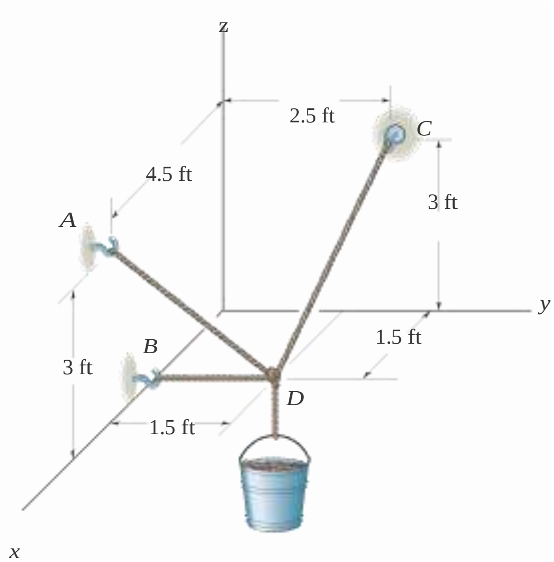
$F_2 = 7.09$ kN

$F_1 = 4.80$ kN

$F_3 = 3.54$ kN

3–45.

If the bucket and its contents have a total weight of 20 lb, determine the force in the supporting cables *DA*, *DB*, and *DC*.



SOLUTION

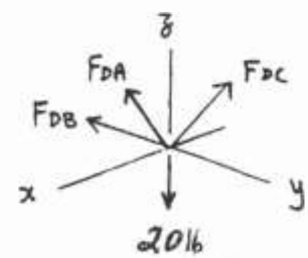
$$\mathbf{u}_{DA} = \{\frac{3}{4.5}\,\mathbf{i} - \frac{1.5}{4.5}\,\mathbf{j} + \frac{3}{4.5}\,\mathbf{k}\}$$

$$\mathbf{u}_{DC} = \{-\frac{1.5}{3.5}\,\mathbf{i} + \frac{1}{3.5}\,\mathbf{j} + \frac{3}{3.5}\,\mathbf{k}\}$$

$$\Sigma F_x = 0; \qquad \frac{3}{4.5}F_{DA} - \frac{1.5}{3.5}F_{DC} = 0$$

$$\Sigma F_y = 0; \qquad -\frac{1.5}{4.5}F_{DA} - F_{DB} + \frac{1}{3.5}F_{DC} = 0$$

$$\Sigma F_z = 0; \qquad \frac{3}{4.5}F_{DA} + \frac{3}{3.5}F_{DC} - 20 = 0$$



$F_{DA} = 10.0$ lb **Ans.**

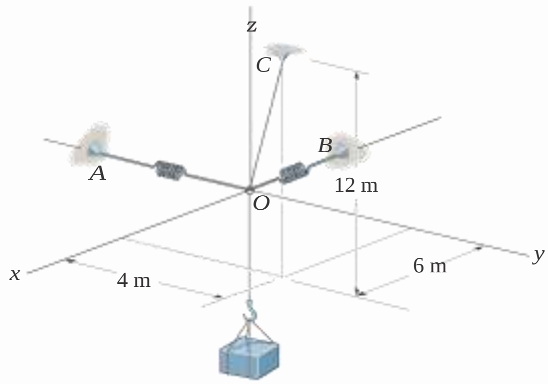
$F_{DB} = 1.11$ lb **Ans.**

$F_{DC} = 15.6$ lb **Ans.**

Ans:
F_{DA} = 10.0 lb
F_{DB} = 1.11 lb
F_{DC} = 15.6 lb

3–46.

Determine the stretch in each of the two springs required to hold the 20-kg crate in the equilibrium position shown. Each spring has an unstretched length of 2 m and a stiffness of $k = 360$ N/m.



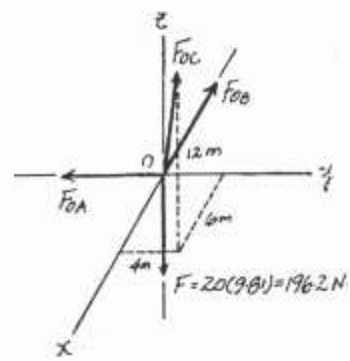
SOLUTION

Cartesian Vector Notation:

$$\mathbf{F}_{OC} = F_{OC}\left(\frac{6\mathbf{i} + 4\mathbf{j} + 12\mathbf{k}}{\sqrt{6^2 + 4^2 + 12^2}}\right) = \frac{3}{7}F_{OC}\mathbf{i} + \frac{2}{7}F_{OC}\mathbf{j} + \frac{6}{7}F_{OC}\mathbf{k}$$

$$\mathbf{F}_{OA} = -F_{OA}\,\mathbf{j} \qquad \mathbf{F}_{OB} = -F_{OB}\,\mathbf{i}$$

$$\mathbf{F} = \{-196.2\mathbf{k}\}\text{ N}$$



Equations of Equilibrium:

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{OC} + \mathbf{F}_{OA} + \mathbf{F}_{OB} + \mathbf{F} = \mathbf{0}$$

$$\left(\frac{3}{7}F_{OC} - F_{OB}\right)\mathbf{i} + \left(\frac{2}{7}F_{OC} - F_{OA}\right)\mathbf{j} + \left(\frac{6}{7}F_{OC} - 196.2\right)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j**, and **k** components, we have

$$\frac{3}{7}F_{OC} - F_{OB} = 0 \qquad \textbf{(1)}$$

$$\frac{2}{7}F_{OC} - F_{OA} = 0 \qquad \textbf{(2)}$$

$$\frac{6}{7}F_{OC} - 196.2 = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1), (2) and (3) yields

$$F_{OC} = 228.9\text{ N} \qquad F_{OB} = 98.1\text{ N} \qquad F_{OA} = 65.4\text{ N}$$

Spring Elongation: Using spring formula, Eq. 3–2, the spring elongation is $s = \frac{F}{k}$.

$$s_{OB} = \frac{98.1}{300} = 0.327\text{ m} = 327\text{ mm} \qquad \textbf{Ans.}$$

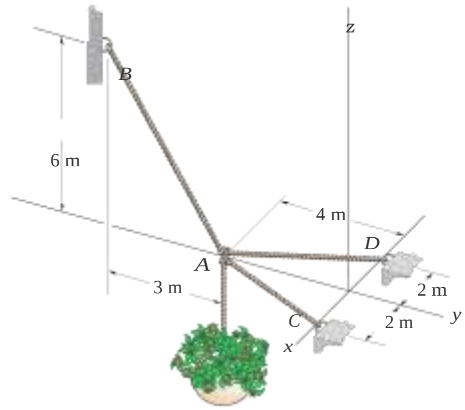
$$s_{OA} = \frac{65.4}{300} = 0.218\text{ m} = 218\text{ mm} \qquad \textbf{Ans.}$$

Ans:

$s_{OB} = 327$ mm
$s_{OA} = 218$ mm

3–47.

Determine the force in each cable needed to support the 20-kg flowerpot.



Solution

Equations of Equilibrium.

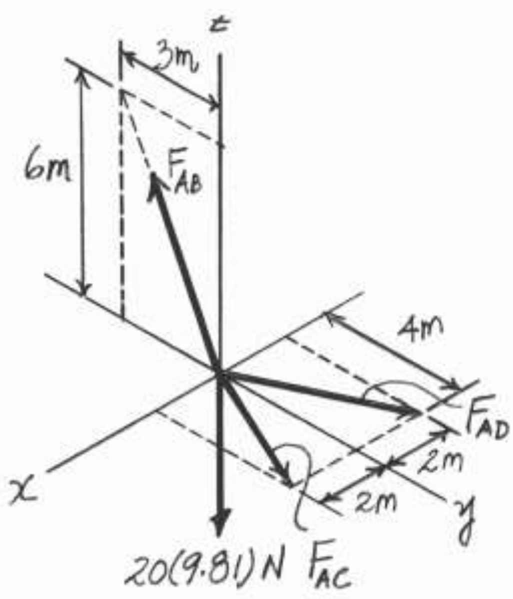
$\Sigma F_z = 0;\qquad F_{AB}\left(\frac{6}{\sqrt{45}}\right) - 20(9.81) = 0 \qquad F_{AB} = 219.36\text{ N} = 219\text{ N}$ **Ans.**

$\Sigma F_x = 0;\qquad F_{AC}\left(\frac{2}{\sqrt{20}}\right) - F_{AD}\left(\frac{2}{\sqrt{20}}\right) = 0 \qquad F_{AC} = F_{AD} = F$

Using the results of $F_{AB} = 219.36$ N and $F_{AC} = F_{AD} = F$,

$\Sigma F_y = 0;\qquad 2\left[F\left(\frac{4}{\sqrt{20}}\right)\right] - 219.36\left(\frac{3}{\sqrt{45}}\right) = 0$

$$F_{AC} = F_{AD} = F = 54.84\text{ N} = 54.8\text{ N}$$ **Ans.**



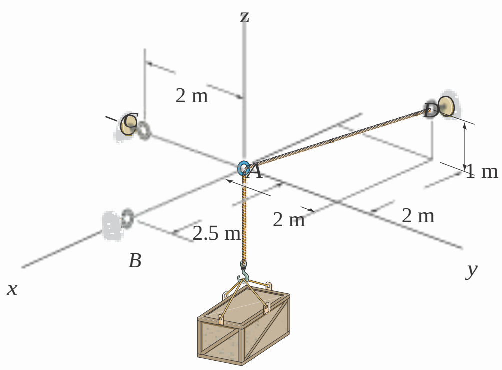
(a)

Ans:
$F_{AB} = 219$ N

$F_{AC} = F_{AD} = 54.8$ N

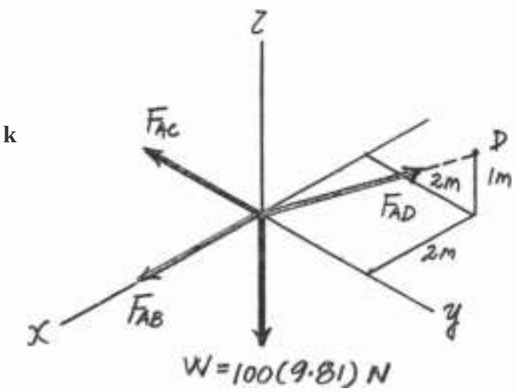
***3–48.**

Determine the tension in the cables in order to support the 100-kg crate in the equilibrium position shown.



SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as



$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{i}$$

$$\mathbf{F}_{AC} = -F_{AC}\,\mathbf{j}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-2-0)\mathbf{i}+(2-0)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-2-0)^2+(2-0)^2+(1-0)^2}}\right] = -\frac{2}{3}F_{AD}\,\mathbf{i} + \frac{2}{3}F_{AD}\,\mathbf{j} + \frac{1}{3}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = [-100(9.81)\mathbf{k}]\text{N} = [-981\,\mathbf{k}]\text{N}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$F_{AB}\,\mathbf{i} + (-F_{AC}\,\mathbf{j}) + \left(-\frac{2}{3}F_{AD}\,\mathbf{i} + \frac{2}{3}F_{AD}\,\mathbf{j} + \frac{1}{3}F_{AD}\,\mathbf{k}\right) + (-981\mathbf{k}) = \mathbf{0}$$

$$\left(F_{AB} - \frac{2}{3}F_{AD}\right)\mathbf{i} + \left(-F_{AC} + \frac{2}{3}F_{AD}\right)\mathbf{j} + \left(\frac{1}{3}F_{AD} - 981\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$F_{AB} - \frac{2}{3}F_{AD} = 0 \qquad \textbf{(1)}$$

$$-F_{AC} + \frac{2}{3}F_{AD} = 0 \qquad \textbf{(2)}$$

$$\frac{1}{3}F_{AD} - 981 = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1) through (3) yields

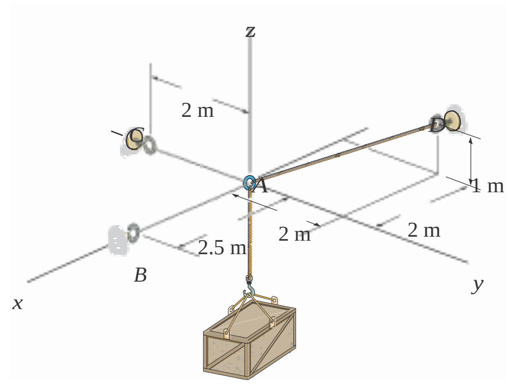
$$F_{AD} = 2943\text{ N} = 2.94\text{ kN} \qquad \textbf{Ans.}$$

$$F_{AB} = F_{AC} = 1962\text{ N} = 1.96\text{ kN} \qquad \textbf{Ans.}$$

Ans:
F_{AD} = 2.94 kN
F_{AB} = 1.96 kN

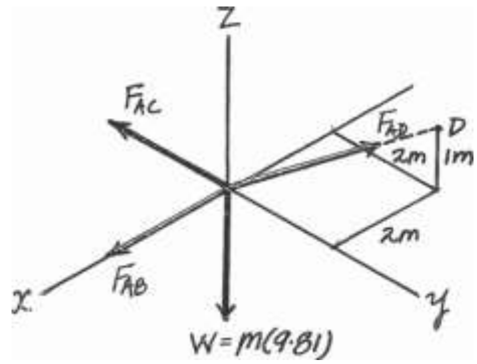
3–49.

Determine the maximum mass of the crate so that the tension developed in any cable does not exceeded 3 kN.



SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as



$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{i}$$

$$\mathbf{F}_{AC} = -F_{AC}\,\mathbf{j}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-2-0)\mathbf{i} + (2-0)\mathbf{j} + (1-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (2-0)^2 + (1-0)^2}}\right] = -\frac{2}{3}F_{AD}\,\mathbf{i} + \frac{2}{3}F_{AD}\,\mathbf{j} + \frac{1}{3}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = [-m(9.81)\mathbf{k}]$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$F_{AB}\,\mathbf{i} + (-F_{AC}\,\mathbf{j}) + \left(-\frac{2}{3}F_{AD}\,\mathbf{i} + \frac{2}{3}F_{AD}\,\mathbf{j} + \frac{1}{3}F_{AD}\,\mathbf{k}\right) + [-m(9.81)\mathbf{k}] = \mathbf{0}$$

$$\left(F_{AB} - \frac{2}{3}F_{AD}\right)\mathbf{i} + \left(-F_{AC} + \frac{2}{3}F_{AD}\right)\mathbf{j} + \left(\frac{1}{3}F_{AD} - 9.81m\right)\mathbf{k} = 0$$

Equating the **i, j**, and **k** components yields

$$F_{AB} - \frac{2}{3}F_{AD} = 0 \qquad \textbf{(1)}$$

$$-F_{AC} + \frac{2}{3}F_{AD} = 0 \qquad \textbf{(2)}$$

$$\frac{1}{3}F_{AD} - 9.81m = 0 \qquad \textbf{(3)}$$

When cable *AD* is subjected to maximum tension, $F_{AD} = 3000$ N. Thus, by substituting this value into Eqs. (1) through (3), we have

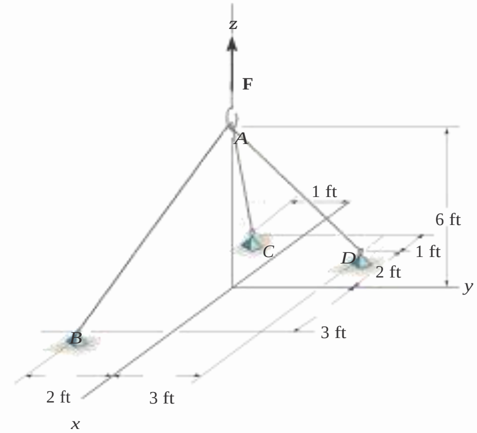
$$F_{AB} = F_{AC} = 2000 \text{ N}$$

$$m = 102 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m = 102$ kg

3–50.

Determine the force in each cable if $F = 500$ lb.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_x = 0; \quad F_{AB}\left(\frac{3}{7}\right) - F_{AC}\left(\frac{3}{\sqrt{46}}\right) - F_{AD}\left(\frac{2}{7}\right) = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0; \quad -F_{AB}\left(\frac{2}{7}\right) - F_{AC}\left(\frac{1}{\sqrt{46}}\right) + F_{AD}\left(\frac{3}{7}\right) = 0 \qquad \textbf{(2)}$$

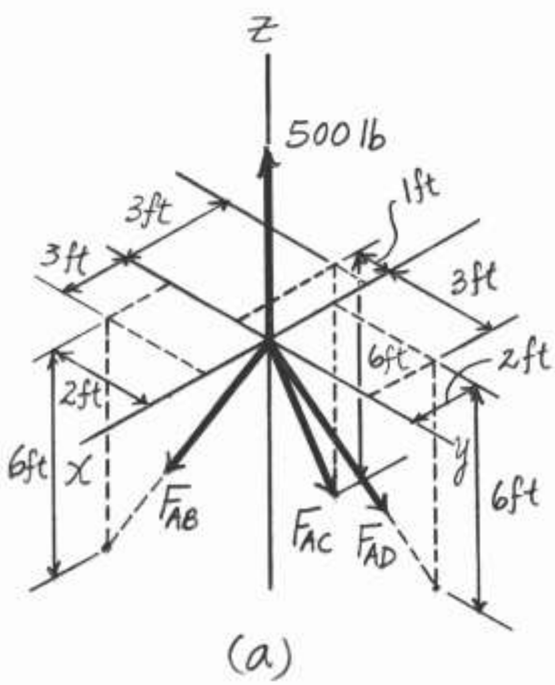
$$\Sigma F_z = 0; \quad -F_{AB}\left(\frac{6}{7}\right) - F_{AC}\left(\frac{6}{\sqrt{46}}\right) - F_{AD}\left(\frac{6}{7}\right) + 500 = 0 \qquad \textbf{(3)}$$

Solving Eqs (1), (2) and (3)

$F_{AC} = 113.04 \text{ lb} = 113 \text{ lb}$ **Ans.**

$F_{AB} = 256.67 \text{ lb} = 257 \text{ lb}$ **Ans.**

$F_{AD} = 210 \text{ lb}$ **Ans.**



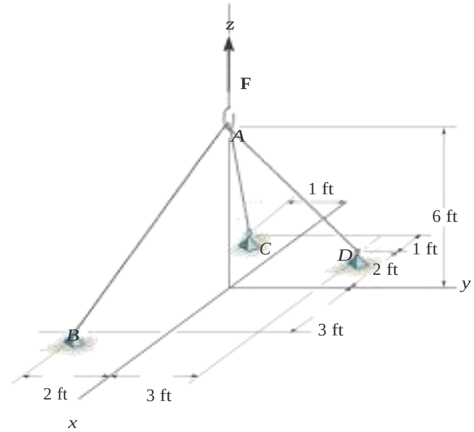
(a)

Ans:

F_{AC} = 113 lb
F_{AB} = 257 lb
F_{AD} = 210 lb

3–51.

Determine the greatest force **F** that can be applied to the ring if each cable can support a maximum force of 800 lb.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_x = 0;\quad F_{AB}\left(\frac{3}{7}\right) - F_{AC}\left(\frac{3}{\sqrt{46}}\right) - F_{AD}\left(\frac{2}{7}\right) = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0;\quad -F_{AB}\left(\frac{2}{7}\right) - F_{AC}\left(\frac{1}{\sqrt{46}}\right) + F_{AD}\left(\frac{3}{7}\right) = 0 \qquad \textbf{(2)}$$

$$\Sigma F_z = 0;\quad -F_{AB}\left(\frac{6}{7}\right) - F_{AC}\left(\frac{6}{\sqrt{46}}\right) - F_{AD}\left(\frac{6}{7}\right) + F = 0 \qquad \textbf{(3)}$$

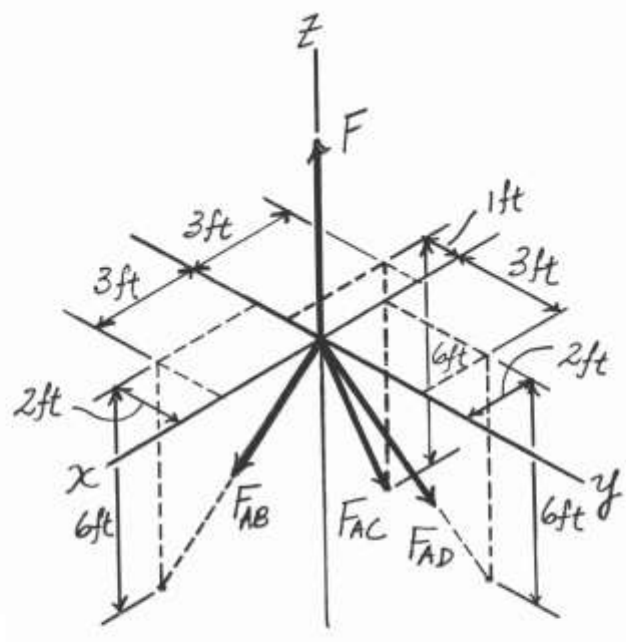
Solving Eqs (1), (2) and (3)

$$F_{AC} = 0.2261\,F \qquad F_{AB} = 0.5133\,F \qquad F_{AD} = 0.42\,F$$

Since cable *AB* is subjected to the greatest tension, its tension will reach the limit first that is $F_{AB} = 800$ lb. Then

$$800 = 0.5133\,F$$

$$F = 1558.44 \text{ lb} = 1558 \text{ lb} \qquad \textbf{Ans.}$$



(a)

Ans:
F = 1558 lb

***3–52.**

Determine the tension developed in cables *AB* and *AC* and the force developed along strut *AD* for equilibrium of the 400-lb crate.

z
2 ft
2 ft
B
C
4 ft
5.5 ft
A
D
2.5 ft
6 ft
x
y

SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i} + (-6-0)\mathbf{j} + (1.5-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (-6-0)^2 + (1.5-0)^2}}\right] = -\frac{4}{13}F_{AB}\,\mathbf{i} - \frac{12}{13}F_{AB}\,\mathbf{j} + \frac{3}{13}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i} + (-6-0)\mathbf{j} + (3-0)\mathbf{k}}{\sqrt{(2-0)^2 + (-6-0)^2 + (3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(0-0)\mathbf{i} + [0-(-6)]\mathbf{j} + [0-(-2.5)]\mathbf{k}}{\sqrt{(0-0)^2 + [0-(-6)]^2 + (0-(-2.5))^2}}\right] = \frac{12}{13}F_{AD}\,\mathbf{j} + \frac{5}{13}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = \{-400\mathbf{k}\}\text{ lb}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$\left(-\frac{4}{13}F_{AB}\,\mathbf{i} - \frac{12}{13}F_{AB}\,\mathbf{j} + \frac{3}{13}F_{AB}\,\mathbf{k}\right) + \left(\frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{12}{13}F_{AD}\,\mathbf{j} + \frac{5}{13}F_{AD}\,\mathbf{k}\right) + (-400\mathbf{k}) = 0$$

$$\left(-\frac{4}{13}F_{AB} + \frac{2}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} + \frac{12}{13}F_{AD}\right)\mathbf{j} + \left(\frac{3}{13}F_{AB} + \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} - 400\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

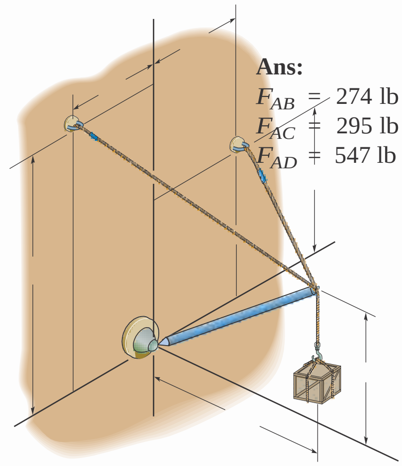
$$-\frac{4}{13}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

$$-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} + \frac{12}{13}F_{AD} = 0 \qquad \textbf{(2)}$$

$$\frac{3}{13}F_{AB} + \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} - 400 = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1) through (3) yields

$F_{AB} = 274$ lb **Ans.**
$F_{AC} = 295$ lb **Ans.**
$F_{AD} = 547$ lb **Ans.**

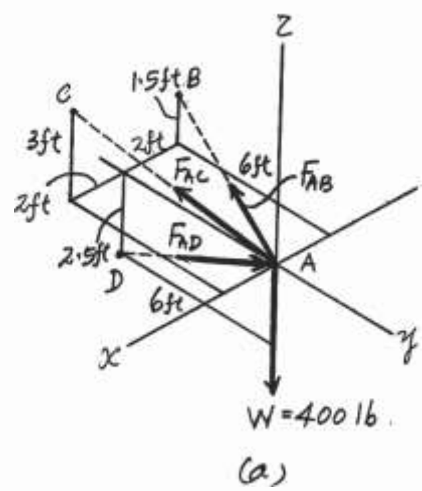


Ans:

F_{AB} = 274 lb

F_{AC} = 295 lb

F_{AD} = 547 lb



3–53.

If the tension developed in each of the cables cannot exceed 300 lb, determine the largest weight of the crate that can be supported. Also, what is the force developed along strut AD?

z 2 ft 2 ft B C 4 ft 5.5 ft A D 2.5 ft x 6 ft y

SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i} + (-6-0)\mathbf{j} + (1.5-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (-6-0)^2 + (1.5-0)^2}}\right] = -\frac{4}{13}F_{AB}\,\mathbf{i} - \frac{12}{13}F_{AB}\,\mathbf{j} + \frac{3}{13}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i} + (-6-0)\mathbf{j} + (3-0)\mathbf{k}}{\sqrt{(2-0)^2 + (-6-0)^2 + (3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(0-0)\mathbf{i} + [0-(-6)]\mathbf{j} + [0-(-2.5)]\mathbf{k}}{\sqrt{(0-0)^2 + [0-(-6)]^2 + [0-(-2.5)]^2}}\right] = \frac{12}{13}F_{AD}\,\mathbf{j} + \frac{5}{13}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = -W\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$\left(-\frac{4}{13}F_{AB}\,\mathbf{i} - \frac{12}{13}F_{AB}\,\mathbf{j} + \frac{3}{13}F_{AB}\,\mathbf{k}\right) + \left(\frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{12}{13}F_{AD}\,\mathbf{j} + \frac{5}{13}F_{AD}\,\mathbf{k}\right) + (-W\mathbf{k}) = 0$$

$$\left(-\frac{4}{13}F_{AB} + \frac{2}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} + \frac{12}{13}F_{AD}\right)\mathbf{j} + \left(\frac{3}{13}F_{AB} + \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} - W\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{4}{13}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

$$-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} + \frac{12}{13}F_{AD} = 0 \qquad \textbf{(2)}$$

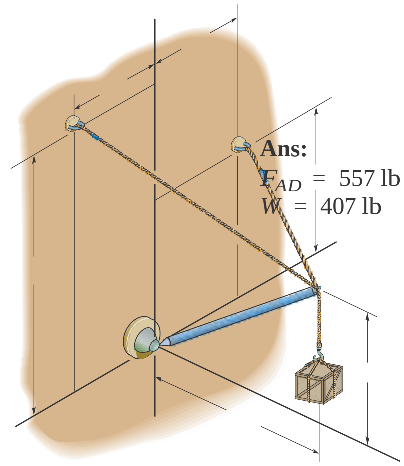
$$\frac{3}{13}F_{AB} + \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} - W = 0 \qquad \textbf{(3)}$$

Let us assume that cable AC achieves maximum tension first. Substituting $F_{AC} = 300$ lb into Eqs. (1) through (3) and solving, yields

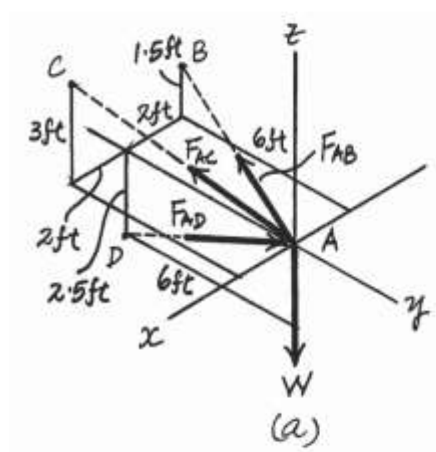
$F_{AB} = 278.57$ lb

$F_{AD} = 557$ lb $\qquad W = 407$ lb $\qquad$ **Ans.**

Since $F_{AB} = 278.57 \text{ lb} < 300 \text{ lb}$, our assumption is correct.

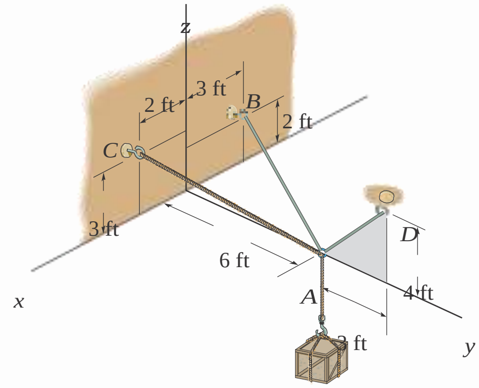


Ans:
$F_{AD} = 557$ lb
$W = 407$ lb



3–54.

Determine the tension developed in each cable for equilibrium of the 300-lb crate.



SOLUTION

Force Vectors: We can express each of the forces shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-3-0)\mathbf{i} + (-6-0)\mathbf{j} + (2-0)\mathbf{k}}{\sqrt{(-3-0)^2 + (-6-0)^2 + (2-0)^2}}\right] = -\frac{3}{7}F_{AB}\,\mathbf{i} - \frac{6}{7}F_{AB}\,\mathbf{j} + \frac{2}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i} + (-6-0)\mathbf{j} + (3-0)\mathbf{k}}{\sqrt{(2-0)^2 + (-6-0)^2 + (3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(0-0)\mathbf{i} + (3-0)\mathbf{j} + (4-0)\mathbf{k}}{\sqrt{(0-0)^2 + (3-0)^2 + (4-0)^2}}\right] = \frac{3}{5}F_{AD}\,\mathbf{j} + \frac{4}{5}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = \{-300\mathbf{k}\}\text{ lb}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

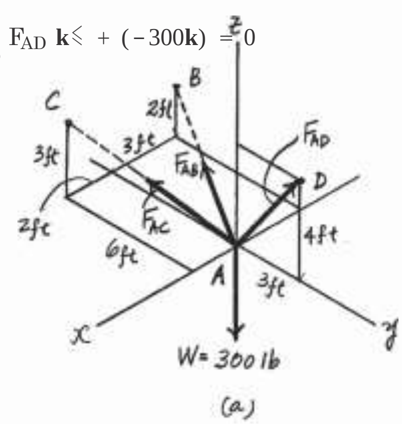
$$\left(-\frac{3}{7}F_{AB}\,\mathbf{i} - \frac{6}{7}F_{AB}\,\mathbf{j} + \frac{2}{7}F_{AB}\,\mathbf{k}\right) + \left(\frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{3}{5}F_{AD}\,\mathbf{j} + \frac{4}{5}F_{AD}\,\mathbf{k}\right) + (-300\mathbf{k}) = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{3}{7}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad (1)$$

$$-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} + \frac{3}{5}F_{AD} = 0 \qquad (2)$$

$$\frac{2}{7}F_{AB} + \frac{3}{7}F_{AC} + \frac{4}{5}F_{AD} - 300 = 0 \qquad (3)$$



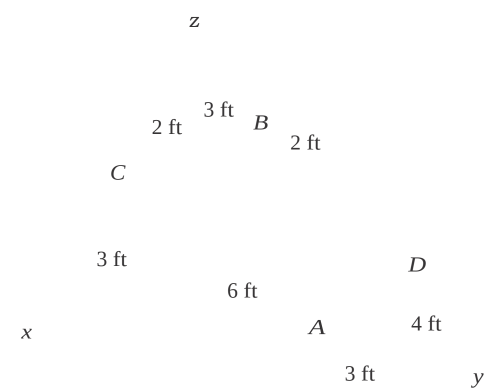
Solving Eqs. (1) through (3) yields

$F_{AB} = 79.2$ lb $\qquad F_{AC} = 119$ lb $\qquad F_{AD} = 283$ lb $\qquad$ **Ans.**

Ans:
F_{AB} = 79.2 lb
F_{AC} = 119 lb
F_{AD} = 283 lb

3–55.

Determine the maximum weight of the crate that can be suspended from cables *AB*, *AC*, and *AD* so that the tension developed in any one of the cables does not exceed 250 lb.



SOLUTION

Force Vectors: We can express each of the forces shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-3-0)\mathbf{i} + (-6-0)\mathbf{j} + (2-0)\mathbf{k}}{\sqrt{(-3-0)^2 + (-6-0)^2 + (2-0)^2}}\right] = -\frac{3}{7}F_{AB}\,\mathbf{i} - \frac{6}{7}F_{AB}\,\mathbf{j} + \frac{2}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i} + (-6-0)\mathbf{j} + (3-0)\mathbf{k}}{\sqrt{(2-0)^2 + (-6-0)^2 + (3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(0-0)\mathbf{i} + (3-0)\mathbf{j} + (4-0)\mathbf{k}}{\sqrt{(0-0)^2 + (3-0)^2 + (4-0)^2}}\right] = \frac{3}{5}F_{AD}\,\mathbf{j} + \frac{4}{5}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = -W_C\,\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$\left(-\frac{3}{7}F_{AB}\,\mathbf{i} - \frac{6}{7}F_{AB}\,\mathbf{j} + \frac{2}{7}F_{AB}\,\mathbf{k}\right) + \left(\frac{2}{7}F_{AC}\,\mathbf{i} - \frac{6}{7}F_{AC}\,\mathbf{j} + \frac{3}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{3}{5}F_{AD}\,\mathbf{j} + \frac{4}{5}F_{AD}\,\mathbf{k}\right) + (-W_C\,\mathbf{k}) = 0$$

$$\left(-\frac{3}{7}F_{AB} + \frac{2}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} + \frac{3}{5}F_{AD}\right)\mathbf{j} + \left(\frac{2}{7}F_{AB} + \frac{3}{7}F_{AC} + \frac{4}{5}F_{AD} - W_C\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{3}{7}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

$$-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} + \frac{3}{5}F_{AD} = 0 \qquad \textbf{(2)}$$

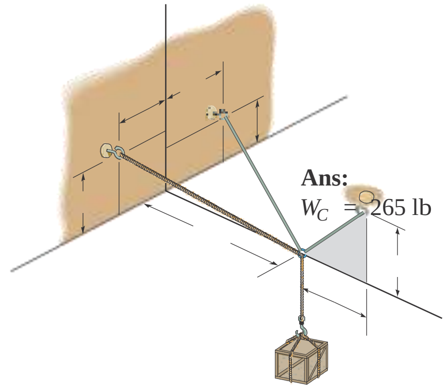
$$\frac{2}{7}F_{AB} + \frac{3}{7}F_{AC} + \frac{4}{5}F_{AD} - W_C = 0 \qquad \textbf{(3)}$$

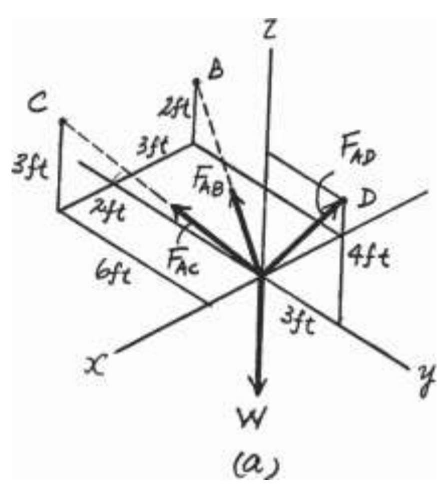
Assuming that cable *AD* achieves maximum tension first, substituting $F_{AD} = 250$ lb into Eqs. (2) and (3), and solving Eqs. (1) through (3) yields

$F_{AB} = 70$ lb $\qquad F_{AC} = 105$ lb

$W_C = 265$ lb **Ans.**

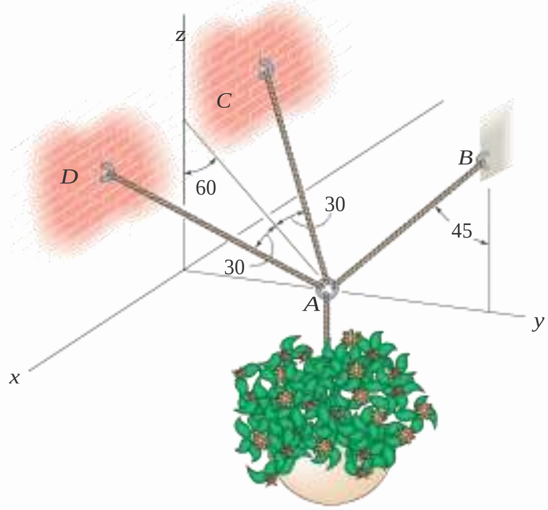
Since $F_{AB} = 70$ lb < 250 lb and $F_{AC} = 105$ lb, the above assumption is correct.





***3–56.**

The 25-kg flowerpot is supported at A by the three cords. Determine the force acting in each cord for equilibrium.



SOLUTION

$$\mathbf{F}_{AD} = F_{AD}\,(\sin 30°\mathbf{i} - \cos 30° \sin 60°\mathbf{j} + \cos 30° \cos 60°\mathbf{k})$$

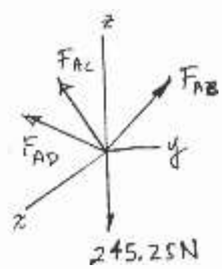
$$= 0.5F_{AD}\mathbf{i} - 0.75F_{AD}\mathbf{j} + 0.4330F_{AD}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\,(-\sin 30°\mathbf{i} - \cos 30° \sin 60°\mathbf{j} + \cos 30° \cos 60°\mathbf{k})$$

$$= -0.5F_{AC}\,\mathbf{i} - 0.75F_{AC}\mathbf{j} + 0.4330F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AB} = F_{AB}(\sin 45°\mathbf{j} + \cos 45°\mathbf{k}) = 0.7071F_{AB}\,\mathbf{j} + 0.7071F_{AB}\,\mathbf{k}$$

$$\mathbf{F} = -25(9.81)\mathbf{k} = \{-245.25\mathbf{k}\}\text{ N}$$



$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AD} + \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F} = \mathbf{0}$$

$$(0.5F_{AD}\,\mathbf{i} - 0.75F_{AD}\,\mathbf{j}) + 0.4330F_{AD}\,\mathbf{k} + (0.7071F_{AB}\,\mathbf{j} + 0.7071F_{AB}\,\mathbf{k})$$

$$+(-0.5F_{AC}\mathbf{i} - 0.75F_{AC}\mathbf{j} + 0.4330F_{AC}\mathbf{k}) + (-245.25\mathbf{k}) = \mathbf{0}$$

$$(0.5F_{AD} - 0.5F_{AC})\mathbf{i} + (-0.75F_{AD} + 0.7071F_{AB} - 0.75F_{AC})\,\mathbf{j}$$

$$+(0.4330F_{AD} + 0.7071F_{AB} + 0.4330F_{AC} - 245.25)\,\mathbf{k} = \mathbf{0}$$

Thus,

$\Sigma F_x = 0; \quad 0.5F_{AD} - 0.5F_{AC} = 0$ **[1]**

$\Sigma F_y = 0; \quad -0.75F_{AD} + 0.7071F_{AB} - 0.75F_{AC} = 0$ **[2]**

$\Sigma F_z = 0; \quad 0.4330F_{AD} + 0.7071F_{AB} + 0.4330F_{AC} - 245.25 = 0$ **[3]**

Solving Eqs. [1], [2], and [3] yields:

$F_{AD} = F_{AC} = 104\text{ N} \qquad F_{AB} = 220\text{ N}$ **Ans.**

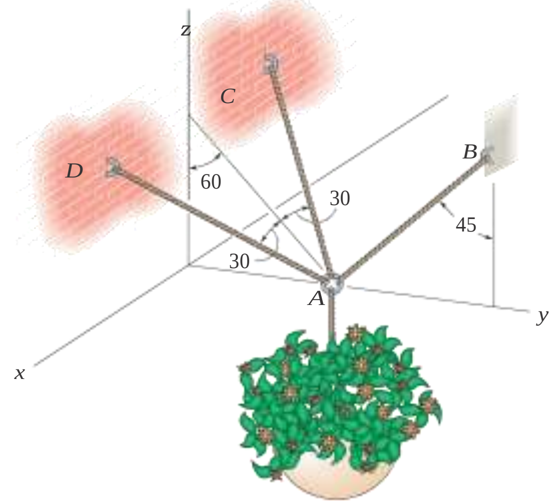
Ans:

$F_{AD} = F_{AC} = 104$ N

$F_{AB} = 220$ N

3–57.

If each cord can sustain a maximum tension of 50 N before it fails, determine the greatest weight of the flowerpot the cords can support.



SOLUTION

$\mathbf{F}_{AD} = F_{AD}(\sin 30°\mathbf{i} - \cos 30° \sin 60°\mathbf{j} + \cos 30° \cos 60°\mathbf{k})$

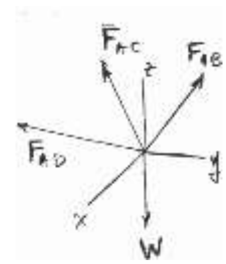
$= 0.5F_{AD}\,\mathbf{i} - 0.75F_{AD}\,\mathbf{j} + 0.4330F_{AD}\,\mathbf{k}$

$\mathbf{F}_{AC} = F_{AC}(-\sin 30°\mathbf{i} - \cos 30° \sin 60°\mathbf{j} + \cos 30° \cos 60°\mathbf{k})$

$= -0.5F_{AC}\mathbf{i} - 0.75F_{AC}\,\mathbf{j} + 0.4330F_{AC}\,\mathbf{k}$

$\mathbf{F}_{AB} = F_{AB}(\sin 45°\mathbf{j} + \cos 45°\mathbf{k}) = 0.7071F_{AB}\,\mathbf{j} + 0.7071F_{AB}\,\mathbf{k}$

$\mathbf{W} = -W\mathbf{k}$



©$F_x = 0;$ $\quad 0.5F_{AD} - 0.5F_{AC} = 0$

$F_{AD} = F_{AC}$ **(1)**

©$F_y = 0;$ $\quad -0.75F_{AD} + 0.7071F_{AB} - 0.75F_{AC} = 0$

$0.7071F_{AB} = 1.5F_{AC}$ **(2)**

©$F_z = 0;$ $\quad 0.4330F_{AD} + 0.7071F_{AB} + 0.4330F_{AC} - W = 0$

$0.8660F_{AC} + 1.5F_{AC} - W = 0$

$2.366F_{AC} = W$

Assume $F_{AC} = 50$ N then

$$F_{AB} = \frac{1.5(50)}{0.7071} = 106.07 \text{ N } 7 \text{ 50 N } (\textbf{N.G!})$$

Assume $F_{AB} = 50$ N. Then

$$F_{AC} = \frac{0.7071(50)}{1.5} = 23.57 \text{ N } 6 \text{ 50 N } (\textbf{O.K!})$$

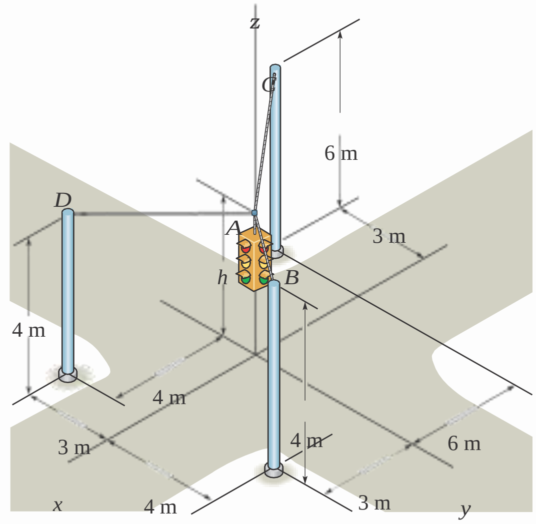
Thus,

$$W = 2.366(23.57) = 55.767 = 55.8 \text{ N}$$ **Ans.**

Ans:
$W = 55.8$ N

3–58.

Determine the tension developed in the three cables required to support the traffic light, which has a mass of 15 kg. Take $h = 4$ m.



Solution

$$\mathbf{u}_{AB} = \left\{\frac{3}{5}\,\mathbf{i} + \frac{4}{5}\,\mathbf{j}\right\}$$

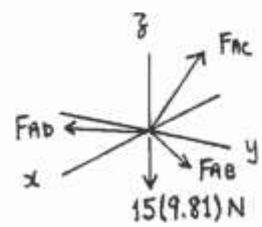
$$\mathbf{u}_{AC} = \left\{-\frac{6}{7}\,\mathbf{i} - \frac{3}{7}\,\mathbf{j} + \frac{2}{7}\,\mathbf{k}\right\}$$

$$\mathbf{u}_{AD} = \left\{\frac{4}{5}\,\mathbf{i} - \frac{3}{5}\,\mathbf{j}\right\}$$

$$\Sigma F_x = 0; \qquad \frac{3}{5}F_{AB} - \frac{6}{7}F_{AC} + \frac{4}{5}F_{AD} = 0$$

$$\Sigma F_y = 0; \qquad \frac{4}{5}F_{AB} - \frac{3}{7}F_{AC} - \frac{3}{5}F_{AD} = 0$$

$$\Sigma F_z = 0; \qquad \frac{2}{7}F_{AC} - 15(9.81) = 0$$



$F_{AB} = 441$ N **Ans.**

$F_{AC} = 515$ N **Ans.**

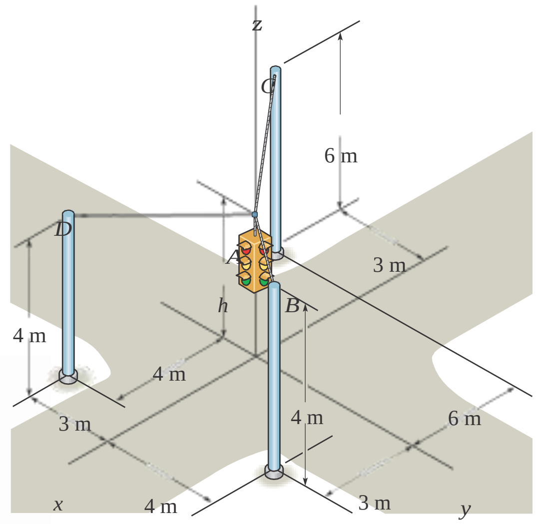
$F_{AD} = 221$ N **Ans.**

Ans:

F_{AB} = 441 N
F_{AC} = 515 N
F_{AD} = 221 N

3–59.

Determine the tension developed in the three cables required to support the traffic light, which has a mass of 20 kg. Take $h = 3.5$ m.

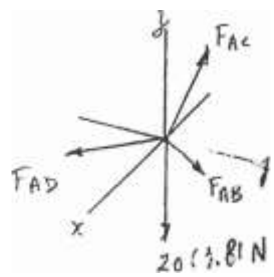


Solution

$$\mathbf{u}_{AB} = \frac{3\mathbf{i} + 4\mathbf{j} + 0.5\mathbf{k}}{\sqrt{3^2 + 4^2 + (0.5)^2}} = \frac{3\mathbf{i} + 4\mathbf{j} + 0.5\mathbf{k}}{\sqrt{25.25}}$$

$$\mathbf{u}_{AC} = \frac{-6\mathbf{i} - 3\mathbf{j} + 2.5\mathbf{k}}{\sqrt{(-6)^2 + (-3)^2 + 2.5^2}} = \frac{-6\mathbf{i} - 3\mathbf{j} + 2.5\mathbf{k}}{\sqrt{51.25}}$$

$$\mathbf{u}_{AD} = \frac{4\mathbf{i} - 3\mathbf{j} + 0.5\mathbf{k}}{\sqrt{4^2 + (-3)^2 + 0.5^2}} = \frac{4\mathbf{i} - 3\mathbf{j} + 0.5\mathbf{k}}{\sqrt{25.25}}$$



$$\Sigma F_x = 0; \quad \frac{3}{\sqrt{25.25}}F_{AB} - \frac{6}{\sqrt{51.25}}F_{AC} + \frac{4}{\sqrt{25.25}}F_{AD} = 0$$

$$\Sigma F_y = 0; \quad \frac{4}{\sqrt{25.25}}F_{AB} - \frac{3}{\sqrt{51.25}}F_{AC} - \frac{3}{\sqrt{25.25}}F_{AD} = 0$$

$$\Sigma F_z = 0; \quad \frac{0.5}{\sqrt{25.25}}F_{AB} + \frac{2.5}{\sqrt{51.25}}F_{AC} + \frac{0.5}{\sqrt{25.25}}F_{AD} - 20(9.81) = 0$$

Solving,

$F_{AB} = 348$ N **Ans.**

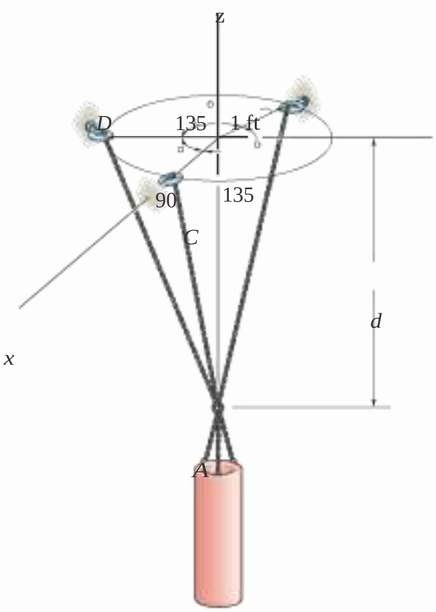
$F_{AC} = 413$ N **Ans.**

$F_{AD} = 174$ N **Ans.**

Ans:
F_{AB} = 348 N
F_{AC} = 413 N
F_{AD} = 174 N

***3–60.**

The 800-lb cylinder is supported by three chains as shown. Determine the force in each chain for equilibrium. Take $d = 1$ ft.



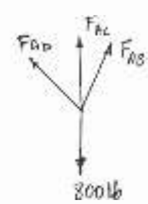
SOLUTION

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-1\mathbf{j} + 1\mathbf{k}}{\sqrt{(-1)^2 + 1^2}}\right) = -0.7071F_{AD}\mathbf{j} + 0.7071F_{AD}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{1\mathbf{i} + 1\mathbf{k}}{\sqrt{1^2 + 1^2}}\right) = 0.7071F_{AC}\mathbf{i} + 0.7071F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{-0.7071\mathbf{i} + 0.7071\mathbf{j} + 1\mathbf{k}}{\sqrt{(-0.7071)^2 + 0.7071^2 + 1^2}}\right)$$

$$= -0.5F_{AB}\mathbf{i} + 0.5F_{AB}\mathbf{j} + 0.7071F_{AB}\mathbf{k}$$



$$\mathbf{F} = \{-800\mathbf{k}\}\text{ lb}$$

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AD} + \mathbf{F}_{AC} + \mathbf{F}_{AB} + \mathbf{F} = \mathbf{0}$$

$$(-0.7071F_{AD}\mathbf{j} + 0.7071F_{AD}\mathbf{k}) + (0.7071F_{AC}\mathbf{i} + 0.7071F_{AC}\mathbf{k})$$

$$+ (-0.5F_{AB}\mathbf{i} + 0.5F_{AB}\mathbf{j} + 0.7071F_{AB}\mathbf{k}) + (-800\mathbf{k}) = \mathbf{0}$$

$$(0.7071F_{AC} - 0.5F_{AB})\mathbf{i} + (-0.7071F_{AD} + 0.5F_{AB})\mathbf{j}$$

$$+ (0.7071F_{AD} + 0.7071F_{AC} + 0.7071F_{AB} - 800)\mathbf{k} = \mathbf{0}$$

$$\Sigma F_x = 0; \qquad 0.7071F_{AC} - 0.5F_{AB} = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0; \qquad -0.7071F_{AD} + 0.5F_{AB} = 0 \qquad \textbf{(2)}$$

$$\Sigma F_z = 0; \qquad 0.7071F_{AD} + 0.7071F_{AC} + 0.7071F_{AB} - 800 = 0 \qquad \textbf{(3)}$$

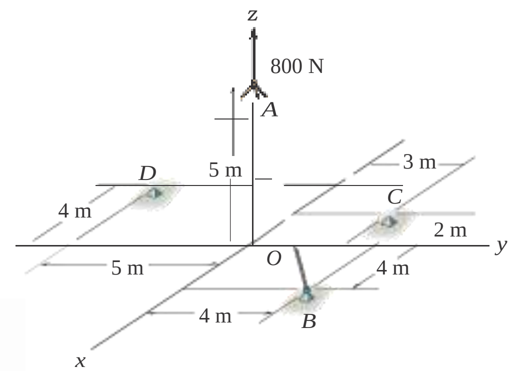
Solving Eqs. (1), (2), and (3) yields:

$F_{AB} = 469$ lb $\qquad F_{AC} = F_{AD} = 331$ lb **Ans.**

Ans:
F_{AB} = 469 lb
F_{AC} = F_{AD} = 331 lb

3–61.

Determine the tension in each cable for equilibrium.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_x = 0;\quad F_{AB}\left(\frac{4}{\sqrt{57}}\right) - F_{AC}\left(\frac{2}{\sqrt{38}}\right) - F_{AD}\left(\frac{4}{\sqrt{66}}\right) = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0;\quad F_{AB}\left(\frac{4}{\sqrt{57}}\right) + F_{AC}\left(\frac{3}{\sqrt{38}}\right) - F_{AD}\left(\frac{5}{\sqrt{66}}\right) = 0 \qquad \textbf{(2)}$$

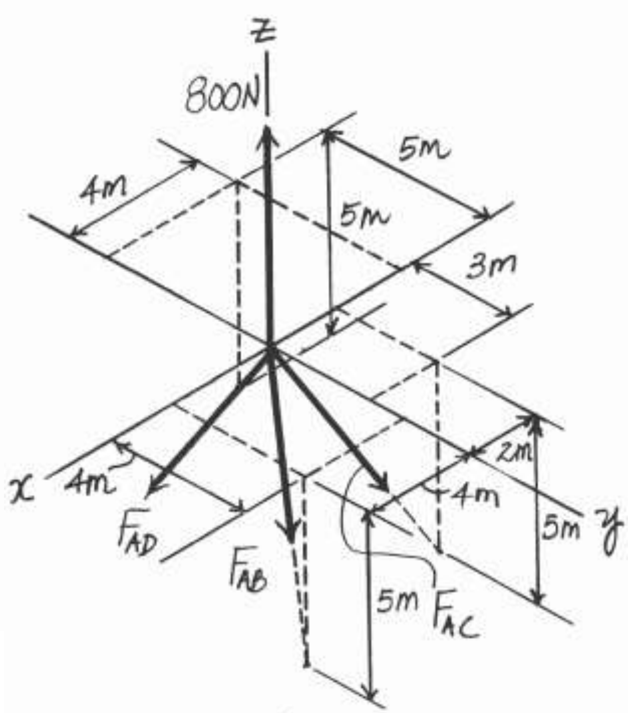
$$\Sigma F_z = 0;\quad -F_{AB}\left(\frac{5}{\sqrt{57}}\right) - F_{AC}\left(\frac{5}{\sqrt{38}}\right) - F_{AD}\left(\frac{5}{\sqrt{66}}\right) + 800 = 0 \qquad \textbf{(3)}$$

Solving Eqs (1), (2) and (3)

$F_{AC} = 85.77\text{ N} = 85.8\text{ N}$ **Ans.**

$F_{AB} = 577.73\text{ N} = 578\text{ N}$ **Ans.**

$F_{AD} = 565.15\text{ N} = 565\text{ N}$ **Ans.**



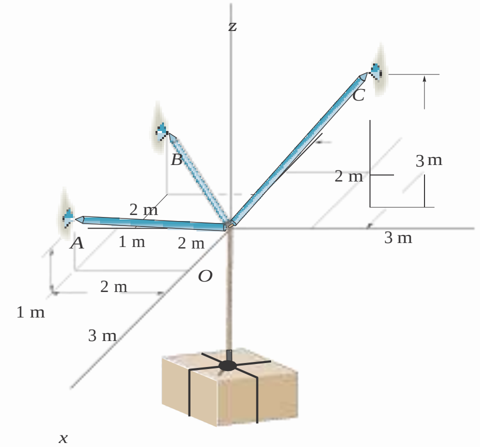
(a)

Ans:

$F_{AC} = 85.8$ N
$F_{AB} = 578$ N
$F_{AD} = 565$ N

3–62.

If the maximum force in each rod can not exceed 1500 N, determine the greatest mass of the crate that can be supported.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_x = 0; \quad F_{OA}\left(\frac{2}{\sqrt{14}}\right) - F_{OC}\left(\frac{3}{\sqrt{22}}\right) + F_{OB}\left(\frac{1}{3}\right) = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0; \quad -F_{OA}\left(\frac{3}{\sqrt{14}}\right) + F_{OC}\left(\frac{2}{\sqrt{22}}\right) + F_{OB}\left(\frac{2}{3}\right) = 0 \qquad \textbf{(2)}$$

$$\Sigma F_z = 0; \quad F_{OA}\left(\frac{1}{\sqrt{14}}\right) + F_{OC}\left(\frac{3}{\sqrt{22}}\right) - F_{OB}\left(\frac{2}{3}\right) - m(9.81) = 0 \qquad \textbf{(3)}$$

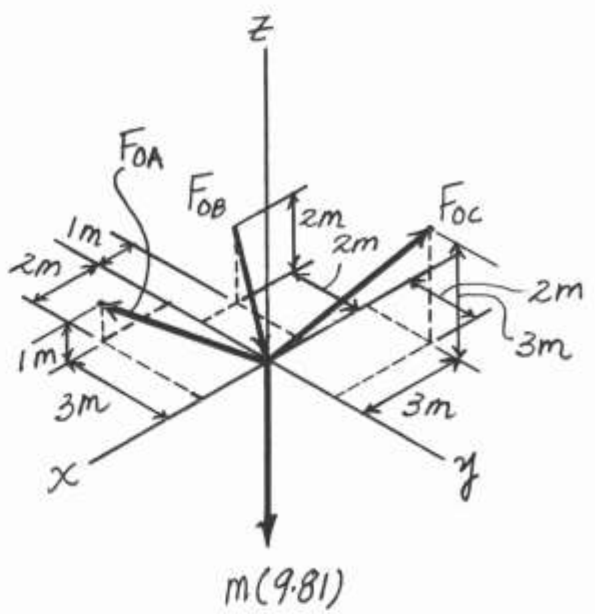
Solving Eqs (1), (2) and (3),

$$F_{OC} = 16.95m \qquad F_{OA} = 15.46m \qquad F_{OB} = 7.745m$$

Since link *OC* subjected to the greatest force, it will reach the limiting force first, that is $F_{OC} = 1500$ N. Then

$$1500 = 16.95\,m$$

$$m = 88.48 \text{ kg} = 88.5 \text{ kg} \qquad \textbf{Ans.}$$

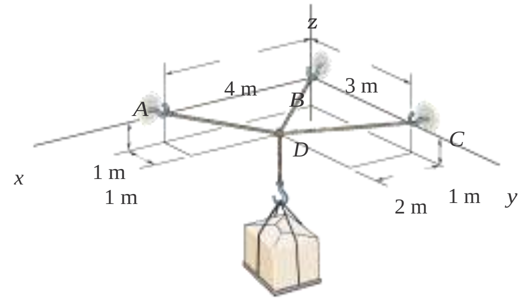


(a)

Ans:
$m = 88.5$ kg

3–63.

The crate has a mass of 130 kg. Determine the tension developed in each cable for equilibrium.



Solution

Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$$\Sigma F_x = 0; \quad F_{AD}\left(\frac{2}{\sqrt{6}}\right) - F_{BD}\left(\frac{2}{\sqrt{6}}\right) - F_{CD}\left(\frac{2}{3}\right) = 0 \qquad \textbf{(1)}$$

$$\Sigma F_y = 0; \quad -F_{AD}\left(\frac{1}{\sqrt{6}}\right) - F_{BD}\left(\frac{1}{\sqrt{6}}\right) + F_{CD}\left(\frac{2}{3}\right) = 0 \qquad \textbf{(2)}$$

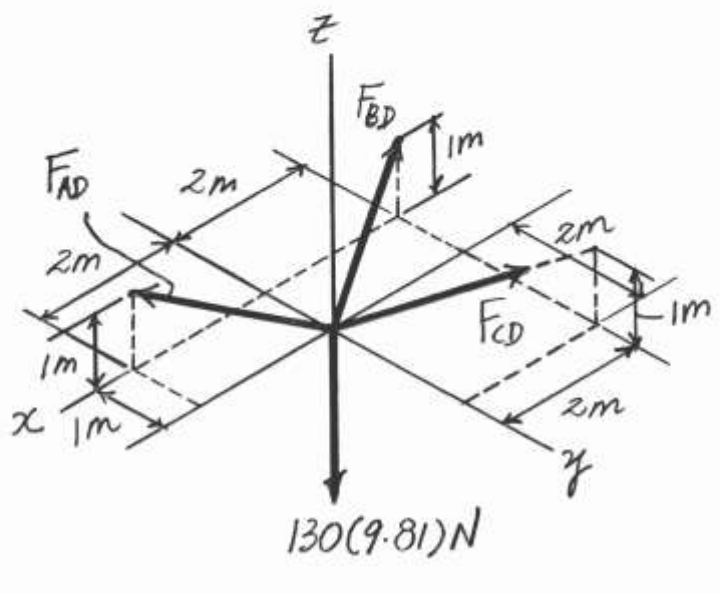
$$\Sigma F_z = 0; \quad F_{AD}\left(\frac{1}{\sqrt{6}}\right) + F_{BD}\left(\frac{1}{\sqrt{6}}\right) + F_{CD}\left(\frac{1}{3}\right) - 130(9.81) = 0 \qquad \textbf{(3)}$$

Solving Eqs (1), (2) and (3)

$F_{AD} = 1561.92 \text{ N} = 1.56 \text{ kN}$ **Ans.**

$F_{BD} = 520.64 \text{ N} = 521 \text{ N}$ **Ans.**

$F_{CD} = 1275.3 \text{ N} = 1.28 \text{ kN}$ **Ans.**



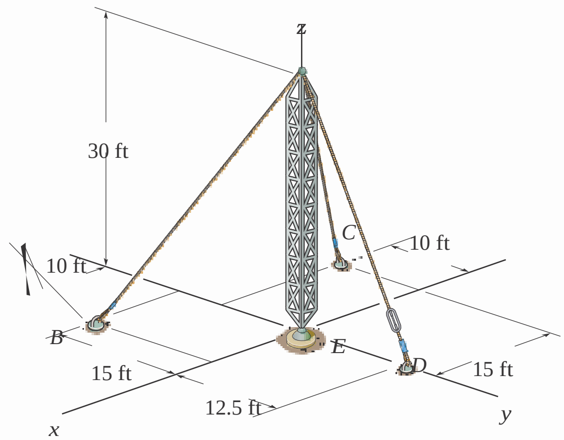
(a)

Ans:

$F_{AD} = 1.56\ \text{kN}$
$F_{BD} = 521\ \text{N}$
$F_{CD} = 1.28\ \text{kN}$

***3–64.**

If cable *AD* is tightened by a turnbuckle and develops a tension of 1300 lb, determine the tension developed in cables *AB* and *AC* and the force developed along the antenna tower *AE* at point *A*.



SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(10-0)\mathbf{i} + (-15-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(10-0)^2 + (-15-0)^2 + (-30-0)^2}}\right] = \frac{2}{7}F_{AB}\,\mathbf{i} - \frac{3}{7}F_{AB}\,\mathbf{j} - \frac{6}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-15-0)\mathbf{i} + (-10-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(-15-0)^2 + (-10-0)^2 + (-30-0)^2}}\right] = -\frac{3}{7}F_{AC}\,\mathbf{i} - \frac{2}{7}F_{AC}\,\mathbf{j} - \frac{6}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(0-0)\mathbf{i} + (12.5-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(0-0)^2 + (12.5-0)^2 + (-30-0)^2}}\right] = \{500\mathbf{j} - 1200\mathbf{k}\}\text{ lb}$$

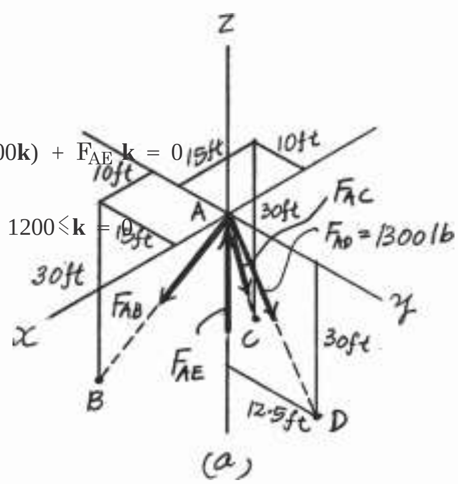
$$\mathbf{F}_{AE} = F_{AE}\,\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0};\quad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F}_{AE} = \mathbf{0}$$

$$\left(\frac{2}{7}F_{AB}\,\mathbf{i} - \frac{3}{7}F_{AB}\,\mathbf{j} - \frac{6}{7}F_{AB}\,\mathbf{k}\right) + \left(-\frac{3}{7}F_{AC}\,\mathbf{i} - \frac{2}{7}F_{AC}\,\mathbf{j} - \frac{6}{7}F_{AC}\,\mathbf{k}\right) + (500\mathbf{j} - 1200\mathbf{k}) + F_{AE}\,\mathbf{k} = \mathbf{0}$$

$$\left(\frac{2}{7}F_{AB} - \frac{3}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{3}{7}F_{AB} - \frac{2}{7}F_{AC} + 500\right)\mathbf{j} + \left(-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} + F_{AE} - 1200\right)\mathbf{k} = \mathbf{0}$$



Equating the **i**, **j**, and **k** components yields

$$\frac{2}{7}F_{AB} - \frac{3}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

$$-\frac{3}{7}F_{AB} - \frac{2}{7}F_{AC} + 500 = 0 \qquad \textbf{(2)}$$

$$-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} + F_{AE} - 1200 = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1) through (3) yields $F_{AB} = 808$ lb

$F_{AC} = 538$ lb

$F_{AE} = 2354$ lb $= 2.35$ kip

Ans.

Ans.

Ans.

Ans:

$F_{AB} = 808$ lb

$F_{AC} = 538$ lb

$F_{AE} = 2.35$ kip

3–65.

If the tension developed in either cable *AB* or *AC* cannot exceed 1000 lb, determine the maximum tension that can be developed in cable *AD* when it is tightened by the turnbuckle. Also, what is the force developed along the antenna tower at point *A*?

z
A
30 ft
C
10 ft
10 ft
B
E
D
15 ft
15 ft
12.5 ft
y
x

SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. *a* in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(10-0)\mathbf{i} + (-15-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(10-0)^2 + (-15-0)^2 + (-30-0)^2}}\right] = \frac{2}{7}F_{AB}\,\mathbf{i} - \frac{3}{7}F_{AB}\,\mathbf{j} - \frac{6}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-15-0)\mathbf{i} + (-10-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(-15-0)^2 + (-10-0)^2 + (-30-0)^2}}\right] = -\frac{3}{7}F_{AC}\,\mathbf{i} - \frac{2}{7}F_{AC}\,\mathbf{j} - \frac{6}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F\left[\frac{(0-0)\mathbf{i} + (12.5-0)\mathbf{j} + (-30-0)\mathbf{k}}{\sqrt{(0-0)^2 + (12.5-0)^2 + (-30-0)^2}}\right] = \frac{5}{13}F\mathbf{j} - \frac{12}{13}F\,\mathbf{k}$$

$$\mathbf{F}_{AE} = F_{AE}\,\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F}_{AE} = \mathbf{0}$$

$$\left(\frac{2}{7}F_{AB}\,\mathbf{i} - \frac{3}{7}F_{AB}\,\mathbf{j} - \frac{6}{7}F_{AB}\,\mathbf{k}\right) + \left(-\frac{3}{7}F_{AC}\,\mathbf{i} - \frac{2}{7}F_{AC}\,\mathbf{j} - \frac{6}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{5}{13}F\mathbf{j} - \frac{12}{13}F\mathbf{k}\right) + F_{AE}\,\mathbf{k} = 0$$

$$\left(\frac{2}{7}F_{AB} - \frac{3}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{3}{7}F_{AB} - \frac{2}{7}F_{AC} + \frac{5}{13}F\right)\mathbf{j} + \left(-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F + F_{AE}\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$\frac{2}{7}F_{AB} - \frac{3}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

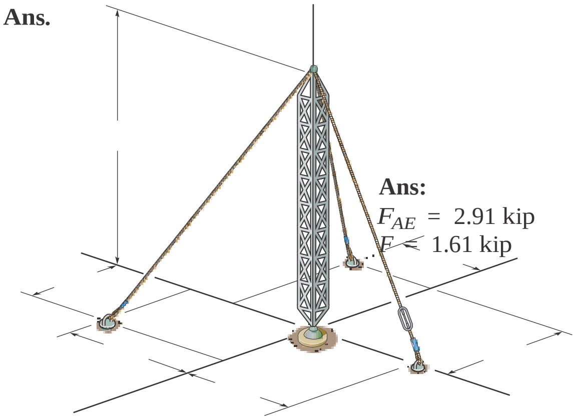
$$-\frac{3}{7}F_{AB} - \frac{2}{7}F_{AC} + \frac{5}{13}F = 0 \qquad \textbf{(2)}$$

$$-\frac{6}{7}F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F + F_{AE} = 0 \qquad \textbf{(3)}$$

Let us assume that cable *AB* achieves maximum tension first. Substituting $F_{AB} = 1000$ lb into Eqs. (1) through (3) and solving yields

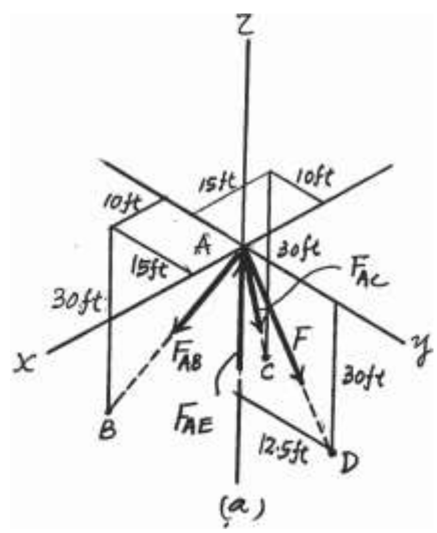
$F_{AC} = 666.67$ lb

$F_{AE} = 2914$ lb $= 2.91$ kip $F = 1610$ lb $= 1.61$ kip **Ans.**



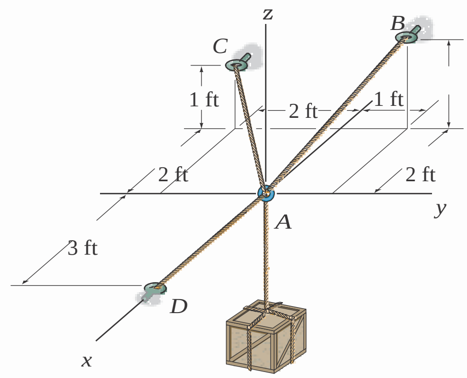
Since $F_{AC} = 666.67$ lb $<$ 1000 lb, our assumption is correct.

Ans:
$F_{AE} = 2.91$ kip
$F = 1.61$ kip



3–66.

Determine the tension developed in cables AB, AC, and AD required for equilibrium of the 300-lb crate.



SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i} + (1-0)\mathbf{j} + (2-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (1-0)^2 + (2-0)^2}}\right] = -\frac{2}{3}F_{AB}\,\mathbf{i} + \frac{1}{3}F_{AB}\,\mathbf{j} + \frac{2}{3}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-2-0)\mathbf{i} + (-2-0)\mathbf{j} + (1-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (-2-0)^2 + (1-0)^2}}\right] = -\frac{2}{3}F_{AC}\,\mathbf{i} - \frac{2}{3}F_{AC}\,\mathbf{j} + \frac{1}{3}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\,\mathbf{i}$$

$$\mathbf{W} = [-300\mathbf{k}]\text{ lb}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}\,\mathbf{i} + \frac{1}{3}F_{AB}\,\mathbf{j} + \frac{2}{3}F_{AB}\,\mathbf{k}\right) + \left(-\frac{2}{3}F_{AC}\,\mathbf{i} - \frac{2}{3}F_{AC}\,\mathbf{j} + \frac{1}{3}F_{AC}\,\mathbf{k}\right) + F_{AD}\,\mathbf{i} + (-300\mathbf{k}) = \mathbf{0}$$

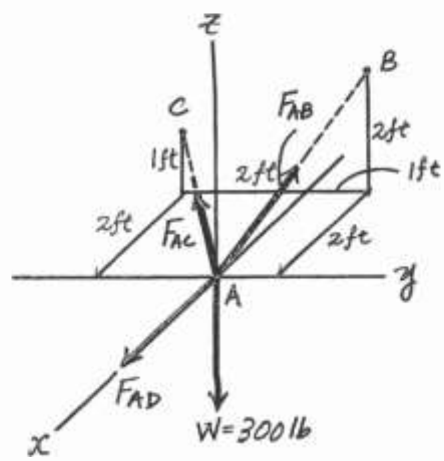
$$\left(-\frac{2}{3}F_{AB} - \frac{2}{3}F_{AC} + F_{AD}\right)\mathbf{i} + \left(\frac{1}{3}F_{AB} - \frac{2}{3}F_{AC}\right)\mathbf{j} + \left(\frac{2}{3}F_{AB} + \frac{1}{3}F_{AC} - 300\right)\mathbf{k} = \mathbf{0}$$

Equating the **i, j**, and **k** components yields

$$-\frac{2}{3}F_{AB} - \frac{2}{3}F_{AC} + F_{AD} = 0 \qquad \textbf{(1)}$$

$$\frac{1}{3}F_{AB} - \frac{2}{3}F_{AC} = 0 \qquad \textbf{(2)}$$

$$\frac{2}{3}F_{AB} + \frac{1}{3}F_{AC} - 300 = 0 \qquad \textbf{(3)}$$



Solving Eqs. (1) through (3) yields

$F_{AB} = 360$ lb **Ans.**

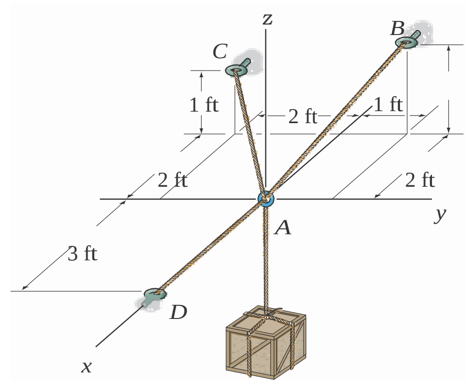
$F_{AC} = 180$ lb **Ans.**

$F_{AD} = 360$ lb **Ans.**

Ans:
F_{AB} = 360 lb
F_{AC} = 180 lb
F_{AD} = 360 lb

3–67.

Determine the maximum weight of the crate so that the tension developed in any cable does not exceed 450 lb.



SOLUTION

Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i} + (1-0)\mathbf{j} + (2-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (1-0)^2 + (2-0)^2}}\right] = -\frac{2}{3}F_{AB}\,\mathbf{i} + \frac{1}{3}F_{AB}\,\mathbf{j} + \frac{2}{3}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-2-0)\mathbf{i} + (-2-0)\mathbf{j} + (1-0)\mathbf{k}}{\sqrt{(-2-0)^2 + (-2-0)^2 + (1-0)^2}}\right] = -\frac{2}{3}F_{AC}\,\mathbf{i} - \frac{2}{3}F_{AC}\,\mathbf{j} + \frac{1}{3}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\,\mathbf{i}$$

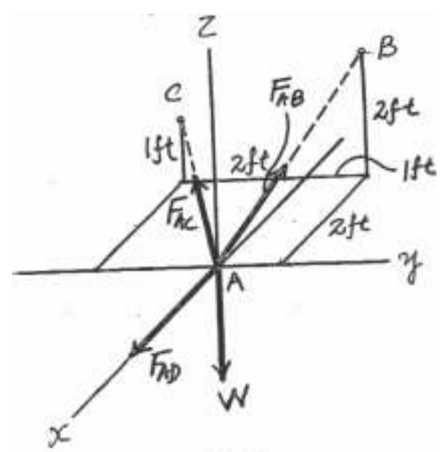
$$\mathbf{W} = -W\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}\,\mathbf{i} + \frac{1}{3}F_{AB}\,\mathbf{j} + \frac{2}{3}F_{AB}\,\mathbf{k}\right) + \left(-\frac{2}{3}F_{AC}\,\mathbf{i} - \frac{2}{3}F_{AC}\,\mathbf{j} + \frac{1}{3}F_{AC}\,\mathbf{k}\right) + F_{AD}\,\mathbf{i} + (-W\mathbf{k}) = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB} - \frac{2}{3}F_{AC} + F_{AD}\right)\mathbf{i} + \left(\frac{1}{3}F_{AB} - \frac{2}{3}F_{AC}\right)\mathbf{j} + \left(\frac{2}{3}F_{AB} + \frac{1}{3}F_{AC} - W\right)\mathbf{k} = \mathbf{0}$$



(a)

Equating the **i**, **j**, and **k** components yields

$$-\frac{2}{3}F_{AB} - \frac{2}{3}F_{AC} + F_{AD} = 0 \qquad \textbf{(1)}$$

$$\frac{1}{3}F_{AB} - \frac{2}{3}F_{AC} = 0 \qquad \textbf{(2)}$$

$$\frac{2}{3}F_{AB} + \frac{1}{3}F_{AC} - W = 0 \qquad \textbf{(3)}$$

Let us assume that cable *AB* achieves maximum tension first. Substituting $F_{AB} = 450$ lb into Eqs. (1) through (3) and solving, yields

$F_{AC} = 225$ lb $\qquad F_{AD} = 450$ lb

$W = 375$ lb **Ans.**

Since $F_{AC} = 225$ lb $<$ 450 lb, our assumption is correct.

Ans:
$W = 375$ lb