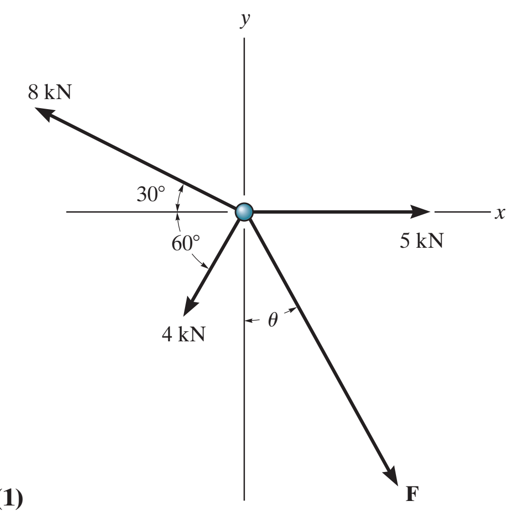
3–1.

Determine the magnitude and direction θ of $\mathbf{F}$ so that the particle is in equilibrium.



SOLUTION

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

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F\sin\theta + 5 - 4\cos 60^\circ - 8\cos 30^\circ = 0$$

$$F\sin\theta = 3.9282 \qquad \textbf{(1)}$$

$$+\uparrow\Sigma F_y = 0; \qquad 8\sin 30^\circ - 4\sin 60^\circ - F\cos\theta = 0$$

$$F\cos\theta = 0.5359 \qquad \textbf{(2)}$$

Divide Eq (1) by (2),

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

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

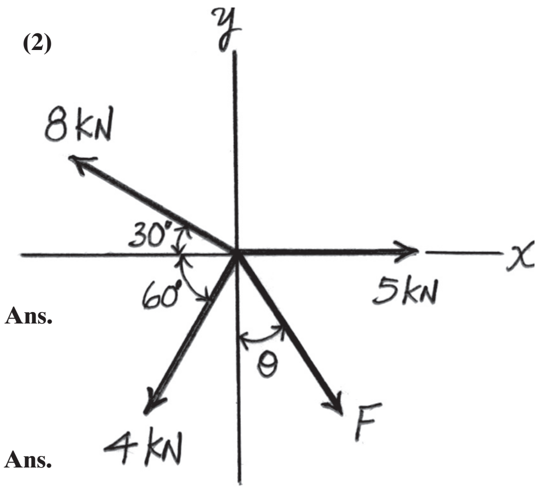
$$\tan\theta = 7.3301$$

$$\theta = 82.23^\circ = 82.2^\circ \qquad \textbf{Ans.}$$

Substitute this result into Eq. (1),

$$F\sin 82.23^\circ = 3.9282$$

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

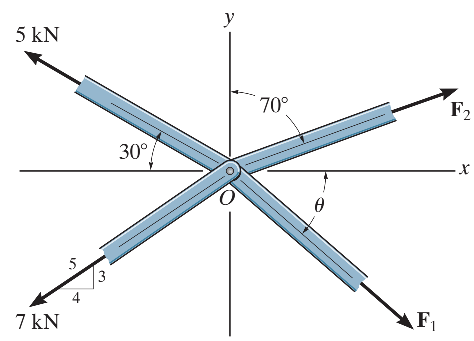


(a)

Ans:
$\theta = 82.2^\circ$
$F = 3.96$ kN

3–2.

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 $\theta = 60°$.



SOLUTION

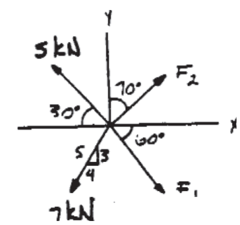
$\xrightarrow{+} \Sigma F_x = 0;\qquad F_2 \sin 70° + F_1 \cos 60° - 5 \cos 30° - \frac{4}{5}(7) = 0$

$0.9397F_2 + 0.5F_1 = 9.930$

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

$0.3420F_2 - 0.8660F_1 = 1.7$

Solving:



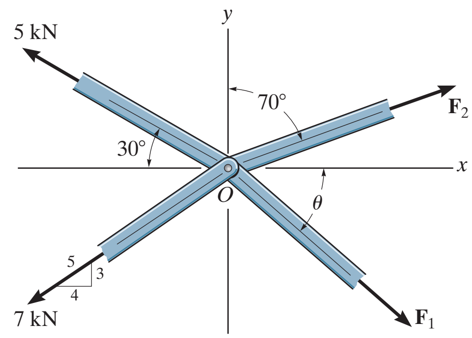
$F_2 = 9.60 \text{ kN}$ **Ans.**

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

Ans:
$F_2 = 9.60 \text{ kN}$
$F_1 = 1.83 \text{ kN}$

3–3.

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

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

$F_1 \cos \theta = 4.2920$

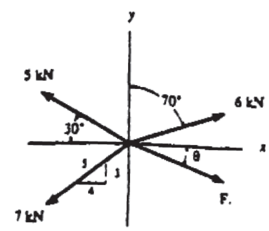
$+\uparrow \Sigma F_y = 0; \quad 6 \cos 70° + 5 \sin 30° - F_1 \sin \theta - \frac{3}{5}(7) = 0$

$F_1 \sin \theta = 0.3521$

Solving:

$\theta = 4.69°$ **Ans.**

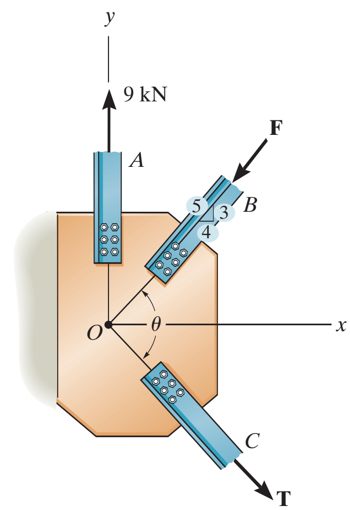
$F_1 = 4.31$ kN **Ans.**



Ans:
$\theta = 4.69°$
$F_1 = 4.31$ kN

***3–4.**

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

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

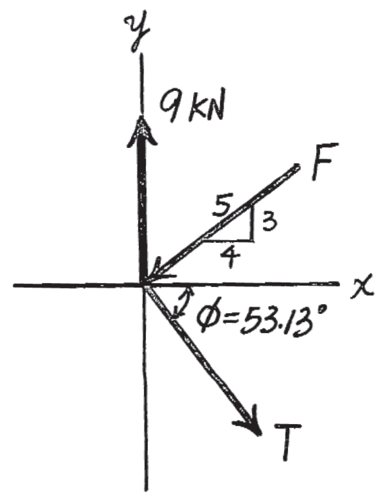
$\stackrel{+}{\rightarrow} \Sigma F_x = 0; \qquad T \cos 53.13° - F\left(\frac{4}{5}\right) = 0$

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

Solving,

$T = 7.20 \text{ kN}$ **Ans.**

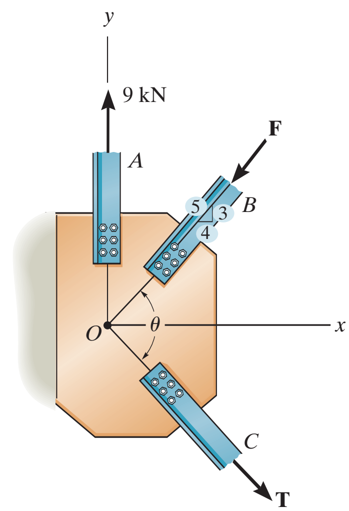
$F = 5.40 \text{ kN}$ **Ans.**



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

3–5.

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

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

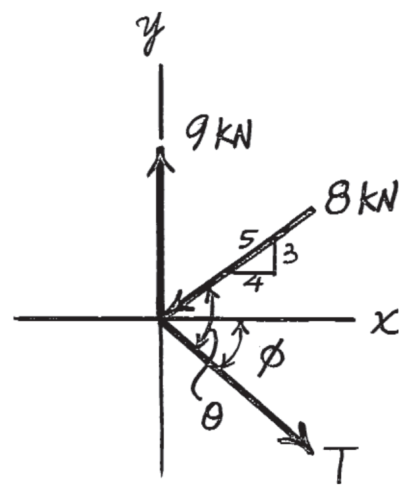
$+\uparrow \Sigma F_y = 0; \qquad 9 - 8\left(\frac{3}{5}\right) - T\sin\phi = 0$ **(2)**

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

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

$$T = 7.66 \text{ kN}$$ **Ans.**

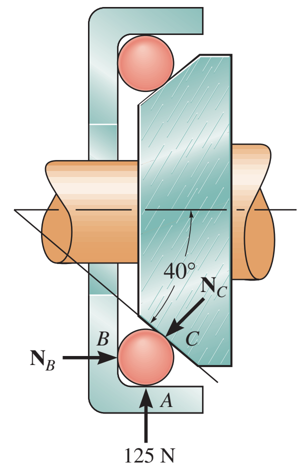
$$\theta = \phi + \tan^{-1}\left(\frac{3}{4}\right) = 70.1°$$ **Ans.**



Ans:
$T = 7.66$ kN
$\theta = 70.1°$

3–6.

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.



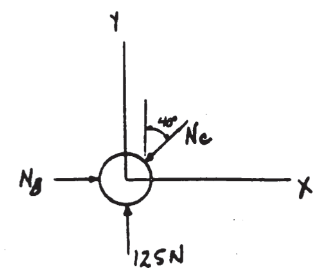
SOLUTION

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

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

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

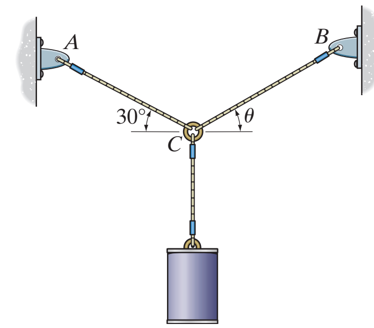
$N_B = 105 \text{ N}$ **Ans.**



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

3–7.

Determine the tension developed in wires CA and CB required for equilibrium of the 10-kg cylinder. Take $\theta = 40°$.



SOLUTION

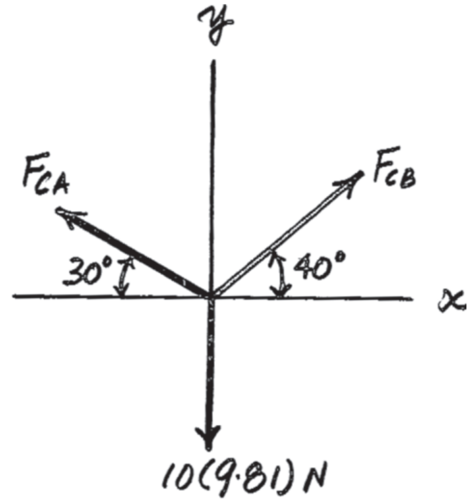
Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram shown in Fig. a,

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad F_{CB} \cos 40° - F_{CA} \cos 30° = 0$ **(1)**

$+\uparrow \Sigma F_y = 0; \quad F_{CB} \sin 40° + F_{CA} \sin 30° - 10(9.81) = 0$ **(2)**

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

$F_{CA} = 80.0 \text{ N} \qquad F_{CB} = 90.4 \text{ N}$ **Ans.**

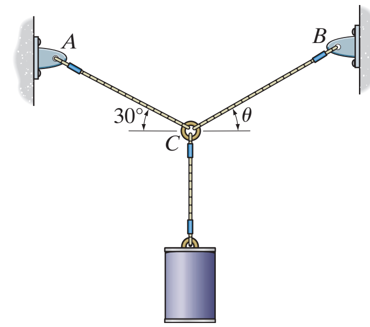


(a)

Ans:
$F_{CA} = 80.0$ N
$F_{CB} = 90.4$ N

***3–8.**

If cable CB is subjected to a tension that is twice that of cable CA, determine the angle θ for equilibrium of the 10-kg cylinder. Also, what are the tensions in wires CA and CB?



SOLUTION

Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes,

$\overset{+}{\rightarrow}\Sigma F_x = 0;\qquad F_{CB}\cos\theta - F_{CA}\cos 30° = 0 \qquad \textbf{(1)}$

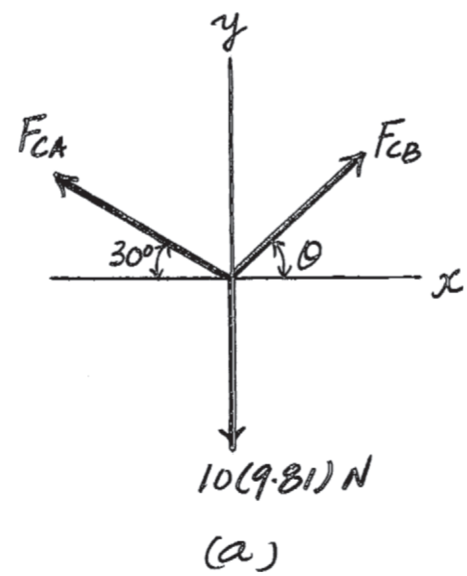
$+\uparrow\Sigma F_y = 0;\qquad F_{CB}\sin\theta + F_{CA}\sin 30° - 10(9.81) = 0 \qquad \textbf{(2)}$

However, it is required that

$$F_{CB} = 2F_{CA} \qquad \textbf{(3)}$$

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

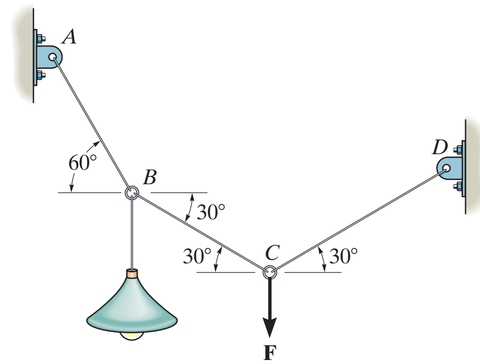
$\theta = 64.3°\qquad F_{CB} = 85.2\text{ N}\qquad F_{CA} = 42.6\text{ N}$ **Ans.**



Ans:

$\theta = 64.3°$
$F_{CB} = 85.2\text{ N}$
$F_{CA} = 42.6\text{ N}$

3–9. Determine the force in each cable and the force **F** needed to hold the 4-kg lamp in the position shown. *Hint:* First analyze the equilibrium at *B*; then, using the result for the force in *BC*, analyze the equilibrium at *C*.



SOLUTION

Initial guesses:

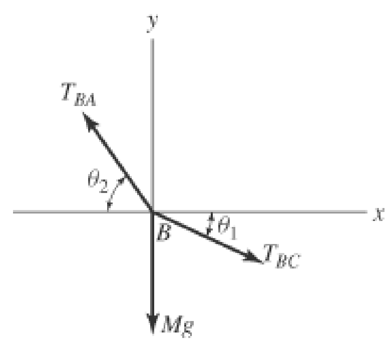
$T_{BC} = 1 \text{ N} \qquad T_{BA} = 2 \text{ N}$

Given

At *B*:

$\xrightarrow{+} \Sigma F_x = 0; \quad T_{BC}\cos(\theta_1) - T_{BA}\cos(\theta_2) = 0$

$+\uparrow \Sigma F_y = 0; \quad T_{BA}\sin(\theta_2) - T_{BC}\sin(\theta_1) - Mg = 0$



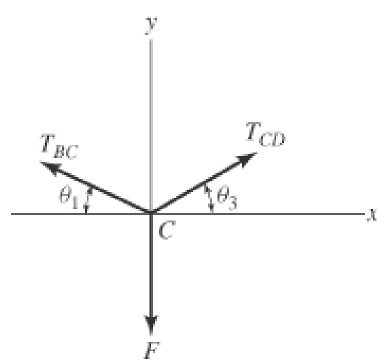
$M = 4 \text{ kg}$

$\theta_1 = 30°$

$\theta_2 = 60°$

$\theta_3 = 30°$

$$\begin{pmatrix} T_{BC} \\ T_{BA} \end{pmatrix} = \text{Find}(T_{BC}, T_{BA}) \qquad \begin{pmatrix} T_{BC} \\ T_{BA} \end{pmatrix} = \begin{pmatrix} 39.24 \\ 67.97 \end{pmatrix} \text{N} \qquad \textbf{Ans.}$$



At *C*: $\quad T_{CD} = 1 \text{ N} \qquad F = 2 \text{ N}$

Given

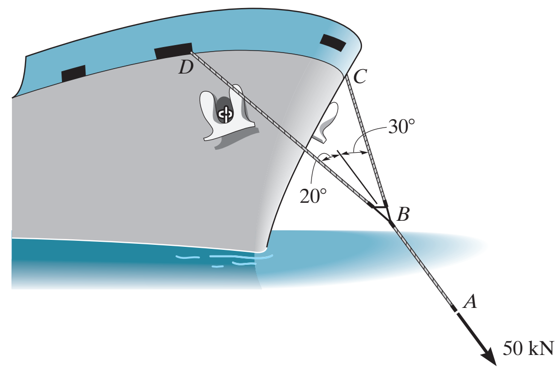
$\xrightarrow{+} \Sigma F_x = 0; \quad -T_{BC}\cos(\theta_1) + T_{CD}\cos(\theta_3) = 0$

$+\uparrow \Sigma F_y = 0; \quad T_{BC}\sin(\theta_1) + T_{CD}\sin(\theta_3) - F = 0$

$$\begin{pmatrix} T_{CD} \\ F \end{pmatrix} = \text{Find}(T_{CD}, F) \qquad \begin{pmatrix} T_{CD} \\ F \end{pmatrix} = \begin{pmatrix} 39.24 \\ 39.24 \end{pmatrix} \text{N} \qquad \textbf{Ans.}$$

Ans.
$T_{BC} = 39.24 \text{ N}$
$T_{BA} = 67.97 \text{ N}$
$T_{CD} = 39.24 \text{ N}$
$F = 39.24 \text{ N}$

3–10. The towing pendant AB is subjected to the force of 50 kN exerted by a tugboat. Determine the force in each of the bridles, BC and BD, if the ship is moving forward with constant velocity.



SOLUTION

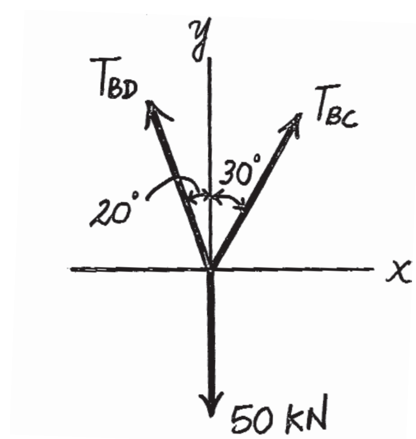
$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad T_{BC} \sin 30° - T_{BD} \sin 20° = 0$

$+\uparrow \Sigma F_y = 0; \quad T_{BC} \cos 30° + T_{BD} \cos 20° - 50 = 0$

Solving,

$T_{BC} = 22.3 \text{ kN}$ **Ans.**

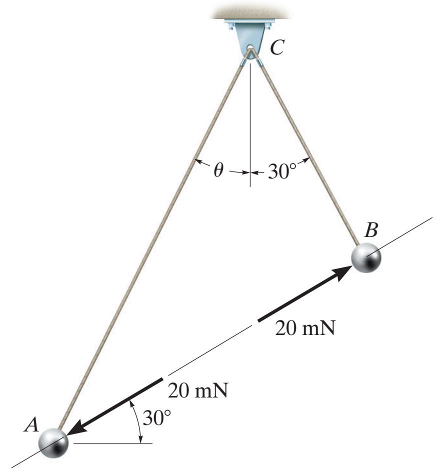
$T_{BD} = 32.6 \text{ kN}$ **Ans.**



Ans.
$T_{BC} = 22.3 \text{ kN}$
$T_{BD} = 32.6 \text{ kN}$

3–11.

Two spheres A and B have an equal mass and are electrostatically charged such that the repulsive force acting between them has magnitude of 20 mN and is directed along line AB. Determine the angle θ, the tension in cords AC and BC, and the mass m of each sphere.



SOLUTION

Guesses $T_B = 1 \text{ mN}$ $\quad m = 1 \text{ g}$

$T_A = 1 \text{ mN}$ $\quad \theta = 30°$

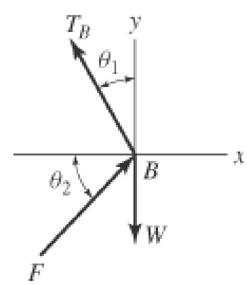
Given:

$F = 20 \text{ mN}$

$g = 9.81 \text{ m/s}^2$

$\theta_1 = 30°$

$\theta_2 = 30°$



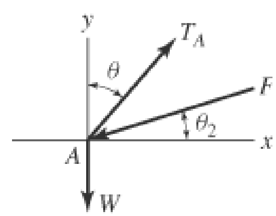
Given

For B:

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad F\cos(\theta_2) - T_B\sin(\theta_1) = 0$

$+\uparrow \Sigma F_y = 0;\quad F\sin(\theta_2) + T_B\cos(\theta_1) - mg = 0$

For A:



$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad T_A\sin(\theta) - F\cos(\theta_2) = 0$

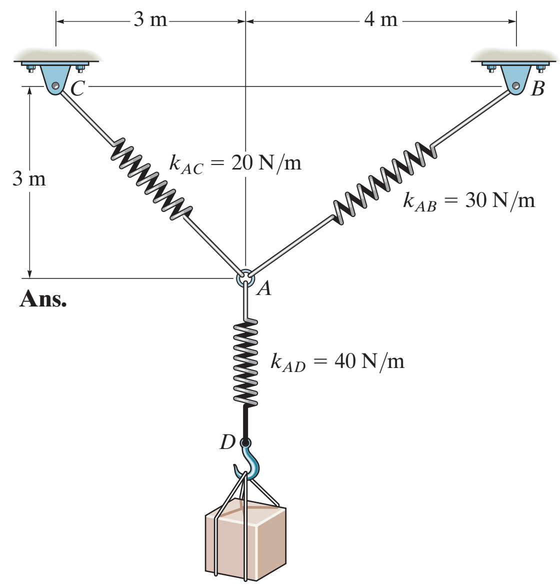
$+\uparrow \Sigma F_y = 0;\quad T_A\cos(\theta) - F\sin(\theta_2) - mg = 0$

$$\begin{pmatrix} T_A \\ T_B \\ \theta \\ m \end{pmatrix} = \text{Find}(T_A, T_B, \theta, M) \qquad \begin{pmatrix} T_A \\ T_B \end{pmatrix} = \begin{pmatrix} 52.92 \\ 34.64 \end{pmatrix} \text{mN} \qquad \theta = 19.11° \qquad m = 4.08 \text{ g} \qquad \textbf{Ans.}$$

Ans.
$T_A = 52.92$ mN, $T_B = 34.64$ mN,
$\theta = 19.11°$, $m = 4.08$ g

***3–12.**

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.**

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

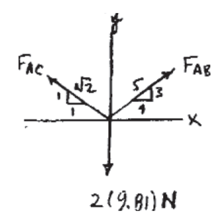
$+\uparrow \Sigma F_y = 0; \qquad F_{AC}\left(\frac{1}{\sqrt{2}}\right) + F_{AB}\left(\frac{3}{5}\right) - 2(9.81) = 0$

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

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

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

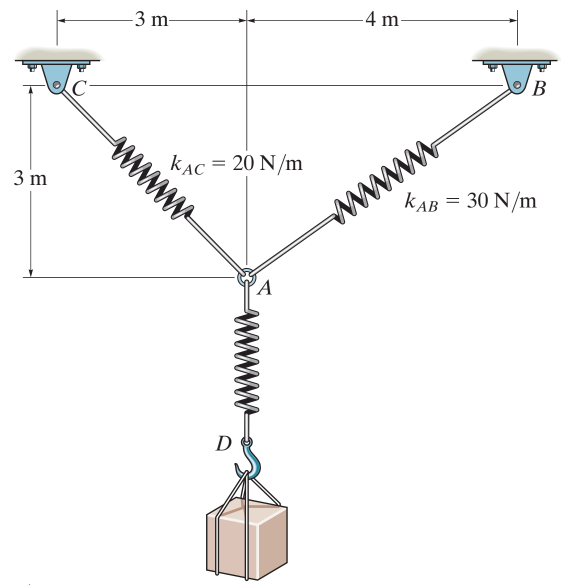
$x_{AB} = \frac{14.01}{30} = 0.467 \text{ m}$ **Ans.**



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

3–13.

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

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

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

$T = 67.88 \text{ N}$

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

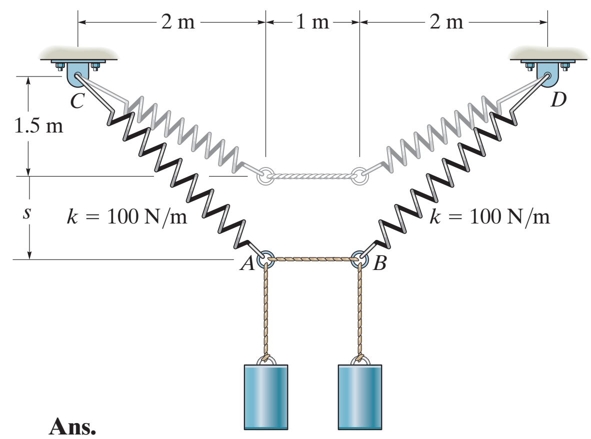
$W = 84 \text{ N}$

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

Ans:
$m = 8.56 \text{ kg}$

3–14.

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.

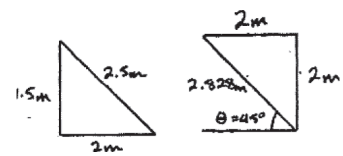


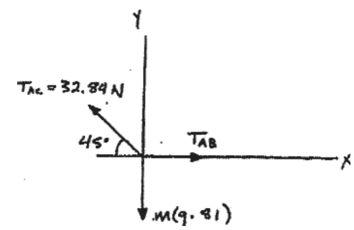
SOLUTION

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

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

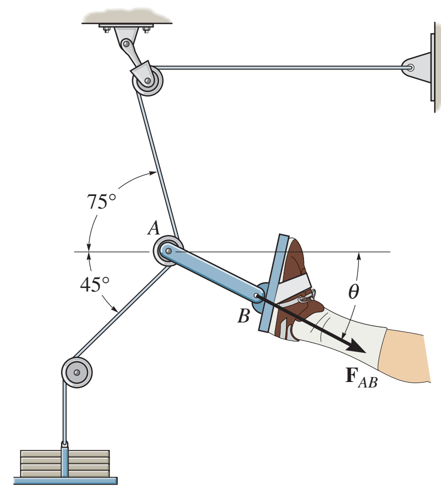
$m = 2.37\text{ kg}$ **Ans.**





Ans:
$m = 2.37$ kg

3–15. Determine the magnitude and direction θ of the equlibrium force F_{AB} exerted along link AB by the tractive apparatus shown. The suspended mass is 10 kg. Neglect the size of the pulley at A.



SOLUTION

Free Body Diagram: The tension in the cord is the same throughout the cord, that is 10(9.81) = 9.81 N.

Equations of Equilibrium:

$$\xrightarrow{+} \Sigma F_x = 0; \quad F_{AB} \cos\theta - 98.1 \cos 75° - 98.1 \cos 45° = 0$$

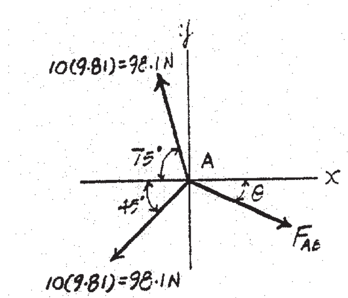
$$F_{AB} \cos\theta = 94.757 \qquad [1]$$

$$+\uparrow \Sigma F_y = 0; \quad 98.1 \sin 75° - 98.1 \sin 45° - F_{AB} \sin\theta = 0$$

$$F_{AB} \sin\theta = 25.390 \qquad [2]$$

Solving Eqs. [1]and [2] yields

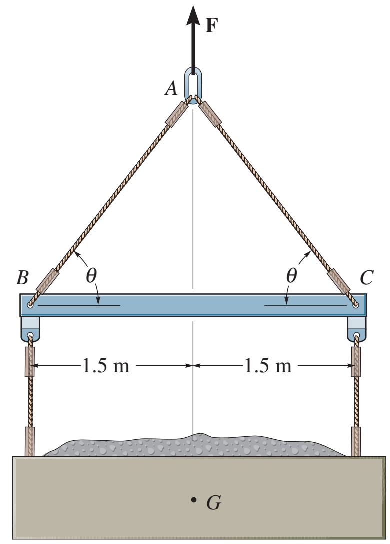
$$\theta = 15.0° \quad F_{AB} = 98.1 \text{ N}$$ **Ans.**



Ans:
$\theta = 15.0°$
$F_{AB} = 98.1$ N

***3–16.**

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 length 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 of the container. Thus, $F_1 = 500(9.81) = 4905$ N.

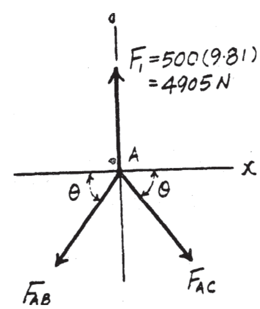
Equations of Equilibrium:

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

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

Thus,

$$F_{AC} = F_{AB} = F = \{2.45\cos\theta\}\text{ kN}$$ **Ans.**



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

$$2452.5\cos\theta = 5000$$

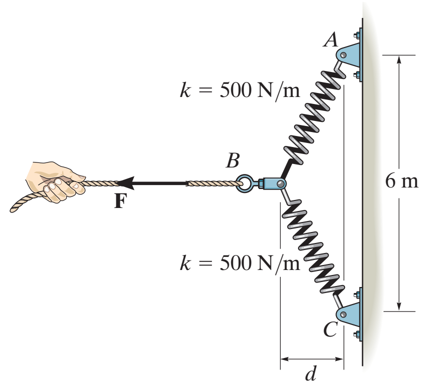
$$\theta = 29.37^\circ$$

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

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

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

3–17. 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 AB from the wall is $d = 1.5$ m.

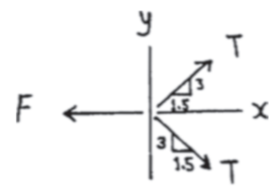


SOLUTION

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

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

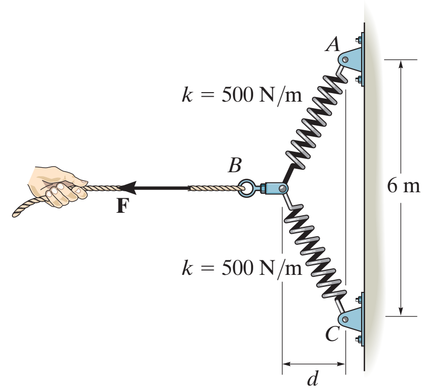
$F = 158 \text{ N}$ **Ans.**



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

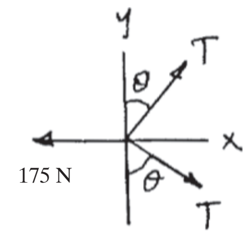
3–18.

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

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 175 = 2T \sin\theta$



$$T \sin\theta = 87.5$$

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

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

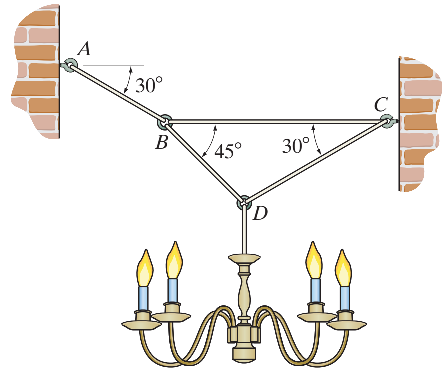
$$d\left(1 - \frac{3}{\sqrt{9 + d^2}}\right) = 0.175$$

By trial and error:

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

Ans:
$d = 1.56$ m

3–19. Determine the tension developed in each wire used to support the 50-kg chandelier.



SOLUTION

Equations of Equilibrium: First, we will apply the equations of equilibrium along the x and y axes to the free-body diagram of joint D shown in Fig. (a).

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad F_{CD}\cos 30^\circ - F_{BD}\cos 45^\circ = 0 \tag{1}$$

$$+\uparrow\Sigma F_y = 0; \quad F_{CD}\sin 30^\circ + F_{BD}\sin 45^\circ - 50(9.81) = 0 \tag{2}$$

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

$$F_{CD} = 359\text{ N} \quad F_{BD} = 439.77\text{ N} = 440\text{ N}$$ **Ans.**

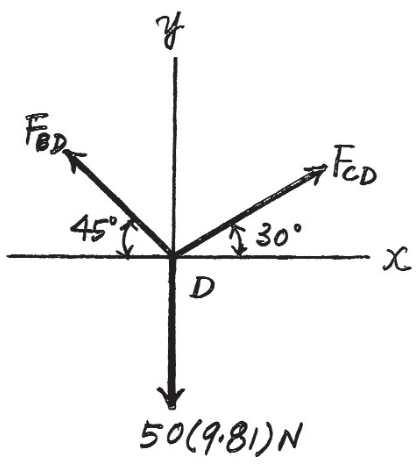
Using the result $F_{BD} = 439.77$ N and applying the equations of equilibrium along the x and y axes to the free-body diagram of joint B shown in Fig. (b),

$$+\uparrow\Sigma F_y = 0; \quad F_{AB}\sin 30^\circ - 439.77\sin 45^\circ = 0$$

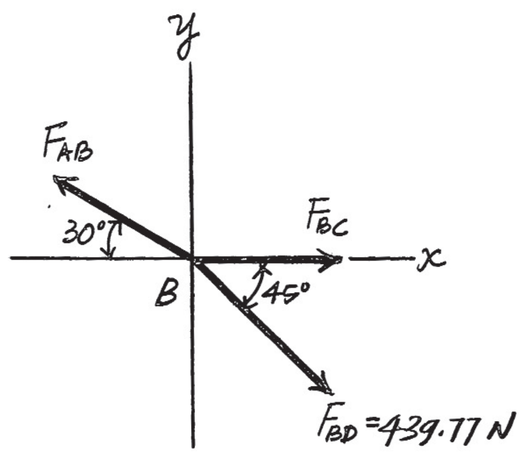
$$F_{AB} = 621.93\text{N} = 622\text{ N}$$ **Ans.**

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad F_{BC} + 439.77\cos 45^\circ - 621.93\cos 30^\circ = 0$$

$$F_{BC} = 228\text{ N}$$ **Ans.**



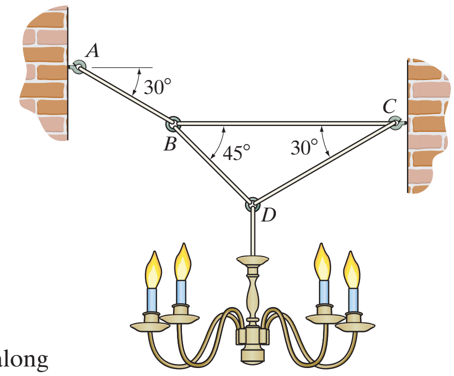
(a)



(b)

Ans:
$F_{BD} = 440$ N
$F_{AB} = 622$ N
$F_{BC} = 228$ N

***3–20.** If the tension developed in each of the four wires is not allowed to exceed 600 N, determine the maximum mass of the chandelier that can be supported.



SOLUTION

Equations of Equilibrium: First, we will apply the equations of equilibrium along the x and y axes to the free-body diagram of joint D shown in Fig. (a).

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad F_{CD}\cos 30^\circ - F_{BD}\cos 45^\circ = 0 \qquad (1)$$

$$+\uparrow\Sigma F_y = 0; \quad F_{CD}\sin 30^\circ + F_{BD}\sin 45^\circ - m(9.81) = 0 \qquad (2)$$

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

$$F_{CD} = 7.1841m \qquad F_{BD} = 8.7954m$$

Using the result $F_{BD} = 8.7954\,m$ and applying the equations of equilibrium along the x and y axes to the free-body diagram of joint B shown in Fig. (b),

$$+\uparrow\Sigma F_y = 0; \quad F_{AB}\sin 30^\circ - 8.7954m\sin 45^\circ = 0$$

$$F_{AB} = 12.4386m$$

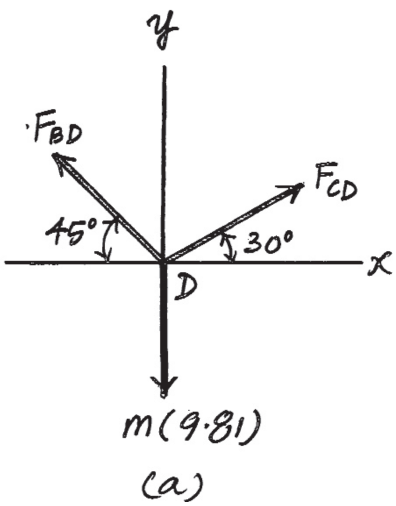
$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad F_{BC} + 8.7954m\cos 45^\circ - 12.4386m\cos 30^\circ = 0$$

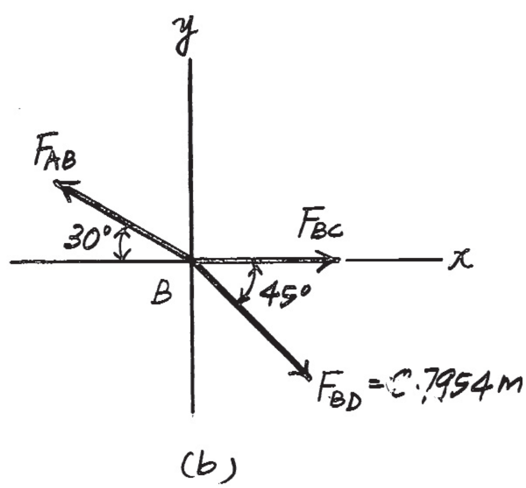
$$F_{BC} = 4.5528m$$

From this result, notice that cable AB is subjected to the greatest tensile force. Thus, it will achieve the maximum allowable tensile force first.

$$F_{AB} = 600 = 12.4386m$$

$$m = 48.2 \text{ kg}$$ **Ans.**

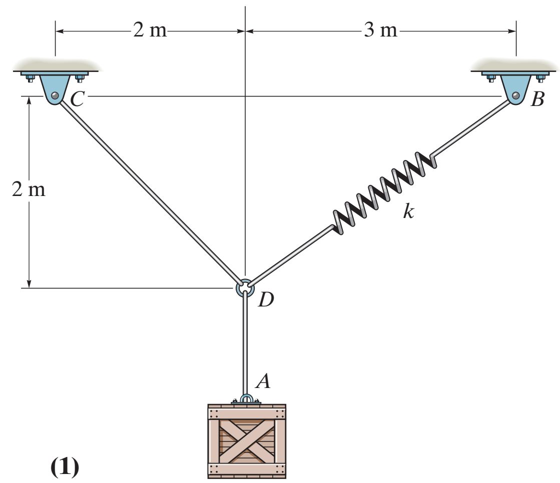




Ans:
$m = 48.2$ kg

3–21.

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)

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

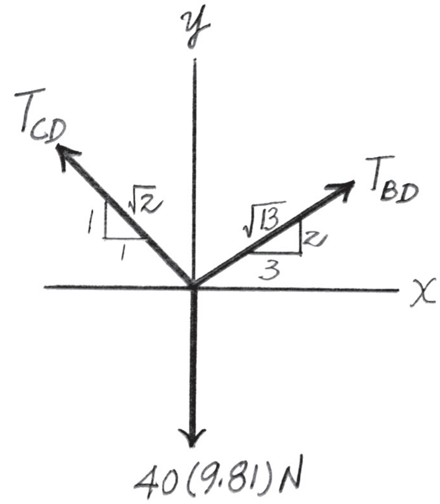
The stretched length of the spring is

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

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

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

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

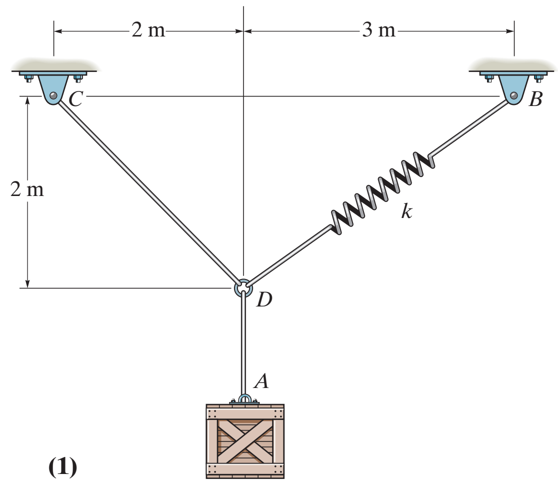


(a)

Ans:
$k = 176$ N/m

3–22.

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)

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

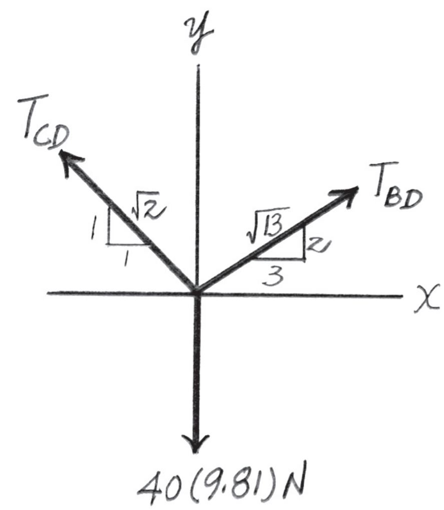
The stretched length of the spring is

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

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

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

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

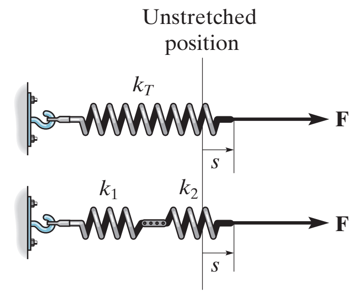


(a)

Ans:
$l_0 = 2.03$ m

3–23.

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

$$F = ks$$

$$s = s_1 + s_2$$

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

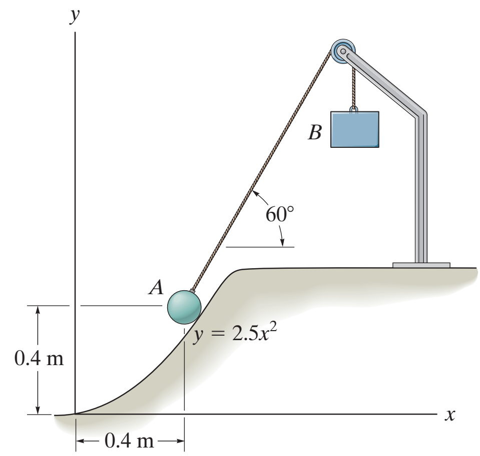
$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2}$$ **Ans.**

Ans:

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

***3–24.**

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.

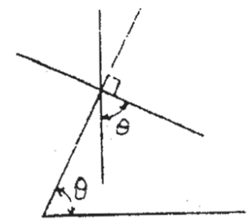


SOLUTION

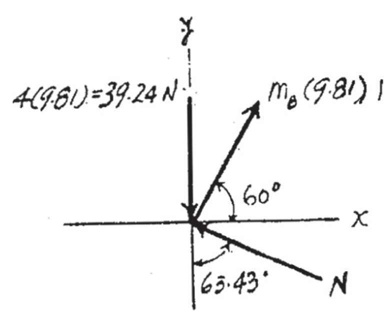
Geometry: The angle θ which the surface make with the horizontal is to be determined first.

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

$$\theta = 63.43°$$



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:

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

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

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

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

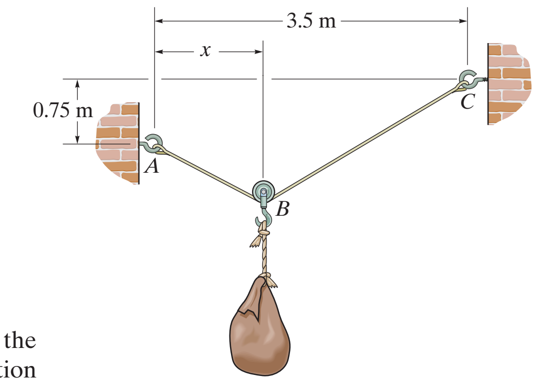
Solving Eqs. [1] and [2] yields

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

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

3–25.

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

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

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

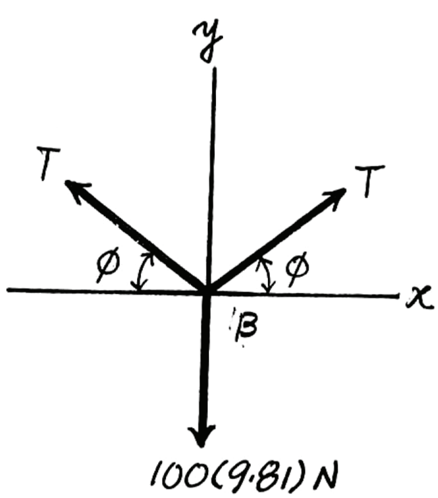
Also,

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

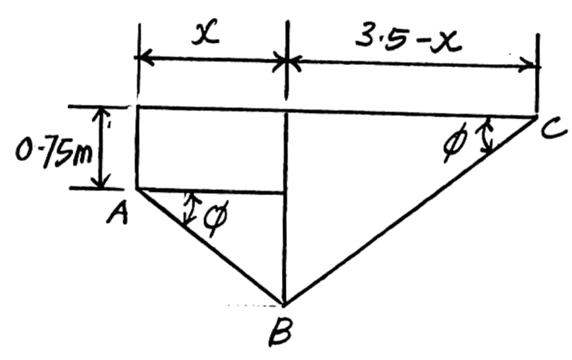
$$x = 1.38 \text{ m} \qquad \textbf{Ans.}$$

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

$$T = 687 \text{ N} \qquad \textbf{Ans.}$$



(a)

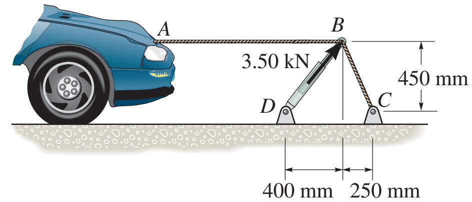


(b)

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

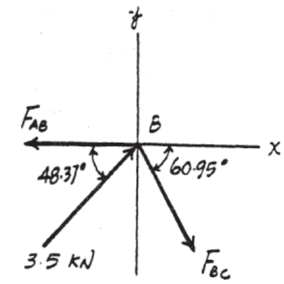
3–26.

The device shown is used to straighten the frames of wrecked autos. Determine the tension of each segment of the chain, i.e., AB and BC, if the force which the hydraulic cylinder DB exerts on point B is 3.50 kN, as shown.



SOLUTION

Equations of Equilibrium: A direct solution for F_{BC} can be obtained by summing forces along the y axis.



$+\uparrow \Sigma F_y = 0; \qquad 3.5 \sin 48.37° - F_{BC} \sin 60.95° = 0$

$$F_{BC} = 2.993 \text{ kN} = 2.99 \text{ kN} \qquad \textbf{Ans.}$$

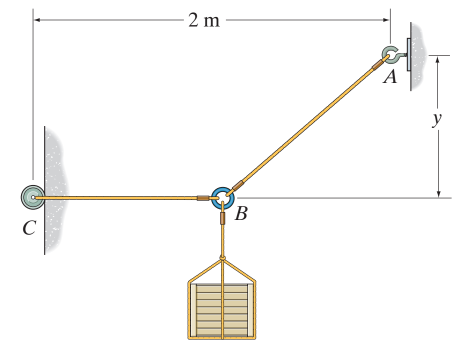
Using the result $F_{BC} = 2.993$ kN and summing forces along x axis, we have

$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 3.5 \cos 48.37° + 2.993 \cos 60.95° - F_{AB} = 0$

$$F_{AB} = 3.78 \text{ kN} \qquad \textbf{Ans.}$$

Ans:
$F_{BC} = 2.99$ kN
$F_{AB} = 3.78$ kN

3–27. Determine the force in each cord for equilibrium of the 200-kg crate. Cord BC remains horizontal due to the roller at C, and AB has a length of 1.5 m. Set $y = 0.75$ m.



SOLUTION

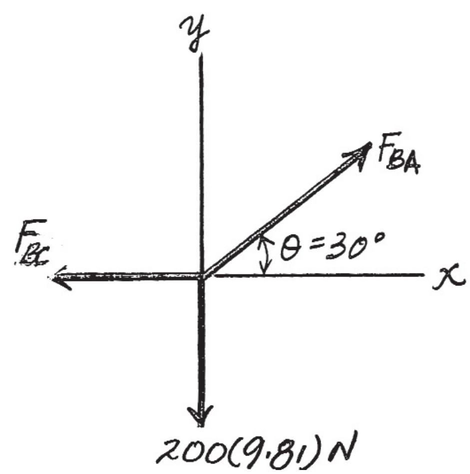
Geometry: From the geometry of the figure,

$$\theta = \sin^{-1}\left(\frac{0.75}{1.5}\right) = 30^\circ$$

Equations of Equilibrium: Applying the equations of equilibrium to the free-body diagram in Fig. (*a*),

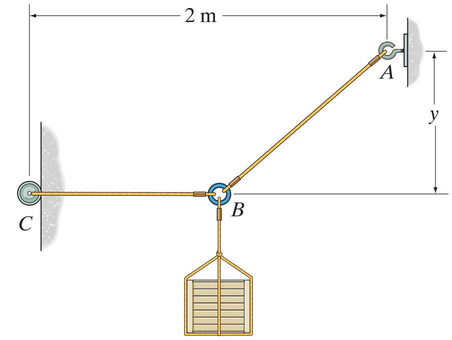
$+\uparrow \Sigma F_y = 0;\quad F_{BA} \sin 30^\circ - 200(9.81) = 0 \quad F_{BA} = 3924 \text{ N} = 3.92 \text{ kN}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad 3924 \cos 30^\circ - F_{BC} = 0 \quad F_{BC} = 3398.28 \text{ N} = 3.40 \text{ kN}$ **Ans.**



Ans:
$F_{BA} = 3.92$ kN
$F_{BC} = 3.40$ kN

*3–28. If the 1.5-m-long cord AB can withstand a maximum force of 3500 N, determine the force in cord BC and the distance y so that the 200-kg crate can be supported.



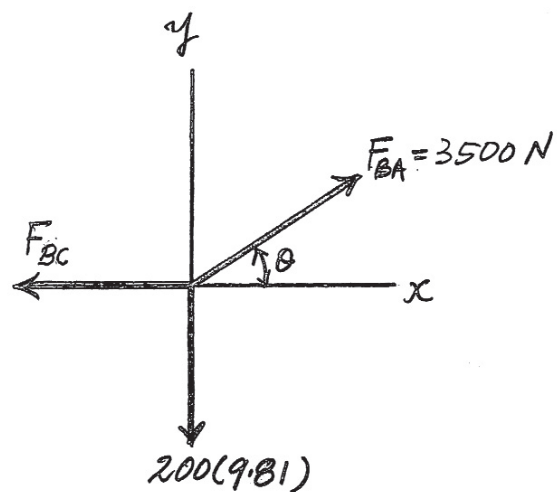
SOLUTION

Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram in Fig. (a),

$$+\uparrow \Sigma F_y = 0; \quad 3500 \sin\theta - 200(9.81) = 0 \quad \theta = 34.10°$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 3500 \cos 34.10° - F_{BC} = 0 \quad F_{BC} = 2898.37 \text{ N} = 2.90 \text{ kN} \qquad \textbf{Ans.}$$

$$y = 1.5 \sin 34.10° = 0.841 \text{ m} = 841 \text{ mm} \qquad \textbf{Ans.}$$

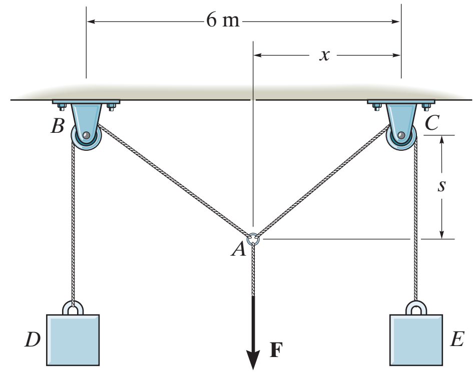


Ans:

$F_{BC} = 2.90$ kN
$y = 841$ mm

3–29.

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,

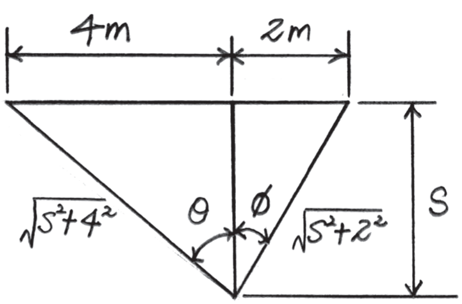
$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad 6(9.81)\left(\frac{2}{\sqrt{s^2 + 2^2}}\right) - 4(9.81)\left(\frac{4}{\sqrt{s^2 + 4^2}}\right) = 0$$

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

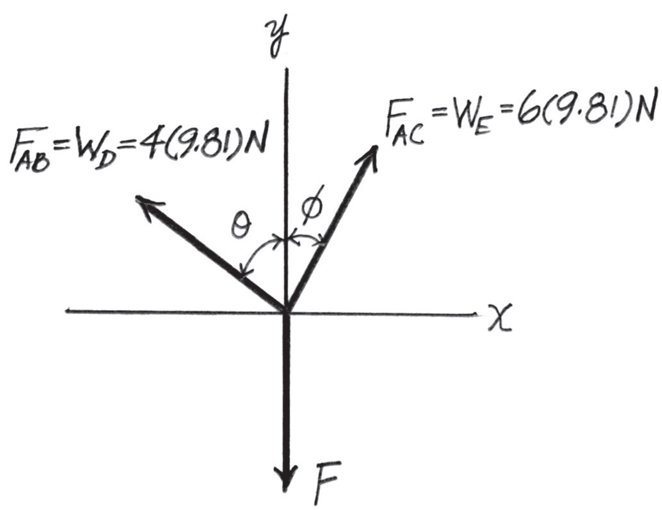
$$s = 3.381 \text{ m} = 3.38 \text{ m} \qquad \textbf{Ans.}$$

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

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



(a)

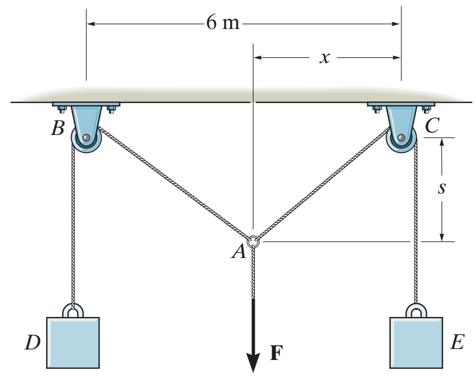


(b)

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

3–30.

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

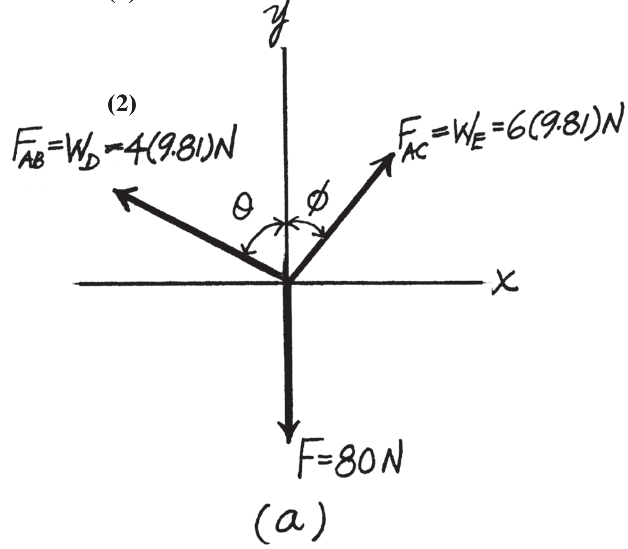
Equations of Equilibrium. Referring to the *FBD* shown in Fig. *a*,

$\overset{+}{\rightarrow}\Sigma F_x = 0;\quad 6(9.81)\sin\phi - 4(9.81)\sin\theta = 0$

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

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

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



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),

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

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

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

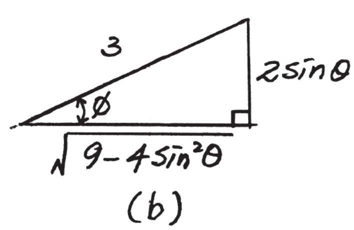
$$16.310\cos\theta = 4\left(\cos^2\theta + \sin^2\theta\right) + 7.6258$$

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, $\dfrac{6-x}{s} = \tan 44.54°$ and $\dfrac{x}{s} = \tan 27.88°$.

So then,

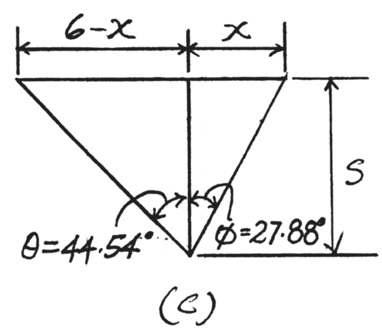
$$\frac{6-x}{s} + \frac{x}{s} = \tan 44.54° + \tan 27.88°$$

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

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

$$x = 3.9659\tan 27.88°$$

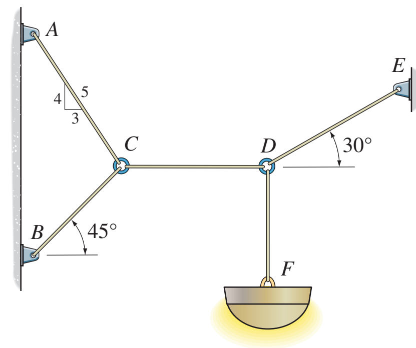
$$= 2.0978 \text{ m} = 2.10 \text{ m} \qquad \textbf{Ans.}$$



Ans:
$s = 3.97$ m
$x = 2.10$ m

3–31.

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

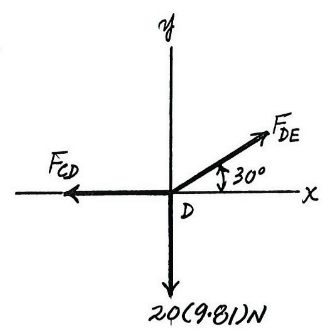


SOLUTION

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

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

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



(a)

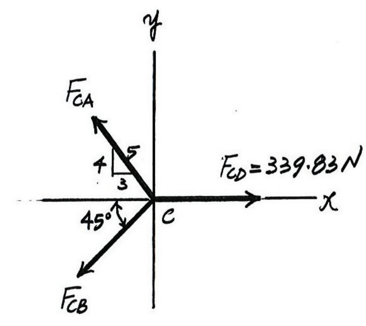
Using the result $F_{CD} = 339.83$ N and applying the equations of equilibrium along the x and y axes to the free-body diagram of joint D shown in Fig. b, we have

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

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

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

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

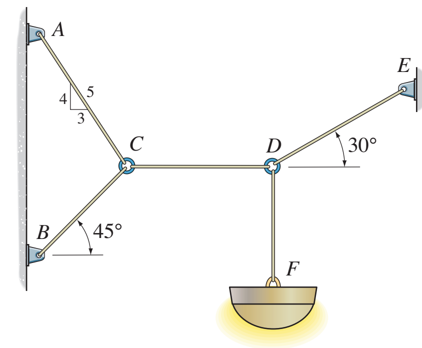


(b)

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

***3–32.**

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

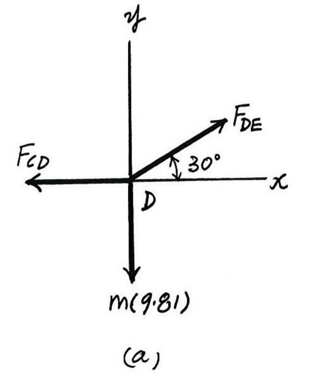


SOLUTION

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

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

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



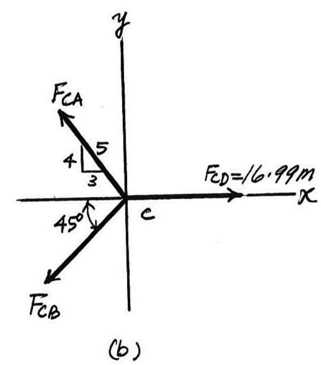
Using the result $F_{CD} = 16.99m$ and applying the equations of equilibrium along the x and y axes to the free-body diagram of joint D shown in Fig. b, we have

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

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

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

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



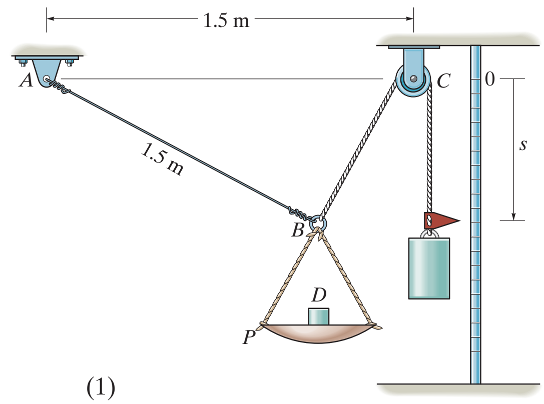
Notice that cord DE is subjected to the greatest tensile force, and so it will achieve the maximum allowable tensile force first. Thus

$$F_{DE} = 400 = 19.62m$$

$$m = 20.4 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m = 20.4$ kg

3–33. A scale is constructed using the 10-kg mass, the 2-kg pan P, and the pulley and cord arrangement. Cord BCA is 2 m long. If $s = 0.75$ m, determine the mass D in the pan. Neglect the size of the pulley.



SOLUTION

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad 98.1\cos\theta - T_{AB}\cos\phi = 0 \qquad (1)$$

$$+\uparrow\Sigma F_y = 0; \quad T_{AB}\sin\phi + 98.1\sin\theta - m(9.81) = 0 \qquad (2)$$

$$(1.5)^2 = x^2 + y^2$$

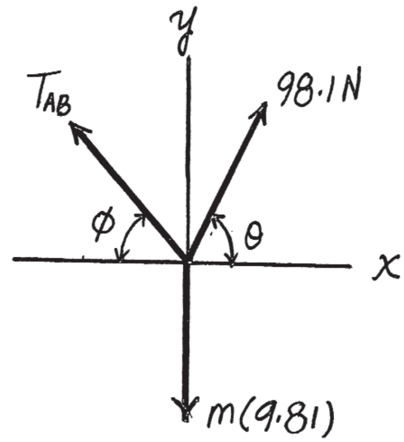
$$(1.25)^2 = (1.5 - x)^2 + y^2$$

$$(1.25)^2 = (1.5 - x)^2 + (1.5)^2 - x^2$$

$$-3x + 2.9375 = 0$$

$$x = 0.9792 \text{ m}$$

$$y = 1.1363 \text{ m}$$



Thus,

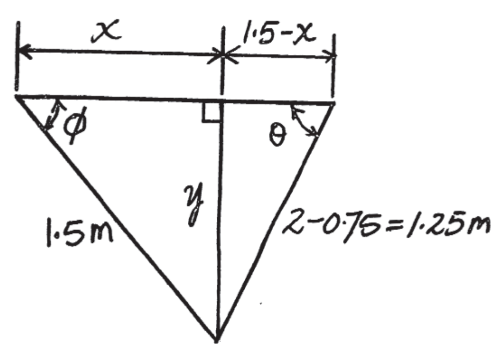
$$\phi = \sin^{-1}\left(\frac{1.1363}{1.5}\right) = 49.25°$$

$$\theta = \sin^{-1}\left(\frac{1.1363}{1.25}\right) = 65.38°$$

Solving Eq. (1) and (2),

$$T_{AB} = 62.62 \text{ N}$$

$$m = 13.9 \text{ kg}$$



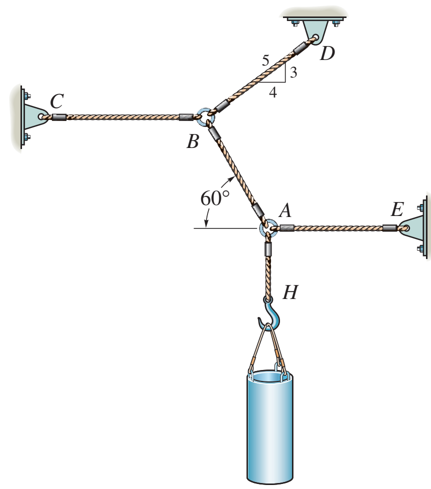
Therefore,

$$m_D = 13.9 \text{ kg} - 2 \text{ kg} = 11.9 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m_D = 11.9$ kg

3–34.

The 30-kg pipe is supported at A by a system of five 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.**

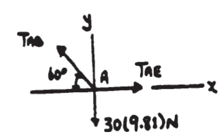
At *A*:

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

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

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

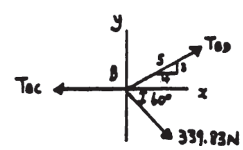
$T_{AE} = 170 \text{ N}$ **Ans.**



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.**



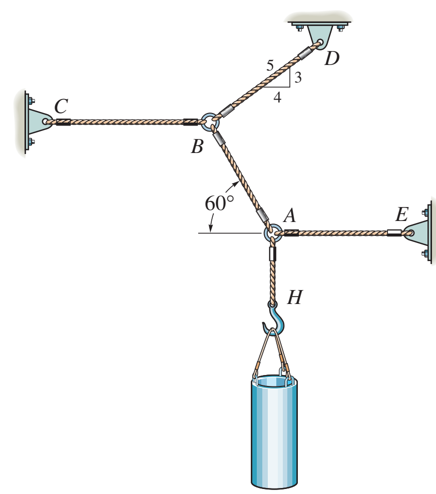
$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 490.50\left(\frac{4}{5}\right) + 339.83 \cos 60° - T_{BC} = 0$

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

Ans:
$T_{HA} = 294 \text{ N}$
$T_{AB} = 340 \text{ N}$
$T_{AE} = 170 \text{ N}$
$T_{BD} = 490 \text{ N}$
$T_{BC} = 562 \text{ N}$

3–35.

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

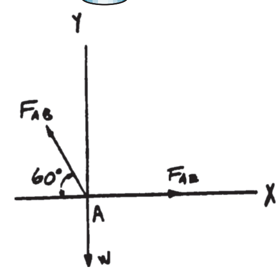


SOLUTION

At H:

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

At A:



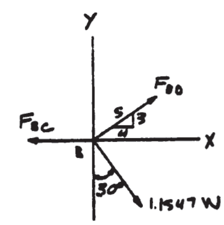
$$+\uparrow \Sigma F_y = 0; \qquad F_{AB} \sin 60° - W = 0$$

$$F_{AB} = 1.1547\, W$$

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

$$F_{AE} = 0.5774\, W$$

At B:



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

$$F_{BD} = 1.667\, W$$

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

$$F_{BC} = 1.9107\, W$$

By comparison, cord BC carries the largest load. Thus

$$500 = 1.9107\, W$$

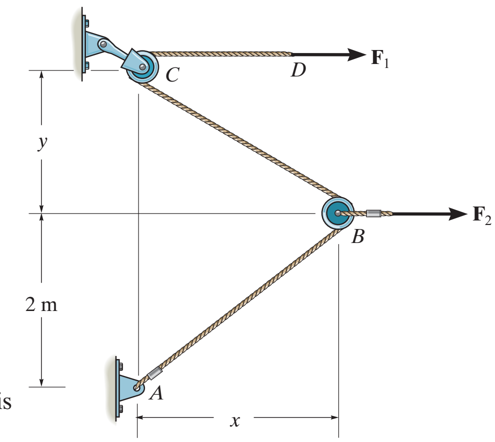
$$W = 261.69 \text{ N}$$

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

Ans:
$m = 26.7$ kg

***3–36.**

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,

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

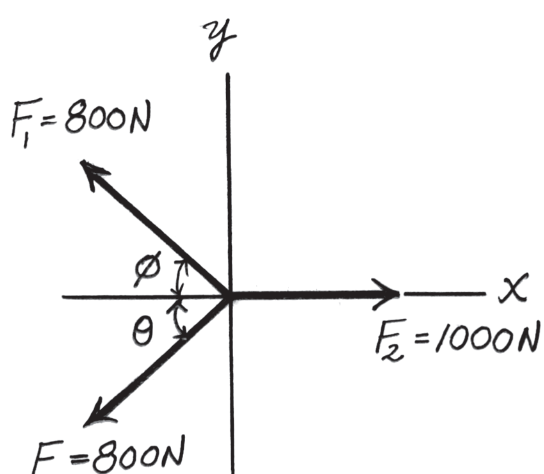
$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad 1000 - 2[800 \cos \theta] = 0 \quad \theta = 51.32°$

Referring to the geometry shown in Fig. b,

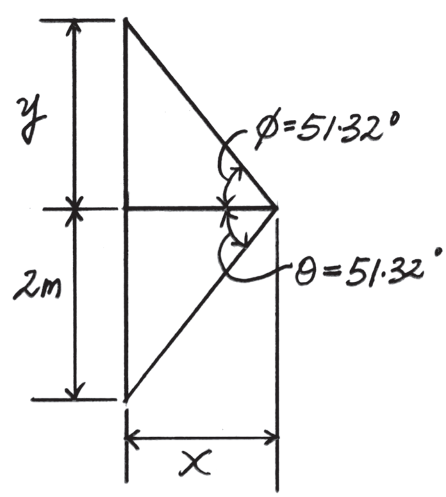
$$y = 2 \text{ m}$$ **Ans.**

and

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



(a)

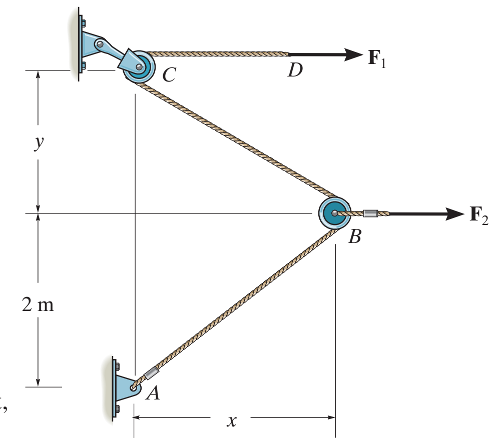


(b)

Ans:
$y = 2$ m
$x = 1.60$ m

3–37.

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,

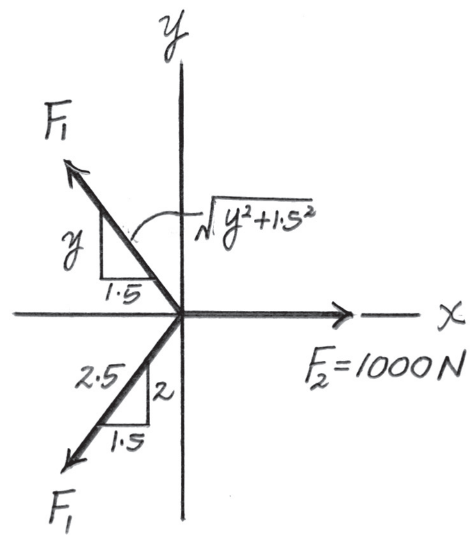
$$+\uparrow \Sigma F_y = 0; \qquad F_1\left(\frac{y}{\sqrt{y^2 + 1.5^2}}\right) - F_1\left(\frac{2}{2.5}\right) = 0$$

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

$$y = 2 \text{ m} \qquad \textbf{Ans.}$$

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

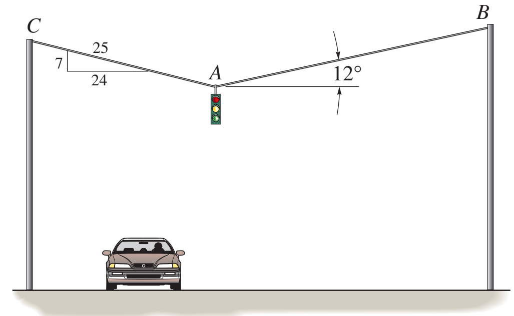
$$F_1 = 833.33 \text{ N} = 833 \text{ N} \qquad \textbf{Ans.}$$



(a)

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

3–38. Determine the force in cables AB and AC necessary to support the 12-kg traffic light.



SOLUTION

Equations of Equilibrium:

$$\xrightarrow{+} \Sigma F_x = 0; \quad F_{AB}\cos 12° - F_{AC}\left(\frac{24}{25}\right) = 0$$

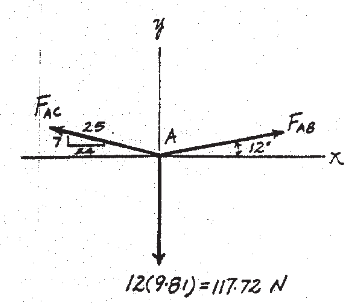
$$F_{AB} = 0.9814 F_{AC} \qquad [1]$$

$$+\uparrow \Sigma F_y = 0; \quad F_{AB}\sin 12° + F_{AC}\left(\frac{7}{25}\right) - 117.72 = 0$$

$$0.2079 F_{AB} + 0.28 F_{AC} = 117.72 \qquad [2]$$

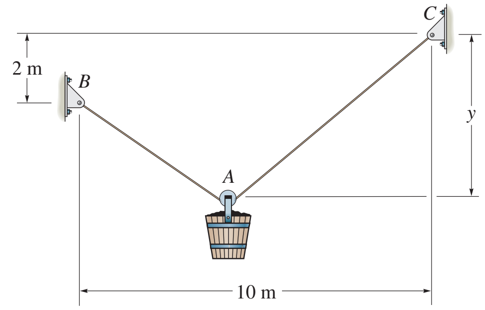
Solving Eqs. [1] and [2] yields

$$F_{AB} = 239 \text{ N} \quad F_{AC} = 243 \text{ N} \qquad \textbf{Ans.}$$



Ans:
$F_{AB} = 239$ N
$F_{AC} = 243$ N

3–39. The pail and its contents have a mass of 60 kg. If the cable is 15 m long, determine the distance y of the pulley for equilibrium. Neglect the size of the pulley at A.



SOLUTION

Free Body Diagram: Since the pulley is smooth, the tension in the cable is the same throughout the cable.

Equations of Equilibrium:

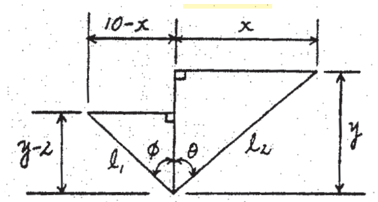
$$\xrightarrow{+} \Sigma F_x = 0; \quad T\sin\theta - T\sin\phi = 0 \quad \theta = \phi$$

Geometry:

$$l_1 = \sqrt{(10-x)^2 + (y-2)^2} \; l_2 = \sqrt{x^2 + y^2}$$

Since $\theta = \phi$, two triangles are similar.

$$\frac{10-x}{x} = \frac{y-2}{y} = \frac{\sqrt{(10-x)^2 + (y-2)^2}}{\sqrt{x^2+y^2}} \qquad [1]$$

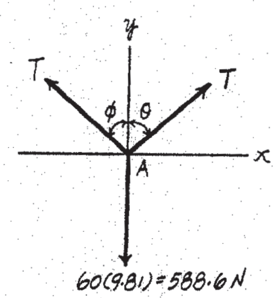


Also,

$$l_1 + l_2 = 15$$

$$\sqrt{(10-x)^2 + (y-2)^2} + \sqrt{x^2+y^2} = 15$$

$$\left(\frac{\sqrt{x^2+y^2}}{\sqrt{x^2+y^2}}\right)\sqrt{(10-x)^2 + (y-2)^2} + \sqrt{x^2+y^2} = 15 \qquad [2]$$



However, from Eq.[1] $\dfrac{\sqrt{(10-x)^2 + (y-2)^2}}{\sqrt{x^2+y^2}} = \dfrac{10-x}{x}$, Eq.[2] becomes

$$\sqrt{x^2+y^2}\left(\frac{10-x}{x}\right) + \sqrt{x^2+y^2} = 15 \qquad [3]$$

Dividing both sides of Eq.[3] by $\sqrt{x^2+y^2}$ yields

$$\frac{10}{x} = \frac{15}{\sqrt{x^2+y^2}} \qquad x = \sqrt{0.8}y \qquad [4]$$

From Eq.[1] $\dfrac{10-x}{x} = \dfrac{y-2}{y}$ $x = \dfrac{5y}{y-1}$ [5]

Equating Eq.[1] and [5] yields

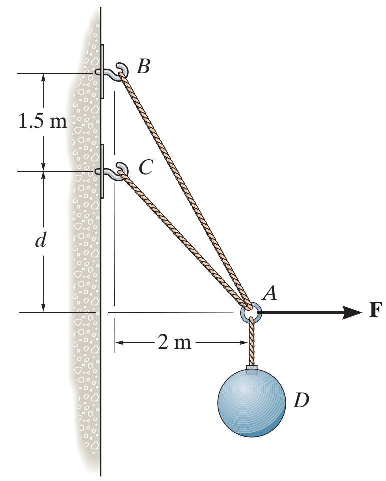
$$\sqrt{0.8}y = \frac{5y}{y-1}$$

$$y = 6.59\text{m} \qquad \textbf{Ans.}$$

Ans:
$y = 6.59$ m

***3–40.**

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

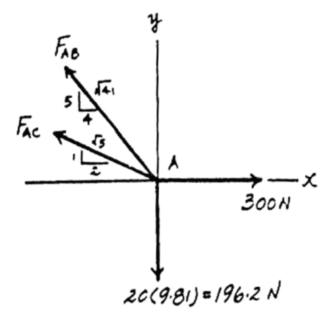
Equations of Equilibrium:

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

$$06247F_{AB} + 0.8944F_{AC} = 300 \qquad \textbf{(1)}$$

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

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



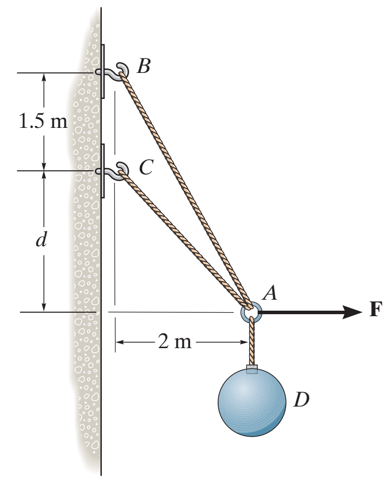
Solving Eqs. (1) and (2) yields

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

Ans:
$F = \{73.6 \sec \theta\}$ N

3–41.

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

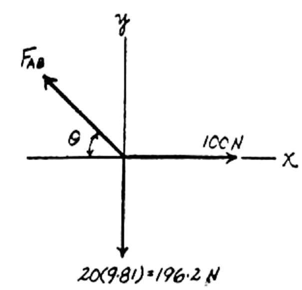
Equations of Equilibrium:

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

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

Solving Eqs. (1) and (2) yields

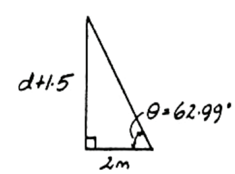
$$\theta = 62.99^\circ \qquad F_{AB} = 220.21 \text{ N}$$



From the geometry,

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

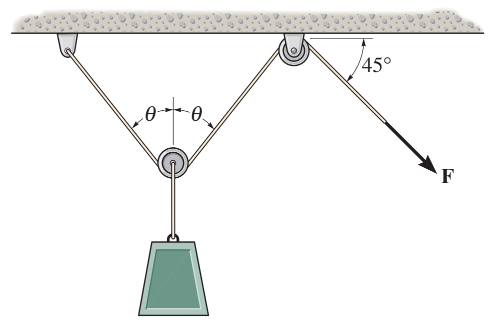
$$d = 2.42 \text{ m} \qquad \textbf{Ans.}$$



Ans:
$d = 2.42$ m

3–42.

The load has a mass of 15 kg and is lifted by the pulley system shown. Determine the force **F** in the cord as a function of the angle θ. Plot the function of force F versus the angle θ for $0 \leq \theta \leq 90°$.



SOLUTION

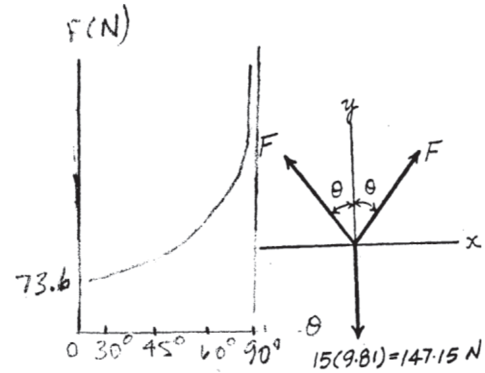
Free-Body Diagram: The tension force is the same throughout the cord.

Equations of Equilibrium:

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

$+\uparrow \Sigma F_y = 0;$ $\quad 2F \cos\theta - 147.15 = 0$

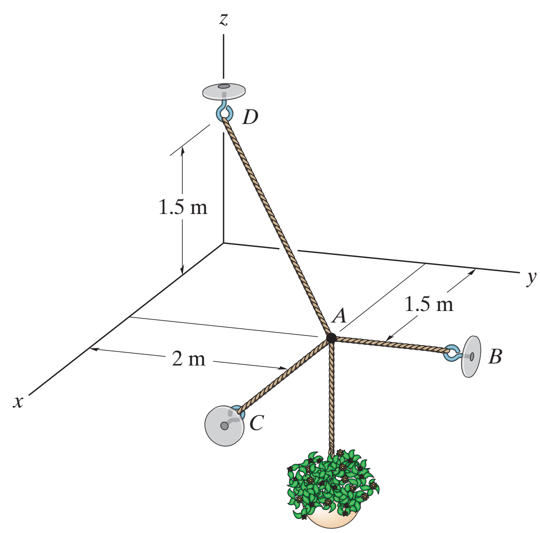
$$F = \{73.6 \sec\theta\}\ \text{N}$$ **Ans.**



Ans:
$F = \{73.6 \sec\theta\}\ \text{N}$

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*,

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

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

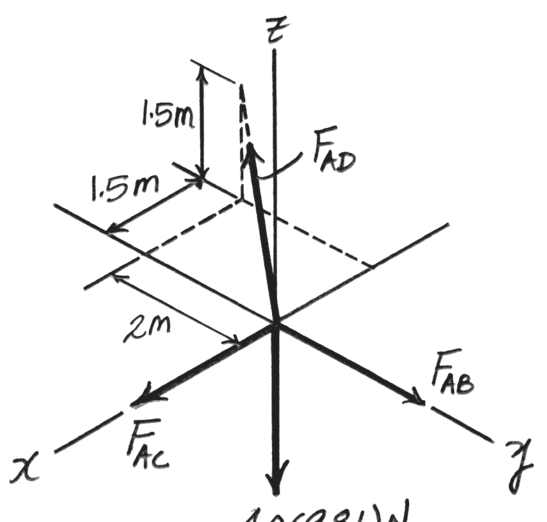
Using this result,

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

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

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

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

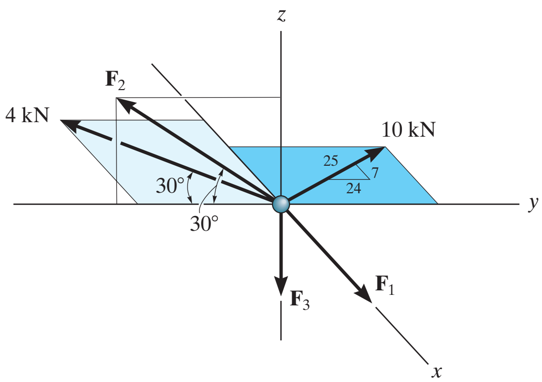


(a)

Ans:
$F_{AD} = 763$ 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,

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

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

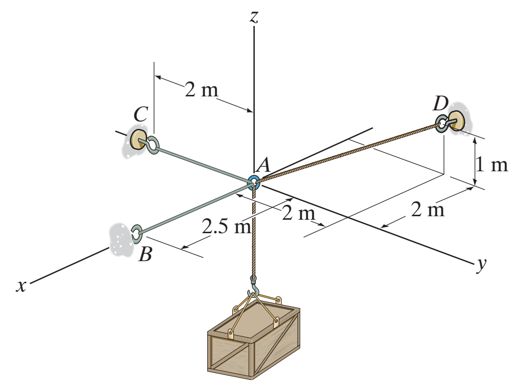
Using the result of $F_2 = 7.085$ kN,

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

Ans:
$F_2 = 7.09$ kN
$F_1 = 4.80$ kN
$F_3 = 3.54$ kN

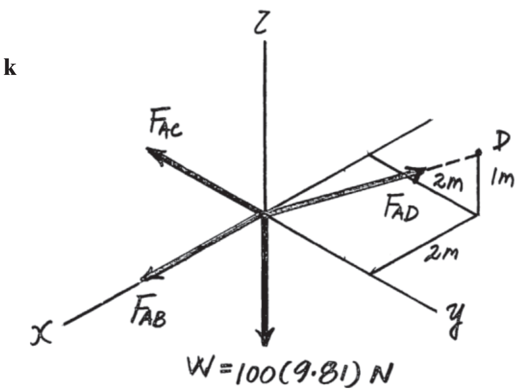
3–45.

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

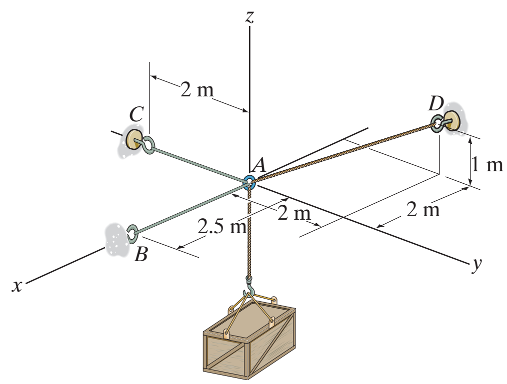
$$F_{AD} = 2943\text{ N} = 2.94\text{ kN} \qquad \textbf{Ans.}$$

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

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

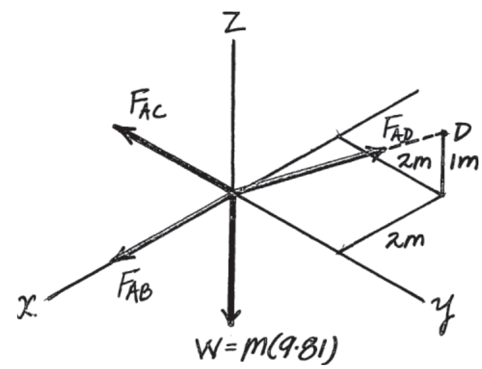
3–46.

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



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

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

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

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

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

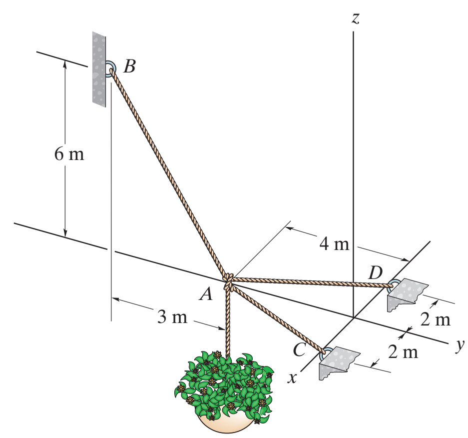
$$F_{AB} = F_{AC} = 2000\text{ N}$$

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

Ans:
$m = 102$ kg

3–47.

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



SOLUTION

Equations of Equilibrium.

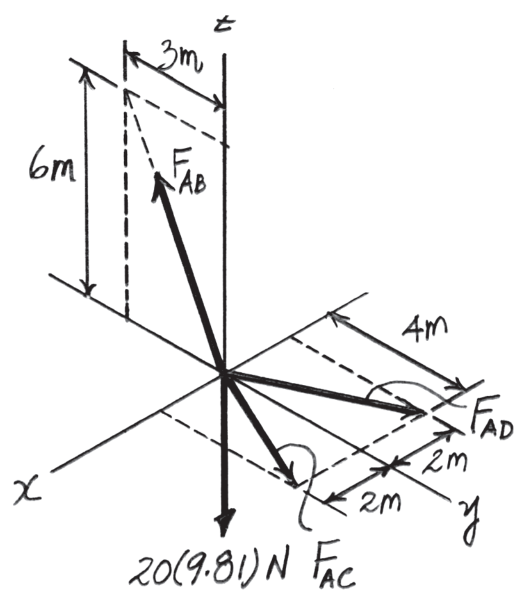
$\Sigma F_z = 0;\quad F_{AB}\left(\frac{6}{\sqrt{45}}\right) - 20(9.81) = 0 \qquad F_{AB} = 219.36 \text{ N} = 219 \text{ N}$ **Ans.**

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

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

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

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

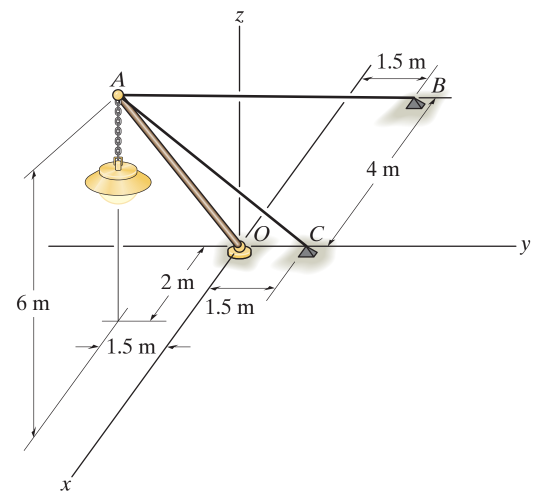


(a)

Ans:
$F_{AB} = 219$ N
$F_{AC} = F_{AD} = 54.8$ N

***3–48.**

The lamp has a mass of 15 kg and is supported by a pole AO and cables AB and AC. If the force in the pole acts along its axis, determine the forces in AO, AB, and AC for equilibrium.



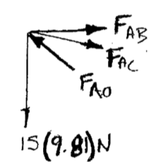
SOLUTION

$$\mathbf{F}_{AO} = F_{AO}\{\frac{2}{6.5}\mathbf{i} - \frac{1.5}{6.5}\mathbf{j} + \frac{6}{6.5}\mathbf{k}\}\text{ N}$$

$$\mathbf{F}_{AB} = F_{AB}\{-\frac{6}{9}\mathbf{i} + \frac{3}{9}\mathbf{j} - \frac{6}{9}\mathbf{k}\}\text{ N}$$

$$\mathbf{F}_{AC} = F_{AC}\{-\frac{2}{7}\mathbf{i} + \frac{3}{7}\mathbf{j} - \frac{6}{7}\mathbf{k}\}\text{ N}$$

$$\mathbf{W} = 15(9.81)\mathbf{k} = \{-147.15\mathbf{k}\}\text{N}$$



$\Sigma F_x = 0;\quad 0.3077F_{AO} - 0.6667F_{AB} - 0.2857F_{AC} = 0$

$\Sigma F_y = 0;\quad -0.2308F_{AO} + 0.3333F_{AB} + 0.4286F_{AC} = 0$

$\Sigma F_z = 0;\quad 0.9231F_{AO} - 0.667F_{AB} - 0.8571F_{AC} - 147.15 = 0$

$F_{AO} = 319\text{ N}$ **Ans.**

$F_{AB} = 110\text{ N}$ **Ans.**

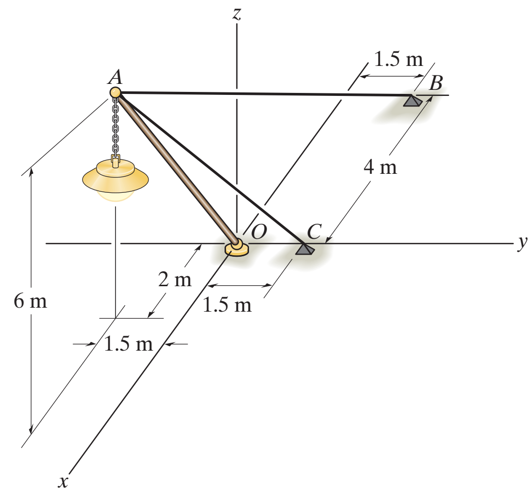
$F_{AC} = 85.8\text{ N}$ **Ans.**

Ans:

$F_{AO} = 319\text{ N}$
$F_{AB} = 110\text{ N}$
$F_{AC} = 85.8\text{ N}$

3–49.

Cables AB and AC can sustain a maximum tension of 500 N, and the pole can support a maximum compression of 300 N. Determine the maximum weight of the lamp that can be supported in the position shown. The force in the pole acts along the axis of the pole.



SOLUTION

$$\mathbf{F}_{AO} = F_{AO}\{\frac{2}{6.5}\mathbf{i} - \frac{1.5}{6.5}\mathbf{j} + \frac{6}{6.5}\mathbf{k}\}\text{ N}$$

$$\mathbf{F}_{AB} = F_{AB}\{-\frac{6}{9}\mathbf{i} + \frac{3}{9}\mathbf{j} - \frac{6}{9}\mathbf{k}\}\text{ N}$$

$$\mathbf{F}_{AC} = F_{AC}\{-\frac{2}{7}\mathbf{i} + \frac{3}{7}\mathbf{j} - \frac{6}{7}\mathbf{k}\}\text{ N}$$

$$\mathbf{W} = \{W\mathbf{k}\}\text{ N}$$

$$\Sigma F_x = 0; \quad \frac{2}{6.5}F_{AO} - \frac{6}{9}F_{AB} - \frac{2}{7}F_{AC} = 0$$

$$\Sigma F_y = 0; \quad -\frac{1.5}{6.5}F_{AO} + \frac{3}{9}F_{AB} + \frac{3}{7}F_{AC} = 0$$

$$\Sigma F_z = 0; \quad \frac{6}{6.5}F_{AO} - \frac{6}{9}F_{AB} - \frac{6}{7}F_{AC} - W = 0$$

1) Assume $F_{AB} = 500$ N

$$\frac{2}{6.5}F_{AO} - \frac{6}{9}(500) - \frac{2}{7}F_{AC} = 0$$

$$-\frac{1.5}{6.5}F_{AO} + \frac{3}{9}(500) + \frac{3}{7}F_{AC} = 0$$

$$\frac{6}{6.5}F_{AO} - \frac{6}{9}(500) - \frac{6}{7}F_{AC} - W = 0$$

Solving,

$$F_{AO} = 1444.444\text{ N} > 300\text{ N } (\mathbf{N.G!})$$
$$F_{AC} = 388.889\text{ N}$$
$$W = 666.667\text{ N}$$

2) Assume $F_{AC} = 500$ N

$$\frac{2}{6.5}F_{AO} - \frac{6}{9}F_{AB} - \frac{2}{7}(500) = 0$$

$$-\frac{1.5}{6.5}F_{AO} + \frac{3}{9}F_{AB} + \frac{3}{7}(500) = 0$$

$$\frac{6}{6.5}F_{AO} - \frac{6}{9}F_{AB} - \frac{6}{7}(500) - W = 0$$

Solving,

$$F_{AO} = 1857.143\text{ N} > 300\text{ N } (\mathbf{N.G!})$$
$$F_{AB} = 642.857\text{ N} > 500\text{ N } (\mathbf{N.G!})$$

3) Assume $F_{AO} = 300$ N

$$\frac{2}{6.5}(300) - \frac{6}{9}F_{AB} - \frac{2}{7}F_{AC} = 0$$

$$-\frac{1.5}{6.5}(300) + \frac{3}{9}F_{AB} + \frac{3}{7}F_{AC} = 0$$

$$\frac{6}{6.5}(300) - \frac{6}{9}F_{AB} - \frac{6}{7}F_{AC} - W = 0$$

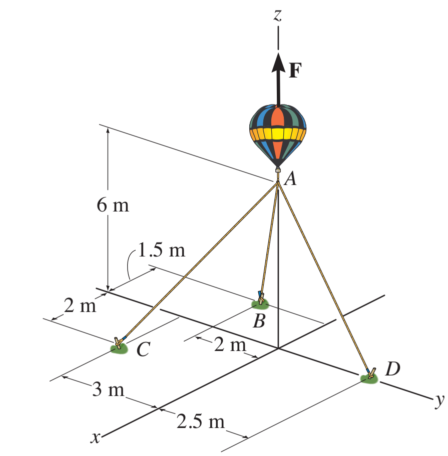
Solving,

$$F_{AC} = 80.8\text{ N}$$
$$F_{AB} = 104\text{ N}$$
$$W = 138\text{ N} \quad \textbf{Ans.}$$

Ans:
$W = 138$ N

3–50.

If the balloon is subjected to a net uplift force of $F = 800$ N, determine the tension developed in ropes AB, AC, AD.



SOLUTION

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

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

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

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

$$\mathbf{W} = \{800\mathbf{k}\}\text{N}$$

Equations of Equilibrium: Equilibrium requires

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

$$\left(-\frac{3}{13}F_{AB}\,\mathbf{i} - \frac{4}{13}F_{AB}\,\mathbf{j} - \frac{12}{13}F_{AB}\,\mathbf{k}\right) + \left(\frac{2}{7}F_{AC}\,\mathbf{i} - \frac{3}{7}F_{AC}\,\mathbf{j} - \frac{6}{7}F_{AC}\,\mathbf{k}\right) + \left(\frac{5}{13}F_{AD}\,\mathbf{j} - \frac{12}{13}F_{AD}\,\mathbf{k}\right) + 800\mathbf{k} = 0$$

$$\left(-\frac{3}{13}F_{AB} + \frac{2}{7}F_{AC}\right)\mathbf{i} + \left(-\frac{4}{13}F_{AB} - \frac{3}{7}F_{AC} - \frac{5}{13}F_{AD}\right)\mathbf{j} + \left(-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F_{AD} + 800\right)\mathbf{k} = 0$$

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

$$-\frac{3}{13}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

$$-\frac{4}{13}F_{AB} - \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} = 0 \qquad \textbf{(2)}$$

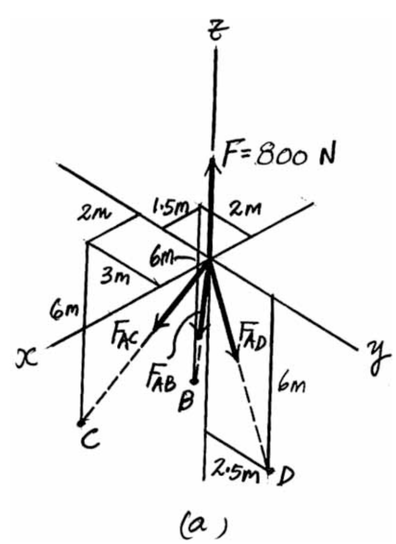
$$-\frac{12}{13}F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F_{AD} + 800 = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1) through (3) yields

$\mathbf{F}_{AC} = 203$ N **Ans.**

$\mathbf{F}_{AB} = 251$ N **Ans.**

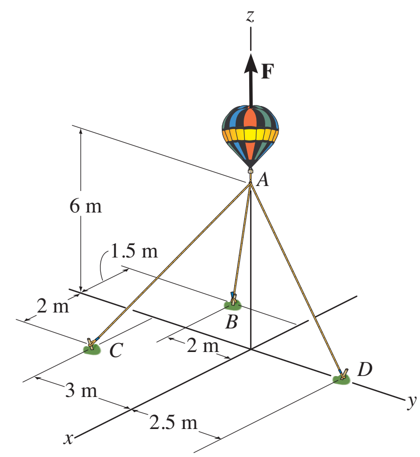
$\mathbf{F}_{AD} = 427$ N **Ans.**



(a)

3-51.

If each one of the ropes will break when it is subjected to a tensile force of 450 N, determine the maximum uplift force **F** the balloon can have before one of the ropes breaks.



SOLUTION

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

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

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

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

$$\mathbf{F} = F\,\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

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

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

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

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

$$-\frac{3}{13}F_{AB} + \frac{2}{7}F_{AC} = 0 \qquad \textbf{(1)}$$

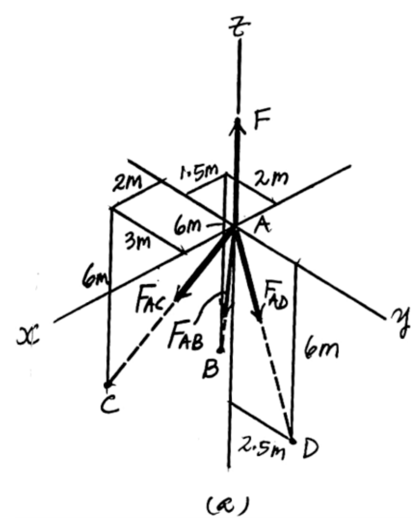
$$-\frac{4}{13}F_{AB} - \frac{3}{7}F_{AC} + \frac{5}{13}F_{AD} = 0 \qquad \textbf{(2)}$$

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

Assume that cord AD will break first. Substituting $F_{AD} = 450$ N into Eqs. (2) and (3) and solving Eqs. (1) through (3), yields

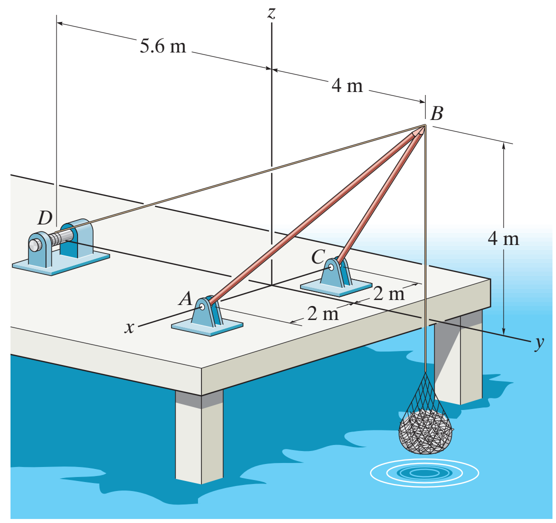
$F_{AB} = 264.71$ N
$F_{AC} = 213.8$ N
$F = 842.99 \text{ N} = 843 \text{ N}$ **Ans.**

Since $F_{AC} = 213.8 \text{ N} < 450 \text{ N}$ and $F_{AB} = 264.71 \text{ N} < 450 \text{ N}$, our assumption is correct.



(a)

***3–52.** The shear leg derrick is used to haul the 200-kg net of fish onto the dock. Determine the compressive force along each of the legs *AB* and *CB* and the tension in the winch cable *DB*. Assume the force in each leg acts along its axis.



SOLUTION

$$\mathbf{F}_{AB} = F_{AB}\left(-\frac{2}{6}\mathbf{i} + \frac{4}{6}\mathbf{j} + \frac{4}{6}\mathbf{k}\right)$$

$$= -0.3333F_{AB}\mathbf{i} + 0.6667F_{AB}\mathbf{j} + 0.6667F_{AB}\mathbf{k}$$

$$\mathbf{F}_{CB} = F_{CB}\left(\frac{2}{6}\mathbf{i} + \frac{4}{6}\mathbf{j} + \frac{4}{6}\mathbf{k}\right)$$

$$= 0.3333F_{CB}\mathbf{i} + 0.6667F_{CB}\mathbf{j} + 0.6667F_{CB}\mathbf{k}$$

$$\mathbf{F}_{BD} = F_{BD}\left(-\frac{9.6}{10.4}\mathbf{j} - \frac{4}{10.4}\mathbf{k}\right)$$

$$= -0.9231F_{BD}\mathbf{j} - 0.3846F_{BB}\mathbf{k}$$

$$\text{W} = -1962\ \mathbf{k}$$

$$\Sigma F_x = 0; \quad -0.3333F_{AB} + 0.3333F_{CB} = 0$$

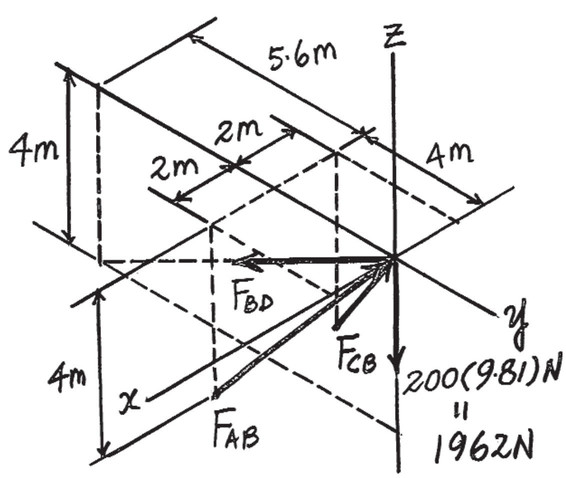
$$\Sigma F_y = 0; \quad 0.6667F_{AB} + 0.6667F_{CB} - 0.9231F_{BD} = 0$$

$$\Sigma F_z = 0; \quad 0.6667F_{AB} + 0.6667F_{CB} - 0.3846F_{BD} - 1962 = 0$$

$F_{AB} = 2.52\text{ kN}$ **Ans.**

$F_{CB} = 2.52\text{ kN}$ **Ans.**

$F_{BD} = 3.64\text{ kN}$ **Ans.**

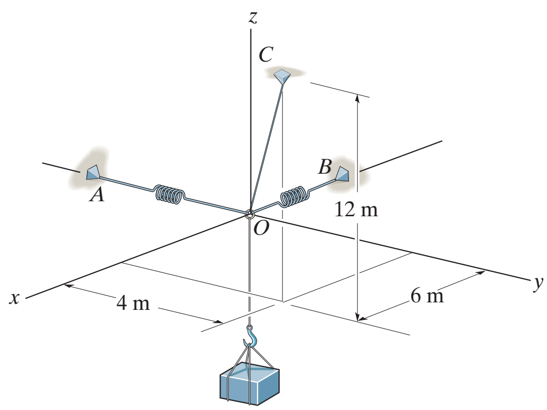


Ans:

$F_{AB} = 2.52\text{ kN}$
$F_{CB} = 2.52\text{ kN}$
$F_{BD} = 3.64\text{ kN}$

3–53.

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.



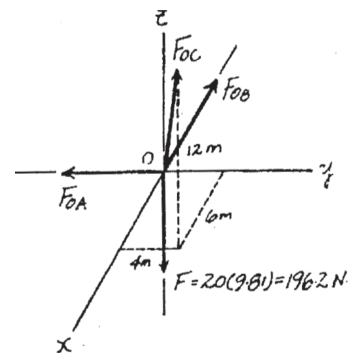
SOLUTION

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:

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

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

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 $s = \dfrac{F}{k}$.

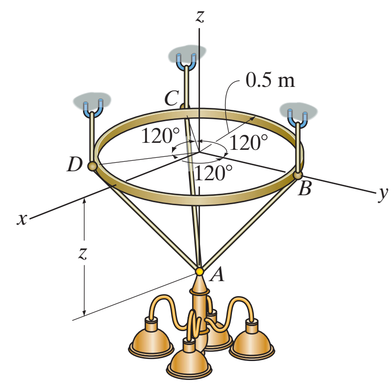
$$s_{OB} = \frac{98.1}{300} = 0.327\ \text{m} = 327\ \text{mm} \qquad \textbf{Ans.}$$

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

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

3–54.

The thin ring can be adjusted vertically between three equally long cables from which the 100-kg chandelier is suspended. If the ring remains in the horizontal plane and $z = 600$ mm, determine the tension in each cable.



SOLUTION

Geometry: Referring to the geometry of the free-body diagram shown in Fig. *a*, the lengths of cables AB, AC, and AD are all $l = \sqrt{0.5^2 + 0.6^2} = \sqrt{0.61}$ m

Equations of Equilibrium: Equilibrium requires

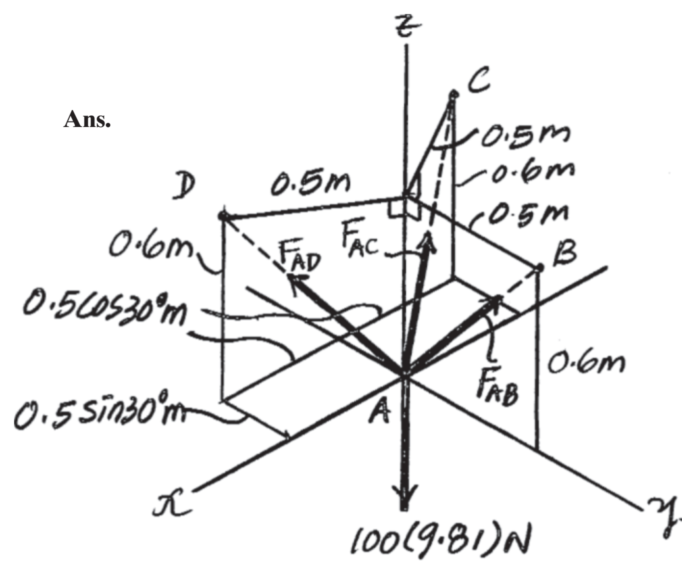
$$\Sigma F_x = 0; \quad F_{AD}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.61}}\right) - F_{AC}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.61}}\right) = 0 \quad F_{AD} = F_{AC} = F$$

$$\Sigma F_y = 0; \quad F_{AB}\left(\frac{0.5}{\sqrt{0.61}}\right) - 2\left[F\left(\frac{0.5\sin 30^\circ}{\sqrt{0.61}}\right)\right] = 0 \qquad F_{AB} = F$$

Thus, cables AB, AC, and AD all develop the same tension.

$$\Sigma F_z = 0; \quad 3F\left(\frac{0.6}{\sqrt{0.61}}\right) - 100(9.81) = 0$$

$$F_{AB} = F_{AC} = F_{AD} = 426 \text{ N}$$ **Ans.**

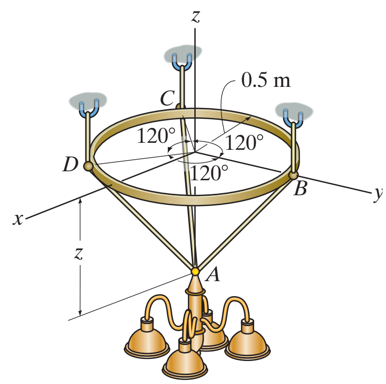


(a)

Ans:
$F_{AB} = F_{AC} = F_{AD} = 426$ N

3–55.

The thin ring can be adjusted vertically between three equally long cables from which the 100-kg chandelier is suspended. If the ring remains in the horizontal plane and the tension in each cable is not allowed to exceed 1 kN, determine the smallest allowable distance z required for equilibrium.



SOLUTION

Geometry: Referring to the geometry of the free-body diagram shown in Fig. *a*, the lengths of cables AB, AC, and AD are all $l = \sqrt{0.5^2 + z^2}$.

Equations of Equilibrium: Equilibrium requires

$$\Sigma F_x = 0; \quad F_{AD}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.5^2 + z^2}}\right) - F_{AC}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.5^2 + z^2}}\right) = 0 \qquad F_{AD} = F_{AC} = F$$

$$\Sigma F_y = 0; \quad F_{AB}\left(\frac{0.5}{\sqrt{0.5^2 + z^2}}\right) - 2\left[F\left(\frac{0.5\sin 30^\circ}{\sqrt{0.5^2 + z^2}}\right)\right] = 0 \qquad F_{AB} = F$$

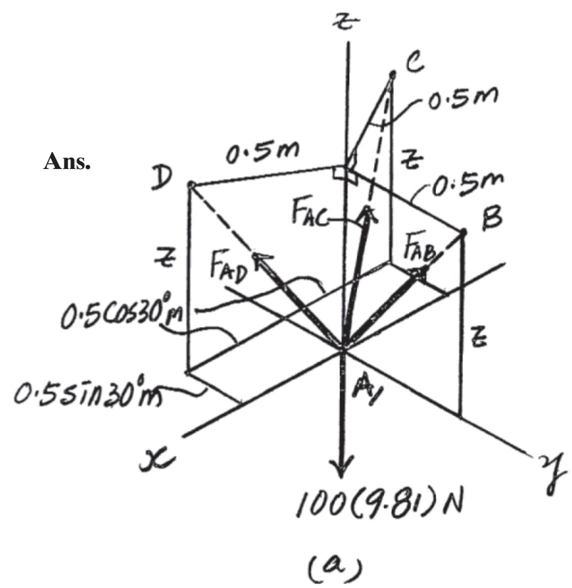
Thus, cables AB, AC, and AD all develop the same tension.

$$\Sigma F_z = 0; \quad 3F\left(\frac{z}{\sqrt{0.5^2 + z^2}}\right) - 100(9.81) = 0$$

Cables AB, AC, and AD will also achieve maximum tension simultaneously. Substituting $F = 1000$ N, we obtain

$$3(1000)\left(\frac{z}{\sqrt{0.5^2 + z^2}}\right) - 100(9.81) = 0$$

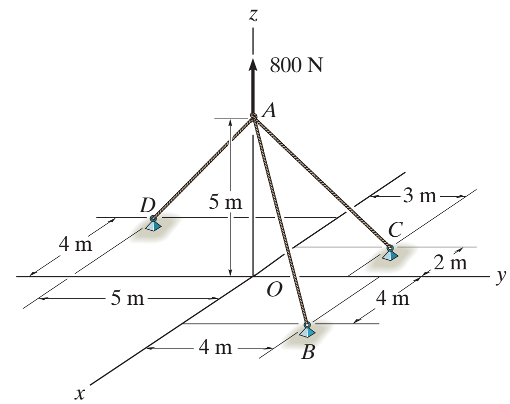
$$z = 0.1730 \text{ m} = 173 \text{ mm}$$ **Ans.**



Ans:
$z = 173$ mm

***3–56.**

Determine the tension in each cable for equilibrium.



SOLUTION

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

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

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

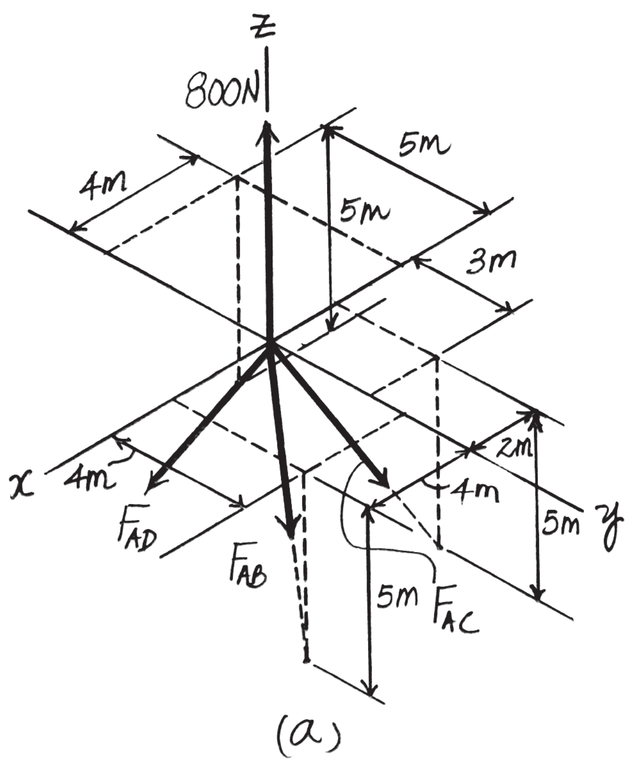
$$\Sigma F_z = 0; \quad -F_{AB}\left(\frac{5}{\sqrt{57}}\right) - F_{AC}\left(\frac{5}{\sqrt{38}}\right) - F_{AD}\left(\frac{5}{\sqrt{66}}\right) + 800 = 0 \qquad \textbf{(3)}$$

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.**

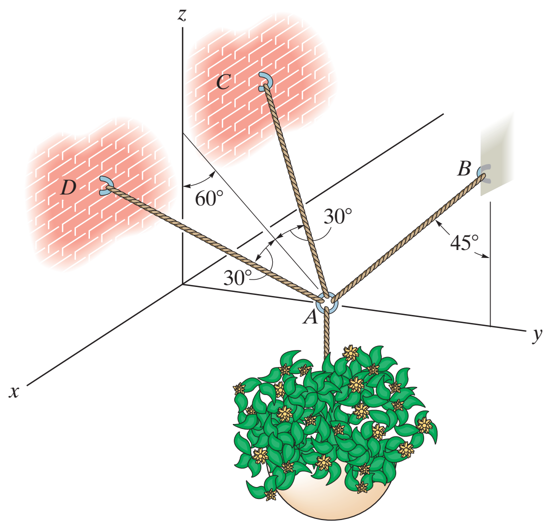


(a)

Ans:
$F_{AC} = 85.8 \text{ N}$
$F_{AB} = 578 \text{ N}$
$F_{AD} = 565 \text{ N}$

3–57.

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



SOLUTION

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

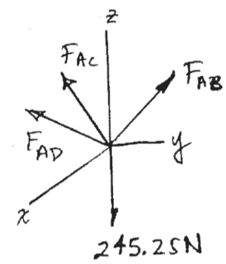
$$= 0.5F_{AD}\mathbf{i} - 0.75F_{AD}\mathbf{j} + 0.4330F_{AD}\mathbf{k}$$

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

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

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

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



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

$$(0.5F_{AD}\mathbf{i} - 0.75F_{AD}\mathbf{j}) + 0.4330F_{AD}\mathbf{k} + (0.7071F_{AB}\mathbf{j} + 0.7071F_{AB}\mathbf{k})$$
$$+(-0.5F_{AC}\mathbf{i} - 0.75F_{AC}\mathbf{j} + 0.4330F_{AC}\mathbf{k}) + (-245.25\mathbf{k}) = \mathbf{0}$$

$$(0.5F_{AD} - 0.5F_{AC})\mathbf{i} + (-0.75F_{AD} + 0.7071F_{AB} - 0.75F_{AC})\mathbf{j}$$
$$+(0.4330F_{AD} + 0.7071F_{AB} + 0.4330F_{AC} - 245.25)\mathbf{k} = \mathbf{0}$$

Thus,

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

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

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

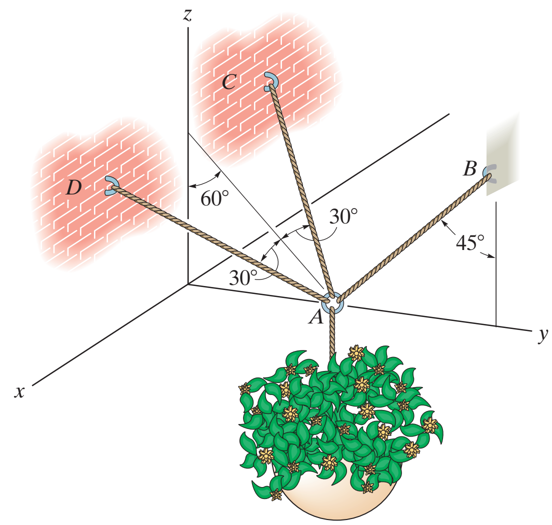
Solving Eqs. [1], [2], and [3] yields:

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

Ans:
$F_{AD} = F_{AC} = 104\text{ N}$
$F_{AB} = 220\text{ N}$

3–58.

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

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

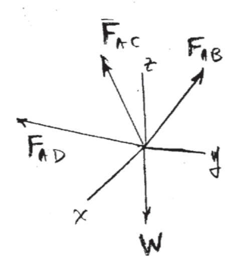
$= 0.5F_{AD}\mathbf{i} - 0.75F_{AD}\mathbf{j} + 0.4330F_{AD}\mathbf{k}$

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

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

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

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



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

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

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

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

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

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

$2.366F_{AC} = W$

Assume $F_{AC} = 50$ N then

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

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

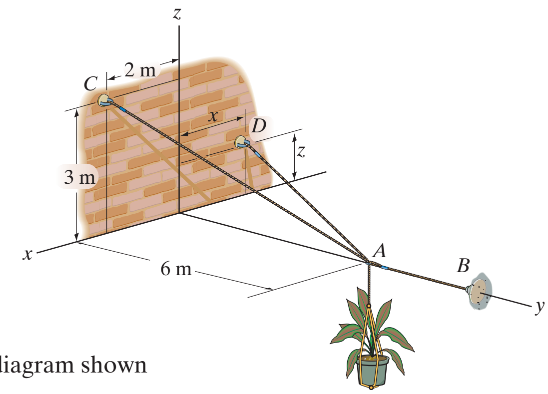
$$F_{AC} = \frac{0.7071(50)}{1.5} = 23.57 \text{ N} < 50 \text{ N } (\textbf{O.K!})$$

Thus,

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

Ans:
$W = 55.8$ N

3–59. If the mass of the flowerpot is 50 kg, determine the tension developed in each wire for equilibrium. Set $x = 1.5$ m and $z = 2$ m.



SOLUTION

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

$$\mathbf{F}_{AB} = F_{AB}\mathbf{j}$$

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

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

$$\mathbf{W} = [-50(9.81)\mathbf{k}]\text{N} = [-490.5\mathbf{k}]\text{N}$$

Equations of Equilibrium: Equilibrium requires

$$\sum \text{F} = 0; \quad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = 0$$

$$F_{AB}\mathbf{j} + \left(\frac{2}{7}F_{AC}\mathbf{i} - \frac{6}{7}F_{AC}\mathbf{j} + \frac{3}{7}F_{AC}\mathbf{k}\right) + \left(-\frac{3}{13}F_{AD}\mathbf{i} - \frac{12}{13}F_{AD}\mathbf{j} + \frac{4}{13}F_{AD}\mathbf{k}\right) + (-490.5\mathbf{k}) = 0$$

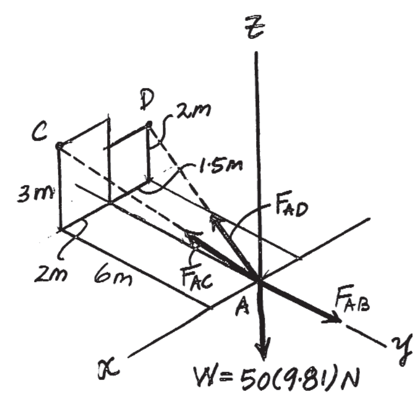
$$\left(\frac{2}{7}F_{AC} - \frac{3}{13}F_{AD}\right)\mathbf{i} + \left(F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F_{AD}\right)\mathbf{j} + \left(\frac{3}{7}F_{AC} + \frac{4}{13}F_{AD} - 490.5\right)\mathbf{k} = 0$$

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

$$\frac{2}{7}F_{AC} - \frac{3}{13}F_{AD} = 0 \qquad (1)$$

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

$$\frac{3}{7}F_{AC} + \frac{4}{13}F_{AD} - 490.5 = 0 \qquad (3)$$



Solving Eqs. (1) through (3) yields

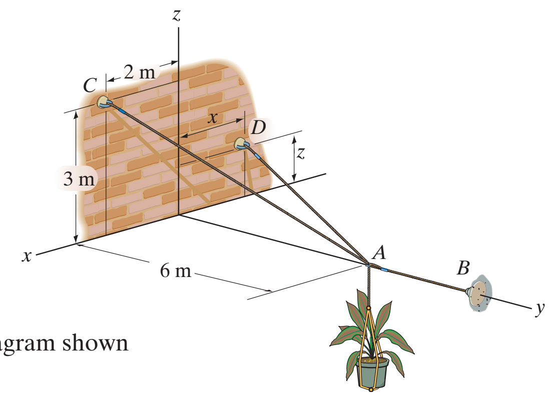
$F_{AB} = 1211.82 \text{ N} = 1.21 \text{ kN}$ **Ans.**

$F_{AC} = 606 \text{ N}$ **Ans.**

$F_{AD} = 750 \text{ N}$ **Ans.**

Ans:
$F_{AB} = 1.21 \text{ kN}$
$F_{AC} = 606 \text{ N}$
$F_{AD} = 750 \text{ N}$

***3–60.** If the mass of the flowerpot is 50 kg, determine the tension developed in each wire for equilibrium. Set $x = 2$ m and $z = 1.5$ m.



SOLUTION

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

$$\mathbf{F}_{AB} = F_{AB}\mathbf{j}$$

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

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

$$\mathbf{W} = [-50(9.81)\mathbf{k}]\text{N} = [-490.5\mathbf{k}]\text{N}$$

Equations of Equilibrium: Equilibrium requires

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

$$F_{AB}\mathbf{j} + \left(\frac{2}{7}F_{AC}\mathbf{i} - \frac{6}{7}F_{AC}\mathbf{j} + \frac{3}{7}F_{AC}\mathbf{k}\right) + \left(-\frac{4}{13}F_{AD}\mathbf{i} - \frac{12}{13}F_{AD}\mathbf{j} + \frac{3}{13}F_{AD}\mathbf{k}\right) + (-490.5\mathbf{k}) = \mathbf{0}$$

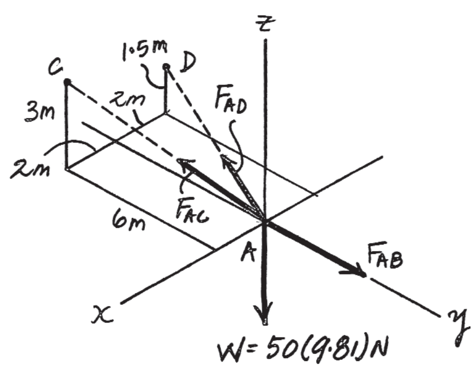
$$\left(\frac{2}{7}F_{AC} - \frac{4}{13}F_{AD}\right)\mathbf{i} + \left(F_{AB} - \frac{6}{7}F_{AC} - \frac{12}{13}F_{AD}\right)\mathbf{j} + \left(\frac{3}{7}F_{AC} + \frac{3}{13}F_{AD} - 490.5\right)\mathbf{k} = \mathbf{0}$$

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

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

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

$$\frac{3}{7}F_{AC} + \frac{4}{13}F_{AD} - 490.5 = 0 \qquad (3)$$



Solving Eqs. (1) through (3) yields

$F_{AB} = 1308\text{ N} = 1.31\text{ kN}$ **Ans.**

$F_{AC} = 763\text{ N}$ **Ans.**

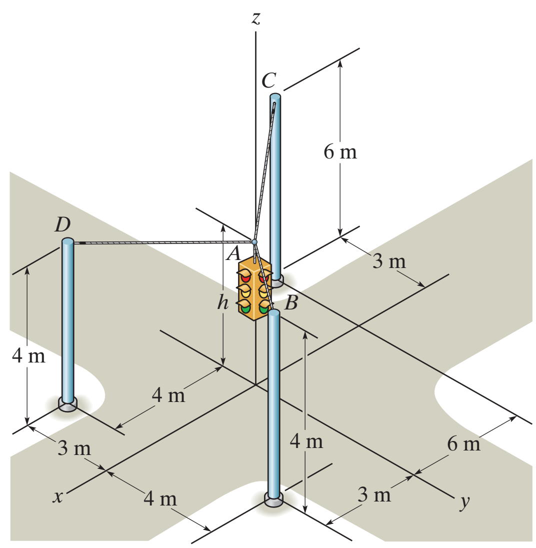
$F_{AD} = 708.5\text{ N}$ **Ans.**

Ans:

$F_{AB} = 1.31$ kN
$F_{AC} = 763$ N
$F_{AD} = 708.5$ N

3–61.

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

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

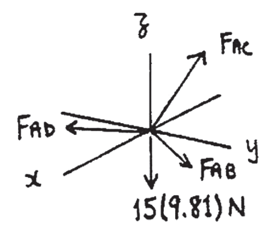
$$\mathbf{u}_{AC} = \left\{-\frac{6}{7}\mathbf{i} - \frac{3}{7}\mathbf{j} + \frac{2}{7}\mathbf{k}\right\}$$

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

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

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

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



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

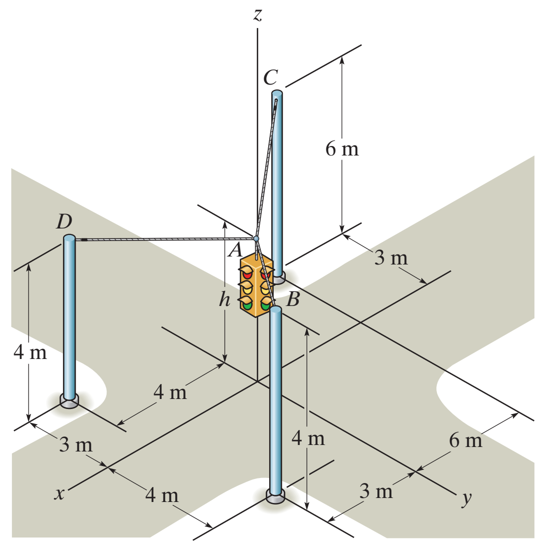
$F_{AC} = 515$ N **Ans.**

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

Ans:
$F_{AB} = 441$ N
$F_{AC} = 515$ N
$F_{AD} = 221$ N

3–62.

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

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

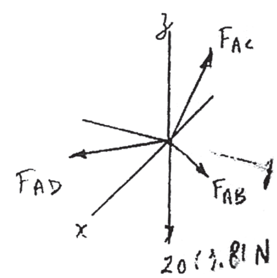
$$\mathbf{u}_{AC} = \frac{-6\mathbf{i} - 3\mathbf{j} + 2.5\mathbf{k}}{\sqrt{(-6)^2 + (-3)^2 + 2.5^2}} = \frac{-6\mathbf{i} - 3\mathbf{j} + 2.5\mathbf{k}}{\sqrt{51.25}}$$

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

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

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

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



Solving,

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

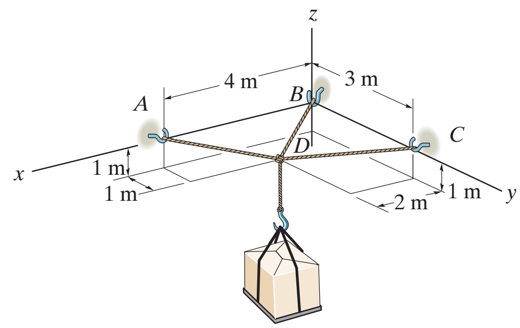
$F_{AC} = 413$ N **Ans.**

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

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

3–63.

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*,

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

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

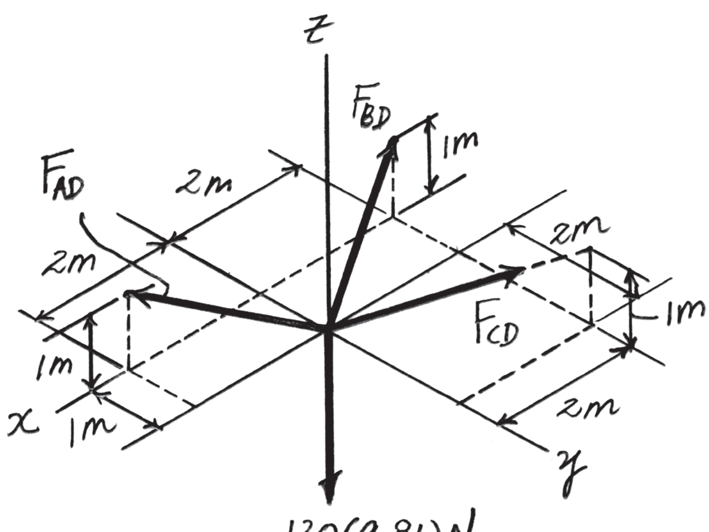
$$\Sigma F_z = 0;\quad F_{AD}\left(\frac{1}{\sqrt{6}}\right) + F_{BD}\left(\frac{1}{\sqrt{6}}\right) + F_{CD}\left(\frac{1}{3}\right) - 130(9.81) = 0 \qquad \textbf{(3)}$$

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.**

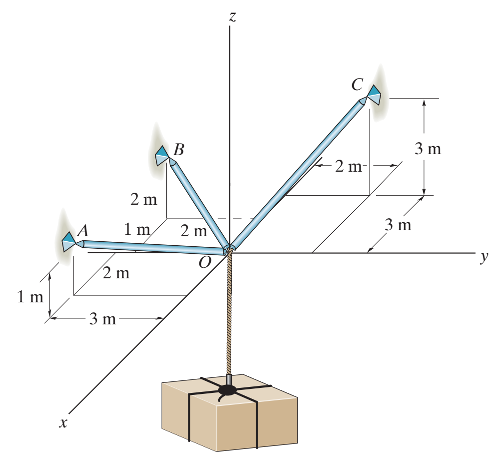


(a)

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

***3–64.**

If 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*,

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

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

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

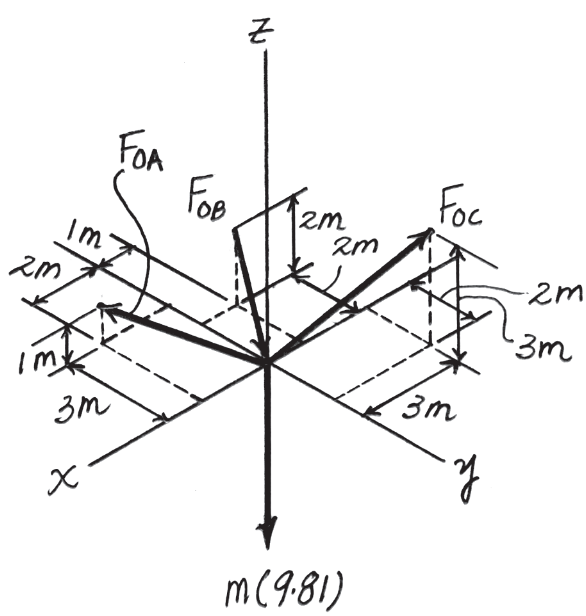
Solving Eqs (1), (2) and (3),

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

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

$$1500 = 16.95\text{ m}$$

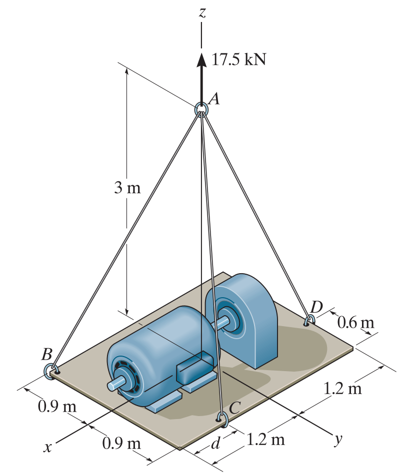
$$m = 88.48\text{ kg} = 88.5\text{ kg} \qquad \textbf{Ans.}$$



(a)

Ans:
$m = 88.5$ kg

3–65. Determine the force in each cable needed to support the 17.5-kN (≈1750-kg) platform. Set $d = 1.2$ m.



SOLUTION

Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{1.2\mathbf{i} - 0.9\mathbf{j} - 3\mathbf{k}}{\sqrt{1.2^2 + (-0.9)^2 + (-3)^2}}\right) = 0.3578F_{AB}\mathbf{i} - 0.2683F_{AB}\mathbf{j} - 0.8944F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{0.9\mathbf{j} - 3\mathbf{k}}{\sqrt{0.9^2 + (-3)^2}}\right) = 0.2873F_{AC}\mathbf{j} - 0.9578F_{AC}\mathbf{k}$$

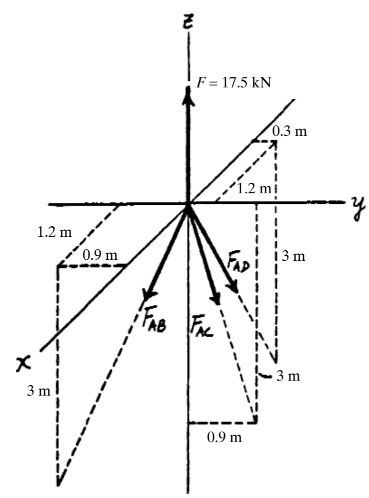
$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-1.2\mathbf{i} + 0.3\mathbf{j} - 3\mathbf{k}}{\sqrt{(-1.2)^2 + 0.3^2 + (-3)^2}}\right) = -0.3698F_{AD}\mathbf{i} + 0.09245F_{AD}\mathbf{j} - 0.9245F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{17.5\mathbf{k}\}\text{ kN}$$

Equations of Equilibrium :

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

$$(0.3578F_{AB} - 0.3698F_{AD})\mathbf{i} + (-0.2683F_{AB} + 0.2873F_{AC} + 0.09245F_{AD})\mathbf{j}$$
$$+ (-0.8944F_{AB} - 0.9578F_{AC} - 0.9245F_{AD} + 17.5)\mathbf{k} = 0$$



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

$$0.3578F_{AB} - 0.3698F_{AD} = 0 \qquad [1]$$
$$-0.2683F_{AB} + 0.2873F_{AC} + 0.09245F_{AD} = 0 \qquad [2]$$
$$-0.8944F_{AB} - 0.9578F_{AC} - 0.9245F_{AD} + 17.5 = 0 \qquad [3]$$

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

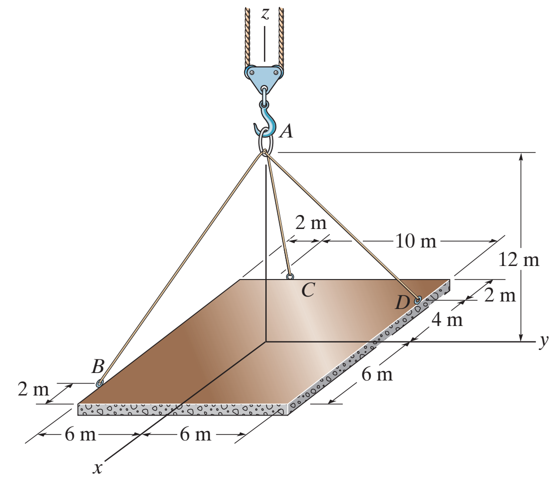
$F_{AB} = 7.337$ kN **Ans.**

$F_{AC} = 4.568$ kN **Ans.**

$F_{AD} = 7.098$ kN **Ans.**

Ans:
$F_{AB} = 7.337$ kN
$F_{AC} = 4.568$ kN
$F_{AD} = 7.098$ kN

3–66. The ends of the three cables are attached to a ring at A and to the edge of the uniform plate. Determine the largest mass the plate can have if each cable can support a maximum tension of 15 kN.



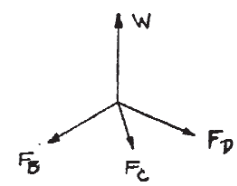
SOLUTION

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

$$\mathbf{F}_B = F_B\left(\frac{4}{14}\mathbf{i} - \frac{6}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$

$$\mathbf{F}_C = F_C\left(-\frac{6}{14}\mathbf{i} - \frac{4}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$

$$\mathbf{F}_D = F_D\left(-\frac{4}{14}\mathbf{i} + \frac{6}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$



$$\Sigma F_x = 0; \quad \frac{4}{14}F_B - \frac{6}{14}F_C - \frac{4}{14}F_D = 0$$

$$\Sigma F_y = 0; \quad -\frac{6}{14}F_B - \frac{4}{14}F_C + \frac{6}{14}F_D = 0$$

$$\Sigma F_z = 0; \quad -\frac{12}{14}F_B - \frac{12}{14}F_C - \frac{12}{14}F_D + W = 0$$

Assume $F_B = 15$ kN. Solving,

$F_C = 0 < 15$ kN (OK)

$F_D = 15$ kN (OK)

Thus,

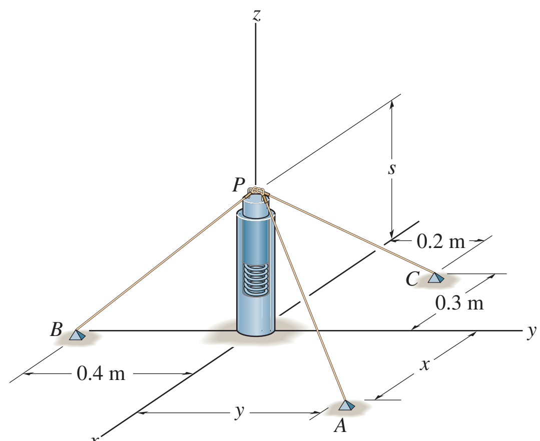
$$-\frac{12}{14}(15) - 0 - \frac{12}{14}(15) + W = 0$$

$W = 25.714$ kN

$$m = \frac{W}{g} = \frac{25.714}{9.81} = 2.62 \text{ Mg}$$ **Ans.**

Ans:
$m = 2.62$ Mg

3–67. A small peg P rests on a spring that is contained inside the smooth pipe. When the spring is compressed so that $s = 0.15$ m, the spring exerts an upward force of 60 N on the peg. Determine the point of attachment $A(x, y, 0)$ of cord PA so that the tension in cords PB and PC equals 30 N and 50 N, respectively.



SOLUTION

Cartesian Vector Notation:

$$\mathbf{F}_{PA} = (F_{PA})_x\mathbf{i} + (F_{PA})_y\mathbf{j} + (F_{PA})_z\mathbf{k}$$

$$\mathbf{F}_{PB} = 30\left(\frac{-0.4\mathbf{j} - 0.15\mathbf{k}}{\sqrt{(-0.4)^2 + (-0.15)^2}}\right) = \{-28.09\mathbf{j} - 10.53\mathbf{k}\}\text{ N}$$

$$\mathbf{F}_{PC} = 50\left(\frac{-0.3\mathbf{i} + 0.2\mathbf{j} - 0.15\mathbf{k}}{\sqrt{(-0.3)^2 + 0.2^2 + (-0.15)^2}}\right) = \{-38.41\mathbf{i} + 25.61\mathbf{j} - 19.21\mathbf{k}\}\text{ N}$$

$$\mathbf{F} = \{60\mathbf{k}\}\text{ N}$$

Equations of Equilibrium:

$\Sigma\mathbf{F} = 0;\quad \mathbf{F}_{PA} + \mathbf{F}_{PB} + \mathbf{F}_{PC} + \mathbf{F} = \mathbf{0}$

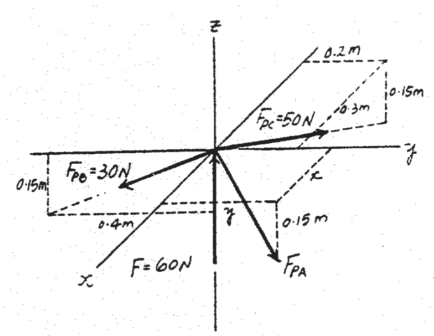
$$[(F_{PA})_x - 38.41]\mathbf{i} + [(F_{PA})_y - 28.09 + 25.61]\mathbf{j} + [(F_{PA})_z - 10.53 - 19.21 + 60]\mathbf{k} = 0$$

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

$(F_{PA})_x - 38.41 = 0 \qquad (F_{PA})_x = 38.41\text{ N}$

$(F_{PA})_y - 28.09 + 25.61 = 0 \qquad (F_{PA})_y = 2.48\text{ N}$

$(F_{PA})_z - 10.53 - 19.21 + 60 = 0 \qquad (F_{PA})_z = -30.26\text{ N}$



The magnitude of $\mathbf{F}_{PA}$ is

$$F_{PA} = \sqrt{(F_{PA})_x^2 + (F_{PA})_y^2 + (F_{PA})_z^2}$$

$$= \sqrt{38.41^2 + 2.48^2 + (-30.26)^2} = 48.96\text{ N}$$

The coordinate direction angles are

$$\alpha = \cos^{-1}\left[\frac{(F_{PA})_x}{F_{PA}}\right] = \cos^{-1}\left(\frac{38.41}{48.96}\right) = 38.32°$$

$$\beta = \cos^{-1}\left[\frac{(F_{PA})_y}{F_{PA}}\right] = \cos^{-1}\left(\frac{2.48}{48.96}\right) = 87.09°$$

$$\gamma = \cos^{-1}\left[\frac{(F_{PA})_z}{F_{PA}}\right] = \cos^{-1}\left(\frac{-30.26}{48.96}\right) = 128.17°$$

The wire PA has a length of

$$PA = \frac{(PA)_z}{\cos\gamma} = \frac{-0.15}{\cos 128.17°} = 0.2427\text{ m}$$

Thus,

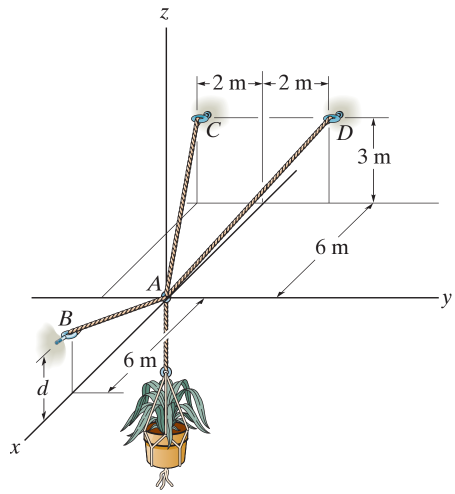
$$x = PA\cos\alpha = 0.2427\cos 38.32° = 0.190\text{ m} \qquad \textbf{Ans.}$$

$$y = PA\cos\beta = 0.2427\cos 87.09° = 0.0123\text{ m} \qquad \textbf{Ans.}$$

Ans:
$x = 0.190$ m
$y = 0.0123$ m

***3–68.**

Determine the height d of cable AB so that the force in cables AD and AC is one-half as great as the force in cable AB. What is the force in each cable for this case? The flower pot has a mass of 50 kg.



SOLUTION

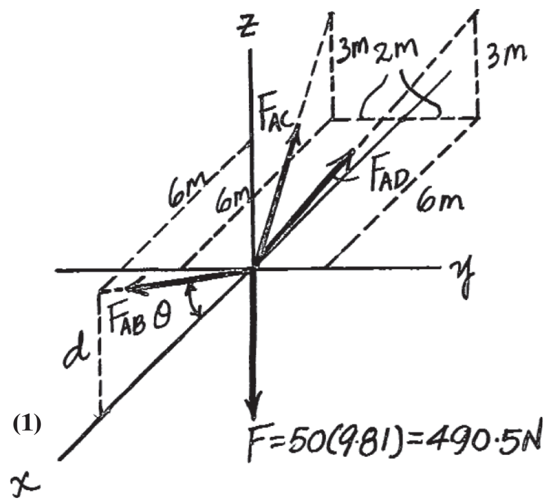
Cartesian Vector Notation:

$$\mathbf{F}_{AB} = (F_{AB})_x\,\mathbf{i} + (F_{AB})_y\,\mathbf{k}$$

$$\mathbf{F}_{AC} = \frac{F_{AB}}{2}\left(\frac{-6\mathbf{i} - 2\mathbf{j} + 3\mathbf{k}}{\sqrt{(-6)^2 + (-2)^2 + 3^2}}\right) = -\frac{3}{7}F_{AB}\mathbf{i} - \frac{1}{7}F_{AB}\,\mathbf{j} + \frac{3}{14}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = \frac{F_{AB}}{2}\left(\frac{-6\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}}{\sqrt{(-6)^2 + 2^2 + 3^2}}\right) = -\frac{3}{7}F_{AB}\mathbf{i} + \frac{1}{7}F_{AB}\,\mathbf{j} + \frac{3}{14}F_{AB}\,\mathbf{k}$$

$$\mathbf{F} = \{-490.5\mathbf{k}\}\text{ N}$$



Equations of Equilibrium:

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

$$\left((F_{AB})_x - \frac{3}{7}F_{AB} - \frac{3}{7}F_{AB}\right)\mathbf{i} + \left(-\frac{1}{7}F_{AB} + \frac{1}{7}F_{AB}\right)\mathbf{j}$$

$$+\left((F_{AB})_z + \frac{3}{14}F_{AB} + \frac{3}{14}F_{AB} - 490.5\right)\mathbf{k} = \mathbf{0}$$

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

$$(F_{AB})_x - \frac{3}{7}F_{AB} - \frac{3}{7}F_{AB} = 0 \qquad (F_{AB})_x = \frac{6}{7}F_{AB} \qquad \textbf{(1)}$$

$$-\frac{1}{7}F_{AB} + \frac{1}{7}F_{AB} = 0 \qquad \textit{(Satisfied!)}$$

$$(F_{AB})_z + \frac{3}{14}F_{AB} + \frac{3}{14}F_{AB} - 490.5 = 0 \qquad (F_{AB})_z = 490.5 - \frac{3}{7}F_{AB} \qquad \textbf{(2)}$$

However, $F_{AB}^2 = (F_{AB})_x^2 + (F_{AB})_z^2$, then substitute Eqs. (1) and (2) into this expression yields

$$F_{AB}^2 = \left(\frac{6}{7}F_{AB}\right)^2 + \left(490.5 - \frac{3}{7}F_{AB}\right)^2$$

Solving for positive root, we have

$$F_{AB} = 519.79\text{ N} = 520\text{ N} \qquad \textbf{Ans.}$$

Thus, $$F_{AC} = F_{AD} = \frac{1}{2}(519.79) = 260\text{ N} \qquad \textbf{Ans.}$$

Also,

$$(F_{AB})_x = \frac{6}{7}(519.79) = 445.53\text{ N}$$

$$(F_{AB})_z = 490.5 - \frac{3}{7}(519.79) = 267.73\text{ N}$$

then, $$\theta = \tan^{-1}\left[\frac{(F_{AB})_z}{(F_{AB})_x}\right] = \tan^{-1}\left(\frac{267.73}{445.53}\right) = 31.00^\circ$$

$$d = 6\tan\theta = 6\tan 31.00^\circ = 3.61\text{ m} \qquad \textbf{Ans.}$$

Ans:
$F_{AB} = 520$ N
$F_{AC} = 260$ N
$d = 3.61$ m