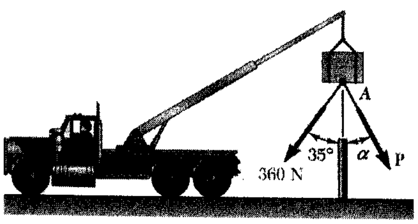
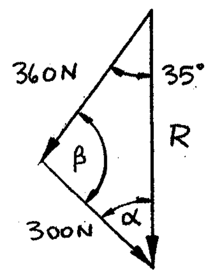


PROBLEM 2.10

To steady a sign as it is being lowered, two cables are attached to the sign at A. Using trigonometry and knowing that the magnitude of **P** is 300 N, determine (a) the required angle α if the resultant **R** of the two forces applied at A is to be vertical, (b) the corresponding magnitude of **R**.

SOLUTION



Using the triangle rule and the Law of Sines

(a) Have:

$$\frac{360\text{ N}}{\sin\alpha} = \frac{300\text{ N}}{\sin 35°}$$

$$\sin\alpha = 0.68829$$

$\alpha = 43.5°$ ◀

(b)

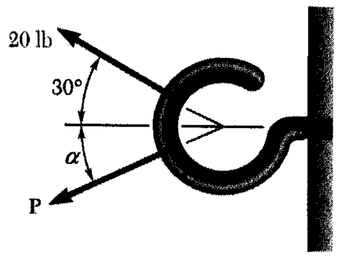
$$\beta = 180 - (35° + 43.5°)$$

$$= 101.5°$$

Then:

$$\frac{R}{\sin 101.5°} = \frac{300\text{ N}}{\sin 35°}$$

or $R = 513\text{ N}$ ◀



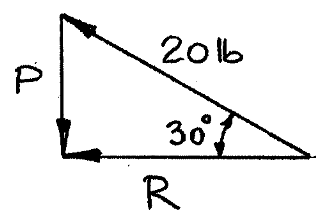
PROBLEM 2.13

For the hook support of Problem 2.11, determine, using trigonometry, (*a*) the magnitude and direction of the smallest force **P** for which the resultant **R** of the two forces applied to the support is horizontal, (*b*) the corresponding magnitude of **R**.

Problem 2.11: Two forces are applied as shown to a hook support. Using trigonometry and knowing that the magnitude of **P** is 14 lb, determine (*a*) the required angle α if the resultant **R** of the two forces applied to the support is to be horizontal, (*b*) the corresponding magnitude of **R**.

SOLUTION

(*a*) The smallest force **P** will be perpendicular to **R**, that is, vertical



$$P = (20\text{ lb})\sin 30°$$

$$= 10\text{ lb}$$

$\mathbf{P} = 10\text{ lb}\downarrow$ ◀

(*b*)

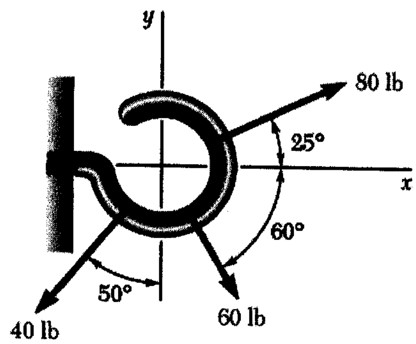
$$R = (20\text{ lb})\cos 30°$$

$$= 17.32\text{ lb}$$

$R = 17.32\text{ lb}$ ◀

PROBLEM 2.22

Determine the x and y components of each of the forces shown.



SOLUTION

40 lb Force:

$$F_x = -(40\text{ lb})\sin 50°, \qquad F_x = -30.6\text{ lb} ◀$$

$$F_y = -(40\text{ lb})\cos 50°, \qquad F_y = -25.7\text{ lb} ◀$$

60 lb Force:

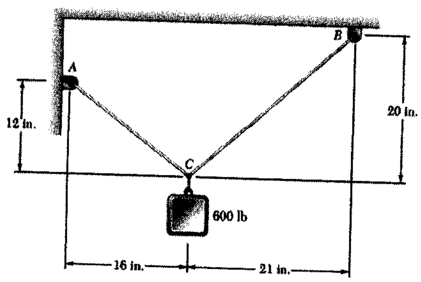
$$F_x = +(60\text{ lb})\cos 60°, \qquad F_x = 30.0\text{ lb} ◀$$

$$F_y = -(60\text{ lb})\sin 60°, \qquad F_y = -52.0\text{ lb} ◀$$

80 lb Force:

$$F_x = +(80\text{ lb})\cos 25°, \qquad F_x = 72.5\text{ lb} ◀$$

$$F_y = +(80\text{ lb})\sin 25°, \qquad F_y = 33.8\text{ lb} ◀$$

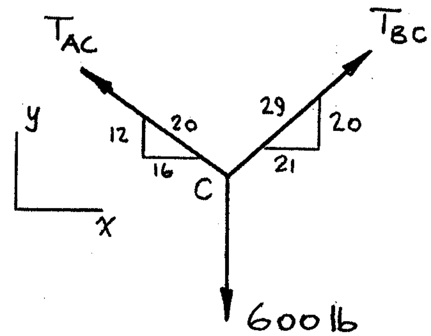


PROBLEM 2.43

Two cables are tied together at C and are loaded as shown. Determine the tension (*a*) in cable AC, (*b*) in cable BC.

SOLUTION

Free-Body Diagram



From the geometry, we calculate the distances:

$$AC = \sqrt{(16\text{ in.})^2 + (12\text{ in.})^2} = 20\text{ in.}$$

$$BC = \sqrt{(20\text{ in.})^2 + (21\text{ in.})^2} = 29\text{ in.}$$

Then, from the Free Body Diagram of point C:

$$\xrightarrow{+} \Sigma F_x = 0: \quad -\frac{16}{20}T_{AC} + \frac{21}{29}T_{BC} = 0$$

or

$$T_{BC} = \frac{29}{21} \times \frac{4}{5}T_{AC}$$

and

$$+\uparrow \Sigma F_y = 0: \quad \frac{12}{20}T_{AC} + \frac{20}{29}T_{BC} - 600\text{ lb} = 0$$

or

$$\frac{12}{20}T_{AC} + \frac{20}{29}\left(\frac{29}{21} \times \frac{4}{5}T_{AC}\right) - 600\text{ lb} = 0$$

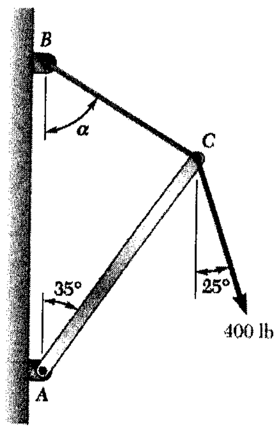
Hence:

$$T_{AC} = 440.56\text{ lb}$$

(*a*) $T_{AC} = 441\text{ lb}$ ◀

(*b*) $T_{BC} = 487\text{ lb}$ ◀

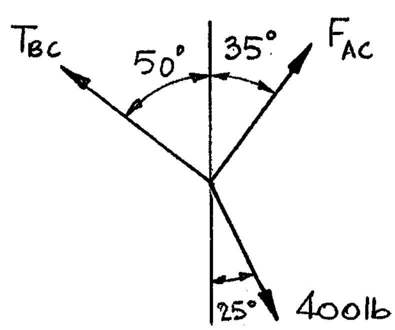
PROBLEM 2.45



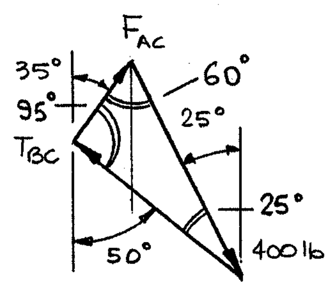
Knowing that $\alpha = 50°$ and that boom AC exerts on pin C a force directed long line AC, determine (*a*) the magnitude of that force, (*b*) the tension in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



Law of Sines:

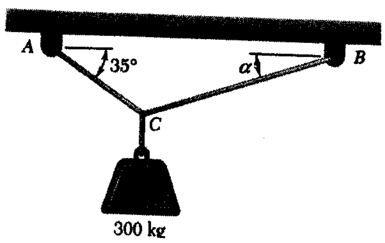
$$\frac{F_{AC}}{\sin 25°} = \frac{T_{BC}}{\sin 60°} = \frac{400 \text{ lb}}{\sin 95°}$$

(*a*) $$F_{AC} = \frac{400 \text{ lb}}{\sin 95°}\sin 25° = 169.69 \text{ lb}$$

$F_{AC} = 169.7 \text{ lb}$ ◀

(*b*) $$T_{BC} = \frac{400}{\sin 95°}\sin 60° = 347.73 \text{ lb}$$

$T_{BC} = 348 \text{ lb}$ ◀

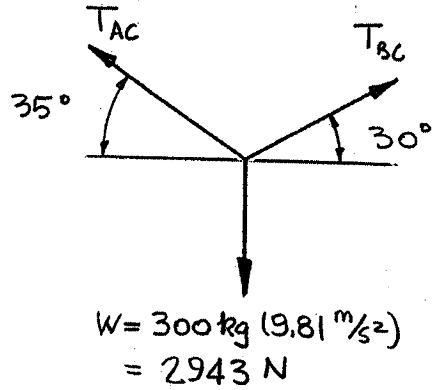


PROBLEM 2.46

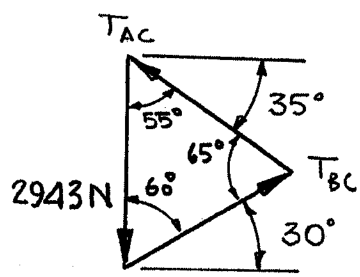
Two cables are tied together at C and are loaded as shown. Knowing that $\alpha = 30°$, determine the tension (*a*) in cable AC, (*b*) in cable BC.

SOLUTION

Free-Body Diagram



Force Triangle



Law of Sines:

$$\frac{T_{AC}}{\sin 60°} = \frac{T_{BC}}{\sin 55°} = \frac{2943 \text{ N}}{\sin 65°}$$

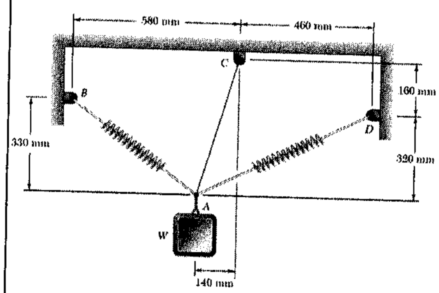
(*a*) $$T_{AC} = \frac{2943 \text{ N}}{\sin 65°}\sin 60° = 2812.19 \text{ N}$$

$T_{AC} = 2.81$ kN ◀

(*b*) $$T_{BC} = \frac{2943 \text{ N}}{\sin 65°}\sin 55° = 2659.98 \text{ N}$$

$T_{BC} = 2.66$ kN ◀

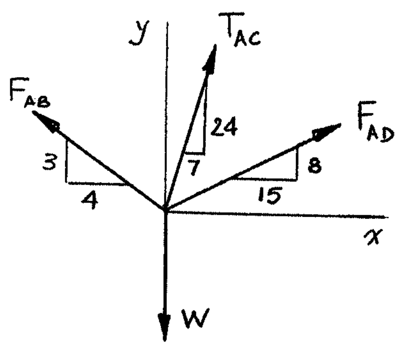
PROBLEM 2.57



A block of weight W is suspended from a 500-mm long cord and two springs of which the unstretched lengths are 450 mm. Knowing that the constants of the springs are $k_{AB} = 1500$ N/m and $k_{AD} = 500$ N/m, determine (*a*) the tension in the cord, (*b*) the weight of the block.

SOLUTION

Free-Body Diagram At A



First note from geometry:

The sides of the triangle with hypotenuse AD are in the ratio 8:15:17.

The sides of the triangle with hypotenuse AB are in the ratio 3:4:5.

The sides of the triangle with hypotenuse AC are in the ratio 7:24:25.

Then:

$$F_{AB} = k_{AB}\left(L_{AB} - L_o\right)$$

and

$$L_{AB} = \sqrt{(0.44\text{ m})^2 + (0.33\text{ m})^2} = 0.55\text{ m}$$

So:

$$F_{AB} = 1500\text{ N/m}\left(0.55\text{ m} - 0.45\text{ m}\right)$$

$$= 150\text{ N}$$

Similarly,

$$F_{AD} = k_{AD}\left(L_{AD} - L_o\right)$$

Then:

$$L_{AD} = \sqrt{(0.66\text{ m})^2 + (0.32\text{ m})^2} = 0.68\text{ m}$$

$$F_{AD} = 1500\text{ N/m}\left(0.68\text{ m} - 0.45\text{ m}\right)$$

$$= 115\text{ N}$$

(*a*)

$$\xrightarrow{+} \Sigma F_x = 0: \quad -\frac{4}{5}(150\text{ N}) + \frac{7}{25}T_{AC} - \frac{15}{17}(115\text{ N}) = 0$$

or

$$T_{AC} = 66.18\text{ N} \qquad T_{AC} = 66.2\text{ N} \blacktriangleleft$$

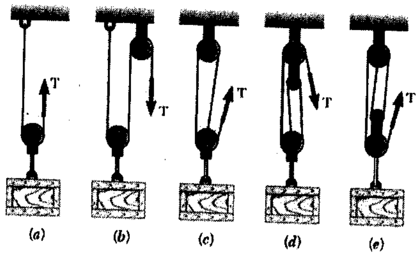
PROBLEM 2.57 CONTINUED

(*b*) and

$$+\uparrow \Sigma F_y = 0: \quad \frac{3}{5}(150\ \text{N}) + \frac{24}{25}(66.18\ \text{N}) + \frac{8}{17}(115\ \text{N}) - W = 0$$

or $W = 208\ \text{N}$ ◀

PROBLEM 2.67

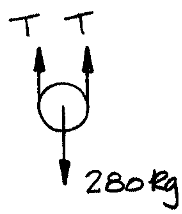


A 280-kg crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (*Hint:* The tension in the rope is the same on each side of a simple pulley. This can be proved by the methods of Chapter 4.)

SOLUTION

Free-Body Diagram of pulley

(*a*)

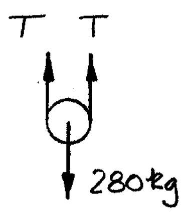


$$+\uparrow \Sigma F_y = 0: \quad 2T - (280\text{ kg})(9.81\text{ m/s}^2) = 0$$

$$T = \frac{1}{2}(2746.8\text{ N})$$

$T = 1373\text{ N}$ ◀

(*b*)

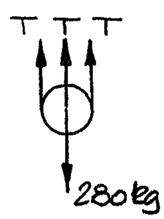


$$+\uparrow \Sigma F_y = 0: \quad 2T - (280\text{ kg})(9.81\text{ m/s}^2) = 0$$

$$T = \frac{1}{2}(2746.8\text{ N})$$

$T = 1373\text{ N}$ ◀

(*c*)

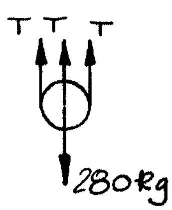


$$+\uparrow \Sigma F_y = 0: \quad 3T - (280\text{ kg})(9.81\text{ m/s}^2) = 0$$

$$T = \frac{1}{3}(2746.8\text{ N})$$

$T = 916\text{ N}$ ◀

(*d*)

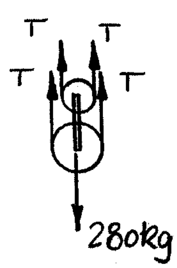


$$+\uparrow \Sigma F_y = 0: \quad 3T - (280\text{ kg})(9.81\text{ m/s}^2) = 0$$

$$T = \frac{1}{3}(2746.8\text{ N})$$

$T = 916\text{ N}$ ◀

(*e*)

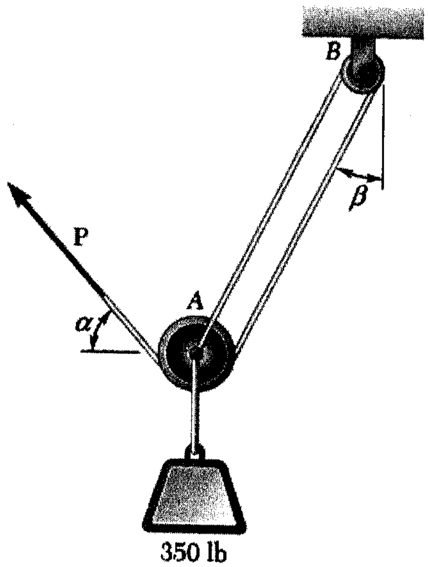


$$+\uparrow \Sigma F_y = 0: 4T - (280\text{ kg})(9.81\text{ m/s}^2) = 0$$

$$T = \frac{1}{4}(2746.8\text{ N})$$

$T = 687\text{ N}$ ◀

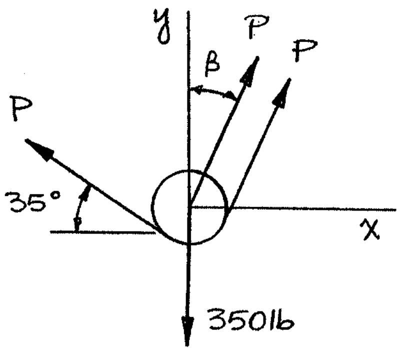
PROBLEM 2.70



A 350-lb load is supported by the rope-and-pulley arrangement shown. Knowing that $\alpha = 35°$, determine (*a*) the angle β, (*b*) the magnitude of the force **P** which should be exerted on the free end of the rope to maintain equilibrium. (*Hint:* The tension in the rope is the same on each side of a simple pulley. This can be proved by the methods of Chapter 4.)

SOLUTION

Free-Body Diagram: Pulley A



$$\xrightarrow{+} \Sigma F_x = 0: \quad 2P\sin\beta - P\cos 25° = 0$$

Hence:

(*a*) $$\sin\beta = \frac{1}{2}\cos 25°$$ or $\beta = 24.2°$ ◀

(*b*) $$+\uparrow \Sigma F_y = 0: \quad 2P\cos\beta + P\sin 35° - 350 \text{ lb} = 0$$

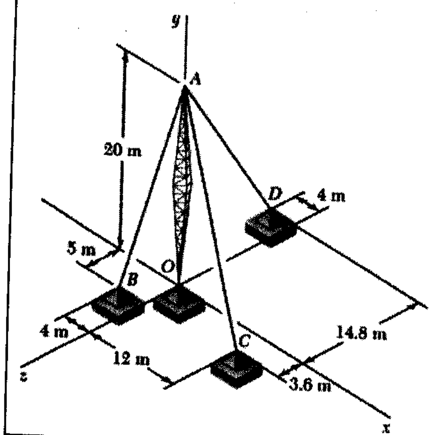
Hence:

$$2P\cos 24.2° + P\sin 35° - 350 \text{ lb} = 0$$

or $P = 145.97$ lb $\qquad P = 146.0$ lb ◀

PROBLEM 2.88

A transmission tower is held by three guy wires anchored by bolts at B, C, and D. If the tension in wire AD is 1260 N, determine the components of the force exerted by the wire on the bolt at D.



SOLUTION

$$\overrightarrow{DA} = (4\text{ m})\mathbf{i} + (20\text{ m})\mathbf{j} + (14.8\text{ m})\mathbf{k}$$

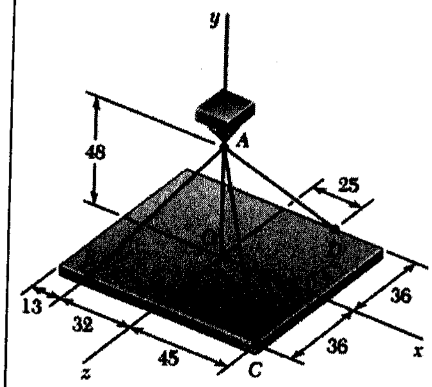
$$DA = \sqrt{(4\text{ m})^2 + (20\text{ m})^2 + (14.8\text{ m})^2} = 25.2\text{ m}$$

$$\mathbf{F} = F\boldsymbol{\lambda}_{DA} = F\frac{\overrightarrow{DA}}{DA} = \frac{1260\text{ N}}{25.2\text{ m}}\left[(4\text{ m})\mathbf{i} + (20\text{ m})\mathbf{j} + (14.8\text{ m})\mathbf{k}\right]$$

$$\mathbf{F} = (200\text{ N})\mathbf{i} + (1000\text{ N})\mathbf{j} + (740\text{ N})\mathbf{k}$$

$F_x = +200\text{ N},\ F_y = +1000\text{ N},\ F_z = +740\text{ N}$ ◀

PROBLEM 2.90



Dimensions in inches

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable AD is 195 lb, determine the components of the force exerted on the plate at D.

SOLUTION

$$\overrightarrow{DA} = -(25\text{ in.})\mathbf{i} + (48\text{ in.})\mathbf{j} + (36\text{ in.})\mathbf{k}$$

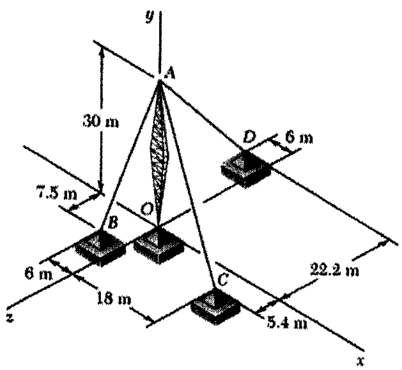
$$DA = \sqrt{(-25\text{ in.})^2 + (48\text{ in.})^2 + (36\text{ in.})^2} = 65\text{ in.}$$

$$\mathbf{F} = F\boldsymbol{\lambda}_{DA} = F\frac{\overrightarrow{DA}}{DA} = \frac{195\text{ lb}}{65\text{ in.}}\left[(-25\text{ in.})\mathbf{i} + (48\text{ in.})\mathbf{j} + (36\text{ in.})\mathbf{k}\right]$$

$$\mathbf{F} = -(75\text{ lb})\mathbf{i} + (144\text{ lb})\mathbf{j} + (108\text{ lb})\mathbf{k}$$

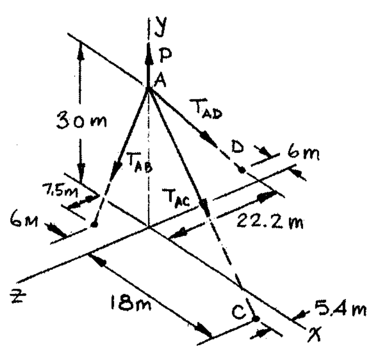
$$F_x = -75.0\text{ lb},\ F_y = +144.0\text{ lb},\ F_z = +108.0\text{ lb} \blacktriangleleft$$

PROBLEM 2.111



A transmission tower is held by three guy wires attached to a pin at A and anchored by bolts at B, C, and D. If the tension in wire AB is 3.6 kN, determine the vertical force $\mathbf{P}$ exerted by the tower on the pin at A.

SOLUTION



The force in each cable can be written as the product of the magnitude of the force and the unit vector along the cable. That is, with

$$\overrightarrow{AC} = (18\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} + (5.4\text{ m})\mathbf{k}$$

$$AC = \sqrt{(18\text{ m})^2 + (-30\text{ m})^2 + (5.4\text{ m})^2} = 35.4\text{ m}$$

$$\mathbf{T}_{AC} = T\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = \frac{T_{AC}}{35.4\text{ m}}\left[(18\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} + (5.4\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AC} = T_{AC}(0.5085\mathbf{i} - 0.8475\mathbf{j} + 0.1525\mathbf{k})$$

and

$$\overrightarrow{AB} = -(6\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} + (7.5\text{ m})\mathbf{k}$$

$$AB = \sqrt{(-6\text{ m})^2 + (-30\text{ m})^2 + (7.5\text{ m})^2} = 31.5\text{ m}$$

$$\mathbf{T}_{AB} = T\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = \frac{T_{AB}}{31.5\text{ m}}\left[-(6\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} + (7.5\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AB} = T_{AB}(-0.1905\mathbf{i} - 0.9524\mathbf{j} + 0.2381\mathbf{k})$$

Finally

$$\overrightarrow{AD} = -(6\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} - (22.2\text{ m})\mathbf{k}$$

$$AD = \sqrt{(-6\text{ m})^2 + (-30\text{ m})^2 + (-22.2\text{ m})^2} = 37.8\text{ m}$$

$$\mathbf{T}_{AD} = T\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = \frac{T_{AD}}{37.8\text{ m}}\left[-(6\text{ m})\mathbf{i} - (30\text{ m})\mathbf{j} - (22.2\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AD} = T_{AD}(-0.1587\mathbf{i} - 0.7937\mathbf{j} - 0.5873\mathbf{k})$$

PROBLEM 2.111 CONTINUED

With $\mathbf{P} = P\mathbf{j}$, at A:

$$\Sigma\mathbf{F} = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + P\mathbf{j} = 0$$

Equating the factors of **i**, **j**, and **k** to zero, we obtain the linear algebraic equations:

$$\mathbf{i}: \quad -0.1905T_{AB} + 0.5085T_{AC} - 0.1587T_{AD} = 0 \qquad (1)$$

$$\mathbf{j}: \quad -0.9524T_{AB} - 0.8475T_{AC} - 0.7937T_{AD} + P = 0 \qquad (2)$$

$$\mathbf{k}: \quad 0.2381T_{AB} + 0.1525T_{AC} - 0.5873T_{AD} = 0 \qquad (3)$$

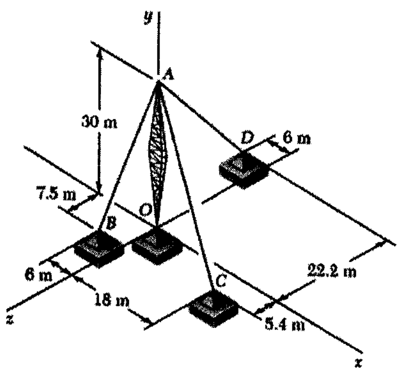
In Equations (1), (2) and (3), set $T_{AB} = 3.6$ kN, and, using conventional methods for solving Linear Algebraic Equations (MATLAB or Maple, for example), we obtain:

$$T_{AC} = 1.963 \text{ kN}$$

$$T_{AD} = 1.969 \text{ kN}$$

$$\mathbf{P} = 6.66 \text{ kN} \uparrow \blacktriangleleft$$

PROBLEM 2.112



A transmission tower is held by three guy wires attached to a pin at A and anchored by bolts at B, C, and D. If the tension in wire AC is 2.6 kN, determine the vertical force **P** exerted by the tower on the pin at A.

SOLUTION

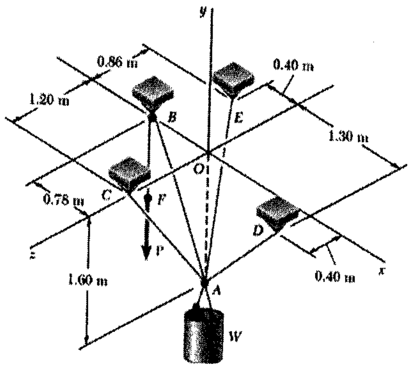
Based on the results of Problem 2.111, particularly Equations (1), (2) and (3), we substitute $T_{AC} = 2.6$ kN and solve the three resulting linear equations using conventional tools for solving Linear Algebraic Equations (MATLAB or Maple, for example), to obtain

$$T_{AB} = 4.77 \text{ kN}$$

$$T_{AD} = 2.61 \text{ kN}$$

$\mathbf{P} = 8.81 \text{ kN} \uparrow$ ◀

PROBLEM 2.130



A container of weight W is suspended from ring A, to which cables AC and AE are attached. A force **P** is applied to the end F of a third cable which passes over a pulley at B and through ring A and which is attached to a support at D. Knowing that $W = 1000$ N, determine the magnitude of **P**. (*Hint:* The tension is the same in all portions of cable $FBAD$.)

SOLUTION

The (vector) force in each cable can be written as the product of the (scalar) force and the unit vector along the cable. That is, with

$$\overrightarrow{AB} = -(0.78\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} + (0\text{ m})\mathbf{k}$$

$$AB = \sqrt{(-0.78\text{ m})^2 + (1.6\text{ m})^2 + (0)^2} = 1.78\text{ m}$$

$$\mathbf{T}_{AB} = T\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = \frac{T_{AB}}{1.78\text{ m}}\left[-(0.78\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} + (0\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AB} = T_{AB}(-0.4382\mathbf{i} + 0.8989\mathbf{j} + 0\mathbf{k})$$

and

$$\overrightarrow{AC} = (0)\mathbf{i} + (1.6\text{ m})\mathbf{j} + (1.2\text{ m})\mathbf{k}$$

$$AC = \sqrt{(0\text{ m})^2 + (1.6\text{ m})^2 + (1.2\text{ m})^2} = 2\text{ m}$$

$$\mathbf{T}_{AC} = T\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = \frac{T_{AC}}{2\text{ m}}\left[(0)\mathbf{i} + (1.6\text{ m})\mathbf{j} + (1.2\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AC} = T_{AC}(0.8\mathbf{j} + 0.6\mathbf{k})$$

and

$$\overrightarrow{AD} = (1.3\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} + (0.4\text{ m})\mathbf{k}$$

$$AD = \sqrt{(1.3\text{ m})^2 + (1.6\text{ m})^2 + (0.4\text{ m})^2} = 2.1\text{ m}$$

$$\mathbf{T}_{AD} = T\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = \frac{T_{AD}}{2.1\text{ m}}\left[(1.3\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} + (0.4\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AD} = T_{AD}(0.6190\mathbf{i} + 0.7619\mathbf{j} + 0.1905\mathbf{k})$$

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Finally,

$$\overrightarrow{AE} = -(0.4\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} - (0.86\text{ m})\mathbf{k}$$

$$AE = \sqrt{(-0.4\text{ m})^2 + (1.6\text{ m})^2 + (-0.86\text{ m})^2} = 1.86\text{ m}$$

$$\mathbf{T}_{AE} = T\boldsymbol{\lambda}_{AE} = T_{AE}\frac{\overrightarrow{AE}}{AE} = \frac{T_{AE}}{1.86\text{ m}}\left[-(0.4\text{ m})\mathbf{i} + (1.6\text{ m})\mathbf{j} - (0.86\text{ m})\mathbf{k}\right]$$

$$\mathbf{T}_{AE} = T_{AE}(-0.2151\mathbf{i} + 0.8602\mathbf{j} - 0.4624\mathbf{k})$$

With the weight of the container $\mathbf{W} = -W\mathbf{j}$, at A we have:

$$\Sigma\mathbf{F} = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} - W\mathbf{j} = 0$$

Equating the factors of **i**, **j**, and **k** to zero, we obtain the following linear algebraic equations:

$$-0.4382T_{AB} + 0.6190T_{AD} - 0.2151T_{AE} = 0 \qquad (1)$$

$$0.8989T_{AB} + 0.8T_{AC} + 0.7619T_{AD} + 0.8602T_{AE} - W = 0 \qquad (2)$$

$$0.6T_{AC} + 0.1905T_{AD} - 0.4624T_{AE} = 0 \qquad (3)$$

Knowing that $W = 1000\text{ N}$ and that because of the pulley system at B $T_{AB} = T_{AD} = P$, where P is the externally applied (unknown) force, we can solve the system of linear equations (1), (2) and (3) uniquely for P.

$P = 378\text{ N}$ ◀