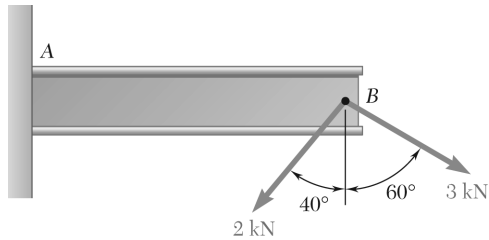


# CHAPTER 2



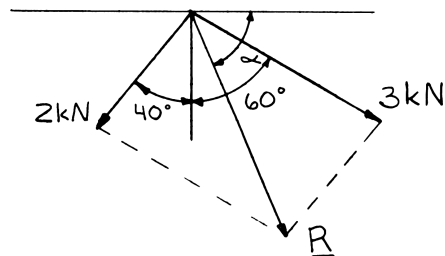


## PROBLEM 2.1

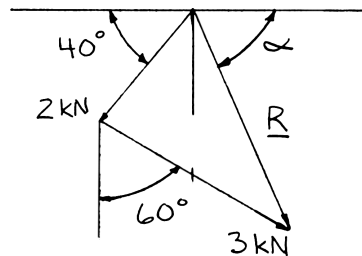
Two forces are applied at point  $B$  of beam  $AB$ . Determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

## SOLUTION

(a) Parallelogram law:



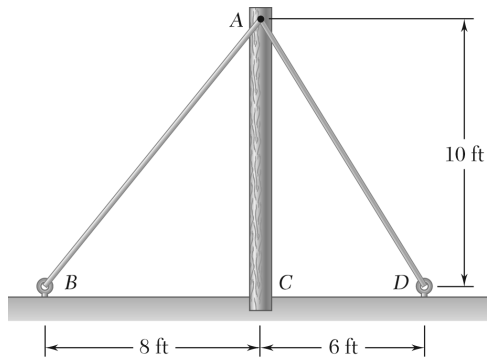
(b) Triangle rule:



We measure:

$$R = 3.30 \text{ kN}, \quad \alpha = 66.6^\circ$$

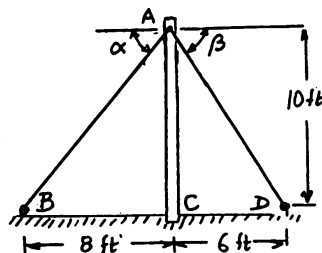
$$\mathbf{R} = 3.30 \text{ kN} \searrow 66.6^\circ \blacktriangleleft$$



## PROBLEM 2.2

The cable stays  $AB$  and  $AD$  help support pole  $AC$ . Knowing that the tension is 120 lb in  $AB$  and 40 lb in  $AD$ , determine graphically the magnitude and direction of the resultant of the forces exerted by the stays at  $A$  using (a) the parallelogram law, (b) the triangle rule.

## SOLUTION

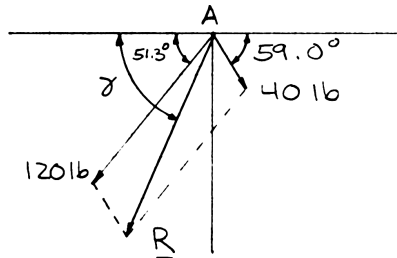


We measure:

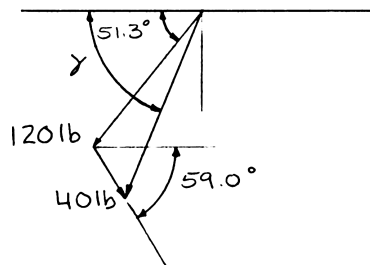
$$\alpha = 51.3^\circ$$

$$\beta = 59.0^\circ$$

(a) Parallelogram law:



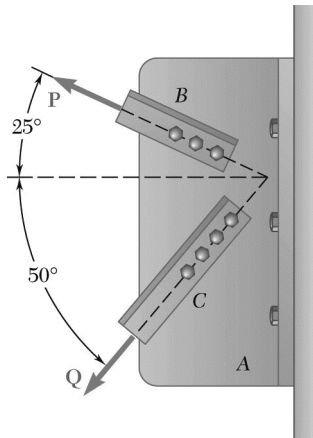
(b) Triangle rule:



We measure:

$$R = 139.1 \text{ lb}, \quad \gamma = 67.0^\circ$$

$$R = 139.1 \text{ lb} \nearrow 67.0^\circ \nwarrow$$

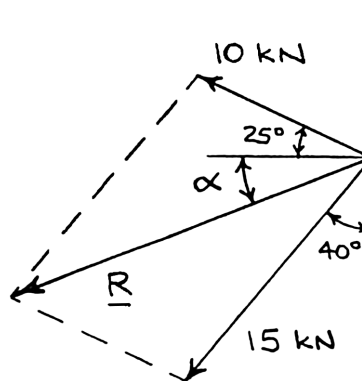


### PROBLEM 2.3

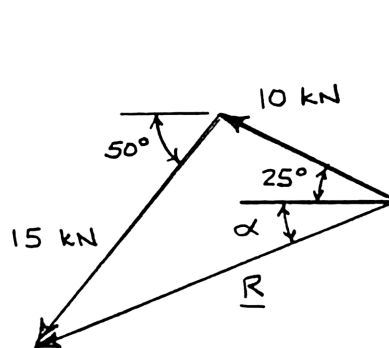
Two structural members  $B$  and  $C$  are bolted to bracket  $A$ . Knowing that both members are in tension and that  $P = 10$  kN and  $Q = 15$  kN, determine graphically the magnitude and direction of the resultant force exerted on the bracket using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

(a) Parallelogram law:



(b) Triangle rule:

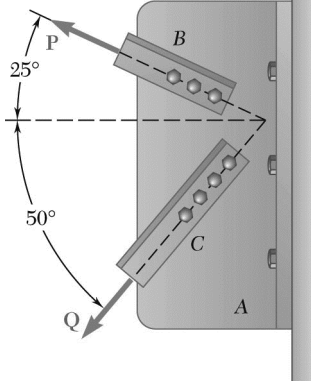


We measure:

$$R = 20.1 \text{ kN}, \quad \alpha = 21.2^\circ$$

$$\mathbf{R} = 20.1 \text{ kN} \nearrow 21.2^\circ \blacktriangleleft$$

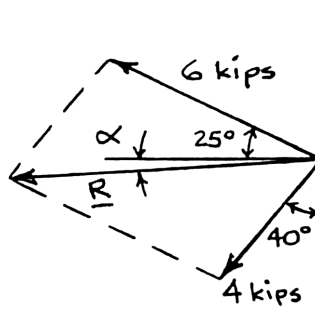
## PROBLEM 2.4



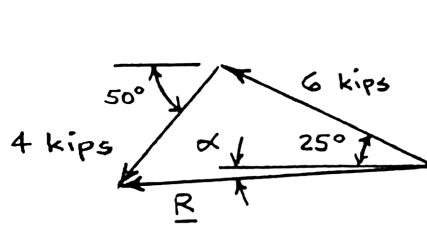
Two structural members  $B$  and  $C$  are bolted to bracket  $A$ . Knowing that both members are in tension and that  $P = 6$  kips and  $Q = 4$  kips, determine graphically the magnitude and direction of the resultant force exerted on the bracket using (a) the parallelogram law, (b) the triangle rule.

## SOLUTION

(a) Parallelogram law:



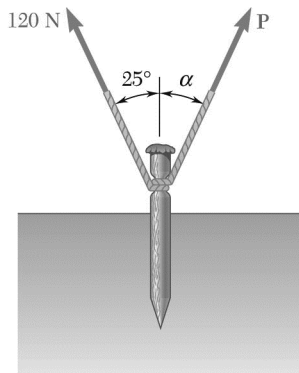
(b) Triangle rule:



We measure:

$$R = 8.03 \text{ kips}, \quad \alpha = 3.8^\circ$$

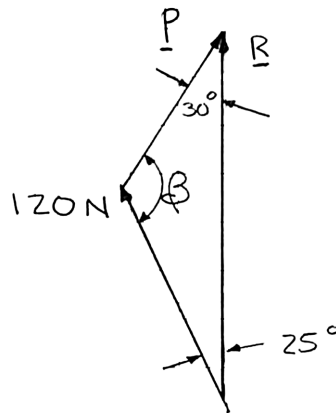
$$R = 8.03 \text{ kips} \nearrow 3.8^\circ \nwarrow$$



### PROBLEM 2.5

A stake is being pulled out of the ground by means of two ropes as shown. Knowing that  $\alpha = 30^\circ$ , determine by trigonometry (a) the magnitude of the force  $\mathbf{P}$  so that the resultant force exerted on the stake is vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION

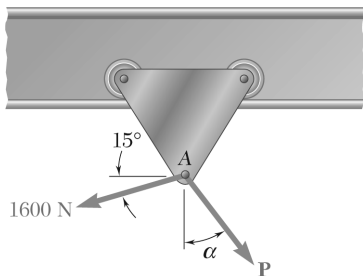


Using the triangle rule and the law of sines:

$$(a) \quad \frac{120 \text{ N}}{\sin 30^\circ} = \frac{P}{\sin 25^\circ} \quad P = 101.4 \text{ N} \quad \blacktriangleleft$$

$$(b) \quad \begin{aligned} 30^\circ + \beta + 25^\circ &= 180^\circ \\ \beta &= 180^\circ - 25^\circ - 30^\circ \\ &= 125^\circ \end{aligned}$$

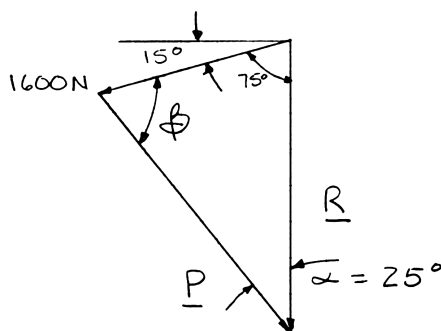
$$\frac{120 \text{ N}}{\sin 30^\circ} = \frac{R}{\sin 125^\circ} \quad R = 196.6 \text{ N} \quad \blacktriangleleft$$



## PROBLEM 2.6

A trolley that moves along a horizontal beam is acted upon by two forces as shown. (a) Knowing that  $\alpha = 25^\circ$ , determine by trigonometry the magnitude of the force  $\mathbf{P}$  so that the resultant force exerted on the trolley is vertical. (b) What is the corresponding magnitude of the resultant?

## SOLUTION



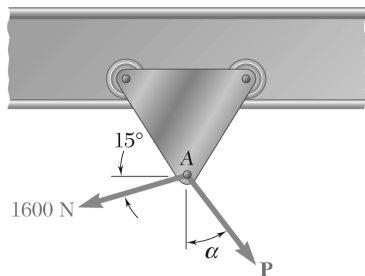
Using the triangle rule and the law of sines:

$$(a) \quad \frac{1600 \text{ N}}{\sin 25^\circ} = \frac{P}{\sin 75^\circ} \quad P = 3660 \text{ N} \quad \blacktriangleleft$$

$$(b) \quad \begin{aligned} 25^\circ + \beta + 75^\circ &= 180^\circ \\ \beta &= 180^\circ - 25^\circ - 75^\circ \\ &= 80^\circ \end{aligned}$$

$$\frac{1600 \text{ N}}{\sin 25^\circ} = \frac{R}{\sin 80^\circ} \quad R = 3730 \text{ N} \quad \blacktriangleleft$$

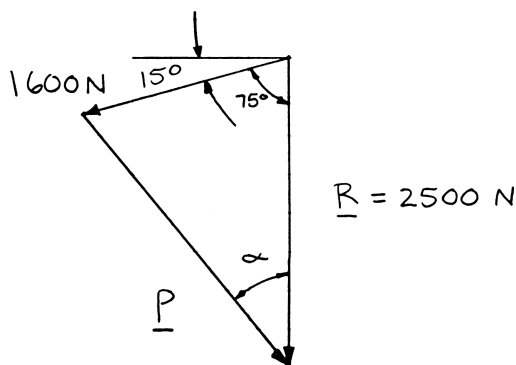




### PROBLEM 2.7

A trolley that moves along a horizontal beam is acted upon by two forces as shown. Determine by trigonometry the magnitude and direction of the force **P** so that the resultant is a vertical force of 2500 N.

### SOLUTION



Using the law of cosines:

$$P^2 = (1600 \text{ N})^2 + (2500 \text{ N})^2 - 2(1600 \text{ N})(2500 \text{ N})\cos 75^\circ$$

$$P = 2596 \text{ N}$$

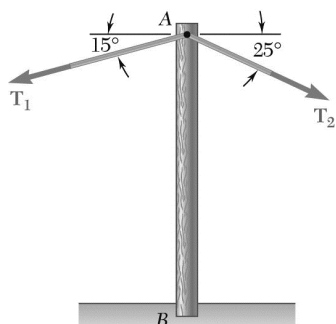
Using the law of sines:

$$\frac{\sin \alpha}{1600 \text{ N}} = \frac{\sin 75^\circ}{2596 \text{ N}}$$

$$\alpha = 36.5^\circ$$

**P** is directed  $90^\circ - 36.5^\circ$  or  $53.5^\circ$  below the horizontal.

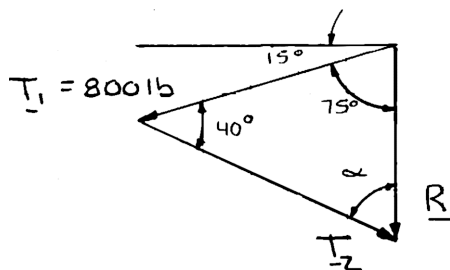
$$\mathbf{P} = 2600 \text{ N} \swarrow 53.5^\circ \blacktriangleleft$$



### PROBLEM 2.8

A telephone cable is clamped at  $A$  to the pole  $AB$ . Knowing that the tension in the left-hand portion of the cable is  $T_1 = 800$  lb, determine by trigonometry (a) the required tension  $T_2$  in the right-hand portion if the resultant  $\mathbf{R}$  of the forces exerted by the cable at  $A$  is to be vertical, (b) the corresponding magnitude of  $\mathbf{R}$ .

### SOLUTION

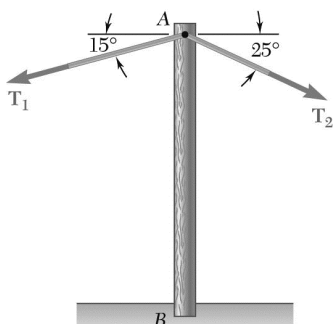


Using the triangle rule and the law of sines:

$$\begin{aligned}
 (a) \quad 75^\circ + 40^\circ + \alpha &= 180^\circ \\
 \alpha &= 180^\circ - 75^\circ - 40^\circ \\
 &= 65^\circ
 \end{aligned}$$

$$\frac{800 \text{ lb}}{\sin 65^\circ} = \frac{T_2}{\sin 75^\circ} \qquad T_2 = 853 \text{ lb} \quad \blacktriangleleft$$

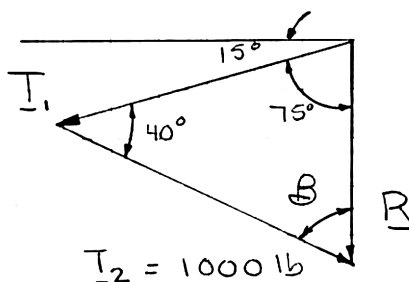
$$(b) \quad \frac{800 \text{ lb}}{\sin 65^\circ} = \frac{R}{\sin 40^\circ} \qquad R = 567 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.9

A telephone cable is clamped at A to the pole AB. Knowing that the tension in the right-hand portion of the cable is  $T_2 = 1000$  lb, determine by trigonometry (a) the required tension  $T_1$  in the left-hand portion if the resultant  $\mathbf{R}$  of the forces exerted by the cable at A is to be vertical, (b) the corresponding magnitude of  $\mathbf{R}$ .

### SOLUTION



Using the triangle rule and the law of sines:

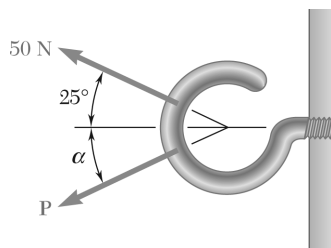
$$\begin{aligned} (a) \quad 75^\circ + 40^\circ + \beta &= 180^\circ \\ \beta &= 180^\circ - 75^\circ - 40^\circ \\ &= 65^\circ \end{aligned}$$

$$\frac{1000 \text{ lb}}{\sin 75^\circ} = \frac{T_1}{\sin 65^\circ}$$

$$T_1 = 938 \text{ lb} \quad \blacktriangleleft$$

$$(b) \quad \frac{1000 \text{ lb}}{\sin 75^\circ} = \frac{R}{\sin 40^\circ}$$

$$R = 665 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.10

Two forces are applied as shown to a hook support. Knowing that the magnitude of **P** is 35 N, determine by trigonometry (a) the required angle  $\alpha$  if the resultant **R** of the two forces applied to the support is to be horizontal, (b) the corresponding magnitude of **R**.

### SOLUTION

Using the triangle rule and law of sines:

$$(a) \quad \frac{\sin \alpha}{50 \text{ N}} = \frac{\sin 25^\circ}{35 \text{ N}}$$

$$\sin \alpha = 0.60374$$

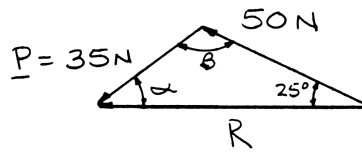
$$\alpha = 37.138^\circ$$

$$(b) \quad \alpha + \beta + 25^\circ = 180^\circ$$

$$\beta = 180^\circ - 25^\circ - 37.138^\circ$$

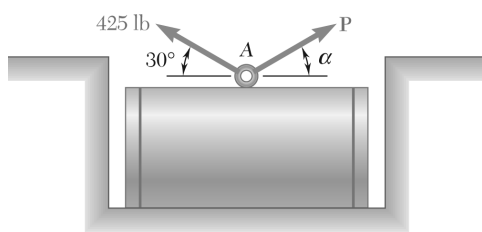
$$= 117.862^\circ$$

$$\frac{R}{\sin 117.862^\circ} = \frac{35 \text{ N}}{\sin 25^\circ}$$



$$\alpha = 37.1^\circ \quad \blacktriangleleft$$

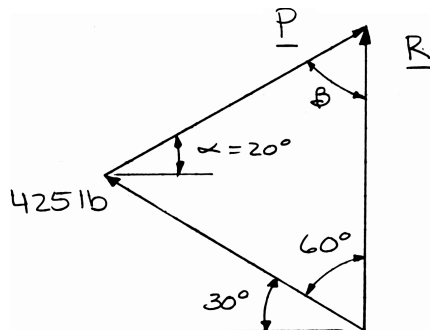
$$R = 73.2 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.11

A steel tank is to be positioned in an excavation. Knowing that  $\alpha = 20^\circ$ , determine by trigonometry (a) the required magnitude of the force  $\mathbf{P}$  if the resultant  $\mathbf{R}$  of the two forces applied at A is to be vertical, (b) the corresponding magnitude of  $\mathbf{R}$ .

### SOLUTION



Using the triangle rule and the law of sines:

(a)

$$\beta + 50^\circ + 60^\circ = 180^\circ$$

$$\beta = 180^\circ - 50^\circ - 60^\circ$$

$$= 70^\circ$$

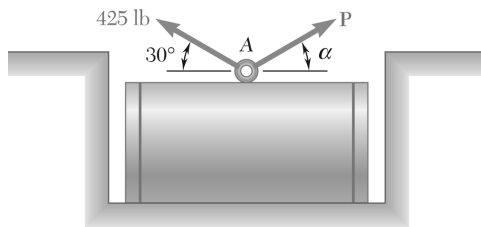
$$\frac{425 \text{ lb}}{\sin 70^\circ} = \frac{P}{\sin 60^\circ}$$

$$P = 392 \text{ lb} \quad \blacktriangleleft$$

(b)

$$\frac{425 \text{ lb}}{\sin 70^\circ} = \frac{R}{\sin 50^\circ}$$

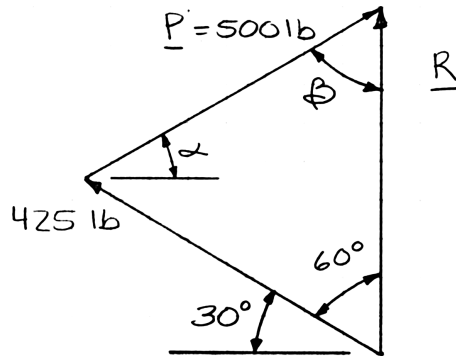
$$R = 346 \text{ lb} \quad \blacktriangleleft$$



## PROBLEM 2.12

A steel tank is to be positioned in an excavation. Knowing that the magnitude of  $\mathbf{P}$  is 500 lb, determine by trigonometry (a) the required angle  $\alpha$  if the resultant  $\mathbf{R}$  of the two forces applied at A is to be vertical, (b) the corresponding magnitude of  $\mathbf{R}$ .

## SOLUTION



Using the triangle rule and the law of sines:

$$\begin{aligned} (a) \quad (\alpha + 30^\circ) + 60^\circ + \beta &= 180^\circ \\ \beta &= 180^\circ - (\alpha + 30^\circ) - 60^\circ \\ \beta &= 90^\circ - \alpha \end{aligned}$$

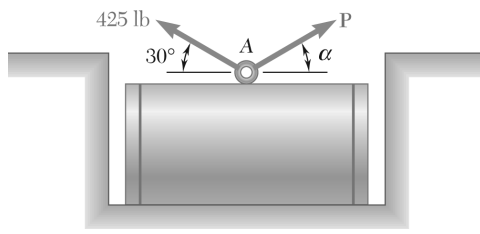
$$\frac{\sin(90^\circ - \alpha)}{425 \text{ lb}} = \frac{\sin 60^\circ}{500 \text{ lb}}$$

$$90^\circ - \alpha = 47.402^\circ$$

$$\alpha = 42.6^\circ \quad \blacktriangleleft$$

$$(b) \quad \frac{R}{\sin(42.598^\circ + 30^\circ)} = \frac{500 \text{ lb}}{\sin 60^\circ}$$

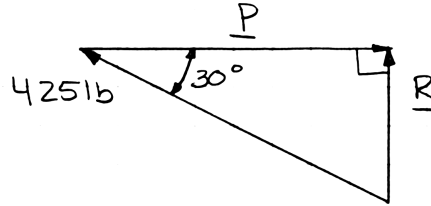
$$R = 551 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.13

A steel tank is to be positioned in an excavation. Determine by trigonometry (a) the magnitude and direction of the smallest force **P** for which the resultant **R** of the two forces applied at A is vertical, (b) the corresponding magnitude of **R**.

### SOLUTION



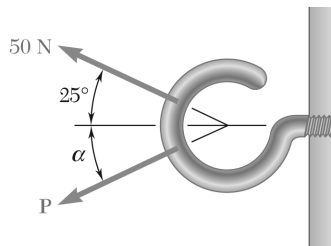
The smallest force  $P$  will be perpendicular to  $R$ .

(a)  $P = (425 \text{ lb}) \cos 30^\circ$

$P = 368 \text{ lb} \rightarrow \blacktriangleleft$

(b)  $R = (425 \text{ lb}) \sin 30^\circ$

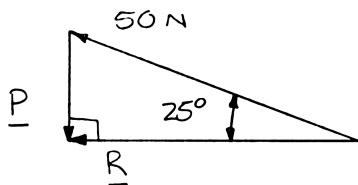
$R = 213 \text{ lb} \blacktriangleleft$



### PROBLEM 2.14

For the hook support of Prob. 2.10, determine by 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**.

### SOLUTION



The smallest force  $P$  will be perpendicular to  $R$ .

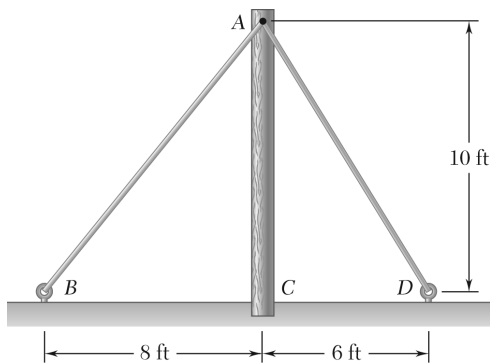
(a)  $P = (50 \text{ N}) \sin 25^\circ$

$P = 21.1 \text{ N} \downarrow \blacktriangleleft$

(b)  $R = (50 \text{ N}) \cos 25^\circ$

$R = 45.3 \text{ N} \blacktriangleleft$



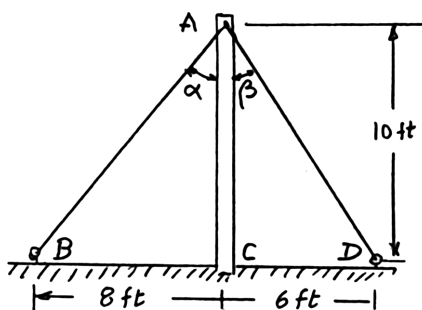


## PROBLEM 2.15

Solve Problem 2.2 by trigonometry.

**PROBLEM 2.2** The cable stays  $AB$  and  $AD$  help support pole  $AC$ . Knowing that the tension is 120 lb in  $AB$  and 40 lb in  $AD$ , determine graphically the magnitude and direction of the resultant of the forces exerted by the stays at  $A$  using (a) the parallelogram law, (b) the triangle rule.

## SOLUTION



$$\tan \alpha = \frac{8}{10}$$

$$\alpha = 38.66^\circ$$

$$\tan \beta = \frac{6}{10}$$

$$\beta = 30.96^\circ$$

Using the triangle rule:

$$\alpha + \beta + \psi = 180^\circ$$

$$38.66^\circ + 30.96^\circ + \psi = 180^\circ$$

$$\psi = 110.38^\circ$$

Using the law of cosines:

$$R^2 = (120 \text{ lb})^2 + (40 \text{ lb})^2 - 2(120 \text{ lb})(40 \text{ lb})\cos 110.38^\circ$$

$$R = 139.08 \text{ lb}$$

Using the law of sines:

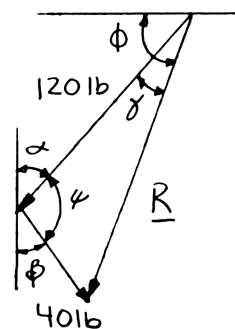
$$\frac{\sin \gamma}{40 \text{ lb}} = \frac{\sin 110.38^\circ}{139.08 \text{ lb}}$$

$$\gamma = 15.64^\circ$$

$$\phi = (90^\circ - \alpha) + \gamma$$

$$\phi = (90^\circ - 38.66^\circ) + 15.64^\circ$$

$$\phi = 66.98^\circ$$

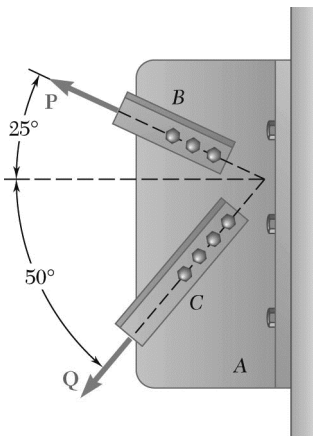


$$\mathbf{R} = 139.1 \text{ lb} \nearrow 67.0^\circ \blacktriangleleft$$

## PROBLEM 2.16

Solve Problem 2.4 by trigonometry.

**PROBLEM 2.4** Two structural members *B* and *C* are bolted to bracket *A*. Knowing that both members are in tension and that  $P = 6$  kips and  $Q = 4$  kips, determine graphically the magnitude and direction of the resultant force exerted on the bracket using (a) the parallelogram law, (b) the triangle rule.

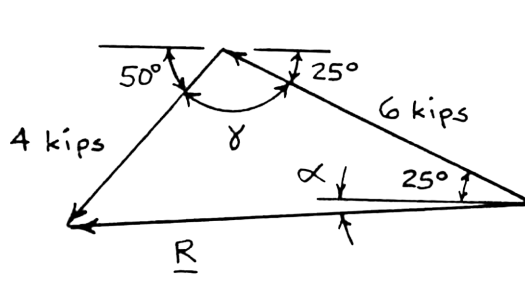


## SOLUTION

Using the force triangle and the laws of cosines and sines:

We have:

$$\begin{aligned}\gamma &= 180^\circ - (50^\circ + 25^\circ) \\ &= 105^\circ\end{aligned}$$



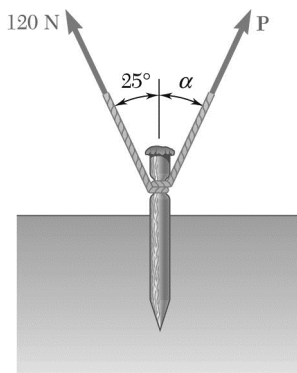
Then

$$\begin{aligned}R^2 &= (4 \text{ kips})^2 + (6 \text{ kips})^2 - 2(4 \text{ kips})(6 \text{ kips})\cos 105^\circ \\ &= 64.423 \text{ kips}^2 \\ R &= 8.0264 \text{ kips}\end{aligned}$$

And

$$\begin{aligned}\frac{4 \text{ kips}}{\sin(25^\circ + \alpha)} &= \frac{8.0264 \text{ kips}}{\sin 105^\circ} \\ \sin(25^\circ + \alpha) &= 0.48137 \\ 25^\circ + \alpha &= 28.775^\circ \\ \alpha &= 3.775^\circ\end{aligned}$$

$$R = 8.03 \text{ kips} \nearrow 3.8^\circ \blacktriangleleft$$

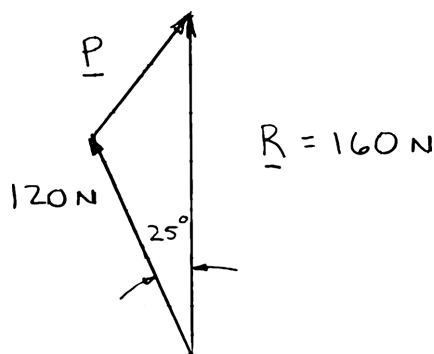


### PROBLEM 2.17

For the stake of Prob. 2.5, knowing that the tension in one rope is 120 N, determine by trigonometry the magnitude and direction of the force **P** so that the resultant is a vertical force of 160 N.

**PROBLEM 2.5** A stake is being pulled out of the ground by means of two ropes as shown. Knowing that  $\alpha = 30^\circ$ , determine by trigonometry (a) the magnitude of the force **P** so that the resultant force exerted on the stake is vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION



Using the laws of cosines and sines:

$$P^2 = (120 \text{ N})^2 + (160 \text{ N})^2 - 2(120 \text{ N})(160 \text{ N})\cos 25^\circ$$

$$P = 72.096 \text{ N}$$

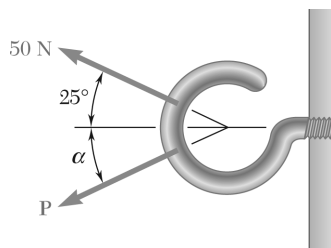
And

$$\frac{\sin \alpha}{120 \text{ N}} = \frac{\sin 25^\circ}{72.096 \text{ N}}$$

$$\sin \alpha = 0.70343$$

$$\alpha = 44.703^\circ$$

$$\mathbf{P} = 72.1 \text{ N } \nearrow 44.7^\circ \blacktriangleleft$$



### PROBLEM 2.18

For the hook support of Prob. 2.10, knowing that  $P = 75 \text{ N}$  and  $\alpha = 50^\circ$ , determine by trigonometry the magnitude and direction of the resultant of the two forces applied to the support.

**PROBLEM 2.10** Two forces are applied as shown to a hook support. Knowing that the magnitude of  $\mathbf{P}$  is  $35 \text{ N}$ , determine by trigonometry (a) the required angle  $\alpha$  if the resultant  $\mathbf{R}$  of the two forces applied to the support is to be horizontal, (b) the corresponding magnitude of  $\mathbf{R}$ .

### SOLUTION

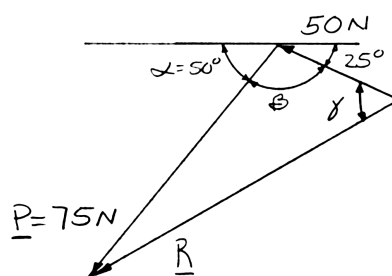
Using the force triangle and the laws of cosines and sines:

We have 
$$\beta = 180^\circ - (50^\circ + 25^\circ) = 105^\circ$$

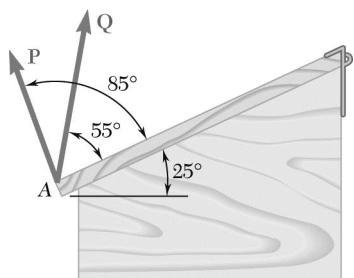
Then 
$$\begin{aligned} R^2 &= (75 \text{ N})^2 + (50 \text{ N})^2 \\ &\quad - 2(75 \text{ N})(50 \text{ N}) \cos 105^\circ \\ R^2 &= 10,066.1 \text{ N}^2 \\ R &= 100.330 \text{ N} \end{aligned}$$

and 
$$\begin{aligned} \frac{\sin \gamma}{75 \text{ N}} &= \frac{\sin 105^\circ}{100.330 \text{ N}} \\ \sin \gamma &= 0.72206 \\ \gamma &= 46.225^\circ \end{aligned}$$

Hence: 
$$\gamma - 25^\circ = 46.225^\circ - 25^\circ = 21.225^\circ$$



$$\mathbf{R} = 100.3 \text{ N} \nearrow 21.2^\circ \blacktriangleleft$$



### PROBLEM 2.19

Two forces **P** and **Q** are applied to the lid of a storage bin as shown. Knowing that  $P = 48 \text{ N}$  and  $Q = 60 \text{ N}$ , determine by trigonometry the magnitude and direction of the resultant of the two forces.

### SOLUTION

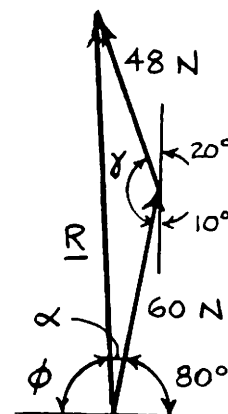
Using the force triangle and the laws of cosines and sines:

We have 
$$\gamma = 180^\circ - (20^\circ + 10^\circ) = 150^\circ$$

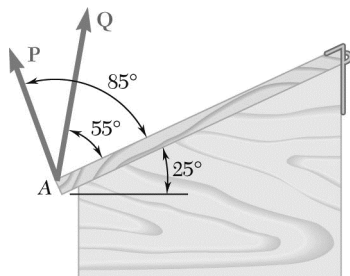
Then 
$$R^2 = (48 \text{ N})^2 + (60 \text{ N})^2 - 2(48 \text{ N})(60 \text{ N})\cos 150^\circ$$
$$R = 104.366 \text{ N}$$

and 
$$\frac{48 \text{ N}}{\sin \alpha} = \frac{104.366 \text{ N}}{\sin 150^\circ}$$
$$\sin \alpha = 0.22996$$
$$\alpha = 13.2947^\circ$$

Hence: 
$$\phi = 180^\circ - \alpha - 80^\circ$$
$$= 180^\circ - 13.2947^\circ - 80^\circ$$
$$= 86.705^\circ$$



$R = 104.4 \text{ N} \searrow 86.7^\circ \blacktriangleleft$



### PROBLEM 2.20

Two forces **P** and **Q** are applied to the lid of a storage bin as shown. Knowing that  $P = 60 \text{ N}$  and  $Q = 48 \text{ N}$ , determine by trigonometry the magnitude and direction of the resultant of the two forces.

### SOLUTION

Using the force triangle and the laws of cosines and sines:

We have 
$$\gamma = 180^\circ - (20^\circ + 10^\circ) = 150^\circ$$

Then 
$$R^2 = (60 \text{ N})^2 + (48 \text{ N})^2 - 2(60 \text{ N})(48 \text{ N})\cos 150^\circ$$
  

$$R = 104.366 \text{ N}$$

and 
$$\frac{60 \text{ N}}{\sin \alpha} = \frac{104.366 \text{ N}}{\sin 150^\circ}$$
  

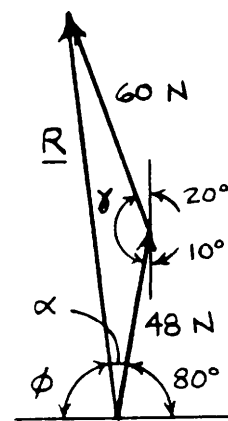
$$\sin \alpha = 0.28745$$
  

$$\alpha = 16.7054^\circ$$

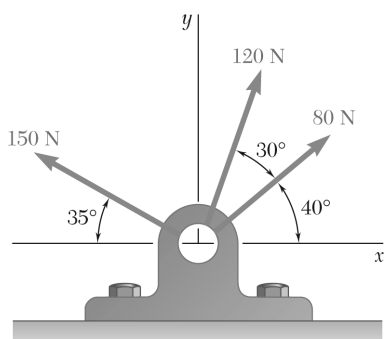
Hence: 
$$\phi = 180^\circ - \alpha - 80^\circ$$
  

$$= 180^\circ - 16.7054^\circ - 80^\circ$$
  

$$= 83.295^\circ$$



$$\mathbf{R} = 104.4 \text{ N} \nearrow 83.3^\circ \blacktriangleleft$$



## PROBLEM 2.21

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

## SOLUTION

80-N Force:

$$F_x = +(80 \text{ N}) \cos 40^\circ$$

$$F_x = 61.3 \text{ N} \quad \blacktriangleleft$$

$$F_y = +(80 \text{ N}) \sin 40^\circ$$

$$F_y = 51.4 \text{ N} \quad \blacktriangleleft$$

120-N Force:

$$F_x = +(120 \text{ N}) \cos 70^\circ$$

$$F_x = 41.0 \text{ N} \quad \blacktriangleleft$$

$$F_y = +(120 \text{ N}) \sin 70^\circ$$

$$F_y = 112.8 \text{ N} \quad \blacktriangleleft$$

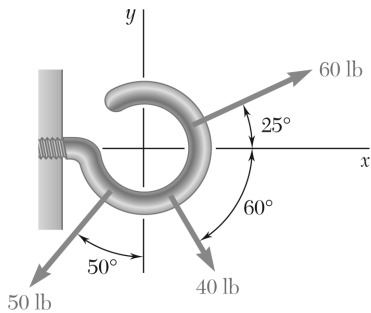
150-N Force:

$$F_x = -(150 \text{ N}) \cos 35^\circ$$

$$F_x = -122.9 \text{ N} \quad \blacktriangleleft$$

$$F_y = +(150 \text{ N}) \sin 35^\circ$$

$$F_y = 86.0 \text{ N} \quad \blacktriangleleft$$



## PROBLEM 2.22

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

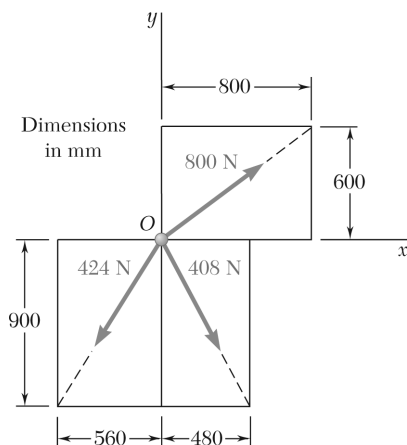
## SOLUTION

40-lb Force:	$F_x = +(40 \text{ lb}) \cos 60^\circ$	$F_x = 20.0 \text{ lb} \quad \blacktriangleleft$
	$F_y = -(40 \text{ lb}) \sin 60^\circ$	$F_y = -34.6 \text{ lb} \quad \blacktriangleleft$
50-lb Force:	$F_x = -(50 \text{ lb}) \sin 50^\circ$	$F_x = -38.3 \text{ lb} \quad \blacktriangleleft$
	$F_y = -(50 \text{ lb}) \cos 50^\circ$	$F_y = -32.1 \text{ lb} \quad \blacktriangleleft$
60-lb Force:	$F_x = +(60 \text{ lb}) \cos 25^\circ$	$F_x = 54.4 \text{ lb} \quad \blacktriangleleft$
	$F_y = +(60 \text{ lb}) \sin 25^\circ$	$F_y = 25.4 \text{ lb} \quad \blacktriangleleft$



### PROBLEM 2.23

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



### SOLUTION

Compute the following distances:

$$OA = \sqrt{(600)^2 + (800)^2} \\ = 1000 \text{ mm}$$

$$OB = \sqrt{(560)^2 + (900)^2} \\ = 1060 \text{ mm}$$

$$OC = \sqrt{(480)^2 + (900)^2} \\ = 1020 \text{ mm}$$

800-N Force:

$$F_x = +(800 \text{ N}) \frac{800}{1000}$$

$$F_x = +640 \text{ N} \quad \blacktriangleleft$$

$$F_y = +(800 \text{ N}) \frac{600}{1000}$$

$$F_y = +480 \text{ N} \quad \blacktriangleleft$$

424-N Force:

$$F_x = -(424 \text{ N}) \frac{560}{1060}$$

$$F_x = -224 \text{ N} \quad \blacktriangleleft$$

$$F_y = -(424 \text{ N}) \frac{900}{1060}$$

$$F_y = -360 \text{ N} \quad \blacktriangleleft$$

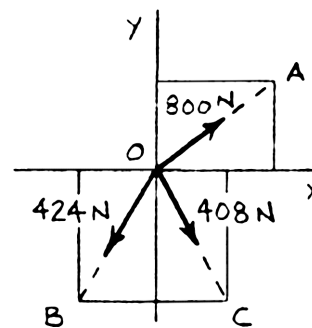
408-N Force:

$$F_x = +(408 \text{ N}) \frac{480}{1020}$$

$$F_x = +192.0 \text{ N} \quad \blacktriangleleft$$

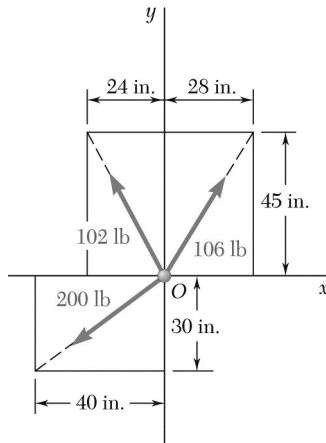
$$F_y = -(408 \text{ N}) \frac{900}{1020}$$

$$F_y = -360 \text{ N} \quad \blacktriangleleft$$



## PROBLEM 2.24

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



## SOLUTION

Compute the following distances:

$$OA = \sqrt{(24 \text{ in.})^2 + (45 \text{ in.})^2} \\ = 51.0 \text{ in.}$$

$$OB = \sqrt{(28 \text{ in.})^2 + (45 \text{ in.})^2} \\ = 53.0 \text{ in.}$$

$$OC = \sqrt{(40 \text{ in.})^2 + (30 \text{ in.})^2} \\ = 50.0 \text{ in.}$$

102-lb Force:

$$F_x = -102 \text{ lb} \frac{24 \text{ in.}}{51.0 \text{ in.}}$$

$$F_x = -48.0 \text{ lb} \quad \blacktriangleleft$$

$$F_y = +102 \text{ lb} \frac{45 \text{ in.}}{51.0 \text{ in.}}$$

$$F_y = +90.0 \text{ lb} \quad \blacktriangleleft$$

106-lb Force:

$$F_x = +106 \text{ lb} \frac{28 \text{ in.}}{53.0 \text{ in.}}$$

$$F_x = +56.0 \text{ lb} \quad \blacktriangleleft$$

$$F_y = +106 \text{ lb} \frac{45 \text{ in.}}{53.0 \text{ in.}}$$

$$F_y = +90.0 \text{ lb} \quad \blacktriangleleft$$

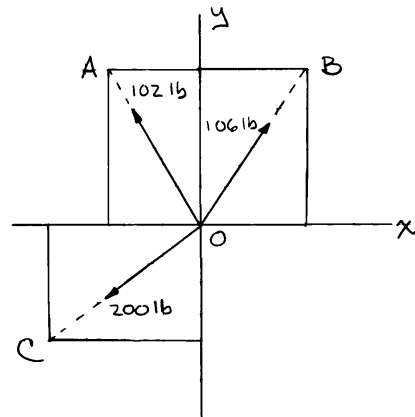
200-lb Force:

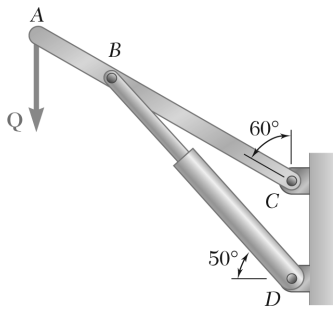
$$F_x = -200 \text{ lb} \frac{40 \text{ in.}}{50.0 \text{ in.}}$$

$$F_x = -160.0 \text{ lb} \quad \blacktriangleleft$$

$$F_y = -200 \text{ lb} \frac{30 \text{ in.}}{50.0 \text{ in.}}$$

$$F_y = -120.0 \text{ lb} \quad \blacktriangleleft$$

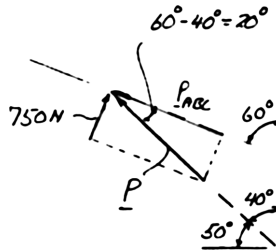




### PROBLEM 2.25

The hydraulic cylinder  $BD$  exerts on member  $ABC$  a force  $\mathbf{P}$  directed along line  $BD$ . Knowing that  $\mathbf{P}$  must have a 750-N component perpendicular to member  $ABC$ , determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its component parallel to  $ABC$ .

### SOLUTION



(a)

$$750 \text{ N} = P \sin 20^\circ$$

$$P = 2192.9 \text{ N}$$

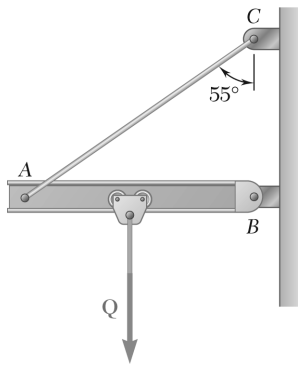
$$P = 2190 \text{ N} \quad \blacktriangleleft$$

(b)

$$P_{ABC} = P \cos 20^\circ$$

$$= (2192.9 \text{ N}) \cos 20^\circ$$

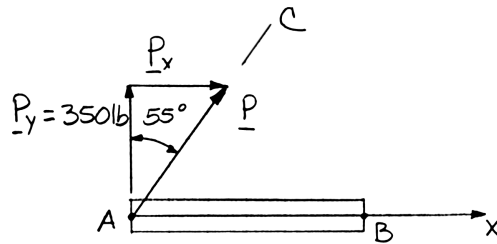
$$P_{ABC} = 2060 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.26

Cable  $AC$  exerts on beam  $AB$  a force  $\mathbf{P}$  directed along line  $AC$ . Knowing that  $\mathbf{P}$  must have a 350-lb vertical component, determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its horizontal component.

### SOLUTION



(a)

$$P = \frac{P_y}{\cos 55^\circ}$$

$$= \frac{350 \text{ lb}}{\cos 55^\circ}$$

$$= 610.21 \text{ lb}$$

$$P = 610 \text{ lb} \quad \blacktriangleleft$$

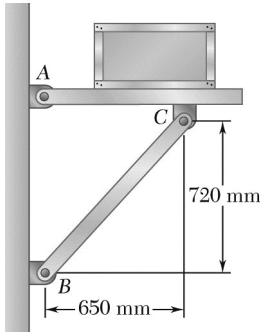
(b)

$$P_x = P \sin 55^\circ$$

$$= (610.21 \text{ lb}) \sin 55^\circ$$

$$= 499.85 \text{ lb}$$

$$P_x = 500 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.27

Member  $BC$  exerts on member  $AC$  a force  $\mathbf{P}$  directed along line  $BC$ . Knowing that  $\mathbf{P}$  must have a 325-N horizontal component, determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its vertical component.

### SOLUTION

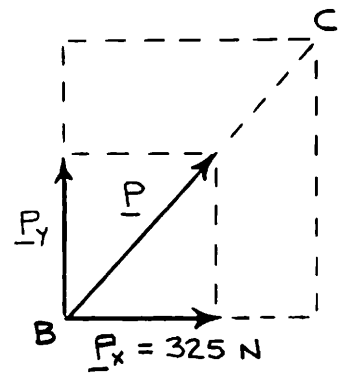
(a)

or

$$BC = \sqrt{(650 \text{ mm})^2 + (720 \text{ mm})^2} \\ = 970 \text{ mm}$$

$$P_x = P \left( \frac{650}{970} \right)$$

$$P = P_x \left( \frac{970}{650} \right) \\ = 325 \text{ N} \left( \frac{970}{650} \right) \\ = 485 \text{ N}$$

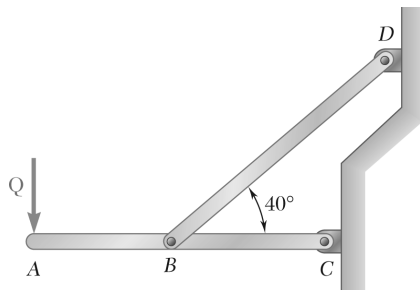


$$P = 485 \text{ N} \quad \blacktriangleleft$$

(b)

$$P_y = P \left( \frac{720}{970} \right) \\ = 485 \text{ N} \left( \frac{720}{970} \right) \\ = 360 \text{ N}$$

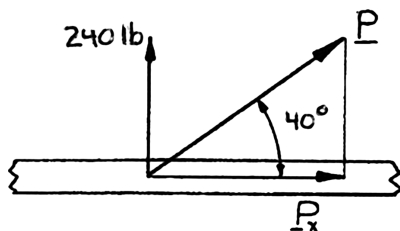
$$P_y = 360 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.28

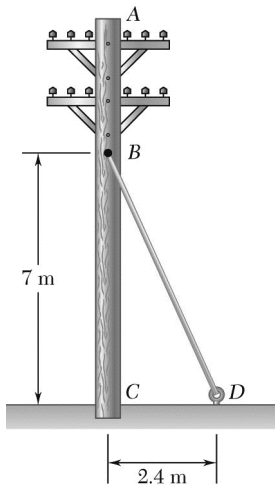
Member  $BD$  exerts on member  $ABC$  a force  $\mathbf{P}$  directed along line  $BD$ . Knowing that  $\mathbf{P}$  must have a 240-lb vertical component, determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its horizontal component.

### SOLUTION



$$(a) \quad P = \frac{P_y}{\sin 40^\circ} = \frac{240 \text{ lb}}{\sin 40^\circ} \quad \text{or } P = 373 \text{ lb} \quad \blacktriangleleft$$

$$(b) \quad P_x = \frac{P_y}{\tan 40^\circ} = \frac{240 \text{ lb}}{\tan 40^\circ} \quad \text{or } P_x = 286 \text{ lb} \quad \blacktriangleleft$$



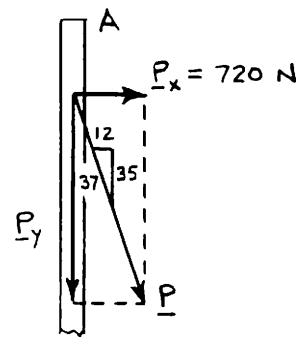
### PROBLEM 2.29

The guy wire  $BD$  exerts on the telephone pole  $AC$  a force  $\mathbf{P}$  directed along  $BD$ . Knowing that  $\mathbf{P}$  must have a 720-N component perpendicular to the pole  $AC$ , determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its component along line  $AC$ .

### SOLUTION

(a)

$$\begin{aligned} P &= \frac{37}{12} P_x \\ &= \frac{37}{12} (720 \text{ N}) \\ &= 2220 \text{ N} \end{aligned}$$



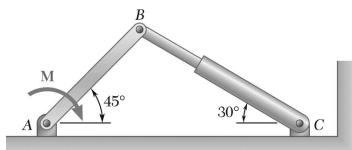
$$P = 2.22 \text{ kN} \quad \blacktriangleleft$$

(b)

$$\begin{aligned} P_y &= \frac{35}{12} P_x \\ &= \frac{35}{12} (720 \text{ N}) \\ &= 2100 \text{ N} \end{aligned}$$

$$P_y = 2.10 \text{ kN} \quad \blacktriangleleft$$

### PROBLEM 2.30



The hydraulic cylinder  $BC$  exerts on member  $AB$  a force  $\mathbf{P}$  directed along line  $BC$ . Knowing that  $\mathbf{P}$  must have a 600-N component perpendicular to member  $AB$ , determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its component along line  $AB$ .

### SOLUTION

$$180^\circ = 45^\circ + \alpha + 90^\circ + 30^\circ$$

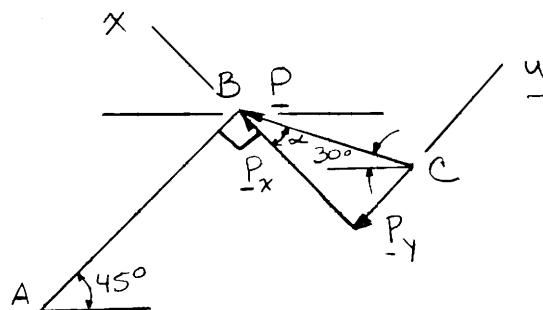
$$\alpha = 180^\circ - 45^\circ - 90^\circ - 30^\circ$$

$$= 15^\circ$$

(a)

$$\cos \alpha = \frac{P_x}{P}$$

$$\begin{aligned} P &= \frac{P_x}{\cos \alpha} \\ &= \frac{600 \text{ N}}{\cos 15^\circ} \\ &= 621.17 \text{ N} \end{aligned}$$



$$P = 621 \text{ N} \quad \blacktriangleleft$$

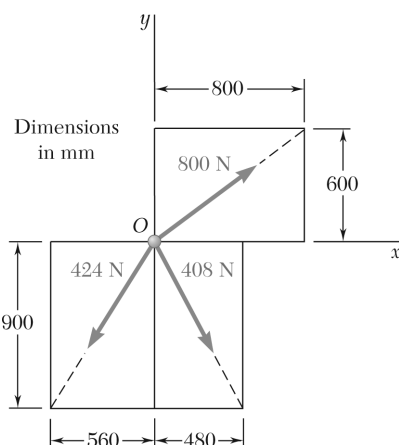
(b)

$$\tan \alpha = \frac{P_y}{P_x}$$

$$\begin{aligned} P_y &= P_x \tan \alpha \\ &= (600 \text{ N}) \tan 15^\circ \\ &= 160.770 \text{ N} \end{aligned}$$

$$P_y = 160.8 \text{ N} \quad \blacktriangleleft$$





### PROBLEM 2.31

Determine the resultant of the three forces of Problem 2.23.

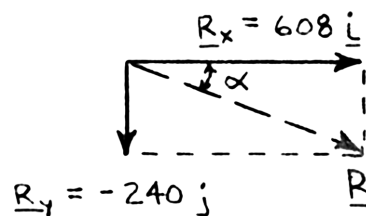
**PROBLEM 2.23** Determine the  $x$  and  $y$  components of each of the forces shown.

### SOLUTION

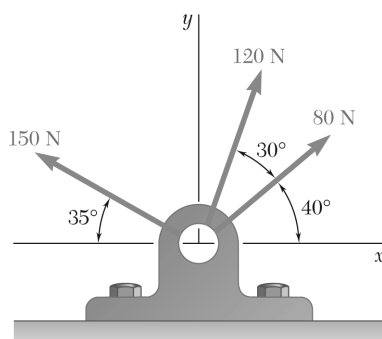
Components of the forces were determined in Problem 2.23:

Force	$x$ Comp. (N)	$y$ Comp. (N)
800 lb	+640	+480
424 lb	-224	-360
408 lb	+192	-360
	$R_x = +608$	$R_y = -240$

$$\begin{aligned}
 \mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\
 &= (608 \text{ lb})\mathbf{i} + (-240 \text{ lb})\mathbf{j} \\
 \tan \alpha &= \frac{R_y}{R_x} \\
 &= \frac{240}{608} \\
 \alpha &= 21.541^\circ \\
 R &= \frac{240 \text{ N}}{\sin(21.541^\circ)} \\
 &= 653.65 \text{ N}
 \end{aligned}$$



$$\mathbf{R} = 654 \text{ N} \searrow 21.5^\circ \blacktriangleleft$$



### PROBLEM 2.32

Determine the resultant of the three forces of Problem 2.21.

**PROBLEM 2.21** Determine the  $x$  and  $y$  components of each of the forces shown.

### SOLUTION

Components of the forces were determined in Problem 2.21:

Force	$x$ Comp. (N)	$y$ Comp. (N)
80 N	+61.3	+51.4
120 N	+41.0	+112.8
150 N	-122.9	+86.0
	$R_x = -20.6$	$R_y = +250.2$

$$\mathbf{R} = R_x \mathbf{i} + R_y \mathbf{j}$$

$$= (-20.6 \text{ N})\mathbf{i} + (250.2 \text{ N})\mathbf{j}$$

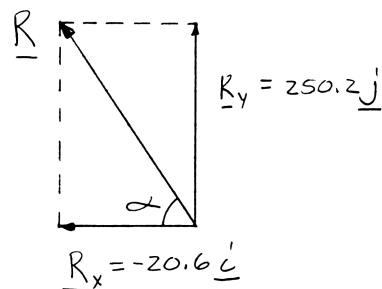
$$\tan \alpha = \frac{R_y}{R_x}$$

$$\tan \alpha = \frac{250.2 \text{ N}}{20.6 \text{ N}}$$

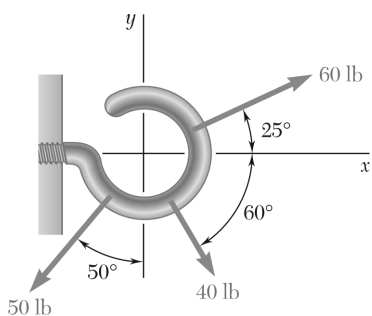
$$\tan \alpha = 12.1456$$

$$\alpha = 85.293^\circ$$

$$R = \frac{250.2 \text{ N}}{\sin 85.293^\circ}$$



$$\mathbf{R} = 251 \text{ N} \nearrow 85.3^\circ \blacktriangleleft$$



### PROBLEM 2.33

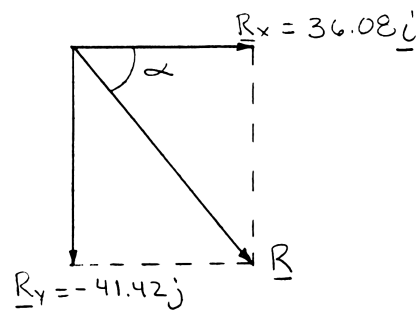
Determine the resultant of the three forces of Problem 2.22.

**PROBLEM 2.22** Determine the  $x$  and  $y$  components of each of the forces shown.

### SOLUTION

Force	$x$ Comp. (lb)	$y$ Comp. (lb)
40 lb	+20.00	-34.64
50 lb	-38.30	-32.14
60 lb	+54.38	+25.36
	$R_x = +36.08$	$R_y = -41.42$

$$\begin{aligned}
 \mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\
 &= (+36.08 \text{ lb}) \mathbf{i} + (-41.42 \text{ lb}) \mathbf{j} \\
 \tan \alpha &= \frac{R_y}{R_x} \\
 \tan \alpha &= \frac{41.42 \text{ lb}}{36.08 \text{ lb}} \\
 \tan \alpha &= 1.14800 \\
 \alpha &= 48.942^\circ \\
 R &= \frac{41.42 \text{ lb}}{\sin 48.942^\circ}
 \end{aligned}$$

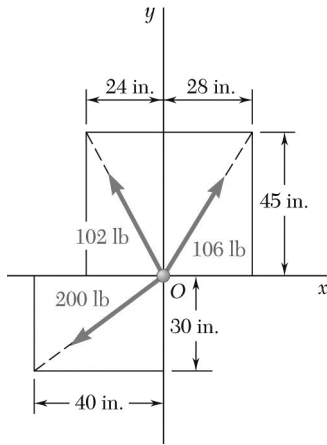


$$\mathbf{R} = 54.9 \text{ lb} \searrow 48.9^\circ \blacktriangleleft$$

### PROBLEM 2.34

Determine the resultant of the three forces of Problem 2.24.

**PROBLEM 2.24** Determine the  $x$  and  $y$  components of each of the forces shown.



### SOLUTION

Components of the forces were determined in Problem 2.24:

Force	$x$ Comp. (lb)	$y$ Comp. (lb)
102 lb	-48.0	+90.0
106 lb	+56.0	+90.0
200 lb	-160.0	-120.0
	$R_x = -152.0$	$R_y = 60.0$

$$\begin{aligned}\mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\ &= (-152 \text{ lb})\mathbf{i} + (60.0 \text{ lb})\mathbf{j}\end{aligned}$$

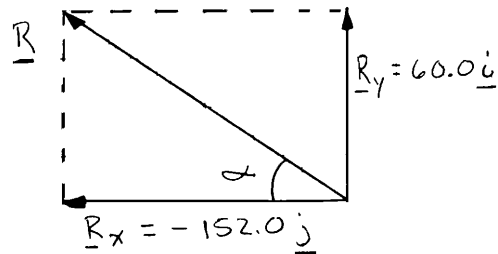
$$\tan \alpha = \frac{R_y}{R_x}$$

$$\tan \alpha = \frac{60.0 \text{ lb}}{152.0 \text{ lb}}$$

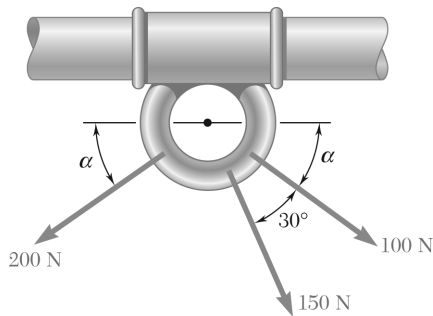
$$\tan \alpha = 0.39474$$

$$\alpha = 21.541^\circ$$

$$R = \frac{60.0 \text{ lb}}{\sin 21.541^\circ}$$



$$\mathbf{R} = 163.4 \text{ lb} \nearrow 21.5^\circ \nwarrow$$



### PROBLEM 2.35

Knowing that  $\alpha = 35^\circ$ , determine the resultant of the three forces shown.

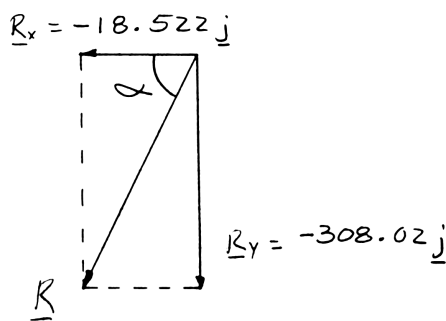
### SOLUTION

100-N Force:  $F_x = +(100 \text{ N}) \cos 35^\circ = +81.915 \text{ N}$   
 $F_y = -(100 \text{ N}) \sin 35^\circ = -57.358 \text{ N}$

150-N Force:  $F_x = +(150 \text{ N}) \cos 65^\circ = +63.393 \text{ N}$   
 $F_y = -(150 \text{ N}) \sin 65^\circ = -135.946 \text{ N}$

200-N Force:  $F_x = -(200 \text{ N}) \cos 35^\circ = -163.830 \text{ N}$   
 $F_y = -(200 \text{ N}) \sin 35^\circ = -114.715 \text{ N}$

Force	$x$ Comp. (N)	$y$ Comp. (N)
100 N	+81.915	-57.358
150 N	+63.393	-135.946
200 N	-163.830	-114.715
	$R_x = -18.522$	$R_y = -308.02$



$$\mathbf{R} = R_x \mathbf{i} + R_y \mathbf{j}$$

$$= (-18.522 \text{ N}) \mathbf{i} + (-308.02 \text{ N}) \mathbf{j}$$

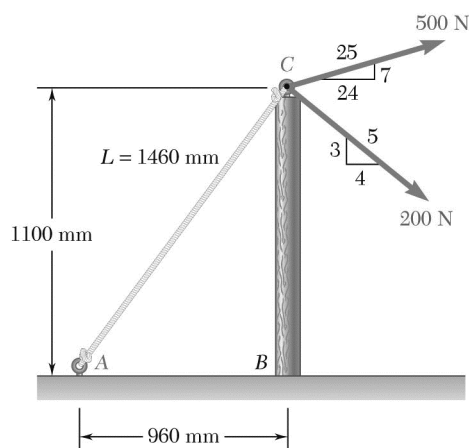
$$\tan \alpha = \frac{R_y}{R_x}$$

$$= \frac{308.02}{18.522}$$

$$\alpha = 86.559^\circ$$

$$R = \frac{308.02 \text{ N}}{\sin 86.559^\circ}$$

$$\mathbf{R} = 309 \text{ N} \nearrow 86.6^\circ \blacktriangleleft$$



### PROBLEM 2.36

Knowing that the tension in rope AC is 365 N, determine the resultant of the three forces exerted at point C of post BC.

### SOLUTION

Determine force components:

Cable force AC:

$$F_x = -(365 \text{ N}) \frac{960}{1460} = -240 \text{ N}$$

$$F_y = -(365 \text{ N}) \frac{1100}{1460} = -275 \text{ N}$$

500-N Force:

$$F_x = (500 \text{ N}) \frac{24}{25} = 480 \text{ N}$$

$$F_y = (500 \text{ N}) \frac{7}{25} = 140 \text{ N}$$

200-N Force:

$$F_x = (200 \text{ N}) \frac{4}{5} = 160 \text{ N}$$

$$F_y = -(200 \text{ N}) \frac{3}{5} = -120 \text{ N}$$

and

$$R_x = \Sigma F_x = -240 \text{ N} + 480 \text{ N} + 160 \text{ N} = 400 \text{ N}$$

$$R_y = \Sigma F_y = -275 \text{ N} + 140 \text{ N} - 120 \text{ N} = -255 \text{ N}$$

$$R = \sqrt{R_x^2 + R_y^2}$$

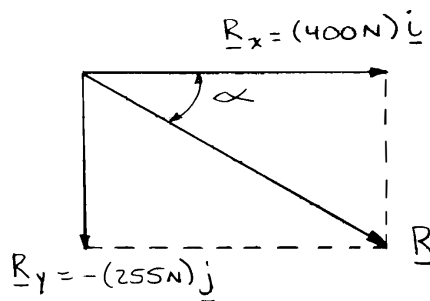
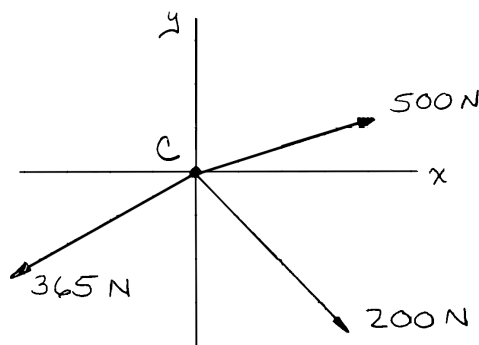
$$= \sqrt{(400 \text{ N})^2 + (-255 \text{ N})^2}$$

$$= 474.37 \text{ N}$$

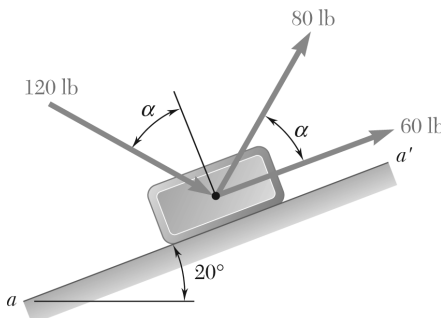
Further:

$$\tan \alpha = \frac{255}{400}$$

$$\alpha = 32.5^\circ$$



$$\mathbf{R} = 474 \text{ N} \searrow 32.5^\circ \blacktriangleleft$$



### PROBLEM 2.37

Knowing that  $\alpha = 40^\circ$ , determine the resultant of the three forces shown.

### SOLUTION

60-lb Force:

$$F_x = (60 \text{ lb}) \cos 20^\circ = 56.382 \text{ lb}$$

$$F_y = (60 \text{ lb}) \sin 20^\circ = 20.521 \text{ lb}$$

80-lb Force:

$$F_x = (80 \text{ lb}) \cos 60^\circ = 40.000 \text{ lb}$$

$$F_y = (80 \text{ lb}) \sin 60^\circ = 69.282 \text{ lb}$$

120-lb Force:

$$F_x = (120 \text{ lb}) \cos 30^\circ = 103.923 \text{ lb}$$

$$F_y = -(120 \text{ lb}) \sin 30^\circ = -60.000 \text{ lb}$$

and

$$R_x = \Sigma F_x = 200.305 \text{ lb}$$

$$R_y = \Sigma F_y = 29.803 \text{ lb}$$

$$R = \sqrt{(200.305 \text{ lb})^2 + (29.803 \text{ lb})^2}$$

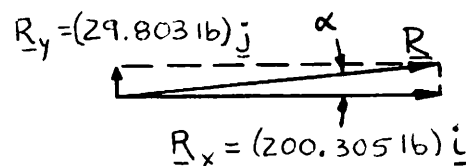
$$= 202.510 \text{ lb}$$

Further:

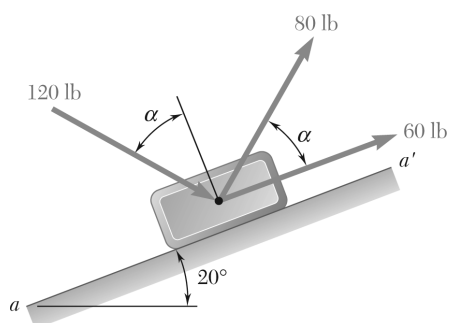
$$\tan \alpha = \frac{29.803}{200.305}$$

$$\alpha = \tan^{-1} \frac{29.803}{200.305}$$

$$= 8.46^\circ$$



$$\mathbf{R} = 203 \text{ lb} \angle 8.46^\circ \blacktriangleleft$$



### PROBLEM 2.38

Knowing that  $\alpha = 75^\circ$ , determine the resultant of the three forces shown.

### SOLUTION

60-lb Force:  $F_x = (60 \text{ lb}) \cos 20^\circ = 56.382 \text{ lb}$

$$F_y = (60 \text{ lb}) \sin 20^\circ = 20.521 \text{ lb}$$

80-lb Force:  $F_x = (80 \text{ lb}) \cos 95^\circ = -6.9725 \text{ lb}$

$$F_y = (80 \text{ lb}) \sin 95^\circ = 79.696 \text{ lb}$$

120-lb Force:  $F_x = (120 \text{ lb}) \cos 5^\circ = 119.543 \text{ lb}$

$$F_y = (120 \text{ lb}) \sin 5^\circ = 10.459 \text{ lb}$$

Then  $R_x = \Sigma F_x = 168.953 \text{ lb}$

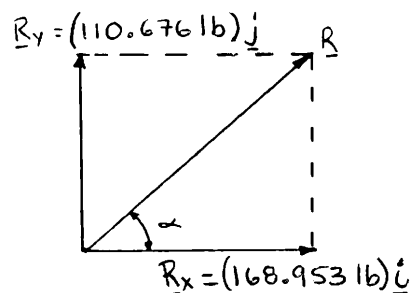
$$R_y = \Sigma F_y = 110.676 \text{ lb}$$

and  $R = \sqrt{(168.953 \text{ lb})^2 + (110.676 \text{ lb})^2}$   
 $= 201.976 \text{ lb}$

$$\tan \alpha = \frac{110.676}{168.953}$$

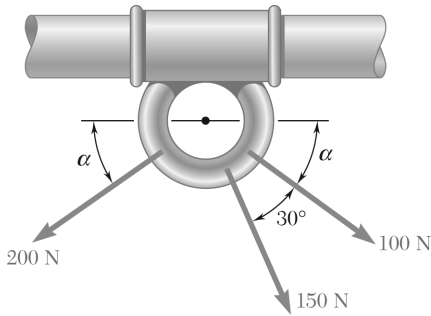
$$\tan \alpha = 0.65507$$

$$\alpha = 33.228^\circ$$



$$\mathbf{R} = 202 \text{ lb} \nearrow 33.2^\circ \blacktriangleleft$$





### PROBLEM 2.39

For the collar of Problem 2.35, determine (a) the required value of  $\alpha$  if the resultant of the three forces shown is to be vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$\begin{aligned}
 R_x &= \Sigma F_x \\
 &= (100 \text{ N}) \cos \alpha + (150 \text{ N}) \cos(\alpha + 30^\circ) - (200 \text{ N}) \cos \alpha \\
 R_x &= -(100 \text{ N}) \cos \alpha + (150 \text{ N}) \cos(\alpha + 30^\circ)
 \end{aligned} \tag{1}$$

$$\begin{aligned}
 R_y &= \Sigma F_y \\
 &= -(100 \text{ N}) \sin \alpha - (150 \text{ N}) \sin(\alpha + 30^\circ) - (200 \text{ N}) \sin \alpha \\
 R_y &= -(300 \text{ N}) \sin \alpha - (150 \text{ N}) \sin(\alpha + 30^\circ)
 \end{aligned} \tag{2}$$

(a) For  $\mathbf{R}$  to be vertical, we must have  $R_x = 0$ . We make  $R_x = 0$  in Eq. (1):

$$\begin{aligned}
 -100 \cos \alpha + 150 \cos(\alpha + 30^\circ) &= 0 \\
 -100 \cos \alpha + 150(\cos \alpha \cos 30^\circ - \sin \alpha \sin 30^\circ) &= 0 \\
 29.904 \cos \alpha &= 75 \sin \alpha
 \end{aligned}$$

$$\begin{aligned}
 \tan \alpha &= \frac{29.904}{75} \\
 &= 0.39872 \\
 \alpha &= 21.738^\circ
 \end{aligned}$$

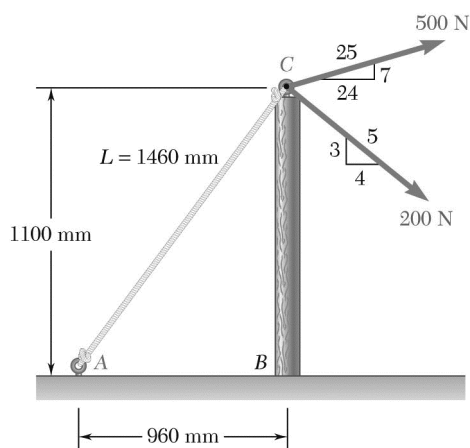
$$\alpha = 21.7^\circ \blacktriangleleft$$

(b) Substituting for  $\alpha$  in Eq. (2):

$$\begin{aligned}
 R_y &= -300 \sin 21.738^\circ - 150 \sin 51.738^\circ \\
 &= -228.89 \text{ N}
 \end{aligned}$$

$$R = |R_y| = 228.89 \text{ N}$$

$$R = 229 \text{ N} \blacktriangleleft$$



### PROBLEM 2.40

For the post of Prob. 2.36, determine (a) the required tension in rope AC if the resultant of the three forces exerted at point C is to be horizontal, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$R_x = \Sigma F_x = -\frac{960}{1460}T_{AC} + \frac{24}{25}(500 \text{ N}) + \frac{4}{5}(200 \text{ N})$$

$$R_x = -\frac{48}{73}T_{AC} + 640 \text{ N} \quad (1)$$

$$R_y = \Sigma F_y = -\frac{1100}{1460}T_{AC} + \frac{7}{25}(500 \text{ N}) - \frac{3}{5}(200 \text{ N})$$

$$R_y = -\frac{55}{73}T_{AC} + 20 \text{ N} \quad (2)$$

(a) For  $\mathbf{R}$  to be horizontal, we must have  $R_y = 0$ .

Set  $R_y = 0$  in Eq. (2):

$$-\frac{55}{73}T_{AC} + 20 \text{ N} = 0$$

$$T_{AC} = 26.545 \text{ N}$$

$$T_{AC} = 26.5 \text{ N} \quad \blacktriangleleft$$

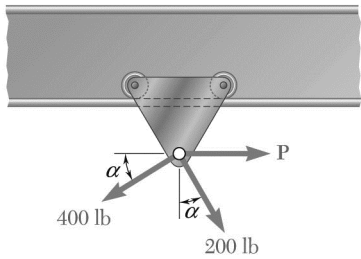
(b) Substituting for  $T_{AC}$  into Eq. (1) gives

$$R_x = -\frac{48}{73}(26.545 \text{ N}) + 640 \text{ N}$$

$$R_x = 622.55 \text{ N}$$

$$R = R_x = 623 \text{ N}$$

$$R = 623 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.41

A hoist trolley is subjected to the three forces shown. Knowing that  $\alpha = 40^\circ$ , determine (a) the required magnitude of the force **P** if the resultant of the three forces is to be vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$R_x = \pm \Sigma F_x = P + (200 \text{ lb}) \sin 40^\circ - (400 \text{ lb}) \cos 40^\circ$$

$$R_x = P - 177.860 \text{ lb} \quad (1)$$

$$R_y = + \downarrow \Sigma F_y = (200 \text{ lb}) \cos 40^\circ + (400 \text{ lb}) \sin 40^\circ$$

$$R_y = 410.32 \text{ lb} \quad (2)$$

(a) For **R** to be vertical, we must have  $R_x = 0$ .

Set  $R_x = 0$  in Eq. (1)

$$0 = P - 177.860 \text{ lb}$$

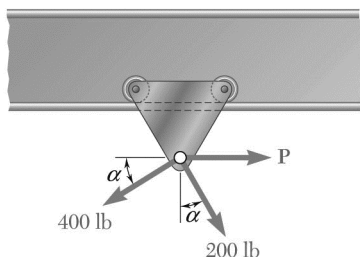
$$P = 177.860 \text{ lb}$$

$$P = 177.9 \text{ lb} \quad \blacktriangleleft$$

(b) Since **R** is to be vertical:

$$R = R_y = 410 \text{ lb}$$

$$R = 410 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.42

A hoist trolley is subjected to the three forces shown. Knowing that  $P = 250$  lb, determine (a) the required value of  $\alpha$  if the resultant of the three forces is to be vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$R_x = \rightarrow \Sigma F_x = 250 \text{ lb} + (200 \text{ lb}) \sin \alpha - (400 \text{ lb}) \cos \alpha$$

$$R_x = 250 \text{ lb} + (200 \text{ lb}) \sin \alpha - (400 \text{ lb}) \cos \alpha \quad (1)$$

$$R_y = \uparrow \Sigma F_y = (200 \text{ lb}) \cos \alpha + (400 \text{ lb}) \sin \alpha$$

(a) For  $\mathbf{R}$  to be vertical, we must have  $R_x = 0$ .

Set

$$R_x = 0 \text{ in Eq. (1)}$$

$$0 = 250 \text{ lb} + (200 \text{ lb}) \sin \alpha - (400 \text{ lb}) \cos \alpha$$

$$(400 \text{ lb}) \cos \alpha = (200 \text{ lb}) \sin \alpha + 250 \text{ lb}$$

$$2 \cos \alpha = \sin \alpha + 1.25$$

$$4 \cos^2 \alpha = \sin^2 \alpha + 2.5 \sin \alpha + 1.5625$$

$$4(1 - \sin^2 \alpha) = \sin^2 \alpha + 2.5 \sin \alpha + 1.5625$$

$$0 = 5 \sin^2 \alpha + 2.5 \sin \alpha - 2.4375$$

Using the quadratic formula to solve for the roots gives

$$\sin \alpha = 0.49162$$

or

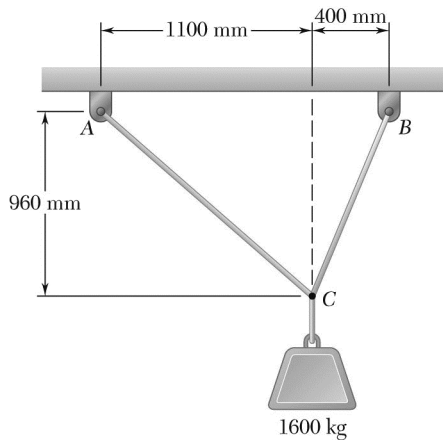
$$\alpha = 29.447^\circ$$

$$\alpha = 29.4^\circ \blacktriangleleft$$

(b) Since  $\mathbf{R}$  is to be vertical:

$$R = R_y = (200 \text{ lb}) \cos 29.447^\circ + (400 \text{ lb}) \sin 29.447^\circ$$

$$\mathbf{R} = 371 \text{ lb} \blacktriangleleft$$



### 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

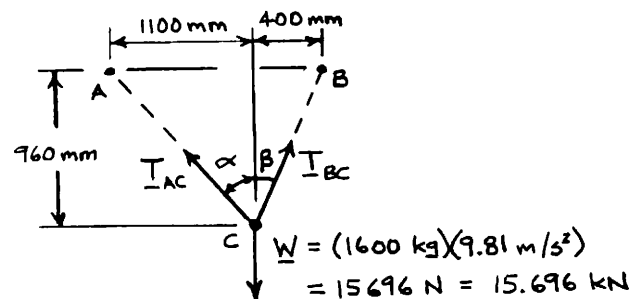
$$\tan \alpha = \frac{1100}{960}$$

$$\alpha = 48.888^\circ$$

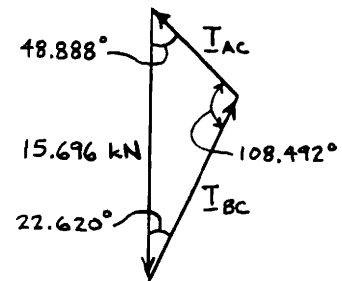
$$\tan \beta = \frac{400}{960}$$

$$\beta = 22.620^\circ$$

#### Free-Body Diagram



#### Force Triangle



Law of sines:

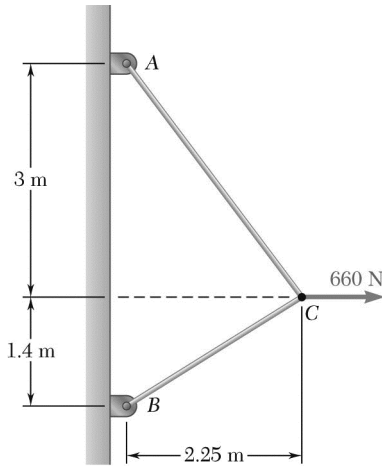
$$\frac{T_{AC}}{\sin 22.620^\circ} = \frac{T_{BC}}{\sin 48.888^\circ} = \frac{15.696 \text{ kN}}{\sin 108.492^\circ}$$

$$(a) \quad T_{AC} = \frac{15.696 \text{ kN}}{\sin 108.492^\circ} (\sin 22.620^\circ) \quad T_{AC} = 6.37 \text{ kN} \quad \blacktriangleleft$$

$$(b) \quad T_{BC} = \frac{15.696 \text{ kN}}{\sin 108.492^\circ} (\sin 48.888^\circ) \quad T_{BC} = 12.47 \text{ kN} \quad \blacktriangleleft$$

### PROBLEM 2.44

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



### SOLUTION

$$\tan \alpha = \frac{3}{2.25}$$

$$\alpha = 53.130^\circ$$

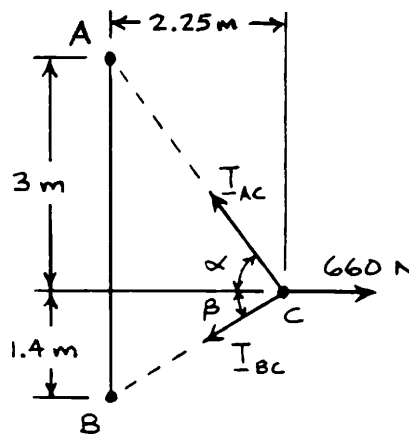
$$\tan \beta = \frac{1.4}{2.25}$$

$$\beta = 31.891^\circ$$

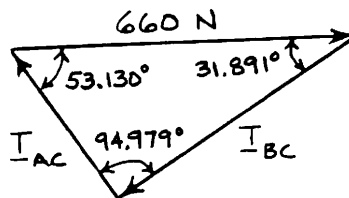
Law of sines:

$$\frac{T_{AC}}{\sin 31.891^\circ} = \frac{T_{BC}}{\sin 53.130^\circ} = \frac{660 \text{ N}}{\sin 94.979^\circ}$$

Free-Body Diagram

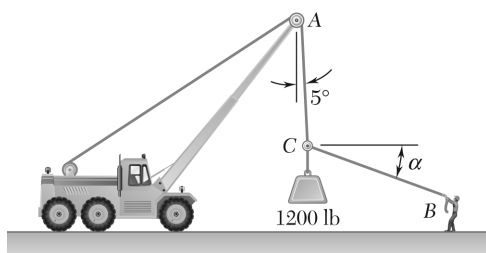


Force-Triangle



- (a)  $T_{AC} = \frac{660 \text{ N}}{\sin 94.979^\circ} (\sin 31.891^\circ)$   $T_{AC} = 350 \text{ N} \blacktriangleleft$
- (b)  $T_{BC} = \frac{660 \text{ N}}{\sin 94.979^\circ} (\sin 53.130^\circ)$   $T_{BC} = 530 \text{ N} \blacktriangleleft$

**PROPRIETARY MATERIAL.** © 2013 The McGraw-Hill Companies, Inc. All rights reserved. No part of this Manual may be displayed, reproduced or distributed in any form or by any means, without the prior written permission of the publisher, or used beyond the limited distribution to teachers and educators permitted by McGraw-Hill for their individual course preparation. If you are a student using this Manual, you are using it without permission.

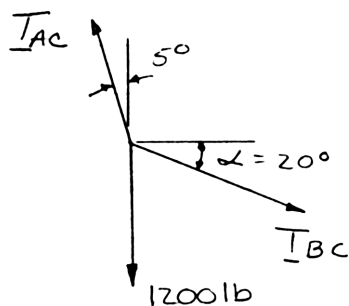


### PROBLEM 2.45

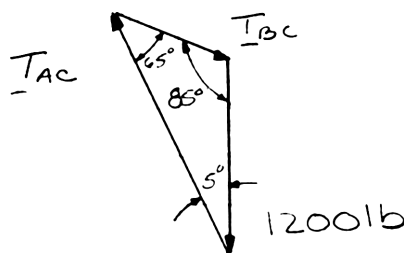
Knowing that  $\alpha = 20^\circ$ , determine the tension (a) in cable AC, (b) in rope BC.

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



Law of sines:

$$\frac{T_{AC}}{\sin 110^\circ} = \frac{T_{BC}}{\sin 5^\circ} = \frac{1200 \text{ lb}}{\sin 65^\circ}$$

(a)

$$T_{AC} = \frac{1200 \text{ lb}}{\sin 65^\circ} \sin 110^\circ$$

$$T_{AC} = 1244 \text{ lb} \quad \blacktriangleleft$$

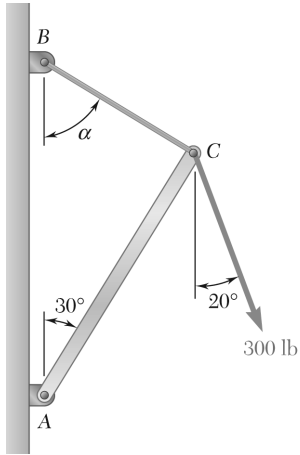
(b)

$$T_{BC} = \frac{1200 \text{ lb}}{\sin 65^\circ} \sin 5^\circ$$

$$T_{BC} = 115.4 \text{ lb} \quad \blacktriangleleft$$

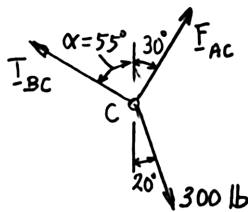
### PROBLEM 2.46

Knowing that  $\alpha = 55^\circ$  and that boom  $AC$  exerts on pin  $C$  a force directed along line  $AC$ , determine (a) the magnitude of that force, (b) the tension in cable  $BC$ .

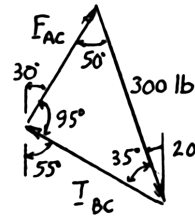


### SOLUTION

Free-Body Diagram



Force Triangle



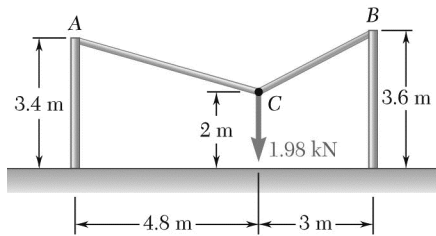
Law of sines:

$$\frac{F_{AC}}{\sin 35^\circ} = \frac{T_{BC}}{\sin 50^\circ} = \frac{300 \text{ lb}}{\sin 95^\circ}$$

(a)  $F_{AC} = \frac{300 \text{ lb}}{\sin 95^\circ} \sin 35^\circ$   $F_{AC} = 172.7 \text{ lb} \quad \blacktriangleleft$

(b)  $T_{BC} = \frac{300 \text{ lb}}{\sin 95^\circ} \sin 50^\circ$   $T_{BC} = 231 \text{ lb} \quad \blacktriangleleft$



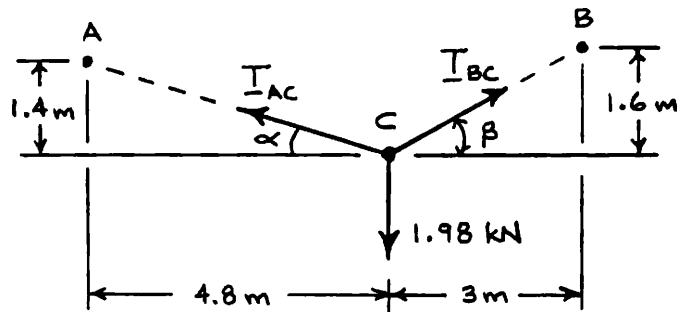


### PROBLEM 2.47

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

### SOLUTION

#### Free-Body Diagram



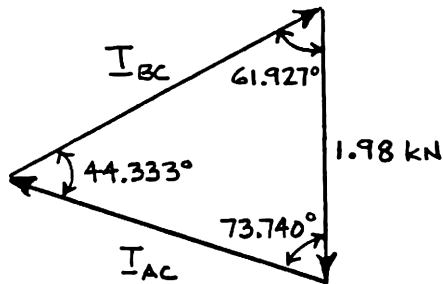
$$\tan \alpha = \frac{1.4}{4.8}$$

$$\alpha = 16.2602^\circ$$

$$\tan \beta = \frac{1.6}{3}$$

$$\beta = 28.073^\circ$$

#### Force Triangle

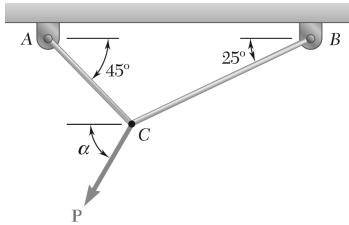


Law of sines:

$$\frac{T_{AC}}{\sin 61.927^\circ} = \frac{T_{BC}}{\sin 73.740^\circ} = \frac{1.98 \text{ kN}}{\sin 44.333^\circ}$$

(a)  $T_{AC} = \frac{1.98 \text{ kN}}{\sin 44.333^\circ} \sin 61.927^\circ$   $T_{AC} = 2.50 \text{ kN} \blacktriangleleft$

(b)  $T_{BC} = \frac{1.98 \text{ kN}}{\sin 44.333^\circ} \sin 73.740^\circ$   $T_{BC} = 2.72 \text{ kN} \blacktriangleleft$

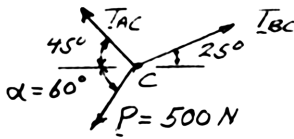


### PROBLEM 2.48

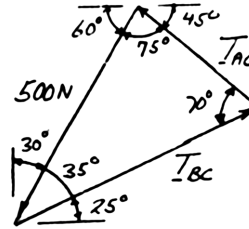
Two cables are tied together at  $C$  and are loaded as shown. Knowing that  $P = 500 \text{ N}$  and  $\alpha = 60^\circ$ , determine the tension in (a) in cable  $AC$ , (b) in cable  $BC$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



Law of sines:

$$\frac{T_{AC}}{\sin 35^\circ} = \frac{T_{BC}}{\sin 75^\circ} = \frac{500 \text{ N}}{\sin 70^\circ}$$

(a)

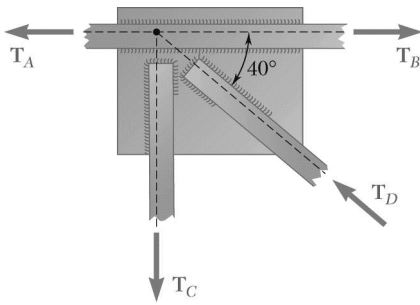
$$T_{AC} = \frac{500 \text{ N}}{\sin 70^\circ} \sin 35^\circ$$

$$T_{AC} = 305 \text{ N} \quad \blacktriangleleft$$

(b)

$$T_{BC} = \frac{500 \text{ N}}{\sin 70^\circ} \sin 75^\circ$$

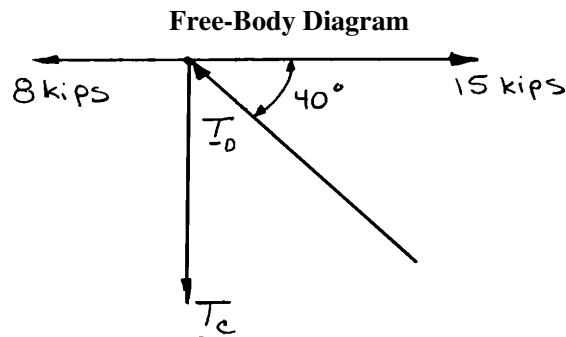
$$T_{BC} = 514 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.49

Two forces of magnitude  $T_A = 8$  kips and  $T_B = 15$  kips are applied as shown to a welded connection. Knowing that the connection is in equilibrium, determine the magnitudes of the forces  $T_C$  and  $T_D$ .

### SOLUTION



$$+\rightarrow \Sigma F_x = 0 \quad 15 \text{ kips} - 8 \text{ kips} - T_D \cos 40^\circ = 0$$

$$T_D = 9.1379 \text{ kips}$$

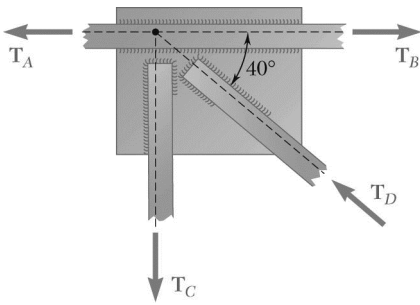
$$+\uparrow \Sigma F_y = 0 \quad T_D \sin 40^\circ - T_C = 0$$

$$(9.1379 \text{ kips}) \sin 40^\circ - T_C = 0$$

$$T_C = 5.8737 \text{ kips}$$

$$T_C = 5.87 \text{ kips} \quad \blacktriangleleft$$

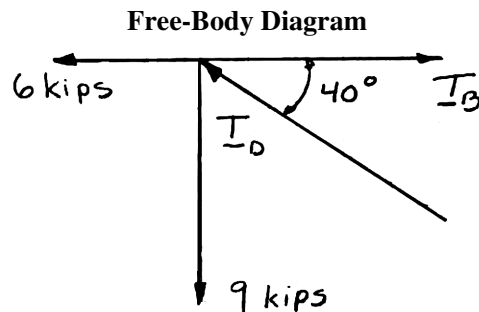
$$T_D = 9.14 \text{ kips} \quad \blacktriangleleft$$



### PROBLEM 2.50

Two forces of magnitude  $T_A = 6$  kips and  $T_C = 9$  kips are applied as shown to a welded connection. Knowing that the connection is in equilibrium, determine the magnitudes of the forces  $T_B$  and  $T_D$ .

### SOLUTION



$$\rightarrow \Sigma F_x = 0$$

$$T_B - 6 \text{ kips} - T_D \cos 40^\circ = 0 \quad (1)$$

$$\uparrow \Sigma F_y = 0$$

$$T_D \sin 40^\circ - 9 \text{ kips} = 0$$

$$T_D = \frac{9 \text{ kips}}{\sin 40^\circ}$$

$$T_D = 14.0015 \text{ kips}$$

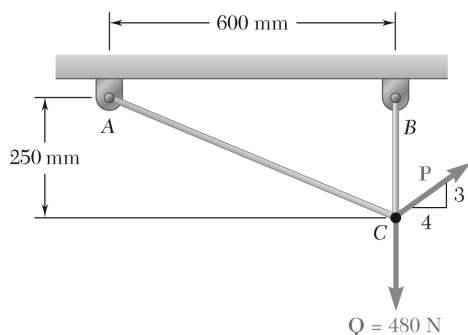
Substituting for  $T_D$  into Eq. (1) gives:

$$T_B - 6 \text{ kips} - (14.0015 \text{ kips}) \cos 40^\circ = 0$$

$$T_B = 16.7258 \text{ kips}$$

$$T_B = 16.73 \text{ kips} \quad \blacktriangleleft$$

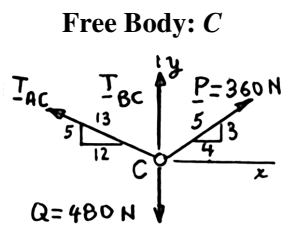
$$T_D = 14.00 \text{ kips} \quad \blacktriangleleft$$



### PROBLEM 2.51

Two cables are tied together at  $C$  and loaded as shown. Knowing that  $P = 360$  N, determine the tension (a) in cable  $AC$ , (b) in cable  $BC$ .

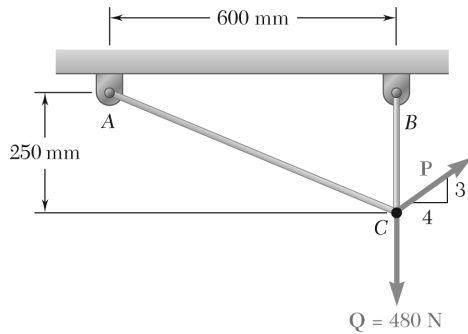
### SOLUTION



$$(a) \quad \Sigma F_x = 0: \quad -\frac{12}{13}T_{AC} + \frac{4}{5}(360 \text{ N}) = 0 \quad T_{AC} = 312 \text{ N} \quad \blacktriangleleft$$

$$(b) \quad \Sigma F_y = 0: \quad \frac{5}{13}(312 \text{ N}) + T_{BC} + \frac{3}{5}(360 \text{ N}) - 480 \text{ N} = 0$$

$$T_{BC} = 480 \text{ N} - 120 \text{ N} - 216 \text{ N} \quad T_{BC} = 144 \text{ N} \quad \blacktriangleleft$$

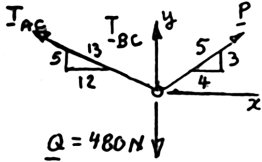


### PROBLEM 2.52

Two cables are tied together at  $C$  and loaded as shown. Determine the range of values of  $P$  for which both cables remain taut.

### SOLUTION

Free Body:  $C$



$$\Sigma F_x = 0: -\frac{12}{13}T_{AC} + \frac{4}{5}P = 0$$

$$T_{AC} = \frac{13}{15}P \quad (1)$$

$$\Sigma F_y = 0: \frac{5}{13}T_{AC} + T_{BC} + \frac{3}{5}P - 480 \text{ N} = 0$$

Substitute for  $T_{AC}$  from (1):

$$\left(\frac{5}{13}\right)\left(\frac{13}{15}\right)P + T_{BC} + \frac{3}{5}P - 480 \text{ N} = 0$$

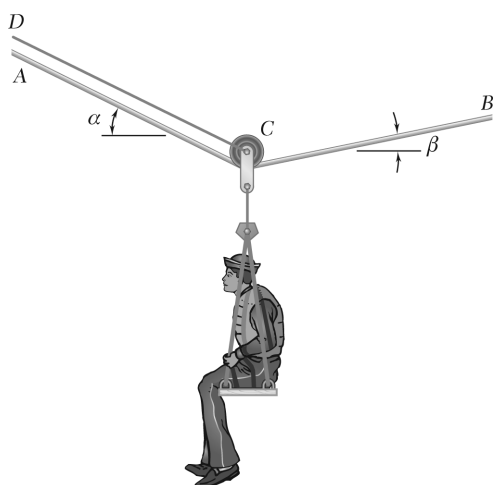
$$T_{BC} = 480 \text{ N} - \frac{14}{15}P \quad (2)$$

From (1),  $T_{AC} > 0$  requires  $P > 0$ .

From (2),  $T_{BC} > 0$  requires  $\frac{14}{15}P < 480 \text{ N}$ ,  $P < 514.29 \text{ N}$

Allowable range:

$$0 < P < 514 \text{ N} \quad \blacktriangleleft$$

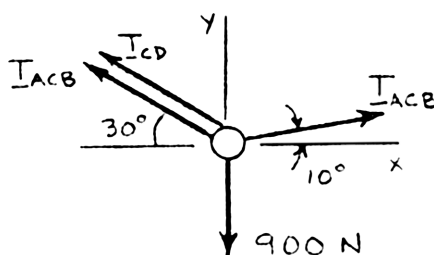


### PROBLEM 2.53

A sailor is being rescued using a boatswain's chair that is suspended from a pulley that can roll freely on the support cable  $ACB$  and is pulled at a constant speed by cable  $CD$ . Knowing that  $\alpha = 30^\circ$  and  $\beta = 10^\circ$  and that the combined weight of the boatswain's chair and the sailor is 900 N, determine the tension (a) in the support cable  $ACB$ , (b) in the traction cable  $CD$ .

### SOLUTION

#### Free-Body Diagram



$$\rightarrow \Sigma F_x = 0: T_{ACB} \cos 10^\circ - T_{ACB} \cos 30^\circ - T_{CD} \cos 30^\circ = 0$$

$$T_{CD} = 0.137158 T_{ACB} \quad (1)$$

$$+\uparrow \Sigma F_y = 0: T_{ACB} \sin 10^\circ + T_{ACB} \sin 30^\circ + T_{CD} \sin 30^\circ - 900 = 0$$

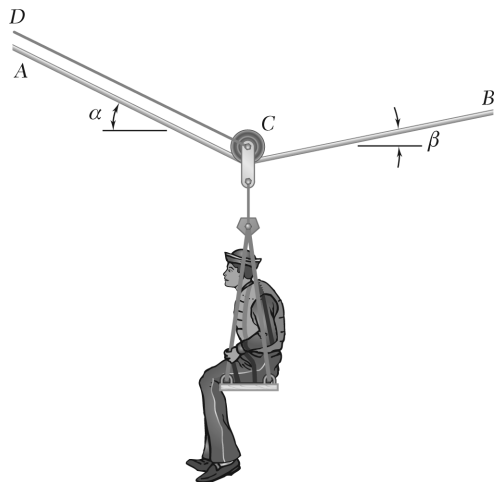
$$0.67365 T_{ACB} + 0.5 T_{CD} = 900 \quad (2)$$

(a) Substitute (1) into (2):  $0.67365 T_{ACB} + 0.5(0.137158 T_{ACB}) = 900$

$$T_{ACB} = 1212.56 \text{ N} \quad T_{ACB} = 1213 \text{ N} \quad \blacktriangleleft$$

(b) From (1):  $T_{CD} = 0.137158(1212.56 \text{ N})$

$$T_{CD} = 166.3 \text{ N} \quad \blacktriangleleft$$

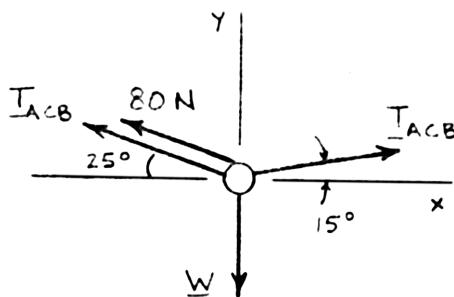


### PROBLEM 2.54

A sailor is being rescued using a boatswain's chair that is suspended from a pulley that can roll freely on the support cable  $ACB$  and is pulled at a constant speed by cable  $CD$ . Knowing that  $\alpha = 25^\circ$  and  $\beta = 15^\circ$  and that the tension in cable  $CD$  is 80 N, determine (a) the combined weight of the boatswain's chair and the sailor, (b) in tension in the support cable  $ACB$ .

### SOLUTION

#### Free-Body Diagram



$$\pm \rightarrow \Sigma F_x = 0: T_{ACB} \cos 15^\circ - T_{ACB} \cos 25^\circ - (80 \text{ N}) \cos 25^\circ = 0$$

$$T_{ACB} = 1216.15 \text{ N}$$

$$+\uparrow \Sigma F_y = 0: (1216.15 \text{ N}) \sin 15^\circ + (1216.15 \text{ N}) \sin 25^\circ$$

$$+ (80 \text{ N}) \sin 25^\circ - W = 0$$

$$W = 862.54 \text{ N}$$

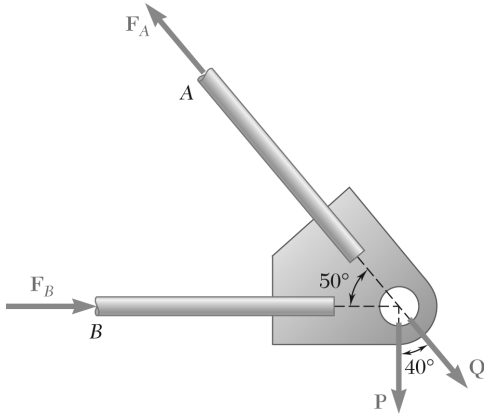
$$(a) \quad W = 863 \text{ N} \quad \blacktriangleleft$$

$$(b) \quad T_{ACB} = 1216 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.55

Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that  $P = 500$  lb and  $Q = 650$  lb, determine the magnitudes of the forces exerted on the rods **A** and **B**.



### SOLUTION

Resolving the forces into  $x$ - and  $y$ -directions:

$$\mathbf{R} = \mathbf{P} + \mathbf{Q} + \mathbf{F}_A + \mathbf{F}_B = 0$$

Substituting components:

$$\begin{aligned} \mathbf{R} = & -(500 \text{ lb})\mathbf{j} + [(650 \text{ lb})\cos 50^\circ]\mathbf{i} \\ & - [(650 \text{ lb})\sin 50^\circ]\mathbf{j} \\ & + F_B\mathbf{i} - (F_A \cos 50^\circ)\mathbf{i} + (F_A \sin 50^\circ)\mathbf{j} = 0 \end{aligned}$$

In the  $y$ -direction (one unknown force):

$$-500 \text{ lb} - (650 \text{ lb})\sin 50^\circ + F_A \sin 50^\circ = 0$$

Thus,

$$F_A = \frac{500 \text{ lb} + (650 \text{ lb})\sin 50^\circ}{\sin 50^\circ}$$

$$= 1302.70 \text{ lb}$$

$$F_A = 1303 \text{ lb} \quad \blacktriangleleft$$

In the  $x$ -direction:

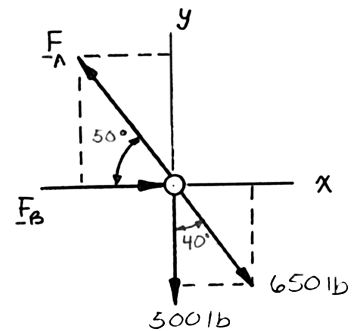
$$(650 \text{ lb})\cos 50^\circ + F_B - F_A \cos 50^\circ = 0$$

Thus,

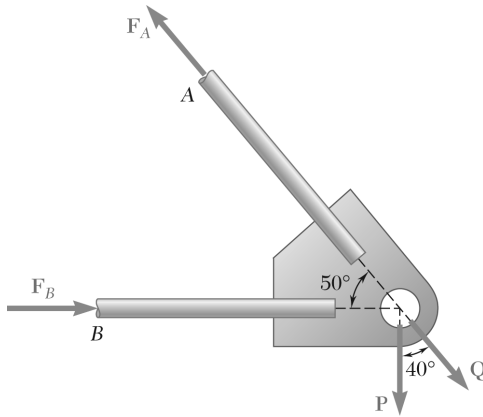
$$\begin{aligned} F_B &= F_A \cos 50^\circ - (650 \text{ lb})\cos 50^\circ \\ &= (1302.70 \text{ lb})\cos 50^\circ - (650 \text{ lb})\cos 50^\circ \\ &= 419.55 \text{ lb} \end{aligned}$$

$$F_B = 420 \text{ lb} \quad \blacktriangleleft$$

### Free-Body Diagram



## PROBLEM 2.56



Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that the magnitudes of the forces exerted on rods **A** and **B** are  $F_A = 750$  lb and  $F_B = 400$  lb, determine the magnitudes of **P** and **Q**.

## SOLUTION

Resolving the forces into  $x$ - and  $y$ -directions:

$$\mathbf{R} = \mathbf{P} + \mathbf{Q} + \mathbf{F}_A + \mathbf{F}_B = 0$$

Substituting components:  $\mathbf{R} = -P\mathbf{j} + Q \cos 50^\circ \mathbf{i} - Q \sin 50^\circ \mathbf{j}$   
 $-[(750 \text{ lb}) \cos 50^\circ] \mathbf{i}$   
 $+ [(750 \text{ lb}) \sin 50^\circ] \mathbf{j} + (400 \text{ lb}) \mathbf{i}$

In the  $x$ -direction (one unknown force):

$$Q \cos 50^\circ - [(750 \text{ lb}) \cos 50^\circ] + 400 \text{ lb} = 0$$

$$Q = \frac{(750 \text{ lb}) \cos 50^\circ - 400 \text{ lb}}{\cos 50^\circ}$$

$$= 127.710 \text{ lb}$$

In the  $y$ -direction:

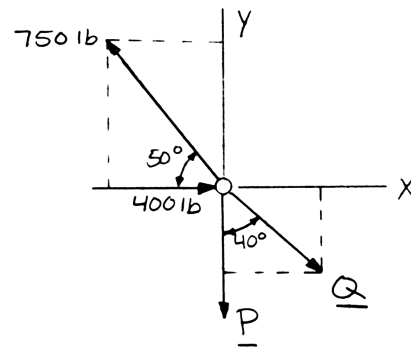
$$-P - Q \sin 50^\circ + (750 \text{ lb}) \sin 50^\circ = 0$$

$$P = -Q \sin 50^\circ + (750 \text{ lb}) \sin 50^\circ$$

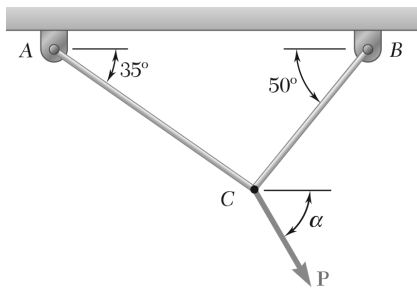
$$= -(127.710 \text{ lb}) \sin 50^\circ + (750 \text{ lb}) \sin 50^\circ$$

$$= 476.70 \text{ lb}$$

### Free-Body Diagram



$$P = 477 \text{ lb}; \quad Q = 127.7 \text{ lb} \quad \blacktriangleleft$$

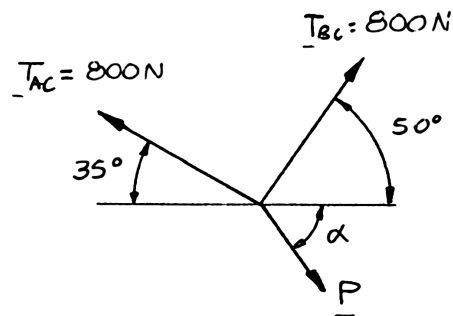


### PROBLEM 2.57

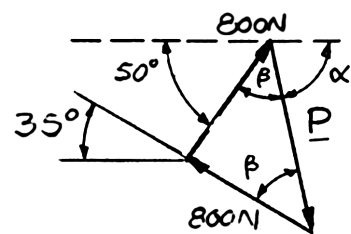
Two cables tied together at  $C$  are loaded as shown. Knowing that the maximum allowable tension in each cable is 800 N, determine  
 (a) the magnitude of the largest force  $P$  that can be applied at  $C$ ,  
 (b) the corresponding value of  $\alpha$ .

### SOLUTION

Free-Body Diagram:  $C$



Force Triangle



Force triangle is isosceles with

$$2\beta = 180^\circ - 85^\circ$$

$$\beta = 47.5^\circ$$

(a)

$$P = 2(800 \text{ N})\cos 47.5^\circ = 1081 \text{ N}$$

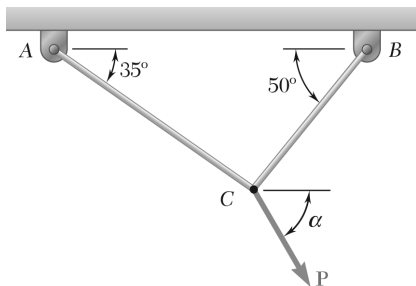
Since  $P > 0$ , the solution is correct.

$$P = 1081 \text{ N} \quad \blacktriangleleft$$

(b)

$$\alpha = 180^\circ - 50^\circ - 47.5^\circ = 82.5^\circ$$

$$\alpha = 82.5^\circ \quad \blacktriangleleft$$

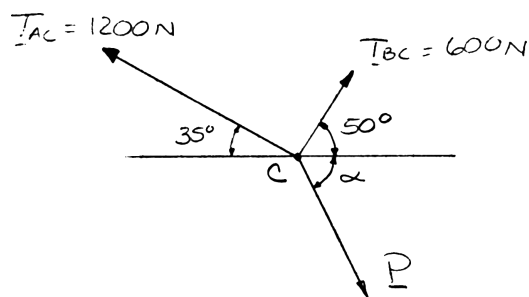


### PROBLEM 2.58

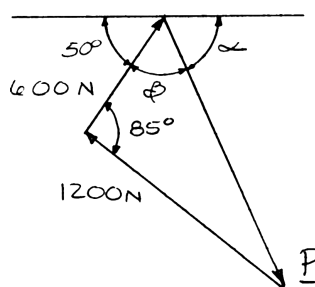
Two cables tied together at  $C$  are loaded as shown. Knowing that the maximum allowable tension is 1200 N in cable  $AC$  and 600 N in cable  $BC$ , determine (a) the magnitude of the largest force  $P$  that can be applied at  $C$ , (b) the corresponding value of  $\alpha$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



(a) Law of cosines:  $P^2 = (1200 \text{ N})^2 + (600 \text{ N})^2 - 2(1200 \text{ N})(600 \text{ N})\cos 85^\circ$   
 $P = 1294.02 \text{ N}$

Since  $P > 1200 \text{ N}$ , the solution is correct.

$P = 1294 \text{ N} \quad \blacktriangleleft$

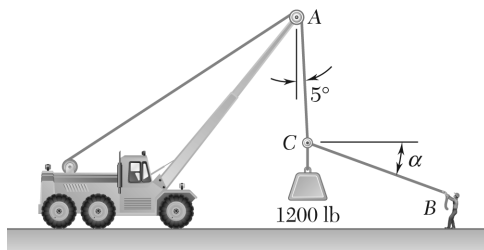
(b) Law of sines:

$$\frac{\sin \beta}{1200 \text{ N}} = \frac{\sin 85^\circ}{1294.02 \text{ N}}$$

$$\beta = 67.5^\circ$$

$$\alpha = 180^\circ - 50^\circ - 67.5^\circ$$

$\alpha = 62.5^\circ \quad \blacktriangleleft$



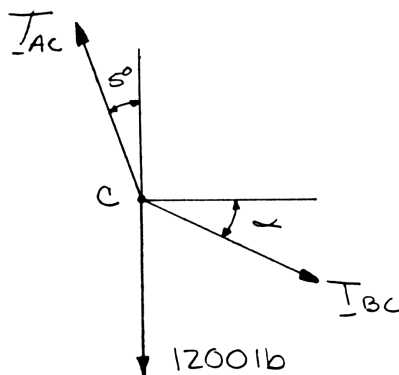
### PROBLEM 2.59

For the situation described in Figure P2.45, determine (a) the value of  $\alpha$  for which the tension in rope  $BC$  is as small as possible, (b) the corresponding value of the tension.

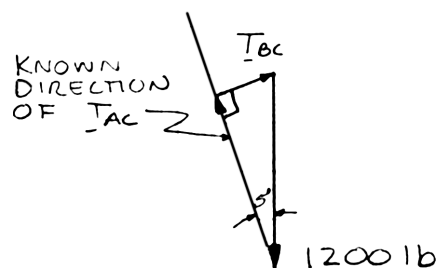
**PROBLEM 2.45** Knowing that  $\alpha = 20^\circ$ , determine the tension (a) in cable  $AC$ , (b) in rope  $BC$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



To be smallest,  $T_{BC}$  must be perpendicular to the direction of  $T_{AC}$ .

(a) Thus,  $\alpha = 5^\circ$

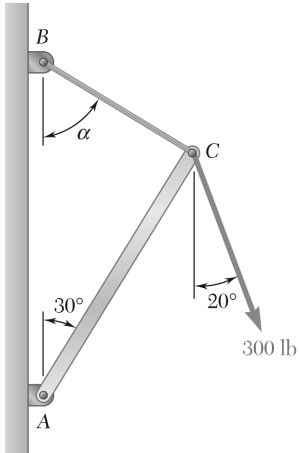
$\alpha = 5.00^\circ$  ◀

(b)  $T_{BC} = (1200 \text{ lb}) \sin 5^\circ$

$T_{BC} = 104.6 \text{ lb}$  ◀

## PROBLEM 2.60

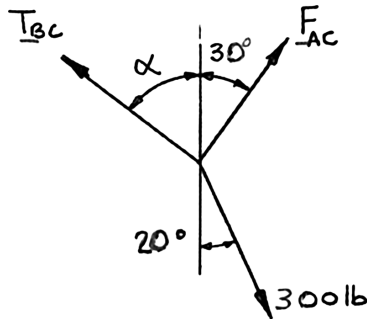
For the structure and loading of Problem 2.46, determine (a) the value of  $\alpha$  for which the tension in cable  $BC$  is as small as possible, (b) the corresponding value of the tension.



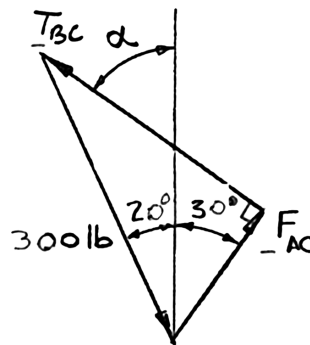
## SOLUTION

$T_{BC}$  must be perpendicular to  $F_{AC}$  to be as small as possible.

Free-Body Diagram:  $C$



Force Triangle is a right triangle



To be a minimum,  $T_{BC}$  must be perpendicular to  $F_{AC}$ .

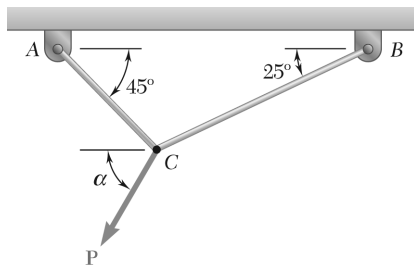
(a) We observe:  $\alpha = 90^\circ - 30^\circ$

$\alpha = 60.0^\circ \blacktriangleleft$

(b)  $T_{BC} = (300 \text{ lb}) \sin 50^\circ$

or  $T_{BC} = 229.81 \text{ lb}$

$T_{BC} = 230 \text{ lb} \blacktriangleleft$

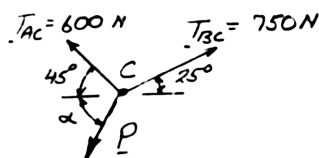


### PROBLEM 2.61

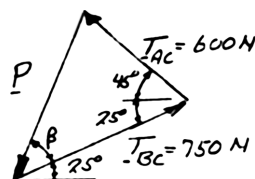
For the cables of Problem 2.48, it is known that the maximum allowable tension is 600 N in cable AC and 750 N in cable BC. Determine (a) the maximum force **P** that can be applied at C, (b) the corresponding value of  $\alpha$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



(a) Law of cosines

$$P^2 = (600)^2 + (750)^2 - 2(600)(750)\cos(25^\circ + 45^\circ)$$

$$P = 784.02 \text{ N}$$

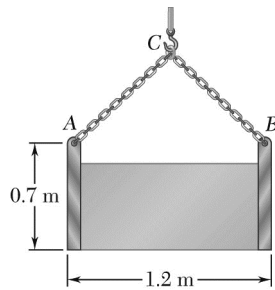
$$P = 784 \text{ N} \quad \blacktriangleleft$$

(b) Law of sines

$$\frac{\sin \beta}{600 \text{ N}} = \frac{\sin(25^\circ + 45^\circ)}{784.02 \text{ N}}$$

$$\beta = 46.0^\circ \quad \therefore \alpha = 46.0^\circ + 25^\circ$$

$$\alpha = 71.0^\circ \quad \blacktriangleleft$$

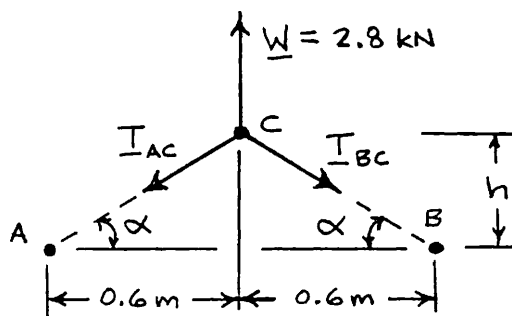


### PROBLEM 2.62

A movable bin and its contents have a combined weight of 2.8 kN. Determine the shortest chain sling  $ACB$  that can be used to lift the loaded bin if the tension in the chain is not to exceed 5 kN.

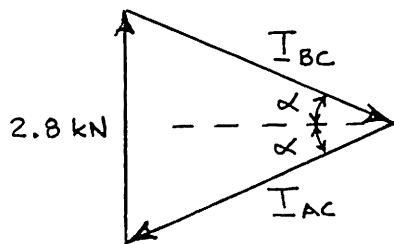
### SOLUTION

#### Free-Body Diagram



$$\tan \alpha = \frac{h}{0.6 \text{ m}} \quad (1)$$

#### Isosceles Force Triangle



$$\text{Law of sines: } \sin \alpha = \frac{\frac{1}{2}(2.8 \text{ kN})}{T_{AC}}$$

$$T_{AC} = 5 \text{ kN}$$

$$\sin \alpha = \frac{\frac{1}{2}(2.8 \text{ kN})}{5 \text{ kN}}$$

$$\alpha = 16.2602^\circ$$

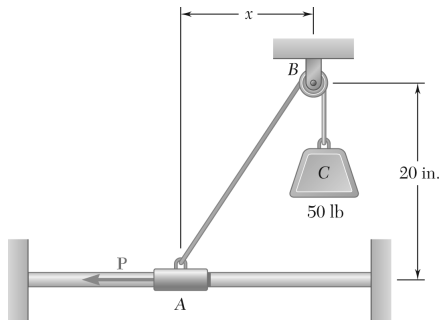
$$\text{From Eq. (1): } \tan 16.2602^\circ = \frac{h}{0.6 \text{ m}} \quad \therefore h = 0.175000 \text{ m}$$

$$\begin{aligned} \text{Half length of chain} = AC &= \sqrt{(0.6 \text{ m})^2 + (0.175 \text{ m})^2} \\ &= 0.625 \text{ m} \end{aligned}$$

$$\text{Total length: } = 2 \times 0.625 \text{ m}$$

$$1.250 \text{ m} \quad \blacktriangleleft$$



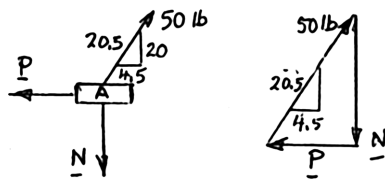


### PROBLEM 2.63

Collar A is connected as shown to a 50-lb load and can slide on a frictionless horizontal rod. Determine the magnitude of the force **P** required to maintain the equilibrium of the collar when (a)  $x = 4.5$  in., (b)  $x = 15$  in.

### SOLUTION

(a) **Free Body: Collar A**

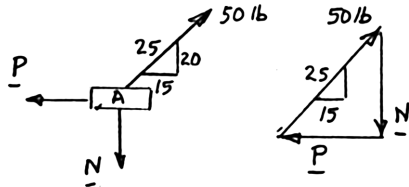


**Force Triangle**

$$\frac{P}{4.5} = \frac{50 \text{ lb}}{20.5}$$

$$P = 10.98 \text{ lb} \quad \blacktriangleleft$$

(b) **Free Body: Collar A**



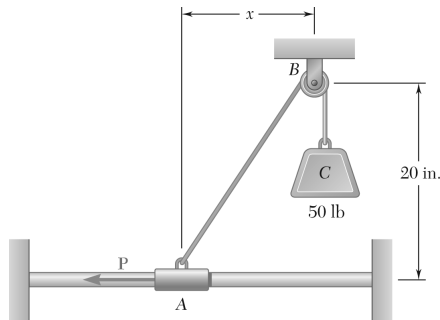
**Force Triangle**

$$\frac{P}{15} = \frac{50 \text{ lb}}{25}$$

$$P = 30.0 \text{ lb} \quad \blacktriangleleft$$

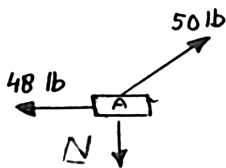
### PROBLEM 2.64

Collar A is connected as shown to a 50-lb load and can slide on a frictionless horizontal rod. Determine the distance  $x$  for which the collar is in equilibrium when  $P = 48$  lb.



### SOLUTION

Free Body: Collar A



Force Triangle

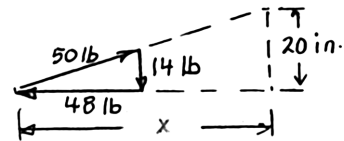


$$N^2 = (50)^2 - (48)^2 = 196$$

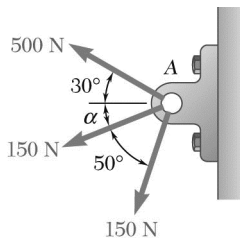
$$N = 14.00 \text{ lb}$$

Similar Triangles

$$\frac{x}{20 \text{ in.}} = \frac{48 \text{ lb}}{14 \text{ lb}}$$



$$x = 68.6 \text{ in.} \quad \blacktriangleleft$$

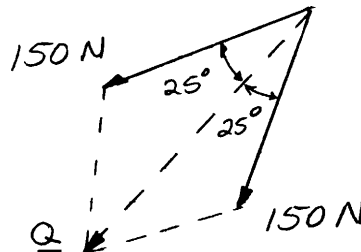


### PROBLEM 2.65

Three forces are applied to a bracket as shown. The directions of the two 150-N forces may vary, but the angle between these forces is always  $50^\circ$ . Determine the range of values of  $\alpha$  for which the magnitude of the resultant of the forces acting at A is less than 600 N.

### SOLUTION

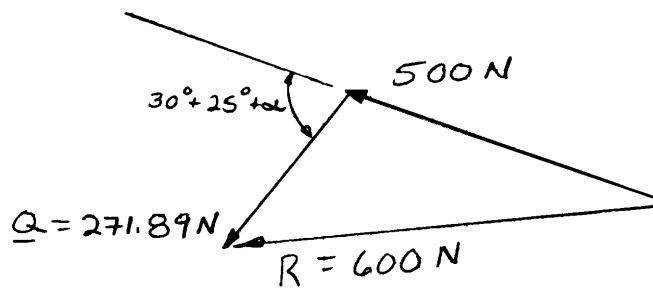
Combine the two 150-N forces into a resultant force  $Q$ :



$$Q = 2(150 \text{ N}) \cos 25^\circ$$

$$= 271.89 \text{ N}$$

Equivalent loading at A:



Using the law of cosines:

$$(600 \text{ N})^2 = (500 \text{ N})^2 + (271.89 \text{ N})^2 + 2(500 \text{ N})(271.89 \text{ N}) \cos(55^\circ + \alpha)$$

$$\cos(55^\circ + \alpha) = 0.132685$$

Two values for  $\alpha$ :  $55^\circ + \alpha = 82.375$

$$\alpha = 27.4^\circ$$

or  $55^\circ + \alpha = -82.375^\circ$

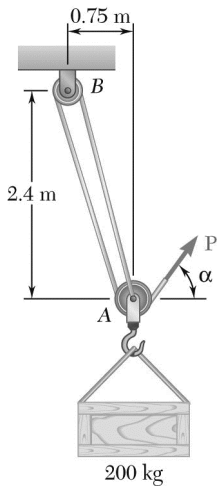
$$55^\circ + \alpha = 360^\circ - 82.375^\circ$$

$$\alpha = 222.6^\circ$$

For  $R < 600 \text{ lb}$ :

$$27.4^\circ < \alpha < 222.6^\circ \quad \blacktriangleleft$$

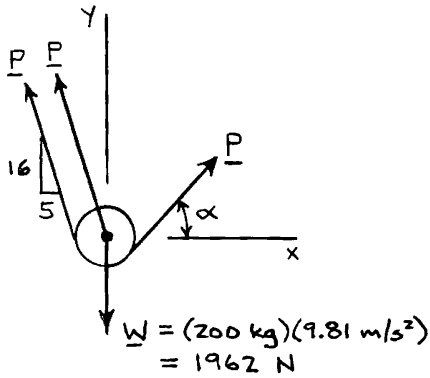
### PROBLEM 2.66



A 200-kg crate is to be supported by the rope-and-pulley arrangement shown. Determine the magnitude and direction of the force  $\mathbf{P}$  that must 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 Ch. 4.)

### SOLUTION

#### Free-Body Diagram: Pulley A



$$\pm \rightarrow \Sigma F_x = 0: -2P \left( \frac{5}{\sqrt{281}} \right) + P \cos \alpha = 0$$

$$\cos \alpha = 0.59655$$

$$\alpha = \pm 53.377^\circ$$

For  $\alpha = +53.377^\circ$ :

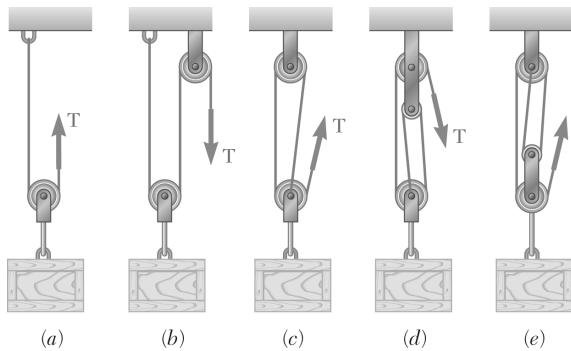
$$+\uparrow \Sigma F_y = 0: 2P \left( \frac{16}{\sqrt{281}} \right) + P \sin 53.377^\circ - 1962 \text{ N} = 0$$

$$\mathbf{P} = 724 \text{ N} \nearrow 53.4^\circ \blacktriangleleft$$

For  $\alpha = -53.377^\circ$ :

$$+\uparrow \Sigma F_y = 0: 2P \left( \frac{16}{\sqrt{281}} \right) + P \sin(-53.377^\circ) - 1962 \text{ N} = 0$$

$$\mathbf{P} = 1773 \text{ N} \nwarrow 53.4^\circ \blacktriangleleft$$

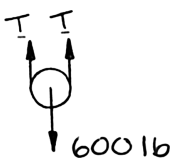


### PROBLEM 2.67

A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.66.)

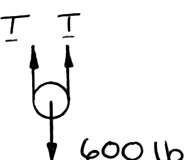
### SOLUTION

#### Free-Body Diagram of Pulley

(a)  
$$+\uparrow \Sigma F_y = 0: 2T - (600 \text{ lb}) = 0$$

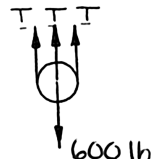
$$T = \frac{1}{2}(600 \text{ lb})$$

$$T = 300 \text{ lb} \quad \blacktriangleleft$$

(b)  
$$+\uparrow \Sigma F_y = 0: 2T - (600 \text{ lb}) = 0$$

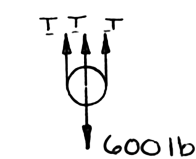
$$T = \frac{1}{2}(600 \text{ lb})$$

$$T = 300 \text{ lb} \quad \blacktriangleleft$$

(c)  
$$+\uparrow \Sigma F_y = 0: 3T - (600 \text{ lb}) = 0$$

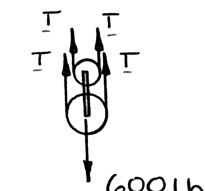
$$T = \frac{1}{3}(600 \text{ lb})$$

$$T = 200 \text{ lb} \quad \blacktriangleleft$$

(d)  
$$+\uparrow \Sigma F_y = 0: 3T - (600 \text{ lb}) = 0$$

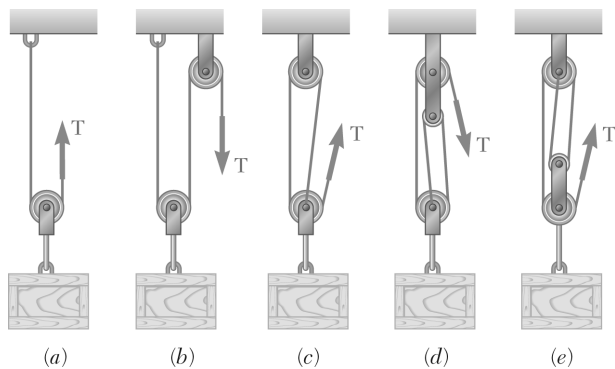
$$T = \frac{1}{3}(600 \text{ lb})$$

$$T = 200 \text{ lb} \quad \blacktriangleleft$$

(e)  
$$+\uparrow \Sigma F_y = 0: 4T - (600 \text{ lb}) = 0$$

$$T = \frac{1}{4}(600 \text{ lb})$$

$$T = 150.0 \text{ lb} \quad \blacktriangleleft$$



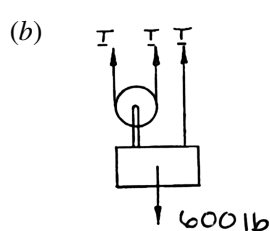
## PROBLEM 2.68

Solve Parts *b* and *d* of Problem 2.67, assuming that the free end of the rope is attached to the crate.

**PROBLEM 2.67** A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.66.)

## SOLUTION

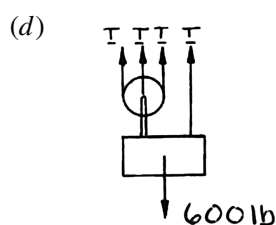
### Free-Body Diagram of Pulley and Crate



$$+\uparrow \Sigma F_y = 0: 3T - (600 \text{ lb}) = 0$$

$$T = \frac{1}{3}(600 \text{ lb})$$

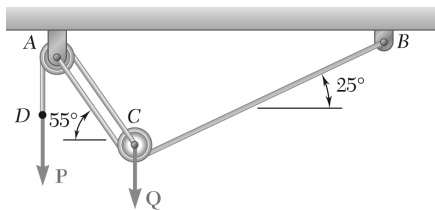
$$T = 200 \text{ lb} \quad \blacktriangleleft$$



$$+\uparrow \Sigma F_y = 0: 4T - (600 \text{ lb}) = 0$$

$$T = \frac{1}{4}(600 \text{ lb})$$

$$T = 150.0 \text{ lb} \quad \blacktriangleleft$$

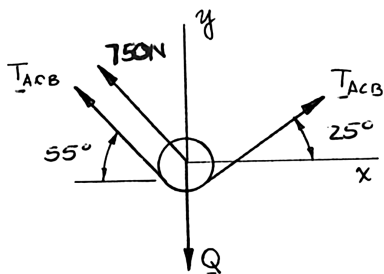


### PROBLEM 2.69

A load **Q** is applied to the pulley **C**, which can roll on the cable **ACB**. The pulley is held in the position shown by a second cable **CAD**, which passes over the pulley **A** and supports a load **P**. Knowing that  $P = 750 \text{ N}$ , determine (a) the tension in cable **ACB**, (b) the magnitude of load **Q**.

### SOLUTION

Free-Body Diagram: Pulley **C**



$$(a) \quad \sum F_x = 0: T_{ACB}(\cos 25^\circ - \cos 55^\circ) - (750 \text{ N})\cos 55^\circ = 0$$

Hence:

$$T_{ACB} = 1292.88 \text{ N}$$

$$T_{ACB} = 1293 \text{ N} \quad \blacktriangleleft$$

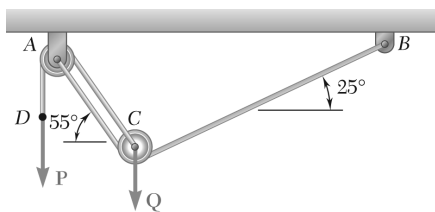
$$(b) \quad \sum F_y = 0: T_{ACB}(\sin 25^\circ + \sin 55^\circ) + (750 \text{ N})\sin 55^\circ - Q = 0$$

$$(1292.88 \text{ N})(\sin 25^\circ + \sin 55^\circ) + (750 \text{ N})\sin 55^\circ - Q = 0$$

or

$$Q = 2219.8 \text{ N}$$

$$Q = 2220 \text{ N} \quad \blacktriangleleft$$

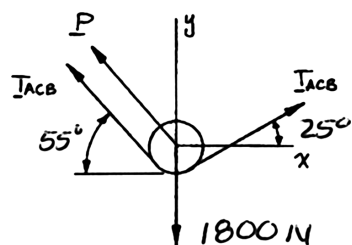


## PROBLEM 2.70

An 1800-N load **Q** is applied to the pulley **C**, which can roll on the cable **ACB**. The pulley is held in the position shown by a second cable **CAD**, which passes over the pulley **A** and supports a load **P**. Determine (a) the tension in cable **ACB**, (b) the magnitude of load **P**.

## SOLUTION

### Free-Body Diagram: Pulley C



$$\rightarrow \Sigma F_x = 0: T_{ACB}(\cos 25^\circ - \cos 55^\circ) - P \cos 55^\circ = 0$$

$$\text{or} \quad P = 0.58010 T_{ACB} \quad (1)$$

$$+\uparrow \Sigma F_y = 0: T_{ACB}(\sin 25^\circ + \sin 55^\circ) + P \sin 55^\circ - 1800 \text{ N} = 0$$

$$\text{or} \quad 1.24177 T_{ACB} + 0.81915 P = 1800 \text{ N} \quad (2)$$

(a) Substitute Equation (1) into Equation (2):

$$1.24177 T_{ACB} + 0.81915(0.58010 T_{ACB}) = 1800 \text{ N}$$

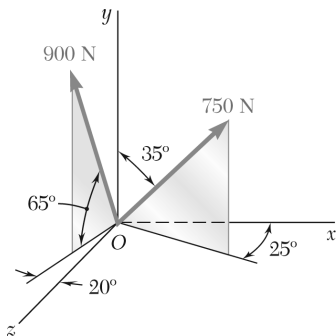
$$\text{Hence:} \quad T_{ACB} = 1048.37 \text{ N}$$

$$T_{ACB} = 1048 \text{ N} \quad \blacktriangleleft$$

(b) Using (1),  $P = 0.58010(1048.37 \text{ N}) = 608.16 \text{ N}$

$$P = 608 \text{ N} \quad \blacktriangleleft$$



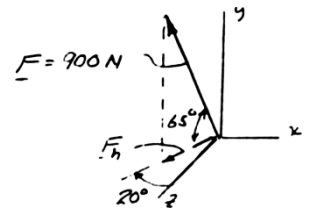


## PROBLEM 2.71

Determine (a) the  $x$ ,  $y$ , and  $z$  components of the 900-N force, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

## SOLUTION

$$\begin{aligned} F_h &= F \cos 65^\circ \\ &= (900 \text{ N}) \cos 65^\circ \\ F_h &= 380.36 \text{ N} \end{aligned}$$



(a)

$$\begin{aligned} F_x &= F_h \sin 20^\circ \\ &= (380.36 \text{ N}) \sin 20^\circ \end{aligned}$$

$$F_x = -130.091 \text{ N},$$

$$F_x = -130.1 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned} F_y &= F \sin 65^\circ \\ &= (900 \text{ N}) \sin 65^\circ \end{aligned}$$

$$F_y = +815.68 \text{ N},$$

$$F_y = +816 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned} F_z &= F_h \cos 20^\circ \\ &= (380.36 \text{ N}) \cos 20^\circ \end{aligned}$$

$$F_z = +357.42 \text{ N}$$

$$F_z = +357 \text{ N} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{-130.091 \text{ N}}{900 \text{ N}}$$

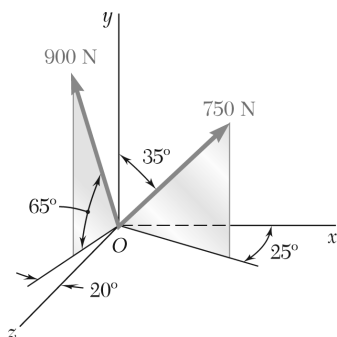
$$\theta_x = 98.3^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{+815.68 \text{ N}}{900 \text{ N}}$$

$$\theta_y = 25.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{+357.42 \text{ N}}{900 \text{ N}}$$

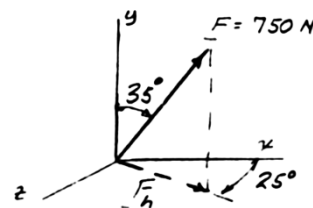
$$\theta_z = 66.6^\circ \quad \blacktriangleleft$$



## PROBLEM 2.72

Determine (a) the  $x$ ,  $y$ , and  $z$  components of the 750-N force, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

## SOLUTION



$$\begin{aligned} F_h &= F \sin 35^\circ \\ &= (750 \text{ N}) \sin 35^\circ \\ F_h &= 430.18 \text{ N} \end{aligned}$$

(a)

$$\begin{aligned} F_x &= F_h \cos 25^\circ \\ &= (430.18 \text{ N}) \cos 25^\circ \end{aligned}$$

$$F_x = +389.88 \text{ N},$$

$$F_x = +390 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned} F_y &= F \cos 35^\circ \\ &= (750 \text{ N}) \cos 35^\circ \end{aligned}$$

$$F_y = +614.36 \text{ N},$$

$$F_y = +614 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned} F_z &= F_h \sin 25^\circ \\ &= (430.18 \text{ N}) \sin 25^\circ \end{aligned}$$

$$F_z = +181.802 \text{ N}$$

$$F_z = +181.8 \text{ N} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{+389.88 \text{ N}}{750 \text{ N}}$$

$$\theta_x = 58.7^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{+614.36 \text{ N}}{750 \text{ N}}$$

$$\theta_y = 35.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{+181.802 \text{ N}}{750 \text{ N}}$$

$$\theta_z = 76.0^\circ \quad \blacktriangleleft$$

### PROBLEM 2.73

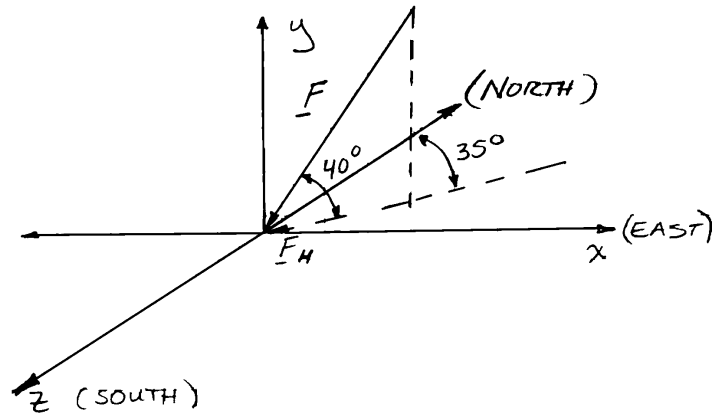
A gun is aimed at a point  $A$  located  $35^\circ$  east of north. Knowing that the barrel of the gun forms an angle of  $40^\circ$  with the horizontal and that the maximum recoil force is  $400\text{ N}$ , determine (a) the  $x$ ,  $y$ , and  $z$  components of that force, (b) the values of the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of the recoil force. (Assume that the  $x$ ,  $y$ , and  $z$  axes are directed, respectively, east, up, and south.)

### SOLUTION

Recoil force

$$F = 400\text{ N}$$

$$\begin{aligned}\therefore F_H &= (400\text{ N})\cos 40^\circ \\ &= 306.42\text{ N}\end{aligned}$$



(a)

$$\begin{aligned}F_x &= -F_H \sin 35^\circ \\ &= -(306.42\text{ N})\sin 35^\circ \\ &= -175.755\text{ N}\end{aligned}$$

$$F_x = -175.8\text{ N} \quad \blacktriangleleft$$

$$\begin{aligned}F_y &= -F \sin 40^\circ \\ &= -(400\text{ N})\sin 40^\circ \\ &= -257.12\text{ N}\end{aligned}$$

$$F_y = -257\text{ N} \quad \blacktriangleleft$$

$$\begin{aligned}F_z &= +F_H \cos 35^\circ \\ &= +(306.42\text{ N})\cos 35^\circ \\ &= +251.00\text{ N}\end{aligned}$$

$$F_z = +251\text{ N} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{-175.755\text{ N}}{400\text{ N}}$$

$$\theta_x = 116.1^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-257.12\text{ N}}{400\text{ N}}$$

$$\theta_y = 130.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{251.00\text{ N}}{400\text{ N}}$$

$$\theta_z = 51.1^\circ \quad \blacktriangleleft$$

## PROBLEM 2.74

Solve Problem 2.73, assuming that point A is located  $15^\circ$  north of west and that the barrel of the gun forms an angle of  $25^\circ$  with the horizontal.

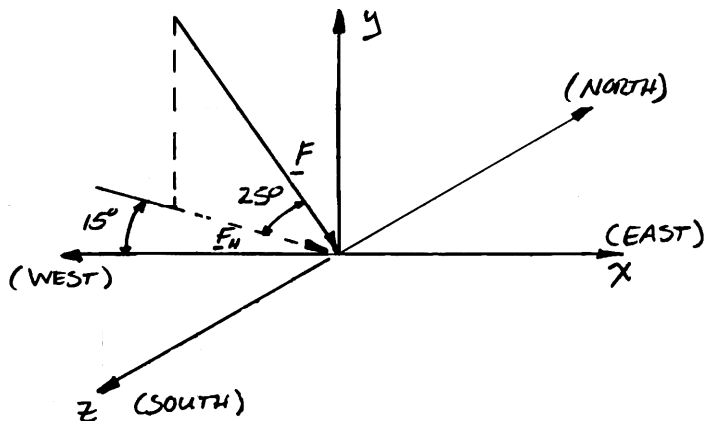
**PROBLEM 2.73** A gun is aimed at a point A located  $35^\circ$  east of north. Knowing that the barrel of the gun forms an angle of  $40^\circ$  with the horizontal and that the maximum recoil force is 400 N, determine (a) the x, y, and z components of that force, (b) the values of the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of the recoil force. (Assume that the x, y, and z axes are directed, respectively, east, up, and south.)

## SOLUTION

Recoil force

$$F = 400 \text{ N}$$

$$\begin{aligned}\therefore F_H &= (400 \text{ N}) \cos 25^\circ \\ &= 362.52 \text{ N}\end{aligned}$$



$$\begin{aligned}(a) \quad F_x &= +F_H \cos 15^\circ \\ &= +(362.52 \text{ N}) \cos 15^\circ \\ &= +350.17 \text{ N}\end{aligned}$$

$$F_x = +350 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned}F_y &= -F \sin 25^\circ \\ &= -(400 \text{ N}) \sin 25^\circ \\ &= -169.047 \text{ N}\end{aligned}$$

$$F_y = -169.0 \text{ N} \quad \blacktriangleleft$$

$$\begin{aligned}F_z &= +F_H \sin 15^\circ \\ &= +(362.52 \text{ N}) \sin 15^\circ \\ &= +93.827 \text{ N}\end{aligned}$$

$$F_z = +93.8 \text{ N} \quad \blacktriangleleft$$

$$(b) \quad \cos \theta_x = \frac{F_x}{F} = \frac{+350.17 \text{ N}}{400 \text{ N}}$$

$$\theta_x = 28.9^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-169.047 \text{ N}}{400 \text{ N}}$$

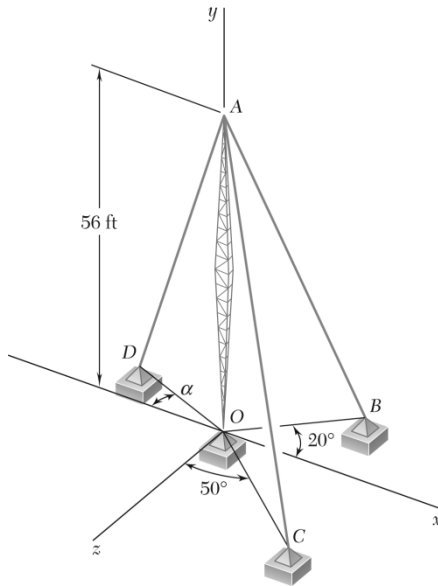
$$\theta_y = 115.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{+93.827 \text{ N}}{400 \text{ N}}$$

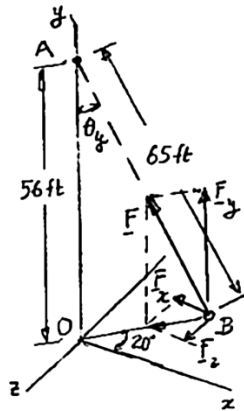
$$\theta_z = 76.4^\circ \quad \blacktriangleleft$$

## PROBLEM 2.75

Cable  $AB$  is 65 ft long, and the tension in that cable is 3900 lb. Determine (a) the  $x$ ,  $y$ , and  $z$  components of the force exerted by the cable on the anchor  $B$ , (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of that force.



## SOLUTION



From triangle  $AOB$ :

$$\begin{aligned}\cos \theta_y &= \frac{56 \text{ ft}}{65 \text{ ft}} \\ &= 0.86154 \\ \theta_y &= 30.51^\circ\end{aligned}$$

$$\begin{aligned}F_x &= -F \sin \theta_y \cos 20^\circ \\ &= -(3900 \text{ lb}) \sin 30.51^\circ \cos 20^\circ\end{aligned}$$

$$F_x = -1861 \text{ lb} \quad \blacktriangleleft$$

$$F_y = +F \cos \theta_y = (3900 \text{ lb})(0.86154)$$

$$F_y = +3360 \text{ lb} \quad \blacktriangleleft$$

$$F_z = +(3900 \text{ lb}) \sin 30.51^\circ \sin 20^\circ$$

$$F_z = +677 \text{ lb} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = -\frac{1861 \text{ lb}}{3900 \text{ lb}} = -0.4771$$

$$\theta_x = 118.5^\circ \quad \blacktriangleleft$$

From above:

$$\theta_y = 30.51^\circ$$

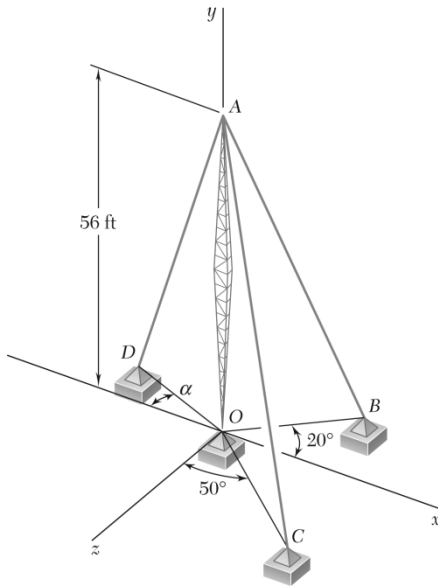
$$\theta_y = 30.5^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = +\frac{677 \text{ lb}}{3900 \text{ lb}} = +0.1736$$

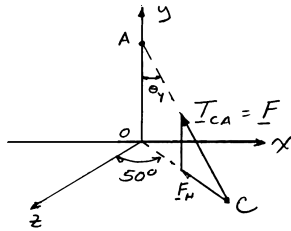
$$\theta_z = 80.0^\circ \quad \blacktriangleleft$$

## PROBLEM 2.76

Cable AC is 70 ft long, and the tension in that cable is 5250 lb. Determine (a) the  $x$ ,  $y$ , and  $z$  components of the force exerted by the cable on the anchor C, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of that force.



## SOLUTION



In triangle AOB:

$$AC = 70 \text{ ft}$$

$$OA = 56 \text{ ft}$$

$$F = 5250 \text{ lb}$$

$$\cos \theta_y = \frac{56 \text{ ft}}{70 \text{ ft}}$$

$$\theta_y = 36.870^\circ$$

$$F_H = F \sin \theta_y$$

$$= (5250 \text{ lb}) \sin 36.870^\circ$$

$$= 3150.0 \text{ lb}$$

$$(a) \quad F_x = -F_H \sin 50^\circ = -(3150.0 \text{ lb}) \sin 50^\circ = -2413.04 \text{ lb} \quad F_x = -2413 \text{ lb} \quad \blacktriangleleft$$

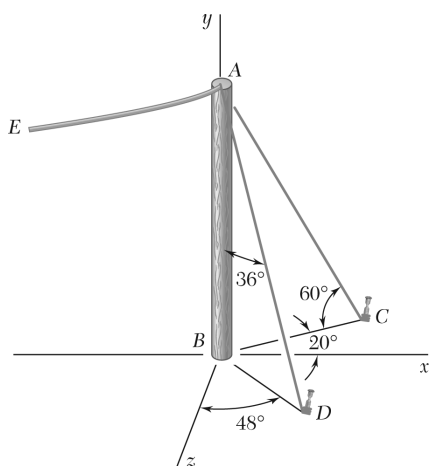
$$F_y = +F \cos \theta_y = +(5250 \text{ lb}) \cos 36.870^\circ = +4200.0 \text{ lb} \quad F_y = +4200 \text{ lb} \quad \blacktriangleleft$$

$$F_z = -F_H \cos 50^\circ = -3150 \cos 50^\circ = -2024.8 \text{ lb} \quad F_z = -2025 \text{ lb} \quad \blacktriangleleft$$

$$(b) \quad \cos \theta_x = \frac{F_x}{F} = \frac{-2413.04 \text{ lb}}{5250 \text{ lb}} \quad \theta_x = 117.4^\circ \quad \blacktriangleleft$$

$$\text{From above:} \quad \theta_y = 36.870^\circ \quad \theta_y = 36.9^\circ \quad \blacktriangleleft$$

$$\theta_z = \frac{F_z}{F} = \frac{-2024.8 \text{ lb}}{5250 \text{ lb}} \quad \theta_z = 112.7^\circ \quad \blacktriangleleft$$



### PROBLEM 2.77

The end of the coaxial cable  $AE$  is attached to the pole  $AB$ , which is strengthened by the guy wires  $AC$  and  $AD$ . Knowing that the tension in wire  $AC$  is 120 lb, determine (a) the components of the force exerted by this wire on the pole, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

### SOLUTION

(a)

$$F_x = (120 \text{ lb}) \cos 60^\circ \cos 20^\circ$$

$$F_x = 56.382 \text{ lb}$$

$$F_x = +56.4 \text{ lb} \quad \blacktriangleleft$$

$$F_y = -(120 \text{ lb}) \sin 60^\circ$$

$$F_y = -103.923 \text{ lb}$$

$$F_y = -103.9 \text{ lb} \quad \blacktriangleleft$$

$$F_z = -(120 \text{ lb}) \cos 60^\circ \sin 20^\circ$$

$$F_z = -20.521 \text{ lb}$$

$$F_z = -20.5 \text{ lb} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{56.382 \text{ lb}}{120 \text{ lb}}$$

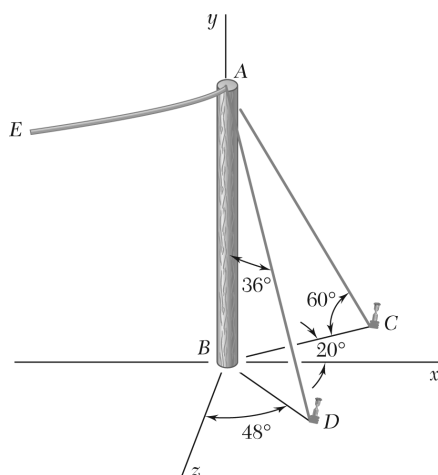
$$\theta_x = 62.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-103.923 \text{ lb}}{120 \text{ lb}}$$

$$\theta_y = 150.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{-20.52 \text{ lb}}{120 \text{ lb}}$$

$$\theta_z = 99.8^\circ \quad \blacktriangleleft$$



### PROBLEM 2.78

The end of the coaxial cable  $AE$  is attached to the pole  $AB$ , which is strengthened by the guy wires  $AC$  and  $AD$ . Knowing that the tension in wire  $AD$  is 85 lb, determine (a) the components of the force exerted by this wire on the pole, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

### SOLUTION

(a)

$$F_x = (85 \text{ lb}) \sin 36^\circ \sin 48^\circ$$

$$= 37.129 \text{ lb} \qquad F_x = 37.1 \text{ lb} \quad \blacktriangleleft$$

$$F_y = -(85 \text{ lb}) \cos 36^\circ$$

$$= -68.766 \text{ lb} \qquad F_y = -68.8 \text{ lb} \quad \blacktriangleleft$$

$$F_z = (85 \text{ lb}) \sin 36^\circ \cos 48^\circ$$

$$= 33.431 \text{ lb} \qquad F_z = 33.4 \text{ lb} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{37.129 \text{ lb}}{85 \text{ lb}} \qquad \theta_x = 64.1^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-68.766 \text{ lb}}{85 \text{ lb}} \qquad \theta_y = 144.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{33.431 \text{ lb}}{85 \text{ lb}} \qquad \theta_z = 66.8^\circ \quad \blacktriangleleft$$



### PROBLEM 2.79

Determine the magnitude and direction of the force  $\mathbf{F} = (690 \text{ lb})\mathbf{i} + (300 \text{ lb})\mathbf{j} - (580 \text{ lb})\mathbf{k}$ .

### SOLUTION

$$\mathbf{F} = (690 \text{ N})\mathbf{i} + (300 \text{ N})\mathbf{j} - (580 \text{ N})\mathbf{k}$$

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

$$= \sqrt{(690 \text{ N})^2 + (300 \text{ N})^2 + (-580 \text{ N})^2}$$

$$= 950 \text{ N}$$

$$F = 950 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{F_x}{F} = \frac{690 \text{ N}}{950 \text{ N}}$$

$$\theta_x = 43.4^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{300 \text{ N}}{950 \text{ N}}$$

$$\theta_y = 71.6^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{-580 \text{ N}}{950 \text{ N}}$$

$$\theta_z = 127.6^\circ \quad \blacktriangleleft$$

## PROBLEM 2.80

Determine the magnitude and direction of the force  $\mathbf{F} = (650 \text{ N})\mathbf{i} - (320 \text{ N})\mathbf{j} + (760 \text{ N})\mathbf{k}$ .

## SOLUTION

$$\mathbf{F} = (650 \text{ N})\mathbf{i} - (320 \text{ N})\mathbf{j} + (760 \text{ N})\mathbf{k}$$

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

$$= \sqrt{(650 \text{ N})^2 + (-320 \text{ N})^2 + (760 \text{ N})^2} \quad F = 1050 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{F_x}{F} = \frac{650 \text{ N}}{1050 \text{ N}} \quad \theta_x = 51.8^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-320 \text{ N}}{1050 \text{ N}} \quad \theta_y = 107.7^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{760 \text{ N}}{1050 \text{ N}} \quad \theta_z = 43.6^\circ \quad \blacktriangleleft$$

### PROBLEM 2.81

A force acts at the origin of a coordinate system in a direction defined by the angles  $\theta_x = 75^\circ$  and  $\theta_z = 130^\circ$ . Knowing that the y component of the force is +300 lb, determine (a) the angle  $\theta_y$ , (b) the other components and the magnitude of the force.

### SOLUTION

$$\cos^2 \theta_x + \cos^2 \theta_y + \cos^2 \theta_z = 1$$

$$\cos^2(75^\circ) + \cos^2 \theta_y + \cos^2(130^\circ) = 1$$

$$\cos \theta_y = \pm 0.72100$$

(a) Since  $F_y > 0$ , we choose  $\cos \theta_y = +0.72100$   $\therefore \theta_y = 43.9^\circ \blacktriangleleft$

(b)  $F_y = F \cos \theta_y$   
 $300 \text{ lb} = F(0.72100)$

$$F = 416.09 \text{ lb} \qquad F = 416 \text{ lb} \blacktriangleleft$$

$$F_x = F \cos \theta_x = 416.09 \text{ lb} \cos 75^\circ \qquad F_x = +107.7 \text{ lb} \blacktriangleleft$$

$$F_z = F \cos \theta_z = 416.09 \text{ lb} \cos 130^\circ \qquad F_z = -267 \text{ lb} \blacktriangleleft$$

## PROBLEM 2.82

A force acts at the origin of a coordinate system in a direction defined by the angles  $\theta_y = 55^\circ$  and  $\theta_z = 45^\circ$ . Knowing that the  $x$  component of the force is  $-500$  N, determine (a) the angle  $\theta_x$ , (b) the other components and the magnitude of the force.

## SOLUTION

$$\cos^2 \theta_x + \cos^2 \theta_y + \cos^2 \theta_z = 1$$

$$\cos^2 \theta_x + \cos^2 55^\circ + \cos^2 45^\circ = 1$$

$$\cos \theta_x = \pm 0.41353$$

(a) Since  $F_x < 0$ , we choose  $\cos \theta_x = -0.41353$   $\therefore \theta_x = 114.4^\circ \blacktriangleleft$

(b)  $F_x = F \cos \theta_x$   
 $-500 \text{ N} = F(-0.41353)$

$$F = 1209.10 \text{ N} \qquad F = 1209.1 \text{ N} \blacktriangleleft$$

$$F_y = F \cos \theta_y = 1209.10 \text{ N} \cos 55^\circ \qquad F_y = +694 \text{ N} \blacktriangleleft$$

$$F_z = F \cos \theta_z = 1209.10 \text{ N} \cos 45^\circ \qquad F_z = +855 \text{ N} \blacktriangleleft$$

### PROBLEM 2.83

A force  $\mathbf{F}$  of magnitude 230 N acts at the origin of a coordinate system. Knowing that  $\theta_x = 32.5^\circ$ ,  $F_y = -60$  N, and  $F_z > 0$ , determine (a) the components  $F_x$  and  $F_z$ , (b) the angles  $\theta_y$  and  $\theta_z$ .

### SOLUTION

(a) We have

$$F_x = F \cos \theta_x = (230 \text{ N}) \cos 32.5^\circ \qquad F_x = -194.0 \text{ N} \quad \blacktriangleleft$$

Then:  $F_x = 193.980 \text{ N}$

$$F^2 = F_x^2 + F_y^2 + F_z^2$$

So:  $(230 \text{ N})^2 = (193.980 \text{ N})^2 + (-60 \text{ N})^2 + F_z^2$

Hence:  $F_z = +\sqrt{(230 \text{ N})^2 - (193.980 \text{ N})^2 - (-60 \text{ N})^2} \qquad F_z = 108.0 \text{ N} \quad \blacktriangleleft$

(b)  $F_z = 108.036 \text{ N}$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-60 \text{ N}}{230 \text{ N}} = -0.26087 \qquad \theta_y = 105.1^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{108.036 \text{ N}}{230 \text{ N}} = 0.46972 \qquad \theta_z = 62.0^\circ \quad \blacktriangleleft$$

## PROBLEM 2.84

A force  $\mathbf{F}$  of magnitude 210 N acts at the origin of a coordinate system. Knowing that  $F_x = 80$  N,  $\theta_z = 151.2^\circ$ , and  $F_y < 0$ , determine (a) the components  $F_y$  and  $F_z$ , (b) the angles  $\theta_x$  and  $\theta_y$ .

## SOLUTION

$$\begin{aligned}(a) \quad F_z &= F \cos \theta_z = (210 \text{ N}) \cos 151.2^\circ \\ &= -184.024 \text{ N} \qquad F_z = -184.0 \text{ N} \quad \blacktriangleleft\end{aligned}$$

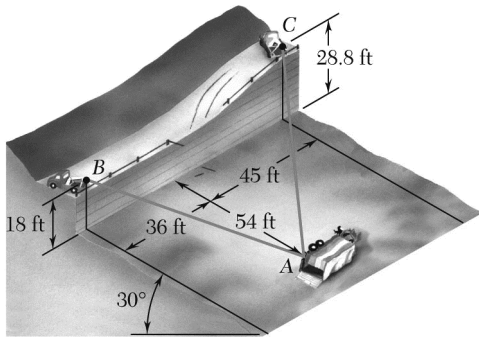
$$\text{Then:} \quad F^2 = F_x^2 + F_y^2 + F_z^2$$

$$\text{So:} \quad (210 \text{ N})^2 = (80 \text{ N})^2 + (F_y)^2 + (184.024 \text{ N})^2$$

$$\begin{aligned}\text{Hence:} \quad F_y &= -\sqrt{(210 \text{ N})^2 - (80 \text{ N})^2 - (184.024 \text{ N})^2} \\ &= -61.929 \text{ N} \qquad F_y = -62.0 \text{ lb} \quad \blacktriangleleft\end{aligned}$$

$$(b) \quad \cos \theta_x = \frac{F_x}{F} = \frac{80 \text{ N}}{210 \text{ N}} = 0.38095 \qquad \theta_x = 67.6^\circ \quad \blacktriangleleft$$

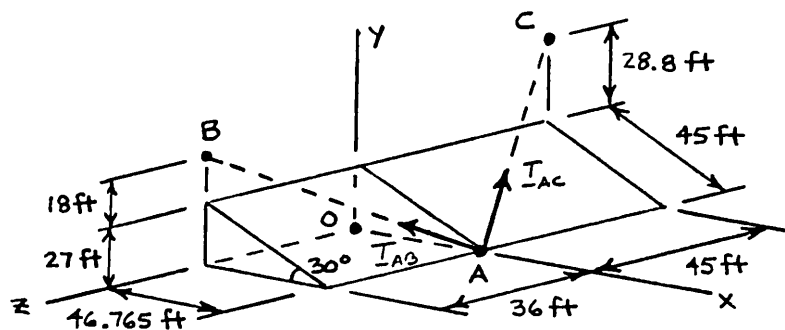
$$\cos \theta_y = \frac{F_y}{F} = \frac{61.929 \text{ N}}{210 \text{ N}} = -0.29490 \qquad \theta_y = 107.2^\circ \quad \blacktriangleleft$$



### PROBLEM 2.85

In order to move a wrecked truck, two cables are attached at  $A$  and pulled by winches  $B$  and  $C$  as shown. Knowing that the tension in cable  $AB$  is 2 kips, determine the components of the force exerted at  $A$  by the cable.

### SOLUTION



$$AB = 74.216 \text{ ft}$$

$$AC = 85.590 \text{ ft}$$

Cable  $AB$ :

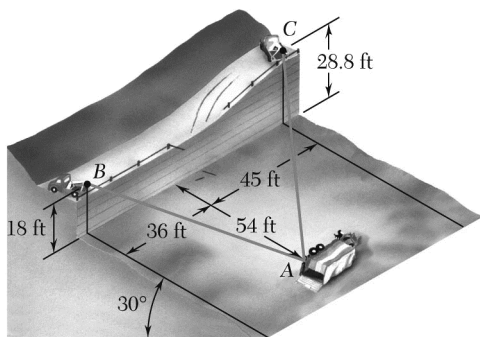
$$\lambda_{AB} = \frac{\overline{AB}}{AB} = \frac{(-46.765 \text{ ft})\mathbf{i} + (45 \text{ ft})\mathbf{j} + (36 \text{ ft})\mathbf{k}}{74.216 \text{ ft}}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = \frac{-46.765\mathbf{i} + 45\mathbf{j} + 36\mathbf{k}}{74.216}$$

$$(T_{AB})_x = -1.260 \text{ kips} \quad \blacktriangleleft$$

$$(T_{AB})_y = +1.213 \text{ kips} \quad \blacktriangleleft$$

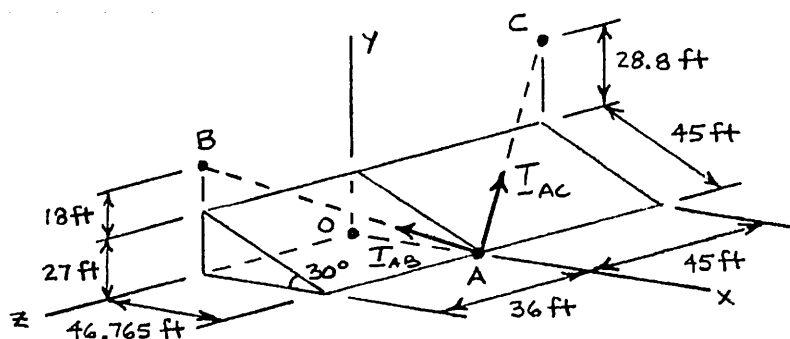
$$(T_{AB})_z = +0.970 \text{ kips} \quad \blacktriangleleft$$



### PROBLEM 2.86

In order to move a wrecked truck, two cables are attached at *A* and pulled by winches *B* and *C* as shown. Knowing that the tension in cable *AC* is 1.5 kips, determine the components of the force exerted at *A* by the cable.

### SOLUTION



$$\underline{AB} = 74.216 \text{ ft} \quad \underline{AC} = 85.590 \text{ ft}$$

Cable *AB*:

$$\lambda_{AC} = \frac{\overrightarrow{AC}}{AC} = \frac{(-46.765 \text{ ft})\mathbf{i} + (55.8 \text{ ft})\mathbf{j} + (-45 \text{ ft})\mathbf{k}}{85.590 \text{ ft}}$$

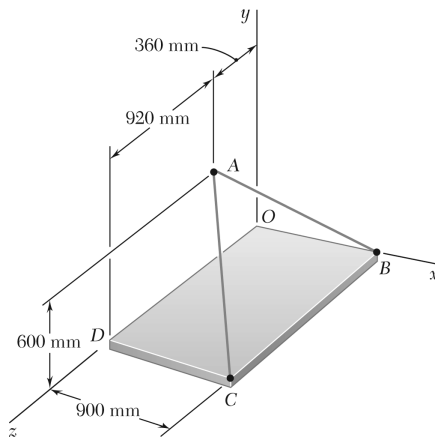
$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = (1.5 \text{ kips}) \frac{-46.765\mathbf{i} + 55.8\mathbf{j} - 45\mathbf{k}}{85.590}$$

$$(T_{AC})_x = -0.820 \text{ kips} \quad \blacktriangleleft$$

$$(T_{AC})_y = +0.978 \text{ kips} \quad \blacktriangleleft$$

$$(T_{AC})_z = -0.789 \text{ kips} \quad \blacktriangleleft$$





### PROBLEM 2.87

Knowing that the tension in cable  $AB$  is 1425 N, determine the components of the force exerted on the plate at  $B$ .

### SOLUTION

$$\overline{BA} = -(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}$$

$$BA = \sqrt{(900 \text{ mm})^2 + (600 \text{ mm})^2 + (360 \text{ mm})^2}$$

$$= 1140 \text{ mm}$$

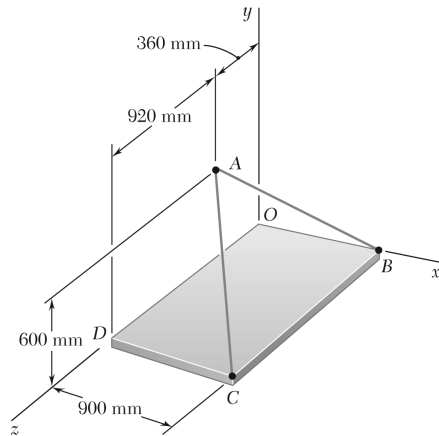
$$\mathbf{T}_{BA} = T_{BA} \lambda_{BA}$$

$$= T_{BA} \frac{\overline{BA}}{BA}$$

$$\mathbf{T}_{BA} = \frac{1425 \text{ N}}{1140 \text{ mm}} [-(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}]$$

$$= -(1125 \text{ N})\mathbf{i} + (750 \text{ N})\mathbf{j} + (450 \text{ N})\mathbf{k}$$

$$(T_{BA})_x = -1125 \text{ N}, \quad (T_{BA})_y = 750 \text{ N}, \quad (T_{BA})_z = 450 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.88

Knowing that the tension in cable  $AC$  is 2130 N, determine the components of the force exerted on the plate at  $C$ .

### SOLUTION

$$\overline{CA} = -(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} - (920 \text{ mm})\mathbf{k}$$

$$CA = \sqrt{(900 \text{ mm})^2 + (600 \text{ mm})^2 + (920 \text{ mm})^2}$$

$$= 1420 \text{ mm}$$

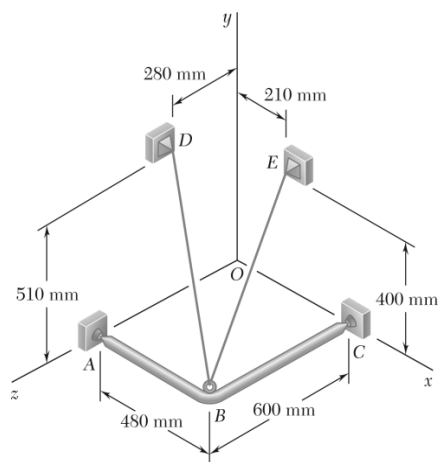
$$\mathbf{T}_{CA} = T_{CA} \lambda_{CA}$$

$$= T_{CA} \frac{\overline{CA}}{CA}$$

$$\mathbf{T}_{CA} = \frac{2130 \text{ N}}{1420 \text{ mm}} [-(900 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} - (920 \text{ mm})\mathbf{k}]$$

$$= -(1350 \text{ N})\mathbf{i} + (900 \text{ N})\mathbf{j} - (1380 \text{ N})\mathbf{k}$$

$$(T_{CA})_x = -1350 \text{ N}, \quad (T_{CA})_y = 900 \text{ N}, \quad (T_{CA})_z = -1380 \text{ N} \quad \blacktriangleleft$$



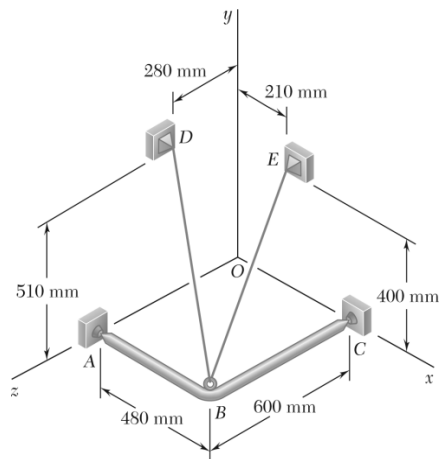
### PROBLEM 2.89

A frame  $ABC$  is supported in part by cable  $DBE$  that passes through a frictionless ring at  $B$ . Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at  $D$ .

### SOLUTION

$$\begin{aligned}\overrightarrow{DB} &= (480 \text{ mm})\mathbf{i} - (510 \text{ mm})\mathbf{j} + (320 \text{ mm})\mathbf{k} \\ DB &= \sqrt{(480 \text{ mm})^2 + (510 \text{ mm})^2 + (320 \text{ mm})^2} \\ &= 770 \text{ mm} \\ \mathbf{F} &= F\lambda_{DB} \\ &= F \frac{\overrightarrow{DB}}{DB} \\ &= \frac{385 \text{ N}}{770 \text{ mm}} [(480 \text{ mm})\mathbf{i} - (510 \text{ mm})\mathbf{j} + (320 \text{ mm})\mathbf{k}] \\ &= (240 \text{ N})\mathbf{i} - (255 \text{ N})\mathbf{j} + (160 \text{ N})\mathbf{k}\end{aligned}$$

$$F_x = +240 \text{ N}, \quad F_y = -255 \text{ N}, \quad F_z = +160.0 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.90

For the frame and cable of Problem 2.89, determine the components of the force exerted by the cable on the support at E.

**PROBLEM 2.89** A frame  $ABC$  is supported in part by cable  $DBE$  that passes through a frictionless ring at  $B$ . Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at  $D$ .

### SOLUTION

$$\overline{EB} = (270 \text{ mm})\mathbf{i} - (400 \text{ mm})\mathbf{j} + (600 \text{ mm})\mathbf{k}$$

$$EB = \sqrt{(270 \text{ mm})^2 + (400 \text{ mm})^2 + (600 \text{ mm})^2}$$

$$= 770 \text{ mm}$$

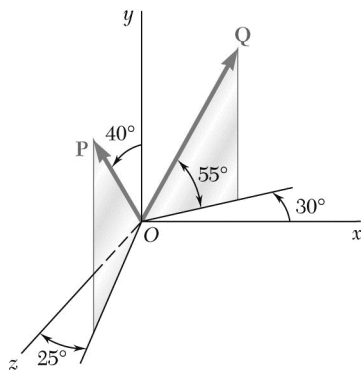
$$\mathbf{F} = F\lambda_{EB}$$

$$= F \frac{\overline{EB}}{EB}$$

$$= \frac{385 \text{ N}}{770 \text{ mm}} [(270 \text{ mm})\mathbf{i} - (400 \text{ mm})\mathbf{j} + (600 \text{ mm})\mathbf{k}]$$

$$\mathbf{F} = (135 \text{ N})\mathbf{i} - (200 \text{ N})\mathbf{j} + (300 \text{ N})\mathbf{k}$$

$$F_x = +135.0 \text{ N}, \quad F_y = -200 \text{ N}, \quad F_z = +300 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.91

Find the magnitude and direction of the resultant of the two forces shown knowing that  $P = 600 \text{ N}$  and  $Q = 450 \text{ N}$ .

### SOLUTION

$$\mathbf{P} = (600 \text{ N})[\sin 40^\circ \sin 25^\circ \mathbf{i} + \cos 40^\circ \mathbf{j} + \sin 40^\circ \cos 25^\circ \mathbf{k}]$$

$$= (162.992 \text{ N})\mathbf{i} + (459.63 \text{ N})\mathbf{j} + (349.54 \text{ N})\mathbf{k}$$

$$\mathbf{Q} = (450 \text{ N})[\cos 55^\circ \cos 30^\circ \mathbf{i} + \sin 55^\circ \mathbf{j} - \cos 55^\circ \sin 30^\circ \mathbf{k}]$$

$$= (223.53 \text{ N})\mathbf{i} + (368.62 \text{ N})\mathbf{j} - (129.055 \text{ N})\mathbf{k}$$

$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$

$$= (386.52 \text{ N})\mathbf{i} + (828.25 \text{ N})\mathbf{j} + (220.49 \text{ N})\mathbf{k}$$

$$R = \sqrt{(386.52 \text{ N})^2 + (828.25 \text{ N})^2 + (220.49 \text{ N})^2}$$

$$= 940.22 \text{ N}$$

$$R = 940 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{386.52 \text{ N}}{940.22 \text{ N}}$$

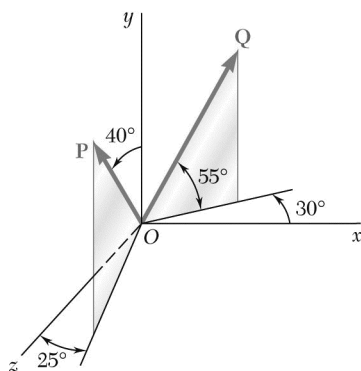
$$\theta_x = 65.7^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{R_y}{R} = \frac{828.25 \text{ N}}{940.22 \text{ N}}$$

$$\theta_y = 28.2^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{220.49 \text{ N}}{940.22 \text{ N}}$$

$$\theta_z = 76.4^\circ \quad \blacktriangleleft$$



### PROBLEM 2.92

Find the magnitude and direction of the resultant of the two forces shown knowing that  $P = 450 \text{ N}$  and  $Q = 600 \text{ N}$ .

### SOLUTION

$$\mathbf{P} = (450 \text{ N})[\sin 40^\circ \sin 25^\circ \mathbf{i} + \cos 40^\circ \mathbf{j} + \sin 40^\circ \cos 25^\circ \mathbf{k}]$$

$$= (122.244 \text{ N})\mathbf{i} + (344.72 \text{ N})\mathbf{j} + (262.154 \text{ N})\mathbf{k}$$

$$\mathbf{Q} = (600 \text{ N})[\cos 55^\circ \cos 30^\circ \mathbf{i} + \sin 55^\circ \mathbf{j} - \cos 55^\circ \sin 30^\circ \mathbf{k}]$$

$$= (298.04 \text{ N})\mathbf{i} + (491.49 \text{ N})\mathbf{j} - (172.073 \text{ N})\mathbf{k}$$

$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$

$$= (420.28 \text{ N})\mathbf{i} + (836.21 \text{ N})\mathbf{j} + (90.081 \text{ N})\mathbf{k}$$

$$R = \sqrt{(420.28 \text{ N})^2 + (836.21 \text{ N})^2 + (90.081 \text{ N})^2}$$

$$= 940.21 \text{ N}$$

$$R = 940 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{420.28}{940.21}$$

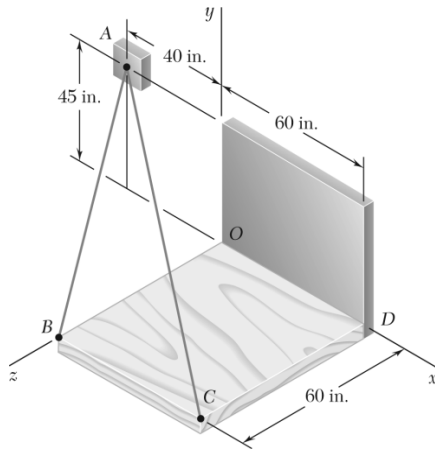
$$\theta_x = 63.4^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{R_y}{R} = \frac{836.21}{940.21}$$

$$\theta_y = 27.2^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{90.081}{940.21}$$

$$\theta_z = 84.5^\circ \quad \blacktriangleleft$$



### PROBLEM 2.93

Knowing that the tension is 425 lb in cable  $AB$  and 510 lb in cable  $AC$ , determine the magnitude and direction of the resultant of the forces exerted at  $A$  by the two cables.

### SOLUTION

$$\overrightarrow{AB} = (40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AB = \sqrt{(40 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 85 \text{ in.}$$

$$\overrightarrow{AC} = (100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AC = \sqrt{(100 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 125 \text{ in.}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = (425 \text{ lb}) \left[ \frac{(40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{85 \text{ in.}} \right]$$

$$\mathbf{T}_{AB} = (200 \text{ lb})\mathbf{i} - (225 \text{ lb})\mathbf{j} + (300 \text{ lb})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = (510 \text{ lb}) \left[ \frac{(100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{125 \text{ in.}} \right]$$

$$\mathbf{T}_{AC} = (408 \text{ lb})\mathbf{i} - (183.6 \text{ lb})\mathbf{j} + (244.8 \text{ lb})\mathbf{k}$$

$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = (608 \text{ lb})\mathbf{i} - (408.6 \text{ lb})\mathbf{j} + (544.8 \text{ lb})\mathbf{k}$$

Then:

$$R = 912.92 \text{ lb}$$

$$R = 913 \text{ lb} \quad \blacktriangleleft$$

and

$$\cos \theta_x = \frac{608 \text{ lb}}{912.92 \text{ lb}} = 0.66599$$

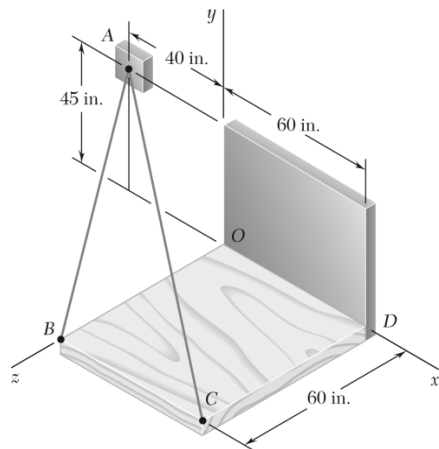
$$\theta_x = 48.2^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{408.6 \text{ lb}}{912.92 \text{ lb}} = -0.44757$$

$$\theta_y = 116.6^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{544.8 \text{ lb}}{912.92 \text{ lb}} = 0.59677$$

$$\theta_z = 53.4^\circ \quad \blacktriangleleft$$



### PROBLEM 2.94

Knowing that the tension is 510 lb in cable  $AB$  and 425 lb in cable  $AC$ , determine the magnitude and direction of the resultant of the forces exerted at  $A$  by the two cables.

### SOLUTION

$$\overline{AB} = (40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AB = \sqrt{(40 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 85 \text{ in.}$$

$$\overline{AC} = (100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}$$

$$AC = \sqrt{(100 \text{ in.})^2 + (45 \text{ in.})^2 + (60 \text{ in.})^2} = 125 \text{ in.}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = (510 \text{ lb}) \left[ \frac{(40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{85 \text{ in.}} \right]$$

$$\mathbf{T}_{AB} = (240 \text{ lb})\mathbf{i} - (270 \text{ lb})\mathbf{j} + (360 \text{ lb})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = (425 \text{ lb}) \left[ \frac{(100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{125 \text{ in.}} \right]$$

$$\mathbf{T}_{AC} = (340 \text{ lb})\mathbf{i} - (153 \text{ lb})\mathbf{j} + (204 \text{ lb})\mathbf{k}$$

$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = (580 \text{ lb})\mathbf{i} - (423 \text{ lb})\mathbf{j} + (564 \text{ lb})\mathbf{k}$$

Then:

$$R = 912.92 \text{ lb}$$

$$R = 913 \text{ lb} \quad \blacktriangleleft$$

and

$$\cos \theta_x = \frac{580 \text{ lb}}{912.92 \text{ lb}} = 0.63532$$

$$\theta_x = 50.6^\circ \quad \blacktriangleleft$$

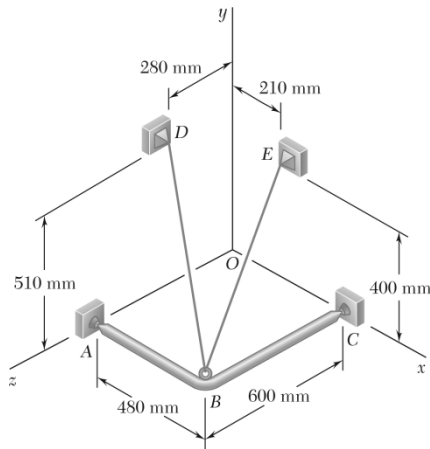
$$\cos \theta_y = \frac{-423 \text{ lb}}{912.92 \text{ lb}} = -0.46335$$

$$\theta_y = 117.6^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{564 \text{ lb}}{912.92 \text{ lb}} = 0.61780$$

$$\theta_z = 51.8^\circ \quad \blacktriangleleft$$





### PROBLEM 2.95

For the frame of Problem 2.89, determine the magnitude and direction of the resultant of the forces exerted by the cable at  $B$  knowing that the tension in the cable is 385 N.

**PROBLEM 2.89** A frame  $ABC$  is supported in part by cable  $DBE$  that passes through a frictionless ring at  $B$ . Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at  $D$ .

### SOLUTION

$$\overrightarrow{BD} = -(480 \text{ mm})\mathbf{i} + (510 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k}$$

$$BD = \sqrt{(480 \text{ mm})^2 + (510 \text{ mm})^2 + (320 \text{ mm})^2} = 770 \text{ mm}$$

$$\begin{aligned}\mathbf{F}_{BD} &= T_{BD}\lambda_{BD} = T_{BD} \frac{\overrightarrow{BD}}{BD} \\ &= \frac{(385 \text{ N})}{(770 \text{ mm})} [-(480 \text{ mm})\mathbf{i} + (510 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k}] \\ &= -(240 \text{ N})\mathbf{i} + (255 \text{ N})\mathbf{j} - (160 \text{ N})\mathbf{k}\end{aligned}$$

$$\overrightarrow{BE} = -(270 \text{ mm})\mathbf{i} + (400 \text{ mm})\mathbf{j} - (600 \text{ mm})\mathbf{k}$$

$$BE = \sqrt{(270 \text{ mm})^2 + (400 \text{ mm})^2 + (600 \text{ mm})^2} = 770 \text{ mm}$$

$$\begin{aligned}\mathbf{F}_{BE} &= T_{BE}\lambda_{BE} = T_{BE} \frac{\overrightarrow{BE}}{BE} \\ &= \frac{(385 \text{ N})}{(770 \text{ mm})} [-(270 \text{ mm})\mathbf{i} + (400 \text{ mm})\mathbf{j} - (600 \text{ mm})\mathbf{k}] \\ &= -(135 \text{ N})\mathbf{i} + (200 \text{ N})\mathbf{j} - (300 \text{ N})\mathbf{k}\end{aligned}$$

$$\mathbf{R} = \mathbf{F}_{BD} + \mathbf{F}_{BE} = -(375 \text{ N})\mathbf{i} + (455 \text{ N})\mathbf{j} - (460 \text{ N})\mathbf{k}$$

$$R = \sqrt{(375 \text{ N})^2 + (455 \text{ N})^2 + (460 \text{ N})^2} = 747.83 \text{ N}$$

$$R = 748 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{-375 \text{ N}}{747.83 \text{ N}}$$

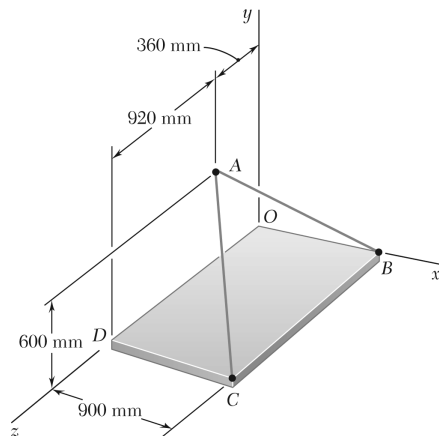
$$\theta_x = 120.1^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{455 \text{ N}}{747.83 \text{ N}}$$

$$\theta_y = 52.5^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{-460 \text{ N}}{747.83 \text{ N}}$$

$$\theta_z = 128.0^\circ \quad \blacktriangleleft$$



## PROBLEM 2.96

For the cables of Problem 2.87, knowing that the tension is 1425 N in cable AB and 2130 N in cable AC, determine the magnitude and direction of the resultant of the forces exerted at A by the two cables.

## SOLUTION

$$T_{AB} = -T_{BA} \quad (\text{use results of Problem 2.87})$$

$$(T_{AB})_x = +1125 \text{ N} \quad (T_{AB})_y = -750 \text{ N} \quad (T_{AB})_z = -450 \text{ N}$$

$$T_{AC} = -T_{CA} \quad (\text{use results of Problem 2.88})$$

$$(T_{AC})_x = +1350 \text{ N} \quad (T_{AC})_y = -900 \text{ N} \quad (T_{AC})_z = +1380 \text{ N}$$

Resultant:

$$R_x = \Sigma F_x = +1125 + 1350 = +2475 \text{ N}$$

$$R_y = \Sigma F_y = -750 - 900 = -1650 \text{ N}$$

$$R_z = \Sigma F_z = -450 + 1380 = +930 \text{ N}$$

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

$$= \sqrt{(+2475)^2 + (-1650)^2 + (+930)^2}$$

$$= 3116.6 \text{ N}$$

$$R = 3120 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{+2475}{3116.6}$$

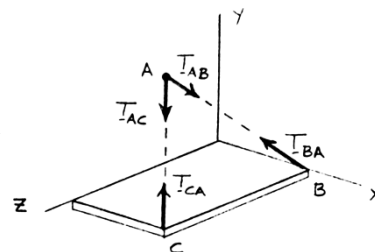
$$\theta_x = 37.4^\circ \quad \blacktriangleleft$$

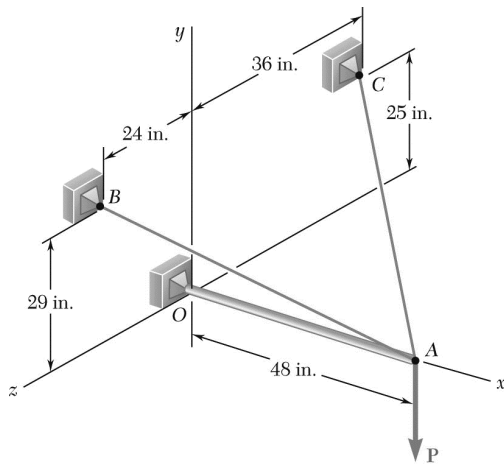
$$\cos \theta_y = \frac{R_y}{R} = \frac{-1650}{3116.6}$$

$$\theta_y = 122.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{+930}{3116.6}$$

$$\theta_z = 72.6^\circ \quad \blacktriangleleft$$

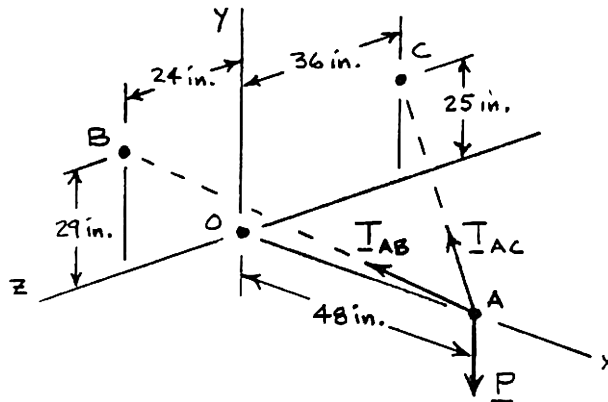




### PROBLEM 2.97

The boom  $OA$  carries a load  $\mathbf{P}$  and is supported by two cables as shown. Knowing that the tension in cable  $AB$  is 183 lb and that the resultant of the load  $\mathbf{P}$  and of the forces exerted at  $A$  by the two cables must be directed along  $OA$ , determine the tension in cable  $AC$ .

### SOLUTION



Cable  $AB$ :

$$T_{AB} = 183 \text{ lb}$$

$$\mathbf{T}_{AB} = T_{AB} \boldsymbol{\lambda}_{AB} = T_{AB} \frac{\overline{AB}}{AB} = (183 \text{ lb}) \frac{(-48 \text{ in.})\mathbf{i} + (29 \text{ in.})\mathbf{j} + (24 \text{ in.})\mathbf{k}}{61 \text{ in.}}$$

$$\mathbf{T}_{AB} = -(144 \text{ lb})\mathbf{i} + (87 \text{ lb})\mathbf{j} + (72 \text{ lb})\mathbf{k}$$

Cable  $AC$ :

$$\mathbf{T}_{AC} = T_{AC} \boldsymbol{\lambda}_{AC} = T_{AC} \frac{\overline{AC}}{AC} = T_{AC} \frac{(-48 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j} + (-36 \text{ in.})\mathbf{k}}{65 \text{ in.}}$$

$$\mathbf{T}_{AC} = -\frac{48}{65}T_{AC}\mathbf{i} + \frac{25}{65}T_{AC}\mathbf{j} - \frac{36}{65}T_{AC}\mathbf{k}$$

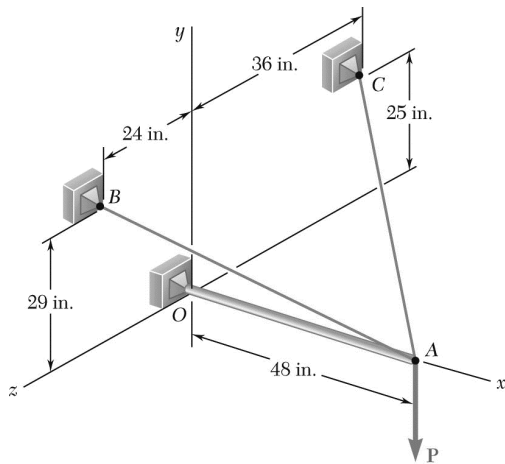
Load  $P$ :

$$\mathbf{P} = P\mathbf{j}$$

For resultant to be directed along  $OA$ , i.e.,  $x$ -axis

$$R_z = 0: \quad \Sigma F_z = (72 \text{ lb}) - \frac{36}{65}T_{AC} = 0$$

$$T_{AC} = 130.0 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.98

For the boom and loading of Problem. 2.97, determine the magnitude of the load **P**.

**PROBLEM 2.97** The boom *OA* carries a load **P** and is supported by two cables as shown. Knowing that the tension in cable *AB* is 183 lb and that the resultant of the load **P** and of the forces exerted at *A* by the two cables must be directed along *OA*, determine the tension in cable *AC*.

### SOLUTION

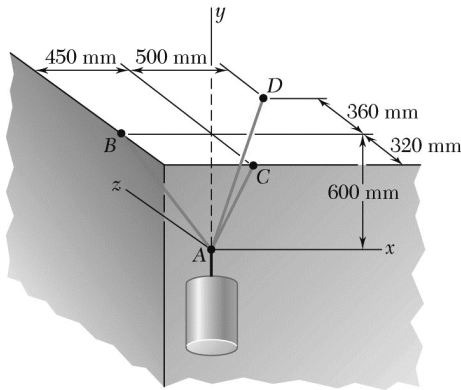
See Problem 2.97. Since resultant must be directed along *OA*, i.e., the *x*-axis, we write

$$R_y = 0: \quad \Sigma F_y = (87 \text{ lb}) + \frac{25}{65} T_{AC} - P = 0$$

$T_{AC} = 130.0 \text{ lb}$  from Problem 2.97.

$$\text{Then} \quad (87 \text{ lb}) + \frac{25}{65} (130.0 \text{ lb}) - P = 0$$

$$P = 137.0 \text{ lb} \quad \blacktriangleleft$$

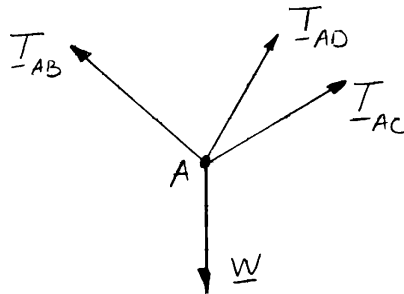


## PROBLEM 2.99

A container is supported by three cables that are attached to a ceiling as shown. Determine the weight  $W$  of the container, knowing that the tension in cable  $AB$  is 6 kN.

## SOLUTION

Free-Body Diagram at A:



The forces applied at A are:

$\mathbf{T}_{AB}$ ,  $\mathbf{T}_{AC}$ ,  $\mathbf{T}_{AD}$ , and  $\mathbf{W}$

where  $\mathbf{W} = W\mathbf{j}$ . To express the other forces in terms of the unit vectors  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ , we write

$$\overline{AB} = -(450 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} \quad AB = 750 \text{ mm}$$

$$\overline{AC} = +(600 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 680 \text{ mm}$$

$$\overline{AD} = +(500 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AD = 860 \text{ mm}$$

and

$$\begin{aligned} \mathbf{T}_{AB} &= \lambda_{AB} T_{AB} = T_{AB} \frac{\overline{AB}}{AB} = T_{AB} \frac{(-450 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j}}{750 \text{ mm}} \\ &= \left( -\frac{45}{75}\mathbf{i} + \frac{60}{75}\mathbf{j} \right) T_{AB} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AC} &= \lambda_{AC} T_{AC} = T_{AC} \frac{\overline{AC}}{AC} = T_{AC} \frac{(600 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k}}{680 \text{ mm}} \\ &= \left( \frac{60}{68}\mathbf{j} - \frac{32}{68}\mathbf{k} \right) T_{AC} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AD} &= \lambda_{AD} T_{AD} = T_{AD} \frac{\overline{AD}}{AD} = T_{AD} \frac{(500 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}}{860 \text{ mm}} \\ &= \left( \frac{50}{86}\mathbf{i} + \frac{60}{86}\mathbf{j} + \frac{36}{86}\mathbf{k} \right) T_{AD} \end{aligned}$$

**PROPRIETARY MATERIAL.** © 2013 The McGraw-Hill Companies, Inc. All rights reserved. No part of this Manual may be displayed, reproduced or distributed in any form or by any means, without the prior written permission of the publisher, or used beyond the limited distribution to teachers and educators permitted by McGraw-Hill for their individual course preparation. If you are a student using this Manual, you are using it without permission.

### PROBLEM 2.99 (Continued)

Equilibrium condition:  $\Sigma F = 0: \therefore \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{W} = 0$

Substituting the expressions obtained for  $\mathbf{T}_{AB}$ ,  $\mathbf{T}_{AC}$ , and  $\mathbf{T}_{AD}$ ; factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ ; and equating each of the coefficients to zero gives the following equations:

From  $\mathbf{i}$ : 
$$-\frac{45}{75}T_{AB} + \frac{50}{86}T_{AD} = 0 \quad (1)$$

From  $\mathbf{j}$ : 
$$\frac{60}{75}T_{AB} + \frac{60}{68}T_{AC} + \frac{60}{86}T_{AD} - W = 0 \quad (2)$$

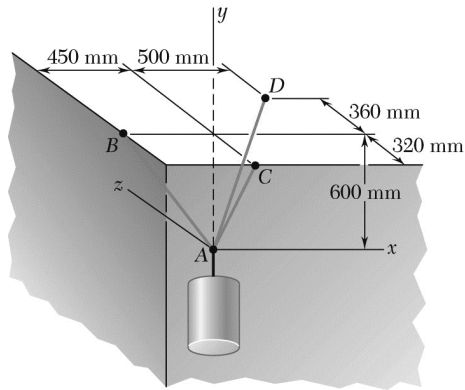
From  $\mathbf{k}$ : 
$$-\frac{32}{68}T_{AC} + \frac{36}{86}T_{AD} = 0 \quad (3)$$

Setting  $T_{AB} = 6 \text{ kN}$  in (1) and (2), and solving the resulting set of equations gives

$$T_{AC} = 6.1920 \text{ kN}$$

$$T_{AD} = 5.5080 \text{ kN}$$

$$W = 13.98 \text{ kN} \quad \blacktriangleleft$$



### PROBLEM 2.100

A container is supported by three cables that are attached to a ceiling as shown. Determine the weight  $W$  of the container, knowing that the tension in cable  $AD$  is 4.3 kN.

### SOLUTION

See Problem 2.99 for the figure and analysis leading to the following set of linear algebraic equations:

$$-\frac{45}{75}T_{AB} + \frac{50}{86}T_{AD} = 0 \quad (1)$$

$$\frac{60}{75}T_{AB} + \frac{60}{68}T_{AC} + \frac{60}{86}T_{AD} - W = 0 \quad (2)$$

$$-\frac{32}{68}T_{AC} + \frac{36}{86}T_{AD} = 0 \quad (3)$$

Setting  $T_{AD} = 4.3$  kN into the above equations gives

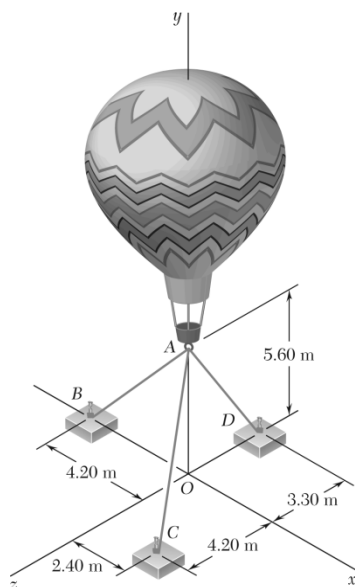
$$T_{AB} = 4.1667 \text{ kN}$$

$$T_{AC} = 3.8250 \text{ kN}$$

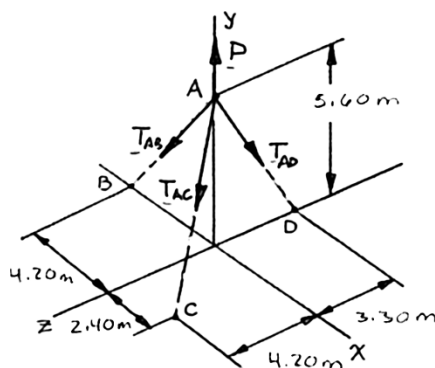
$$W = 9.71 \text{ kN} \quad \blacktriangleleft$$

## PROBLEM 2.101

Three cables are used to tether a balloon as shown. Determine the vertical force  $\mathbf{P}$  exerted by the balloon at A knowing that the tension in cable AD is 481 N.



## SOLUTION



The forces applied at A are:

$\mathbf{T}_{AB}$ ,  $\mathbf{T}_{AC}$ ,  $\mathbf{T}_{AD}$ , and  $\mathbf{P}$

where  $\mathbf{P} = P\mathbf{j}$ . To express the other forces in terms of the unit vectors  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ , we write

$$\overline{AB} = -(4.20 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} \quad AB = 7.00 \text{ m}$$

$$\overline{AC} = (2.40 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} + (4.20 \text{ m})\mathbf{k} \quad AC = 7.40 \text{ m}$$

$$\overline{AD} = -(5.60 \text{ m})\mathbf{j} - (3.30 \text{ m})\mathbf{k} \quad AD = 6.50 \text{ m}$$

and

$$\mathbf{T}_{AB} = T_{AB}\lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = (-0.6\mathbf{i} - 0.8\mathbf{j})T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC}\lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = (0.32432\mathbf{i} - 0.75676\mathbf{j} + 0.56757\mathbf{k})T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD}\lambda_{AD} = T_{AD} \frac{\overline{AD}}{AD} = (-0.86154\mathbf{j} - 0.50769\mathbf{k})T_{AD}$$



### PROBLEM 2.101 (Continued)

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

Substituting the expressions obtained for  $\mathbf{T}_{AB}$ ,  $\mathbf{T}_{AC}$ , and  $\mathbf{T}_{AD}$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ :

$$(-0.6T_{AB} + 0.32432T_{AC})\mathbf{i} + (-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P)\mathbf{j} \\ + (0.56757T_{AC} - 0.50769T_{AD})\mathbf{k} = 0$$

Equating to zero the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \quad (1)$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \quad (2)$$

$$0.56757T_{AC} - 0.50769T_{AD} = 0 \quad (3)$$

Setting  $T_{AD} = 481 \text{ N}$  in (2) and (3), and solving the resulting set of equations gives

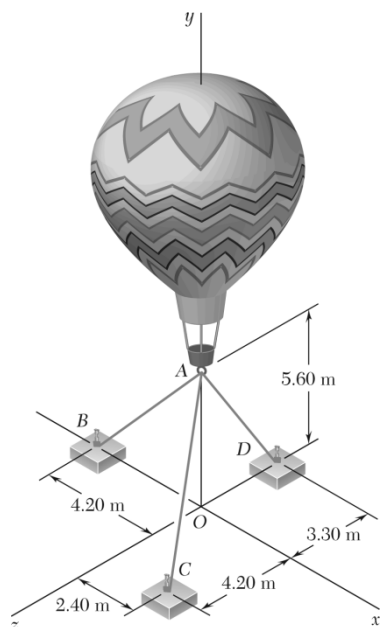
$$T_{AC} = 430.26 \text{ N}$$

$$T_{AD} = 232.57 \text{ N}$$

$$\mathbf{P} = 926 \text{ N} \uparrow \blacktriangleleft$$

## PROBLEM 2.102

Three cables are used to tether a balloon as shown. Knowing that the balloon exerts an 800-N vertical force at A, determine the tension in each cable.



## SOLUTION

See Problem 2.101 for the figure and analysis leading to the linear algebraic Equations (1), (2), and (3).

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \quad (1)$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \quad (2)$$

$$0.56757T_{AC} - 0.50769T_{AD} = 0 \quad (3)$$

From Eq. (1):  $T_{AB} = 0.54053T_{AC}$

From Eq. (3):  $T_{AD} = 1.11795T_{AC}$

Substituting for  $T_{AB}$  and  $T_{AD}$  in terms of  $T_{AC}$  into Eq. (2) gives

$$-0.8(0.54053T_{AC}) - 0.75676T_{AC} - 0.86154(1.11795T_{AC}) + P = 0$$

$$2.1523T_{AC} = P; \quad P = 800 \text{ N}$$

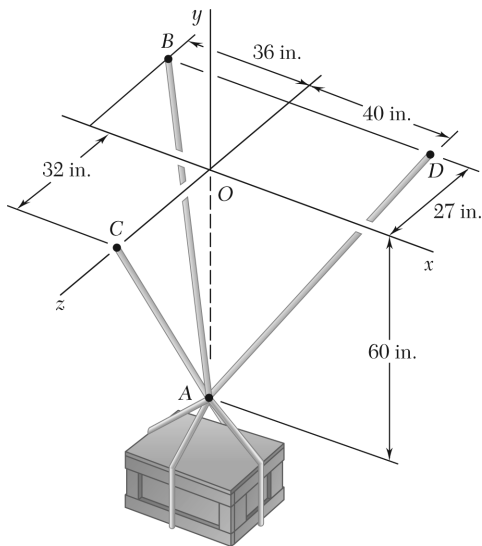
$$T_{AC} = \frac{800 \text{ N}}{2.1523} \\ = 371.69 \text{ N}$$

Substituting into expressions for  $T_{AB}$  and  $T_{AD}$  gives

$$T_{AB} = 0.54053(371.69 \text{ N})$$

$$T_{AD} = 1.11795(371.69 \text{ N})$$

$$T_{AB} = 201 \text{ N}, \quad T_{AC} = 372 \text{ N}, \quad T_{AD} = 416 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.103

A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable AB is 750 lb.

### SOLUTION

The forces applied at A are:

$$\mathbf{T}_{AB}, \mathbf{T}_{AC}, \mathbf{T}_{AD} \text{ and } \mathbf{W}$$

where  $\mathbf{P} = P\mathbf{j}$ . To express the other forces in terms of the unit vectors  $\mathbf{i}, \mathbf{j}, \mathbf{k}$ , we write

$$\overline{AB} = -(36 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (27 \text{ in.})\mathbf{k}$$

$$AB = 75 \text{ in.}$$

$$\overline{AC} = (60 \text{ in.})\mathbf{j} + (32 \text{ in.})\mathbf{k}$$

$$AC = 68 \text{ in.}$$

$$\overline{AD} = (40 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j} - (27 \text{ in.})\mathbf{k}$$

$$AD = 77 \text{ in.}$$

and

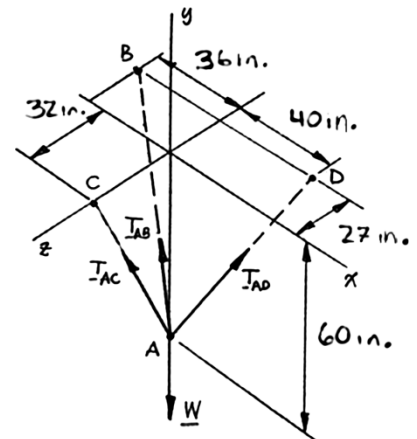
$$\begin{aligned} \mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} \\ &= (-0.48\mathbf{i} + 0.8\mathbf{j} - 0.36\mathbf{k})T_{AB} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} \\ &= (0.88235\mathbf{j} + 0.47059\mathbf{k})T_{AC} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = T_{AD} \frac{\overline{AD}}{AD} \\ &= (0.51948\mathbf{i} + 0.77922\mathbf{j} - 0.35065\mathbf{k})T_{AD} \end{aligned}$$

Equilibrium Condition with  $\mathbf{W} = -W\mathbf{j}$

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



### PROBLEM 2.103 (Continued)

Substituting the expressions obtained for  $T_{AB}$ ,  $T_{AC}$ , and  $T_{AD}$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ :

$$(-0.48T_{AB} + 0.51948T_{AD})\mathbf{i} + (0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W)\mathbf{j} \\ + (-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD})\mathbf{k} = 0$$

Equating to zero the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

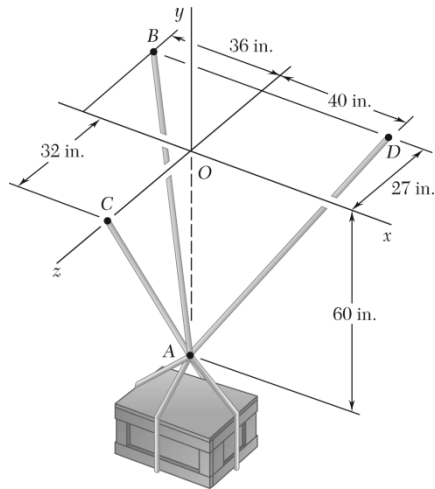
$$\begin{aligned} -0.48T_{AB} + 0.51948T_{AD} &= 0 \\ 0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W &= 0 \\ -0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} &= 0 \end{aligned}$$

Substituting  $T_{AB} = 750$  lb in Equations (1), (2), and (3) and solving the resulting set of equations, using conventional algorithms for solving linear algebraic equations, gives:

$$T_{AC} = 1090.1 \text{ lb}$$

$$T_{AD} = 693 \text{ lb}$$

$$W = 2100 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.104

A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable  $AD$  is 616 lb.

### SOLUTION

See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.48T_{AB} + 0.51948T_{AD} = 0 \quad (1)$$

$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0 \quad (2)$$

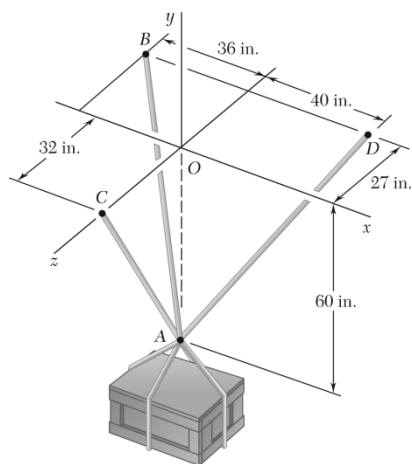
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0 \quad (3)$$

Substituting  $T_{AD} = 616$  lb in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$$T_{AB} = 667.67 \text{ lb}$$

$$T_{AC} = 969.00 \text{ lb}$$

$$W = 1868 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.105

A crate is supported by three cables as shown. Determine the weight of the crate knowing that the tension in cable AC is 544 lb.

### SOLUTION

See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.48T_{AB} + 0.51948T_{AD} = 0 \quad (1)$$

$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0 \quad (2)$$

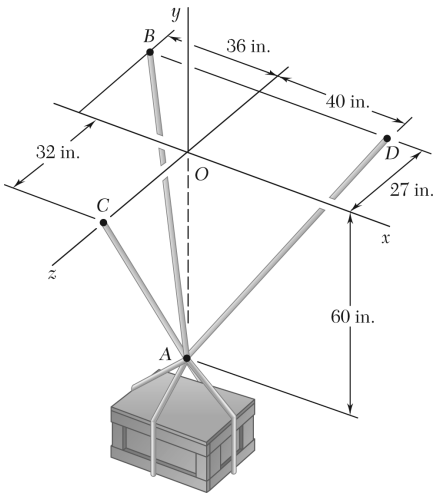
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0 \quad (3)$$

Substituting  $T_{AC} = 544$  lb in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$$T_{AB} = 374.27 \text{ lb}$$

$$T_{AD} = 345.82 \text{ lb}$$

$$W = 1049 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.106

A 1600-lb crate is supported by three cables as shown. Determine the tension in each cable.

### SOLUTION

See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.48T_{AB} + 0.51948T_{AD} = 0 \quad (1)$$

$$0.8T_{AB} + 0.88235T_{AC} + 0.77922T_{AD} - W = 0 \quad (2)$$

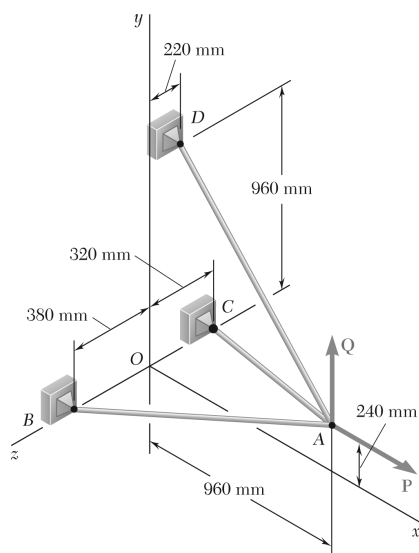
$$-0.36T_{AB} + 0.47059T_{AC} - 0.35065T_{AD} = 0 \quad (3)$$

Substituting  $W = 1600$  lb in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives

$$T_{AB} = 571 \text{ lb} \quad \blacktriangleleft$$

$$T_{AC} = 830 \text{ lb} \quad \blacktriangleleft$$

$$T_{AD} = 528 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.107

Three cables are connected at A, where the forces  $\mathbf{P}$  and  $\mathbf{Q}$  are applied as shown. Knowing that  $Q = 0$ , find the value of  $P$  for which the tension in cable AD is 305 N.

### SOLUTION

$$\Sigma \mathbf{F}_A = 0: \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{P} = 0 \quad \text{where} \quad \mathbf{P} = P\mathbf{i}$$

$$\overline{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overline{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\overline{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \quad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = T_{AB} \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right)$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = T_{AC} \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right)$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = \frac{305 \text{ N}}{1220 \text{ mm}} [(-960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k}] \\ &= -(240 \text{ N})\mathbf{i} + (180 \text{ N})\mathbf{j} - (55 \text{ N})\mathbf{k} \end{aligned}$$

Substituting into  $\Sigma \mathbf{F}_A = 0$ , factoring  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ , and setting each coefficient equal to  $\phi$  gives:

$$\mathbf{i}: P = \frac{48}{53}T_{AB} + \frac{12}{13}T_{AC} + 240 \text{ N} \quad (1)$$

$$\mathbf{j}: \frac{12}{53}T_{AB} + \frac{3}{13}T_{AC} = 180 \text{ N} \quad (2)$$

$$\mathbf{k}: \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 55 \text{ N} \quad (3)$$

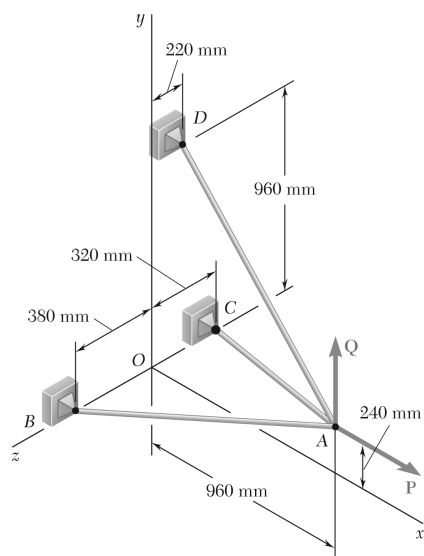
Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 446.71 \text{ N}$$

$$T_{AC} = 341.71 \text{ N}$$

$$P = 960 \text{ N} \quad \blacktriangleleft$$





## PROBLEM 2.108

Three cables are connected at A, where the forces **P** and **Q** are applied as shown. Knowing that  $P = 1200$  N, determine the values of  $Q$  for which cable AD is taut.

## SOLUTION

We assume that  $T_{AD} = 0$  and write  $\Sigma \mathbf{F}_A = 0$ :  $\mathbf{T}_{AB} + \mathbf{T}_{AC} + Q\mathbf{j} + (1200 \text{ N})\mathbf{i} = 0$

$$\overline{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overline{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right) T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right) T_{AC}$$

Substituting into  $\Sigma \mathbf{F}_A = 0$ , factoring **i**, **j**, **k**, and setting each coefficient equal to  $\phi$  gives:

$$\mathbf{i}: -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} + 1200 \text{ N} = 0 \quad (1)$$

$$\mathbf{j}: -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + Q = 0 \quad (2)$$

$$\mathbf{k}: \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 0 \quad (3)$$

Solving the resulting system of linear equations using conventional algorithms gives:

$$T_{AB} = 605.71 \text{ N}$$

$$T_{AC} = 705.71 \text{ N}$$

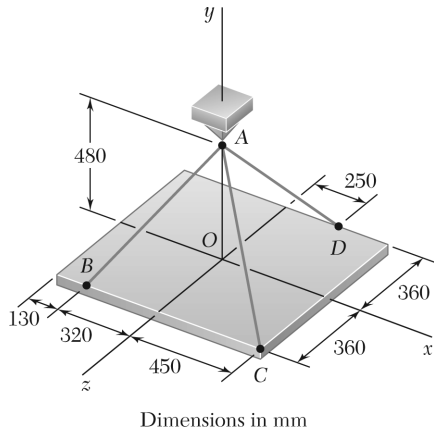
$$Q = 300.00 \text{ N}$$

$$0 \leq Q < 300 \text{ N} \quad \blacktriangleleft$$

*Note:* This solution assumes that  $Q$  is directed upward as shown ( $Q \geq 0$ ), if negative values of  $Q$  are considered, cable AD remains taut, but AC becomes slack for  $Q = -460$  N.

## PROBLEM 2.109

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable AC is 60 N, determine the weight of the plate.



## SOLUTION

We note that the weight of the plate is equal in magnitude to the force  $\mathbf{P}$  exerted by the support on Point A.

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

We have:

$$\overline{AB} = -(320 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AB = 680 \text{ mm}$$

$$\overline{AC} = (450 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AC = 750 \text{ mm}$$

$$\overline{AD} = (250 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} - (360 \text{ mm})\mathbf{k} \quad AD = 650 \text{ mm}$$

Thus:

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = \left( -\frac{8}{17}\mathbf{i} - \frac{12}{17}\mathbf{j} + \frac{9}{17}\mathbf{k} \right) T_{AB}$$

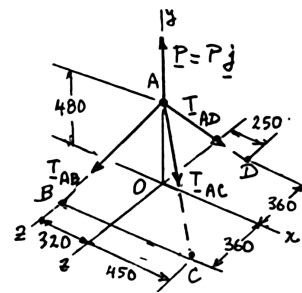
$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = (0.6\mathbf{i} - 0.64\mathbf{j} + 0.48\mathbf{k}) T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overline{AD}}{AD} = \left( \frac{5}{13}\mathbf{i} - \frac{9.6}{13}\mathbf{j} - \frac{7.2}{13}\mathbf{k} \right) T_{AD}$$

Substituting into the Eq.  $\Sigma \mathbf{F} = 0$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$\begin{aligned} & \left( -\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} \right) \mathbf{i} \\ & + \left( -\frac{12}{17}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P \right) \mathbf{j} \\ & + \left( \frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} \right) \mathbf{k} = 0 \end{aligned}$$

Free Body A:



### PROBLEM 2.109 (Continued)

Setting the coefficient of **i**, **j**, **k** equal to zero:

$$\mathbf{i}: \quad -\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \quad (1)$$

$$\mathbf{j}: \quad -\frac{12}{7}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P = 0 \quad (2)$$

$$\mathbf{k}: \quad \frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \quad (3)$$

Making  $T_{AC} = 60 \text{ N}$  in (1) and (3):

$$-\frac{8}{17}T_{AB} + 36 \text{ N} + \frac{5}{13}T_{AD} = 0 \quad (1')$$

$$\frac{9}{17}T_{AB} + 28.8 \text{ N} - \frac{7.2}{13}T_{AD} = 0 \quad (3')$$

Multiply (1') by 9, (3') by 8, and add:

$$554.4 \text{ N} - \frac{12.6}{13}T_{AD} = 0 \quad T_{AD} = 572.0 \text{ N}$$

Substitute into (1') and solve for  $T_{AB}$ :

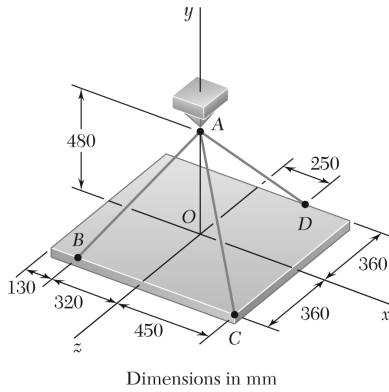
$$T_{AB} = \frac{17}{8} \left( 36 + \frac{5}{13} \times 572 \right) \quad T_{AB} = 544.0 \text{ N}$$

Substitute for the tensions in Eq. (2) and solve for  $P$ :

$$\begin{aligned} P &= \frac{12}{17}(544 \text{ N}) + 0.64(60 \text{ N}) + \frac{9.6}{13}(572 \text{ N}) \\ &= 844.8 \text{ N} \end{aligned}$$

Weight of plate =  $P = 845 \text{ N}$  ◀

### PROBLEM 2.110



A rectangular plate is supported by three cables as shown. Knowing that the tension in cable  $AD$  is 520 N, determine the weight of the plate.

### SOLUTION

See Problem 2.109 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \quad (1)$$

$$-\frac{12}{17}T_{AB} + 0.64T_{AC} - \frac{9.6}{13}T_{AD} + P = 0 \quad (2)$$

$$\frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \quad (3)$$

Making  $T_{AD} = 520$  N in Eqs. (1) and (3):

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + 200 \text{ N} = 0 \quad (1')$$

$$\frac{9}{17}T_{AB} + 0.48T_{AC} - 288 \text{ N} = 0 \quad (3')$$

Multiply (1') by 9, (3') by 8, and add:

$$9.24T_{AC} - 504 \text{ N} = 0 \quad T_{AC} = 54.5455 \text{ N}$$

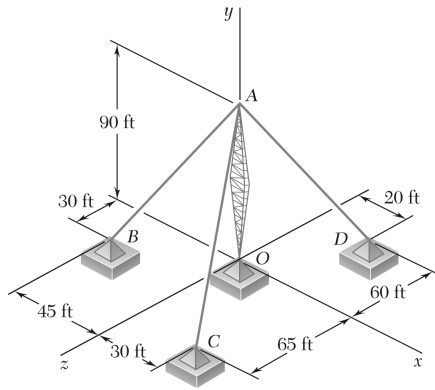
Substitute into (1') and solve for  $T_{AB}$ :

$$T_{AB} = \frac{17}{8}(0.6 \times 54.5455 + 200) \quad T_{AB} = 494.545 \text{ N}$$

Substitute for the tensions in Eq. (2) and solve for  $P$ :

$$\begin{aligned} P &= \frac{12}{17}(494.545 \text{ N}) + 0.64(54.5455 \text{ N}) + \frac{9.6}{13}(520 \text{ N}) \\ &= 768.00 \text{ N} \end{aligned}$$

Weight of plate =  $P = 768$  N ◀



### 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 630 lb, determine the vertical force **P** exerted by the tower on the pin at A.

### SOLUTION

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

$$\overline{AB} = -45\mathbf{i} - 90\mathbf{j} + 30\mathbf{k} \quad AB = 105 \text{ ft}$$

$$\overline{AC} = 30\mathbf{i} - 90\mathbf{j} + 65\mathbf{k} \quad AC = 115 \text{ ft}$$

$$\overline{AD} = 20\mathbf{i} - 90\mathbf{j} - 60\mathbf{k} \quad AD = 110 \text{ ft}$$

We write

$$\begin{aligned} \mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} \\ &= \left( -\frac{3}{7}\mathbf{i} - \frac{6}{7}\mathbf{j} + \frac{2}{7}\mathbf{k} \right) T_{AB} \end{aligned}$$

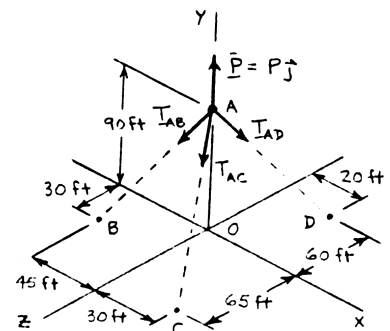
$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} \\ &= \left( \frac{6}{23}\mathbf{i} - \frac{18}{23}\mathbf{j} + \frac{13}{23}\mathbf{k} \right) T_{AC} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = T_{AD} \frac{\overline{AD}}{AD} \\ &= \left( \frac{2}{11}\mathbf{i} - \frac{9}{11}\mathbf{j} - \frac{6}{11}\mathbf{k} \right) T_{AD} \end{aligned}$$

Substituting into the Eq.  $\Sigma \mathbf{F} = 0$  and factoring **i**, **j**, **k**:

$$\begin{aligned} &\left( -\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} \right) \mathbf{i} \\ &+ \left( -\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P \right) \mathbf{j} \\ &+ \left( \frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} \right) \mathbf{k} = 0 \end{aligned}$$

### Free Body A:



### PROBLEM 2.111 (Continued)

Setting the coefficients of **i**, **j**, **k**, equal to zero:

$$\mathbf{i}: \quad -\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \quad (1)$$

$$\mathbf{j}: \quad -\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \quad (2)$$

$$\mathbf{k}: \quad \frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \quad (3)$$

Set  $T_{AB} = 630$  lb in Eqs. (1) – (3):

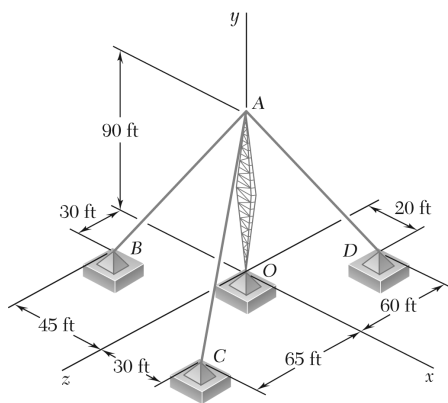
$$-270 \text{ lb} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \quad (1')$$

$$-540 \text{ lb} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \quad (2')$$

$$180 \text{ lb} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \quad (3')$$

Solving,  $T_{AC} = 467.42$  lb  $T_{AD} = 814.35$  lb  $P = 1572.10$  lb

$P = 1572$  lb ◀



## 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 920 lb, determine the vertical force **P** exerted by the tower on the pin at A.

## SOLUTION

See Problem 2.111 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \quad (1)$$

$$-\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \quad (2)$$

$$\frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \quad (3)$$

Substituting for  $T_{AC} = 920$  lb in Equations (1), (2), and (3) above and solving the resulting set of equations using conventional algorithms gives:

$$-\frac{3}{7}T_{AB} + 240 \text{ lb} + \frac{2}{11}T_{AD} = 0 \quad (1')$$

$$-\frac{6}{7}T_{AB} - 720 \text{ lb} - \frac{9}{11}T_{AD} + P = 0 \quad (2')$$

$$\frac{2}{7}T_{AB} + 520 \text{ lb} - \frac{6}{11}T_{AD} = 0 \quad (3')$$

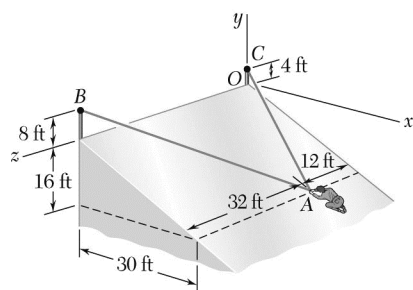
Solving,

$$T_{AB} = 1240.00 \text{ lb}$$

$$T_{AD} = 1602.86 \text{ lb}$$

$$P = 3094.3 \text{ lb}$$

$$P = 3090 \text{ lb} \quad \blacktriangleleft$$

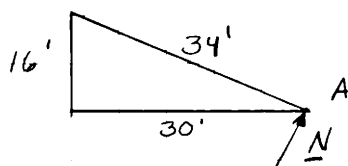
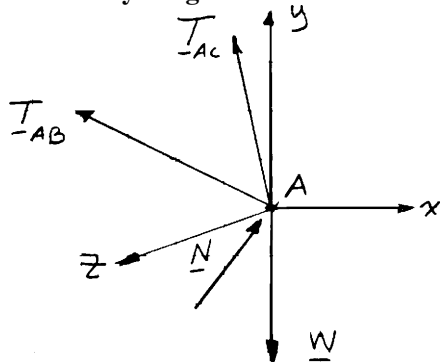


### PROBLEM 2.113

In trying to move across a slippery icy surface, a 180-lb man uses two ropes  $AB$  and  $AC$ . Knowing that the force exerted on the man by the icy surface is perpendicular to that surface, determine the tension in each rope.

### SOLUTION

#### Free-Body Diagram at A



$$\mathbf{N} = N \left( \frac{16}{34} \mathbf{i} + \frac{30}{34} \mathbf{j} \right)$$

and  $\mathbf{W} = W \mathbf{j} = -(180 \text{ lb}) \mathbf{j}$

$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = T_{AC} \frac{(-30 \text{ ft}) \mathbf{i} + (20 \text{ ft}) \mathbf{j} - (12 \text{ ft}) \mathbf{k}}{38 \text{ ft}} \\ &= T_{AC} \left( -\frac{15}{19} \mathbf{i} + \frac{10}{19} \mathbf{j} - \frac{6}{19} \mathbf{k} \right) \\ \mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = T_{AB} \frac{(-30 \text{ ft}) \mathbf{i} + (24 \text{ ft}) \mathbf{j} + (32 \text{ ft}) \mathbf{k}}{50 \text{ ft}} \\ &= T_{AB} \left( -\frac{15}{25} \mathbf{i} + \frac{12}{25} \mathbf{j} + \frac{16}{25} \mathbf{k} \right) \end{aligned}$$

Equilibrium condition:  $\Sigma \mathbf{F} = 0$

$$\mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{N} + \mathbf{W} = 0$$



### PROBLEM 2.113 (Continued)

Substituting the expressions obtained for  $T_{AB}$ ,  $T_{AC}$ ,  $N$ , and  $W$ ; factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ ; and equating each of the coefficients to zero gives the following equations:

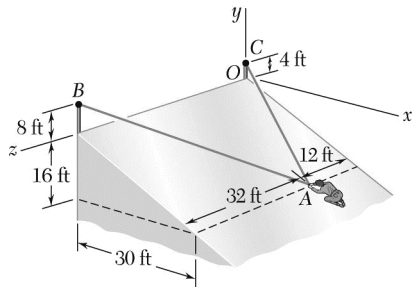
$$\text{From } \mathbf{i}: \quad -\frac{15}{25}T_{AB} - \frac{15}{19}T_{AC} + \frac{16}{34}N = 0 \quad (1)$$

$$\text{From } \mathbf{j}: \quad \frac{12}{25}T_{AB} + \frac{10}{19}T_{AC} + \frac{30}{34}N - (180 \text{ lb}) = 0 \quad (2)$$

$$\text{From } \mathbf{k}: \quad \frac{16}{25}T_{AB} - \frac{6}{19}T_{AC} = 0 \quad (3)$$

Solving the resulting set of equations gives:

$$T_{AB} = 31.7 \text{ lb}; \quad T_{AC} = 64.3 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.114

Solve Problem 2.113, assuming that a friend is helping the man at A by pulling on him with a force  $\mathbf{P} = -(60 \text{ lb})\mathbf{k}$ .

**PROBLEM 2.113** In trying to move across a slippery icy surface, a 180-lb man uses two ropes AB and AC. Knowing that the force exerted on the man by the icy surface is perpendicular to that surface, determine the tension in each rope.

### SOLUTION

Refer to Problem 2.113 for the figure and analysis leading to the following set of equations, Equation (3) being modified to include the additional force  $\mathbf{P} = -(60 \text{ lb})\mathbf{k}$ .

$$-\frac{15}{25}T_{AB} - \frac{15}{19}T_{AC} + \frac{16}{34}N = 0 \quad (1)$$

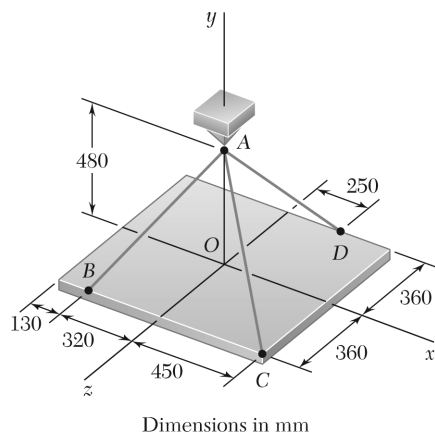
$$\frac{12}{25}T_{AB} + \frac{10}{19}T_{AC} + \frac{30}{34}N - (180 \text{ lb}) = 0 \quad (2)$$

$$\frac{16}{25}T_{AB} - \frac{6}{19}T_{AC} - (60 \text{ lb}) = 0 \quad (3)$$

Solving the resulting set of equations simultaneously gives:

$$T_{AB} = 99.0 \text{ lb} \quad \blacktriangleleft$$

$$T_{AC} = 10.55 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.115

For the rectangular plate of Problems 2.109 and 2.110, determine the tension in each of the three cables knowing that the weight of the plate is 792 N.

### SOLUTION

See Problem 2.109 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below. Setting  $P = 792 \text{ N}$  gives:

$$-\frac{8}{17}T_{AB} + 0.6T_{AC} + \frac{5}{13}T_{AD} = 0 \quad (1)$$

$$-\frac{12}{17}T_{AB} - 0.64T_{AC} - \frac{9.6}{13}T_{AD} + 792 \text{ N} = 0 \quad (2)$$

$$\frac{9}{17}T_{AB} + 0.48T_{AC} - \frac{7.2}{13}T_{AD} = 0 \quad (3)$$

Solving Equations (1), (2), and (3) by conventional algorithms gives

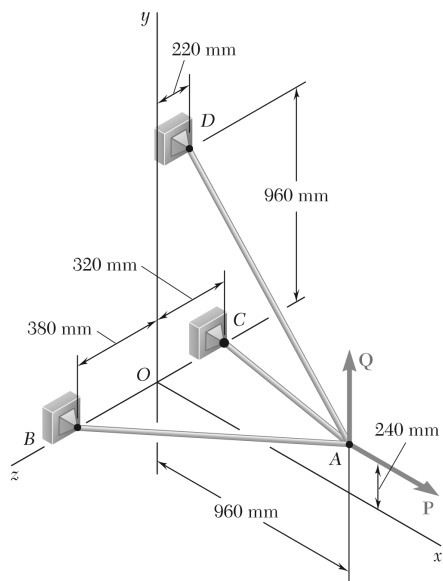
$$T_{AB} = 510.00 \text{ N} \quad T_{AB} = 510 \text{ N} \quad \blacktriangleleft$$

$$T_{AC} = 56.250 \text{ N} \quad T_{AC} = 56.2 \text{ N} \quad \blacktriangleleft$$

$$T_{AD} = 536.25 \text{ N} \quad T_{AD} = 536 \text{ N} \quad \blacktriangleleft$$

## PROBLEM 2.116

For the cable system of Problems 2.107 and 2.108, determine the tension in each cable knowing that  $P = 2880 \text{ N}$  and  $Q = 0$ .



## SOLUTION

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

Where

$$\mathbf{P} = P\mathbf{i} \text{ and } \mathbf{Q} = Q\mathbf{j}$$

$$\overline{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overline{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\overline{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \quad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overline{AB}}{AB} = T_{AB} \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right)$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overline{AC}}{AC} = T_{AC} \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right)$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overline{AD}}{AD} = T_{AD} \left( -\frac{48}{61}\mathbf{i} + \frac{36}{61}\mathbf{j} - \frac{11}{61}\mathbf{k} \right)$$

Substituting into  $\Sigma \mathbf{F}_A = 0$ , setting  $P = (2880 \text{ N})\mathbf{i}$  and  $Q = 0$ , and setting the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$  equal to 0, we obtain the following three equilibrium equations:

$$\mathbf{i}: -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \quad (1)$$

$$\mathbf{j}: -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} = 0 \quad (2)$$

$$\mathbf{k}: \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3)$$

**PROPRIETARY MATERIAL.** © 2013 The McGraw-Hill Companies, Inc. All rights reserved. No part of this Manual may be displayed, reproduced or distributed in any form or by any means, without the prior written permission of the publisher, or used beyond the limited distribution to teachers and educators permitted by McGraw-Hill for their individual course preparation. If you are a student using this Manual, you are using it without permission.

### PROBLEM 2.116 (Continued)

Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 1340.14 \text{ N}$$

$$T_{AC} = 1025.12 \text{ N}$$

$$T_{AD} = 915.03 \text{ N}$$

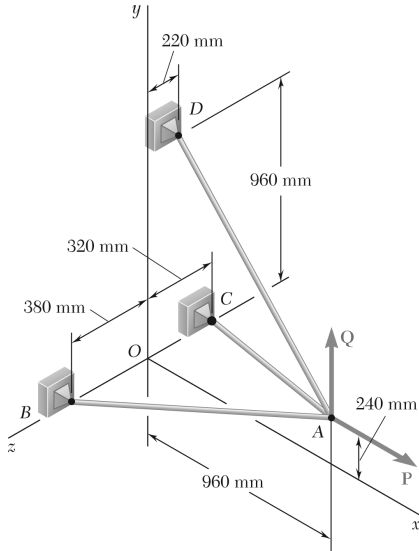
$$T_{AB} = 1340 \text{ N} \quad \blacktriangleleft$$

$$T_{AC} = 1025 \text{ N} \quad \blacktriangleleft$$

$$T_{AD} = 915 \text{ N} \quad \blacktriangleleft$$

### PROBLEM 2.117

For the cable system of Problems 2.107 and 2.108, determine the tension in each cable knowing that  $P = 2880 \text{ N}$  and  $Q = 576 \text{ N}$ .



### SOLUTION

See Problem 2.116 for the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + P = 0 \quad (1)$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + Q = 0 \quad (2)$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3)$$

Setting  $P = 2880 \text{ N}$  and  $Q = 576 \text{ N}$  gives:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \quad (1')$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + 576 \text{ N} = 0 \quad (2')$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3')$$

Solving the resulting set of equations using conventional algorithms gives:

$$T_{AB} = 1431.00 \text{ N}$$

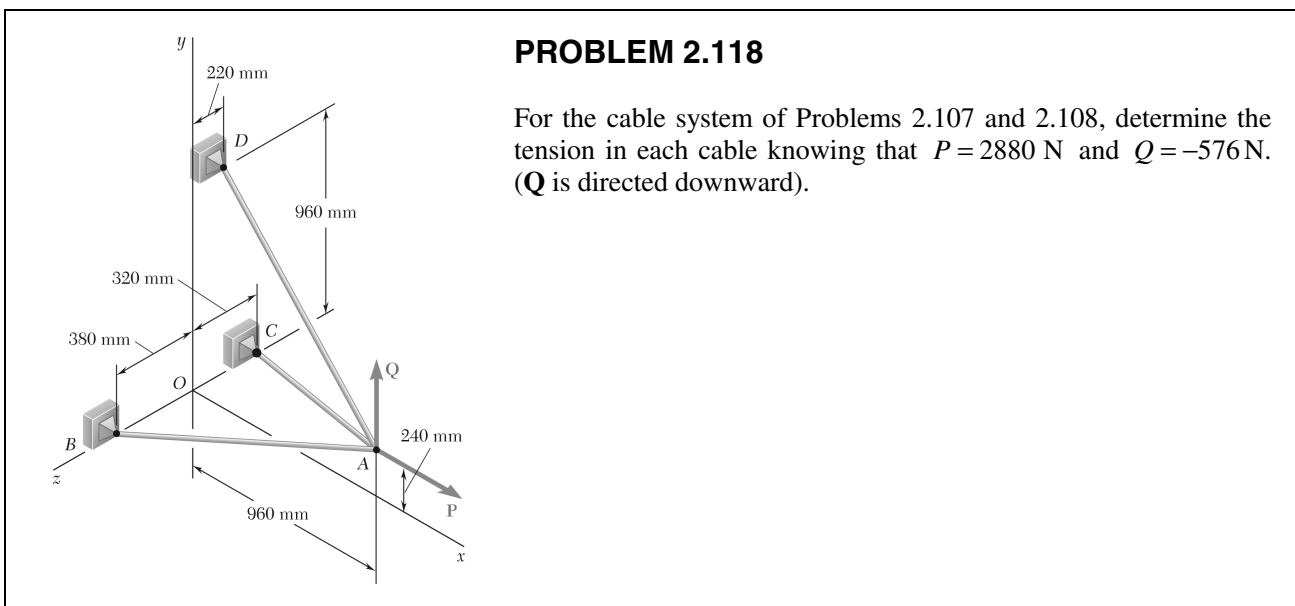
$$T_{AC} = 1560.00 \text{ N}$$

$$T_{AD} = 183.010 \text{ N}$$

$$T_{AB} = 1431 \text{ N} \quad \blacktriangleleft$$

$$T_{AC} = 1560 \text{ N} \quad \blacktriangleleft$$

$$T_{AD} = 183.0 \text{ N} \quad \blacktriangleleft$$



### SOLUTION

See Problem 2.116 for the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + P = 0 \quad (1)$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} + Q = 0 \quad (2)$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3)$$

Setting  $P = 2880 \text{ N}$  and  $Q = -576 \text{ N}$  gives:

$$-\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \quad (1')$$

$$-\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} - 576 \text{ N} = 0 \quad (2')$$

$$\frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3')$$

Solving the resulting set of equations using conventional algorithms gives:

$$T_{AB} = 1249.29 \text{ N}$$

$$T_{AC} = 490.31 \text{ N}$$

$$T_{AD} = 1646.97 \text{ N}$$

$$T_{AB} = 1249 \text{ N} \quad \blacktriangleleft$$

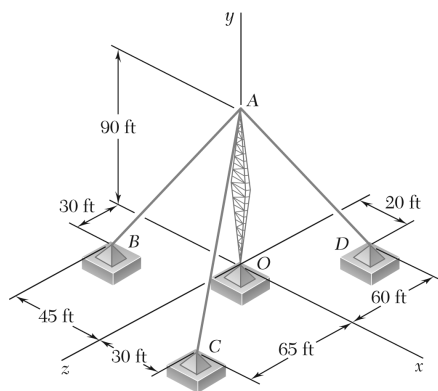
$$T_{AC} = 490 \text{ N} \quad \blacktriangleleft$$

$$T_{AD} = 1647 \text{ N} \quad \blacktriangleleft$$

**PROPRIETARY MATERIAL.** © 2013 The McGraw-Hill Companies, Inc. All rights reserved. No part of this Manual may be displayed, reproduced or distributed in any form or by any means, without the prior written permission of the publisher, or used beyond the limited distribution to teachers and educators permitted by McGraw-Hill for their individual course preparation. If you are a student using this Manual, you are using it without permission.

### PROBLEM 2.119

For the transmission tower of Problems 2.111 and 2.112, determine the tension in each guy wire knowing that the tower exerts on the pin at A an upward vertical force of 2100 lb.



### SOLUTION

See Problem 2.111 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \quad (1)$$

$$-\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + P = 0 \quad (2)$$

$$\frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \quad (3)$$

Substituting for  $P = 2100$  lb in Equations (1), (2), and (3) above and solving the resulting set of equations using conventional algorithms gives:

$$-\frac{3}{7}T_{AB} + \frac{6}{23}T_{AC} + \frac{2}{11}T_{AD} = 0 \quad (1')$$

$$-\frac{6}{7}T_{AB} - \frac{18}{23}T_{AC} - \frac{9}{11}T_{AD} + 2100 \text{ lb} = 0 \quad (2')$$

$$\frac{2}{7}T_{AB} + \frac{13}{23}T_{AC} - \frac{6}{11}T_{AD} = 0 \quad (3')$$

$$T_{AB} = 841.55 \text{ lb}$$

$$T_{AC} = 624.38 \text{ lb}$$

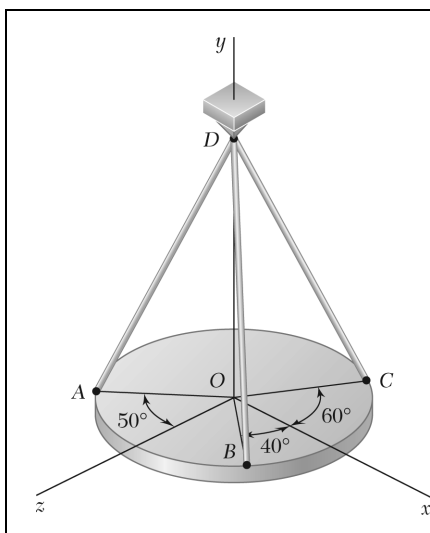
$$T_{AD} = 1087.81 \text{ lb}$$

$$T_{AB} = 842 \text{ lb} \quad \blacktriangleleft$$

$$T_{AC} = 624 \text{ lb} \quad \blacktriangleleft$$

$$T_{AD} = 1088 \text{ lb} \quad \blacktriangleleft$$

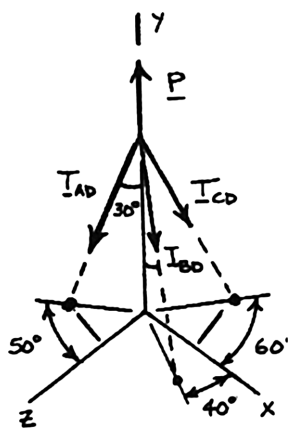




### PROBLEM 2.120

A horizontal circular plate weighing 60 lb is suspended as shown from three wires that are attached to a support at  $D$  and form  $30^\circ$  angles with the vertical. Determine the tension in each wire.

### SOLUTION



$$\Sigma F_x = 0:$$

$$-T_{AD}(\sin 30^\circ)(\sin 50^\circ) + T_{BD}(\sin 30^\circ)(\cos 40^\circ) + T_{CD}(\sin 30^\circ)(\cos 60^\circ) = 0$$

Dividing through by  $\sin 30^\circ$  and evaluating:

$$-0.76604T_{AD} + 0.76604T_{BD} + 0.5T_{CD} = 0 \quad (1)$$

$$\Sigma F_y = 0: -T_{AD}(\cos 30^\circ) - T_{BD}(\cos 30^\circ) - T_{CD}(\cos 30^\circ) + 60 \text{ lb} = 0$$

$$\text{or} \quad T_{AD} + T_{BD} + T_{CD} = 69.282 \text{ lb} \quad (2)$$

$$\Sigma F_z = 0: T_{AD} \sin 30^\circ \cos 50^\circ + T_{BD} \sin 30^\circ \sin 40^\circ - T_{CD} \sin 30^\circ \sin 60^\circ = 0$$

$$\text{or} \quad 0.64279T_{AD} + 0.64279T_{BD} - 0.86603T_{CD} = 0 \quad (3)$$

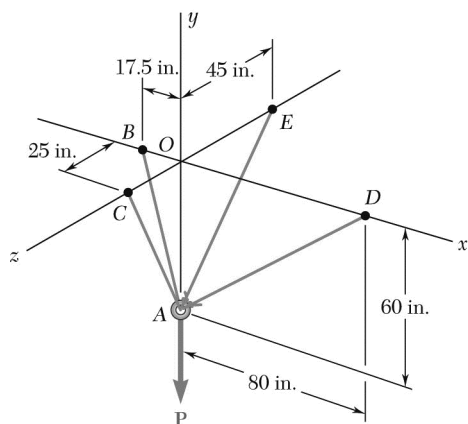
Solving Equations (1), (2), and (3) simultaneously:

$$T_{AD} = 29.5 \text{ lb} \quad \blacktriangleleft$$

$$T_{BD} = 10.25 \text{ lb} \quad \blacktriangleleft$$

$$T_{CD} = 29.5 \text{ lb} \quad \blacktriangleleft$$

### PROBLEM 2.121



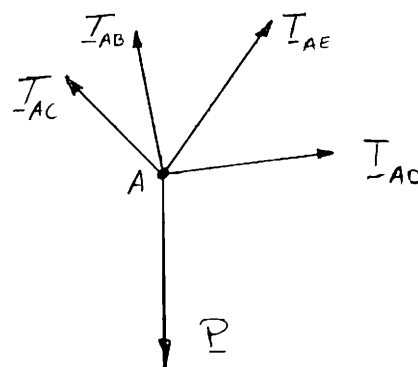
Cable  $BAC$  passes through a frictionless ring  $A$  and is attached to fixed supports at  $B$  and  $C$ , while cables  $AD$  and  $AE$  are both tied to the ring and are attached, respectively, to supports at  $D$  and  $E$ . Knowing that a 200-lb vertical load  $\mathbf{P}$  is applied to ring  $A$ , determine the tension in each of the three cables.

### SOLUTION

Since  $T_{BAC}$  = tension in cable  $BAC$ , it follows that

$$T_{AB} = T_{AC} = T_{BAC}$$

Free Body Diagram at  $A$ :



$$\mathbf{T}_{AB} = T_{BAC} \lambda_{AB} = T_{BAC} \frac{(-17.5 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j}}{62.5 \text{ in.}} = T_{BAC} \left( \frac{-17.5}{62.5} \mathbf{i} + \frac{60}{62.5} \mathbf{j} \right)$$

$$\mathbf{T}_{AC} = T_{BAC} \lambda_{AC} = T_{BAC} \frac{(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{k}}{65 \text{ in.}} = T_{BAC} \left( \frac{60}{65} \mathbf{j} + \frac{25}{65} \mathbf{k} \right)$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{(80 \text{ in.})\mathbf{i} + (60 \text{ in.})\mathbf{j}}{100 \text{ in.}} = T_{AD} \left( \frac{4}{5} \mathbf{i} + \frac{3}{5} \mathbf{j} \right)$$

$$\mathbf{T}_{AE} = T_{AE} \lambda_{AE} = T_{AE} \frac{(60 \text{ in.})\mathbf{j} - (45 \text{ in.})\mathbf{k}}{75 \text{ in.}} = T_{AE} \left( \frac{4}{5} \mathbf{j} - \frac{3}{5} \mathbf{k} \right)$$

### PROBLEM 2.121 (Continued)

Substituting into  $\Sigma \mathbf{F}_A = 0$ , setting  $\mathbf{P} = (-200 \text{ lb})\mathbf{j}$ , and setting the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$  equal to  $\phi$ , we obtain the following three equilibrium equations:

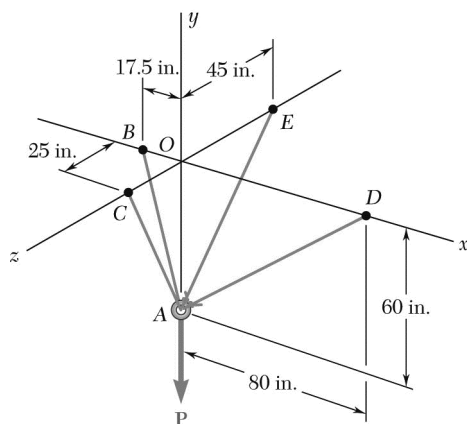
$$\text{From } \mathbf{i}: -\frac{17.5}{62.5}T_{BAC} + \frac{4}{5}T_{AD} = 0 \quad (1)$$

$$\text{From } \mathbf{j}: \left( \frac{60}{62.5} + \frac{60}{65} \right) T_{BAC} + \frac{3}{5}T_{AD} + \frac{4}{5}T_{AE} - 200 \text{ lb} = 0 \quad (2)$$

$$\text{From } \mathbf{k}: \frac{25}{65}T_{BAC} - \frac{3}{5}T_{AE} = 0 \quad (3)$$

Solving the system of linear equations using conventional algorithms gives:

$$T_{BAC} = 76.7 \text{ lb}; T_{AD} = 26.9 \text{ lb}; T_{AE} = 49.2 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.122

Knowing that the tension in cable  $AE$  of Prob. 2.121 is 75 lb, determine (a) the magnitude of the load  $\mathbf{P}$ , (b) the tension in cables  $BAC$  and  $AD$ .

**PROBLEM 2.121** Cable  $BAC$  passes through a frictionless ring  $A$  and is attached to fixed supports at  $B$  and  $C$ , while cables  $AD$  and  $AE$  are both tied to the ring and are attached, respectively, to supports at  $D$  and  $E$ . Knowing that a 200-lb vertical load  $\mathbf{P}$  is applied to ring  $A$ , determine the tension in each of the three cables.

### SOLUTION

Refer to the solution to Problem 2.121 for the figure and analysis leading to the following set of equilibrium equations, Equation (2) being modified to include  $P\mathbf{j}$  as an unknown quantity:

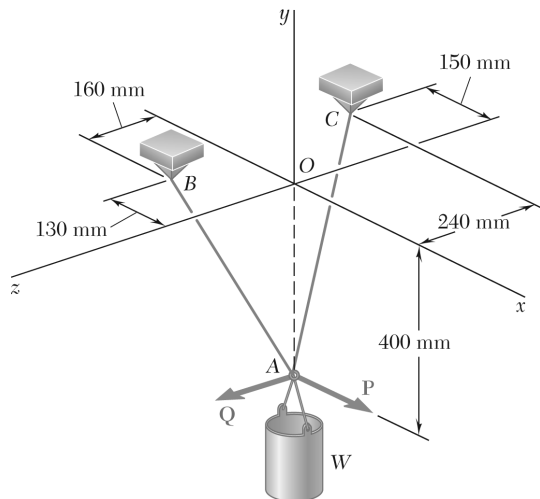
$$-\frac{17.5}{62.5}T_{BAC} + \frac{4}{5}T_{AD} = 0 \quad (1)$$

$$\left(\frac{60}{62.5} + \frac{60}{65}\right)T_{BAC} + \frac{3}{5}T_{AD} + \frac{4}{5}T_{AE} - P = 0 \quad (2)$$

$$\frac{25}{65}T_{BAC} - \frac{3}{5}T_{AE} = 0 \quad (3)$$

Substituting for  $T_{AE} = 75$  lb and solving simultaneously gives:

$$P = 305 \text{ lb}; \quad T_{BAC} = 117.0 \text{ lb}; \quad T_{AD} = 40.9 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.123

A container of weight  $W$  is suspended from ring  $A$ . Cable  $BAC$  passes through the ring and is attached to fixed supports at  $B$  and  $C$ . Two forces  $\mathbf{P} = P\mathbf{i}$  and  $\mathbf{Q} = Q\mathbf{k}$  are applied to the ring to maintain the container in the position shown. Knowing that  $W = 376 \text{ N}$ , determine  $P$  and  $Q$ . (Hint: The tension is the same in both portions of cable  $BAC$ .)

### SOLUTION

$$\begin{aligned}\mathbf{T}_{AB} &= T\lambda_{AB} \\ &= T \frac{\overline{AB}}{AB} \\ &= T \frac{(-130 \text{ mm})\mathbf{i} + (400 \text{ mm})\mathbf{j} + (160 \text{ mm})\mathbf{k}}{450 \text{ mm}} \\ &= T \left( -\frac{13}{45}\mathbf{i} + \frac{40}{45}\mathbf{j} + \frac{16}{45}\mathbf{k} \right)\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{AC} &= T\lambda_{AC} \\ &= T \frac{\overline{AC}}{AC} \\ &= T \frac{(-150 \text{ mm})\mathbf{i} + (400 \text{ mm})\mathbf{j} + (-240 \text{ mm})\mathbf{k}}{490 \text{ mm}} \\ &= T \left( -\frac{15}{49}\mathbf{i} + \frac{40}{49}\mathbf{j} - \frac{24}{49}\mathbf{k} \right)\end{aligned}$$

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

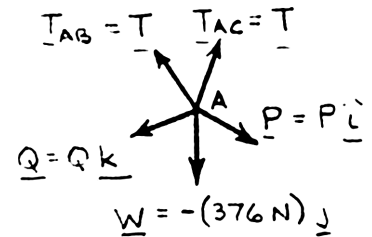
Setting coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$  equal to zero:

$$\mathbf{i}: \quad -\frac{13}{45}T - \frac{15}{49}T + P = 0 \qquad 0.59501T = P \qquad (1)$$

$$\mathbf{j}: \quad +\frac{40}{45}T + \frac{40}{49}T - W = 0 \qquad 1.70521T = W \qquad (2)$$

$$\mathbf{k}: \quad +\frac{16}{45}T - \frac{24}{49}T + Q = 0 \qquad 0.134240T = Q \qquad (3)$$

Free-Body A:



### PROBLEM 2.123 (Continued)

Data:

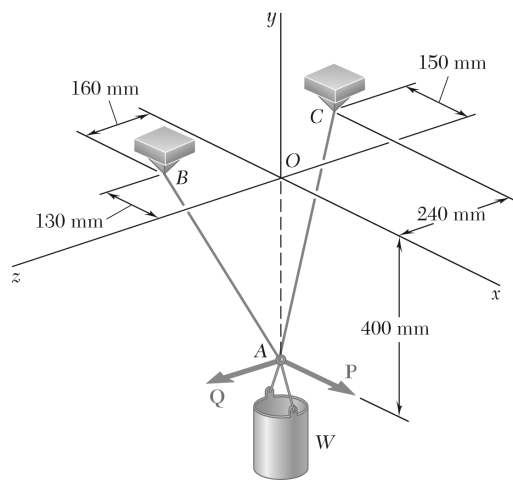
$$W = 376 \text{ N} \quad 1.70521T = 376 \text{ N} \quad T = 220.50 \text{ N}$$

$$0.59501(220.50 \text{ N}) = P$$

$$P = 131.2 \text{ N} \quad \blacktriangleleft$$

$$0.134240(220.50 \text{ N}) = Q$$

$$Q = 29.6 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.124

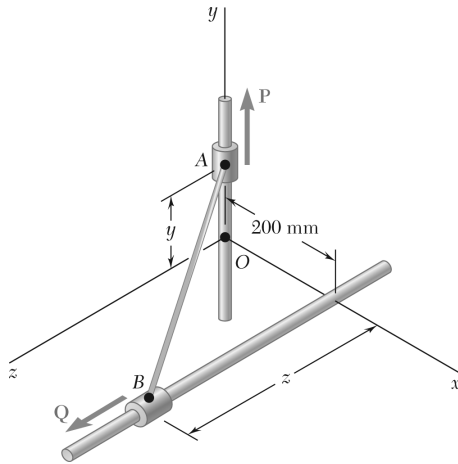
For the system of Problem 2.123, determine  $W$  and  $Q$  knowing that  $P = 164 \text{ N}$ .

**PROBLEM 2.123** A container of weight  $W$  is suspended from ring  $A$ . Cable  $BAC$  passes through the ring and is attached to fixed supports at  $B$  and  $C$ . Two forces  $\mathbf{P} = P\mathbf{i}$  and  $\mathbf{Q} = Q\mathbf{k}$  are applied to the ring to maintain the container in the position shown. Knowing that  $W = 376 \text{ N}$ , determine  $P$  and  $Q$ . (*Hint: The tension is the same in both portions of cable  $BAC$ .*)

### SOLUTION

Refer to Problem 2.123 for the figure and analysis resulting in Equations (1), (2), and (3) for  $P$ ,  $W$ , and  $Q$  in terms of  $T$  below. Setting  $P = 164 \text{ N}$  we have:

Eq. (1):	$0.59501T = 164 \text{ N}$	$T = 275.63 \text{ N}$
Eq. (2):	$1.70521(275.63 \text{ N}) = W$	$W = 470 \text{ N} \quad \blacktriangleleft$
Eq. (3):	$0.134240(275.63 \text{ N}) = Q$	$Q = 37.0 \text{ N} \quad \blacktriangleleft$



### PROBLEM 2.125

Collars *A* and *B* are connected by a 525-mm-long wire and can slide freely on frictionless rods. If a force  $\mathbf{P} = (341 \text{ N})\mathbf{j}$  is applied to collar *A*, determine (a) the tension in the wire when  $y = 155 \text{ mm}$ , (b) the magnitude of the force *Q* required to maintain the equilibrium of the system.

### SOLUTION

For both Problems 2.125 and 2.126:

$$(AB)^2 = x^2 + y^2 + z^2$$

Here

$$(0.525 \text{ m})^2 = (0.20 \text{ m})^2 + y^2 + z^2$$

or

$$y^2 + z^2 = 0.23563 \text{ m}^2$$

Thus, when *y* is given, *z* is determined,

Now

$$\begin{aligned}\lambda_{AB} &= \frac{\overline{AB}}{AB} \\ &= \frac{1}{0.525 \text{ m}} (0.20\mathbf{i} - y\mathbf{j} + z\mathbf{k})\text{m} \\ &= 0.38095\mathbf{i} - 1.90476y\mathbf{j} + 1.90476z\mathbf{k}\end{aligned}$$

Where *y* and *z* are in units of meters, m.

From the F.B. Diagram of collar *A*:  $\Sigma \mathbf{F} = 0: N_x\mathbf{i} + N_z\mathbf{k} + P\mathbf{j} + T_{AB}\lambda_{AB} = 0$

Setting the *j* coefficient to zero gives  $P - (1.90476y)T_{AB} = 0$

With

$$P = 341 \text{ N}$$

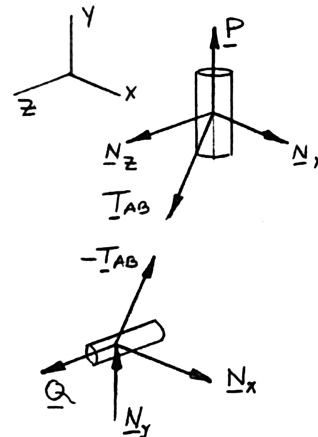
$$T_{AB} = \frac{341 \text{ N}}{1.90476y}$$

Now, from the free body diagram of collar *B*:  $\Sigma \mathbf{F} = 0: N_x\mathbf{i} + N_y\mathbf{j} + Q\mathbf{k} - T_{AB}\lambda_{AB} = 0$

Setting the *k* coefficient to zero gives  $Q - T_{AB}(1.90476z) = 0$

And using the above result for  $T_{AB}$ , we have  $Q = T_{AB}z = \frac{341 \text{ N}}{(1.90476)y} (1.90476z) = \frac{(341 \text{ N})(z)}{y}$

Free-Body Diagrams of Collars:





### PROBLEM 2.125 (Continued)

Then from the specifications of the problem,  $y = 155 \text{ mm} = 0.155 \text{ m}$

$$z^2 = 0.23563 \text{ m}^2 - (0.155 \text{ m})^2$$

$$z = 0.46 \text{ m}$$

and

$$\begin{aligned} (a) \quad T_{AB} &= \frac{341 \text{ N}}{0.155(1.90476)} \\ &= 1155.00 \text{ N} \end{aligned}$$

or

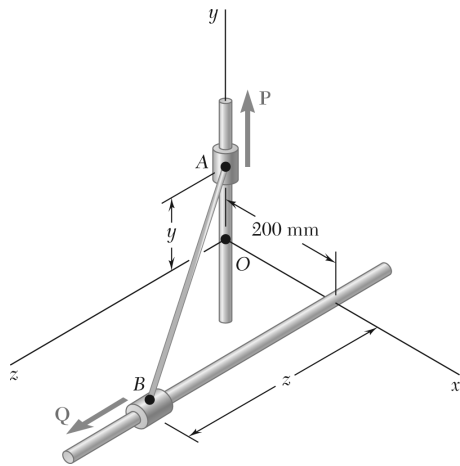
$$T_{AB} = 1155 \text{ N} \quad \blacktriangleleft$$

and

$$\begin{aligned} (b) \quad Q &= \frac{341 \text{ N}(0.46 \text{ m})(0.866)}{(0.155 \text{ m})} \\ &= (1012.00 \text{ N}) \end{aligned}$$

or

$$Q = 1012 \text{ N} \quad \blacktriangleleft$$



## PROBLEM 2.126

Solve Problem 2.125 assuming that  $y = 275$  mm.

**PROBLEM 2.125** Collars  $A$  and  $B$  are connected by a 525-mm-long wire and can slide freely on frictionless rods. If a force  $\mathbf{P} = (341 \text{ N})\mathbf{j}$  is applied to collar  $A$ , determine (a) the tension in the wire when  $y = 155$  mm, (b) the magnitude of the force  $\mathbf{Q}$  required to maintain the equilibrium of the system.

## SOLUTION

From the analysis of Problem 2.125, particularly the results:

$$y^2 + z^2 = 0.23563 \text{ m}^2$$

$$T_{AB} = \frac{341 \text{ N}}{1.90476 y}$$

$$Q = \frac{341 \text{ N}}{y} z$$

With  $y = 275 \text{ mm} = 0.275 \text{ m}$ , we obtain:

$$z^2 = 0.23563 \text{ m}^2 - (0.275 \text{ m})^2$$

$$z = 0.40 \text{ m}$$

and

$$(a) \quad T_{AB} = \frac{341 \text{ N}}{(1.90476)(0.275 \text{ m})} = 651.00$$

or

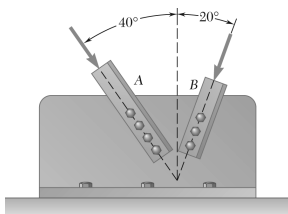
$$T_{AB} = 651 \text{ N} \quad \blacktriangleleft$$

and

$$(b) \quad Q = \frac{341 \text{ N}(0.40 \text{ m})}{(0.275 \text{ m})}$$

or

$$Q = 496 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.127

Two structural members *A* and *B* are bolted to a bracket as shown. Knowing that both members are in compression and that the force is 15 kN in member *A* and 10 kN in member *B*, determine by trigonometry the magnitude and direction of the resultant of the forces applied to the bracket by members *A* and *B*.

### SOLUTION

Using the force triangle and the laws of cosines and sines,

we have

$$\gamma = 180^\circ - (40^\circ + 20^\circ) \\ = 120^\circ$$

Then

$$R^2 = (15 \text{ kN})^2 + (10 \text{ kN})^2 \\ - 2(15 \text{ kN})(10 \text{ kN})\cos 120^\circ \\ = 475 \text{ kN}^2 \\ R = 21.794 \text{ kN}$$

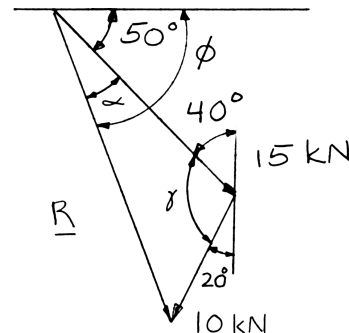
and

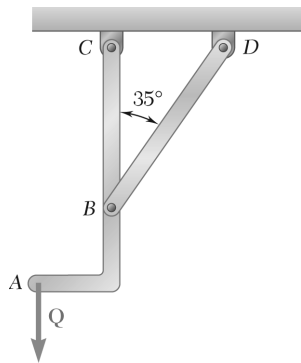
$$\frac{10 \text{ kN}}{\sin \alpha} = \frac{21.794 \text{ kN}}{\sin 120^\circ} \\ \sin \alpha = \left( \frac{10 \text{ kN}}{21.794 \text{ kN}} \right) \sin 120^\circ \\ = 0.39737 \\ \alpha = 23.414$$

Hence:

$$\phi = \alpha + 50^\circ = 73.414$$

$$\mathbf{R} = 21.8 \text{ kN} \searrow 73.4^\circ \blacktriangleleft$$

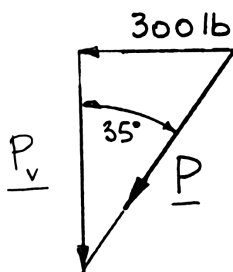




### PROBLEM 2.128

Member  $BD$  exerts on member  $ABC$  a force  $\mathbf{P}$  directed along line  $BD$ . Knowing that  $\mathbf{P}$  must have a 300-lb horizontal component, determine (a) the magnitude of the force  $\mathbf{P}$ , (b) its vertical component.

### SOLUTION



(a)

$$P \sin 35^\circ = 300 \text{ lb}$$

$$P = \frac{300 \text{ lb}}{\sin 35^\circ}$$

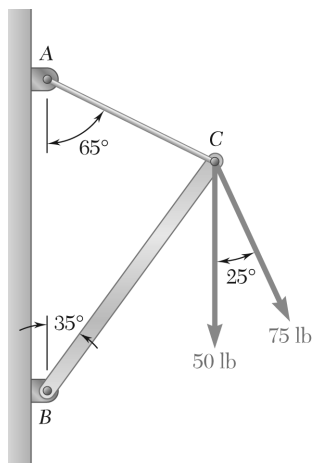
$$P = 523 \text{ lb} \quad \blacktriangleleft$$

(b) Vertical component

$$P_v = P \cos 35^\circ$$

$$= (523 \text{ lb}) \cos 35^\circ$$

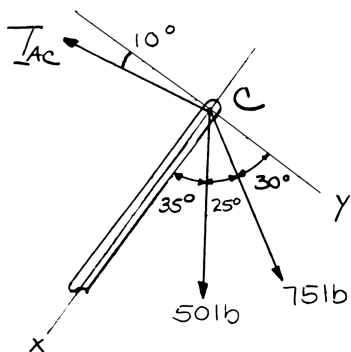
$$P_v = 428 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.129

Determine (a) the required tension in cable AC, knowing that the resultant of the three forces exerted at Point C of boom BC must be directed along BC, (b) the corresponding magnitude of the resultant.

### SOLUTION



Using the x and y axes shown:

$$R_x = \Sigma F_x = T_{AC} \sin 10^\circ + (50 \text{ lb}) \cos 35^\circ + (75 \text{ lb}) \cos 60^\circ$$

$$= T_{AC} \sin 10^\circ + 78.458 \text{ lb} \quad (1)$$

$$R_y = \Sigma F_y = (50 \text{ lb}) \sin 35^\circ + (75 \text{ lb}) \sin 60^\circ - T_{AC} \cos 10^\circ$$

$$R_y = 93.631 \text{ lb} - T_{AC} \cos 10^\circ \quad (2)$$

(a) Set  $R_y = 0$  in Eq. (2):

$$93.631 \text{ lb} - T_{AC} \cos 10^\circ = 0$$

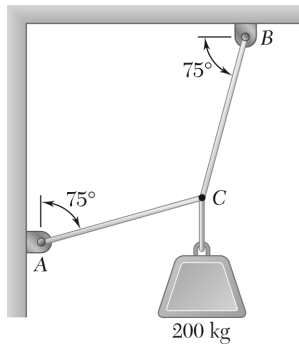
$$T_{AC} = 95.075 \text{ lb} \quad T_{AC} = 95.1 \text{ lb} \quad \blacktriangleleft$$

(b) Substituting for  $T_{AC}$  in Eq. (1):

$$R_x = (95.075 \text{ lb}) \sin 10^\circ + 78.458 \text{ lb}$$

$$= 94.968 \text{ lb}$$

$$R = R_x \quad R = 95.0 \text{ lb} \quad \blacktriangleleft$$

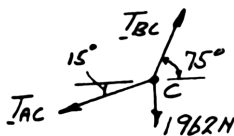


### PROBLEM 2.130

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



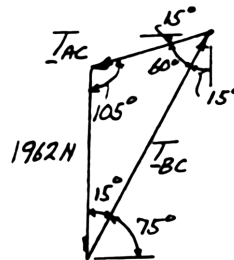
$$\begin{aligned} W &= mg \\ &= (200 \text{ kg})(9.81 \text{ m/s}^2) \\ &= 1962 \text{ N} \end{aligned}$$

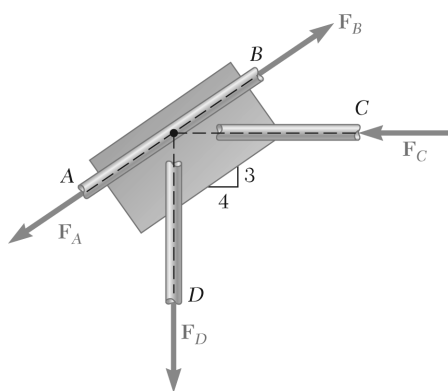
Law of sines: 
$$\frac{T_{AC}}{\sin 15^\circ} = \frac{T_{BC}}{\sin 105^\circ} = \frac{1962 \text{ N}}{\sin 60^\circ}$$

(a) 
$$T_{AC} = \frac{(1962 \text{ N}) \sin 15^\circ}{\sin 60^\circ} \quad T_{AC} = 586 \text{ N} \blacktriangleleft$$

(b) 
$$T_{BC} = \frac{(1962 \text{ N}) \sin 105^\circ}{\sin 60^\circ} \quad T_{BC} = 2190 \text{ N} \blacktriangleleft$$

#### Force Triangle



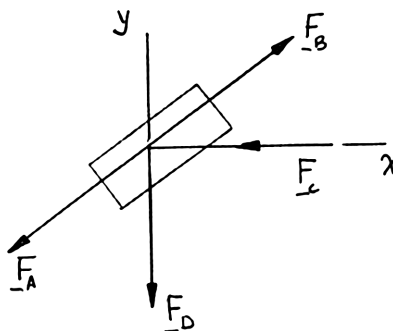


### PROBLEM 2.131

A welded connection is in equilibrium under the action of the four forces shown. Knowing that  $F_A = 8 \text{ kN}$  and  $F_B = 16 \text{ kN}$ , determine the magnitudes of the other two forces.

### SOLUTION

#### Free-Body Diagram of Connection



$$\Sigma F_x = 0: \quad \frac{3}{5}F_B - F_C - \frac{3}{5}F_A = 0$$

With

$$F_A = 8 \text{ kN}$$

$$F_B = 16 \text{ kN}$$

$$F_C = \frac{4}{5}(16 \text{ kN}) - \frac{4}{5}(8 \text{ kN})$$

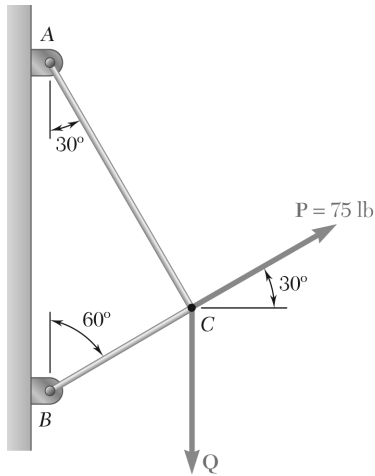
$$F_C = 6.40 \text{ kN} \quad \blacktriangleleft$$

$$\Sigma F_y = 0: \quad -F_D + \frac{3}{5}F_B - \frac{3}{5}F_A = 0$$

With  $F_A$  and  $F_B$  as above:

$$F_D = \frac{3}{5}(16 \text{ kN}) - \frac{3}{5}(8 \text{ kN})$$

$$F_D = 4.80 \text{ kN} \quad \blacktriangleleft$$

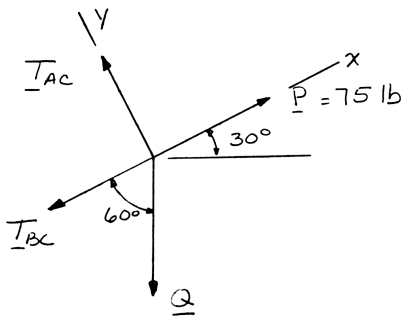


### PROBLEM 2.132

Two cables tied together at  $C$  are loaded as shown. Determine the range of values of  $Q$  for which the tension will not exceed 60 lb in either cable.

### SOLUTION

#### Free-Body Diagram



$$\Sigma F_x = 0: -T_{BC} - Q \cos 60^\circ + 75 \text{ lb} = 0$$

$$T_{BC} = 75 \text{ lb} - Q \cos 60^\circ \quad (1)$$

$$\Sigma F_y = 0: T_{AC} - Q \sin 60^\circ = 0$$

$$T_{AC} = Q \sin 60^\circ \quad (2)$$

$$\text{Requirement: } T_{AC} \leq 60 \text{ lb:}$$

$$\text{From Eq. (2): } Q \sin 60^\circ \leq 60 \text{ lb}$$

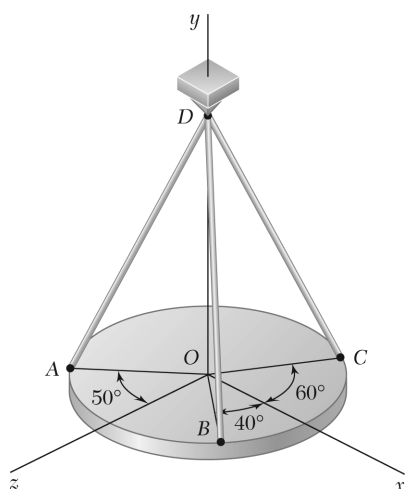
$$Q \leq 69.3 \text{ lb}$$

$$\text{Requirement: } T_{BC} \leq 60 \text{ lb:}$$

$$\text{From Eq. (1): } 75 \text{ lb} - Q \sin 60^\circ \leq 60 \text{ lb}$$

$$Q \geq 30.0 \text{ lb} \quad 30.0 \text{ lb} \leq Q \leq 69.3 \text{ lb} \quad \blacktriangleleft$$





### PROBLEM 2.133

A horizontal circular plate is suspended as shown from three wires that are attached to a support at  $D$  and form  $30^\circ$  angles with the vertical. Knowing that the  $x$  component of the force exerted by wire  $AD$  on the plate is  $110.3$  N, determine (a) the tension in wire  $AD$ , (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force exerted at  $A$  forms with the coordinate axes.

### SOLUTION

(a)  $F_x = F \sin 30^\circ \sin 50^\circ = 110.3 \text{ N} \quad (\text{Given})$

$$F = \frac{110.3 \text{ N}}{\sin 30^\circ \sin 50^\circ} = 287.97 \text{ N} \quad F = 288 \text{ N} \quad \blacktriangleleft$$

(b)  $\cos \theta_x = \frac{F_x}{F} = \frac{110.3 \text{ N}}{287.97 \text{ N}} = 0.38303 \quad \theta_x = 67.5^\circ \quad \blacktriangleleft$

$$F_y = F \cos 30^\circ = 249.39$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{249.39 \text{ N}}{287.97 \text{ N}} = 0.86603 \quad \theta_y = 30.0^\circ \quad \blacktriangleleft$$

$$\begin{aligned} F_z &= -F \sin 30^\circ \cos 50^\circ \\ &= -(287.97 \text{ N}) \sin 30^\circ \cos 50^\circ \\ &= -92.552 \text{ N} \end{aligned}$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{-92.552 \text{ N}}{287.97 \text{ N}} = -0.32139 \quad \theta_z = 108.7^\circ \quad \blacktriangleleft$$

## PROBLEM 2.134

A force acts at the origin of a coordinate system in a direction defined by the angles  $\theta_y = 55^\circ$  and  $\theta_z = 45^\circ$ . Knowing that the  $x$  component of the force is  $-500$  lb, determine (a) the angle  $\theta_x$ , (b) the other components and the magnitude of the force.

## SOLUTION

(a) We have

$$(\cos \theta_x)^2 + (\cos \theta_y)^2 + (\cos \theta_z)^2 = 1 \Rightarrow (\cos \theta_x)^2 = 1 - (\cos \theta_y)^2 - (\cos \theta_z)^2$$

Since  $F_x < 0$ , we must have  $\cos \theta_x < 0$ .

Thus, taking the negative square root, from above, we have

$$\cos \theta_x = -\sqrt{1 - (\cos 55^\circ)^2 - (\cos 45^\circ)^2} = 0.41353 \qquad \theta_x = 114.4^\circ \quad \blacktriangleleft$$

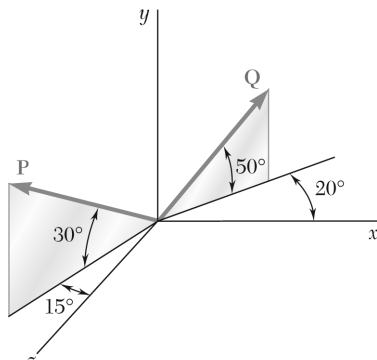
(b) Then

$$F = \frac{F_x}{\cos \theta_x} = \frac{500 \text{ lb}}{0.41353} = 1209.10 \text{ lb} \qquad F = 1209 \text{ lb} \quad \blacktriangleleft$$

and

$$F_y = F \cos \theta_y = (1209.10 \text{ lb}) \cos 55^\circ \qquad F_y = 694 \text{ lb} \quad \blacktriangleleft$$

$$F_z = F \cos \theta_z = (1209.10 \text{ lb}) \cos 45^\circ \qquad F_z = 855 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.135

Find the magnitude and direction of the resultant of the two forces shown knowing that  $P = 300 \text{ N}$  and  $Q = 400 \text{ N}$ .

### SOLUTION

$$\mathbf{P} = (300 \text{ N})[-\cos 30^\circ \sin 15^\circ \mathbf{i} + \sin 30^\circ \mathbf{j} + \cos 30^\circ \cos 15^\circ \mathbf{k}]$$

$$= -(67.243 \text{ N})\mathbf{i} + (150 \text{ N})\mathbf{j} + (250.95 \text{ N})\mathbf{k}$$

$$\mathbf{Q} = (400 \text{ N})[\cos 50^\circ \cos 20^\circ \mathbf{i} + \sin 50^\circ \mathbf{j} - \cos 50^\circ \sin 20^\circ \mathbf{k}]$$

$$= (400 \text{ N})[0.60402\mathbf{i} + 0.76604\mathbf{j} - 0.21985\mathbf{k}]$$

$$= (241.61 \text{ N})\mathbf{i} + (306.42 \text{ N})\mathbf{j} - (87.939 \text{ N})\mathbf{k}$$

$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$

$$= (174.367 \text{ N})\mathbf{i} + (456.42 \text{ N})\mathbf{j} + (163.011 \text{ N})\mathbf{k}$$

$$R = \sqrt{(174.367 \text{ N})^2 + (456.42 \text{ N})^2 + (163.011 \text{ N})^2}$$

$$= 515.07 \text{ N}$$

$$R = 515 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{174.367 \text{ N}}{515.07 \text{ N}} = 0.33853$$

$$\theta_x = 70.2^\circ \quad \blacktriangleleft$$

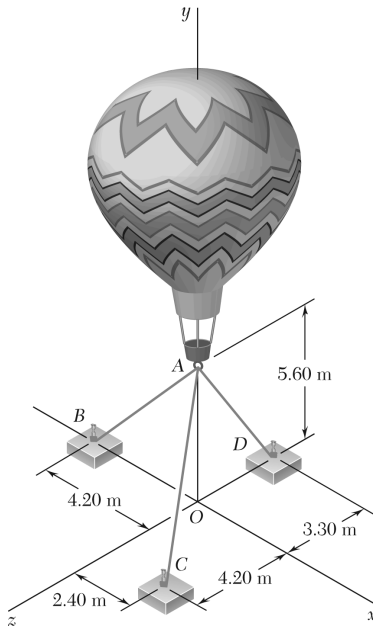
$$\cos \theta_y = \frac{R_y}{R} = \frac{456.42 \text{ N}}{515.07 \text{ N}} = 0.88613$$

$$\theta_y = 27.6^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{163.011 \text{ N}}{515.07 \text{ N}} = 0.31648$$

$$\theta_z = 71.5^\circ \quad \blacktriangleleft$$

### PROBLEM 2.136



Three cables are used to tether a balloon as shown. Determine the vertical force  $\mathbf{P}$  exerted by the balloon at  $A$  knowing that the tension in cable  $AC$  is 444 N.

### SOLUTION

See Problem 2.101 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \quad (1)$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \quad (2)$$

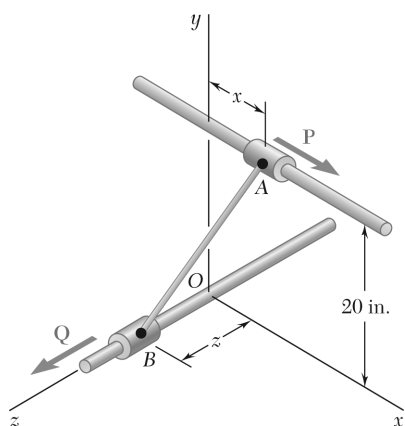
$$0.56757T_{AC} - 0.50769T_{AD} = 0 \quad (3)$$

Substituting  $T_{AC} = 444 \text{ N}$  in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms gives

$$T_{AB} = 240 \text{ N}$$

$$T_{AD} = 496.36 \text{ N}$$

$$\mathbf{P} = 956 \text{ N} \uparrow \blacktriangleleft$$



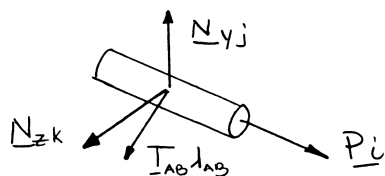
### PROBLEM 2.137

Collars *A* and *B* are connected by a 25-in.-long wire and can slide freely on frictionless rods. If a 60-lb force **Q** is applied to collar *B* as shown, determine (a) the tension in the wire when  $x = 9$  in., (b) the corresponding magnitude of the force **P** required to maintain the equilibrium of the system.

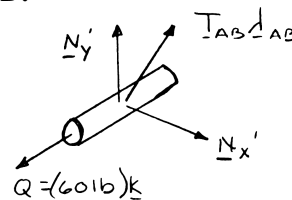
### SOLUTION

Free-Body Diagrams of Collars:

**A:**



**B:**



$$\lambda_{AB} = \frac{\overline{AB}}{AB} = \frac{-x\mathbf{i} - (20 \text{ in.})\mathbf{j} + z\mathbf{k}}{25 \text{ in.}}$$

Collar *A*:  $\Sigma \mathbf{F} = 0: P\mathbf{i} + N_y\mathbf{j} + N_z\mathbf{k} + T_{AB}\lambda_{AB} = 0$

Substitute for  $\lambda_{AB}$  and set coefficient of **i** equal to zero:

$$P - \frac{T_{AB}x}{25 \text{ in.}} = 0 \quad (1)$$

Collar *B*:  $\Sigma \mathbf{F} = 0: (60 \text{ lb})\mathbf{k} + N'_x\mathbf{i} + N'_y\mathbf{j} - T_{AB}\lambda_{AB} = 0$

Substitute for  $\lambda_{AB}$  and set coefficient of **k** equal to zero:

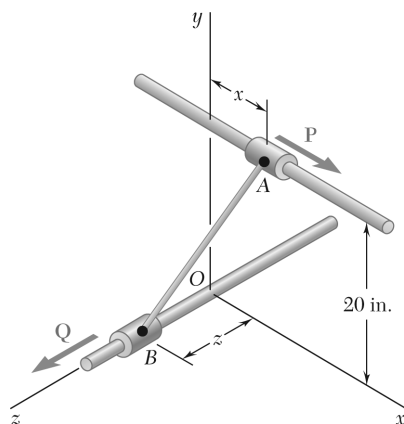
$$60 \text{ lb} - \frac{T_{AB}z}{25 \text{ in.}} = 0 \quad (2)$$

(a)  $x = 9 \text{ in.} \quad (9 \text{ in.})^2 + (20 \text{ in.})^2 + z^2 = (25 \text{ in.})^2$   
 $z = 12 \text{ in.}$

From Eq. (2):  $\frac{60 \text{ lb} - T_{AB}(12 \text{ in.})}{25 \text{ in.}} = 0 \quad T_{AB} = 125.0 \text{ lb} \quad \blacktriangleleft$

(b) From Eq. (1):  $P = \frac{(125.0 \text{ lb})(9 \text{ in.})}{25 \text{ in.}} \quad P = 45.0 \text{ lb} \quad \blacktriangleleft$

### PROBLEM 2.138



Collars A and B are connected by a 25-in.-long wire and can slide freely on frictionless rods. Determine the distances  $x$  and  $z$  for which the equilibrium of the system is maintained when  $P = 120$  lb and  $Q = 60$  lb.

### SOLUTION

See Problem 2.137 for the diagrams and analysis leading to Equations (1) and (2) below:

$$P = \frac{T_{AB}x}{25 \text{ in.}} = 0 \quad (1)$$

$$60 \text{ lb} - \frac{T_{AB}z}{25 \text{ in.}} = 0 \quad (2)$$

For  $P = 120$  lb, Eq. (1) yields  $T_{AB}x = (25 \text{ in.})(20 \text{ lb})$  (1')

From Eq. (2):  $T_{AB}z = (25 \text{ in.})(60 \text{ lb})$  (2')

Dividing Eq. (1') by (2'),  $\frac{x}{z} = 2$  (3)

Now write  $x^2 + z^2 + (20 \text{ in.})^2 = (25 \text{ in.})^2$  (4)

Solving (3) and (4) simultaneously,

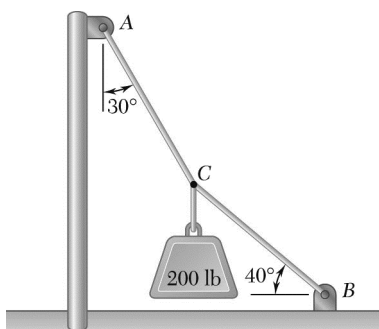
$$4z^2 + z^2 + 400 = 625$$

$$z^2 = 45$$

$$z = 6.7082 \text{ in.}$$

From Eq. (3):  $x = 2z = 2(6.7082 \text{ in.})$   
 $= 13.4164 \text{ in.}$

$$x = 13.42 \text{ in.}, \quad z = 6.71 \text{ in.} \quad \blacktriangleleft$$

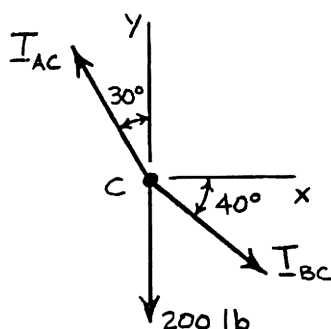


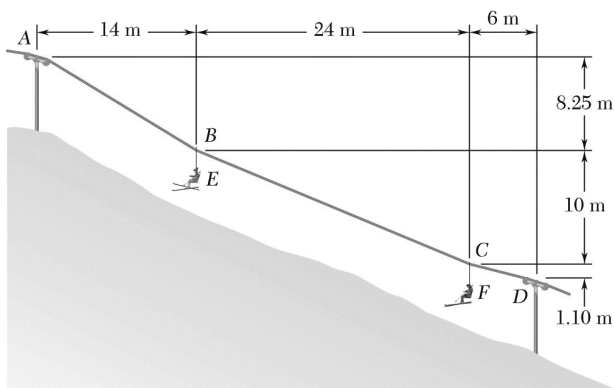
### PROBLEM 2F1

Two cables are tied together at  $C$  and loaded as shown. Draw the free-body diagram needed to determine the tension in  $AC$  and  $BC$ .

### SOLUTION

Free-Body Diagram of Point  $C$ :



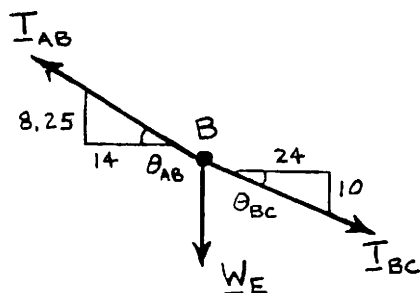


## PROBLEM 2.F2

A chairlift has been stopped in the position shown. Knowing that each chair weighs 250 N and that the skier in chair *E* weighs 765 N, draw the free-body diagrams needed to determine the weight of the skier in chair *F*.

### SOLUTION

#### Free-Body Diagram of Point *B*:



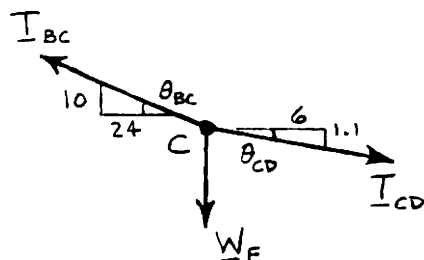
$$W_E = 250 \text{ N} + 765 \text{ N} = 1015 \text{ N}$$

$$\theta_{AB} = \tan^{-1} \frac{8.25}{14} = 30.510^\circ$$

$$\theta_{BC} = \tan^{-1} \frac{10}{24} = 22.620^\circ$$

Use this free body to determine  $T_{AB}$  and  $T_{BC}$ .

#### Free-Body Diagram of Point *C*:



$$\theta_{CD} = \tan^{-1} \frac{1.1}{6} = 10.3889^\circ$$

Use this free body to determine  $T_{CD}$  and  $W_F$ .

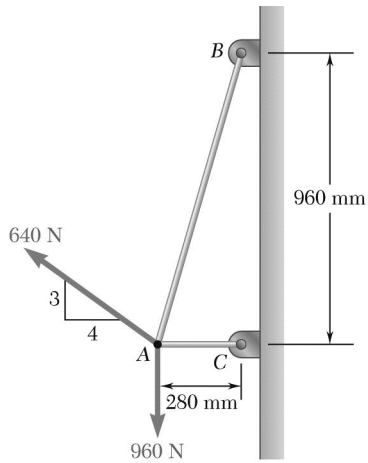
Then weight of skier  $W_S$  is found by

$$W_S = W_F - 250 \text{ N} \quad \blacktriangleleft$$



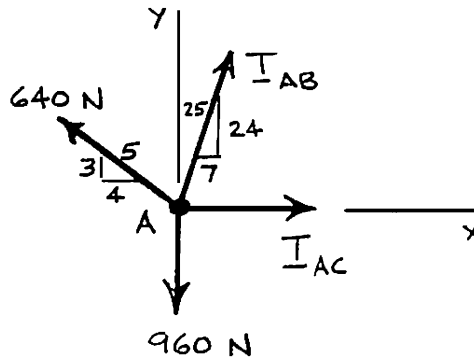
### PROBLEM 2.F3

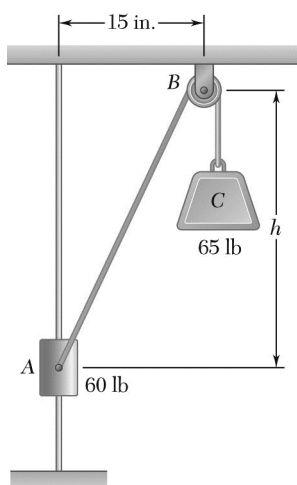
Two cables are tied together at A and loaded as shown. Draw the free-body diagram needed to determine the tension in each cable.



### SOLUTION

Free-Body Diagram of Point A:



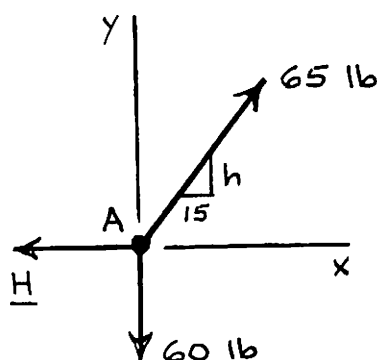


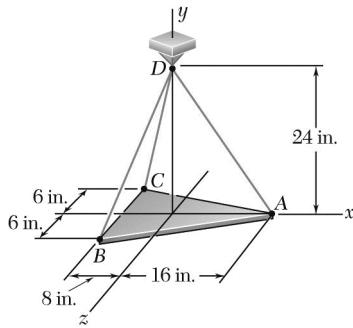
### PROBLEM 2.F4

The 60-lb collar *A* can slide on a frictionless vertical rod and is connected as shown to a 65-lb counterweight *C*. Draw the free-body diagram needed to determine the value of *h* for which the system is in equilibrium.

### SOLUTION

Free-Body Diagram of Point *A*:



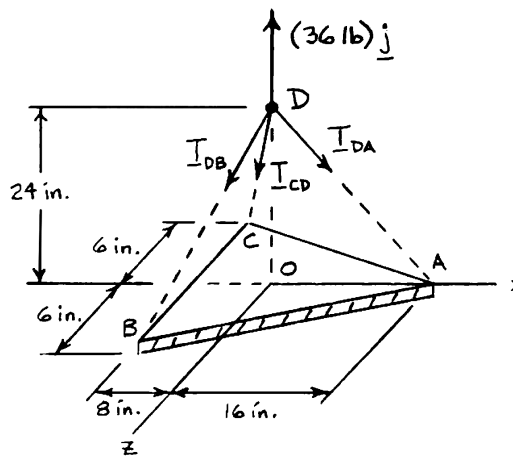


### PROBLEM 2.F5

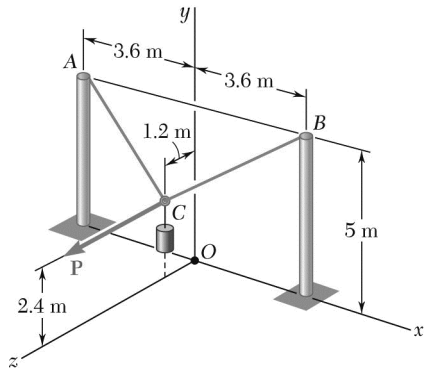
A 36-lb triangular plate is supported by three cables as shown. Draw the free-body diagram needed to determine the tension in each wire.

### SOLUTION

#### Free-Body Diagram of Point D:



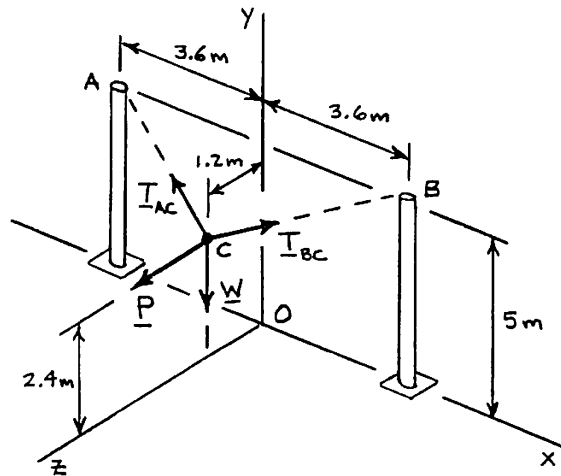
### PROBLEM 2.F6



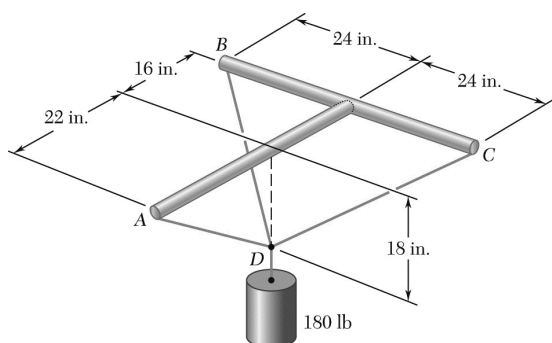
A 70-kg cylinder is supported by two cables  $AC$  and  $BC$ , which are attached to the top of vertical posts. A horizontal force  $\mathbf{P}$ , perpendicular to the plane containing the posts, holds the cylinder in the position shown. Draw the free-body diagram needed to determine the magnitude of  $\mathbf{P}$  and the force in each cable.

### SOLUTION

#### Free-Body Diagram of Point C:



$$\begin{aligned} W &= (70 \text{ kg})(9.81 \text{ m/s}^2) \\ &= 686.7 \text{ N} \\ \mathbf{W} &= -(686.7 \text{ N})\mathbf{j} \end{aligned}$$

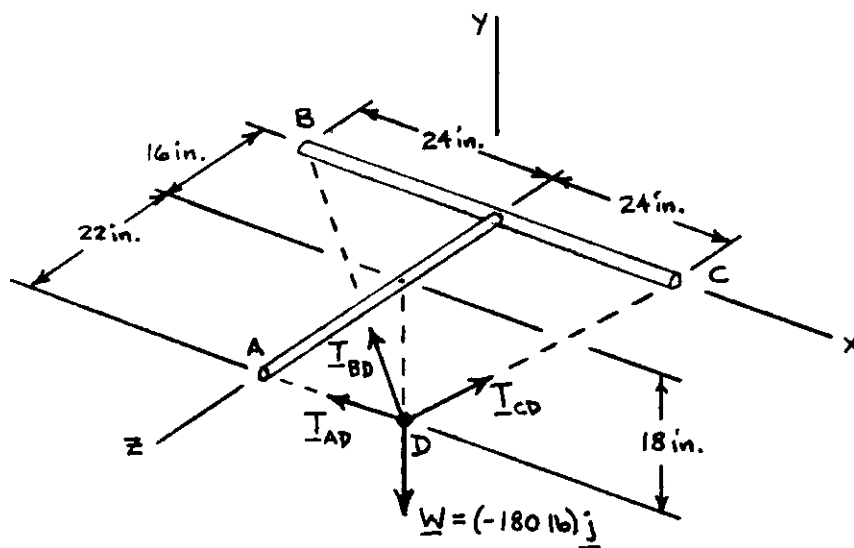


## PROBLEM 2.F7

Three cables are connected at point  $D$ , which is located 18 in. below the T-shaped pipe support  $ABC$ . The cables support a 180-lb cylinder as shown. Draw the free-body diagram needed to determine the tension in each cable.

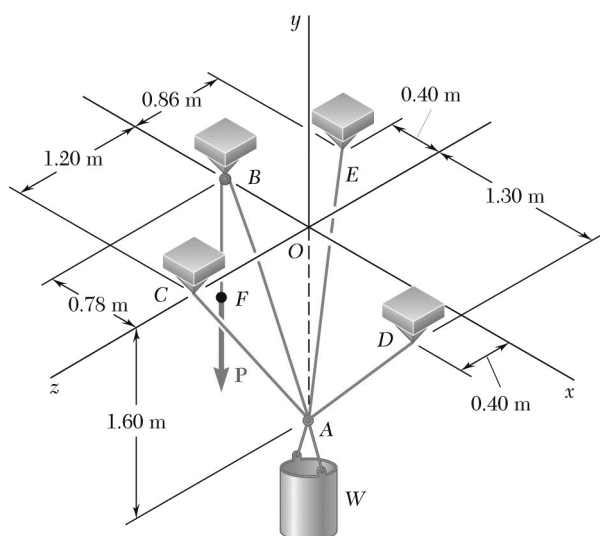
## SOLUTION

Free-Body Diagram of Point  $D$ :



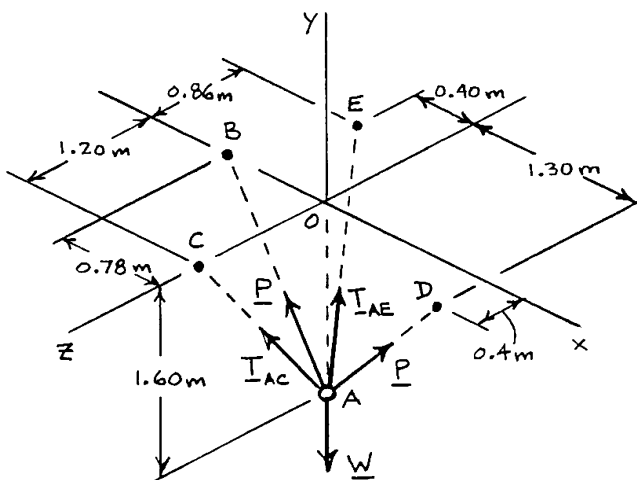
### PROBLEM 2.F8

A 100-kg container is suspended from ring A, to which cables AC and AE are attached. A force  $P$  is applied to end F of a third cable that passes over a pulley at B and through ring A and then is attached to a support at D. Draw the free-body diagram needed to determine the magnitude of  $P$ . (Hint: The tension is the same in all portions of cable FBAD.)



### SOLUTION

#### Free-Body Diagram of Ring A:



$$\begin{aligned} W &= (100 \text{ kg})(9.81 \text{ m/s}^2) \\ &= 981 \text{ N} \\ \mathbf{W} &= -(981 \text{ N})\mathbf{j} \end{aligned}$$