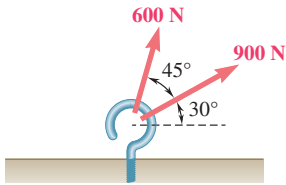


***Vector Mechanics for Engineers Statics and  
Dynamics 12th edition Beer Solutions Manual***

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# CHAPTER 2

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### PROBLEM 2.1

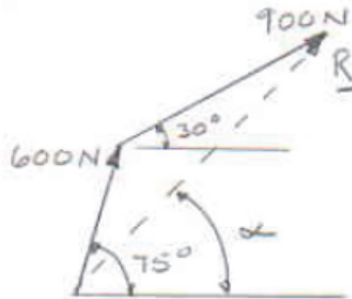
Two forces are applied as shown to a hook. Determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

(a) Parallelogram law:



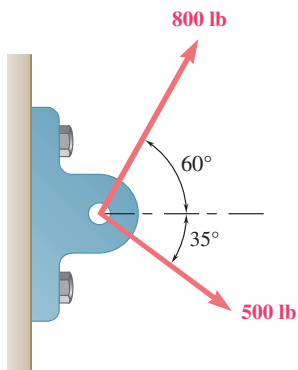
(b) Triangle rule:



We measure:

$$R = 1391 \text{ kN}, \quad \alpha = 47.8^\circ$$

$$\mathbf{R} = 1391 \text{ N} \angle 47.8^\circ \blacktriangleleft$$

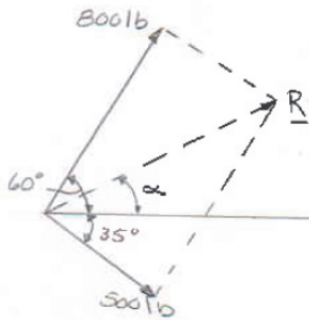


### PROBLEM 2.2

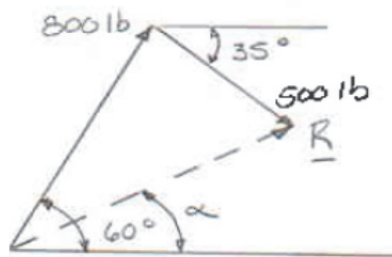
Two forces are applied as shown to a bracket support. Determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

(a) Parallelogram law:



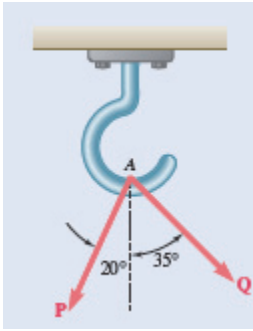
(b) Triangle rule:



We measure:

$$R = 906 \text{ lb}, \alpha = 26.6^\circ$$

$$R = 906 \text{ lb} \nearrow 26.6^\circ \blacktriangleleft$$

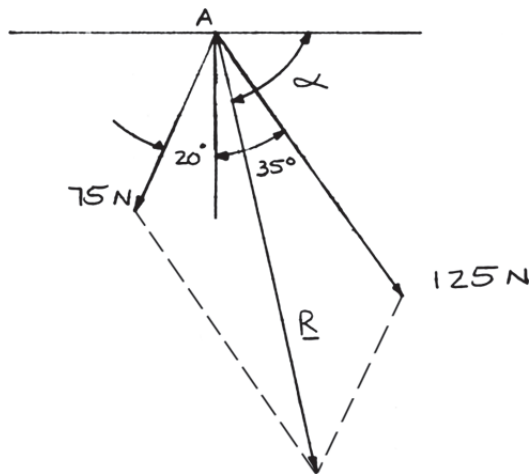


### PROBLEM 2.3

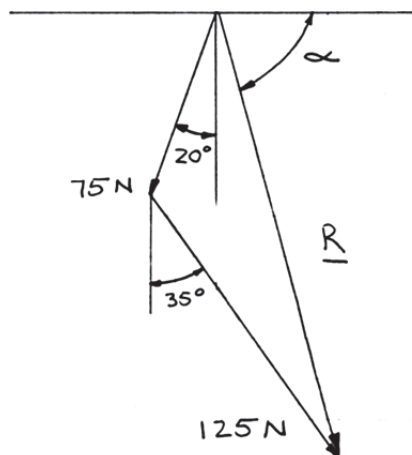
Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that  $P = 75 \text{ N}$  and  $Q = 125 \text{ N}$ , determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

(a) Parallelogram law:



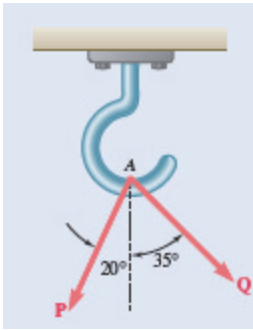
(b) Triangle rule:



We measure:

$$R = 179 \text{ N}, \quad \alpha = 75.1^\circ$$

$$\mathbf{R} = 179 \text{ N} \searrow 75.1^\circ$$

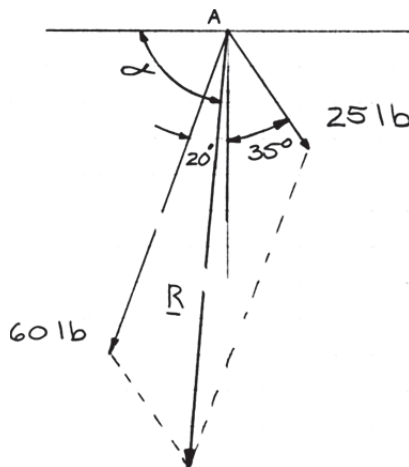


### PROBLEM 2.4

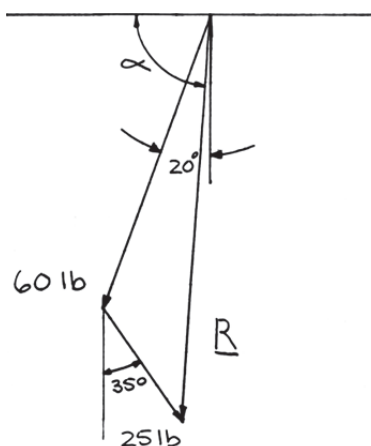
Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that  $P = 60 \text{ lb}$  and  $Q = 25 \text{ lb}$ , determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

(a) Parallelogram law:



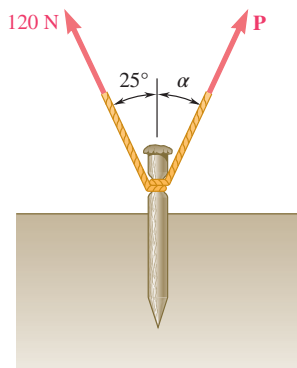
(b) Triangle rule:



We measure:

$$R = 77.1 \text{ lb}, \quad \alpha = 85.4^\circ$$

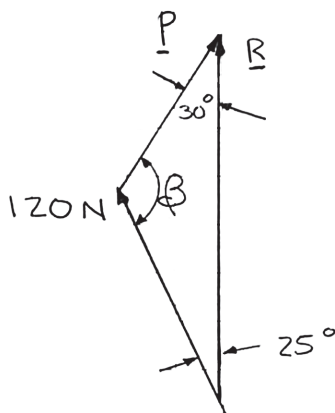
$$\mathbf{R} = 77.1 \text{ lb} \nearrow 85.4^\circ$$



### 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

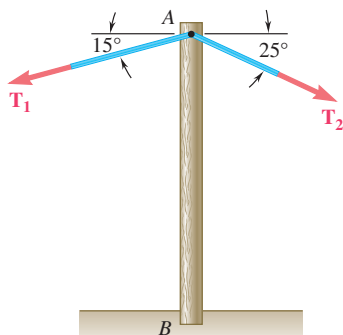


Using the triangle rule and the law of sines:

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

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

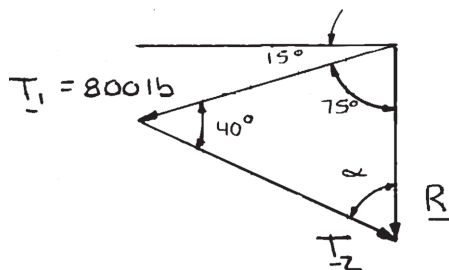
$$\frac{120 \text{ N}}{\sin 30^\circ} = \frac{R}{\sin 125^\circ} \quad R = 196.6 \text{ N} \blacktriangleleft$$



### PROBLEM 2.6

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 **R** of the forces exerted by the cable at A is to be vertical, (b) the corresponding magnitude of **R**.

### SOLUTION



Using the triangle rule and the law of sines:

(a)

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

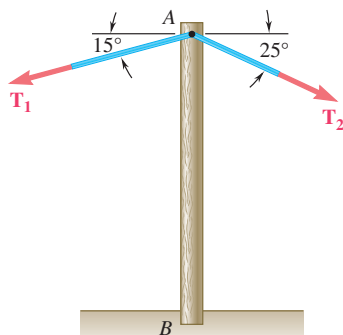
$$\frac{800 \text{ lb}}{\sin 65^\circ} = \frac{T_2}{\sin 75^\circ}$$

$$T_2 = 853 \text{ lb} \blacktriangleleft$$

(b)

$$\frac{800 \text{ lb}}{\sin 65^\circ} = \frac{R}{\sin 40^\circ}$$

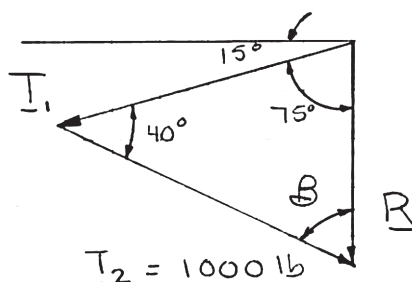
$$R = 567 \text{ lb} \blacktriangleleft$$



### PROBLEM 2.7

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



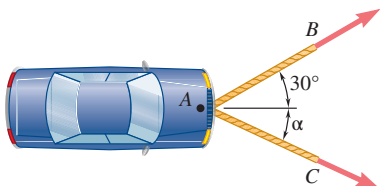
Using the triangle rule and the law of sines:

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

$$\frac{1000 \text{ lb}}{\sin 75^\circ} = \frac{T_1}{\sin 65^\circ} \quad T_1 = 938 \text{ lb} \blacktriangleleft$$

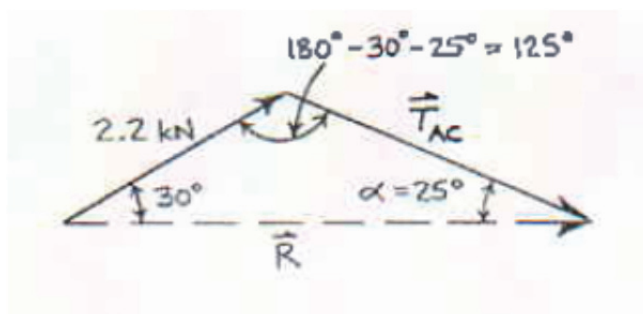
$$(b) \quad \frac{1000 \text{ lb}}{\sin 75^\circ} = \frac{R}{\sin 40^\circ} \quad R = 665 \text{ lb} \blacktriangleleft$$

### PROBLEM 2.8



A disabled automobile is pulled by means of two ropes as shown. The tension in rope  $AB$  is 2.2 kN, and the angle  $\alpha$  is  $25^\circ$ . Knowing that the resultant of the two forces applied at  $A$  is directed along the axis of the automobile, determine by trigonometry (a) the tension in rope  $AC$ , (b) the magnitude of the resultant of the two forces applied at  $A$ .

### SOLUTION



Using the law of sines:

$$\frac{T_{AC}}{\sin 30^\circ} = \frac{R}{\sin 125^\circ} = \frac{2.2 \text{ kN}}{\sin 25^\circ}$$

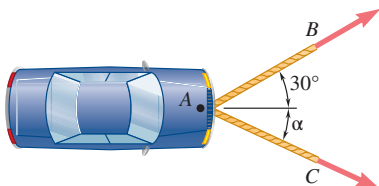
$$T_{AC} = 2.603 \text{ kN}$$

$$R = 4.264 \text{ kN}$$

(a)  $T_{AC} = 2.60 \text{ kN} \blacktriangleleft$

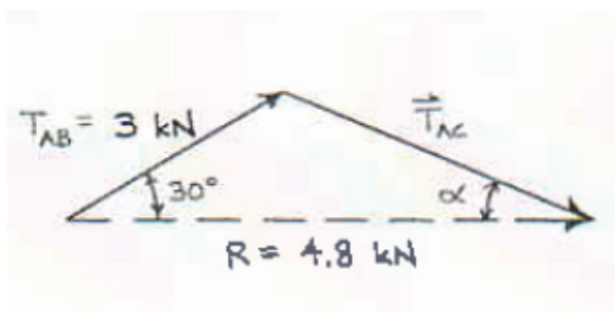
(b)  $R = 4.26 \text{ kN} \blacktriangleleft$

### PROBLEM 2.9



A disabled automobile is pulled by means of two ropes as shown. Knowing that the tension in rope  $AB$  is 3 kN, determine by trigonometry the tension in rope  $AC$  and the value of  $\alpha$  so that the resultant force exerted at  $A$  is a 4.8-kN force directed along the axis of the automobile.

### SOLUTION



Using the law of cosines:

$$T_{AC}^2 = (3 \text{ kN})^2 + (4.8 \text{ kN})^2 - 2(3 \text{ kN})(4.8 \text{ kN})\cos 30^\circ$$

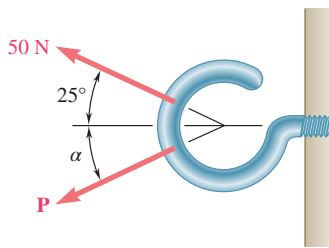
$$T_{AC} = 2.6643 \text{ kN}$$

Using the law of sines:

$$\frac{\sin \alpha}{3 \text{ kN}} = \frac{\sin 30^\circ}{2.6643 \text{ kN}}$$

$$\alpha = 34.3^\circ$$

$$\mathbf{T}_{AC} = 2.66 \text{ kN} \searrow 34.3^\circ \blacktriangleleft$$



### PROBLEM 2.10

Two forces are applied as shown to a hook support. Knowing that the magnitude of  $\mathbf{P}$  is 35 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 triangle rule and law of sines:

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

$$\sin \alpha = 0.60374$$

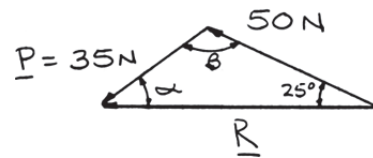
$$\alpha = 37.138^\circ$$

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

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

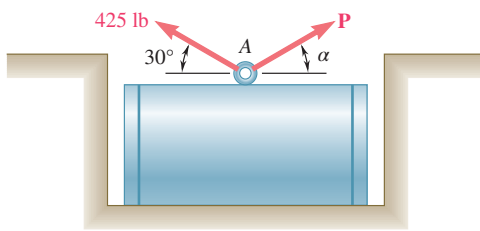
$$= 117.862^\circ$$

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



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

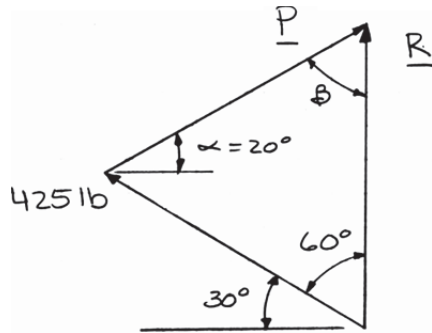
$$R = 73.2 \text{ N} \blacktriangleleft$$



### 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

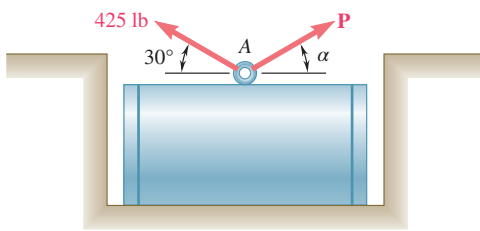


Using the triangle rule and the law of sines:

$$\begin{aligned} (a) \quad \beta + 50^\circ + 60^\circ &= 180^\circ \\ \beta &= 180^\circ - 50^\circ - 60^\circ \\ &= 70^\circ \end{aligned}$$

$$\frac{425 \text{ lb}}{\sin 70^\circ} = \frac{P}{\sin 60^\circ} \quad P = 392 \text{ lb} \blacktriangleleft$$

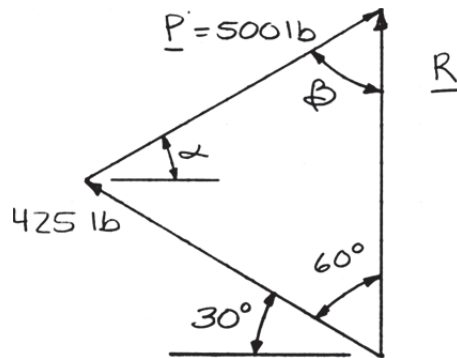
$$(b) \quad \frac{425 \text{ lb}}{\sin 70^\circ} = \frac{R}{\sin 50^\circ} \quad R = 346 \text{ lb} \blacktriangleleft$$



### 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



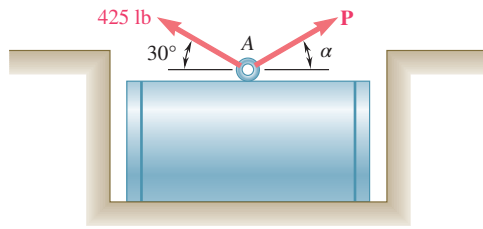
Using the triangle rule and the law of sines:

$$\begin{aligned}
 (a) \quad & (\alpha + 30^\circ) + 60^\circ + \beta = 180^\circ \\
 & \beta = 180^\circ - (\alpha + 30^\circ) - 60^\circ \\
 & \beta = 90^\circ - \alpha \\
 & \frac{\sin(90^\circ - \alpha)}{425 \text{ lb}} = \frac{\sin 60^\circ}{500 \text{ lb}} \\
 & 90^\circ - \alpha = 47.402^\circ
 \end{aligned}$$

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

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

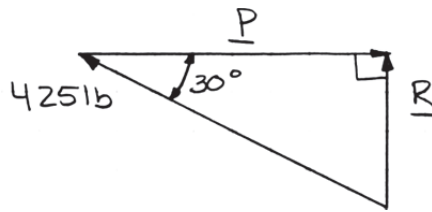
$$R = 551 \text{ lb} \blacktriangleleft$$



### 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  $\mathbf{P}$  for which the resultant  $\mathbf{R}$  of the two forces applied at  $A$  is vertical, (b) the corresponding magnitude of  $\mathbf{R}$ .

### SOLUTION



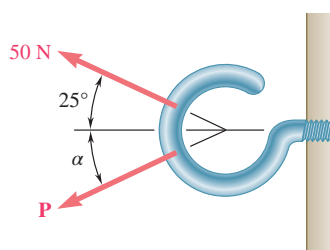
The smallest force  $P$  will be perpendicular to  $R$ .

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

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

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

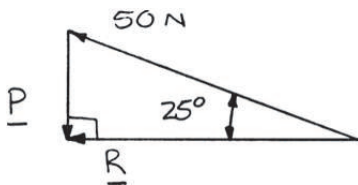
$R = 213 \text{ lb} \blacktriangleleft$



### 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



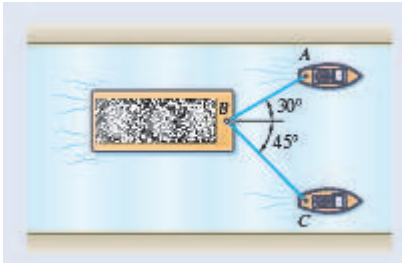
The smallest force  $P$  will be perpendicular to  $R$ .

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

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

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

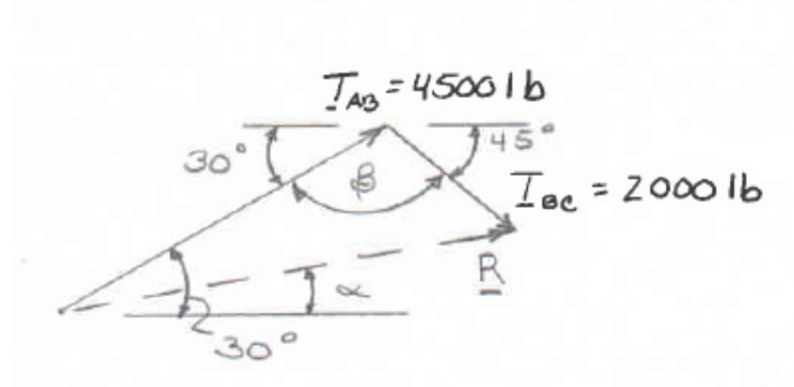
$R = 45.3 \text{ N} \blacktriangleleft$



### PROBLEM 2.15

The barge  $B$  is pulled by two tugboats  $A$  and  $C$ . At a given instant the tension in cable  $AB$  is 4500 lb and the tension in cable  $BC$  is 2000 lb. Determine by trigonometry the magnitude and direction of the resultant of the two forces applied at  $B$  at that instant.

### SOLUTION



Using the law of cosines:

$$\beta = 180^\circ - 30^\circ - 45^\circ$$

$$\beta = 105^\circ$$

$$R^2 = (4500 \text{ lb})^2 + (2000 \text{ lb})^2 - 2(4500 \text{ lb})(2000 \text{ lb})\cos 105^\circ$$

$$R = 5380 \text{ lb}$$

Using the law of sines:

$$\frac{R}{\sin \beta} = \frac{2000 \text{ lb}}{\sin(30^\circ - \alpha)}$$

$$\frac{5380 \text{ lb}}{\sin 105^\circ} = \frac{2000 \text{ lb}}{\sin(30^\circ - \alpha)}$$

$$\alpha = 8.94^\circ$$

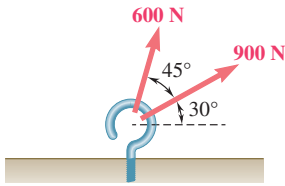
$$\mathbf{R} = 5380 \text{ lb} \nearrow 8.94^\circ \blacktriangleleft$$

### PROBLEM 2.16

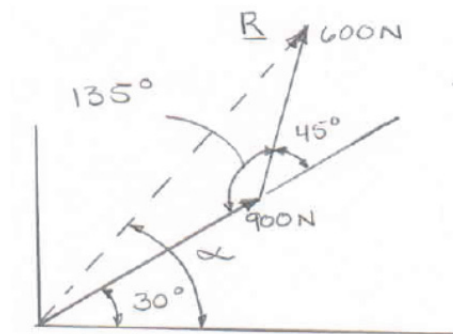
Solve Prob. 2.1 by trigonometry.

### PROBLEM 2.1

Two forces are applied as shown to a hook. Determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.



### SOLUTION



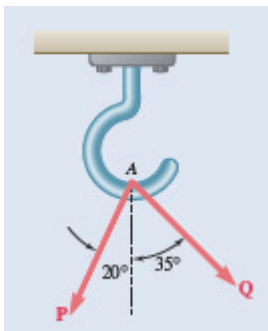
Using the law of cosines:

$$\begin{aligned} R^2 &= (900 \text{ N})^2 + (600 \text{ N})^2 \\ &\quad - 2(900 \text{ N})(600 \text{ N})\cos(135^\circ) \\ R &= 1390.57 \text{ N} \end{aligned}$$

Using the law of sines:

$$\begin{aligned} \frac{\sin(\alpha - 30^\circ)}{600 \text{ N}} &= \frac{\sin(135^\circ)}{1390.57 \text{ N}} \\ \alpha - 30^\circ &= 17.7642^\circ \\ \alpha &= 47.764^\circ \end{aligned}$$

$$\mathbf{R} = 1391 \text{ N} \nearrow 47.8^\circ \blacktriangleleft$$



### PROBLEM 2.17

Solve Problem 2.4 by trigonometry.

**PROBLEM 2.4** Two forces **P** and **Q** are applied as shown at Point A of a hook support. Knowing that  $P = 60 \text{ lb}$  and  $Q = 25 \text{ lb}$ , determine graphically the magnitude and direction of their resultant using (a) the parallelogram law, (b) the triangle rule.

### SOLUTION

Using the triangle rule and the law of cosines:

$$20^\circ + 35^\circ + \alpha = 180^\circ$$

$$\alpha = 125^\circ$$

$$R^2 = P^2 + Q^2 - 2PQ \cos \alpha$$

$$R^2 = (60 \text{ lb})^2 + (25 \text{ lb})^2$$

$$- 2(60 \text{ lb})(25 \text{ lb}) \cos 125^\circ$$

$$R^2 = 3600 + 625 + 3000(0.5736)$$

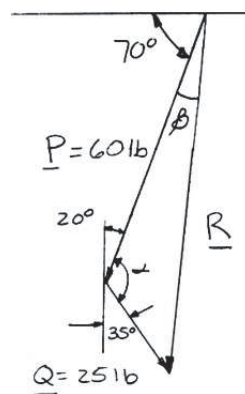
$$R = 77.108 \text{ lb}$$

Using the law of sines:

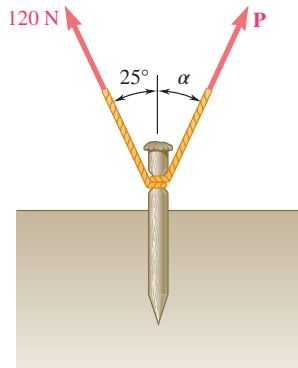
$$\frac{\sin \beta}{25 \text{ lb}} = \frac{\sin 125^\circ}{77.108 \text{ lb}}$$

$$\beta = 15.402^\circ$$

$$70^\circ + \beta = 85.402^\circ$$



$$\mathbf{R} = 77.1 \text{ lb} \nearrow 85.4^\circ \blacktriangleleft$$

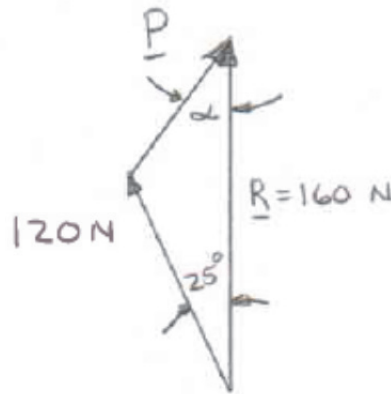


### PROBLEM 2.18

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:

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

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

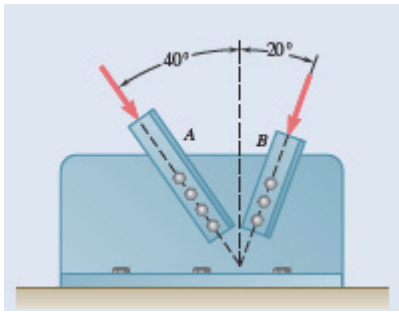
And

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

$$\sin \alpha = 0.70343$$

$$\alpha = 44.703^\circ$$

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



### PROBLEM 2.19

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 10 kN in member  $A$  and 15 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

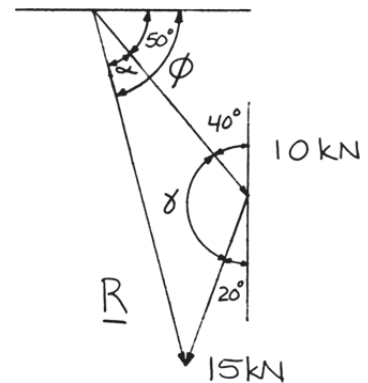
Using the force triangle and the laws of cosines and sines

We have 
$$\gamma = 180^\circ - (40^\circ + 20^\circ) = 120^\circ$$

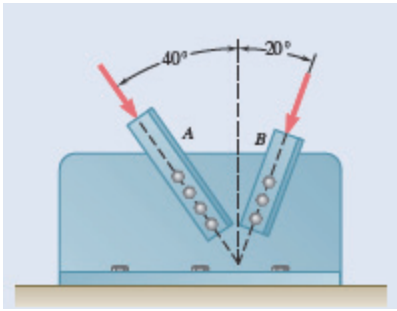
Then 
$$\begin{aligned} R^2 &= (10 \text{ kN})^2 + (15 \text{ kN})^2 \\ &\quad - 2(10 \text{ kN})(15 \text{ kN})\cos 120^\circ \\ &= 475 \text{ kN}^2 \\ R &= 21.794 \text{ kN} \end{aligned}$$

and 
$$\begin{aligned} \frac{15 \text{ kN}}{\sin \alpha} &= \frac{21.794 \text{ kN}}{\sin 120^\circ} \\ \sin \alpha &= \left( \frac{15 \text{ kN}}{21.794 \text{ kN}} \right) \sin 120^\circ \\ &= 0.59605 \\ \alpha &= 36.588^\circ \end{aligned}$$

Hence: 
$$\phi = \alpha + 50^\circ = 86.588^\circ$$



$$\mathbf{R} = 21.8 \text{ kN} \searrow 86.6^\circ$$



### PROBLEM 2.20

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:

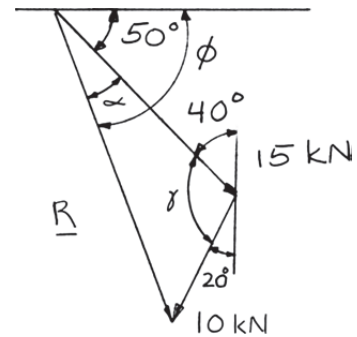
We have 
$$\gamma = 180^\circ - (40^\circ + 20^\circ) = 120^\circ$$

Then 
$$\begin{aligned} R^2 &= (15 \text{ kN})^2 + (10 \text{ kN})^2 \\ &\quad - 2(15 \text{ kN})(10 \text{ kN})\cos 120^\circ \\ &= 475 \text{ kN}^2 \\ R &= 21.794 \text{ kN} \end{aligned}$$

and 
$$\begin{aligned} \frac{10 \text{ kN}}{\sin \alpha} &= \frac{21.794 \text{ kN}}{\sin 120^\circ} \\ \sin \alpha &= \left( \frac{10 \text{ kN}}{21.794 \text{ kN}} \right) \sin 120^\circ \\ &= 0.39737 \\ \alpha &= 23.414 \end{aligned}$$

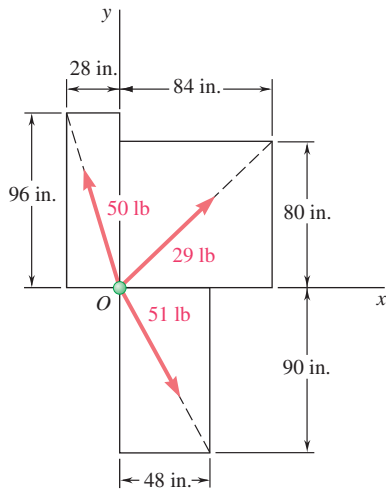
Hence: 
$$\phi = \alpha + 50^\circ = 73.414$$

$$\mathbf{R} = 21.8 \text{ kN} \searrow 73.4^\circ$$



### PROBLEM 2.21

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



### SOLUTION

Compute the following distances:

$$OA = \sqrt{(84)^2 + (80)^2} = 116 \text{ in.}$$

$$OB = \sqrt{(28)^2 + (96)^2} = 100 \text{ in.}$$

$$OC = \sqrt{(48)^2 + (90)^2} = 102 \text{ in.}$$

29-lb Force:

$$F_x = +(29 \text{ lb}) \frac{84}{116}$$

$$F_y = +(29 \text{ lb}) \frac{80}{116}$$

50-lb Force:

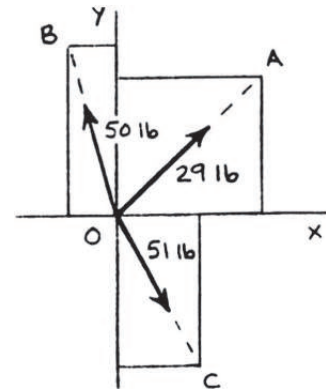
$$F_x = -(50 \text{ lb}) \frac{28}{100}$$

$$F_y = +(50 \text{ lb}) \frac{96}{100}$$

51-lb Force:

$$F_x = +(51 \text{ lb}) \frac{48}{102}$$

$$F_y = -(51 \text{ lb}) \frac{90}{102}$$



$$F_x = +21.0 \text{ lb} \quad \blacktriangleleft$$

$$F_y = +20.0 \text{ lb} \quad \blacktriangleleft$$

$$F_x = -14.00 \text{ lb} \quad \blacktriangleleft$$

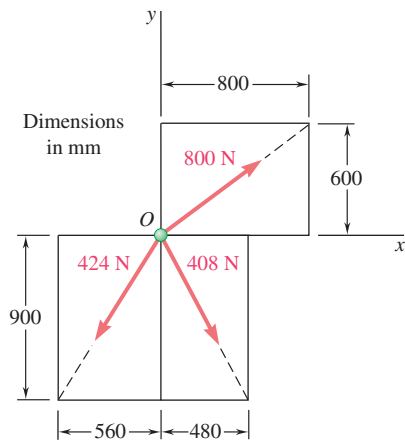
$$F_y = +48.0 \text{ lb} \quad \blacktriangleleft$$

$$F_x = +24.0 \text{ lb} \quad \blacktriangleleft$$

$$F_y = -45.0 \text{ lb} \quad \blacktriangleleft$$

### PROBLEM 2.22

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



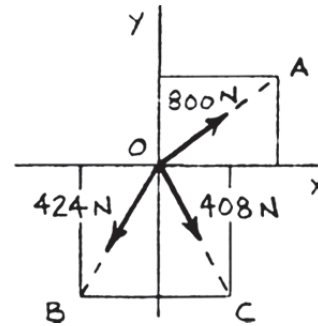
### SOLUTION

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:  $F_x = +(800\text{ N}) \frac{800}{1000} \quad F_x = +640\text{ N} \blacktriangleleft$

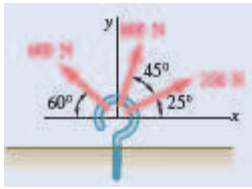
$F_y = +(800\text{ N}) \frac{600}{1000} \quad F_y = +480\text{ N} \blacktriangleleft$

424-N Force:  $F_x = -(424\text{ N}) \frac{560}{1060} \quad F_x = -224\text{ N} \blacktriangleleft$

$F_y = -(424\text{ N}) \frac{900}{1060} \quad F_y = -360\text{ N} \blacktriangleleft$

408-N Force:  $F_x = +(408\text{ N}) \frac{480}{1020} \quad F_x = +192.0\text{ N} \blacktriangleleft$

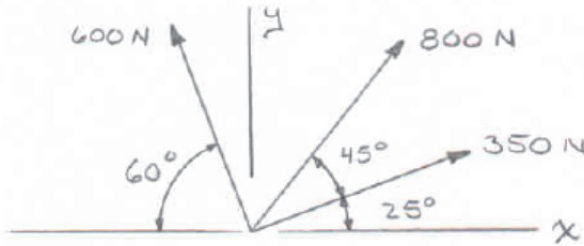
$F_y = -(408\text{ N}) \frac{900}{1020} \quad F_y = -360\text{ N} \blacktriangleleft$



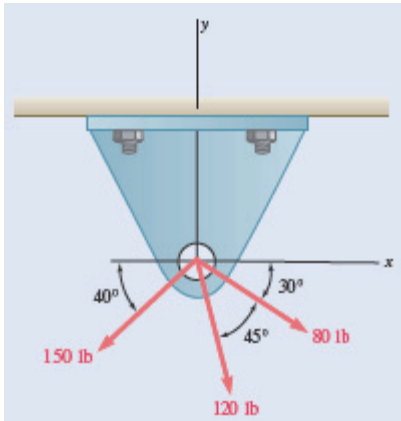
### PROBLEM 2.23

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

### SOLUTION



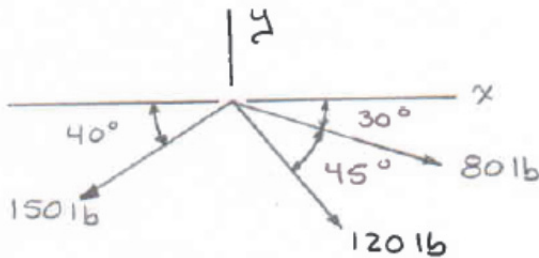
|              |                                       |                                             |
|--------------|---------------------------------------|---------------------------------------------|
| 350-N Force: | $F_x = +(350 \text{ N})\cos 25^\circ$ | $F_x = +317 \text{ N} \blacktriangleleft$   |
|              | $F_y = +(350 \text{ N})\sin 25^\circ$ | $F_y = +147.9 \text{ N} \blacktriangleleft$ |
| 800-N Force: | $F_x = +(800 \text{ N})\cos 70^\circ$ | $F_x = +274 \text{ N} \blacktriangleleft$   |
|              | $F_y = +(800 \text{ N})\sin 70^\circ$ | $F_y = +752 \text{ N} \blacktriangleleft$   |
| 600-N Force: | $F_x = -(600 \text{ N})\cos 60^\circ$ | $F_x = -300 \text{ N} \blacktriangleleft$   |
|              | $F_y = +(600 \text{ N})\sin 60^\circ$ | $F_y = +520 \text{ N} \blacktriangleleft$   |



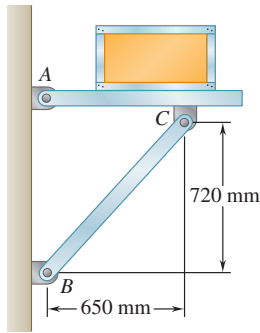
### PROBLEM 2.24

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

### SOLUTION



|               |                                        |                                              |
|---------------|----------------------------------------|----------------------------------------------|
| 80-lb Force:  | $F_x = +(80 \text{ lb})\cos 30^\circ$  | $F_x = +69.3 \text{ lb} \blacktriangleleft$  |
|               | $F_y = -(80 \text{ lb})\sin 30^\circ$  | $F_y = -40.0 \text{ lb} \blacktriangleleft$  |
| 120-lb Force: | $F_x = +(120 \text{ lb})\cos 75^\circ$ | $F_x = +31.1 \text{ lb} \blacktriangleleft$  |
|               | $F_y = -(120 \text{ lb})\sin 75^\circ$ | $F_y = -115.9 \text{ lb} \blacktriangleleft$ |
| 150-lb Force: | $F_x = -(150 \text{ lb})\cos 40^\circ$ | $F_x = -114.9 \text{ lb} \blacktriangleleft$ |
|               | $F_y = -(150 \text{ lb})\sin 40^\circ$ | $F_y = -96.4 \text{ lb} \blacktriangleleft$  |



### PROBLEM 2.25

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

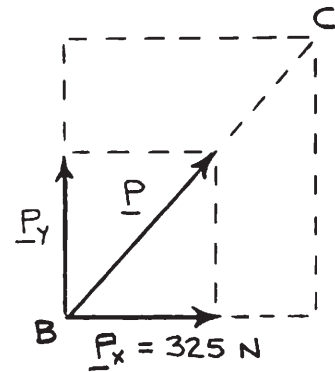
(a)

or

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

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

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

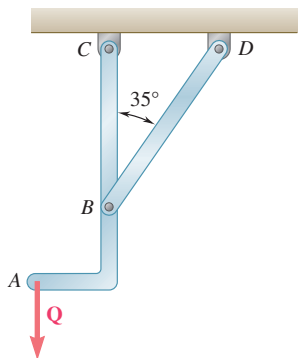


$$P = 485 \text{ N} \blacktriangleleft$$

(b)

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

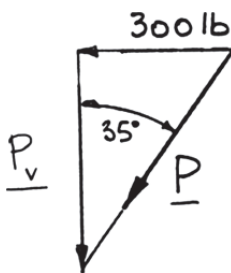
$$P_y = 360 \text{ N} \blacktriangleleft$$



### PROBLEM 2.26

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)

$$P \sin 35^\circ = 300 \text{ lb}$$

$$P = \frac{300 \text{ lb}}{\sin 35^\circ}$$

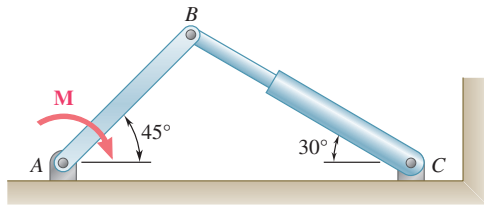
$$P = 523 \text{ lb} \quad \blacktriangleleft$$

(b) Vertical component

$$P_v = P \cos 35^\circ$$

$$= (523 \text{ lb}) \cos 35^\circ$$

$$P_v = 428 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.27

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

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

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

$$= 15^\circ$$

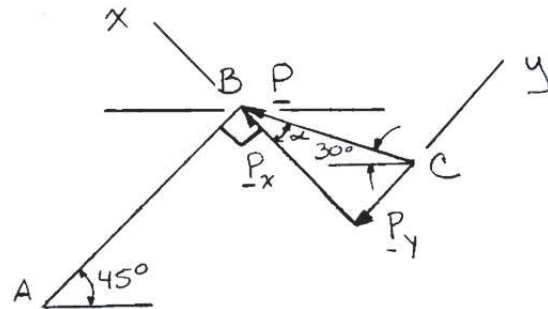
(a)

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

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

$$= \frac{600 \text{ N}}{\cos 15^\circ}$$

$$= 621.17 \text{ N}$$



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

(b)

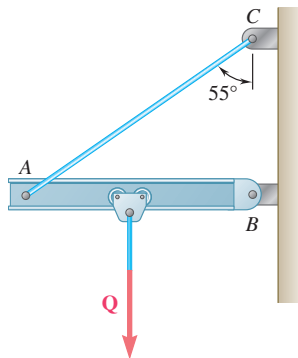
$$\tan \alpha = \frac{P_y}{P_x}$$

$$P_y = P_x \tan \alpha$$

$$= (600 \text{ N}) \tan 15^\circ$$

$$= 160.770 \text{ N}$$

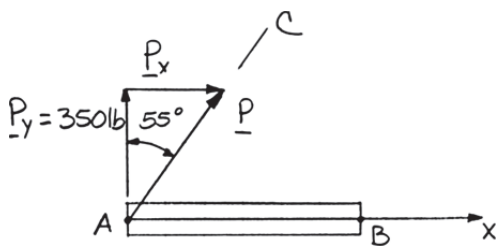
$$P_y = 160.8 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.28

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)

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

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

$$= 610.21 \text{ lb}$$

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

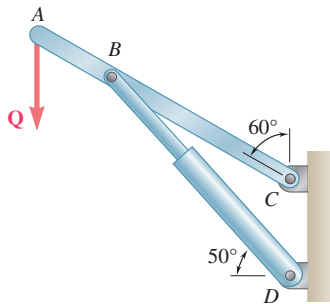
(b)

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

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

$$= 499.85 \text{ lb}$$

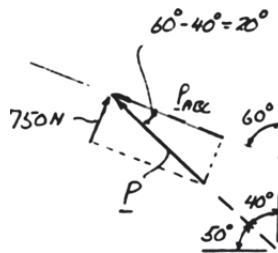
$$P_x = 500 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.29

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)

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

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

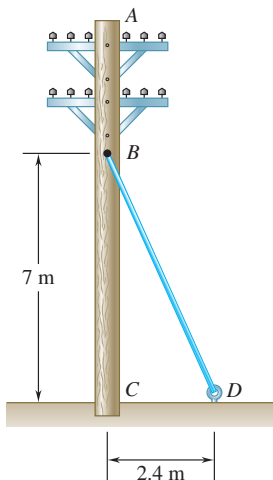
$$P = 2190 \text{ N} \quad \blacktriangleleft$$

(b)

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

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

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



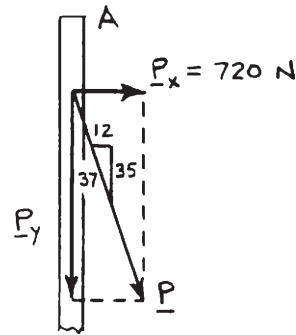
### PROBLEM 2.30

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)

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

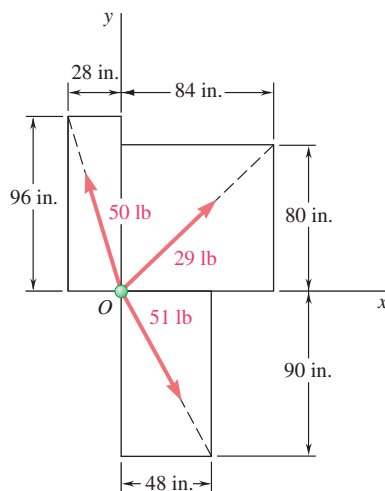


$$P = 2.22 \text{ kN} \quad \blacktriangleleft$$

(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 2.31

Determine the resultant of the three forces of Problem 2.21.

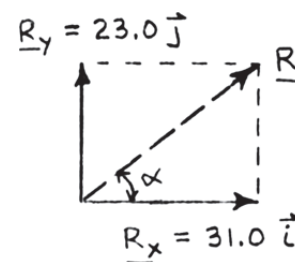
**PROBLEM 2.21** Determine the  $x$  and  $y$  components of each of the forces shown.

### SOLUTION

Components of the forces were determined in Problem 2.21:

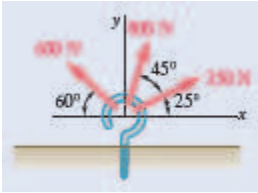
| Force | $x$ Comp. (lb) | $y$ Comp. (lb) |
|-------|----------------|----------------|
| 29 lb | +21.0          | +20.0          |
| 50 lb | -14.00         | +48.0          |
| 51 lb | +24.0          | -45.0          |
|       | $R_x = +31.0$  | $R_y = +23.0$  |

$$\begin{aligned}
 \mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\
 &= (31.0 \text{ lb})\mathbf{i} + (23.0 \text{ lb})\mathbf{j} \\
 \tan \alpha &= \frac{R_y}{R_x} \\
 &= \frac{23.0}{31.0} \\
 \alpha &= 36.573^\circ \\
 R &= \frac{23.0 \text{ lb}}{\sin(36.573^\circ)} \\
 &= 38.601 \text{ lb}
 \end{aligned}$$



$$\mathbf{R} = 38.6 \text{ lb} \angle 36.6^\circ \blacktriangleleft$$

### PROBLEM 2.32



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:

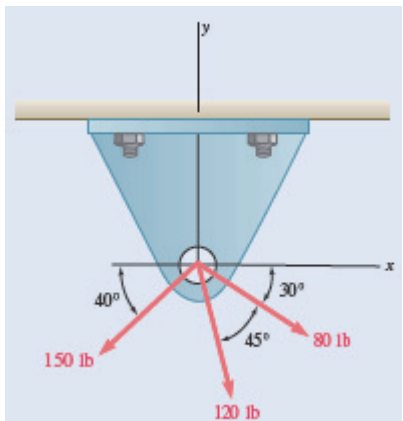
| Force | $x$ Comp. (N) | $y$ Comp. (N)   |
|-------|---------------|-----------------|
| 350 N | +317          | +147.9          |
| 800 N | +274          | +752            |
| 600 N | -300          | +520            |
|       | $R_x = +291$  | $R_y = +1419.9$ |

$$\begin{aligned}\mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\ &= (291 \text{ N})\mathbf{i} + (1419.9 \text{ N})\mathbf{j}\end{aligned}$$

$$\begin{aligned}\tan \alpha &= \frac{R_y}{R_x} \\ &= \frac{1419.9 \text{ N}}{291 \text{ N}} \\ \alpha &= 78.418^\circ \\ R &= \frac{1419.9 \text{ N}}{\sin(78.418^\circ)}\end{aligned}$$

$$= 1449 \text{ N}$$

$$\mathbf{R} = 1449 \text{ N} \angle 78.4^\circ \blacktriangleleft$$



### PROBLEM 2.33

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) |
|--------|----------------|----------------|
| 80 lb  | +69.3          | -40.0          |
| 120 lb | +31.1          | -115.9         |
| 150 lb | -114.9         | -96.4          |
|        | $R_x = -14.50$ | $R_y = -252.3$ |

$$\begin{aligned}\mathbf{R} &= R_x \mathbf{i} + R_y \mathbf{j} \\ &= -(14.50 \text{ lb})\mathbf{i} - (252.3 \text{ lb})\mathbf{j}\end{aligned}$$

$$\begin{aligned}\tan \beta &= \frac{R_x}{R_y} \\ &= \frac{-14.50}{-252.3} \\ \beta &= 3.289^\circ \\ R &= \frac{252.3 \text{ lb}}{\cos(3.289^\circ)} \\ &= 253 \text{ lb}\end{aligned}$$

$$\mathbf{R} = 253 \text{ lb} \nearrow 86.7^\circ \blacktriangleleft$$

Dimensions in mm

**PROBLEM 2.34**

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**

Components of the forces were determined in Problem 2.22:

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

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

$$= (608 \text{ lb})\mathbf{i} + (-240 \text{ lb})\mathbf{j}$$

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

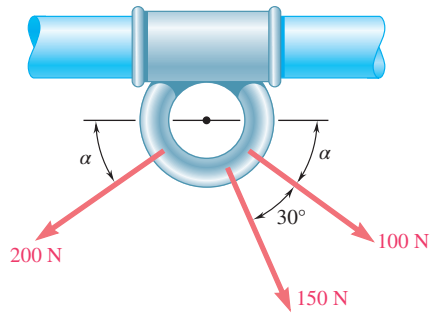
$$= \frac{240}{608}$$

$$\alpha = 21.541^\circ$$

$$R = \frac{240 \text{ N}}{\sin(21.541^\circ)}$$

$$= 653.65 \text{ N}$$

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



### 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:

$$F_x = +(150 \text{ N}) \cos 65^\circ = +63.393 \text{ N}$$

$$F_y = -(150 \text{ N}) \sin 65^\circ = -135.946 \text{ N}$$

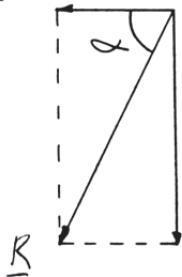
200-N Force:

$$F_x = -(200 \text{ N}) \cos 35^\circ = -163.830 \text{ N}$$

$$F_y = -(200 \text{ N}) \sin 35^\circ = -114.715 \text{ N}$$

| 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        |
|       | $R_x = -18.522$ | $R_y = -308.02$ |

$$R_x = -18.522 \text{ N}$$



$$R_y = -308.02 \text{ N}$$

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

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

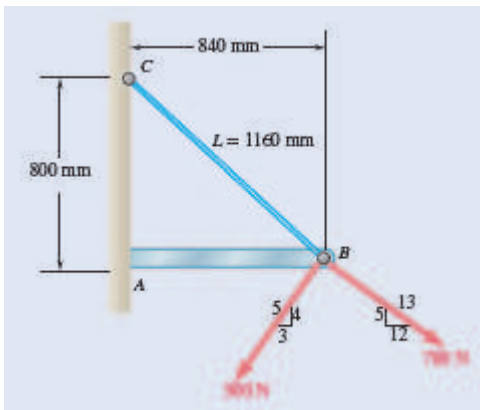
$$\tan \alpha = \frac{R_y}{R_x}$$

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

$$\alpha = 86.559^\circ$$

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

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



### PROBLEM 2.36

Knowing that the tension in cable  $BC$  is 725 N, determine the resultant of the three forces exerted at Point  $B$  of beam  $AB$ .

### SOLUTION

Cable  $BC$  Force:

$$F_x = -(725 \text{ N}) \frac{840}{1160} = -525 \text{ N}$$

$$F_y = (725 \text{ N}) \frac{840}{1160} = 500 \text{ N}$$

500-N Force:

$$F_x = -(500 \text{ N}) \frac{3}{5} = -300 \text{ N}$$

$$F_y = -(500 \text{ N}) \frac{4}{5} = -400 \text{ N}$$

780-N Force:

$$F_x = (780 \text{ N}) \frac{12}{13} = 720 \text{ N}$$

$$F_y = -(780 \text{ N}) \frac{5}{13} = -300 \text{ N}$$

and

$$R_x = \Sigma F_x = -105 \text{ N}$$

$$R_y = \Sigma F_y = -200 \text{ N}$$

$$R = \sqrt{(-105 \text{ N})^2 + (-200 \text{ N})^2}$$

$$= 225.89 \text{ N}$$

Further:

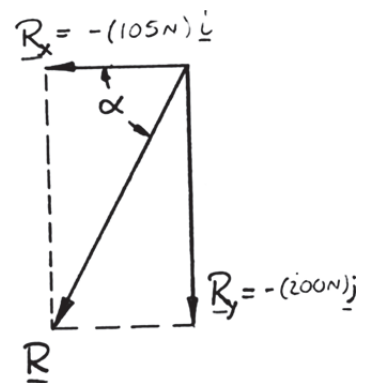
$$\tan \alpha = \frac{200}{105}$$

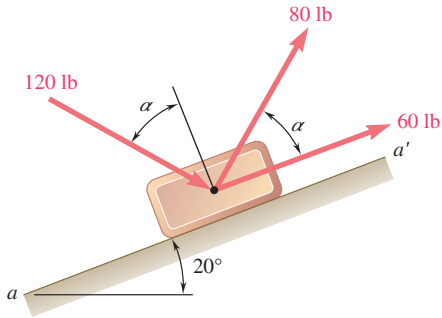
$$\alpha = \tan^{-1} \frac{200}{105}$$

$$= 62.3^\circ$$

Thus:

$$\mathbf{R} = 226 \text{ N} \nearrow 62.3^\circ$$





**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  $R_x = \Sigma F_x = 200.305 \text{ lb}$   
 $R_y = \Sigma F_y = 29.803 \text{ lb}$

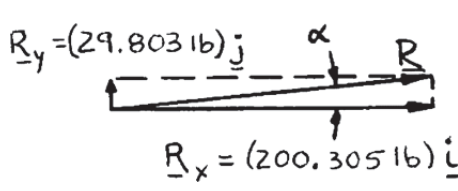
$$R = \sqrt{(200.305 \text{ lb})^2 + (29.803 \text{ lb})^2}$$

$$= 202.510 \text{ lb}$$

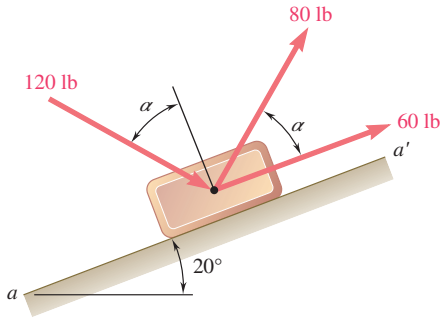
Further:  $\tan \alpha = \frac{29.803}{200.305}$

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

$$= 8.46^\circ$$



**R = 203 lb  $\nearrow$  8.46° ◀**



**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

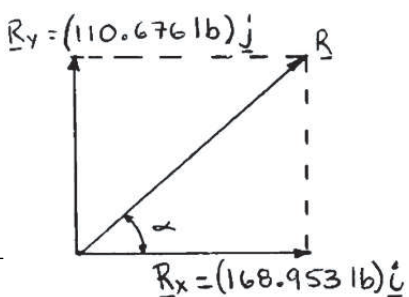
$$R = \sqrt{(168.953 \text{ lb})^2 + (110.676 \text{ lb})^2}$$

$$= 201.976 \text{ lb}$$

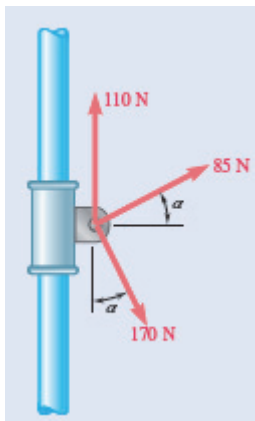
$$\tan \alpha = \frac{110.676}{168.953}$$

$$\tan \alpha = 0.65507$$

$$\alpha = 33.228^\circ$$



$R = 202 \text{ lb} \angle 33.2^\circ$  ◀



### PROBLEM 2.39

A collar that can slide on a vertical rod is subjected to the three forces shown. Determine (a) the required value of  $\alpha$  if the resultant of the three forces is to be horizontal, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$\begin{aligned} R_x &= \Sigma F_x \\ &= (85 \text{ N}) \cos \alpha + (170 \text{ N}) \sin(\alpha) \end{aligned} \quad (1)$$

$$\begin{aligned} R_y &= \Sigma F_y \\ &= +(110 \text{ N}) + (85 \text{ N}) \sin(\alpha) - (170 \text{ N}) \cos \alpha \end{aligned} \quad (2)$$

(a) For  $\mathbf{R}$  to be horizontal, we must have  $R_y = 0$ . We make  $R_y = 0$  in Eq. (2):

$$110 + 85 \sin \alpha - 170 \cos \alpha = 0$$

$$22 + 17 \sin \alpha - 34 \cos \alpha = 0$$

$$17 \sin \alpha + 22 = -34 \sqrt{1 - \sin^2 \alpha}$$

$$289 \sin^2 \alpha + 748 \sin \alpha + 484 = 1156(1 - \sin^2 \alpha)$$

$$1445 \sin^2 \alpha + 748 \sin \alpha - 672 = 0$$

Solving by use of the quadratic formula:

$$\sin \alpha = 0.47059$$

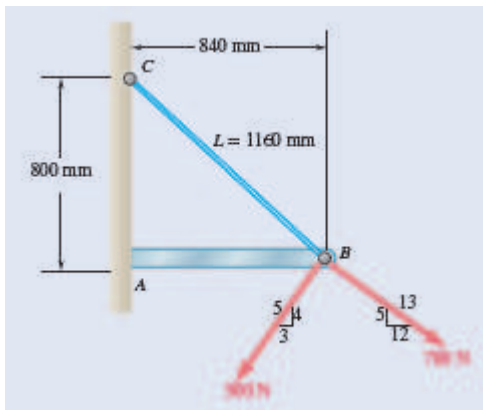
$$\alpha = 28.072^\circ$$

$$\alpha = 28.1^\circ \quad \blacktriangleleft$$

(b) Since  $R = R_x$  using Eq. (1):

$$\begin{aligned} R &= 85 \cos 28.072^\circ + 170 \sin 28.072^\circ \\ &= 155.0 \text{ N} \end{aligned}$$

$$R = 155.0 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.40

For the beam of Problem 2.36, determine (a) the required tension in cable  $BC$  if the resultant of the three forces exerted at Point  $B$  is to be vertical, (b) the corresponding magnitude of the resultant.

### SOLUTION

$$R_x = \Sigma F_x = -\frac{840}{1160}T_{BC} + \frac{12}{13}(780 \text{ N}) - \frac{3}{5}(500 \text{ N})$$

$$R_x = -\frac{21}{29}T_{BC} + 420 \text{ N} \quad (1)$$

$$R_y = \Sigma F_y = \frac{800}{1160}T_{BC} - \frac{5}{13}(780 \text{ N}) - \frac{4}{5}(500 \text{ N})$$

$$R_y = \frac{20}{29}T_{BC} - 700 \text{ N} \quad (2)$$

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

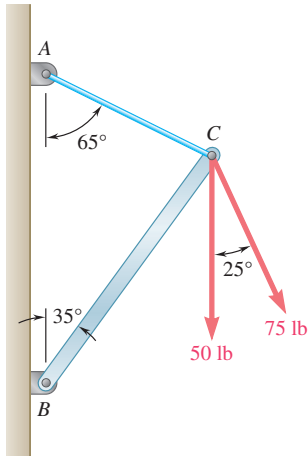
$$\text{Set } R_x = 0 \text{ in Eq. (1)} \quad -\frac{21}{29}T_{BC} + 420 \text{ N} = 0 \quad T_{BC} = 580 \text{ N}$$

(b) Substituting for  $T_{BC}$  in Eq. (2):

$$R_y = \frac{20}{29}(580 \text{ N}) - 700 \text{ N}$$

$$R_y = -300 \text{ N}$$

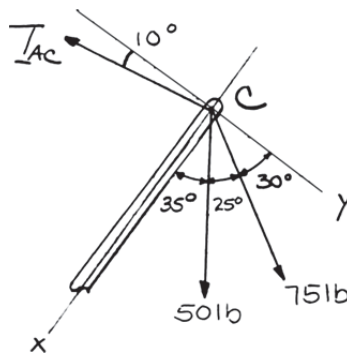
$$R = |R_y| = 300 \text{ N} \quad R = 300 \text{ N}$$



### PROBLEM 2.41

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:

$$\begin{aligned} R_x = \Sigma F_x &= T_{AC} \sin 10^\circ + (50 \text{ lb}) \cos 35^\circ + (75 \text{ lb}) \cos 60^\circ \\ &= T_{AC} \sin 10^\circ + 78.458 \text{ lb} \end{aligned} \quad (1)$$

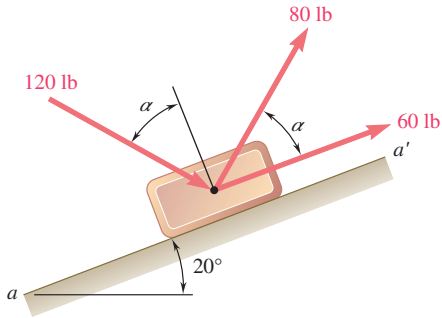
$$\begin{aligned} R_y = \Sigma F_y &= (50 \text{ lb}) \sin 35^\circ + (75 \text{ lb}) \sin 60^\circ - T_{AC} \cos 10^\circ \\ R_y &= 93.631 \text{ lb} - T_{AC} \cos 10^\circ \end{aligned} \quad (2)$$

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

$$\begin{aligned} 93.631 \text{ lb} - T_{AC} \cos 10^\circ &= 0 \\ T_{AC} &= 95.075 \text{ lb} \end{aligned} \quad T_{AC} = 95.1 \text{ lb} \quad \blacktriangleleft$$

(b) Substituting for  $T_{AC}$  in Eq. (1):

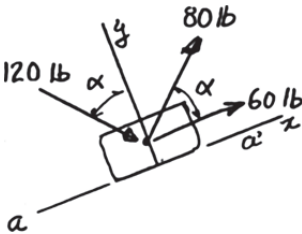
$$\begin{aligned} R_x &= (95.075 \text{ lb}) \sin 10^\circ + 78.458 \text{ lb} \\ &= 94.968 \text{ lb} \\ R &= R_x \end{aligned} \quad R = 95.0 \text{ lb} \quad \blacktriangleleft$$



**PROBLEM 2.42**

For the block of Problems 2.37 and 2.38, determine (a) the required value of  $\alpha$  if the resultant of the three forces shown is to be parallel to the incline, (b) the corresponding magnitude of the resultant.

**SOLUTION**



Select the  $x$  axis to be along  $a a'$ .

Then

$$R_x = \Sigma F_x = (60 \text{ lb}) + (80 \text{ lb})\cos \alpha + (120 \text{ lb})\sin \alpha \quad (1)$$

and

$$R_y = \Sigma F_y = (80 \text{ lb})\sin \alpha - (120 \text{ lb})\cos \alpha \quad (2)$$

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

$$(80 \text{ lb})\sin \alpha - (120 \text{ lb})\cos \alpha = 0$$

Dividing each term by  $\cos \alpha$  gives:

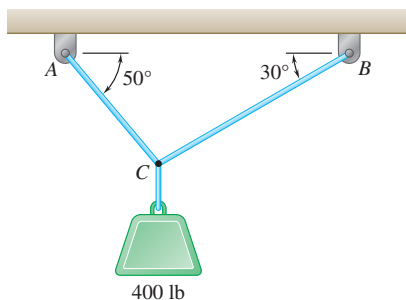
$$(80 \text{ lb})\tan \alpha = 120 \text{ lb}$$

$$\tan \alpha = \frac{120 \text{ lb}}{80 \text{ lb}}$$

$$\alpha = 56.310^\circ \quad \blacktriangleleft$$

(b) Substituting for  $\alpha$  in Eq. (1) gives:

$$R_x = 60 \text{ lb} + (80 \text{ lb})\cos 56.31^\circ + (120 \text{ lb})\sin 56.31^\circ = 204.22 \text{ lb} \quad R_x = 204 \text{ lb} \quad \blacktriangleleft$$

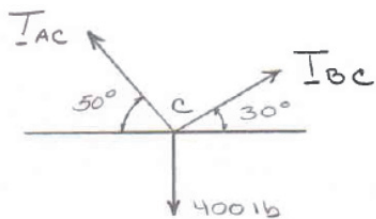


### PROBLEM 2.43

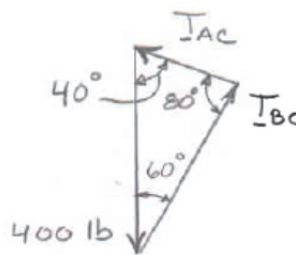
Two cables are tied together at  $C$  and are loaded as shown. Determine the tension (a) in cable  $AC$ , (b) in cable  $BC$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



Law of sines:

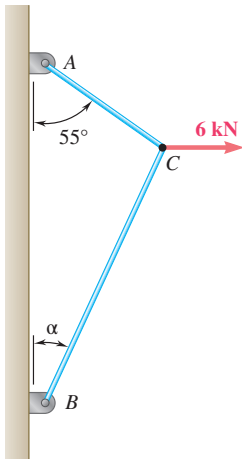
$$\frac{T_{AC}}{\sin 60^\circ} = \frac{T_{BC}}{\sin 40^\circ} = \frac{400 \text{ lb}}{\sin 80^\circ}$$

$$(a) \quad T_{AC} = \frac{400 \text{ lb}}{\sin 80^\circ} (\sin 60^\circ) \quad T_{AC} = 352 \text{ lb} \blacktriangleleft$$

$$(b) \quad T_{BC} = \frac{400 \text{ lb}}{\sin 80^\circ} (\sin 40^\circ) \quad T_{BC} = 261 \text{ lb} \blacktriangleleft$$

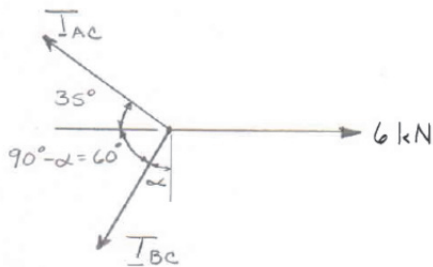
### PROBLEM 2.44

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

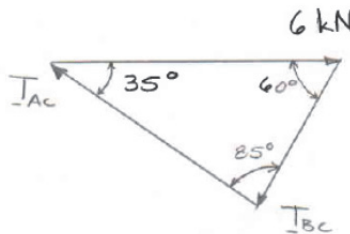


### SOLUTION

#### Free-Body Diagram



#### Force Triangle

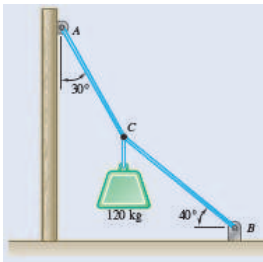


Law of sines:

$$\frac{T_{AC}}{\sin 60^\circ} = \frac{T_{BC}}{\sin 35^\circ} = \frac{6 \text{ kN}}{\sin 85^\circ}$$

$$(a) \quad T_{AC} = \frac{6 \text{ kN}}{\sin 85^\circ} (\sin 60^\circ) \quad T_{AC} = 5.22 \text{ kN} \blacktriangleleft$$

$$(b) \quad T_{BC} = \frac{6 \text{ kN}}{\sin 85^\circ} (\sin 35^\circ) \quad T_{BC} = 3.45 \text{ kN} \blacktriangleleft$$

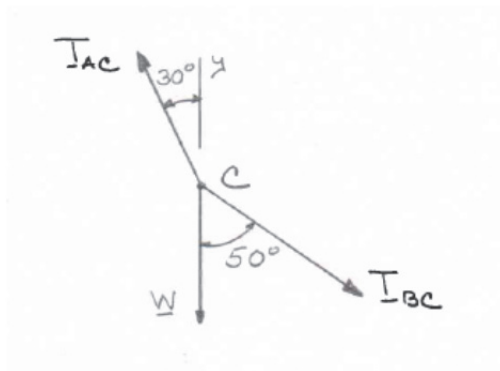


### PROBLEM 2.45

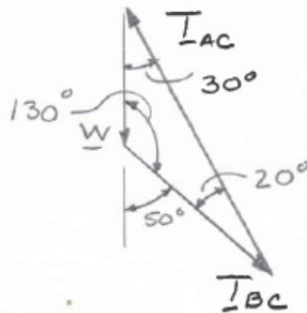
Two cables are tied together at  $C$  and are loaded as shown. Determine the tension (a) in cable  $AC$ , (b) in cable  $BC$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



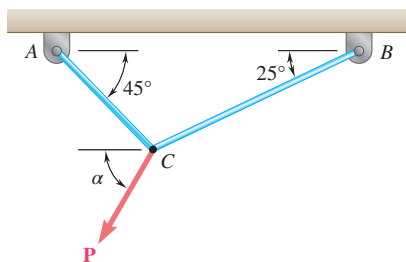
$$W = mg = (120 \text{ kg})(9.81 \text{ m/s}^2) = 1177 \text{ N}$$

Law of sines:

$$\frac{T_{AC}}{\sin 130^\circ} = \frac{T_{BC}}{\sin 30^\circ} = \frac{1.177 \text{ kN}}{\sin 20^\circ}$$

$$(a) \quad T_{AC} = \frac{1.177 \text{ kN}}{\sin 20^\circ} (\sin 130^\circ) \quad T_{AC} = 2.64 \text{ kN} \blacktriangleleft$$

$$(b) \quad T_{BC} = \frac{1.177 \text{ kN}}{\sin 20^\circ} (\sin 30^\circ) \quad T_{BC} = 1.721 \text{ kN} \blacktriangleleft$$

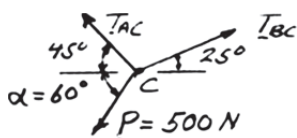


### PROBLEM 2.46

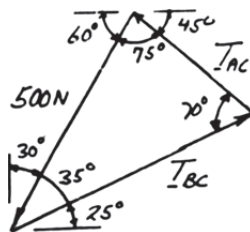
Two cables are tied together at  $C$  and are loaded as shown. Knowing that  $P = 500 \text{ N}$  and  $\alpha = 60^\circ$ , determine the tension in (a) in cable  $AC$ , (b) in cable  $BC$ .

### 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)

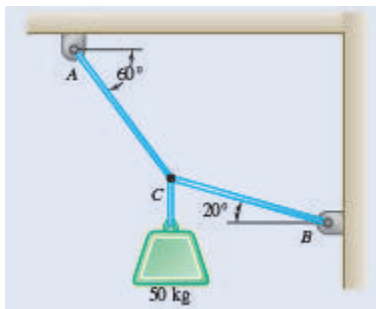
$$T_{AC} = \frac{500 \text{ N}}{\sin 70^\circ} \sin 35^\circ$$

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

(b)

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

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

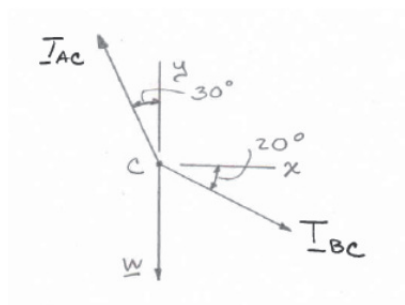


### PROBLEM 2.47

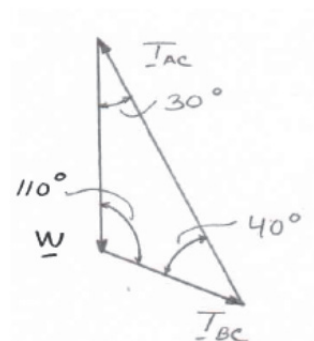
Two cables are tied together at  $C$  and are loaded as shown. Determine the tension (a) in cable  $AC$ , (b) in cable  $BC$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



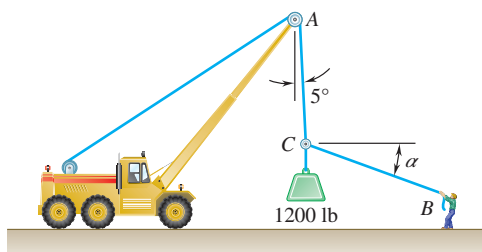
$$W = mg = (50 \text{ kg})(9.81 \text{ m/s}^2) = 490 \text{ N}$$

Law of sines:

$$\frac{T_{AC}}{\sin 110^\circ} = \frac{T_{BC}}{\sin 30^\circ} = \frac{490 \text{ N}}{\sin 40^\circ}$$

$$(a) \quad T_{AC} = \frac{490 \text{ N}}{\sin 40^\circ} \sin 110^\circ \quad T_{AC} = 716 \text{ N} \blacktriangleleft$$

$$(b) \quad T_{BC} = \frac{490 \text{ N}}{\sin 40^\circ} \sin 30^\circ \quad T_{BC} = 381 \text{ N} \blacktriangleleft$$

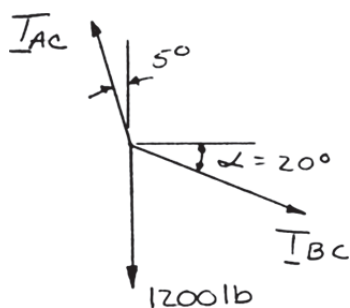


### PROBLEM 2.48

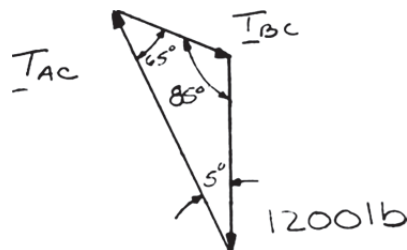
Knowing that  $\alpha = 20^\circ$ , determine the tension (a) in cable AC, (b) in rope BC.

### SOLUTION

Free-Body Diagram



Force Triangle

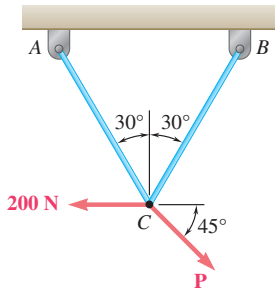


Law of sines:

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

(a)  $T_{AC} = \frac{1200 \text{ lb}}{\sin 65^\circ} \sin 110^\circ$   $T_{AC} = 1244 \text{ lb} \blacktriangleleft$

(b)  $T_{BC} = \frac{1200 \text{ lb}}{\sin 65^\circ} \sin 5^\circ$   $T_{BC} = 115.4 \text{ lb} \blacktriangleleft$

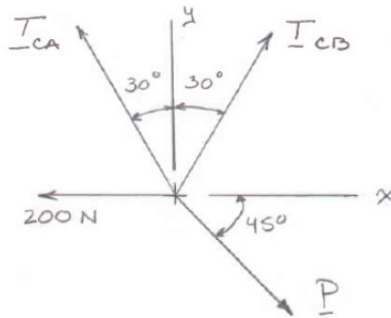


### PROBLEM 2.49

Two cables are tied together at  $C$  and are loaded as shown. Knowing that  $P = 300$  N, determine the tension in cables  $AC$  and  $BC$ .

### SOLUTION

#### Free-Body Diagram



$$\rightarrow \Sigma F_x = 0 \quad -T_{CA} \sin 30^\circ + T_{CB} \sin 30^\circ - P \cos 45^\circ - 200 \text{ N} = 0$$

For  $P = 200$  N we have,

$$-0.5T_{CA} + 0.5T_{CB} + 212.13 - 200 = 0 \quad (1)$$

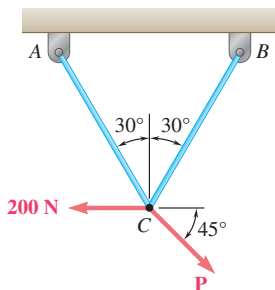
$$+\uparrow \Sigma F_y = 0 \quad T_{CA} \cos 30^\circ - T_{CB} \cos 30^\circ - P \sin 45^\circ = 0$$

$$0.86603T_{CA} + 0.86603T_{CB} - 212.13 = 0 \quad (2)$$

Solving equations (1) and (2) simultaneously gives,

$$T_{CA} = 134.6 \text{ N} \quad \blacktriangleleft$$

$$T_{CB} = 110.4 \text{ N} \quad \blacktriangleleft$$

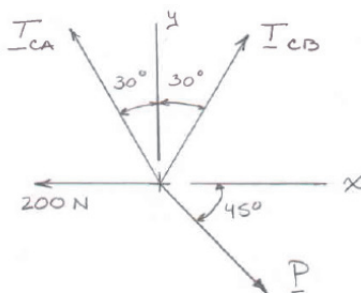


### PROBLEM 2.50

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

### SOLUTION

#### Free-Body Diagram



$$\rightarrow \Sigma F_x = 0 \quad -T_{CA} \sin 30^\circ + T_{CB} \sin 30^\circ - P \cos 45^\circ - 200 \text{ N} = 0$$

For  $T_{CA} = 0$  we have,

$$0.5T_{CB} + 0.70711P - 200 = 0 \quad (1)$$

$$\uparrow \Sigma F_y = 0 \quad T_{CA} \cos 30^\circ - T_{CB} \cos 30^\circ - P \sin 45^\circ = 0; \text{ again setting } T_{CA} = 0 \text{ yields,}$$

$$0.86603T_{CB} - 0.70711P = 0 \quad (2)$$

Adding equations (1) and (2) gives,  $1.36603T_{CB} = 200$  hence  $T_{CB} = 146.410 \text{ N}$  and  $P = 179.315 \text{ N}$

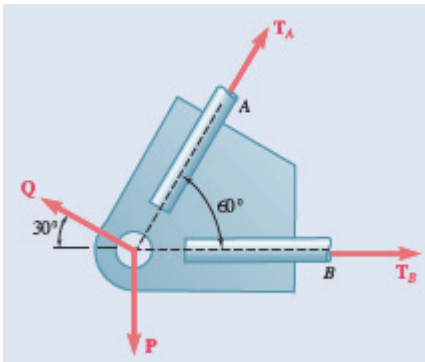
Substituting for  $T_{CB} = 0$  into the equilibrium equations and solving simultaneously gives,

$$-0.5T_{CA} + 0.70711P - 200 = 0$$

$$0.86603T_{CA} - 0.70711P = 0$$

And  $T_{CA} = 546.40 \text{ N}$ ,  $P = 669.20 \text{ N}$  Thus for both cables to remain taut, load  $P$  must be within the range of  $179.315 \text{ N}$  and  $669.20 \text{ N}$ .

$$179.3 \text{ N} < P < 669 \text{ N} \quad \blacktriangleleft$$

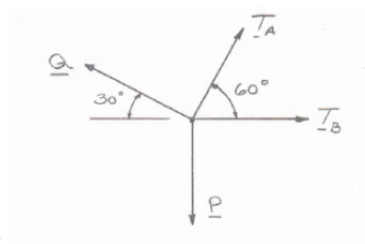


### PROBLEM 2.51

Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that  $P = 600$  lb and  $Q = 800$  lb, determine the tension in rods **A** and **B**.

### SOLUTION

#### Free-Body Diagram



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

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

Substituting components:

$$\begin{aligned} \mathbf{R} = & -(600 \text{ lb})\mathbf{j} - [(800 \text{ lb})\cos 30^\circ]\mathbf{i} \\ & + [(800 \text{ lb})\sin 30^\circ]\mathbf{j} \\ & + T_B\mathbf{i} + (T_A \cos 60^\circ)\mathbf{i} + (T_A \sin 60^\circ)\mathbf{j} = 0 \end{aligned}$$

Summing forces in the  $y$ -direction:

$$-600 \text{ lb} + (800 \text{ lb})\sin 30^\circ + T_A \sin 60^\circ = 0$$

$$T_A = 230.94 \text{ lb}$$

$$T_A = 231 \text{ lb} \quad \blacktriangleleft$$

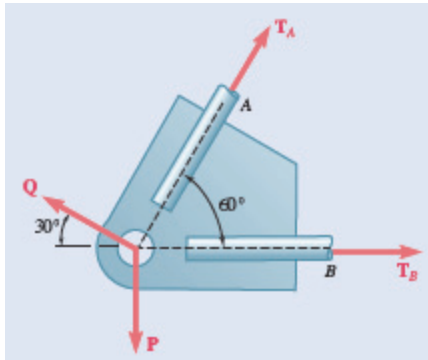
Summing forces in the  $x$ -direction:

$$-(800 \text{ lb})\cos 30^\circ + T_B + T_A \cos 60^\circ = 0$$

Thus,

$$\begin{aligned} T_B = & -(230.94 \text{ lb})\cos 60^\circ + (800 \text{ lb})\cos 30^\circ \\ = & 577.35 \text{ lb} \end{aligned}$$

$$T_B = 577 \text{ lb} \quad \blacktriangleleft$$

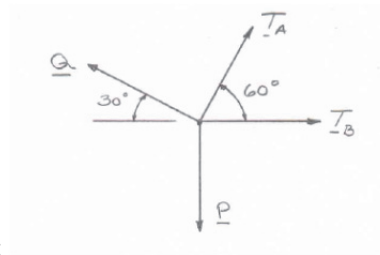


### PROBLEM 2.52

Two forces **P** and **Q** are applied as shown to an aircraft connection. Knowing that the connection is in equilibrium and that the tensions in rods *A* and *B* are  $T_A = 240$  lb and  $T_B = 500$  lb, determine the magnitudes of **P** and **Q**.

### SOLUTION

#### Free-Body Diagram



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

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

Substituting components:  $\mathbf{R} = -P\mathbf{j} - Q \cos 30^\circ \mathbf{i} + Q \sin 30^\circ \mathbf{j}$   
 $+ [(240 \text{ lb}) \cos 60^\circ] \mathbf{i}$   
 $+ [(240 \text{ lb}) \sin 60^\circ] \mathbf{j} + (500 \text{ lb}) \mathbf{i}$

Summing forces in the *x*-direction:

$$-Q \cos 30^\circ + (240 \text{ lb}) \cos 60^\circ + 500 \text{ lb} = 0$$

$$Q = 715.91 \text{ lb}$$

Summing forces in the *y*-direction:

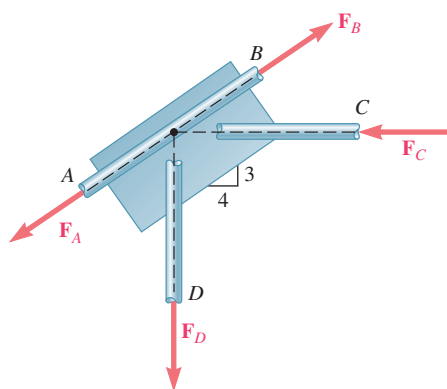
$$-P + Q \sin 30^\circ + (240 \text{ lb}) \sin 60^\circ = 0$$

$$P = Q \sin 30^\circ + (240 \text{ lb}) \sin 60^\circ$$

$$= (715.91 \text{ lb}) \sin 30^\circ + (240 \text{ lb}) \sin 60^\circ$$

$$= 565.80 \text{ lb}$$

$$P = 566 \text{ lb}; \quad Q = 716 \text{ lb} \quad \blacktriangleleft$$

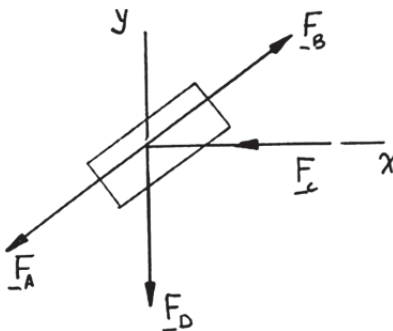


### PROBLEM 2.53

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

$$F_A = 8 \text{ kN}$$

$$F_B = 16 \text{ kN}$$

$$F_C = \frac{4}{5}(16 \text{ kN}) - \frac{4}{5}(8 \text{ kN})$$

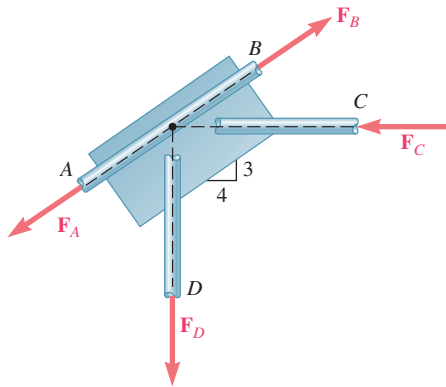
$$F_C = 6.40 \text{ kN} \quad \blacktriangleleft$$

$$\Sigma F_y = 0: \quad -F_D + \frac{3}{5}F_B - \frac{3}{5}F_A = 0$$

With  $F_A$  and  $F_B$  as above:

$$F_D = \frac{3}{5}(16 \text{ kN}) - \frac{3}{5}(8 \text{ kN})$$

$$F_D = 4.80 \text{ kN} \quad \blacktriangleleft$$

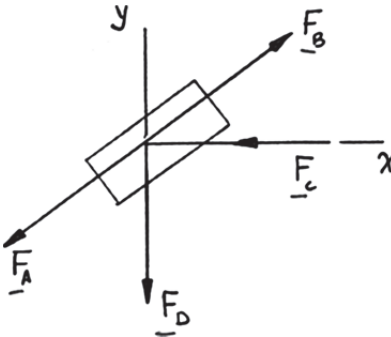


### PROBLEM 2.54

A welded connection is in equilibrium under the action of the four forces shown. Knowing that  $F_A = 5$  kN and  $F_D = 6$  kN, determine the magnitudes of the other two forces.

### SOLUTION

#### Free-Body Diagram of Connection



$$\Sigma F_y = 0: -F_D - \frac{3}{5}F_A + \frac{3}{5}F_B = 0$$

or

$$F_B = F_D + \frac{3}{5}F_A$$

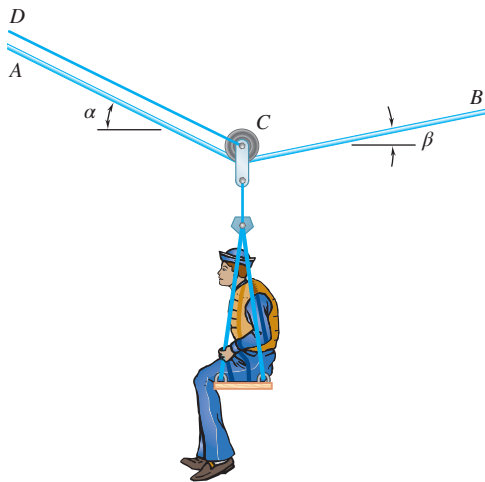
With

$$F_A = 5 \text{ kN}, \quad F_D = 6 \text{ kN}$$

$$F_B = \frac{5}{3} \left[ 6 \text{ kN} + \frac{3}{5}(5 \text{ kN}) \right] \qquad F_B = 15.00 \text{ kN} \blacktriangleleft$$

$$\Sigma F_x = 0: -F_C + \frac{4}{5}F_B - \frac{4}{5}F_A = 0$$

$$\begin{aligned} F_C &= \frac{4}{5}(F_B - F_A) \\ &= \frac{4}{5}(15 \text{ kN} - 5 \text{ kN}) \qquad F_C = 8.00 \text{ kN} \blacktriangleleft \end{aligned}$$

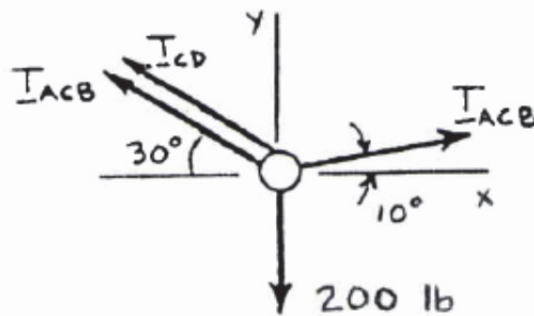


### PROBLEM 2.55

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 200 lb, determine the tension (a) in the support cable  $ACB$ , (b) in the traction cable  $CD$ .

### SOLUTION

#### Free-Body Diagram



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

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

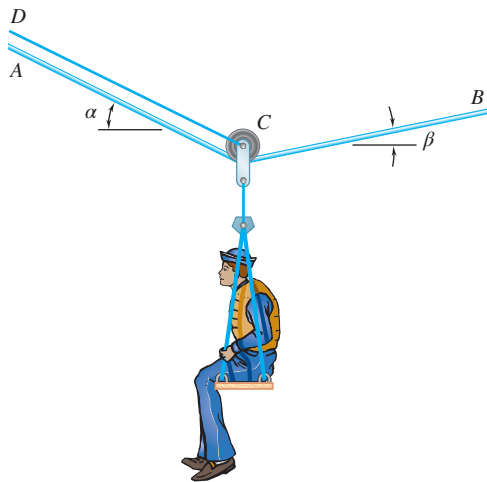
$$+\uparrow \Sigma F_y = 0: T_{ACB} \sin 10^\circ + T_{ACB} \sin 30^\circ + T_{CD} \sin 30^\circ - 200 = 0$$

$$0.67365 T_{ACB} + 0.5 T_{CD} = 200 \quad (2)$$

(a) Substitute (1) into (2):  $0.67365 T_{ACB} + 0.5(0.137158 T_{ACB}) = 200$

$$T_{ACB} = 269.46 \text{ lb} \quad T_{ACB} = 269 \text{ lb} \quad \blacktriangleleft$$

(b) From (1):  $T_{CD} = 0.137158(269.46 \text{ lb}) \quad T_{CD} = 37.0 \text{ lb} \quad \blacktriangleleft$

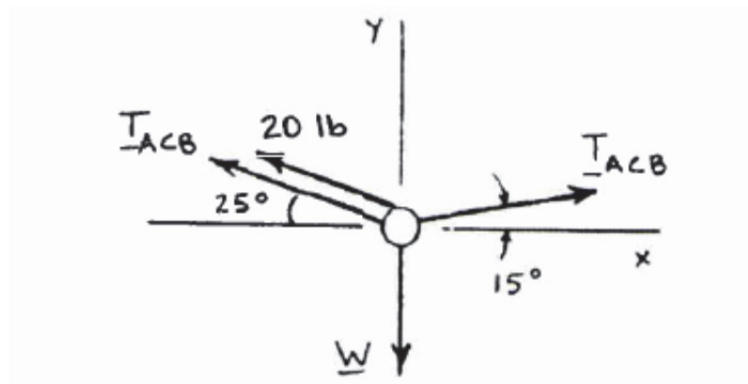


### PROBLEM 2.56

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 20 lb, determine (a) the combined weight of the boatswain's chair and the sailor, (b) the tension in the support cable  $ACB$ .

### SOLUTION

#### Free-Body Diagram



$$\pm \rightarrow \Sigma F_x = 0: T_{ACB} \cos 15^\circ - T_{ACB} \cos 25^\circ - (20 \text{ lb}) \cos 25^\circ = 0$$

$$T_{ACB} = 304.04 \text{ lb}$$

$$+\uparrow \Sigma F_y = 0: (304.04 \text{ lb}) \sin 15^\circ + (304.04 \text{ lb}) \sin 25^\circ$$

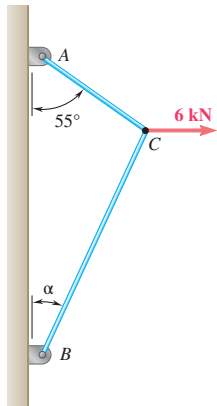
$$+ (20 \text{ lb}) \sin 25^\circ - W = 0$$

$$W = 215.64 \text{ lb}$$

$$(a) \quad W = 216 \text{ lb} \quad \blacktriangleleft$$

$$(b) \quad T_{ACB} = 304 \text{ lb} \quad \blacktriangleleft$$

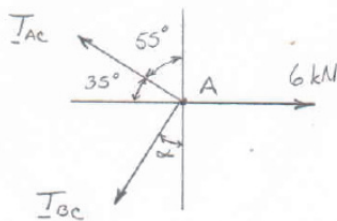
### PROBLEM 2.57



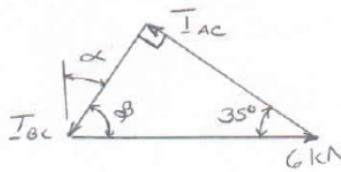
For the cables of prob. 2.44, find the value of  $\alpha$  for which the tension is as small as possible (a) in cable  $bc$ , (b) in both cables simultaneously. In each case determine the tension in each cable.

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



(a) For a minimum tension in cable  $BC$ , set angle between cables to 90 degrees.

By inspection,

$$\alpha = 35.0^\circ \blacktriangleleft$$

$$T_{AC} = (6 \text{ kN}) \cos 35^\circ$$

$$T_{AC} = 4.91 \text{ kN} \blacktriangleleft$$

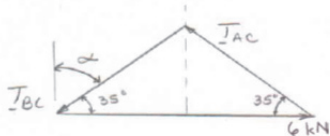
$$T_{BC} = (6 \text{ kN}) \sin 35^\circ$$

$$T_{BC} = 3.44 \text{ kN} \blacktriangleleft$$

(b) For equal tension in both cables, the force triangle will be an isosceles.

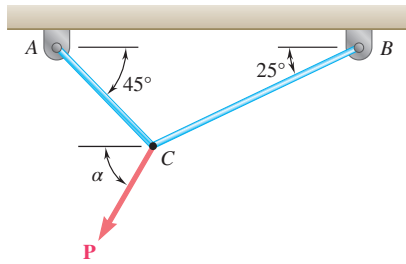
Therefore, by inspection,

$$\alpha = 55.0^\circ \blacktriangleleft$$



$$T_{AC} = T_{BC} = (1/2) \frac{6 \text{ kN}}{\cos 35^\circ}$$

$$T_{AC} = T_{BC} = 3.66 \text{ kN} \blacktriangleleft$$

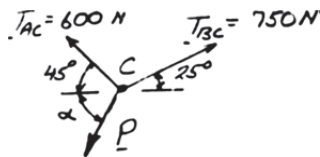


### PROBLEM 2.58

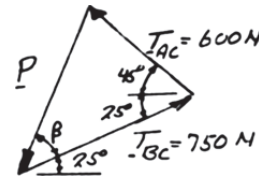
For the cables of Problem 2.46, it is known that the maximum allowable tension is 600 N in cable AC and 750 N in cable BC. Determine (a) the maximum force **P** that can be applied at C, (b) the corresponding value of  $\alpha$ .

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



(a) Law of cosines

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

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

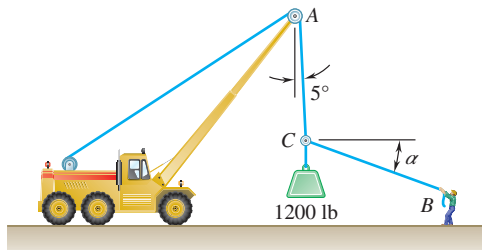
$$P = 784 \text{ N} \blacktriangleleft$$

(b) Law of sines

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

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

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

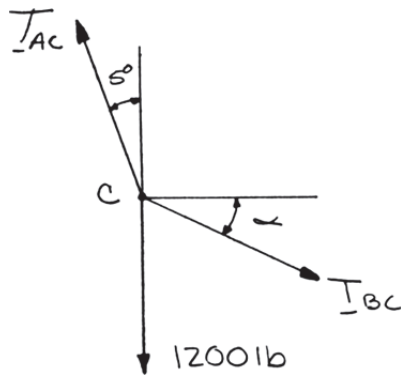


### PROBLEM 2.59

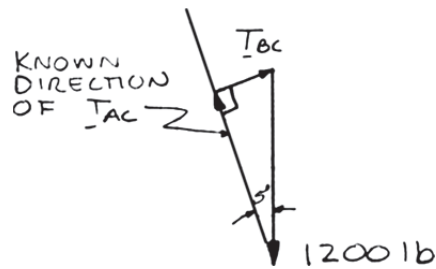
For the situation described in Figure P2.48, determine (a) the value of  $\alpha$  for which the tension in rope  $BC$  is as small as possible, (b) the corresponding value of the tension.

### SOLUTION

#### Free-Body Diagram



#### Force Triangle



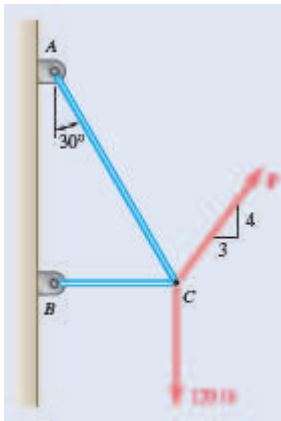
To be smallest,  $T_{BC}$  must be perpendicular to the direction of  $T_{AC}$ .

(a) Thus,  $\alpha = 5.00^\circ$

$\alpha = 5.00^\circ$  ◀

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

$T_{BC} = 104.6 \text{ lb}$  ◀

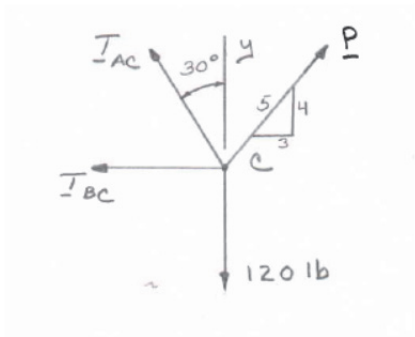


### PROBLEM 2.60

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

### SOLUTION

#### Free-Body Diagram



$$\Sigma F_x = 0: \quad \frac{3}{5}P - T_{BC} - T_{AC} \sin 30^\circ = 0$$

$$P = \frac{5}{3}(T_{BC} + T_{AC} \sin 30^\circ) \quad (1)$$

$$\Sigma F_y = 0: \quad \frac{4}{5}P + T_{AC} \cos 30^\circ - 120 = 0$$

$$P = \frac{5}{4}(120 - T_{AC} \cos 30^\circ) \quad (2)$$

Requirement:  $T_{AC} = 0:$

From Eq. (2):  $P = 150.0 \text{ lb}$

Requirement:  $T_{BC} = 0:$

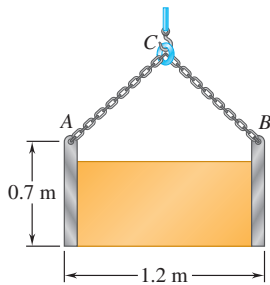
From Eq. (1):  $P = \frac{5}{3}(T_{AC} \sin 30^\circ)$

From Eq. (2):  $P = \frac{5}{4}(120 - T_{AC} \cos 30^\circ)$

Solving simultaneously yields:

$$T_{AC} = 78.294 \text{ lb} \quad \text{and} \quad P = 65.2 \text{ lb}$$

$$65.2 \text{ lb} < P < 150.0 \text{ lb} \quad \blacktriangleleft$$

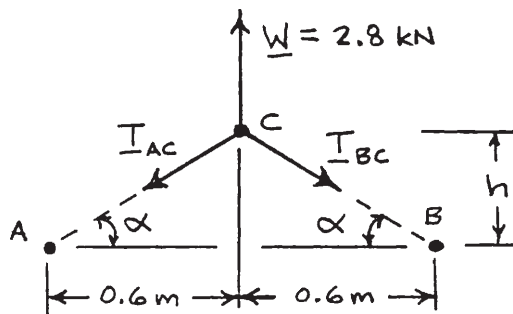


### PROBLEM 2.61

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.

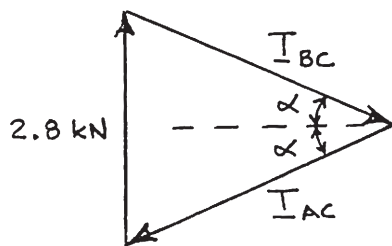
### SOLUTION

#### Free-Body Diagram



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

#### Isosceles Force Triangle

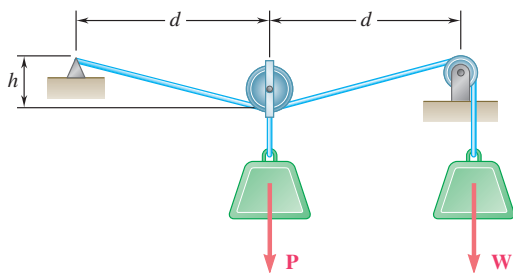


Law of sines:  $\sin \alpha = \frac{\frac{1}{2}(2.8 \text{ kN})}{T_{AC}}$   
 $T_{AC} = 5 \text{ kN}$   
 $\sin \alpha = \frac{\frac{1}{2}(2.8 \text{ kN})}{5 \text{ kN}}$   
 $\alpha = 16.2602^\circ$

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

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

Total length:  $= 2 \times 0.625 \text{ m} \quad 1.250 \text{ m} \blacktriangleleft$

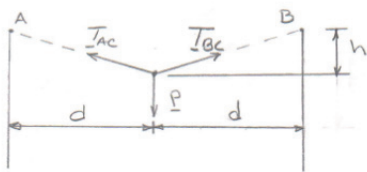


### PROBLEM 2.62

For  $W = 800 \text{ N}$ ,  $P = 200 \text{ N}$ , and  $d = 600 \text{ mm}$ , determine the value of  $h$  consistent with equilibrium.

### SOLUTION

#### Free-Body Diagram



$$T_{AC} = T_{BC} = 800 \text{ N}$$

$$AC = BC = \sqrt{h^2 + d^2}$$

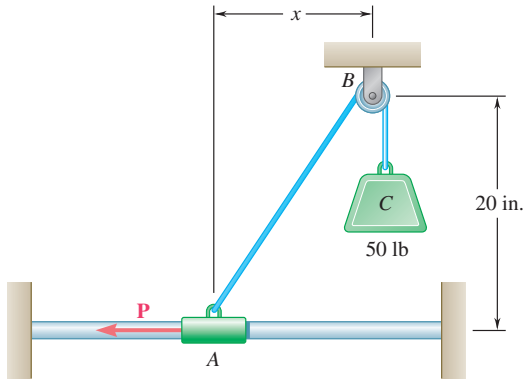
$$\Sigma F_y = 0: 2(800 \text{ N}) \frac{h}{\sqrt{h^2 + d^2}} - P = 0$$

$$800 = \frac{P}{2} \sqrt{1 + \left(\frac{d}{h}\right)^2}$$

Data:  $P = 200 \text{ N}$ ,  $d = 600 \text{ mm}$  and solving for  $h$

$$800 \text{ N} = \frac{200 \text{ N}}{2} \sqrt{1 + \left(\frac{600 \text{ mm}}{h}\right)^2}$$

$$h = 75.6 \text{ mm} \blacktriangleleft$$

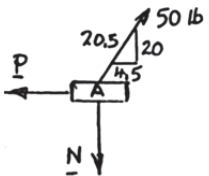
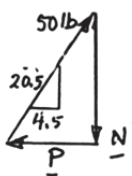


### PROBLEM 2.63

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**

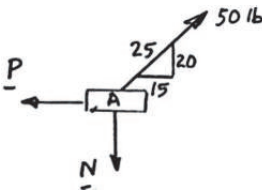
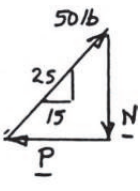



### Force Triangle

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

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

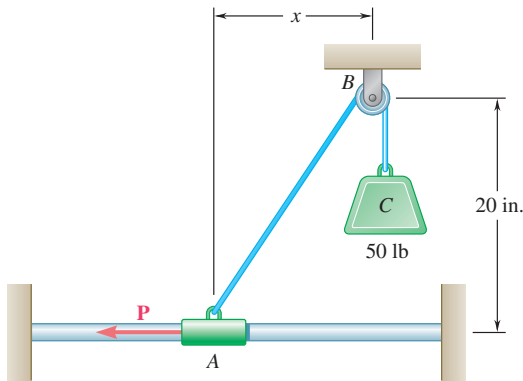
(b) **Free Body: Collar A**

### Force Triangle

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

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

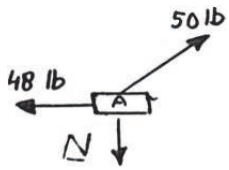


**PROBLEM 2.64**

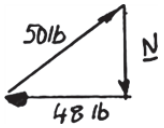
Collar A is connected as shown to a 50-lb load and can slide on a frictionless horizontal rod. Determine the distance  $x$  for which the collar is in equilibrium when  $P = 48$  lb.

**SOLUTION**

**Free Body: Collar A**



**Force Triangle**

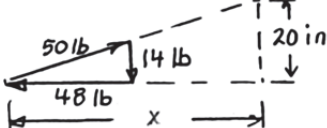


$$N^2 = (50)^2 - (48)^2 = 196$$

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

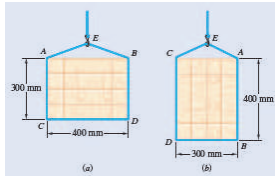
**Similar Triangles**

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



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

### PROBLEM 2.65

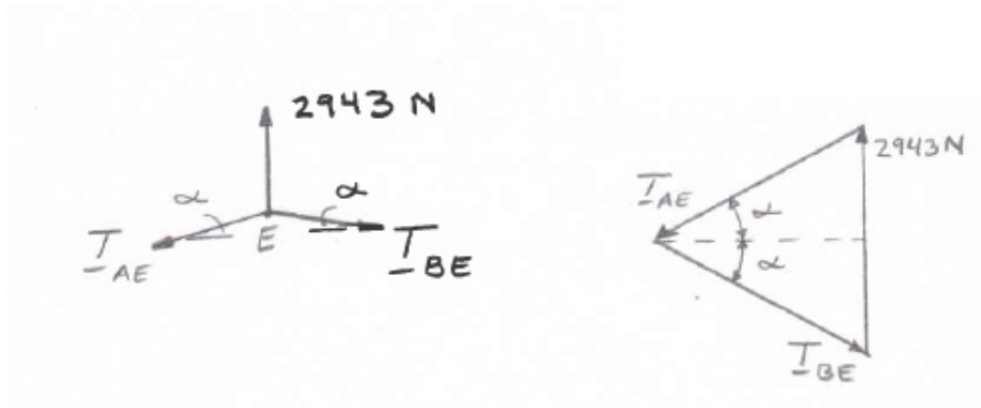


A cable loop of length 1.5 m is placed around a crate. Knowing that the mass of the crate is 300 kg, determine the tension in the cable for each of the arrangements shown.

### SOLUTION

#### Free-Body Diagram

#### Isosceles Force Triangle



$$W = (300 \text{ kg})(9.81 \text{ m/s}^2) = 2943.0 \text{ N}$$

$$EB = \frac{1}{2}(1500 \text{ mm} - 400 \text{ mm} - 300 \text{ mm} - 300 \text{ mm})$$

$$EB = 250 \text{ mm}$$

$$\alpha = \cos^{-1}\left(\frac{200 \text{ mm}}{250 \text{ mm}}\right) = 36.87^\circ$$

$$T_{AE} = T_{BE}$$

$$T_{AE} \sin \alpha = \frac{1}{2}(2943.0 \text{ N})$$

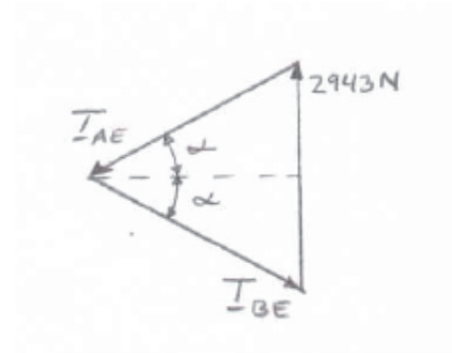
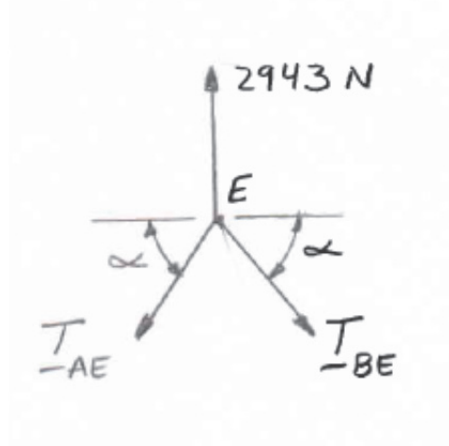
$$T_{AE} \sin 36.87^\circ = \frac{1}{2}(2943.0 \text{ N})$$

$$T_{AE} = 2452.5 \text{ N}$$

(a)

$$T_{AE} = 2450 \text{ N} \blacktriangleleft$$

### Problem 2.65 (Continued)



Isosceles Force Triangle

### Free-Body Diagram

$$EB = \frac{1}{2}(1500 \text{ mm} - 300 \text{ mm} - 400 \text{ mm} - 400 \text{ mm})$$

$$EB = 250 \text{ mm}$$

$$\alpha = \cos^{-1} \left( \frac{150 \text{ mm}}{200 \text{ mm}} \right) = 41.41^\circ$$

$$T_{AE} = T_{BE}$$

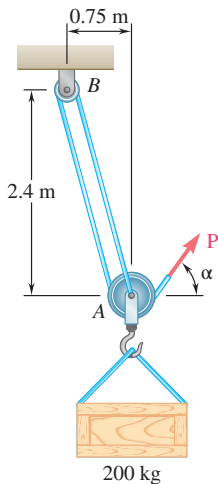
$$T_{AE} \sin \alpha = \frac{1}{2}(2943.0 \text{ N})$$

$$T_{AE} \sin 41.41^\circ = \frac{1}{2}(2943.0 \text{ N})$$

$$T_{AE} = 2224.7 \text{ N}$$

(b)

$$T_{AE} = 2220 \text{ N} \blacktriangleleft$$

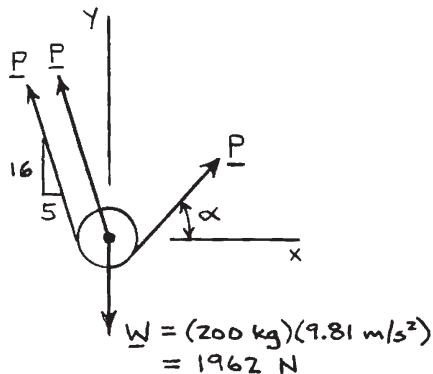


### PROBLEM 2.66

A 200-kg crate is to be supported by the rope-and-pulley arrangement shown. Determine the magnitude and direction of the force **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  $\alpha = +53.377^\circ$ :

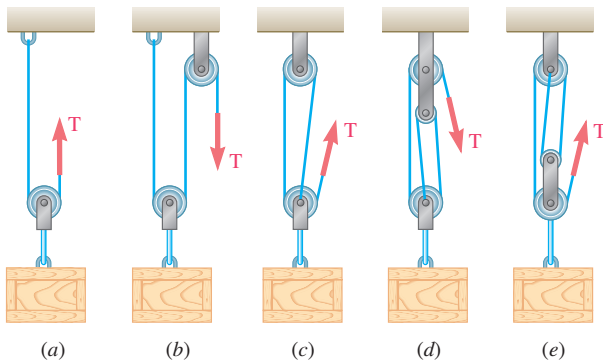
$$+\uparrow \Sigma F_y = 0: 2P \left( \frac{16}{\sqrt{281}} \right) + P \sin 53.377^\circ - 1962 \text{ N} = 0$$

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

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

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

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

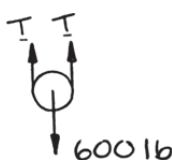


### PROBLEM 2.67

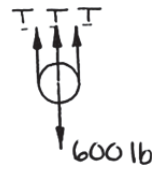
A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.66.)

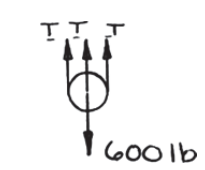
### SOLUTION

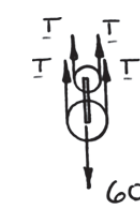
#### Free-Body Diagram of Pulley

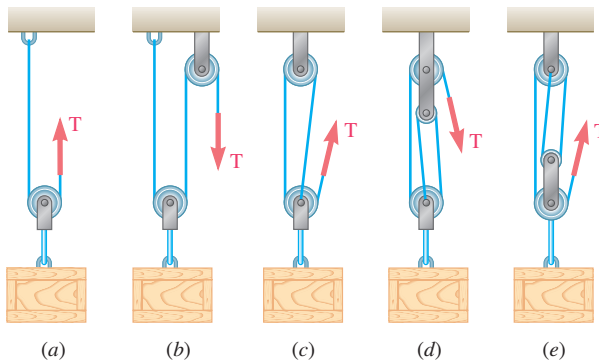
(a)  
$$+\uparrow \Sigma F_y = 0: 2T - (600 \text{ lb}) = 0$$
$$T = \frac{1}{2}(600 \text{ lb})$$
$$T = 300 \text{ lb} \blacktriangleleft$$

(b)  
$$+\uparrow \Sigma F_y = 0: 2T - (600 \text{ lb}) = 0$$
$$T = \frac{1}{2}(600 \text{ lb})$$
$$T = 300 \text{ lb} \blacktriangleleft$$

(c)  
$$+\uparrow \Sigma F_y = 0: 3T - (600 \text{ lb}) = 0$$
$$T = \frac{1}{3}(600 \text{ lb})$$
$$T = 200 \text{ lb} \blacktriangleleft$$

(d)  
$$+\uparrow \Sigma F_y = 0: 3T - (600 \text{ lb}) = 0$$
$$T = \frac{1}{3}(600 \text{ lb})$$
$$T = 200 \text{ lb} \blacktriangleleft$$

(e)  
$$+\uparrow \Sigma F_y = 0: 4T - (600 \text{ lb}) = 0$$
$$T = \frac{1}{4}(600 \text{ lb})$$
$$T = 150.0 \text{ lb} \blacktriangleleft$$



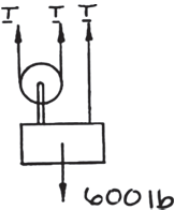
### PROBLEM 2.68

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

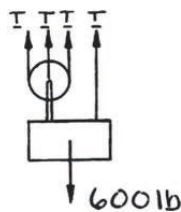
#### Free-Body Diagram of Pulley and Crate

(b) 

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

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

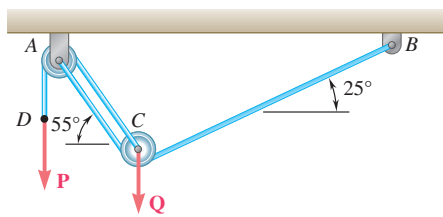
$T = 200 \text{ lb} \blacktriangleleft$

(d) 

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

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

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

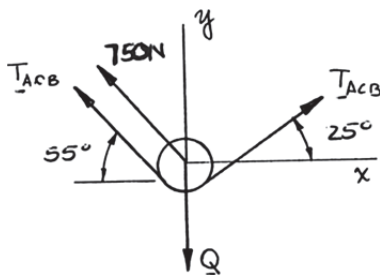


### PROBLEM 2.69

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**



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

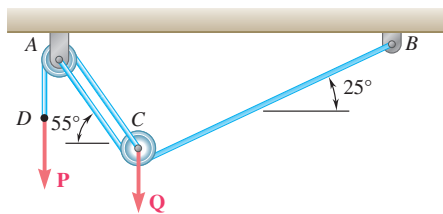
Hence:  $T_{ACB} = 1292.88 \text{ N}$

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

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

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

or  $Q = 2219.8 \text{ N} \quad Q = 2220 \text{ N} \quad \blacktriangleleft$

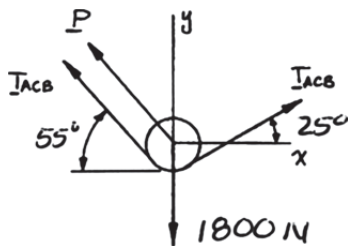


### PROBLEM 2.70

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):

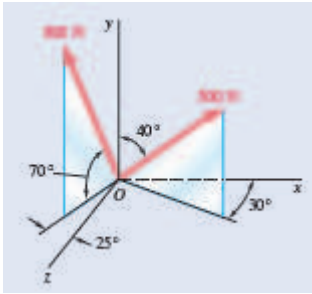
$$1.24177 T_{ACB} + 0.81915(0.58010 T_{ACB}) = 1800 \text{ N}$$

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

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

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

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



### PROBLEM 2.71

Determine (a) the  $x$ ,  $y$ , and  $z$  components of the 500-N force, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

### SOLUTION

(a)

$$F_x = (500 \text{ N}) \sin 40^\circ \cos 30^\circ$$

$$F_x = 278.34 \text{ N}$$

$$F_x = 278 \text{ N} \quad \blacktriangleleft$$

$$F_y = (500 \text{ N}) \cos 40^\circ$$

$$F_y = 383.02 \text{ N}$$

$$F_y = 383 \text{ N} \quad \blacktriangleleft$$

$$F_z = (500 \text{ N}) \sin 40^\circ \sin 30^\circ$$

$$F_z = 160.697 \text{ N}$$

$$F_z = 160.7 \text{ N} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{278.34 \text{ N}}{500 \text{ N}}$$

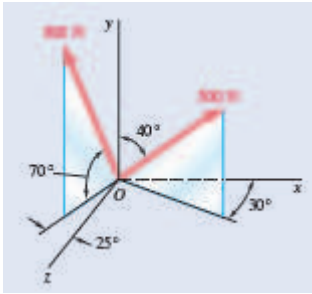
$$\theta_x = 56.2^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{383.02 \text{ N}}{500 \text{ N}}$$

$$\theta_y = 40.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{160.697 \text{ N}}{500 \text{ N}}$$

$$\theta_z = 71.3^\circ \quad \blacktriangleleft$$



### PROBLEM 2.72

Determine (a) the  $x$ ,  $y$ , and  $z$  components of the 800-N force, (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  that the force forms with the coordinate axes.

### SOLUTION

(a)

$$F_x = -(800 \text{ N}) \cos 70^\circ \sin 25^\circ$$

$$F_x = -115.635 \text{ N}$$

$$F_x = -115.6 \text{ N} \blacktriangleleft$$

$$F_y = (800 \text{ N}) \sin 70^\circ$$

$$F_y = 751.75 \text{ N}$$

$$F_y = 752 \text{ N} \blacktriangleleft$$

$$F_z = (800 \text{ N}) \cos 70^\circ \cos 25^\circ$$

$$F_z = 247.98 \text{ N}$$

$$F_z = 248 \text{ N} \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{-115.635 \text{ N}}{800 \text{ N}}$$

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

$$\cos \theta_y = \frac{F_y}{F} = \frac{751.75 \text{ N}}{800 \text{ N}}$$

$$\theta_y = 20.0^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{247.98 \text{ N}}{800 \text{ N}}$$

$$\theta_z = 71.9^\circ \blacktriangleleft$$

Note: From the given data, we could have computed directly  
 $\theta_y = 90^\circ - 35^\circ = 55^\circ$ , which checks with the answer obtained.

### PROBLEM 2.73

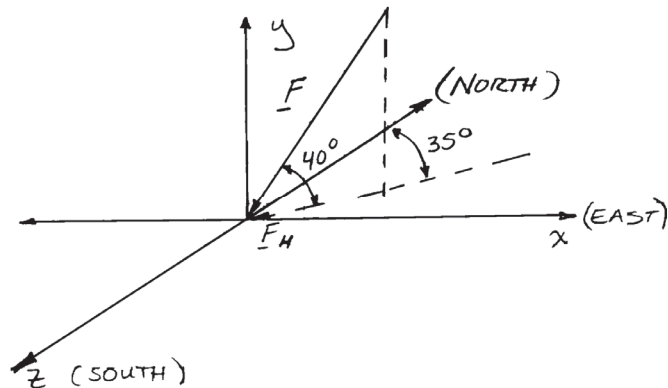
A gun is aimed at a point  $A$  located  $35^\circ$  east of north. Knowing that the barrel of the gun forms an angle of  $40^\circ$  with the horizontal and that the maximum recoil force is  $400\text{ N}$ , determine (a) the  $x$ ,  $y$ , and  $z$  components of that force, (b) the values of the angles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

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

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

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

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

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

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

(b)

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

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

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

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

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

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

**PROBLEM 2.74**

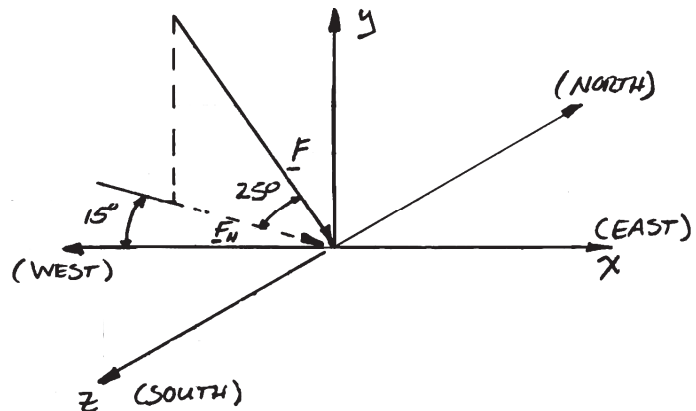
Solve Problem 2.73, assuming that point A is located  $15^\circ$  north of west and that the barrel of the gun forms an angle of  $25^\circ$  with the horizontal.

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

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



$$\begin{aligned}(a) \quad F_x &= +F_H \cos 15^\circ \\ &= +(362.52 \text{ N}) \cos 15^\circ \\ &= +350.17 \text{ N} \qquad F_x = +350 \text{ N} \blacktriangleleft\end{aligned}$$

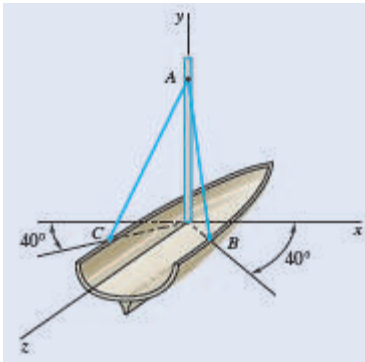
$$\begin{aligned}F_y &= -F \sin 25^\circ \\ &= -(400 \text{ N}) \sin 25^\circ \\ &= -169.047 \text{ N} \qquad F_y = -169.0 \text{ N} \blacktriangleleft\end{aligned}$$

$$\begin{aligned}F_z &= +F_H \sin 15^\circ \\ &= +(362.52 \text{ N}) \sin 15^\circ \\ &= +93.827 \text{ N} \qquad F_z = +93.8 \text{ N} \blacktriangleleft\end{aligned}$$

$$(b) \quad \cos \theta_x = \frac{F_x}{F} = \frac{+350.17 \text{ N}}{400 \text{ N}} \qquad \theta_x = 28.9^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-169.047 \text{ N}}{400 \text{ N}} \qquad \theta_y = 115.0^\circ \blacktriangleleft$$

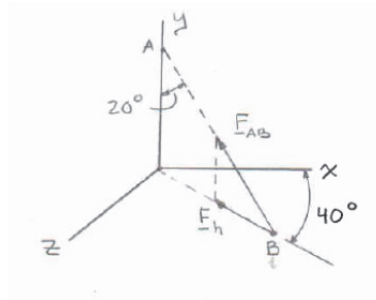
$$\cos \theta_z = \frac{F_z}{F} = \frac{+93.827 \text{ N}}{400 \text{ N}} \qquad \theta_z = 76.4^\circ \blacktriangleleft$$



### PROBLEM 2.75

The angle between the guy wire  $AB$  and the mast is  $20^\circ$ . Knowing that the tension in  $AB$  is 300 lb, determine (a) the  $x$ ,  $y$ , and  $z$  components of the force exerted on the boat at  $B$ , (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of the force exerted at  $B$ .

### SOLUTION



$$F_h = F_{AB} \sin 20^\circ$$

$$= (300 \text{ lb}) \sin 20^\circ$$

$$F_h = 102.606 \text{ lb}$$

$$F_x = -F_h \cos 40^\circ$$

$$F_x = (-102.606 \text{ lb}) \cos 40^\circ$$

$$F_x = -78.601 \text{ lb}$$

$$F_y = F_{AB} \cos 20^\circ$$

$$F_y = (300 \text{ lb}) \cos 20^\circ$$

$$F_y = 281.91 \text{ lb}$$

$$F_z = -F_h \sin 40^\circ$$

$$F_z = (-102.606 \text{ lb}) \sin 40^\circ$$

$$F_z = -65.954 \text{ lb}$$

(a)

$$F_x = -78.6 \text{ lb} \blacktriangleleft$$

$$F_y = 282 \text{ lb} \blacktriangleleft$$

$$F_z = -66.0 \text{ lb} \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{-78.601 \text{ lb}}{300 \text{ lb}}$$

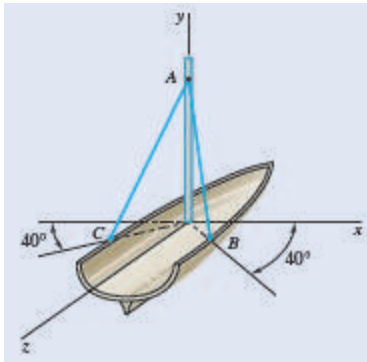
$$\theta_x = 105.2^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{281.91 \text{ lb}}{300 \text{ lb}}$$

$$\theta_y = 20.0^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{-65.954 \text{ lb}}{300 \text{ lb}}$$

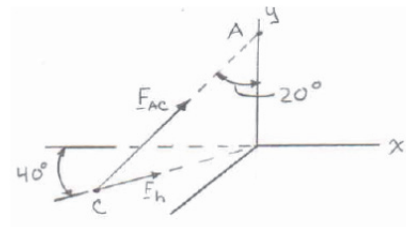
$$\theta_z = 102.7^\circ \blacktriangleleft$$



### PROBLEM 2.76

The angle between the guy wire  $AC$  and the mast is  $20^\circ$ . Knowing that the tension in  $AC$  is 300 lb, determine (a) the  $x$ ,  $y$ , and  $z$  components of the force exerted on the boat at  $C$ , (b) the angles  $\theta_x$ ,  $\theta_y$ , and  $\theta_z$  defining the direction of the force exerted at  $C$ .

### SOLUTION



$$\begin{aligned} F_h &= F_{AC} \sin 20^\circ \\ &= (300 \text{ lb}) \sin 20^\circ \\ F_h &= 102.606 \text{ lb} \end{aligned}$$

$$\begin{aligned} F_x &= F_h \cos 40^\circ & F_y &= F_{AC} \cos 20^\circ & F_z &= -F_h \sin 40^\circ \\ F_x &= (102.606 \text{ lb}) \cos 40^\circ & F_y &= (300 \text{ lb}) \cos 20^\circ & F_z &= (-102.606 \text{ lb}) \sin 40^\circ \\ F_x &= 78.601 \text{ lb} & F_y &= 281.91 \text{ lb} & F_z &= -65.954 \text{ lb} \end{aligned}$$

(a)

$$F_x = 78.6 \text{ lb} \blacktriangleleft$$

$$F_y = 282 \text{ lb} \blacktriangleleft$$

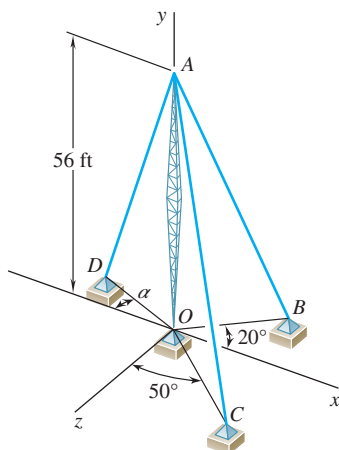
$$F_z = -66.0 \text{ lb} \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = \frac{78.601 \text{ lb}}{300 \text{ lb}} \quad \theta_x = 74.8^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{281.91 \text{ lb}}{300 \text{ lb}} \quad \theta_y = 20.0^\circ \blacktriangleleft$$

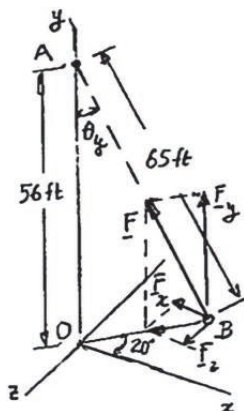
$$\cos \theta_z = \frac{F_z}{F} = \frac{-65.954 \text{ lb}}{300 \text{ lb}} \quad \theta_z = 102.7^\circ \blacktriangleleft$$



### PROBLEM 2.77

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  $AOB$ :

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

(a)

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

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

$$F_y = +F \cos \theta_y = (3900 \text{ lb})(0.86154) \quad F_y = +3360 \text{ lb} \quad \blacktriangleleft$$

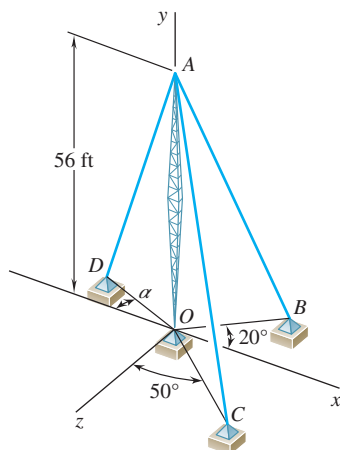
$$F_z = +(3900 \text{ lb}) \sin 30.51^\circ \sin 20^\circ \quad F_z = +677 \text{ lb} \quad \blacktriangleleft$$

(b)

$$\cos \theta_x = \frac{F_x}{F} = -\frac{1861 \text{ lb}}{3900 \text{ lb}} = -0.4771 \quad \theta_x = 118.5^\circ \quad \blacktriangleleft$$

$$\text{From above:} \quad \theta_y = 30.51^\circ \quad \theta_y = 30.5^\circ \quad \blacktriangleleft$$

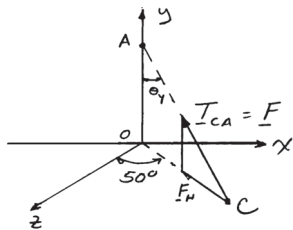
$$\cos \theta_z = \frac{F_z}{F} = +\frac{677 \text{ lb}}{3900 \text{ lb}} = +0.1736 \quad \theta_z = 80.0^\circ \quad \blacktriangleleft$$



### PROBLEM 2.78

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:

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

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

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

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

$$\theta_y = 36.870^\circ$$

$$F_H = F \sin \theta_y$$

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

$$= 3150.0 \text{ lb}$$

$$(a) \quad F_x = -F_H \sin 50^\circ = -(3150.0 \text{ lb}) \sin 50^\circ = -2413.0 \text{ lb}$$

$$F_x = -2410 \text{ lb} \quad \blacktriangleleft$$

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

$$F_y = +4200 \text{ lb} \quad \blacktriangleleft$$

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

$$(b) \quad \cos \theta_x = \frac{F_x}{F} = \frac{-2413.0 \text{ lb}}{5250 \text{ lb}}$$

$$\theta_x = 117.4^\circ \quad \blacktriangleleft$$

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

$$\theta_y = 36.9^\circ \quad \blacktriangleleft$$

$$\theta_z = \frac{F_z}{F} = \frac{-2024.8 \text{ lb}}{5250 \text{ lb}}$$

$$\theta_z = 112.7^\circ \quad \blacktriangleleft$$

**PROBLEM 2.79**

Determine the magnitude and direction of the force  $\mathbf{F} = (260 \text{ N})\mathbf{i} - (320 \text{ N})\mathbf{j} + (800 \text{ N})\mathbf{k}$ .

**SOLUTION**

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

$$F = \sqrt{(260 \text{ N})^2 + (-320 \text{ N})^2 + (800 \text{ N})^2} \quad F = 900 \text{ N} \blacktriangleleft$$

$$\cos \theta_x = \frac{F_x}{F} = \frac{260 \text{ N}}{900 \text{ N}} \quad \theta_x = 73.2^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-320 \text{ N}}{900 \text{ N}} \quad \theta_y = 110.8^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{800 \text{ N}}{900 \text{ N}} \quad \theta_z = 27.3^\circ \blacktriangleleft$$

**PROBLEM 2.80**

Determine the magnitude and direction of the force  $\mathbf{F} = (700 \text{ N})\mathbf{i} - (820 \text{ N})\mathbf{j} + (960 \text{ N})\mathbf{k}$ .

**SOLUTION**

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

$$F = \sqrt{(700 \text{ N})^2 + (820 \text{ N})^2 + (960 \text{ N})^2}$$

$$F = 1443.61 \text{ N}$$

$$F = 1444 \text{ N} \quad \blacktriangleleft$$

$$\cos \theta_x = \frac{F_x}{F} = \frac{700 \text{ N}}{1443.61 \text{ N}}$$

$$\theta_x = 61.0^\circ \quad \blacktriangleleft$$

$$\cos \theta_y = \frac{F_y}{F} = \frac{-820 \text{ N}}{1443.61 \text{ N}}$$

$$\theta_y = 124.6^\circ \quad \blacktriangleleft$$

$$\cos \theta_z = \frac{F_z}{F} = \frac{960 \text{ N}}{1443.61 \text{ N}}$$

$$\theta_z = 48.3^\circ \quad \blacktriangleleft$$

**PROBLEM 2.81**

A force  $\mathbf{F}$  of magnitude 250 lb acts at the origin of a coordinate system. Knowing that  $\theta_x = 65^\circ$ ,  $\theta_y = 40^\circ$ , and  $F_z > 0$ , determine (a) the components of the force, (b) the angle  $\theta_z$ .

**SOLUTION**

$$\begin{aligned}\cos^2 \theta_x + \cos^2 \theta_y + \cos^2 \theta_z &= 1 \\ \cos^2(65^\circ) + \cos^2(40^\circ) + \cos^2 \theta_z &= 1 \\ \cos \theta_z &= \pm 0.48432\end{aligned}$$

(b) Since  $F_z > 0$ , we choose  $\cos \theta_z = 0.48432$   $\therefore \theta_z = 61.0^\circ \blacktriangleleft$

(a)

$$F_x = F \cos \theta_x = (250 \text{ lb}) \cos 65^\circ \qquad F_x = 105.7 \text{ lb} \blacktriangleleft$$

$$F_y = F \cos \theta_y = (250 \text{ lb}) \cos 40^\circ \qquad F_y = 191.5 \text{ lb} \blacktriangleleft$$

$$F_z = F \cos \theta_z = (250 \text{ lb}) \cos 61^\circ \qquad F_z = 121.2 \text{ lb} \blacktriangleleft$$

**PROBLEM 2.82**

A force acts at the origin of a coordinate system in a direction defined by the angles  $\theta_x = 70.9^\circ$  and  $\theta_y = 144.9^\circ$ . Knowing that the  $z$  component of the force is  $-52.0$  lb, determine (a) the angle  $\theta_z$ , (b) the other components and the magnitude of the force.

**SOLUTION**

$$\begin{aligned}\cos^2 \theta_x + \cos^2 \theta_y + \cos^2 \theta_z &= 1 \\ \cos^2 70.9^\circ + \cos^2 144.9^\circ + \cos^2 \theta_z &= 1 \\ \cos \theta_z &= \pm 0.47282\end{aligned}$$

(a) Since  $F_z < 0$ , we choose  $\cos \theta_z = -0.47282$   $\therefore \theta_z = 118.2^\circ \blacktriangleleft$

(b)  $F_z = F \cos \theta_z$   
 $-52.0 \text{ lb} = F(-0.47282)$

$$F = 110.0 \text{ lb} \qquad F = 110.0 \text{ lb} \blacktriangleleft$$

$$F_x = F \cos \theta_x = (110.0 \text{ lb}) \cos 70.9^\circ \qquad F_x = 36.0 \text{ lb} \blacktriangleleft$$

$$F_y = F \cos \theta_y = (110.0 \text{ lb}) \cos 144.9^\circ \qquad F_y = -90.0 \text{ lb} \blacktriangleleft$$

**PROBLEM 2.83**

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**

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

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

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

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

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

$$\begin{aligned}\cos \theta_y &= \frac{F_y}{F} = \frac{61.929 \text{ N}}{210 \text{ N}} = -0.29490 \\ \theta_y &= 107.2^\circ \blacktriangleleft\end{aligned}$$

**PROBLEM 2.84**

A force acts at the origin of a coordinate system in a direction defined by the angles  $\theta_y = 120^\circ$  and  $\theta_z = 75^\circ$ . Knowing that the  $x$  component of the force is +40 N, determine (a) the angle  $\theta_x$ , (b) the magnitude of the force.

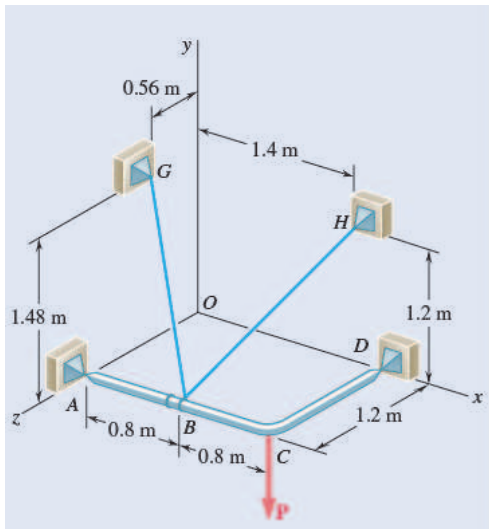
**SOLUTION**

$$\begin{aligned}\cos^2 \theta_x + \cos^2 \theta_y + \cos^2 \theta_z &= 1 \\ \cos^2 \theta_x + \cos^2 120^\circ + \cos^2 75^\circ &= 1 \\ \cos \theta_x &= \pm 0.82644\end{aligned}$$

(b) Since  $F_x > 0$ , we choose  $\cos \theta_x = 0.82644$   $\therefore \theta_x = 34.3^\circ \blacktriangleleft$

(a)

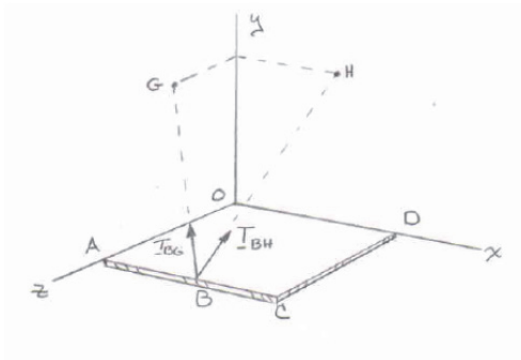
$$\begin{aligned}F_x &= F \cos \theta_x \\ 40 \text{ N} &= F \cos 34.3^\circ \\ F &= 48.4 \text{ N} \blacktriangleleft\end{aligned}$$



### PROBLEM 2.85

Two cables  $BG$  and  $BH$  are attached to frame  $ACD$  as shown. Knowing that the tension in cable  $BG$  is 540 N, determine the components of the force exerted by cable  $BG$  on the frame at  $B$ .

### SOLUTION



$$\overrightarrow{BG} = -(0.8 \text{ m})\mathbf{i} + (1.48 \text{ m})\mathbf{j} - (0.64 \text{ m})\mathbf{k}$$

$$BG = \sqrt{(-0.8 \text{ m})^2 + (1.48 \text{ m})^2 + (-0.64 \text{ m})^2}$$

$$= 1.8 \text{ m}$$

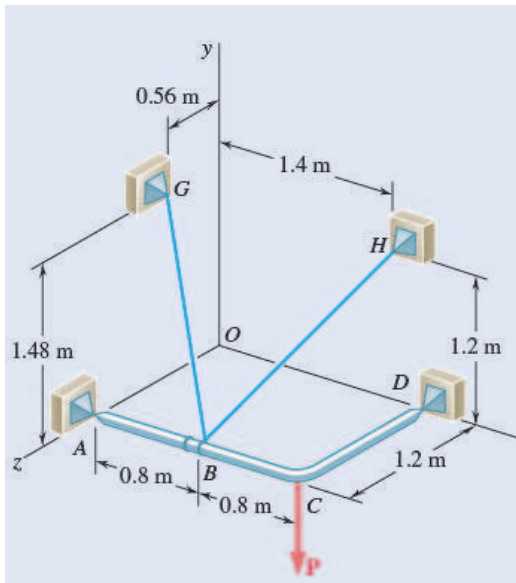
$$\mathbf{T}_{BG} = T_{BG} \lambda_{BG}$$

$$= T_{BG} \frac{\overrightarrow{BG}}{BG}$$

$$= \frac{540 \text{ N}}{1.8 \text{ m}} [(-0.8 \text{ m})\mathbf{i} + (1.48 \text{ m})\mathbf{j} + (-0.64 \text{ m})\mathbf{k}]$$

$$\mathbf{T}_{BG} = (-240 \text{ N})\mathbf{i} + (444 \text{ N})\mathbf{j} - (192.0 \text{ N})\mathbf{k}$$

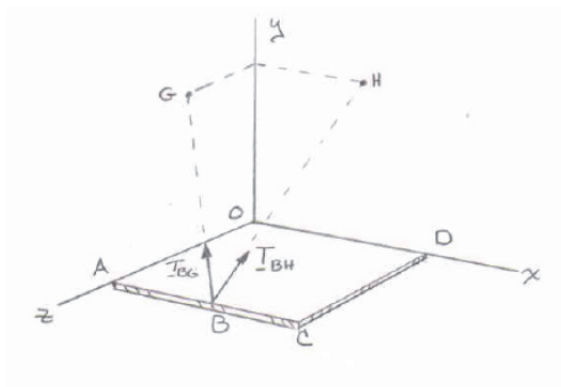
$$F_x = -240 \text{ N}, \quad F_y = +444 \text{ N}, \quad F_z = +192.0 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.86

Two cables  $BG$  and  $BH$  are attached to frame  $ACD$  as shown. Knowing that the tension in cable  $BH$  is 750 N, determine the components of the force exerted by cable  $BH$  on the frame at  $B$ .

### SOLUTION



$$\overrightarrow{BH} = (0.6 \text{ m})\mathbf{i} + (1.2 \text{ m})\mathbf{j} - (1.2 \text{ m})\mathbf{k}$$

$$BH = \sqrt{(0.6 \text{ m})^2 + (1.2 \text{ m})^2 + (1.2 \text{ m})^2}$$

$$= 1.8 \text{ m}$$

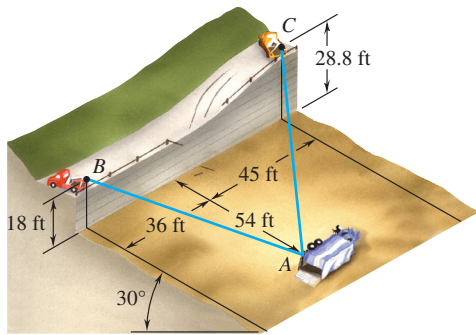
$$\mathbf{T}_{BH} = T_{BH} \frac{\overrightarrow{BH}}{BH}$$

$$= T_{BH} \frac{\overrightarrow{BH}}{BH}$$

$$= \frac{750 \text{ N}}{1.8 \text{ m}} [\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}] (\text{m})$$

$$\mathbf{T}_{BH} = (250 \text{ N})\mathbf{i} + (500 \text{ N})\mathbf{j} - (500 \text{ N})\mathbf{k}$$

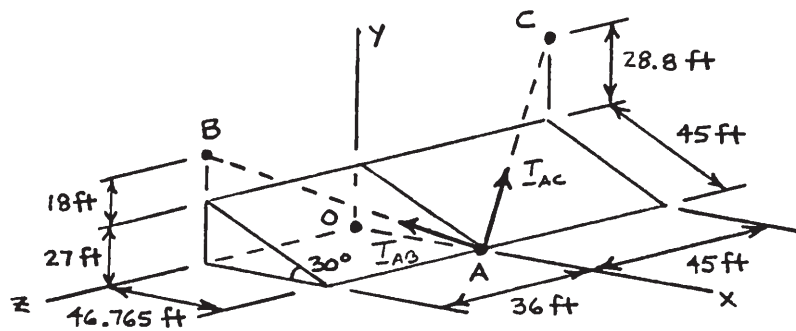
$$F_x = +250 \text{ N}, \quad F_y = +500 \text{ N}, \quad F_z = -500 \text{ N} \quad \blacktriangleleft$$



### PROBLEM 2.87

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  $AB$ :

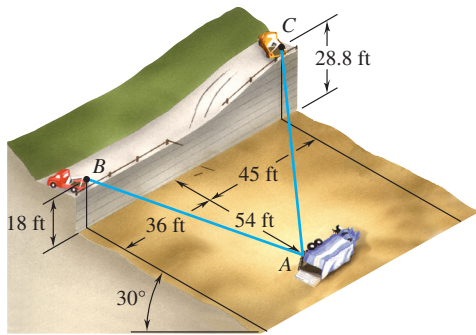
$$\lambda_{AB} = \frac{\vec{AB}}{AB} = \frac{(-46.765 \text{ ft})\mathbf{i} + (45 \text{ ft})\mathbf{j} + (36 \text{ ft})\mathbf{k}}{74.216 \text{ ft}}$$

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

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

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

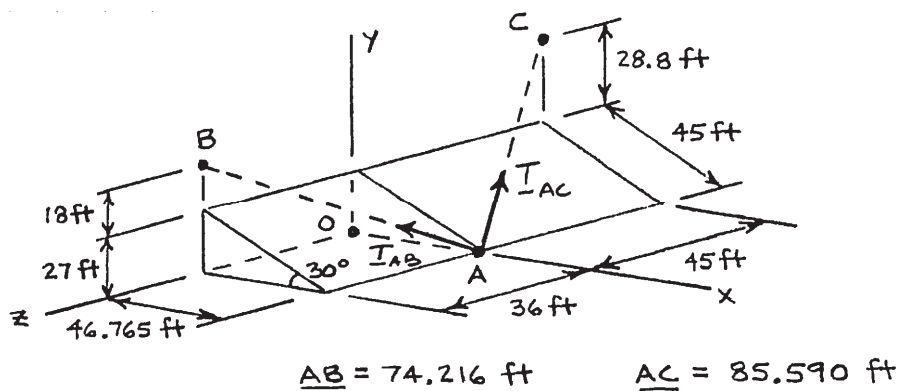
$$(T_{AB})_z = +0.970 \text{ kips} \quad \blacktriangleleft$$



### PROBLEM 2.88

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



Cable  $AC$ :

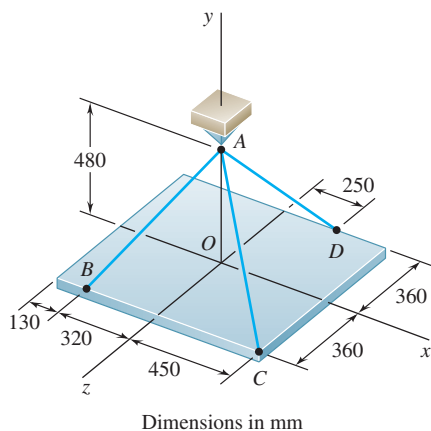
$$\lambda_{AC} = \frac{\vec{AC}}{AC} = \frac{(-46.765 \text{ ft})\mathbf{i} + (55.8 \text{ ft})\mathbf{j} + (-45 \text{ ft})\mathbf{k}}{85.590 \text{ ft}}$$

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

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

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

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



### PROBLEM 2.89

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable  $AB$  is 408 N, determine the components of the force exerted on the plate at  $B$ .

### SOLUTION

We have:

$$\vec{BA} = +(320 \text{ mm})\mathbf{i} + (480 \text{ mm})\mathbf{j} - (360 \text{ mm})\mathbf{k} \quad BA = 680 \text{ mm}$$

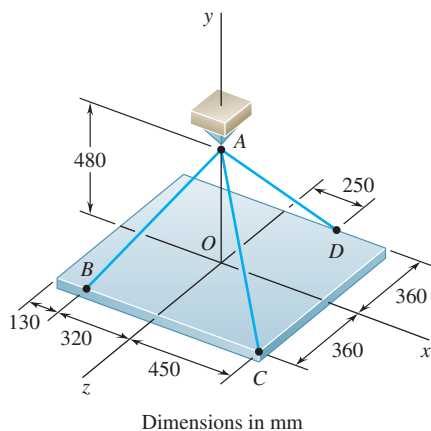
Thus:

$$\mathbf{F}_B = T_{BA} \lambda_{BA} = T_{BA} \frac{\vec{BA}}{BA} = T_{BA} \left( \frac{8}{17} \mathbf{i} + \frac{12}{17} \mathbf{j} - \frac{9}{17} \mathbf{k} \right)$$

$$\left( \frac{8}{17} T_{BA} \right) \mathbf{i} + \left( \frac{12}{17} T_{BA} \right) \mathbf{j} - \left( \frac{9}{17} T_{BA} \right) \mathbf{k} = 0$$

Setting  $T_{BA} = 408 \text{ N}$  yields,

$$F_x = +192.0 \text{ N}, \quad F_y = +288 \text{ N}, \quad F_z = -216 \text{ N} \blacktriangleleft$$



### PROBLEM 2.90

A rectangular plate is supported by three cables as shown. Knowing that the tension in cable  $AD$  is 429 N, determine the components of the force exerted on the plate at  $D$ .

### SOLUTION

We have:

$$\overrightarrow{DA} = -(250 \text{ mm})\mathbf{i} + (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad DA = 650 \text{ mm}$$

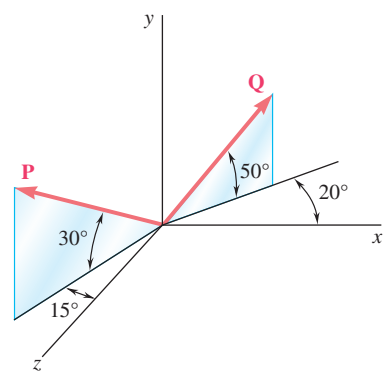
Thus:

$$\mathbf{F}_D = T_{DA} \lambda_{DA} = T_{DA} \frac{\overrightarrow{DA}}{DA} = T_{DA} \left( -\frac{5}{13} \mathbf{i} + \frac{48}{65} \mathbf{j} + \frac{36}{65} \mathbf{k} \right)$$

$$-\left( \frac{5}{13} T_{DA} \right) \mathbf{i} + \left( \frac{48}{65} T_{DA} \right) \mathbf{j} + \left( \frac{36}{65} T_{DA} \right) \mathbf{k} = 0$$

Setting  $T_{DA} = 429 \text{ N}$  yields,

$$F_x = -165.0 \text{ N}, \quad F_y = +317 \text{ N}, \quad F_z = +238 \text{ N} \quad \blacktriangleleft$$



**PROBLEM 2.91**

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**

$$\mathbf{P} = (300 \text{ N})[-\cos 30^\circ \sin 15^\circ \mathbf{i} + \sin 30^\circ \mathbf{j} + \cos 30^\circ \cos 15^\circ \mathbf{k}]$$

$$= -(67.243 \text{ N})\mathbf{i} + (150 \text{ N})\mathbf{j} + (250.95 \text{ N})\mathbf{k}$$

$$\mathbf{Q} = (400 \text{ N})[\cos 50^\circ \cos 20^\circ \mathbf{i} + \sin 50^\circ \mathbf{j} - \cos 50^\circ \sin 20^\circ \mathbf{k}]$$

$$= (400 \text{ N})[0.60402\mathbf{i} + 0.76604\mathbf{j} - 0.21985\mathbf{k}]$$

$$= (241.61 \text{ N})\mathbf{i} + (306.42 \text{ N})\mathbf{j} - (87.939 \text{ N})\mathbf{k}$$

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

$$= (174.367 \text{ N})\mathbf{i} + (456.42 \text{ N})\mathbf{j} + (163.011 \text{ N})\mathbf{k}$$

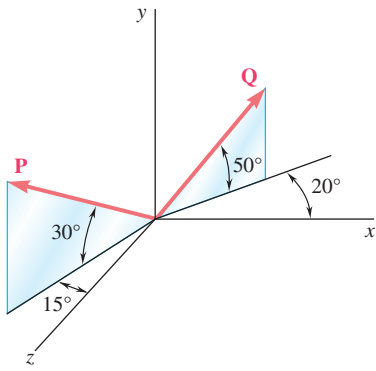
$$R = \sqrt{(174.367 \text{ N})^2 + (456.42 \text{ N})^2 + (163.011 \text{ N})^2}$$

$$= 515.07 \text{ N} \qquad R = 515 \text{ N} \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{174.367 \text{ N}}{515.07 \text{ N}} = 0.33853 \qquad \theta_x = 70.2^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{R_y}{R} = \frac{456.42 \text{ N}}{515.07 \text{ N}} = 0.88613 \qquad \theta_y = 27.6^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{163.011 \text{ N}}{515.07 \text{ N}} = 0.31648 \qquad \theta_z = 71.5^\circ \blacktriangleleft$$



### PROBLEM 2.92

Find the magnitude and direction of the resultant of the two forces shown knowing that  $P = 400 \text{ N}$  and  $Q = 300 \text{ N}$ .

### SOLUTION

$$\mathbf{P} = (400 \text{ N})[-\cos 30^\circ \sin 15^\circ \mathbf{i} + \sin 30^\circ \mathbf{j} + \cos 30^\circ \cos 15^\circ \mathbf{k}]$$

$$= -(89.678 \text{ N})\mathbf{i} + (200 \text{ N})\mathbf{j} + (334.61 \text{ N})\mathbf{k}$$

$$\mathbf{Q} = (300 \text{ N})[\cos 50^\circ \cos 20^\circ \mathbf{i} + \sin 50^\circ \mathbf{j} - \cos 50^\circ \sin 20^\circ \mathbf{k}]$$

$$= (181.21 \text{ N})\mathbf{i} + (229.81 \text{ N})\mathbf{j} - (65.954 \text{ N})\mathbf{k}$$

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

$$= (91.532 \text{ N})\mathbf{i} + (429.81 \text{ N})\mathbf{j} + (268.66 \text{ N})\mathbf{k}$$

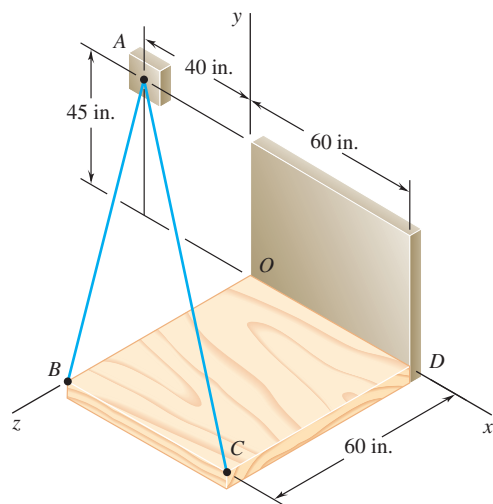
$$R = \sqrt{(91.532 \text{ N})^2 + (429.81 \text{ N})^2 + (268.66 \text{ N})^2}$$

$$= 515.07 \text{ N} \qquad R = 515 \text{ N} \blacktriangleleft$$

$$\cos \theta_x = \frac{R_x}{R} = \frac{91.532 \text{ N}}{515.07 \text{ N}} = 0.177708 \qquad \theta_x = 79.8^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{R_y}{R} = \frac{429.81 \text{ N}}{515.07 \text{ N}} = 0.83447 \qquad \theta_y = 33.4^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{268.66 \text{ N}}{515.07 \text{ N}} = 0.52160 \qquad \theta_z = 58.6^\circ \blacktriangleleft$$



### 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

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

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

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

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

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

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

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

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

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

Then:

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

$$R = 913 \text{ lb} \blacktriangleleft$$

and

$$\cos \theta_x = \frac{608 \text{ lb}}{912.92 \text{ lb}} = 0.66599$$

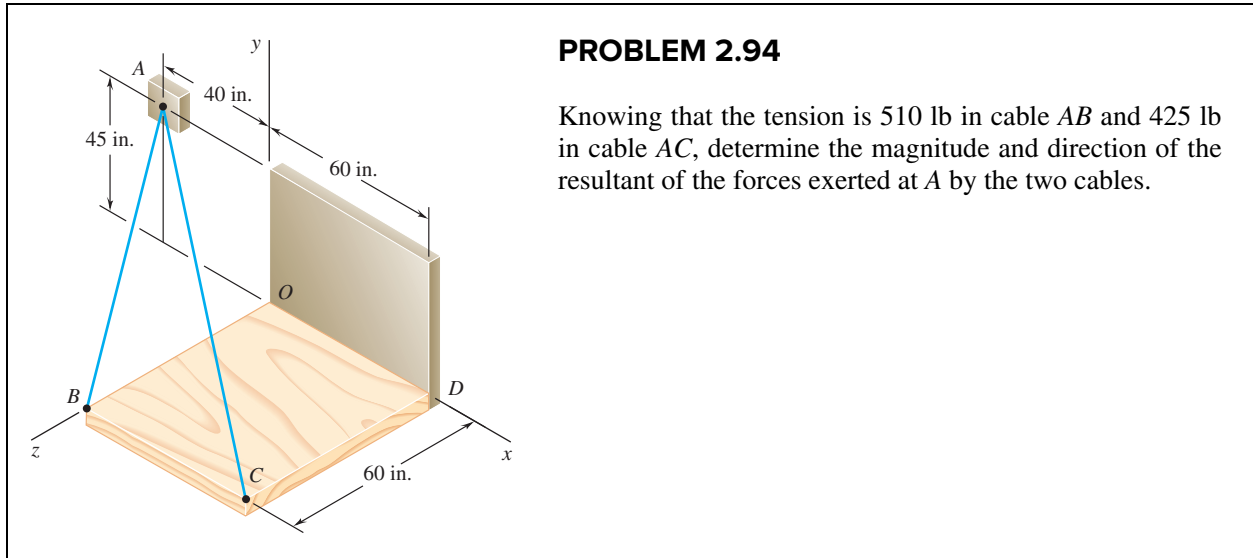
$$\theta_x = 48.2^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{408.6 \text{ lb}}{912.92 \text{ lb}} = -0.44757$$

$$\theta_y = 116.6^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{544.8 \text{ lb}}{912.92 \text{ lb}} = 0.59677$$

$$\theta_z = 53.4^\circ \blacktriangleleft$$



**SOLUTION**

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

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

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

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

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = (510 \text{ lb}) \left[ \frac{(40 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{85 \text{ in.}} \right]$$

$$\mathbf{T}_{AB} = (240 \text{ lb})\mathbf{i} - (270 \text{ lb})\mathbf{j} + (360 \text{ lb})\mathbf{k}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = (425 \text{ lb}) \left[ \frac{(100 \text{ in.})\mathbf{i} - (45 \text{ in.})\mathbf{j} + (60 \text{ in.})\mathbf{k}}{125 \text{ in.}} \right]$$

$$\mathbf{T}_{AC} = (340 \text{ lb})\mathbf{i} - (153 \text{ lb})\mathbf{j} + (204 \text{ lb})\mathbf{k}$$

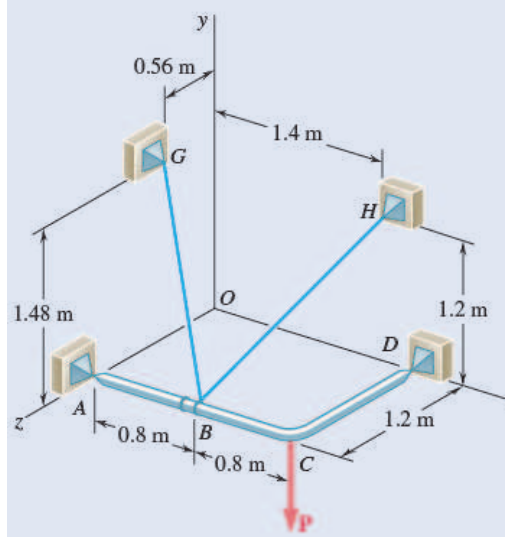
$$\mathbf{R} = \mathbf{T}_{AB} + \mathbf{T}_{AC} = (580 \text{ lb})\mathbf{i} - (423 \text{ lb})\mathbf{j} + (564 \text{ lb})\mathbf{k}$$

Then:  $R = 912.92 \text{ lb}$   $R = 913 \text{ lb} \blacktriangleleft$

and  $\cos \theta_x = \frac{580 \text{ lb}}{912.92 \text{ lb}} = 0.63532$   $\theta_x = 50.6^\circ \blacktriangleleft$

$\cos \theta_y = \frac{-423 \text{ lb}}{912.92 \text{ lb}} = -0.46335$   $\theta_y = 117.6^\circ \blacktriangleleft$

$\cos \theta_z = \frac{564 \text{ lb}}{912.92 \text{ lb}} = 0.61780$   $\theta_z = 51.8^\circ \blacktriangleleft$

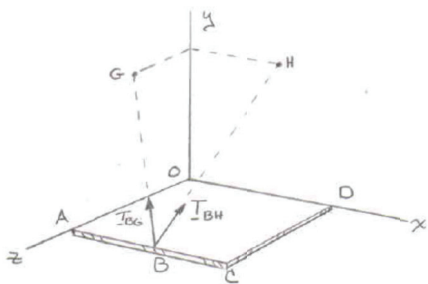


### PROBLEM 2.95

For the frame of Prob. 2.85, determine the magnitude and direction of the resultant of the forces exerted by the cables at  $B$  knowing that the tension is 540 N in cable  $BG$  and 750 N in cable  $BH$ .

**PROBLEM 2.85** Two cables  $BG$  and  $BH$  are attached to frame  $ACD$  as shown. Knowing that the tension in cable  $BG$  is 540 N, determine the components of the force exerted by cable  $BG$  on the frame at  $B$ .

### SOLUTION



$$\overrightarrow{BG} = -(0.8 \text{ m})\mathbf{i} + (1.48 \text{ m})\mathbf{j} - (0.64 \text{ m})\mathbf{k}$$

$$BG = \sqrt{(-0.8 \text{ m})^2 + (1.48 \text{ m})^2 + (-0.64 \text{ m})^2} = 1.8 \text{ m}$$

$$\overrightarrow{BH} = (0.6 \text{ m})\mathbf{i} + (1.2 \text{ m})\mathbf{j} - (1.2 \text{ m})\mathbf{k}$$

$$BH = \sqrt{(0.6 \text{ m})^2 + (1.2 \text{ m})^2 + (-1.2 \text{ m})^2} = 1.8 \text{ m}$$

$$\begin{aligned} \mathbf{T}_{BG} &= T_{BG} \lambda_{BG} \\ &= T_{BG} \frac{\overrightarrow{BG}}{BG} = \frac{540 \text{ N}}{1.8 \text{ m}} [(-0.8 \text{ m})\mathbf{i} + (1.48 \text{ m})\mathbf{j} + (-0.64 \text{ m})\mathbf{k}] \\ &= (-240 \text{ N})\mathbf{i} + (444 \text{ N})\mathbf{j} - (192.0 \text{ N})\mathbf{k} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{BH} &= T_{BH} \lambda_{BH} \\ &= T_{BH} \frac{\overrightarrow{BH}}{BH} = \frac{750 \text{ N}}{1.8 \text{ m}} [\mathbf{i} + 2\mathbf{j} - 2\mathbf{k}] \end{aligned}$$

$$\mathbf{T}_{BH} = (250 \text{ N})\mathbf{i} + (500 \text{ N})\mathbf{j} - (500 \text{ N})\mathbf{k}$$

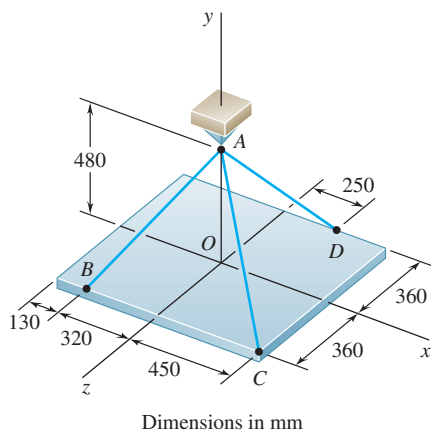
$$\mathbf{R} = \mathbf{T}_{BG} + \mathbf{T}_{BH} = (10 \text{ N})\mathbf{i} + (944 \text{ N})\mathbf{j} - (692 \text{ N})\mathbf{k}$$

$$\text{Then: } R = \sqrt{(10)^2 + 944^2 + (-692)^2} = 1170.51 \text{ N} \quad R = 1171 \text{ N} \blacktriangleleft$$

$$\text{and } \cos \theta_x = \frac{10 \text{ N}}{1170.51 \text{ N}} \quad \theta_x = 89.5^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{944 \text{ N}}{1170.51 \text{ N}} \quad \theta_y = 36.2^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{-692 \text{ N}}{1170.51 \text{ N}} \quad \theta_z = 126.2^\circ \blacktriangleleft$$



### PROBLEM 2.96

For the plate of Prob. 2.89, determine the tensions in cables  $AB$  and  $AD$  knowing that the tension in cable  $AC$  is 54 N and that the resultant of the forces exerted by the three cables at  $A$  must be vertical.

### SOLUTION

We have:

$$\overrightarrow{AB} = -(320 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AB = 680 \text{ mm}$$

$$\overrightarrow{AC} = (450 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AC = 750 \text{ mm}$$

$$\overrightarrow{AD} = (250 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} - (360 \text{ mm})\mathbf{k} \quad AD = 650 \text{ mm}$$

Thus:

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = \frac{T_{AB}}{680} (-320\mathbf{i} - 480\mathbf{j} + 360\mathbf{k})$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = \frac{54}{750} (450\mathbf{i} - 480\mathbf{j} + 360\mathbf{k})$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = \frac{T_{AD}}{650} (250\mathbf{i} - 480\mathbf{j} - 360\mathbf{k})$$

Substituting into the Eq.  $\mathbf{R} = \Sigma \mathbf{F}$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$\begin{aligned} \mathbf{R} = & \left( -\frac{320}{680}T_{AB} + 32.40 + \frac{250}{650}T_{AD} \right) \mathbf{i} \\ & + \left( -\frac{480}{680}T_{AB} - 34.560 - \frac{480}{650}T_{AD} \right) \mathbf{j} \\ & + \left( \frac{360}{680}T_{AB} + 25.920 - \frac{360}{650}T_{AD} \right) \mathbf{k} \end{aligned}$$

### PROBLEM 2.96 (Continued)

Since  $\mathbf{R}$  is vertical, the coefficients of  $\mathbf{i}$  and  $\mathbf{k}$  are zero:

$$\mathbf{i}: \quad -\frac{320}{680}T_{AB} + 32.40 + \frac{250}{650}T_{AD} = 0 \quad (1)$$

$$\mathbf{k}: \quad \frac{360}{680}T_{AB} + 25.920 - \frac{360}{650}T_{AD} = 0 \quad (2)$$

Multiply (1) by 3.6 and (2) by 2.5 then add:

$$-\frac{252}{680}T_{AB} + 181.440 = 0$$

$$T_{AB} = 489.60 \text{ N}$$

$$T_{AB} = 490 \text{ N} \quad \blacktriangleleft$$

Substitute into (2) and solve for  $T_{AD}$ :

$$\frac{360}{680}(489.60 \text{ N}) + 25.920 - \frac{360}{650}T_{AD} = 0$$

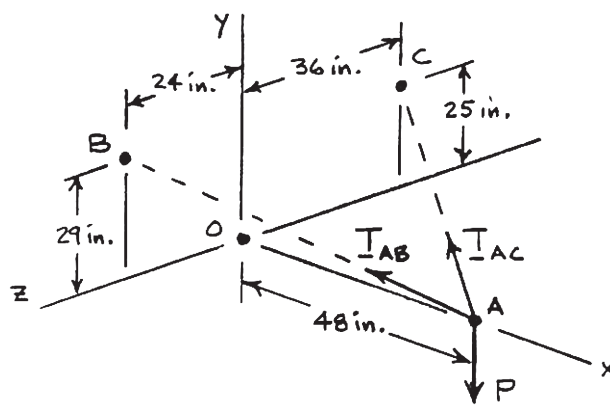
$$T_{AD} = 514.80 \text{ N}$$

$$T_{AD} = 515 \text{ N} \quad \blacktriangleleft$$

### 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  $AB$ :

$$T_{AB} = 183 \text{ lb}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = (183 \text{ lb}) \frac{(-48 \text{ in.})\mathbf{i} + (29 \text{ in.})\mathbf{j} + (24 \text{ in.})\mathbf{k}}{61 \text{ in.}}$$

$$\mathbf{T}_{AB} = -(144 \text{ lb})\mathbf{i} + (87 \text{ lb})\mathbf{j} + (72 \text{ lb})\mathbf{k}$$

Cable  $AC$ :

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = T_{AC} \frac{(-48 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j} + (-36 \text{ in.})\mathbf{k}}{65 \text{ in.}}$$

$$\mathbf{T}_{AC} = -\frac{48}{65}T_{AC}\mathbf{i} + \frac{25}{65}T_{AC}\mathbf{j} - \frac{36}{65}T_{AC}\mathbf{k}$$

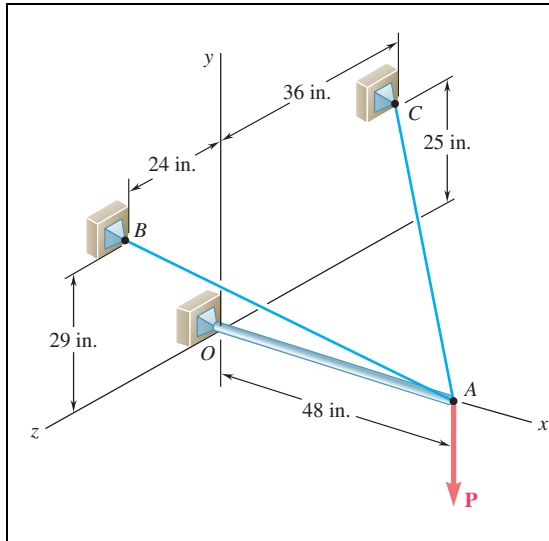
Load  $\mathbf{P}$ :

$$\mathbf{P} = P\mathbf{j}$$

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  $\mathbf{P}$ .

**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  $AC$ .

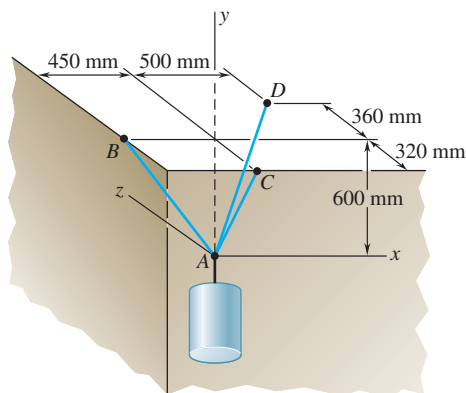
### SOLUTION

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.

$$\text{Then} \quad (87 \text{ lb}) + \frac{25}{65} (130.0 \text{ lb}) - P = 0 \quad P = 137.0 \text{ lb} \quad \blacktriangleleft$$

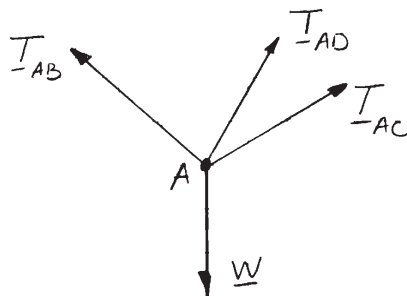


### PROBLEM 2.99

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

$$\overrightarrow{AB} = -(450 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} \quad AB = 750 \text{ mm}$$

$$\overrightarrow{AC} = +(600 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 680 \text{ mm}$$

$$\overrightarrow{AD} = +(500 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AD = 860 \text{ mm}$$

and

$$\mathbf{T}_{AB} = \lambda_{AB} T_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = T_{AB} \frac{(-450 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j}}{750 \text{ mm}}$$

$$= \left( -\frac{45}{75} \mathbf{i} + \frac{60}{75} \mathbf{j} \right) T_{AB}$$

$$\mathbf{T}_{AC} = \lambda_{AC} T_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = T_{AC} \frac{(600 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k}}{680 \text{ mm}}$$

$$= \left( \frac{60}{68} \mathbf{j} - \frac{32}{68} \mathbf{k} \right) T_{AC}$$

$$\mathbf{T}_{AD} = \lambda_{AD} T_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = T_{AD} \frac{(500 \text{ mm})\mathbf{i} + (600 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k}}{860 \text{ mm}}$$

$$= \left( \frac{50}{86} \mathbf{i} + \frac{60}{86} \mathbf{j} + \frac{36}{86} \mathbf{k} \right) T_{AD}$$

### 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  $\mathbf{j}$ :  $\frac{60}{75}T_{AB} + \frac{60}{68}T_{AC} + \frac{60}{86}T_{AD} - W = 0 \quad (2)$

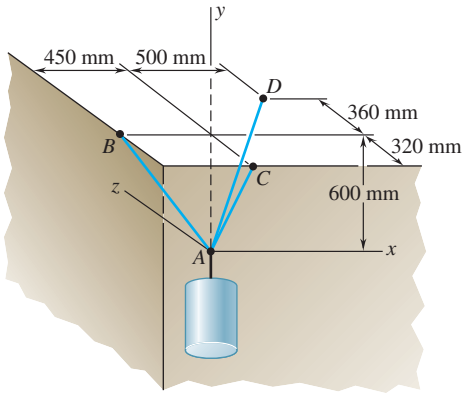
From  $\mathbf{k}$ :  $-\frac{32}{68}T_{AC} + \frac{36}{86}T_{AD} = 0 \quad (3)$

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:

$$-\frac{45}{75}T_{AB} + \frac{50}{86}T_{AD} = 0 \quad (1)$$

$$\frac{60}{75}T_{AB} + \frac{60}{68}T_{AC} + \frac{60}{86}T_{AD} - W = 0 \quad (2)$$

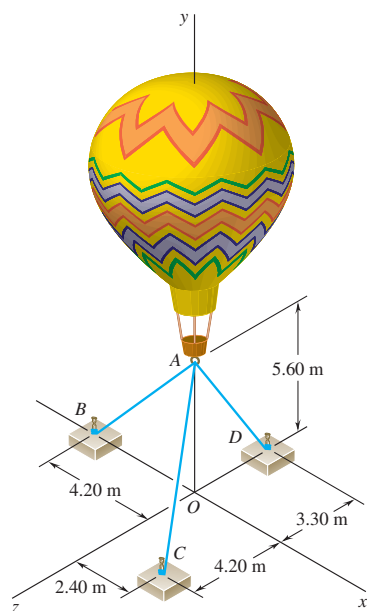
$$-\frac{32}{68}T_{AC} + \frac{36}{86}T_{AD} = 0 \quad (3)$$

Setting  $T_{AD} = 4.3$  kN into the above equations gives

$$T_{AB} = 4.1667 \text{ kN}$$

$$T_{AC} = 3.8250 \text{ kN}$$

$$W = 9.71 \text{ kN} \quad \blacktriangleleft$$

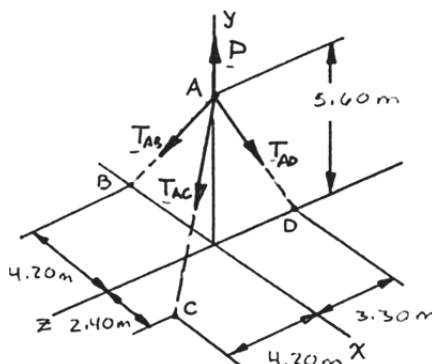


### PROBLEM 2.101

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

### FREE-BODY DIAGRAM AT A



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

$$\overrightarrow{AB} = -(4.20 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} \quad AB = 7.00 \text{ m}$$

$$\overrightarrow{AC} = (2.40 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} + (4.20 \text{ m})\mathbf{k} \quad AC = 7.40 \text{ m}$$

$$\overrightarrow{AD} = -(5.60 \text{ m})\mathbf{j} - (3.30 \text{ m})\mathbf{k} \quad AD = 6.50 \text{ m}$$

and

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = (-0.6\mathbf{i} - 0.8\mathbf{j})T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = (0.32432\mathbf{i} - 0.75676\mathbf{j} + 0.56757\mathbf{k})T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = (-0.86154\mathbf{j} - 0.50769\mathbf{k})T_{AD}$$

**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  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$-0.6T_{AB} + 0.32432T_{AC} = 0 \quad (1)$$

$$-0.8T_{AB} - 0.75676T_{AC} - 0.86154T_{AD} + P = 0 \quad (2)$$

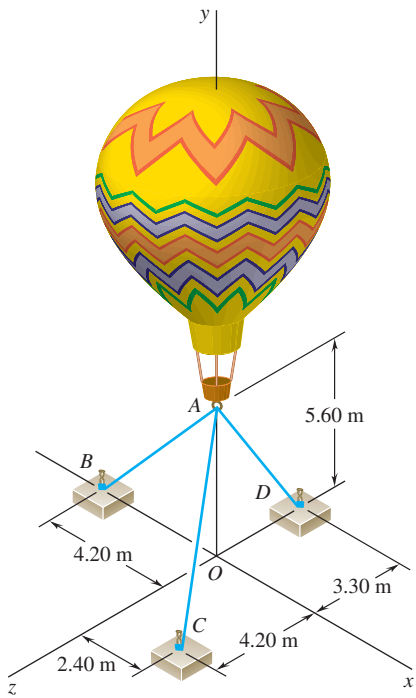
$$0.56757T_{AC} - 0.50769T_{AD} = 0 \quad (3)$$

Setting  $T_{AD} = 481 \text{ N}$  in (2) and (3), and solving the resulting set of equations gives

$$T_{AC} = 430.26 \text{ N}$$

$$T_{AD} = 232.57 \text{ N}$$

$$P = 926 \text{ N} \uparrow \blacktriangleleft$$



### 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

$$-0.8(0.54053T_{AC}) - 0.75676T_{AC} - 0.86154(1.11795T_{AC}) + P = 0$$

$$2.1523T_{AC} = P; \quad P = 800 \text{ N}$$

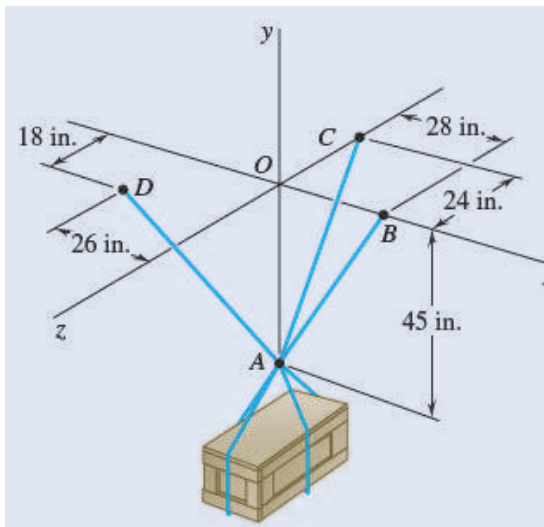
$$T_{AC} = \frac{800 \text{ N}}{2.1523} = 371.69 \text{ N}$$

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

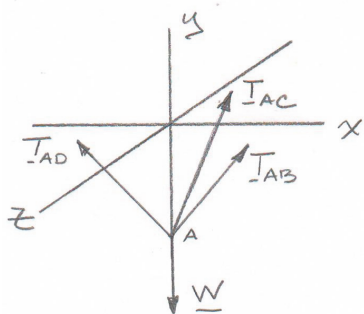
A crate is supported by three cables as shown. Determine the weight  $W$  of the crate, knowing that the tension in cable  $AD$  is 924 lb.

### 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



$$\overrightarrow{AB} = (28 \text{ in.})\mathbf{i} + (45 \text{ in.})\mathbf{j}$$

$$AB = 53 \text{ in.}$$

$$\overrightarrow{AC} = (45 \text{ in.})\mathbf{j} - (24 \text{ in.})\mathbf{k}$$

$$AC = 51 \text{ in.}$$

$$\overrightarrow{AD} = -(26 \text{ in.})\mathbf{i} + (45 \text{ in.})\mathbf{j} + (18 \text{ in.})\mathbf{k}$$

$$AD = 55 \text{ in.}$$

and

$$\begin{aligned}\mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} \\ &= (0.5283\mathbf{i} + 0.84906\mathbf{j})T_{AB}\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} \\ &= (0.88235\mathbf{j} - 0.47059\mathbf{k})T_{AC}\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} \\ &= (-0.47273\mathbf{i} + 0.81818\mathbf{j} + 0.32727\mathbf{k})T_{AD}\end{aligned}$$

Equilibrium Condition with  $\mathbf{W} = -W\mathbf{j}$

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

### PROBLEM 2.103 (Continued)

Substituting the expressions obtained for  $\mathbf{T}_{AB}$ ,  $\mathbf{T}_{AC}$ , and  $\mathbf{T}_{AD}$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ :

$$\begin{aligned}(0.5283T_{AB} - 0.47273T_{AD})\mathbf{i} + (0.84906T_{AB} + 0.88235T_{AC} + 0.81818T_{AD} - W)\mathbf{j} \\ + (-0.47059T_{AC} + 0.32727T_{AD})\mathbf{k} = 0\end{aligned}$$

Equating to zero the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$0.5283T_{AB} - 0.47273T_{AD} = 0 \quad (1)$$

$$0.84906T_{AB} + 0.88235T_{AC} + 0.81818T_{AD} - W = 0 \quad (2)$$

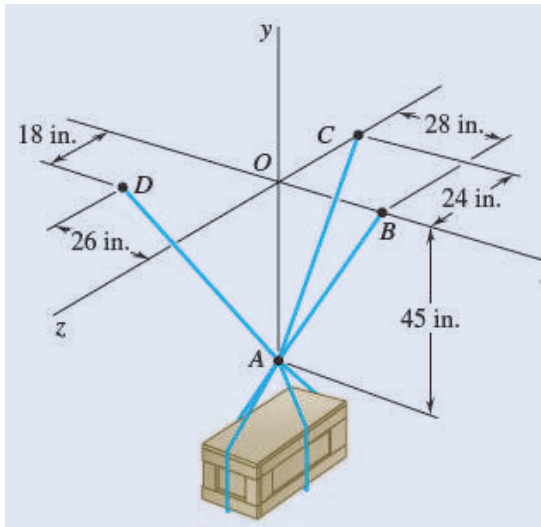
$$-0.47059T_{AC} + 0.32727T_{AD} = 0 \quad (3)$$

Substituting  $T_{AD} = 924 \text{ lb}$  in Equations (1), (2), and (3) and solving the resulting set of equations, using conventional algorithms for solving linear algebraic equations, gives:

$$T_{AB} = 826.81 \text{ lb}$$

$$T_{AC} = 642.59 \text{ lb}$$

$$W = 2030 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.104

A crate is supported by three cables as shown. Determine the weight  $W$  of the crate, knowing that the tension in cable  $AB$  is 1378 lb.

### SOLUTION

See Problem 2.103 for the figure and the analysis leading to the linear algebraic Equations (1), (2), and (3) below:

$$0.5283T_{AB} - 0.47273T_{AD} = 0 \quad (1)$$

$$0.84906T_{AB} + 0.88235T_{AC} + 0.81818T_{AD} - W = 0 \quad (2)$$

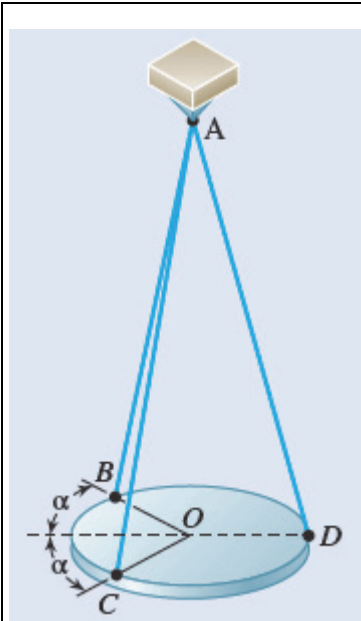
$$-0.47059T_{AC} + 0.32727T_{AD} = 0 \quad (3)$$

Substituting  $T_{AB} = 1378$  lb in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms, gives:

$$T_{AD} = 1539.99 \text{ lb}$$

$$T_{AC} = 1070.98 \text{ lb}$$

$$W = 3380 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.105

A 12-lb circular plate of 7-in. radius is supported as shown by three wires, each of 25-in. length. Determine the tension in each wire, knowing that  $\alpha = 30^\circ$ .

### SOLUTION

Let  $\theta$  be angle between the vertical and any wire.

$$OA = \sqrt{(25^2 - 7^2)} = 24 \text{ in. thus } \cos \theta = \frac{24}{25}$$

By symmetry  $T_{AB} = T_{AC}$

$$\Sigma F_x = 0:$$

$$-2(T_{AB} \sin \theta)(\cos \alpha) + T_{AD}(\sin \theta) = 0$$

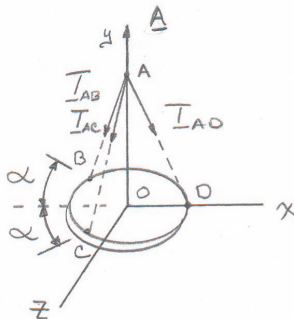
For  $\alpha = 30^\circ$ :

$$T_{AD} = 2(\cos 30^\circ)T_{AB} = 1.73205T_{AB}$$

$$\Sigma F_y = 0: 12 \text{ lb} - 2T_{AB}(\cos \theta) - T_{AD}(\cos \theta) = 0$$

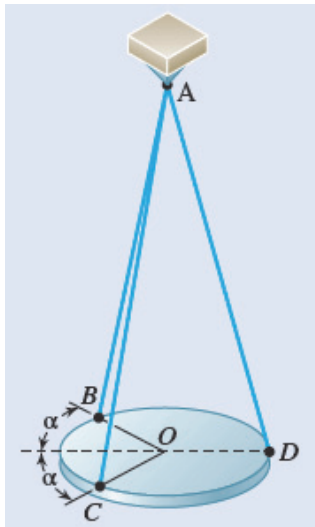
$$\text{or } 12 \text{ lb} = (2T_{AB} + T_{AD})\cos \theta$$

$$12 \text{ lb} = (2T_{AB} + 1.73205T_{AB})\left(\frac{24}{25}\right)$$



$$T_{AB} = T_{AC} = 3.35 \text{ lb} \quad \blacktriangleleft$$

$$T_{AD} = 5.80 \text{ lb} \quad \blacktriangleleft$$

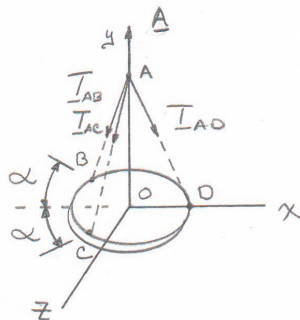


### PROBLEM 2.106

Solve Prob. 2.105, knowing that  $\alpha = 45^\circ$ .

**PROBLEM 2.105** A 12-lb circular plate of 7-in. radius is supported as shown by three wires, each of 25-in. length. Determine the tension in each wire, knowing that  $\alpha = 30^\circ$ .

### SOLUTION



Let  $\theta$  be angle between the vertical and any wire.

$$OA = \sqrt{(25^2 - 7^2)} = 24 \text{ in. thus } \cos \theta = \frac{24}{25}$$

By symmetry  $T_{AB} = T_{AC}$

$$\Sigma F_x = 0:$$

$$-2(T_{AB} \sin \theta)(\cos \alpha) + T_{AD}(\sin \theta) = 0$$

For  $\alpha = 45^\circ$  :

$$T_{AD} = 2(\cos 45^\circ)T_{AB} = 1.41421T_{AB}$$

$$\Sigma F_y = 0: 12 \text{ lb} - 2T_{AB}(\cos \theta) - T_{AD}(\cos \theta) = 0$$

$$\text{or } 12 \text{ lb} = (2T_{AB} + T_{AD})\cos \theta$$

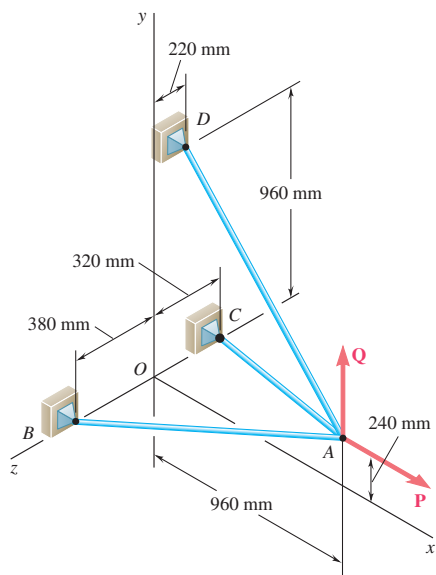
$$12 \text{ lb} = (2T_{AB} + 1.41421T_{AB})\left(\frac{24}{25}\right)$$

$$T_{AB} = T_{AC} = 3.66 \text{ lb} \quad \blacktriangleleft$$

$$T_{AD} = 5.18 \text{ lb} \quad \blacktriangleleft$$

### PROBLEM 2.107

Three cables are connected at A, where the forces **P** and **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

$$\Sigma \mathbf{F}_A = 0: \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{P} = 0 \quad \text{where} \quad \mathbf{P} = P\mathbf{i}$$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\overrightarrow{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \quad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = T_{AB} \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right)$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = T_{AC} \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right)$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = \frac{305 \text{ N}}{1220 \text{ mm}} [(-960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k}] \\ &= -(240 \text{ N})\mathbf{i} + (180 \text{ N})\mathbf{j} - (55 \text{ N})\mathbf{k} \end{aligned}$$

Substituting into  $\Sigma \mathbf{F}_A = 0$ , factoring **i**, **j**, **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  $\Sigma \mathbf{F}_A = 0$ :  $\mathbf{T}_{AB} + \mathbf{T}_{AC} + Q\mathbf{j} + (1200 \text{ N})\mathbf{i} = 0$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right) T_{AB}$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right) T_{AC}$$

Substituting into  $\Sigma \mathbf{F}_A = 0$ , factoring **i**, **j**, **k**, and setting each coefficient equal to  $\phi$  gives:

$$\mathbf{i}: -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} + 1200 \text{ N} = 0 \quad (1)$$

$$\mathbf{j}: -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + Q = 0 \quad (2)$$

$$\mathbf{k}: \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 0 \quad (3)$$

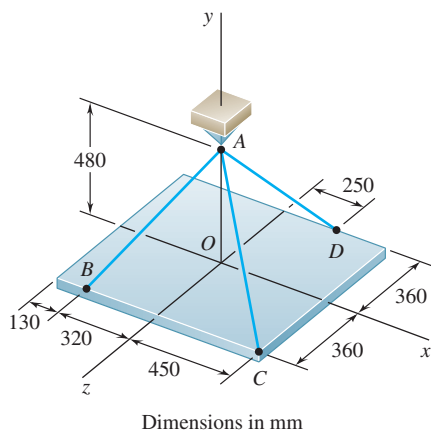
Solving the resulting system of linear equations using conventional algorithms gives:

$$T_{AB} = 605.71 \text{ N}$$

$$T_{AC} = 705.71 \text{ N}$$

$$Q = 300.00 \text{ N} \quad 0 \leq Q < 300 \text{ N} \blacktriangleleft$$

*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.

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

We have:

$$\overrightarrow{AB} = -(320 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AB = 680 \text{ mm}$$

$$\overrightarrow{AC} = (450 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} + (360 \text{ mm})\mathbf{k} \quad AC = 750 \text{ mm}$$

$$\overrightarrow{AD} = (250 \text{ mm})\mathbf{i} - (480 \text{ mm})\mathbf{j} - (360 \text{ mm})\mathbf{k} \quad AD = 650 \text{ mm}$$

Thus:

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = \left( -\frac{8}{17}\mathbf{i} - \frac{12}{17}\mathbf{j} + \frac{9}{17}\mathbf{k} \right) T_{AB} \quad \text{Dimensions in mm}$$

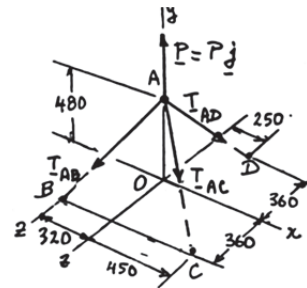
$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = (0.6\mathbf{i} - 0.64\mathbf{j} + 0.48\mathbf{k}) T_{AC}$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = \left( \frac{5}{13}\mathbf{i} - \frac{9.6}{13}\mathbf{j} - \frac{7.2}{13}\mathbf{k} \right) T_{AD}$$

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:

$$554.4 \text{ N} - \frac{12.6}{13}T_{AD} = 0 \quad T_{AD} = 572.0 \text{ N}$$

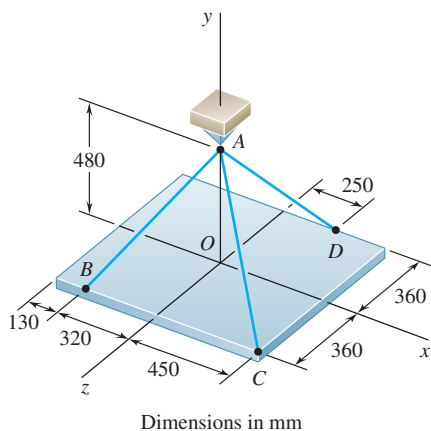
Substitute into (1') and solve for  $T_{AB}$ :

$$T_{AB} = \frac{17}{8} \left( 36 + \frac{5}{13} \times 572 \right) \quad T_{AB} = 544.0 \text{ N}$$

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:

$$9.24T_{AC} - 504 \text{ N} = 0 \quad T_{AC} = 54.5455 \text{ N}$$

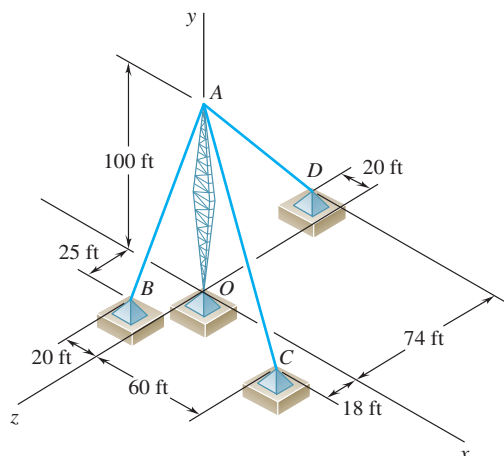
Substitute into (1') and solve for  $T_{AB}$ :

$$T_{AB} = \frac{17}{8}(0.6 \times 54.5455 + 200) \quad T_{AB} = 494.545 \text{ N}$$

Substitute for the tensions in Eq. (2) and solve for  $P$ :

$$P = \frac{12}{17}(494.545 \text{ N}) + 0.64(54.5455 \text{ N}) + \frac{9.6}{13}(520 \text{ N}) \\ = 768.00 \text{ N}$$

Weight of plate =  $P = 768 \text{ N}$  ◀



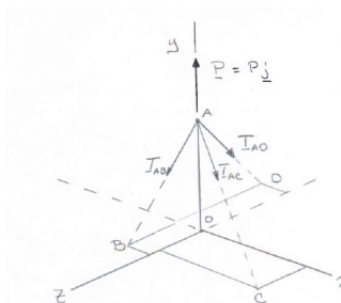
### PROBLEM 2.111

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 840 lb, determine the vertical force **P** exerted by the tower on the pin at A.

### SOLUTION

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

Free-Body Diagram at A:



$$\overrightarrow{AB} = -20\mathbf{i} - 100\mathbf{j} + 25\mathbf{k} \quad AB = 105 \text{ ft}$$

$$\overrightarrow{AC} = 60\mathbf{i} - 100\mathbf{j} + 18\mathbf{k} \quad AC = 118 \text{ ft}$$

$$\overrightarrow{AD} = -20\mathbf{i} - 100\mathbf{j} - 74\mathbf{k} \quad AD = 126 \text{ ft}$$

We write

$$\begin{aligned} \mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} \\ &= \left( -\frac{4}{21}\mathbf{i} - \frac{20}{21}\mathbf{j} + \frac{5}{21}\mathbf{k} \right) T_{AB} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} \\ &= \left( \frac{30}{59}\mathbf{i} - \frac{50}{59}\mathbf{j} + \frac{9}{59}\mathbf{k} \right) T_{AC} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} \\ &= \left( -\frac{10}{63}\mathbf{i} - \frac{50}{63}\mathbf{j} - \frac{37}{63}\mathbf{k} \right) T_{AD} \end{aligned}$$

Substituting into the Eq.  $\Sigma \mathbf{F} = 0$  and factoring **i**, **j**, **k**:

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**PROBLEM 2.111 (Continued)**

$$\begin{aligned} & \left( -\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} \right) \mathbf{i} \\ & + \left( -\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P \right) \mathbf{j} \\ & + \left( \frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} \right) \mathbf{k} = 0 \end{aligned}$$

Setting the coefficients of **i**, **j**, **k**, equal to zero:

$$\mathbf{i}: \quad -\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} = 0 \quad (1)$$

$$\mathbf{j}: \quad -\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P = 0 \quad (2)$$

$$\mathbf{k}: \quad \frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} = 0 \quad (3)$$

Set  $T_{AB} = 840$  lb in Eqs. (1) – (3):

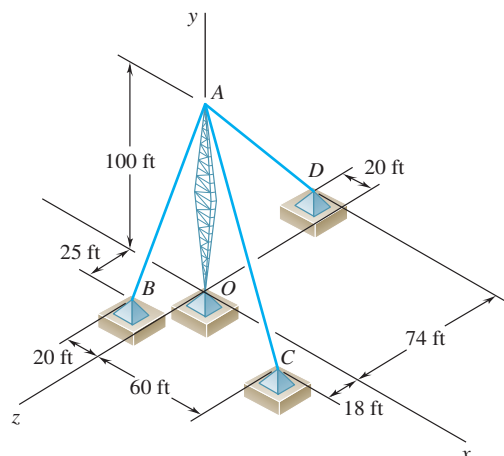
$$-160 \text{ lb} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} = 0 \quad (1')$$

$$-800 \text{ lb} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P = 0 \quad (2')$$

$$200 \text{ lb} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} = 0 \quad (3')$$

Solving,  $T_{AC} = 458.12$  lb  $T_{AD} = 459.53$  lb  $P = 1552.94$  lb

$P = 1553$  lb ◀



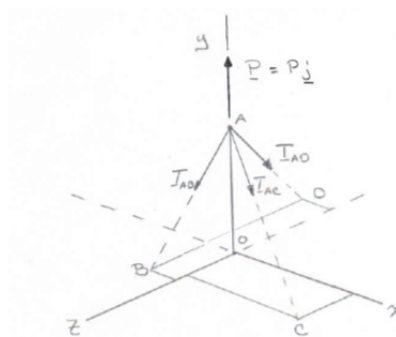
### PROBLEM 2.112

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 590 lb, determine the vertical force **P** exerted by the tower on the pin at A.

### SOLUTION

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

Free-Body Diagram at A:



$$\overrightarrow{AB} = -20\mathbf{i} - 100\mathbf{j} + 25\mathbf{k} \quad AB = 105 \text{ ft}$$

$$\overrightarrow{AC} = 60\mathbf{i} - 100\mathbf{j} + 18\mathbf{k} \quad AC = 118 \text{ ft}$$

$$\overrightarrow{AD} = -20\mathbf{i} - 100\mathbf{j} - 74\mathbf{k} \quad AD = 126 \text{ ft}$$

We write

$$\begin{aligned} \mathbf{T}_{AB} &= T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} \\ &= \left( -\frac{4}{21}\mathbf{i} - \frac{20}{21}\mathbf{j} + \frac{5}{21}\mathbf{k} \right) T_{AB} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} \\ &= \left( \frac{30}{59}\mathbf{i} - \frac{50}{59}\mathbf{j} + \frac{9}{59}\mathbf{k} \right) T_{AC} \end{aligned}$$

$$\begin{aligned} \mathbf{T}_{AD} &= T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} \\ &= \left( -\frac{10}{63}\mathbf{i} - \frac{50}{63}\mathbf{j} - \frac{37}{63}\mathbf{k} \right) T_{AD} \end{aligned}$$

Substituting into the Eq.  $\Sigma \mathbf{F} = 0$  and factoring **i**, **j**, **k**:

**PROBLEM 2.112 (Continued)**

$$\begin{aligned} & \left( -\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} \right) \mathbf{i} \\ & + \left( -\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P \right) \mathbf{j} \\ & + \left( \frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} \right) \mathbf{k} = 0 \end{aligned}$$

Setting the coefficients of **i**, **j**, **k**, equal to zero:

$$\mathbf{i}: \quad -\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} = 0 \quad (1)$$

$$\mathbf{j}: \quad -\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P = 0 \quad (2)$$

$$\mathbf{k}: \quad \frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} = 0 \quad (3)$$

Set  $T_{AC} = 590 \text{ lb}$  in Eqs. (1) – (3):

$$-\frac{4}{21}T_{AB} + 300 \text{ lb} - \frac{10}{63}T_{AD} = 0 \quad (1')$$

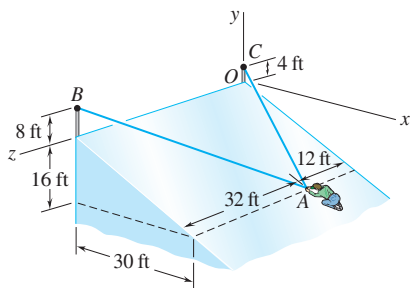
$$-\frac{20}{21}T_{AB} - 500 \text{ lb} - \frac{50}{63}T_{AD} + P = 0 \quad (2')$$

$$\frac{5}{21}T_{AB} + 90 \text{ lb} - \frac{37}{63}T_{AD} = 0 \quad (3')$$

Solving,

$$T_{AB} = 1081.82 \text{ lb} \quad T_{AD} = 591.82 \text{ lb}$$

$$P = 2000 \text{ lb} \quad \blacktriangleleft$$

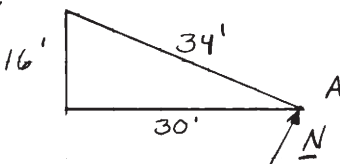
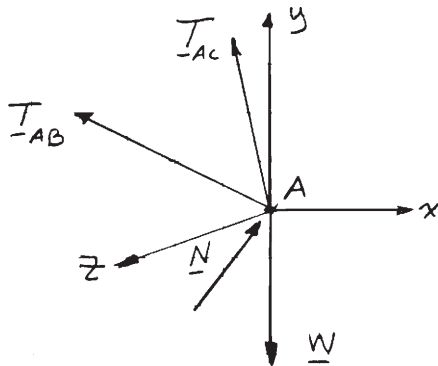


### PROBLEM 2.113

In trying to move across a slippery icy surface, a 175-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  $\mathbf{W} = W \mathbf{j} = -(175 \text{ lb}) \mathbf{j}$

$$\begin{aligned} \mathbf{T}_{AC} &= T_{AC} \boldsymbol{\lambda}_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = T_{AC} \frac{(-30 \text{ ft}) \mathbf{i} + (20 \text{ ft}) \mathbf{j} - (12 \text{ ft}) \mathbf{k}}{38 \text{ ft}} \\ &= T_{AC} \left( -\frac{15}{19} \mathbf{i} + \frac{10}{19} \mathbf{j} - \frac{6}{19} \mathbf{k} \right) \\ \mathbf{T}_{AB} &= T_{AB} \boldsymbol{\lambda}_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = T_{AB} \frac{(-30 \text{ ft}) \mathbf{i} + (24 \text{ ft}) \mathbf{j} + (32 \text{ ft}) \mathbf{k}}{50 \text{ ft}} \\ &= T_{AB} \left( -\frac{15}{25} \mathbf{i} + \frac{12}{25} \mathbf{j} + \frac{16}{25} \mathbf{k} \right) \end{aligned}$$

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:

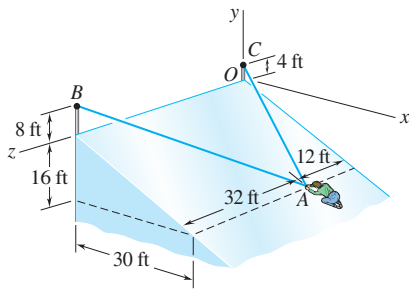
From  $\mathbf{i}$ : 
$$-\frac{15}{25}T_{AB} - \frac{15}{19}T_{AC} + \frac{16}{34}N = 0 \quad (1)$$

From  $\mathbf{j}$ : 
$$\frac{12}{25}T_{AB} + \frac{10}{19}T_{AC} + \frac{30}{34}N - (175 \text{ lb}) = 0 \quad (2)$$

From  $\mathbf{k}$ : 
$$\frac{16}{25}T_{AB} - \frac{6}{19}T_{AC} = 0 \quad (3)$$

Solving the resulting set of equations gives:

$$T_{AB} = 30.8 \text{ lb}; T_{AC} = 62.5 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.114

Solve Problem 2.113, assuming that a friend is helping the man at A by pulling on him with a force  $\mathbf{P} = -(45 \text{ lb})\mathbf{k}$ .

**PROBLEM 2.113** In trying to move across a slippery icy surface, a 175-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  $\mathbf{P} = (-45 \text{ lb})\mathbf{k}$ .

$$-\frac{15}{25}T_{AB} - \frac{15}{19}T_{AC} + \frac{16}{34}N = 0 \quad (1)$$

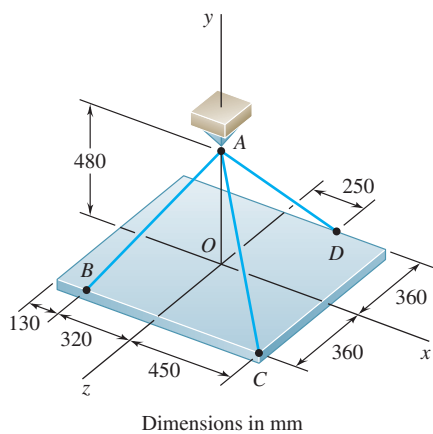
$$\frac{12}{25}T_{AB} + \frac{10}{19}T_{AC} + \frac{30}{34}N - (175 \text{ lb}) = 0 \quad (2)$$

$$\frac{16}{25}T_{AB} - \frac{6}{19}T_{AC} - (45 \text{ lb}) = 0 \quad (3)$$

Solving the resulting set of equations simultaneously gives:

$$T_{AB} = 81.3 \text{ lb} \quad \blacktriangleleft$$

$$T_{AC} = 22.2 \text{ lb} \quad \blacktriangleleft$$



### 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

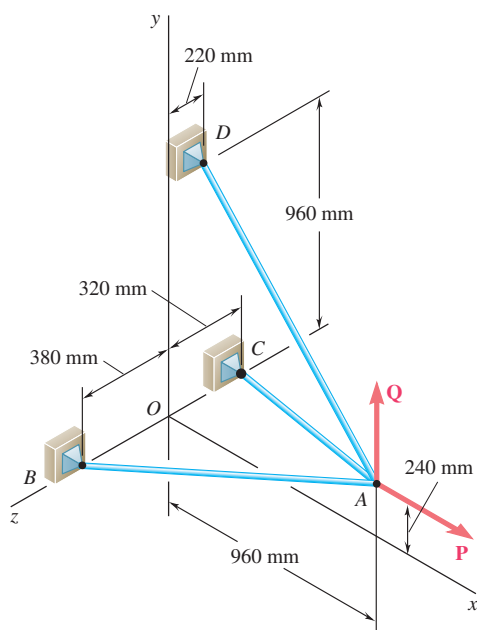
$$T_{AB} = 510.00 \text{ N} \quad T_{AB} = 510 \text{ N} \blacktriangleleft$$

$$T_{AC} = 56.250 \text{ N} \quad T_{AC} = 56.2 \text{ N} \blacktriangleleft$$

$$T_{AD} = 536.25 \text{ N} \quad T_{AD} = 536 \text{ N} \blacktriangleleft$$

### 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

$$\mathbf{P} = P\mathbf{i} \text{ and } \mathbf{Q} = Q\mathbf{j}$$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \quad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \quad AC = 1040 \text{ mm}$$

$$\overrightarrow{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \quad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB} \lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} = T_{AB} \left( -\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k} \right)$$

$$\mathbf{T}_{AC} = T_{AC} \lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = T_{AC} \left( -\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right)$$

$$\mathbf{T}_{AD} = T_{AD} \lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = T_{AD} \left( -\frac{48}{61}\mathbf{i} + \frac{36}{61}\mathbf{j} - \frac{11}{61}\mathbf{k} \right)$$

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:

$$\mathbf{i}: -\frac{48}{53}T_{AB} - \frac{12}{13}T_{AC} - \frac{48}{61}T_{AD} + 2880 \text{ N} = 0 \quad (1)$$

$$\mathbf{j}: -\frac{12}{53}T_{AB} - \frac{3}{13}T_{AC} + \frac{36}{61}T_{AD} = 0 \quad (2)$$

$$\mathbf{k}: \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} - \frac{11}{61}T_{AD} = 0 \quad (3)$$

**PROBLEM 2.116 (Continued)**

Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 1340.14 \text{ N}$$

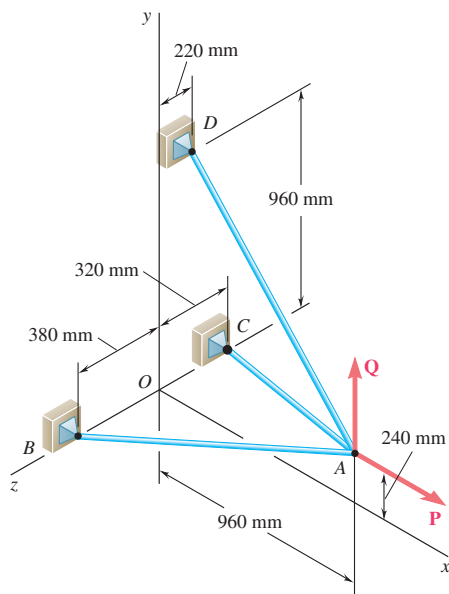
$$T_{AC} = 1025.12 \text{ N}$$

$$T_{AD} = 915.03 \text{ N}$$

$$T_{AB} = 1340 \text{ N} \blacktriangleleft$$

$$T_{AC} = 1025 \text{ N} \blacktriangleleft$$

$$T_{AD} = 915 \text{ N} \blacktriangleleft$$



### 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:

$$T_{AB} = 1431.00 \text{ N}$$

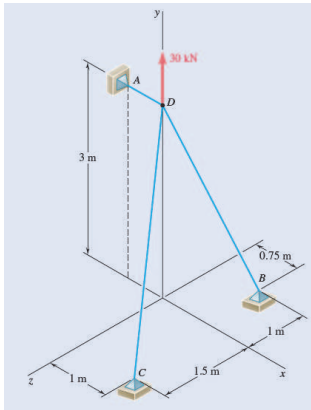
$$T_{AC} = 1560.00 \text{ N}$$

$$T_{AD} = 183.010 \text{ N}$$

$$T_{AB} = 1431 \text{ N} \quad \blacktriangleleft$$

$$T_{AC} = 1560 \text{ N} \quad \blacktriangleleft$$

$$T_{AD} = 183.0 \text{ N} \quad \blacktriangleleft$$

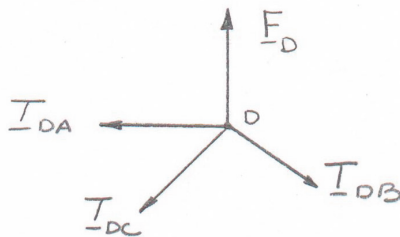


### PROBLEM 2.118

Three cables are connected at  $D$ , where an upward force of 30 kN is applied. Determine the tension in each cable.

### SOLUTION

#### Free-Body Diagram of Point $D$ :



$$\Sigma \mathbf{F}_D = 0: \mathbf{T}_{DA} + \mathbf{T}_{DB} + \mathbf{T}_{DC} + \mathbf{P} = 0$$

Where

$$\mathbf{P} = P\mathbf{j}$$

$$\overrightarrow{DA} = -(1\text{ m})\mathbf{i} \quad DA = 1\text{ m}$$

$$\overrightarrow{DB} = +(0.75\text{ m})\mathbf{i} - (3\text{ m})\mathbf{j} - (1\text{ m})\mathbf{k} \quad DB = 3.25\text{ m}$$

$$\overrightarrow{DC} = +(1\text{ m})\mathbf{i} - (3\text{ m})\mathbf{j} + (1.5\text{ m})\mathbf{k} \quad DC = 3.5\text{ m}$$

$$\mathbf{T}_{DA} = T_{DA} \lambda_{DA} = T_{DA} \frac{\overrightarrow{DA}}{DA} = T_{DA} (-\mathbf{i})$$

$$\mathbf{T}_{DB} = T_{DB} \lambda_{DB} = T_{DB} \frac{\overrightarrow{DB}}{DB} = T_{DB} \left( \frac{3}{13}\mathbf{i} - \frac{12}{13}\mathbf{j} - \frac{4}{13}\mathbf{k} \right)$$

$$\mathbf{T}_{DC} = T_{DC} \lambda_{DC} = T_{DC} \frac{\overrightarrow{DC}}{DC} = T_{DC} \left( \frac{2}{7}\mathbf{i} - \frac{6}{7}\mathbf{j} + \frac{3}{7}\mathbf{k} \right)$$

Substituting into  $\Sigma \mathbf{F}_D = 0$ , setting  $\mathbf{P} = (30\text{ kN})\mathbf{j}$  and setting the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$  equal to 0, we obtain the following three equilibrium equations:

$$\mathbf{i}: -T_{DA} + \frac{3}{13}T_{DB} + \frac{2}{7}T_{DC} = 0 \quad (1)$$

**PROBLEM 2.118 (Continued)**

$$\mathbf{j}: -\frac{12}{13}T_{DB} - \frac{6}{7}T_{DC} + 30 \text{ kN} = 0 \quad (2)$$

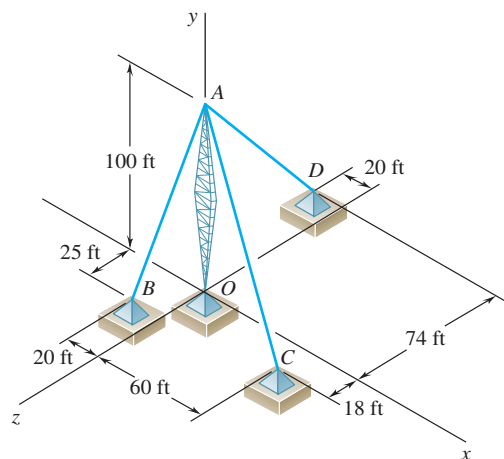
$$\mathbf{k}: -\frac{4}{13}T_{DB} + \frac{3}{7}T_{DC} = 0 \quad (3)$$

Solving the system of linear equations using conventional algorithms gives:

$$T_{DA} = 8.50 \text{ kN} \quad \blacktriangleleft$$

$$T_{DB} = 19.50 \text{ kN} \quad \blacktriangleleft$$

$$T_{DC} = 14.00 \text{ kN} \quad \blacktriangleleft$$



### PROBLEM 2.119

For the transmission tower of Probs. 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 1800 lb.

**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 840 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:

$$\text{i:} \quad -\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} = 0 \quad (1)$$

$$\text{j:} \quad -\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + P = 0 \quad (2)$$

$$\text{k:} \quad \frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} = 0 \quad (3)$$

Substituting for  $P = 1800$  lb in Equations (1), (2), and (3) above and solving the resulting set of equations using conventional algorithms gives:

$$-\frac{4}{21}T_{AB} + \frac{30}{59}T_{AC} - \frac{10}{63}T_{AD} = 0 \quad (1')$$

$$-\frac{20}{21}T_{AB} - \frac{50}{59}T_{AC} - \frac{50}{63}T_{AD} + 1800 \text{ lb} = 0 \quad (2')$$

$$\frac{5}{21}T_{AB} + \frac{9}{59}T_{AC} - \frac{37}{63}T_{AD} = 0 \quad (3')$$

$$T_{AB} = 973.64 \text{ lb}$$

$$T_{AC} = 531.00 \text{ lb}$$

$$T_{AD} = 532.64 \text{ lb}$$

$$T_{AB} = 974 \text{ lb} \quad \blacktriangleleft$$

$$T_{AC} = 531 \text{ lb} \quad \blacktriangleleft$$

$$T_{AD} = 533 \text{ lb} \quad \blacktriangleleft$$

**PROBLEM 2.120**

Three wires are connected at point  $D$ , which is located 18 in. below the T-shaped pipe support  $ABC$ . Determine the tension in each wire when a 180-lb cylinder is suspended from point  $D$  as shown.

Three wires are connected at point  $D$ , which is located 18 in. below the T-shaped pipe support  $ABC$ . Determine the tension in each wire when a 180-lb cylinder is suspended from point  $D$  as shown.

**SOLUTION**

**Free-Body Diagram of Point  $D$ :**

The forces applied at  $D$  are:

$\mathbf{T}_{DA}, \mathbf{T}_{DB}, \mathbf{T}_{DC}$  and  $\mathbf{W}$

where  $\mathbf{W} = -180.0 \text{ lb}\mathbf{j}$ . To express the other forces in terms of the unit vectors  $\mathbf{i}, \mathbf{j}, \mathbf{k}$ , we write

$$\overrightarrow{DA} = (18 \text{ in.})\mathbf{j} + (22 \text{ in.})\mathbf{k}$$

$$DA = 28.425 \text{ in.}$$

$$\overrightarrow{DB} = -(24 \text{ in.})\mathbf{i} + (18 \text{ in.})\mathbf{j} - (16 \text{ in.})\mathbf{k}$$

$$DB = 34.0 \text{ in.}$$

$$\overrightarrow{DC} = (24 \text{ in.})\mathbf{i} + (18 \text{ in.})\mathbf{j} - (16 \text{ in.})\mathbf{k}$$

$$DC = 34.0 \text{ in.}$$

### PROBLEM 2.120 (Continued)

and

$$\begin{aligned}\mathbf{T}_{DA} &= T_{DA} \lambda_{DA} = T_{DA} \frac{\overrightarrow{DA}}{DA} \\ &= (0.63324\mathbf{j} + 0.77397\mathbf{k})T_{DA}\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{DB} &= T_{DB} \lambda_{DB} = T_{DB} \frac{\overrightarrow{DB}}{DB} \\ &= (-0.70588\mathbf{i} + 0.52941\mathbf{j} - 0.47059\mathbf{k})T_{DB}\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{DC} &= T_{DC} \lambda_{DC} = T_{DC} \frac{\overrightarrow{DC}}{DC} \\ &= (0.70588\mathbf{i} + 0.52941\mathbf{j} - 0.47059\mathbf{k})T_{DC}\end{aligned}$$

Equilibrium Condition with  $\mathbf{W} = -W\mathbf{j}$

$$\Sigma F = 0: \mathbf{T}_{DA} + \mathbf{T}_{DB} + \mathbf{T}_{DC} - W\mathbf{j} = 0$$

Substituting the expressions obtained for  $\mathbf{T}_{DA}$ ,  $\mathbf{T}_{DB}$ , and  $\mathbf{T}_{DC}$  and factoring  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$ :

$$\begin{aligned}&(-0.70588T_{DB} + 0.70588T_{DC})\mathbf{i} \\ &(0.63324T_{DA} + 0.52941T_{DB} + 0.52941T_{DC} - W)\mathbf{j} \\ &(0.77397T_{DA} - 0.47059T_{DB} - 0.47059T_{DC})\mathbf{k}\end{aligned}$$

Equating to zero the coefficients of  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ :

$$-0.70588T_{DB} + 0.70588T_{DC} = 0 \quad (1)$$

$$0.63324T_{DA} + 0.52941T_{DB} + 0.52941T_{DC} - W = 0 \quad (2)$$

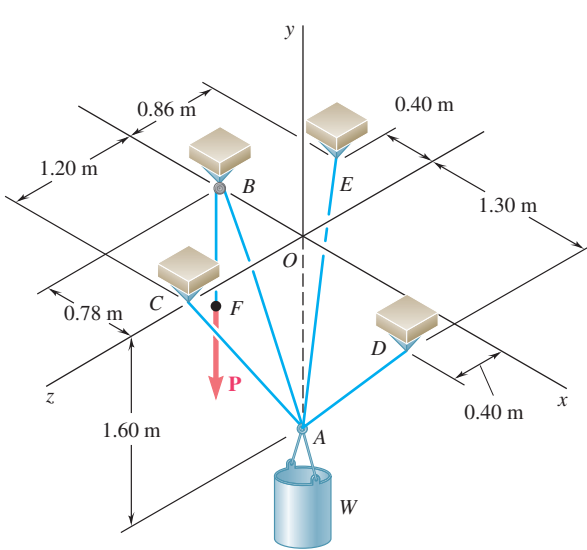
$$0.77397T_{DA} - 0.47059T_{DB} - 0.47059T_{DC} = 0 \quad (3)$$

Substituting  $W = 180 \text{ lb}$  in Equations (1), (2), and (3) above, and solving the resulting set of equations using conventional algorithms gives,

$$T_{DA} = 119.7 \text{ lb} \blacktriangleleft$$

$$T_{DB} = 98.4 \text{ lb} \blacktriangleleft$$

$$T_{DC} = 98.4 \text{ lb} \blacktriangleleft$$



**PROBLEM 2.121**

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

### SOLUTION

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

$$\begin{aligned}\overrightarrow{AB} &= -(0.78 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0 \text{ m})\mathbf{k} \\ AB &= \sqrt{(-0.78 \text{ m})^2 + (1.6 \text{ m})^2 + (0)^2} \\ &= 1.78 \text{ m}\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{AB} &= T\lambda_{AB} = T_{AB} \frac{\overrightarrow{AB}}{AB} \\ &= \frac{T_{AB}}{1.78 \text{ m}} [-(0.78 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0 \text{ m})\mathbf{k}] \\ \mathbf{T}_{AB} &= T_{AB} (-0.4382\mathbf{i} + 0.8989\mathbf{j} + 0\mathbf{k})\end{aligned}$$

and

$$\begin{aligned}\overrightarrow{AC} &= (0)\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (1.2 \text{ m})\mathbf{k} \\ AC &= \sqrt{(0 \text{ m})^2 + (1.6 \text{ m})^2 + (1.2 \text{ m})^2} = 2 \text{ m} \\ \mathbf{T}_{AC} &= T\lambda_{AC} = T_{AC} \frac{\overrightarrow{AC}}{AC} = \frac{T_{AC}}{2 \text{ m}} [(0)\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (1.2 \text{ m})\mathbf{k}] \\ \mathbf{T}_{AC} &= T_{AC} (0.8\mathbf{j} + 0.6\mathbf{k})\end{aligned}$$

and

$$\begin{aligned}\overrightarrow{AD} &= (1.3 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0.4 \text{ m})\mathbf{k} \\ AD &= \sqrt{(1.3 \text{ m})^2 + (1.6 \text{ m})^2 + (0.4 \text{ m})^2} = 2.1 \text{ m} \\ \mathbf{T}_{AD} &= T\lambda_{AD} = T_{AD} \frac{\overrightarrow{AD}}{AD} = \frac{T_{AD}}{2.1 \text{ m}} [(1.3 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} + (0.4 \text{ m})\mathbf{k}] \\ \mathbf{T}_{AD} &= T_{AD} (0.6190\mathbf{i} + 0.7619\mathbf{j} + 0.1905\mathbf{k})\end{aligned}$$

**PROBLEM 2.121 (Continued)**

Finally,

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

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

$$\mathbf{T}_{AE} = T_{AE} \frac{\overrightarrow{AE}}{AE}$$

$$= \frac{T_{AE}}{1.86 \text{ m}} [-(0.4 \text{ m})\mathbf{i} + (1.6 \text{ m})\mathbf{j} - (0.86 \text{ m})\mathbf{k}]$$

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

With the weight of the container

$\mathbf{W} = -W\mathbf{j}$ , at A we have:

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

Equating the factors of  $\mathbf{i}$ ,  $\mathbf{j}$ , and  $\mathbf{k}$  to zero, we obtain the following linear algebraic equations:

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

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

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

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

$$P = 378 \text{ N} \quad \blacktriangleleft$$

**PROBLEM 2.122**

Knowing that the tension in cable  $AC$  of the system described in Problem 2.121 is 150 N, determine (a) the magnitude of the force  $\mathbf{P}$ , (b) the weight  $W$  of the container.

**PROBLEM 2.121** A container of weight  $W$  is suspended from ring  $A$ , to which cables  $AC$  and  $AE$  are attached. A force  $\mathbf{P}$  is applied to the end  $F$  of a third cable that passes over a pulley at  $B$  and through ring  $A$  and that is attached to a support at  $D$ . Knowing that  $W = 1000$  N, determine the magnitude of  $P$ . (*Hint: The tension is the same in all portions of cable  $FBAD$ .*)

### SOLUTION

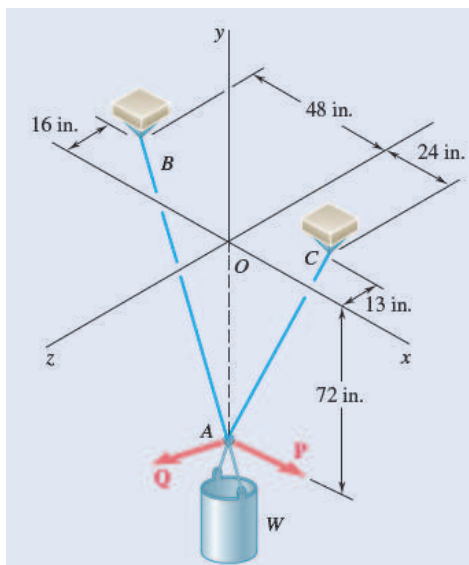
Here, as in Problem 2.121, the support of the container consists of the four cables  $AE$ ,  $AC$ ,  $AD$ , and  $AB$ , with the condition that the force in cables  $AB$  and  $AD$  is equal to the externally applied force  $P$ . Thus, with the condition

$$T_{AB} = T_{AD} = P$$

and using the linear algebraic equations of Problem 2.131 with  $T_{AC} = 150$  N, we obtain

(a)  $P = 454$  N ◀

(b)  $W = 1202$  N ◀

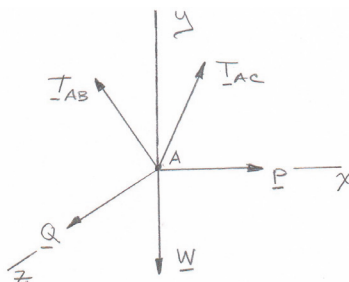


### PROBLEM 2.123

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  $W = 270$  lb, determine  $P$  and  $Q$ . (*Hint*: The tension is the same in both portions of cable  $BAC$ .)

### SOLUTION

Free-Body Diagram of Point A:



$$\begin{aligned}\mathbf{T}_{AB} &= T\lambda_{AB} \\ &= T \frac{\overline{AB}}{AB} \\ &= T \frac{(-48 \text{ in.})\mathbf{i} + (72 \text{ in.})\mathbf{j} - (16 \text{ in.})\mathbf{k}}{88 \text{ in.}} \\ &= T \left( -\frac{6}{11}\mathbf{i} + \frac{9}{11}\mathbf{j} - \frac{2}{11}\mathbf{k} \right)\end{aligned}$$

$$\begin{aligned}\mathbf{T}_{AC} &= T\lambda_{AC} \\ &= T \frac{\overline{AC}}{AC} \\ &= T \frac{(24 \text{ in.})\mathbf{i} + (72 \text{ in.})\mathbf{j} + (-13 \text{ in.})\mathbf{k}}{77 \text{ in.}} \\ &= T \left( \frac{24}{77}\mathbf{i} + \frac{72}{77}\mathbf{j} - \frac{13}{77}\mathbf{k} \right)\end{aligned}$$

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

**PROBLEM 2.123 (continued)**

Setting coefficients of **i**, **j**, **k** equal to zero:

$$\mathbf{i}: -\frac{6}{11}T + \frac{24}{77}T + P = 0 \qquad -\left(\frac{18}{77}\right)T + P = 0 \qquad (1)$$

$$\mathbf{j}: +\frac{9}{11}T + \frac{72}{77}T - W = 0 \qquad \left(\frac{135}{77}\right)T - W = 0 \qquad (2)$$

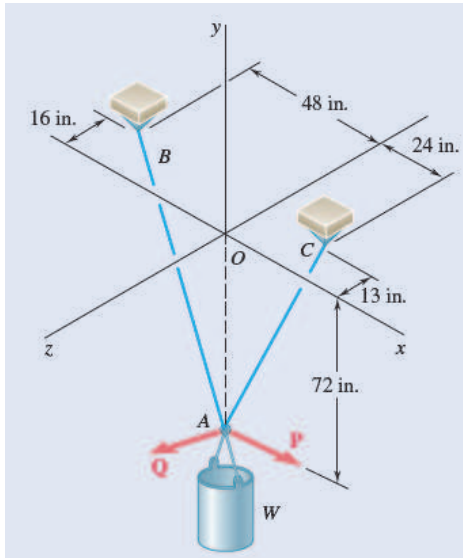
$$\mathbf{k}: -\frac{2}{11}T - \frac{13}{77}T + Q = 0 \qquad -\left(\frac{27}{77}\right)T + Q = 0 \qquad (3)$$

Data:  $W = 270 \text{ lb} \quad T = \left(\frac{77}{135}\right)270 \text{ lb} \quad T = 154.0 \text{ lb}$

Substituting for  $T$  in Eqn . (1) and (2):

$$P = 36.0 \text{ lb} \quad \blacktriangleleft$$

$$Q = 54.0 \text{ lb} \quad \blacktriangleleft$$



### PROBLEM 2.124

For the system of Prob. 2.123, determine  $W$  and  $P$  knowing that  $Q = 36$  lb.

**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  $W = 270$  lb, determine  $P$  and  $Q$ . (Hint: The tension is the same in both portions of cable  $BAC$ .)

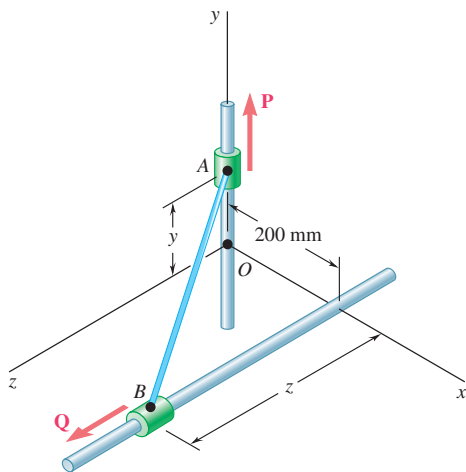
### SOLUTION

Refer to Problem 2.123 for the figure and analysis resulting in Equations (1), (2), and (3). Setting  $Q = 36$  lb we have:

$$\text{Eq. (3):} \quad T = \left( \frac{77}{27} \right) 36 \text{ lb} \quad T = 102.667 \text{ lb}$$

$$\text{Eq. (1):} \quad -\frac{18}{77} (102.667 \text{ lb}) + P = 0 \quad P = 24.0 \text{ lb} \quad \blacktriangleleft$$

$$\text{Eq. (2):} \quad \frac{135}{77} (102.667 \text{ lb}) - W = 0 \quad W = 180.0 \text{ lb} \quad \blacktriangleleft$$



### 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  $\mathbf{Q}$  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  $y$  given,  $z$  is determined,

Now

$$\begin{aligned}\lambda_{AB} &= \frac{\overrightarrow{AB}}{AB} \\ &= \frac{1}{0.525 \text{ m}}(0.20\mathbf{i} - y\mathbf{j} + z\mathbf{k})\text{m} \\ &= 0.38095\mathbf{i} - 1.90476y\mathbf{j} + 1.90476z\mathbf{k}\end{aligned}$$

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  $\mathbf{j}$  coefficient to zero gives  $P - (1.90476y)T_{AB} = 0$

With

$$P = 341 \text{ N}$$

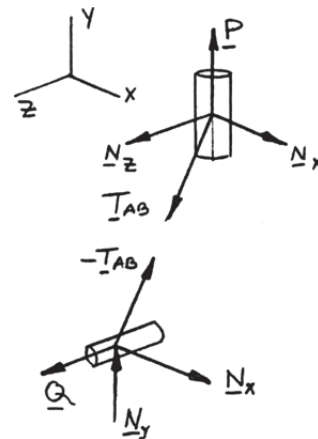
$$T_{AB} = \frac{341 \text{ N}}{1.90476y}$$

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  $\mathbf{k}$  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

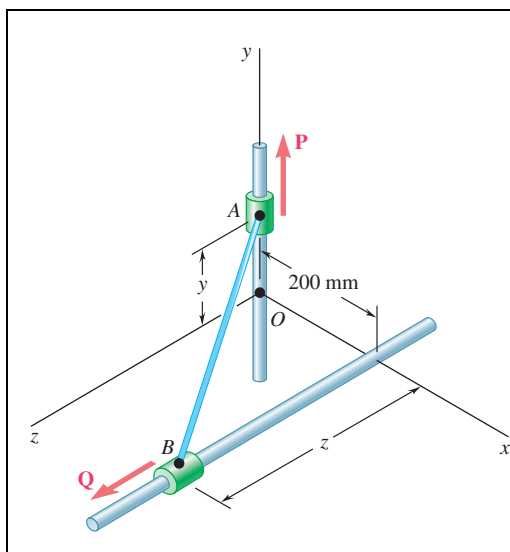
$$T_{AB} = 1155 \text{ N} \blacktriangleleft$$

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

$$Q = 1012 \text{ N} \blacktriangleleft$$



### 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:

$$y^2 + z^2 = 0.23563 \text{ m}^2$$

$$T_{AB} = \frac{341 \text{ N}}{1.90476y}$$

$$Q = \frac{341 \text{ N}}{y} z$$

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

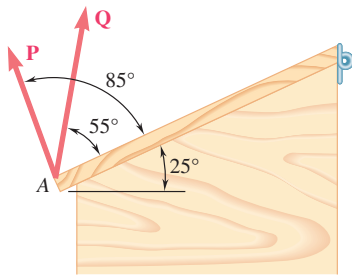
$$T_{AB} = 651 \text{ N} \blacktriangleleft$$

and

$$(b) \quad Q = \frac{341 \text{ N}(0.40 \text{ m})}{(0.275 \text{ m})}$$

or

$$Q = 496 \text{ N} \blacktriangleleft$$



### PROBLEM 2.127

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

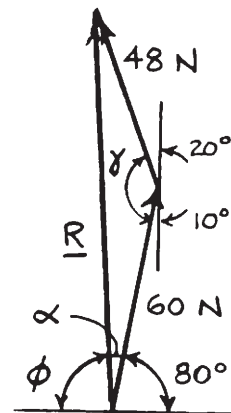
$$R = 104.366 \text{ N}$$

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

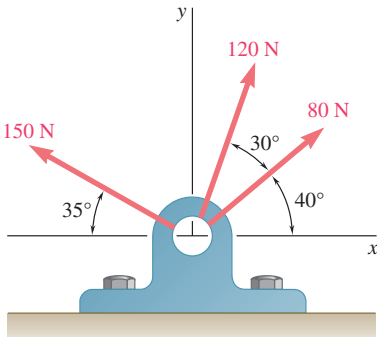
$$\sin \alpha = 0.22996$$

$$\alpha = 13.2947^\circ$$

Hence: 
$$\begin{aligned} \phi &= 180^\circ - \alpha - 80^\circ \\ &= 180^\circ - 13.2947^\circ - 80^\circ \\ &= 86.705^\circ \end{aligned}$$



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



### PROBLEM 2.128

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

### SOLUTION

80-N Force:

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

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

120-N Force:

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

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

150-N Force:

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

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

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

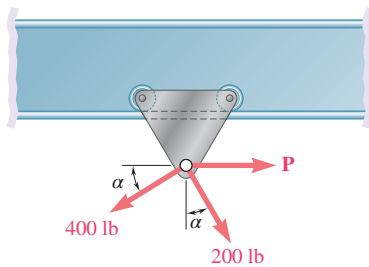
$$F_y = 51.4 \text{ N} \quad \blacktriangleleft$$

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

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

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

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



### PROBLEM 2.129

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

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

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

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

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

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

Set

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

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

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

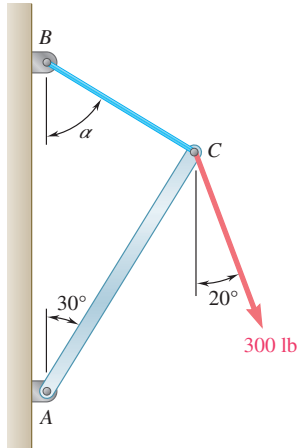
$$P = 177.9 \text{ lb} \blacktriangleleft$$

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

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

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

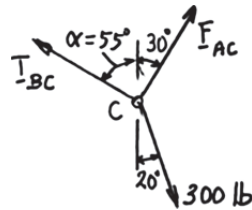
### PROBLEM 2.130



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)

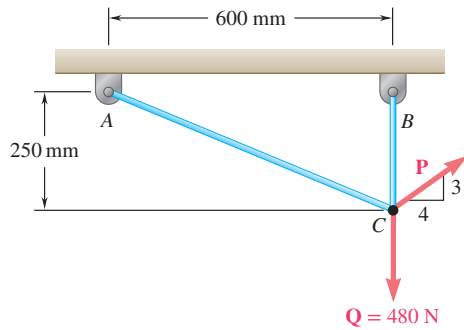
$$F_{AC} = \frac{300 \text{ lb}}{\sin 95^\circ} \sin 35^\circ$$

$$F_{AC} = 172.7 \text{ lb} \quad \blacktriangleleft$$

(b)

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

$$T_{BC} = 231 \text{ lb} \quad \blacktriangleleft$$

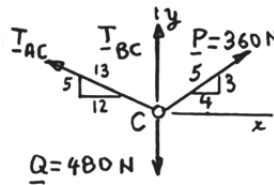


### PROBLEM 2.131

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

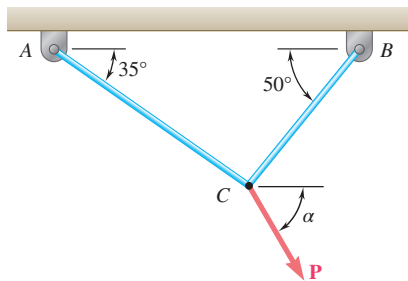
Free Body:  $C$



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

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

$$T_{BC} = 480 \text{ N} - 120 \text{ N} - 216 \text{ N} \quad T_{BC} = 144.0 \text{ N} \blacktriangleleft$$

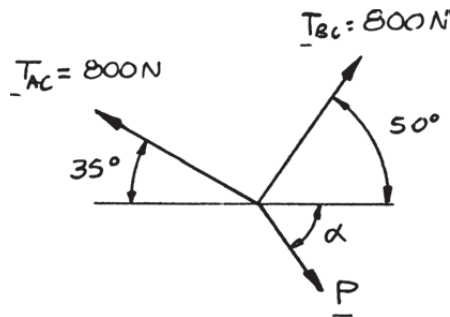


### PROBLEM 2.132

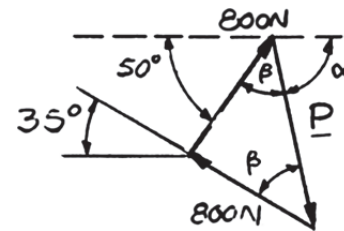
Two cables tied together at  $C$  are loaded as shown. Knowing that the maximum allowable tension in each cable is 800 N, determine (a) the magnitude of the largest force  $P$  that can be applied at  $C$ , (b) the corresponding value of  $\alpha$ .

### SOLUTION

#### Free-Body Diagram: $C$



#### Force Triangle



Force triangle is isosceles with

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

$$\beta = 47.5^\circ$$

(a)

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

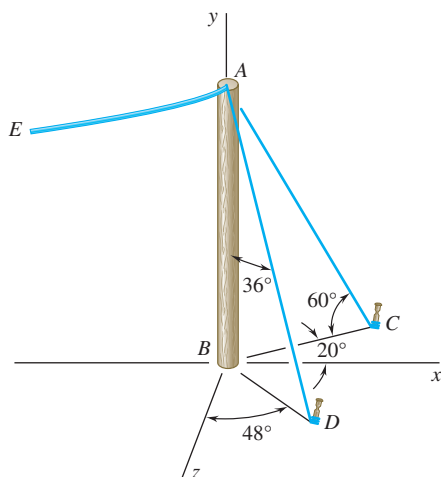
Since  $P > 0$ , the solution is correct.

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

(b)

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

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



### PROBLEM 2.133

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 2.134**

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

**SOLUTION**

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

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

$$= 1420 \text{ mm}$$

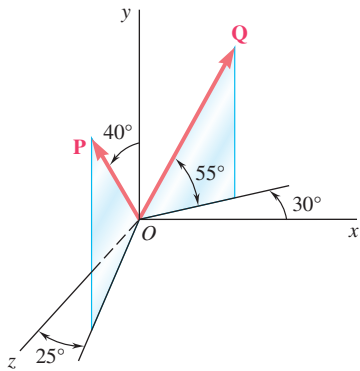
$$\mathbf{T}_{CA} = T_{CA} \lambda_{CA}$$

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

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

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

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



### PROBLEM 2.135

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

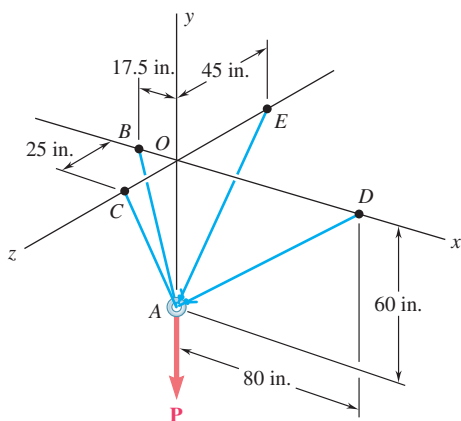
$$\begin{aligned} \mathbf{P} &= (600 \text{ N})[\sin 40^\circ \sin 25^\circ \mathbf{i} + \cos 40^\circ \mathbf{j} + \sin 40^\circ \cos 25^\circ \mathbf{k}] \\ &= (162.992 \text{ N})\mathbf{i} + (459.63 \text{ N})\mathbf{j} + (349.54 \text{ N})\mathbf{k} \\ \mathbf{Q} &= (450 \text{ N})[\cos 55^\circ \cos 30^\circ \mathbf{i} + \sin 55^\circ \mathbf{j} - \cos 55^\circ \sin 30^\circ \mathbf{k}] \\ &= (223.53 \text{ N})\mathbf{i} + (368.62 \text{ N})\mathbf{j} - (129.055 \text{ N})\mathbf{k} \\ \mathbf{R} &= \mathbf{P} + \mathbf{Q} \\ &= (386.52 \text{ N})\mathbf{i} + (828.25 \text{ N})\mathbf{j} + (220.49 \text{ N})\mathbf{k} \\ R &= \sqrt{(386.52 \text{ N})^2 + (828.25 \text{ N})^2 + (220.49 \text{ N})^2} \\ &= 940.22 \text{ N} \end{aligned}$$

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

$$\cos \theta_x = \frac{R_x}{R} = \frac{386.52 \text{ N}}{940.22 \text{ N}} \quad \theta_x = 65.7^\circ \blacktriangleleft$$

$$\cos \theta_y = \frac{R_y}{R} = \frac{828.25 \text{ N}}{940.22 \text{ N}} \quad \theta_y = 28.2^\circ \blacktriangleleft$$

$$\cos \theta_z = \frac{R_z}{R} = \frac{220.49 \text{ N}}{940.22 \text{ N}} \quad \theta_z = 76.4^\circ \blacktriangleleft$$



### PROBLEM 2.136

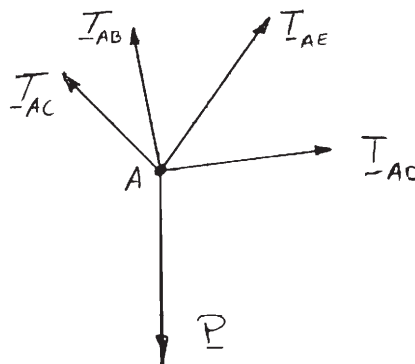
Cable  $BAC$  passes through a frictionless ring  $A$  and is attached to fixed supports at  $B$  and  $C$ , while cables  $AD$  and  $AE$  are both tied to the ring and are attached, respectively, to supports at  $D$  and  $E$ . Knowing that a 200-lb vertical load  $\mathbf{P}$  is applied to ring  $A$ , 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 2.136 (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:

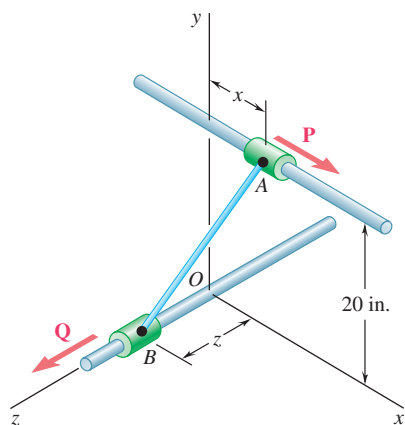
$$\text{From } \mathbf{i}: -\frac{17.5}{62.5}T_{BAC} + \frac{4}{5}T_{AD} = 0 \quad (1)$$

$$\text{From } \mathbf{j}: \left( \frac{60}{62.5} + \frac{60}{65} \right)T_{BAC} + \frac{3}{5}T_{AD} + \frac{4}{5}T_{AE} - 200 \text{ lb} = 0 \quad (2)$$

$$\text{From } \mathbf{k}: \frac{25}{65}T_{BAC} - \frac{3}{5}T_{AE} = 0 \quad (3)$$

Solving the system of linear equations using conventional algorithms gives:

$$T_{BAC} = 76.7 \text{ lb}; T_{AD} = 26.9 \text{ lb}; T_{AE} = 49.2 \text{ lb} \blacktriangleleft$$

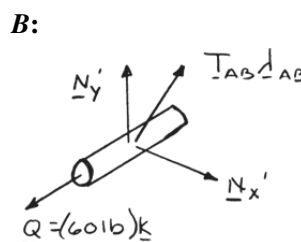
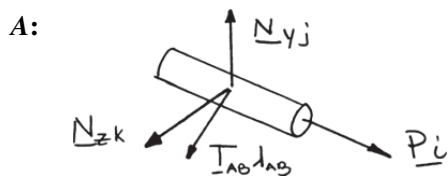


### PROBLEM 2.137

Collars A and B are connected by a 25-in.-long wire and can slide freely on frictionless rods. If a 60-lb force  $\mathbf{Q}$  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  $\mathbf{P}$  required to maintain the equilibrium of the system.

### SOLUTION

#### Free-Body Diagrams of Collars:



$$\lambda_{AB} = \frac{\overrightarrow{AB}}{AB} = \frac{-x\mathbf{i} - (20 \text{ in.})\mathbf{j} + z\mathbf{k}}{25 \text{ in.}}$$

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  $\mathbf{i}$  equal to zero:

$$P - \frac{T_{AB}x}{25 \text{ in.}} = 0 \quad (1)$$

Collar B:  $\Sigma \mathbf{F} = 0: (60 \text{ lb})\mathbf{k} + N'_x\mathbf{i} + N'_y\mathbf{j} - T_{AB}\lambda_{AB} = 0$

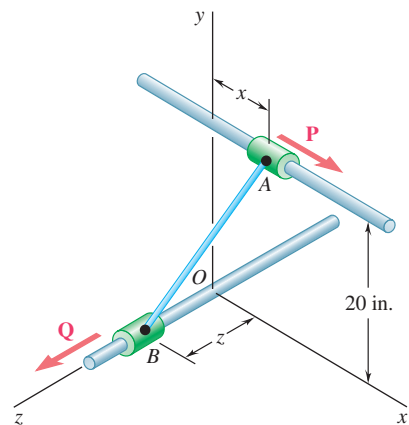
Substitute for  $\lambda_{AB}$  and set coefficient of  $\mathbf{k}$  equal to zero:

$$60 \text{ lb} - \frac{T_{AB}z}{25 \text{ in.}} = 0 \quad (2)$$

(a)  $x = 9 \text{ in.}$   $(9 \text{ in.})^2 + (20 \text{ in.})^2 + z^2 = (25 \text{ in.})^2$   
 $z = 12 \text{ in.}$

From Eq. (2):  $\frac{60 \text{ lb} - T_{AB}(12 \text{ in.})}{25 \text{ in.}} = 0$   $T_{AB} = 125.0 \text{ lb} \blacktriangleleft$

(b) From Eq. (1):  $P = \frac{(125.0 \text{ lb})(9 \text{ in.})}{25 \text{ in.}}$   $P = 45.0 \text{ lb} \blacktriangleleft$



### 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  $T_{AB}x = (25 \text{ in.})(20 \text{ lb}) \quad (1')$

From Eq. (2):  $T_{AB}z = (25 \text{ in.})(60 \text{ lb}) \quad (2')$

Dividing Eq. (1') by (2'),  $\frac{x}{z} = 2 \quad (3)$

Now write  $x^2 + z^2 + (20 \text{ in.})^2 = (25 \text{ in.})^2 \quad (4)$

Solving (3) and (4) simultaneously,

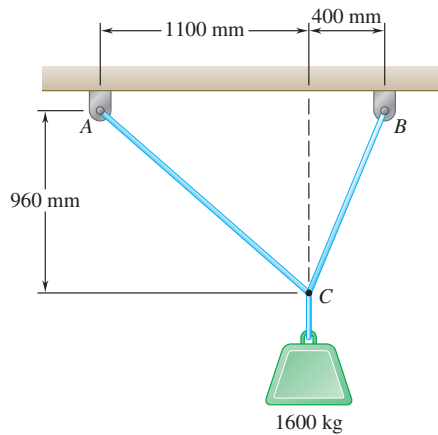
$$4z^2 + z^2 + 400 = 625$$

$$z^2 = 45$$

$$z = 6.7082 \text{ in.}$$

From Eq. (3):  $x = 2z = 2(6.7082 \text{ in.}) = 13.4164 \text{ in.}$

$$x = 13.42 \text{ in.}, \quad z = 6.71 \text{ in.} \quad \blacktriangleleft$$

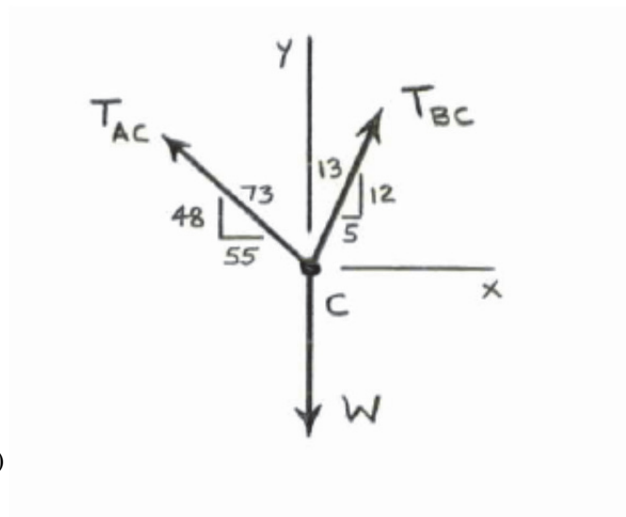


### PROBLEM 2F1

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

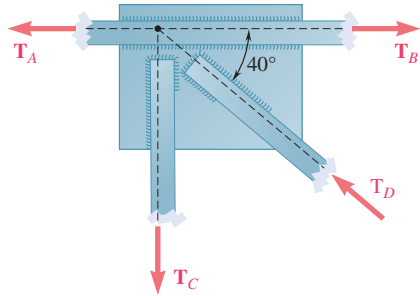
Free-Body Diagram of Point  $C$ :



$$W = (1600 \text{ kg})(9.81 \text{ m/s}^2)$$

$$W = 15.696(10^3) \text{ N}$$

$$W = 15.696 \text{ kN}$$

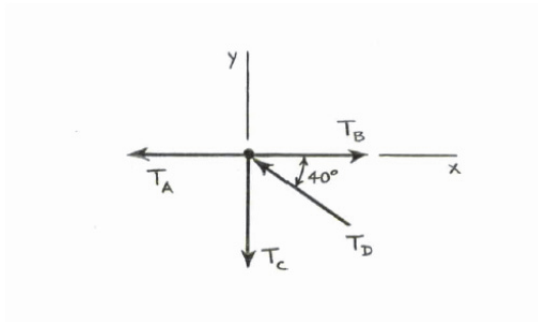


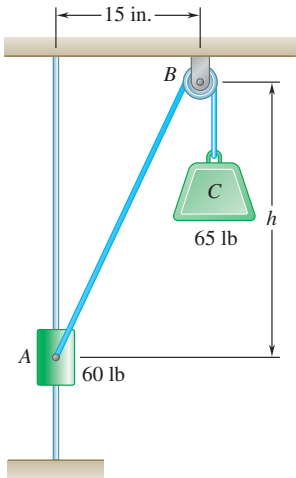
### PROBLEM 2.F2

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, draw the free-body diagram needed to determine the magnitudes of the forces  $T_C$  and  $T_D$ .

### SOLUTION

**Free-Body Diagram of Point E:**



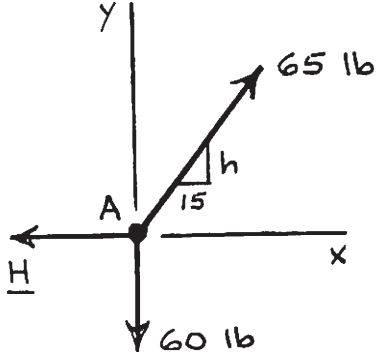


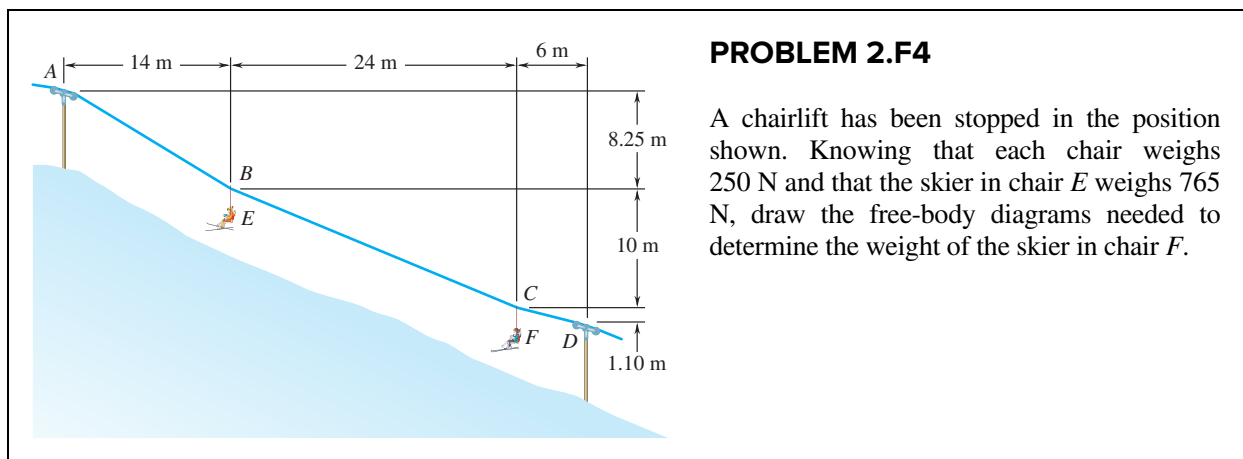
**PROBLEM 2.F3**

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:**



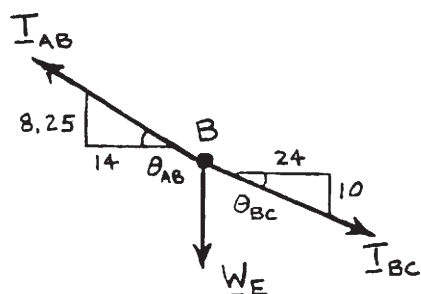


# **PROBLEM 2.F4**

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*:**



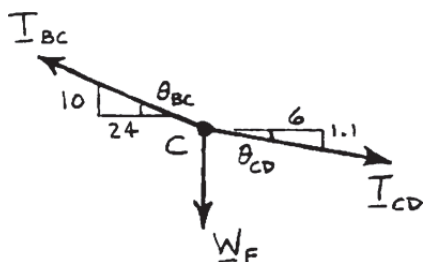
$$W_E = 250 \text{ N} + 765 \text{ N} = 1015 \text{ N}$$

$$\theta_{AB} = \tan^{-1} \frac{8.25}{14} = 30.510^\circ$$

$$\theta_{BC} = \tan^{-1} \frac{10}{24} = 22.620^\circ$$

Use this free body to determine  $T_{AB}$  and  $T_{BC}$ .

### **Free-Body Diagram of Point *C*:**



$$\theta_{CD} = \tan^{-1} \frac{1.1}{6} = 10.3889^\circ$$

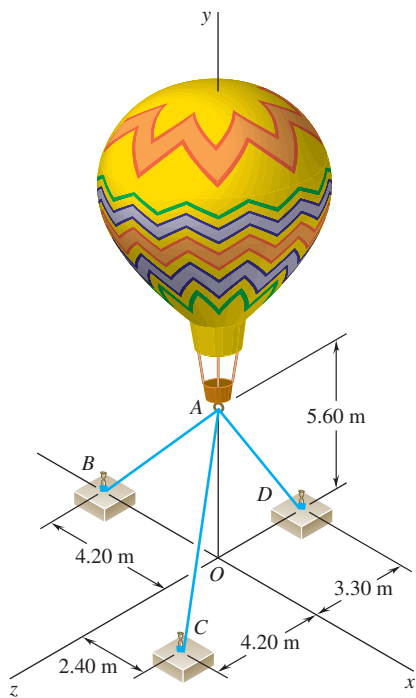
Use this free body to determine  $T_{CD}$  and  $W_F$ .

Then weight of skier  $W_S$  is found by

$$W_S = W_F - 250 \text{ N} \blacktriangleleft$$

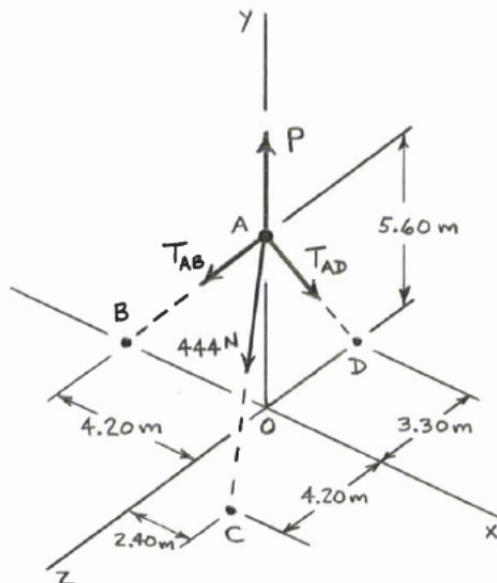
### PROBLEM 2.F5

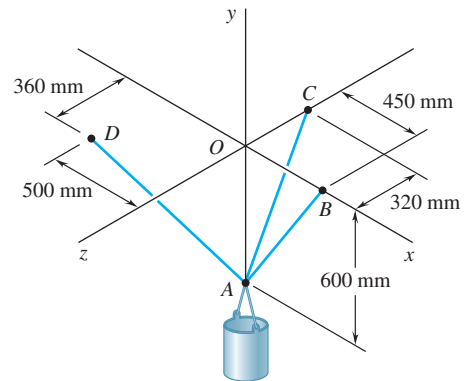
Three cables are used to tether a balloon as shown. Knowing that the tension in cable  $AC$  is  $444\text{ N}$ , draw the free-body diagram needed to determine the vertical force  $\mathbf{P}$  exerted by the balloon at  $A$ .



### SOLUTION

Free-Body Diagram of Point  $A$ :



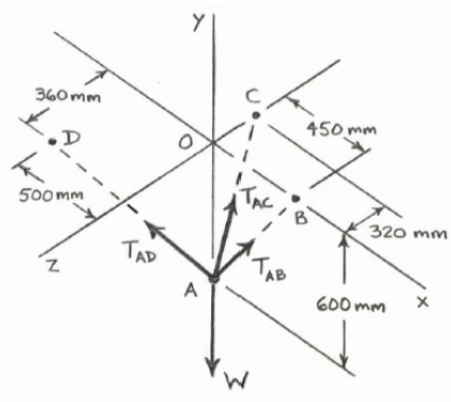


**PROBLEM 2.F6**

A container of mass  $m = 120 \text{ kg}$  is supported by three cables as shown. Draw the free-body diagram needed to determine the tension in each cable.

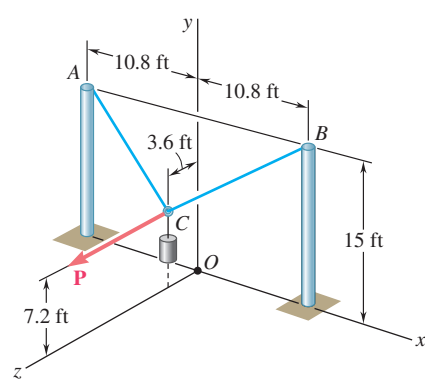
**SOLUTION**

**Free-Body Diagram of Point A:**



$$W = (120 \text{ kg})(9.81 \text{ m/s}^2)$$

$$= 1177.2 \text{ N}$$

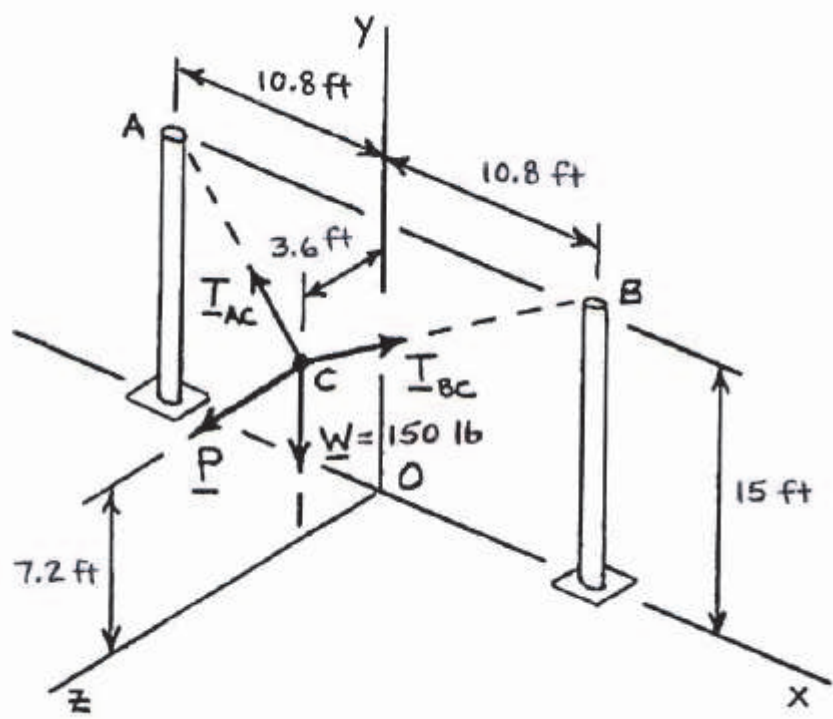


### PROBLEM 2.F7

A 150-lb cylinder is supported by two cables  $AC$  and  $BC$  that are attached to the top of vertical posts. A horizontal force  $\mathbf{P}$ , which is 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.

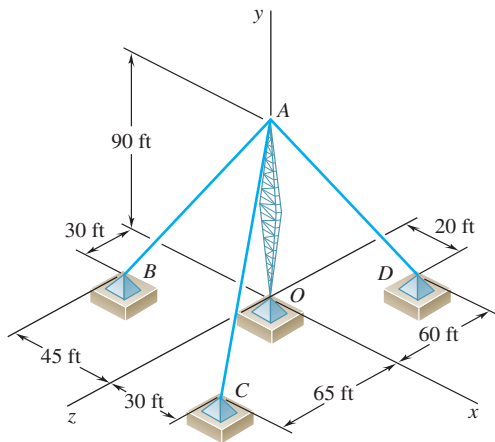
### SOLUTION

#### Free-Body Diagram of Point C:



### PROBLEM 2.F8

A transmission tower is held by three guy wires attached to a pin at  $A$  and anchored by bolts at  $B$ ,  $C$ , and  $D$ . Knowing that the tension in wire  $AB$  is 630 lb, draw the free-body diagram needed to determine the vertical force  $P$  exerted by the tower on the pin at  $A$ .



### SOLUTION

Free-Body Diagram of point  $A$ :

