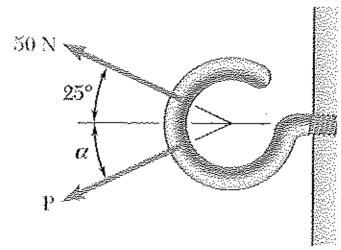
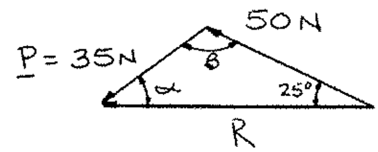


PROBLEM 2.7

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

SOLUTION

Using the triangle rule and law of sines:



(*a*)

$$\frac{\sin\alpha}{50\text{ N}} = \frac{\sin 25^\circ}{35\text{ N}}$$

$$\sin\alpha = 0.60374$$

$$\alpha = 37.138^\circ$$

$\alpha = 37.1^\circ$ ◀

(*b*)

$$\alpha + \beta + 25^\circ = 180^\circ$$

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

$$= 117.86^\circ$$

$$\frac{R}{\sin 117.86} = \frac{35\text{ N}}{\sin 25^\circ}$$

$R = 73.2$ N ◀

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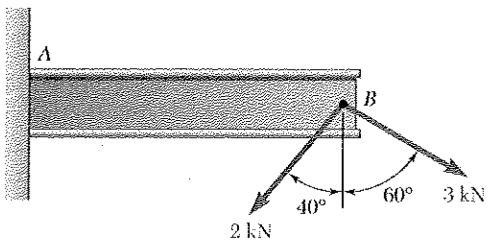


PROBLEM 2.17

Solve Problem 2.4 by trigonometry.

PROBLEM 2.4 Two forces are applied at Point *B* of beam *AB*. Determine graphically the magnitude and direction of their resultant using (*a*) the parallelogram law, (*b*) the triangle rule.

SOLUTION

Using the law of cosines:

$$R^2 = (2\text{ kN})^2 + (3\text{ kN})^2 - 2(2\text{ kN})(3\text{ kN})\cos 80°$$

$$R = 3.304\text{ kN}$$

Using the law of sines:

$$\frac{\sin\gamma}{2\text{ kN}} = \frac{\sin 80°}{3.304\text{ kN}}$$

$$\gamma = 36.59°$$

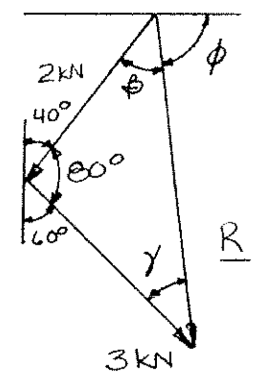
$$\beta + \gamma + 80° = 180°$$

$$\gamma = 180° - 80° - 36.59°$$

$$\gamma = 63.41°$$

$$\phi = 180° - \beta + 50°$$

$$\phi = 66.59°$$



R = 3.30 kN ⦪ 66.6° ◀

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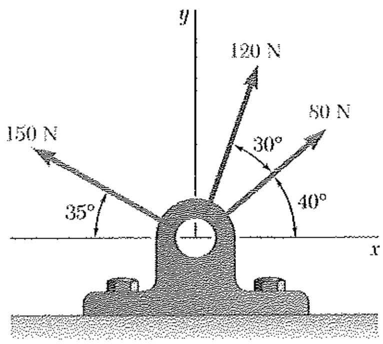


PROBLEM 2.32

Determine the resultant of the three forces of Problem 2.24.

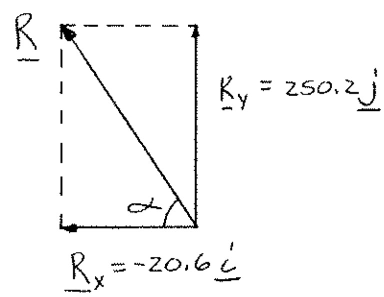
PROBLEM 2.24 Determine the x and y components of each of the forces shown.

SOLUTION

Components of the forces were determined in Problem 2.24:

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

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



$$\tan\alpha = \frac{R_y}{R_x}$$
$$\tan\alpha = \frac{250.2 \text{ N}}{20.6 \text{ N}}$$
$$\tan\alpha = 12.1456$$
$$\alpha = 85.293^\circ$$
$$R = \frac{250.2 \text{ N}}{\sin 85.293^\circ}$$

R = 251 N ⦪ 85.3° ◀

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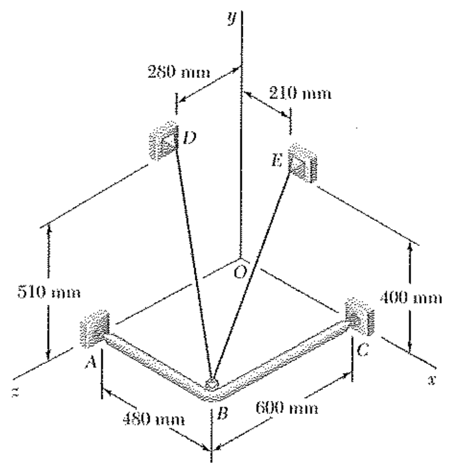

PROBLEM 2.87

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

SOLUTION

$$\overrightarrow{DB} = (480\text{ mm})\mathbf{i} - (510\text{ mm})\mathbf{j} + (320\text{ mm})\mathbf{k}$$

$$DB = \sqrt{(480\text{ mm})^2 + (510\text{ mm}^2) + (320\text{ mm})^2}$$

$$= 770\text{ mm}$$

$$\mathbf{F} = F\boldsymbol{\lambda}_{DB}$$

$$= F\frac{\overrightarrow{DB}}{DB}$$

$$= \frac{385\text{ N}}{770\text{ mm}}[(480\text{ mm})\mathbf{i} - (510\text{ mm})\mathbf{j} + (320\text{ mm})\mathbf{k}]$$

$$= (240\text{ N})\mathbf{i} - (255\text{ N})\mathbf{j} + (160\text{ N})\mathbf{k}$$

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

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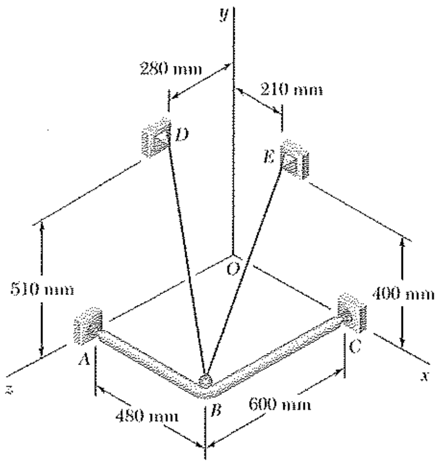

PROBLEM 2.88

For the frame and cable of Problem 2.87, determine the components of the force exerted by the cable on the support at E.

PROBLEM 2.87 A frame ABC is supported in part by cable DBE that passes through a frictionless ring at B. Knowing that the tension in the cable is 385 N, determine the components of the force exerted by the cable on the support at D.

SOLUTION

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

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

$$= 770 \text{ mm}$$

$$\mathbf{F} = F\boldsymbol{\lambda}_{EB}$$

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

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

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

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

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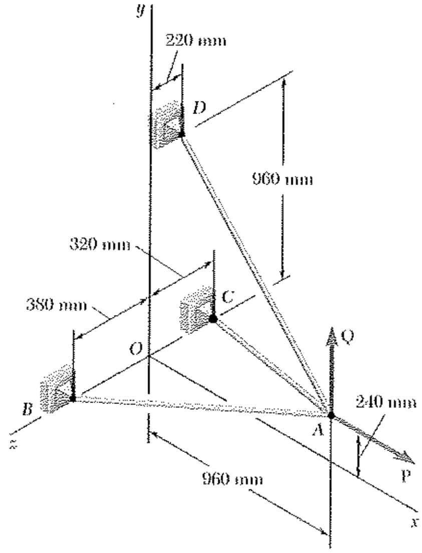

PROBLEM 2.107

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

$$\Sigma \mathbf{F}_A = 0: \quad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{T}_{AD} + \mathbf{P} = 0 \quad \text{where} \quad \mathbf{P} = P\mathbf{i}$$

$$\overrightarrow{AB} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} + (380 \text{ mm})\mathbf{k} \qquad AB = 1060 \text{ mm}$$

$$\overrightarrow{AC} = -(960 \text{ mm})\mathbf{i} - (240 \text{ mm})\mathbf{j} - (320 \text{ mm})\mathbf{k} \qquad AC = 1040 \text{ mm}$$

$$\overrightarrow{AD} = -(960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k} \qquad AD = 1220 \text{ mm}$$

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = T_{AB}\left(-\frac{48}{53}\mathbf{i} - \frac{12}{53}\mathbf{j} + \frac{19}{53}\mathbf{k}\right)$$

$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = T_{AC}\left(-\frac{12}{13}\mathbf{i} - \frac{3}{13}\mathbf{j} - \frac{4}{13}\mathbf{k}\right)$$

$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = \frac{305 \text{ N}}{1220 \text{ mm}}[(-960 \text{ mm})\mathbf{i} + (720 \text{ mm})\mathbf{j} - (220 \text{ mm})\mathbf{k}]$$

$$= -(240 \text{ N})\mathbf{i} + (180 \text{ N})\mathbf{j} - (55 \text{ N})\mathbf{k}$$

Substituting into $\Sigma \mathbf{F}_A = 0$, factoring **i**, **j**, **k**, and setting each coefficient equal to ϕ gives:

$$\mathbf{i}: \quad P = \frac{48}{53}T_{AB} + \frac{12}{13}T_{AC} + 240 \text{ N} \qquad (1)$$

$$\mathbf{j}: \quad \frac{12}{53}T_{AB} + \frac{3}{13}T_{AC} = 180 \text{ N} \qquad (2)$$

$$\mathbf{k}: \quad \frac{19}{53}T_{AB} - \frac{4}{13}T_{AC} = 55 \text{ N} \qquad (3)$$

Solving the system of linear equations using conventional algorithms gives:

$$T_{AB} = 446.71 \text{ N}$$
$$T_{AC} = 341.71 \text{ N}$$

$P = 960$ N ◀

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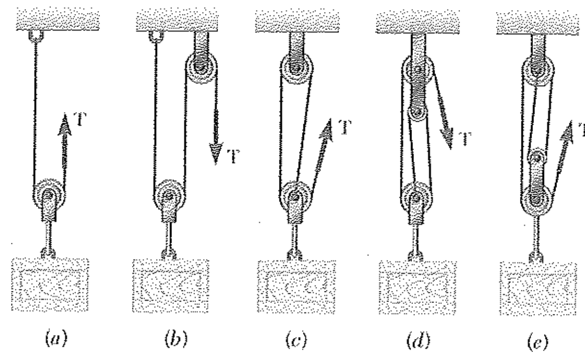
PROBLEM 2.67

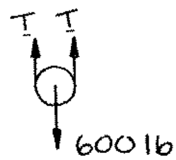


A 600-lb crate is supported by several rope-and-pulley arrangements as shown. Determine for each arrangement the tension in the rope. (See the hint for Problem 2.65.)

SOLUTION

Free-Body Diagram of Pulley

(*a*)

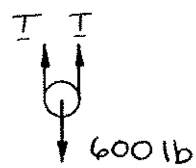


$$+\uparrow \Sigma F_y = 0: \quad 2T - (600 \text{ lb}) = 0$$

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

$T = 300$ lb ◀

(*b*)

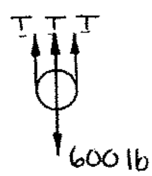


$$+\uparrow \Sigma F_y = 0: \quad 2T - (600 \text{ lb}) = 0$$

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

$T = 300$ lb ◀

(*c*)

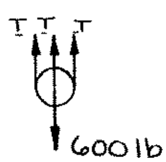


$$+\uparrow \Sigma F_y = 0: \quad 3T - (600 \text{ lb}) = 0$$

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

$T = 200$ lb ◀

(*d*)

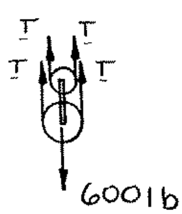


$$+\uparrow \Sigma F_y = 0: \quad 3T - (600 \text{ lb}) = 0$$

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

$T = 200$ lb ◀

(*e*)



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

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

$T = 150.0$ lb ◀

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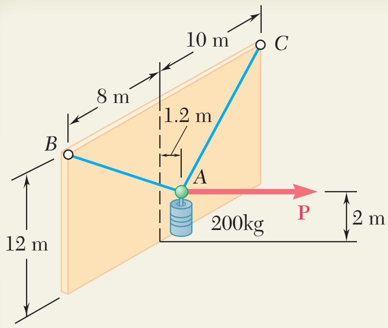
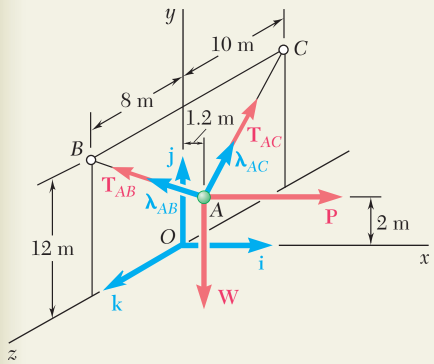
SAMPLE PROBLEM 2.9



A 200-kg cylinder is hung by means of two cables AB and AC, which are attached to the top of a vertical wall. A horizontal force $\mathbf{P}$ perpendicular to the wall holds the cylinder in the position shown. Determine the magnitude of $\mathbf{P}$ and the tension in each cable.

SOLUTION



Free-body Diagram. Point A is chosen as a free body; this point is subjected to four forces, three of which are of unknown magnitude.

Introducing the unit vectors $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$, we resolve each force into rectangular components.

$$\mathbf{P} = P\mathbf{i}$$
$$\mathbf{W} = -mg\mathbf{j} = -(200\text{ kg})(9.81\text{ m/s}^2)\mathbf{j} = -(1962\text{ N})\mathbf{j} \qquad (1)$$

In the case of $\mathbf{T}_{AB}$ and $\mathbf{T}_{AC}$, it is necessary first to determine the components and magnitudes of the vectors $\overrightarrow{AB}$ and $\overrightarrow{AC}$. Denoting by $\boldsymbol{\lambda}_{AB}$ the unit vector along AB, we write

$$\overrightarrow{AB} = -(1.2\text{ m})\mathbf{i} + (10\text{ m})\mathbf{j} + (8\text{ m})\mathbf{k} \qquad AB = 12.862\text{ m}$$
$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{12.862\text{ m}} = -0.09330\mathbf{i} + 0.7775\mathbf{j} + 0.6220\mathbf{k}$$
$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = -0.09330T_{AB}\mathbf{i} + 0.7775T_{AB}\mathbf{j} + 0.6220T_{AB}\mathbf{k} \qquad (2)$$

Denoting by $\boldsymbol{\lambda}_{AC}$ the unit vector along AC, we write in a similar way

$$\overrightarrow{AC} = -(1.2\text{ m})\mathbf{i} + (10\text{ m})\mathbf{j} - (10\text{ m})\mathbf{k} \qquad AC = 14.193\text{ m}$$
$$\boldsymbol{\lambda}_{AC} = \frac{\overrightarrow{AC}}{14.193\text{ m}} = -0.08455\mathbf{i} + 0.7046\mathbf{j} - 0.7046\mathbf{k}$$
$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = -0.08455T_{AC}\mathbf{i} + 0.7046T_{AC}\mathbf{j} - 0.7046T_{AC}\mathbf{k} \qquad (3)$$

Equilibrium Condition. Since A is in equilibrium, we must have

$$\Sigma\mathbf{F} = 0: \qquad \mathbf{T}_{AB} + \mathbf{T}_{AC} + \mathbf{P} + \mathbf{W} = 0$$

or, substituting from (1), (2), (3) for the forces and factoring $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$,

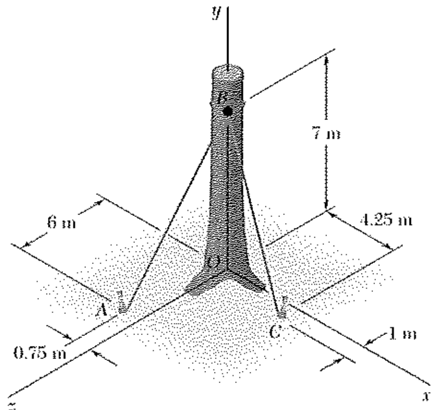
$$(-0.09330T_{AB} - 0.08455T_{AC} + P)\mathbf{i} + (0.7775T_{AB} + 0.7046T_{AC} - 1962\text{ N})\mathbf{j} + (0.6220T_{AB} - 0.7046T_{AC})\mathbf{k} = 0$$

Setting the coefficients of $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$ equal to zero, we write three scalar equations, which express that the sums of the x, y, and z components of the forces are respectively equal to zero.

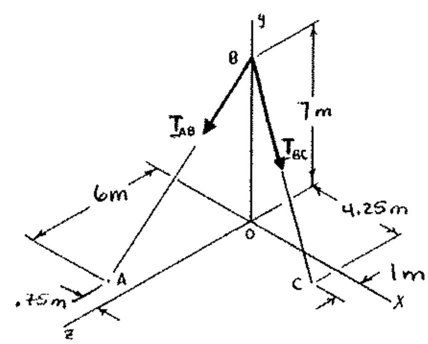
$$(\Sigma F_x = 0:) \qquad -0.09330T_{AB} - 0.08455T_{AC} + P = 0$$
$$(\Sigma F_y = 0:) \qquad +0.7775T_{AB} + 0.7046T_{AC} - 1962\text{ N} = 0$$
$$(\Sigma F_z = 0:) \qquad +0.6220T_{AB} - 0.7046T_{AC} = 0$$

Solving these equations, we obtain

$$P = 235\text{ N} \qquad T_{AB} = 1402\text{ N} \qquad T_{AC} = 1238\text{ N}$$

	**PROBLEM 3.22** Before the trunk of a large tree is felled, cables AB and BC are attached as shown. Knowing that the tensions in cables AB and BC are 555 N and 660 N, respectively, determine the moment about O of the resultant force exerted on the tree by the cables at B.

SOLUTION



We have $\quad \mathbf{M}_O = \mathbf{r}_{B/O} \times \mathbf{F}_B$

where $\quad \mathbf{r}_{B/O} = (7\text{ m})\mathbf{j}$

$$\mathbf{F}_B = \mathbf{T}_{AB} + \mathbf{T}_{BC}$$

$$\mathbf{T}_{AB} = \boldsymbol{\lambda}_{BA} T_{AB}$$

$$= \frac{-(0.75\text{ m})\mathbf{i} - (7\text{ m})\mathbf{j} + (6\text{ m})\mathbf{k}}{\sqrt{(.75)^2 + (7)^2 + (6)^2}\text{ m}}(555\text{ N})$$

$$\mathbf{T}_{BC} = \boldsymbol{\lambda}_{BC} T_{BC}$$

$$= \frac{(4.25\text{ m})\mathbf{i} - (7\text{ m})\mathbf{j} + (1\text{ m})\mathbf{k}}{\sqrt{(4.25)^2 + (7)^2 + (1)^2}\text{ m}}(660\text{ N})$$

$$\mathbf{F}_B = [-(45.00\text{ N})\mathbf{i} - (420.0\text{ N})\mathbf{j} + (360.0\text{ N})\mathbf{k}]$$
$$+[(340.0\text{ N})\mathbf{i} - (560.0\text{ N})\mathbf{j} + (80.00\text{ N})\mathbf{k}]$$
$$= (295.0\text{ N})\mathbf{i} - (980.0\text{ N})\mathbf{j} + (440.0\text{ N})\mathbf{k}$$

and
$$\mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 7 & 0 \\ 295 & 980 & 440 \end{vmatrix} \text{N}\cdot\text{m}$$

$$= (3080\text{ N}\cdot\text{m})\mathbf{i} - (2070\text{ N}\cdot\text{m})\mathbf{k}$$

or $\mathbf{M}_O = (3080\text{ N}\cdot\text{m})\mathbf{i} - (2070\text{ N}\cdot\text{m})\mathbf{k}$ ◄

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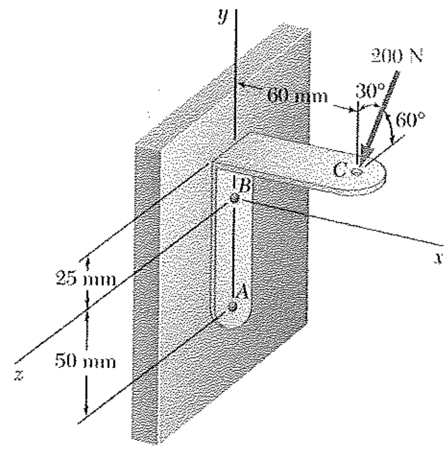

PROBLEM 3.21

A 200-N force is applied as shown to the bracket *ABC*. Determine the moment of the force about *A*.

SOLUTION

We have $\mathbf{M}_A = \mathbf{r}_{C/A} \times \mathbf{F}_C$

where $\mathbf{r}_{C/A} = (0.06 \text{ m})\mathbf{i} + (0.075 \text{ m})\mathbf{j}$

$\mathbf{F}_C = -(200 \text{ N})\cos 30°\mathbf{j} + (200 \text{ N})\sin 30°\mathbf{k}$

Then

$$\mathbf{M}_A = 200\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.06 & 0.075 & 0 \\ 0 & -\cos 30° & \sin 30° \end{vmatrix}$$

$$= 200[(0.075\sin 30°)\mathbf{i} - (0.06\sin 30°)\mathbf{j} - (0.06\cos 30°)\mathbf{k}]$$

or $\mathbf{M}_A = (7.50 \text{ N}\cdot\text{m})\mathbf{i} - (6.00 \text{ N}\cdot\text{m})\mathbf{j} - (10.39 \text{ N}\cdot\text{m})\mathbf{k}$ ◀

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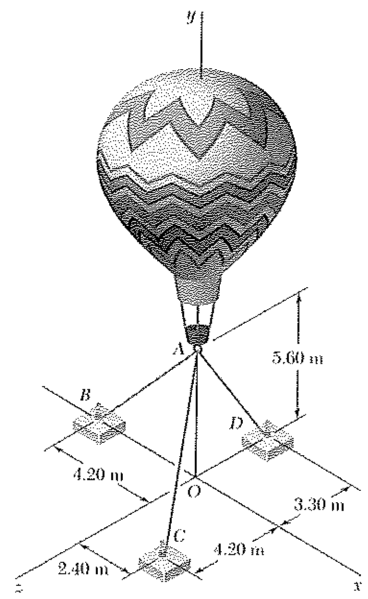
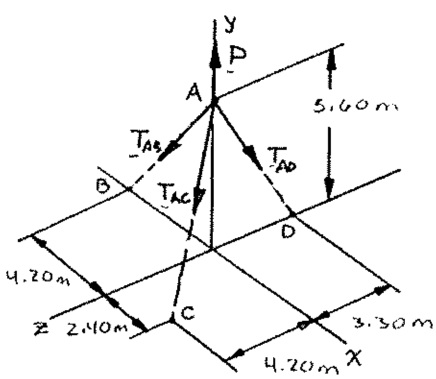
PROBLEM 2.99



Three cables are used to tether a balloon as shown. Determine the vertical force **P** exerted by the balloon at A knowing that the tension in cable AB is 259 N.

SOLUTION



The forces applied at A are: $\mathbf{T}_{AB}, \mathbf{T}_{AC}, \mathbf{T}_{AD}$, and $\mathbf{P}$

where $\mathbf{P} = P\mathbf{j}$. To express the other forces in terms of the unit vectors $\mathbf{i}, \mathbf{j}, \mathbf{k}$, we write

$$\overrightarrow{AB} = -(4.20 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} \qquad AB = 7.00 \text{ m}$$
$$\overrightarrow{AC} = (2.40 \text{ m})\mathbf{i} - (5.60 \text{ m})\mathbf{j} + (4.20 \text{ m})\mathbf{k} \qquad AC = 7.40 \text{ m}$$
$$\overrightarrow{AD} = -(5.60 \text{ m})\mathbf{j} - (3.30 \text{ m})\mathbf{k} \qquad AD = 6.50 \text{ m}$$

and

$$\mathbf{T}_{AB} = T_{AB}\boldsymbol{\lambda}_{AB} = T_{AB}\frac{\overrightarrow{AB}}{AB} = (-0.6\mathbf{i} - 0.8\mathbf{j})T_{AB}$$
$$\mathbf{T}_{AC} = T_{AC}\boldsymbol{\lambda}_{AC} = T_{AC}\frac{\overrightarrow{AC}}{AC} = (0.32432 - 0.75676\mathbf{j} + 0.56757\mathbf{k})T_{AC}$$
$$\mathbf{T}_{AD} = T_{AD}\boldsymbol{\lambda}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = (-0.86154\mathbf{j} - 0.50769\mathbf{k})T_{AD}$$

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PROBLEM 2.99 (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 **i**, **j**, and **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 **i**, **j**, **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 $T_{AB} = 259$ N in (1) and (2), and solving the resulting set of equations gives

$$T_{AC} = 479.15 \text{ N}$$
$$T_{AD} = 535.66 \text{ N}$$

$\mathbf{P} = 1031 \text{ N}\uparrow$ ◀

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