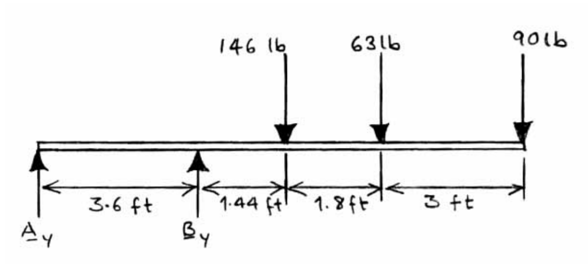
Chapter 4, Solution 1.

Free-Body Diagram:



(a) $+\circlearrowleft \Sigma M_B = 0$: $\quad -A_y(3.6\text{ ft}) - (146\text{ lb})(1.44\text{ ft}) - (63\text{ lb})(3.24\text{ ft}) - (90\text{ lb})(6.24\text{ ft}) = 0$

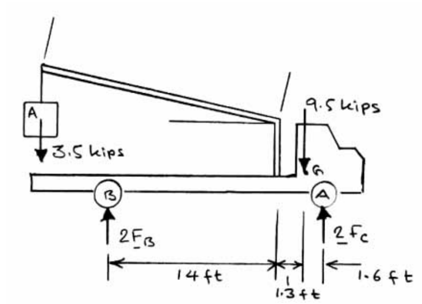
$A_y = -271.10\text{ lb}$ or $\mathbf{A}_y = 271\text{ lb}\downarrow$ ◀

(b) $+\circlearrowleft \Sigma M_A = 0$: $\quad B_y(3.6\text{ ft}) - (146\text{ lb})(5.04\text{ ft}) - (63\text{ lb})(6.84\text{ ft}) - (90\text{ lb})(9.84\text{ ft}) = 0$

$B_y = 570.10\text{ lb}$ or $\mathbf{B}_y = 570\text{ lb}\uparrow$ ◀

Chapter 4, Solution 2.

Free-Body Diagram:



(*a*)

$$+\circlearrowleft \Sigma M_C = 0: \quad (3.5 \text{ kips})\left[\left(1.6 + 1.3 + 19.5\cos 15^\circ\right)\text{ft}\right] - 2F_B\left[(1.6 + 1.3 + 14)\text{ft}\right] + (9.5 \text{ kips})(1.6 \text{ ft}) = 0$$

$$2F_B = 5.4009 \text{ kips}$$

or $\mathbf{F}_B = 2.70 \text{ kips} \uparrow$ ◀

(*b*)

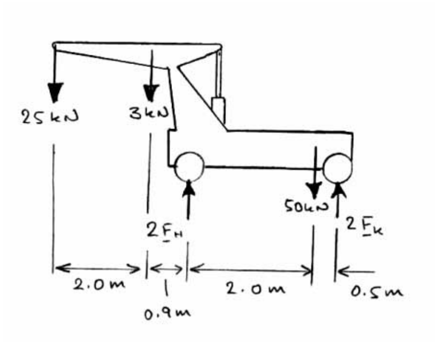
$$+\circlearrowleft \Sigma M_B = 0: \quad (3.5 \text{ kips})\left[\left(19.5\cos 15^\circ - 14\right)\text{ft}\right] - (9.5 \text{ kips})\left[(14 + 1.3)\text{ft}\right] + 2F_C\left[(14 + 1.3 + 1.6)\text{ft}\right] = 0$$

$$2F_C = 7.5991 \text{ kips, or}$$

or $\mathbf{F}_C = 3.80 \text{ kips} \uparrow$ ◀

Chapter 4, Solution 3.

Free-Body Diagram:



(a) $+\circlearrowleft\ \Sigma M_K = 0$: $(25\text{ kN})(5.4\text{ m}) + (3\text{ kN})(3.4\text{ m}) - 2F_H(2.5\text{ m}) + (50\text{ kN})(0.5\text{ m}) = 0$

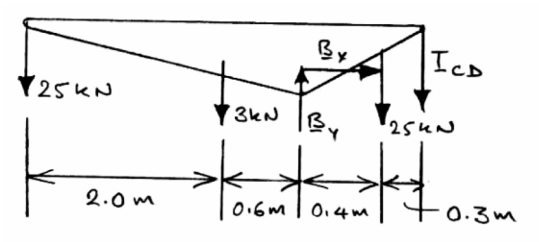
$2F_H = 68.080\text{ kN}$ or $\mathbf{F}_H = 34.0\text{ kN}\uparrow$ ◀

(b) $+\circlearrowleft\ \Sigma M_H = 0$: $(25\text{ kN})(2.9\text{ m}) + (3\text{ kN})(0.9\text{ m}) - (50\text{ kN})(2.0\text{ m}) + 2F_K(2.5\text{ m}) = 0$

$2F_K = 9.9200\text{ kN}$ or $\mathbf{F}_K = 4.96\text{ kN}\uparrow$ ◀

Chapter 4, Solution 4.

Free-Body Diagram: (boom)



(a) $+\circlearrowleft \Sigma M_B = 0$: $(25 \text{ kN})(2.6 \text{ m}) + (3 \text{ kN})(0.6 \text{ m}) - (25 \text{ kN})(0.4 \text{ m}) - T_{CD}(0.7 \text{ m}) = 0$

$T_{CD} = 81.143 \text{ kN}$ or $T_{CD} = 81.1 \text{ kN}$ ◀

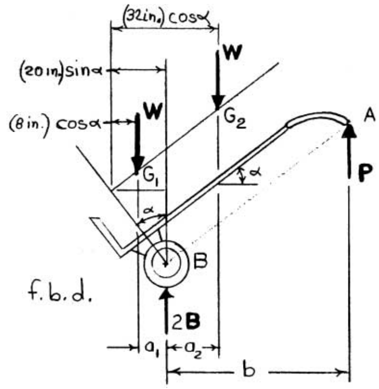
(b) $\xrightarrow{+} \Sigma F_x = 0$: $B_x = 0$ so that $B = B_y$

$+\uparrow \Sigma F_y = 0$: $(-25 - 3 - 25 - 81.143)\text{kN} + B = 0$

$B = 134.143 \text{ kN}$ or $\mathbf{B} = 134.1 \text{ kN} \uparrow$ ◀

Chapter 4, Solution 5.

Free-Body Diagram:



$$a_1 = (20\text{ in.})\sin\alpha - (8\text{ in.})\cos\alpha$$

$$a_2 = (32\text{ in.})\cos\alpha - (20\text{ in.})\sin\alpha$$

$$b = (64\text{ in.})\cos\alpha$$

From free-body diagram of hand truck

$$+\circlearrowleft \Sigma M_B = 0: \quad P(b) - W(a_2) + W(a_1) = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0: \quad P - 2w + 2B = 0 \qquad (2)$$

For $\alpha = 35°$

$$a_1 = 20\sin 35° - 8\cos 35° = 4.9183\text{ in.}$$

$$a_2 = 32\cos 35° - 20\sin 35° = 14.7413\text{ in.}$$

$$b = 64\cos 35° = 52.426\text{ in.}$$

(*a*) From Equation (1)

$$P(52.426\text{ in.}) - 80\text{ lb}(14.7413\text{ in.}) + 80\text{ lb}(4.9183\text{ in.}) = 0$$

$\therefore P = 14.9896$ lb or $\mathbf{P} = 14.99$ lb $\uparrow$ ◀

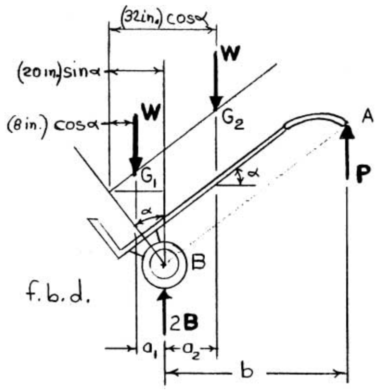
(*b*) From Equation (2)

$$14.9896\text{ lb} - 2(80\text{ lb}) + 2B = 0$$

$\therefore B = 72.505$ lb or $\mathbf{B} = 72.5$ lb $\uparrow$ ◀

Chapter 4, Solution 6.

Free-Body Diagram:



$$a_1 = (20\text{ in.})\sin\alpha - (8\text{ in.})\cos\alpha$$

$$a_2 = (32\text{ in.})\cos\alpha - (20\text{ in.})\sin\alpha$$

$$b = (64\text{ in.})\cos\alpha$$

From free-body diagram of hand truck

$$+\circlearrowleft \Sigma M_B = 0: \quad P(b) - W(a_2) + W(a_1) = 0 \quad (1)$$

$$+\uparrow \Sigma F_y = 0: \quad P - 2w + 2B = 0 \qquad (2)$$

For $\alpha = 40°$

$$a_1 = 20\sin 40° - 8\cos 40° = 6.7274\text{ in.}$$

$$a_2 = 32\cos 40° - 20\sin 40° = 11.6577\text{ in.}$$

$$b = 64\cos 40° = 49.027\text{ in.}$$

(*a*) From Equation (1)

$$P(49.027\text{ in.}) - 80\text{ lb}(11.6577\text{ in.}) + 80\text{ lb}(6.7274\text{ in.}) = 0$$

$$P = 8.0450\text{ lb}$$

or $\mathbf{P} = 8.05\text{ lb}\uparrow$ ◀

(*b*) From Equation (2)

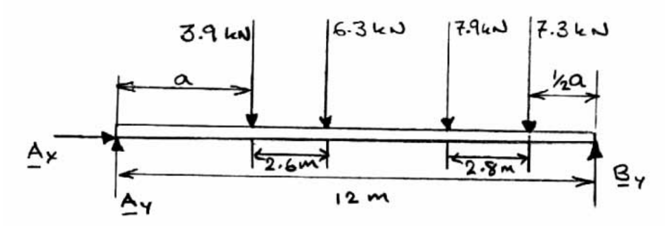
$$8.0450\text{ lb} - 2(80\text{ lb}) + 2B = 0$$

$$B = 75.9775\text{ lb}$$

or $\mathbf{B} = 76.0\text{ lb}\uparrow$ ◀

Chapter 4, Solution 7.

Free-Body Diagram:



(*a*) $a = 2.9$ m

$\xrightarrow{+} \Sigma F_x = 0$: $A_x = 0$

$+\circlearrowleft \Sigma M_B = 0$: $-(12\text{ m})A_y + \left[(12 - 2.9)\text{m}\right](3.9\text{ kN}) + \left[(12 - 2.9 - 2.6)\text{m}\right](6.3\text{ kN})$

$+\left[(2.8 + 1.45)\text{m}\right](7.9\text{ kN}) + (1.45\text{ m})(7.3\text{ kN}) = 0$

or $A_y = 10.0500$ kN — or $\mathbf{A} = 10.05$ kN ↑ ◀

$+\uparrow \Sigma F_y = 0$: $10.0500\text{ kN} - 3.9\text{ kN} - 6.3\text{ kN} - 7.9\text{ kN} - 7.3\text{ kN} + B_y = 0$

or $B_y = 15.3500$ kN — or $\mathbf{B} = 15.35$ kN ↑ ◀

(*b*) $a = 8.1$ m

$+\circlearrowleft \Sigma M_B = 0$: $-(12\text{ m})A_y + \left[(12 - 8.1)\text{m}\right](3.9\text{ kN}) + \left[(12 - 8.1 - 2.6)\text{m}\right](6.3\text{ kN})$

$+\left[(2.8 + 4.05)\text{m}\right](7.9\text{ kN}) + (4.05\text{ m})(7.3\text{ kN}) = 0$

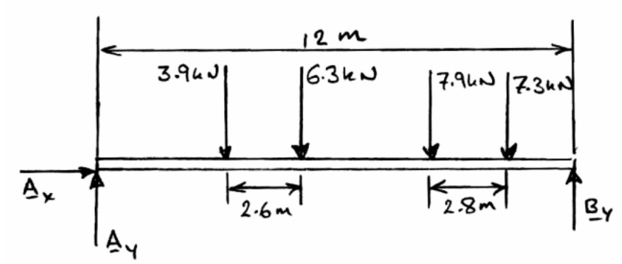
or $A_y = 8.9233$ kN — or $\mathbf{A} = 8.92$ kN ↑ ◀

$+\uparrow \Sigma F_y = 0$: $8.9233\text{ kN} - 3.9\text{ kN} - 6.3\text{ kN} - 7.9\text{ kN} - 7.3\text{ kN} + B_y = 0$

or $B_y = 16.4767$ kN — or $\mathbf{B} = 16.48$ kN ↑ ◀

Chapter 4, Solution 8.

Free-Body Diagram:



(*a*)

$\xrightarrow{+} \Sigma F_x = 0$: $\quad A_x = 0$

$+\circlearrowleft \Sigma M_B = 0$: $\quad -(12\text{ m})A_y + (12\text{ m} - a)(3.9\text{ kN}) + \left[(12 - 2.6)\text{m} - a\right](6.3\text{ kN})$

$$+\left(2.8\text{ m} + \frac{a}{2}\right)(7.9\text{ kN}) + \frac{a}{2}(7.3\text{ kN}) = 0$$

or $\quad (12\text{ m})A_y = 128.14\text{ kN}\cdot\text{m} - (10.2\text{ kN})a + (15.2\text{ kN})\frac{a}{2}$

$$(12\text{ m})A_y = 128.14\text{ kN}\cdot\text{m} - (2.6\text{ kN})a$$

Thus A_y is maximum for the smallest possible value of *a:*

$a = 0$ ◀

(*b*) The corresponding value of A_y is

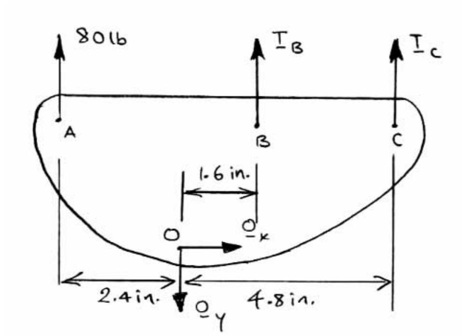
$(A_y)_{\max} = 10.6783\text{ kN}$, and $\qquad$ or $\mathbf{A} = 10.68\text{ kN} \uparrow$ ◀

$+\uparrow \Sigma F_y = 0$: $\quad 10.6783\text{ kN} - 3.9\text{ kN} - 6.3\text{ kN} - 7.9\text{ kN} - 7.3\text{ kN} + B_y = 0$

$B_y = 14.7217\text{ kN}$ $\qquad$ or $\mathbf{B} = 14.72\text{ kN} \uparrow$ ◀

Chapter 4, Solution 9.

Free-Body Diagram:



For $(T_C)_{max}, T_B = 0$

$+\circlearrowleft \Sigma M_O = 0: \quad (T_C)_{max}(4.8 \text{ in.}) - (80 \text{ lb})(2.4 \text{ in.}) = 0$

$$\left[(T_C)_{max} = 40 \text{ lb}\right] > \left[T_{max} = 36 \text{ lb}\right]$$

$$(T_C)_{max} = 36.0 \text{ lb}$$

For $(T_C)_{min}, T_B = T_{max} = 36 \text{ lb}$

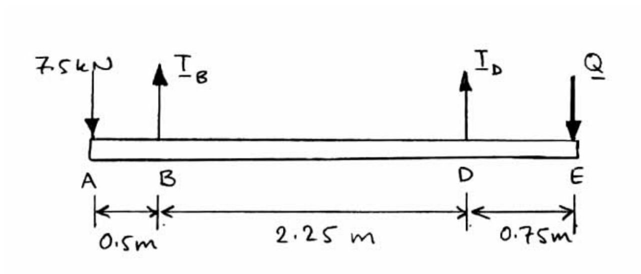
$+\circlearrowleft \Sigma M_O = 0: \quad (T_C)_{min}(4.8 \text{ in.}) + (36 \text{ lb})(1.6 \text{ in.}) - (80 \text{ lb})(2.4 \text{ in.}) = 0$

$$(T_C)_{min} = 28.0 \text{ lb}$$

Therefore: $28.0 \text{ lb} \le T_C \le 36.0 \text{ lb}$ ◀

Chapter 4, Solution 10.

Free-Body Diagram:



For $Q_{\min}$, $T_D = 0$

$+\circlearrowleft \Sigma M_B = 0$: $\quad (7.5 \text{ kN})(0.5 \text{ m}) - Q_{\min}(3 \text{ m}) = 0$

$$Q_{\min} = 1.250 \text{ kN}$$

For $Q_{\max}$, $T_B = 0$

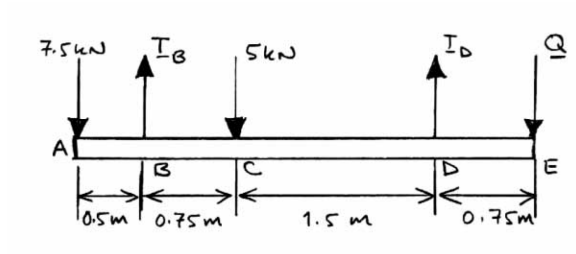
$+\circlearrowleft \Sigma M_D = 0$: $\quad (7.5 \text{ kN})(2.75 \text{ m}) - Q_{\max}(0.75 \text{ m}) = 0$

$$Q_{\max} = 27.5 \text{ kN}$$

Therefore: $1.250 \text{ kN} \le Q \le 27.5 \text{ kN}$ ◀

Chapter 4, Solution 11.

Free-Body Diagram:



$+\circlearrowleft \Sigma M_D = 0$: $(7.5 \text{ kN})(2.75 \text{ m}) - T_B(2.25 \text{ m}) + (5 \text{ kN})(1.5 \text{ m}) - Q(0.75 \text{ m}) = 0$

$$Q = (37.5 - 3T_B) \text{ kN} \qquad (1)$$

$+\circlearrowleft \Sigma M_B = 0$: $(7.5 \text{ kN})(0.5 \text{ m}) - (5 \text{ kN})(0.75 \text{ m}) + T_D(2.25 \text{ m}) - Q(3 \text{ m}) = 0$

$$Q = (0.75\, T_D) \text{ kN} \qquad (2)$$

For the loading to be safe, cables must not be slack and tension must not exceed 12 kN.

Thus, making $0 \le T_B \le 12$ kN in. (1), we have

$$1.500 \text{ kN} \le Q \le 37.5 \text{ kN} \qquad (3)$$

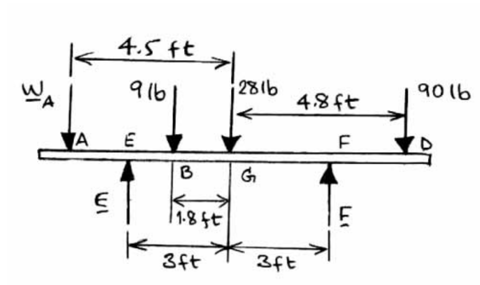
And making $0 \le T_D \le 12$ kN in. (2), we have

$$0 \le Q \le 9.00 \text{ kN} \qquad (4)$$

(3) and (4) now give: $1.500 \text{ kN} \le Q \le 9.00 \text{ kN}$ ◀

Chapter 4, Solution 12.

Free-Body Diagram:



For $(W_A)_{min}$, $E = 0$

W= 25 lb not 28 lb

$$+\circlearrowleft \Sigma M_F = 0: \quad (W_A)_{min}(7.5 \text{ ft}) + (9 \text{ lb})(4.8 \text{ ft}) + (28 \text{ lb})(3 \text{ ft}) - (90 \text{ lb})(1.8 \text{ ft}) = 0$$

$$(W_A)_{min} = 4.6400 \text{ lb}$$

For $(W_A)_{max}$, $F = 0$

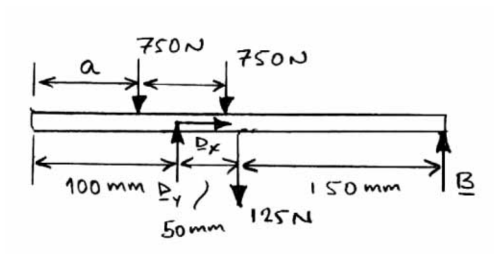
$$+\circlearrowleft \Sigma M_E = 0: \quad (W_A)_{max}(1.5 \text{ ft}) - (9 \text{ lb})(1.2 \text{ ft}) - (28 \text{ lb})(3 \text{ ft}) - (90 \text{ lb})(7.8 \text{ ft}) = 0$$

$$(W_A)_{max} = 531.20 \text{ lb}$$

Thus $\quad 4.64 \text{ lb} \le W_A \le 531 \text{ lb}$ ◀

Chapter 4, Solution 13.

Free-Body Diagram:



$+\circlearrowleft \Sigma M_D = 0$: $\quad (750 \text{ N})(0.1 \text{ m} - a) - (750 \text{ N})(a + 0.075 \text{ m} - 0.1 \text{ m}) - (125 \text{ N})(0.05 \text{ m}) + B(0.2 \text{ m}) = 0$

$$a = \left(\frac{87.5 \text{ N} + 0.2B}{1500 \text{ N}}\right) \qquad (1)$$

Using the bounds on *B:*

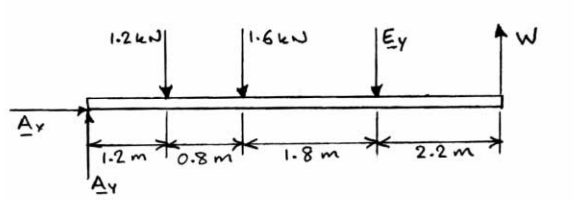
$B = -250$ N (i.e. 250 N downward) in (1) gives $a_{\text{min}} = 0.0250$ m

$B = 500$ N (i.e. 500 N upward) in (1) gives $a_{\text{max}} = 0.1250$ m

Therefore: $25.0 \text{ mm} \le a \le 125.0 \text{ mm}$ ◀

Chapter 4, Solution 14.

Free-Body Diagram:



Note that $W = mg$ is the weight of the crate in the free-body diagram, and that

$0 \le E_y \le 2.5$ kN

$\xrightarrow{+} \Sigma F_x = 0$: $\quad A_x = 0$

$+\circlearrowleft \Sigma M_A = 0$: $\quad -(1.2\text{ m})(1.2\text{ kN}) - (2.0\text{ m})(1.6\text{ kN}) - (3.8\text{ m})E_y + (6\text{ m})W = 0$

or $\quad 6W = 4.64\text{ kN} + 3.8E_y$ 1 $\qquad$ (1)

$+\uparrow \Sigma F_y = 0$: $\quad A_y - 1.2\text{ kN} - 1.6\text{ kN} - E_y + W = 0$

or $\quad A_y = 2.8\text{ kN} + E_y - W$ 2 $\qquad$ (2)

Considering the smallest possible value of E_y:

For $\quad E_y = 0, \; W = W_{\min} = 0.77333\text{ kN}$

From (2) the corresponding value of A_y is:

Wmin=0.7733 =>> $\quad A_y = 2.02667\text{ kN} \le 2.5\text{ kN}$, which satisfies the constraint on A_y.

For the largest allowable value of E_y:

$E_y = 2.5\text{ kN}, \; W = W_{\max} = 2.3567\text{ kN}$

From (2) the corresponding value of A_y is:

Wmax=2.3567 =>> $\quad A_y = 2.9433\text{ kN} \ge 2.5\text{ kN}$ which violates the constraint on A_y.

Thus $\quad (A_y)_{\max} = 2.5\text{ kN}.$ Solving (1) and (2) for W with $(A_y)_{\max} = 2.5\text{ kN}$,

$W = W_{\max} = 1.59091\text{ kN}$?!?

Therefore:

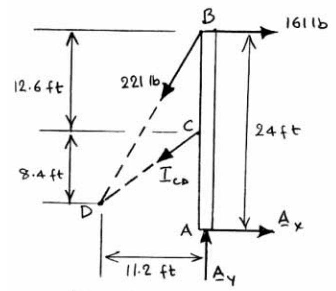
$773.33\text{ N} \le W \le 1590.91\text{ N}$, or

$773.33\text{ N} \le m(9.81\text{ m/s}^2) \le 1590.91\text{ N}$, and

$78.8\text{ kg} \le m \le 162.2\text{ kg}$ ◀

Chapter 4, Solution 15.

Free-Body Diagram:



Calculate lengths of vectors **BD** and **CD**:

$$BD = \sqrt{(11.2)^2 + (21.0)^2} \text{ ft} = 23.8 \text{ ft}$$

$$CD = \sqrt{(11.2)\ \ + (8.4)^2} \text{ ft} = 14.0 \text{ ft}$$

(*a*) $+\circlearrowleft \Sigma M_A = 0$: $\quad -(161 \text{ lb})(24 \text{ ft}) + \left(\frac{11.2 \text{ ft}}{23.8 \text{ ft}}\right)(221 \text{ lb})(24 \text{ ft}) + \left(\frac{11.2 \text{ ft}}{14.0 \text{ ft}}\right)T_{CD}(11.4 \text{ ft}) = 0$

$T_{CD} = 150.000 \text{ lb}$ $\quad\quad T_{CD} = 150.0 \text{ lb}$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $\quad 161 \text{ lb} - \left(\frac{11.2 \text{ ft}}{23.8 \text{ ft}}\right)(221 \text{ lb}) - \left(\frac{11.2 \text{ ft}}{14.0 \text{ ft}}\right)(150 \text{ lb}) + A_x = 0$

$A_x = 63.000 \text{ lb}$ or $\mathbf{A}_x = 63.000 \text{ lb} \longrightarrow$

$+\uparrow \Sigma Fy = 0$: $\quad A_y - \left(\frac{21.0 \text{ ft}}{23.8 \text{ ft}}\right)(221 \text{ lb}) - \left(\frac{11.2 \text{ ft}}{14.0 \text{ ft}}\right)(150 \text{ lb}) = 0$

$A_y = 285.00 \text{ lb}$ or $\mathbf{A}_y = 285.00 \text{ lb} \uparrow$

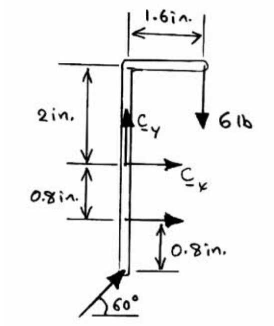
$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(63)^2 + (285)^2} = 291.88 \text{ lb}$$

$$\theta = \tan^{-1}\left(\frac{285}{63}\right) = 77.535°$$

Therefore $\quad\quad \mathbf{A} = 292 \text{ lb} \measuredangle 77.5°$ ◀

Chapter 4, Solution 16.

Free-Body Diagram:



(*a*) Equilibrium for *ABCD:*

$+\circlearrowleft \Sigma M_C = 0$: $\quad (A\cos 60°)(1.6 \text{ in.}) - (6 \text{ lb})(1.6 \text{ in.}) + (4 \text{ lb})(0.8 \text{ in.}) = 0$

$A = 8.0000 \text{ lb}$ $\qquad$ $\mathbf{A} = 8.00 \text{ lb} \measuredangle\ 60°$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $\quad C_x + 4 \text{ lb} + (8 \text{ lb})\cos 60° = 0$

or $C_x = -8.0000 \text{ lb}$ $\quad$ or $\quad \boldsymbol{C}_x = 8.0000 \text{ lb} \longleftarrow$

$+\uparrow \Sigma F_y = 0$: $\quad C_y - 6 \text{ lb} + (8 \text{ lb})\sin 60° = 0$

or $C_y = -0.92820 \text{ lb}$ $\quad$ or $\quad \boldsymbol{C}_y = 0.92820 \text{ lb} \downarrow$

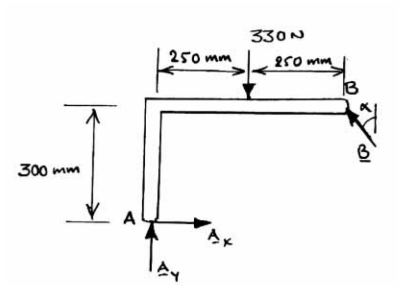
$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(8)^2 + (0.92820)^2} = 8.0537 \text{ lb}$$

$$\theta = \tan^{-1}\left(\frac{-0.92820}{-8}\right) = 6.6182°$$

Therefore: $\qquad$ $\mathbf{C} = 8.05 \text{ lb}$ ⦪ $6.62°$ ◀

Chapter 4, Solution 17.

Free-Body Diagram:



Equations of equilibrium:

$$+\circlearrowleft \Sigma M_A = 0: \quad -(330\text{ N})(0.25\text{ m}) + B\sin\alpha(0.3\text{ m}) + B\cos\alpha(0.5\text{ m}) = 0 \quad (1)$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x - B\sin\alpha = 0 \quad (2)$$

$$+\uparrow \Sigma F_y = 0: \quad A_y - (330\text{ N}) + B\cos\alpha = 0 \quad (3)$$

(a) Substitution $\alpha = 0$ into (1), (2), and (3) and solving for A and B:

$$B = 165.000\text{ N}, \quad A_x = 0, \quad A_y = 165.0\text{ N}$$

or $\mathbf{A} = 165.0\text{ N}\uparrow$, $\mathbf{B} = 165.0\text{ N}\uparrow$ ◀

(b) Substituting $\alpha = 90°$ into (1), (2), and (3) and solving for A and B:

$$B = 275.00\text{ N}, \quad A_x = 275.00\text{ N}, \quad A_y = 330.00\text{ N}$$

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(275)^2 + (330)^2} = 429.56\text{ N}$$

$$\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{330}{275} = 50.194°$$

$\therefore$ $\mathbf{A} = 430\text{ N}$ ∠ $50.2°$, $\mathbf{B} = 275\text{ N}\longleftarrow$ ◀

(c) Substituting $\alpha = 30°$ into (1), (2), and (3) and solving for A and B:

$$B = 141.506\text{ N}, \quad A_x = 70.753\text{ N}, \quad A_y = 207.45\text{ N}, \Rightarrow$$

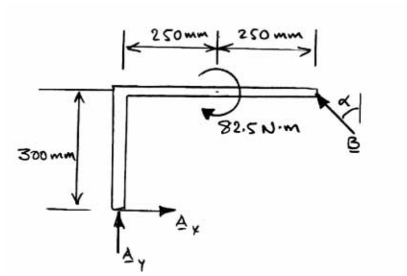
$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(70.753)^2 + (207.45)^2} = 219.18\text{ N}$$

$$\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{207.45}{70.753} = 71.168°$$

$\therefore$ $\mathbf{A} = 219\text{ N}$ ∠ $71.2°$, $\mathbf{B} = 141.5\text{ N}$ ⦩ $60°$ ◀

Chapter 4, Solution 18.

Free-Body Diagram:



Equations of equilibrium:

$+\circlearrowleft\ \Sigma M_A = 0: \quad -(82.5\ \text{N}\cdot\text{m}) + B\sin\alpha(0.3\ \text{m}) + B\cos\alpha(0.5\ \text{m}) = 0$ (1)

$\xrightarrow{+}\ \Sigma F_x = 0: \quad A_x - B\sin\alpha = 0$ (2)

$+\uparrow\ \Sigma F_y = 0: \quad A_y + B\cos\alpha = 0$ (3)

(*a*) Substituting $\alpha = 0$ into (1), (2), and (3) and solving for *A* and *B*:

$$B = 165.000\ \text{N},\ A_x = 0,\quad A_y = -165.0\ \text{N}$$

or $\mathbf{A} = 165.0\ \text{N}\downarrow$, $\mathbf{B} = 165.0\ \text{N}\uparrow$ ◀

(*b*) Substituting $\alpha = 90°$ into (1), (2), and (3) and solving for *A* and *B*:

$$B = 275.00\ \text{N},\quad A_x = 275.00\ \text{N},\quad A_y = 0$$

$\therefore\ \mathbf{A} = 275\ \text{N}\longrightarrow$, $\mathbf{B} = 275\ \text{N}\longleftarrow$ ◀

(*c*) Substituting $\alpha = 30°$ into (1), (2), and (3) and solving for *A* and *B*:

$$B = 141.506\ \text{N},\quad A_x = 70.753\ \text{N},\quad A_y = -122.548\ \text{N}$$

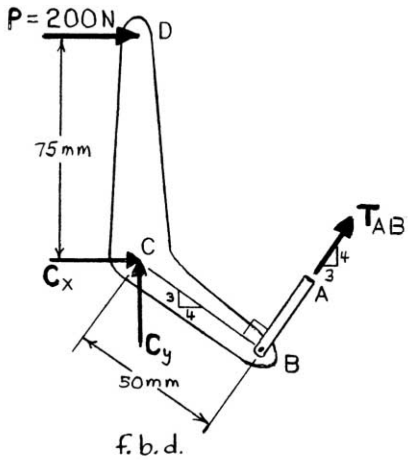
$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(70.753)^2 + (-122.548)^2} = 141.506\ \text{N}$$

$$\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{122.548}{70.753} = 60.000°$$

$\therefore\ \mathbf{A} = 141.5\ \text{N}$ ⦫ $60.0°$, $\mathbf{B} = 141.5\ \text{N}$ ⦪ $60°$ ◀

Chapter 4, Solution 19.

Free-Body Diagram:



(*a*) From free-body diagram of lever *BCD*

$$+\circlearrowleft \Sigma M_C = 0: \quad T_{AB}(50 \text{ mm}) - 200 \text{ N}(75 \text{ mm}) = 0$$

$$\therefore T_{AB} = 30$$

(*b*) From free-body diagram of lever *BCD*

$$\xrightarrow{+} \Sigma F_x = 0: \quad 200 \text{ N} + C_x + 0.6(300 \text{ N}) = 0$$

$$\therefore C_x = -380 \text{ N} \qquad \text{or} \qquad \mathbf{C}_x = 380 \text{ N} \longleftarrow$$

$$+\uparrow \Sigma F_y = 0: \quad C_y + 0.8(300 \text{ N}) = 0$$

$$\therefore C_y = -240 \text{ N} \qquad \text{or} \qquad \mathbf{C}_y = 240 \text{ N} \downarrow$$

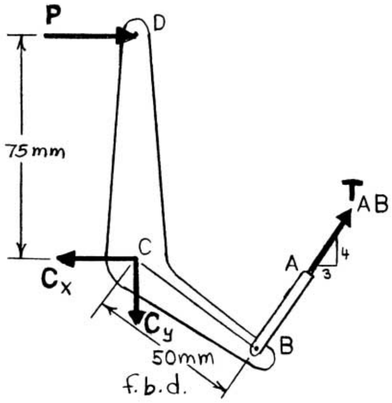
Then $\quad C = \sqrt{C_x^2 + C_y^2} = \sqrt{(380)^2 + (240)^2} = 449.44 \text{ N}$

and $\quad \theta = \tan^{-1}\left(\dfrac{C_y}{C_x}\right) = \tan^{-1}\left(\dfrac{-240}{-380}\right) = 32.276°$

or $\mathbf{C} = 449 \text{ N} \measuredangle 32.3° \blacktriangleleft$

Chapter 4, Solution 20.

Free-Body Diagram:



From free-body diagram of lever *BCD*

$$+\circlearrowleft \Sigma M_C = 0: \quad T_{AB}(50\text{ mm}) - P(75\text{ mm}) = 0$$

$$\therefore\ T_{AB} = 1.5P \qquad (1)$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad 0.6T_{AB} + P - C_x = 0$$

$$\therefore\ C_x = P + 0.6T_{AB} \qquad (2)$$

From Equation (1) $\quad C_x = P + 0.6(1.5P) = 1.9P$

$$+\uparrow \Sigma F_y = 0: \quad 0.8T_{AB} - C_y = 0$$

$$\therefore\ C_y = 0.8T_{AB} \qquad (3)$$

From Equation (1) $\quad C_y = 0.8(1.5P) = 1.2P$

From Equations (2) and (3)

$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(1.9P)^2 + (1.2P)^2} = 2.2472P$$

Since $C_{max} = 500$ N,

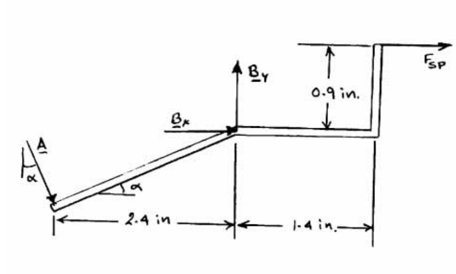
$$\therefore\ 500\text{ N} = 2.2472P_{max}$$

or $\quad P_{max} = 222.49$ lb

or $\mathbf{P} = 222$ lb $\longrightarrow$ ◀

Chapter 4, Solution 21.

Free-Body Diagram:



(*a*)

$$+\circlearrowright\ \Sigma M_{Bx} = 0: \qquad -\left(\frac{2.4\text{ in.}}{\cos\alpha}\right)A - (0.9\text{ in.})F_{sp} = 0$$

$$\text{or}\quad F_{sp} = \frac{8}{\cos 30^\circ}\text{lb} = kx = k(1.2\text{ in.})$$

Solving for k:

$$k = 7.69800\text{ lb/in.}$$

$k = 7.70$ lb/in. ◀

(*b*)

$$\xrightarrow{+}\ \Sigma F_x = 0: \qquad (3\text{ lb})\sin 30^\circ + B_x + \left(\frac{8\text{ lb}}{\cos 30^\circ}\right) = 0$$

$$\text{or}\qquad B_x = -10.7376\text{ lb}$$

$$+\uparrow\ \Sigma F_y = 0: \qquad -(3\text{ lb})\cos 30^\circ + B_y = 0$$

$$\text{or}\qquad B_y = 2.5981\text{ lb}$$

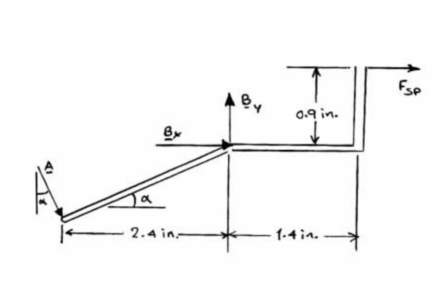
$$B = \sqrt{(-10.7376)^2 + (2.5981)^2} = 11.0475\text{ lb, and}$$

$$\theta = \tan^{-1}\frac{2.5981}{10.7376} = 13.6020^\circ$$

Therefore: **B** = 11.05 lb ⦪ 13.60° ◀

Chapter 4, Solution 22.

Free-Body Diagram:



(*a*)

$$+\circlearrowleft \Sigma M_{Bx} = 0: \quad \left(\frac{2.4 \text{ in.}}{\cos\alpha}\right)(3.6 \text{ lb}) - (0.9 \text{ in.})(12 \text{ lb}) = 0$$

or $\cos\alpha = 0.80000$, or $\alpha = 36.870°$

$\alpha = 36.9°$ ◀

(*b*)

$$\xrightarrow{+} \Sigma F_x = 0: \quad (3 \text{ lb})\sin 36.870° + B_x + (12 \text{ lb}) = 0$$

or $B_x = -14.1600$ lb

$$+\uparrow \Sigma F_y = 0: \quad -(3.6 \text{ lb})\cos 36.870° + B_y = 0$$

or $B_y = 2.8800$ lb

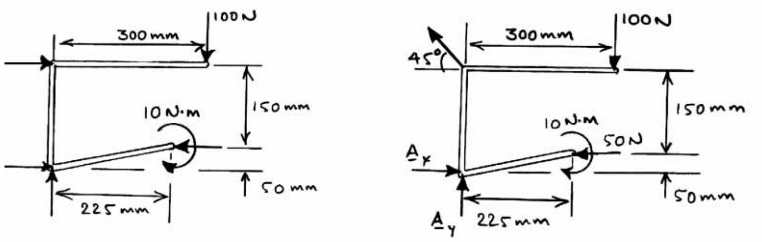
$$B = \sqrt{(-14.1600)^2 + (2.8800)^2} = 14.4499 \text{ lb, and}$$

$$\theta = \tan^{-1}\frac{2.8800}{14.1600} = 11.4966°$$

Therefore: **B** = 14.45 lb ⦪ 11.50° ◀

Chapter 4, Solution 23.

Free-Body Diagram:



From free-body diagram for (*a*):

$$+\circlearrowleft\ \Sigma M_A = 0: \quad -B(0.2 \text{ m}) - (100 \text{ N})(0.3 \text{ m}) + (50 \text{ N})(0.05 \text{ m}) - 10 \text{ N}\cdot\text{m} = 0$$

$$B = -187.50 \text{ N}$$

or $\mathbf{B} = 187.5 \text{ N} \longleftarrow$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad -187.5 \text{ N} - 50 \text{ N} + A_x = 0$$

$$A_x = 237.50 \text{ N}$$

$$+\uparrow \Sigma F_y = 0: \quad A_y - 100 \text{ N} = 0$$

$$A_y = 100.000 \text{ N}$$

and: $$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(237.5)^2 + (100)^2} = 257.69 \text{ N}$$

$$\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{100}{237.5} = 22.834°$$

$\therefore$ $\mathbf{A} = 258 \text{ N} \measuredangle\ 22.8°$ ◀

From For (*b*)

$$+\circlearrowleft\ \Sigma M_A = 0: \quad -B\cos 45°(0.2 \text{ m}) - (100 \text{ N})(0.3 \text{ m}) + (50 \text{ N})(0.05 \text{ m}) - 10 \text{ N}\cdot\text{m} = 0$$

$$B = 265.17 \text{ N}$$

or $\mathbf{B} = 265.17 \text{ N} \searrow 45°$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad -(265.17 \text{ N})\cos 45° - 50 \text{ N} + A_x = 0$$

$$A_x = 237.50 \text{ N}$$

$$+\uparrow \Sigma F_y = 0: \quad A_y + (265.17)\sin 45° - 100 \text{ N} = 0$$

$$A_y = -87.504 \text{ N}$$

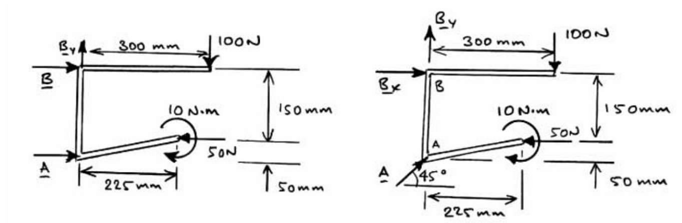
and: $$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(237.50)^2 + (-87.504)^2} = 253.11 \text{ N}$$

$$\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{87.504}{237.50} = 20.226°$$

$\therefore$ $\mathbf{A} = 253 \text{ N} \searrow\ 20.2°$ ◀

Chapter 4, Solution 24.

Free-Body Diagram:



From free-body diagram for (*a*):

$$+\circlearrowleft\ \Sigma M_B = 0: \quad -(100\text{ N})(0.3\text{ m}) + A(0.2\text{ m}) - (50\text{ N})(0.15\text{ m}) - 10\text{ N}\cdot\text{m} = 0$$

$$A = 237.50\text{ N} \qquad \text{or} \quad \mathbf{A} = 238\text{ N} \longrightarrow \blacktriangleleft$$

$$\xrightarrow{+}\ \Sigma F_x = 0: \quad B_x + 237.5\text{ N} - 50\text{ N} = 0$$

$$B_x = -187.50\text{ N}$$

$$+\!\uparrow \Sigma F_y = 0: \quad B_y - 100\text{ N} = 0$$

$$B_y = 100.000\text{ N}$$

and: $$B = \sqrt{B_x^2 + B_y^2} = \sqrt{(-187.5)^2 + (100)^2} = 212.50\text{ N}$$

$$\theta = \tan^{-1}\frac{B_y}{B_x} = \tan^{-1}\frac{100}{187.5} = 28.072°$$

$$\therefore \mathbf{B} = 213\text{ N} \measuredangle\ 28.1° \blacktriangleleft$$

From free-body diagram or (*b*):

$$+\circlearrowleft\ \Sigma M_B = 0: \quad -(100\text{ N})(0.3\text{ m}) + A\cos 45°(0.2\text{ m}) - (50\text{ N})(0.15\text{ m}) - 10\text{ N}\cdot\text{m} = 0$$

$$A = 335.88\text{ N} \qquad \text{or} \quad \mathbf{A} = 336\text{ N} \measuredangle\ 45° \blacktriangleleft$$

$$\xrightarrow{+}\ \Sigma F_x = 0: \quad B_x + (335.88\text{ N})\cos 45° - 50\text{ N} = 0$$

$$B_x = -187.503\text{ N}$$

$$+\!\uparrow \Sigma F_y = 0: \quad B_y + (335.88\text{ N})\sin 45° - 100\text{ N} = 0$$

$$B_y = -137.503\text{ N}$$

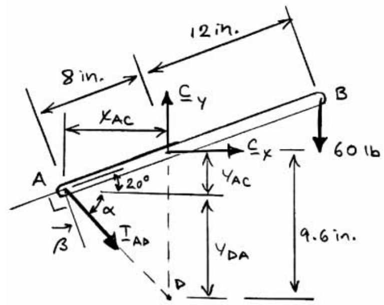
and: $$B = \sqrt{B_x^2 + B_y^2} = \sqrt{(-187.503)^2 + (-137.503)^2} = 232.52\text{ N}$$

$$\theta = \tan^{-1}\frac{B_y}{B_x} = \tan^{-1}\frac{137.503}{187.503} = 36.254°$$

$$\therefore \mathbf{B} = 233\text{ N} \measuredangle\ 36.3° \blacktriangleleft$$

Chapter 4, Solution 25.

Free-Body Diagram:



Geometry:

$$x_{AC} = (8 \text{ in.})\cos 20° = 7.5175 \text{ in.}$$

$$y_{AC} = (8 \text{ in.})\sin 20° = 2.7362 \text{ in.}$$

$$\Rightarrow y_{DA} = 9.6 \text{ in.} - 2.7362 \text{ in.} = 6.8638 \text{ in.}$$

$$\alpha = \tan^{-1}\left(\frac{y_{DA}}{x_{AC}}\right) = \tan^{-1}\left(\frac{6.8638}{7.5175}\right) = 42.397°$$

$$\beta = 90° - 20° - 42.397° = 27.603°$$

Equilibrium for lever:

(*a*) $+\circlearrowleft \Sigma M_C = 0$: $\quad T_{AD}\cos 27.603°(8 \text{ in.}) - (60 \text{ lb})\left[(12 \text{ in.})\cos 20°\right] = 0$

$T_{AD} = 95.435 \text{ lb}$ $\qquad$ $T_{AD} = 95.4 \text{ lb}$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $\quad C_x + (95.435 \text{ lb})\cos 42.397° = 0$

$C_x = -70.478 \text{ lb}$

$+\uparrow \Sigma F_y = 0$: $\quad C_y - 60 \text{ lb} - (95.435 \text{ lb})\sin 42.397° = 0$

$C_y = 124.348 \text{ lb}$

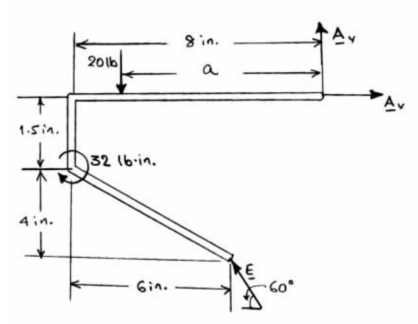
Thus: $\quad C = \sqrt{C_x^2 + C_y^2} = \sqrt{(-70.478)^2 + (124.348)^2} = 142.932 \text{ lb}$

and $\quad \theta = \tan^{-1}\dfrac{C_y}{C_x} = \tan^{-1}\dfrac{124.348}{70.478} = 60.456°$

$\therefore$ **C** $= 142.9$ lb ⦫ 60.5° ◀

Chapter 4, Solution 26.

Free-Body Diagram:



(*a*) $a = 2$ in.

$+\circlearrowleft \Sigma M_A = 0$: $(2 \text{ in.})(20 \text{ lb}) - (1.5 \text{ in.})(16 \text{ lb}) - 32 \text{ lb}\cdot\text{in.} - (2 \text{ in.})E\sin 60° - (5.5 \text{ in.})E\cos 60° = 0$

$E = -3.5698$ lb — or $\mathbf{E} = 3.57$ lb ∠ 60.0° ◀

$\xrightarrow{+} \Sigma F_x = 0$: $A_x - 16 \text{ lb} + (3.5698 \text{ lb})\cos 60° = 0$

$A_x = 14.2151$ lb

$+\uparrow \Sigma F_y = 0$: $A_y - 20 \text{ lb} - (3.5698 \text{ lb})\sin 60° = 0$

$A_y = 23.092$ lb

$$A = \sqrt{(14.2151)^2 + (23.092)^2} = 27.117 \text{ lb}$$

$$\theta = \tan^{-1}\frac{23.092}{14.2151} = 58.384°$$

Therefore: $\mathbf{A} = 27.1$ lb ∠ 58.4° ◀

(*b*) $a = 7.5$ in.

$+\circlearrowleft \Sigma M_A = 0$: $(7.5 \text{ in.})(20 \text{ lb}) - (1.5 \text{ in.})(16 \text{ lb}) - 32 \text{ lb}\cdot\text{in.} - (2 \text{ in.})E\sin 60° - (5.5 \text{ in.})E\cos 60° = 0$

$E = 20.973$ lb — or $\mathbf{E} = 21.0$ lb ∠ 60.0° ◀

$\xrightarrow{+} \Sigma F_x = 0$: $A_x - 16 \text{ lb} - (20.973 \text{ lb})\cos 60° = 0$

$A_x = 26.487$ lb

$+\uparrow \Sigma F_y = 0$: $A_y - 20 \text{ lb} + (20.973 \text{ lb})\sin 60° = 0$

$A_y = 1.83685$ lb

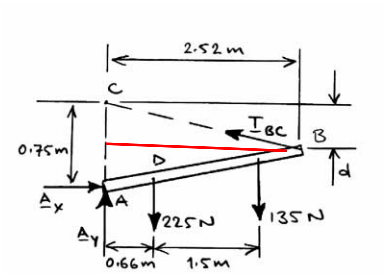
$$A = \sqrt{(26.487)^2 + (1.83685)^2} = 26.551 \text{ lb}$$

$$\theta = \tan^{-1}\frac{1.83685}{26.487} = 3.9671°$$

Therefore: $\mathbf{A} = 26.6$ lb ∠ 3.97° ◀

Chapter 4, Solution 27.

Free-Body Diagram:



Geometry:

Distance $BC = \sqrt{(2.52)^2 + (0.39)^2} = 2.55 \text{ m}$

Equilibrium for mast:

(*a*) $+\circlearrowleft \Sigma M_A = 0$: $\left[\left(\frac{2.52}{2.55}\right)T_{BC}\right](0.75 \text{ m}) - (135 \text{ N})(2.16 \text{ m}) - (225 \text{ N})(0.66 \text{ m}) = 0$

$T_{BC} = 593.79 \text{ N}$ or $T_{BC} = 594 \text{ N}$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $A_x - \left(\frac{2.52}{2.55}\right)(593.79 \text{ N}) - 225 \text{ N} - 135 \text{ N} = 0$

$A_x = 586.80 \text{ N}$

$+\uparrow \Sigma F_y = 0$: $A_y + \left(\frac{0.39}{2.55}\right)(593.79 \text{ N}) - 225 \text{ N} - 135 \text{ N} = 0$

$A_y = 269.19 \text{ N}$

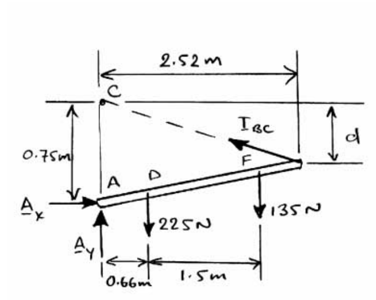
Thus: $A = \sqrt{A_x^2 + A_y^2} = \sqrt{(586.80)^2 + (269.19)^2} = 645.60 \text{ N}$

and $\theta = \tan^{-1}\frac{A_y}{A_x} = \tan^{-1}\frac{269.19}{586.80} = 24.643°$

$\therefore \mathbf{A} = 646 \text{ N} \measuredangle 24.6°$ ◀

Chapter 4, Solution 28.

Free-Body Diagram:



Geometry:

Distance $BC = \sqrt{(2.52)^2 + (0.462)^2} = 2.562 \text{ m}$

Equilibrium for mast:

(*a*) $+\circlearrowleft \Sigma M_A = 0$: $\left[\left(\dfrac{2.52}{2.562}\right)T_{BC}\right](0.75 \text{ m}) - (90 \text{ N})(2.16 \text{ m}) - (135 \text{ N})(0.66 \text{ m}) = 0$

$T_{BC} = 384.30 \text{ N}$ or $T_{BC} = 384 \text{ N}$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $A_x - \left(\dfrac{2.52}{2.562}\right)(384.30 \text{ N}) = 0$

$A_x = 378.00 \text{ N}$

$+\uparrow \Sigma F_y = 0$: $A_y + \left(\dfrac{0.462}{2.562}\right)(384.30 \text{ N}) - 135 \text{ N} - 90 \text{ N} = 0$

$A_y = 155.700 \text{ N}$

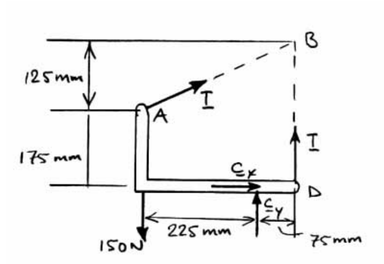
Thus: $A = \sqrt{A_x^2 + A_y^2} = \sqrt{(378.00)^2 + (155.700)^2} = 408.81 \text{ N}$

and $\theta = \tan^{-1}\dfrac{A_y}{A_x} = \tan^{-1}\dfrac{155.700}{378.00} = 22.387°$

$\therefore \mathbf{A} = 409 \text{ N} \measuredangle 22.4°$ ◀

Chapter 4, Solution 29.

Free-Body Diagram:



Geometry:

Distance $AB = \sqrt{(0.3)^2 + (0.125)^2} = 0.325 \text{ m}$

Equilibrium for bracket:

$$+\circlearrowleft \Sigma M_C = 0: \quad (150 \text{ N})(0.225 \text{ m}) - \left(\frac{0.3}{0.325}T\right)(0.175 \text{ m}) - \left(\frac{0.125}{0.325}T\right)(0.225 \text{ m}) + T(0.075 \text{ m}) = 0$$

$T = 195.000 \text{ N}$

$T = 195.0 \text{ N}$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad C_x + \left(\frac{0.3}{0.325}T\right)(195 \text{ N}) = 0$$

$C_x = -180.000 \text{ N}$

$$+\circlearrowleft \Sigma F_y = 0: \quad C_y - 150 \text{ N} + \left(\frac{0.125}{0.325}T\right)(195 \text{ N}) + 195 \text{ N} = 0$$

$C_y = -120.000 \text{ N}$

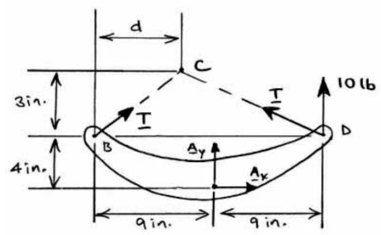
Thus: $C = \sqrt{C_x^2 + C_y^2} = \sqrt{(-180)^2 + (-120)^2} = 216.33 \text{ N}$

and $\theta = \tan^{-1}\dfrac{C_y}{C_x} = \tan^{-1}\dfrac{120}{180} = 33.690°$

$\therefore$ **C** $= 216 \text{ N}$ ↙ $33.7°$ ◀

Chapter 4, Solution 30.

Free-Body Diagram:



Geometry:

Distance $BC = \sqrt{(4)^2 + (3)^2} = 5$ in.

Distance $CD = \sqrt{(14)^2 + (3)^2} = 14.3178$ in.

Equilibrium for bracket:

$$+\circlearrowleft\ \Sigma M_A = 0: \quad (10 \text{ lb})(9 \text{ in.}) - \left(\frac{4}{5}T\right)(4 \text{ in.}) - \left(\frac{3}{5}T\right)(9 \text{ in.}) + \left(\frac{14}{14.3178}T\right)(4 \text{ in.}) + \left(\frac{3}{14.3178}T\right)(9 \text{ in.}) = 0$$

$T = 32.108$ lb   or $T = 32.1$ lb ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x + \left(\frac{4}{5}\right)(32.108 \text{ lb}) - \left(\frac{14}{14.3178}\right)(32.108 \text{ lb}) = 0$$

$A_x = 5.7089$ lb

$$+\uparrow \Sigma F_y = 0: \quad A_y + \frac{3}{5}(32.108 \text{ lb}) + \left(\frac{3}{14.3178}\right)(32.108 \text{ lb}) + 10 \text{ lb} = 0$$

$A_y = -35.992$ lb

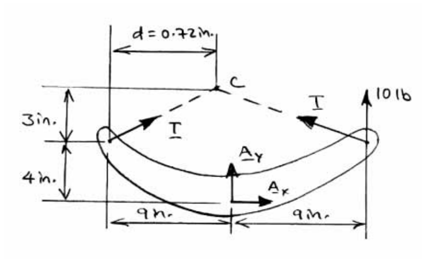
Thus: $A = \sqrt{A_x^2 + A_y^2} = \sqrt{(5.7089)^2 + (-35.992)^2} = 36.442$ lb

and $\theta = \tan^{-1}\dfrac{A_y}{A_x} = \tan^{-1}\dfrac{35.992}{5.7089} = 80.987°$

$\therefore$ **A** $= 36.4$ lb ⦪ 81.0° ◀

Chapter 4, Solution 31.

Free-Body Diagram:



Geometry:

$$\text{Distance } BC = \sqrt{(7.2)^2 + (3)^2} = 7.8 \text{ in.}$$

$$\text{Distance } CD = \sqrt{(10.8)^2 + (3)^2} = 11.2089 \text{ in.}$$

Equilibrium for bracket:

$$+\circlearrowleft \Sigma M_A = 0: \quad (10 \text{ lb})(9 \text{ in.}) - \left(\frac{7.2}{7.8}T\right)(4 \text{ in.}) - \left(\frac{3}{7.8}T\right)(9 \text{ in.}) + \left(\frac{10.8}{11.2089}T\right)(4 \text{ in.})$$

$$+\left(\frac{3}{11.2089}T\right)(9 \text{ in.}) = 0$$

$$T = 101.014 \text{ lb}$$

or $T = 101.0$ lb ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x + \left(\frac{7.2}{7.8}\right)(101.014 \text{ lb}) - \left(\frac{10.8}{11.2089}\right)(101.014 \text{ lb}) = 0$$

$$A_x = 4.0853 \text{ lb}$$

$$+\uparrow \Sigma F_y = 0: \quad A_y + \left(\frac{3}{7.8}\right)(101.014 \text{ lb}) + \left(\frac{3}{11.2089}\right)(101.014 \text{ lb}) + 10 \text{ lb} = 0$$

$$A_y = -75.887 \text{ lb}$$

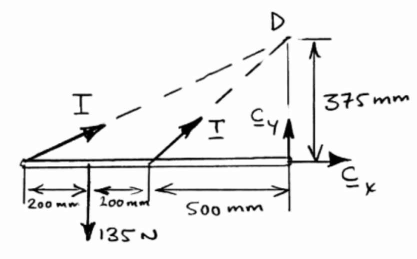
Thus: $\quad A = \sqrt{A_x^2 + A_y^2} = \sqrt{(4.0853)^2 + (-75.887)^2} = 75.997 \text{ lb}$

and $\quad \theta = \tan^{-1}\dfrac{A_y}{A_x} = \tan^{-1}\dfrac{75.887}{4.0853} = 86.919°$

$\therefore$ **A** $= 76.0$ lb ↘ 86.9° ◀

Chapter 4, Solution 32.

Free-Body Diagram:



Geometry:

$$\text{Distance } AD = \sqrt{(0.9)^2 + (0.375)^2} = 0.975 \text{ m}$$

$$\text{Distance } BD = \sqrt{(0.5)^2 + (0.375)^2} = 0.625 \text{ m}$$

Equilibrium for beam:

(*a*) $+\circlearrowleft \Sigma M_C = 0: \quad (135 \text{ N})(0.7 \text{ m}) - \left(\frac{0.375}{0.975}T\right)(0.9 \text{ m}) - \left(\frac{0.375}{0.625}T\right)(0.5 \text{ m}) = 0$

$T = 146.250$ N

or $T = 146.3$ N ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0: \quad C_x + \left(\frac{0.9}{0.975}T\right)(146.250 \text{ N}) + \left(\frac{0.5}{0.625}T\right)(146.250 \text{ N}) = 0$

$C_x = -252.00$ N

$+\uparrow \Sigma F_y = 0: \quad C_y + \left(\frac{0.375}{0.975}T\right)(146.250 \text{ N}) + \left(\frac{0.375}{0.625}T\right)(146.250 \text{ N}) - 135 \text{ N} = 0$

$C_y = -9.0000$ N

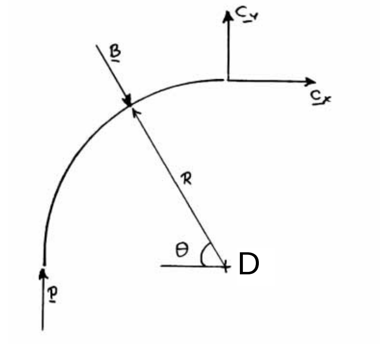
Thus: $C = \sqrt{C_x^2 + C_y^2} = \sqrt{(-252)^2 + (-9)^2} = 252.16$ N

and $\theta = \tan^{-1}\frac{C_y}{C_x} = \tan^{-1}\frac{9}{252} = 2.0454°$

C = 252 N ⦪ 2.05° ◀

Chapter 4, Solution 33.

Free-Body Diagram:



For both parts (*a*) and (*b*)

$+\circlearrowleft\ \Sigma M_D = 0: \qquad -RP - RC_x = 0$

$$C_x = -P \qquad (1)$$

$\xrightarrow{+}\ \Sigma F_x = 0: \qquad B\cos\theta - P = 0$

$$B = \frac{P}{\cos\theta} \qquad (2)$$

$+\uparrow\ \Sigma F_y = 0: \qquad C_y - \left(\frac{P}{\cos\theta}\right)\sin\theta + P = 0$

$$C_y = P(\tan\theta - 1) \qquad (3)$$

(*a*) The magnitudes of the forces at *B* and *C* are equal:

$$B = \sqrt{C_x^2 + C_y^2}$$

$$\left(\frac{P}{\cos\theta}\right)^2 = (-P)^2 + \left[P(\tan\theta - 1)\right]^2$$

or

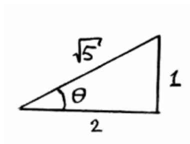
$$\frac{1}{\cos^2\theta} = 1 + \left(\tan^2\theta - 2\tan\theta + 1\right)$$

continued

Noting that $\tan^2\theta + 1 = \dfrac{1}{\cos^2\theta}$, this gives

$$\frac{1}{\cos^2\theta} = 1 + \frac{1}{\cos^2\theta} - 2\tan\theta \text{, or}$$

$$\tan\theta = \frac{1}{2} \text{, so}$$



$$\theta = 26.565^\circ \qquad\qquad \theta = 26.6^\circ \blacktriangleleft$$

(b) Using (2)

$$B = \frac{P}{2/\sqrt{5}} \text{, or} \qquad\qquad \therefore\ \mathbf{B} = \frac{\sqrt{5}}{2}P \ \searrow 26.6^\circ \blacktriangleleft$$

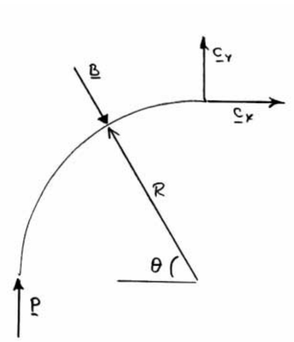
and using (1) and (3)

$$C_x = -P, \qquad C_y = -\frac{P}{2}$$

$$C = \sqrt{(-P)^2 + \left(-\frac{P}{2}\right)^2} = \frac{\sqrt{5}}{2}P \qquad\qquad \therefore\ \mathbf{C} = \frac{\sqrt{5}}{2}P \ \swarrow 26.6^\circ \blacktriangleleft$$

Chapter 4, Solution 34.

Free-Body Diagram:



For both parts (*a*) and (*b*)

$+\circlearrowleft \Sigma M_D = 0: \quad -RP - RC_x = 0$

$$C_x = -P \qquad (1)$$

$\xrightarrow{+} \Sigma F_x = 0: \quad B\cos\theta - P = 0$

$$B = \frac{P}{\cos\theta} \qquad (2)$$

$+\uparrow \Sigma F_y = 0: \quad C_y - \left(\frac{P}{\cos\theta}\right)\sin\theta + P = 0$

$$C_y = P(\tan\theta - 1) \qquad (3)$$

(*a*) The magnitude of the reaction at *C*:

$$C = \sqrt{C_x^2 + C_y^2}$$

$$C = \sqrt{(-P)^2 + \left[P(\tan\theta - 1)\right]^2}$$

which is smallest when $\tan\theta = 1$, or

$$\theta = 45.0° \blacktriangleleft$$

(*b*) Using (2)

$$B = \frac{P}{\cos 45°} \qquad \text{or } \mathbf{B} = \sqrt{2}P \searrow 45.0° \blacktriangleleft$$

and

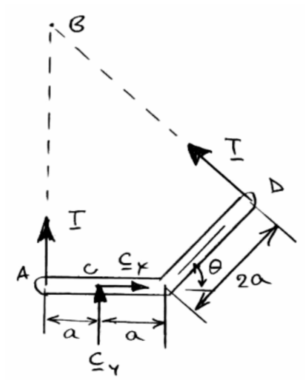
$$C_x = -P, \quad C_y = 0$$

or $\mathbf{C} = P \longleftarrow \blacktriangleleft$

Vector Mechanics for Engineers: Statics and Dynamics, 8/e, Ferdinand P. Beer, E. Russell Johnston, Jr., Elliot R. Eisenberg, William E. Clausen, David Mazurek, Phillip J. Cornwell

Chapter 4, Solution 35.

Free-Body Diagram:



Equilibrium for bracket:

$$+\circlearrowleft \Sigma M_C = 0: \quad -T(a) - P(a) + (T\sin 40°)(2a\sin 40°) + (T\cos 40°)(a + 2a\cos 40°) = 0$$

$$T = 0.56624P$$

or $T = 0.566P$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad C_x + (0.56624P)\sin 40° = 0$$

$$C_x = 0.36397P$$

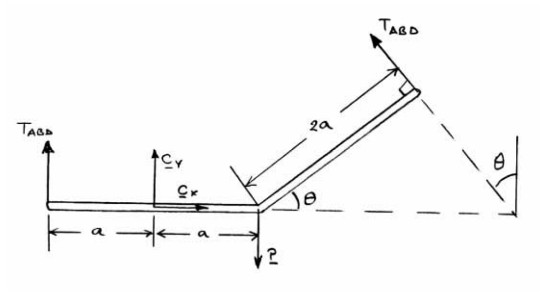
$$+\uparrow \Sigma F_y = 0: \quad C_y + 0.56624P - P + (0.56624P)\cos 40° = 0$$

$$C_y = 0$$

or $\mathbf{C} = 0.364P \longrightarrow$ ◀

Chapter 4, Solution 36.

Free-Body Diagram:



(*a*) $+\circlearrowleft \Sigma M_C = 0$: $\quad -aT_{ABD} - aP + \left(\dfrac{2a}{\cos\theta} + a\right)T_{ABD}\cos\theta = 0$

or with $T_{ABD} = 3P/4$:

$$-a\frac{3}{4}P - aP + \left(\frac{2}{\cos\theta} + 1\right)\frac{3}{4}P\cos\theta = 0$$

$\cos\theta = \dfrac{1}{3}$, and $\theta = 70.529°$ $\qquad \theta = 70.5°$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $\quad C_x - \dfrac{\sqrt{8}}{3}\left(\dfrac{3}{4}P\right) = 0$

$$C_x = \frac{\sqrt{2}}{2}P$$

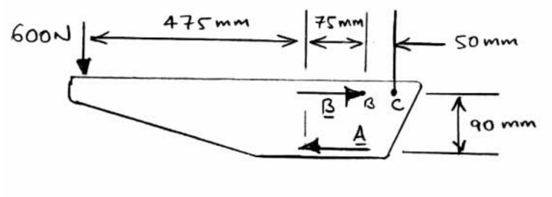
$+\uparrow \Sigma F_y = 0$: $\quad \dfrac{3}{4}P + C_y - P + \dfrac{1}{3}\left(\dfrac{3}{4}P\right) = 0$

$$C_y = 0$$

Therefore: $\qquad \mathbf{C} = \dfrac{1}{\sqrt{2}}P \longrightarrow$ ◀

Chapter 4, Solution 37.

Free-Body Diagram:



Equilibrium for bracket:

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

$T = 600 \text{ N}$ or $T = 600 \text{ N}$ ◀

(*b*) $+\circlearrowleft \Sigma M_C = 0$: $-(600 \text{ N})(0.6 \text{ m}) + A(0.09 \text{ m}) = 0$

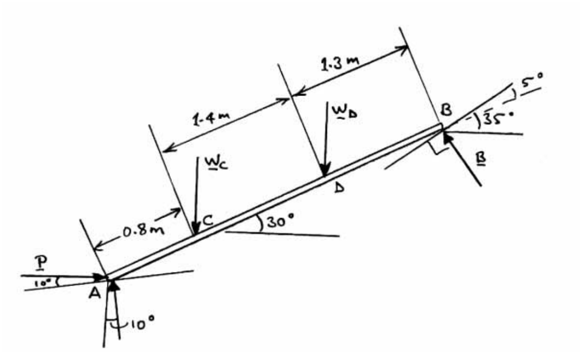
$A = 4000 \text{ N}$ or $\mathbf{A} = 4 \text{ kN} \longleftarrow$ ◀

$\xrightarrow{+} \Sigma F_x = 0$: $B - 4000 \text{ N} = 0$

$B = 4000 \text{ N}$ or $\mathbf{B} = 4 \text{ kN} \longrightarrow$ ◀

Chapter 4, Solution 38.

Free-Body Diagram:



Note that $\mathbf{W}_C = -(80\text{ kg})(9.81\text{ m/s}^2) = 784.80\text{ N}$

$\mathbf{W}_D = -(52\text{ kg})(9.81\text{ m/s}^2) = 510.12\text{ N}$

(*a*)

$+\circlearrowleft\ \Sigma M_A = 0: \quad -(784.80\text{ N})(0.8\text{ m})\cos 30° - (510.12\text{ N})(2.2\text{ m})\cos 30° + B(3.5\text{ m})\cos 5° = 0$

$B = 434.69\text{ N}$ or $\mathbf{B} = 435\text{ N} \searrow 55°$ ◀

(*b*)

$+\uparrow\ \Sigma F_y = 0: \quad A\cos 10° - 784.80\text{ N} - 510.12\text{ N} + (434.69\text{ N})\cos 35° = 0$

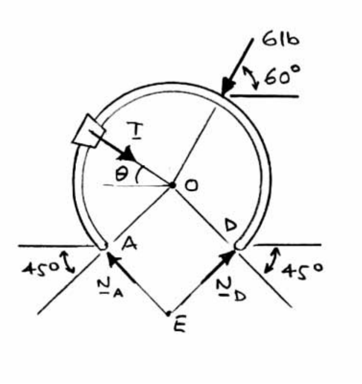
$A = 953.33\text{ N}$ or $\mathbf{A} = 953\text{ N} \searrow 80°$ ◀

$\xrightarrow{+}\ \Sigma F_x = 0: \quad P - (953.33\text{ N})\sin 10° - (434.69\text{ N})\sin 35° = 0$

$P = 414.87\text{ N}$ or $\mathbf{P} = 415\text{ N} \longrightarrow$ ◀

Chapter 4, Solution 39.

Free-Body Diagram:



Equilibrium for rod:

(*a*) $+\circlearrowleft\ \Sigma M_E = 0$: $(6 \text{ lb})\cos 60°(d_{OE}) - (T\cos 45°)(d_{OE}) = 0$

$T = 4.2426$ lb

$T = 4.24$ lb ◀

(*b*) $\xrightarrow{+}\ \Sigma F_x = 0$: $(4.2426 \text{ lb})\cos 45° - (6 \text{ lb})\cos 60° - N_A \sin 45° + N_D \cos 45° = 0$

$N_A = N_D$ (1)

$+\uparrow\ \Sigma F_y = 0$: $-(6 \text{ lb})\sin 60° - (4.2426 \text{ lb})\sin 45° + N_A \cos 45° + N_D \cos 45° = 0$

$N_A + N_D = 11.5911$ lb (2)

Solving (1) and (2) gives:

$N_A = N_D = 5.7956$ lb

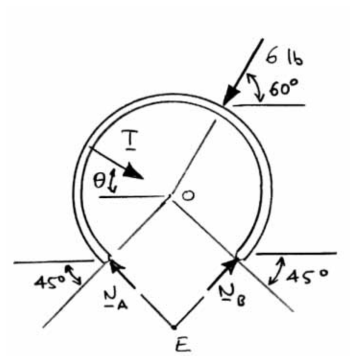
Therefore:

$\mathbf{N}_A = 5.80$ lb ⦪ 45° ◀

$\mathbf{N}_D = 5.80$ lb ⦩ 45° ◀

Chapter 4, Solution 40.

Free-Body Diagram:



Equilibrium for rod:

(*a*) $+\circlearrowleft \Sigma M_E = 0$: $\quad (6 \text{ lb})\cos 60°(d_{OE}) - (T\cos\theta)(d_{OE}) = 0$

$$T = \frac{3}{\cos\theta} \text{ lb} \qquad (1)$$

Thus T is minimum when $\cos\theta$ is maximum: $\theta = 0°$ ◀

(*b*) With $\theta = 0°$, (1) gives: $T = 3$ lb $\qquad T = 3.00$ lb ◀

(*c*) $\xrightarrow{+} \Sigma F_x = 0$: $\quad 3 \text{ lb} - (6 \text{ lb})\cos 60° - N_A \sin 45° - N_D \sin 45° = 0$

$$N_A = N_D \qquad (2)$$

$+\uparrow \Sigma F_y = 0$: $\quad -(6 \text{ lb})\sin 60° + N_A \cos 45° + N_D \cos 45° = 0$

$$N_A + N_D = 7.3485 \text{ lb} \qquad (3)$$

Solving (2) and (3) gives:

$$N_A = N_D = 3.6742 \text{ lb}$$

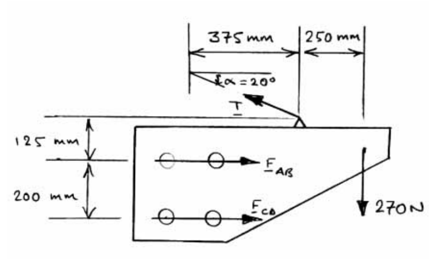
Therefore:

$\mathbf{N}_A = 3.67$ lb ⦣ 45° ◀

$\mathbf{N}_D = 3.67$ lb ⦣ 45° ◀

Chapter 4, Solution 41.

Free-Body Diagram:



Equilibrium for bracket:

$+\uparrow \Sigma F_y = 0: \quad T\sin 20° - 270 \text{ N} = 0$

$T = 789.43 \text{ N}$

Note that: $T_x = (789.43 \text{ N})\cos 20° = 741.82 \text{ N},$ and

$T_y = (789.43 \text{ N})\sin 20° = 270 \text{ N}$

Thus T_y and the 270-N force form a couple:

$270 \text{ N}(0.25 \text{ m}) = 67.5 \text{ N}\cdot\text{m}$ clockwise

$+\circlearrowleft \Sigma M_B = 0: \quad (741.82 \text{ N})(0.125 \text{ m}) - 67.5 \text{ N}\cdot\text{m} + F_{CD}(0.2 \text{ m}) = 0$

$F_{CD} = -126.138 \text{ N}$ or $\mathbf{F}_{CD} = 126.138 \text{ N} \longleftarrow$

$+\uparrow \Sigma F_y = 0: \quad F_{AB} - 126.138 \text{ N} - 741.82 \text{ N} = 0$

$F_{AB} = 867.96 \text{ N}$ or $\mathbf{F}_{AB} = 867.96 \text{ N} \longrightarrow$

Thus, F_{CD} acts to the left, while F_{AB} acts to the right, i.e. these forces are exerted by rollers *B* and *C*, respectively. Rollers *A* and *B* exert no force. The forces exerted on the post are the opposites of the forces exerted by the rollers:

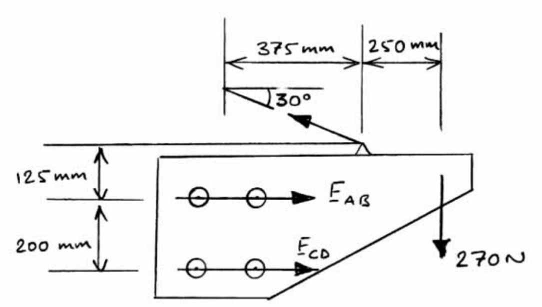
$\mathbf{A} = \mathbf{D} = 0$ ◀

$\mathbf{B} = 868 \text{ N} \longrightarrow$ ◀

$\mathbf{C} = 126.1 \text{ N} \longleftarrow$ ◀

Chapter 4, Solution 42.

Free-Body Diagram:



Equilibrium for bracket:

$$+\uparrow \Sigma F_y = 0: \qquad T\sin 30° - 270 \text{ N} = 0$$

$$T = 540 \text{ N}$$

Note that: $$T_x = (540 \text{ N})\cos 30° = 467.65 \text{ N, and}$$

$$T_y = (540 \text{ N})\sin 30° = 270 \text{ N}$$

Thus T_y and the 270-N force form a couple:

$$270 \text{ N}(0.25 \text{ m}) = 67.5 \text{ N}\cdot\text{m} \text{ clockwise}$$

$$+\circlearrowleft \Sigma M_B = 0: \qquad (467.65 \text{ N})(0.125 \text{ m}) - 67.5 \text{ N}\cdot\text{m} + F_{CD}(0.2 \text{ m}) = 0$$

$$F_{CD} = 45.219 \text{ N} \quad \text{or} \quad \mathbf{F}_{CD} = 45.219 \text{ N} \longrightarrow$$

$$+\uparrow \Sigma F_y = 0: \qquad F_{AB} + 45.219 \text{ N} - 467.65 \text{ N} = 0$$

$$F_{AB} = 422.43 \text{ N} \quad \text{or} \quad \mathbf{F}_{AB} = 422.43 \text{ N} \longrightarrow$$

Thus, both F_{CD} and F_{AB} act to the right, i.e. these forces are exerted on the bracket by rollers D and B, respectively. Rollers A and C exert no force. The forces exerted on the post are the opposites of the forces exerted on the bracket:

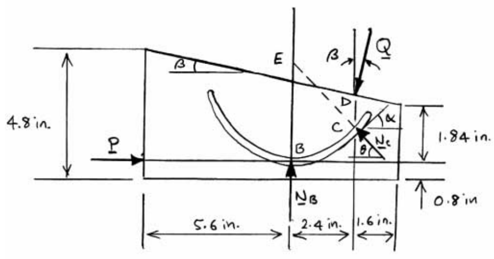
A = **C** = 0 ◀

B = 422 N ⟵ ◀

D = 45.2 N ⟵ ◀

Chapter 4, Solution 43.

Free-Body Diagram:



Geometry:

Equation of the slot: $y = \dfrac{x^2}{4}$

$$\left(\frac{dy}{dx}\right)_C = \text{slope of slot at } C = \left[\frac{2x}{4}\right]_{(x\,=\,2.4\text{ in.})} = 1.20000$$

It follows for the angles that:

$$\alpha = \tan^{-1}(1.2) = 50.194°$$

$$\theta = 90° - \alpha = 90° - 50.194° = 39.806°$$

$$\beta = \tan^{-1}\left(\frac{4.8 - 2.64}{9.6}\right) = 12.6804°$$

Coordinates for *C, D,* and *E*:

$$x_C = 2.4 \text{ in.}, \qquad y_C = \frac{(2.4)^2}{4} = 2.44 \text{ in.}$$

$$x_D = 2.4 \text{ in.}, \qquad y_D = 1.84 \text{ in.} + (1.6 \text{ in.})\tan\beta$$

$$= 1.84 \text{ in.} + (1.6 \text{ in.})\tan 12.6804° = 2.20000 \text{ in.}$$

$$x_E = 0, \qquad y_E = y_C + (2.4 \text{ in.})\tan\theta$$

$$= 1.44 \text{ in.} + (2.4 \text{ in.})\tan 39.806° = 3.4400 \text{ in.}$$

continued

With $P = 1\text{ lb}$:

$+\circlearrowleft \Sigma M_E = 0$: $\quad P(y_E) - (Q\sin\beta)(y_E - y_D) - (Q\cos\beta)(2.4\text{ in.}) = 0$

$$(1\text{ lb})(3.44\text{ in.}) - (Q\sin 12.6804°)(1.24\text{ in.}) - (Q\cos 12.6804°)(2.4\text{ in.}) = 0$$

$$Q = 1.31616\text{ lb}$$

$\xrightarrow{+} \Sigma F_x = 0$: $\quad P - N_C\cos\theta - Q\sin\beta = 0$

$$1\text{ lb} - N_C\cos 39.806° - (1.31616\text{ lb})\sin 12.6804° = 0$$

$$N_C = 0.92563\text{ lb}$$

$+\uparrow \Sigma F_y = 0$: $\quad N_B + N_C\sin\theta - Q\cos\beta = 0$

$$N_B + (0.92563\text{ lb})\sin 39.806° - (1.31616\text{ lb})\cos 12.6804° = 0$$

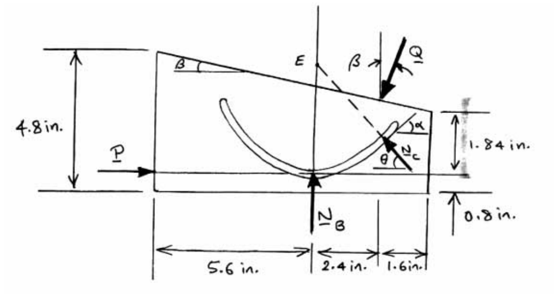
$$N_B = 0.69148\text{ lb}$$

(*a*) $\mathbf{N}_B = 0.691\text{ lb}\uparrow$, $\mathbf{N}_C = 0.926\text{ lb}$ ⦪ 39.8° ◀

(*b*) $\boldsymbol{Q} = 1.316\text{ lb}$ ⦫ 77.3° ◀

Chapter 4, Solution 44.

Free-Body Diagram:



Geometry:

Equation of the slot: $y = \dfrac{x^2}{4}$

$$\left(\frac{dy}{dx}\right)_C = \text{ slope of slot at } C = \left[\frac{2x}{4}\right]_{(x=2.4\text{ in.})} = 1.20000$$

It follows for the angles that:

$$\alpha = \tan^{-1}(1.2) = 50.194°$$

$$\theta = 90° - \alpha = 90° - 50.194° = 39.806°$$

$$\beta = \tan^{-1}\left(\frac{4.8 - 2.64}{9.6}\right) = 12.6804°$$

Coordinates for *C, D,* and *E:*

$$x_C = 2.4\text{ in.},\qquad y_C = \frac{(2.4)^2}{4} = 2.44\text{ in.}$$

$$x_D = 2.4\text{ in.},\qquad y_D = 1.84\text{ in.} + (1.6\text{ in.})\tan\beta$$

$$= 1.84\text{ in.} + (1.6\text{ in.})\tan 12.6804° = 2.20000\text{ in.}$$

$$x_E = 0,\qquad y_E = y_C + (2.4\text{ in.})\tan\theta$$

$$= 1.44\text{ in.} + (2.4\text{ in.})\tan 39.806° = 3.4400\text{ in.}$$

continued

With $Q = 2$ lb:

(*a*) $+\circlearrowright \Sigma M_E = 0$: $P(y_E) - (Q\sin\beta)(y_E - y_D) - (Q\cos\beta)(2.4 \text{ in.}) = 0$

$P(3.44 \text{ in.}) - [(2 \text{ lb})\sin 12.6804°](1.24 \text{ in.}) - [(2 \text{ lb}) \cos 12.6804°](2.4 \text{ in.}) = 0$

$P = 1.51957$ lb or $\mathbf{P} = 1.520 \text{ lb} \longrightarrow$ ◀

(*b*) $\xrightarrow{+} \Sigma F_x = 0$: $P - N_C\cos\theta - Q\sin\beta = 0$

$1.51957 \text{ lb} - N_C\cos 39.806° - (2 \text{ lb})\sin 12.6804° = 0$

$N_C = 1.40656$ lb or $\mathbf{N}_C = 1.407 \text{ lb} \searrow 39.8°$ ◀

$+\uparrow \Sigma F_y = 0$: $N_B + N_C\sin\theta - Q\cos\beta = 0$

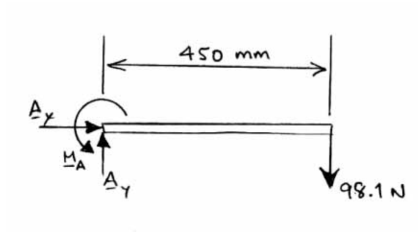
$N_B + (1.40656 \text{ lb})\sin 39.806° - (2 \text{ lb})\cos 12.6804° = 0$

$N_B = 1.05075$ lb or $\mathbf{N}_B = 1.051 \text{ lb} \uparrow$ ◀

Chapter 4, Solution 45.

Note: Weight of block is $W = (10\text{ kg})(9.81\text{ m/s}^2) = 98.1\text{ N}$

(*a*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0: \qquad A_x = 0$

$+\uparrow \Sigma F_y = 0: \qquad A_y - 98.1\text{ N} = 0$

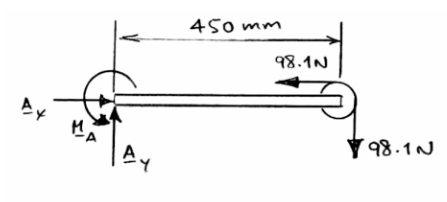
$A_y = 98.1\text{ N}$

Therefore: or $\mathbf{A} = 98.1\text{ N}\uparrow$ ◀

$+\circlearrowleft \Sigma M_A = 0: \qquad M_A - (98.1\text{ N})(0.45\text{ m}) = 0$

$M_A = 44.145\text{ N}\cdot\text{m}$ or $\mathbf{M}_A = 44.1\text{ N}\cdot\text{m} \circlearrowleft$ ◀

(*b*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0: \qquad A_x - 98.1\text{ N} = 0$

$A_x = 98.1\text{ N}$

$+\uparrow \Sigma F_y = 0: \qquad A_y - 98.1\text{ N} = 0$

$A_y = 98.1\text{ N}$

continued

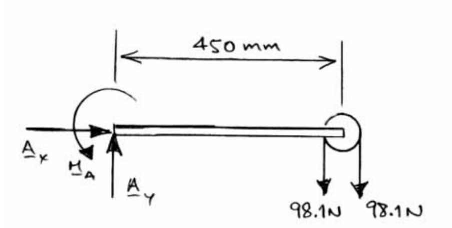
Thus: $A = \sqrt{A_x^2 + A_y^2} = \sqrt{(98.1)^2 + (98.1)^2} = 138.734 \text{ N}$

or $\mathbf{A} = 138.7 \text{ N} \measuredangle 45°$ ◀

$+\circlearrowleft \Sigma M_A = 0: \quad M_A + (98.1 \text{ N})(0.45 \text{ m} + 0.1 \text{ m}) = 0$

$M_A = 44.145 \text{ N}\cdot\text{m}$ or $\mathbf{M}_A = 44.1 \text{ N}\cdot\text{m} \circlearrowleft$ ◀

(*c*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0: \quad A_x = 0$

$+\uparrow \Sigma F_y = 0: \quad A_y - 98.1 \text{ N} - 98.1 \text{ N} = 0$

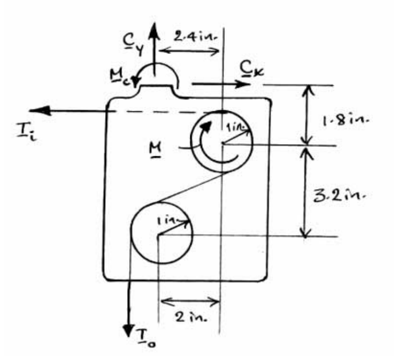
$A_y = 196.2 \text{ N}$ or $\mathbf{A} = 196.2 \text{ N} \uparrow$ ◀

$+\circlearrowleft \Sigma M_A = 0: \quad M_A - (98.1 \text{ N})(0.45 \text{ m} - 0.1 \text{ m}) - (98.1 \text{ N})(0.45 \text{ m} + 0.1 \text{ m}) = 0$

$M_A = 88.290 \text{ N}\cdot\text{m}$ or $\mathbf{M}_A = 88.3 \text{ N}\cdot\text{m} \circlearrowleft$ ◀

Chapter 4, Solution 46.

Free-Body Diagram:



With $M = 0$ and $T_i = T_0 = 12$ lb

$\xrightarrow{+} \Sigma F_x = 0$: $\quad C_x - 12 \text{ lb} = 0$

$C_x = 12$ lb

$+\uparrow \Sigma F_y = 0$: $\quad C_y - 12 \text{ lb} = 0$

$C_Y = 12$ lb

Thus: $C = \sqrt{C_x^2 + C_y^2} = \sqrt{(12)^2 + (12)^2} = 16.9706$ lb

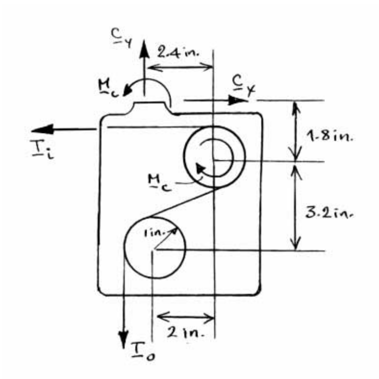
or $\mathbf{C} = 16.97 \text{ lb} \measuredangle 45°$ ◀

$+\circlearrowright \Sigma M_C = 0$: $\quad M_C - (12 \text{ lb})[(1.8 - 1) \text{ in.}] + (12 \text{ lb})[(2 + 1 - 2.4) \text{ in.}] = 0$

$M_C = 2.40 \text{ lb} \cdot \text{in.}$ or $\mathbf{M}_C = 2.40 \text{ lb} \cdot \text{in.} \circlearrowright$ ◀

Chapter 4, Solution 47.

Free-Body Diagram:



With $M = 8$ lb·in. and $T_i = 16$ lb, $T_o = 8$ lb

$\xrightarrow{+} \Sigma F_x = 0$: $C_x - 16 \text{ lb} = 0$

$C_x = 16$ lb

$+\uparrow \Sigma F_y = 0$: $C_y - 8 \text{ lb} = 0$

$C_y = 8$ lb

Thus: $C = \sqrt{C_x^2 + C_y^2} = \sqrt{(16)^2 + (8)^2} = 17.8885$ lb

and $\theta = \tan^{-1}\dfrac{C_y}{C_x} = \tan^{-1}\left(\dfrac{8}{16}\right) = 26.565°$

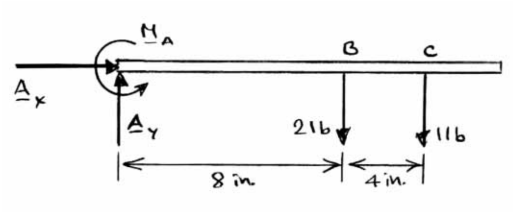
$\therefore$ $\mathbf{C} = 17.89 \measuredangle 26.6°$ ◀

$+\circlearrowright \Sigma M_C = 0$: $M_C - (16 \text{ lb})[(1.8 - 1) \text{ in.}] + (8 \text{ lb})[(2 + 1 - 2.4) \text{ in.}] - 8 \text{ lb}\cdot\text{in.} = 0$

$M_C = 16.00$ lb·in. or $\mathbf{M}_C = 16.00$ lb·in. $\circlearrowright$ ◀

Chapter 4, Solution 48.

(*a*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0$: $A_x = 0$

$+\uparrow \Sigma F_y = 0$: $A_y - 2\text{ lb} - 1\text{lb} = 0$

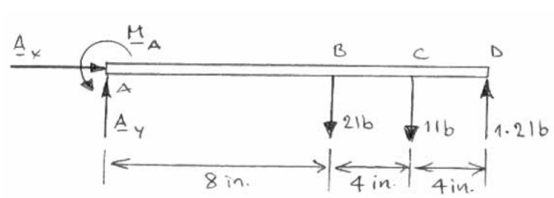
$A_y = 3\text{ lb}$

or $\mathbf{A} = 3\text{ lb}\uparrow$ ◀

$+\circlearrowleft \Sigma M_A = 0$: $M_A - (2\text{ lb})(8\text{ in.}) - (1\text{ lb})(12\text{ in.}) = 0$

$M_A = 28\text{ lb}\cdot\text{in.}$ or $\mathbf{M}_A = 28\text{ lb}\cdot\text{in.}\circlearrowleft$ ◀

(*b*) **Free Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0$: $A_x = 0$

$+\uparrow \Sigma F_y = 0$: $A_y - 2\text{ lb} - 1\text{ lb} + 1.2\text{ lb} = 0$

$A_y = 1.8\text{ lb}$

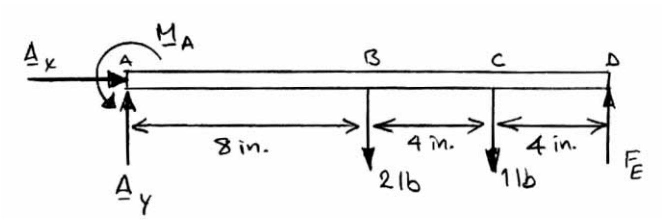
or $\mathbf{A} = 1.8\text{ lb}\uparrow$ ◀

$+\circlearrowleft \Sigma M_A = 0$: $M_A - (2\text{ lb})(8\text{ in.}) - (1\text{ lb})(12\text{ in.}) + (1.2\text{ lb})(16\text{ in.}) = 0$

$M_A = 8.8\text{ lb}\cdot\text{in.}$ or $\mathbf{M}_A = 8.8\text{ lb}\cdot\text{in.}\circlearrowleft$ ◀

Chapter 4, Solution 49.

Free-Body Diagram:



Set $\mathbf{M}_A = 20$ lb·in. counter-clockwise to find $F_{\min}$:

$$+\circlearrowleft \Sigma M_A = 0: \qquad 20 \text{ lb}\cdot\text{in.} - (2 \text{ lb})(8 \text{ in.}) - (1 \text{ lb})(12 \text{ in.}) + F_{\min}(16 \text{ in.}) = 0$$

$$F_{\min} = 0.5 \text{ lb}$$

Set $\mathbf{M}_A = 20$ lb·in. clockwise to find $F_{\max}$:

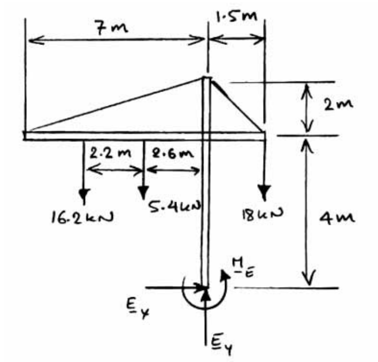
$$+\circlearrowleft \Sigma M_A = 0: \qquad -20 \text{ lb}\cdot\text{in.} - (2 \text{ lb})(8 \text{ in.}) - (1 \text{ lb})(12 \text{ in.}) + F_{\min}(16 \text{ in.}) = 0$$

$$F_{\max} = 3 \text{ lb}$$

Therefore: $0.5 \text{ lb} \le F_E \le 3 \text{ lb}$ ◀

Chapter 4, Solution 50.

(*a*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0$: $E_x = 0$

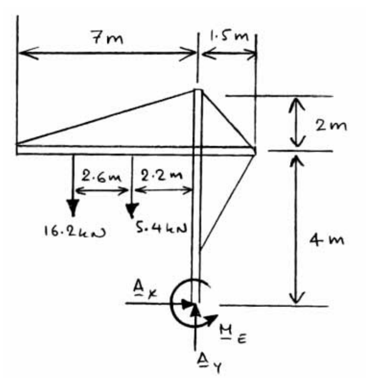
$+\uparrow \Sigma F_y = 0$: $E_y - 16.2 \text{ kN} - 5.4 \text{ kN} - 18 \text{ kN} = 0$

$E_y = 39.6 \text{ kN}$ or $\mathbf{E} = 39.6 \text{ kN} \uparrow$ ◀

$+\circlearrowleft \Sigma M_E = 0$: $M_E + (16.2 \text{ kN})(4.8 \text{ m}) + (5.4 \text{ kN})(2.6 \text{ m}) - (18 \text{ kN})(1.5 \text{ m}) = 0$

$M_E = -64.8 \text{ kN}\cdot\text{m}$ or $\mathbf{M}_E = 64.8 \text{ kN}\cdot\text{m} \circlearrowright$ ◀

(*b*) **Free-Body Diagram:**



$\xrightarrow{+} \Sigma F_x = 0$: $E_x = 0$

$+\uparrow \Sigma F_y = 0$: $E_y - 16.2 \text{ kN} - 5.4 \text{ kN} = 0$

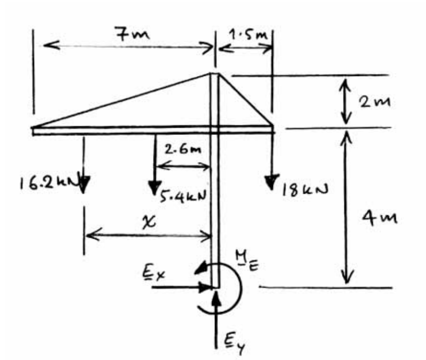
$E_y = 21.6 \text{ kN}$ or $\mathbf{E} = 21.6 \text{ kN} \uparrow$ ◀

$+\circlearrowleft \Sigma M_E = 0$: $M_E + (16.2 \text{ kN})(4.8 \text{ m}) + (5.4 \text{ kN})(2.6 \text{ m}) = 0$

$M_E = -91.8 \text{ kN}\cdot\text{m}$ or $\mathbf{M}_E = 91.8 \text{ kN}\cdot\text{m} \circlearrowright$ ◀

Chapter 4, Solution 51.

Free-Body Diagram:



$+\circlearrowright \Sigma M_E = 0$: $M_E + (16.2 \text{ kN})x + (5.4 \text{ kN})(2.6 \text{ m}) - T(1.5 \text{ m}) = 0$

$$M_E = (1.5\,T - 16.2\,x - 14.04) \text{ kN}\cdot\text{m} \qquad (1)$$

For $x = 0.6$ m, (1) gives:

$$(M_E)_1 = (1.5\,T - 23.76) \text{ kN}\cdot\text{m}$$

For $x = 7$ m, (1) gives:

$$(M_E)_2 = (1.5\,T - 127.44) \text{ kN}\cdot\text{m}$$

(*a*) The maximum absolute value of M_E is obtained when $(M_E)_1 = -(M_E)$ and

$$1.5\,T - 23.76 \text{ kN} = -(1.5\,T - 127.44 \text{ kN})$$

$$T = 50.400 \text{ kN}$$

or $T = 50.4$ kN ◀

(*b*) For this value of T:

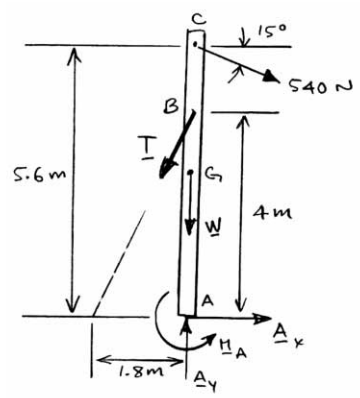
$$M_E = 1.5(50.400) \text{ kN}\cdot\text{m} - 23.76 \text{ kN}\cdot\text{m}$$

$$= 51.84 \text{ kN}\cdot\text{m}$$

or $\mathbf{M}_E = 51.8 \text{ kN}\cdot\text{m} \circlearrowright$ ◀

Chapter 4, Solution 52.

Free-Body Diagram:



Geometry:

Distance $BD = \sqrt{(1.8)^2 + (4)^2} = 4.3863$ m

Note also that: $W = mg = (160\text{ kg})(9.81\text{ m/s}^2) = 1569.60$ N

With $\mathbf{M}_A = 360\ \text{N}\cdot\text{m}$ clockwise: (i.e. corresponding to T_{max})

$$+\circlearrowleft \Sigma M_A = 0: \quad -360\ \text{N}\cdot\text{m} - [(540\text{ N})\cos 15^\circ](5.6\text{ m}) + \left[\left(\frac{1.8}{4.3863}\right)T_{max}\right](4\text{ m}) = 0$$

$T_{max} = 1998.79$ N or $T_{max} = 1.999$ kN ◀

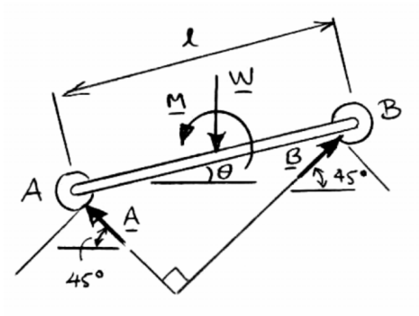
With $\mathbf{M}_A = 360\ \text{N}\cdot\text{m}$ counter-clockwise: (i.e. corresponding to T_{min})

$$+\circlearrowleft \Sigma M_A = 0: \quad 360\ \text{N}\cdot\text{m} - [(540\text{ N})\cos 15^\circ](5.6\text{ m}) + \left[\left(\frac{1.8}{4.3863}\right)T_{min}\right](4\text{ m}) = 0$$

$T_{min} = 1560.16$ N or $T_{min} = 1.560$ kN ◀

Chapter 4, Solution 53.

Free-Body Diagram:



(*a*) Using $W = mg$:

$\xrightarrow{+}$ $\Sigma F_x = 0$: $\quad -A\cos 45° + B\sin 45° = 0$

$$B = A \qquad (1)$$

$+\uparrow$ $\Sigma F_y = 0$: $\quad A\sin 45° + B\sin 45° - mg = 0$

$$A + B = \sqrt{2}mg \qquad (2)$$

From (1) and (2) it follows that

$$2A = \sqrt{2}mg \quad \text{and} \quad A = \frac{1}{\sqrt{2}}mg$$

$+\circlearrowleft$ $\Sigma M_B = 0$: $\quad mg\left[\left(\frac{l}{2}\right)\cos\theta\right] + M - \left(\frac{1}{\sqrt{2}}mg\right)\left[l\cos(45° - \theta)\right] = 0 \qquad (3)$

Using that $\cos(\alpha - \beta) = \cos\alpha\cos\beta + \sin\alpha\sin\beta$, (3) gives

$$\left(\frac{mgl}{2}\right)\cos\theta + M - \left(\frac{mgl}{2}\right)(\cos\theta + \sin\theta) = 0$$

$$M - \left(\frac{mgl}{2}\right)\sin\theta = 0, \text{ and}$$

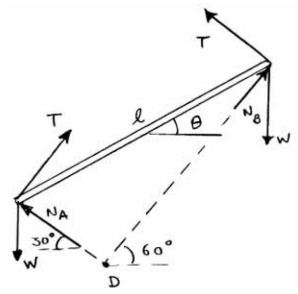
$$\sin\theta = \frac{2M}{mgl} \qquad \text{or } \theta = \sin^{-1}\left(\frac{2M}{mgl}\right) \blacktriangleleft$$

(*b*) $\quad \theta = \sin^{-1}\left[\frac{2(2.7\ \text{N}\cdot\text{m})}{(2\text{kg})(9.81\ \text{m/s}^2)(0.8\ \text{m})}\right] = 20.122° \qquad$ or $\theta = 20.1° \blacktriangleleft$

Vector Mechanics for Engineers: Statics and Dynamics, 8/e, Ferdinand P. Beer, E. Russell Johnston, Jr.,
Elliot R. Eisenberg, William E. Clausen, David Mazurek, Phillip J. Cornwell

Chapter 4, Solution 54.

Free-Body Diagram:



For both parts (*a*) and (*b*)

$$+\circlearrowleft \Sigma M_D = 0: \quad \left[l\cos(\theta + 30°)\cos 30°\right]W - \left[l\cos(\theta + 30°)\right]T$$

$$+\left[l\sin(\theta + 30°)\cos 60°\right]W + \left[l\sin(\theta + 30°)\right]T = 0$$

$$\text{or } W\cos(\theta + 60°) + T\left[\sin(\theta + 30°) - \cos(\theta + 30°)\right] = 0 \qquad (1)$$

(*a*) For $T = 0$, (1) gives

$$\cos(\theta + 60°) = 0 \qquad \text{or } \theta = 30.0° \blacktriangleleft$$

(*b*) For $T = W$, (1) gives:

$$\cos\theta\cos 60° - \sin\theta\sin 60° + \sin\theta\cos 30° + \cos\theta\sin 30°$$

$$-\cos\theta\cos 30° + \sin\theta\sin 30° = 0$$

$$\text{or } \tan\theta\sin 30° + \left(\cos 60° + \sin 30° - \cos 30°\right) = 0$$

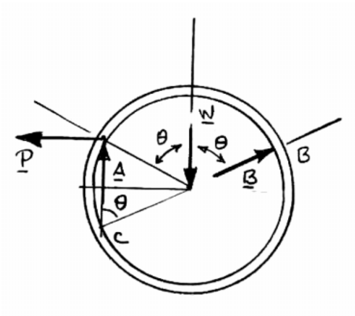
Solving for θ:

$$\tan\theta = 2\left(\cos 30° - 1\right)$$

$$\text{or } \theta = -150000° \qquad \text{or } \theta = -15.00° \blacktriangleleft$$

Chapter 4, Solution 55.

Free-Body Diagram:



Using $W = mg$:

(a) $+\circlearrowleft \Sigma M_C = 0$: $P(R\cos\theta + R\cos\theta) - mg\left(R\sin\theta\right) = 0$

$$2P = mg\tan\theta$$

$$\tan\theta = \frac{2P}{mg} \quad \text{or} \quad \theta = \tan^{-1}\left(\frac{2P}{mg}\right) \blacktriangleleft$$

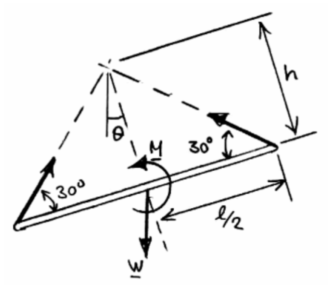
(*b*) With $m = 0.7$ kg and $P = 3$ N:

$$\theta = \tan^{-1}\left[\frac{2(3\text{ N})}{(0.7\text{ kg})(9.81\text{ m/s}^2)}\right]$$

$$= 41.145° \quad \text{or} \quad \theta = 41.1° \blacktriangleleft$$

Chapter 4, Solution 56.

Free-Body Diagram:



Using $W = mg,$ and $h = \dfrac{l}{2}\tan\alpha$

$$+\circlearrowleft \Sigma M_C = 0: \qquad M - (mg)(h\sin\theta) = 0$$

$$\text{or } \sin\theta = \frac{M}{mgh}$$

$$= \frac{M}{mg}\left(\frac{2}{l}\cot\alpha\right)$$

$$\text{or } \theta = \sin^{-1}\left(2M\frac{\cot\alpha}{mgl}\right)$$

Note: $\theta \leq 90° - \alpha$ for cord BC to remain taut, (i.e. for $T_{BC} > 0$).

With $l = 1$ m, $m = 2$ kg, and $M = 3$ N·m:

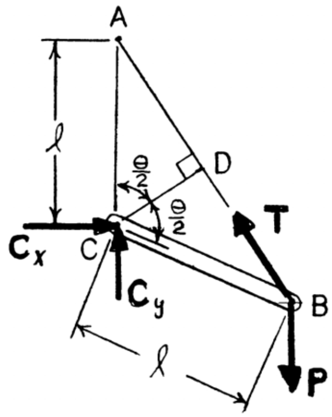
$$\theta = \sin^{-1}\left[\frac{2(3\text{ N}\cdot\text{m})\cot 30°}{(2\text{ kg})(9.81\text{ m/s}^2)(1\text{ m})}\right]$$

$$= 31.984°$$

or $\theta = 32.0°$ ◀

Chapter 4, Solution 57.

Free-Body Diagram:



First note

$$T = \text{tension in spring} = ks$$

where $s = \text{elongation of spring}$

$$= \left(\overline{AB}\right)_\theta - \left(\overline{AB}\right)_{\theta = 90°}$$

$$= 2l\sin\left(\frac{\theta}{2}\right) - 2l\sin\left(\frac{90°}{2}\right)$$

$$= 2l\left[\sin\left(\frac{\theta}{2}\right) - \left(\frac{1}{\sqrt{2}}\right)\right]$$

$$\therefore\quad T = 2kl\left[\sin\left(\frac{\theta}{2}\right) - \left(\frac{1}{\sqrt{2}}\right)\right] \qquad (1)$$

(a) From free-body diagram of rod BC

$$+\circlearrowleft \Sigma M_C = 0:\quad T\left[l\cos\left(\frac{\theta}{2}\right)\right] - P\left(l\sin\theta\right) = 0$$

Substituting T From Equation (1)

$$2kl\left[\sin\left(\frac{\theta}{2}\right) - \left(\frac{1}{\sqrt{2}}\right)\right]\left[l\cos\left(\frac{\theta}{2}\right)\right] - P\left(l\sin\theta\right) = 0$$

$$2kl^2\left[\sin\left(\frac{\theta}{2}\right) - \left(\frac{1}{\sqrt{2}}\right)\right]\cos\left(\frac{\theta}{2}\right) - Pl\left[2\sin\left(\frac{\theta}{2}\right)\cos\left(\frac{\theta}{2}\right)\right] = 0$$

Factoring out $2l\cos\left(\frac{\theta}{2}\right)$, leaves

continued

$$kl\left[\sin\left(\frac{\theta}{2}\right) - \left(\frac{1}{\sqrt{2}}\right)\right] - P\sin\left(\frac{\theta}{2}\right) = 0$$

or

$$\sin\left(\frac{\theta}{2}\right) = \frac{1}{\sqrt{2}}\left(\frac{kl}{kl - P}\right)$$

$$\therefore \quad \theta = 2\sin^{-1}\left[\frac{kl}{\sqrt{2}\left(kl - P\right)}\right] \blacktriangleleft$$

(b) $P = \dfrac{kl}{4}$

$$\theta = 2\sin^{-1}\left[\frac{kl}{\sqrt{2}\left(kl - \frac{kl}{4}\right)}\right] = 2\sin^{-1}\left[\frac{kl}{\sqrt{2}}\left(\frac{4}{3\,\mathrm{kl}}\right)\right] = 2\sin^{-1}\left(\frac{4}{3\sqrt{2}}\right)$$

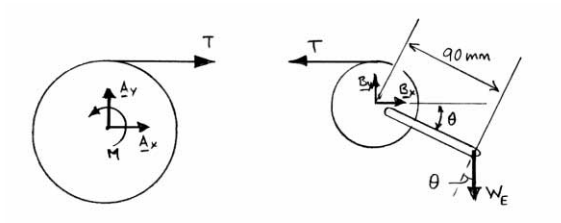
$$= 2\sin^{-1}\left(0.94281\right)$$

$$= 141.058°$$

or $\theta = 141.1° \blacktriangleleft$

Chapter 4, Solution 58.

Free-Body Diagrams:



Note that $W_E = mg = (10\text{ kg})(9.81\text{ m/s}^2) = 98.1\text{ N}$

$$+\circlearrowleft\ \Sigma M_A = 0: \qquad M - r_A T = 0$$

$$T = \frac{M}{r_A} = \frac{(58\text{ N}\cdot\text{m})\phi}{0.035\text{ m}}$$

Since the torsion spring is unstretched when $\theta = 0$:

$$(70\text{ mm})\phi = (35\text{ mm})\theta$$

$$\phi = \frac{1}{2}\theta$$

Therefore:

$$T = \frac{(58\text{ N}\cdot\text{m})\theta}{2(0.035\text{ m})}$$

$$+\circlearrowleft\ \Sigma M_B = 0: \qquad r_B T - lW_E\cos\theta = 0$$

$$(0.070\text{ m})\frac{(58\text{ N}\cdot\text{m})\theta}{2(0.035\text{ m})} - (0.090\text{ m})(98.1\text{ N})\cos\theta = 0$$

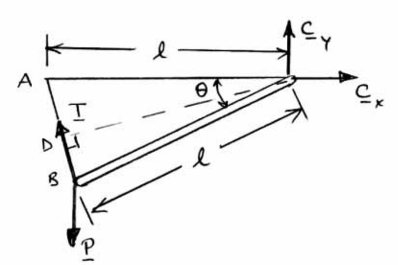
$$\theta = 0.60890\cos\theta$$

Solving for θ numerically:

$\theta = 0.52645$ rad or $\theta = 30.2°$ ◀

Chapter 4, Solution 59.

Free-Body Diagram:



Geometry:

Triangle ABC is isosceles. Thus distance $CD = l\cos\frac{\theta}{2}$,

Elongation of spring is equal to distance AB:

$$x = 2l\sin\frac{\theta}{2},$$

and $T = kx = 2kl\sin\frac{\theta}{2}$.

(a) Equilibrium for rod:

$$+\circlearrowleft \Sigma M_C = 0: \quad P\left(l\cos\theta\right) - T\left(l\cos\frac{\theta}{2}\right) = 0$$

$$Pl\cos\theta - kl^2\left(2\sin\frac{\theta}{2}\cos\frac{\theta}{2}\right) = 0$$

$$P\cos\theta - kl\sin\theta = 0$$

$$\tan\theta = \frac{P}{kl}$$

or $\theta = \tan^{-1}\left(\frac{P}{kl}\right)$ ◀

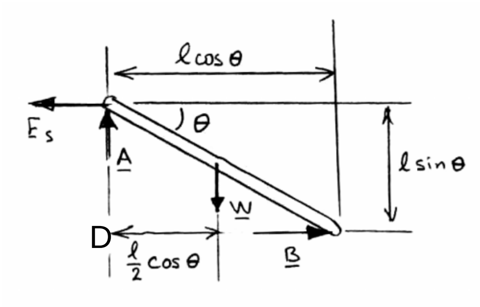
(b) For $p = 2kl$:

$$\theta = \tan^{-1}\left(\frac{2kl}{kl}\right) = \tan^{-1}(2) = 63.435°$$

or $\theta = 63.4°$ ◀

Chapter 4, Solution 60.

Free-Body Diagram:



Spring force: $F_s = ks = k(l - l\cos\theta) = kl(1 - \cos\theta)$

(*a*) $\circlearrowleft + \Sigma M_D = 0$: $\quad F_s(l\sin\theta) - W\left(\frac{l}{2}\cos\theta\right) = 0$

$$kl(\sin\theta - \cos\theta\sin\theta) - \frac{W}{2}\cos\theta = 0$$

$$kl(\tan\theta - \sin\theta) - \frac{W}{2} = 0$$

or $\tan\theta - \sin\theta = \dfrac{W}{2kl}$ ◀

(*b*) For given values of $W = 4$ lb, $l = 30$ in., $k = 1.8$ lb/ft $= 0.15$ lb/in. or 30in = 2.5ft

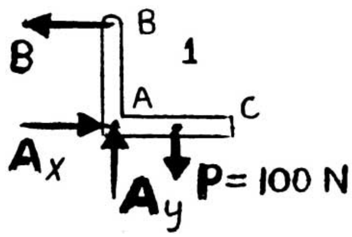
$$\tan\theta - \sin\theta = \frac{4 \text{ lb}}{2(0.15 \text{ lb/in.})(30 \text{ in.})} = 0.44444$$

Solving numerically: $\theta = 50.584°$

or $\theta = 50.6°$ ◀

Chapter 4, Solution 61.

Free-Body Diagram:



1. Three non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

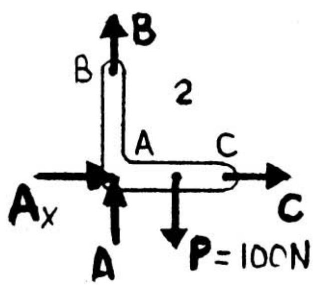
From free-body diagram of bracket:

$$+\circlearrowleft \Sigma M_A = 0: \quad B(1\text{ m}) - (100\text{ N})(0.6\text{ m}) = 0$$

$$\therefore \quad \mathbf{B} = 60.0\text{ N} \longleftarrow \blacktriangleleft$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x - 60\text{ N} = 0$$

$$\therefore \quad \mathbf{A}_x = 60.0\text{ N} \longrightarrow$$



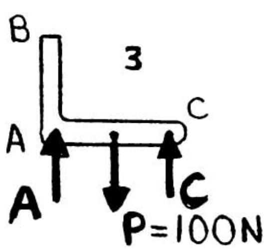
$$+\uparrow \Sigma F_y = 0: \quad A_y - 100\text{ N} = 0$$

$$\therefore \quad \mathbf{A}_y = 100\text{ N} \uparrow$$

Then $$A = \sqrt{(60.0)^2 + (100)^2} = 116.619\text{ N}$$

and $$\theta = \tan^{-1}\left(\frac{100}{60.0}\right) = 59.036°$$

$$\therefore \quad \mathbf{A} = 116.6\text{ N} \measuredangle 59.0° \blacktriangleleft$$



2. Four concurrent reactions through *A*

(*a*) Improperly constrained ◀

(*b*) Indeterminate ◀

(*c*) No equilibrium ◀

3. Two reactions

(*a*) Partially constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

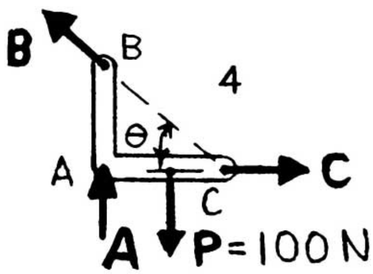
From free-body diagram of bracket

$$+\circlearrowleft \Sigma M_A = 0: \quad C(1.2\text{ m}) - (100\text{ N})(0.6\text{ m}) = 0$$

$\therefore$ **C** $= 50.0$ N $\uparrow$ ◀

$$+\uparrow \Sigma F_y = 0: \quad A - 100\text{ N} + 50\text{ N} = 0$$

$\therefore$ **A** $= 50.0$ N $\uparrow$ ◀



4. Three non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

From free-body diagram of bracket

$$\theta = \tan^{-1}\left(\frac{1.0}{1.2}\right) = 39.8°$$

$$\overline{BC} = \sqrt{(1.2)^2 + (1.0)^2} = 1.56205\text{ m}$$

$$+\circlearrowleft \Sigma M_A = 0: \quad \left[\left(\frac{1.2}{1.56205}\right)B\right](1\text{ m}) - (100\text{ N})(0.6\text{ m}) = 0$$

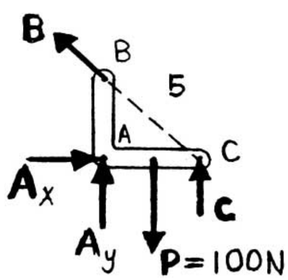
$\therefore$ **B** $= 78.1$ N $\measuredangle$ 39.8° ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad C - (78.102\text{ N})\cos 39.806° = 0$$

$\therefore$ **C** $= 60.0$ N $\longrightarrow$ ◀

$$+\uparrow \Sigma F_y = 0: \quad A + (78.102\text{ N})\sin 39.806° - 100\text{ N} = 0$$

$\therefore$ **A** $= 50.0$ N $\uparrow$ ◀



5. Four non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

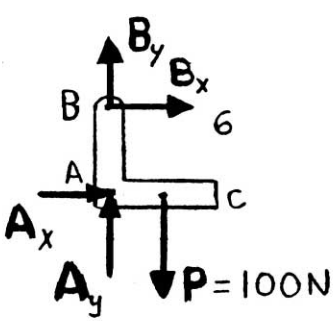
(*b*) Indeterminate ◀

(*c*) Equilibrium ◀

From free-body diagram of bracket

$$+\circlearrowleft \Sigma M_C = 0: \quad (100\text{ N})(0.6\text{ m}) - A_y(1.2\text{ m}) = 0$$

$\therefore A_y = 50$ N or **A**$_y = 50.0$ N $\uparrow$ ◀



6. Four non-concurrent non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Indeterminate ◀

(*c*) Equilibrium ◀

continued

From free-body diagram of bracket

$$+\circlearrowleft \Sigma M_A = 0: \quad -B_x(1\text{ m}) - (100\text{ N})(0.6\text{ m}) = 0$$

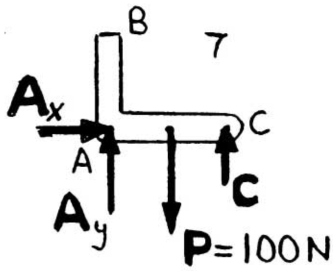
$$\therefore \quad B_x = -60.0\text{ N}$$

$$\text{or } \mathbf{B}_x = 60.0\text{ N} \longleftarrow \blacktriangleleft$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad -60 + A_x = 0$$

$$\therefore \quad A_x = 60.0\text{ N}$$

$$\text{or } \mathbf{A}_x = 60.0\text{ N} \longrightarrow \blacktriangleleft$$



7. Three non-concurrent, non-parallel reactions

(a) Completely constrained ◀

(b) Determinate ◀

(c) Equilibrium ◀

From free-body diagram of bracket

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x = 0$$

$$+\circlearrowleft \Sigma M_A = 0: \quad C(1.2\text{ m}) - (100\text{ N})(0.6\text{ m}) = 0$$

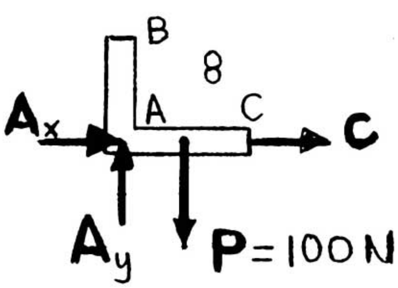
$$\therefore \quad C = 50.0\text{ N}$$

$$\text{or } \mathbf{C} = 50.0\text{ N} \uparrow \blacktriangleleft$$

$$+\uparrow \Sigma F_y = 0: \quad A_y - 100\text{ N} + 50.0\text{ N} = 0$$

$$\therefore \quad A_y = 50.0\text{ N}$$

$$\therefore \quad \mathbf{A} = 50.0\text{ N} \uparrow \blacktriangleleft$$



8. Three concurrent, non-parallel reactions

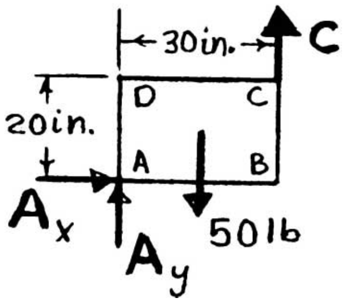
(a) Improperly constrained ◀

(b) Indeterminate ◀

(c) No equilibrium ◀

Chapter 4, Solution 62.

Free-Body Diagram:



1. Three non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

From free-body diagram of plate

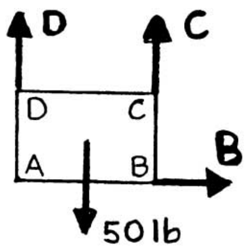
$$+\circlearrowleft \Sigma M_A = 0: \quad C(30 \text{ in.}) - 50 \text{ lb}(15 \text{ in.}) = 0$$

$\mathbf{C} = 25.0 \text{ lb} \uparrow$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x = 0$$

$$+\uparrow \Sigma F_y = 0: \quad A_y - 50 \text{ lb} + 25 \text{ lb} = 0$$

$A_y = 25 \text{ lb}$ $\mathbf{A} = 25.0 \text{ lb} \uparrow$ ◀



2. Three non-current, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

From free-body diagram of plate

$\xrightarrow{+} \Sigma F_x = 0:$ $\mathbf{B} = 0$ ◀

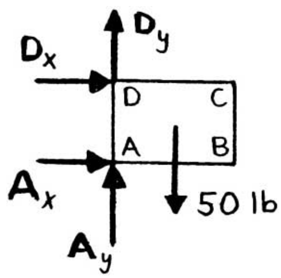
$$+\circlearrowleft \Sigma M_B = 0: \quad (50 \text{ lb})(15 \text{ in.}) - D(30 \text{ in.}) = 0$$

$\mathbf{D} = 25.0 \text{ lb} \uparrow$ ◀

$$+\uparrow \Sigma F_y = 0: \quad 25.0 \text{ lb} - 50 \text{ lb} + C = 0$$

$\mathbf{C} = 25.0 \text{ lb} \uparrow$ ◀

continued



3. Four non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Indeterminate ◀

(*c*) Equilibrium ◀

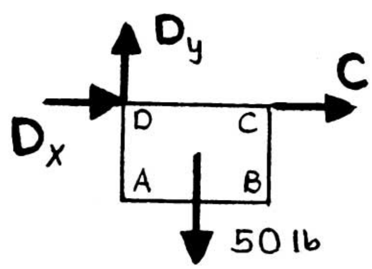
From free-body diagram of plate

$$+\circlearrowright \Sigma M_D = 0: \quad A_x(20 \text{ in.}) - (50 \text{ lb})(15 \text{ in.})$$

$\therefore$ $\mathbf{A}_x = 37.5$ lb $\longrightarrow$ ◀

$$\overset{+}{\longrightarrow} \Sigma F_x = 0: \quad D_x + 37.5 \text{ lb} = 0$$

$\therefore$ $\mathbf{D}_x = 37.5$ lb $\longleftarrow$ ◀



4. Three concurrent reactions

(*a*) Improperly constrained ◀

(*b*) Indeterminate ◀

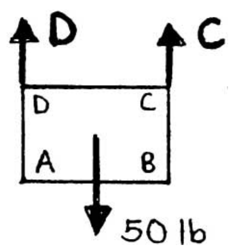
(*c*) No equilibrium ◀

5. Two parallel reactions

(*a*) Partial constraint ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀



From free-body diagram of plate

$$+\circlearrowright \Sigma M_D = 0: \quad C(30 \text{ in.}) - (50 \text{ lb})(15 \text{ in.}) = 0$$

$\mathbf{C} = 25.0$ lb $\uparrow$ ◀

$$+\uparrow \Sigma F_y = 0: \quad D - 50 \text{ lb} + 25 \text{ lb} = 0$$

$\mathbf{D} = 25.0$ lb $\uparrow$ ◀

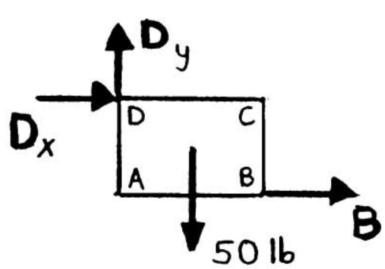
6. Three non-concurrent, non-parallel reactions

(*a*) Completely constrained ◀

(*b*) Determinate ◀

(*c*) Equilibrium ◀

From free-body diagram of plate



$$+\circlearrowright \Sigma M_D = 0: \quad B(20 \text{ in.}) - (50 \text{ lb})(15 \text{ in.}) = 0$$

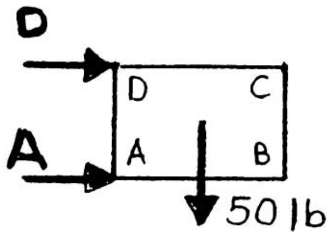
$\mathbf{B} = 37.5$ lb $\longrightarrow$ ◀

$$\overset{+}{\longrightarrow} \Sigma F_x = 0: \quad D_x + 37.5 \text{ lb} = 0 \qquad \mathbf{D}_x = 37.5 \text{ lb} \longrightarrow$$

$$+\uparrow \Sigma F_y = 0: \quad D_y - 50 \text{ lb} = 0 \qquad \mathbf{D}_y = 50.0 \text{ lb} \uparrow$$

or $\mathbf{D} = 62.5$ lb $\measuredangle$ 53.1° ◀

continued



7. Two parallel reactions

(a) Improperly constrained ◀

(b) Reactions determined by dynamics ◀

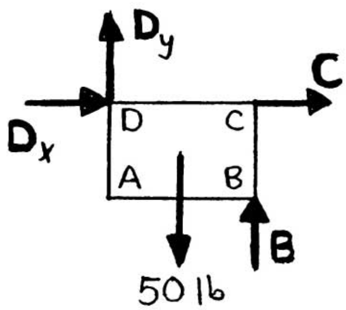
(c) No equilibrium ◀

8. Four non-concurrent, non-parallel reactions

(a) Completely constrained ◀

(b) Indeterminate ◀

(c) Equilibrium ◀



From free-body diagram of plate

$$+\circlearrowleft \Sigma M_D = 0: \quad B(30 \text{ in.}) - (50 \text{ lb})(15 \text{ in.}) = 0$$

$$\mathbf{B} = 25.0 \text{ lb} \uparrow \blacktriangleleft$$

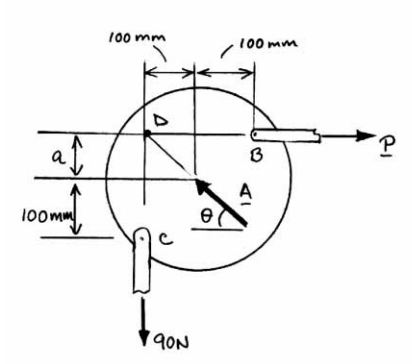
$$+\uparrow \Sigma F_y = 0: \quad D_y - 50 \text{ lb} + 25.0 \text{ lb} = 0$$

$$\mathbf{D}_y = 25.0 \text{ lb} \uparrow \blacktriangleleft$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad D_x + C = 0$$

Chapter 4, Solution 63.

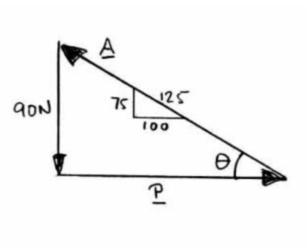
Free-Body Diagram:



Note that the wheel is a three-force body, and let point *D* be the intersection of the three forces.

With $a = 75$ mm, it follows from the force triangle that

$$\frac{A}{125} = \frac{P}{100} = \frac{90\text{ N}}{75}$$



Then:

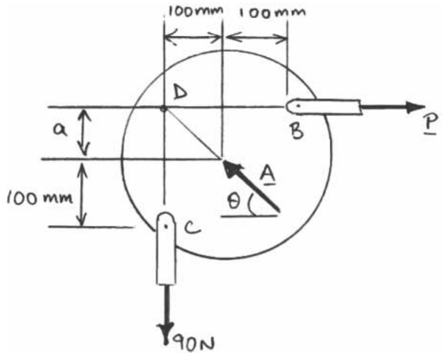
$$P = \frac{100}{75}(90\text{ N}) = 120\text{ N}$$ or $P = 120.0\text{ N}$ ◀

$$A = \frac{125}{75}(90\text{ N}) = 150\text{ N, and}$$

$$\theta = \tan^{-1}\left(\frac{75}{100}\right) = 36.870°$$ or $\mathbf{A} = 150.0\text{ N}$ ⦣ $36.9°$ ◀

Chapter 4, Solution 64.

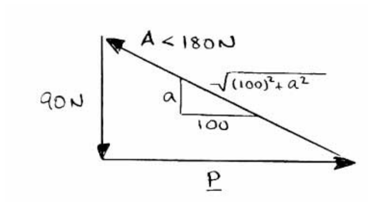
Free-Body Diagram:



Note that the wheel is a three-force body, and let point *D* be the intersection of the three forces.

From the force triangle it follows that

$$\frac{90\text{ N}}{a} = \frac{A}{\sqrt{(100)^2 + (a)^2}}$$



$$A = 90\sqrt{\frac{(100)^2}{\left(a^2\right)} + 1} \qquad (1)$$

Setting $A = 180$ N and solving for *a:*

$$\frac{90\text{ N}}{a} = \frac{180\text{ N}}{\sqrt{(100)^2 + \left(a^2\right)}}$$

$$a^2 = \frac{(100)^2 + \left(a^2\right)}{4}$$

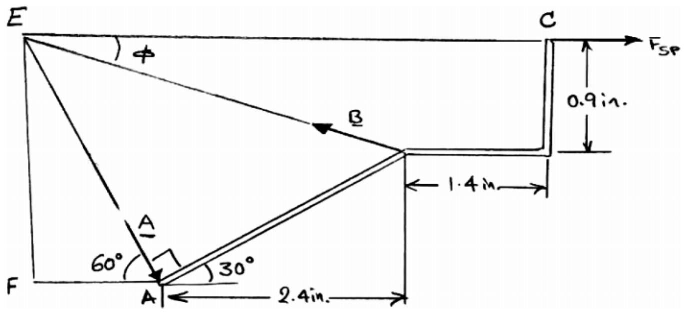
$$a = \sqrt{\frac{(100)^2}{3}} = 57.735\text{ mm}$$

From (1) it follows that *A* will decrease as *a* increases. Therefore the value of *a* calculated is a lower limit:

$a \geq 57.7$ mm ◀

Chapter 4, Solution 65.

Free-Body Diagram:



Geometry:

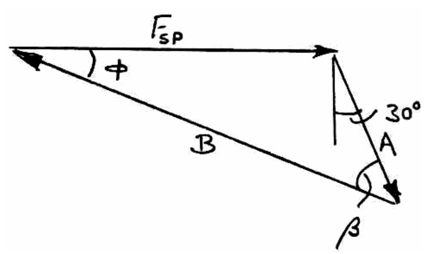
$$EF = \left(2.4\tan 30° + 0.9\right)\text{in.}$$

$$AF = EF\tan 30°$$

$$\tan\phi = \frac{0.9}{\left(2.4\tan 30° + 0.9\right)\tan 30° + 2.4}$$

$$\phi = 13.6019°$$

Equilibrium: force triangle



Using the law of sines on the force triangle:

$$\frac{B}{\sin 120°} = \frac{F_{sp}}{\sin\left(60° - \phi\right)} = \frac{3\text{ lb}}{\sin\phi}$$

$$B = 11.05\text{ lb}$$

$$F_{sp} = 9.2376\text{ lb}$$

(a) $F_{sp} = kx$

$$9.2376\text{ lb} = k\left(1.2\text{ in.}\right)$$

Solving for k:

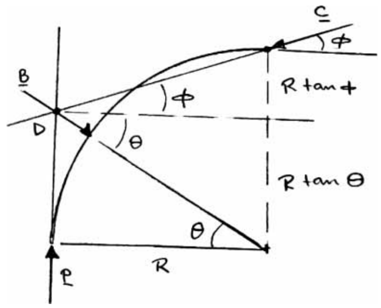
$$k = 7.698\text{ lb/in.}$$

or $k = 7.70$ lb/in. ◀

(b) **B** = 11.05 lb ⦪ 13.60° ◀

Chapter 4, Solution 66.

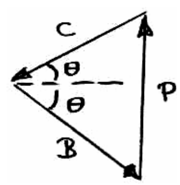
Free-Body Diagram:



Note that the bent rod is a three-force body. D is the point where the lines of action of the three forces intersect.

(a) The requirement $B = C$ means that the force triangle must be isosceles. Therefore $\theta = \phi$.

Which leads to the force triangle shown.



From the geometry it follows that

$$\tan\theta = \frac{1}{2}$$

$$\theta = 26.565°$$ or $\theta = 26.6°$ ◀

(b) From the force triangle:

$$2B\sin\theta = P, \text{ or with } \sin\theta = \frac{1}{\sqrt{5}}$$

$$B = C = \frac{P}{2\left(\frac{1}{\sqrt{5}}\right)} = \frac{\sqrt{5}P}{2}$$

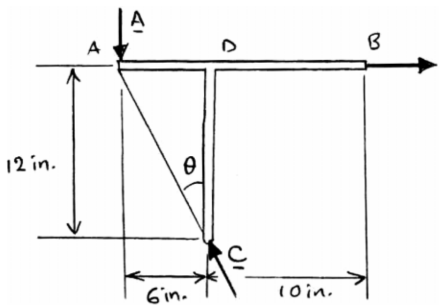
Therefore:

$$\mathbf{B} = \frac{\sqrt{5}P}{2} \ \searrow\ 26.6°$$ ◀

$$\mathbf{C} = \frac{\sqrt{5}P}{2} \ \swarrow\ 26.6°$$ ◀

Chapter 4, Solution 67.

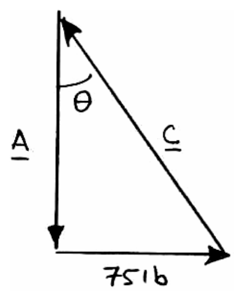
(*a*) **Free-Body Diagram:** $(\alpha = 90°)$



The bracket is a three-force body and *A* is the intersection of the lines of action of the three forces.

$$\theta = \tan^{-1}\left(\frac{6}{12}\right) = 26.565°$$

From the force triangle:



$$A = (75\text{ lb})\cot\theta$$
$$= (75\text{ lb})\cot 26.565°$$
$$= 150.000\text{ lb}$$

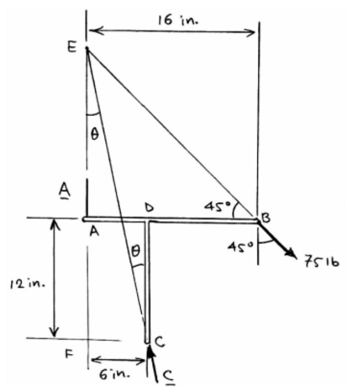
$$C = \frac{75\text{ lb}}{\sin\theta} = \frac{75\text{ lb}}{\sin 26.565°} = 167.705\text{ lb}$$

or **A** = 150.0 lb ↓ ◀

or **C** = 167.7 lb ⦪ 63.4° ◀

continued

(*b*) **Free-Body Diagram:** $(\alpha = 45°)$



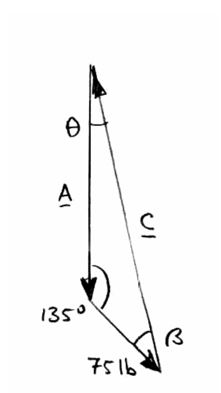
Let E be the intersection of the lines of action of the three forces acting on the bracket.

Triangle ABE is isosceles and therefore

$$AE = AB = 16 \text{ in.}$$

From triangle CEF

$$\theta = \tan^{-1}\left(\frac{CF}{EF}\right) = \tan^{-1}\left(\frac{6}{28}\right) = 12.0948°$$



From force triangle:

$$\beta = 180° - 135° - \theta$$
$$= 180° - 135° - 12.0948°$$
$$= 32.905°$$

Using the law of sines:

$$\frac{A}{\sin 32.905°} = \frac{C}{\sin 135°} = \frac{75 \text{ lb}}{\sin 12.0948°}$$

Solving for A and C:

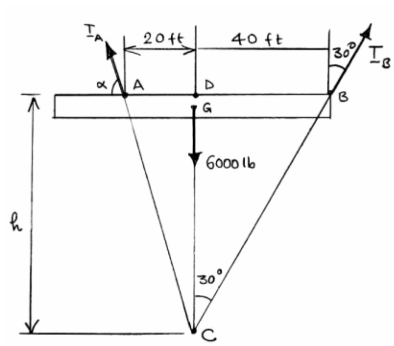
$$A = 194.452 \text{ lb}$$
$$C = 253.10 \text{ lb}$$

or $\mathbf{A} = 194.5$ lb ↓ ◀

or $\mathbf{C} = 253$ lb ⦪ 77.9° ◀

Chapter 4, Solution 68.

Free-Body Diagram:



Let C be the intersection of the lines of action of the three forces acting on the girder

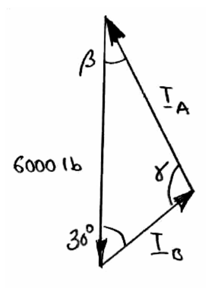
From triangle *BCD:*

$$h = (40\text{ ft})\cot 30° = 69.282\text{ ft}$$

From triangle *ACD:*

$$\alpha = \tan^{-1}\left(\frac{69.282\text{ ft}}{20\text{ ft}}\right) = 73.8979°$$

or $\alpha = 73.9°$ ◀



From force triangle:

$\beta = 90° - \alpha = 90° - 73.8979° = 16.1021°$

$\gamma = 180° - 30° - \beta = 180° - 30° - 16.1021° = 133.898°$

Using the law of sines:

$$\frac{T_A}{\sin 30°} = \frac{T_B}{\sin 16.1021°} = \frac{6000\text{ lb}}{\sin 133.898°}$$

Solving for T_A and T_B:

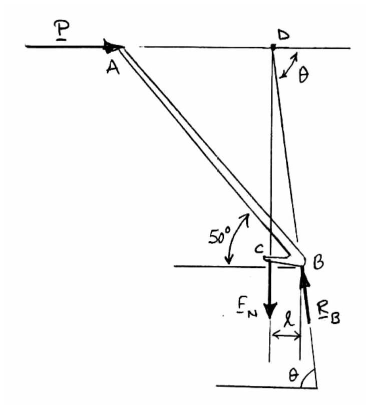
$$T_A = 4163.3\text{ lb}, \qquad T_B = 2309.4\text{ lb}$$

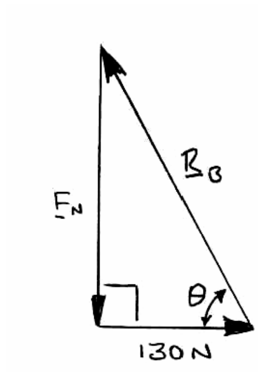
or $T_A = 4160\text{ lb}$ ◀

and $T_B = 2310\text{ lb}$ ◀

Chapter 4, Solution 69.

Free-Body Diagram:





From the free-body diagram:

$$\theta = \tan^{-1}\left[\frac{(900\text{ mm})\sin 50°}{88\text{ mm}}\right] = 82.726°$$

From the force triangle:

$$F_N = (130\text{ N})\tan\theta = (130\text{ N})\tan 82.726° = 1018.48\text{ N}$$

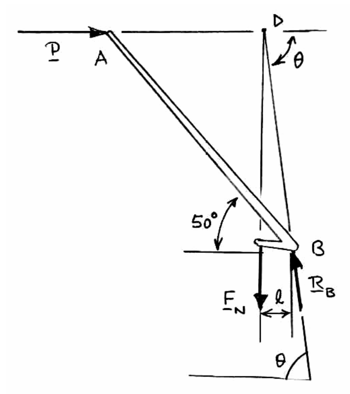
Force on nail is therefore or $\mathbf{F}_N = 1.018$ kN ↑ ◀

$$R_B = \frac{130\text{ N}}{\cos\theta} = \frac{130\text{ N}}{\cos 82.726°} = 1026.74\text{ N}$$

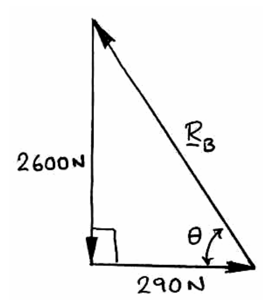
or $\mathbf{R}_B = 1.027$ kN ⦣ 82.7° ◀

Chapter 4, Solution 70.

Free-Body Diagram:



From force triangle:



$$\theta = \tan^{-1}\left(\frac{2600 \text{ N}}{290 \text{ N}}\right) = 83.636°$$

From free-body diagram:

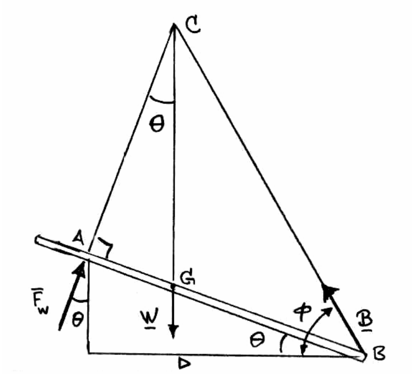
$$\tan\theta = \frac{(900 \text{ mm})\sin 50°}{l}$$

$$l = \frac{(900 \text{ mm})\sin 50°}{\tan 83.636°} = 76.894 \text{ mm}$$

or $l = 76.9$ mm ◀

Chapter 4, Solution 71.

Free-Body Diagram:



We note from the free-body diagram that the ladder is a three-force body. Point *C* in the free-body diagram is the intersection between the lines of action of the three forces.

It then follows that:

$$\sin\theta = \frac{1.75 \text{ m}}{(9.2 - 1.8) \text{ m}}$$

$$\theta = 13.6793°$$

Also:

$$AG = \left(\frac{9.2}{2} - 1.8\right)\text{m} = 2.8 \text{ m}$$

$$BD = \left(\frac{9.2}{2}\text{m}\right)\cos\theta = (4.6 \text{ m})\cos\theta$$

$$CD = CG + GD$$

$$= \frac{AG}{\sin\theta} + BG\sin\theta$$

$$= \frac{2.8}{\sin\theta} + \frac{9.2}{2}\sin\theta$$

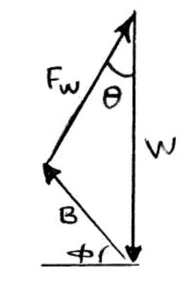
continued

Then

$$\tan\phi = \frac{CD}{BD} = \frac{\dfrac{2.8}{\sin 13.6793^\circ} + 4.6\sin 13.6793^\circ}{4.6\cos 13.6793^\circ}$$

$$\phi = 70.928^\circ$$

Now using the law of sines on the force triangle:



$$\frac{F_W}{\sin(90^\circ - \phi)} = \frac{B}{\sin\theta} = \frac{W}{\sin[\phi + (90^\circ - \theta)]}$$

$$\frac{F_W}{\cos\phi} = \frac{B}{\sin\theta} = \frac{W}{\sin(\phi - \theta)}$$

(*a*) From the law of sines and noting that

$$W = (53\text{ kg})(9.81\text{ m/s}^2) = 519.93\text{ N}$$

$$\frac{F_W}{\cos 70.928^\circ} = \frac{519.93\text{ N}}{\cos(70.928^\circ - 13.6793^\circ)}$$

$$F_W = 314.03\text{ N}$$

or $\mathbf{F}_W = 314\text{ N} \measuredangle\ 76.3^\circ$ ◀

(*b*) In the same way

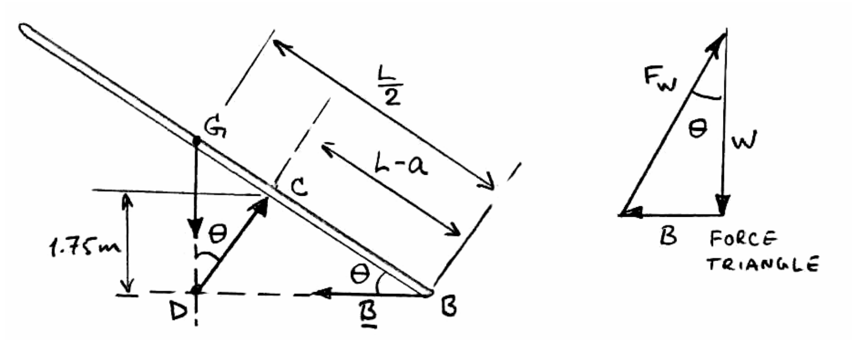
$$\frac{B}{\sin 13.6793^\circ} = \frac{519.93\ N}{\cos(70.928^\circ - 13.6793^\circ)}$$

$$B = 227.28\text{ N}$$

or $\mathbf{B} = 227\text{ N} \searrow 70.9^\circ$ ◀

Chapter 4, Solution 72.

Free-Body Diagram:



We note from the free-body diagram that the ladder is a three-force body. Point *D* in the free-body diagram is the intersection between the lines of action of the three forces.

It then follows that:

$$BD = \frac{9.2\text{ m}}{2}\cos\theta = (4.6\text{ m})\cos\theta =,\text{ but also that}$$

$$BD = \left(1.75\tan\theta + \frac{1.75}{\tan\theta}\right)\text{m}$$

Therefore

$$BD = \frac{9.2\text{ m}}{2}\cos\theta = (4.6\text{ m})\cos\theta$$

This implies:

$$4.6\cos\theta = 1.75\tan\theta + \frac{1.75}{\tan\theta}$$

$$92\sin\theta = 35(1 + \tan^2\theta) = 35\sec^2\theta$$

$$92\sin\theta\cos^2\theta = 35$$

continued

Solving numerically for the smallest possible root:

$$\theta = 31.722°$$

Then $$\sin 31.722° = \frac{1.75}{9.2 - a}$$

$$a = 5.8717 \text{ m}$$ or $a = 5.87$ m ◀

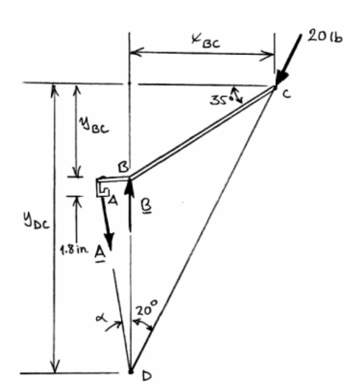
(*b*) From the force triangle

$$F_W = \frac{W}{\cos 31.722°}$$

$$F_W = 611.24 \text{ N}$$ or $\mathbf{F}_W = 611$ N ∠ 58.3° ◀

Chapter 4, Solution 73.

Free-Body Diagram:



Let D be the intersection of the lines of action of the three forces acting on the tool.

From the free-body diagram:

$$y_{DC} = \frac{x_{BC}}{\tan 20°} = \frac{(14.4 \text{ in.})\cos 35°}{\tan 20°} = 32.409 \text{ in.}$$

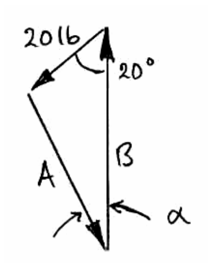
$$y_{BC} = (14.4 \text{ in.})\sin 35° = 8.2595 \text{ in.}$$

$$\alpha = \tan^{-1}\left(\frac{3.6 \text{ in.}}{y_{DC} - y_{BC} - 1.8 \text{ in.}}\right)$$

$$= \tan^{-1}\left[\frac{3.6 \text{ in.}}{(32.409 - 8.2595 - 1.8) \text{ in.}}\right]$$

$$= 9.1505°$$

From the force triangle, using the law of sines:



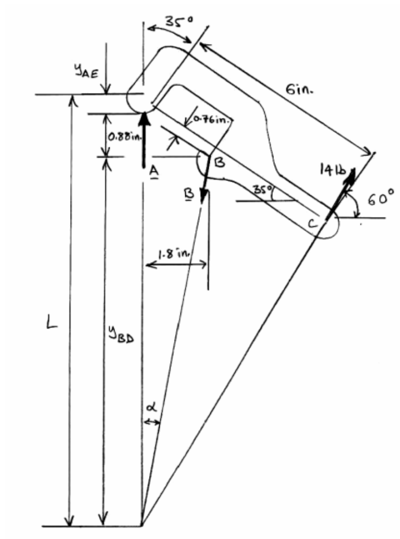
$$\frac{20 \text{ lb}}{\sin\alpha} = \frac{A}{\sin 20°}$$

or $\mathbf{A} = 43.0$ lb

◺ 80.8° on tool, and $\mathbf{A} = 43.0$ lb ◹ 80.8° on rim of can. ◀

Chapter 4, Solution 74.

Free-Body Diagram:



Let E be the intersection of the lines of action of the three forces acting on the tool.

From the free-body diagram, using law of sines:

$$\frac{L}{\sin 95^\circ} = \frac{6\text{ in.} + (0.76\text{ in.})\tan 35^\circ}{\sin 30^\circ}$$

$$L = 13.0146\text{ in.}$$

Also:

$$y_{BD} = L - y_{AE} - 0.88\text{ in.}$$

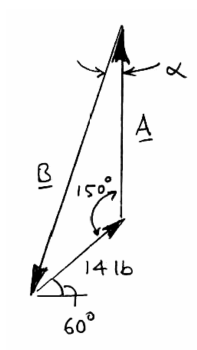
$$= 13.0146\text{ in.} - \frac{0.76\text{ in.}}{\cos 35^\circ} - 0.88\text{ in.}$$

$$= 11.2068\text{ in.}$$

And

$$\alpha = \tan^{-1}\left(\frac{1.8\text{ in.}}{y_{BD}}\right)$$

$$= \tan^{-1}\left(\frac{1.8\text{ in.}}{11.2086\text{ in.}}\right) = 9.1247^\circ$$



Then from the force triangle and using the law of sines:

$$\frac{B}{\sin 150^\circ} = \frac{14\text{ lb}}{\sin 9.1247^\circ}$$

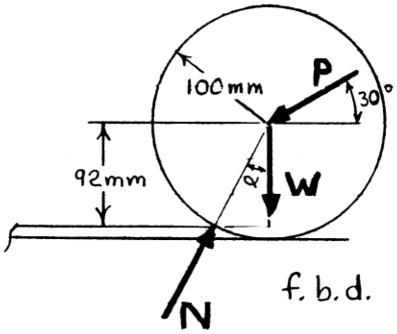
Solving for B:

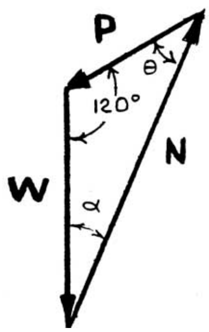
$B = 44.141$ lb, or

on the member $\mathbf{B} = 44.141\text{ lb} \measuredangle 80.9^\circ$, and on the lid $\mathbf{B} = 44.1\text{ lb} \measuredangle 80.9^\circ$ ◀

Chapter 4, Solution 75.

Free-Body Diagram:





Based on the roller having impending motion to the left, the only contact between the roller and floor will be at the edge of the tile.

First note $$W = mg = (20\text{ kg})(9.81\text{ m/s}^2) = 196.2\text{ N}$$

From the geometry of the three forces acting on the roller

$$\alpha = \cos^{-1}\left(\frac{92\text{ mm}}{100\text{ mm}}\right) = 23.074°$$

and $$\theta = 90° - 30° - \alpha$$

$$= 60° - 23.074$$

$$= 36.926°$$

Applying the law of sines to the force triangle,

$$\frac{W}{\sin\theta} = \frac{P}{\sin\alpha}$$

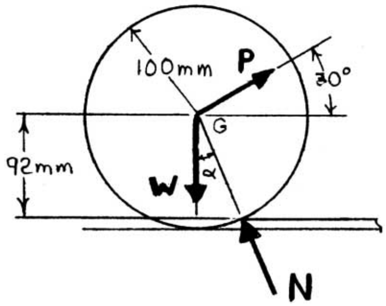
or $$\frac{196.2\text{ N}}{\sin 36.926°} = \frac{P}{\sin 23.074°}$$

$$\therefore P = 127.991\text{ N}$$

or $\mathbf{P} = 128.0\text{ N} \nearrow 30°$ ◀

Chapter 4, Solution 76.

Free-Body Diagram:



Based on the roller having impending motion to the right, the only contact between the roller and floor will be at the edge of the tile.

First note $W = mg = (20\text{ kg})(9.81\text{ m/s}^2)$

$$= 196.2\text{ N}$$

From the geometry of the three forces acting on the roller

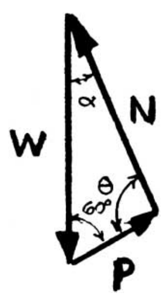
$$\alpha = \cos^{-1}\left(\frac{92\text{ mm}}{100\text{ mm}}\right) = 23.074°$$

and $\theta = 90° + 30° - \alpha$

$$= 120° - 23.074°$$

$$= 96.926°$$

Applying the law of sines to the force triangle,



$$\frac{W}{\sin\theta} = \frac{P}{\sin\alpha}$$

or

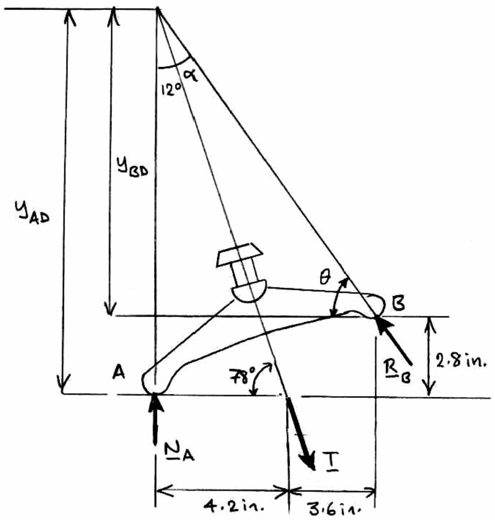
$$\frac{196.2\text{ N}}{\sin 96.926°} = \frac{P}{\sin 23.074}$$

$$\therefore P = 77.460\text{ N}$$

or $\mathbf{P} = 77.5\text{ N} \measuredangle 30°$ ◀

Chapter 4, Solution 77.

Free-Body Diagram:



Note that the clamp is a three-force body. *D* is the intersection of the lines of action of the three forces.

From the free-body diagram it follows that:

$$y_{AD} = (4.2 \text{ in.})\tan 78^\circ = 19.7594 \text{ in.}$$

$$y_{BD} = y_{AD} - 2.8 \text{ in.}$$
$$= (19.7594 - 2.8) \text{ in.} = 16.9594 \text{ in.}$$

Then

$$\theta = \tan^{-1}\left(\frac{y_{BD}}{7.8 \text{ in.}}\right)$$

$$= \tan^{-1}\left(\frac{16.9594 \text{ in.}}{7.8 \text{ in.}}\right) = 65.3013^\circ, \text{ and}$$

$$\alpha = 90^\circ - \theta - 12^\circ$$
$$= 90^\circ - 65.3013^\circ - 12^\circ = 12.6987^\circ$$

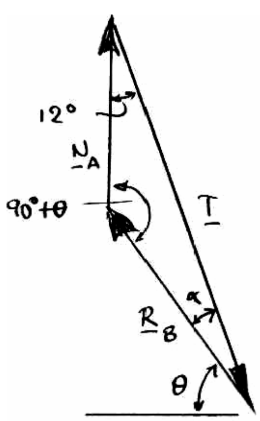
(*a*) Using the maximum allowable compressive force on the clamp:

$$(R_B)_y = R_B \sin\theta = 40 \text{ lb}$$

$$\text{or } R_B = \frac{40 \text{ lb}}{\sin 65.301^\circ} = 44.028 \text{ lb}$$

or $\mathbf{R}_B = 44.0 \text{ lb} \measuredangle 65.3^\circ$ ◀

(*b*) Using the law of sines for the force triangle:



$$\frac{R_B}{\sin 12^\circ} = \frac{N_A}{\sin\alpha} = \frac{T}{\sin(90^\circ + \theta)}$$

$$\frac{44.028 \text{ lb}}{\sin 12^\circ} = \frac{N_A}{\sin 12.6987^\circ} = \frac{T}{\sin 155.301^\circ}$$

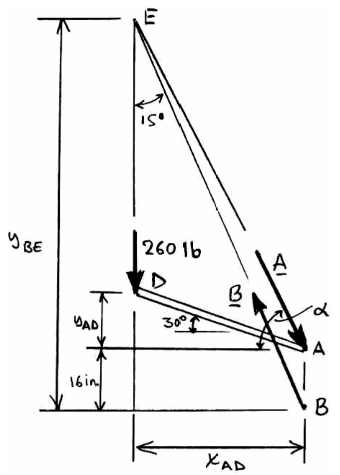
which gives:

$N_A = 46.551 \text{ lb}$ or $\mathbf{N}_A = 46.6 \text{ lb} \uparrow$ ◀

$T = 88.485 \text{ lb}$ or $T = 88.5 \text{ lb}$ ◀

Chapter 4, Solution 78.

Free-Body Diagram: (for hoist AD)



Note that the hoist AD is a three-force body.

E is the intersection between the lines of action of the three forces acting on the hoist.

From the free-body diagram:

$$x_{AE} = (48 \text{ in.})\cos 30° = 41.5692 \text{ in.}$$

$$y_{AD} = (48 \text{ in.})\sin 30° = 24 \text{ in.}$$

$$y_{BE} = x_{AD}\tan 75° = (41.5692 \text{ in.})\tan 75°$$

$$= 155.1384 \text{ in.}$$

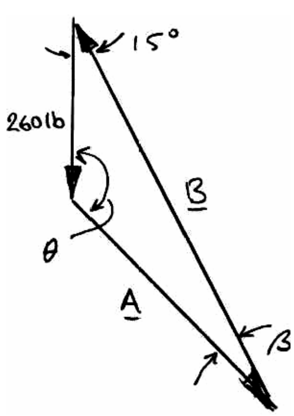
Then:

$$\alpha = \tan^{-1}\left(\frac{y_{BE} - 16 \text{ in.}}{x_{AD}}\right) = \tan^{-1}\left(\frac{139.1384}{41.5692}\right)$$

$$= 73.36588°$$

$$\beta = 75° - \alpha = 75° - 73.36588° = 1.63412°$$

$$\theta = 180° - 15° - \beta = 165° - 1.63412° = 163.366°$$



From the force triangle and using the law of sines:

$$\frac{260 \text{ lb}}{\sin\beta} = \frac{B}{\sin\theta} = \frac{A}{\sin 15°}$$

$$\frac{260 \text{ lb}}{\sin 1.63412°} = \frac{B}{\sin 163.366°} = \frac{A}{\sin 15°}$$

Solving for A and B:

(a) $B = 2609.9$ lb

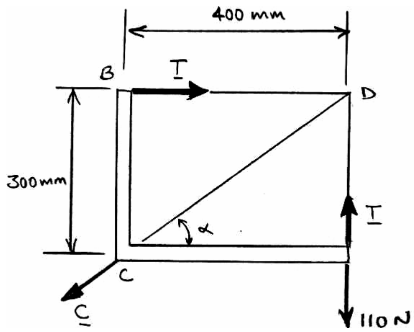
or $\mathbf{B} = 2.61$kips ⦪ $75.0°$ ◀

(b) $A = 2359.8$ lb

or $\mathbf{A} = 2.36$ kips ⦫ $73.4°$ ◀

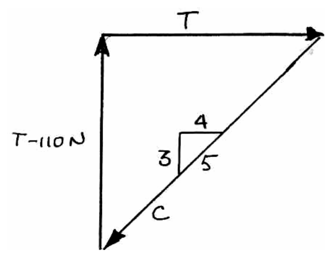
Chapter 4, Solution 79.

Free-Body Diagram:



Note that the member is a three-force body. In the free-body diagram, D is the intersection between the lines of action of the three forces.

(*a*) From the force triangle:



$$\frac{T - 110\text{ N}}{T} = \frac{3}{4}$$

$$3T = 4T - 440\text{ N}$$

$T = 440$ N ◀

(*b*) From the force triangle:

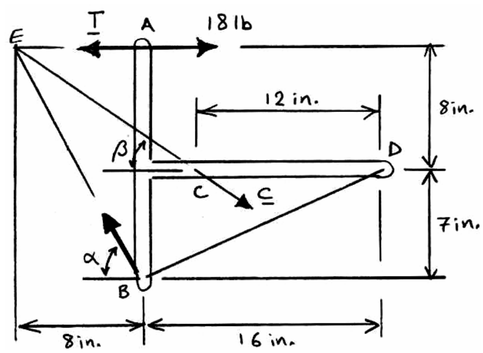
$$\frac{C}{T} = \frac{5}{4}$$

$$C = \frac{5}{4}T = \frac{5}{4}(440\text{ N}) = 550\text{ N}$$

or **C** = 550 N ↙ 36.9° ◀

Chapter 4, Solution 80.

Free-Body Diagram:



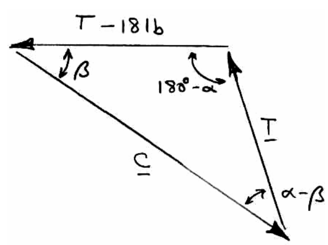
Note that the member is a three-force body. In the free-body diagram, *E* is the intersection between the lines of action of the three forces.

From the free-body diagram:

$$\alpha = \tan^{-1}\left(\frac{15}{8}\right) = 61.928°$$

$$\beta = \tan^{-1}\left(\frac{8}{12}\right) = 33.690°$$

From the force triangle:



$$\alpha - \beta = 61.928° - 33.690° = 28.238°$$

$$180° - \alpha = 180° - 61.928° = 118.072°$$

Using the law of sines:

$$\frac{T - 18 \text{ lb}}{\sin(\alpha - \beta)} = \frac{T}{\sin\beta} = \frac{C}{\sin(180° - \alpha)}$$

$$\frac{T - 18 \text{ lb}}{\sin(22.238°)} = \frac{T}{\sin(33.690°)} = \frac{C}{\sin(118.072°)}$$

Then:

$$(T - 18 \text{ lb})\sin(33.690°) = T\sin(28.238°)$$

$$T = 122.414 \text{ lb}$$

or $T = 122.4$ lb ◀

and $(122.414 \text{ lb})\sin(118.072°) = C\sin(33.690°)$

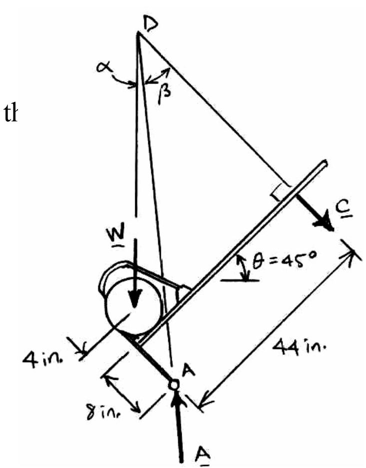
$$C = 194.723 \text{ lb}$$

or $\mathbf{C} = 194.7$ lb ⦪ 33.7° ◀

Chapter 4, Solution 81.

Free-Body Diagram:

It tl

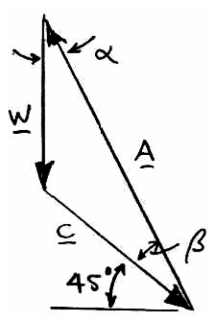


Note that the peavey is a three-force body.

In the free-body diagram, D is the intersection of the lines of action of the three forces acting on the peavey.

$$\beta = \tan^{-1}\left(\frac{44 \text{ in.}}{44 \text{ in.} + 8 \text{ in.}}\right) = 40.2364°$$

$$\alpha = 45° - \beta = 45° - 40.2364° = 4.7636°$$



From the force triangle, using the law of sines:

$$\frac{W}{\sin\beta} = \frac{C}{\sin\alpha} = \frac{A}{\sin 135°}$$

$$\frac{80 \text{ lb}}{\sin 40.236°} = \frac{C}{\sin 4.7636°} = \frac{A}{\sin 135°}$$

Solving for C and A:

(a) $C = 10.2852$ lb

or $\mathbf{C} = 10.29$ lb ⦪ 45.0° ◀

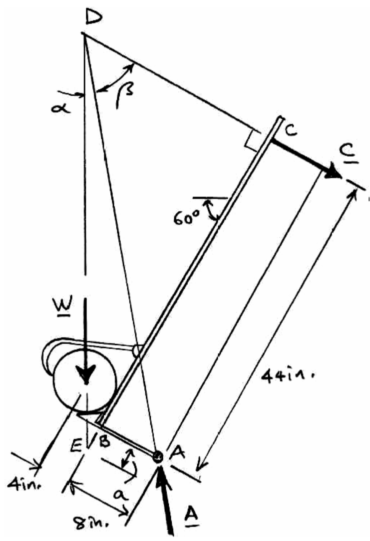
(b) $A = 87.576$ lb

or $\mathbf{A} = 87.6$ lb ⦩ 85.2° ◀

Chapter 4, Solution 82.

Free-Body Diagram:

Note that the peavey is a three-force body.



In the free-body diagram, D is the intersection of the lines of action of the three forces acting on the peavey.

$$\beta = \tan^{-1}\left(\frac{44 \text{ in.}}{DC + 8 \text{ in.}}\right)$$

where $DC = (44 \text{ in.} + a)\tan 30°$

$$a = \left(\frac{R}{\tan 30°}\right) - R$$

$$= \left(\frac{4 \text{ in.}}{\tan 30°}\right) - 4 \text{ in.}$$

$$= 2.9282 \text{ in.}$$

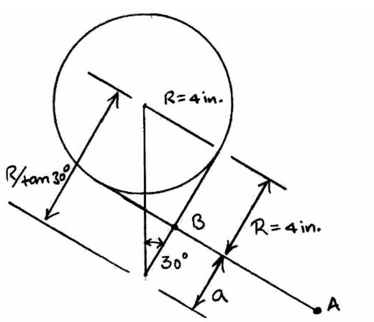
Then:

$$DC = (46.9282 \text{ in.})\tan 30° = 27.0940 \text{ in.}$$

and

$$\beta = \tan^{-1}\left(\frac{44 \text{ in.}}{35.0940 \text{ in.}}\right) = 51.4245°$$

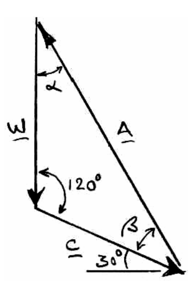
$$\alpha = 60° - \beta = 60° - 51.4245° = 8.5755°$$



Now from the force triangle, using the law of sines:

$$\frac{W}{\sin\beta} = \frac{C}{\sin\alpha} = \frac{A}{\sin 120°}$$

$$\frac{80 \text{ lb}}{\sin 51.424°} = \frac{C}{\sin 8.5755°} = \frac{A}{\sin 120°}$$



Solving for C and A:

(a) $C = 15.2587$ lb

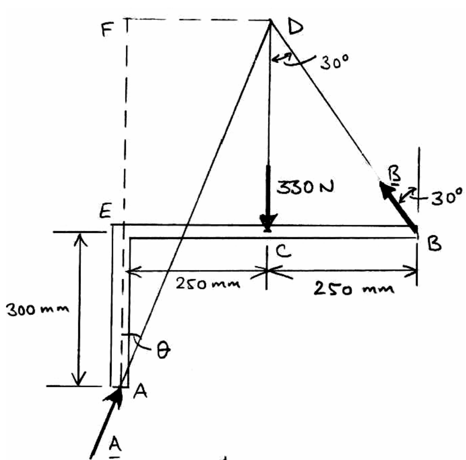
or $\mathbf{C} = 15.26$ lb ⦨ 30.0° ◀

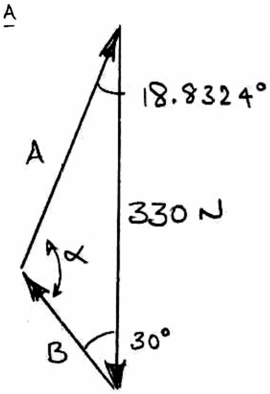
(b) $A = 88.621$ lb

or $\mathbf{A} = 88.6$ lb ⦪ 81.4° ◀

Chapter 4, Solution 83.

Free-Body Diagram:





From the free-body diagram, the member AB is a three-force body. Let D be the intersection of the lines of action of the three forces acting on AB. Then, using triangle BCD:

$$CD = (250 \text{ mm})\tan 60° = 433.01 \text{ mm}$$

Also:

$$AF = AE + EF = AE + CD$$
$$= (300 + 433.01) \text{ mm}$$
$$= 733.01 \text{ mm}$$

$$\theta = \tan^{-1}\frac{FD}{AF} = \tan^{-1}\frac{250}{733.01}$$
$$= 18.8324°$$

From the force triangle

$$\alpha = 180° - 30° - 18.8324°$$
$$= 131.168°$$

Using the law of sines

$$\frac{A}{\sin 30°} = \frac{B}{\sin 18.8324°} = \frac{330 \text{ N}}{\sin 131.168°}$$

Solving for A and B:

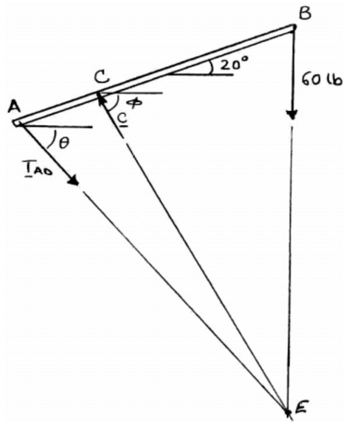
$$A = 219.19 \text{ N}, \quad B = 141.507 \text{ N}$$

or **A** = 219 N ⦣ 71.2° ◀

or **B** = 141.5 N ⦪ 60.0° ◀

Chapter 4, Solution 84.

Free-Body Diagram:



From the free-body diagram it follows that

$$\tan\theta = \frac{9.6 - 8\sin 20°}{8\cos 20°}$$

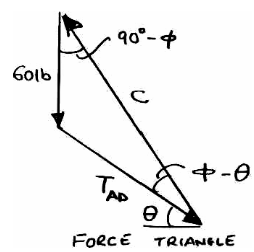
$$\theta = 42.397°$$

Also:

$$BE = 20\sin 20° + (20\cos 20°)\tan 42.397° = 12\sin 20°(12\cos 20°)\tan\phi$$

$$\phi = 60.456°$$

Then using the law of sines on the force triangle:



$$\frac{T_{AD}}{\sin(90° - \phi)} = \frac{C}{\sin(90° + \theta)} = \frac{60 \text{ lb}}{\sin(\phi - \theta)}$$

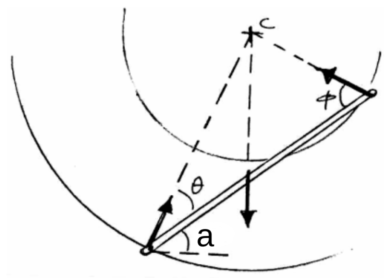
$$\frac{T_{AD}}{\cos 60.456°} = \frac{C}{\cos 42.397°} = \frac{60 \text{ lb}}{\sin 18.059°}$$

(*a*) $T_{AD} = 95.438$ lb — or $T_{AD} = 95.41$ lb ◀

(*b*) $C = 142.935$ lb — or **C** = 142.935 lb ⦪ 60.5° ◀

Chapter 4, Solution 85.

Free-Body Diagram:



(*a*) Using the law of cosines on triangle *ABC*:

$$R^2 = (2R)^2 + (2R)^2 - 2(2R)(2R)\cos\theta$$

$$1 = 8 - 8\cos\theta$$

$$\cos\theta = \frac{7}{8}$$

$$\theta = 28.955°$$

Also,

$$2R\cos(\theta + \alpha) = R\cos\alpha$$

$$2R(\cos\theta\cos\alpha - \sin\theta\sin\alpha) = R\cos\alpha$$

$$\tan\alpha = \frac{2\cos\theta - 1}{2\sin\theta} = \frac{2\cos 28.955° - 1}{2\sin 28.955°}$$

$$\alpha = 37.761°$$

or $\alpha = 37.8°$ ◀

(*b*) From the free-body diagram:

$$\frac{2R}{\sin\phi} = \frac{R}{\sin\theta}$$

$$\sin\phi = 2\sin\theta = 2\sin 28.955°$$

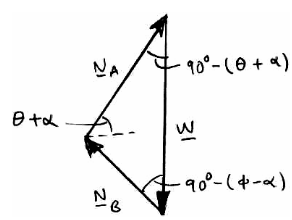
$$\phi = 75.522°$$

Now using the law of sines on the force triangle:

$$\frac{N_A}{\sin[90° - (\phi - \alpha)]} = \frac{N_B}{\sin[90° - (\theta + \alpha)]} = \frac{W}{\sin[(\theta + \alpha) + (\phi - \alpha)]}$$

$$\frac{N_A}{\cos(\phi - \alpha)} = \frac{N_B}{\cos(\theta + \alpha)} = \frac{mg}{\sin(\theta + \phi)}$$

$$\frac{N_A}{\cos 37.762°} = \frac{N_B}{\cos 66.716°} = \frac{mg}{\sin 104.478°}$$



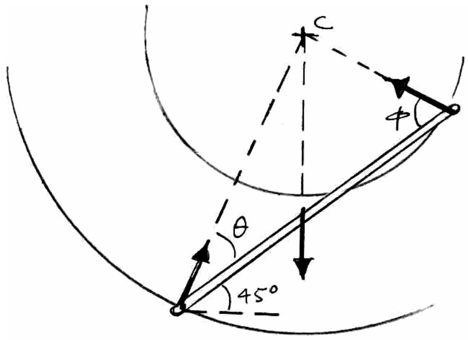
Solving for N_A and N_B:

$\mathbf{N}_A = 0.816$ mg ∠ 66.7° ◀

$\mathbf{N}_B = 0.408$ mg ∖ 37.8° ◀

Chapter 4, Solution 86.

Free-Body Diagram:



(a) Note that the rod is a three-force body. Using the law of cosines on triangle ABC:

$$R^2 = (2R)^2 + L^2 - 2(2R)L\cos\theta$$

$$\cos\theta = \frac{3R^2 + L^2}{4RL} \qquad (1)$$

Also,

$$\frac{L}{2}\cos 45° = 2R\cos(\theta + 45°)$$

$$\frac{L}{2}\cos 45° = 2R(\cos\theta\cos 45° - \sin\theta\sin 45°)$$

$$\frac{L}{4R} = \cos\theta - \sin\theta$$

Using (1) and that $\sin\theta = \sqrt{1 - \cos^2\theta}$

$$\sin\theta = \frac{\sqrt{(4RL)^2 - (3R^2 + L^2)^2}}{4RL}, \text{ this gives}$$

continued

$$\frac{L}{4R} = \frac{3R^2 + L^2}{4RL} - \frac{\sqrt{(4RL)^2 - \left(3R^2 + L^2\right)^2}}{4RL}$$

$$L^2 - \left(3R^2 + L^2\right) = -\sqrt{(4RL)^2 - \left(3R^2 + L^2\right)^2}$$

Squaring both sides and simplifying:

$$9R^4 = 16R^2L^2 - \left(9R^4 + 6R^2L^2 + L^4\right), \text{ or}$$

$$L^4 - 10R^2L^2 + 18R^4 = 0$$

Solving for L^2:

$$L^2 = \left(5 \pm \sqrt{7}\right)R^2, \text{ and taking the largest root}$$

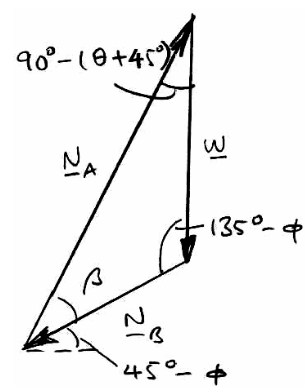
$$L^2 = \left(5 + \sqrt{7}\right)R^2$$

or $L = 2.77R$ ◀

(*b*) Using the value of *L* obtained in (*a*) and (1)

$$\cos\theta = \frac{3R^2 + \left(5 + \sqrt{7}\right)R^2}{4R\left(5 + \sqrt{7}\right)^{1/2} R}$$

$$\theta = 15.7380°$$



Now using the law of sines on triangle *ABC* in the free body diagram:

$$\frac{2R}{\sin\phi} = \frac{R}{\sin\theta}$$

$$\sin\phi = 2\sin\theta = 2\sin 15.7380°$$

$$\phi = 32.852°$$

Now using the law of sines on the force triangle:

$$\frac{N_A}{\cos(135° - 32.852°)} = \frac{N_B}{\sin(45° - 15.7380°)} = \frac{mg}{\sin(15.7380° + 32.852°)}$$

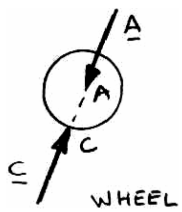
Solving for N_A and N_B:

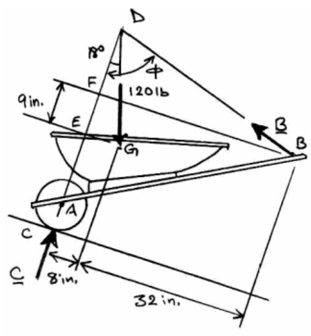
$\mathbf{N}_A = 1.303$ mg ⦣ 60.7° ◀

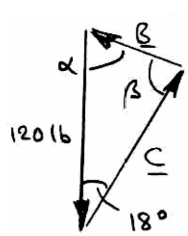
$\mathbf{N}_B = 0.652$ mg ⦤ 12.15° ◀

Chapter 4, Solution 87.

Free-Body Diagram:







Note that the wheel is a two-force body and therefore the force at *C* is directed along *CA* and perpendicular to the incline.

The wheelbarrow is a three-force body. Let *D* be the intersection of the lines of action of the three forces acting on the wheelbarrow. Then, using the triangle *DEG*

$$DE = EG\tan 72° = (8\text{ in.})\tan 72° = 24.6215\text{ in.}$$

$$DF = DE - EF = 24.6215\text{ in.} - 9\text{ in.} = 15.6215\text{ in.}$$

Using triangle *DFB*:

$$\phi = \tan^{-1}\frac{FB}{DF} = \tan^{-1}\left(\frac{40}{15.6215}\right) = 68.667°$$

From the force triangle:

$$\alpha = \phi - 18° = 68.667° - 18° = 50.667°$$

$$\beta = 180° - 50.667° - 18° = 111.333°$$

Using the law of sines:

$$\frac{B}{\sin 18°} = \frac{C}{\sin 50.667°} = \frac{120\text{ lb}}{\sin 111.333°}$$

$$B = 39.809\text{ lb}, \qquad C = 9.644\text{ lb}$$

(*a*) Noting that the force on each handle is *B/2*:

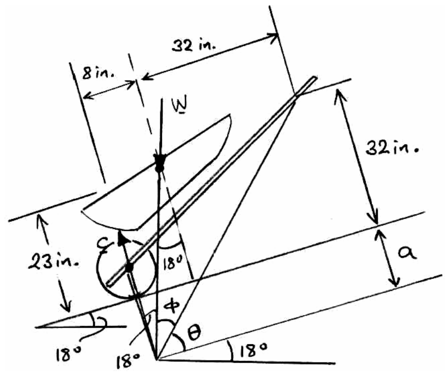
$$\frac{1}{2}\mathbf{B} = 19.90\text{ lb} \;\searrow\; 39.3° \blacktriangleleft$$

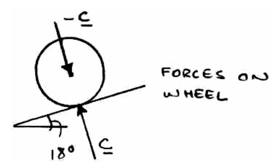
(*b*) Reaction at *C*:

$$\mathbf{C} = 99.6\text{ lb} \;\measuredangle\; 72.0° \blacktriangleleft$$

Chapter 4, Solution 88.

Free-Body Diagram:





From the free-body diagram:

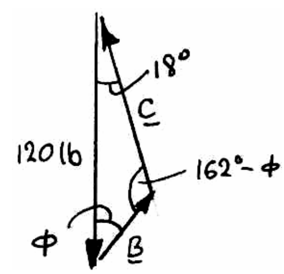
$$a = (40 \text{ in.})\tan\theta - 32 \text{ in.} = \frac{8 \text{ in.} - (23 \text{ in.})\tan 18°}{\tan 18°}$$

$$\theta = 40.048°$$

Then,

$$\phi = 90° - 18° - 40.048° = 31.952°$$

Now, using the law of sines on the force triangle:



$$\frac{2(B/2)}{\sin 18°} = \frac{C}{\sin 31.952°} = \frac{120 \text{ lb}}{\sin(162° - 31.952°)}$$

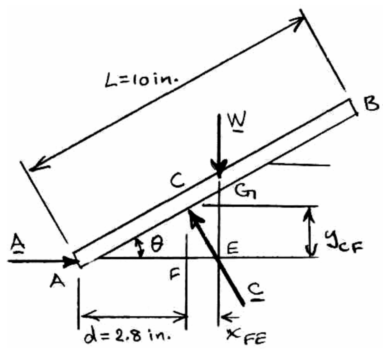
and solving for *B/2* and *C*:

(*a*) $\frac{1}{2}\mathbf{B} = 24.2$ lb ⦣ 58.0° ◀

(*b*) $\mathbf{C} = 83.0$ lb ⦨ 72.0° ◀

Chapter 4, Solution 89.

Free-Body Diagram:



Note that the rod is a three-force body. In the free-body diagram, E is the intersection between the lines of action of the three forces.

Using triangle ACF in the free-body diagram:

$$y_{CF} = d\tan\theta$$

From triangle CEF:

$$x_{FE} = y_{CF}\tan\theta = d\tan^2\theta$$

?!

and from triangle AGE:

$$\cos\theta = \frac{d + x_{FE}}{\left(\frac{L}{2}\right)} = \frac{d + d\tan^2\theta}{\left(\frac{L}{2}\right)} \qquad (1)$$

Noting that $1 + \tan^2\theta = \sec^2\theta = \dfrac{1}{\cos^2\theta}$

(1) gives

$$\cos\theta = \frac{2d}{L}\left(\frac{1}{\cos^2\theta}\right), \text{ or}$$

$$\cos^3\theta = \frac{2d}{L}$$

Using the given values of $d = 2.8$ in., and $L = 10$ in.

$$\cos^3\theta = \frac{2(2.8 \text{ in.})}{10 \quad \text{in.}} = 0.56$$

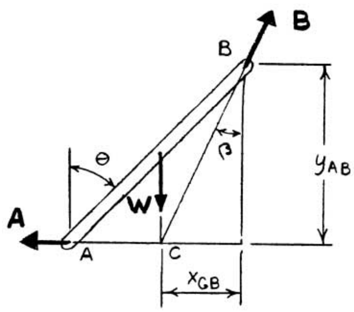
$$\cos\theta = 0.82426$$

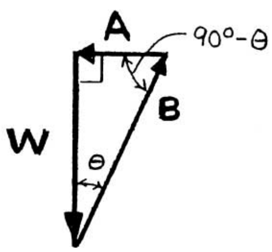
$$\theta = 34.486°$$

or $\theta = 34.5°$ ◀

Chapter 4, Solution 90.

Free-Body Diagram:





As shown in the free-body diagram of the slender rod *AB*, the three forces intersect at *C*. From the force geometry

$$\tan\beta = \frac{x_{GB}}{y_{AB}}$$

where

$$y_{AB} = L\cos\theta$$

and

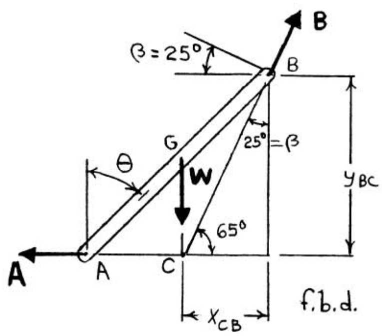
$$x_{GB} = \frac{1}{2}L\sin\theta$$

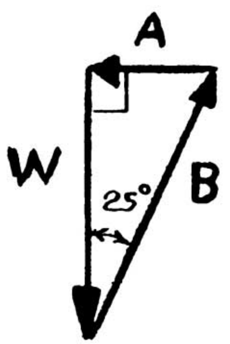
$$\therefore \quad \tan\beta = \frac{\frac{1}{2}L\sin\theta}{L\cos\theta} = \frac{1}{2}\tan\theta$$

or $\tan\theta = 2\tan\beta$ ◀

Chapter 4, Solution 91.

Free-Body Diagram





(*a*) As shown in the free-body diagram. of the slender rod *AB*, the three forces intersect at *C*. From the geometry of the forces

$$\tan\beta = \frac{x_{CB}}{y_{BC}}$$

where

$$x_{CB} = \frac{1}{2}L\sin\theta$$

and

$$y_{BC} = L\cos\theta$$

$$\therefore \quad \tan\beta = \frac{1}{2}\tan\theta$$

or

$$\tan\theta = 2\tan\beta$$

For

$$\beta = 25°$$

$$\tan\theta = 2\tan 25° = 0.93262$$

$$\therefore \quad \theta = 43.003°$$

or $\theta = 43.0°$ ◀

(*b*) $W = mg = (10\text{ kg})(9.81\text{ m/s}^2) = 98.1\text{ N}$

From force triangle

$$A = W\tan\beta$$

$$= (98.1\text{ N})\tan 25°$$

$$= 45.745\text{ N}$$

or $\mathbf{A} = 45.7\text{ N} \longleftarrow$ ◀

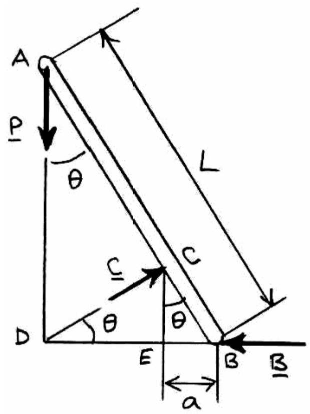
and

$$B = \frac{W}{\cos\beta} = \frac{98.1\text{ N}}{\cos 25°} = 108.241\text{ N}$$

or $\mathbf{B} = 108.2\text{ N} \measuredangle 65.0°$ ◀

Chapter 4, Solution 92.

Free-Body Diagram:



Note that the rod is a three-force body. In the free-body diagram, *D* is the intersection between the lines of action of the three forces.

Using triangle *BCE*:

$$a = BE = BC\sin\theta$$

and from triangle *BCD*

$$BC = BD\sin\theta$$

Then $a = BD\sin^2\theta$

Also from triangle *ABD*

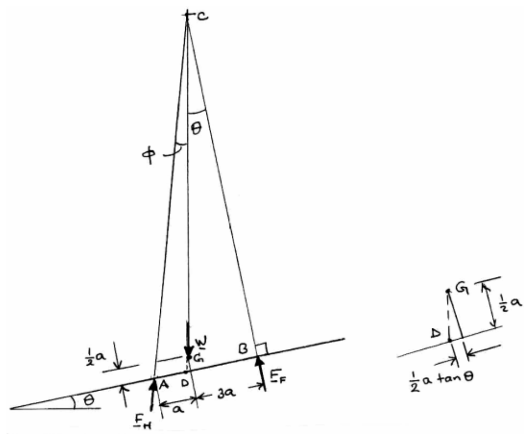
$$BD = L\sin\theta, \text{ so}$$

$$a = L\sin^3\theta$$

$$\text{or } \theta = \sin^{-1}\left(\frac{a}{L}\right)^{\frac{1}{3}} \blacktriangleleft$$

Chapter 4, Solution 93.

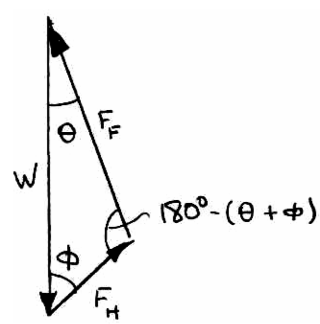
Free-Body Diagram:



Note that the athlete is a three-force body. From the free-body diagram

$$\frac{3a + \frac{1}{2}a\tan\theta}{\tan\theta} = \frac{4a}{\tan(\theta + \phi)}$$

$$\tan(\theta+\phi) = \frac{4\tan\theta}{3 + \frac{1}{2}\tan\theta} \qquad (1)$$



From the force triangle, using the law of sines

$$\frac{F_H}{\sin\theta} = \frac{W}{\sin\left[180° - (\theta + \phi)\right]}$$ or, using $F_H = 0.8W$

$$\sin(\theta + \phi) = 1.25\sin\theta$$

Now, using (1)

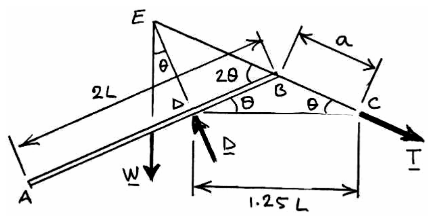
$$\theta + \phi = \tan^{-1}\left(\frac{4\tan\theta}{3 + \frac{1}{2}\tan\theta}\right) = \sin^{-1}(1.25\sin\theta)$$

Solving numerically for θ

$\theta = 15.04°$ ◀

Chapter 4, Solution 94.

Free-Body Diagram:



Note that the rod is a three-force body. In the free-body diagram, E is the intersection of the lines of action of the three forces.

(a) Using triangle DBC which is isosceles

$$DB = a$$

and using triangle BDE

$$ED = DB\tan 2\theta = a\tan 2\theta$$

From triangle GED

$$ED = \frac{(L-a)}{\tan\theta}, \text{ and therefore}$$

$$a\tan 2\theta = \frac{L-a}{\tan\theta}, \text{ or}$$

$$a(\tan\theta\tan 2\theta + 1) = L \qquad (1)$$

From triangle BCD:

$$a = \frac{\frac{1.25L}{2}}{\cos\theta}$$

$$\frac{L}{a} = 1.6\cos\theta \qquad (2)$$

Using (2) in (1):

$$1.6\cos\theta = 1 + \tan\theta\tan 2\theta \qquad (3)$$

Noting that $\tan\theta\tan 2\theta = \dfrac{\sin\theta}{\cos\theta}\dfrac{\sin 2\theta}{\cos 2\theta} = \dfrac{\sin\theta}{\cos\theta}\dfrac{2\sin\theta\cos\theta}{2\cos^2\theta - 1} = \dfrac{2\left(1-\cos^2\theta\right)}{2\cos^2\theta - 1}$, (3) gives

$$1.6\cos\theta = 1 + \frac{2\left(1-\cos^2\theta\right)}{2\cos^2\theta - 1}, \text{ or}$$

$$3.2\cos^3\theta - 1.6\cos\theta - 1 = 0$$

Solving numerically, $\theta = 23.515°$ or $\theta = 23.5°$ ◀

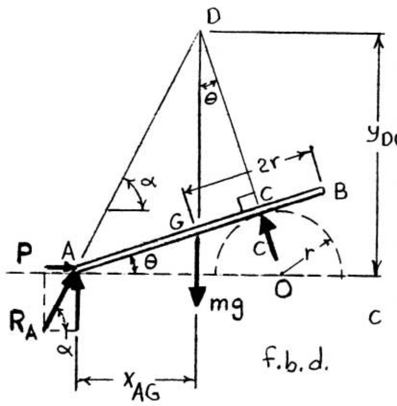
(b) Substituting into (2) for $L = 8$ in.,

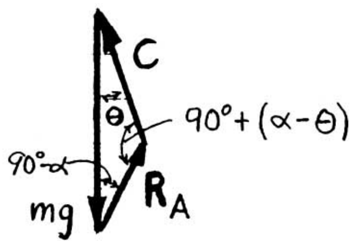
$$a = \frac{5}{8}\frac{(8\text{ in.})}{\cos 23.515°} = 5.4528°$$

or $a = 5.45$ in. ◀

Chapter 4, Solution 95.

Free-Body Diagram:





The forces acting on the three-force member intersect at *D*.

(*a*) From triangle *ACO*

$$\theta = \tan^{-1}\left(\frac{r}{3r}\right) = \tan^{-1}\left(\frac{1}{3}\right) = 18.4349° \qquad \text{or } \theta = 18.43° ◀$$

(*b*) From triangle *DCG*

$$\tan\theta = \frac{r}{DC}$$

$$\therefore\ DC = \frac{r}{\tan\theta} = \frac{r}{\tan 18.4349°} = 3r$$

and

$$DO = DC + r = 3r + r = 4r$$

$$\alpha = \tan^{-1}\left(\frac{y_{DO}}{x_{AG}}\right)$$

where

$$y_{DO} = (DO)\cos\theta = (4r)\cos 18.4349°$$

$$= 3.4947r$$

and

$$x_{AG} = (2r)\cos\theta = (2r)\cos 18.4349°$$

$$= 1.89737r$$

$$\therefore\ \alpha = \tan^{-1}\left(\frac{3.4947r}{1.89737r}\right) = 63.435°$$

where

$$90° + (\alpha - \theta) = 90° + 45° = 135.00°$$

Applying the law of sines to the force triangle,

$$\frac{mg}{\sin\left[90° + (\alpha - \theta)\right]} = \frac{R_A}{\sin\theta}$$

$$\therefore\ R_A = (0.44721)mg$$

Finally,

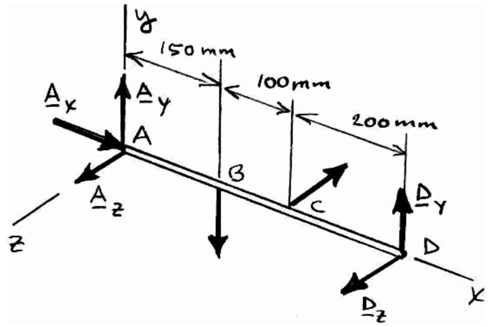
$$P = R_A\cos\alpha$$

$$= (0.44721mg)\cos 63.435°$$

$$= 0.20000mg \qquad \text{or } P = \frac{mg}{5} ◀$$

Chapter 4, Solution 96.

Free-Body Diagram:



$\Sigma \mathbf{M}_A = 0$: $\quad \left[(450 \text{ mm})\mathbf{i}\right] \times \mathbf{D} + \left[(150 \text{ mm})\mathbf{i}\right] \times \left[(-180 \text{ N})\mathbf{j}\right] + \left[(250 \text{ mm})\mathbf{i}\right] \times \left[(-300 \text{ N})\mathbf{k}\right] = 0$

$$(450 \text{ mm}) D_y\mathbf{k} - (450 \text{ mm})D_z\mathbf{j} - (150 \text{ mm})(180 \text{ N})\mathbf{k} + (250 \text{ mm})(300 \text{ N})\mathbf{j} = 0$$

Setting the coefficients of the unit vectors equal to zero:

$\mathbf{k}$: $\quad D_y(450 \text{ mm}) - (180 \text{ N})(150 \text{ mm}) = 0, \quad$ or $\quad D_y = 60.000 \text{ N}$

$\mathbf{i}$: $\quad (300 \text{ N})(250 \text{ mm}) - D_z(450 \text{ mm}) = 0, \quad$ or $\quad D_z = 166.667 \text{ N}$

$$\mathbf{D} = (60.0 \text{ N})\mathbf{j} + (166.7 \text{ N})\mathbf{k} \blacktriangleleft$$

$\Sigma F_x = 0$: $\quad A_x = 0$

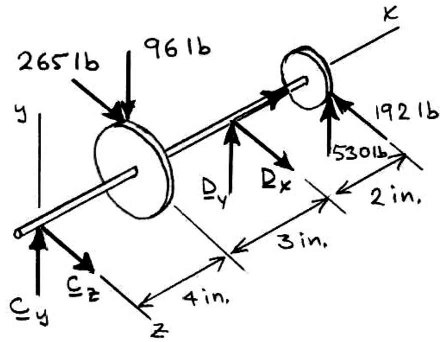
$\Sigma F_y = 0$: $\quad A_y + 60.000 \text{ N} - 180 \text{ N} = 0$, or $A_y = 120.000 \text{ N}$

$\Sigma F_z = 0$: $\quad A_z + 166.667 \text{ N} - 300 \text{ N} = 0$, or $A_z = 133.333 \text{ N}$

$$\mathbf{A} = (120.0 \text{ N})\mathbf{j} + (133.3 \text{ N})\mathbf{k} \blacktriangleleft$$

Chapter 4, Solution 97.

Free-Body Diagram:



$\Sigma F_x = 0$: $D_x = 0$

$\Sigma \mathbf{M}_D = 0$: $\left[(-7 \text{ in.})\mathbf{i}\right] \times \mathbf{C} + \left[(2 \text{ in.})\mathbf{i} + (3 \text{ in.})\mathbf{k}\right] \times \left[(530 \text{ lb})\mathbf{j} + (-192 \text{ lb})\mathbf{k}\right]$

$+\left[(-3 \text{ in.})\mathbf{i} + (6 \text{ in.})\mathbf{j}\right] \times \left[(-96 \text{ lb})\mathbf{j} + (265 \text{ lb})\mathbf{k}\right] = 0$

or $-(7 \text{ in.})C_y\mathbf{k} + (7 \text{ in.})C_z\mathbf{j} + (2 \text{ in.})(530 \text{ lb})\mathbf{k} + (2 \text{ in.})(192 \text{ lb})\mathbf{j} - (3 \text{ in.})(530 \text{ lb})\mathbf{i}$

$+ (3 \text{ in.})(96 \text{ lb})\mathbf{k} + (3 \text{ in.})(265 \text{ lb})\mathbf{j} + (6 \text{ in.})(265 \text{ lb})\mathbf{i} = 0$

Setting the coefficients of the unit vectors to zero:

$\mathbf{k}$: $-C_y(7 \text{ in.}) + (96 \text{ lb})(3 \text{ in.}) + (530 \text{ lb})(2 \text{ in.}) = 0,$ or $C_y = 192.571 \text{ lb}$

$\mathbf{j}$: $C_z(7 \text{ in.}) + (265 \text{ lb})(3 \text{ in.}) + (192 \text{ lb})(2 \text{ in.}) = 0,$ or $C_z = -168.429 \text{ lb}$

$\mathbf{C} = (192.6 \text{ lb})\mathbf{j} - (168.4 \text{ lb})\mathbf{k}$ ◀

Then:

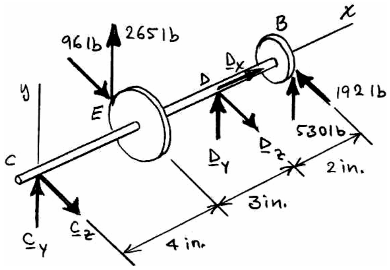
$\Sigma F_y = 0$: $192.571 \text{ lb} - 96 \text{ lb} + D_y + 530 \text{ lb} = 0,$ or $D_y = -626.57 \text{ lb}$

$\Sigma F_z = 0$: $-168.429 \text{ lb} + 265 \text{ lb} + D_z - 192 \text{ lb} = 0,$ or $D_z = 95.429 \text{ lb}$

$\mathbf{D} = -(626 \text{ lb})\mathbf{j} + (95.4 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 98.

Free-Body Diagram:



$\Sigma F_x = 0$: $\quad D_x = 0$

$$\Sigma \mathbf{M}_D = 0: \quad \left[(-7\text{ in.})\mathbf{i}\right]\times\mathbf{C} + \left[(2\text{ in.})\mathbf{i} + (3\text{ in.})\mathbf{k}\right]\times\left[(530\text{ lb})\mathbf{j} + (-192\text{ lb})\mathbf{k}\right]$$

$$+\left[(-3\text{ in.})\mathbf{i} + (6\text{ in.})\mathbf{j}\right]\times\left[(265\text{ lb})\mathbf{j} + (-96\text{ lb})\mathbf{k}\right] = 0$$

or $$-(7\text{ in.})C_y\mathbf{k} + (7\text{ in.})C_z\mathbf{j} + (2\text{ in.})(530\text{ lb})\mathbf{k} + (2\text{ in.})(192\text{ lb})\mathbf{j} - (3\text{ in.})(530\text{ lb})\mathbf{i}$$

$$-(3\text{ in.})(265\text{ lb})\mathbf{k} - (3\text{ in.})(96\text{ lb})\mathbf{j} - (6\text{ in.})(96\text{ lb})\mathbf{i} = 0$$

Setting the coefficients of the unit vectors equal to zero:

$\mathbf{k}$: $\quad -C_y(7\text{ in.}) - (265\text{ lb})(3\text{ in.}) + (530\text{ lb})(2\text{ in.}) = 0,\quad$ or $\quad C_y = 37.857\text{ lb}$

$\mathbf{j}$: $\quad C_z(7\text{ in.}) + (96\text{ lb})(3\text{ in.}) + (192\text{ lb})(2\text{ in.}) = 0,\quad$ or $\quad C_z = -96.000\text{ lb}$

$$\mathbf{C} = (37.9\text{ lb})\mathbf{j} - (96.0\text{ lb})\mathbf{k} \blacktriangleleft$$

Then:

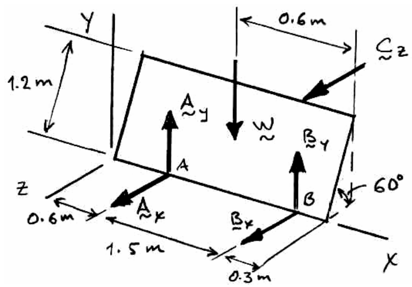
$\Sigma F_y = 0$: $\quad 37.857\text{ lb} + 265\text{ lb} + D_y + 530\text{ lb} = 0,\quad$ or $\quad D_y = -832.86\text{ lb}$

$\Sigma F_z = 0$: $\quad -96\text{ lb} + 96\text{ lb} + D_z - 192\text{ lb} = 0,\quad$ or $\quad D_z = 192.000\text{ lb}$

$$\mathbf{D} = -(833\text{ lb})\mathbf{j} + (192.0\text{ lb})\mathbf{k} \blacktriangleleft$$

Chapter 4, Solution 99.

Free-Body Diagram:



Note that $W = mg = (18 \text{ kg})(9.81 \text{ m/s}^2) = 176.580 \text{ N}$

Moment equilibrium:

$$\Sigma \mathbf{M}_A = 0: \quad \mathbf{r}_{B/A} \times (B_y\mathbf{j} + B_z\mathbf{k}) + \mathbf{r}_{C/A} \times C_z\mathbf{k} + \mathbf{r}_{G/A} \times (-176.580 \text{ N})\mathbf{j} = 0$$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 1.5 & 0 & 0 \\ 0 & B_y & B_z \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 1.2 & 1.2\sin 60^\circ & -1.2\cos 60^\circ \\ 0 & 0 & C_z \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.6 & 0.6\sin 60^\circ & -0.6\cos 60^\circ \\ 0 & -176.580 & 0 \end{vmatrix} = 0$$

or $$\left[1.2C_z \sin 60^\circ - (105.948 \text{ N})\cos 60^\circ\right]\mathbf{i} + (-1.5B_z - 1.2C_z)\mathbf{j} + (1.5B_y - 105.948 \text{ N})\mathbf{k} = 0$$

Solving the equation one component at a time:

From **i** component: $1.2C_z \sin 60^\circ - (105.948 \text{ N})\cos 60^\circ = 0, \quad \text{or} \quad C_z = 50.974 \text{ N}$

From **j** component: $-1.5B_z - 1.2C_z = 0, \quad \text{or} \quad B_z = -0.8(50.974 \text{ N}) = -40.779 \text{ N}$

From **k** component: $1.5B_y - 105.948 \text{ N} = 0, \quad \text{or} \quad B_y = 70.632 \text{ N}$

Force equations:

$$\Sigma F_y = 0: \quad A_y - 176.580 \text{ N} + 70.632 \text{ N} = 0, \quad \text{or} \quad A_y = 105.948 \text{ N}$$

$$\Sigma F_z = 0: \quad A_z + 50.974 \text{ N} - 40.779 \text{ N} = 0, \quad \text{or} \quad A_z = -10.195 \text{ N}$$

Therefore:

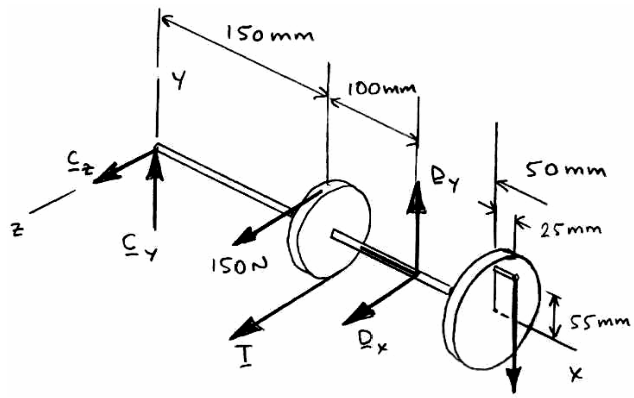
$\mathbf{A} = (105.9 \text{ N})\mathbf{j} - (10.20 \text{ N})\mathbf{k}$ ◀

$\mathbf{B} = (70.6 \text{ N})\mathbf{j} - (40.8 \text{ N})\mathbf{k}$ ◀

$\mathbf{C} = (51.0 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 100.

Free-Body Diagram:



(*a*) $\Sigma \mathbf{M}_C = 0$: $\left[(250\text{ mm})\mathbf{i}\right]\times\mathbf{D} + \left[(150\text{ mm})\mathbf{i} + (50\text{ mm})\mathbf{j}\right]\times(150\text{ N})\mathbf{k}$

$$+\left[(150\text{ mm})\mathbf{i} + (-50\text{ mm})\,\mathbf{j}\right]\times T\,\mathbf{k} + \left[(325\text{ mm})\mathbf{i} + (55\text{ mm})\mathbf{j}\right]\times(-F_E)\mathbf{j} = 0$$

or $(250\text{ mm})D_y\mathbf{k} - (250\text{ mm})D_z\mathbf{j} + (150\text{ mm})(150\text{ N})\,\mathbf{j} - (50\text{ mm})(150\text{ N})\mathbf{i}$

$$-(150\text{ mm})T\,\mathbf{j} - (50\text{ mm})T\,\mathbf{j} - (325\text{ mm})F_E\mathbf{k} = 0$$

continued

Setting the coefficients of the unit vectors equal to zero:

i: $(150 \text{ N})(50 \text{ mm}) - T(50 \text{ mm}) = 0$, or $T = 150 \text{ N}$ $\qquad T = 150 \text{ N}$ ◀

j: $(-150 \text{ N})(150 \text{ mm}) - (150 \text{ N})(150 \text{ mm}) - D_z(250 \text{ mm}) = 0$, or $D_z = -180 \text{ N}$

k: $(D_y)(250 \text{ mm}) - F_E(325 \text{ mm}) = 0$, or $D_y = \frac{325}{250}F_E$

Spring force $F_E = kx$, where

$k = 366 \text{ N/m}$

elongation of spring $x = (y_E)_{\theta=180°} - (y_E)_{\theta=0°}$

$= (300 + 55) \text{ mm} - (300 - 55)\text{mm}$

$= 110 \text{ mm}$

So, $F_E = (366 \text{ N/m})(0.110 \text{ m}) = 40.26 \text{ N}$

Substituting into expression for D_y:

$$D_y = 52.338 \text{ N}$$

Force equations:

$\Sigma F_x = 0$: $\quad D_x = 0$

$\Sigma F_y = 0$: $\quad C_y + 52.338 \text{ N} - 40.26 \text{ N} = 0$, or $C_y = -12.078 \text{ N}$

$\Sigma F_z = 0$: $\quad C_z + 150 \text{ N} + 150 \text{ N} - 180 \text{ N} = 0$, or $C_z = -120.000 \text{ N}$

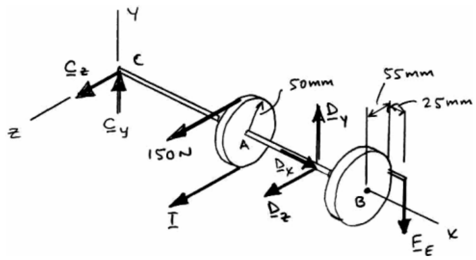
Therefore:

$\mathbf{C} = -(12.08 \text{ N})\mathbf{j} - (120.0 \text{ N})\mathbf{k}$ ◀

$\mathbf{D} = (52.3 \text{ N})\mathbf{j} - (180.0 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 101.

Free-Body Diagram:



Start by determining the spring force, $\boldsymbol{F}_E$:

$$\mathbf{F}_E = -F_E \cos\theta \mathbf{j} + F_E \sin\theta \mathbf{k}$$

The magnitude $F_E = kx$, where

$$k = 366 \text{ N/m, and}$$

elongation of spring $x = (y_E)_{\theta=90°} - (y_E)_{\theta=0°}$

$$= \sqrt{(300 \text{ mm})^2 + (55 \text{ mm})^2} - (300 \text{ mm} - 55\text{mm})$$

$$= 305 \text{ mm} - 245 \text{ mm} = 60 \text{ mm}$$

So, $F_E = (366 \text{ N/m})(0.06 \text{ m}) = 21.96 \text{ N}$. Note that the length of the spring at $\theta = 90°$ is therefore 305 mm. Then

$$\mathbf{F}_E = -(21.96 \text{ N})\left(\frac{300}{305}\right)\mathbf{j} + (21.96 \text{ N})\left(\frac{55}{305}\right)\mathbf{k}$$

or $\mathbf{F}_E = -(21.6 \text{ N})\mathbf{j} + (3.96 \text{ N})\mathbf{k}$

continued

$\Sigma \mathbf{M}_C = 0$: $\quad \left[(250 \text{ mm})\mathbf{i}\right] \times \mathbf{D} + \left[(150 \text{ mm})\mathbf{i} + (50 \text{ mm})\mathbf{j}\right] \times (150 \text{ N})\mathbf{k}$

$+\left[(150 \text{ mm})\mathbf{i} + (-50 \text{ mm})\mathbf{j}\right] \times T\,\mathbf{k}$

$+\left[(325 \text{ mm})\mathbf{i} + (-55 \text{ mm})\mathbf{k}\right] \times \left[-(21.6 \text{ N})\mathbf{j} + (3.96 \text{ N})\mathbf{k}\right] = 0$

or $\quad (250 \text{ mm})D_y\mathbf{k} - (250 \text{ mm})D_z\mathbf{j} + (150 \text{ mm})(150 \text{ N})\mathbf{j}$

$-(50 \text{ mm})(150 \text{ N})\mathbf{i} - (150 \text{ mm})T\,\mathbf{j} - (50 \text{ mm})T\,\mathbf{j}$

$-(325 \text{ mm})(21.6 \text{ N})\mathbf{k} - (325 \text{ mm})(3.96 \text{ N})\mathbf{j} - (55 \text{ mm})(21.6 \text{ N})\mathbf{i} = 0$

Setting the coefficients of the unit vectors equal to zero:

(*a*)

$\mathbf{i}$: $\quad (150 \text{ N})(50 \text{ mm}) - T(50 \text{ mm}) - (21.6 \text{ N})(55 \text{ mm}) = 0, \quad$ or $\quad T = 126.240 \text{ N}$

$T = 126.2 \text{ N}$ ◀

$\mathbf{j}$: $\quad (-150 \text{ N})(150 \text{ mm}) - (126.24 \text{ N})(150 \text{ mm}) - (3.96 \text{ N})(325 \text{ mm}) - D_z(250 \text{ mm}) = 0,$

or $\quad D_z = -170.892 \text{ N}$

$\mathbf{k}$: $\quad (D_y)(250 \text{ mm}) - (21.6 \text{ N})(325 \text{ mm}) = 0, \quad$ or $\quad D_y = 28.080 \text{ N}$

Force equations:

$\Sigma F_x = 0$: $\quad D_x = 0$

$\Sigma F_y = 0$: $\quad C_y + 28.080 \text{ N} - 21.6 \text{ N} = 0, \quad$ or $\quad C_y = -6.4800 \text{ N}$

$\Sigma F_z = 0$: $\quad C_z + 126.240 \text{ N} + 150 \text{ N} - 170.892 \text{ N} + 3.96 \text{ N} = 0, \quad$ or $\quad C_z = -109.308 \text{ N}$

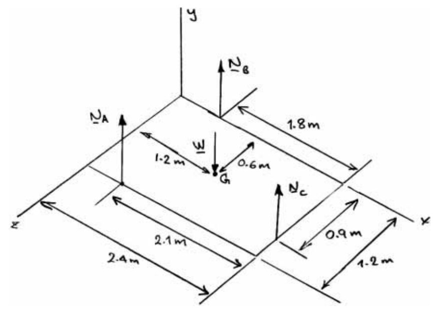
Therefore:

$\mathbf{C} = -(6.48 \text{ N})\mathbf{j} - (109.3 \text{ N})\mathbf{k}$ ◀

$\mathbf{D} = (28.1 \text{ N})\,\mathbf{j} - (170.9 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 102.

Free-Body Diagram:



The weight W is $W = mg = (170 \text{ kg})(9.81 \text{ m/s}^2) = 1667.7 \text{ N}$

$\Sigma \mathbf{M}_C = 0$: $\quad \mathbf{r}_{CA} \times \mathbf{N}_A + \mathbf{r}_{CB} \times \mathbf{N}_B + \mathbf{r}_{CG} \times \mathbf{W} = 0$

or $\quad \left[(-0.3 \text{ m})\mathbf{i} + (1.2 \text{ m})\mathbf{k}\right] \times N_A\mathbf{j} + \left[(1.8 \text{ m})\mathbf{i} + (0.9 \text{ m})\mathbf{k}\right] \times N_B\mathbf{j}$

$+\left[(0.6 \text{ m})\mathbf{i} + (0.6 \text{ m})\mathbf{k}\right] \times (-W)\mathbf{j} = 0$

or $\quad -(0.3 \text{ m})N_A\mathbf{k} - (1.2 \text{ m})N_A\mathbf{i} + (1.8 \text{ m})N_B\mathbf{k} - (0.9 \text{ m})N_B\mathbf{i} - (0.6 \text{ m})W\mathbf{k} + (0.6 \text{ m})W\mathbf{i} = 0$

Equating the coefficients of the unit vectors to zero:

$\mathbf{i}$: $\quad -1.2N_A - 0.9N_B + 0.6W = 0$

$$4N_A + 3N_B0 = 2W \tag{1}$$

$\mathbf{j}$: $\quad -0.3N_A + 1.8N_B - 0.6W = 0$

$$-N_A + 6N_B0 = 2W \tag{2}$$

$-2 \times \left[\text{Eq. } (1)\right] + \text{Eq. } (2)$ gives

$$-9N_A = 2W$$

$$N_A = \frac{2}{9}W = 370.60 \text{ N}$$

continued

Now (2) gives

$$N_B = \frac{1}{6}\left(2W + \frac{2}{9}W\right) = \frac{10}{27}W$$

$$N_B = 617.67 \text{ N},$$

and from (1)

$$\Sigma F_y = 0: \qquad N_A + N_B + N_C - W = 0$$

$$370.60 \text{ N} + 617.67 \text{ N} + N_C - 1667.7 \text{ N} = 0$$

$$N_C = 679.43 \text{ N}$$

Therefore the forces on the blocks are:

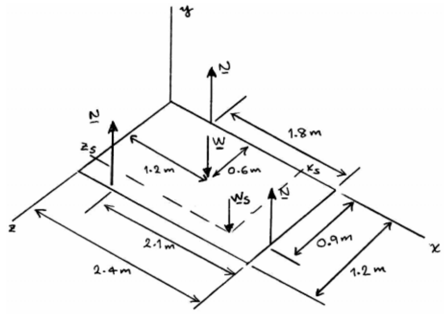
$\mathbf{N}_A = 371 \text{ N} \downarrow$ ◀

$\mathbf{N}_B = 618 \text{ N} \downarrow$ ◀

$\mathbf{N}_C = 679 \text{ N} \downarrow$ ◀

Chapter 4, Solution 103.

Free-Body Diagram:



The location of the bucket of sand will be (x_S, c, z_S).

The weight W is $W = mg = (170\text{ kg})\left(9.81\text{ m/s}^2\right) = 1667.7\text{ N}$

$$\Sigma F_y = 0: \quad 3N - W - W_S = 0$$

$$N = \frac{1}{3}\left(W + W_S\right) \tag{1}$$

$$\Sigma \mathbf{M}_O = 0: \quad \mathbf{r}_{OA} \times \mathbf{N} + \mathbf{r}_{OB} \times \mathbf{N} + \mathbf{r}_{OC} \times \mathbf{N} + \mathbf{r}_{OG} \times \mathbf{W} - \mathbf{r}_{OS} \times \mathbf{W}_S = 0$$

or $$\left[(0.3\text{ m})\mathbf{i} + (1.2\text{ m})\mathbf{k}\right] \times N\mathbf{j} + \left[(2.4\text{ m})\mathbf{i} + (0.9\text{ m})\mathbf{k}\right] \times N\mathbf{j}$$

$$+(0.6\text{ m})\mathbf{i} \times N\mathbf{j} + \left[(1.2\text{ m})\mathbf{i} + (0.6\text{ m})\mathbf{k}\right] \times (-W)\,\mathbf{j} + \left(x_S\mathbf{i} + z_S\mathbf{k}\right) \times \left(-W_S\right)\mathbf{j} = 0$$

or $$(0.3\text{ m})N\,\mathbf{k} - (1.2\text{ m})N\,\mathbf{i} + (2.4\text{ m})N\,\mathbf{k} - (0.9\text{ m})N\,\mathbf{i} + (0.6\text{ m})N\,\mathbf{k}$$

$$-(1.2\text{ m})W\,\mathbf{k} + (0.6\text{ m})W\,\mathbf{i} - x_S W_S \mathbf{k} + z_S W_S \mathbf{i} = 0$$

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \quad -(1.2)N - (0.9)N + (0.6)W + z_S W_S = 0$$

continued

or, using (1)

$$-2.1\left[\frac{1}{3}(W + W_S)\right] + 0.6W + z_S W_S = 0$$

$$W_S = \frac{0.1W}{z_S - 0.7 \text{ m}}$$

$\mathbf{k}$: $\quad 0.3N + 2.4N + 0.6N - 1.2W - x_S W_S = 0$

or, using (1)

$$3.3\left[\frac{1}{3}(W + W_S)\right] - 1.2W - x_S W_S = 0$$

$$W_S = \frac{0.1W}{1.1 \text{ m} - x_S} \qquad (2)$$

For $(W_S)_{\min}$, (1) and (2) imply that x_S, should be chosen as small as possible and that z_S should be chosen as large as possible with the constraint that

$$(1.1 \text{ m} - x_S) = (z_S - 0.7 \text{ m})$$

or $\quad x_S + z_S = 1.8 \text{ m}.$

The smallest x_S and the largest z_S that satisfy this condition are

$x_S = 0.6 \text{ m}$ ◀

$z_S = 1.2 \text{ m}$ ◀

The corresponding value of W_S is:

$$W_S = \frac{0.1(1667.7 \text{ N})}{1.1 \text{ m} - 0.6 \text{ m}} = 333.54 \text{ N}$$

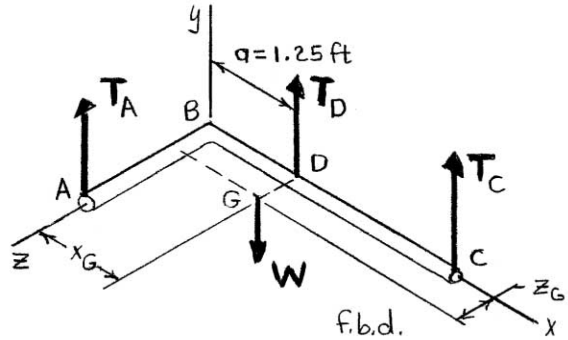
Therefore the smallest mass of the bucket of sand is

$$(m_S)_{\min} = \frac{333.54 \text{ N}}{9.81 \text{ m/s}^2} = 34.000\text{kg}$$

or $(m_S)_{\min} = 34.0 \text{ kg}$ ◀

Chapter 4, Solution 104.

Free-Body Diagram:



First note $$W_{AB} = (5\text{ lb/ft})(2\text{ ft}) = 10\text{ lb}$$

$$W_{BC} = (5\text{ lb/ft})(4\text{ ft}) = 20\text{ lb}$$

$$W = W_{AB} + W_{BC} = 30\text{ lb}$$

To locate the equivalent force of the pipe assembly weight

$$\mathbf{r}_{G/B} \times \mathbf{W} = \Sigma(\mathbf{r_i} \times \mathbf{W_i}) = \mathbf{r}_{G(AB)} \times \mathbf{W}_{AB} + \mathbf{r}_{G(BC)} \times \mathbf{W}_{BC}$$

or $$(x_G\mathbf{i} + z_G\mathbf{k}) \times (-30\text{ lb})\mathbf{j} = (1\text{ ft})\mathbf{k} \times (-10\text{ lb})\mathbf{j} + (2\text{ ft})\mathbf{i} \times (-20\text{ lb})\mathbf{j}$$

$$\therefore\quad -(30\text{ lb})x_G\mathbf{k} + (30\text{ lb})z_G\mathbf{i} = (10\text{ lb}\cdot\text{ft})\mathbf{i} - (40\text{ lb}\cdot\text{ft})\mathbf{k}$$

From **i**-coefficient $$z_G = \frac{10\text{ lb}\cdot\text{ft}}{30\text{ lb}} = \frac{1}{3}\text{ft}$$

k-coefficient $$x_G = \frac{40\text{ lb}\cdot\text{ft}}{30\text{ lb}} = 1\frac{1}{3}\text{ft}$$

From free-body diagram. of piping

$$\Sigma M_x = 0:\quad W(z_G) - T_A(2\text{ ft}) = 0$$

$$\therefore\quad T_A = \left(\frac{1}{2}\text{ ft}\right)30\text{ lb}\left(\frac{1}{3}\text{ft}\right) = 5\text{ lb} \qquad \text{or} \qquad T_A = 5.00\text{ lb}$$

$$\Sigma F_y = 0:\quad 5\text{ lb} + T_D + T_C - 30\text{ lb} = 0$$

$$\therefore\quad T_D + T_C = 25\text{ lb} \quad (1)$$

continued

$\Sigma M_z = 0$: $\quad T_D(1.25\text{ ft}) + T_C(4\text{ ft}) - 30\text{ lb}\left(\dfrac{4}{3}\text{ft}\right) = 0$

$$\therefore \quad 1.25T_D + 4T_C = 40\text{ lb}\cdot\text{ft} \qquad (2)$$

$-4[\text{Equation (1)}]$

$$-4T_D - 4T_C = -100 \qquad (3)$$

Equation (2) + Equation (3)

$$-2.75T_D = -60$$

$$\therefore \quad T_D = 21.818\text{ lb} \quad \text{or} \quad T_D = 21.8\text{ lb}$$

From Equation (1)

$$T_C = 25 - 21.818 = 3.1818\text{ lb} \quad \text{or} \quad T_C = 3.18\text{ lb}$$

Results:

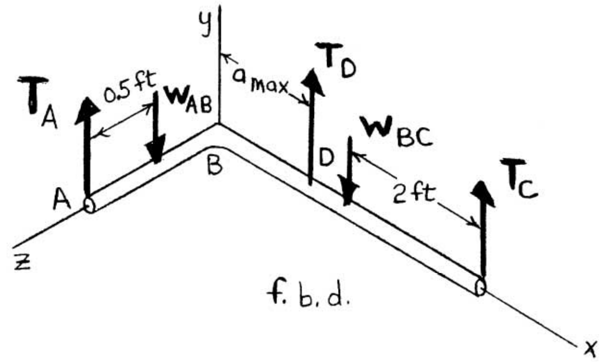
$T_A = 5.00\text{ lb}$ ◀

$T_C = 3.18\text{ lb}$ ◀

$T_D = 21.8\text{ lb}$ ◀

Chapter 4, Solution 105.

Free-Body Diagram:



First note $$W_{AB} = (5 \text{ lb/ft})(2 \text{ ft}) = 10 \text{ lb}$$

$$W_{BC} = (5 \text{ lb/ft})(4 \text{ ft}) = 20 \text{ lb}$$

From free-body diagram. of pipe assembly

$$\Sigma F_y = 0: \quad T_A + T_C + T_D - 10 \text{ lb} - 20 \text{ lb} = 0$$

$$\therefore \quad T_A + T_C + T_D = 30 \text{ lb} \qquad (1)$$

$$\Sigma M_x = 0: \quad (10 \text{ lb})(1 \text{ ft}) - T_A(2 \text{ ft}) = 0$$

or $$T_A = 5.00 \text{ lb} \qquad (2)$$

From Equations (1) and (2) $$T_C + T_D = 25 \text{ lb} \qquad (3)$$

$$\Sigma M_z = 0: \quad T_C(4 \text{ ft}) + T_D(a_{\max}) - 20 \text{ lb}(2 \text{ ft}) = 0$$

or $$(4 \text{ ft})T_C + T_D a_{\max} = 40 \text{ lb}\cdot\text{ft} \qquad (4)$$

continued

Using Equation (3) to eliminate T_C

$$4(25 - T_D) + T_D a_{max} = 40$$

?!

or

$$a_{max} = 4 - \frac{60}{T_D}$$

By observation, a is maximum when T_D is maximum. From Equation (3), $(T_D)_{max}$ occurs when $T_C = 0$.

Therefore, $(T_D)_{max} = 25\text{ lb}$ and

$$a_{max} = 4 - \frac{60}{25}$$

$$= 1.600\text{ ft}$$

Results: (*a*)

$a_{max} = 1.600\text{ ft}$ ◀

(*b*)

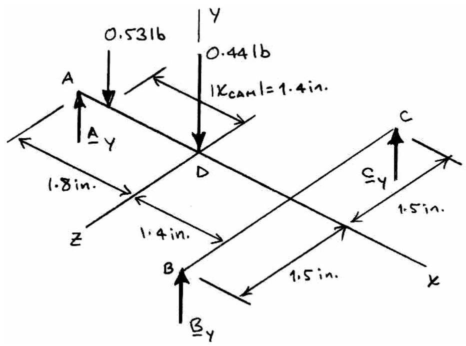
$T_A = 5.00\text{ lb}$ ◀

$T_C = 0$ ◀

$T_D = 25.0\text{ lb}$ ◀

Chapter 4, Solution 106.

Free-Body Diagram:



The free-body diagram indicates the forces on the camera and tripod slid along their lines of action to the plane *ABCD*.

Note that the *x*-coordinate of the center of mass of the camera is:

$$x_{\text{CAM}} = -(2.4\text{ in.} - 1\text{ in.}) = -1.4\text{ in.}$$

$$\Sigma \mathbf{M}_B = 0: \quad (-3\text{ in.})\mathbf{k} \times C_y\mathbf{j} + \left[(-1.5\text{ in.})\mathbf{k} - (1.4\text{ in.})\mathbf{i}\right] \times (-0.44\text{ lb})\mathbf{j}$$

$$+\left[(-1.5\text{ in.})\mathbf{k} - (2.8\text{ in.})\mathbf{i}\right] \times (-0.53\text{ lb})\mathbf{j} + \left[(-1.5\text{ in.})\mathbf{k} - (3.2\text{ in.})\mathbf{i}\right] \times A_y\mathbf{j} = 0$$

or

$$(3\text{ in.})C_y\mathbf{i} - (1.5\text{ in.})(0.44\text{ lb})\mathbf{i} + (1.4\text{ in.})(0.44\text{ lb})\mathbf{k} - (1.5\text{ in.})(0.53\text{ lb})\mathbf{i}$$

$$+(2.8\text{ in.})(0.53\text{ lb})\mathbf{k} + (1.5\text{ in.})A_y\mathbf{i} - (3.2\text{ in.})A_y\mathbf{k} = 0$$

Setting the coefficients of the unit vectors equal to zero:

$$\mathbf{k}: \quad -A_y(3.2\text{ in.}) + (0.53\text{ lb})(2.8\text{ in.}) + (0.44\text{ lb})(1.4\text{ in.}) = 0$$

$$A_y = 0.65625\text{ lb} \qquad \text{or } \mathbf{A}_y = 0.656\text{ lb} \uparrow \blacktriangleleft$$

continued

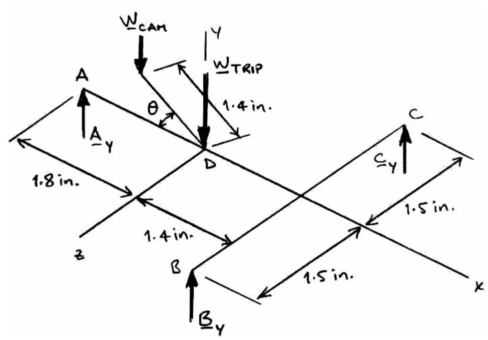
$\mathbf{i}$: $(3 \text{ in.})C_y - (1.5 \text{ in.})(0.44 \text{ lb}) - (1.5 \text{ in})(0.53 \text{ lb}) + (1.5 \text{ in.})(0.65625 \text{ lb}) = 0$

$C_y = 0.156875 \text{ lb}$ or $\mathbf{C}_y = 0.1569 \text{ lb} \uparrow$ ◀

$\Sigma F_x = B_y - 0.53 \text{ lb} - 0.44 \text{ lb} + 0.156875 \text{ lb} + 0.156875 \text{ lb} = 0$

$B_y = 0.156875 \text{ lb}$ or $\mathbf{B}_y = 0.1569 \text{ lb} \uparrow$ ◀

(*b*) **Free-Body Diagram:**



Condition for no tipping: $B_y > 0$

$\Sigma \mathbf{M}_A = 0$: $\left[(3.2 \text{ in.})\mathbf{i} + (-1.5 \text{ in.})\mathbf{k}\right] \times C_y\mathbf{j} + \left[(3.2 \text{ in.})\mathbf{i} + (1.5 \text{ in.})\mathbf{k}\right] \times B_y\mathbf{j}$

$+(1.8 \text{ in.})\mathbf{i} \times (-0.44 \text{ lb})\mathbf{j} + \left\{\left[1.8 \text{ in.} - (1.4 \text{ in.})\cos\theta\right]\mathbf{i} - (1.4 \text{ in.})\sin\theta\,\mathbf{k}\right\} \times (-0.53 \text{ lb})\mathbf{j} = 0$

or $(3.2 \text{ in.})C_y\mathbf{k} + (1.5 \text{ in.})C_y\mathbf{i} + (3.2 \text{ in.})B_y\mathbf{k} - (1.5 \text{ in.})B_y\mathbf{i} - (1.8 \text{ in.})(0.44 \text{ lb})\mathbf{k}$

$+\left[1.8 \text{ in.} - (1.4 \text{ in.})\cos\theta\right](-0.53 \text{ lb})\mathbf{k} + (1.4 \text{ in.})\sin\theta(-0.53 \text{ lb})\mathbf{i} = 0$

Setting the coefficients of the unit vectors equal to zero:

$\mathbf{i}$: $C_y(1.5 \text{ in.}) - B_y(1.5 \text{ in.}) - (0.53 \text{ lb})(1.4 \text{ in.})\sin\theta = 0$

$$C_y = B_y + (0.53 \text{ lb})\frac{1.4}{1.5}\sin\theta$$

$\mathbf{k}$: $(B_y + C_y)(3.2 \text{ in.}) - (0.44 \text{ lb})(1.8 \text{ in.}) - (0.53 \text{ lb})\left[1.8 \text{ in.} - (1.4 \text{ in})\cos\theta\right] = 0$

or

$$2B_y(3.2 \text{ in.}) + (0.53 \text{ lb})\left[\left(\frac{1.4}{1.5}\right)(3.2 \text{ in.})\sin\theta + (1.4 \text{ in.})\cos\theta\right] - (0.44 \text{ lb} + 0.53 \text{ lb})(1.8 \text{ in.}) = 0$$

continued

Solving for B_y:

$$B_y = \frac{1}{2(3.2 \text{ in.})}\left\{(0.44 \text{ lb} + 0.53 \text{ lb})1.8 \text{ in.} - 0.53 \text{ lb}\left[\left(\frac{1.4}{1.5}\right)(3.2 \text{ in.})\sin\theta + (1.4 \text{ in.})\cos\theta\right]\right\}$$

and $B_y > 0$

$$2.3531 > 2.1333\sin\theta + \cos\theta$$

To solve for θ:

$$2.1333\sin\theta + \cos\theta = A\cos(\theta + \alpha)$$

$$= A(\cos\theta\cos\alpha - \sin\theta\sin\alpha)$$

where

$$A = \sqrt{(2.1333)^2 + (1)^2} = 2.3561, \text{ and}$$

$\alpha = \tan^{-1}\left(\dfrac{-2.1333}{1}\right)$, which (noting that $\cos\alpha > 0$) gives

$$\alpha = -64.885°$$

The inequality for B_y becomes:

$$2.3531 > 2.3561\cos(\theta - 64.885°)$$

or $\cos(\theta - 64.885°) < 0.99873$

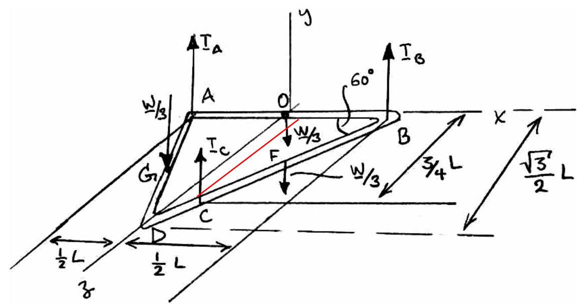
or $\theta - 64.885° < \cos^{-1}(0.99873)$

or $\theta < 64.885° \pm 2.8879°$

$\theta_{max} = 62.00°$ ◀

Chapter 4, Solution 107.

Free-Body Diagram:



$$\Sigma \mathbf{M}_B = 0: \quad \mathbf{r}_{BA} \times \mathbf{T}_A + \mathbf{r}_{BC} \times \mathbf{T}_C + \mathbf{r}_{BO} \times \mathbf{W}_{AB} + \mathbf{r}_{BF} \times \mathbf{W}_{BD} + \mathbf{r}_{BG} \times \mathbf{W}_{AD} = 0$$

or

$$-L\mathbf{i} \times T_A\mathbf{j} + \left[\left(-\frac{\left(\frac{3}{4}\right)L}{\tan 60^\circ}\mathbf{i} + \frac{3}{4}L\mathbf{k}\right)\right] \times T_C\mathbf{j} - \frac{L}{2}\mathbf{i} \times \left(-\frac{1}{3}W\mathbf{j}\right)$$

$$+\left(-\frac{L}{4}\mathbf{i} + \frac{\sqrt{3}}{4}L\mathbf{k}\right) \times \left(-\frac{1}{3}W\mathbf{j}\right) + \left(-\frac{3L}{4}\mathbf{i} + \frac{\sqrt{3}}{4}L\mathbf{k}\right) \times \left(-\frac{1}{3}W\mathbf{j}\right) = 0$$

or

$$-LT_A\mathbf{k} - \frac{\sqrt{3}}{4}LT_C\mathbf{k} - \frac{3}{4}LT_C\mathbf{i} + \frac{L}{6}W\mathbf{k} + \frac{L}{12}W\mathbf{k} + \frac{\sqrt{3}}{12}LW\mathbf{i} - \frac{L}{4}W\mathbf{k} + \frac{\sqrt{3}}{12}LW\mathbf{i} = 0$$

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \quad \frac{W}{3}\frac{\sqrt{3}}{4}L + \frac{W}{3}\frac{\sqrt{3}}{4}L - T_C\frac{3}{4}L = 0$$

$$T_C = \frac{2W}{3\sqrt{3}}$$

$$\mathbf{k}: \quad -T_AL + \frac{W}{3}\frac{3L}{4} + \frac{W}{3}\frac{L}{4} + \frac{W}{3}\frac{L}{2} - \frac{2W}{3\sqrt{3}}\frac{3}{4}\frac{L}{\sqrt{3}} = 0$$

$$T_A = \frac{W}{3}$$

continued

$$\Sigma F_y = 0: \qquad T_B + \frac{W}{3} + \frac{2W}{3\sqrt{3}} - W = 0$$

$$T_B = \frac{2}{3}\left(1 - \frac{1}{\sqrt{3}}\right)W$$

Therefore:

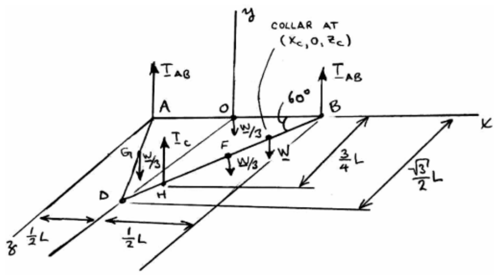
$$T_A = \frac{W}{3} \blacktriangleleft$$

$$T_B = \frac{2}{3}\left(1 - \frac{1}{\sqrt{3}}\right)W \blacktriangleleft$$

$$T_C = \frac{2W}{3\sqrt{3}} \blacktriangleleft$$

Chapter 4, Solution 108.

Free-Body Diagram:



Note that:

$$x_C = \frac{L}{2} - \frac{1}{\sqrt{3}} z_C$$

(*a*) Setting: $T_A = T_B = T$

$$\Sigma \mathbf{M}_O = 0: \quad \mathbf{r}_{OA} \times \mathbf{T}_A + \mathbf{r}_{OB} \times \mathbf{T}_B + \mathbf{r}_{OC} \times \mathbf{T}_C + \mathbf{r}_{OH} \times \mathbf{W} + \mathbf{r}_{OF} \times \mathbf{W}_{BD} + \mathbf{r}_{OG} \times \mathbf{W}_{AD} = 0$$

or

$$-\frac{L}{2}\mathbf{i} \times T_A\mathbf{j} + \frac{L}{2}\mathbf{i} \times T_B\mathbf{j} + \left[\left(\frac{L}{2} - \frac{\left(\frac{3}{4}\right)L}{\tan 60^\circ}\right)\mathbf{i} + \frac{3}{4}L\mathbf{k}\right] \times T_C\mathbf{j}$$

$$+\left(\frac{L}{4}\mathbf{i} + \frac{\sqrt{3}}{4}L\mathbf{k}\right) \times \left(-\frac{1}{3}W\mathbf{j}\right) + \left(-\frac{L}{4}\mathbf{i} + \frac{\sqrt{3}}{4}L\mathbf{k}\right) \times \left(-\frac{1}{3}W\mathbf{j}\right) + \left(x_C\mathbf{i} + z_C\mathbf{k}\right) \times \left(-W\mathbf{j}\right) = 0$$

or

$$-\frac{L}{2}T_A\mathbf{k} + \frac{L}{2}T_A\mathbf{k} + \left(\frac{L}{2} - \frac{\left(\frac{3}{4}\right)L}{\tan 60^\circ}\right)T_C\mathbf{k} + \frac{3}{4}LT_C\mathbf{i}$$

$$-\frac{1}{3}\frac{L}{4}W\mathbf{k} + \frac{1}{3}\frac{\sqrt{3}}{4}LW\mathbf{i} + \frac{1}{3}\frac{L}{4}W\mathbf{k} + \frac{1}{3}\frac{\sqrt{3}}{4}LW\mathbf{i} - x_C W\mathbf{k} + z_C W\mathbf{i} = 0$$

continued

Equating the coefficients of the unit vectors to zero:

i: $$\frac{W}{3}\frac{\sqrt{3}}{4}L + \frac{W}{3}\frac{\sqrt{3}}{4}L - T_C\frac{3L}{4} + Wz_C = 0 \qquad (1)$$

or, using the relation between x_C, and z_C:

$$-\frac{3}{4}LT_C + \left[\frac{L}{2\sqrt{3}} + \left(-\sqrt{3}x_C + \frac{\sqrt{3}}{2}L\right)\right]W = 0 \qquad (2)$$

k: $$-\frac{L}{2}T + \frac{L}{2}T + L\left(\frac{1}{2} - \frac{\sqrt{3}}{4}\right)T_C - \frac{1}{12}LW + \frac{1}{12}LW - x_CW = 0$$

$$L\left(\frac{1}{2} - \frac{\sqrt{3}}{4}\right)T_C = x_CW \qquad (3)$$

Substituting (3) into (2)

$$-\frac{3}{4}LT_C + \left(\frac{1}{2\sqrt{3}} + \frac{\sqrt{3}}{2}\right)LW - \sqrt{3\left[L\left(\frac{1}{2} - \frac{\sqrt{3}}{4}\right)T_C\right]} = 0$$

$$T_C = \frac{4}{3}W$$

$\Sigma F_y = 0$: $$2T + \frac{4}{3}W - 2W = 0$$

$$T = \frac{W}{3}$$

Therefore: $T_A = T_B = \dfrac{W}{3}$ ◀

$T_C = \dfrac{4}{3}W$ ◀

(*b*) Using T_C in (1):

$$\frac{W}{3}\frac{\sqrt{3}}{4}L + \frac{W}{3}\frac{\sqrt{3}}{4}L - \left(\frac{4}{3}W\right)\frac{3}{4}L + Wz_C = 0$$

$$z_C = \left(1 - \frac{1}{2\sqrt{3}}\right)L$$

and from geometry

$$x_C = \frac{L}{2} - \frac{1}{\sqrt{3}}z_C = \frac{1}{3}\left(2 - \sqrt{3}\right)L$$

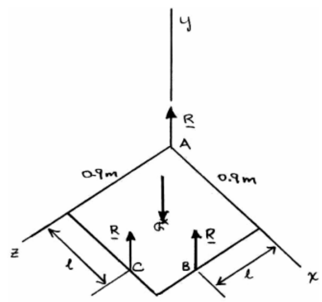
Therefore:

$x_C = \dfrac{1}{3}\left(2 - \sqrt{3}\right)L$ ◀

$z_C = \left(1 - \dfrac{1}{2\sqrt{3}}\right)L$ ◀

Chapter 4, Solution 109.

Free-Body Diagram:



(a) $\Sigma F_y = 0$: $3(R) - 135 \text{ N} = 0$

$R = 45.0 \text{ N}$

$\Sigma \mathbf{M}_A = 0$: $\mathbf{r}_{AB} \times \mathbf{R}_B + \mathbf{r}_{AC} \times \mathbf{R}_C + \mathbf{r}_{AG} \times \mathbf{F}_W = 0$

or $\left[(0.9 \text{ m})\mathbf{i} + l\,\mathbf{k}\right] \times R\,\mathbf{j} + \left[l\,\mathbf{i} + (0.9 \text{ m})\mathbf{k}\right] \times R\,\mathbf{j} + \left[(0.450 \text{ m})\mathbf{i} + (0.450 \text{ m})\mathbf{k}\right] \times (-F_W\,\mathbf{j}) = 0$

or $(0.9 \text{ m})R\,\mathbf{k} - lR\,\mathbf{i} + lR\,\mathbf{k} - (0.9 \text{ m})R\,\mathbf{i} - (0.450 \text{ m})F_W\,\mathbf{k} + (0.450 \text{ m})F_W\,\mathbf{i} = 0$

Equating the coefficients of the **i** unit vector to zero:

i: $-lR - (0.9 \text{ m})R + (0.45 \text{ m})F_W = 0$

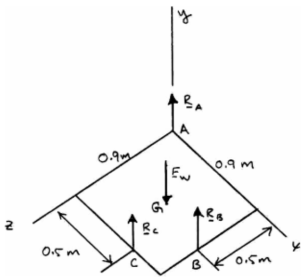
Using that $F_W = 3\text{R}$

$-l - (0.9 \text{ m}) + (0.45 \text{ m})(3) = 0$

$l = 0.450 \text{ m}$ or $l = 450 \text{ mm}$ ◀

continued

(*b*) **Free-Body Diagram:**



$\Sigma \mathbf{M}_A = 0$: $\quad \mathbf{r}_{AB} \times \mathbf{R}_B + \mathbf{r}_{AC} \times \mathbf{R}_C + \mathbf{r}_{AG} \times \mathbf{F}_W = 0$

or

$$\left[(0.9 \text{ m})\mathbf{i} + (0.5 \text{ m})\mathbf{k}\right] \times R\,\mathbf{j} + \left[(0.5 \text{ m})\mathbf{i} + (0.9 \text{ m})\mathbf{k}\right] \times R\,\mathbf{j} + \left[(0.450 \text{ m})\mathbf{i} + (0.450 \text{ m})\mathbf{k}\right] \times (-135 \text{ N})\mathbf{j} = 0$$

$$(0.9 \text{ m})R\mathbf{k} - (0.5 \text{ m})R\mathbf{i} + (0.5 \text{ m})R\mathbf{k} - (0.9 \text{ m})R\mathbf{i} - (0.450 \text{ m})F_W\mathbf{k} + (0.450 \text{ m})F_W\mathbf{i} = 0$$

Equating the coefficients of the unit vectors to zero

$$\mathbf{i}: \quad -0.5R_B - 0.9R_C + 60.75 = 0 \qquad (1)$$

$$\mathbf{k}: \quad 0.9R_B + 0.5R_C - 60.75 = 0 \qquad (2)$$

$0.5 \times [\text{Eq. (1)}] + 0.9 \times [\text{Eq. (2)}]$ gives

$$\left[-0.5(0.5) + (0.9)(0.9)\right]R_B + (0.5 - 0.9)60.75 = 0$$

$$R_B = 43.393 \text{ N}$$

Now using (1)

$$-0.5(43.393) - 0.9R_C + 60.67 = 0$$

$$R_C = 43.393 \text{ N}$$

$\Sigma F_y = 0$: $\quad R_A + 43.393 + 43.393 - 135 = 0$

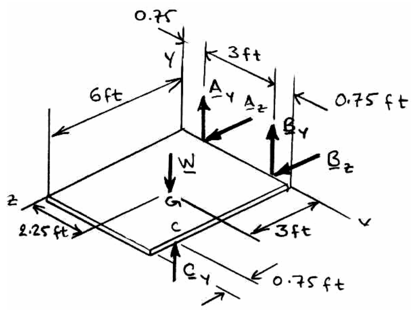
$R_A = 48.2 \text{ N}$ ◀

$R_B = 43.4 \text{ N}$ ◀

$R_C = 43.4 \text{ N}$ ◀

Chapter 4, Solution 110.

Free-Body Diagram:



$\Sigma \mathbf{M}_O = 0$: $\quad (0.75\text{ ft})\mathbf{i} \times (A_y\mathbf{j} + A_z\mathbf{k}) + (3.75\text{ ft})\mathbf{i} \times (B_y\mathbf{j} + B_z\mathbf{k}) + [(2.25\text{ ft})\mathbf{i} + (3\text{ ft})\mathbf{k}] \times (-27\text{ lb})\mathbf{j}$

$+[(4.5\text{ ft})\mathbf{i} + (5.25\text{ ft})\mathbf{k}] \times C_y\mathbf{j} = 0$

or $\quad (0.75\text{ ft})A_y\mathbf{k} - (0.75\text{ ft})A_z\mathbf{j} + (3.75\text{ ft})B_y\mathbf{k} - (3.75\text{ ft})B_z\mathbf{j} - (2.25\text{ ft})(27\text{ lb})\mathbf{k}$

$+ (3\text{ ft})(27\text{ lb})\mathbf{i} + (4.5\text{ ft})C_y\mathbf{k} - (5.25\text{ ft})C_y\mathbf{i} = 0$

Setting the coefficients of the unit vectors equal to zero:

$\mathbf{i}$: $\quad (27\text{ lb})(3\text{ ft}) - C_y(5.25\text{ ft}) = 0$

$C_y = 15.4286\text{ lb}$

$\mathbf{k}$: $\quad (27\text{ lb})(1.5\text{ ft}) + B_y(3\text{ ft}) - (15.4286\text{ lb})(3.75\text{ ft}) = 0$

$B_y = -5.78575\text{ lb}$

$\Sigma F_y = 0$: $\quad A_y - 5.78575\text{ lb} - 27\text{ lb} + 15.4286\text{ lb} = 0$

$A_y = 17.3572\text{ lb}$

Therefore:

(*a*) $\mathbf{A}_y = 17.36\text{ lb} \uparrow$ ◀

(*b*) $\mathbf{B}_y = 5.79\text{ lb} \downarrow$ ◀

(*c*) $\mathbf{C}_y = 15.43\text{ lb} \uparrow$ ◀

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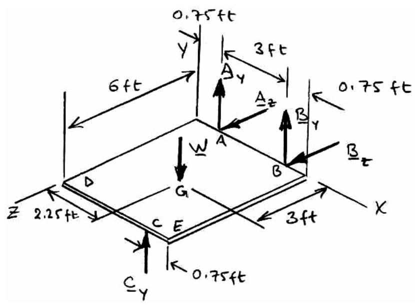
Chapter 4, Solution 111.

Free-Body Diagram:



$\Sigma \mathbf{M}_O = 0$: $\quad (0.75 \text{ ft})\mathbf{i} \times (A_y\mathbf{j} + A_z\mathbf{k}) + (3.75 \text{ ft})\mathbf{i} \times (B_y\mathbf{j} + B_z\mathbf{k}) + [(2.25 \text{ ft})\mathbf{i} + (3 \text{ ft})\mathbf{k}] \times (-27 \text{ lb})\mathbf{j}$

$+ [(3.75 \text{ ft})\mathbf{i} + (6 \text{ ft})\mathbf{k}] \times C_y\mathbf{j} = 0$

or $\quad (0.75 \text{ ft})A_y\mathbf{k} - (0.75 \text{ ft})A_z\mathbf{j} + (3.75 \text{ ft})B_y\mathbf{k} - (3.75 \text{ ft})B_z\mathbf{j} - (2.25 \text{ ft})(27 \text{ lb})\mathbf{k}$

$+ (3 \text{ ft})(27 \text{ lb})\mathbf{i} + (3.75 \text{ ft})C_y\mathbf{k} - (6.0 \text{ ft})C_y\mathbf{i} = 0$

Setting the coefficients of the unit vectors equal to zero:

$\Sigma M_x = 0$: $\quad (27 \text{ lb})(3 \text{ ft}) - C_y(6 \text{ ft}) = 0$

$C_y = 13.5000 \text{ lb}$

$\Sigma M_z = 0$: $\quad -(27 \text{ lb})(1.5 \text{ ft}) + B_y(3 \text{ ft}) - (13.5000 \text{ lb})(3 \text{ ft}) = 0$

$B_y = 0$

$\Sigma F_y = 0$: $\quad A_y + 13.5000 \text{ lb} - 27 \text{ lb} = 0$

$A_y = 13.5000 \text{ lb}$

Therefore:

(*a*) $\mathbf{A}_y = 13.50 \text{ lb} \uparrow$ ◀

(*b*) $\mathbf{B}_y = 0$ ◀

(*c*) $\mathbf{C}_y = 13.50 \text{ lb} \uparrow$ ◀

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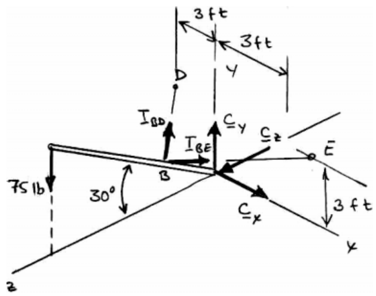
Chapter 4, Solution 112

Free-Body Diagram:



Express all forces in terms of rectangular components:

$$\mathbf{r}_E = (3\text{ ft})\mathbf{i} + (3\text{ ft})\mathbf{j}$$

$$\mathbf{r}_B = (3\text{ ft})\sin 30°\mathbf{j} + (3\text{ ft})\cos 30°\mathbf{k} = (1.5\text{ ft})\mathbf{j} + (2.598\text{ ft})\mathbf{k}$$

$$\mathbf{r}_D = -(3\text{ ft})\mathbf{i} + (3\text{ ft})\mathbf{j}$$

$$\mathbf{r}_A = (10\text{ ft})\sin 30°\mathbf{j} - (10\text{ ft})\cos 30°\mathbf{k} = (5\text{ ft})\mathbf{j} + (8.66\text{ ft})\mathbf{k}$$

$$\overrightarrow{BE} = \mathbf{r}_E - \mathbf{r}_B = (3\text{ ft})\mathbf{i} + (3\text{ ft})\mathbf{j} - (1.5\text{ ft})\mathbf{j} - (2.598\text{ ft})\mathbf{k}$$

or $\overrightarrow{BE} = (3\text{ ft})\mathbf{i} + (1.5\text{ ft})\mathbf{j} - (2.598\text{ ft})\mathbf{k}$, and $BE = 4.243\text{ ft}$

$$\overrightarrow{BD} = \mathbf{r}_D - \mathbf{r}_B = -(3\text{ ft})\mathbf{i} + (3\text{ ft})\mathbf{j} - (1.5\text{ ft})\mathbf{j} - (2.598\text{ ft})\mathbf{k}$$

or $\overrightarrow{BD} = -(3\text{ ft})\mathbf{i} + (1.5\text{ ft})\mathbf{j} - (2.598\text{ ft})\mathbf{k}$, and $BD = 4.243\text{ ft}$

Then

$$\vec{T}_{BD} = T_{BD}\frac{\overrightarrow{BD}}{BD} = T_{BD}(-0.707\mathbf{i} + 0.3535\mathbf{j} - 0.6123\mathbf{k})$$

$$\vec{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = T_{BE}(0.707\mathbf{i} + 0.3535\mathbf{j} - 0.6123\mathbf{k})$$

continued

$\Sigma\mathbf{M}_C = 0$: $\quad \mathbf{r}_B \times \mathbf{T}_{BD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \left[(5\text{ ft})\mathbf{j} + (8.66\text{ ft})\mathbf{k}\right] \times (-75\text{ lb})\mathbf{j}$

or $\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 1.5 & 2.598 \\ -0.707 & 0.3535 & -0.6123 \end{vmatrix} T_{BD} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 1.5 & 2.598 \\ 0.707 & 0.3535 & -0.6123 \end{vmatrix} + 649.5\mathbf{i} = 0$

Equating the coefficients of the unit vectors to zero:

$\mathbf{j}$: $\quad -1.837T_{BD} + 1.837T_{BE} = 0$

$\mathbf{i}$: $\quad -1.837T_{BD} + 1.837T_{BE} + 649.5\text{ lb} = 0$

$T_{BD} = 176.8\text{ lb}$ ◀

$T_{BE} = 176.8\text{ lb}$ ◀

Force equations:

$C_x + (176.8)(-0.707) + (176.8)(0.707) = 0, \quad \text{or} \quad C_x = 0$

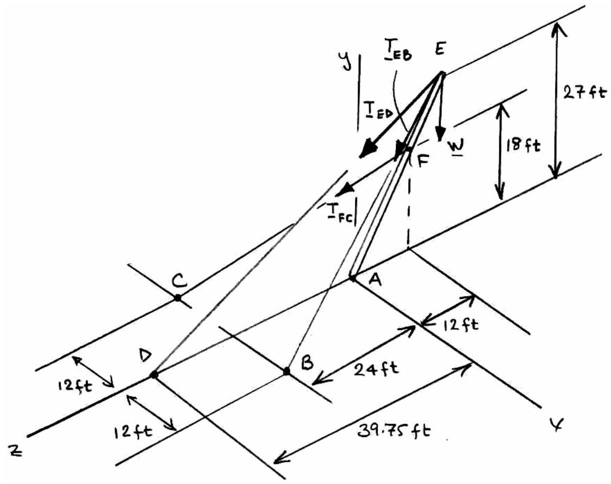
$C_y + (176.8)(0.3535) + (176.8)(0.3535) - 75\text{ lb} = 0, \quad \text{or} \quad C_y = -50\text{ lb}$

$C_z + (176.8)(-0.6123) + (176.8)(-0.6123) = 0, \quad \text{or} \quad C_z = 216.5\text{ lb}$

$\mathbf{C} = -(50\text{ lb})\mathbf{j} + (216.5\text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 113.

Free-Body Diagram:



Express the forces in terms of their rectangular components:

$$\mathbf{T}_{FB} = T_{FB}\frac{\overrightarrow{FB}}{FB} = T_{FB}\frac{12\mathbf{i} - 18\mathbf{j} + 36\mathbf{k}}{\sqrt{(12)^2 + (-18)^2 + (36)^2}} = \frac{2}{7}T_{FB}\mathbf{i} - \frac{3}{7}T_{FB}\mathbf{j} + \frac{6}{7}T_{FB}\mathbf{k}$$

$$\mathbf{T}_{FC} = T_{FC}\frac{\overrightarrow{FC}}{FC} = T_{FC}\frac{-12\mathbf{i} - 18\mathbf{j} + 36\mathbf{k}}{\sqrt{(-12)^2 + (-18)^2 + (36)^2}} = -\frac{2}{7}T_{FB}\mathbf{i} - \frac{3}{7}T_{FB}\mathbf{j} + \frac{6}{7}T_{FB}\mathbf{k}$$

From the free-body diagram, note that

$$\frac{z_E}{27} = \frac{12}{18}$$

$$z_E = 18.00 \text{ ft}$$

continued

Then, using $T_{ED} = 2720$ lb

$$\mathbf{T}_{ED} = 2720\frac{-27\mathbf{j} + 57.75\mathbf{k}}{\sqrt{(-27)^2 + (18 + 39.75)^2}}$$

$$\mathbf{T}_{ED} = (32 \text{ lb})(-36\mathbf{j} + 77\mathbf{k})$$

(*a*) $\Sigma \mathbf{M}_A = 0$: $\quad \mathbf{r}_{AD} \times \mathbf{T}_{ED} + \mathbf{r}_{AF} \times \mathbf{T}_{FB} + \mathbf{r}_{AE} \times \mathbf{W} = 0$

$$\text{or } 32\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 39.75 \\ 0 & -36 & 77 \end{vmatrix} + \frac{T_{FB}}{7}\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 18 & -12 \\ 2 & -3 & 6 \end{vmatrix} + \frac{T_{FC}}{7}\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 18 & -12 \\ -2 & -3 & 6 \end{vmatrix} + 2720\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 27 & -18 \\ 0 & -1 & 0 \end{vmatrix} = 0$$

Equating the coefficients of the unit vectors to zero

$$\mathbf{i}: \quad 32(39.75)(36) + \frac{T_{FB}}{7}(72) + \frac{T_{FC}}{7}(72) + 2720(-18) = 0$$

$$\frac{72}{7}T_{FB} + \frac{72}{7}T_{FC} - 3168 = 0 \qquad (1)$$

$$\mathbf{j}: \quad \frac{T_{FB}}{7}(-24) + \frac{T_{FC}}{7}(24) = 0$$

$$T_{FB} = T_{FC} \qquad (2)$$

Substituting Eq. (2) in (1) gives

$$2\left(\frac{72}{7}\right)T_{FB} - 3168 = 0$$

or $T_{FB} = 154.0$ lb ◀

$T_{FC} = 154.0$ lb ◀

(*b*) $\Sigma F_x = 0$: $\quad A_x + \frac{2}{7}(154.0) - \frac{2}{7}(154.0) = 0$

$$A_x = 0$$

$\Sigma F_y = 0$: $\quad A_y - \frac{3}{7}(154.0) - \frac{3}{7}(154.0) - (32)(36) - 2720 = 0$

$$A_y = 4004 \text{ lb}$$

$\Sigma F_z = 0$: $\quad A_z + \frac{6}{7}(154.0) + \frac{6}{7}(154.0) + (32)(77) = 0$

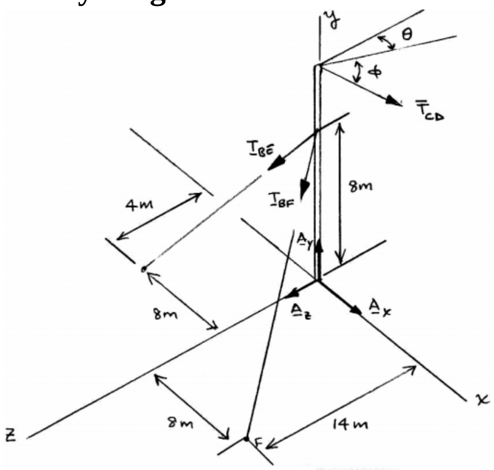
$$A_z = -2728 \text{ lb}$$

Therefore:

$\mathbf{A} = (4.00 \text{ kips})\mathbf{j} - (2.73 \text{ kips})\mathbf{k}$ ◀

Chapter 4, Solution 114.

Free-Body Diagram



First express tensions in terms of rectangular components:

$$\mathbf{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = T_{BE}\frac{-8\mathbf{i} - 8\mathbf{j} + 4\mathbf{k}}{\sqrt{(-8)^2 + (-8)^2 + (4)^2}} = -\frac{2}{3}T_{BE}\mathbf{i} - \frac{2}{3}T_{BE}\mathbf{j} + \frac{1}{3}T_{BE}\mathbf{k}$$

$$\mathbf{T}_{BF} = T_{BF}\frac{\overrightarrow{BF}}{BF} = T_{BF}\frac{8\mathbf{i} - 8\mathbf{j} + 14\mathbf{k}}{\sqrt{(8)^2 + (-8)^2 + (14)^2}} = \frac{4}{9}T_{BF}\mathbf{i} - \frac{4}{9}T_{BF}\mathbf{j} + \frac{7}{9}T_{BF}\mathbf{k}$$

$$\mathbf{T}_{CD} = T_{CD}\left(\cos\phi\sin\theta\mathbf{i} - \sin\phi\mathbf{j} - \cos\phi\cos\theta\mathbf{k}\right)$$

$$\Sigma\mathbf{M}_A = 0: \qquad \mathbf{r}_{AB}\times\mathbf{T}_{BE} + \mathbf{r}_{AB}\times\mathbf{T}_{BF} + \mathbf{r}_{AC}\times\mathbf{T}_{CD} = 0$$

or $$8\mathbf{j}\times\frac{T_{BE}}{3}\left(-2\mathbf{i} - 2\mathbf{j} + \mathbf{k}\right) + 8\mathbf{j}\times\frac{T_{BF}}{9}\left(4\mathbf{i} - 4\mathbf{j} + 7\mathbf{k}\right)$$

$$+ 10\mathbf{j}\times T_{CD}\left(\cos\phi\sin\theta\mathbf{i} - \sin\phi\mathbf{j} - \cos\phi\cos\theta\mathbf{k}\right) = 0$$

continued

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \quad \frac{8}{3}T_{BE} + \frac{56}{9}T_{BF} - 10T_{CD}\cos\phi\cos\theta = 0 \tag{1}$$

$$\mathbf{k}: \quad \frac{16}{3}T_{BE} - \frac{32}{9}T_{BF} - 10T_{CD}\cos\phi\sin\theta = 0 \tag{2}$$

(a) $-2\times\left[\text{Eq. }(1)\right] + \text{Eq. }(2)$ gives:

$$\left[-2\left(\frac{56}{9}\right) - \frac{32}{9}\right]T_{BF} - 10(600)\cos10°\left(-2\cos30° + \sin30°\right) = 0$$

$$T_{BF} = 455.00 \text{ N}$$

Using this in Eq. (1),

$$\frac{8}{3}T_{BE} + \frac{56}{9}(455.00) - 10(600)\cos10°\cos30° = 0$$

$$T_{BE} = 857.29 \text{ N}$$

Therefore:

$T_{BE} = 857 \text{ N}$ ◀

$T_{BF} = 455 \text{ N}$ ◀

(b) $\Sigma F_x = 0$: $\quad A_x - \frac{2}{3}(857.29 \text{ N}) + \frac{4}{9}(455.00 \text{ N}) + (600 \text{ N})\cos10°\sin30° = 0$

$$A_x = 73.9 \text{ N}$$

$\Sigma F_y = 0$: $\quad A_y - \frac{2}{3}(857.29 \text{ N}) - \frac{4}{9}(455.00 \text{ N}) + (600 \text{ N})\sin10° = 0$

$$A_y = 878 \text{ N}$$

$\Sigma F_z = 0$: $\quad A_z + \frac{1}{3}(857.29 \text{ N}) + \frac{7}{9}(455.00 \text{ N}) - (600 \text{ N})\cos10°\cos30° = 0$

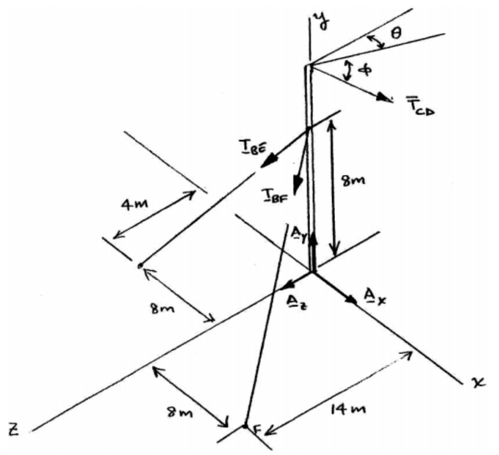
$$A_z = -127.9 \text{ N}$$

Therefore:

$\mathbf{A} = (73.9 \text{ N})\mathbf{i} + (878 \text{ N})\mathbf{j} - (127.9 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 115.

Free-Body Diagram:



First express tensions in terms of rectangular components:

$$\mathbf{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = T_{BE}\frac{-8\mathbf{i} - 8\mathbf{j} + 4\mathbf{k}}{\sqrt{(-8)^2 + (-8)^2 + (4)^2}} = -\frac{2}{3}T_{BE}\mathbf{i} - \frac{2}{3}T_{BE}\mathbf{j} + \frac{1}{3}T_{BE}\mathbf{k}$$

$$\mathbf{T}_{BF} = T_{BF}\frac{\overrightarrow{BF}}{BF} = T_{BF}\frac{8\mathbf{i} - 8\mathbf{j} + 14\mathbf{k}}{\sqrt{(8)^2 + (-8)^2 + (14)^2}} = \frac{4}{9}T_{BF}\mathbf{i} - \frac{4}{9}T_{BF}\mathbf{j} + \frac{7}{9}T_{BF}\mathbf{k}$$

$$\mathbf{T}_{CD} = T_{CD}\left(\cos\phi\sin\theta\mathbf{i} - \sin\phi\mathbf{j} - \cos\phi\cos\theta\mathbf{k}\right)$$

$\Sigma\mathbf{M}_A = 0$: $\quad \mathbf{r}_{AB}\times\mathbf{T}_{BE} + \mathbf{r}_{AB}\times\mathbf{T}_{BF} + \mathbf{r}_{AC}\times\mathbf{T}_{CD} = 0$

or $\quad 8\mathbf{j}\times\frac{T_{BE}}{3}(-2\mathbf{i} - 2\mathbf{j} + \mathbf{k}) + 8\mathbf{j}\times\frac{T_{BF}}{9}(4\mathbf{i} - 4\mathbf{j} + 7\mathbf{k})$

$\quad + 10\mathbf{j}\times T_{CD}\left(\cos\phi\sin\theta\mathbf{i} - \sin\phi\mathbf{j} - \cos\phi\cos\theta\mathbf{k}\right) = 0$

continued

Equating the coefficients of the unit vectors to zero:

i: $\frac{8}{3}T_{BE} + \frac{56}{9}T_{BF} - 10T_{CD}\cos\phi\cos\theta = 0$

$$\frac{8}{3}(840\text{ N}) + \frac{56}{9}(450\text{ N}) = 10T_{CD}\cos\phi\cos\theta \qquad (1)$$

k: $\frac{16}{3}T_{BE} - \frac{32}{9}T_{BF} - 10T_{CD}\cos\phi\sin\theta = 0$

$$\frac{16}{3}(840\text{ N}) - \frac{32}{9}(450\text{ N}) = 10T_{CD}\cos\phi\sin\theta \qquad (2)$$

(*a*) $\frac{[\text{Eq. }(2)]}{[\text{Eq. }(1)]}$ gives:

$$\frac{10T_{CD}\cos\phi\sin\theta}{10T_{CD}\cos\phi\cos\theta} = \frac{\frac{16}{3}(840) - \frac{32}{9}(450)}{\frac{8}{3}(840) + \frac{56}{9}(450)}$$

$$\tan\theta = \frac{1}{1.75}$$

$\theta = 29.745°$ $\qquad\qquad$ $\theta = 29.7°$ ◀

(*b*) Substituting into (1) gives:

$$\frac{8}{3}(840\text{ N}) + \frac{56}{9}(450\text{ N}) - 10T_{CD}\cos 8°\cos 29.745° = 0, \quad \text{or} \quad T_{CD} = 586.19\text{ N}$$

or $T_{CD} = 586\text{ N}$ ◀

(*c*) $\Sigma F_x = 0$: $\quad A_x - \frac{2}{3}(840\text{ N}) + \frac{4}{9}(450\text{ N}) + (586.19\text{ N})\cos 8°\sin 29.745° = 0$

$A_x = 72.0\text{ N}$

$\Sigma F_y = 0$: $\quad A_y - \frac{2}{3}(840\text{ N}) - \frac{4}{9}(450\text{ N}) - (586.19\text{ N})\sin 8° = 0$

$A_y = 842\text{ N}$

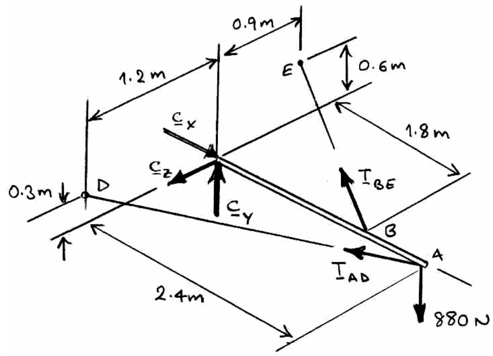
$\Sigma F_z = 0$: $\quad A_z + \frac{1}{3}(840\text{ N}) + \frac{3}{9}(450\text{ N}) - (586.19\text{ N})\cos 8°\cos 29.745° = 0$

$A_z = -126.0\text{ N}$

Therefore: $\qquad \mathbf{A} = (72.0\text{ N})\mathbf{i} + (842\text{ N})\mathbf{j} - (126.0\text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 116.

Free-Body Diagram:



Express all forces in terms of rectangular components:

$$\mathbf{r}_A = (2.4\text{ m})\mathbf{i}$$

$$\mathbf{r}_B = (1.8\text{ m})\mathbf{j}$$

$$\overrightarrow{AD} = -(2.4\text{ m})\mathbf{i} + (0.3\text{ m})\mathbf{j} + (1.2\text{ m})\mathbf{k}$$

$$\overrightarrow{BE} = -(1.8\text{ m})\mathbf{i} + (0.6\text{ m})\mathbf{j} - (0.9\text{ m})\mathbf{k}$$

$$\mathbf{W} = -(880\text{ N})\mathbf{j}$$

Then

$$\vec{T}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = T_{AD}\frac{-2.4\mathbf{i} + 0.3\mathbf{j} + 1.2\mathbf{k}}{\sqrt{(-2.4)^2 + (0.3)^2 + (1.2)^2}} = -\frac{8}{9}T_{AD}\mathbf{i} + \frac{1}{9}T_{AD}\mathbf{j} + \frac{4}{9}T_{AD}\mathbf{k}$$

$$\vec{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = T_{BE}\frac{-1.8\mathbf{i} + 0.6\mathbf{j} - 0.9\mathbf{k}}{\sqrt{(-1.8)^2 + (0.6)^2 + (-0.9)^2}} = -\frac{6}{7}T_{AD}\mathbf{i} + \frac{2}{7}T_{AD}\mathbf{j} - \frac{3}{7}T_{AD}\mathbf{k}$$

continued

$\Sigma \mathbf{M}_C = 0: \qquad \mathbf{r}_A \times \mathbf{T}_{AD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_A \times \mathbf{W} = 0$

or
$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2.4 & 0 & 0 \\ -\frac{8}{9} & \frac{1}{9} & \frac{4}{9} \end{vmatrix} T_{AD} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 1.8 & 0 & 0 \\ -\frac{6}{7} & \frac{2}{7} & -\frac{3}{7} \end{vmatrix} T_{BE} + (2.4)\mathbf{i} \times (-880)\mathbf{j} = 0$$

Equating the coefficients of the unit vectors to zero:

$$\mathbf{j}: \quad -\frac{9.6}{9}T_{AD} + \frac{5.4}{7}T_{BE} = 0$$

$$\mathbf{k}: \quad \frac{2.4}{9}T_{AD} + \frac{3.6}{7}T_{BE} - 2112 = 0$$

or $T_{AD} = 2160\text{ N}$ ◀

$T_{BE} = 2990\text{ N}$ ◀

Force equations:

$$C_x - \frac{8}{9}(2160.0\text{ N}) - \frac{6}{7}(2986.7\text{ N}) = 0, \quad \text{or} \quad C_x = 4480.0\text{ N}$$

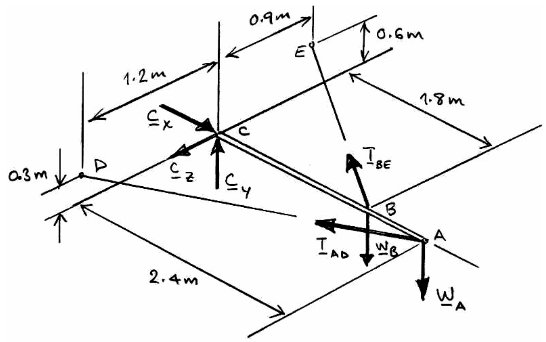
$$C_y + \frac{1}{9}(2160.0\text{ N}) + \frac{2}{7}(2986.7\text{ N}) - 880\text{ N} = 0, \quad \text{or} \quad C_y = -213.34\text{ N}$$

$$C_z + \frac{4}{9}(2160.0\text{ N}) - \frac{3}{7}(2986.7\text{ N}) = 0, \quad \text{or} \quad C_z = 320.01\text{ N}$$

$\mathbf{C} = (4480\text{ N})\mathbf{i} - (213\text{ N})\mathbf{j} + (320\text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 117.

Free-Body Diagram:



Express all forces in terms of rectangular components:

$$\mathbf{r}_A = (2.4 \text{ m})\mathbf{i}$$

$$\mathbf{r}_B = (1.8 \text{ m})\mathbf{j}$$

$$\overrightarrow{AD} = -(2.4 \text{ m})\mathbf{i} + (0.3 \text{ m})\mathbf{j} + (1.2 \text{ m})\mathbf{k}$$

$$\overrightarrow{BE} = -(1.8 \text{ m})\mathbf{i} + (0.6 \text{ m})\mathbf{j} - (0.9 \text{ m})\mathbf{k}$$

$$\mathbf{W}_A = -(440 \text{ N})\mathbf{j}$$

$$\mathbf{W}_B = -(440 \text{ N})\mathbf{j}$$

Then

$$\vec{T}_{AD} = T_{AD}\frac{\overrightarrow{AD}}{AD} = T_{AD}\frac{-2.4\mathbf{i} + 0.3\mathbf{j} + 1.2\mathbf{k}}{\sqrt{(-2.4)^2 + (0.3)^2 + (1.2)^2}} = -\frac{8}{9}T_{AD}\mathbf{i} + \frac{1}{9}T_{AD}\mathbf{j} + \frac{4}{9}T_{AD}\mathbf{k}$$

$$\vec{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = T_{BE}\frac{-1.8\mathbf{i} + 0.6\mathbf{j} - 0.9\mathbf{k}}{\sqrt{(-1.8)^2 + (0.6)^2 + (-0.9)^2}} = -\frac{6}{7}T_{AD}\mathbf{i} + \frac{2}{7}T_{AD}\mathbf{j} - \frac{3}{7}T_{AD}\mathbf{k}$$

continued

$\Sigma \mathbf{M}_C = 0: \quad \mathbf{r}_A \times \mathbf{T}_{AD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_A \times \mathbf{W}_A + \mathbf{r}_B \times \mathbf{W}_B = 0$

or $$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2.4 & 0 & 0 \\ -\frac{8}{9} & \frac{1}{9} & \frac{4}{9} \end{vmatrix} T_{AD} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 1.8 & 0 & 0 \\ -\frac{6}{7} & \frac{2}{7} & -\frac{3}{7} \end{vmatrix} T_{BE} + (2.4)\mathbf{i} \times (-440)\mathbf{j} + (1.8)\mathbf{i} \times (-440)\mathbf{j} = 0$$

Equating the coefficients of the unit vectors to zero:

$\mathbf{j}$: $$-\frac{9.6}{9} T_{AD} + \frac{5.4}{7} T_{BE} = 0$$

$\mathbf{k}$: $$\frac{2.4}{9} T_{AD} + \frac{3.6}{7} T_{BE} - 1848 = 0$$

or $T_{AD} = 1890 \text{ N}$ ◀

$T_{BE} = 2610 \text{ N}$ ◀

Force equations:

$$C_x - \frac{8}{9}(1890.00 \text{ N}) - \frac{6}{7}(2613.3 \text{ N}) = 0, \quad \text{or} \quad C_x = 3920.0 \text{ N}$$

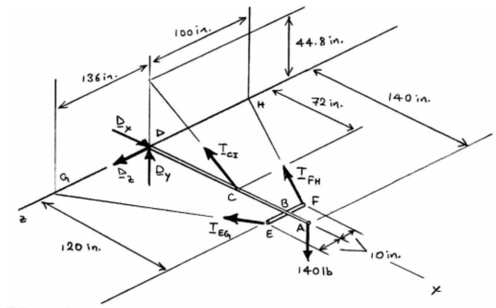
$$C_y + \frac{1}{9}(1890.00 \text{ N}) + \frac{2}{7}(2613.3 \text{ N}) - 440 \text{ N} - 440 \text{ N} = 0, \quad \text{or} \quad C_y = -76.657 \text{ N}$$

$$C_z + \frac{4}{9}(1890.00 \text{ N}) - \frac{3}{7}(2613.3 \text{ N}) = 0, \quad \text{or} \quad C_z = 279.99 \text{ N}$$

$\mathbf{C} = (3920 \text{ N})\mathbf{i} - (76.7 \text{ N})\mathbf{j} + (280 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 118.

Free-Body Diagram:



Express all forces in terms of rectangular components:

$$\mathbf{r}_A = (140 \text{ in.})\mathbf{i}$$

$$\mathbf{r}_C = (72 \text{ in.})\mathbf{i}$$

$$\overrightarrow{EG} = -(120 \text{ in.})\mathbf{i} + (126 \text{ in.})\mathbf{k}$$

$$\overrightarrow{FH} = -(120 \text{ in.})\mathbf{i} - (90 \text{ in.})\mathbf{k}$$

$$\overrightarrow{CI} = -(72 \text{ in.})\mathbf{i} + (44.8 \text{ in.})\mathbf{j}$$

$$\mathbf{W} = -(140 \text{ lb})\mathbf{j}$$

Then

$$\vec{T}_{EG} = T_{EG}\frac{\overrightarrow{EG}}{EG} = T_{EG}\frac{-120\mathbf{i} + 126\mathbf{k}}{\sqrt{(-120)^2 + (126)^2}} = -\frac{20}{29}T_{EG}\mathbf{i} + \frac{21}{29}T_{EG}\mathbf{k}$$

$$\vec{T}_{FH} = T_{FH}\frac{\overrightarrow{FH}}{FH} = T_{FH}\frac{-120\mathbf{i} - 90\mathbf{k}}{\sqrt{(-120)^2 + (-90)^2}} = -0.8T_{FH}\mathbf{i} - 0.6T_{FH}\mathbf{k}$$

$$\vec{T}_{CI} = T_{CI}\frac{\overrightarrow{CI}}{CI} = T_{CI}\frac{-72\mathbf{i} + 44.8\mathbf{j}}{\sqrt{(-72)^2 + (44.8)^2}} = -\frac{45}{53}T_{CI}\mathbf{i} + \frac{28}{53}T_{CI}\mathbf{j}$$

continued

$\Sigma \mathbf{M}_D = 0$: $\quad \mathbf{r}_E \times \mathbf{T}_{EG} + \mathbf{r}_F \times \mathbf{T}_{FH} + \mathbf{r}_C \times \mathbf{T}_{CI} + \mathbf{r}_A \times \mathbf{W} = 0$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 120 & 0 & 10 \\ -20 & 0 & 21 \end{vmatrix} \frac{T_{EG}}{29} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 120 & 0 & -10 \\ -4 & 0 & -3 \end{vmatrix} \frac{T_{FH}}{5} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 72 & 0 & 0 \\ -45 & 28 & 0 \end{vmatrix} \frac{T_{CI}}{53} - 19600 \text{ lb}\cdot\text{in.} = 0$$

Noting that $T_{CI} = T_{FH}$ and equating the coefficients of the unit vectors to zero:

$\mathbf{j}$: $\quad -93.793T_{EG} + 80T_{CI} = 0$

$\mathbf{k}$: $\quad 38.038T_{CI} - 19600 \text{ lb}\cdot\text{in.} = 0$

or $T_{CI} = T_{FH} = 515 \text{ lb}$ ◀

or $T_{EG} = 440 \text{ lb}$ ◀

Force equations:

$\Sigma F_x = 0$: $\quad D_x - \frac{20}{29}(439.50 \text{ lb}) - \frac{45}{53}(515.28 \text{ lb}) - \frac{4}{5}(515.28 \text{ lb}) = 0,$ or $D_x = 1152.83 \text{ lb}$

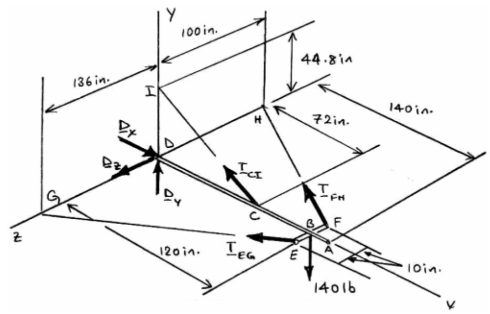
$\Sigma F_y = 0$: $\quad D_y + \frac{28}{53}(515.28 \text{ lb}) - 140 \text{ lb} = 0,$ or $D_y = -132.223 \text{ lb}$

$\Sigma F_z = 0$: $\quad D_z + \frac{21}{29}(439.50 \text{ lb}) - \frac{3}{5}(515.28) \text{ lb} = 0,$ or $D_z = -9.0906 \text{ lb}$

$\mathbf{D} = (1153 \text{ lb})\mathbf{i} - (132.2 \text{ lb})\mathbf{j} - (9.09 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 119.

Free-Body Diagram:



Express all forces in terms of rectangular components:

$$\mathbf{r}_B = (120 \text{ in.})\mathbf{i}$$

$$\mathbf{r}_C = (72 \text{ in.})\mathbf{i}$$

$$\overrightarrow{EG} = -(120 \text{ in.})\mathbf{i} + (126 \text{ in.})\mathbf{k}$$

$$\overrightarrow{FH} = -(120 \text{ in.})\mathbf{i} - (90 \text{ in.})\mathbf{k}$$

$$\overrightarrow{CI} = -(72 \text{ in.})\mathbf{i} + (44.8 \text{ in.})\mathbf{j}$$

$$\mathbf{W} = -(140 \text{ lb})\mathbf{j}$$

Then

$$\vec{T}_{EG} = T_{EG}\frac{\overrightarrow{EG}}{EG} = T_{EG}\frac{-120\mathbf{i} + 126\mathbf{k}}{\sqrt{(-120)^2 + (126)^2}} = -\frac{20}{29}T_{EG}\mathbf{i} + \frac{21}{29}T_{EG}\mathbf{k}$$

$$\vec{T}_{FH} = T_{FH}\frac{\overrightarrow{FH}}{FH} = T_{FH}\frac{-120\mathbf{i} - 90\mathbf{k}}{\sqrt{(-120)^2 + (-90)^2}} = -0.8T_{FH}\mathbf{i} - 0.6T_{FH}\mathbf{k}$$

$$\vec{T}_{CI} = T_{CI}\frac{\overrightarrow{CI}}{CI} = T_{CI}\frac{-72\mathbf{i} + 44.8\mathbf{j}}{\sqrt{(-72)^2 + (44.8)^2}} = -\frac{45}{53}T_{CI}\mathbf{i} + \frac{28}{53}T_{CI}\mathbf{j}$$

continued

$\Sigma \mathbf{M}_D = 0$: $\quad \mathbf{r}_E \times \mathbf{T}_{EG} + \mathbf{r}_F \times \mathbf{T}_{FH} + \mathbf{r}_C \times \mathbf{T}_{CI} + \mathbf{r}_A \times \mathbf{W} = 0$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 120 & 0 & 10 \\ -20 & 0 & 21 \end{vmatrix} \frac{T_{EG}}{29} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 120 & 0 & -10 \\ -4 & 0 & -3 \end{vmatrix} \frac{T_{FH}}{5} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 72 & 0 & 0 \\ -45 & 28 & 0 \end{vmatrix} \frac{T_{CI}}{53} - 19600 \text{ lb} \cdot \text{in.} = 0$$

Noting that $T_{CI} = T_{FH}$ and equating the coefficients of the unit vectors to zero:

$\mathbf{j}$: $\quad -93.793 T_{EG} + 80 T_{CI} = 0$

$\mathbf{k}$: $\quad 38.038 T_{CI} - 16800 \text{ lb} \cdot \text{in.} = 0$

or $T_{CI} = T_{FH} = 442 \text{ lb}$ ◀

$T_{EG} = 377 \text{ lb}$ ◀

Force equations:

$$\Sigma F_x = 0: \quad D_x - \frac{20}{29}(376.72 \text{ lb}) - \frac{45}{53}(441.67 \text{ lb}) - \frac{4}{5}(441.67 \text{ lb}) = 0, \quad \text{or} \quad D_x = 988.15 \text{ lb}$$

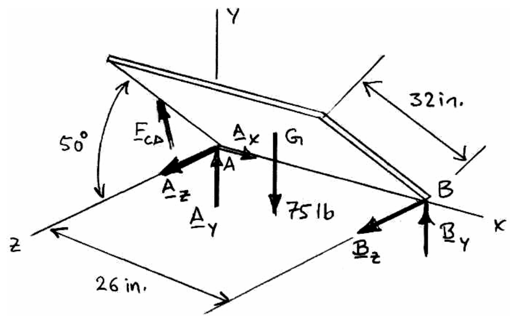
$$\Sigma F_y = 0: \quad D_y + \frac{28}{53}(441.67 \text{ lb}) - 140 \text{ lb} = 0, \quad \text{or} \quad D_y = -93.335 \text{ lb}$$

$$\Sigma F_z = 0: \quad D_z + \frac{21}{29}(376.72 \text{ lb}) - \frac{3}{5}(441.67 \text{ lb}) = 0, \quad \text{or} \quad D_z = -7.7952 \text{ lb}$$

$\mathbf{D} = (998 \text{ lb})\mathbf{i} - (93.3 \text{ lb})\mathbf{j} - (7.80 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 120.

Free-Body Diagram:



Geometry:

Using triangle *ACD* and the law of sines

$$\frac{\sin\alpha}{7\text{ in.}} = \frac{\sin 50^\circ}{15\text{ in.}} \quad \text{or} \quad \alpha = 20.946^\circ$$

$$\beta = 50^\circ + 20.946^\circ = 70.946^\circ$$

Expressing $\mathbf{F}_{CD}$ in terms of its rectangular coordinates:

$$\mathbf{F}_{CD} = F_{CD}\sin\beta\mathbf{j} + F_{CD}\cos\beta\mathbf{k}$$

$$= F_{CD}\sin 70.946^\circ\mathbf{j} + F_{CD}\cos 70.946^\circ\mathbf{k}$$

$$\mathbf{F}_{CD} = 0.94521F_{CD}\mathbf{j} + 0.32646F_{CD}\mathbf{k}$$

$\Sigma\mathbf{M}_B = 0$: $\quad (-26\text{ in.})\mathbf{i}\times\mathbf{A} + \left[(-13\text{ in.})\mathbf{i} + (16\text{ in.})\sin 50^\circ\mathbf{j} + (16\text{ in.})\cos 50^\circ\mathbf{k}\right]\times(-75\text{ lb})\mathbf{j}$

$$+\left[(-26\text{ in.})\mathbf{i} + (7\text{ in.})\mathbf{k}\right]\times\mathbf{F}_{CD} = 0$$

or $\quad -(26\text{ in.})A_y\mathbf{k} + (26\text{ in.})A_z\mathbf{j} + (13\text{ in.})(75\text{ lb})\mathbf{k} + (16\text{ in.})(75\text{ lb})\cos 50^\circ\mathbf{i}$

$$-(26\text{ in.})(0.94521F_{CD})\mathbf{k} + (26\text{ in.})(0.32646F_{CD})\mathbf{j} - (7\text{ in.})(0.94521F_{CD})\mathbf{i} = 0$$

continued

(*a*) Setting the coefficients of the unit vectors to zero:

$\mathbf{i}$: $(75 \text{ lb})\left[(16 \text{ in.})\cos 50°\right] - (0.94521F_{CD})(7 \text{ in.}) = 0$

$F_{CD} = 116.6 \text{ lb}$ ◀

(*b*) $\Sigma F_x = 0$: $A_x = 0$

$\mathbf{k}$: $-\left[0.94521(116.580 \text{ lb})\right](26 \text{ in.}) + (75 \text{ lb})(13 \text{ in.}) - A_y(26 \text{ in.}) = 0$

$A_y = -72.693 \text{ lb}$

$\mathbf{j}$: $\left[0.32646(116.580 \text{ lb})\right](26 \text{ in.}) + A_z(26 \text{ in.}) = 0$

$A_z = -38.059 \text{ lb}$

$\Sigma F_y = 0$: $-72.693 \text{ lb} + 0.94521(116.580 \text{ lb}) - 75 \text{ lb} + B_y = 0$

$B_y = 37.500 \text{ lb}$

$\Sigma F_z = 0$: $-38.059 \text{ lb} + 0.32646(116.580 \text{ lb}) + B_z = 0$

$B_z = 0$

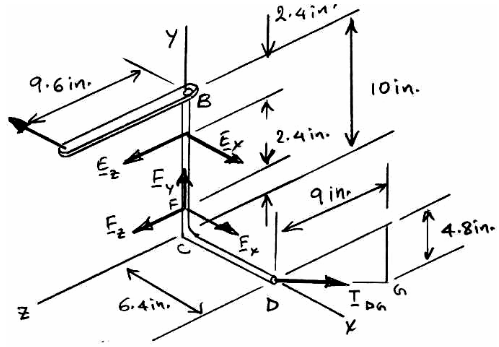
Therefore:

$\mathbf{A} = -(72.7 \text{ lb})\mathbf{j} - (38.1 \text{ lb})\mathbf{k}$ ◀

$\mathbf{B} = (37.5 \text{ lb})\mathbf{j}$ ◀

Chapter 4, Solution 121.

Free-Body Diagram:



Express tension in terms of rectangular components:

$$\overline{DG} = -(4.8 \text{ in.})\,\mathbf{j} - (9 \text{ in.})\,\mathbf{k}$$

$$\mathbf{T}_{DG} = T_{DG}\frac{\overrightarrow{DG}}{DG} = T_{DG}\frac{-4.7\mathbf{j} - 9\mathbf{k}}{\sqrt{(-4.8)^2 + (-9)^2}} = -\frac{8}{17}T_{DG}\,\mathbf{j} - \frac{15}{17}T_{DG}\,\mathbf{k}$$

Equilibrium:

$$\Sigma\mathbf{M}_F = 0: \quad \left[(6.4 \text{ in.})\,\mathbf{i} + (-2.4 \text{ in.})\,\mathbf{j}\right] \times \mathbf{T}_{DG} + (5.2 \text{ in.})\,\mathbf{j} \times \mathbf{E}$$
$$+\left[(7.6 \text{ in.})\,\mathbf{j} + (9.6 \text{ in.})\,\mathbf{k}\right] \times (-55 \text{ lb})\,\mathbf{i} = 0$$

or

$$(2.4 \text{ in.})\left(\frac{15}{17}\right)T_{DG}\,\mathbf{i} - (6.4 \text{ in.})\left(\frac{8}{17}\right)T_{DG}\,\mathbf{k} + (6.4 \text{ in.})\left(\frac{15}{17}\right)T_{DG}\,\mathbf{j}$$
$$-(5.2 \text{ in.})E_x\,\mathbf{k} + (5.2 \text{ in.})E_z\,\mathbf{i} + (7.6 \text{ in.})(55 \text{ lb})\mathbf{k} - (9.6 \text{ in.})(55 \text{ lb})\mathbf{j} = 0$$

Setting the coefficients of the unit vectors equal to zero:

(*a*) $\mathbf{j}$: $\dfrac{15}{17}T_{DG}(6.4 \text{ in.}) - (55 \text{ lb})(9.6 \text{ in.}) = 0$

$T_{DG} = 93.5$ lb ◀

continued

(*b*) **k**: $(55\text{ lb})(7.6\text{ in.}) - E_x(5.2\text{ in.}) - \left[\frac{8}{17}(93.500\text{ lb})\right](6.4\text{ in.}) = 0$

$E_x = 26.231\text{ lb}$

i: $E_z(5.2\text{ in.}) + \left[\frac{15}{17}(93.500\text{ lb})\right](2.4\text{ in.}) = 0$

$E_z = -38.077\text{ lb}$

$\Sigma F_x = 0$: $-55\text{ lb} + 26.231\text{ lb} + F_x = 0$

$F_x = 28.796\text{ lb}$

$\Sigma F_y = 0$: $F_y - \frac{8}{17}(93.500\text{ lb}) = 0$

$F_y = 44.000\text{ lb}$

$\Sigma F_z = 0$: $-38.077\text{ lb} + F_z - \frac{15}{17}(93.500\text{ lb}) = 0$

$F_z = 120.577\text{ lb}$

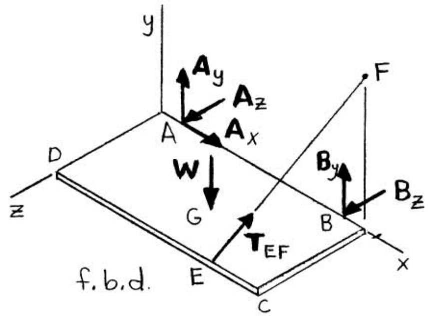
Therefore:

$\mathbf{E} = (26.2\text{ lb})\mathbf{i} - (38.1\text{ lb})\mathbf{k}$ ◀

$\mathbf{F} = (28.8\text{ lb})\mathbf{i} + (44.0\text{ lb})\mathbf{j} + (120.6\text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 122.

Free-Body Diagram:



First note $W = mg = (15\text{ kg})(9.81\text{ m/s}^2) = 147.15\text{ N}$

(*a*)

$$\mathbf{T}_{EF} = \boldsymbol{\lambda}_{EF}T_{EF} = \left[\frac{(0.08\text{ m})\mathbf{i} + (0.25\text{ m})\mathbf{j} - (0.2\text{ m})\mathbf{k}}{\sqrt{(0.08)^2 + (0.25)^2 + (0.2)^2}\text{ m}}\right]T_{EF} = \frac{T_{EF}}{0.33}(0.08\mathbf{i} + 0.25\mathbf{j} - 0.2\mathbf{k})$$

From free-body diagram of rectangular plate

$$\Sigma M_x = 0: \quad (147.15\text{ N})(0.1\text{ m}) - (T_{EF})_y(0.2\text{ m}) = 0$$

or

$$14.715\text{ N}\cdot\text{m} - \left[\left(\frac{0.25}{0.33}\right)T_{EF}\right](0.2\text{ m}) = 0$$

or

$$T_{EF} = 97.119\text{ N}$$

$$\text{or } T_{EF} = 97.1\text{ N} \blacktriangleleft$$

(*b*)

$$\Sigma F_x = 0: \quad A_x + (T_{EF})_x = 0$$

$$A_x + \left(\frac{0.08}{0.33}\right)(97.119\text{ N}) = 0$$

$$\therefore \quad A_x = -23.544\text{ N}$$

continued

$\Sigma M_{B(z\text{-axis})} = 0: \quad -A_y(0.3\text{ m}) - (T_{EF})_y(0.04\text{ m}) + W(0.15\text{ m}) = 0$

or $\quad -A_y(0.3\text{ m}) - \left[\left(\dfrac{0.25}{0.33}\right)97.119\text{ N}\right](0.04\text{ m}) + 147.15\text{ N}(0.15\text{ m}) = 0$

$$\therefore \quad A_y = 63.765\text{ N}$$

$\Sigma M_{B(y\text{-axis})} = 0: \quad A_z(0.3\text{ m}) + (T_{EF})_x(0.2\text{ m}) + (T_{EF})_z(0.04\text{ m}) = 0$

$$A_z(0.3\text{ m}) + \left[\left(\frac{0.08}{0.33}\right)T_{EF}\right](0.2\text{ m}) - \left[\left(\frac{0.2}{0.33}\right)T_{EF}\right](0.04\text{ m}) = 0$$

$$\therefore \quad A_z = -7.848\text{ N}$$

and $\mathbf{A} = -(23.5\text{ N})\mathbf{i} + (63.8\text{ N})\mathbf{j} - (7.85\text{ N})\mathbf{k}$ ◀

$\Sigma F_y = 0: \quad A_y - W + (T_{EF})_y + B_y = 0$

$$63.765\text{ N} - 147.15\text{ N} + \left(\frac{0.25}{0.33}\right)(97.119\text{ N}) + B_y = 0$$

$$\therefore \quad B_y = 9.81\text{ N}$$

$\Sigma F_z = 0: \quad A_z - (T_{EF})_z + B_z = 0$

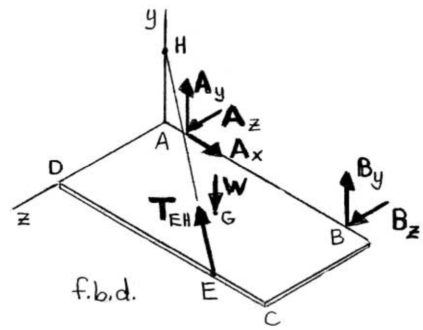
$$-7.848\text{ N} - \left(\frac{0.2}{0.33}\right)(97.119\text{ N}) + B_z = 0$$

$$\therefore \quad B_z = 66.708\text{ N}$$

and $\mathbf{B} = (9.81\text{ N})\mathbf{j} + (66.7\text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 123.

Free-Body Diagram:



First note $$W = mg = (15 \text{ kg})(9.81 \text{ m/s}^2) = 147.15 \text{ N}$$

(*a*) $$\mathbf{T}_{EH} = \boldsymbol{\lambda}_{EH} T_{EH} = \left[\frac{-(0.3 \text{ m})\mathbf{i} + (0.12 \text{ m})\mathbf{j} - (0.2 \text{ m})\mathbf{k}}{\sqrt{(0.3)^2 + (0.12)^2 + (0.2)^2} \text{ m}}\right] T_{EH} = \frac{T_{EH}}{0.38}\left[-(0.3)\mathbf{i} + (0.12)\mathbf{j} - (0.2)\mathbf{k}\right]$$

From free-body diagram of rectangular plate

$$\Sigma M_x = 0: \quad (147.15 \text{ N})(0.1 \text{ m}) - (T_{EH})_y (0.2 \text{ m}) = 0$$

or $$(147.15 \text{ N})(0.1 \text{ m}) - \left[\left(\frac{0.12}{0.38}\right) T_{EH}\right](0.2 \text{ m}) = 0$$

or $$T_{EH} = 232.99 \text{ N}$$

or $T_{EH} = 233$ N ◀

(*b*) $$\Sigma F_x = 0: \quad A_x + (T_{EH})_x = 0$$

$$A_x - \left(\frac{0.3}{0.38}\right)(232.99 \text{ N}) = 0$$

$$\therefore \quad A_x = 183.938 \text{ N}$$

continued

$\Sigma M_{B(z\text{-axis})} = 0$: $\quad -A_y(0.3\text{ m}) - (T_{EH})_y(0.04\text{ m}) + W(0.15\text{ m}) = 0$

or $\quad -A_y(0.3\text{ m}) - \left[\dfrac{0.12}{0.38}(232.99\text{ N})\right](0.04\text{ m}) + (147.15\text{ N})(0.15\text{ m}) = 0$

$\therefore \quad A_y = 63.765\text{ N}$

$\Sigma M_{B(y\text{-axis})} = 0$: $\quad A_z(0.3\text{ m}) + (T_{EH})_x(0.2\text{ m}) + (T_{EH})_z(0.04\text{ m}) = 0$

or $\quad A_z(0.3\text{ m}) - \left[\left(\dfrac{0.3}{0.38}\right)(232.99\text{ N})\right](0.2\text{ m}) - \left[\left(\dfrac{0.2}{0.38}\right)(232.99)\right](0.04\text{ m}) = 0$

$\therefore \quad A_z = 138.976\text{ N}$

and $\mathbf{A} = (183.9\text{ N})\mathbf{i} + (63.8\text{ N})\mathbf{j} + (139.0\text{ N})\mathbf{k}$ ◀

$\Sigma F_y = 0$: $\quad A_y + B_y - W + (T_{EH})_y = 0$

$63.765\text{ N} + B_y - 147.15\text{ N} + \left(\dfrac{0.12}{0.38}\right)(232.99\text{ N}) = 0$

$\therefore \quad B_y = 9.8092\text{ N}$

$\Sigma F_z = 0$: $\quad A_z + B_z - (T_{EH})_z = 0$

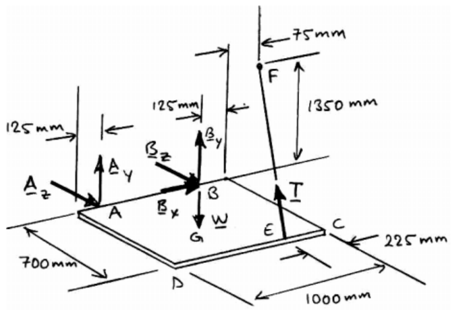
$138.976\text{ N} + B_z - \left(\dfrac{0.2}{0.38}\right)(232.99\text{ N}) = 0$

$\therefore \quad B_z = -16.3497\text{ N}$

and $\mathbf{B} = (9.81\text{ N})\mathbf{j} - (16.35\text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 124.

Free-Body Diagram:



Express tension, weight in terms of rectangular components:

$$\overrightarrow{EF} = (300 \text{ mm})\mathbf{i} + (1350 \text{ mm})\mathbf{j} - (700 \text{ mm})\mathbf{k}$$

$$\mathbf{T} = T\frac{\overrightarrow{EF}}{EF} = T\frac{300\mathbf{i} + 1350\mathbf{j} - 700\mathbf{k}}{\sqrt{(300)^2 + (1350)^2 + (-700)^2}}$$

$$= \frac{6}{31}T\,\mathbf{i} + \frac{27}{31}T\,\mathbf{j} - \frac{14}{31}T\,\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(7 \text{ kg})(9.81 \text{ m/s}^2)\mathbf{j} = -(68.67 \text{ N})\mathbf{j}$$

$$\Sigma\mathbf{M}_B = 0: \quad -(750 \text{ mm})\mathbf{i}\times\mathbf{A} + \left[-(375 \text{ mm})\mathbf{i} + (350 \text{ mm})\mathbf{k}\right]\times(-68.7 \text{ N})\mathbf{j}$$
$$+\left[(-100 \text{ mm})\mathbf{i} + (700 \text{ mm})\mathbf{k}\right]\times\mathbf{T} = 0$$

or

$$-(750 \text{ mm})A_y\mathbf{k} + (125 \text{ mm})A_z\mathbf{j} + (375 \text{ mm})(68.7 \text{ N})\mathbf{k} + (350 \text{ mm})(68.7 \text{ N})\mathbf{i}$$
$$+\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -100 & 0 & 700 \\ 6 & 27 & -14 \end{vmatrix}\frac{T}{31}(\text{mm}) = 0$$

continued

Setting the coefficients of the unit vectors equal to zero:

(*a*) **i**: $-\frac{27}{31}T(700 \text{ mm}) + (68.67 \text{ N})(350 \text{ mm}) = 0$

$T = 39.422 \text{ N}$ or $T = 39.4\text{N}$ ◀

(*b*) **k**: $-A_y(750 \text{ mm}) + (68.67 \text{ N})(375 \text{ mm}) - \left[\frac{27}{31}(39.422 \text{ N})\right](100 \text{ mm}) = 0$

$A_y = 29.757 \text{ N}$

j: $A_z(750 \text{ mm}) - \left[\frac{14}{31}(39.422 \text{ N})\right](100 \text{ mm}) + \left[\frac{6}{31}(39.422 \text{ N})\right](700 \text{ mm}) = 0$

$A_z = -4.7476 \text{ N}$

$\Sigma F_x = 0$: $B_x + \frac{6}{31}(39.422 \text{ N}) = 0$

$B_x = -7.6301 \text{ N}$

$\Sigma F_y = 0$: $29.757 \text{ N} + B_y - 68.67 \text{ N} + \frac{27}{31}(39.422 \text{ N}) = 0$

$B_y = 4.5777 \text{ N}$

$\Sigma F_z = 0$: $-4.7476 \text{ N} + B_z - \frac{14}{31}(39.422 \text{ N}) = 0$

$B_z = 22.551 \text{ N}$

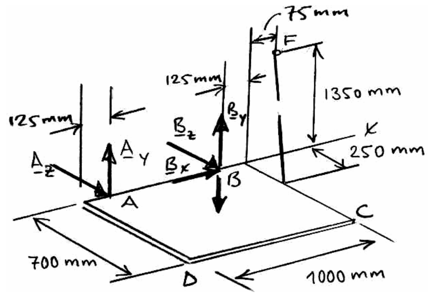
Therefore:

$\mathbf{A} = (29.8 \text{ N})\mathbf{j} - (4.75 \text{ N})\mathbf{k}$ ◀

$\mathbf{B} = -(7.63 \text{ N})\mathbf{i} + (4.58 \text{ N})\mathbf{j} + (22.6 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 125.

Free-Body Diagram:



Express tension, weight in terms of rectangular components:

$$\overrightarrow{IF} = (75 \text{ mm})\mathbf{i} + (1350 \text{ mm})\mathbf{j} - (250 \text{ mm})\mathbf{k}$$

$$\mathbf{T} = T\frac{\overrightarrow{IF}}{IF} = T\frac{75\mathbf{i} + 1350\mathbf{j} - 250\mathbf{k}}{\sqrt{(75)^2 + (1350)^2 + (-250)^2}}$$

$$= \frac{3}{55}T\,\mathbf{i} + \frac{54}{55}T\,\mathbf{j} - \frac{10}{55}T\,\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(7 \text{ kg})\left(9.81 \text{ m/s}^2\right)\mathbf{j} = -(68.67 \text{ N})\mathbf{j}$$

$\Sigma\mathbf{M}_B = 0$: $\quad -(750 \text{ mm})\mathbf{i} \times \mathbf{A} + \left[-(375 \text{ mm})\mathbf{i} + (350 \text{ mm})\mathbf{k}\right] \times (-68.7 \text{ N})\mathbf{j}$

$$+ \left[(125 \text{ mm})\mathbf{i} + (250 \text{ mm})\mathbf{k}\right] \times \mathbf{T} = 0$$

or $\quad -(750 \text{ mm})A_y\mathbf{k} + (125 \text{ mm})A_z\mathbf{j} + (375 \text{ mm})(68.7 \text{ N})\mathbf{k} + (350 \text{ mm})(68.7 \text{ N})\mathbf{i}$

$$+ \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 125 & 0 & 250 \\ 3 & 54 & -10 \end{vmatrix} \frac{T}{55}(\text{mm}) = 0$$

continued

Setting the coefficients of the unit vectors equal to zero:

(*a*) **i**: $-\frac{54}{55}T(250 \text{ mm}) + (68.67 \text{ N})(350 \text{ mm}) = 0$

$T = 97.918 \text{ N}$ or $T = 97.9 \text{ N}$ ◀

(*b*) **k**: $-A_y(750 \text{ mm}) + (68.67 \text{ N})(375 \text{ mm}) - \left[\frac{54}{55}(97.918 \text{ N})\right](125 \text{ mm}) = 0$

$A_y = 50.358 \text{ N}$

j: $A_z(750 \text{ mm}) - \left[\frac{10}{55}(97.918 \text{ N})\right](125 \text{ mm}) + \left[\frac{3}{55}(97.918 \text{ N})\right](250 \text{ mm}) = 0$

$A_z = -4.7475 \text{ N}$

$\Sigma F_x = 0$: $B_x + \frac{3}{55}(97.918 \text{ N}) = 0$

$B_x = -5.3410 \text{ N}$

$\Sigma F_y = 0$: $50.358 \text{ N} + B_y - 68.67 \text{ N} + \frac{54}{55}(97.918 \text{ N}) = 0$

$B_y = -77.826 \text{ N}$

$\Sigma F_z = 0$: $-4.7475 \text{ N} + B_z - \frac{10}{55}(97.918 \text{ N}) = 0$

$B_z = 22.551 \text{ N}$

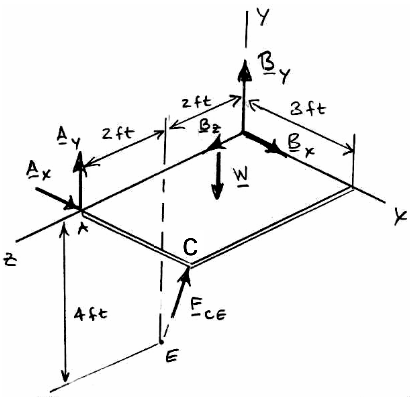
Therefore:

$\mathbf{A} = (50.4 \text{ N})\mathbf{j} - (4.75 \text{ N})\mathbf{k}$ ◀

$\mathbf{B} = -(5.34 \text{ N})\mathbf{i} - (77.8 \text{ N})\mathbf{j} + (22.6 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 126.

Free-Body Diagram:



Express forces, weight in terms of rectangular components:

$$\overline{CE} = (3\text{ ft})\mathbf{i} + (4\text{ ft})\mathbf{j} - (2\text{ ft})\mathbf{k}$$

$$\mathbf{F}_{CE} = F_{CE}\frac{\overrightarrow{CE}}{CE} = F_{CE}\frac{3\mathbf{i} + 4\mathbf{j} + 2\mathbf{k}}{\sqrt{(3)^2 + (4)^2 + (2)^2}}$$

$$= 0.55709 F_{CE}\,\mathbf{i} + 0.74278 F_{CE}\,\mathbf{j} + 0.37139 F_{CE}\,\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(300\text{ lb})\mathbf{j}$$

$$\Sigma\mathbf{M}_B = 0: \quad (4\text{ ft})\mathbf{k}\times\mathbf{A} + \left[(1.5\text{ ft})\mathbf{i} + (2\text{ ft})\mathbf{k}\right]\times(-300\text{ lb})\mathbf{j}$$

$$+\left[(3\text{ ft})\mathbf{i} + (4\text{ ft})\mathbf{k}\right]\times\mathbf{F}_{CE} = 0$$

or $$-(4\text{ ft})A_y\mathbf{i} + (4\text{ ft})A_z\mathbf{j} - (1.5\text{ ft})(300\text{ lb})\mathbf{k} + (2\text{ ft})(300\text{ lb})\mathbf{i}$$

$$+\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 3 & 0 & 4 \\ 0.55709 & 0.74278 & 0.37139 \end{vmatrix} F_{CE}(\text{ft}) = 0$$

continued

Setting the coefficients of the unit vectors equal to zero:

$\mathbf{k}$: $(0.74278F_{CE})(3\text{ ft}) - (300\text{ lb})(1.5\text{ ft}) = 0$

$F_{CE} = 201.94\text{ lb}$

or $F_{CE} = 202\text{ lb}$ ◀

$\mathbf{j}$: $A_x(4\text{ ft}) + [0.55709(201.94\text{ lb})](4\text{ ft}) - [0.37139(201.94\text{ lb})](3\text{ ft}) = 0$

$A_x = -56.250\text{ lb}$

$\mathbf{i}$: $-A_y(4\text{ ft}) - [0.74278(201.94\text{ lb})](4\text{ ft}) + (300\text{ lb})(2\text{ ft}) = 0$

$A_y = 0$

$\Sigma F_x = 0$: $-56.250\text{ lb} + B_x + 0.55709(201.94\text{ lb}) = 0$

$B_x = -56.249\text{ lb}$

$\Sigma F_y = 0$: $0 + B_y - 300\text{ lb} + 0.74278(201.94\text{ lb}) = 0$

$B_y = 150.003\text{ lb}$

$\Sigma F_z = 0$: $B_z + 0.371391(201.94\text{ lb}) = 0$

$B_z = -74.999\text{ lb}$

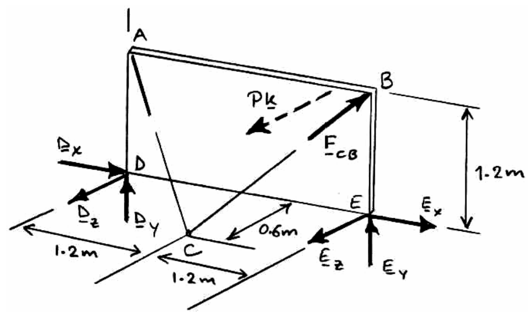
Therefore:

$\mathbf{A} = -(56.3\text{ lb})\mathbf{i}$ ◀

$\mathbf{B} = -(56.2\text{ lb})\mathbf{i} + (150.0\text{ lb})\mathbf{j} - (75.0\text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 127.

Free-Body Diagram:



Express forces, weight in terms of rectangular components:

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

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

By symmetry $F_{CA} = F_{CB}$, and at the load corresponding to buckling ?!

$$F_{CA} = F_{CB} = 1.8 \text{ kN}$$

$$\mathbf{F}_{CA} = F_{CA}\frac{\overrightarrow{CA}}{CA} = (1.8 \text{ kN})\frac{-1.2\mathbf{i} + 1.2\mathbf{j} - 0.6\mathbf{k}}{\sqrt{(-1.2)^2 + (1.2)^2 + (-0.6)^2}}$$

$$\mathbf{F}_{CA} = -(1.2 \text{ kN})\mathbf{i} + (1.2 \text{ kN})\mathbf{j} - (0.6 \text{ kN})\mathbf{k}$$

$$\mathbf{F}_{CB} = F_{CB}\frac{\overrightarrow{CB}}{CB} = (1.8 \text{ kN})\frac{1.2\mathbf{i} + 1.2\mathbf{j} - 0.6\mathbf{k}}{\sqrt{(1.2)^2 + (1.2)^2 + (-0.6)^2}}$$

$$\mathbf{F}_{CB} = (1.2 \text{ kN})\mathbf{i} + (1.2 \text{ kN})\mathbf{j} - (0.6 \text{ kN})\mathbf{k}$$

continued

$\Sigma \mathbf{M}_D = 0$: $\quad (2.4 \text{ m})\mathbf{i} \times \mathbf{E} + \left[(2.4 \text{ m})\mathbf{i} + (1.2 \text{ m})\mathbf{j}\right] \times \mathbf{F}_{CB} + (1.2 \text{ m})\mathbf{j} \times \mathbf{F}_{CA}$

$$+\left[(1.2 \text{ m})\mathbf{i} + (0.6 \text{ m})\mathbf{j}\right] \times P\mathbf{k} = 0$$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ (2.4 \text{ m}) & 0 & 0 \\ E_x & E_y & E_z \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2.4 & 1.2 & 0 \\ 1.2 & 1.2 & -0.6 \end{vmatrix} \text{kN} \cdot \text{m}$$

$$+ \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 1.2 & 0 \\ -1.2 & 1.2 & -0.6 \end{vmatrix} \text{kN} \cdot \text{m} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ (1.2 \text{ m}) & (0.6 \text{ m}) & 0 \\ 0 & 0 & P \end{vmatrix} = 0$$

Setting the coefficient of the unit vector **i** equal to zero:

(*a*) $\mathbf{i}: P(0.6 \text{ m}) - (0.6)(1.2)\text{kN} \cdot \text{m} - (0.6)(1.2)\text{kN} \cdot \text{m} = 0$

$$P = 2.4000 \text{ kN}$$

or $P = 2.40$ kN ◀

(*b*) By symmetry, $D_z = E_z$

$\Sigma F_z = 0$: $\quad D_z + D_z + 2.4 \text{ kN} - 0.6 \text{ kN} - 0.6 \text{ kN} = 0$

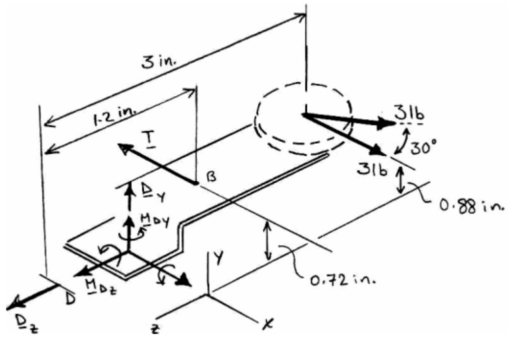
$$D_z = E_z = -0.60000 \text{ kN}$$

Therefore:

$\mathbf{E}_z = -(0.600 \text{ kN})\mathbf{k}$ ◀

Chapter 4, Solution 128.

Free-Body Diagram:



Notice that the forces in the belts can be equivalently moved to the center of the pulley because their net moment about this point is zero.

(*a*) $\Sigma F_x = 0$: $\quad 3\text{ lb} + (3\text{ lb})\cos 30° - T = 0$

$$T = 5.5981\text{ lb}$$

or $T = 5.60\text{ lb}$ ◀

(*b*) $\Sigma F_y = 0$: $\quad D_y = 0$

$\Sigma F_z = 0$: $\quad D_z - (3\text{ lb})\sin 30° = 0$

$\mathbf{D} = (1.500\text{ lb})\mathbf{k}$ ◀

$\Sigma \mathbf{M}_D = 0$: $\quad \mathbf{M}_D + \left[(0.72\text{ in.})\mathbf{j} - (1.2\text{ in.})\mathbf{k}\right]\times(-T)\mathbf{i}$

$$+\left[(0.88\text{ in.})\mathbf{j} - (3\text{ in.})\mathbf{k}\right]\times\left[(3\text{ lb})(1+\cos 30°)\mathbf{i} - (3\text{ lb})\sin 30°\mathbf{k}\right] = 0$$

$$\text{or}\ \left(M_{Dx}\mathbf{i} + M_{Dy}\mathbf{j} + M_{Dz}\mathbf{k}\right) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & (0.72\text{ in.}) & (-1.2\text{ in.}) \\ -T & 0 & 0 \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & (0.88\text{ in.}) & (-3\text{ in.}) \\ 1+\cos 30° & 0 & -\sin 30° \end{vmatrix}(3\text{ lb}) = 0$$

continued

Setting the coefficients of the unit vectors equal to zero:

$$\mathbf{i}: \quad M_{Dx} - \left[(3\text{ lb})\sin 30°\right](0.88\text{ in.}) = 0$$

$$M_{Dx} = 1.3200\text{ lb}\cdot\text{in.}$$

$$\mathbf{j}: \quad M_{Dy} + (5.5981\text{ lb})(1.2\text{ in.}) - (3\text{ lb})(3\text{ in.})(1 + \cos 30°) = 0$$

$$M_{Dy} = 10.0765\text{ lb}\cdot\text{in.}$$

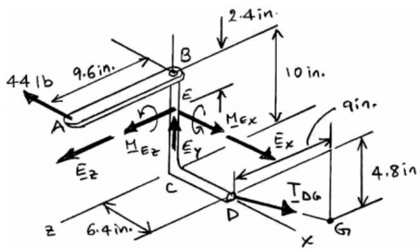
$$\mathbf{k}: \quad M_{Dz} + (5.5981\text{ lb})(0.72\text{ in.}) - (3\text{ lb})(0.88\text{ in.})(1 + \cos 30°) = 0$$

$$M_{Dz} = 0.89568\text{ lb}\cdot\text{in.}$$

or $\mathbf{M}_D = (1.320\text{ lb}\cdot\text{in.})\mathbf{i} + (10.08\text{ lb}\cdot\text{in.})\mathbf{j} + (0.896\text{ lb}\cdot\text{in.})\mathbf{k}$ ◀

Chapter 4, Solution 129.

Free-Body Diagram:



Express the tension in terms of its rectangular components:

$$\overrightarrow{DG} = -(4.8 \text{ in.})\mathbf{j} - (9 \text{ in.})\mathbf{k}$$

$$\mathbf{T}_{DC} = T_{DG}\frac{\overrightarrow{DG}}{DG} = T_{DG}\frac{-4.8\,\mathbf{j} - 9\,\mathbf{k}}{\sqrt{(-4.8)^2 + (-9)^2}} = -\frac{8}{17}T_{DG}\,\mathbf{j} - \frac{15}{17}T_{DG}\,\mathbf{k}$$

$$\Sigma\mathbf{M}_E = 0: \qquad \mathbf{M}_E + \left[(6.4 \text{ in.})\mathbf{i} + (-7.6 \text{ in.})\mathbf{j}\right]\times\mathbf{T}_{DG}$$

$$+\left[(2.4 \text{ in.})\mathbf{j} + (9.6 \text{ in.})\mathbf{k}\right]\times(-44 \text{ lb})\mathbf{i} = 0$$

or $$\left(M_{Ex}\,\mathbf{i} + M_{Ey}\,\mathbf{j} + M_{Ez}\,\mathbf{k}\right) + (7.6 \text{ in.})\left(\frac{15}{17}\right)T_{DG}\mathbf{i} - (6.4 \text{ in.})\left(\frac{8}{17}\right)T_{DG}\mathbf{k} + (6.4 \text{ in.})\left(\frac{15}{17}\right)T_{DG}\mathbf{j}$$

$$+(2.4 \text{ in.})(44 \text{ lb})\mathbf{k} - (9.6 \text{ in.})(44 \text{ lb})\mathbf{j} = 0$$

Setting the coefficient of the unit vector **j** equal to zero:

(*a*) **j**: $$\left(\frac{15}{17}T_{DG}\right)(6.4 \text{ in.}) - (44 \text{ lb})(9.6 \text{ in.}) = 0$$

$$T_{DG} = 74.800 \text{ lb}$$

or $T_{DG} = 74.8 \text{ lb}$ ◀

continued

(*b*) $\Sigma F_x = 0$: $\quad E_x - 44 \text{ lb} = 0, \text{ or } E_x = 44.000 \text{ lb}$

$\Sigma F_y = 0$: $\quad E_y - \frac{8}{17}(74.8 \text{ lb}) = 0, \text{ or } E_y = 35.200 \text{ lb}$

$\Sigma F_z = 0$: $\quad E_z - \frac{15}{17}(74.8 \text{ lb}) = 0, \text{ or } E_z = 66.000 \text{ lb}$

or $\mathbf{E} = (44.0 \text{ lb})\mathbf{i} + (35.2 \text{ lb})\mathbf{j} + (66.0 \text{ lb})\mathbf{k}$ ◀

Using the moment equation again and setting the coefficients of the unit vectors **i** and **k** equal to zero:

i: $\quad M_{Ex} + (7.6 \text{ in.})\left(\frac{15}{17}\right)(74.800 \text{ lb}) = 0$

$$M_{Ex} = -501.60 \text{ lb}\cdot\text{in.}$$

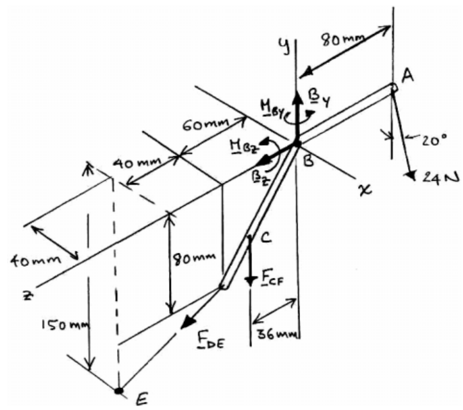
k: $\quad M_{Ez} + (44 \text{ lb})(2.4 \text{ in.}) - \left[\frac{8}{17}(74.8 \text{ lb})\right](6.4 \text{ in.}) = 0$

$$M_{Ex} = 119.680 \text{ lb}\cdot\text{in.}$$

or $\mathbf{M}_E = -(502 \text{ lb}\cdot\text{in.})\mathbf{i} + (119.7 \text{ lb}\cdot\text{in.})\mathbf{k}$ ◀

Chapter 4, Solution 130.

Free-Body Diagram:



60mm	36mm
80mm	Cy

⟶ Cy = 48mm

Express forces and moments in terms of rectangular components:

$$\mathbf{F}_{DE} = F_{DE}\frac{-40\,\mathbf{i} - 70\,\mathbf{j} + 40\mathbf{k}}{\sqrt{(-40)^2 + (-70)^2 + (40)^2}} = \frac{F_{DE}}{9}(-4\,\mathbf{i} - 7\,\mathbf{j} + 4\,\mathbf{k})$$

$$\mathbf{F}_A = (24\text{ N})(\sin 20°\,\mathbf{i} - \cos 20°\,\mathbf{j})$$

$$\mathbf{B} = B_y\mathbf{j} + B_z\mathbf{k}, \qquad \mathbf{M}_B = M_{By}\mathbf{j} + M_{Bz}\mathbf{k}$$

(*a*) $\Sigma F_x = 0$: $\quad -\frac{4}{9}F_{DE} + 24\sin 20° = 0$

$F_{DE} = 18.4691\text{ N}$ $\qquad$ or $F_{DE} = 18.47\text{ N}$ ◀

$\Sigma\mathbf{M}_B = 0$: $\quad \mathbf{r}_{BC}\times\mathbf{F}_{CF} + \mathbf{r}_{BD}\times\mathbf{F}_{DE} + \mathbf{r}_{BA}\times\mathbf{F}_A + \mathbf{M}_B = 0$

$$\text{or}\quad F_{CF}\begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ 0 & -48 & 36\\ 0 & -1 & 0\end{vmatrix} + \frac{18.4691}{9}\begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ 0 & -80 & 60\\ -4 & -7 & 4\end{vmatrix} + (80)(24)\begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ 0 & 0 & -1\\ \sin 20° & -\cos 20° & 0\end{vmatrix} + \left[M_{By}\mathbf{j} + M_{Bz}\mathbf{k}\right]$$

continued

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \quad 36F_{CF} + \frac{18.4691}{9}(100) + (80)(24)(-\cos 20°) = 0$$

$$F_{CF} = 44.417 \text{ N}$$

or $F_{CF} = 44.4$ N ◀

(*b*)

$$\mathbf{j}: \quad \frac{18.4691}{9}(-240) + (80)(24)(-\sin 20°) + M_{By} = 0$$

$$M_{By} = 1149.19 \text{ N}\cdot\text{mm}$$

$$\mathbf{k}: \quad \frac{18.4691}{9}(-320) + M_{Bz} = 0$$

$$M_{Bz} = 656.68 \text{ N}\cdot\text{mm}$$

$$\Sigma F_y = 0: \quad B_y - 44.417 - \frac{7}{9}(18.4691) - 24\cos 20° = 0$$

$$B_y = 81.3 \text{ N}$$

$$\Sigma F_z = 0: \quad B_z + \frac{4}{9}(18.4691) = 0$$

$$B_z = -8.21 \text{ N}$$

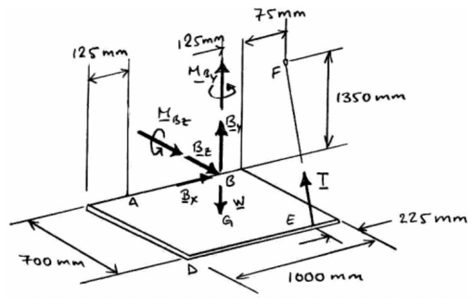
Therefore:

$\mathbf{B} = (81.3 \text{ N})\mathbf{j} - (8.21 \text{ N})\mathbf{k}$ ◀

$\mathbf{M}_B = (1.149 \text{ N}\cdot\text{m})\mathbf{j} + (0.657 \text{ N}\cdot\text{m})\mathbf{k}$ ◀

Chapter 4, Solution 131.

Free-Body Diagram:



Express tension, weight in terms of rectangular components:

$$\overrightarrow{EF} = (300 \text{ mm})\mathbf{i} + (1350 \text{ mm})\mathbf{j} - (700 \text{ mm})\mathbf{k}$$

$$\mathbf{T} = T\frac{\overrightarrow{EF}}{EF} = T\frac{300\mathbf{i} + 1350\mathbf{j} - 700\mathbf{k}}{\sqrt{(300)^2 + (1350)^2 + (-700)^2}}$$

$$= \frac{6}{31}T\,\mathbf{i} + \frac{27}{31}T\,\mathbf{j} - \frac{14}{31}T\,\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(7 \text{ kg})\left(9.81 \text{ m/s}^2\right)\mathbf{j} = -(68.67 \text{ N})\mathbf{j}$$

$$\Sigma\mathbf{M}_B = 0: \quad \mathbf{M}_B + \left[-(375 \text{ mm})\mathbf{i} + (350 \text{ mm})\mathbf{k}\right] \times (-68.7 \text{ N})\mathbf{j}$$

$$+\left[(-100 \text{ mm})\mathbf{i} + (700 \text{ mm})\mathbf{k}\right] \times \mathbf{T} = 0$$

or $$\left(M_{By}\mathbf{j} + M_{Bz}\mathbf{k}\right) + (375 \text{ mm})(68.7 \text{ N})\mathbf{k} + (350 \text{ mm})(68.7 \text{ N})\mathbf{i}$$

$$+\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -100 & 0 & 700 \\ 6 & 27 & -14 \end{vmatrix}\frac{T}{31}(\text{mm}) = 0$$

continued

Setting the coefficients of the unit vector **i** equal to zero:

(*a*) **i**: $-\frac{27}{31}T(700\text{ mm}) - (68.67\text{ N})(350\text{ mm}) = 0$

$T = 39.422\text{ N}$ or $T = 39.4\text{ N}$ ◀

(*b*) $\Sigma F_x = 0$: $B_x + \frac{6}{31}(39.422\text{ N}) = 0$

$B_x = -7.6301\text{ N}$

$\Sigma F_y = 0$: $B_y - 68.67\text{ N} + \frac{27}{31}(39.422\text{ N}) = 0$

$B_y = 34.335\text{ N}$

$\Sigma F_z = 0$: $B_z - \frac{14}{31}(39.422\text{ N}) = 0$

$B_z = 17.8035\text{ N}$

$\mathbf{B} = -(7.63\text{ N})\mathbf{i} + (34.3\text{ N})\mathbf{j} + (17.80\text{ N})\mathbf{k}$ ◀

Using the moment equation again and setting the coefficients of the unit vectors **j** and **k** to zero:

$\Sigma M_{B(y-axis)} = 0$: $M_{By} - \left[\frac{14}{31}(39.422\text{ N})\right](100\text{ mm}) + \left[\frac{6}{31}(39.422\text{ N})\right](700\text{ mm}) = 0$

$M_{By} = -3.5607\text{ N}\cdot\text{m}$

$\Sigma M_{B(z-\text{axis})} = 0$: $M_{Bz} + (68.67\text{ N})(375\text{ mm}) - \left[\frac{27}{31}(39.422\text{ N})\right](100\text{ mm}) = 0$

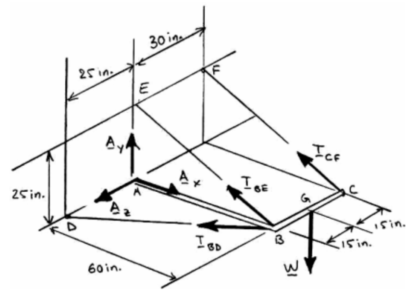
$M_{Bz} = -22.318\text{ N}\cdot\text{m}$,

Therefore:

$\mathbf{M}_B = -(3.56\text{ N}\cdot\text{m})\mathbf{j} - (22.3\text{ N}\cdot\text{m})\mathbf{k}$ ◀

Chapter 4, Solution 132.

Free-Body Diagram:



Express tensions, load in terms of rectangular components:

$$\overrightarrow{BD} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{k}$$

$$\overrightarrow{BE} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$\overrightarrow{CF} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$BD = BE = CF = \sqrt{(-60)^2 + (25)^2} = 65 \text{ in.}$$

$$\mathbf{T}_{BD} = T_{BD}\frac{\overrightarrow{BD}}{BD} = -\frac{12}{13}T_{BD}\,\mathbf{i} + \frac{5}{13}T_{BD}\,\mathbf{k}$$

$$\mathbf{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = -\frac{12}{13}T_{BE}\,\mathbf{i} + \frac{5}{13}T_{BE}\,\mathbf{j}$$

$$\mathbf{T}_{CF} = T_{CF}\frac{\overrightarrow{CF}}{CF} = -\frac{12}{13}T_{CF}\,\mathbf{i} + \frac{5}{13}T_{CF}\,\mathbf{j}$$

$$\Sigma \mathbf{M}_A = 0: \qquad \mathbf{r}_B \times \mathbf{T}_{BD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_C \times \mathbf{T}_{CF} + \mathbf{r}_G \times \mathbf{W} = 0$$

or
$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 0 & 5 \end{vmatrix}\frac{T_{BD}}{13}\text{ in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 5 & 0 \end{vmatrix}\frac{T_{BE}}{13}\text{ in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -30 \\ -12 & 5 & 0 \end{vmatrix}\frac{T_{CF}}{13}\text{ in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -15 \\ 0 & -500 & 0 \end{vmatrix}\text{lb}\cdot\text{in.} = 0$$

continued

Equating the coefficients of the unit vectors to zero:

$\mathbf{i}$: $\frac{150}{13}T_{CF} - 7500 = 0$

$T_{CF} = 650.00 \text{ lb}$ or $T_{CF} = 650 \text{ lb}$ ◀

$\mathbf{j}$: $-\frac{300}{13}T_{BD} + \frac{360}{13}(650 \text{ lb}) = 0$

$T_{BD} = 780.00 \text{ lb}$ or $T_{BD} = 780 \text{ lb}$ ◀

$\mathbf{k}$: $\frac{300}{13}T_{BE} - 30000 + \frac{300}{13}(650.00 \text{ lb}) = 0$

$T_{BE} = 650.00 \text{ lb}$ or $T_{BE} = 650 \text{ lb}$ ◀

$\Sigma F_x = 0$: $A_x - \frac{12}{13}(780 \text{ lb}) - \frac{12}{13}(650 \text{ lb}) - \frac{12}{13}(650 \text{ lb}) = 0$

$A_x = 1920.00 \text{ lb}$

$\Sigma F_y = 0$: $A_y + \frac{5}{13}(780 \text{ lb}) + \frac{5}{13}(650 \text{ lb}) - 500 \text{ lb} = 0$

$A_y = 0$

$\Sigma F_z = 0$: $A_z + \frac{5}{13}(780 \text{ lb}) = 0$

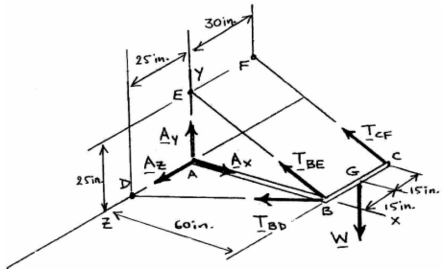
$A_z = -300.00 \text{ lb}$

Therefore,

$\mathbf{A} = (1920 \text{ lb})\mathbf{i} - (300 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 133.

Free-Body Diagram:



Express tensions, load in terms of rectangular components:

$$\overrightarrow{BD} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{k}$$

$$\overrightarrow{BE} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$\overrightarrow{CF} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$BD = BE = CF = \sqrt{(-60)^2 + (25)^2} = 65 \text{ in.}$$

$$\mathbf{T}_{BD} = T_{BD}\frac{\overrightarrow{BD}}{BD} = -\frac{12}{13}T_{BD}\,\mathbf{i} + \frac{5}{13}T_{BD}\,\mathbf{k}$$

$$\mathbf{T}_{BE} = T_{BE}\frac{\overrightarrow{BE}}{BE} = -\frac{12}{13}T_{BE}\,\mathbf{i} + \frac{5}{13}T_{BE}\,\mathbf{j}$$

$$\mathbf{T}_{CF} = T_{CF}\frac{\overrightarrow{CF}}{CF} = -\frac{12}{13}T_{CF}\,\mathbf{i} + \frac{5}{13}T_{CF}\,\mathbf{j}$$

$$\mathbf{W}_G = -(500 \text{ lb})\mathbf{j}$$

$$\mathbf{W}_C = -(800 \text{ lb})\mathbf{j}$$

$\Sigma \mathbf{M}_A = 0$: $\quad \mathbf{r}_B \times \mathbf{T}_{BD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_C \times \mathbf{T}_{CF} + \mathbf{r}_G \times \mathbf{W}_G + \mathbf{r}_C \times \mathbf{W}_C = 0$

$$\text{or} \quad \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 0 & 5 \end{vmatrix} \frac{T_{BD}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 5 & 0 \end{vmatrix} \frac{T_{BE}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -30 \\ -12 & 5 & 0 \end{vmatrix} \frac{T_{CF}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -15 \\ 0 & -500 & 0 \end{vmatrix} \text{lb}\cdot\text{in.}$$

$$+ \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -30 \\ 0 & -800 & 0 \end{vmatrix} \text{lb}\cdot\text{in.} = 0$$

Equating the coefficients of the unit vectors to zero:

$\mathbf{i}$: $\quad \frac{150}{13}T_{CF} - 7500 - 24000 = 0$

$T_{CF} = 2730 \text{ lb}$ $\quad$ or $T_{CF} = 2.73 \text{ kips}$ ◀

$\mathbf{j}$: $\quad -\frac{300}{13}T_{BD} + \frac{360}{13}(2730 \text{ lb}) = 0$

$T_{BD} = 3276 \text{ lb}$ $\quad$ or $T_{BD} = 3.28 \text{ kips}$ ◀

$\mathbf{k}$: $\quad \frac{300}{13}T_{BE} - 30000 + \frac{300}{13}(2730 \text{ lb}) - (60)(800 \text{ lb}) = 0$

$T_{BE} = 650.00 \text{ lb}$ $\quad$ or $T_{BE} = 650 \text{ lb}$ ◀

$\Sigma F_x = 0$: $\quad A_x - \frac{12}{13}(3276 \text{ lb}) - \frac{12}{13}(650 \text{ lb}) - \frac{12}{13}(2730 \text{ lb}) = 0$

$A_x = 6144 \text{ lb}$

$\Sigma F_y = 0$: $\quad A_y + \frac{5}{13}(2730 \text{ lb}) + \frac{5}{13}(650 \text{ lb}) - 500 \text{ lb} - 800 \text{ lb} = 0$

$A_y = 0$

$\Sigma F_z = 0$: $\quad A_z + \frac{5}{13}(3276 \text{ lb}) = 0$

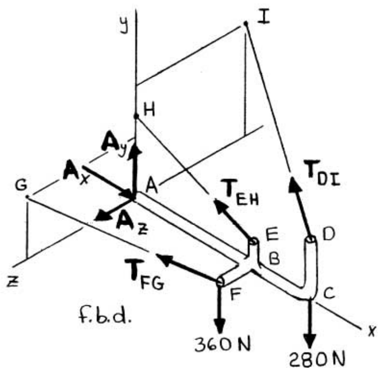
$A_z = -1260.00 \text{ lb}$

Therefore,

$\mathbf{A} = (6.14 \text{ kips})\mathbf{i} - (1.260 \text{ kips})\mathbf{k}$ ◀

Chapter 4, Solution 134.

Free-Body Diagram:



First note

$$\mathbf{T}_{DI} = \boldsymbol{\lambda}_{DI}T_{DI} = \frac{-(0.65\text{ m})\mathbf{i} + (0.2\text{ m})\mathbf{j} - (0.44\text{ m})\mathbf{k}}{\sqrt{(0.65)^2 + (0.2)^2 + (0.44)^2}\text{ m}}T_{DI}$$

$$= \frac{T_{DI}}{0.81}(-0.65\mathbf{i} + 0.2\mathbf{j} - 0.44\mathbf{k})$$

$$\mathbf{T}_{EH} = \boldsymbol{\lambda}_{EH}T_{EH} = \frac{-(0.45\text{ m})\mathbf{i} + (0.24\text{ m})\mathbf{j}}{\sqrt{(0.45)^2 + (0.24)^2}\text{ m}}T_{EH}$$

$$= \frac{T_{EH}}{0.51}(-0.45\mathbf{i}) + (0.24\mathbf{j})$$

$$\mathbf{T}_{FG} = \boldsymbol{\lambda}_{FG}T_{FG} = \frac{-(0.45\text{ m})\mathbf{i} + (0.2\text{ m})\mathbf{j} + (0.36\text{ m})\mathbf{k}}{\sqrt{(0.45\ )^2 + (0.2)^2 + (0.36)^2}\text{ m}}T_{FG}$$

$$= \frac{T_{FG}}{0.61}(-0.45\mathbf{i} + 0.2\mathbf{j} + 0.36\mathbf{k})$$

From free-body diagram of frame

$$\Sigma\mathbf{M}_A = 0\text{:}\quad \mathbf{r}_{D/A} \times \mathbf{T}_{DI} + \mathbf{r}_{C/A} \times (-280\text{ N})\mathbf{j} + \mathbf{r}_{H/A} \times \mathbf{T}_{EH} + \mathbf{r}_{F/A} \times \mathbf{T}_{FG} + \mathbf{r}_{F/A} \times (-360\text{ N})\mathbf{j} = 0$$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.65 & 0.2 & 0 \\ -0.65 & 0.2 & -0.44 \end{vmatrix}\left(\frac{T_{DI}}{0.81}\right) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.65 & 0 & 0 \\ 0 & -1 & 0 \end{vmatrix}(280\text{ N}) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0.32 & 0 \\ -0.45 & 0.24 & 0 \end{vmatrix}\left(\frac{T_{EH}}{0.51}\right) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.45 & 0 & 0.06 \\ -0.45 & 0.2 & 0.36 \end{vmatrix}\left(\frac{T_{FG}}{0.61}\right)$$

$$+ \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.45 & 0 & 0.06 \\ 0 & -1 & 0 \end{vmatrix}(360\text{ N}) = 0$$

or

$$(-0.088\mathbf{i} + 0.286\mathbf{j} + 0.26\mathbf{k})\frac{T_{DI}}{0.81} + (-0.65\mathbf{k})280\text{ N} + (0.144\mathbf{k})\frac{T_{EH}}{0.51}$$

$$+ (-0.012\mathbf{i} - 0.189\mathbf{j} + 0.09\mathbf{k})\frac{T_{FG}}{0.61} + (0.06\mathbf{i} - 0.45\mathbf{k})(360\text{N}) = 0$$

continued

From **i**-coefficient $-0.088\left(\dfrac{T_{DI}}{0.81}\right) - 0.012\left(\dfrac{T_{FG}}{0.61}\right) + 0.06(360\text{ N}) = 0$

$$\therefore\quad 0.108642T_{DI} + 0.0196721T_{FG} = 21.6 \qquad (1)$$

From **j**-coefficient $0.286\left(\dfrac{T_{DI}}{0.81}\right) - 0.189\left(\dfrac{T_{FG}}{0.61}\right) = 0$

$$\therefore\quad T_{FG} = 1.13959T_{DI} \qquad (2)$$

From **k**-coefficient

$$0.26\left(\frac{T_{DI}}{0.81}\right) - 0.65(280\text{ N}) + 0.144\left(\frac{T_{EH}}{0.51}\right) + 0.09\left(\frac{T_{FG}}{0.61}\right)$$

$$-0.45(360\text{ N}) = 0$$

$$\therefore\quad 0.32099T_{DI} + 0.28235T_{EH} + 0.147541T_{FG} = 344\text{ N} \qquad (3)$$

Substitution of Equation (2) into Equation (1)

$$0.108642T_{DI} + 0.0196721(1.13959T_{DI}) = 21.6$$

$$\therefore\quad T_{DI} = 164.810\text{ N}$$

or $T_{DI} = 164.8\text{ N}$ ◀

Then from Equation (2)

$$T_{FG} = 1.13959(164.810\text{ N}) = 187.816\text{ N}$$

or $T_{FG} = 187.8\text{ N}$ ◀

And from Equation (3)

$$0.32099(164.810\text{ N}) + 0.28235T_{EH} + 0.147541(187.816\text{ N}) = 344\text{ N}$$

$$\therefore\quad T_{EH} = 932.84\text{ N}$$

or $T_{EH} = 933\text{ N}$ ◀

The vector forms of the cable forces are:

$$\mathbf{T}_{DI} = \frac{164.810\text{ N}}{0.81}(-0.65\mathbf{i} + 0.2\mathbf{j} - 0.44\mathbf{k})$$

$$= -(132.25\text{ N})\mathbf{i} + (40.694\text{ N})\mathbf{j} - (89.526\text{ N})\mathbf{k}$$

$$\mathbf{T}_{EH} = \frac{932.84\text{ N}}{0.51}(-0.45\mathbf{i} + 0.24\mathbf{j}) = -(823.09\text{ N})\mathbf{i} + (438.98\text{ N})\mathbf{j}$$

$$\mathbf{T}_{FG} = \frac{187.816\text{ N}}{0.61}(-0.45\mathbf{i} + 0.2\mathbf{j} + 0.36\mathbf{k})$$

$$= -(138.553\text{ N})\mathbf{i} + (61.579\text{ N})\mathbf{j} + (110.842\text{ N})\mathbf{k}$$

continued

Then, from free-body diagram of frame

$$\Sigma F_x = 0: \quad A_x - 132.25 - 823.09 - 138.553 = 0$$

$$\therefore \quad A_x = 1093.89 \text{ N}$$

$$\Sigma F_y = 0: \quad A_y + 40.694 + 438.98 + 61.579 - 360 - 280 = 0$$

$$\therefore \quad A_y = 98.747 \text{ N}$$

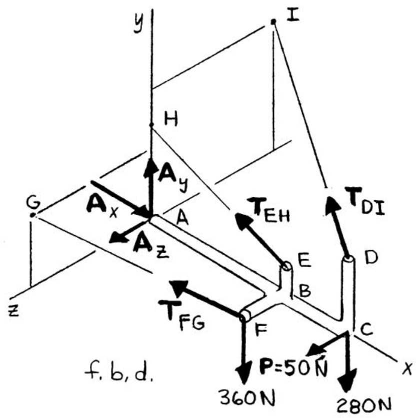
$$\Sigma F_z = 0: \quad A_z - 89.526 + 110.842 = 0$$

$$\therefore \quad A_z = -21.316 \text{ N}$$

or $\mathbf{A} = (1094 \text{ N})\mathbf{i} + (98.7 \text{ N})\mathbf{j} - (21.3 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 135.

Free-Body Diagram:



First note

$$\mathbf{T}_{DI} = \boldsymbol{\lambda}_{DI}T_{DI} = \frac{-(0.65\text{ m})\mathbf{i} + (0.2\text{ m})\mathbf{j} - (0.44\text{ m})\mathbf{k}}{\sqrt{(0.65)^2 + (0.2)^2 + (0.44)^2}\text{ m}}T_{DI}$$

$$= \frac{T_{DI}}{81}(-65\mathbf{i} + 20\mathbf{j} - 44\mathbf{k})$$

$$\mathbf{T}_{EH} = \boldsymbol{\lambda}_{EH}T_{EH} = \frac{-(0.45\text{ m})\mathbf{i} + (0.24\text{ m})\mathbf{j}}{\sqrt{(0.45)^2 + (0.24)^2}\text{ m}}T_{EH}$$

$$= \frac{T_{EH}}{17}(-15\mathbf{i} + 8\mathbf{j})$$

$$\mathbf{T}_{FG} = \boldsymbol{\lambda}_{FG}T_{FG} = \frac{-(0.45\text{ m})\mathbf{i} + (0.2\text{ m})\mathbf{j} + (0.36\text{ m})\mathbf{k}}{\sqrt{(0.45)^2 + (0.2)^2 + (0.36)^2}\text{ m}}T_{FG}$$

$$= \frac{T_{FG}}{61}(-45\mathbf{i} + 20\mathbf{j} + 36\mathbf{k})$$

From free-body diagram of frame

$$\Sigma\mathbf{M}_A = 0: \quad \mathbf{r}_{D/A} \times \mathbf{T}_{DI} + \mathbf{r}_{C/A} \times \left[-(280\text{ N})\mathbf{j} + (50\text{ N})\mathbf{k}\right]$$

$$+ \mathbf{r}_{H/A} \times \mathbf{T}_{EH} + \mathbf{r}_{F/A} \times \mathbf{T}_{FG} + \mathbf{r}_{F/A} \times (-360\text{ N})\mathbf{j}$$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.65 & 0.2 & 0 \\ -65 & 20 & -44 \end{vmatrix}\left(\frac{T_{DI}}{81}\right) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.65 & 0 & 0 \\ 0 & -280 & 50 \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0.32 & 0 \\ -15 & 8 & 0 \end{vmatrix}\left(\frac{T_{EH}}{17}\right)$$

$$+ \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.45 & 0 & 0.06 \\ -45 & 20 & 36 \end{vmatrix}\left(\frac{T_{FG}}{61}\right) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.45 & 0 & 0.06 \\ 0 & -1 & 0 \end{vmatrix}(360\text{ N}) = 0$$

and

$$(-8.8\mathbf{i} + 28.6\mathbf{j} + 26\mathbf{k})\left(\frac{T_{DI}}{81}\right) + (-32.5\mathbf{j} - 182\mathbf{k}) + (4.8\mathbf{k})\left(\frac{T_{EH}}{17}\right)$$

$$+(-1.2\mathbf{i} - 18.9\mathbf{j} + 9.0\mathbf{k})\left(\frac{T_{FG}}{61}\right) + (0.06\mathbf{i} - 0.45\mathbf{k})(360) = 0$$

continued

From **i**-coefficient $-8.8\left(\frac{T_{DI}}{81}\right) - 1.2\left(\frac{T_{FG}}{61}\right) + 0.06(360) = 0$

$$\therefore \quad 0.108642T_{DI} + 0.0196721T_{FG} = 21.6 \qquad (1)$$

From **j**-coefficient $28.6\left(\frac{T_{DI}}{81}\right) - 32.5 - 18.9\left(\frac{T_{FG}}{61}\right) = 0$

$$\therefore \quad 0.35309T_{DI} - 0.30984T_{FG} = 32.5 \qquad (2)$$

From **k**-coefficient

$$26\left(\frac{T_{DI}}{81}\right) - 182 + 4.8\left(\frac{T_{EH}}{17}\right) + 9.0\left(\frac{T_{FG}}{61}\right) - 0.45(360) = 0$$

$$\therefore \quad 0.32099T_{DI} + 0.28235T_{EH} + 0.147541T_{FG} = 344 \qquad (3)$$

$-3.25 \times$ Equation (1) $\qquad -0.35309T_{DI} - 0.063935T_{FG} = -70.201$

Add Equation (2) $\qquad 0.35309T_{DI} - 0.30984T_{FG} = 32.5$

$$-0.37378T_{FG} = -37.701$$

$$\therefore \quad T_{FG} = 100.864 \text{ N}$$

or $\qquad T_{FG} = 100.9 \text{ N}$ ◀

Then from Equation (1)

$$0.108642T_{DI} + 0.0196721(100.864) = 21.6$$

$$\therefore \quad T_{DI} = 180.554 \text{ N}$$

or $\qquad T_{DI} = 180.6 \text{ N}$ ◀

and from Equation (3)

$$0.32099(180.554) + 0.28235T_{EH} + 0.147541(100.864) = 344$$

$$\therefore \quad T_{EH} = 960.38 \text{ N}$$

or $\qquad T_{EH} = 960 \text{ N}$ ◀

The vector forms of the cable forces are:

$$\mathbf{T}_{DI} = \frac{180.554 \text{ N}}{81}(-65\mathbf{i} + 20\mathbf{j} - 44\mathbf{k})$$

$$= -(144.889 \text{ N})\mathbf{i} + (44.581 \text{ N})\mathbf{j} - (98.079 \text{ N})\mathbf{k}$$

$$\mathbf{T}_{EH} = \frac{960.38 \text{ N}}{17}(-15\mathbf{i} + 8\mathbf{j}) = -(847.39 \text{ N})\mathbf{i} + (451.94 \text{ N})\mathbf{j}$$

$$\mathbf{T}_{FG} = \frac{100.864 \text{ N}}{61}(-45\mathbf{i} + 20\mathbf{j} + 36\mathbf{k})$$

$$= -(74.409 \text{ N})\mathbf{i} + (33.070 \text{ N})\mathbf{j} + (59.527 \text{ N})\mathbf{k}$$

Then from free-body diagram of frame

$$\Sigma F_x = 0: \quad A_x - 144.889 - 847.39 - 74.409 = 0$$

$$\therefore \quad A_x = 1066.69 \text{ N}$$

$$\Sigma F_y = 0: \quad A_y + 44.581 + 451.94 + 33.070 - 360 - 280 = 0$$

$$\therefore \quad A_y = 110.409 \text{ N}$$

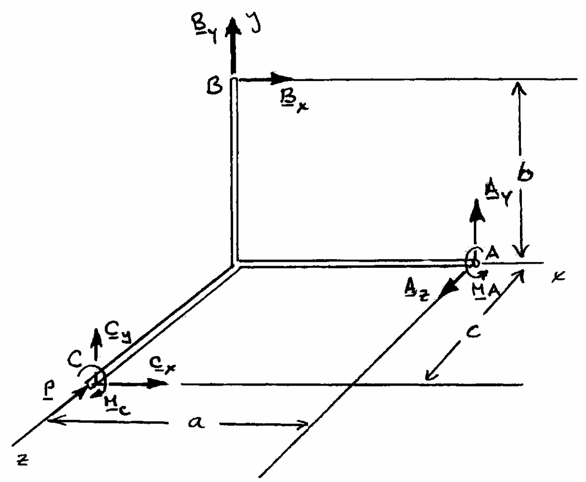
$$\Sigma F_z = 0: \quad A_z - 98.079 + 59.527 + 50 = 0$$

$$\therefore \quad A_z = -11.448 \text{ N}$$

Therefore, $\mathbf{A} = (1067 \text{ N})\mathbf{i} + (110.4 \text{ N})\mathbf{j} - (11.45 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 136.

Free-Body Diagram:



$$\Sigma F_x = 0: \quad B_x + C_x = 0, \text{ or } B_x = -C_x \tag{1}$$

$$\Sigma F_y = 0: \quad A_y + B_y + C_y = 0 \tag{2}$$

$$\Sigma F_y = 0: \quad A_z - P = 0, \text{ or } A_z = P = 40.0 \text{ lb} \tag{3}$$

$$\Sigma \mathbf{M}_O = 0: \quad \mathbf{r}_{OA} \times \mathbf{A} + \mathbf{r}_{OB} \times \mathbf{B} + \mathbf{r}_{OC} \times \mathbf{C} + M_A \mathbf{i} - M_C \mathbf{k} = 0$$

or $$a\mathbf{i} \times \left(A_y \mathbf{j} + A_z \mathbf{k}\right) + b\mathbf{j} \times \left(B_x \mathbf{i} + B_y \mathbf{j}\right) + c\mathbf{k} \times \left(C_x \mathbf{i} + C_y \mathbf{j}\right) + M_A \mathbf{i} - M_C \mathbf{k} = 0$$

or $$a\,A_y \mathbf{k} - a\,A_z \mathbf{j} - bB_x \mathbf{j} + cC_x \mathbf{j} - cC_y \mathbf{i} + M_A \mathbf{i} - M_C \mathbf{k} = 0$$

continued

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \quad -cC_y + M_A = 0$$

$$C_y = \frac{M_A}{c} = \frac{36 \text{ lb}\cdot\text{ft}}{1 \text{ ft}} = 36.0 \text{ lb} \qquad (4)$$

$$\mathbf{j}: \quad -aA_z + cC_x = 0, \text{ or using (3)}$$

$$C_x = \frac{a}{c}P = \frac{9 \text{ in.}}{12 \text{ in.}}(40 \text{ lb}) = 30.0 \text{ lb} \qquad (5)$$

$$\mathbf{k}: \quad aA_y - bB_x - M_C = 0, \text{ or, using (1) and (5)}$$

$$A_y = -\frac{b}{c}P + \frac{M_C}{a} = -\frac{6 \text{ in.}}{12 \text{ in.}}(40 \text{ lb}) + \frac{0}{9 \text{ in.}} = -20.0 \text{ lb} \qquad (6)$$

Finally substituting into (1) and (2) gives:

$$B_x = -30.0 \text{ lb}$$

$$B_y = -A_y - C_y = 20.0 \text{ lb} - 36.0 \text{ lb} = -16.00 \text{ lb}$$

Therefore:

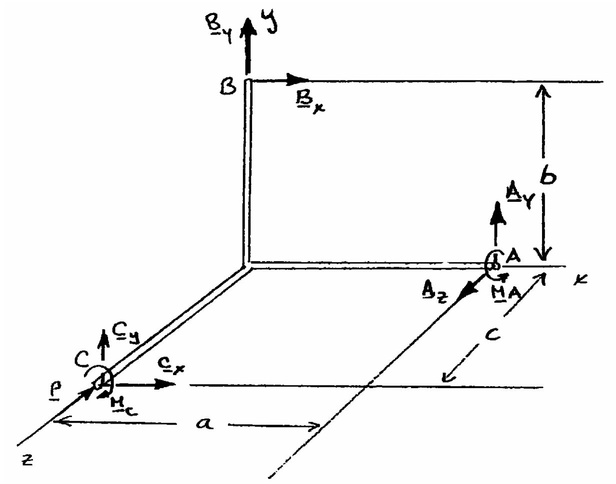
$$\mathbf{A} = -(20.0 \text{ lb})\mathbf{j} + (40.0 \text{ lb})\mathbf{k} \blacktriangleleft$$

$$\mathbf{B} = -(30.0 \text{ lb})\mathbf{i} - (16.00 \text{ lb})\mathbf{j} \blacktriangleleft$$

$$\mathbf{C} = (30.0 \text{ lb})\mathbf{i} + (36.0 \text{ lb})\mathbf{j} \blacktriangleleft$$

Chapter 4, Solution 137.

Free-Body Diagram:



$$\Sigma F_x = 0: \quad B_x + C_x = 0, \text{ or } B_x = -C_x \tag{1}$$

$$\Sigma F_y = 0: \quad A_y + B_y + C_y = 0 \tag{2}$$

$$\Sigma F_z = 0: \quad A_z - P = 0, \text{ or } A_z = P = 60.0 \text{ N} \tag{3}$$

$$\Sigma \mathbf{M}_O = 0: \quad \mathbf{r}_{OA} \times \mathbf{A} + \mathbf{r}_{OB} \times \mathbf{B} + \mathbf{r}_{OC} \times \mathbf{C} + M_A\mathbf{i} - M_C\mathbf{k} = 0$$

or $$a\mathbf{i} \times \left(A_y\mathbf{j} + A_z\mathbf{k}\right) + b\mathbf{j} \times \left(B_x\mathbf{i} + B_y\mathbf{j}\right) + c\mathbf{k} \times \left(C_x\mathbf{i} + C_y\mathbf{j}\right) + M_A\mathbf{i} - M_C\mathbf{k} = 0$$

or $$a A_y\mathbf{k} - a A_z\mathbf{j} - bB_x\mathbf{j} + cC_x\mathbf{j} - cC_y\mathbf{i} + M_A\mathbf{i} - M_C\mathbf{k} = 0$$

continued

Equating the coefficients of the unit vectors to zero:

i: $-cC_y + M_A = 0$

$$C_y = \frac{M_A}{c} = \frac{6.3 \text{ N}\cdot\text{m}}{0.180 \text{ m}} = 35.0 \text{ N} \qquad (4)$$

j: $-a A_z + cC_x = 0$, or using (3)

$$C_x = \frac{a}{c}P = \frac{0.240 \text{ m}}{0.180 \text{ m}}(60 \text{ N}) = 80.0 \text{ N} \qquad (5)$$

k: $a A_y - b B_x - M_C = 0$, or, using (1) and (5)

$$A_y = -\frac{b}{c}P + \frac{M_C}{a} = -\frac{0.200 \text{ m}}{0.180 \text{ m}}(60 \text{ N}) + \frac{13 \text{ N}\cdot\text{m}}{0.240 \text{ m.}} = -12.50 \text{ N} \qquad (6)$$

Finally substituting into (1) and (2) gives:

$$B_x = -80.0 \text{ N}$$

$$B_y = -A_y - C_y = 12.50 \text{ N} - 35.0 \text{ N} = -22.5 \text{ N}$$

Therefore:

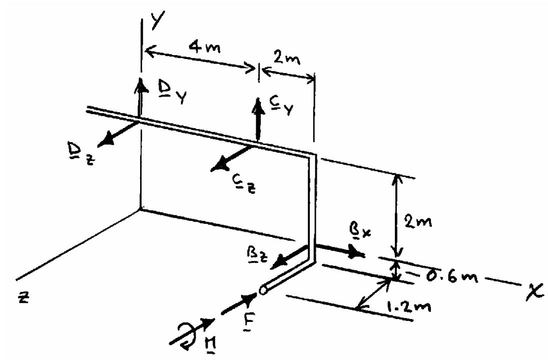
$\mathbf{A} = -(12.50 \text{ N})\mathbf{j} + (60.0 \text{ N})\mathbf{k}$ ◀

$\mathbf{B} = -(80.0 \text{ N})\mathbf{i} - (22.5 \text{ N})\mathbf{j}$ ◀

$\mathbf{C} = (80.0 \text{ N})\mathbf{i} + (35.0 \text{ N})\mathbf{j}$ ◀

Chapter 4, Solution 138.

Free-Body Diagram:



$$\Sigma F_x = 0: \quad B_x = 0$$

$$\Sigma M_{D(x\text{-axis})} = 0: \quad (80\text{ N})(2.6\text{ m}) - B_z(2\text{ m}) = 0$$

$$B_z = 104.000\text{ N}$$

or $\mathbf{B} = (104.0\text{ N})\mathbf{k}$ ◀

$$\Sigma M_{D(z\text{-axis})} = 0: \quad C_y(4\text{ m}) - 144\text{ N}\cdot\text{m} = 0$$

$$C_y = 36.000\text{ N}$$

$$\Sigma M_{D(y\text{-axis})} = 0: \quad -C_z(4\text{ m}) - (104\text{ N})(6\text{ m}) + (80\text{ N})(6\text{ m}) = 0$$

$$C_z = -36.000\text{ N}$$

and $\mathbf{C} = (36.0\text{ N})\mathbf{j} - (36.0\text{ N})\mathbf{k}$ ◀

$$\Sigma F_y = 0: \quad D_y + 36 = 0, \text{ or } D_y = -36.000\text{ N}$$

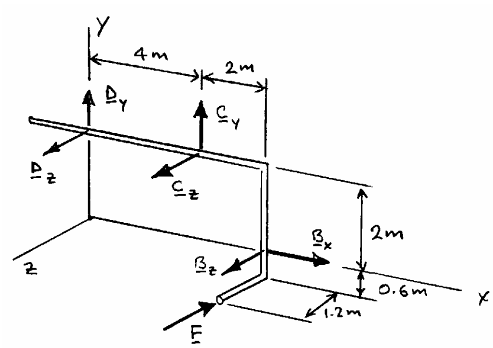
$$\Sigma F_z = 0: \quad D_z - 36 + 104 - 80 = 0, \text{ or } D_z = 12.000\text{ N}$$

Therefore:

$\mathbf{D} = -(36.0\text{ N})\mathbf{j} + (12.00\text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 139.

Free-Body Diagram:



$\Sigma F_x = 0: \quad B_x = 0$

$\Sigma M_{D(x\text{-axis})} = 0: \quad (80 \text{ N})(2.6 \text{ m}) - B_z(2 \text{ m}) = 0$

$B_z = 104.000 \text{ N}$ or $\mathbf{B} = (104.0 \text{ N})\mathbf{k}$ ◀

$\Sigma M_{D(z\text{-axis})} = 0: \quad C_y(4 \text{ m}) = 0$

$C_y = 0$

$\Sigma M_{D(y\text{-axis})} = 0: \quad -C_z(4 \text{ m}) - (104 \text{ N})(6 \text{ m}) + (80 \text{ N})(6 \text{ m}) = 0$

$C_z = -36.000 \text{ N}$

and $\mathbf{C} = -(36.0 \text{ N})\mathbf{k}$ ◀

$\Sigma F_y = 0: \quad D_y = 0$

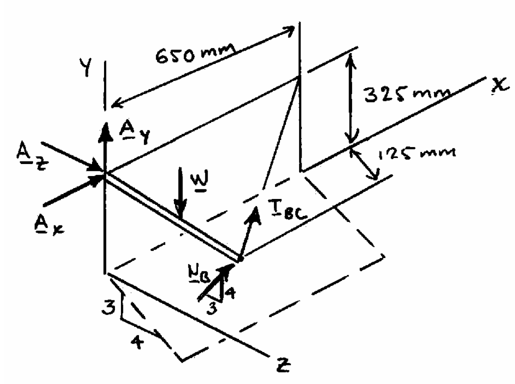
$\Sigma F_z = 0: \quad D_z - 36 + 104 - 80 = 0$, or $D_z = 12.000 \text{ N}$

Therefore:

$\mathbf{D} = (12.00 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 140.

Free-Body Diagram:



Express the forces in terms of rectangular components:

$$\mathbf{W} = -(mg)\mathbf{j} = -(3\text{ kg})(9.81\text{ m/s}^2)\mathbf{j} = -(29.43\text{ N})\mathbf{j}$$

$$\mathbf{N}_B = N_B(0.8\mathbf{j} + 0.6\mathbf{k})$$

$$L_{AB} = 525\text{ mm} = \sqrt{(x_B)^2 + (325+75)^2 + (100)^2}$$

ba tanasob nemishe
Bx ra peyda kard.

$$x_B = 325\text{ mm}$$

Then,

$$\mathbf{T}_{BC} = T_{BC}\frac{\overrightarrow{BC}}{BC} = T_{BC}\frac{325\mathbf{i} + 400\mathbf{j} - 100\mathbf{k}}{\sqrt{(325)^2 + (400)^2 + (-100)^2}} = \frac{13}{21}T_{BC}\,\mathbf{i} + \frac{16}{21}T_{BC}\mathbf{j} - \frac{4}{21}T_{BC}\mathbf{k}$$

continued

Equilibrium:

$$\Sigma \mathbf{M}_A = 0: \qquad \mathbf{r}_{G/A} \times \mathbf{W} + \mathbf{r}_{B/A} \times \mathbf{N}_B + \mathbf{r}_{C/A} \times \mathbf{T}_{BC} = 0$$

$$\text{or} \quad \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 162.5 & -200 & 50 \\ 0 & -29.43 & 0 \end{vmatrix} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 325 & -400 & 100 \\ 0 & 0.8 & 0.6 \end{vmatrix} N_B + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 650 & 0 & 0 \\ 13 & 16 & -4 \end{vmatrix} \frac{T_{BC}}{21} = 0$$

Equating the coefficients of the unit vectors to zero:

$$\mathbf{i}: \qquad 1471.5 - 320\, N_B = 0$$

$$N_B = 4.5984 \text{ N}$$

$$\text{or} \qquad \mathbf{N}_B = (3.6787 \text{ N})\mathbf{j} + (2.7590 \text{ N})\mathbf{k}$$

$$\mathbf{j}: \qquad -195 N_B + \frac{2600}{21} T_{BC} = 0$$

$$T_{BC} = 7.2425 \text{ N}$$

$$\Sigma F_x = 0: \qquad A_x + \frac{13}{21}(7.2425 \text{ N}) = 0$$

$$A_x = -4.4835 \text{ N}$$

$$\Sigma F_y = 0: \qquad A_y - 29.43 \text{ N} + 3.6787 \text{ N} + \frac{16}{21}(7.2425 \text{ N}) = 0$$

$$A_y = 20.233 \text{ N}$$

$$\Sigma F_y = 0: \qquad A_z + 2.7590 \text{ N} - \frac{4}{21}(7.2425 \text{ N}) = 0$$

$$A_z = -1.37948 \text{ N}$$

Therefore:

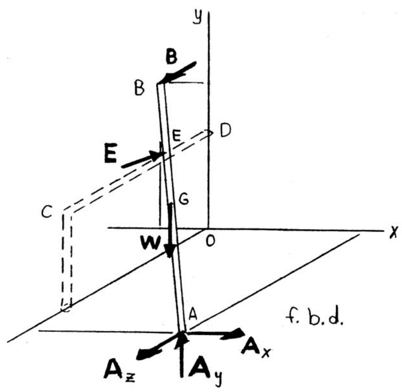
(*a*) $T_{BC} = 7.24 \text{ N}$ ◀

(*b*) $\mathbf{A} = -(4.48 \text{ N})\mathbf{i} + (20.2 \text{ N})\mathbf{j} - (1.379 \text{ N})\mathbf{k}$ ◀

$\mathbf{N}_B = (3.68 \text{ N})\mathbf{j} + (2.76 \text{ N})\mathbf{k}$ ◀

Chapter 4, Solution 141.

Free-Body Diagram:



(*a*) The force acting at *E* on the free-body diagram of rod *AB* is perpendicular to *AB* and *CD*. Letting $\boldsymbol{\lambda}_E$ = direction cosines for force **E**,

$$\boldsymbol{\lambda}_E = \frac{\mathbf{r}_{B/A} \times 40\text{K}}{\left|\mathbf{r}_{B/A} \times 40\text{K}\right|}$$

= DC

$$= \frac{\left[-(32\text{ in.})\mathbf{i} + (24\text{ in.})\mathbf{j} - (40\text{ in.})\mathbf{k}\right] \times \mathbf{k}}{\sqrt{(32)^2 + (24)^2}\text{ in.}}$$

$$= 0.6\mathbf{i} + 0.8\mathbf{j}$$

Also, $\mathbf{W} = -(10\text{ lb})\mathbf{j}$

$$\mathbf{B} = B\mathbf{k}$$

$$\mathbf{E} = E(0.6\mathbf{i} + 0.8\mathbf{j})$$

From free-body diagram of rod *AB*

$$\Sigma \mathbf{M}_A = 0: \quad \mathbf{r}_{G/A} \times \mathbf{W} + \mathbf{r}_{E/A} \times \mathbf{E} + \mathbf{r}_{B/A} \times \mathbf{B} = 0$$

$$\therefore \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -16 & 12 & -20 \\ 0 & -1 & 0 \end{vmatrix}(10\text{ lb}) + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -24 & 18 & -30 \\ 0.6 & 0.8 & 0 \end{vmatrix}E + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -32 & 24 & -40 \\ 0 & 0 & 1 \end{vmatrix}B = 0$$

$$(-20\mathbf{i} + 16\mathbf{k})(10\text{ lb}) + (24\mathbf{i} - 18\mathbf{j} - 30\mathbf{k})E + (24\mathbf{i} + 32\mathbf{j})B = 0$$

From **k**-coefficient $\quad 160 - 30E = 0$

$$\therefore \quad E = 5.3333\text{ lb}$$

and $\quad \mathbf{E} = 5.3333\text{ lb}(0.6\mathbf{i} + 0.8\mathbf{j})$

or $\quad \mathbf{E} = (3.20\text{ lb})\mathbf{i} + (4.27\text{ lb})\mathbf{j}$ ◀

(*b*) From **j**-coefficient $\quad -18(5.3333\text{ lb}) + 32B = 0$

$$\therefore \quad B = 3.00\text{ lb}$$

or $\quad \mathbf{B} = (3.00\text{ lb})\mathbf{k}$ ◀

From free-body diagram of rod *AB*

$$\Sigma\mathbf{F} = 0: \quad \mathbf{A} + \mathbf{W} + \mathbf{E} + \mathbf{B} = 0$$

$$A_x\mathbf{i} + A_y\mathbf{j} + A_z\mathbf{k} - (10 \text{ lb})\mathbf{j} + \left[(3.20 \text{ lb})\mathbf{i} + (4.27 \text{ lb})\mathbf{j}\right] + (3.00 \text{ lb})\mathbf{k} = 0$$

From **i**-coefficient $\quad A_x + 3.20 \text{ lb} = 0$

$$\therefore \quad A_x = -3.20 \text{ lb}$$

j-coefficient $\quad A_y - 10 \text{ lb} + 4.27 \text{ lb} = 0$

$$\therefore \quad A_y = 5.73 \text{ lb}$$

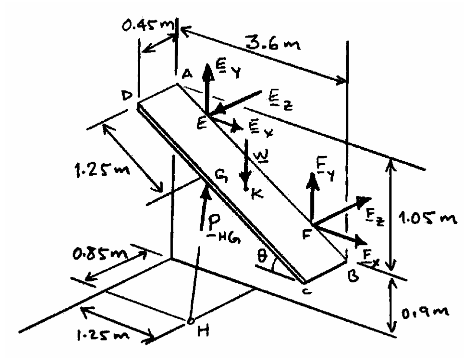
k-coefficient $\quad A_z + 3.00 \text{ lb} = 0$

$$\therefore \quad A_z = -3.00 \text{ lb}$$

Therefore $\quad \mathbf{A} = -(3.20 \text{ lb})\mathbf{i} + (5.73 \text{ lb})\mathbf{j} - (3.00 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 142.

Free-Body Diagram:



There is only one unknown of interest and, therefore only one equation is needed:

$\Sigma M_{AB} = 0$

Geometry:

$$\theta = \tan^{-1}\left(\frac{1.05 \text{ m}}{3.5 \text{ m}}\right) = 16.2602°$$

$$x_G = (1.25 \text{ m})\cos 16.2602° = 1.2 \text{ m}$$

$$y_G = 1.95 \text{ m} - (1.25 \text{ m})\sin 16.2602° = 1.6 \text{ m}$$

$$\boldsymbol{\lambda}_{BA} = \frac{\overrightarrow{BA}}{BA} = \frac{-3.6\mathbf{i} + 1.05\mathbf{j}}{\sqrt{(-3.6)^2 + (1.05)^2}} = -\frac{24}{25}\mathbf{i} + \frac{7}{25}\mathbf{j}$$

continued

$$\mathbf{r}_{K/A} = (1.8\text{ m})\mathbf{i} - (0.525\text{ m})\mathbf{j} + (0.225\text{ m})\mathbf{k}$$

$$\mathbf{r}_{G/A} = (1.2\text{ m})\mathbf{i} - (1.95\text{ m} - 1.6\text{ m})\mathbf{j} + (0.45\text{ m})\mathbf{k}$$

$$= (1.2\text{ m})\mathbf{i} - (0.35\text{ m})\mathbf{j} + (0.45\text{ m})\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(25\text{ kg})\left(9.81\text{ m/s}^2\right)\mathbf{j} = -(245.25\text{ kg})\mathbf{j}$$

$$\mathbf{P}_{HG} = P_{HG}\frac{\overline{HG}}{HG} = P_{HG}\frac{-0.05\mathbf{i} + 1.6\mathbf{j} - 0.4\,\mathbf{k}}{\sqrt{(-0.05)^2 + (1.6)^2 + (-0.4)^2}} = P_{HG}\left(-\frac{1}{33}\mathbf{i} + \frac{32}{33}\mathbf{j} - \frac{8}{33}\mathbf{k}\right)$$

Now,

$$\Sigma M_{BA} = 0: \qquad \boldsymbol{\lambda}_{BA}\cdot\left(\mathbf{r}_{K/A}\times\mathbf{W}\right) + \boldsymbol{\lambda}_{BA}\cdot\left(\mathbf{r}_{G/A}\times\mathbf{P}_{HG}\right) = 0$$

$$\begin{vmatrix} -24 & 7 & 0 \\ 1.8 & -0.525 & 0.225 \\ 0 & -245.25 & 0 \end{vmatrix}\frac{1}{25} + \begin{vmatrix} -24 & 7 & 0 \\ 1.2 & -0.35 & 0.45 \\ -1 & 32 & -8 \end{vmatrix}\frac{P_{HG}}{(25)(33)} = 0$$

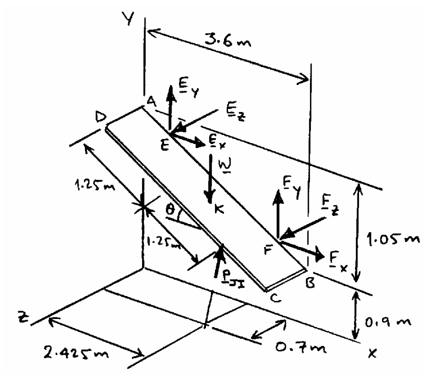
$$-\frac{1324.35}{25} + \frac{342.45}{(25)(35)}P_{HG} = 0$$

Therefore: $P_{HG} = 127.620\text{ N}$

or $P_{HG} = 127.6\text{ N}$ ◀

Chapter 4, Solution 143.

Free-Body Diagram:



There is only one unknown of interest and, therefore only one equation is needed:

$\Sigma M_{AB} = 0$

Geometry:

$$\theta = \tan^{-1}\left(\frac{1.05 \text{ m}}{3.5 \text{ m}}\right) = 16.2602°$$

$$x_I = (2.50 \text{ m})\cos 16.2602° = 2.4 \text{ m}$$

$$y_I = 1.95 \text{ m} - (2.50 \text{ m})\sin 16.2602° = 1.25 \text{ m}$$

$$\boldsymbol{\lambda}_{BA} = \frac{\overrightarrow{BA}}{BA} = \frac{-3.6\mathbf{i} + 1.05\mathbf{j}}{\sqrt{(-3.6)^2 + (1.05)^2}} = -\frac{24}{25}\mathbf{i} + \frac{7}{25}\mathbf{j}$$

continued

$$\mathbf{r}_{K/A} = (1.8\text{ m})\mathbf{i} - (0.525\text{ m})\mathbf{j} + (0.225\text{ m})\mathbf{k}$$

$$\mathbf{r}_{I/A} = (2.4\text{ m})\mathbf{i} - (0.7\text{ m})\mathbf{j} + (0.45\text{ m})\mathbf{k}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(25\text{ kg})\left(9.81\text{ m/s}^2\right)\mathbf{j} = -(245.25\text{ kg})\mathbf{j}$$

$$\mathbf{P}_{JI} = P_{JI}\frac{\overrightarrow{JI}}{JI} = P_{JI}\frac{-0.025\mathbf{i} + 1.25\mathbf{j} - 0.25\mathbf{k}}{\sqrt{(-0.025)^2 + (1.25)^2 + (-0.25)^2}} = P_{JI}\left(-\frac{1}{51}\mathbf{i} + \frac{50}{51}\mathbf{j} + \frac{10}{51}\mathbf{k}\right)$$

Now,

$$\Sigma M_{BA} = 0: \qquad \boldsymbol{\lambda}_{BA}\cdot\left(\mathbf{r}_{K/A}\times\mathbf{W}\right) + \boldsymbol{\lambda}_{BA}\cdot\left(\mathbf{r}_{I/A}\times\mathbf{P}_{JI}\right) = 0$$

$$\begin{vmatrix} -24 & 7 & 0 \\ 1.8 & -0.525 & 0.225 \\ 0 & -245.25 & 0 \end{vmatrix}\frac{1}{25} + \begin{vmatrix} -24 & 7 & 0 \\ 12.4 & -0.7 & 0.45 \\ -1 & 50 & -10 \end{vmatrix}\frac{P_{JI}}{(25)(51)} = 0$$

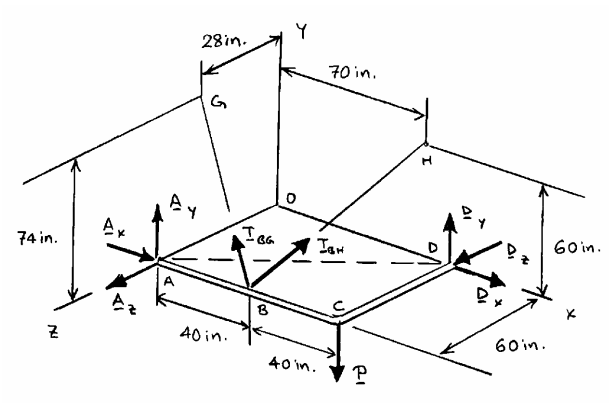
$$-\frac{1324.35}{25} + \frac{536.85}{(25)(51)}P_{JI} = 0$$

Therefore: $P_{JI} = 125.811$ N

or $P_{JI} = 125.8$ N ◀

Chapter 4, Solution 144.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{T}_{BG} = T_{BG}\frac{\overrightarrow{BG}}{BG} = T_{BG}\frac{-40\mathbf{i} + 74\mathbf{j} - 32\mathbf{k}}{\sqrt{(-40)^2 + (74)^2 + (-32)^2}} = T_{BG}\left(-\frac{20}{45}\mathbf{i} + \frac{37}{45}\mathbf{j} - \frac{16}{45}\mathbf{k}\right)$$

$$\mathbf{T}_{BH} = T_{BH}\frac{\overrightarrow{BH}}{BH} = T_{BH}\frac{30\mathbf{i} + 60\mathbf{j} - 60\mathbf{k}}{\sqrt{(30)^2 + (60)^2 + (-60)^2}} = T_{BH}\left(\frac{1}{3}\mathbf{i} + \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}\right)$$

$$\mathbf{P} = -(75\text{ lb})\mathbf{j}$$

$$\boldsymbol{\lambda}_{AD} = \frac{\overrightarrow{AD}}{AD} = \frac{80\mathbf{i} - 60\mathbf{j}}{\sqrt{(80)^2 + (-60)^2}} = 0.8\mathbf{i} - 0.6\mathbf{j}$$

continued

$$\mathbf{r}_{B/A} = (40 \text{ in.})\mathbf{i}$$

$$\mathbf{r}_{C/A} = (80 \text{ in.})\mathbf{i}$$

Now,

$$\Sigma M_{AD} = 0: \quad \boldsymbol{\lambda}_{AD} \cdot \left(\mathbf{r}_{B/A} \times \mathbf{T}_{BG}\right) + \boldsymbol{\lambda}_{AD} \cdot \left(\mathbf{r}_{B/A} \times \mathbf{T}_{BH}\right) + \boldsymbol{\lambda}_{AD} \cdot \left(\mathbf{r}_{C/A} \times \mathbf{P}\right) = 0$$

$$\begin{vmatrix} 0.8 & 0 & -0.6 \\ 40 & 0 & 0 \\ -20 & 37 & -16 \end{vmatrix} \frac{T_{BG}}{45} + \begin{vmatrix} 0.8 & 0 & -0.6 \\ 40 & 0 & 0 \\ 1 & 2 & -2 \end{vmatrix} \frac{T_{BH}}{3} + \begin{vmatrix} 0.8 & 0 & -0.6 \\ 80 & 0 & 0 \\ 0 & -75 & 0 \end{vmatrix} = 0$$

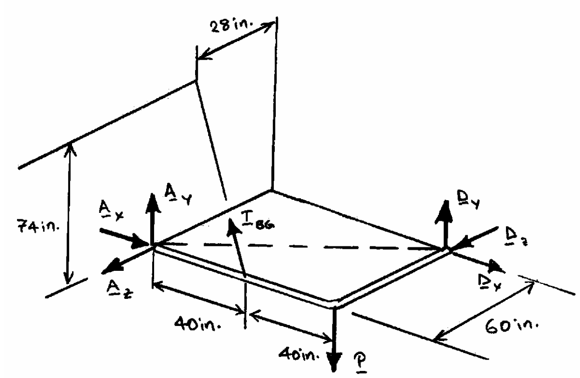
$$-\frac{888}{45} T_{BG} - \frac{48}{3} T_{BH} + 3600 = 0$$

Noting that $T_{BG} = T_{BH} = T$ and solving:

$T = 100.746$ lb　　　　or $T = 100.7$ lb ◀

Chapter 4, Solution 145.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{T}_{BG} = T_{BG}\frac{\overrightarrow{BG}}{BG} = T_{BG}\frac{-40\mathbf{i} + 74\mathbf{j} - 32\mathbf{k}}{\sqrt{(-40)^2 + (74)^2 + (-32)^2}} = T_{BG}\left(-\frac{20}{45}\mathbf{i} + \frac{37}{45}\mathbf{j} - \frac{16}{45}\mathbf{k}\right)$$

$$\mathbf{P} = -(75 \text{ lb})\mathbf{j}$$

$$\boldsymbol{\lambda}_{AD} = \frac{\overrightarrow{AD}}{AD} = \frac{80\mathbf{i} - 60\mathbf{j}}{\sqrt{(80)^2 + (-60)^2}} = 0.8\mathbf{i} - 0.6\mathbf{j}$$

$$\mathbf{r}_{B/A} = (40 \text{ in.})\mathbf{i}$$

$$\mathbf{r}_{C/A} = (80 \text{ in.})\mathbf{i}$$

Now,

$$\Sigma M_{AD} = 0: \qquad \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{B/A}\times\mathbf{T}_{BG}\right) + \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{C/A}\times\mathbf{P}\right) = 0$$

$$\begin{vmatrix} 0.8 & 0 & -0.6 \\ 40 & 0 & 0 \\ -20 & 37 & -16 \end{vmatrix}\frac{T_{BG}}{45} + \begin{vmatrix} 0.8 & 0 & -0.6 \\ 80 & 0 & 0 \\ 0 & -75 & 0 \end{vmatrix} = 0$$

$$-\frac{888}{45}T_{BG} + 3600 = 0$$

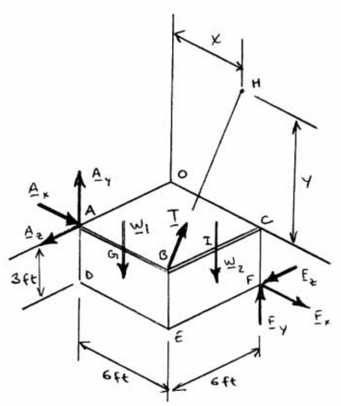
Solving for T_{BG}:

$$T_{BG} = 182.432 \text{ lb}$$

or $T_{BG} = 182.4$ lb ◀

Chapter 4, Solution 146.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{W}_1 = \mathbf{W}_2 = -(30\text{ lb})\mathbf{j}$$

$$\mathbf{T} = T\frac{\overline{BH}}{BH} = T\frac{(x-6)\mathbf{i} + y\,\mathbf{j} - 6\mathbf{k}}{\sqrt{(x-6)^2 + y^2 + (-6)^2}}$$

$$\boldsymbol{\lambda}_{AF} = \frac{\overrightarrow{AF}}{AF} = \frac{6\mathbf{i} - 3\mathbf{j} - 6\mathbf{k}}{\sqrt{(6)^2 + (-3)^2 + (-6)^2}} = \frac{2}{3}\mathbf{i} - \frac{1}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}$$

$$\mathbf{r}_{G/A} = (3\text{ ft})\mathbf{i}$$

$$\mathbf{r}_{B/A} = (6\text{ ft})\mathbf{i}$$

$$\mathbf{r}_{I/A} = (6\text{ ft})\mathbf{i} - (3\text{ ft})\mathbf{k}$$

continued

Now,

$$\Sigma M_{AF} = 0: \qquad \boldsymbol{\lambda}_{AF} \cdot (\mathbf{r}_{G/A} \times \mathbf{W}_1) + \boldsymbol{\lambda}_{AF} \cdot (\mathbf{r}_{B/A} \times \mathbf{T}) + \boldsymbol{\lambda}_{AF} \cdot (\mathbf{r}_{I/A} \times \mathbf{W}_2) = 0$$

$$\begin{vmatrix} 2 & -1 & -2 \\ 3 & 0 & 0 \\ 0 & -30 & 0 \end{vmatrix} \left(\frac{1}{3}\right) + \begin{vmatrix} 2 & -1 & -2 \\ 6 & 0 & 0 \\ (x-6) & y & -6 \end{vmatrix} \frac{\frac{T}{3}}{\sqrt{(x-6)^2 + y^2 + 36}} + \begin{vmatrix} 2 & -1 & -2 \\ 6 & 0 & -3 \\ 0 & -30 & 0 \end{vmatrix} \left(\frac{1}{3}\right) = 0$$

$$60 + (-36 - 12y) \frac{\frac{T}{3}}{\sqrt{(x-6)^2 + y^2 + 36}} + 60 = 0$$

Solving for T:

$$T = \frac{30}{30 + y} \sqrt{(x-6)^2 + y^2 + 36}$$

It is thus clear that for a given y, T will have its minimum value when $x = 6$ ft. Denoting this minimum by T_m:

$$T_m = \frac{30}{3 + y} \sqrt{y^2 + 36}$$

Now to find the minimum of T_m, differentiate T_m with respect to y and equate the derivative to zero.

$$\frac{dT_m}{dy} = \frac{\left[\left(\frac{1}{2}\right)(3+y)(36+y^2)^{-\frac{1}{2}}(2y) - (36+y^2)^{\frac{1}{2}}(1)\right]30}{(3+y)^2} = 0$$

Setting the numerator equal to zero and simplifying:

$$(3 + y)y - y^2 - 36 = 0$$

$$y = 12 \text{ ft}$$

(a) Minimum occurs at: $x = 6$ ft, $y = 12$ ft ◀

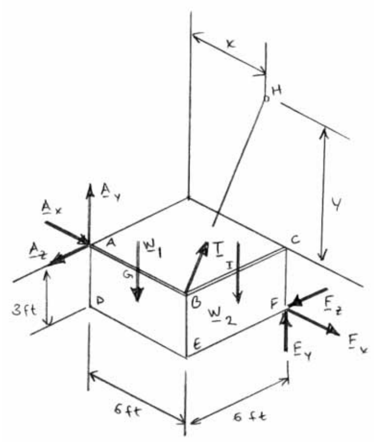
(b) Using the expression for T:

$$T_{\min} = \frac{30}{3 + 12} \sqrt{(6-6)^2 + (12)^2 + 36} = 26.833 \text{ lb}$$

or $T_{\min} = 26.8$ lb ◀

Chapter 4, Solution 147.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{W}_1 = \mathbf{W}_2 = -(30\text{ lb})\mathbf{j}$$

$$\mathbf{T} = T\frac{\overrightarrow{BH}}{BH} = T\frac{-6\mathbf{i} + y\mathbf{j} - 6\mathbf{k}}{\sqrt{(-6)^2 + y^2 + (-6)^2}}$$

$$\boldsymbol{\lambda}_{AF} = \frac{\overrightarrow{AF}}{AF} = \frac{6\mathbf{i} - 3\mathbf{j} - 6\mathbf{k}}{\sqrt{(6)^2 + (-3)^2 + (-6)^2}} = \frac{2}{3}\mathbf{i} - \frac{1}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}$$

$$\mathbf{r}_{G/A} = (3\text{ ft})\mathbf{i}$$

$$\mathbf{r}_{B/A} = (6\text{ ft})\mathbf{i}$$

$$\mathbf{r}_{I/A} = (6\text{ ft})\mathbf{i} - (3\text{ ft})\mathbf{k}$$

continued

Now,

$$\Sigma M_{AF} = 0: \qquad \boldsymbol{\lambda}_{AF} \cdot \left(\mathbf{r}_{G/A} \times \mathbf{W}_1\right) + \boldsymbol{\lambda}_{AF} \cdot \left(\mathbf{r}_{B/A} \times \mathbf{T}\right) + \boldsymbol{\lambda}_{AF} \cdot \left(\mathbf{r}_{I/A} \times \mathbf{W}_2\right) = 0$$

$$\begin{vmatrix} 2 & -1 & -2 \\ 3 & 0 & 0 \\ 0 & -30 & 0 \end{vmatrix}\left(\frac{1}{3}\right) + \begin{vmatrix} 2 & -1 & -2 \\ 6 & 0 & 0 \\ -6 & y & -6 \end{vmatrix}\frac{\frac{T}{3}}{\sqrt{(-6)^2 + y^2 + 36}} + \begin{vmatrix} 2 & -1 & -2 \\ 6 & 0 & -3 \\ 0 & -30 & 0 \end{vmatrix}\left(\frac{1}{3}\right) = 0$$

$$60 + (-36 - 12y)\frac{\frac{T}{3}}{\sqrt{(-6)^2 + y^2 + 36}} + 60 = 0$$

Solving for T:

$$T = \frac{30}{30 + y}\sqrt{(-6)^2 + y^2 + 36}$$

$$T = \frac{30}{3 + y}\sqrt{y^2 + 72}$$

Now to find the minimum of T, differentiate T with respect to y and equate the derivative to zero.

$$\frac{dT_m}{dy} = \frac{\left[\left(\frac{1}{2}\right)(3 + y)\left(72 + y^2\right)^{-\frac{1}{2}}(2y) - \left(72 + y^2\right)^{\frac{1}{2}}(1)\right]30}{(3 + y)^2} = 0$$

Setting the numerator equal to zero and simplifying:

$$(3 + y)y - y^2 - 72 = 0, \text{ or } y = 24 \text{ ft}$$

(a) Minimum occurs at: $x = 0,\ y = 24$ ft ◀

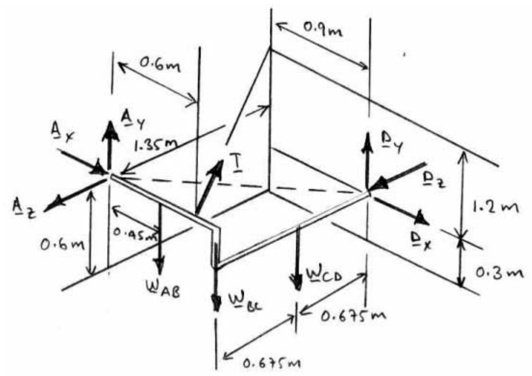
(b) Using the expression for T:

$$T_{\min} = \frac{30}{3 + 24}\sqrt{(24)^2 + 72} = 28.284 \text{ lb}$$

or $T_{\min} = 28.3$ lb ◀

Chapter 4, Solution 148.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{W}_{AB} = -(1.25\ \text{kg/m})(9.81\ \text{m/s}^2)(0.9\ \text{m})\,\mathbf{j} = -(11.0363\ \text{N})\,\mathbf{j}$$

$$\mathbf{W}_{BC} = -(1.25\ \text{kg/m})(9.81\ \text{m/s}^2)(0.3\ \text{m})\,\mathbf{j} = -(3.6788\ \text{N})\,\mathbf{j}$$

$$\mathbf{W}_{CD} = -(1.25\ \text{kg/m})(9.81\ \text{m/s}^2)(1.35\ \text{m})\,\mathbf{j} = -(16.5544\ \text{N})\,\mathbf{j}$$

$$\mathbf{T} = T\frac{\overrightarrow{FE}}{FE} = T\frac{-0.6\mathbf{i} + 0.9\mathbf{j} - 1.35\mathbf{k}}{\sqrt{(-0.6)^2 + (0.9)^2 + (-1.35)^2}} = \frac{T}{\sqrt{33.25}}(-2\mathbf{i} + 3\mathbf{j} - 4.5\mathbf{k})$$

continued

Vector Mechanics for Engineers: Statics and Dynamics, 8/e, Ferdinand P. Beer, E. Russell Johnston, Jr.,
Elliot R. Eisenberg, William E. Clausen, David Mazurek, Phillip J. Cornwell

$$\boldsymbol{\lambda}_{AD} = \frac{\overrightarrow{AD}}{AD} = \frac{0.9\mathbf{i} - 0.3\mathbf{j} - 1.35\mathbf{k}}{\sqrt{(0.9)^2 + (-0.3)^2 + (-1.35)^2}} = \frac{6}{11}\mathbf{i} - \frac{2}{11}\mathbf{j} - \frac{9}{11}\mathbf{k}$$

$$\mathbf{r}_{G/A} = (0.45 \text{ m})\mathbf{i}$$

$$\mathbf{r}_{F/A} = (0.6 \text{ m})\mathbf{i}$$

$$\mathbf{r}_{B/A} = (0.9 \text{ m})\mathbf{i}$$

$$\mathbf{r}_{H/A} = (0.9 \text{ m})\mathbf{i} - (0.3 \text{ m})\mathbf{j} - (0.675 \text{ m})\mathbf{k}$$

Now,

$$\Sigma M_{AD} = 0: \quad \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{G/A}\times\mathbf{W}_{AB}\right) + \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{F/A}\times\mathbf{T}\right) + \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{B/A}\times\mathbf{W}_{BC}\right) + \boldsymbol{\lambda}_{AD}\cdot\left(\mathbf{r}_{H/A}\times\mathbf{W}_{CD}\right) = 0$$

$$\begin{vmatrix} 6 & -2 & -9 \\ 0.45 & 0 & 0 \\ 0 & -11.0363 & 0 \end{vmatrix}\left(\frac{1}{11}\right) + \begin{vmatrix} 6 & -2 & -9 \\ 0.6 & 0 & 0 \\ -2 & 3 & -4.5 \end{vmatrix}\frac{T}{11\sqrt{33.25}} + \begin{vmatrix} 6 & -2 & -9 \\ 0.9 & 0 & 0 \\ 0 & -3.6788 & 0 \end{vmatrix}\left(\frac{1}{11}\right)$$

$$+\begin{vmatrix} 6 & -2 & -9 \\ 0.9 & -0.3 & -0.675 \\ 0 & -16.5544 & 0 \end{vmatrix}\left(\frac{1}{11}\right) = 0$$

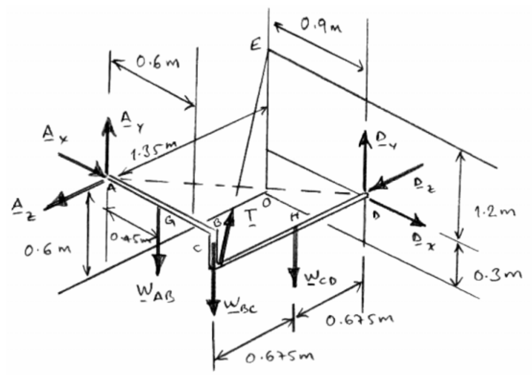
$$4.0634 - 0.34054T + 2.7089 + 6.0950 = 0$$

Solving for T:

$T_{BG} = 37.785$ N or $T_{BG} = 37.8$ N ◀

Chapter 4, Solution 149.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{W}_{AB} = -(1.25 \text{ kg/m})(9.81 \text{ m/s}^2)(0.9 \text{ m})\mathbf{j} = -(11.0363 \text{ N})\mathbf{j}$$

$$\mathbf{W}_{BC} = -(1.25 \text{ kg/m})(9.81 \text{ m/s}^2)(0.3 \text{ m})\mathbf{j} = -(3.6788 \text{ N})\mathbf{j}$$

$$\mathbf{W}_{CD} = -(1.25 \text{ kg/m})(9.81 \text{ m/s}^2)(1.35 \text{ m})\mathbf{j} = -(16.5544 \text{ N})\mathbf{j}$$

$$\mathbf{T} = T\frac{\overline{CE}}{CE} = T\frac{-0.9\mathbf{i} + 1.2\mathbf{j} - 1.35\mathbf{k}}{\sqrt{(-0.9)^2 + (1.2)^2 + (-1.35)^2}} = \frac{T}{\sqrt{45.25}}(-3\mathbf{i} + 4\mathbf{j} - 4.5\mathbf{k})$$

continued

$$\boldsymbol{\lambda}_{AD} = \frac{\overrightarrow{AD}}{AD} = \frac{0.9\mathbf{i} - 0.3\mathbf{j} - 1.35\mathbf{k}}{\sqrt{(0.9)^2 + (-0.3)^2 + (-1.35)^2}} = \frac{6}{11}\mathbf{i} - \frac{2}{11}\mathbf{j} - \frac{9}{11}\mathbf{k}$$

$$\mathbf{r}_{G/A} = (0.45 \text{ m})\mathbf{i}$$

$$\mathbf{r}_{C/A} = (0.9 \text{ m})\mathbf{i} - (0.3 \text{ m})\mathbf{j}$$

$$\mathbf{r}_{B/A} = (0.9 \text{ m})\mathbf{i}$$

$$\mathbf{r}_{H/A} = (0.9 \text{ m})\mathbf{i} - (0.3 \text{ m})\mathbf{j} - (0.675 \text{ m})\mathbf{k}$$

Now,

$$\Sigma M_{AD} = 0: \quad \boldsymbol{\lambda}_{AD}\cdot(\mathbf{r}_{G/A} \times \mathbf{W}_{AB}) + \boldsymbol{\lambda}_{AD}\cdot(\mathbf{r}_{C/A} \times \mathbf{T}) + \boldsymbol{\lambda}_{AD}\cdot(\mathbf{r}_{B/A} \times \mathbf{W}_{BC}) + \boldsymbol{\lambda}_{AD}\cdot(\mathbf{r}_{H/A} \times \mathbf{W}_{CD}) = 0$$

$$\begin{vmatrix} 6 & -2 & -9 \\ 0.45 & 0 & 0 \\ 0 & -11.0363 & 0 \end{vmatrix}\left(\frac{1}{11}\right) + \begin{vmatrix} 6 & -2 & -9 \\ 0.9 & -0.3 & 0 \\ -3 & 4 & -4.5 \end{vmatrix}\frac{T}{11\sqrt{45.25}} + \begin{vmatrix} 6 & -2 & -9 \\ 0.9 & 0 & 0 \\ 0 & -3.6788 & 0 \end{vmatrix}\left(\frac{1}{11}\right)$$

$$+ \begin{vmatrix} 6 & -2 & -9 \\ 0.9 & -0.3 & -0.675 \\ 0 & -16.5544 & 0 \end{vmatrix}\left(\frac{1}{11}\right) = 0$$

$$4.0634 - 0.32840T + 2.7089 + 6.0950 = 0$$

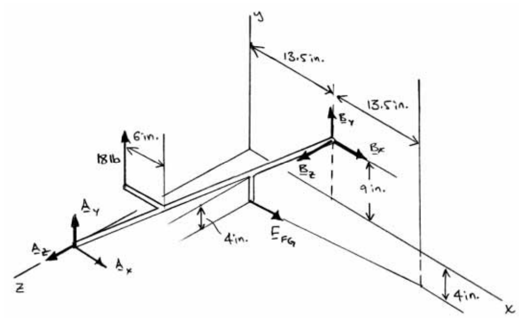
Solving for T:

$T = 39.182 \text{ N}$ or $T = 39.2 \text{ N}$ ◀

Vector Mechanics for Engineers: Statics and Dynamics, 8/e, Ferdinand P. Beer, E. Russell Johnston, Jr.,
Elliot R. Eisenberg, William E. Clausen, David Mazurek, Phillip J. Cornwell

Chapter 4, Solution 150.

Free-Body Diagram:



Express forces in terms of their rectangular components:

$$\mathbf{T}_{FG} = T_{FG}\frac{\overrightarrow{FG}}{FG} = T_{FG}\frac{18\mathbf{i} - 6\mathbf{j} - 9\mathbf{k}}{\sqrt{(18)^2 + (-6)^2 + (-9)^2}} = \frac{T_{FG}}{7}(6\mathbf{i} - 2\mathbf{j} - 3\mathbf{k})$$

$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{AB} = \frac{13.5\mathbf{i} + 9\mathbf{j} - 27\mathbf{k}}{\sqrt{(13.5)^2 + (9)^2 + (-27)^2}} = \frac{3}{7}\mathbf{i} + \frac{2}{7}\mathbf{j} - \frac{6}{7}\mathbf{k}$$

$$\Sigma M_{AB} = 0: \qquad \boldsymbol{\lambda}_{AB}\cdot(\mathbf{r}_{AE}\times\mathbf{F}_E) + \boldsymbol{\lambda}_{AB}\cdot(\mathbf{r}_{BG}\times\mathbf{T}_{FG}) = 0$$

$$\begin{vmatrix} 3 & 2 & -6 \\ -1.5 & 3 & -9 \\ 0 & 1 & 0 \end{vmatrix}\left(\frac{1}{7}\right)18 + \begin{vmatrix} 3 & 2 & -6 \\ 13.5 & -13 & 0 \\ 6 & -2 & -3 \end{vmatrix}\frac{T_{FG}}{7}\left(\frac{1}{7}\right) = 0$$

$$18(9 + 27) + \frac{T_{FG}}{7}(117 + 162 - 468 + 81) = 0$$

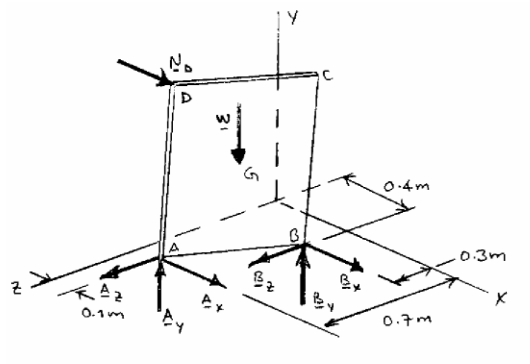
Solving for T_{FG}:

$$T_{FG} = 42.000 \text{ lb}$$

or $T_{FG} = 42.0$ lb ◀

Chapter 4, Solution 151.

Free-Body Diagram:



(*a*) The location of *D* follows from the geometry of the problem. Since the steel plate is rectangular $r_{D/A}$ is perpendicular to $r_{B/A}$ and therefore:

$$\mathbf{r}_{D/A} \cdot \mathbf{r}_{B/A} = 0$$

Denoting the coordinates of *D* by (0, *y*, *z*):

$$\mathbf{r}_{D/A} = -(0.1\text{ m})\mathbf{i} + y\mathbf{j} + (z - 0.7\text{ m})\mathbf{k}$$

and $\mathbf{r}_{B/A} = (0.3\text{ m})\mathbf{i} - (0.4\text{ m})\mathbf{k}$

Thus, $\mathbf{r}_{D/A} \cdot \mathbf{r}_{B/A} = -0.03 - 0.4z + 0.28 = 0$

or $z = 0.625$ m.

$$\left|\mathbf{r}_{D/A}\right| = \sqrt{(-0.1\text{ m})^2 + y^2 + (0.625\text{ m} - 0.7\text{ m})^2} = 0.75\text{ m}$$

continued

Solving for y:

$$y = 0.73951 \text{ m}$$

Location of D is therefore: $x = 0,\ y = 0.740 \text{ m},\ z = 0.625 \text{ m}$ ◀

(b) Consider moment equilibrium about axis AB:

$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{AB} = \frac{0.3\mathbf{i} - 0.4\mathbf{k}}{\sqrt{(0.3)^2 + (-0.4)^2}} = 0.6\mathbf{i} - 0.8\mathbf{k}$$

$$\mathbf{r}_{D/A} = -(0.1 \text{ m})\mathbf{i} + (0.73951 \text{ m})\mathbf{j} - (0.075 \text{ m})\mathbf{k}$$

$$\mathbf{r}_{D/B} = -(0.4 \text{ m})\mathbf{i} + (0.73951 \text{ m})\mathbf{j} + (0.625 \text{ m} - 0.3 \text{ m})\mathbf{k}$$

$$\mathbf{N}_D = N_D\mathbf{i}$$

$$\mathbf{W} = -(mg)\mathbf{j} = -(40 \text{ kg})(9.81 \text{ m/s}^2)\mathbf{j} = -(392.4 \text{ N})\mathbf{j}$$

Then,

$$\Sigma M_{AB} = 0: \qquad \boldsymbol{\lambda}_{AB}\cdot(\mathbf{r}_{D/A}\times\mathbf{N}_D) + \boldsymbol{\lambda}_{AB}\cdot(\mathbf{r}_{G/B}\times\mathbf{W}) = 0$$

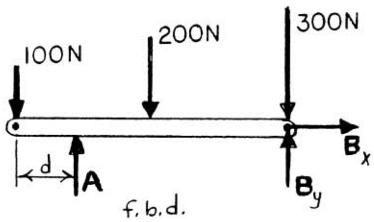
$$\begin{vmatrix} 0.6 & 0 & -0.8 \\ -0.1 & 0.73951 & -0.075 \\ N_D & 0 & 0 \end{vmatrix} + \begin{vmatrix} 0.6 & 0 & -0.8 \\ -0.2 & 0.36976 & 0.1625 \\ 0 & -392.4 & 0 \end{vmatrix} = 0$$

$$0.59161 N_D - 24.525 = 0$$

$N_D = 41.455 \text{ N}$ or $\mathbf{N}_D = (41.455 \text{ N})\mathbf{i}$ ◀

Chapter 4, Solution 152.

Free-Body Diagram:



From free-body diagram of beam

$$\xrightarrow{+} \Sigma F_x = 0: \quad B_x = 0 \qquad \text{so that} \qquad B = B_y$$

$$+\uparrow \Sigma F_y = 0: \quad A + B - (100 + 200 + 300)\text{N} = 0$$

or

$$A + B = 600 \text{ N}$$

Therefore, if either **A** or **B** has a magnitude of the maximum of 360 N, the other support reaction will be $< 360 \text{ N}(600 \text{ N} - 360 \text{ N} = 240 \text{ N})$.

$$+\circlearrowleft \Sigma M_A = 0: \quad (100 \text{ N})(d) - (200 \text{ N})(0.9 - d) - (300 \text{ N})(1.8 - d)$$

$$+ B(1.8 - d) = 0$$

or

$$d = \frac{720 - 1.8B}{600 - B}$$

Since $B \leq 360$ N,

$$d = \frac{720 - 1.8(360)}{600 - 360} = 0.300 \text{ m} \qquad \text{or} \qquad d \geq 300 \text{ mm}$$

$$+\circlearrowleft \Sigma M_B = 0: \quad (100 \text{ N})(1.8) - A(1.8 - d) + (200 \text{ N})(0.9) = 0$$

or

$$d = \frac{1.8A - 360}{A}$$

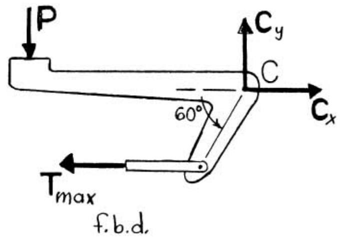
Since $A \leq 360$ N,

$$d = \frac{1.8(360) - 360}{360} = 0.800 \text{ m} \qquad \text{or} \qquad d \leq 800 \text{ mm}$$

or $300 \text{ mm} \leq d \leq 800 \text{ mm}$ ◀

Chapter 4, Solution 153.

Free-Body Diagram:



Have $\qquad C_{max} = 1000 \text{ N}$

Now $\qquad C^2 = C_x^2 + C_y^2$

$$\therefore \quad C_y = \sqrt{(1000)^2 - C_x^2} \qquad (1)$$

From free-body diagram of pedal

$$\xrightarrow{+} \Sigma F_x = 0: \quad C_x - T_{max} = 0$$

$$\therefore \quad C_x = T_{max} \qquad (2)$$

$$+\circlearrowleft \Sigma M_D = 0: \quad C_y(0.4 \text{ m}) - T_{max}\left[(0.18 \text{ m})\sin 60°\right] = 0$$

$$\therefore \quad C_y = 0.38971 T_{max} \qquad (3)$$

Equating the expressions for C_y in Equations (1) and (3), with $C_x = T_{max}$ from Equation (2)

$$\sqrt{(1000)^2 - T_{max}^2} = 0.389711 T_{max}$$

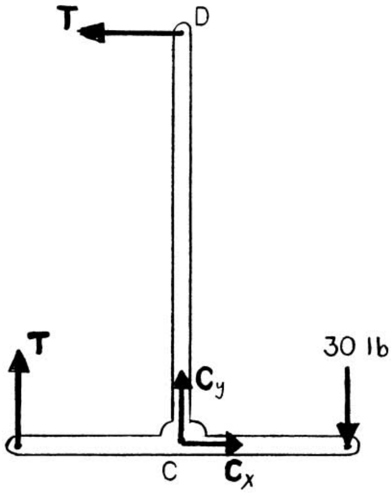
$$\therefore \quad T_{max}^2 = 868{,}150$$

and $\qquad T_{max} = 931.75 \text{ N}$

or $T_{max} = 932 \text{ N}$ ◀

Chapter 4, Solution 154.

Free-Body Diagram:



From free-body diagram of inverted T-member

$$+\circlearrowright \Sigma M_C = 0: \quad T(25 \text{ in.}) - T(10 \text{ in.}) - (30 \text{ lb})(10 \text{ in.}) = 0$$

$$\therefore \quad T = 20 \text{ lb}$$

or $T = 20.0 \text{ lb}$ ◀

$$\xrightarrow{+} \Sigma F_x = 0: \quad C_x - 20 \text{ lb} = 0$$

$$\therefore \quad C_x = 20 \text{ lb}$$

or $\mathbf{C}_x = 20.0 \text{ lb} \longrightarrow$

$$+\uparrow \Sigma F_y = 0: \quad C_y + 20 \text{ lb} - 30 \text{ lb} = 0$$

$$\therefore \quad C_y = 10 \text{ lb}$$

or $\mathbf{C}_y = 10.00 \text{ lb} \uparrow$

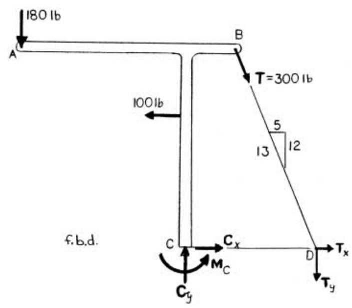
Then $C = \sqrt{C_x^2 + C_y^2} = \sqrt{(20)^2 + (10)^2} = 22.361 \text{ lb}$

and $\theta = \tan^{-1}\left(\dfrac{C_y}{C_x}\right) = \tan^{-1}\left(\dfrac{10}{20}\right) = 26.565°$

or $\mathbf{C} = 22.4 \text{ lb} \measuredangle 26.6°$ ◀

Chapter 4, Solution 155.

Free-Body Diagram:



From free-body diagram of frame with $T = 300$ lb

$$\xrightarrow{+} \Sigma F_x = 0: \quad C_x - 100 \text{ lb} + \left(\frac{5}{13}\right)300 \text{ lb} = 0$$

$$\therefore \quad C_x = -15.3846 \text{ lb} \qquad \text{or} \qquad \mathbf{C}_x = 15.3846 \text{ lb} \longleftarrow$$

$$+\uparrow \Sigma F_y = 0: \quad C_y - 180 \text{ lb} - \left(\frac{12}{13}\right)300 \text{ lb} = 0$$

$$\therefore \quad C_y = 456.92 \text{ lb} \qquad \text{or} \qquad \mathbf{C}_y = 456.92 \text{ lb} \uparrow$$

Then $$C = \sqrt{C_x^2 + C_y^2} = \sqrt{(15.3846)^2 + (456.92)^2} = 457.18 \text{ lb}$$

and $$\theta = \tan^{-1}\left(\frac{C_y}{C_x}\right) = \tan^{-1}\left(\frac{456.92}{-15.3846}\right) = -88.072°$$

or $\mathbf{C} = 457$ lb ⦣ 88.1° ◀

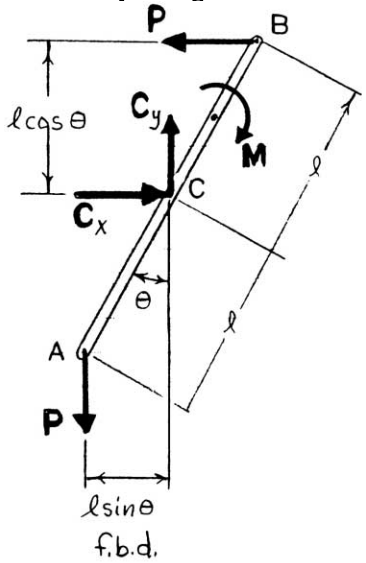
$$+\circlearrowleft \Sigma M_C = 0: \quad M_C + (180 \text{ lb})(20 \text{ in.}) + (100 \text{ lb})(16 \text{ in.}) - \left[\left(\frac{12}{13}\right)300 \text{ lb}\right](16 \text{ in.}) = 0$$

$$\therefore \quad M_C = -769.23 \text{ lb}\cdot\text{in.}$$

or $\mathbf{M}_C = 769$ lb·in. ↻ ◀

Chapter 4, Solution 156.

Free-Body Diagram:



(*a*) From free-body diagram of rod *AB*

$$+\circlearrowleft \Sigma M_C = 0: \quad P(l\cos\theta) + P(l\sin\theta) - M = 0$$

$$\text{or} \quad \sin\theta + \cos\theta = \frac{M}{Pl} \blacktriangleleft$$

(*b*) For $M = 150 \text{ lb}\cdot\text{in.}, \; P = 20 \text{ lb}, \text{ and } l = 6 \text{ in.}$

$$\sin\theta + \cos\theta = \frac{150 \text{ lb}\cdot\text{in.}}{(20 \text{ lb})(6 \text{ in.})} = \frac{5}{4} = 1.25$$

Using identity $\sin^2\theta + \cos^2\theta = 1$

$$\sin\theta + \left(1 - \sin^2\theta\right)^{\frac{1}{2}} = 1.25$$

$$\left(1 - \sin^2\theta\right)^{\frac{1}{2}} = 1.25 - \sin\theta$$

$$1 - \sin^2\theta = 1.5625 - 2.5\sin\theta + \sin^2\theta$$

$$2\sin^2\theta - 2.5\sin\theta + 0.5625 = 0$$

Using quadratic formula

$$\sin\theta = \frac{-(-2.5) \pm \sqrt{(6.25) - 4(2)(0.5625)}}{2(2)}$$

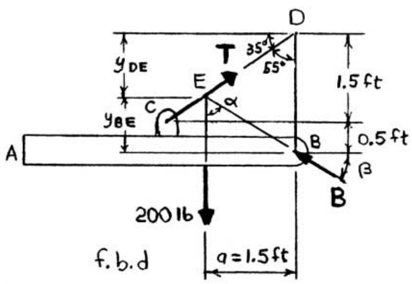
$$= \frac{2.5 \pm \sqrt{1.75}}{4}$$

or $\sin\theta = 0.95572$ and $\sin\theta = 0.29428$

$$\therefore \quad \theta = 72.886^\circ \quad \text{and} \quad \theta = 17.1144^\circ$$

$$\text{or} \quad \theta = 17.11^\circ \text{ and } \theta = 72.9^\circ \blacktriangleleft$$

Chapter 4, Solution 157.



From geometry of forces

$$\beta = \tan^{-1}\left(\frac{y_{BE}}{1.5\text{ ft}}\right)$$

where

$$y_{BE} = 2.0 - y_{DE}$$

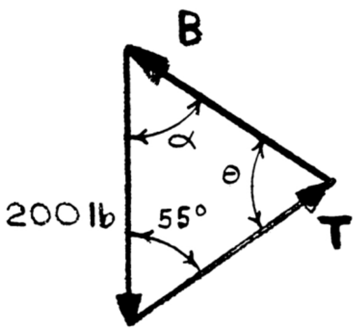
$$= 2.0 - 1.5\tan 35°$$

$$= 0.94969\text{ ft}$$

$$\therefore\ \beta = \tan^{-1}\left(\frac{0.94969}{1.5}\right) = 32.339°$$

and $\alpha = 90° - \beta = 90° - 32.339° = 57.661°$

$$\theta = \beta + 35° = 32.339° + 35° = 67.339°$$



Applying the law of sines to the force triangle,

$$\frac{200\text{ lb}}{\sin\theta} = \frac{T}{\sin\alpha} = \frac{B}{\sin 55°}$$

or

$$\frac{(200\text{ lb})}{\sin 67.339°} = \frac{T}{\sin 57.661°} = \frac{B}{\sin 55°}$$

(*a*) $T = \dfrac{(200\text{ lb})(\sin 57.661°)}{\sin 67.339°} = 183.116\text{ lb}$

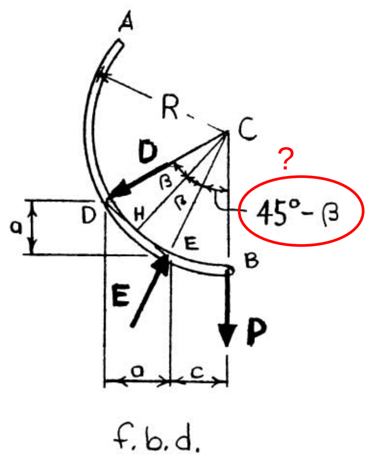
or $T = 183.1$ lb ◀

(*b*) $B = \dfrac{(200\text{ lb})(\sin 55°)}{\sin 67.339°} = 177.536\text{ lb}$

or **B** = 177.5 lb ◥ 32.3° ◀

Chapter 4, Solution 158.

Free-Body Diagram:



Since $y_{ED} = x_{ED} = a,$

Slope of *ED* is ⦣ 45°

$\therefore$ slope of *HC* is ∡ 45°

Also $DE = \sqrt{2}a$

and $DH = HE = \left(\frac{1}{2}\right)DE = \frac{a}{\sqrt{2}}$

For triangles *DHC* and *EHC*

$$\sin\beta = \frac{a/\sqrt{2}}{R} = \frac{a}{\sqrt{2}R}$$

Now $c = R\sin\left(45° - \beta\right)$

For $a = 25 \text{ mm}$ and $R = 125 \text{ mm}$

$$\sin\beta = \frac{25 \text{ mm}}{\sqrt{2}\left(125 \text{ mm}\right)} = 0.141421$$

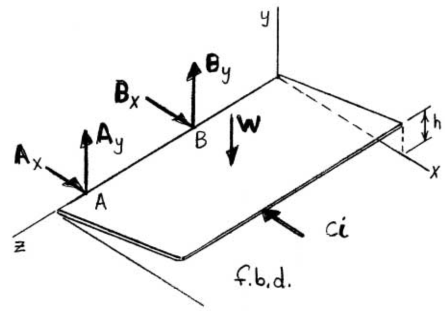
$\therefore\ \beta = 8.1301°$ or $\beta = 8.13°$ ◀

and $c = \left(125 \text{ in.}\right)\sin\left(45° - 8.1301°\right) = 75.00 \text{ in.}$

or $c = 75.0 \text{ in.}$ ◀

Chapter 4, Solution 159.

Free-Body Diagram:



First note $W = mg = (17\text{ kg})(9.81\text{ m/s}^2) = 166.77\text{ N}$

$$h = \sqrt{(1.2)^2 - (1.125)^2} = 0.41758\text{ m}$$

From free-body diagram of plywood sheet

$$\Sigma M_z = 0: \quad C(h) - W\left[\frac{(1.125\text{ m})}{2}\right] = 0$$

$$C(0.41758\text{ m}) - (166.77\text{ N})(0.5625\text{ m}) = 0$$

$$\therefore \quad C = 224.65\text{ N} \qquad \text{or} \qquad \mathbf{C} = -(225\text{ N})\mathbf{i}$$

$$\Sigma M_{B(y\text{-axis})} = 0: \quad -(224.65\text{ N})(0.6\text{ m}) + A_x(1.2\text{ m}) = 0$$

$$\therefore \quad A_x = 112.324\text{ N} \qquad \text{or} \qquad \mathbf{A}_x = (112.3\text{ N})\mathbf{i}$$

$$\Sigma M_{B(x\text{-axis})} = 0: \quad (166.77\text{ N})(0.3\text{ m}) - A_y(1.2\text{ m}) = 0$$

$$\therefore \quad A_y = 41.693\text{ N} \qquad \text{or} \qquad \mathbf{A}_y = (41.7\text{ N})\mathbf{j}$$

$$\Sigma M_{A(y\text{-axis})} = 0: \quad (224.65\text{ N})(0.6\text{ m}) - B_x(1.2\text{ m}) = 0$$

$$\therefore \quad B_x = 112.325\text{ N} \qquad \text{or} \qquad \mathbf{B}_x = (112.3\text{ N})\mathbf{i}$$

$$\Sigma M_{A(x\text{-axis})} = 0: \quad B_y(1.2\text{ m}) - (166.77\text{ N})(0.9\text{ m}) = 0$$

$$\therefore \quad B_y = 125.078\text{ N} \qquad \text{or} \qquad \mathbf{B}_y = (125.1\text{ N})\mathbf{j}$$

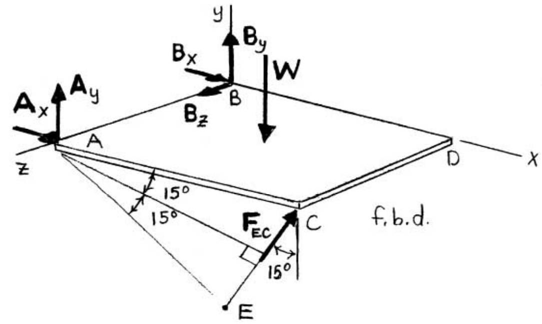
$$\therefore \quad \mathbf{A} = (112.3\text{ N})\mathbf{i} + (41.7\text{ N})\mathbf{j} \blacktriangleleft$$

$$\mathbf{B} = (112.3\text{ N})\mathbf{i} + (125.1\text{ N})\mathbf{j} \blacktriangleleft$$

$$\mathbf{C} = -(225\text{ N})\mathbf{i} \blacktriangleleft$$

Chapter 4, Solution 160.

Free-Body Diagram:



First note $W = mg = (30 \text{ kg})(9.81 \text{ m/s}^2) = 294.3 \text{ N}$

$$\mathbf{F}_{EC} = \boldsymbol{\lambda}_{EC}F_{EC} = \left[(\sin 15°)\mathbf{i} + (\cos 15°)\mathbf{j}\right]F_{EC}$$

From free-body diagram of cover

(*a*) $\Sigma M_z = 0$: $(F_{EC}\cos 15°)(1.0 \text{ m}) - W(0.5 \text{ m}) = 0$

or $F_{EC}\cos 15°(1.0 \text{ m}) - (294.3 \text{ N})(0.5 \text{ m}) = 0$

$\therefore \quad F_{EC} = 152.341 \text{ N}$ or $F_{EC} = 152.3 \text{ N}$ ◀

(*b*) $\Sigma M_x = 0$: $W(0.4 \text{ m}) - A_y(0.8 \text{ m}) - (F_{EC}\cos 15°)(0.8 \text{ m}) = 0$

or $(294.3 \text{ N})(0.4 \text{ m}) - A_y(0.8 \text{ m}) - \left[(152.341 \text{ N})\cos 15°\right](0.8 \text{ m}) = 0$

$\therefore \quad A_y = 0$

$\Sigma M_y = 0$: $A_x(0.8 \text{ m}) + (F_{EC}\sin 15°)(0.8 \text{ m}) = 0$

or $A_x(0.8 \text{ m}) + \left[(152.341 \text{ N})\sin 15°\right](0.8 \text{ m}) = 0$

$\therefore \quad A_x = -39.429 \text{ N}$

$\Sigma F_x = 0$: $A_x + B_x + F_{EC}\sin 15° = 0$

$-39.429 \text{ N} + B_x + (152.341 \text{ N})\sin 15° = 0$

$\therefore \quad B_x = 0$

$\Sigma F_y = 0$: $F_{EC}\cos 15° - W + B_y = 0$

or $(152.341 \text{ N})\cos 15° - 294.3 \text{ N} + B_y = 0$

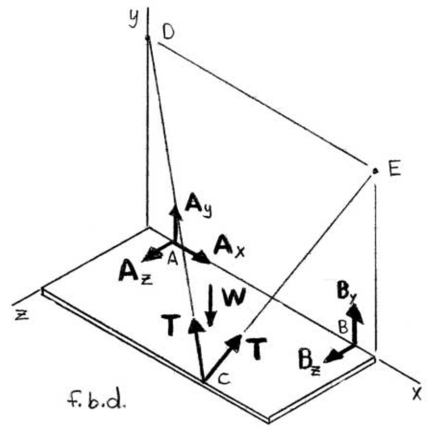
$\therefore \quad B_y = 147.180 \text{ N}$

or $\mathbf{A} = -(39.4 \text{ N})\mathbf{i}$ ◀

$\mathbf{B} = (147.2 \text{ N})\mathbf{j}$ ◀

Chapter 4, Solution 161.

Free-Body Diagram:



First note

$$\lambda_{CD} = \frac{-(23 \text{ in.})\mathbf{i} + (22.5 \text{ in.})\mathbf{j} - (15 \text{ in.})\mathbf{k}}{35.5 \text{ in.}}$$

$$= \frac{1}{35.5}(-23\mathbf{i} + 22.5\mathbf{j} - 15\mathbf{k})$$

$$\lambda_{CE} = \frac{(9 \text{ in.})\mathbf{i} + (22.5 \text{ in.})\mathbf{j} - (15 \text{ in.})\mathbf{k}}{28.5 \text{ in.}}$$

$$= \frac{1}{28.5}(9\mathbf{i} + 22.5\mathbf{j} - 15\mathbf{k})$$

$$\mathbf{W} = -(285 \text{ lb})\mathbf{j}$$

From free-body diagram of plate

(*a*) $$\Sigma M_x = 0: \quad (285 \text{ lb})(7.5 \text{ in.}) - \left[\left(\frac{22.5}{35.5}\right)T\right](15 \text{ in.}) - \left[\left(\frac{22.5}{28.5}\right)T\right](15 \text{ in.}) = 0$$

$$\therefore \quad T = 100.121 \text{ lb}$$

or $T = 100.1$ lb ◀

continued

(*b*)

$$\Sigma F_x = 0: \quad A_x - T\left(\frac{23}{35.5}\right) + T\left(\frac{9}{28.5}\right) = 0$$

$$A_x - (100.121 \text{ lb})\left(\frac{23}{35.5}\right) + (100.121 \text{ lb})\left(\frac{9}{28.5}\right) = 0$$

$$\therefore \quad A_x = 33.250 \text{ lb}$$

$$\Sigma M_{B(z\text{-axis})} = 0: \quad -A_y(26 \text{ in.}) + W(13 \text{ in.}) - \left[T\left(\frac{22.5}{35.5}\right)\right](6 \text{ in.}) - \left[T\left(\frac{22.5}{28.5}\right)\right](6 \text{ in.}) = 0$$

or

$$-A_y(26 \text{ in.}) + (285 \text{ lb})(13 \text{ in.}) - \left[(100.121 \text{ lb})\left(\frac{22.5}{35.5}\right)\right](6 \text{ in.})$$

$$-\left[(100.121 \text{ lb})\left(\frac{22.5}{28.5}\right)\right](6 \text{ in.}) = 0$$

$$\therefore \quad A_y = 109.615 \text{ lb}$$

$$\Sigma M_{B(y\text{-axis})} = 0: \quad A_z(26 \text{ in.}) - \left[T\left(\frac{15}{35.5}\right)\right](6 \text{ in.}) - \left[T\left(\frac{23}{35.5}\right)\right](15 \text{ in.})$$

$$-\left[T\left(\frac{15}{28.5}\right)\right](6 \text{ in.}) + \left[T\left(\frac{9}{28.5}\right)\right](15 \text{ in.}) = 0$$

or

$$A_z(26 \text{ in.}) + \left[\frac{-1}{35.5}(90 + 345) - \frac{1}{28.5}(90 - 135)\right](100.121 \text{ lb}) = 0$$

$$\therefore \quad A_z = 41.106 \text{ lb}$$

or $\mathbf{A} = (33.3 \text{ lb})\mathbf{i} + (109.6 \text{ lb})\mathbf{j} + (41.1 \text{ lb})\mathbf{k}$ ◀

$$\Sigma F_y = 0: \quad B_y - W + T\left(\frac{22.5}{35.5}\right) + T\left(\frac{22.5}{28.5}\right) + A_y = 0$$

$$B_y - 285 \text{ lb} + (100.121 \text{ lb})\left(\frac{22.5}{35.5} + \frac{22.5}{28.5}\right) + 109.615 \text{ lb} = 0$$

$$\therefore \quad B_y = 32.885 \text{ lb}$$

$$\Sigma F_z = 0: \quad B_z + A_z - T\left(\frac{15}{35.5}\right) - T\left(\frac{15}{28.5}\right) = 0$$

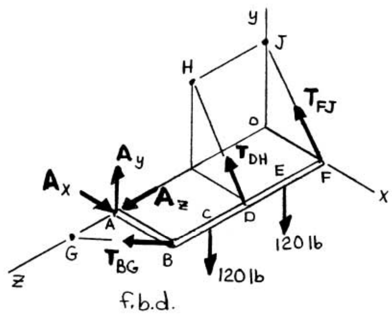
$$B_z + 41.106 \text{ lb} - (100.121 \text{ lb})\left(\frac{15}{35.5} + \frac{15}{28.5}\right) = 0$$

$$\therefore \quad B_z = 53.894 \text{ lb}$$

or $\mathbf{B} = (32.9 \text{ lb})\mathbf{j} + (53.9 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 162.

Free-Body Diagram:



First note

$$\mathbf{T}_{BG} = \lambda_{BG}T_{BG} = \frac{-(18\text{ in.})\mathbf{i} + (13.5\text{ in.})\mathbf{k}}{\sqrt{(18)^2 + (13.5)^2}\text{ in.}}T_{BG}$$

$$= T_{BG}(-0.8\mathbf{i} + 0.6\mathbf{k})$$

$$\mathbf{T}_{DH} = \lambda_{DH}T_{DH} = \frac{-(18\text{ in.})\mathbf{i} + (24\text{ in.})\mathbf{j}}{\sqrt{(18)^2 + (24)^2}\text{ in.}}T_{DH}$$

$$= T_{DH}(-0.6\mathbf{i} + 0.8\mathbf{j})$$

Since $\lambda_{FJ} = \lambda_{DH}$,

$$\mathbf{T}_{FJ} = T_{FJ}(-0.6\mathbf{i} + 0.8\mathbf{j})$$

From free-body diagram of member *ABF*

$$\Sigma M_{A(x\text{-}axis)} = 0: \quad (0.8T_{FJ})(48\text{ in.}) + (0.8T_{DH})(24\text{ in.}) - (120\text{ lb})(36\text{ in.}) - (120\text{ lb})(12\text{ in.}) = 0$$

$$\therefore \quad 3.2T_{FJ} + 1.6T_{DH} = 480 \qquad (1)$$

$$\Sigma M_{A(z\text{-}axis)} = 0: \quad (0.8T_{FJ})(18\text{ in.}) + (0.8T_{DH})(18\text{ in.}) - (120\text{ lb})(18\text{ in.}) - (120\text{ lb})(18\text{ in.}) = 0$$

$$\therefore \quad -3.2T_{FJ} - 3.2T_{DH} = -960 \qquad (2)$$

Equation (1) + Equation (2) $\qquad T_{DH} = 300\text{ lb}$ ◀

Substituting in Equation (1) $\qquad T_{FJ} = 0$ ◀

$$\Sigma M_{A(y\text{-}axis)} = 0: \quad (0.6T_{FJ})(48\text{ in.}) + [0.6(300\text{ lb})](24\text{ in.}) - (0.6T_{BG})(18\text{ in.}) = 0$$

$$\therefore \quad T_{BG} = 400\text{ lb} ◀$$

continued

$$\Sigma F_x = 0: \quad -0.6T_{FJ} - 0.6T_{DH} - 0.8T_{BG} + A_x = 0$$

$$-0.6(300 \text{ lb}) - 0.8(400 \text{ lb}) + A_x = 0$$

$$\therefore \quad A_x = 500 \text{ lb}$$

$$\Sigma F_y = 0: \quad 0.8T_{FJ} + 0.8T_{DH} - 240 \text{ lb} + A_y = 0$$

$$0.8(300 \text{ lb}) - 240 + A_y = 0$$

$$\therefore \quad A_y = 0$$

$$\Sigma F_z = 0: \quad 0.6T_{BG} + A_z = 0$$

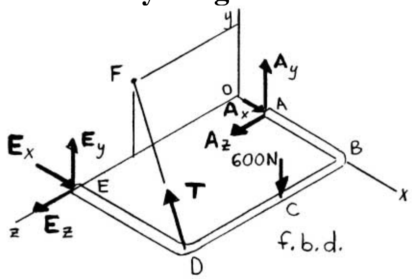
$$0.6(400 \text{ lb}) + A_z = 0$$

$$\therefore \quad A_z = -240 \text{ lb}$$

Therefore, $\mathbf{A} = (500 \text{ lb})\mathbf{i} - (240 \text{ lb})\mathbf{k}$ ◀

Chapter 4, Solution 163.

Free-Body Diagram:



First note

$$\lambda_{AE} = \frac{-(70\text{ mm})\mathbf{i} + (240\text{ mm})\mathbf{k}}{\sqrt{(70)^2 + (240)^2}\text{ mm}} = \frac{1}{25}(-7\mathbf{i} + 24\mathbf{k})$$

$$\mathbf{r}_{C/A} = (90\text{ mm})\mathbf{i} + (100\text{ mm})\mathbf{k}$$

$$\mathbf{F}_C = -(600\text{ N})\mathbf{j}$$

$$\mathbf{r}_{D/A} = (90\text{ mm})\mathbf{i} + (240\text{ mm})\mathbf{k}$$

$$\mathbf{T} = \lambda_{DF}T = \frac{-(160\text{ mm})\mathbf{i} + (110\text{ mm})\mathbf{j} - (80\text{ mm})\mathbf{k}}{\sqrt{(160)^2 + (110)^2 + (80)^2}\text{ mm}}T$$

$$= \frac{T}{21}(-16\,\mathbf{i} + 11\mathbf{j} - 8\mathbf{k})$$

From the free-body diagram of the bend rod

$$\Sigma M_{AE} = 0: \quad \lambda_{AE}\cdot\left(\mathbf{r}_{C/A}\times\mathbf{F}_C\right) + \boldsymbol{\lambda}_{AE}\cdot\left(\mathbf{r}_{D/A}\times\mathbf{T}\right) = 0$$

$$\therefore \quad \begin{vmatrix} -7 & 0 & 24 \\ 90 & 0 & 100 \\ 0 & -1 & 0 \end{vmatrix}\left(\frac{600}{25}\right) + \begin{vmatrix} -7 & 0 & 24 \\ 90 & 0 & 240 \\ -16 & 11 & -8 \end{vmatrix}\left[\frac{T}{25(21)}\right] = 0$$

$$(-700 - 2160)\left(\frac{600}{25}\right) + (18\,480 + 23\,760)\left[\frac{T}{25(21)}\right] = 0$$

$$\therefore \quad T = 853.13\text{ N}$$

or $T = 853\text{ N}$ ◀