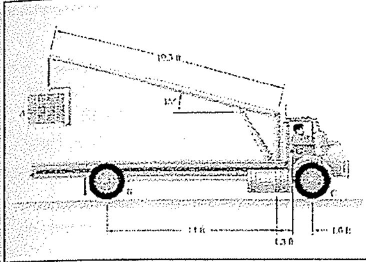
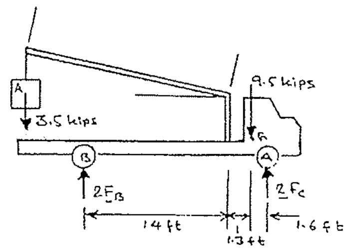


PROBLEM 4.2

The boom on a 9500-lb truck is used to unload a pallet of shingles of weight 3500 lb, Determine the reaction at each of the two (*a*) rear wheels *B*, (*b*) front wheels *C*.

SOLUTION

Free-Body Diagram:



(*a*)

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

$2F_B = 5.4009\text{ kips}$

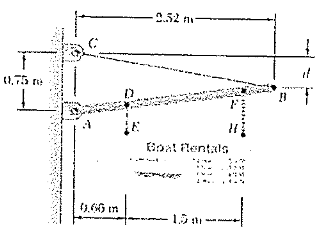
or $\mathbf{F}_B = 2.70\text{ kips}\uparrow$ ◀

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

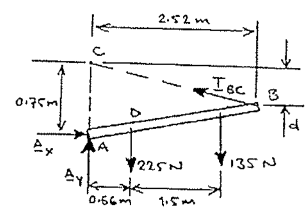


PROBLEM 4.27

A sign is hung by two chains from mast AB. The mast is hinged at A and is supported by cable BC. Knowing that the tensions in chains DE and FH are 225 N and 135 N, respectively, and that $d = 0.39$ m, determine (*a*) the tension in cable BC, (*b*) the reaction at A.

SOLUTION

Free-Body Diagram:



Geometry:

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

Equilibrium for mast:

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

$T_{BC} = 593.79$ N

or $T_{BC} = 594$ N ◀

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

$A_x = 586.80$ N

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

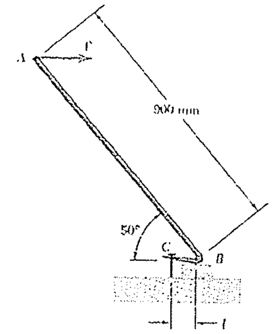
$A_y = 269.19$ N

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

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

$\therefore$ **A** $= 646$ N $\measuredangle$ 24.6° ◀

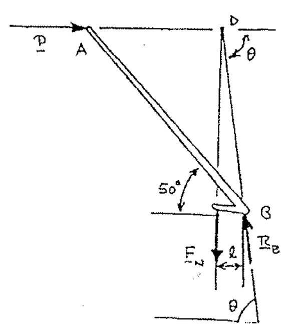
PROBLEM 4.70



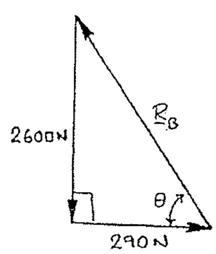
To remove a nail, a small block of wood is placed under a crowbar, and a horizontal force **P** is applied as shown. Knowing that the maximum vertical force needed to extract the nail is 2600 N and that the horizontal force **P** is not to exceed 290 N, determine the largest acceptable value of distance l.

SOLUTION

Free-Body Diagram:



From force triangle:



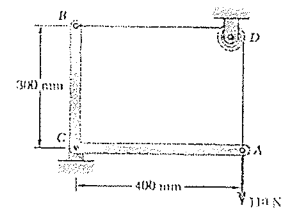
$$\theta = \tan^{-1}\left(\frac{2600 \text{ N}}{290 \text{ N}}\right) = 83.636°$$

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 ◀



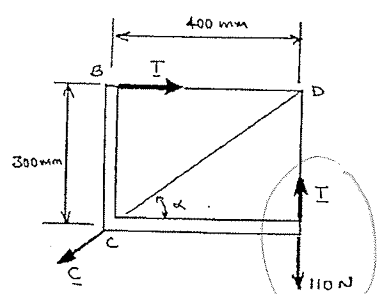
PROBLEM 4.79

The L-shaped member ACB is supported by a pin and bracket at C and by an inextensible cord attached at A and B and passing over a frictionless pulley at D. Determine (a) the tension in the cord, (b) the reaction at C.

Alternative Method:
$\Sigma M_C = 0 \Rightarrow$ solve T
$\Sigma F_x = 0 \rightarrow$ get C_x
$\Sigma F_y = 0 \rightarrow$ get C_y

SOLUTION

Free-Body Diagram:



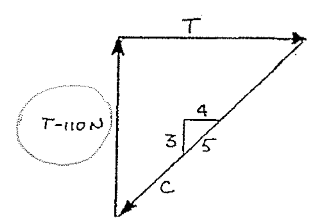
count as one net force

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 ◀

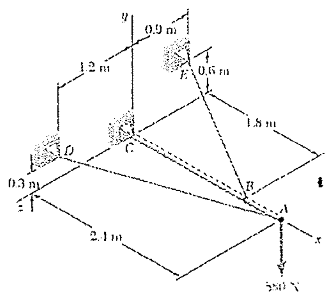
(b) From the force triangle:

$$\frac{C}{T} = \frac{5}{4}$$

$$C = \frac{5}{4}T = \frac{5}{4}(440\text{ N}) = 550\text{ N}$$

or $\mathbf{C} = 550$ N ↗ 36.9° ◀

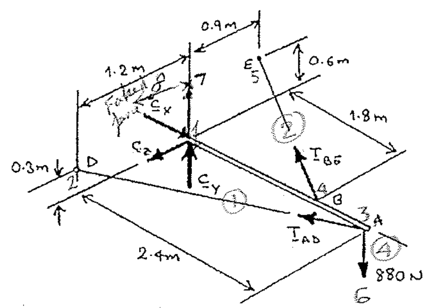
PROBLEM 4.116



A 2.4-m-long boom is held by a ball-and-socket joint at C and by two cables AD and BE. Determine the tension in each cable and the reaction at C.

SOLUTION

Free-Body Diagram:



only 2 unknowns (from the 3 simult. eqs) because the 3rd eq is (0) î = (0) î

fictitious, phantom member (3)!

Express all forces in terms of rectangular components:

$$\mathbf{r}_A = (2.4\text{ m})\mathbf{i}$$

$$\mathbf{r}_B = (1.8\text{ m})\mathbf{j}$$

$$\overline{AD} = -(2.4\text{ m})\mathbf{i} + (0.3\text{ m})\mathbf{j} + (1.2\text{ m})\mathbf{k}$$

$$\overline{BE} = -(1.8\text{ m})\mathbf{i} + (0.6\text{ m})\mathbf{j} - (0.9\text{ m})\mathbf{k}$$

$$\mathbf{W} = -(880\text{ N})\mathbf{j}$$

Then

$$\vec{T}_{AD} = T_{AD}\frac{\overline{AD}}{AD} = T_{AD}\frac{-2.4\mathbf{i} + 0.3\mathbf{j} + 1.2\mathbf{k}}{\sqrt{(-2.4)^2 + (0.3)^2 + (1.2)^2}} = -\frac{8}{9}T_{AD}\mathbf{i} + \frac{1}{9}T_{AD}\mathbf{j} + \frac{4}{9}T_{AD}\mathbf{k}$$

$$\vec{T}_{BE} = T_{BE}\frac{\overline{BE}}{BE} = T_{BE}\frac{-1.8\mathbf{i} + 0.6\mathbf{j} - 0.9\mathbf{k}}{\sqrt{(-1.8)^2 + (0.6)^2 + (-0.9)^2}} = -\frac{6}{7}T_{AD}\mathbf{i} + \frac{2}{7}T_{AD}\mathbf{j} - \frac{3}{7}T_{AD}\mathbf{k}$$

PROBLEM 4.116 CONTINUED

$\Sigma \mathbf{M}_C = 0$: $\quad \mathbf{r}_A \times \mathbf{T}_{AD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_A \times \mathbf{W} = 0$

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 $T_{AD} = 2160$ N ◀

$T_{BE} = 2990$ N ◀

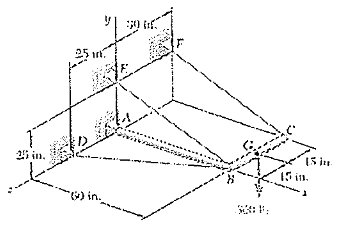
Force equations:

$$C_x - \frac{8}{9}(2160.0 \text{ N}) - \frac{6}{7}(2986.7 \text{ N}) = 0, \quad \text{or} \quad C_x = 4480.0 \text{ N}$$

$$C_y + \frac{1}{9}(2160.0 \text{ N}) + \frac{2}{7}(2986.7 \text{ N}) - 880 \text{ N} = 0, \quad \text{or} \quad C_y = -213.34 \text{ N}$$

$$C_z + \frac{4}{9}(2160.0 \text{ N}) - \frac{3}{7}(2986.7 \text{ N}) = 0, \quad \text{or} \quad C_z = 320.01 \text{ N}$$

$\mathbf{C} = (4480 \text{ N})\mathbf{i} - (213 \text{ N})\mathbf{j} + (320 \text{ N})\mathbf{k}$ ◀

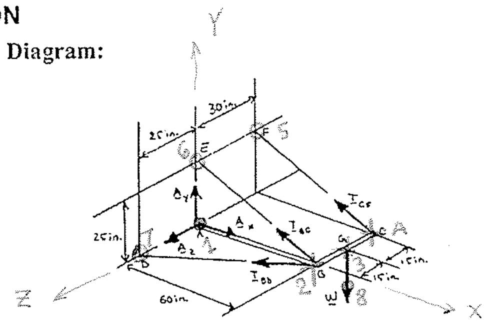


PROBLEM 4.132

The rigid L-shaped member ABC is supported by a ball and socket at A and by three cables. Determine the tension in each cable and the reaction at A caused by the 500-lb load applied at G.

SOLUTION

Free-Body Diagram:



Express tensions, load in terms of rectangular components:

$$\overline{BD} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{k}$$

$$\overline{BE} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$\overline{CF} = -(60 \text{ in.})\mathbf{i} + (25 \text{ in.})\mathbf{j}$$

$$BD = BE = CF = \sqrt{(-60)^2 + (25)^2} = 65 \text{ in.}$$

$$\mathbf{T}_{BD} = T_{BD}\frac{\overline{BD}}{BD} = -\frac{12}{13}T_{BD}\mathbf{i} + \frac{5}{13}T_{BD}\mathbf{k}$$

$$\mathbf{T}_{BE} = T_{BE}\frac{\overline{BE}}{BE} = -\frac{12}{13}T_{BE}\mathbf{i} + \frac{5}{13}T_{BE}\mathbf{j}$$

$$\mathbf{T}_{CF} = T_{CF}\frac{\overline{CF}}{CF} = -\frac{12}{13}T_{CF}\mathbf{i} + \frac{5}{13}T_{CF}\mathbf{j}$$

$\Sigma \mathbf{M}_A = 0$: $\quad \mathbf{r}_B \times \mathbf{T}_{BD} + \mathbf{r}_B \times \mathbf{T}_{BE} + \mathbf{r}_C \times \mathbf{T}_{CF} + \mathbf{r}_G \times \mathbf{W} = 0$

or

$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 0 & 5 \end{vmatrix}\frac{T_{BD}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & 0 \\ -12 & 5 & 0 \end{vmatrix}\frac{T_{BE}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -30 \\ -12 & 5 & 0 \end{vmatrix}\frac{T_{CF}}{13}\text{in.} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 60 & 0 & -15 \\ 0 & -500 & 0 \end{vmatrix}\text{lb}\cdot\text{in.} = 0$$

PROBLEM 4.132 CONTINUED

Equating the coefficients of the unit vectors to zero:

i: $\frac{150}{13}T_{CF} - 7500 = 0$

$T_{CF} = 650.00 \text{ lb}$ or $T_{CF} = 650 \text{ lb}$ ◀

j: $-\frac{300}{13}T_{BD} + \frac{360}{13}(650 \text{ lb}) = 0$

$T_{BD} = 780.00 \text{ lb}$ or $T_{BD} = 780 \text{ lb}$ ◀

k: $\frac{300}{13}T_{BE} - 30000 + \frac{300}{13}(650.00 \text{ lb}) = 0$

$T_{BE} = 650.00 \text{ lb}$ or $T_{BE} = 650 \text{ lb}$ ◀

$\Sigma F_x = 0$: $A_x - \frac{12}{13}(780 \text{ lb}) - \frac{12}{13}(650 \text{ lb}) - \frac{12}{13}(650 \text{ lb}) = 0$

$A_x = 1920.00 \text{ lb}$

$\Sigma F_y = 0$: $A_y + \frac{5}{13}(780 \text{ lb}) + \frac{5}{13}(650 \text{ lb}) - 500 \text{ lb} = 0$

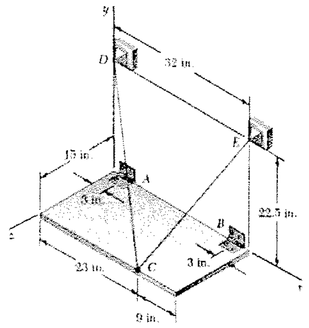
$A_y = 0$

$\Sigma F_z = 0$: $A_z + \frac{5}{13}(780 \text{ lb}) = 0$

$A_z = -300.00 \text{ lb}$

Therefore,

$\mathbf{A} = (1920 \text{ lb})\mathbf{i} - (300 \text{ lb})\mathbf{k}$ ◀

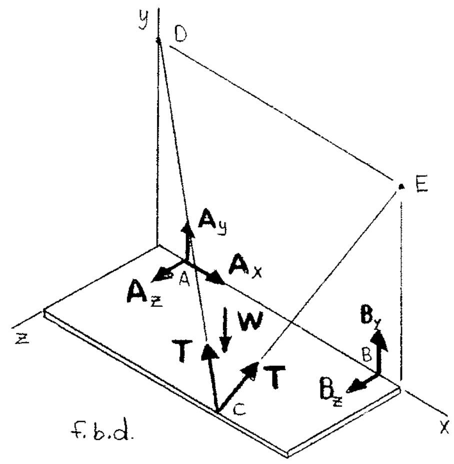


PROBLEM 4.161

A 285-lb uniform rectangular plate is supported in the position shown by hinges A and B and by cable DCE which passes over a frictionless hook at C. Assuming that the tension is the same in both parts of the cable, determine (a) the tension in the cable, (b) the reactions at A and B. Assume that the hinge at B does not exert any axial thrust.

SOLUTION

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 ◀

(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 $\mathbf{B} = (32.9 \text{ lb})\mathbf{j} + (53.9 \text{ lb})\mathbf{k}$ ◀