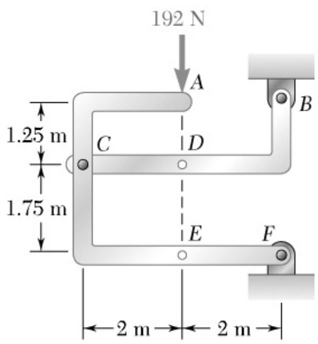
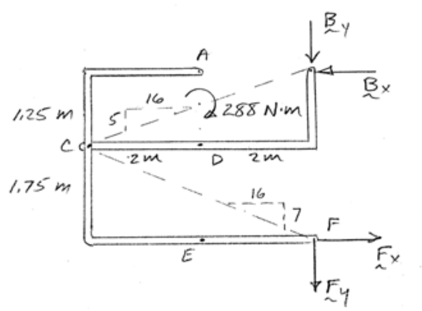


PROBLEM 6.90

The 192-N load is removed and a $288\ \text{N}\cdot\text{m}$ clockwise couple is applied successively at A, D, and E. Determine the components of the reactions at B and F when the couple is applied (*a*) at A, (*b*) at B, (*c*) at E.

SOLUTION

FBD Frame:



Regardless of the location of applied couple,

$$\circlearrowright \Sigma M_B = 0: (3\ \text{m})F_x - 288\ \text{N}\cdot\text{m} = 0 \qquad \mathbf{F}_x = 96.0\ \text{N} \longrightarrow \blacktriangleleft$$

$$\longrightarrow \Sigma F_x = 0: -B_x + 96\ \text{N} = 0 \qquad \mathbf{B}_x = 96.0\ \text{N} \longleftarrow \blacktriangleleft$$

$$\downarrow \Sigma F_y = 0: B_y + F_y = 0$$

(*a*) and (*c*): If couple applied *anywhere* on $ACEF$, BC is a two-force member,

so $$B_y = \frac{5}{16}B_x \qquad \mathbf{B}_y = 30.0\ \text{N} \downarrow \blacktriangleleft$$

Then $$\downarrow \Sigma F_y = 0: 30\ \text{N} + F_y = 0 \qquad F_y = -30\ \text{N}$$

$$\mathbf{F}_y = 30.0\ \text{N} \uparrow \blacktriangleleft$$

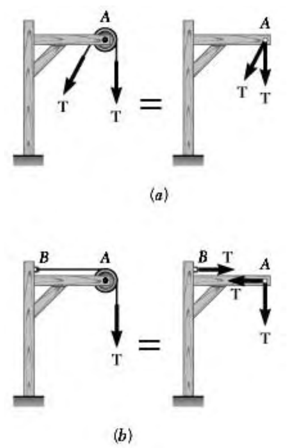
(*b*): If couple is applied *anywhere* on BC, $ACEF$ is a two-force member,

so $$F_y = \frac{7}{16}F_x \qquad \mathbf{F}_y = 42.0\ \text{N} \downarrow \blacktriangleleft$$

$$\downarrow \Sigma F_y = 0: B_y + 42\ \text{N} = 0 \qquad B_y = -42\ \text{N}$$

$$\mathbf{B}_y = 42.0\ \text{N} \uparrow \blacktriangleleft$$

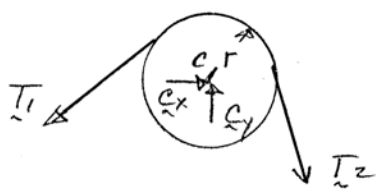
PROBLEM 6.91



(*a*) Show that when a frame supports a pulley at *A*, an equivalent loading of the frame and of each of its component parts can be obtained by removing the pulley and applying at *A* two forces equal and parallel to the forces that the cable exerted on the pulley.
(*b*) Show that if one end of the cable is attached to the frame at point *B*, a force of magnitude equal to the tension in the cable should also be applied at *B*.

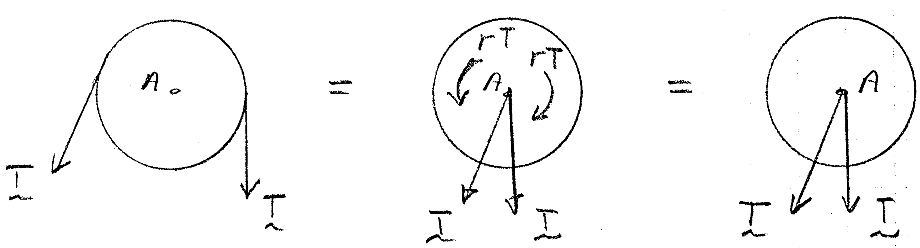
SOLUTION

First note that, when a cable or cord passes over a *frictionless*, *motionless* pulley, the tension is unchanged.

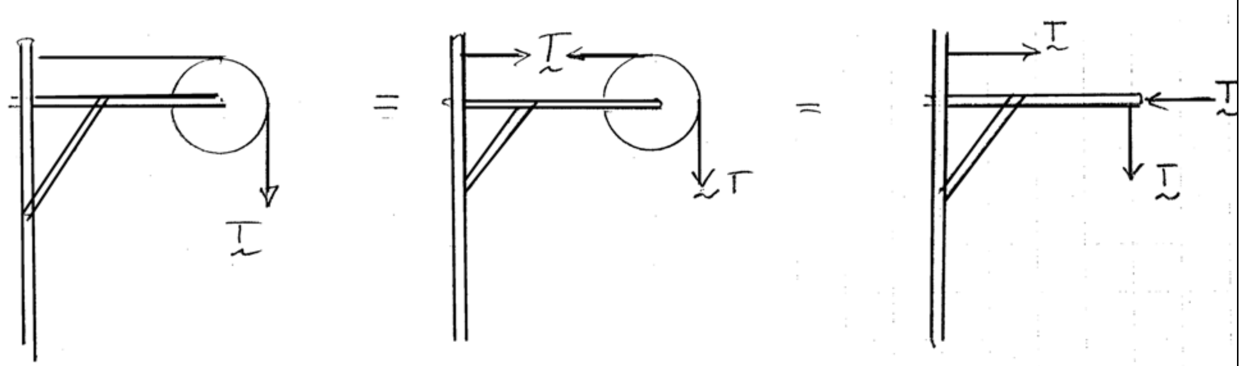


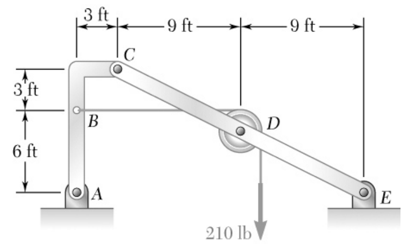
$$\circlearrowleft \Sigma M_C = 0: rT_1 - rT_2 = 0 \qquad T_1 = T_2$$

(*a*) Replace each force with an equivalent force-couple.



(*b*) Cut cable and replace forces on pulley with equivalent pair of forces at *A* as above.



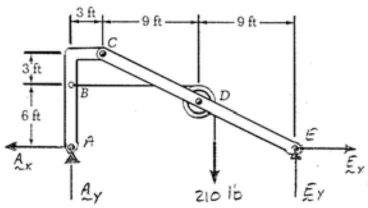


PROBLEM 6.92

Knowing that the pulley has a radius of 1.5 ft, determine the components of the reactions at A and E.

SOLUTION

FBD Frame:



$$\circlearrowleft \Sigma M_A = 0: (21\text{ ft})E_y - (13.5\text{ ft})(210\text{ lb}) = 0$$

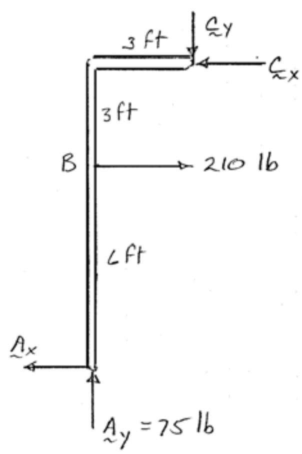
$$\mathbf{E}_y = 135.0\text{ lb} \uparrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: A_y - 210\text{ lb} + 135\text{ lb} = 0$$

$$\mathbf{A}_y = 75.0\text{ lb} \uparrow \blacktriangleleft$$

$$\longrightarrow \Sigma F_x = 0: A_x - E_x = 0 \qquad A_x = E_x$$

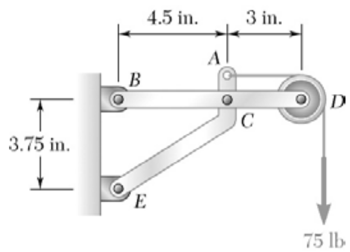
FBD member ABC:



$$\circlearrowleft \Sigma M_C = 0: (3\text{ ft})(210\text{ lb}) - (3\text{ ft})(75\text{ lb}) - (9\text{ ft})A_x = 0$$

$$\mathbf{A}_x = 45.0\text{ lb} \longleftarrow \blacktriangleleft$$

$$\text{so } \mathbf{E}_x = 45.0\text{ lb} \longrightarrow \blacktriangleleft$$

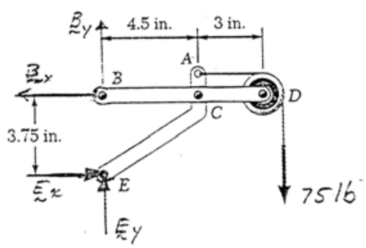


PROBLEM 6.93

Knowing that the pulley has a radius of 1.25 in., determine the components of the reactions at *B* and *E*.

SOLUTION

FBD Frame:



$$\circlearrowleft \Sigma M_E = 0: (3.75 \text{ in.})B_x + (8.75 \text{ in.})(75 \text{ lb}) = 0$$

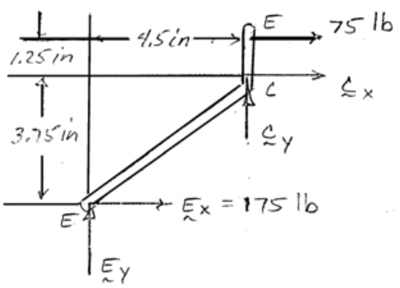
$$B_x = 175 \text{ lb} \qquad \mathbf{B}_x = 175.0 \text{ lb} \longleftarrow \blacktriangleleft$$

$$\longrightarrow \Sigma F_x = 0: E_x - B_x = 0 \qquad \mathbf{E}_x = 175.0 \text{ lb} \longrightarrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: E_y + B_y - 75 \text{ lb} = 0$$

$$B_y = 75 \text{ lb} - E_y$$

FBD member ACE:

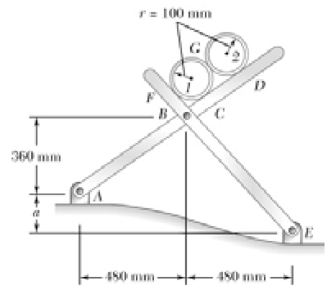


$$\circlearrowleft \Sigma M_C = 0: -(1.25 \text{ in.})(75 \text{ lb}) + (3.75 \text{ in.})(175 \text{ lb}) - (4.5 \text{ in.})E_y = 0$$

$$\mathbf{E}_y = 125.0 \text{ lb} \uparrow \blacktriangleleft$$

Thus $\quad B_y = 75 \text{ lb} - 125 \text{ lb} = -50 \text{ lb}$

$$\mathbf{B}_y = 50.0 \text{ lb} \downarrow \blacktriangleleft$$



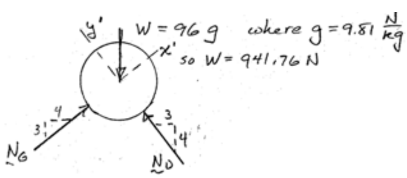
PROBLEM 6.94

Two 200-mm-diameter pipes (pipe *1* and pipe *2*) are supported every 3 m by a small frame like the one shown. Knowing that the combined mass per unit length of each pipe and its contents is 32 kg/m and assuming frictionless surfaces, determine the components of the reactions at *A* and *E* when $a = 0$.

SOLUTION

FBDs:

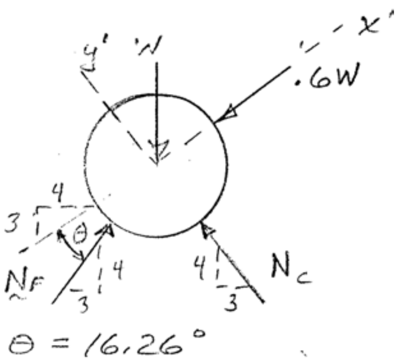
pipe 2:



$$\nearrow \Sigma F_{x'} = 0: N_G - \frac{3}{5}W = 0 \qquad N_G = 0.6W$$

$$\nwarrow \Sigma F_{y'} = 0: N_D - \frac{4}{5}W = 0 \qquad N_D = 0.8W$$

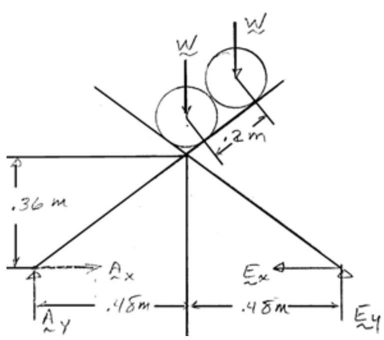
pipe 1:



$$\nearrow \Sigma F_{x'} = 0: N_F \cos 16.26° - \frac{3}{5}W - 0.6W = 0 \qquad N_F = 1.25W$$

$$\nwarrow \Sigma F_{y'} = 0: N_C + 1.25W \sin 16.26° - \frac{4}{5}W = 0 \qquad N_C = 0.45W$$

Frame:



$$\circlearrowleft \Sigma M_A = 0: (0.96\text{ m})E_y - (0.48\text{ m})W - \left\{\left[0.48 + \frac{4}{5}(0.2)\right]\text{m}\right\}W = 0$$

$$E_y = 1.16667W \qquad \mathbf{E}_y = 1099\text{ N} \uparrow \blacktriangleleft$$

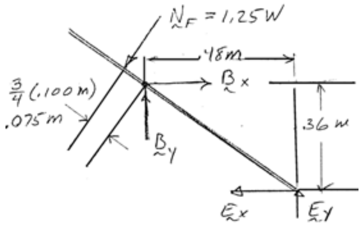
$$\uparrow \Sigma F_y = 0: A_y + 1.16667W - W - W = 0$$

$$A_y = 0.83333W \qquad \mathbf{A}_y = 785\text{ N} \uparrow \blacktriangleleft$$

$$\rightarrow \Sigma F_x = 0: A_x - E_x = 0 \quad \text{so} \quad A_x = E_x$$

PROBLEM 6.94 CONTINUED

member BE:



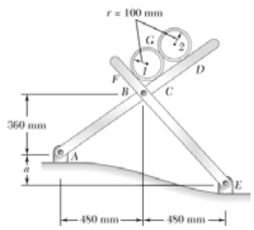
$$\circlearrowright \Sigma M_B = 0: (0.075 \text{ m})(1.25W) + (0.48 \text{ m})(1.16667W)$$

$$-(0.36 \text{ m})E_x = 0$$

$$E_x = 1.816W$$

$$\mathbf{E}_x = 1710 \text{ N} \longleftarrow \blacktriangleleft$$

$$\text{thus } \mathbf{A}_x = 1710 \text{ N} \longrightarrow \blacktriangleleft$$



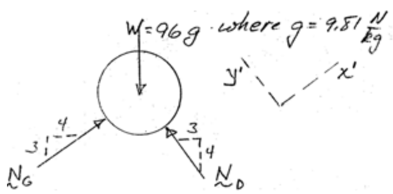
PROBLEM 6.95

Solve Prob. 6.94 when $a = 280$ mm.

SOLUTION

FBDs

pipe 2

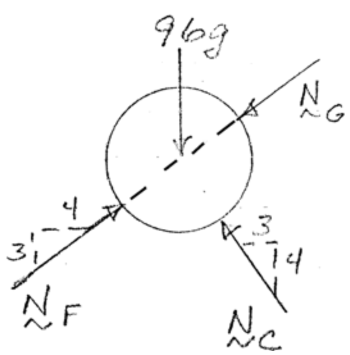


$W = 941.76\,N$

$\Sigma F_{y'} = 0\colon N_D - \frac{4}{5}W = 0 \qquad N_D = 0.8W$

$\Sigma F_{x'} = 0\colon N_G - \frac{3}{5}W = 0 \qquad N_G = 0.6W$

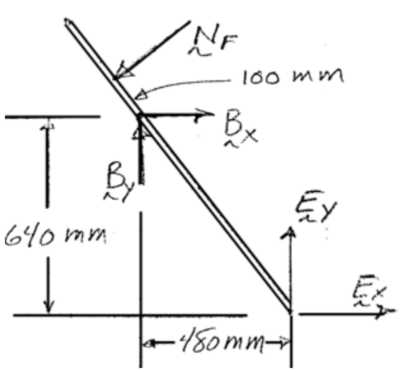
pipe 1:



$\Sigma F_{y'} = 0\colon N_C - \frac{4}{5}W = 0 \qquad N_C = 0.8W$

$\Sigma F_{x'} = 0\colon N_F - \frac{3}{5}\,96\text{ g} - N_G = 0 \qquad N_F = 1.2W$

member BE:



$\Sigma M_B = 0\colon (640\text{ mm})E_x + (480\text{ mm})E_y + (100\text{ mm})N_F = 0$

$\Sigma M_A = 0\colon (280\text{ mm})E_x + (960\text{ mm})E_y + (100\text{ mm})N_F$

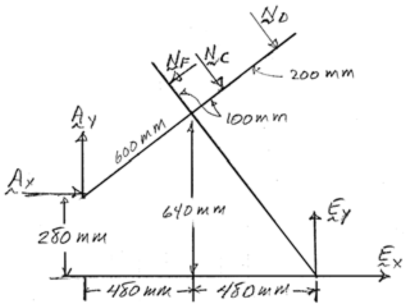
$- (700\text{ mm})N_C - (900\text{ mm})N_D = 0$

$E_x = -1.400W \qquad \mathbf{E}_x = 1318\text{ N} \longleftarrow$ ◀

$E_y = 1.617W \qquad \mathbf{E}_y = 1523\text{ N} \uparrow$ ◀

PROBLEM 6.95 CONTINUED

FBD Frame:



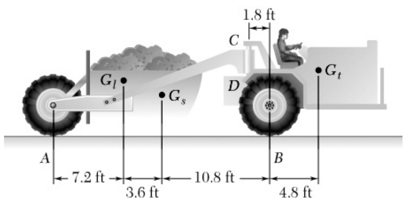
$$\rightarrow \Sigma F_x = 0: A_x + E_x + \frac{3}{5}\left(N_C + N_D\right) - \frac{4}{5}N_F = 0$$

$$A_x = 1.400W \qquad \mathbf{A}_x = 1318 \text{ N} \longrightarrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: A_y + E_y - \frac{4}{5}\left(N_C + N_D\right) - \frac{3}{5}N_F = 0$$

$$A_y = 0.3833W \qquad \mathbf{A}_y = 361 \text{ N} \uparrow \blacktriangleleft$$

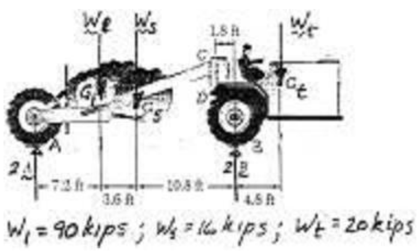
PROBLEM 6.96



The tractor and scraper units shown are connected by a vertical pin located 1.8 ft behind the tractor wheels. The distance from C to D is 2.25 ft. The center of gravity of the 20-kip tractor unit is located at G_t, while the centers of gravity of the 16-kip scraper unit and the 90-kip load are located at G_s and G_l, respectively. Knowing that the tractor is at rest with its brakes released, determine (*a*) the reactions at each of the four wheels, (*b*) the forces exerted on the tractor unit at C and D.

SOLUTION

FBD Entire machine:



(*a*)

$$\circlearrowleft \Sigma M_A = 0: (21.6 \text{ ft})2B - (7.2 \text{ ft})(90 \text{ kips}) - (10.8 \text{ ft})(16 \text{ kips})$$

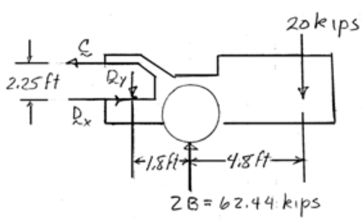
$$- (26.4 \text{ ft})(20 \text{ kips}) = 0$$

$$B = 31.22 \text{ kips} \qquad \mathbf{B} = 31.2 \text{ kips} \uparrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: 2A + 2(31.22 \text{ kips}) - (90 + 16 + 20)\text{kips} = 0$$

$$A = 31.78 \text{ kips} \qquad \mathbf{A} = 31.8 \text{ kips} \uparrow \blacktriangleleft$$

FBD Tractor:



(*b*)

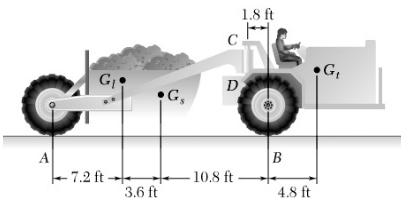
$$\circlearrowleft \Sigma M_D = 0: (2.25 \text{ ft})C + (1.8 \text{ ft})(62.44 \text{ kips}) - (6.6 \text{ ft})(20 \text{ kips}) = 0$$

$$C = 8.7146 \text{ kips} \qquad \mathbf{C} = 8.71 \text{ kips} \longleftarrow \blacktriangleleft$$

$$\longrightarrow \Sigma F_x = 0: D_x - C = 0 \qquad D_x = 8.715 \text{ kips} \longrightarrow$$

$$\uparrow \Sigma F_y = 0: 62.44 \text{ kips} - D_y - 20 \text{ kips} = 0 \qquad D_y = 42.44 \text{ kips} \downarrow$$

$$\text{so } \mathbf{D} = 43.3 \text{ kips} \searrow 78.4° \blacktriangleleft$$

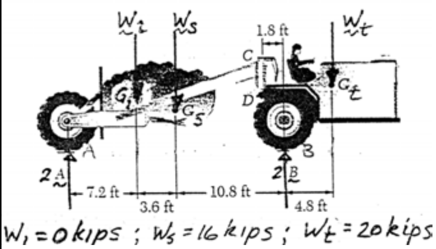


PROBLEM 6.97

Solve Prob. 6.96 assuming that the 90-kip load has been removed.

SOLUTION

FBD Entire machine:



(a)

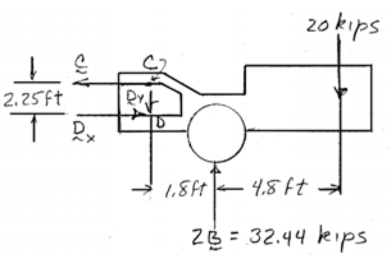
$$\circlearrowleft \Sigma M_A = 0: (21.6 \text{ ft})(2B) - (10.8 \text{ ft})(16 \text{ kips}) - (26.4 \text{ ft})(20 \text{ kips}) = 0$$

$$B = 16.222 \text{ kips} \qquad \mathbf{B} = 16.22 \text{ kips} \uparrow \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: 2A + 2(16.222 \text{ kips}) - (16 + 20)\text{kips} = 0$$

$$A = 1.778 \text{ kips} \qquad \mathbf{A} = 1.778 \text{ kips} \uparrow \blacktriangleleft$$

FBD Tractor:



(b)

$$\circlearrowleft \Sigma M_D = 0: (2.25 \text{ ft})C + (1.8 \text{ ft})(32.44 \text{ kips}) - (6.6 \text{ ft})(20 \text{ kips}) = 0$$

$$C = 32.71 \text{ kips} \qquad \mathbf{C} = 32.7 \text{ kips} \longleftarrow \blacktriangleleft$$

$$\longrightarrow \Sigma F_x = 0: D_x - C = 0 \qquad D_x = 32.71 \text{ kips} \longrightarrow$$

$$\uparrow \Sigma F_y = 0: -D_y + 2(32.44 \text{ kips}) - 20 \text{ kips} = 0$$

$$D_y = 12.44 \text{ kips} \downarrow$$

$$\text{so } \mathbf{D} = 35.0 \text{ kips} \searrow 20.8° \blacktriangleleft$$