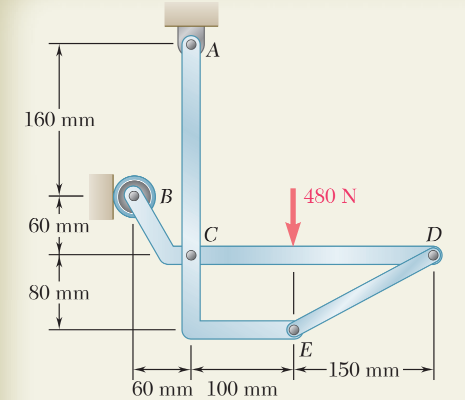
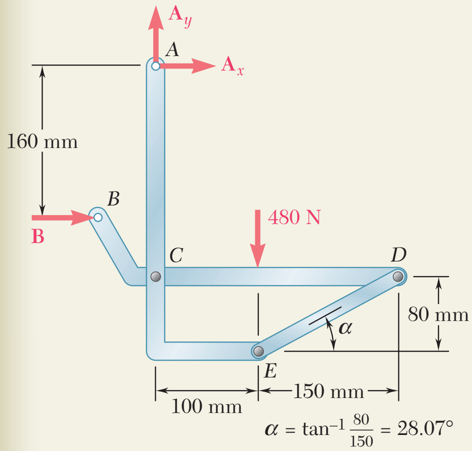
SAMPLE PROBLEM 6.4



In the frame shown, members *ACE* and *BCD* are connected by a pin at *C* and by the link *DE*. For the loading shown, determine the force in link *DE* and the components of the force exerted at *C* on member *BCD*.

SOLUTION

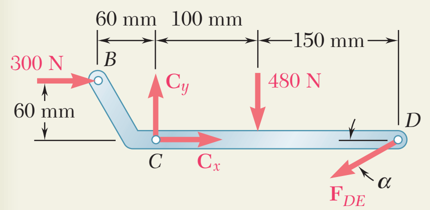


Free Body: Entire Frame. Since the external reactions involve only three unknowns, we compute the reactions by considering the free-body diagram of the entire frame.

$+\uparrow\Sigma F_y = 0$: $A_y - 480\text{ N} = 0$ $\quad A_y = +480\text{ N}$ $\quad \mathbf{A}_y = 480\text{ N}\uparrow$

$+\circlearrowleft\Sigma M_A = 0$: $-(480\text{ N})(100\text{ mm}) + B(160\text{ mm}) = 0$
$B = +300\text{ N}$ $\quad \mathbf{B} = 300\text{ N}\rightarrow$

$\overset{+}{\rightarrow}\Sigma F_x = 0$: $B + A_x = 0$
$300\text{ N} + A_x = 0$ $\quad A_x = -300\text{ N}$ $\quad \mathbf{A}_x = 300\text{ N}\leftarrow$



Members. We now dismember the frame. Since only two members are connected at *C*, the components of the unknown forces acting on *ACE* and *BCD* are, respectively, equal and opposite and are assumed directed as shown. We assume that link *DE* is in tension and exerts equal and opposite forces at *D* and *E*, directed as shown.

Free Body: Member BCD. Using the free body *BCD*, we write

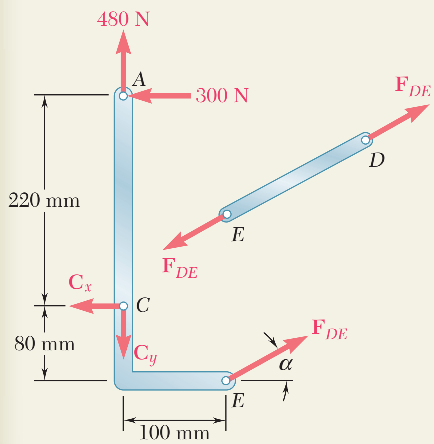
$+\circlearrowleft\Sigma M_C = 0$:
$(F_{DE}\sin\alpha)(250\text{ mm}) + (300\text{ N})(80\text{ mm}) + (480\text{ N})(100\text{ mm}) = 0$
$F_{DE} = -561\text{ N}$ $\qquad F_{DE} = 561\text{ N } C$ ◀

$\overset{+}{\rightarrow}\Sigma F_x = 0$: $C_x - F_{DE}\cos\alpha + 300\text{ N} = 0$
$C_x - (-561\text{ N})\cos 28.07° + 300\text{ N} = 0$ $\quad C_x = -795\text{ N}$

$+\uparrow\Sigma F_y = 0$: $C_y - F_{DE}\sin\alpha - 480\text{ N} = 0$
$C_y - (-561\text{ N})\sin 28.07° - 480\text{ N} = 0$ $\quad C_y = +216\text{ N}$

From the signs obtained for C_x and C_y we conclude that the force components $\mathbf{C}_x$ and $\mathbf{C}_y$ exerted on member *BCD* are directed, respectively, to the left and up. We have

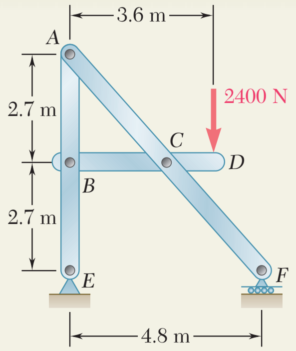
$$\mathbf{C}_x = 795\text{ N}\leftarrow,\ \mathbf{C}_y = 216\text{ N}\uparrow \quad ◀$$



Free Body: Member ACE (Check). The computations are checked by considering the free body *ACE*. For example,

$$+\circlearrowleft\Sigma M_A = (F_{DE}\cos\alpha)(300\text{ mm}) + (F_{DE}\sin\alpha)(100\text{ mm}) - C_x(220\text{ mm})$$
$$= (-561\cos\alpha)(300) + (-561\sin\alpha)(100) - (-795)(220) = 0$$

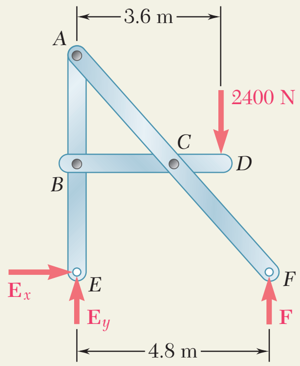
SAMPLE PROBLEM 6.5



Determine the components of the forces acting on each member of the frame shown.

SOLUTION

Free Body: Entire Frame. Since the external reactions involve only three unknowns, we compute the reactions by considering the free-body diagram of the entire frame.



$+\circlearrowleft\Sigma M_E = 0$: $\quad -(2400\text{ N})(3.6\text{ m}) + F(4.8\text{ m}) = 0$

$F = +1800\text{ N} \qquad \mathbf{F} = 1800\text{ N}\uparrow$ ◀

$+\uparrow\Sigma F_y = 0$: $\quad -2400\text{ N} + 1800\text{ N} + E_y = 0$

$E_y = +600\text{ N} \qquad \mathbf{E}_y = 600\text{ N}\uparrow$ ◀

$\overset{+}{\rightarrow}\Sigma F_x = 0$: $\qquad \mathbf{E}_x = 0$ ◀

Members. The frame is now dismembered; since only two members are connected at each joint, equal and opposite components are shown on each member at each joint.

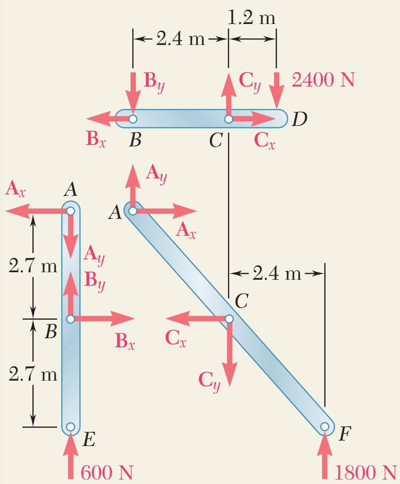
Free Body: Member BCD

$+\circlearrowleft\Sigma M_B = 0$: $\quad -(2400\text{ N})(3.6\text{ m}) + C_y(2.4\text{ m}) = 0 \qquad C_y = +3600\text{ N}$ ◀

$+\circlearrowleft\Sigma M_C = 0$: $\quad -(2400\text{ N})(1.2\text{ m}) + B_y(2.4\text{ m}) = 0 \qquad B_y = +1200\text{ N}$ ◀

$\overset{+}{\rightarrow}\Sigma F_x = 0$: $\quad -B_x + C_x = 0$

We note that neither B_x nor C_x can be obtained by considering only member *BCD*. The positive values obtained for B_y and C_y indicate that the force components $\mathbf{B}_y$ and $\mathbf{C}_y$ are directed as assumed.



Free Body: Member ABE

$+\circlearrowleft\Sigma M_A = 0$: $\quad B_x(2.7\text{ m}) = 0 \qquad B_x = 0$ ◀

$\overset{+}{\rightarrow}\Sigma F_x = 0$: $\quad +B_x - A_x = 0 \qquad A_x = 0$ ◀

$+\uparrow\Sigma F_y = 0$: $\quad -A_y + B_y + 600\text{ N} = 0$

$-A_y + 1200\text{ N} + 600\text{ N} = 0 \qquad A_y = +1800\text{ N}$ ◀

Free Body: Member BCD. Returning now to member *BCD*, we write

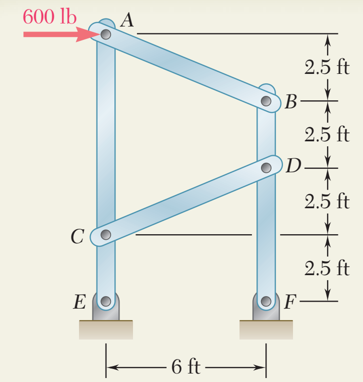
$\overset{+}{\rightarrow}\Sigma F_x = 0$: $\quad -B_x + C_x = 0 \qquad 0 + C_x = 0 \qquad C_x = 0$ ◀

Free Body: Member ACF (Check). All unknown components have now been found; to check the results, we verify that member *ACF* is in equilibrium.

$$+\circlearrowleft\Sigma M_C = (1800\text{ N})(2.4\text{ m}) - A_y(2.4\text{ m}) - A_x(2.7\text{ m})$$
$$= (1800\text{ N})(2.4\text{ m}) - (1800\text{ N})(2.4\text{ m}) - 0 = 0 \qquad \text{(checks)}$$

SAMPLE PROBLEM 6.6

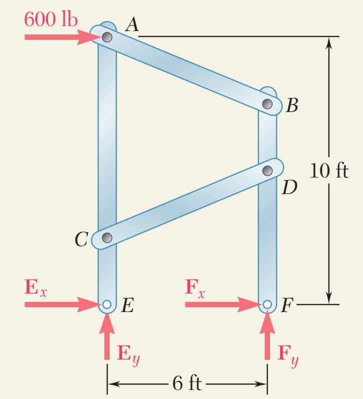
A 600-lb horizontal force is applied to pin A of the frame shown. Determine the forces acting on the two vertical members of the frame.



SOLUTION

Free Body: Entire Frame. The entire frame is chosen as a free body; although the reactions involve four unknowns, $\mathbf{E}_y$ and $\mathbf{F}_y$ may be determined by writing

$$+\circlearrowleft \Sigma M_E = 0: \quad -(600 \text{ lb})(10 \text{ ft}) + F_y(6 \text{ ft}) = 0$$
$$F_y = +1000 \text{ lb} \qquad \mathbf{F}_y = 1000 \text{ lb}\uparrow \blacktriangleleft$$
$$+\uparrow \Sigma F_y = 0: \quad E_y + F_y = 0$$
$$E_y = -1000 \text{ lb} \qquad \mathbf{E}_y = 1000 \text{ lb}\downarrow \blacktriangleleft$$



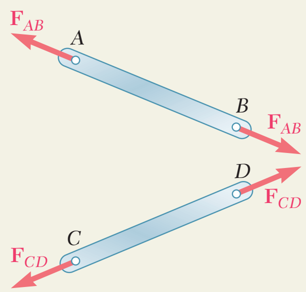
Members. The equations of equilibrium of the entire frame are not sufficient to determine $\mathbf{E}_x$ and $\mathbf{F}_x$. The free-body diagrams of the various members must now be considered in order to proceed with the solution. In dismembering the frame we will assume that pin A is attached to the multiforce member ACE and, thus, that the 600-lb force is applied to that member. We also note that AB and CD are two-force members.

Free Body: Member ACE

$$+\uparrow \Sigma F_y = 0: \quad -\tfrac{5}{13}F_{AB} + \tfrac{5}{13}F_{CD} - 1000 \text{ lb} = 0$$
$$+\circlearrowleft \Sigma M_E = 0: \quad -(600 \text{ lb})(10 \text{ ft}) - (\tfrac{12}{13}F_{AB})(10 \text{ ft}) - (\tfrac{12}{13}F_{CD})(2.5 \text{ ft}) = 0$$

Solving these equations simultaneously, we find

$$F_{AB} = -1040 \text{ lb} \qquad F_{CD} = +1560 \text{ lb} \blacktriangleleft$$



The signs obtained indicate that the sense assumed for F_{CD} was correct and the sense for F_{AB} incorrect. Summing now x components,

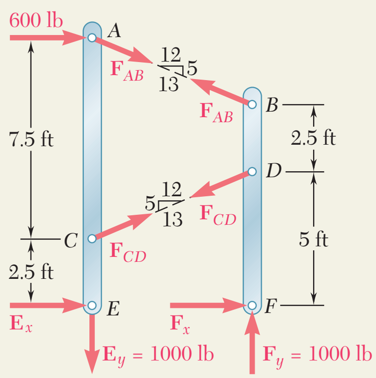
$$\overset{+}{\rightarrow} \Sigma F_x = 0: \quad 600 \text{ lb} + \tfrac{12}{13}(-1040 \text{ lb}) + \tfrac{12}{13}(+1560 \text{ lb}) + E_x = 0$$
$$E_x = -1080 \text{ lb} \qquad \mathbf{E}_x = 1080 \text{ lb}\leftarrow \blacktriangleleft$$

Free Body: Entire Frame. Since $\mathbf{E}_x$ has been determined, we can return to the free-body diagram of the entire frame and write

$$\overset{+}{\rightarrow} \Sigma F_x = 0: \quad 600 \text{ lb} - 1080 \text{ lb} + F_x = 0$$
$$F_x = +480 \text{ lb} \qquad \mathbf{F}_x = 480 \text{ lb}\rightarrow \blacktriangleleft$$

Free Body: Member BDF (Check). We can check our computations by verifying that the equation $\Sigma M_B = 0$ is satisfied by the forces acting on member BDF.

$$+\circlearrowleft \Sigma M_B = -\left(\tfrac{12}{13}F_{CD}\right)(2.5 \text{ ft}) + (F_x)(7.5 \text{ ft})$$
$$= -\tfrac{12}{13}(1560 \text{ lb})(2.5 \text{ ft}) + (480 \text{ lb})(7.5 \text{ ft})$$
$$= -3600 \text{ lb} \cdot \text{ft} + 3600 \text{ lb} \cdot \text{ft} = 0 \qquad \text{(checks)}$$



PROBLEMS

6.75 For the frame and loading shown, determine the force acting on member ABC (*a*) at B, (*b*) at C.

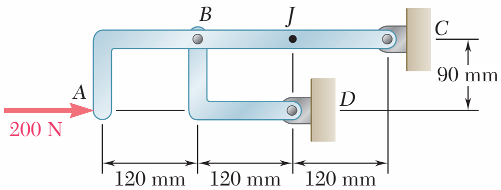


Fig. P6.75

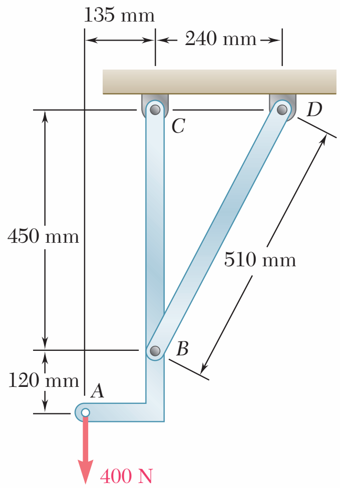


Fig. P6.76

6.76 Determine the force in member BD and the components of the reaction at C.

6.77 Rod CD is fitted with a collar at D that can be moved along rod AB, which is bent in the shape of an arc of circle. For the position when $\theta = 30°$, determine (*a*) the force in rod CD, (*b*) the reaction at B.

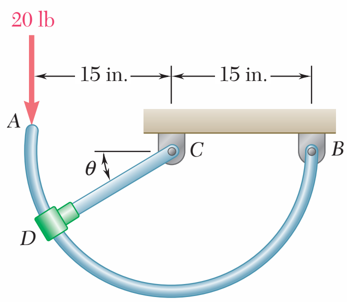


Fig. P6.77

6.78 Solve Prob. 6.77 when $\theta = 150°$.

6.79 Determine the components of all forces acting on member $ABCD$ when $\theta = 0$.

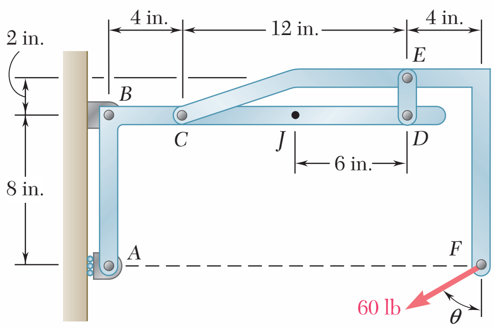


Fig. *P6.79* and *P6.80*

6.80 Determine the components of all forces acting on member $ABCD$ when $\theta = 90°$.

6.81 For the frame and loading shown, determine the components of all forces acting on member ABC.

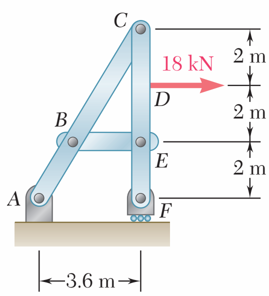


Fig. P6.81

6.82 Solve Prob. 6.81 assuming that the 18-kN load is replaced by a clockwise couple of magnitude 72 kN · m applied to member $CDEF$ at point D.

6.83 and 6.84 Determine the components of the reactions at A and E if a 750-N force directed vertically downward is applied (*a*) at B, (*b*) at D.

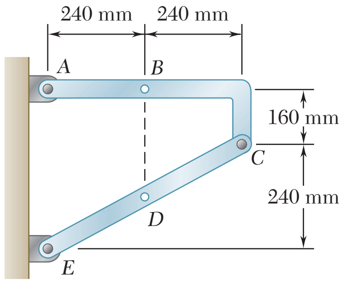


Fig. P6.83 and *P6.85*

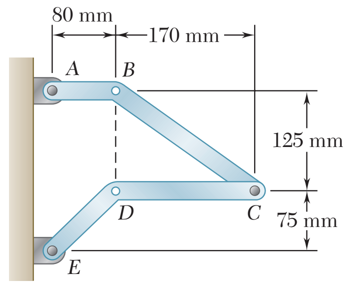


Fig. P6.84 and *P6.86*

6.85* and *6.86 Determine the components of the reactions at A and E if the frame is loaded by a clockwise couple of magnitude 36 N · m applied (*a*) at B, (*b*) at D.

6.87 Determine the components of the reactions at A and B, (*a*) if the 500-N load is applied as shown, (*b*) if the 500-N load is moved along its line of action and is applied at point F.

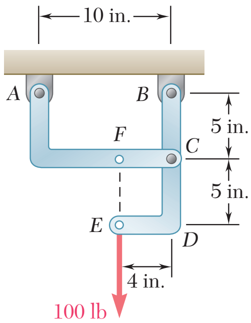


Fig. P6.87

6.88 The 48-lb load can be moved along the line of action shown and applied at A, D, or E. Determine the components of the reactions at B and F if the 48-lb load is applied (*a*) at A, (*b*) at D, (*c*) at E.

6.89 The 48-lb load is removed and a 288-lb · in. clockwise couple is applied successively at A, D, and E. Determine the components of the reactions at B and F if the couple is applied (*a*) at A, (*b*) at D, (*c*) at E.

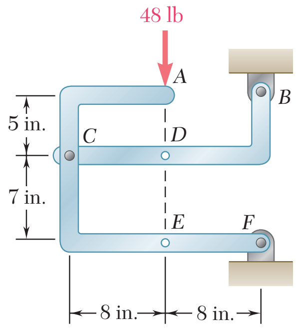


Fig. P6.88 and P6.89

6.90 (*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 a point B, a force of magnitude equal to the tension in the cable should also be applied at B.

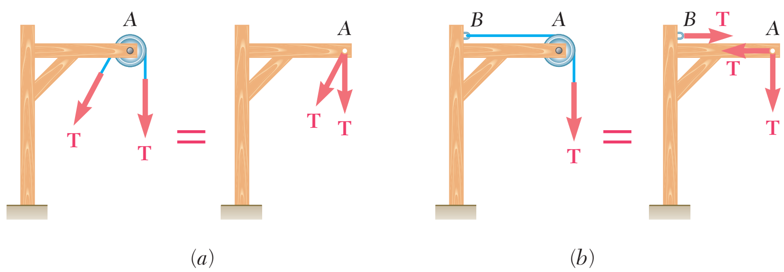


Fig. P6.90

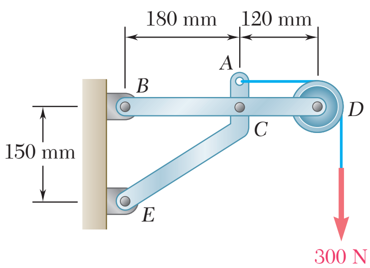


Fig. P6.91

6.91 Knowing that the pulley has a radius of 50 mm, determine the components of the reactions at B and E.

6.92 Knowing that each pulley has a radius of 250 mm, determine the components of the reactions at D and E.

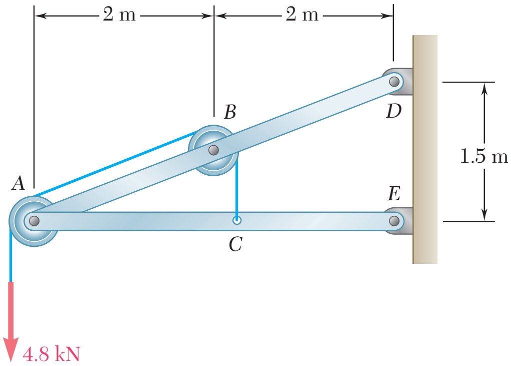


Fig. P6.92

6.93 Two 9-in.-diameter pipes (pipe *1* and pipe *2*) are supported every 7.5 ft by a small frame like that shown. Knowing that the combined weight of each pipe and its contents is 30 lb/ft and assuming frictionless surfaces, determine the components of the reactions at A and G.

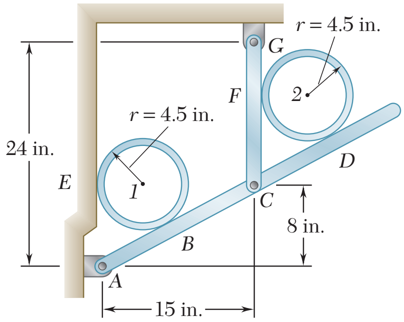


Fig. P6.93

6.94 Solve Prob. 6.93 assuming that pipe *1* is removed and that only pipe *2* is supported by the frames.

6.95 A trailer weighing 2400 lb is attached to a 2900-lb pickup truck by a ball-and-socket truck hitch at D. Determine (*a*) the reactions at each of the six wheels when the truck and trailer are at rest, (*b*) the additional load on each of the truck wheels due to the trailer.

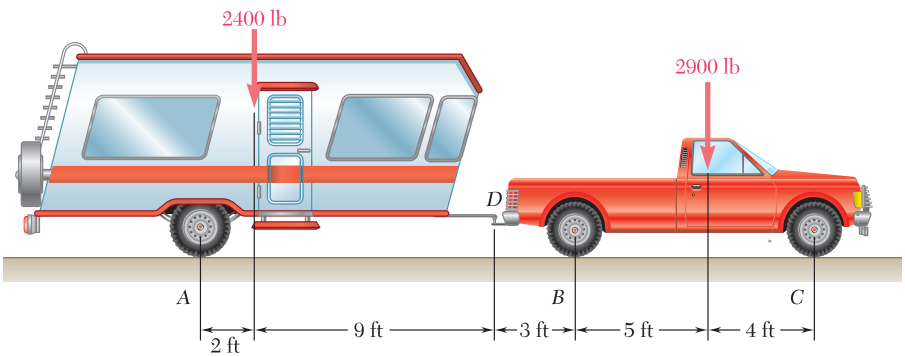


Fig. P6.95

6.96 In order to obtain a better weight distribution over the four wheels of the pickup truck of Prob. 6.95, a compensating hitch of the type shown is used to attach the trailer to the truck. The hitch consists of two bar springs (only one is shown in the figure) that fit into bearings inside a support rigidly attached to the truck. The springs are also connected by chains to the trailer frame, and specially designed hooks make it possible to place both chains in tension. (*a*) Determine the tension T required in each of the two chains if the additional load due to the trailer is to be evenly distributed over the four wheels of the truck. (*b*) What are the resulting reactions at each of the six wheels of the trailer-truck combination?

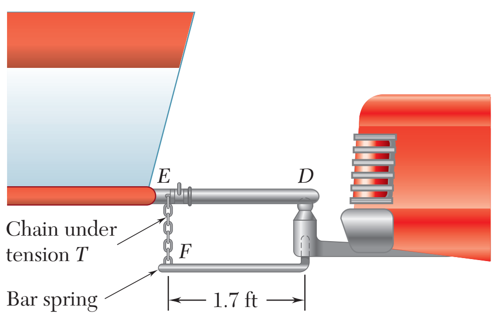


Fig. P6.96

6.97 The cab and motor units of the front-end loader shown are connected by a vertical pin located 2 m behind the cab wheels. The distance from C to D is 1 m. The center of gravity of the 300-kN motor unit is located at G_m, while the centers of gravity of the 100-kN cab and 75-kN load are located, respectively, at G_c and G_l. Knowing that the machine is at rest with its brakes released, determine (*a*) the reactions at each of the four wheels, (*b*) the forces exerted on the motor unit at C and D.

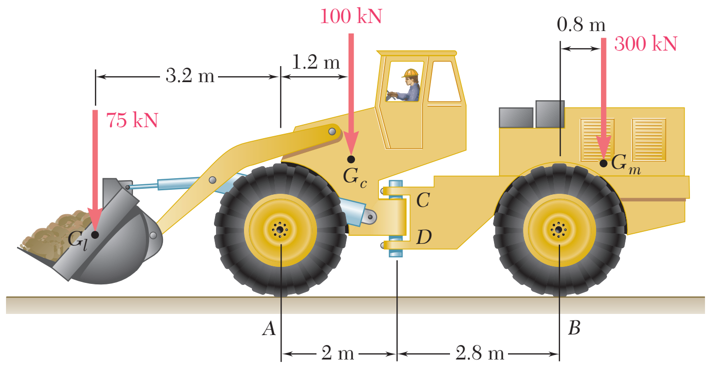


Fig. P6.97

6.98 Solve Prob. 6.97 assuming that the 75-kN load has been removed.

6.99 For the frame and loading shown, determine the components of the forces acting on member CFE at C and F.

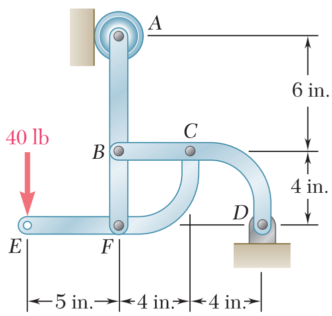


Fig. P6.99

6.100 For the frame and loading shown, determine the components of the forces acting on member CDE at C and D.

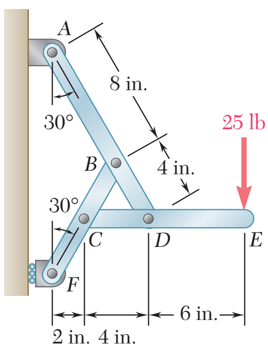


Fig. P6.100

6.101 and 6.102 For the frame and loading shown, determine the components of all forces acting on member ABE.

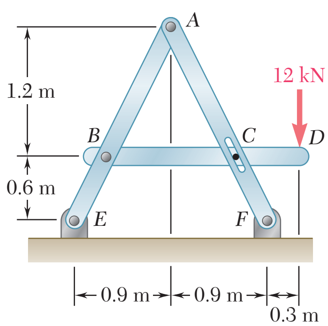


Fig. P6.101

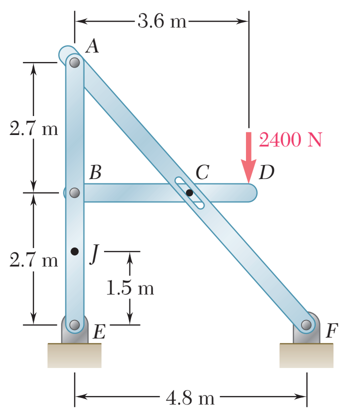


Fig. P6.102

6.103 Knowing that $P = 15$ lb and $Q = 65$ lb, determine the components of the forces exerted (*a*) on member *BCDF* at *C* and *D*, (*b*) on member *ACEG* at *E*.

6.104 Knowing that $P = 25$ lb and $Q = 55$ lb, determine the components of the forces exerted (*a*) on member *BCDF* at *C* and *D*, (*b*) on member *ACEG* at *E*.

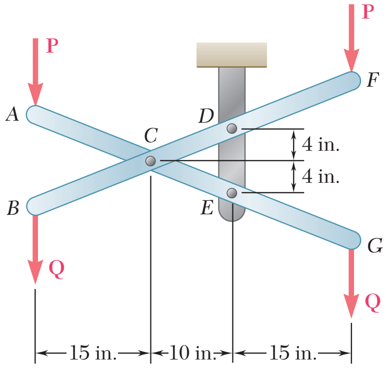


Fig. P6.103 and P6.104

6.105 For the frame and loading shown, determine the components of the forces acting on member *DABC* at *B* and *D*.

6.106 Solve Prob. 6.105 assuming that the 6-kN load has been removed.

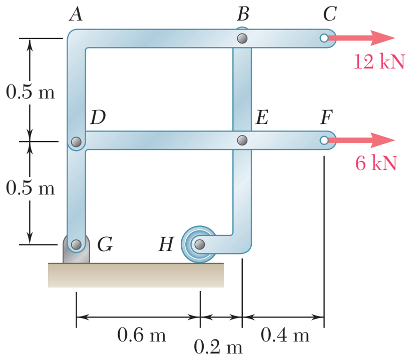


Fig. *P6.105*

6.107 The axis of the three-hinge arch *ABC* is a parabola with vertex at *B*. Knowing that $P = 112$ kN and $Q = 140$ kN, determine (*a*) the components of the reaction at *A*, (*b*) the components of the force exerted at *B* on segment *AB*.

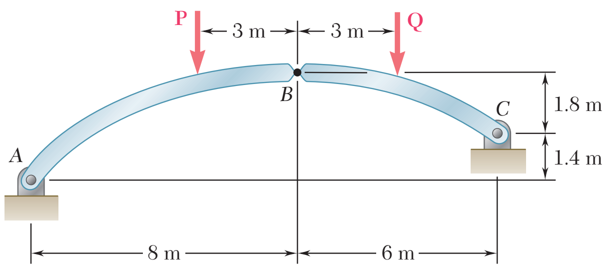


Fig. P6.107 and P6.108

6.108 The axis of the three-hinge arch *ABC* is a parabola with vertex at *B*. Knowing that $P = 140$ kN and $Q = 112$ kN, determine (*a*) the components of the reaction at *A*, (*b*) the components of the force exerted at *B* on segment *AB*.

6.109 Knowing that the surfaces at *A* and *D* are frictionless, determine the forces exerted at *B* and *C* on member *BCE*.

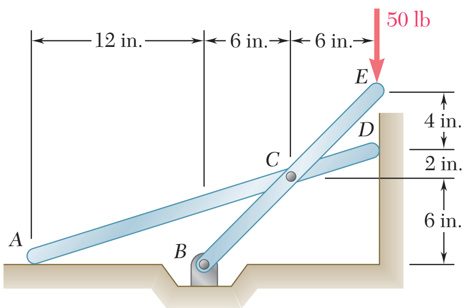


Fig. P6.109

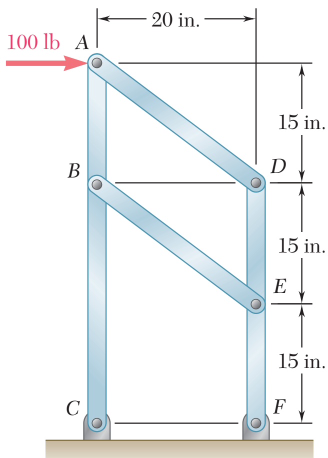


Fig. P6.110

6.110 For the frame and loading shown, determine (*a*) the reaction at *C*, (*b*) the force in member *AD*.

6.111, *6.112*, and 6.113 Members *ABC* and *CDE* are pin-connected at *C* and supported by four links. For the loading shown, determine the force in each link.

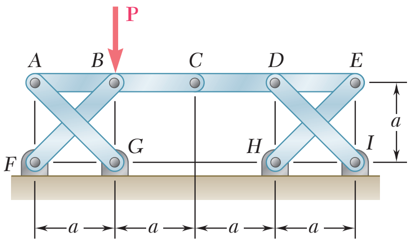


Fig. P6.111

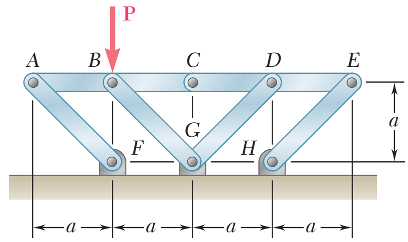


Fig. *P6.112*

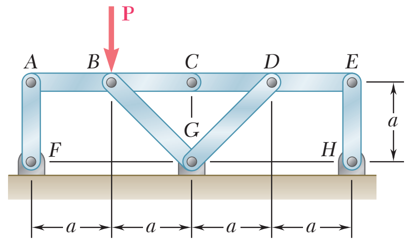


Fig. P6.113

6.114 Members *ABC* and *CDE* are pin-connected at *C* and supported by the four links *AF*, *BG*, *DG*, and *EH*. For the loading shown, determine the force in each link.

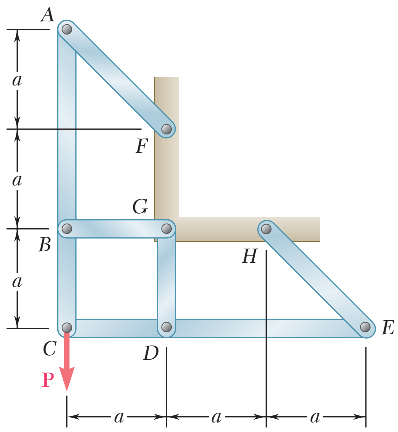


Fig. *P6.114*

6.115 Solve Prob. 6.113 assuming that the force **P** is replaced by a clockwise couple of moment $\mathbf{M}_0$ applied to member *CDE* at *D*.

6.116 Solve Prob. 6.114 assuming that the force **P** is replaced by a clockwise couple of moment $\mathbf{M}_0$ applied to member *CDE* at *D*.

6.117 Four beams, each of length $3a$, are held together by single nails at *A*, *B*, *C*, and *D*. Each beam is attached to a support located at a distance *a* from an end of the beam as shown. Assuming that only vertical forces are exerted at the connections, determine the vertical reactions at *E*, *F*, *G*, and *H*.

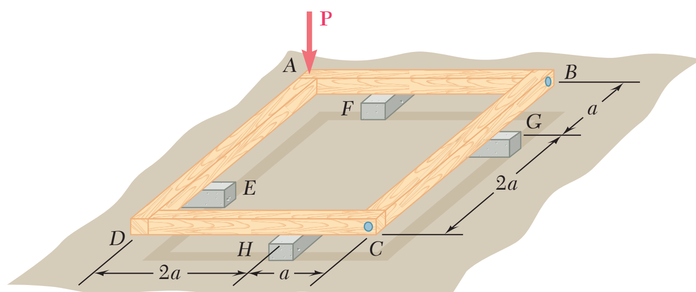


Fig. P6.117

6.118 Four beams, each of length $2a$, are nailed together at their midpoints to form the support system shown. Assuming that only vertical forces are exerted at the connections, determine the vertical reactions at *A*, *D*, *E*, and *H*.

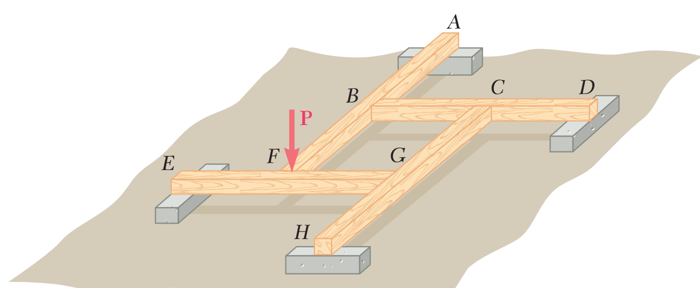
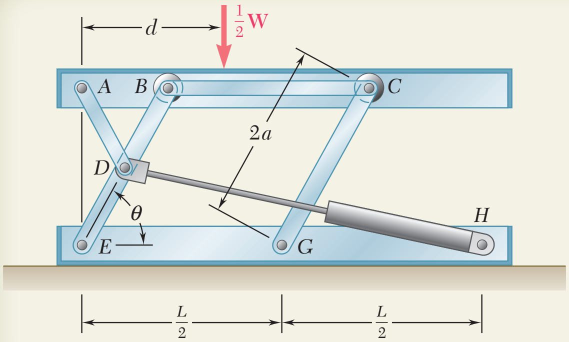
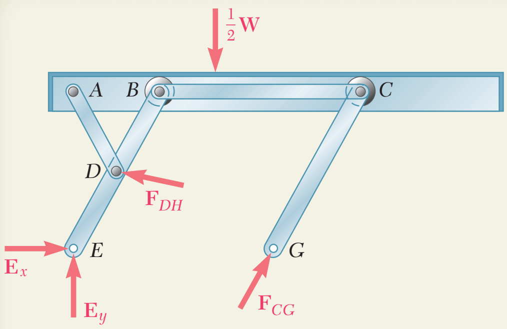


Fig. P6.118



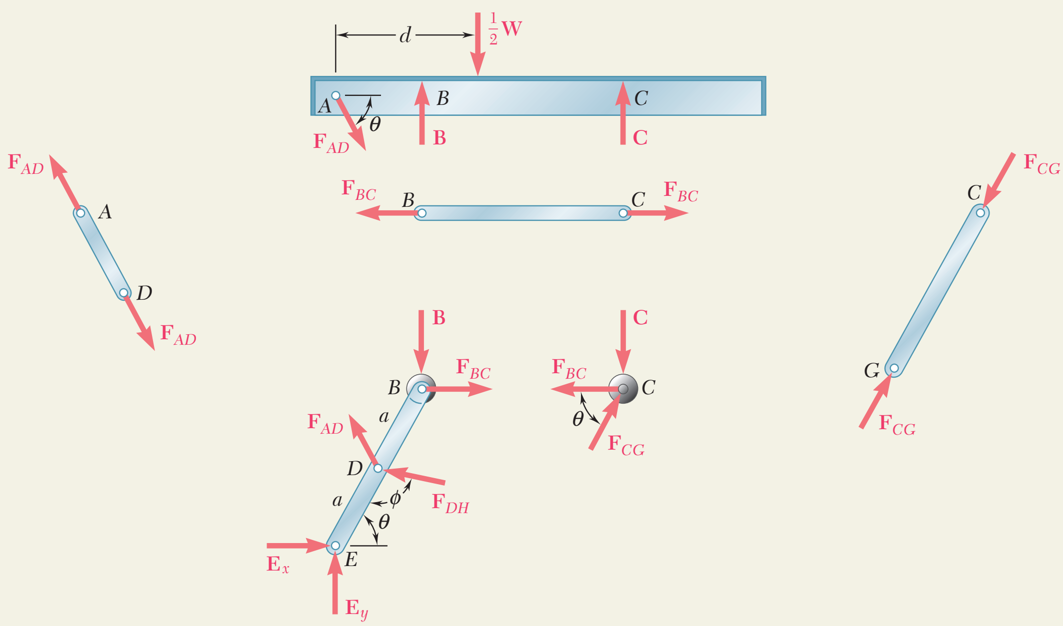
SAMPLE PROBLEM 6.7

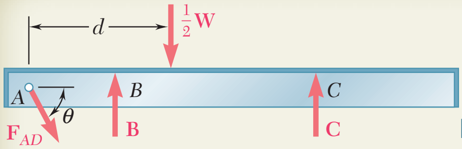
A hydraulic-lift table is used to raise a 1000-kg crate. It consists of a platform and two identical linkages on which hydraulic cylinders exert equal forces. (Only one linkage and one cylinder are shown.) Members *EDB* and *CG* are each of length $2a$, and member *AD* is pinned to the midpoint of *EDB*. If the crate is placed on the table, so that half of its weight is supported by the system shown, determine the force exerted by each cylinder in raising the crate for $\theta = 60°$, $a = 0.70$ m, and $L = 3.20$ m. Show that the result obtained is independent of the distance d.



SOLUTION

The machine considered consists of the platform and of the linkage. Its free-body diagram includes an input force $\mathbf{F}_{DH}$ exerted by the cylinder, the weight $\frac{1}{2}\mathbf{W}$, equal and opposite to the output force, and reactions at *E* and *G* that we assume to be directed as shown. Since more than three unknowns are involved, this diagram will not be used. The mechanism is dismembered and a free-body diagram is drawn for each of its component parts. We note that *AD*, *BC*, and *CG* are two-force members. We already assumed member *CG* to be in compression; we now assume that *AD* and *BC* are in tension and direct as shown the forces exerted on them. Equal and opposite vectors will be used to represent the forces exerted by the two-force members on the platform, on member *BDE*, and on roller *C*.

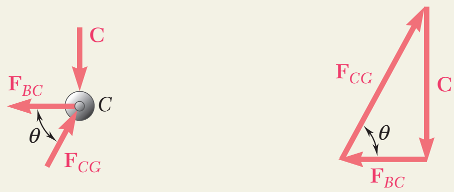


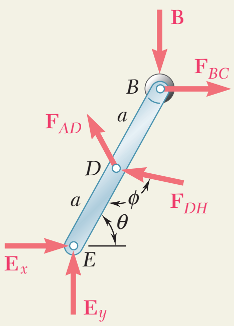


Free Body: Platform *ABC*.

$$\overset{+}{\rightarrow}\Sigma F_x = 0: \qquad F_{AD}\cos\theta = 0 \qquad F_{AD} = 0$$
$$+\uparrow\Sigma F_y = 0: \qquad B + C - \tfrac{1}{2}W = 0 \qquad B + C = \tfrac{1}{2}W \qquad (1)$$

Free Body: Roller *C*. We draw a force triangle and obtain $F_{BC} = C \cot\theta$.





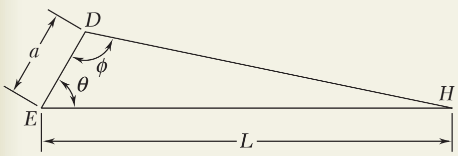
Free Body: Member *BDE*. Recalling that $F_{AD} = 0$,

$$+\circlearrowleft\Sigma M_E = 0: \qquad F_{DH}\cos(\phi - 90°)a - B(2a\cos\theta) - F_{BC}(2a\sin\theta) = 0$$
$$F_{DH}a\sin\phi - B(2a\cos\theta) - (C\cot\theta)(2a\sin\theta) = 0$$
$$F_{DH}\sin\phi - 2(B + C)\cos\theta = 0$$

Recalling Eq. (1), we have

$$F_{DH} = W\frac{\cos\theta}{\sin\phi} \qquad (2)$$

and we observe that *the result obtained is independent of d*. ◀



Applying first the law of sines to triangle EDH, we write

$$\frac{\sin\phi}{EH} = \frac{\sin\theta}{DH} \qquad \sin\phi = \frac{EH}{DH}\sin\theta \qquad (3)$$

Using now the law of cosines, we have

$$(DH)^2 = a^2 + L^2 - 2aL\cos\theta$$
$$= (0.70)^2 + (3.20)^2 - 2(0.70)(3.20)\cos 60°$$
$$(DH)^2 = 8.49 \qquad DH = 2.91 \text{ m}$$

We also note that

$$W = mg = (1000 \text{ kg})(9.81 \text{ m/s}^2) = 9810 \text{ N} = 9.81 \text{ kN}$$

Substituting for $\sin\phi$ from (3) into (2) and using the numerical data, we write

$$F_{DH} = W\frac{DH}{EH}\cot\theta = (9.81 \text{ kN})\frac{2.91 \text{ m}}{3.20 \text{ m}}\cot 60°$$

$$F_{DH} = 5.15 \text{ kN}$$ ◀

PROBLEMS

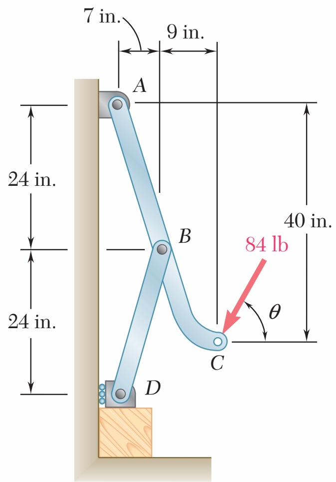


Fig. P6.122

6.122 An 84-lb force is applied to the toggle vise at C. Knowing that $\theta = 90°$, determine (*a*) the vertical force exerted on the block at D, (*b*) the force exerted on member ABC at B.

6.123 Solve Prob. 6.122 when $\theta = 0$.

6.124 The control rod CE passes through a horizontal hole in the body of the toggle system shown. Knowing that link BD is 250 mm long, determine the force **Q** required to hold the system in equilibrium when $\beta = 20°$.

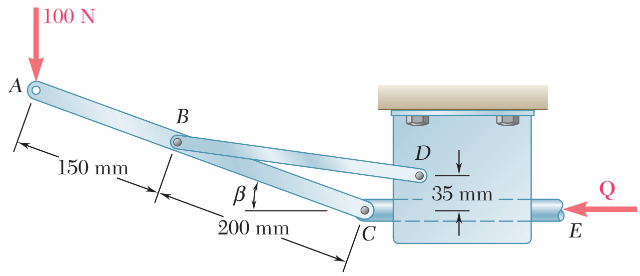


Fig. *P6.124*

6.125 Solve Prob. 6.124 when (*a*) $\beta = 0$, (*b*) $\beta = 6°$.

6.126 The press shown is used to emboss a small seal at E. Knowing that $P = 250$ N, determine (*a*) the vertical component of the force exerted on the seal, (*b*) the reaction at A.

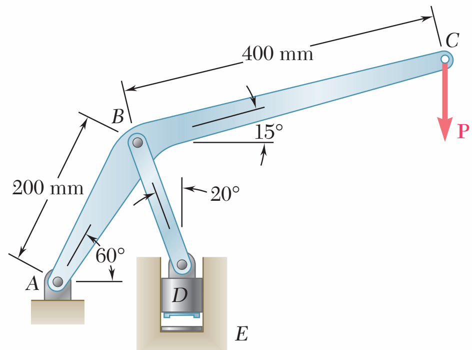


Fig. P6.126 and P6.127

6.127 The press shown is used to emboss a small seal at E. Knowing that the vertical component of the force exerted on the seal must be 900 N, determine (*a*) the required vertical force **P**, (*b*) the corresponding reaction at A.

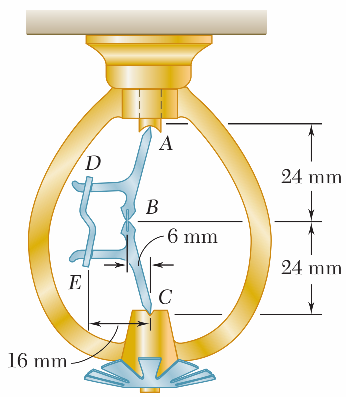


Fig. P6.128

6.128 Water pressure in the supply system exerts a downward force of 135 N on the vertical plug at A. Determine the tension in the fusible link DE and the force exerted on member BCE at B.

6.129 A couple **M** of magnitude 1.5 kN · m is applied to the crank of the engine system shown. For each of the two positions shown, determine the force **P** required to hold the system in equilibrium.

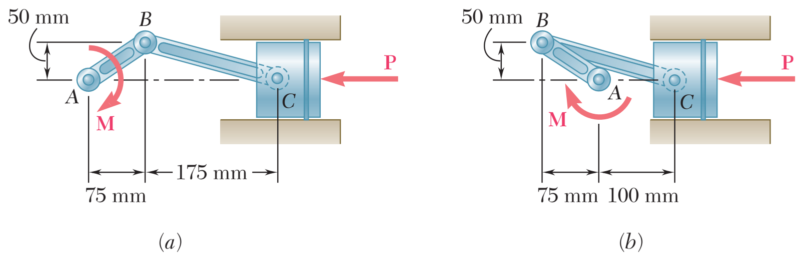


Fig. P6.129 and P6.130

6.130 A force **P** of magnitude 16 kN is applied to the piston of the engine system shown. For each of the two positions shown, determine the couple **M** required to hold the system in equilibrium.

6.131 The pin at B is attached to member ABC and can slide freely along the slot cut in the fixed plate. Neglecting the effect of friction, determine the couple **M** required to hold the system in equilibrium when $\theta = 30°$.

6.132 The pin at B is attached to member ABC and can slide freely along the slot cut in the fixed plate. Neglecting the effect of friction, determine the couple **M** required to hold the system in equilibrium when $\theta = 60°$.

6.133 Arm ABC is connected by pins to a collar at B and to crank CD at C. Neglecting the effect of friction, determine the couple **M** required to hold the system in equilibrium when $\theta = 0$.

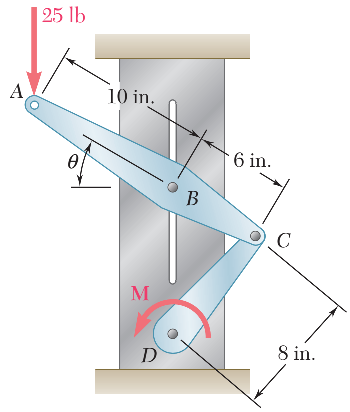


Fig. P6.131 and P6.132

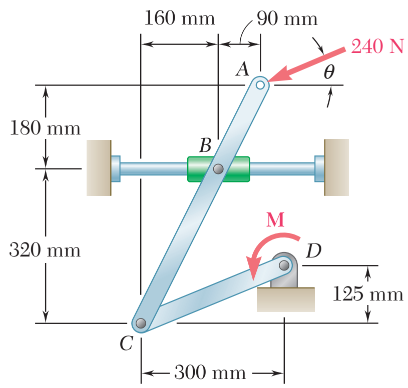


Fig. P6.133 and P6.134

6.134 Arm ABC is connected by pins to a collar at B and to crank CD at C. Neglecting the effect of friction, determine the couple **M** required to hold the system in equilibrium when $\theta = 90°$.

6.135 and 6.136 Two rods are connected by a slider block as shown. Neglecting the effect of friction, determine the couple $\mathbf{M}_A$ required to hold the system in equilibrium.

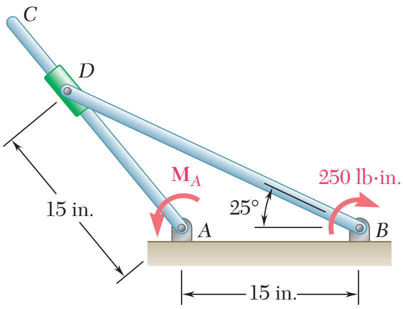


Fig. *P6.135*

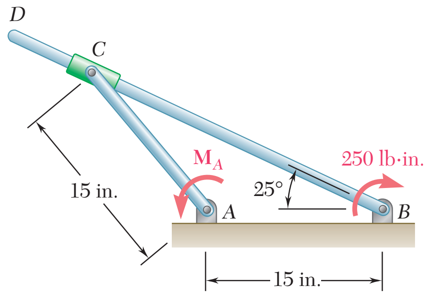


Fig. *P6.136*

6.137 and 6.138 Rod *CD* is attached to the collar *D* and passes through a collar welded to end *B* of lever *AB*. Neglecting the effect of friction, determine the couple **M** required to hold the system in equilibrium when $\theta = 30°$.

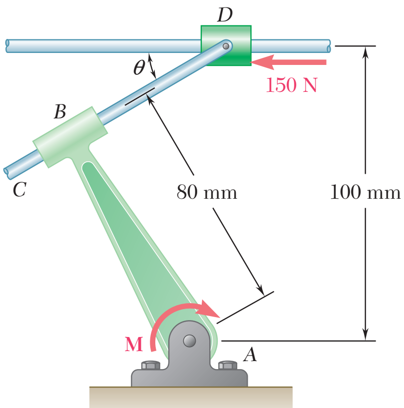


Fig. P6.138

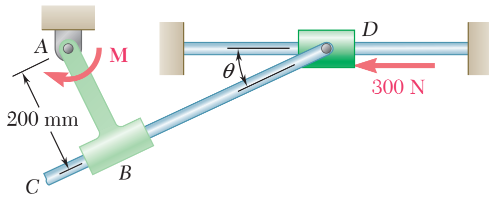


Fig. P6.137

6.139 Two hydraulic cylinders control the position of the robotic arm *ABC*. Knowing that in the position shown the cylinders are parallel, determine the force exerted by each cylinder when $P = 160$ N and $Q = 80$ N.

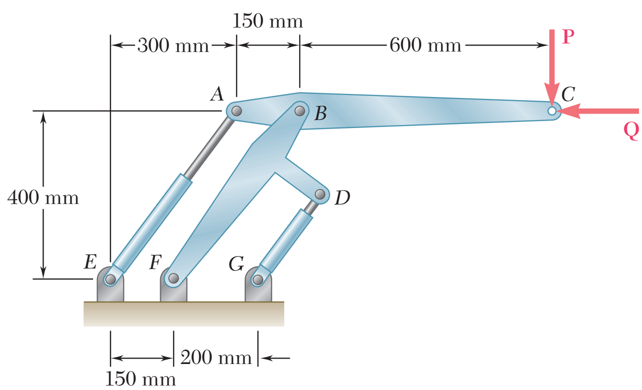


Fig. P6.139 and P6.140

6.140 Two hydraulic cylinders control the position of the robotic arm *ABC*. In the position shown, the cylinders are parallel and both are in tension. Knowing that $F_{AE} = 600$ N and $F_{DG} = 50$ N, determine the forces **P** and **Q** applied at *C* to arm *ABC*.

6.141 A log weighing 800 lb is lifted by a pair of tongs as shown. Determine the forces exerted at E and F on tong DEF.

6.142 A 39-ft length of railroad rail of weight 44 lb/ft is lifted by the tongs shown. Determine the forces exerted at D and F on tong BDF.

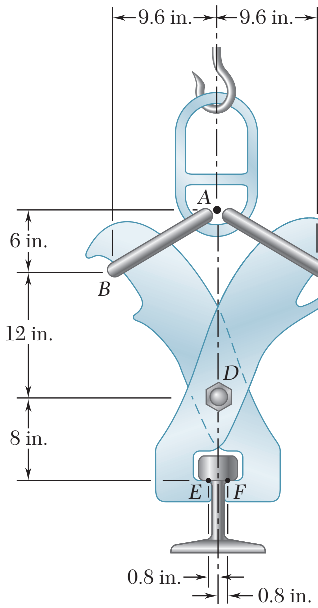


Fig. P6.142

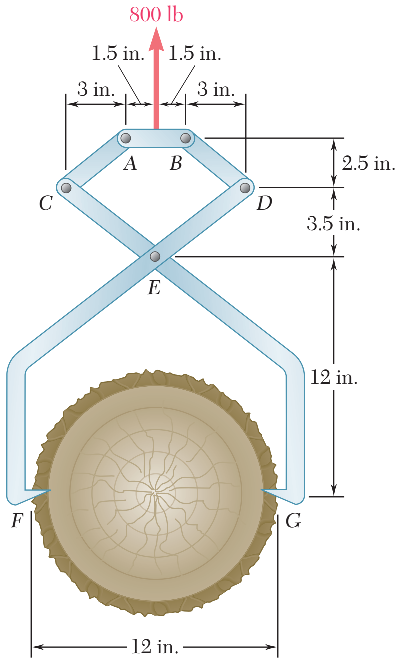


Fig. P6.141

6.143 The tongs shown are used to apply a total upward force of 45 kN on a pipe cap. Determine the forces exerted at D and F on tong ADF.

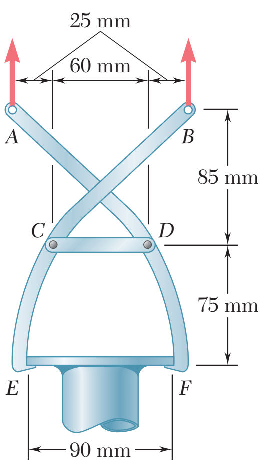


Fig. P6.143

6.144 If the toggle shown is added to the tongs of Prob. 6.143 and a single vertical force is applied at G, determine the forces exerted at D and F on tong ADF.

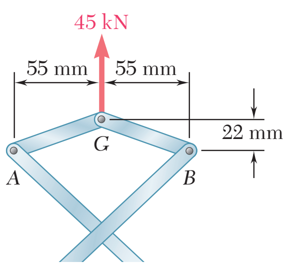


Fig. P6.144

6.145 The pliers shown are used to grip a 0.3-in.-diameter rod. Knowing that two 60-lb forces are applied to the handles, determine (*a*) the magnitude of the forces exerted on the rod, (*b*) the force exerted by the pin at *A* on portion *AB* of the pliers.

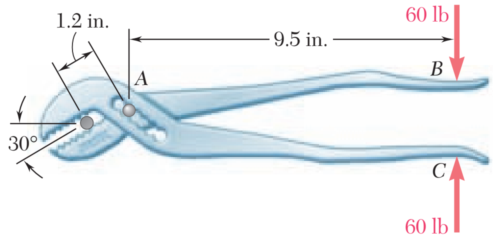


Fig. P6.145

6.146 In using the bolt cutter shown, a worker applies two 300-N forces to the handles. Determine the magnitude of the forces exerted by the cutter on the bolt.

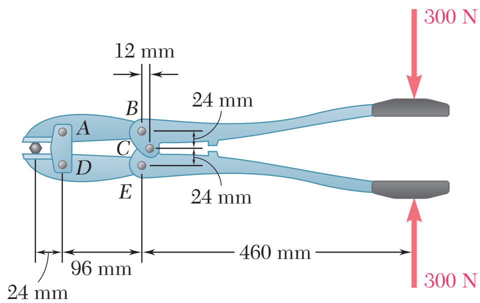


Fig. P6.146

6.147 Determine the magnitude of the gripping forces exerted along line *aa* on the nut when two 50-lb forces are applied to the handles as shown. Assume that pins *A* and *D* slide freely in slots cut in the jaws.

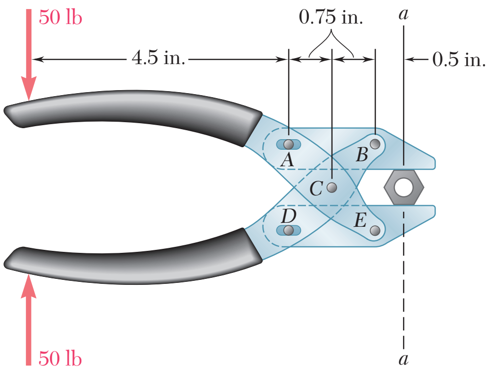


Fig. *P6.147*

6.148 Determine the magnitude of the gripping forces produced when two 300-N forces are applied as shown.

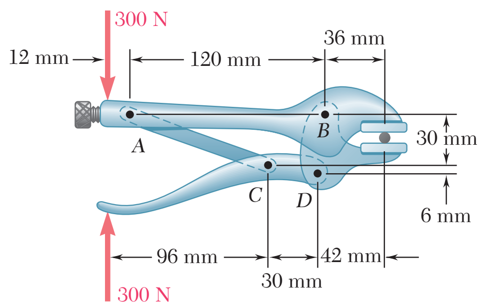


Fig. P6.148

6.149 Knowing that the frame shown has a sag at *B* of $a = 1$ in., determine the force **P** required to maintain equilibrium in the position shown.

6.150 Knowing that the frame shown has a sag at *B* of $a = 0.5$ in., determine the force **P** required to maintain equilibrium in the position shown.

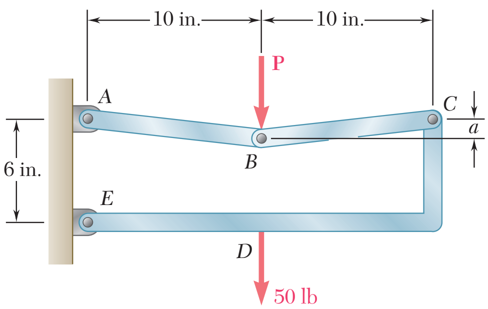


Fig. P6.149 and P6.150

6.151 The garden shears shown consist of two blades and two handles. The two handles are connected by pin C and the two blades are connected by pin D. The left blade and the right handle are connected by pin A; the right blade and the left handle are connected by pin B. Determine the magnitude of the forces exerted on the small branch at E when two 80-N forces are applied to the handles as shown.

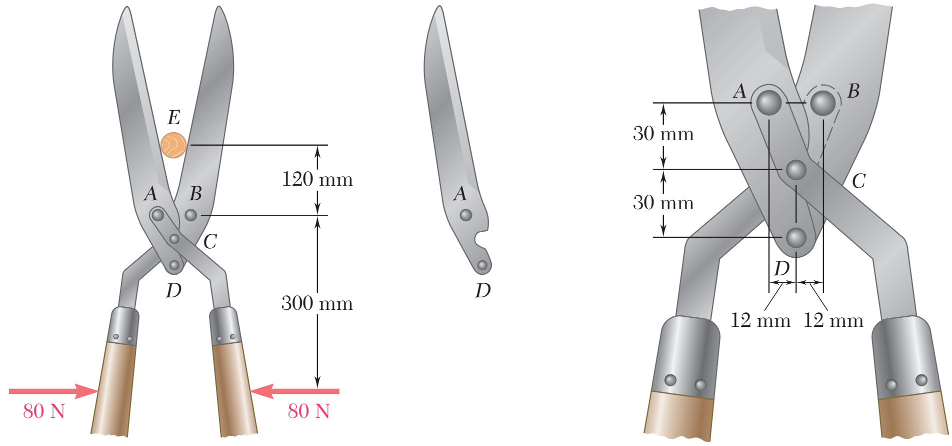


Fig. P6.151

6.152 The telescoping arm ABC is used to provide an elevated platform for construction workers. The workers and the platform together have a mass of 200 kg and have a combined center of gravity located directly above C. For the position when $\theta = 20°$, determine (*a*) the force exerted at B by the single hydraulic cylinder BD, (*b*) the force exerted on the supporting carriage at A.

6.153 The telescoping arm ABC can be lowered until end C is close to the ground, so that workers can easily board the platform. For the position when $\theta = -20°$, determine (*a*) the force exerted at B by the single hydraulic cylinder BD, (*b*) the force exerted on the supporting carriage at A.

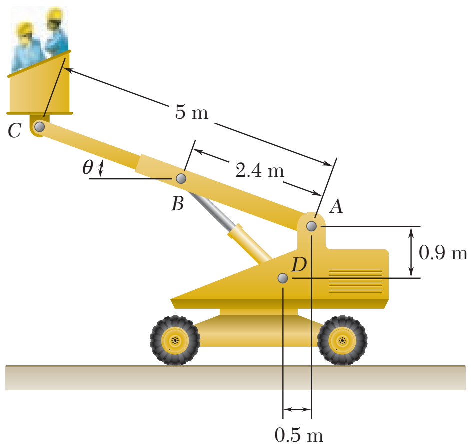


Fig. *P6.152* and *P6.153*

6.154 The position of member ABC is controlled by the hydraulic cylinder CD. Knowing that $\theta = 30°$, determine for the loading shown (*a*) the force exerted by the hydraulic cylinder on pin C, (*b*) the reaction at B.

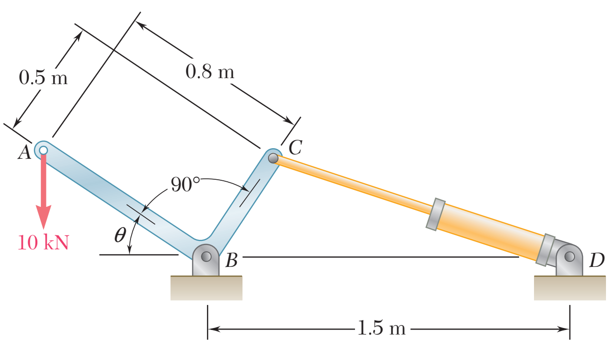


Fig. P6.154

6.155 The motion of the bucket of the front-end loader shown is controlled by two arms and a linkage that are pin-connected at *D*. The arms are located symmetrically with respect to the central, vertical, and longitudinal plane of the loader; one arm *AFJ* and its control cylinder *EF* are shown. The single linkage *GHDB* and its control cylinder *BC* are located in the plane of symmetry. For the position and loading shown, determine the force exerted (*a*) by cylinder *BC*, (*b*) by cylinder *EF*.

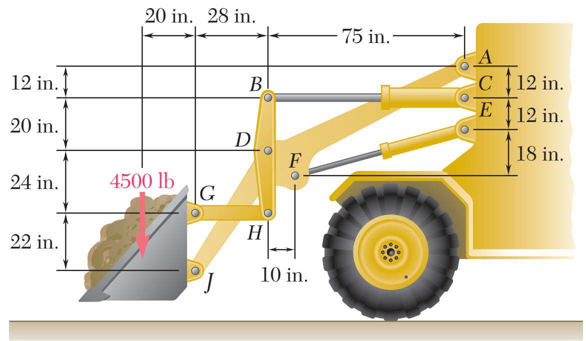


Fig. P6.155

6.156 The bucket of the front-end loader shown carries a 3200-lb load. The motion of the bucket is controlled by two identical mechanisms, only one of which is shown. Knowing that the mechanism shown supports one-half of the 3200-lb load, determine the force exerted (*a*) by cylinder *CD*, (*b*) by cylinder *FH*.

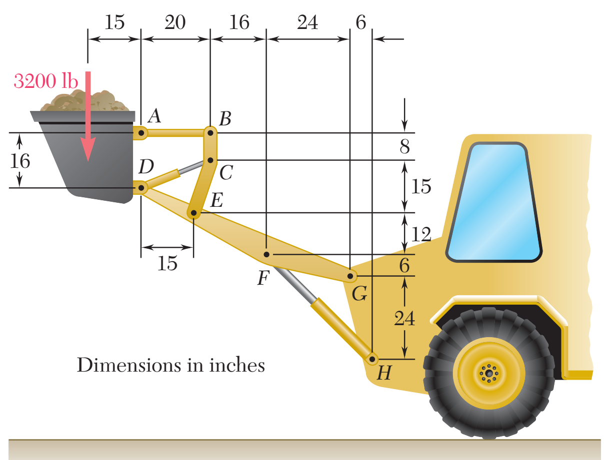


Fig. P6.156

6.157 The motion of the backhoe bucket shown is controlled by the hydraulic cylinders *AD*, *CG*, and *EF*. As a result of an attempt to dislodge a portion of a slab, a 2-kip force **P** is exerted on the bucket teeth at *J*. Knowing that $\theta = 45°$, determine the force exerted by each cylinder.

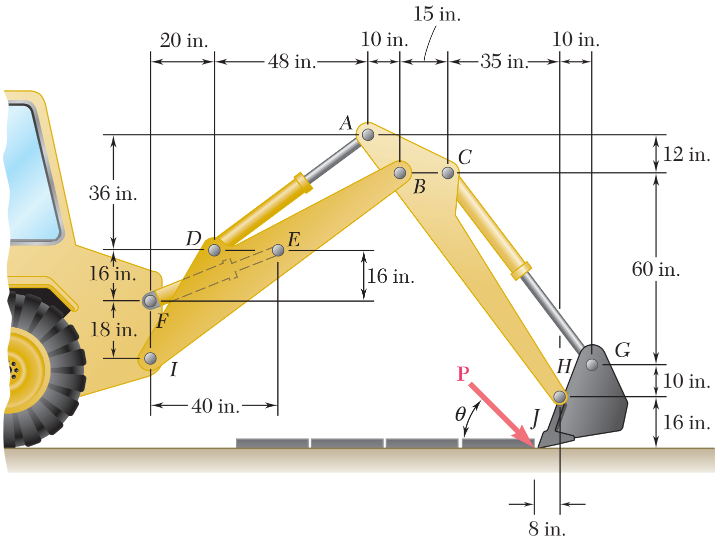


Fig. P6.157

6.158 Solve Prob. 6.157 assuming that the 2-kip force **P** acts horizontally to the right ($\theta = 0$).

6.159 The gears *D* and *G* are rigidly attached to shafts that are held by frictionless bearings. If $r_D = 90$ mm and $r_G = 30$ mm, determine (*a*) the couple $\mathbf{M}_0$ that must be applied for equilibrium, (*b*) the reactions at *A* and *B*.

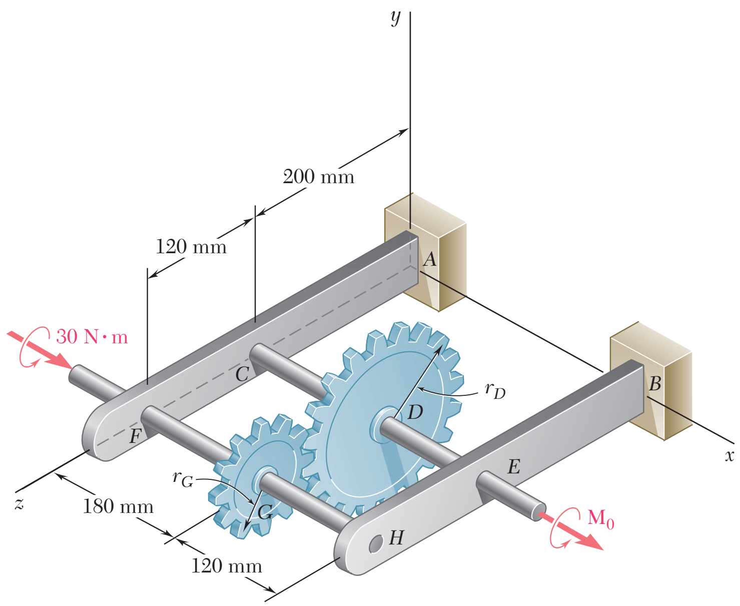


Fig. P6.159

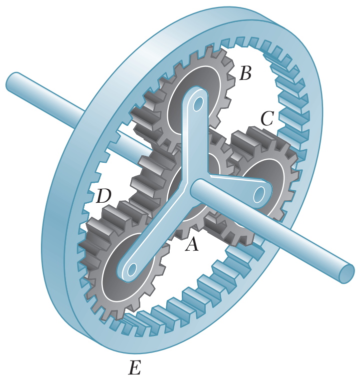


Fig. P6.160

6.160 In the planetary gear system shown, the radius of the central gear A is $a = 18$ mm, the radius of each planetary gear is b, and the radius of the outer gear E is $(a + 2b)$. A clockwise couple of magnitude $M_A = 10$ N · m is applied to the central gear A and a counterclockwise couple of magnitude $M_S = 50$ N · m is applied to the spider BCD. If the system is to be in equilibrium, determine (*a*) the required radius b of the planetary gears, (*b*) the magnitude M_E of the couple that must be applied to the outer gear E.

***6.161** Two shafts AC and CF, which lie in the vertical xy plane, are connected by a universal joint at C. The bearings at B and D do not exert any axial force. A couple of magnitude 500 lb · in. (clockwise when viewed from the positive x axis) is applied to shaft CF at F. At a time when the arm of the crosspiece attached to shaft CF is horizontal, determine (*a*) the magnitude of the couple that must be applied to shaft AC at A to maintain equilibrium, (*b*) the reactions at B, D, and E. (*Hint:* The sum of the couples exerted on the crosspiece must be zero.)

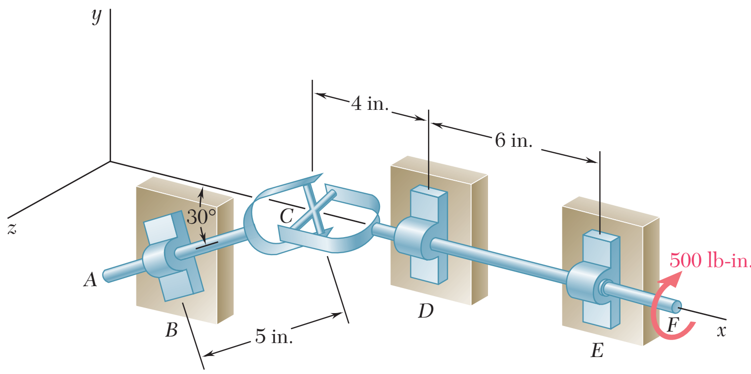


Fig. *P6.161*

***6.162** Solve Prob. 6.161 assuming that the arm of the crosspiece attached to shaft CF is vertical.

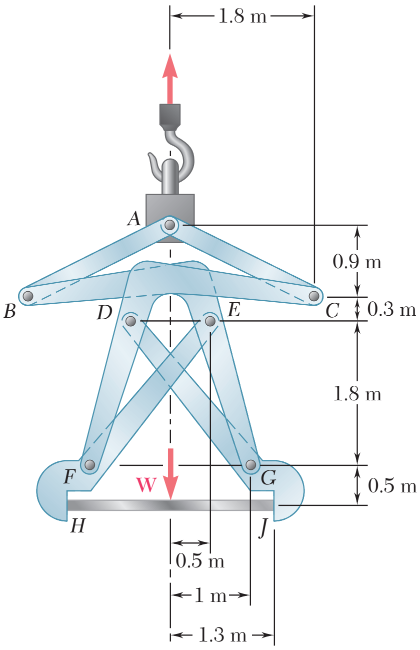


Fig. P6.163

***6.163** The large mechanical tongs shown are used to grab and lift a thick 7500-kg steel slab HJ. Knowing that slipping does not occur between the tong grips and the slab at H and J, determine the components of all forces acting on member EFH. (*Hint:* Consider the symmetry of the tongs to establish relationships between the components of the force acting at E on EFH and the components of the force acting at D on CDF.)