

# PROBLEMS

- 3.1** A 20-lb force is applied to the control rod  $AB$  as shown. Knowing that the length of the rod is 9 in. and that  $\alpha = 25^\circ$ , determine the moment of the force about point  $B$  by resolving the force into horizontal and vertical components.
- 3.2** A 20-lb force is applied to the control rod  $AB$  as shown. Knowing that the length of the rod is 9 in. and that  $\alpha = 25^\circ$ , determine the moment of the force about point  $B$  by resolving the force into components along  $AB$  and in a direction perpendicular to  $AB$ .
- 3.3** A 20-lb force is applied to the control rod  $AB$  as shown. Knowing that the length of the rod is 9 in. and that the moment of the force about  $B$  is  $120 \text{ lb} \cdot \text{in.}$  clockwise, determine the value of  $\alpha$ .

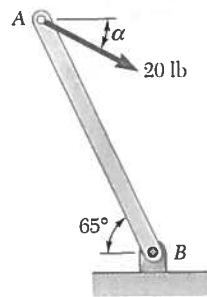


Fig. P3.1, P3.2, and P3.3

- 3.4** A crate of mass 80 kg is held in the position shown. Determine (a) the moment produced by the weight  $W$  of the crate about  $E$ , (b) the smallest force applied at  $B$  that creates a moment of equal magnitude and opposite sense about  $E$ .
- 3.5** A crate of mass 80 kg is held in the position shown. Determine (a) the moment produced by the weight  $W$  of the crate about  $E$ , (b) the smallest force applied at  $A$  that creates a moment of equal magnitude and opposite sense about  $E$ , (c) the magnitude, sense, and point of application on the bottom of the crate of the smallest vertical force that creates a moment of equal magnitude and opposite sense about  $E$ .
- 3.6** A 300-N force  $P$  is applied at point  $A$  of the bell crank shown. (a) Compute the moment of the force  $P$  about  $O$  by resolving it into horizontal and vertical components. (b) Using the result of part  $a$ , determine the perpendicular distance from  $O$  to the line of action of  $P$ .

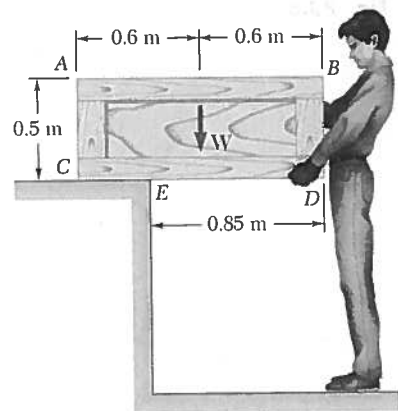


Fig. P3.4 and P3.5

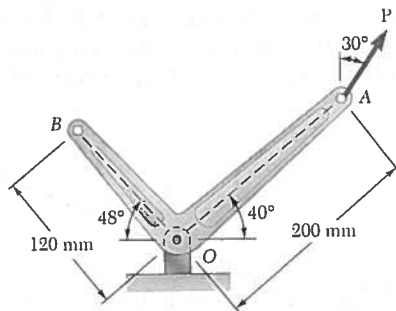


Fig. P3.6 and P3.7

- 3.7** A 400-N force  $P$  is applied at point  $A$  of the bell crank shown. (a) Compute the moment of the force  $P$  about  $O$  by resolving it into components along line  $OA$  and in a direction perpendicular to that line. (b) Determine the magnitude and direction of the smallest force  $Q$  applied at  $B$  that has the same moment as  $P$  about  $O$ .

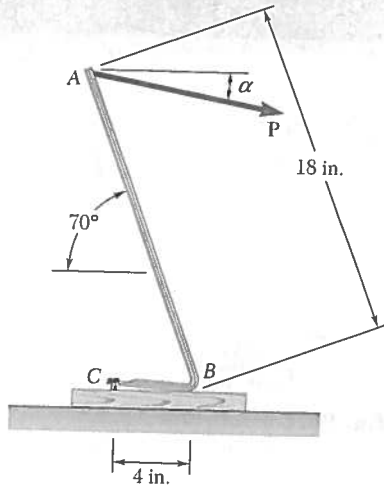


Fig. P3.8

**3.8** It is known that a vertical force of 200 lb is required to remove the nail at *C* from the board. As the nail first starts moving, determine (a) the moment about *B* of the force exerted on the nail, (b) the magnitude of the force *P* that creates the same moment about *B* if  $\alpha \approx 10^\circ$ , (c) the smallest force *P* that creates the same moment about *B*.

**3.9 and 3.10** It is known that the connecting rod *AB* exerts on the crank *BC* a 500-lb force directed down and to the left along the centerline of *AB*. Determine the moment of the force about *C*.

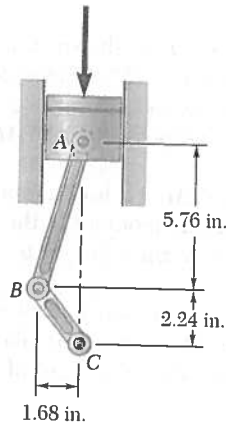


Fig. P3.9

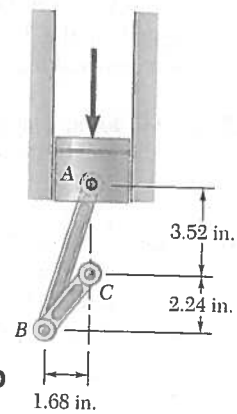


Fig. P3.10

**3.11** A winch puller *AB* is used to straighten a fence post. Knowing that the tension in cable *BC* is 1040 N and length *d* is 1.90 m, determine the moment about *D* of the force exerted by the cable at *C* by resolving that force into horizontal and vertical components applied (a) at point *C*, (b) at point *E*.

**3.12** It is known that a force with a moment of  $960 \text{ N} \cdot \text{m}$  about *D* is required to straighten the fence post *CD*. If  $d = 2.80 \text{ m}$ , determine the tension that must be developed in the cable of winch puller *AB* to create the required moment about point *D*.

**3.13** It is known that a force with a moment of  $960 \text{ N} \cdot \text{m}$  about *D* is required to straighten the fence post *CD*. If the capacity of winch puller *AB* is 2400 N, determine the minimum value of distance *d* to create the specified moment about point *D*.

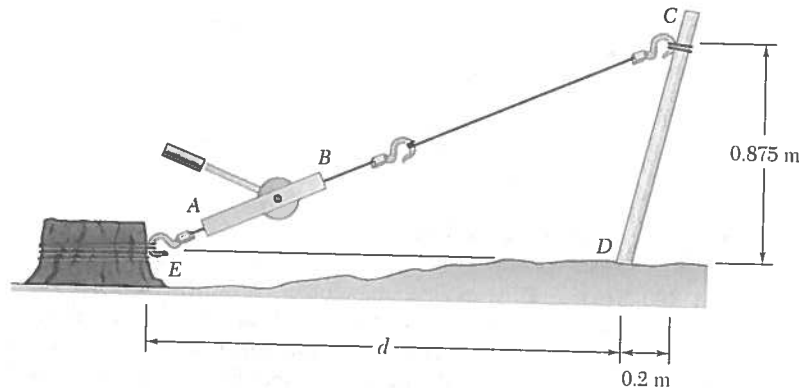


Fig. P3.11, P3.12, and P3.13

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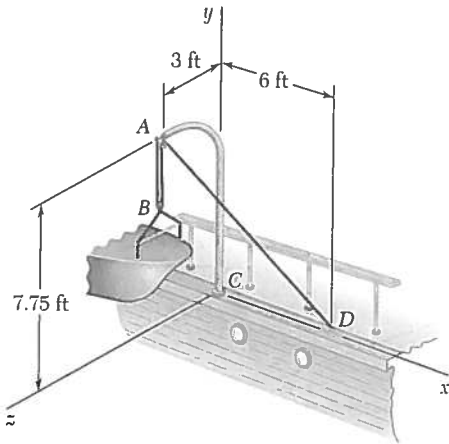


Fig. P3.22

**3.22** A small boat hangs from two davits, one of which is shown in the figure. The tension in line  $ABAD$  is 82 lb. Determine the moment about  $C$  of the resultant force  $\mathbf{R}_A$  exerted on the davit at  $A$ .

**3.23** A 6-ft-long fishing rod  $AB$  is securely anchored in the sand of a beach. After a fish takes the bait, the resulting force in the line is 6 lb. Determine the moment about  $A$  of the force exerted by the line at  $B$ .

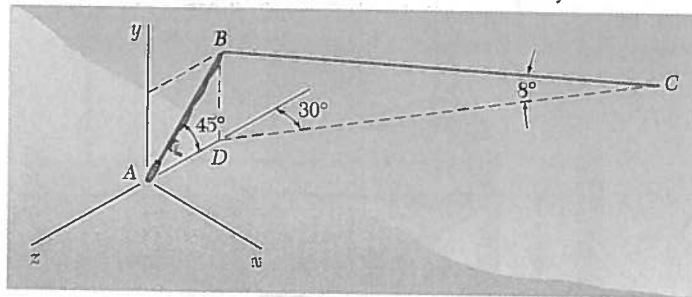


Fig. P3.23

**3.24** A precast concrete wall section is temporarily held by two cables as shown. Knowing that the tension in cable  $BD$  is 900 N, determine the moment about point  $O$  of the force exerted by the cable at  $B$ .

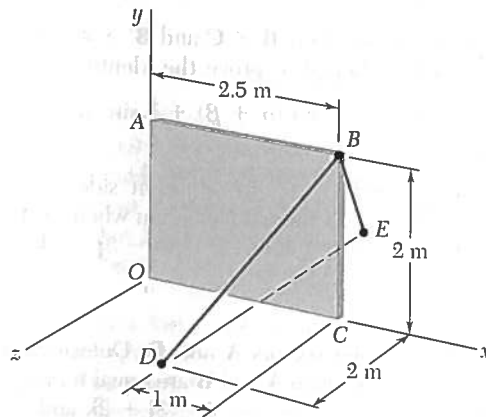


Fig. P3.24

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

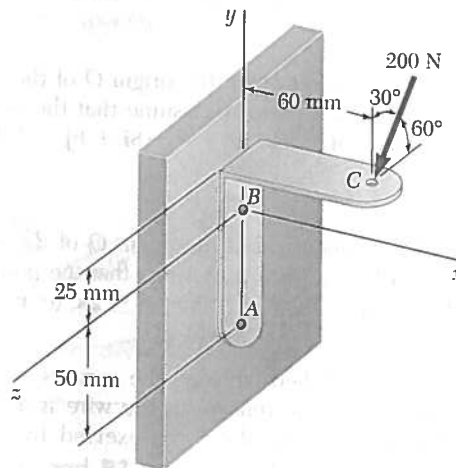


Fig. P3.25

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- 3.26** The 6-m boom  $AB$  has a fixed end  $A$ . A steel cable is stretched from the free end  $B$  of the boom to a point  $C$  located on the vertical wall. If the tension in the cable is 2.5 kN, determine the moment about  $A$  of the force exerted by the cable at  $B$ .

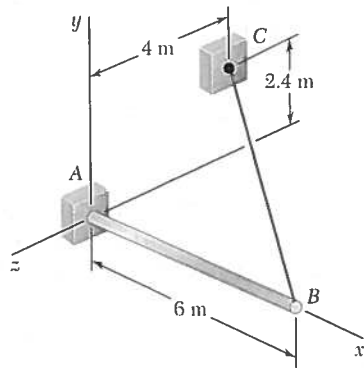


Fig. P3.26

- 3.27** In Prob. 3.21, determine the perpendicular distance from point  $O$  to wire  $AE$ .
- 3.28** In Prob. 3.21, determine the perpendicular distance from point  $B$  to wire  $AE$ .
- 3.29** In Prob. 3.22, determine the perpendicular distance from point  $C$  to portion  $AD$  of the line  $ABAD$ .
- 3.30** In Prob. 3.23, determine the perpendicular distance from point  $A$  to a line drawn through points  $B$  and  $C$ .
- 3.31** In Prob. 3.23, determine the perpendicular distance from point  $D$  to a line drawn through points  $B$  and  $C$ .
- 3.32** In Prob. 3.24, determine the perpendicular distance from point  $O$  to cable  $BD$ .
- 3.33** In Prob. 3.24, determine the perpendicular distance from point  $C$  to cable  $BD$ .
- 3.34** Determine the value of  $a$  that minimizes the perpendicular distance from point  $C$  to a section of pipeline that passes through points  $A$  and  $B$ .

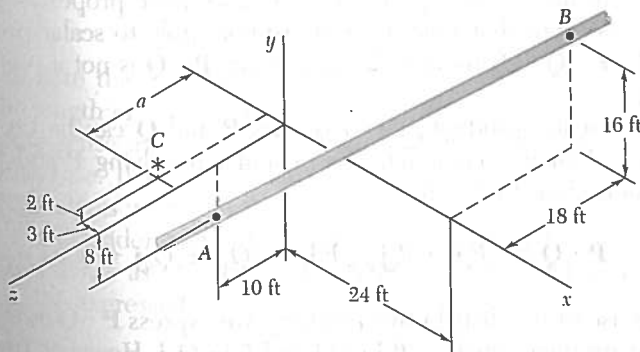


Fig. P3.34

# PROBLEMS

**3.35** Given the vectors  $\mathbf{P} = 3\mathbf{i} - \mathbf{j} + 2\mathbf{k}$ ,  $\mathbf{Q} = 4\mathbf{i} + 5\mathbf{j} - 3\mathbf{k}$ , and  $\mathbf{S} = -2\mathbf{i} + 3\mathbf{j} - \mathbf{k}$ , compute the scalar products  $\mathbf{P} \cdot \mathbf{Q}$ ,  $\mathbf{P} \cdot \mathbf{S}$ , and  $\mathbf{Q} \cdot \mathbf{S}$ .

**3.36** Form the scalar product  $\mathbf{B} \cdot \mathbf{C}$  and use the result obtained to prove the identity

$$\cos(\alpha - \beta) = \cos\alpha \cos\beta + \sin\alpha \sin\beta$$

**3.37** Consider the volleyball net shown. Determine the angle formed by guy wires  $AB$  and  $AC$ .

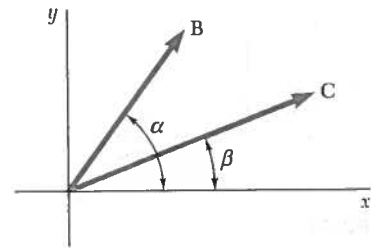


Fig. P3.36

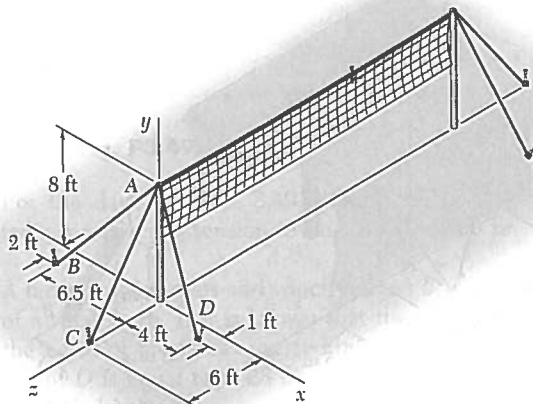


Fig. P3.37 and P3.38

**3.38** Consider the volleyball net shown. Determine the angle formed by guy wires  $AC$  and  $AD$ .

**3.39** Three cables are used to support a container as shown. Determine the angle formed by cables  $AB$  and  $AD$ .

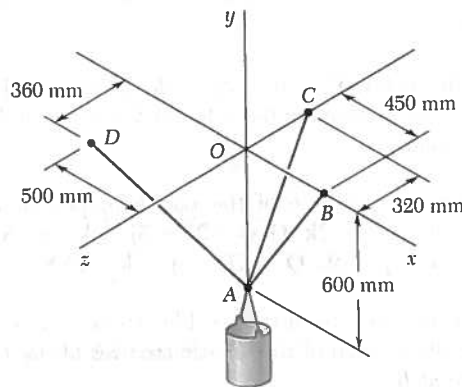


Fig. P3.39 and P3.40

**3.40** Three cables are used to support a container as shown. Determine the angle formed by cables  $AC$  and  $AD$ .

- 3.49** A small boat hangs from two davits, one of which is shown in the figure. It is known that the moment about the  $z$  axis of the resultant force  $\mathbf{R}_A$  exerted on the davit at  $A$  must not exceed  $279 \text{ lb} \cdot \text{ft}$  in absolute value. Determine the largest allowable tension in line  $ABAD$  when  $x = 6 \text{ ft}$ .

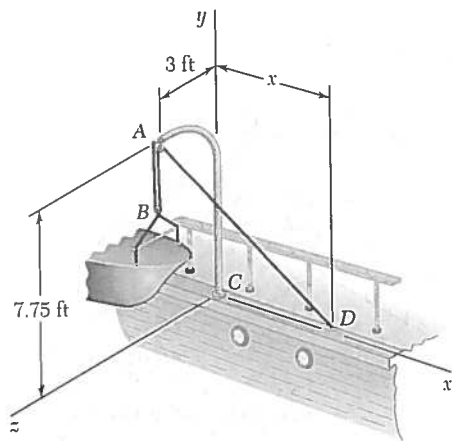


Fig. P3.49

- 3.50** For the davit of Prob. 3.49, determine the largest allowable distance  $x$  when the tension in line  $ABAD$  is  $60 \text{ lb}$ .

- 3.51** A farmer uses cables and winch pullers  $B$  and  $E$  to plumb one side of a small barn. If it is known that the sum of the moments about the  $x$  axis of the forces exerted by the cables on the barn at points  $A$  and  $D$  is equal to  $4728 \text{ lb} \cdot \text{ft}$ , determine the magnitude of  $T_{DE}$  when  $T_{AB} = 255 \text{ lb}$ .

- 3.52** Solve Prob. 3.51 when the tension in cable  $AB$  is  $306 \text{ lb}$ .

- 3.53** A single force  $\mathbf{P}$  acts at  $C$  in a direction perpendicular to the handle  $BC$  of the crank shown. Knowing that  $M_x = +20 \text{ N} \cdot \text{m}$  and  $M_y = -8.75 \text{ N} \cdot \text{m}$ , and  $M_z = -30 \text{ N} \cdot \text{m}$ , determine the magnitude of  $\mathbf{P}$  and the values of  $\phi$  and  $\theta$ .

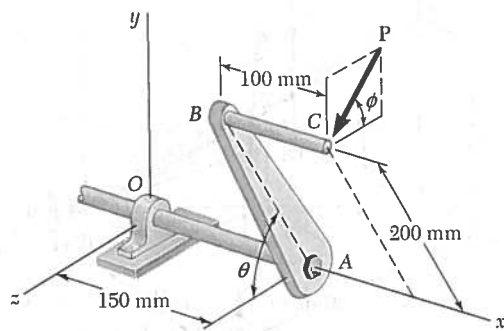


Fig. P3.53 and P3.54

- 3.54** A single force  $\mathbf{P}$  acts at  $C$  in a direction perpendicular to the handle  $BC$  of the crank shown. Determine the moment  $M_x$  of  $\mathbf{P}$  about the  $x$  axis when  $\theta = 65^\circ$ , knowing that  $M_y = -15 \text{ N} \cdot \text{m}$  and  $M_z = -36 \text{ N} \cdot \text{m}$ .

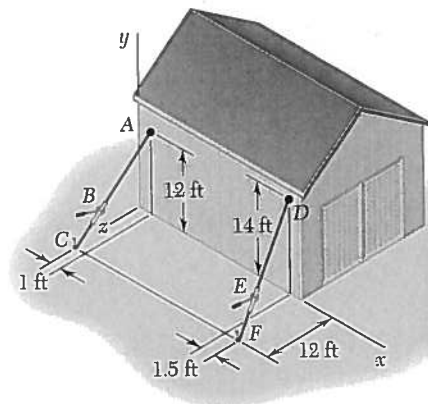


Fig. P3.51

- 3.55** The triangular plate  $ABC$  is supported by ball-and-socket joints at  $B$  and  $D$  and is held in the position shown by cables  $AE$  and  $CF$ . If the force exerted by cable  $AE$  at  $A$  is 55 N, determine the moment of that force about the line joining points  $D$  and  $B$ .

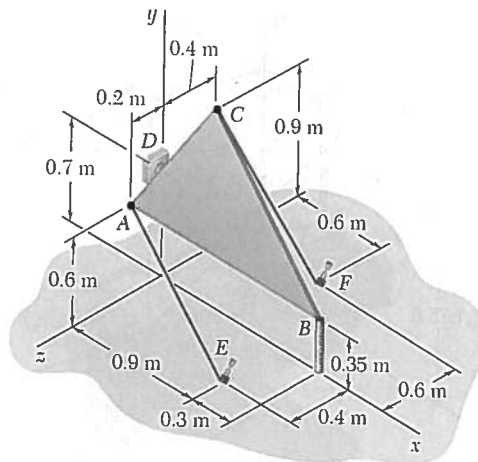


Fig. P3.55 and P3.56

- 3.56** The triangular plate  $ABC$  is supported by ball-and-socket joints at  $B$  and  $D$  and is held in the position shown by cables  $AE$  and  $CF$ . If the force exerted by cable  $CF$  at  $C$  is 33 N, determine the moment of that force about the line joining points  $D$  and  $B$ .
- 3.57** The 23-in. vertical rod  $CD$  is welded to the midpoint  $C$  of the 50-in. rod  $AB$ . Determine the moment about  $AB$  of the 235-lb force  $P$ .

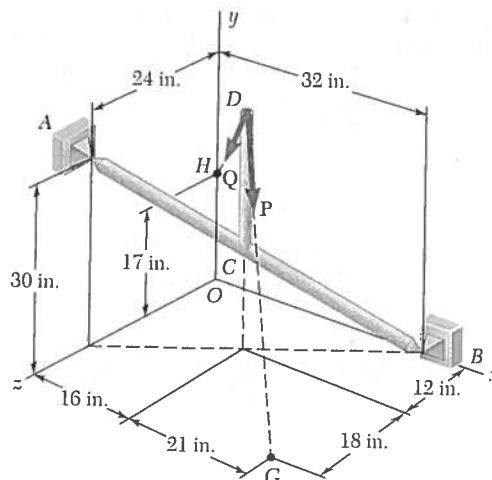


Fig. P3.57 and P3.58

- 3.58** The 23-in. vertical rod  $CD$  is welded to the midpoint  $C$  of the 50-in. rod  $AB$ . Determine the moment about  $AB$  of the 174-lb force  $Q$ .

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**3.59** The frame  $ACD$  is hinged at  $A$  and  $D$  and is supported by a cable that passes through a ring at  $B$  and is attached to hooks at  $G$  and  $H$ . Knowing that the tension in the cable is  $450\text{ N}$ , determine the moment about the diagonal  $AD$  of the force exerted on the frame by portion  $BH$  of the cable.

**3.60** In Prob. 3.59, determine the moment about the diagonal  $AD$  of the force exerted on the frame by portion  $BC$  of the cable.

**3.61** A regular tetrahedron has six edges of length  $a$ . A force  $\mathbf{P}$  is directed as shown along edge  $BC$ . Determine the moment of  $\mathbf{P}$  about edge  $OA$ .

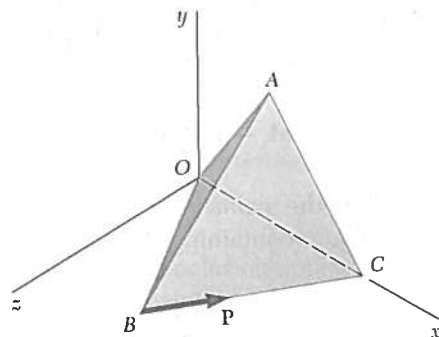


Fig. P3.61 and P3.62

**3.62** A regular tetrahedron has six edges of length  $a$ . (a) Show that two opposite edges, such as  $OA$  and  $BC$ , are perpendicular to each other. (b) Use this property and the result obtained in Prob. 3.61 to determine the perpendicular distance between edges  $OA$  and  $BC$ .

**3.63** Two forces  $\mathbf{F}_1$  and  $\mathbf{F}_2$  in space have the same magnitude  $F$ . Prove that the moment of  $\mathbf{F}_1$  about the line of action of  $\mathbf{F}_2$  is equal to the moment of  $\mathbf{F}_2$  about the line of action of  $\mathbf{F}_1$ .

**\*3.64** In Prob. 3.55, determine the perpendicular distance between cable  $AE$  and the line joining points  $D$  and  $B$ .

**\*3.65** In Prob. 3.56, determine the perpendicular distance between cable  $CF$  and the line joining points  $D$  and  $B$ .

**\*3.66** In Prob. 3.57, determine the perpendicular distance between rod  $AB$  and the line of action of  $\mathbf{P}$ .

**\*3.67** In Prob. 3.58, determine the perpendicular distance between rod  $AB$  and the line of action of  $\mathbf{Q}$ .

**\*3.68** In Prob. 3.59, determine the perpendicular distance between portion  $BH$  of the cable and the diagonal  $AD$ .

**\*3.69** In Prob. 3.60, determine the perpendicular distance between portion  $BG$  of the cable and the diagonal  $AD$ .

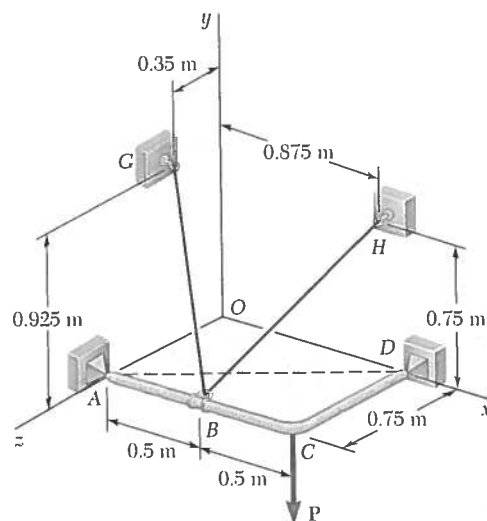


Fig. P3.59



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# PROBLEMS

- 3.70** A plate in the shape of a parallelogram is acted upon by two couples. Determine (a) the moment of the couple formed by the two 21-lb forces, (b) the perpendicular distance between the 12-lb forces if the resultant of the two couples is zero, (c) the value of  $\alpha$  if the resultant couple is  $72 \text{ lb} \cdot \text{in.}$  clockwise and  $d$  is 42 in.

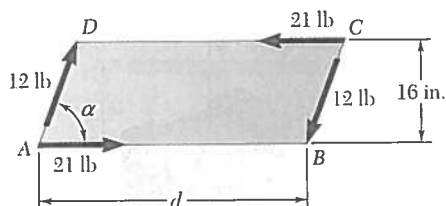


Fig. P3.70

- 3.71** Four 1-in.-diameter pegs are attached to a board as shown. Two strings are passed around the pegs and pulled with the forces indicated. (a) Determine the resultant couple acting on the board. (b) If only one string is used, around which pegs should it pass and in what directions should it be pulled to create the same couple with the minimum tension in the string? (c) What is the value of that minimum tension?

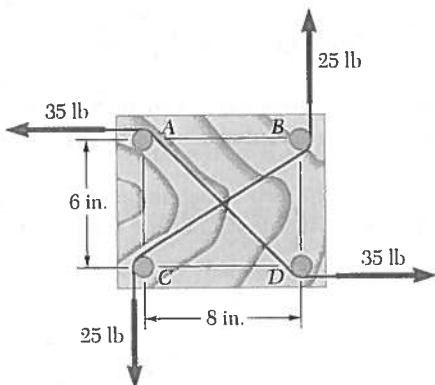


Fig. P3.71 and P3.72

- 3.72** Four pegs of the same diameter are attached to a board as shown. Two strings are passed around the pegs and pulled with the forces indicated. Determine the diameter of the pegs knowing that the resultant couple applied to the board is  $485 \text{ lb} \cdot \text{in.}$  counterclockwise.
- 3.73** A piece of plywood in which several holes are being drilled successively has been secured to a workbench by means of two nails. Knowing that the drill exerts a  $12\text{-N} \cdot \text{m}$  couple on the piece of plywood, determine the magnitude of the resulting forces applied to the nails if they are located (a) at A and B, (b) at B and C, (c) at A and C.

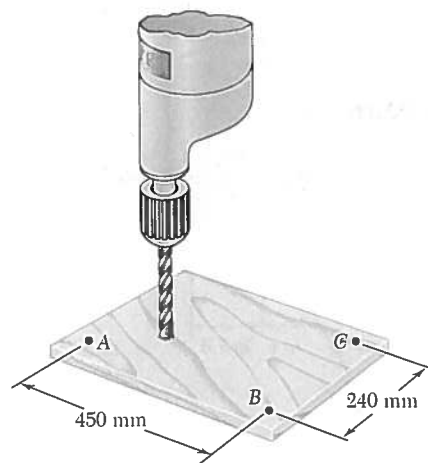
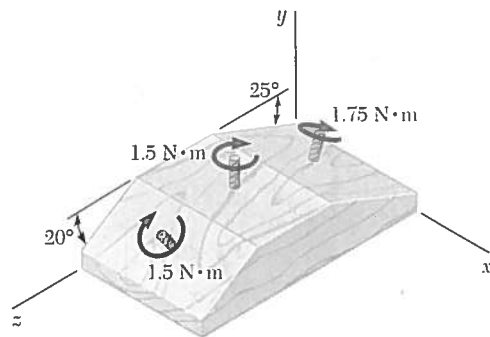


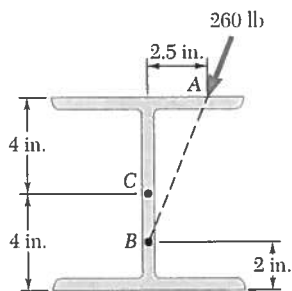
Fig. P3.73

**3.80** In a manufacturing operation, three holes are drilled simultaneously in a workpiece. If the holes are perpendicular to the surfaces of the workpiece, replace the couples applied to the drills with a single equivalent couple, specifying its magnitude and the direction of its axis.



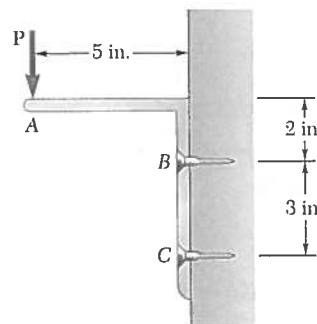
**Fig. P3.80**

**3.81** A 260-lb force is applied at A to the rolled-steel section shown. Replace that force with an equivalent force-couple system at the center C of the section.



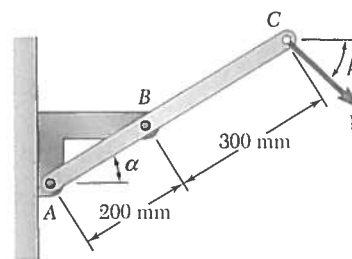
**Fig. P3.81**

**3.82** A 30-lb vertical force  $P$  is applied at A to the bracket shown, which is held by screws at B and C. (a) Replace  $P$  with an equivalent force-couple system at B. (b) Find the two horizontal forces at B and C that are equivalent to the couple obtained in part a.



**Fig. P3.82**

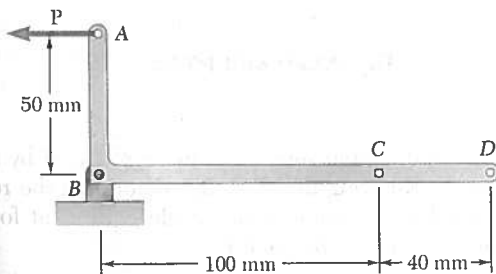
**3.83** The force  $P$  has a magnitude of 250 N and is applied at the end C of a 500-mm rod AC attached to a bracket at A and B. Assuming  $\alpha = 30^\circ$  and  $\beta = 60^\circ$ , replace  $P$  with (a) an equivalent force-couple system at B, (b) an equivalent system formed by two parallel forces applied at A and B.



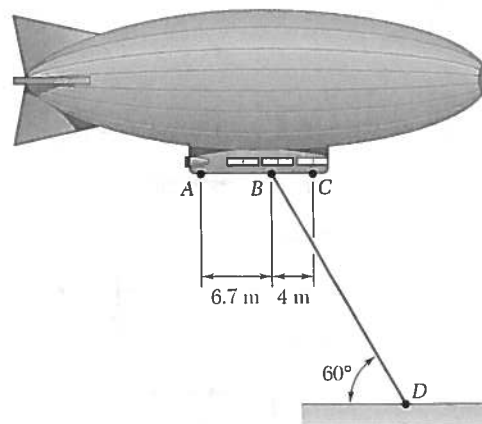
**Fig. P3.83**

**3.84** Solve Prob. 3.83, assuming  $\alpha = \beta = 25^\circ$ .

**3.85** The 80-N horizontal force  $P$  acts on a bell crank as shown. (a) Replace  $P$  with an equivalent force-couple system at B. (b) Find the two vertical forces at C and D that are equivalent to the couple found in part a.



**Fig. P3.85**



**Fig. P3.86**

**3.86** A dirigible is tethered by a cable attached to its cabin at B. If the tension in the cable is 1040 N, replace the force exerted by the cable at B with an equivalent system formed by two parallel forces applied at A and C.

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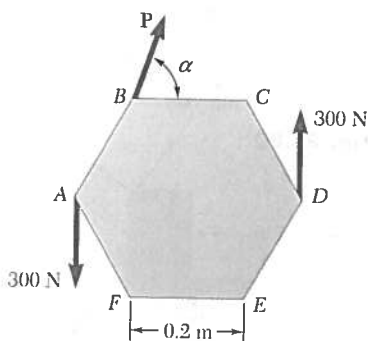


Fig. P3.88

**3.87** Three control rods attached to a lever  $ABC$  exert on it the forces shown. (a) Replace the three forces with an equivalent force-couple system at  $B$ . (b) Determine the single force that is equivalent to the force-couple system obtained in part  $a$ , and specify its point of application on the lever.

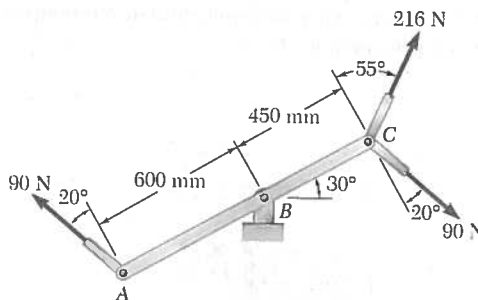


Fig. P3.87

**3.88** A hexagonal plate is acted upon by the force  $P$  and the couple shown. Determine the magnitude and the direction of the smallest force  $P$  for which this system can be replaced with a single force at  $E$ .

**3.89** A force and couple act as shown on a square plate of side  $a = 25$  in. Knowing that  $P = 60$  lb,  $Q = 40$  lb, and  $\alpha = 50^\circ$ , replace the given force and couple with a single force applied at a point located (a) on line  $AB$ , (b) on line  $AC$ . In each case determine the distance from  $A$  to the point of application of the force.

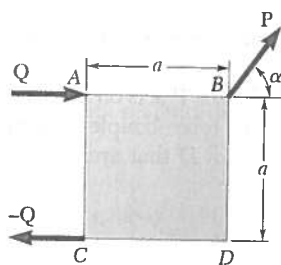


Fig. P3.89 and P3.90

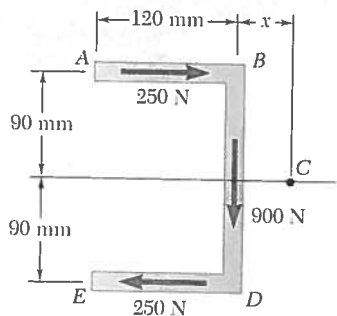


Fig. P3.91

**3.90** The force and couple shown are to be replaced by an equivalent single force. Knowing that  $P = 2Q$ , determine the required value of  $\alpha$  if the line of action of the single equivalent force is to pass through (a) point  $A$ , (b) point  $C$ .

**3.91** The shearing forces exerted on the cross section of a steel channel can be represented by a 900-N vertical force and two 250-N horizontal forces as shown. Replace this force and couple with a single force  $F$  applied at point  $C$ , and determine the distance  $x$  from  $C$  to line  $BD$ . (Point  $C$  is defined as the shear center of the section.)

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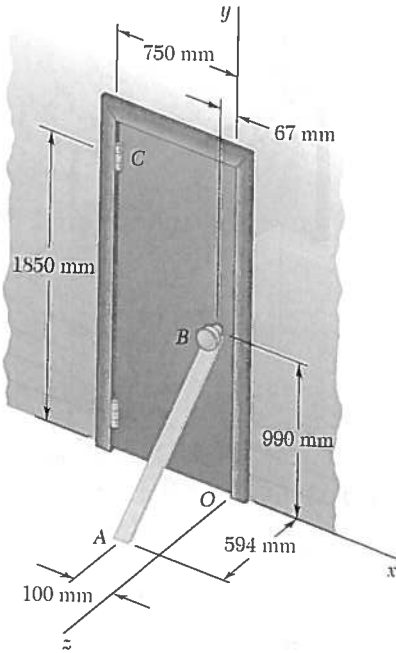


Fig. P3.97

**3.97** To keep a door closed, a wooden stick is wedged between the floor and the doorknob. The stick exerts at  $B$  a 175-N force directed along line  $AB$ . Replace that force with an equivalent force-couple system at  $C$ .

**3.98** A 46-lb force  $\mathbf{F}$  and a 2120-lb · in. couple  $\mathbf{M}$  are applied to corner  $A$  of the block shown. Replace the given force-couple system with an equivalent force-couple system at corner  $H$ .

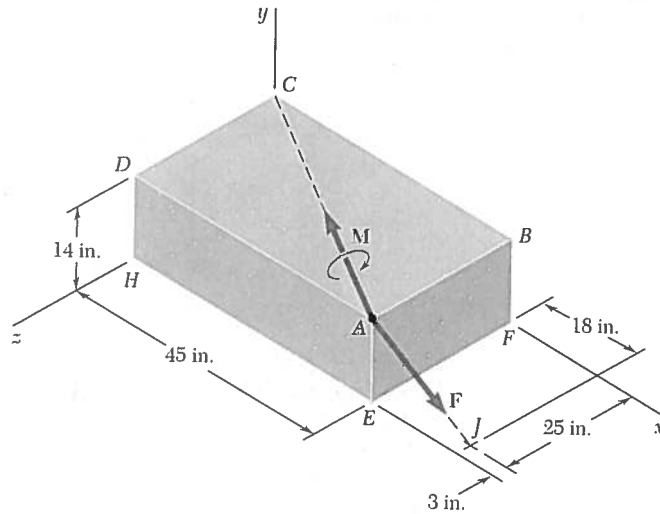


Fig. P3.98

**3.99** A 77-N force  $\mathbf{F}_1$  and a 31-N · m couple  $\mathbf{M}_1$  are applied to corner  $E$  of the bent plate shown. If  $\mathbf{F}_1$  and  $\mathbf{M}_1$  are to be replaced with an equivalent force-couple system ( $\mathbf{F}_2, \mathbf{M}_2$ ) at corner  $B$  and if  $(M_2)_z = 0$ , determine (a) the distance  $d$ , (b)  $\mathbf{F}_2$  and  $\mathbf{M}_2$ .

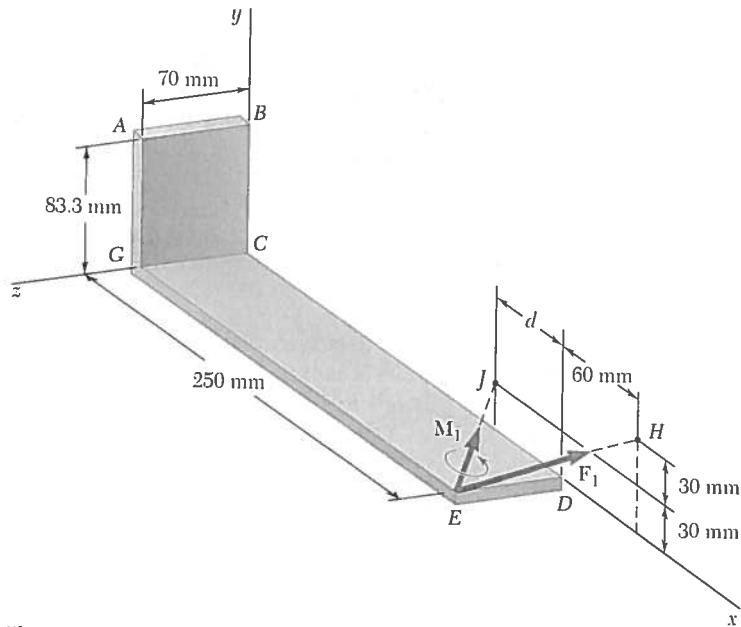


Fig. P3.99

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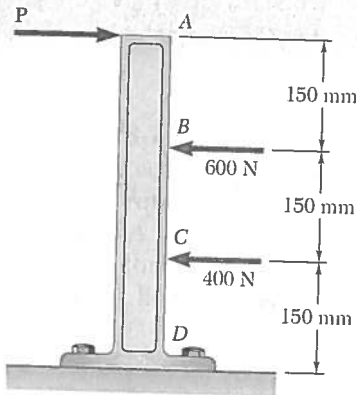


Fig. P3.105

**3.105** Three horizontal forces are applied as shown to a vertical cast-iron arm. Determine the resultant of the forces and the distance from the ground to its line of action when (a)  $P = 200 \text{ N}$ , (b)  $P = 2400 \text{ N}$ , (c)  $P = 1000 \text{ N}$ .

**3.106** Three stage lights are mounted on a pipe as shown. The lights at A and B each weigh 4.1 lb, while the one at C weighs 3.5 lb. (a) If  $d = 25 \text{ in.}$ , determine the distance from D to the line of action of the resultant of the weights of the three lights. (b) Determine the value of  $d$  so that the resultant of the weights passes through the midpoint of the pipe.

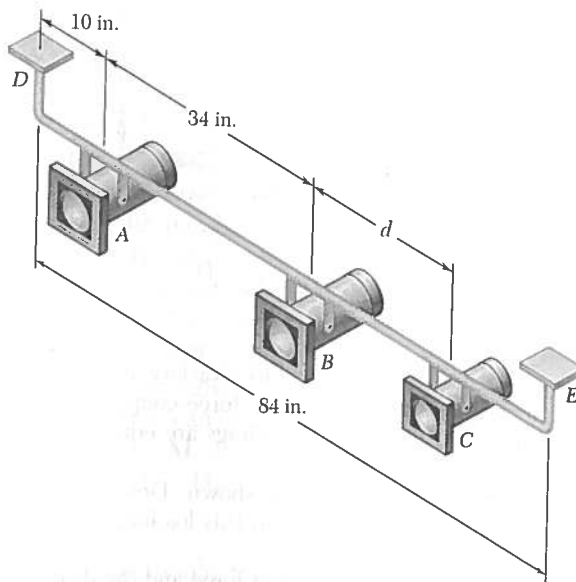


Fig. P3.106

**3.107** The weights of two children sitting at ends A and B of a seesaw are 84 lb and 64 lb, respectively. Where should a third child sit so that the resultant of the weights of the three children will pass through C if she weighs (a) 60 lb, (b) 52 lb?

**3.108** A couple of magnitude  $M = 54 \text{ lb} \cdot \text{in.}$  and the three forces shown are applied to an angle bracket. (a) Find the resultant of this system of forces. (b) Locate the points where the line of action of the resultant intersects line AB and line BC.

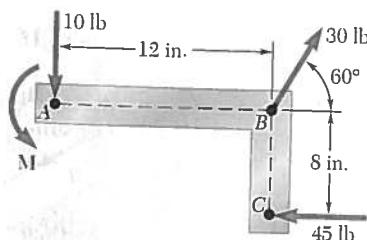


Fig. P3.108 and P3.109

**3.109** A couple  $M$  and the three forces shown are applied to an angle bracket. Find the moment of the couple if the line of action of the resultant of the force system is to pass through (a) point A, (b) point B, (c) point C.

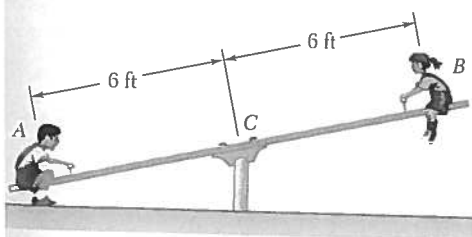


Fig. P3.107

**3.110** A 32-lb weight is applied to the line of action of the resultant of the forces shown.

**3.111** A machine is shown. The component force but the hole if it is shown.

**3.112** Solve Problem 3.108.

**3.113** A truss is shown. The force acting on the truss is shown.

**3.114** Four ropes are attached to a point on a structure. The forces are shown.

**3.115** Solve Problem 3.108.

**3.116** Four forces are applied to a structure. The resultant of the forces is shown.

**3.117** Solve Problem 3.108.

**3.110** A 32-lb motor is mounted on the floor. Find the resultant of the weight and the forces exerted on the belt, and determine where the line of action of the resultant intersects the floor.

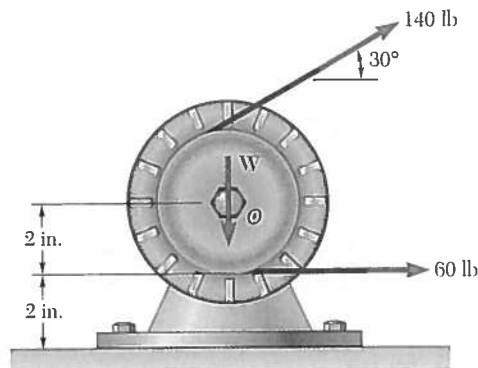


Fig. P3.110

**3.111** A machine component is subjected to the forces and couples shown. The component is to be held in place by a single rivet that can resist a force but not a couple. For  $P = 0$ , determine the location of the rivet hole if it is to be located (a) on line  $FC$ , (b) on line  $GH$ .

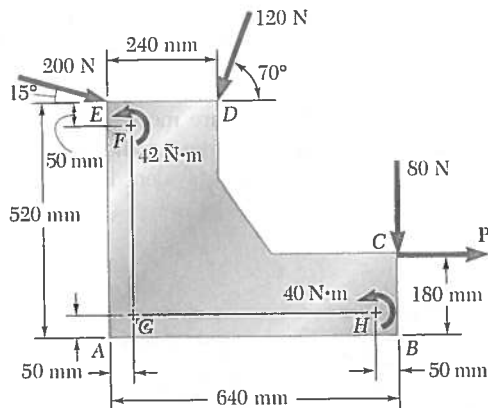


Fig. P3.111

**3.112** Solve Prob. 3.111, assuming that  $P = 60$  N.

**3.113** A truss supports the loading shown. Determine the equivalent force acting on the truss and the point of intersection of its line of action with a line drawn through points  $A$  and  $G$ .

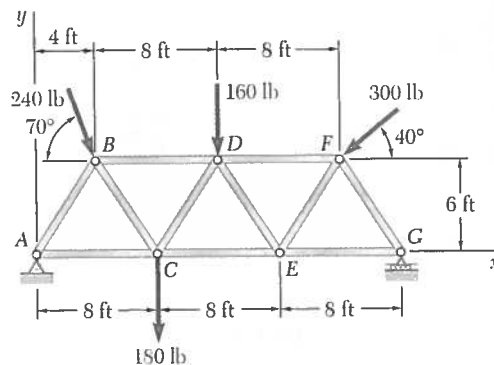


Fig. P3.113

**3.114** Four ropes are attached to a crate and exert the forces shown. If the forces are to be replaced with a single equivalent force applied at a point on line  $AB$ , determine (a) the equivalent force and the distance from  $A$  to the point of application of the force when  $\alpha = 30^\circ$ , (b) the value of  $\alpha$  so that the single equivalent force is applied at point  $B$ .

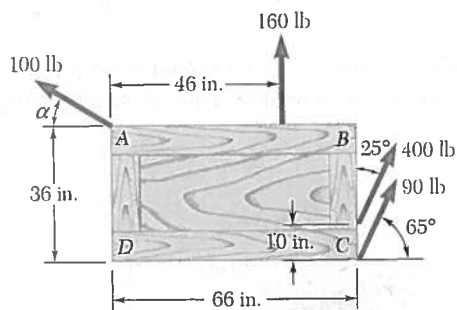


Fig. P3.114

**3.115** Solve Prob. 3.114, assuming that the 90-lb force is removed.

**3.116** Four forces act on a  $700 \times 375$ -mm plate as shown. (a) Find the resultant of these forces. (b) Locate the two points where the line of action of the resultant intersects the edge of the plate.

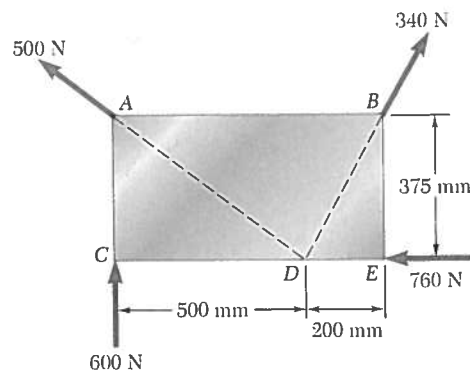


Fig. P3.116

**3.117** Solve Prob. 3.116, assuming that the 760-N force is directed to the right.

**3.124** In order to unscrew the tapped faucet *A*, a plumber uses two pipe wrenches as shown. By exerting a 40-lb force on each wrench, at a distance of 10 in. from the axis of the pipe and in a direction perpendicular to the pipe and to the wrench, he prevents the pipe from rotating, and thus avoids loosening or further tightening the joint between the pipe and the tapped elbow *C*. Determine (a) the angle  $\theta$  that the wrench at *A* should form with the vertical if elbow *C* is not to rotate about the vertical, (b) the force-couple system at *C* equivalent to the two 40-lb forces when this condition is satisfied.

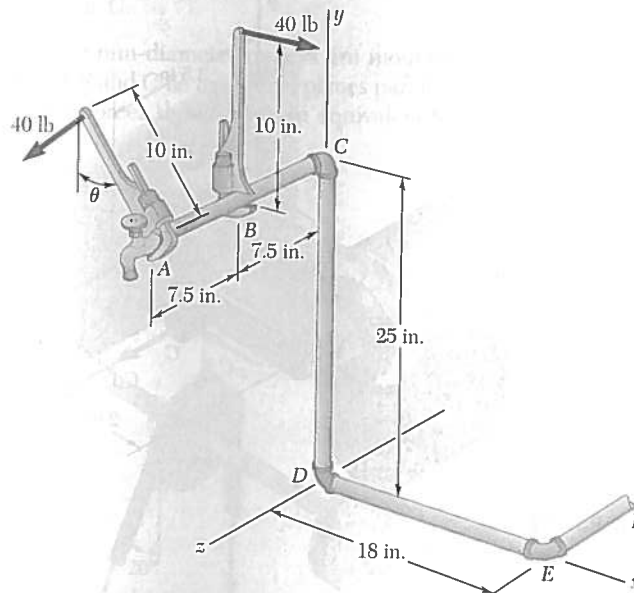


Fig. P3.124

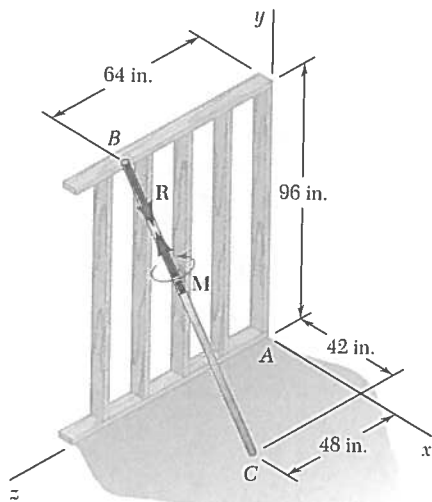


Fig. P3.126

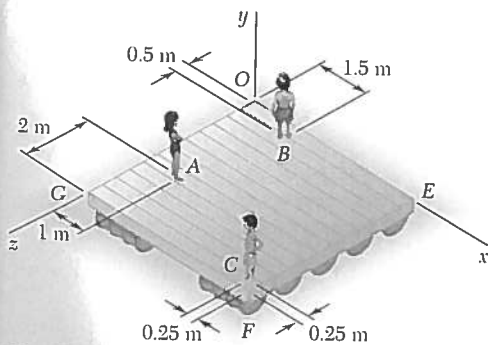


Fig. P3.127 and P3.128

**3.125** Assuming  $\theta = 60^\circ$  in Prob. 3.124, replace the two 40-lb forces with an equivalent force-couple system at *D* and determine whether the plumber's action tends to tighten or loosen the joint between (a) pipe *CD* and elbow *D*, (b) elbow *D* and pipe *DE*. Assume all threads to be right-handed.

**3.126** As an adjustable brace *BC* is used to bring a wall into plumb, the force-couple system shown is exerted on the wall. Replace this force-couple system with an equivalent force-couple system at *A* if  $R = 21.2$  lb and  $M = 13.25$  lb · ft.

**3.127** Three children are standing on a  $5 \times 5$ -m raft. If the weights of the children at points *A*, *B*, and *C* are 375 N, 260 N, and 400 N, respectively, determine the magnitude and the point of application of the resultant of the three weights.

**3.128** Three children are standing on a  $5 \times 5$ -m raft. The weights of the children at points *A*, *B*, and *C* are 375 N, 260 N, and 400 N, respectively. If a fourth child of weight 425 N climbs onto the raft, determine where she should stand if the other children remain in the positions shown and the line of action of the resultant of the four weights is to pass through the center of the raft.

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