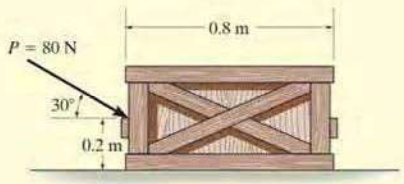
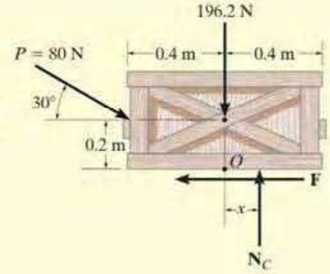
EXAMPLE 8.1

The uniform crate shown in Fig. 8–7*a* has a mass of 20 kg. If a force $P = 80$ N is applied to the crate, determine if it remains in equilibrium. The coefficient of static friction is $\mu_s = 0.3$.



(a)

Fig. 8–7



(b)

SOLUTION

Free-Body Diagram. As shown in Fig. 8–7*b*, the *resultant* normal force $\mathbf{N}_C$ must act a distance x from the crate's center line in order to counteract the tipping effect caused by **P**. There are *three unknowns*, F, N_C, and x, which can be determined strictly from the *three* equations of equilibrium.

Equations of Equilibrium.

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad 80 \cos 30^\circ \text{ N} - F = 0$$

$$+\uparrow \Sigma F_y = 0; \qquad -80 \sin 30^\circ \text{ N} + N_C - 196.2 \text{ N} = 0$$

$$\circlearrowleft + \Sigma M_O = 0; \qquad 80 \sin 30^\circ \text{ N}(0.4 \text{ m}) - 80 \cos 30^\circ \text{ N}(0.2 \text{ m}) + N_C(x) = 0$$

Solving,

$$F = 69.3 \text{ N}$$

$$N_C = 236 \text{ N}$$

$$x = -0.00908 \text{ m} = -9.08 \text{ mm}$$

Since x is negative it indicates the *resultant* normal force acts (slightly) to the *left* of the crate's center line. No tipping will occur since $x < 0.4$ m. Also, the *maximum* frictional force which can be developed at the surface of contact is $F_{\max} = \mu_s N_C = 0.3(236 \text{ N}) = 70.8$ N. Since $F = 69.3 \text{ N} < 70.8$ N, the crate will *not slip*, although it is very close to doing so.

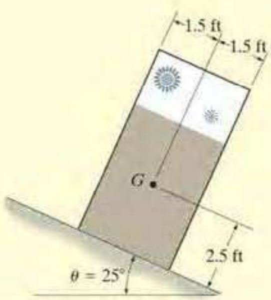
EXAMPLE 8.2

(a)

It is observed that when the bed of the dump truck is raised to an angle of $\theta = 25^\circ$ the vending machines will begin to slide off the bed, Fig. 8–8*a*. Determine the static coefficient of friction between a vending machine and the surface of the truckbed.

SOLUTION

An idealized model of a vending machine resting on the truckbed is shown in Fig. 8–8*b*. The dimensions have been measured and the center of gravity has been located. We will assume that the vending machine weighs W.



(b)

Free-Body Diagram. As shown in Fig. 8–8*c*, the dimension x is used to locate the position of the resultant normal force **N**. There are four unknowns, N, F, μ_s, and x.

Equations of Equilibrium.

$$+\searrow \Sigma F_x = 0; \qquad W \sin 25^\circ - F = 0 \qquad (1)$$

$$+\nearrow \Sigma F_y = 0; \qquad N - W \cos 25^\circ = 0 \qquad (2)$$

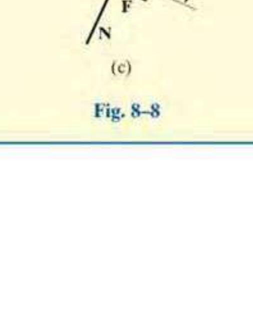
$$\circlearrowleft + \Sigma M_O = 0; \quad -W \sin 25^\circ(2.5 \text{ ft}) + W \cos 25^\circ(x) = 0 \qquad (3)$$

Since slipping impends at $\theta = 25^\circ$, using Eqs. 1 and 2, we have

$$F_s = \mu_s N; \qquad W \sin 25^\circ = \mu_s(W \cos 25^\circ)$$

$$\mu_s = \tan 25^\circ = 0.466 \qquad \textit{Ans.}$$

The angle of $\theta = 25^\circ$ is referred to as the *angle of repose*, and by comparison, it is equal to the angle of static friction, $\theta = \phi_s$. Notice from the calculation that θ is independent of the weight of the vending machine, and so knowing θ provides a convenient method for determining the coefficient of static friction.



(c)

Fig. 8–8

NOTE: From Eq. 3, we find $x = 1.17$ ft. Since $1.17 \text{ ft} < 1.5 \text{ ft}$, indeed the vending machine will slip before it can tip as observed in Fig. 8–8*a*.

EXAMPLE 8.3

The uniform 10-kg ladder in Fig. 8–9*a* rests against the smooth wall at *B*, and the end *A* rests on the rough horizontal plane for which the coefficient of static friction is $\mu_s = 0.3$. Determine the angle of inclination θ of the ladder and the normal reaction at *B* if the ladder is on the verge of slipping.

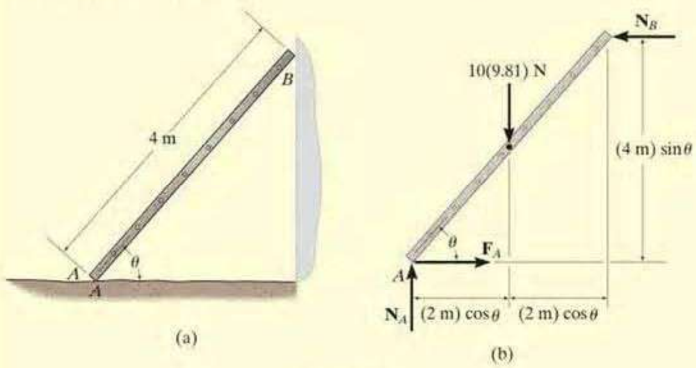


Fig. 8–9

SOLUTION

Free-Body Diagram. As shown on the free-body diagram, Fig. 8–9*b*, the frictional force $\mathbf{F}_A$ must act to the right since impending motion at *A* is to the left.

Equations of Equilibrium and Friction. Since the ladder is on the verge of slipping, then $F_A = \mu_s N_A = 0.3N_A$. By inspection, N_A can be obtained directly.

$+\uparrow \Sigma F_y = 0;$ $\quad N_A - 10(9.81)\text{ N} = 0 \qquad N_A = 98.1\text{ N}$

Using this result, $F_A = 0.3(98.1\text{ N}) = 29.43\text{ N}$. Now N_B can be found.

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 29.43\text{ N} - N_B = 0$

$$N_B = 29.43\text{ N} = 29.4\text{ N} \qquad \textit{Ans.}$$

Finally, the angle θ can be determined by summing moments about point *A*.

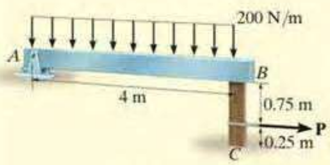
$\circlearrowleft + \Sigma M_A = 0;$ $\quad (29.43\text{ N})(4\text{ m})\sin\theta - [10(9.81)\text{ N}](2\text{ m})\cos\theta = 0$

$$\frac{\sin\theta}{\cos\theta} = \tan\theta = 1.6667$$

$$\theta = 59.04^\circ = 59.0^\circ \qquad \textit{Ans.}$$

8

EXAMPLE 8.4



(a)

Beam AB is subjected to a uniform load of 200 N/m and is supported at B by post BC, Fig. 8–10a. If the coefficients of static friction at B and C are $\mu_B = 0.2$ and $\mu_C = 0.5$, determine the force **P** needed to pull the post out from under the beam. Neglect the weight of the members and the thickness of the beam.

SOLUTION

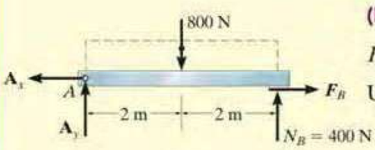
Free-Body Diagrams. The free-body diagram of the beam is shown in Fig. 8–10b. Applying $\Sigma M_A = 0$, we obtain $N_B = 400$ N. This result is shown on the free-body diagram of the post, Fig. 8–10c. Referring to this member, the *four* unknowns F_B, P, F_C, and N_C are determined from the *three* equations of equilibrium and *one* frictional equation applied either at B or C.

Equations of Equilibrium and Friction.

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad P - F_B - F_C = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad N_C - 400\text{ N} = 0 \qquad (2)$$

$$\circlearrowleft + \Sigma M_C = 0; \qquad -P(0.25\text{ m}) + F_B(1\text{ m}) = 0 \qquad (3)$$



(b)

8

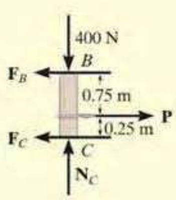
(Post Slips at B and Rotates about C.) This requires $F_C \leq \mu_C N_C$ and

$$F_B = \mu_B N_B; \qquad F_B = 0.2(400\text{ N}) = 80\text{ N}$$

Using this result and solving Eqs. 1 through 3, we obtain

$$P = 320\text{ N}$$
$$F_C = 240\text{ N}$$
$$N_C = 400\text{ N}$$

Since $F_C = 240\text{ N} > \mu_C N_C = 0.5(400\text{ N}) = 200\text{ N}$, slipping at C occurs. Thus the other case of movement must be investigated.



(c)

Fig. 8–10

(Post Slips at C and Rotates about B.) Here $F_B \leq \mu_B N_B$ and

$$F_C = \mu_C N_C; \qquad F_C = 0.5 N_C \qquad (4)$$

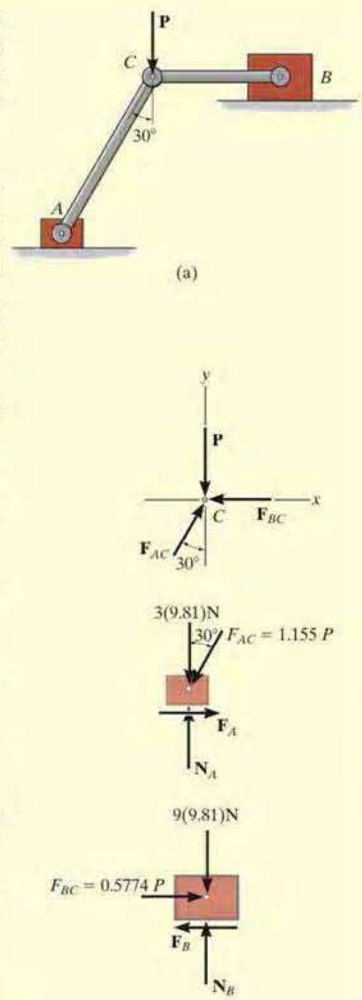
Solving Eqs. 1 through 4 yields

$$P = 267\text{ N} \qquad \textit{Ans.}$$
$$N_C = 400\text{ N}$$
$$F_C = 200\text{ N}$$
$$F_B = 66.7\text{ N}$$

Obviously, this case occurs first since it requires a *smaller* value for P.

EXAMPLE 8.5

Blocks A and B have a mass of 3 kg and 9 kg, respectively, and are connected to the weightless links shown in Fig. 8–11a. Determine the largest vertical force $\mathbf{P}$ that can be applied at the pin C without causing any movement. The coefficient of static friction between the blocks and the contacting surfaces is $\mu_s = 0.3$.



(a) (b)

Fig. 8–11

SOLUTION

Free-Body Diagram. The links are two-force members and so the free-body diagrams of pin C and blocks A and B are shown in Fig. 8–11b. Since the horizontal component of $\mathbf{F}_{AC}$ tends to move block A to the left, $\mathbf{F}_A$ must act to the right. Similarly, $\mathbf{F}_B$ must act to the left to oppose the tendency of motion of block B to the right, caused by $\mathbf{F}_{BC}$. There are seven unknowns and six available force equilibrium equations, two for the pin and two for each block, so that *only one* frictional equation is needed.

Equations of Equilibrium and Friction. The force in links AC and BC can be related to P by considering the equilibrium of pin C.

$$+\uparrow \Sigma F_y = 0; \qquad F_{AC}\cos 30^\circ - P = 0; \qquad F_{AC} = 1.155P$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 1.155P\sin 30^\circ - F_{BC} = 0; \qquad F_{BC} = 0.5774P$$

Using the result for F_{AC}, for block A,

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad F_A - 1.155P\sin 30^\circ = 0; \qquad F_A = 0.5774P \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad N_A - 1.155P\cos 30^\circ - 3(9.81\text{ N}) = 0;$$

$$N_A = P + 29.43\text{ N} \qquad (2)$$

Using the result for F_{BC}, for block B,

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad (0.5774P) - F_B = 0; \qquad F_B = 0.5774P \qquad (3)$$

$$+\uparrow \Sigma F_y = 0; \qquad N_B - 9(9.81)\text{ N} = 0; \qquad N_B = 88.29\text{ N}$$

Movement of the system may be caused by the initial slipping of *either* block A or block B. If we assume that block A slips first, then

$$F_A = \mu_s N_A = 0.3\,N_A \qquad (4)$$

Substituting Eqs. 1 and 2 into Eq. 4,

$$0.5774P = 0.3(P + 29.43)$$

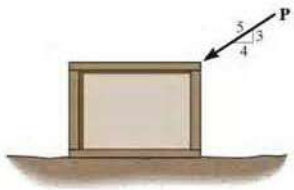
$$P = 31.8\text{ N} \qquad \textit{Ans.}$$

Substituting this result into Eq. 3, we obtain $F_B = 18.4$ N. Since the maximum static frictional force at B is $(F_B)_{max} = \mu_s N_B = 0.3(88.29\text{ N}) = 26.5\text{ N} > F_B$, block B will not slip. Thus, the above assumption is correct. Notice that if the inequality were not satisfied, we would have to assume slipping of block B and then solve for P.

8

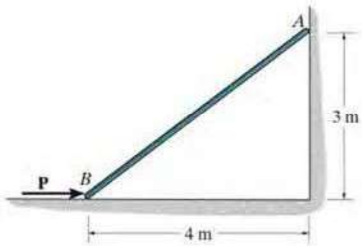
FUNDAMENTAL PROBLEMS

F8–1. If $P = 200$ N, determine the friction developed between the 50-kg crate and the ground. The coefficient of static friction between the crate and the ground is $\mu_s = 0.3$.



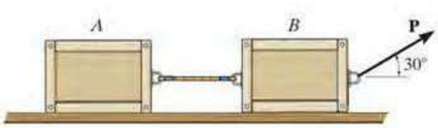
F8–1

F8–2. Determine the minimum force P to prevent the 30-kg rod AB from sliding. The contact surface at B is smooth, whereas the coefficient of static friction between the rod and the wall at A is $\mu_s = 0.2$.



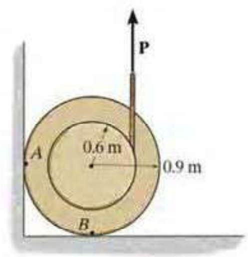
F8–2

F8–3. Determine the maximum force P that can be applied without causing the two 50-kg crates to move. The coefficient of static friction between each crate and the ground is $\mu_s = 0.25$.



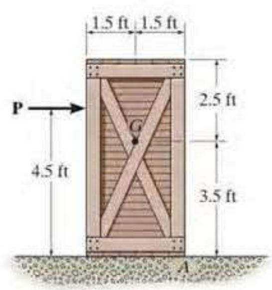
F8–3

F8–4. If the coefficient of static friction at contact points A and B is $\mu_s = 0.3$, determine the maximum force P that can be applied without causing the 100-kg spool to move.



F8–4

F8–5. Determine the minimum force P that can be applied without causing movement of the 250-lb crate which has a center of gravity at G. The coefficient of static friction at the floor is $\mu_s = 0.4$.



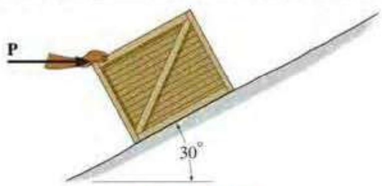
F8–5

PROBLEMS

•**8–1.** Determine the minimum horizontal force P required to hold the crate from sliding down the plane. The crate has a mass of 50 kg and the coefficient of static friction between the crate and the plane is $\mu_s = 0.25$.

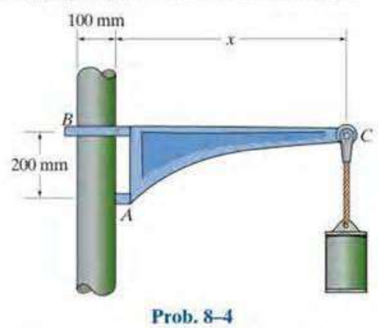
8–2. Determine the minimum force P required to push the crate up the plane. The crate has a mass of 50 kg and the coefficient of static friction between the crate and the plane is $\mu_s = 0.25$.

8–3. A horizontal force of $P = 100$ N is just sufficient to hold the crate from sliding down the plane, and a horizontal force of $P = 350$ N is required to just push the crate up the plane. Determine the coefficient of static friction between the plane and the crate, and find the mass of the crate.



Probs. 8–1/2/3

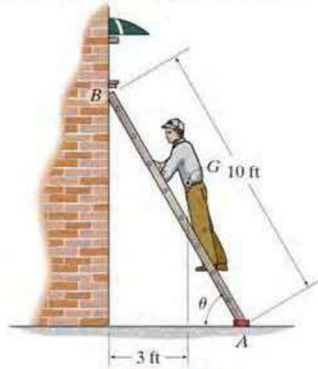
*__8–4.__ If the coefficient of static friction at A is $\mu_s = 0.4$ and the collar at B is smooth so it only exerts a horizontal force on the pipe, determine the minimum distance x so that the bracket can support the cylinder of any mass without slipping. Neglect the mass of the bracket.



Prob. 8–4

•**8–5.** The 180-lb man climbs up the ladder and stops at the position shown after he senses that the ladder is on the verge of slipping. Determine the inclination θ of the ladder if the coefficient of static friction between the friction pad A and the ground is $\mu_s = 0.4$. Assume the wall at B is smooth. The center of gravity for the man is at G. Neglect the weight of the ladder.

8–6. The 180-lb man climbs up the ladder and stops at the position shown after he senses that the ladder is on the verge of slipping. Determine the coefficient of static friction between the friction pad at A and ground if the inclination of the ladder is $\theta = 60°$ and the wall at B is smooth. The center of gravity for the man is at G. Neglect the weight of the ladder.

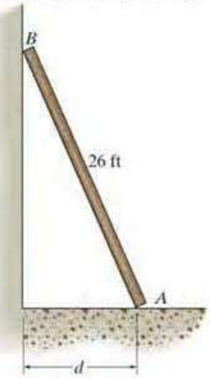


Probs. 8–5/6

8–7. The uniform thin pole has a weight of 30 lb and a length of 26 ft. If it is placed against the smooth wall and on the rough floor in the position $d = 10$ ft, will it remain in this position when it is released? The coefficient of static friction is $\mu_s = 0.3$.

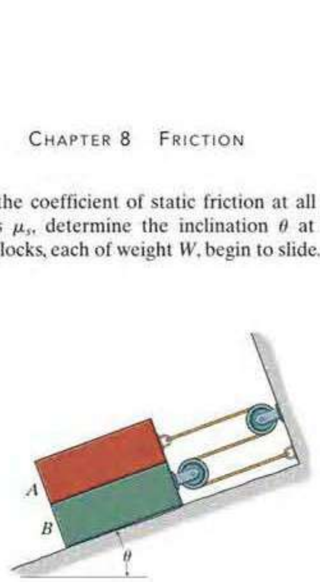
*__8–8.__ The uniform pole has a weight of 30 lb and a length of 26 ft. Determine the maximum distance d it can be placed from the smooth wall and not slip. The coefficient of static friction between the floor and the pole is $\mu_s = 0.3$.

8



Probs. 8–7/8

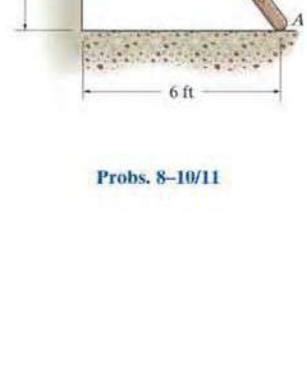
•8–9. If the coefficient of static friction at all contacting surfaces is μ_s, determine the inclination θ at which the identical blocks, each of weight W, begin to slide.



Prob. 8–9

8–10. The uniform 20-lb ladder rests on the rough floor for which the coefficient of static friction is $\mu_s = 0.8$ and against the smooth wall at B. Determine the horizontal force P the man must exert on the ladder in order to cause it to move.

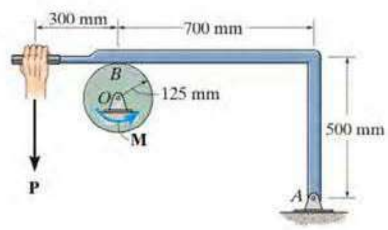
8–11. The uniform 20-lb ladder rests on the rough floor for which the coefficient of static friction is $\mu_s = 0.4$ and against the smooth wall at B. Determine the horizontal force P the man must exert on the ladder in order to cause it to move.



Probs. 8–10/11

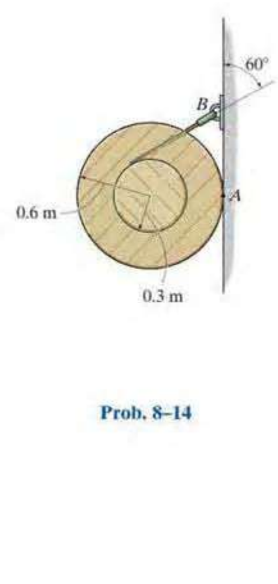
*8–12. The coefficients of static and kinetic friction between the drum and brake bar are $\mu_s = 0.4$ and $\mu_k = 0.3$, respectively. If $M = 50\ \text{N}\cdot\text{m}$ and $P = 85$ N determine the horizontal and vertical components of reaction at the pin O. Neglect the weight and thickness of the brake. The drum has a mass of 25 kg.

•8–13. The coefficient of static friction between the drum and brake bar is $\mu_s = 0.4$. If the moment $M = 35\ \text{N}\cdot\text{m}$, determine the smallest force P that needs to be applied to the brake bar in order to prevent the drum from rotating. Also determine the corresponding horizontal and vertical components of reaction at pin O. Neglect the weight and thickness of the brake bar. The drum has a mass of 25 kg.



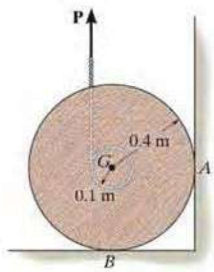
Probs. 8–12/13

8–14. Determine the minimum coefficient of static friction between the uniform 50-kg spool and the wall so that the spool does not slip.



Prob. 8–14

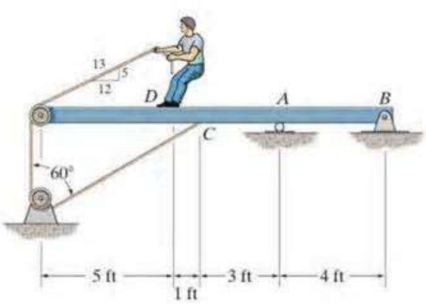
8–15. The spool has a mass of 200 kg and rests against the wall and on the floor. If the coefficient of static friction at B is $(\mu_s)_B = 0.3$, the coefficient of kinetic friction is $(\mu_k)_B = 0.2$, and the wall is smooth, determine the friction force developed at B when the vertical force applied to the cable is $P = 800$ N.



Prob. 8–15

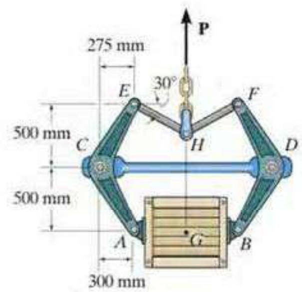
*__8–16.__ The 80-lb boy stands on the beam and pulls on the cord with a force large enough to just cause him to slip. If the coefficient of static friction between his shoes and the beam is $(\mu_s)_D = 0.4$, determine the reactions at A and B. The beam is uniform and has a weight of 100 lb. Neglect the size of the pulleys and the thickness of the beam.

•**8–17.** The 80-lb boy stands on the beam and pulls with a force of 40 lb. If $(\mu_s)_D = 0.4$, determine the frictional force between his shoes and the beam and the reactions at A and B. The beam is uniform and has a weight of 100 lb. Neglect the size of the pulleys and the thickness of the beam.



Probs. 8–16/17

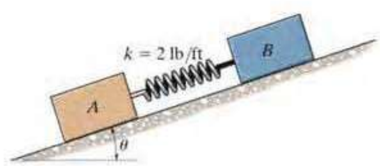
8–18. The tongs are used to lift the 150-kg crate, whose center of mass is at G. Determine the least coefficient of static friction at the pivot blocks so that the crate can be lifted.



Prob. 8–18

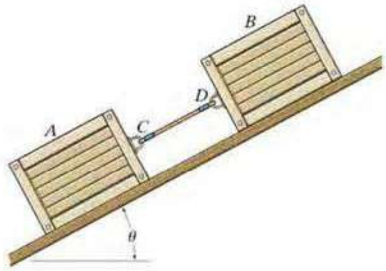
8–19. Two blocks A and B have a weight of 10 lb and 6 lb, respectively. They are resting on the incline for which the coefficients of static friction are $\mu_A = 0.15$ and $\mu_B = 0.25$. Determine the incline angle θ for which both blocks begin to slide. Also find the required stretch or compression in the connecting spring for this to occur. The spring has a stiffness of $k = 2$ lb/ft.

*__8–20.__ Two blocks A and B have a weight of 10 lb and 6 lb, respectively. They are resting on the incline for which the coefficients of static friction are $\mu_A = 0.15$ and $\mu_B = 0.25$. Determine the angle θ which will cause motion of one of the blocks. What is the friction force under each of the blocks when this occurs? The spring has a stiffness of $k = 2$ lb/ft and is originally unstretched.



Probs. 8–19/20

•**8–21.** Crates A and B weigh 200 lb and 150 lb, respectively. They are connected together with a cable and placed on the inclined plane. If the angle θ is gradually increased, determine θ when the crates begin to slide. The coefficients of static friction between the crates and the plane are $\mu_A = 0.25$ and $\mu_B = 0.35$.

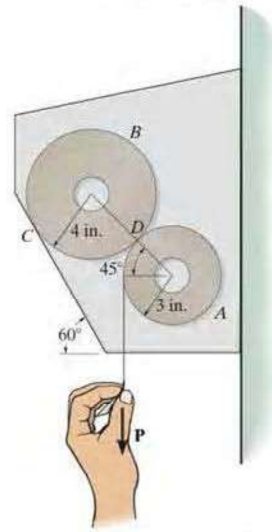


Prob. 8–21

8–22. A man attempts to support a stack of books horizontally by applying a compressive force of $F = 120$ N to the ends of the stack with his hands. If each book has a mass of 0.95 kg, determine the greatest number of books that can be supported in the stack. The coefficient of static friction between the man's hands and a book is $(\mu_s)_h = 0.6$ and between any two books $(\mu_s)_b = 0.4$.

Prob. 8–22

8–23. The paper towel dispenser carries two rolls of paper. The one in use is called the stub roll A and the other is the fresh roll B. They weigh 2 lb and 5 lb, respectively. If the coefficients of static friction at the points of contact C and D are $(\mu_s)_C = 0.2$ and $(\mu_s)_D = 0.5$, determine the initial vertical force P that must be applied to the paper on the stub roll in order to pull down a sheet. The stub roll is pinned in the center, whereas the fresh roll is not. Neglect friction at the pin.



Prob. 8–23

*__8–24.__ The drum has a weight of 100 lb and rests on the floor for which the coefficient of static friction is $\mu_s = 0.6$. If $a = 2$ ft and $b = 3$ ft, determine the smallest magnitude of the force P that will cause impending motion of the drum.

•**8–25.** The drum has a weight of 100 lb and rests on the floor for which the coefficient of static friction is $\mu_s = 0.5$. If $a = 3$ ft and $b = 4$ ft, determine the smallest magnitude of the force P that will cause impending motion of the drum.

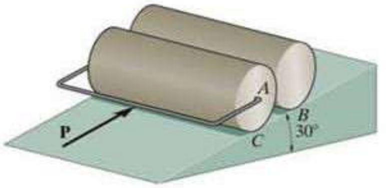
Probs. 8–24/25

8–26. The refrigerator has a weight of 180 lb and rests on a tile floor for which $\mu_s = 0.25$. If the man pushes horizontally on the refrigerator in the direction shown, determine the smallest magnitude of horizontal force needed to move it. Also, if the man has a weight of 150 lb, determine the smallest coefficient of friction between his shoes and the floor so that he does not slip.

8–27. The refrigerator has a weight of 180 lb and rests on a tile floor for which $\mu_s = 0.25$. Also, the man has a weight of 150 lb and the coefficient of static friction between the floor and his shoes is $\mu_s = 0.6$. If he pushes horizontally on the refrigerator, determine if he can move it. If so, does the refrigerator slip or tip?

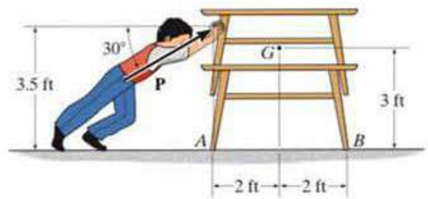
Probs. 8–26/27

*__8–28.__ Determine the minimum force P needed to push the two 75-kg cylinders up the incline. The force acts parallel to the plane and the coefficients of static friction of the contacting surfaces are $\mu_A = 0.3$, $\mu_B = 0.25$, and $\mu_C = 0.4$. Each cylinder has a radius of 150 mm.



Prob. 8–28

•**8–29.** If the center of gravity of the stacked tables is at G, and the stack weighs 100 lb, determine the smallest force P the boy must push on the stack in order to cause movement. The coefficient of static friction at A and B is $\mu_s = 0.3$. The tables are locked together.

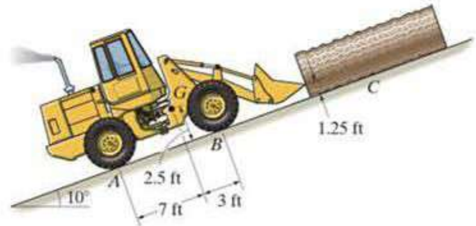


Prob. 8–29

8–30. The tractor has a weight of 8000 lb with center of gravity at G. Determine if it can push the 550-lb log up the incline. The coefficient of static friction between the log and the ground is $\mu_s = 0.5$, and between the rear wheels of the tractor and the ground $\mu_s' = 0.8$. The front wheels are free to roll. Assume the engine can develop enough torque to cause the rear wheels to slip.

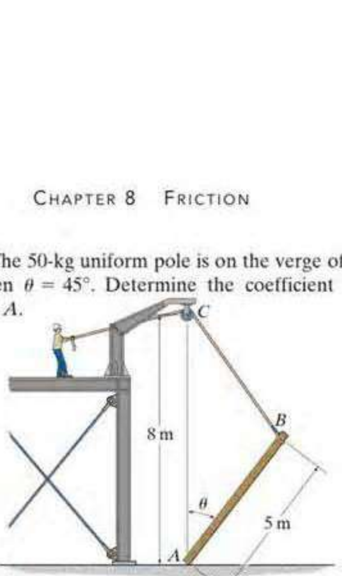
8–31. The tractor has a weight of 8000 lb with center of gravity at G. Determine the greatest weight of the log that can be pushed up the incline. The coefficient of static friction between the log and the ground is $\mu_s = 0.5$, and between the rear wheels of the tractor and the ground $\mu_s' = 0.7$. The front wheels are free to roll. Assume the engine can develop enough torque to cause the rear wheels to slip.

8



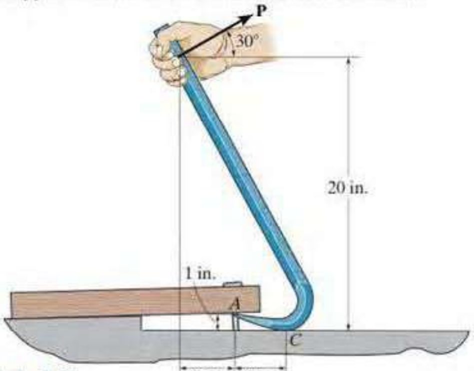
Probs. 8–30/31

*8–32. The 50-kg uniform pole is on the verge of slipping at A when $\theta = 45^\circ$. Determine the coefficient of static friction at A.



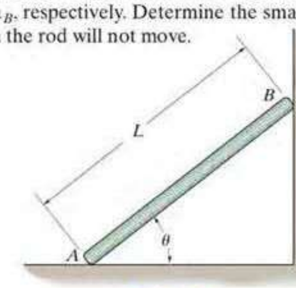
Prob. 8–32

•8–33. A force of $P = 20$ lb is applied perpendicular to the handle of the gooseneck wrecking bar as shown. If the coefficient of static friction between the bar and the wood is $\mu_s = 0.5$, determine the normal force of the tines at A on the upper board. Assume the surface at C is smooth.



Prob. 8–33

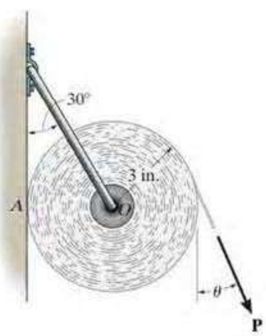
8–34. The thin rod has a weight W and rests against the floor and wall for which the coefficients of static friction are μ_A and μ_B, respectively. Determine the smallest value of θ for which the rod will not move.



Prob. 8–34

8–35. A roll of paper has a uniform weight of 0.75 lb and is suspended from the wire hanger so that it rests against the wall. If the hanger has a negligible weight and the bearing at O can be considered frictionless, determine the force P needed to start turning the roll if $\theta = 30^\circ$. The coefficient of static friction between the wall and the paper is $\mu_s = 0.25$.

*8–36. A roll of paper has a uniform weight of 0.75 lb and is suspended from the wire hanger so that it rests against the wall. If the hanger has a negligible weight and the bearing at O can be considered frictionless, determine the minimum force P and the associated angle θ needed to start turning the roll. The coefficient of static friction between the wall and the paper is $\mu_s = 0.25$.



Probs. 8–35/36

•8–37. If the coefficient of static friction between the chain and the inclined plane is $\mu_s = \tan\theta$, determine the overhang length b so that the chain is on the verge of slipping up the plane. The chain weighs w per unit length.

Prob. 8–37

EXAMPLE 10.4

Determine the moment of inertia of the area shown in Fig. 10–8*a* about the *x* axis.

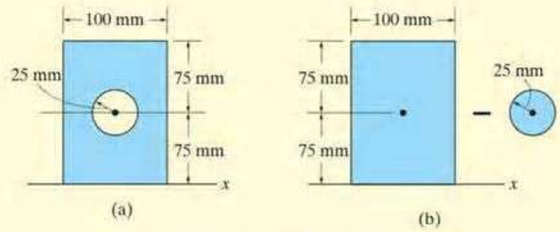


Fig. 10–8

SOLUTION

Composite Parts. The area can be obtained by *subtracting* the circle from the rectangle shown in Fig. 10–8*b*. The centroid of each area is located in the figure.

Parallel-Axis Theorem. The moments of inertia about the *x* axis are determined using the parallel-axis theorem and the data in the table on the inside back cover.

Circle

$$I_x = \bar{I}_{x'} + Ad_y^2$$
$$= \frac{1}{4}\pi(25)^4 + \pi(25)^2(75)^2 = 11.4(10^6)\text{ mm}^4$$

Rectangle

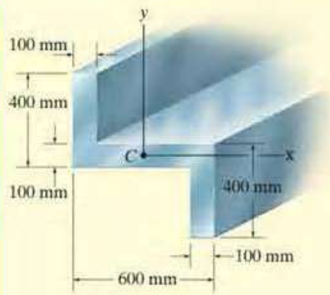
$$I_x = \bar{I}_{x'} + Ad_y^2$$
$$= \frac{1}{12}(100)(150)^3 + (100)(150)(75)^2 = 112.5(10^6)\text{ mm}^4$$

Summation. The moment of inertia for the area is therefore

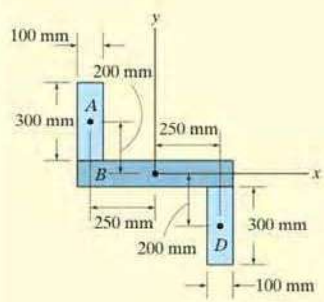
$$I_x = -11.4(10^6) + 112.5(10^6)$$
$$= 101(10^6)\text{ mm}^4 \qquad \textit{Ans.}$$

10

EXAMPLE 10.5



(a)



(b)

Fig. 10–9

Determine the moments of inertia for the cross-sectional area of the member shown in Fig. 10–9*a* about the *x* and *y* centroidal axes.

SOLUTION

Composite Parts. The cross section can be subdivided into the three rectangular areas *A*, *B*, and *D* shown in Fig. 10–9*b*. For the calculation, the centroid of each of these rectangles is located in the figure.

Parallel-Axis Theorem. From the table on the inside back cover, or Example 10.1, the moment of inertia of a rectangle about its centroidal axis is $\bar{I} = \frac{1}{12}bh^3$. Hence, using the parallel-axis theorem for rectangles *A* and *D*, the calculations are as follows:

Rectangles A and D

$$I_x = \bar{I}_{x'} + Ad_y^2 = \frac{1}{12}(100)(300)^3 + (100)(300)(200)^2$$

$$= 1.425(10^9)\text{ mm}^4$$

$$I_y = \bar{I}_{y'} + Ad_x^2 = \frac{1}{12}(300)(100)^3 + (100)(300)(250)^2$$

$$= 1.90(10^9)\text{ mm}^4$$

Rectangle B

$$I_x = \frac{1}{12}(600)(100)^3 = 0.05(10^9)\text{ mm}^4$$

$$I_y = \frac{1}{12}(100)(600)^3 = 1.80(10^9)\text{ mm}^4$$

Summation. The moments of inertia for the entire cross section are thus

$$I_x = 2[1.425(10^9)] + 0.05(10^9)$$

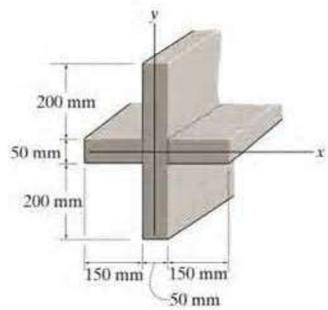
$$= 2.90(10^9)\text{ mm}^4 \qquad \textit{Ans.}$$

$$I_y = 2[1.90(10^9)] + 1.80(10^9)$$

$$= 5.60(10^9)\text{ mm}^4 \qquad \textit{Ans.}$$

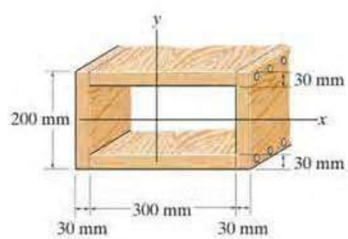
FUNDAMENTAL PROBLEMS

F10–5. Determine the moment of inertia of the beam's cross-sectional area about the centroidal x and y axes.



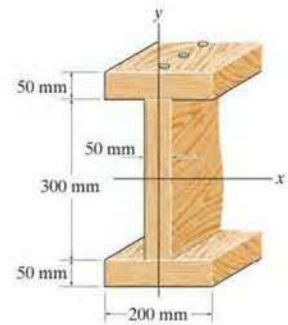
F10–5

F10–6. Determine the moment of inertia of the beam's cross-sectional area about the centroidal x and y axes.



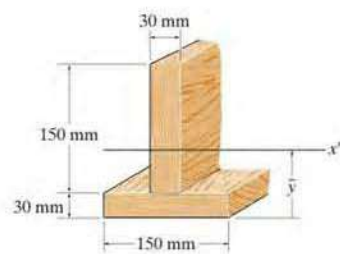
F10–6

F10–7. Determine the moment of inertia of the cross-sectional area of the channel with respect to the y axis.



F10–7

F10–8. Determine the moment of inertia of the cross-sectional area of the T-beam with respect to the x' axis passing through the centroid of the cross section.



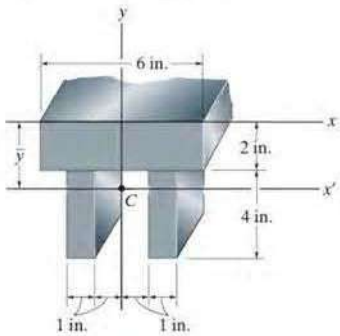
F10–8

PROBLEMS

10–27. Determine the distance $\bar{y}$ to the centroid of the beam's cross-sectional area; then find the moment of inertia about the x' axis.

***10–28.** Determine the moment of inertia of the beam's cross-sectional area about the x axis.

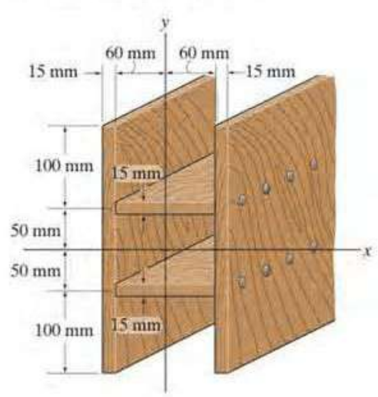
•10–29. Determine the moment of inertia of the beam's cross-sectional area about the y axis.



Probs. 10–27/28/29

10–30. Determine the moment of inertia of the beam's cross-sectional area about the x axis.

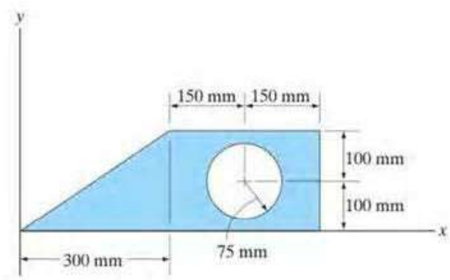
10–31. Determine the moment of inertia of the beam's cross-sectional area about the y axis.



Probs. 10–30/31

***10–32.** Determine the moment of inertia of the composite area about the x axis.

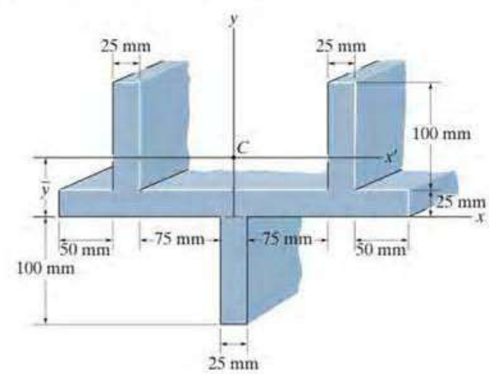
•10–33. Determine the moment of inertia of the composite area about the y axis.



Probs. 10–32/33

10–34. Determine the distance $\bar{y}$ to the centroid of the beam's cross-sectional area; then determine the moment of inertia about the x' axis.

10–35. Determine the moment of inertia of the beam's cross-sectional area about the y axis.



Probs. 10–34/35

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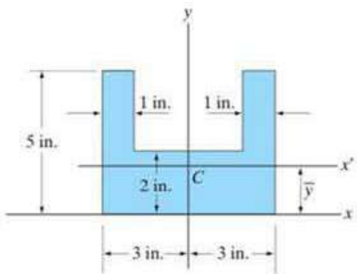
*10–36. Locate the centroid $\bar{y}$ of the composite area, then determine the moment of inertia of this area about the centroidal x' axis.

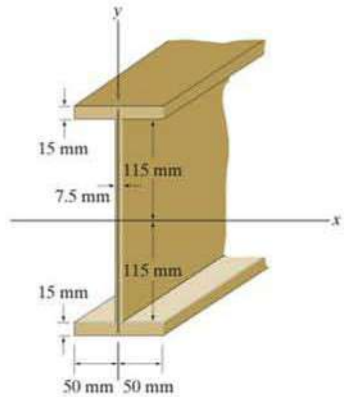
•10–37. Determine the moment of inertia of the composite area about the centroidal y axis.



Probs. 10–36/37

•10–41. Determine the moment of inertia of the beam's cross-sectional area about the x axis.

10–42. Determine the moment of inertia of the beam's cross-sectional area about the y axis.

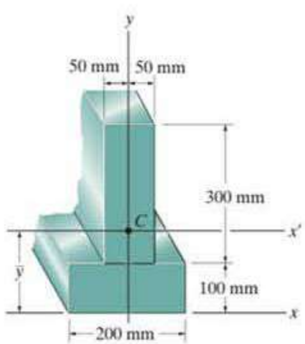


Probs. 10–41/42

10–38. Determine the distance $\bar{y}$ to the centroid of the beam's cross-sectional area; then find the moment of inertia about the x' axis.

10–39. Determine the moment of inertia of the beam's cross-sectional area about the x axis.

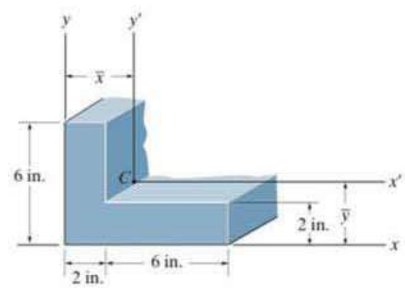
*10–40. Determine the moment of inertia of the beam's cross-sectional area about the y axis.



Probs. 10–38/39/40

10–43. Locate the centroid $\bar{y}$ of the cross-sectional area for the angle. Then find the moment of inertia $I_{x'}$ about the x' centroidal axis.

*10–44. Locate the centroid $\bar{x}$ of the cross-sectional area for the angle. Then find the moment of inertia $I_{y'}$ about the y' centroidal axis.



Probs. 10–43/44

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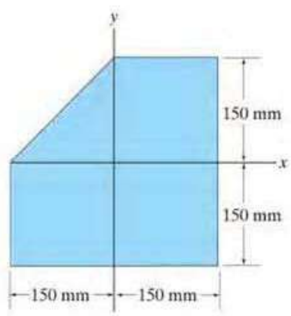
•**10–45.** Determine the moment of inertia of the composite area about the x axis.

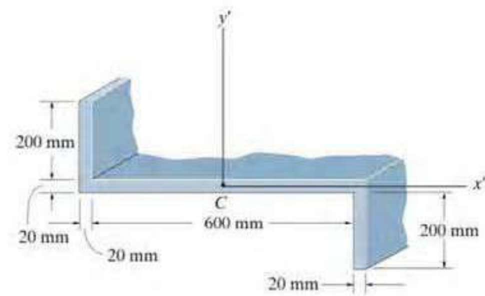
10–46. Determine the moment of inertia of the composite area about the y axis.



Probs. 10–45/46

•**10–49.** Determine the moment of inertia $I_{x'}$ of the section. The origin of coordinates is at the centroid C.

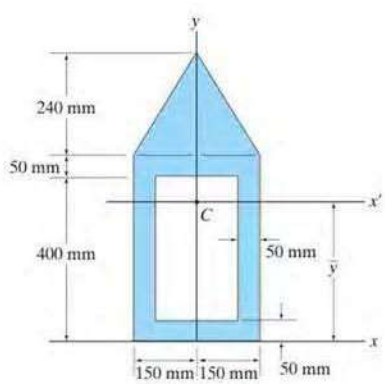
10–50. Determine the moment of inertia $I_{y'}$ of the section. The origin of coordinates is at the centroid C.



Probs. 10–49/50

10–47. Determine the moment of inertia of the composite area about the centroidal y axis.

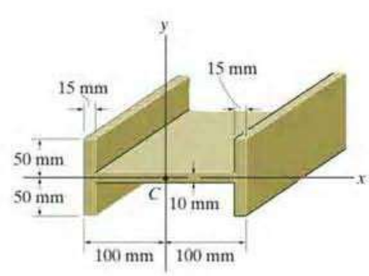
*__10–48.__ Locate the centroid $\bar{y}$ of the composite area, then determine the moment of inertia of this area about the x' axis.



Probs. 10–47/48

10–51. Determine the beam's moment of inertia I_x about the centroidal x axis.

*__10–52.__ Determine the beam's moment of inertia I_y about the centroidal y axis.

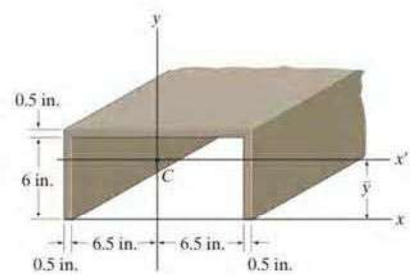


Probs. 10–51/52

10

•**10–53.** Locate the centroid $\bar{y}$ of the channel's cross-sectional area, then determine the moment of inertia of the area about the centroidal x' axis.

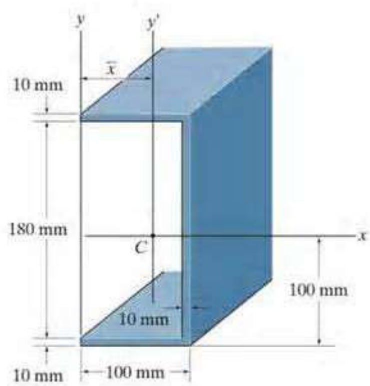
10–54. Determine the moment of inertia of the area of the channel about the y axis.



Probs. 10–53/54

10–55. Determine the moment of inertia of the cross-sectional area about the x axis.

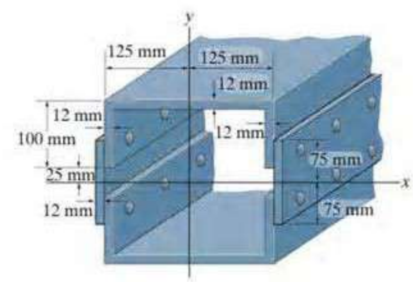
*__10–56.__ Locate the centroid $\bar{x}$ of the beam's cross-sectional area, and then determine the moment of inertia of the area about the centroidal y' axis.



Probs. 10–55/56

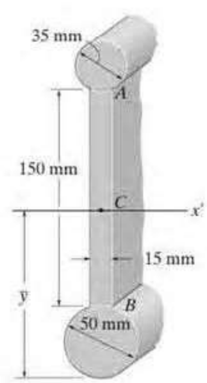
•**10–57.** Determine the moment of inertia of the beam's cross-sectional area about the x axis.

10–58. Determine the moment of inertia of the beam's cross-sectional area about the y axis.



Probs. 10–57/58

10–59. Determine the moment of inertia of the beam's cross-sectional area with respect to the x' axis passing through the centroid C of the cross section. $\bar{y} = 104.3$ mm.



Prob. 10–59

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