Questions

1. Describe several situations in which an object is not in equilibrium, even though the net force on it is zero.

2. A bungee jumper momentarily comes to rest at the bottom of the dive before he springs back upward. At that moment, is the bungee jumper in equilibrium? Explain.

3. You can find the center of gravity of a meter stick by resting it horizontally on your two index fingers, and then slowly drawing your fingers together. First the meter stick will slip on one finger, and then on the other, but eventually the fingers meet at the CG. Why does this work?

4. Your doctor's scale has arms on which weights slide to counter your weight, Fig. 9–35. These weights are much lighter than you are. How does this work?

FIGURE 9–35 Question 4.

5. A ground retaining wall is shown in Fig. 9–36a. The ground, particularly when wet, can exert a significant force F on the wall. (*a*) What force produces the torque to keep the wall upright? (*b*) Explain why the retaining wall in Fig. 9–36b would be much less likely to overturn than that in Fig. 9–36a.

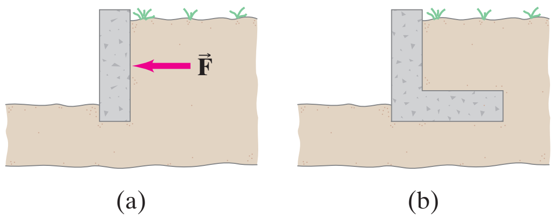

FIGURE 9–36 Question 5.

6. Can the sum of the torques on an object be zero while the net force on the object is nonzero? Explain.

7. A ladder, leaning against a wall, makes a 60° angle with the ground. When is it more likely to slip: when a person stands on the ladder near the top or near the bottom? Explain.

8. A uniform meter stick supported at the 25-cm mark is in equilibrium when a 1-kg rock is suspended at the 0-cm end (as shown in Fig. 9–37). Is the mass of the meter stick greater than, equal to, or less than the mass of the rock? Explain your reasoning.

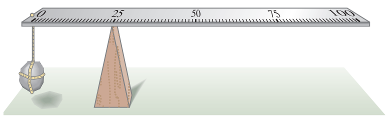

FIGURE 9–37 Question 8.

9. Why do you tend to lean backward when carrying a heavy load in your arms?

10. Figure 9–38 shows a cone. Explain how to lay it on a flat table so that it is in (*a*) stable equilibrium, (*b*) unstable equilibrium, (*c*) neutral equilibrium.

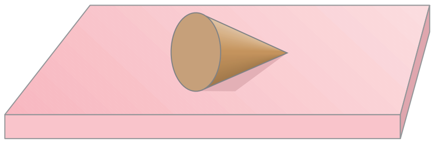

FIGURE 9–38 Question 10.

11. Place yourself facing the edge of an open door. Position your feet astride the door with your nose and abdomen touching the door's edge. Try to rise on your tiptoes. Why can't this be done?

12. Why is it not possible to sit upright in a chair and rise to your feet without first leaning forward?

13. Why is it more difficult to do sit-ups when your knees are bent than when your legs are stretched out?

14. Explain why touching your toes while you are seated on the floor with outstretched legs produces less stress on the lower spinal column than when touching your toes from a standing position. Use a diagram.

15. Which configuration of bricks, Fig. 9–39a or Fig. 9–39b, is the more likely to be stable? Why?

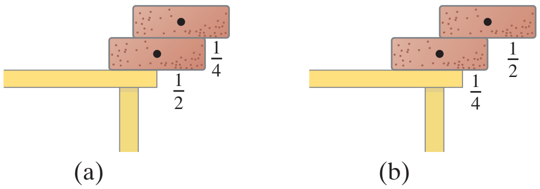

FIGURE 9–39 Question 15. The dots indicate the CG of each brick (assumed uniform). The fractions $\frac{1}{4}$ and $\frac{1}{2}$ indicate what portion of each brick is hanging beyond its support.

16. Name the type of equilibrium for each position of the ball in Fig. 9–40.

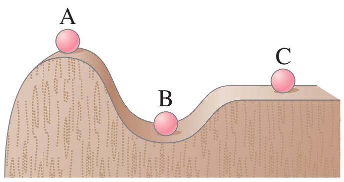

FIGURE 9–40 Question 16.

17. Is the Young's modulus for a bungee cord smaller or larger than that for an ordinary rope?

18. Examine how a pair of scissors or shears cuts through a piece of cardboard. Is the name "shears" justified? Explain.

19. Materials such as ordinary concrete and stone are very weak under tension or shear. Would it be wise to use such a material for either of the supports of the cantilever shown in Fig. 9–9? If so, which one(s)? Explain.

MisConceptual Questions

1. A 60-kg woman stands on the very end of a uniform board, of length ℓ, which is supported one-quarter of the way from one end and is balanced (Fig. 9–41). What is the mass of the board?
(*a*) 15 kg. (*b*) 20 kg. (*c*) 30 kg. (*d*) 60 kg. (*e*) 120 kg.

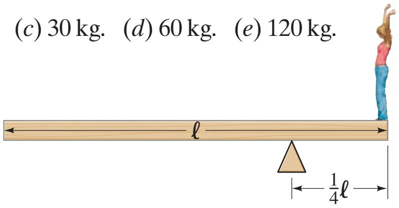

FIGURE 9–41 MisConceptual Question 1.

2. When you apply the torque equation $\Sigma\tau = 0$ to an object in equilibrium, the axis about which torques are calculated
(*a*) must be located at a pivot.
(*b*) must be located at the object's center of gravity.
(*c*) should be located at the edge of the object.
(*d*) can be located anywhere.

3. A uniform beam is hinged at one end and held in a horizontal position by a cable, as shown in Fig. 9–42. The tension in the cable
(*a*) must be at least half the weight of the beam, no matter what the angle of the cable.
(*b*) could be less than half the beam's weight for some angles.
(*c*) will be half the beam's weight for all angles.
(*d*) will equal the beam's weight for all angles.

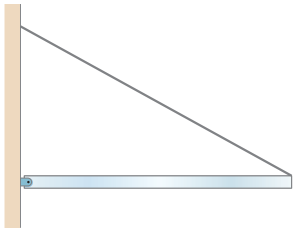

FIGURE 9–42 MisConceptual Question 3: beam and cable.

4. A heavy ball suspended by a cable is pulled to the side by a horizontal force $\vec{\mathbf{F}}$ as shown in Fig. 9–43. If angle θ is small, the magnitude of the force F can be less than the weight of the ball because:
(*a*) the force holds up only part of the ball's weight.
(*b*) even though the ball is stationary, it is not really in equilibrium.
(*c*) $\vec{\mathbf{F}}$ is equal to only the x component of the tension in the cable.
(*d*) the original statement is not true. To move the ball, $\vec{\mathbf{F}}$ must be at least equal to the ball's weight.

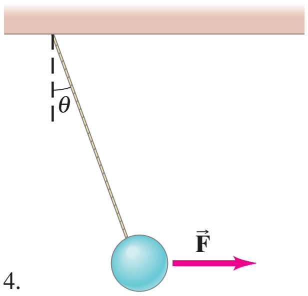

FIGURE 9–43 MisConceptual Question 4.

5. Two children are balanced on opposite sides of a seesaw. If one child leans inward toward the pivot point, her side will
(*a*) rise. (*b*) fall. (*c*) neither rise nor fall.

6. A 10.0-N weight is suspended by two cords as shown in Fig. 9–44. What can you say about the tension in the two cords?
(*a*) The tension in both cords is 5.0 N.
(*b*) The tension in both cords is equal but not 5.0 N.
(*c*) The tension in cord A is greater than that in cord B.
(*d*) The tension in cord B is greater than that in cord A.

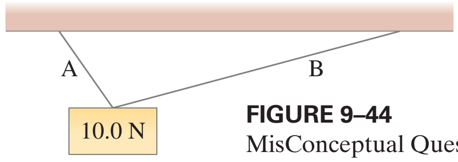

FIGURE 9–44 MisConceptual Question 6.

7. As you increase the force that you apply while pulling on a rope, which of the following is NOT affected?
(*a*) The stress on the rope.
(*b*) The strain on the rope.
(*c*) The Young's modulus of the rope.
(*d*) All of the above.
(*e*) None of the above.

8. A woman is balancing on a high wire which is tightly strung, as shown in Fig. 9–45. The tension in the wire is
(*a*) about half the woman's weight.
(*b*) about twice the woman's weight.
(*c*) about equal to the woman's weight.
(*d*) much less than the woman's weight.
(*e*) much more than the woman's weight.

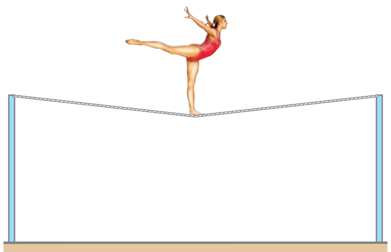

FIGURE 9–45 MisConceptual Question 8.

9. A parking garage is designed for two levels of cars. To make more money, the owner decides to double the size of the garage in each dimension (length, width, and number of levels). For the support columns to hold up four floors instead of two, how should he change the columns' diameter?
(*a*) Double the area of the columns by increasing their diameter by a factor of 2.
(*b*) Double the area of the columns by increasing their diameter by a factor of $\sqrt{2}$.
(*c*) Quadruple the area of the columns by increasing their diameter by a factor of 2.
(*d*) Increase the area of the columns by a factor of 8 by increasing their diameter by a factor of $2\sqrt{2}$.
(*e*) He doesn't need to increase the diameter of the columns.

10. A rubber band is stretched by 1.0 cm when a force of 0.35 N is applied to each end. If instead a force of 0.70 N is applied to each end, estimate how far the rubber band will stretch from its unstretched length:
(*a*) 0.25 cm. (*b*) 0.5 cm. (*c*) 1.0 cm. (*d*) 2.0 cm. (*e*) 4.0 cm.

For assigned homework and other learning materials, go to the MasteringPhysics website.

Problems

9–1 and 9–2 Equilibrium

1. (I) Three forces are applied to a tree sapling, as shown in Fig. 9–46, to stabilize it. If $\vec{\mathbf{F}}_A = 385\text{ N}$ and $\vec{\mathbf{F}}_B = 475\text{ N}$, find $\vec{\mathbf{F}}_C$ in magnitude and direction.

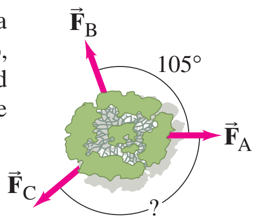

FIGURE 9–46 Problem 1.

2. (I) Calculate the mass m needed in order to suspend the leg shown in Fig. 9–47. Assume the leg (with cast) has a mass of 15.0 kg, and its CG is 35.0 cm from the hip joint; the cord holding the sling is 78.0 cm from the hip joint.

FIGURE 9–47 Problem 2.

3. (I) A tower crane (Fig. 9–48a) must always be carefully balanced so that there is no net torque tending to tip it. A particular crane at a building site is about to lift a 2800-kg air-conditioning unit. The crane's dimensions are shown in Fig. 9–48b. (*a*) Where must the crane's 9500-kg counterweight be placed when the load is lifted from the ground? (The counterweight is usually moved automatically via sensors and motors to precisely compensate for the load.) (*b*) Determine the maximum load that can be lifted with this counterweight when it is placed at its full extent. Ignore the mass of the beam.

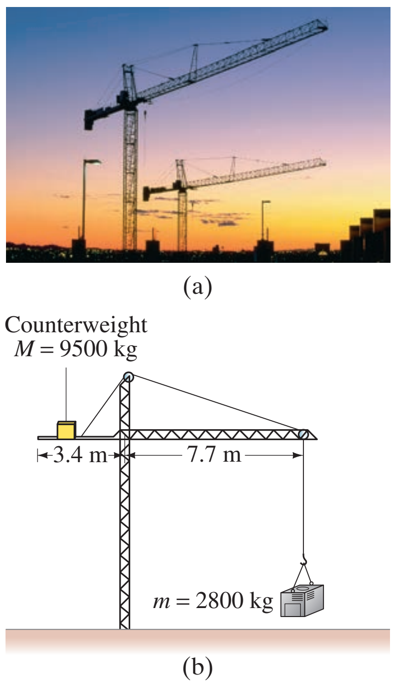

FIGURE 9–48 Problem 3.

4. (I) What is the mass of the diver in Fig. 9–49 if she exerts a torque of $1800\text{ m}\cdot\text{N}$ on the board, relative to the left (A) support post?

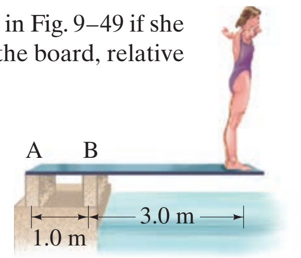

FIGURE 9–49 Problems 4 and 5.

5. (II) Calculate the forces F_A and F_B that the supports exert on the diving board of Fig. 9–49 when a 52-kg person stands at its tip. (*a*) Ignore the weight of the board. (*b*) Take into account the board's mass of 28 kg. Assume the board's CG is at its center.

6. (II) Figure 9–50 shows a pair of forceps used to hold a thin plastic rod firmly. If the thumb and finger each squeeze with a force $F_T = F_F = 11.0\text{ N}$, what force do the forceps jaws exert on the plastic rod?

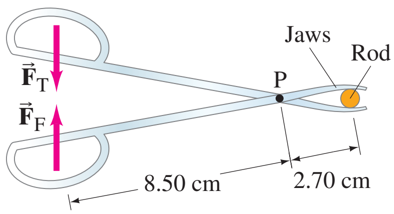

FIGURE 9–50 Problem 6.

7. (II) Two cords support a chandelier in the manner shown in Fig. 9–4 except that the upper cord makes an angle of 45° with the ceiling. If the cords can sustain a force of 1660 N without breaking, what is the maximum chandelier weight that can be supported?

8. (II) The two trees in Fig. 9–51 are 6.6 m apart. A backpacker is trying to lift his pack out of the reach of bears. Calculate the magnitude of the force $\vec{\mathbf{F}}$ that he must exert downward to hold a 19-kg backpack so that the rope sags at its midpoint by (*a*) 1.5 m, (*b*) 0.15 m.

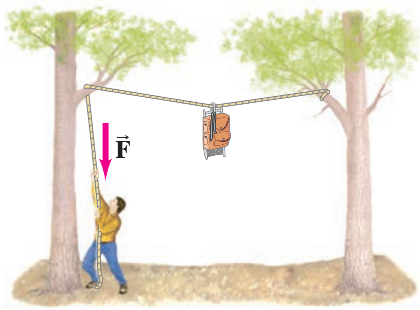

FIGURE 9–51 Problems 8 and 70.

9. (II) A 110-kg horizontal beam is supported at each end. A 320-kg piano rests a quarter of the way from one end. What is the vertical force on each of the supports?

10. (II) Calculate F_A and F_B for the uniform cantilever shown in Fig. 9–9 whose mass is 1200 kg.

11. (II) A 75-kg adult sits at one end of a 9.0-m-long board. His 25-kg child sits on the other end. (*a*) Where should the pivot be placed so that the board is balanced, ignoring the board's mass? (*b*) Find the pivot point if the board is uniform and has a mass of 15 kg.

12. (II) Find the tension in the two cords shown in Fig. 9–52. Neglect the mass of the cords, and assume that the angle θ is 33° and the mass m is 190 kg.

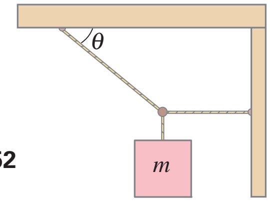

FIGURE 9–52 Problem 12.

13. (II) Find the tension in the two wires supporting the traffic light shown in Fig. 9–53.

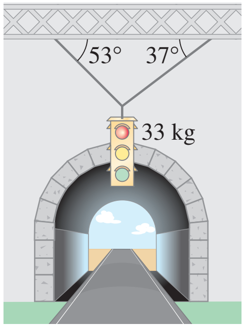

FIGURE 9–53 Problem 13.

14. (II) How close to the edge of the 24.0-kg table shown in Fig. 9–54 can a 66.0-kg person sit without tipping it over?

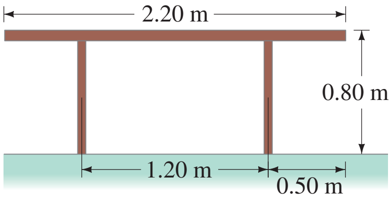

FIGURE 9–54 Problem 14.

15. (II) The force required to pull the cork out of the top of a wine bottle is in the range of 200 to 400 N. What range of forces F is required to open a wine bottle with the bottle opener shown in Fig. 9–55?

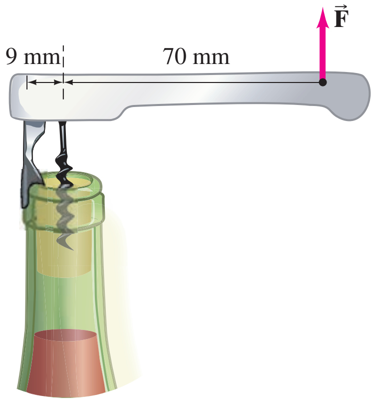

FIGURE 9–55 Problem 15.

16. (II) Calculate F_A and F_B for the beam shown in Fig. 9–56. The downward forces represent the weights of machinery on the beam. Assume the beam is uniform and has a mass of 280 kg.

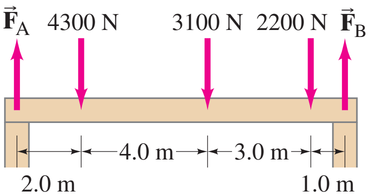

FIGURE 9–56 Problem 16.

17. (II) Three children are trying to balance on a seesaw, which includes a fulcrum rock acting as a pivot at the center, and a very light board 3.2 m long (Fig. 9–57). Two playmates are already on either end. Boy A has a mass of 45 kg, and boy B a mass of 35 kg. Where should girl C, whose mass is 25 kg, place herself so as to balance the seesaw?

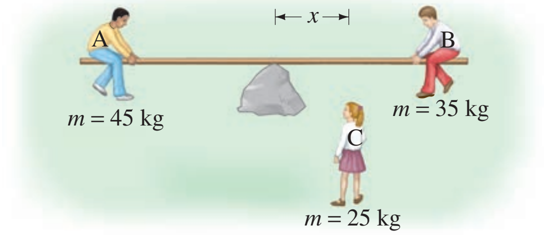

FIGURE 9–57 Problem 17.

18. (II) A shop sign weighing 215 N hangs from the end of a uniform 155-N beam as shown in Fig. 9–58. Find the tension in the supporting wire (at 35.0°), and the horizontal and vertical forces exerted by the hinge on the beam at the wall. [*Hint*: First draw a free-body diagram.]

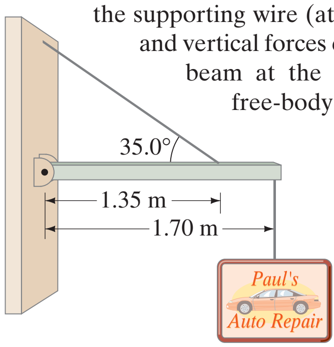

FIGURE 9–58 Problem 18.

19. (II) A traffic light hangs from a pole as shown in Fig. 9–59. The uniform aluminum pole AB is 7.20 m long and has a mass of 12.0 kg. The mass of the traffic light is 21.5 kg. Determine (*a*) the tension in the horizontal massless cable CD, and (*b*) the vertical and horizontal components of the force exerted by the pivot A on the aluminum pole.

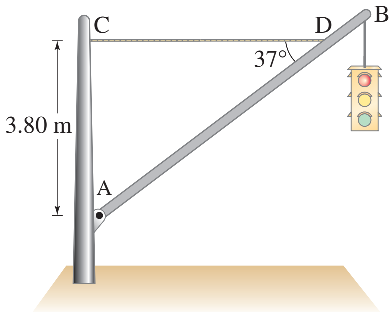

FIGURE 9–59 Problem 19.

20. (II) A uniform steel beam has a mass of 940 kg. On it is resting half of an identical beam, as shown in Fig. 9–60. What is the vertical support force at each end?

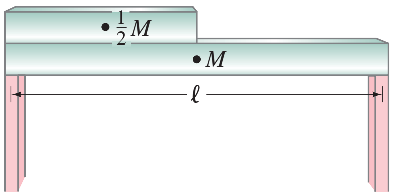

FIGURE 9–60 Problem 20.

21. (II) A 2500-kg trailer is attached to a stationary truck at point B, Fig. 9–61. Determine the normal force exerted by the road on the rear tires at A, and the vertical force exerted on the trailer by the support B.

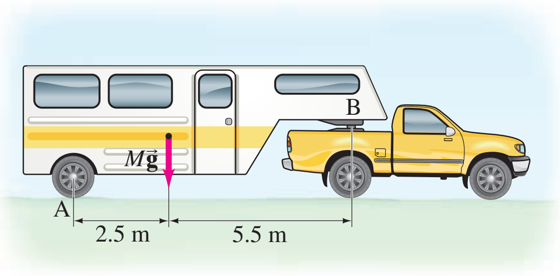

FIGURE 9–61 Problem 21.

22. (II) A 20.0-m-long uniform beam weighing 650 N rests on walls A and B, as shown in Fig. 9–62. (*a*) Find the maximum weight of a person who can walk to the extreme end D without tipping the beam. Find the forces that the walls A and B exert on the beam when the person is standing: (*b*) at D; (*c*) 2.0 m to the right of A.

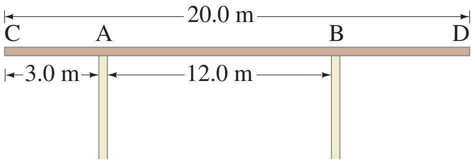

FIGURE 9–62 Problem 22.

23. (II) A 0.75-kg sheet is centered on a clothesline as shown in Fig. 9–63. The clothesline on either side of the hanging sheet makes an angle of 3.5° with the horizontal. Calculate the tension in the clothesline (ignore its mass) on either side of the sheet. Why is the tension so much greater than the weight of the sheet?

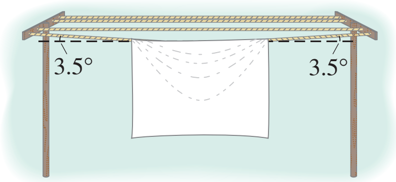

FIGURE 9–63 Problem 23.

24. (II) A 172-cm-tall person lies on a light (massless) board which is supported by two scales, one under the top of her head and one beneath the bottom of her feet (Fig. 9–64). The two scales read, respectively, 35.1 and 31.6 kg. What distance is the center of gravity of this person from the bottom of her feet?

FIGURE 9–64 Problem 24.

25. (II) A man doing push-ups pauses in the position shown in Fig. 9–65. His mass $m = 68$ kg. Determine the normal force exerted by the floor (*a*) on each hand; (*b*) on each foot.

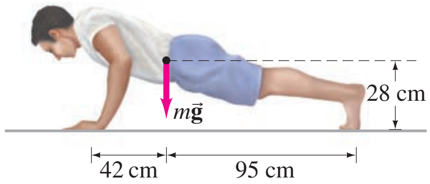

FIGURE 9–65 Problem 25.

26. (III) Two wires run from the top of a pole 2.6 m tall that supports a volleyball net. The two wires are anchored to the ground 2.0 m apart, and each is 2.0 m from the pole (Fig. 9–66). The tension in each wire is 115 N. What is the tension in the net, assumed horizontal and attached at the top of the pole?

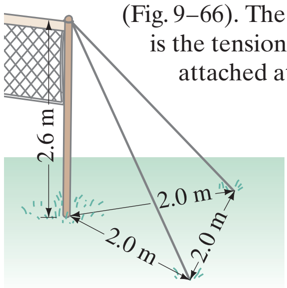

FIGURE 9–66 Problem 26.

27. (III) A uniform rod AB of length 5.0 m and mass $M = 3.8$ kg is hinged at A and held in equilibrium by a light cord, as shown in Fig. 9–67. A load $W = 22$ N hangs from the rod at a distance d so that the tension in the cord is 85 N. (*a*) Draw a free-body diagram for the rod. (*b*) Determine the vertical and horizontal forces on the rod exerted by the hinge. (*c*) Determine d from the appropriate torque equation.

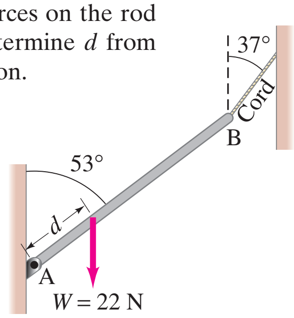

FIGURE 9–67 Problem 27.

28. (III) You are on a pirate ship and being forced to walk the plank (Fig. 9–68). You are standing at the point marked C. The plank is nailed onto the deck at point A, and rests on the support 0.75 m away from A. The center of mass of the uniform plank is located at point B. Your mass is 65 kg and the mass of the plank is 45 kg. What is the minimum downward force the nails must exert on the plank to hold it in place?

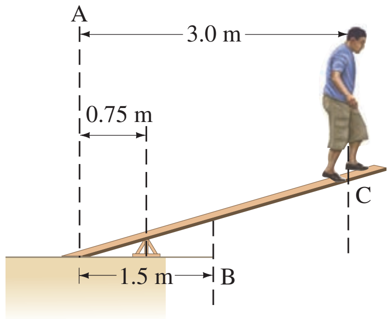

FIGURE 9–68 Problem 28.

29. (III) A door 2.30 m high and 1.30 m wide has a mass of 13.0 kg. A hinge 0.40 m from the top and another hinge 0.40 m from the bottom each support half the door's weight (Fig. 9–69). Assume that the center of gravity is at the geometrical center of the door, and determine the horizontal and vertical force components exerted by each hinge on the door.

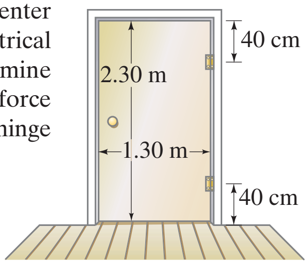

FIGURE 9–69 Problem 29.

9–3 Muscles and Joints

30. (I) Suppose the point of insertion of the biceps muscle into the lower arm shown in Fig. 9–13a (Example 9–8) is 6.0 cm instead of 5.0 cm; how much mass could the person hold with a muscle exertion of 450 N?

31. (I) Approximately what magnitude force, F_M, must the extensor muscle in the upper arm exert on the lower arm to hold a 7.3-kg shot put (Fig. 9–70)? Assume the lower arm has a mass of 2.3 kg and its CG is 12.0 cm from the elbow-joint pivot.

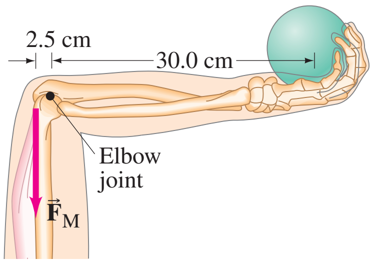

FIGURE 9–70 Problem 31.

32. (II) (*a*) Calculate the magnitude of the force, F_M, required of the "deltoid" muscle to hold up the outstretched arm shown in Fig. 9–71. The total mass of the arm is 3.3 kg. (*b*) Calculate the magnitude of the force F_J exerted by the shoulder joint on the upper arm and the angle (to the horizontal) at which it acts.

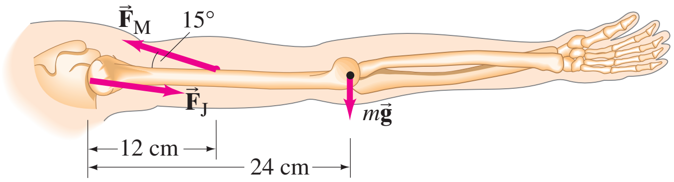

FIGURE 9–71 Problems 32 and 33.

33. (II) Suppose the hand in Problem 32 holds an 8.5-kg mass. What force, F_M, is required of the deltoid muscle, assuming the mass is 52 cm from the shoulder joint?

34. (II) If 25 kg is the maximum mass m that a person can hold in a hand when the arm is positioned with a 105° angle at the elbow as shown in Fig. 9–72, what is the maximum force F_{max} that the biceps muscle exerts on the forearm? Assume the forearm and hand have a total mass of 2.0 kg with a CG that is 15 cm from the elbow, and that the biceps muscle attaches 5.0 cm from the elbow.

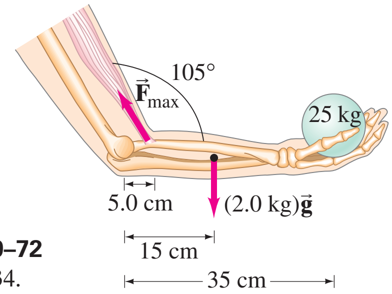

FIGURE 9–72 Problem 34.

9–4 Stability and Balance

35. (II) The Leaning Tower of Pisa is 55 m tall and about 7.7 m in radius. The top is 4.5 m off center. Is the tower in stable equilibrium? If so, how much farther can it lean before it becomes unstable? Assume the tower is of uniform composition.

36. (III) Four bricks are to be stacked at the edge of a table, each brick overhanging the one below it, so that the top brick extends as far as possible beyond the edge of the table. (*a*) To achieve this, show that successive bricks must extend no more than (starting at the top) $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{6}$, and $\frac{1}{8}$ of their length beyond the one below (Fig. 9–73a). (*b*) Is the top brick completely beyond the base? (*c*) Determine a general formula for the maximum total distance spanned by n bricks if they are to remain stable. (*d*) A builder wants to construct a corbeled arch (Fig. 9–73b) based on the principle of stability discussed in (*a*) and (*c*) above. What minimum number of bricks, each 0.30 m long and uniform, is needed if the arch is to span 1.0 m?

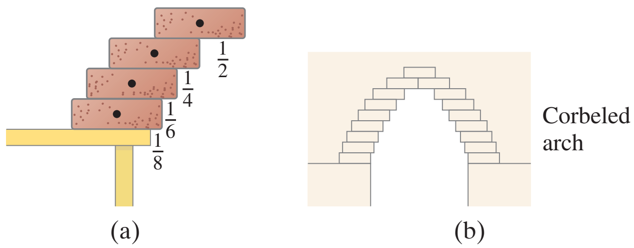

FIGURE 9–73 Problem 36.

9–5 Elasticity; Stress and Strain

37. (I) A nylon string on a tennis racket is under a tension of 275 N. If its diameter is 1.00 mm, by how much is it lengthened from its untensioned length of 30.0 cm?

38. (I) A marble column of cross-sectional area 1.4 m^2 supports a mass of 25,000 kg. (*a*) What is the stress within the column? (*b*) What is the strain?

39. (I) By how much is the column in Problem 38 shortened if it is 8.6 m high?

40. (I) A sign (mass 1700 kg) hangs from the bottom end of a vertical steel girder with a cross-sectional area of 0.012 m^2. (*a*) What is the stress within the girder? (*b*) What is the strain on the girder? (*c*) If the girder is 9.50 m long, how much is it lengthened? (Ignore the mass of the girder itself.)

41. (II) One liter of alcohol $(1000\ \text{cm}^3)$ in a flexible container is carried to the bottom of the sea, where the pressure is $2.6 \times 10^6\ \text{N/m}^2$. What will be its volume there?

42. (II) How much pressure is needed to compress the volume of an iron block by 0.10%? Express your answer in N/m^2, and compare it to atmospheric pressure $(1.0 \times 10^5\ \text{N/m}^2)$.

43. (II) A 15-cm-long tendon was found to stretch 3.7 mm by a force of 13.4 N. The tendon was approximately round with an average diameter of 8.5 mm. Calculate Young's modulus of this tendon.

44. (II) A steel wire 2.3 mm in diameter stretches by 0.030% when a mass is suspended from it. How large is the mass?

45. (II) At depths of 2000 m in the sea, the pressure is about 200 times atmospheric pressure $(1\ \text{atm} = 1.0 \times 10^5\ \text{N/m}^2)$. By what percentage does the interior space of an iron bathysphere's volume change at this depth?

9–6 Fracture

46. (I) The femur bone in the human leg has a minimum effective cross section of about 3.0 cm^2 $(= 3.0 \times 10^{-4}\ \text{m}^2)$. How much compressive force can it withstand before breaking?

47. (II) (*a*) What is the maximum tension possible in a 1.00-mm-diameter nylon tennis racket string? (*b*) If you want tighter strings, what do you do to prevent breakage: use thinner or thicker strings? Why? What causes strings to break when they are hit by the ball?

48. (II) (*a*) What is the minimum cross-sectional area required of a vertical steel cable from which is suspended a 270-kg chandelier? Assume a safety factor of 7.0. (*b*) If the cable is 7.5 m long, how much does it elongate?

49. (II) Assume the supports of the uniform cantilever shown in Fig. 9–74 (m = 2900 kg) are made of wood. Calculate the minimum cross-sectional area required of each, assuming a safety factor of 9.0.

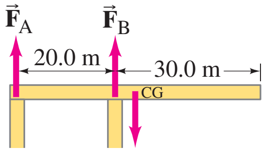

FIGURE 9–74 Problem 49.

50. (II) An iron bolt is used to connect two iron plates together. The bolt must withstand shear forces up to about 3300 N. Calculate the minimum diameter for the bolt, based on a safety factor of 7.0.

51. (III) A steel cable is to support an elevator whose total (loaded) mass is not to exceed 3100 kg. If the maximum acceleration of the elevator is 1.8 m/s^2, calculate the diameter of cable required. Assume a safety factor of 8.0.

*9–7 Arches and Domes

***52.** (II) How high must a pointed arch be if it is to span a space 8.0 m wide and exert one-third the horizontal force at its base that a round arch would?

***53.** (II) The subterranean tension ring that exerts the balancing horizontal force on the abutments for the dome in Fig. 9–34 is 36-sided, so each segment makes a 10° angle with the adjacent one (Fig. 9–75). Calculate the tension F that must exist in each segment so that the required force of 4.2×10^5 N can be exerted at each corner (Example 9–13).

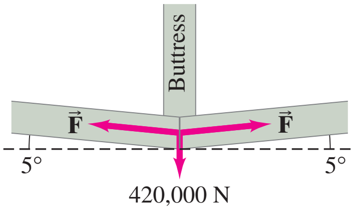

FIGURE 9–75 Problem 53.

General Problems

54. A woman holds a 2.0-m-long uniform 10.0-kg pole as shown in Fig. 9–76. (*a*) Determine the forces she must exert with each hand (magnitude and direction). To what position should she move her left hand so that neither hand has to exert a force greater than (*b*) 150 N? (*c*) 85 N?

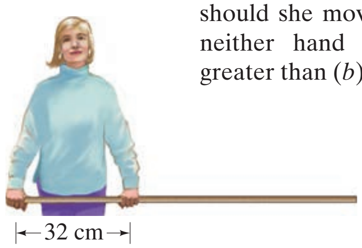

FIGURE 9–76 Problem 54.

55. A cube of side ℓ rests on a rough floor. It is subjected to a steady horizontal pull F, exerted a distance h above the floor as shown in Fig. 9–77. As F is increased, the block will either begin to slide, or begin to tip over. Determine the coefficient of static friction μ_s so that (*a*) the block begins to slide rather than tip; (*b*) the block begins to tip. [*Hint*: Where will the normal force on the block act if it tips?]

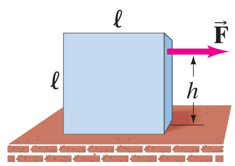

FIGURE 9–77 Problem 55.

56. A 50-story building is being planned. It is to be 180.0 m high with a base 46.0 m by 76.0 m. Its total mass will be about 1.8×10^7 kg, and its weight therefore about 1.8×10^8 N. Suppose a 200-km/h wind exerts a force of 950 N/m² over the 76.0-m-wide face (Fig. 9–78). Calculate the torque about the potential pivot point, the rear edge of the building (where $\vec{\mathbf{F}}_E$ acts in Fig. 9–78), and determine whether the building will topple. Assume the total force of the wind acts at the midpoint of the building's face, and that the building is not anchored in bedrock. [*Hint*: $\vec{\mathbf{F}}_E$ in Fig. 9–78 represents the force that the Earth would exert on the building in the case where the building would just begin to tip.]

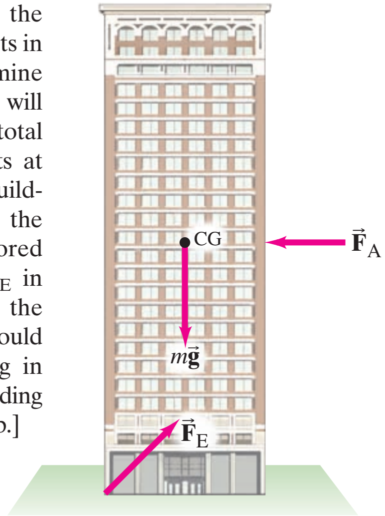

FIGURE 9–78 Forces on a building subjected to wind $(\vec{\mathbf{F}}_A)$, gravity $(m\vec{\mathbf{g}})$, and the force $\vec{\mathbf{F}}_E$ on the building due to the Earth if the building were just about to tip. Problem 56.

57. A uniform meter stick with a mass of 180 g is supported horizontally by two vertical strings, one at the 0-cm mark and the other at the 90-cm mark (Fig. 9–79). What is the tension in the string (*a*) at 0 cm? (*b*) at 90 cm?

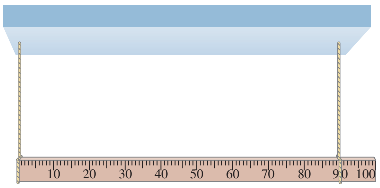

FIGURE 9–79 Problem 57.

58. There is a maximum height of a uniform vertical column made of any material that can support itself without buckling, and it is independent of the cross-sectional area (why?). Calculate this height for (*a*) steel (density 7.8×10^3 kg/m³), and (*b*) granite (density 2.7×10^3 kg/m³).

59. When a mass of 25 kg is hung from the middle of a fixed straight aluminum wire, the wire sags to make an angle of 12° with the horizontal as shown in Fig. 9–80. Determine the radius of the wire.

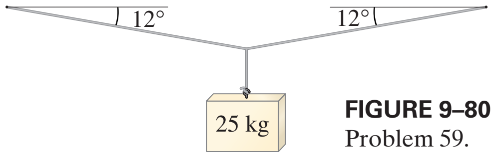

FIGURE 9–80 Problem 59.

60. A 65.0-kg painter is on a uniform 25-kg scaffold supported from above by ropes (Fig. 9–81). There is a 4.0-kg pail of paint to one side, as shown. Can the painter walk safely to both ends of the scaffold? If not, which end(s) is dangerous, and how close to the end can he approach safely?

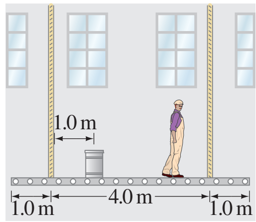

FIGURE 9–81 Problem 60.

61. A 15.0-kg ball is supported from the ceiling by rope A. Rope B pulls downward and to the side on the ball. If the angle of A to the vertical is 22° and if B makes an angle of 53° to the vertical (Fig. 9–82), find the tensions in ropes A and B.

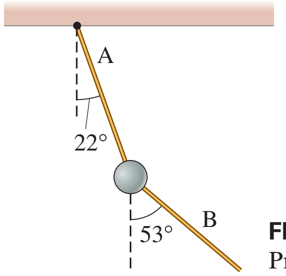

FIGURE 9–82 Problem 61.

62. The roof over a 9.0-m × 10.0-m room in a school has a total mass of 13,600 kg. The roof is to be supported by vertical wooden "2 × 4s" (actually about 4.0 cm × 9.0 cm) equally spaced along the 10.0-m sides. How many supports are required on each side, and how far apart must they be? Consider only compression, and assume a safety factor of 12.

63. A 23.0-kg backpack is suspended midway between two trees by a light cord as in Fig. 9–51. A bear grabs the backpack and pulls vertically downward with a constant force, so that each section of cord makes an angle of 27° below the horizontal. Initially, without the bear pulling, the angle was 15°; the tension in the cord with the bear pulling is double what it was when he was not. Calculate the force the bear is exerting on the backpack.

64. Two identical, uniform beams are symmetrically set up against each other (Fig. 9–83) on a floor with which they have a coefficient of friction $\mu_s = 0.50$. What is the minimum angle the beams can make with the floor and still not fall?

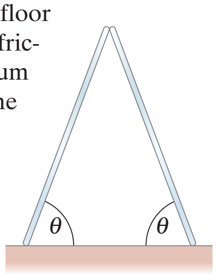

FIGURE 9–83 Problem 64.

65. A steel rod of radius $R = 15$ cm and length ℓ_0 stands upright on a firm surface. A 65-kg man climbs atop the rod. (*a*) Determine the percent decrease in the rod's length. (*b*) When a metal is compressed, each atom moves closer to its neighboring atom by exactly the same fractional amount. If iron atoms in steel are normally 2.0×10^{-10} m apart, by what distance did this interatomic spacing have to change in order to produce the normal force required to support the man? [*Note*: Neighboring atoms repel each other, and this repulsion accounts for the observed normal force.]

66. A 2.0-m-high box with a 1.0-m-square base is moved across a rough floor as in Fig. 9–84. The uniform box weighs 250 N and has a coefficient of static friction with the floor of 0.60. What minimum force must be exerted on the box to make it slide? What is the maximum height h above the floor that this force can be applied without tipping the box over? Note that as the box tips, the normal force and the friction force will act at the lowest corner.

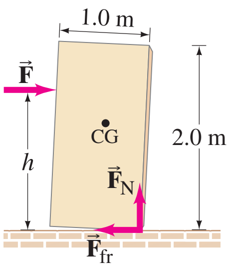

FIGURE 9–84 Problem 66.

67. A tightly stretched horizontal "high wire" is 36 m long. It sags vertically 2.1 m when a 60.0-kg tightrope walker stands at its center. What is the tension in the wire? Is it possible to increase the tension in the wire so that there is no sag?

68. Parachutists whose chutes have failed to open have been known to survive if they land in deep snow. Assume that a 75-kg parachutist hits the ground with an area of impact of $0.30\ \text{m}^2$ at a velocity of 55 m/s, and that the ultimate strength of body tissue is $5 \times 10^5\ \text{N/m}^2$. Assume that the person is brought to rest in 1.0 m of snow. Show that the person may escape serious injury.

69. If the left vertical support column in Example 9–5 is made of steel, what is its cross-sectional area? Assume that a safety factor of 3 was used in its design to avoid fracture.

70. The mobile in Fig. 9–85 is in equilibrium. Object B has mass of 0.748 kg. Determine the masses of objects A, C, and D. (Neglect the weights of the crossbars.)

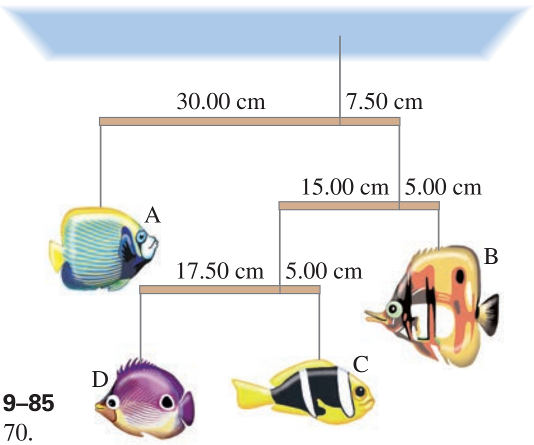

FIGURE 9–85 Problem 70.

71. When a wood shelf of mass 6.6 kg is fastened inside a slot in a vertical support as shown in Fig. 9–86, the support exerts a torque on the shelf. (*a*) Draw a free-body diagram for the shelf, assuming three vertical forces (two exerted by the support slot—explain why). Then calculate (*b*) the magnitudes of the three forces and (*c*) the torque exerted by the support (about the left end of the shelf).

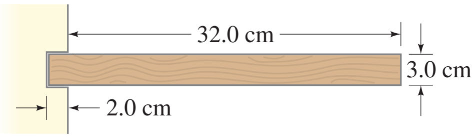

FIGURE 9–86 Problem 71.

72. A cubic crate of side $s = 2.0\,\text{m}$ is top-heavy: its CG is 18 cm above its true center. How steep an incline can the crate rest on without tipping over? [*Hint*: The normal force would act at the lowest corner.]

Search and Learn

1. Suppose a 65-kg person jumps from a height of 3.0 m down to the ground. (*a*) What is the speed of the person just before landing (Chapter 2)? (*b*) Estimate the average force on the person's feet exerted by the ground to bring the person to rest, if the knees are bent so the person's CG moves a distance $d = 50\,\text{cm}$ during the deceleration period (Fig. 9–87). [*Hint*: This force exerted by the ground ≠ net force. You may want to consult Chapters 2, 4, and 7, and be sure to draw a careful free-body diagram of the person.] (*c*) Estimate the decelerating force if the person lands stiff-legged so $d \approx 1.0\,\text{cm}$. (*d*) Estimate the stress in the tibia (a lower leg bone of area $= 3.0 \times 10^{-4}\,\text{m}^2$), and determine whether or not the bone will break if the landing is made with bent legs ($d = 50\,\text{cm}$). (*e*) Estimate the stress and determine if the tibia will break in a stiff-legged landing ($d = 1.0\,\text{cm}$).

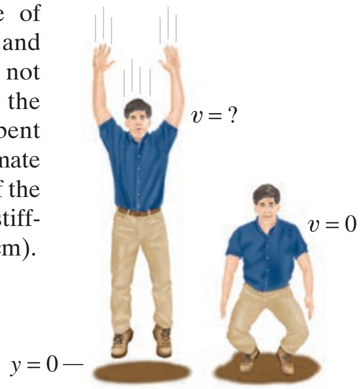

FIGURE 9–87 Search and Learn 1.

2. From what minimum height must a 1.2-kg rectangular brick $15.0\,\text{cm} \times 6.0\,\text{cm} \times 4.0\,\text{cm}$ be dropped above a rigid steel floor in order to break the brick? Assume the brick strikes the floor directly on its largest face, and that the compression of the brick is much greater than that of the steel (that is, ignore compression of the steel). State other simplifying assumptions that may be necessary.

3. Consider a ladder with a painter climbing up it (Fig. 9–88). The mass of the uniform ladder is 12.0 kg, and the mass of the painter is 55.0 kg. If the ladder begins to slip at its base when the painter's feet are 70% of the way up the length of the ladder, what is the coefficient of static friction between the ladder and the floor? Assume the wall is frictionless.

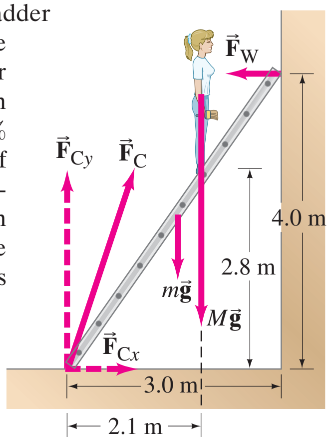

FIGURE 9–88 Search and Learn 3.

ANSWERS TO EXERCISES

A: F_A also has a component to balance the sideways force F_B.

B: Yes: $\cos\theta$ (angle of bar with ground) appears on both sides and cancels out.

C: $F_N = m_A g + m_B g + Mg$
$= (30\,\text{kg} + 25\,\text{kg} + 4.0\,\text{kg})\,g = 560\,\text{N}.$

D: (*a*).

E: (*b*).