Summary

An object at rest is said to be in **equilibrium**. The subject concerned with the determination of the forces within a structure at rest is called **statics**.

The two necessary conditions for an object to be in equilibrium are that (1) the vector sum of all the forces on it must be zero, and (2) the sum of all the torques (calculated about any arbitrary axis) must also be zero:

$$\Sigma F_x = 0, \qquad \Sigma F_y = 0, \qquad \Sigma\tau = 0. \qquad \textbf{(9–1, 9–2)}$$

It is important when doing statics problems to apply the equilibrium conditions to only one object at a time.

[*An object in static equilibrium is said to be in (*a*) **stable**, (*b*) **unstable**, or (*c*) **neutral equilibrium**, depending on whether a slight displacement leads to (*a*) a return to the original position, (*b*) further movement away from the original position, or (*c*) rest in the new position. An object in stable equilibrium is also said to be in **balance**.]

[***Hooke's law** applies to many elastic solids, and states that the change in length of an object is proportional to the applied force:

$$F = k\,\Delta L. \qquad \textbf{(9–3)}$$

If the force is too great, the object will exceed its **elastic limit**, which means it will no longer return to its original shape when the distorting force is removed. If the force is even greater, the **ultimate strength** of the material can be exceeded, and the object will **fracture**. The force per unit area acting on an object is called the **stress**, and the resulting fractional change in length is called the **strain**. The stress on an object is present within the object and can be of three types: **compression**, **tension**, or **shear**. The ratio of stress to strain is called the **elastic modulus** of the material. **Young's modulus** applies for compression and tension, and the **shear modulus** for shear; **bulk modulus** applies to an object whose volume changes as a result of pressure on all sides. All three moduli are constants for a given material when distorted within the elastic region.]

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?

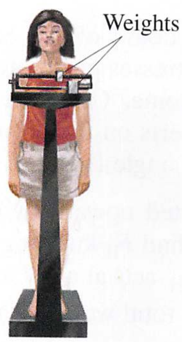
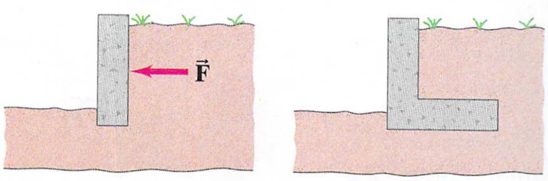


FIGURE 9–35 Question 4.

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.



(a) (b)

FIGURE 9–36 Question 5.

6. 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.
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.

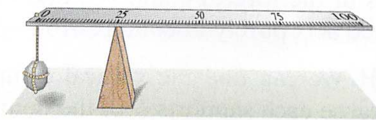


FIGURE 9–37 Question 8.

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

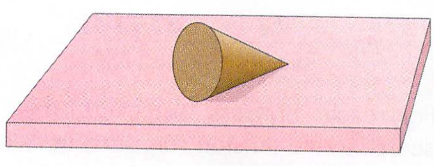


FIGURE 9–38 Question 10.

11. Which of the configurations of brick, (*a*) or (*b*) of Fig. 9–39, is the more likely to be stable? Why?

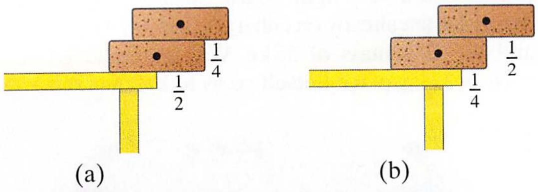


FIGURE 9–39 Question 11. The dots indicate the CG of each brick. The fractions $\frac{1}{4}$ and $\frac{1}{2}$ indicate what portion of each brick is hanging beyond its support.

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

13. 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?

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

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

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

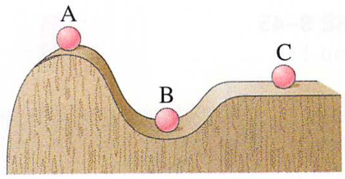


FIGURE 9–40 Question 16.

* 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.

Problems

9–1 and 9–2 Equilibrium

1. (I) Three forces are applied to a tree sapling, as shown in Fig. 9–41, to stabilize it. If $\vec{\mathbf{F}}_A = 310\,\text{N}$ and $\vec{\mathbf{F}}_B = 425\,\text{N}$, find $\vec{\mathbf{F}}_C$ in magnitude and direction.

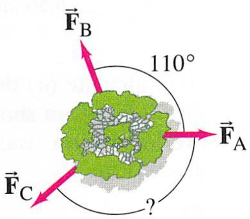


FIGURE 9–41 Problem 1.

2. (I) Calculate the torque about the front support post (B) of a diving board, Fig. 9–42, exerted by a 58-kg person 3.0 m from that post.

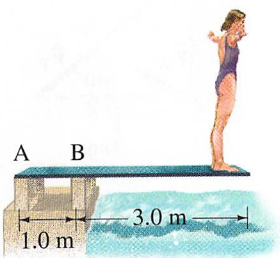


FIGURE 9–42 Problems 2, 4, and 6.

3. (I) Calculate the mass m needed in order to suspend the leg shown in Fig. 9–43. Assume the leg (with cast) has a mass of 15.0 kg, and its CG is 35.0 cm from the hip joint; the sling is 80.5 cm from the hip joint.

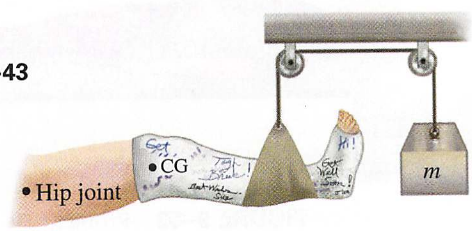


FIGURE 9–43 Problem 3.

4. (I) How far out on the diving board (Fig. 9–42) would a 58-kg diver have to be to exert a torque of 1100 m·N on the board, relative to the left (A) support post?

5. (II) Two cords support a chandelier in the manner shown in Fig. 9–4 except that the upper wire makes an angle of 45° with the ceiling. If the cords can sustain a force of 1550 N without breaking, what is the maximum chandelier weight that can be supported?

6. (II) Calculate the forces F_A and F_B that the supports exert on the diving board of Fig. 9–42 when a 58-kg person stands at its tip. (*a*) Ignore the weight of the board. (*b*) Take into account the board's mass of 35 kg. Assume the board's CG is at its center.

7. (II) A uniform steel beam has a mass of 940 kg. On it is resting half of an identical beam, as shown in Fig. 9–44. What is the vertical support force at each end?

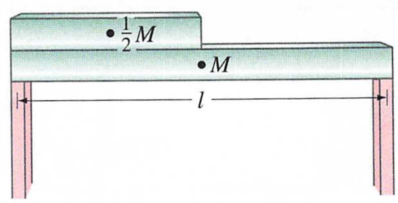


FIGURE 9–44 Problem 7.

8. (II) A 140-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?

9. (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.

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

11. (II) Find the tension in the two cords shown in Fig. 9–45. Neglect the mass of the cords, and assume that the angle θ is 33° and the mass m is 170 kg.

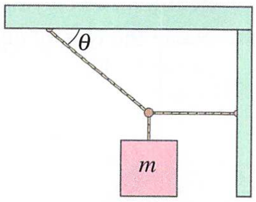


FIGURE 9–45 Problem 11.

12. (II) Find the tension in the two wires supporting the traffic light shown in Fig. 9–46.

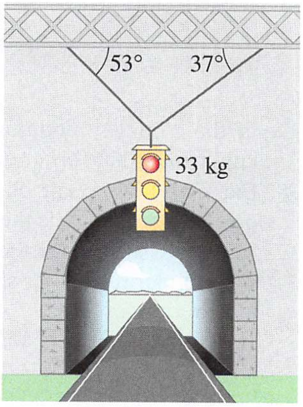


FIGURE 9–46 Problem 12.

13. (II) How close to the edge of the 20.0-kg table shown in Fig. 9–47 can a 66.0-kg person sit without tipping it over?

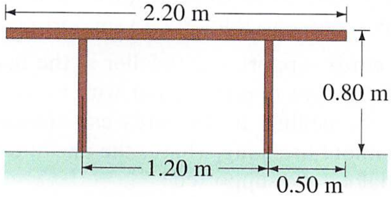


FIGURE 9–47 Problem 13.

14. (II) A 0.60-kg sheet hangs from a massless clothesline as shown in Fig. 9–48. The clothesline on either side of the sheet makes an angle of 3.5° with the horizontal. Calculate the tension in the clothesline on either side of the sheet. Why is the tension so much greater than the weight of the sheet?

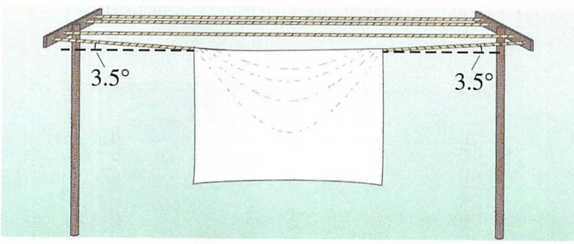


FIGURE 9–48 Problem 14.

15. (II) Calculate F_A and F_B for the beam shown in Fig. 9–49. The downward forces represent the weights of machinery on the beam. Assume the beam is uniform and has a mass of 250 kg.

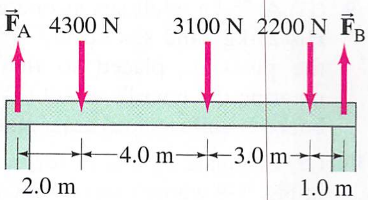


FIGURE 9–49 Problem 15.

16. (II) Three children are trying to balance on a seesaw, which consists of a fulcrum rock, acting as a pivot at the center, and a very light board 3.6 m long (Fig. 9–50). Two playmates are already on either end. Boy A has a mass of 50 kg, and girl B a mass of 35 kg. Where should girl C, whose mass is 25 kg, place herself so as to balance the seesaw?

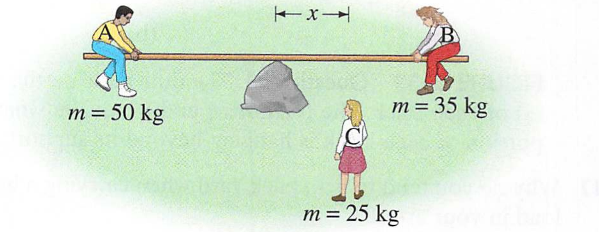


FIGURE 9–50 Problem 16.

17. (II) Figure 9–51 shows a pair of forceps used to hold a thin plastic rod firmly. If each finger squeezes with a force $F_T = F_B = 11.0\,\text{N}$, what force do the forceps jaws exert on the plastic rod?

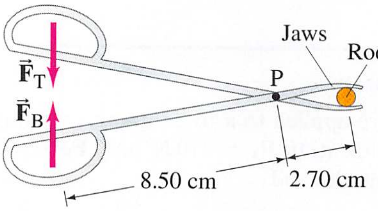


FIGURE 9–51 Problem 17.

18. (II) Calculate (*a*) the tension F_T in the wire that supports the 27-kg beam shown in Fig. 9–52, and (*b*) the force $\vec{F}_W$ exerted by the wall on the beam (give magnitude and direction).

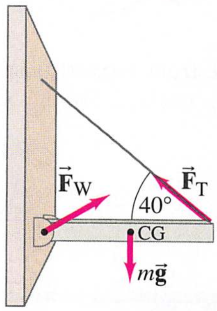


FIGURE 9–52 Problem 18.

19. (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. 9–53). 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 9–53 Problem 19.

20. (II) A shop sign weighing 245 N is supported by a uniform 155-N beam as shown in Fig. 9–54. Find the tension in the guy wire and the horizontal and vertical forces exerted by the hinge on the beam.

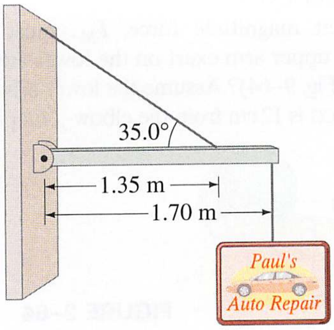


FIGURE 9–54 Problem 20.

21. (II) A traffic light hangs from a pole as shown in Fig. 9–55. The uniform aluminum pole AB is 7.50 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.

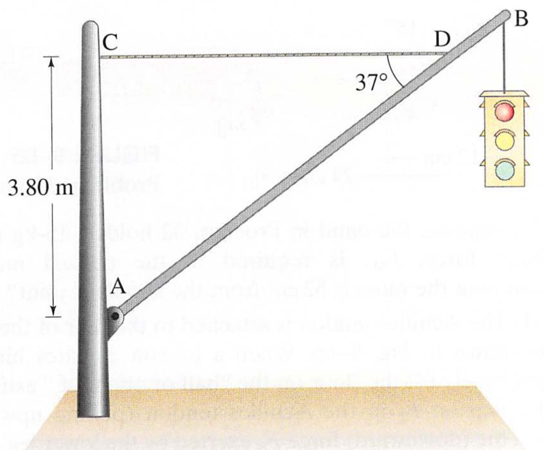


FIGURE 9–55 Problem 21.

22. (II) The 72-kg-man's hands in Fig. 9–56 are 36 cm apart. His CG is located 75% of the distance from his right hand toward his left. Find the force on each hand due to the ground.

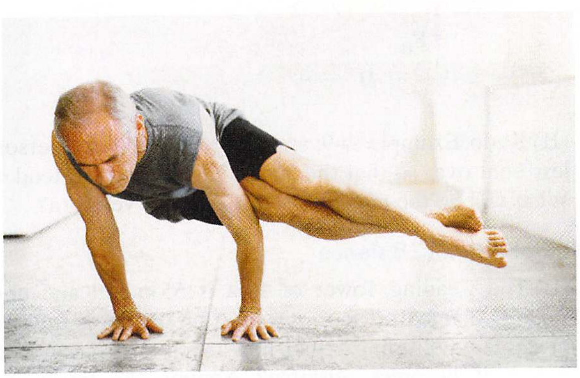


FIGURE 9–56 Problem 22.

23. (II) 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. 9–57). What is the tension in the string (*a*) at 0 cm? (*b*) at 90 cm?

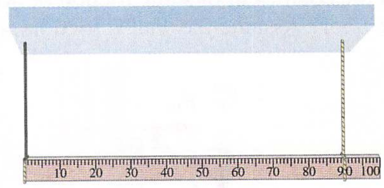


FIGURE 9–57 Problem 23.

24. (II) The two trees in Fig. 9–58 are 7.6 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.

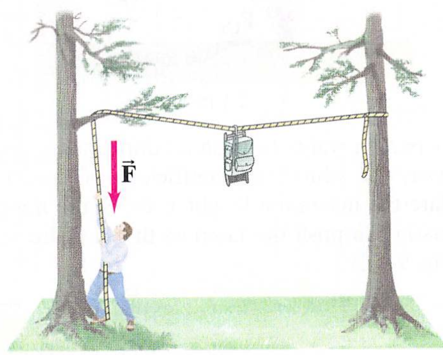


FIGURE 9–58 Problem 24.

25. (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. 9–59). 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.

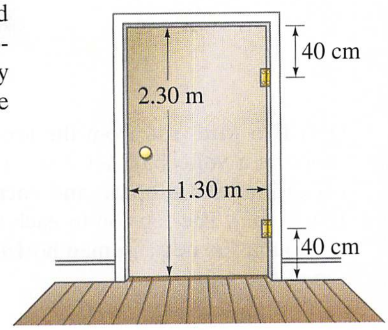


FIGURE 9–59 Problem 25.

26. (III) A uniform ladder of mass m and length l leans at an angle θ against a frictionless wall, Fig. 9–60. If the coefficient of static friction between the ladder and the ground is μ, determine a formula for the minimum angle at which the ladder will not slip.

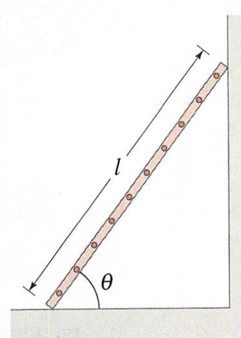


FIGURE 9–60 Problem 26.

27. (III) Consider a ladder with a painter climbing up it (Fig. 9–61). If the mass of the ladder is 12.0 kg, the mass of the painter is 55.0 kg, and the ladder begins to slip at its base when her 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.

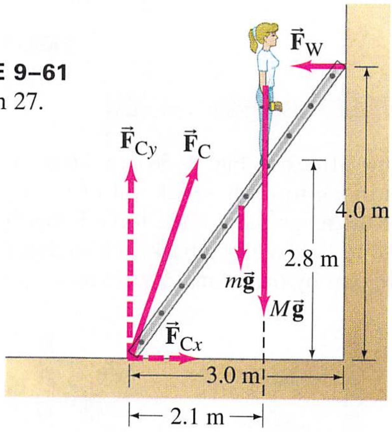


FIGURE 9–61 Problem 27.

28. (III) A person wants to push a lamp (mass 7.2 kg) across the floor, for which the coefficient of friction is 0.20. Calculate the maximum height x above the floor at which the person can push the lamp so that it slides rather than tips (Fig. 9–62).

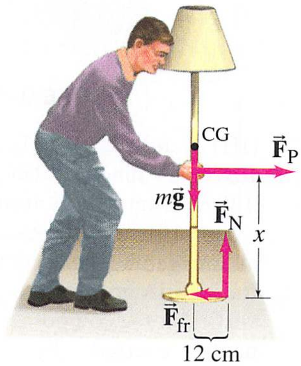


FIGURE 9–62 Problem 28.

29. (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. 9–63). The tension in each wire is 95 N. What is the tension in the net, assumed horizontal and attached at the top of the pole?

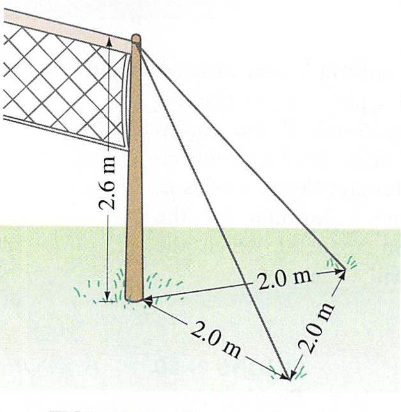


FIGURE 9–63 Problem 29.

* 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. 9–64)? Assume the lower arm has a mass of 2.8 kg and its CG is 12 cm from the elbow-joint pivot.

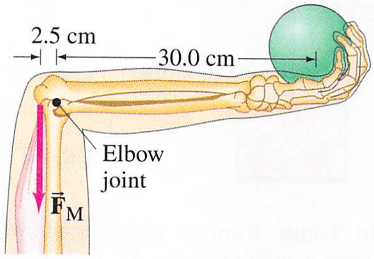


FIGURE 9–64 Problem 31.

* 32. (II) (*a*) Calculate the force, F_M, required of the "deltoid" muscle to hold up the outstretched arm shown in Fig. 9–65. 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.

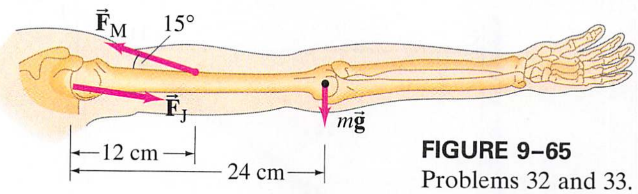


FIGURE 9–65 Problems 32 and 33.

* 33. (II) Suppose the hand in Problem 32 holds a 15-kg mass. What force, F_M, is required of the deltoid muscle, assuming the mass is 52 cm from the shoulder joint?

* 34. (II) The Achilles tendon is attached to the rear of the foot as shown in Fig. 9–66. When a person elevates himself just barely off the floor on the "ball of one foot," estimate the tension F_T in the Achilles tendon (pulling upward), and the (downward) force F_B exerted by the lower leg bone on the foot. Assume the person has a mass of 72 kg and D is twice as long as d.

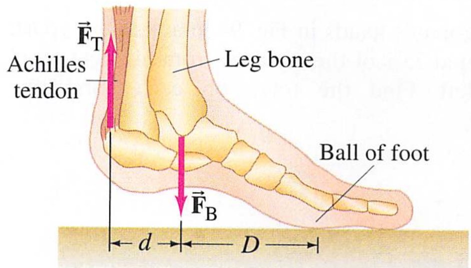


FIGURE 9–66 Problem 34.

* 35. (II) Redo Example 9–9, assuming now that the person is less bent over so that the 30° in Fig. 9–14b is instead 45°. What will be the magnitude of F_V on the vertebra?

9–4 Stability and Balance

36. (II) The Leaning Tower of Pisa is 55 m tall and about 7.0 m in diameter. 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.

37. (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. 9–67a). (*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. 9–67b) based on the principle of stability discussed in (*a*) and (*c*) above. What minimum number of bricks, each 0.30 m long, is needed if the arch is to span 1.0 m?

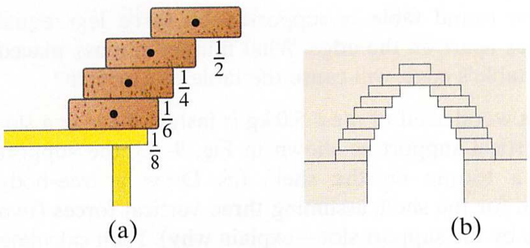


FIGURE 9–67 Problem 37.

* 9–5 Elasticity; Stress and Strain

* **38.** (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?

* **39.** (I) A marble column of cross-sectional area $1.2\ \text{m}^2$ supports a mass of 25,000 kg. (*a*) What is the stress within the column? (*b*) What is the strain?

* **40.** (I) By how much is the column in Problem 39 shortened if it is 9.6 m high?

* **41.** (I) A sign (mass 2100 kg) hangs from the end of a vertical steel girder with a cross-sectional area of $0.15\ \text{m}^2$. (*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.)

* **42.** (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?

* **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 the Young's modulus of this tendon.

* **44.** (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 $(1.0 \times 10^5\ \text{N/m}^2)$.

* **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?

* **46.** (III) A scallop forces open its shell with an elastic material called abductin, whose Young's modulus is about $2.0 \times 10^6\ \text{N/m}^2$. If this piece of abductin is 3.0 mm thick and has a cross-sectional area of $0.50\ \text{cm}^2$, how much potential energy does it store when compressed 1.0 mm?

* **47.** (III) A pole projects horizontally from the front wall of a shop. A 5.1-kg sign hangs from the pole at a point 2.2 m from the wall (Fig. 9–68). (*a*) What is the torque due to this sign calculated about the point where the pole meets the wall? (*b*) If the pole is not to fall off, there must be another torque exerted to balance it. What exerts this torque? Use a diagram to show how this torque must act. (*c*) Discuss whether compression, tension, and/or shear play a role in part (*b*).

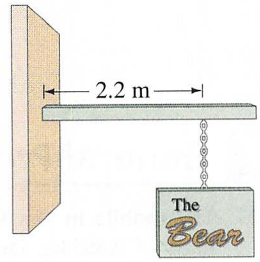


FIGURE 9–68 Problem 47.

* 9–6 Fracture

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

* **49.** (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?

* **50.** (II) If a compressive force of $3.6 \times 10^4\ \text{N}$ is exerted on the end of a 22-cm-long bone of cross-sectional area $3.6\ \text{cm}^2$, (*a*) will the bone break, and (*b*) if not, by how much does it shorten?

* **51.** (II) (*a*) What is the minimum cross-sectional area required of a vertical steel cable from which is suspended a 320-kg chandelier? Assume a safety factor of 7.0 (*b*) If the cable is 7.5 m long, how much does it elongate?

* **52.** (II) Assume the supports of the uniform cantilever shown in Fig. 9–69 (mass = 2600 kg) are made of wood. Calculate the minimum cross-sectional area required of each, assuming a safety factor of 8.5.

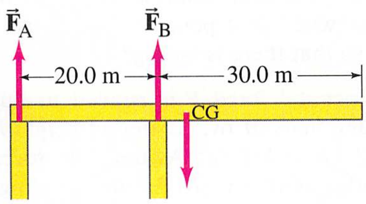


FIGURE 9–69 Problem 52.

* **53.** (II) An iron bolt is used to connect two iron plates together. The bolt must withstand shear forces up to about 3200 N. Calculate the minimum diameter for the bolt, based on a safety factor of 6.0.

* **54.** (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 $1.2\ \text{m/s}^2$, calculate the diameter of cable required. Assume a safety factor of 7.0.

* 9–7 Arches and Domes

* **55.** (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?

* **56.** (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. 9–70). 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).

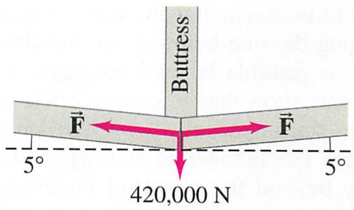


FIGURE 9–70 Problem 56.

General Problems

57. The mobile in Fig. 9–71 is in equilibrium. Object B has mass of 0.885 kg. Determine the masses of objects A, C, and D. (Neglect the weights of the crossbars.)

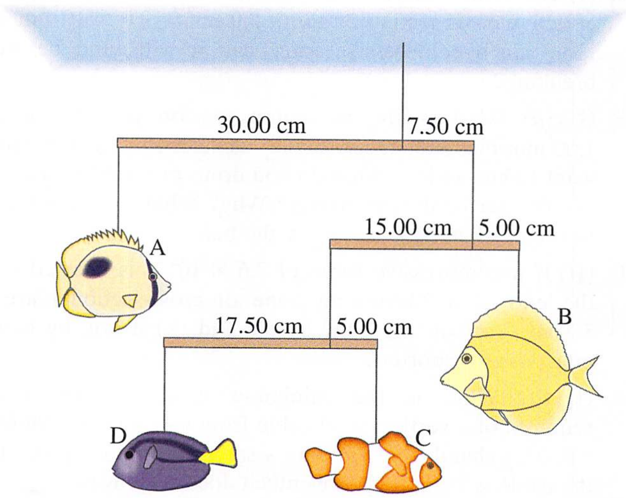


FIGURE 9–71 Problem 57.

58. A tightly stretched "high wire" is 46 m long. It sags 2.2 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?

59. What minimum horizontal force F is needed to pull a wheel of radius R and mass M over a step of height h as shown in Fig. 9–72 ($R > h$)? (*a*) Assume the force is applied at the top edge as shown. (*b*) Assume the force is applied instead at the wheel's center.

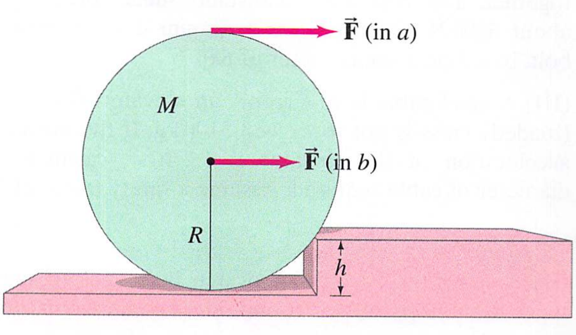


FIGURE 9–72 Problem 59.

60. A 25-kg round table is supported by three legs equal distances apart on the edge. What minimum mass, placed on the table's edge, will cause the table to overturn?

61. When a wood shelf of mass 5.0 kg is fastened inside a slot in a vertical support as shown in Fig. 9–73, 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).

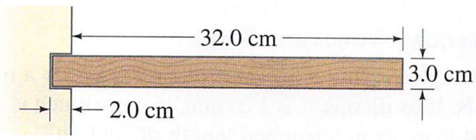


FIGURE 9–73 Problem 61.

62. A 50-story building is being planned. It is to be 200.0 m high with a base 40.0 m by 70.0 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/m^2 over the 70.0-m-wide face (Fig. 9–74). Calculate the torque about the potential pivot point, the rear edge of the building (where $\vec{\mathbf{F}}_E$ acts in Fig. 9–74), 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. 9–74 represents the force that the Earth would exert on the building in the case where the building would just begin to tip.]

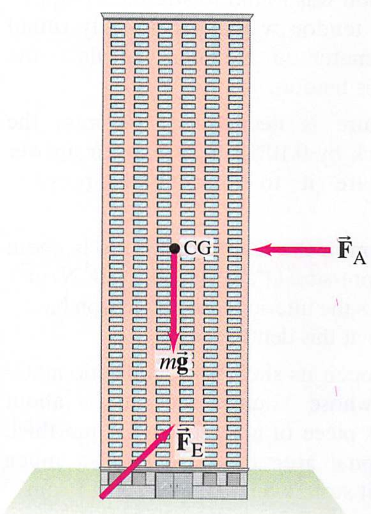


FIGURE 9–74 Forces on a building subjected to wind ($\vec{\mathbf{F}}_A$), gravity ($m\vec{\mathbf{g}}$), and the force $\vec{\mathbf{F}}_E$ on the building due to the Earth if the building were just about to tip. Problem 62.

63. The center of gravity of a loaded truck depends on how the truck is packed. If it is 4.0 m high and 2.4 m wide, and its CG is 2.2 m above the ground, how steep a slope can the truck be parked on without tipping over (Fig. 9–75)?

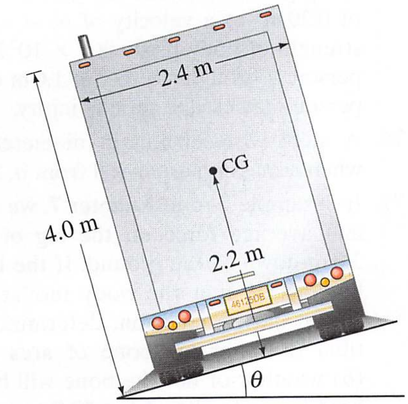


FIGURE 9–75 Problem 63.

64. In Fig. 9–76, consider the right-hand (northernmost) section of the Golden Gate Bridge, which has a length $d_1 = 343$ m. Assume the CG of this span is halfway between the tower and anchor. Determine F_{T1} and F_{T2} (which act on the northernmost cable) in terms of mg, the weight of the northernmost span, and calculate the tower height h needed for equilibrium. Assume the roadway is supported only by the suspension cables, and neglect the mass of the cables and vertical wires. [*Hint*: F_{T3} does not act on this section.]

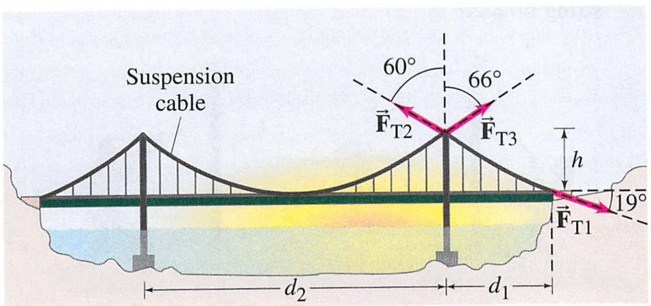


FIGURE 9–76 Problem 64.

65. 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. 9–77. Determine the radius of the wire.

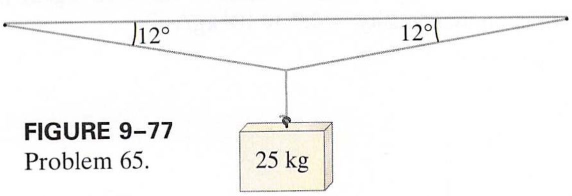


FIGURE 9–77 Problem 65.

66. The forces acting on a 67,000-kg aircraft flying at constant velocity are shown in Fig. 9–78. The engine thrust, $F_T = 5.0 \times 10^5$ N, acts on a line 1.6 m below the CM. Determine the drag force F_D and the distance above the CM that it acts. Assume $\vec{F}_D$ and $\vec{F}_T$ are horizontal.

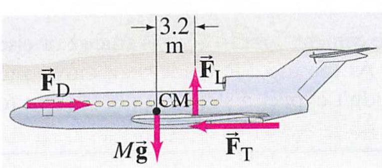


FIGURE 9–78 Problem 66.

67. A uniform flexible steel cable of weight mg is suspended between two points at the same elevation as shown in Fig. 9–79, where $\theta = 60°$. Determine the tension in the cable (*a*) at its lowest point, and (*b*) at the points of attachment. (*c*) What is the direction of the tension force in each case?

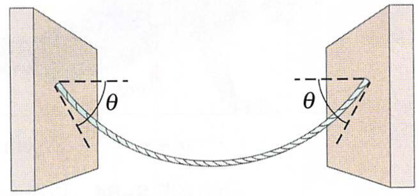


FIGURE 9–79 Problem 67.

68. A 20.0-m-long uniform beam weighing 550 N rests on walls A and B, as shown in Fig. 9–80. (*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*) at a point 2.0 m to the right of B; (*d*) 2.0 m to the right of A.

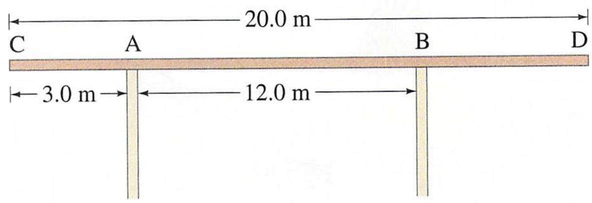


FIGURE 9–80 Problem 68.

69. 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. 9–81. 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?]

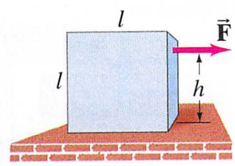


FIGURE 9–81 Problem 69.

70. A 60.0-kg painter is on a uniform 25-kg scaffold supported from above by ropes (Fig. 9–82). 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?

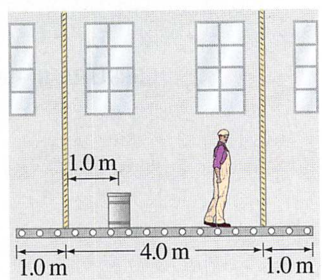


FIGURE 9–82 Problem 70.

71. A woman holds a 2.0-m-long uniform 10.0-kg pole as shown in Fig. 9–83. (*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?

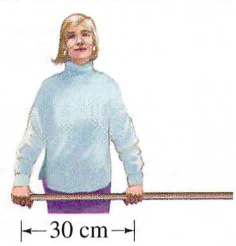


FIGURE 9–83 Problem 71.

72. A man doing push-ups pauses in the position shown in Fig. 9–84. His mass $m = 75$ kg. Determine the normal force exerted by the floor (*a*) on each hand; (*b*) on each foot.

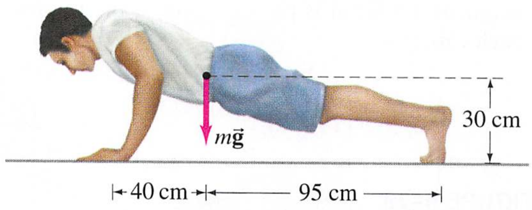


FIGURE 9–84 Problem 72.

73. A 20-kg sphere rests between two smooth planes as shown in Fig. 9–85. Determine the magnitude of the force acting on the sphere exerted by each plane.

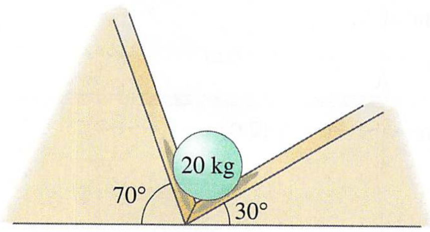


FIGURE 9–85 Problem 73.

74. A 2200-kg trailer is attached to a stationary truck at point B, Fig. 9–86. 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.

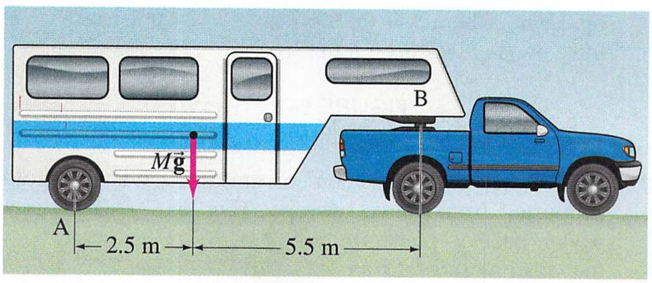


FIGURE 9–86 Problem 74.

* 75. 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 $0.30\ \mathrm{m}^2$ at a velocity of 60 m/s, and that the ultimate strength of body tissue is $5 \times 10^5\ \mathrm{N/m^2}$. Assume that the person is brought to rest in 1.0 m of snow. Show that the person may escape serious injury.

* 76. A steel wire 2.0 mm in diameter stretches by 0.030% when a mass is suspended from it. How large is the mass?

* 77. In Example 7–6 in Chapter 7, we calculated the impulse and average force on the leg of a person who jumps 3.0 m down to the ground. If the legs are not bent upon landing, so that the body moves a distance *d* of only 1.0 cm during collision, determine (*a*) the stress in the tibia (a lower leg bone of area $= 3.0 \times 10^{-4}\ \mathrm{m}^2$), and (*b*) whether or not the bone will break. (*c*) Repeat for a bent-knees landing ($d = 50.0$ cm).

* 78. The roof over a 7.0-m × 10.0-m room in a school has a total mass of 12,600 kg. The roof is to be supported by vertical "2 × 4s" (actually about 4.0 cm × 9.0 cm) 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.

* 79. A 25-kg object is being lifted by pulling on the ends of a 1.00-mm-diameter nylon string that goes over two 3.00-m-high poles that are 4.0 m apart, as shown in Fig. 9–87. How high above the floor will the object be when the string breaks?

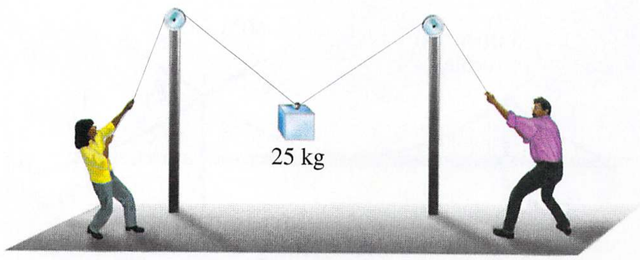


FIGURE 9–87 Problem 79.

* 80. 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 = mass/volume = $7.8 \times 10^3\ \mathrm{kg/m^3}$), and (*b*) granite (density = $2.7 \times 10^3\ \mathrm{kg/m^3}$).

Answers to Exercises

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

B: Yes: $\sin\theta$ appears on both sides and cancels out.

C: $F_N = m_A g + m_B g + Mg = 560$ N.

D: Static friction at the cement floor ($= F_{Cx}$) is crucial, or else the ladder would slip. At the top, the ladder can move and adjust, so we wouldn't expect a strong static friction force there.