8–12 Early critics of Robert Goddard, a pioneer in the use of rocket propulsion, claimed that rocket engines could not be used in outer space where there is no air for the rocket to push against. How would you answer such criticism? Would the criticism be valid for a jet engine in an ordinary airplane?

8–13 In a zero-gravity environment, can a rocket-propelled spaceship ever attain a speed greater than the relative speed with which the burnt fuel is exhausted?

Exercises

Section 8–1 Impulse and Momentum

8–1

a) What is the momentum of a 10,000-kg truck whose speed is 30.0 $m \cdot s^{-1}$?

b) What speed must a 5,000-kg truck attain in order to have

i) the same momentum?

ii) the same kinetic energy?

8–2 A block of ice with a mass of 2.50 kg is moving on a frictionless, horizontal surface. At $t = 0$ the block is moving to the right with a velocity of magnitude 8.00 $m \cdot s^{-1}$. Calculate the velocity of the block (magnitude and direction) after each of the following forces has been applied for 5.00 s:

a) a force of 5.00 N, directed to the right;

b) a force of 7.00 N, directed to the left.

8–3 A bullet with a mass of 0.0050 kg and moving with a speed of 400 $m \cdot s^{-1}$ penetrates a distance of 0.0800 m into a wooden block firmly attached to the earth. Assume that the force that stops it is constant. Use a coordinate system for which the direction of the initial velocity of the bullet is the positive x-direction. Compute

a) the acceleration of the bullet,

b) the accelerating force,

c) the time of the acceleration,

d) the impulse of the force.

Compare the answer to part (d) with the initial momentum of the bullet.

8–4 A baseball has mass 0.200 kg.

a) If the velocity of a pitched ball has a magnitude of 35.0 $m \cdot s^{-1}$, and after the ball is batted the velocity is 55.0 $m \cdot s^{-1}$ in the opposite direction, find the change in momentum of the ball and the impulse applied to it by the bat.

b) If the ball remains in contact with the bat for 2.00×10^{-3} s, find the average force applied by the bat.

8–5 A baseball with a mass of 0.250 kg is struck by a bat. Just before impact, the ball is traveling horizontally at 40.0 $m \cdot s^{-1}$, and it leaves the bat traveling in the opposite direction at an angle of 30.0° above horizontal with a speed of 55.0 $m \cdot s^{-1}$. If the ball and bat are in contact for 4.00×10^{-3} s, find the horizontal and vertical components of the average force on the ball.

8–6 A golf ball with a mass of 0.080 kg initially at rest is given a speed of 50 $m \cdot s^{-1}$ when it is struck by a club. If the club and ball are in contact for 1.5×10^{-3} s, what average force acts on the ball? Is the effect of the ball's weight during the time of contact significant?

Section 8–2 Conservation of Momentum

8–7 On a frictionless, horizontal surface, block A having a mass of 3.00 kg is moving to the right toward block B having a mass of 5.00 kg, which is initially at rest. After the collision, block A has a velocity of 1.20 $m \cdot s^{-1}$ to the left, and block B has velocity 5.40 $m \cdot s^{-1}$ to the right.

a) What was the speed of block A before the collision?

b) Calculate the change in the total kinetic energy of the system that occurs in the collision.

8–8 An 80.0-kg man standing on ice throws a 0.400-kg ball horizontally with a speed of 30.0 $m \cdot s^{-1}$. With what speed and in what direction will the man begin to move if there is no friction between his feet and the ice?

8–9 You are standing on a sheet of ice that covers a parking lot; there is negligible friction between your feet and the ice. A friend throws you a 0.400-kg ball that is traveling horizontally at 15.0 $m \cdot s^{-1}$. Your mass is 80.0 kg.

a) If you catch the ball, with what speed do you and the ball move afterward?

b) If the ball hits you and bounces off your chest, so that afterward it is moving horizontally at 15.0 $m \cdot s^{-1}$ in the opposite direction, what is your speed after the collision?

8–10 A railroad handcar is moving along straight, frictionless tracks. In each of the following cases the car

ANSWER THE CIRCLED QUESTIONS!

5–2 A box of bananas weighing 25.0 N rests on a horizontal surface. The coefficient of static friction between the box and the surface is 0.40, and the coefficient of kinetic friction is 0.20.

a) If no horizontal force is applied to the box and the box is at rest, how large is the friction force exerted on the box?

b) How great is the friction force if a horizontal force of 6.0 N is exerted on the box and the box is initially at rest?

c) What is the minimum horizontal force that will start the box in motion?

d) What is the minimum horizontal force that will keep the box in motion once it has been started?

e) If a horizontal force of 15.0 N is applied to the box, how great is the friction force?

5–3 In a physics lab experiment a 10.0-kg box is pushed across a flat table by a horizontal force $\boldsymbol{F}$.

a) If the box is moving at a constant speed of 3.50 $m \cdot s^{-1}$ and the coefficient of kinetic friction is 0.14, what is the magnitude of the force $\boldsymbol{F}$?

b) What is the magnitude of $\boldsymbol{F}$ if the box is accelerating with a constant acceleration of 0.220 $m \cdot s^{-2}$?

c) How would your answers to parts (a) and (b) change if the experiments were performed on the moon, where $g = 1.67$ $m \cdot s^{-2}$?

5–4 A hockey puck leaves a player's stick with a speed of 14.0 $m \cdot s^{-1}$ and slides 32.0 m before coming to rest. Find the coefficient of friction between the puck and the ice.

5–5

a) If the coefficient of friction between tires and dry pavement is 0.80, what is the shortest distance in which an automobile can be stopped by locking the brakes when traveling at 22.0 $m \cdot s^{-1}$ (about 50 $mi \cdot hr^{-1}$)?

b) On wet pavement the coefficient of friction may be only 0.25. How fast should you drive on wet pavement in order to be able to stop in the same distance as in part (a)?

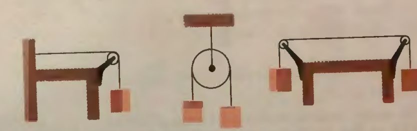
(*Note:* Locking the brakes is *not* the safest way to stop.)

5–6 Find the ratio of the stopping distance of an automobile on wet concrete with the wheels locked ($\mu_k =$ 0.25) to the stopping distance of the same automobile stopped by tractive friction only (where the tractive resistance $\mu_r = 0.0120$). Assume the same initial speed for both cases.

5–7 Air pressure greatly affects the tractive resistance of bicycle tires. To study this effect, two tires are set rolling with the same initial speed of 6.00 $m \cdot s^{-1}$ along a long, straight road, and the distance each travels before its speed is reduced by half is measured. One tire is inflated to a pressure of 40 psi, and the other is at 105 psi. The low-pressure tire goes 45.6 m, and the high-pressure tire goes 213.2 m. What is the tractive resistance μ_r for each? Assume that the net horizontal force is due to tractive friction only.

Section 5–3 Equilibrium of a Particle

5–8 In each of the situations in Fig. 5–16 the blocks suspended from the rope have weight w. The pulleys are frictionless. Calculate in each case the tension T in the rope in terms of the weight w.



(a) (b) (c)

FIGURE 5–16

5–9 Two 20.0-N weights are suspended at opposite ends of a rope that passes over a light, frictionless pulley. The pulley is attached to a chain that goes to the ceiling.

a) What is the tension in the rope?

b) What is the tension in the chain?

5–10 A picture frame hung against a wall is suspended by two wires attached to its upper corners. If the two wires make the same angle with the vertical, what must this angle be if the tension in each wire is equal to the weight of the frame? (Neglect any friction between the wall and the picture frame.)

5–11 Figure 5–17 illustrates a mountaineering technique called a Tyrolean traverse. A rope is stretched tightly between two points, and the climber slides across the rope. The climber's weight is 700 N, and the breaking strength of the rope (typically 11-mm-diameter nylon) is 22,000 N.

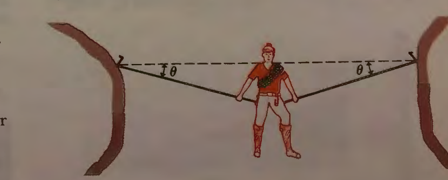


FIGURE 5–17

a) If the angle θ is 15.0°, find the tension in the rope.

b) What is the smallest value the angle θ can have if the rope is not to break?

5–12 Find the tension in each cord in Fig. 5–18 if the weight of the suspended object is w.

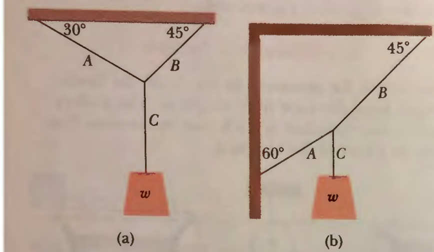


FIGURE 5–18

5–13 In Fig. 5–19 the tension in the diagonal string is 30.0 N.

a) Find the magnitudes of the horizontal forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ that must be applied to hold the system in the position shown.

b) What is the weight of the suspended block?

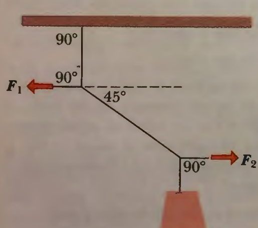


FIGURE 5–19

5–14 A tether ball leans against the post to which it is attached, as shown in Fig. 5–20. If the string to which the ball is attached is 1.80 m long, the ball has a radius of 0.200 m, and the ball has a mass of 0.500 kg, what are the tension in the rope and the force the pole exerts on the ball? Assume that there is so little friction between the ball and the pole that friction can be neglected. (The string is attached to the ball such that a line along the string passes through the center of the ball.)

FIGURE 5–20

5–15 Two blocks, each with weight w, are held in place on a frictionless incline as shown in Fig. 5–21. In terms of w and the angle θ of the incline, calculate the tension in

a) the rope connecting the blocks;

b) the rope that connects block A to the wall.

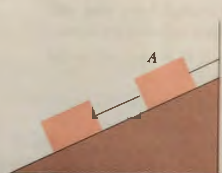


FIGURE 5–21

5–16 A man is pushing a piano weighing 420 lb at constant velocity up a ramp that is inclined at 34.0° above the horizontal. Neglect friction. If the force applied by the man is parallel to the incline, calculate the magnitude of this force.

5–17 Two crates connected by a rope lie on a horizontal surface as shown in Fig. 5–22. Crate A has weight w_A, and crate B has weight w_B. The coefficient of kinetic friction between the crates and the surface is μ_k. The crates are pulled to the right at constant velocity by a horizontal force P. In terms of w_A, w_B, and μ_k, calculate

a) the magnitude of the force P;

b) the tension in the rope connecting the blocks.

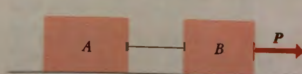


FIGURE 5–22

5–18 Consider the system shown in Fig. 5–23. The coefficient of kinetic friction between block A (weight w_A) and the tabletop is μ_k. Calculate the weight w_B of the hanging block required if this block is to descend at constant speed once it has been set into motion.

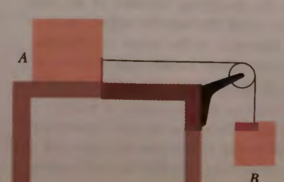


FIGURE 5–23

5–19 In emergency situations with major blood loss, the doctor will order the patient placed in the Trendelberg position, which is to raise the foot of the bed to get maximum blood flow to the brain. If the coefficient of static friction between the typical patient and the bed sheets is 1.8, what is the maximum angle at which the bed can be tilted with respect to the floor before the patient begins to slide?

5–20 A child pushes on a box resting on the floor. The box weighs 260 N, and the child is pushing down on the box with a force that makes an angle of 45.0° with the horizontal, as shown in Fig. 4–1b. If the smallest force the child can apply that gets the box moving is 150 N, what is the coefficient of static friction between the box and the floor?

5–21 A safe weighing 2500 N is to be lowered at constant speed down skids 4.80 m long, from a truck 2.40 m high.

a) If the coefficient of kinetic friction between safe and skids is 0.30, will the safe need to be pulled down or held back?

b) How great a force parallel to the skids is needed?

5–22

a) If a force with magnitude 95.0 N parallel to the surface of a 20.0° ramp will push a 120-N mailbag up the ramp at constant speed, what force parallel to the ramp will push it down at constant speed?

b) What is the coefficient of kinetic friction?

5–23 A large crate with weight w rests on a horizontal floor. The coefficients of friction between the crate and the floor are μ_s and μ_k. A man pushes downward at an angle θ below the horizontal on the crate with a force $\boldsymbol{P}$.

a) What magnitude of force $\boldsymbol{P}$ is required to keep the crate moving at constant velocity?

b) If μ_s is larger than some critical value, the man cannot start the crate moving no matter how hard he pushes. Calculate this critical value of μ_s.

5–24 Two blocks, A and B, are placed as in Fig. 5–24 and connected by ropes to block C. Both A and B weigh 30.0 N each, and the coefficient of kinetic friction between each block and the surface is 0.50. Block C descends with constant velocity.

a) Draw two separate force diagrams showing the forces acting on A and on B.

b) Find the tension in the rope connecting blocks A and B.

c) What is the weight of block C?

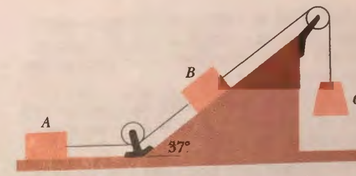


FIGURE 5–24

Section 5–4 *Applications of Newton's Second Law*

5–25 The first two steps in the solution of Newton's second law problems are to select an object for analysis and then to draw free-body diagrams for that object. Draw a free-body diagram for each of the following situations:

a) a mass M sliding down a frictionless inclined plane of angle θ;

b) a mass M sliding up a frictionless inclined plane of angle θ;

c) a mass M sliding up an inclined plane of angle θ with kinetic friction present;

d) masses M and m sliding down an inclined plane of angle θ with friction present, as shown in Fig. 5–25a. Here draw free-body diagrams for both m and M. Identify the forces that are action–reaction pairs.

e) Draw free-body diagrams for masses m and M shown in Fig. 5–25b. Identify all action–reaction pairs. There are frictional forces between all surfaces in contact. The pulley is frictionless and massless.

In all cases, be sure you have the correct direction of the forces and are completely clear on what object is causing each force in your free-body diagram.

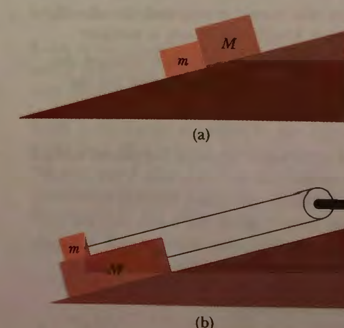


FIGURE 5–25

7–3 In Fig. 7–9 the projectile has the same initial kinetic energy in each case. Why does it not then rise to the same maximum height in each case?

7–4 Are there any cases in which a frictional force can *increase* the mechanical energy of a system? If so, give examples.

7–5 An automobile jack is used to lift a heavy weight by exerting a force that is much smaller in magnitude than the weight. Does this mean that less work is done than if the weight had been lifted directly?

7–6 A compressed spring is clamped in its compressed position and is then dissolved in acid. What becomes of its potential energy?

7–7 A child standing on a playground swing can increase the amplitude of his motion by "pumping up," pulling back on the swing ropes at the appropriate points during the motion. Where does the added energy come from?

7–8 In a siphon, water is lifted above its original level during its flow from one container to another. Where does it get the needed potential energy?

7–9 A woman bounces on a trampoline, going a little higher with each bounce. Explain how she increases her total mechanical energy.

7–10 Is it possible for the second hill on a roller coaster track to be higher than the first? What would happen if it were higher?

7–11 Does the kinetic energy of a car change more when it speeds up from 10 to 15 $m \cdot s^{-1}$ or from 15 to 20 $m \cdot s^{-1}$?

7–12 A car accelerates from an initial speed to a greater final speed while the engine develops constant power. Is the acceleration greater at the beginning of this process or at the end?

7–13 Time yourself while running up a flight of steps, and compute your maximum power in horsepower. Are you stronger than a horse?

7–14 When a constant force is applied to a body moving with constant acceleration, is the power of the force constant? If not, how would the force have to vary with speed for the power to be constant?

7–15 An advertisement for a power saw states: "This power tool uses the energy of the motor to stop the blade rotation within 5 seconds after the switch is turned off." Is this an accurate statement? Please explain.

Exercises

Section 7–2 Work

7–1 A fisherman reels in 20.0 m of line while pulling in a fish that exerts a constant resisting force of 16.0 N. If the fish is pulled in at constant speed, how much work is done on it by the tension in the line?

7–2 A physics book is pushed 1.20 m along a horizontal tabletop by a horizontal force of 2.00 N. The opposing force of friction is 0.400 N.

a) How much work is done on the book by the 2.00-N force?

b) What is the work done on the book by the friction force?

7–3 A water skier is pulled by a tow rope behind a boat. He skies off to the side, and the rope makes an angle of 20.0° with his direction of motion. The tension in the rope is 120 N. How much work is done on the skier by the rope during a displacement of 250 m?

7–4 A factory worker pushes a 50.0-kg crate a distance of 8.00 m along a level floor, at constant speed, by pushing horizontally on it. The coefficient of kinetic friction between the crate and floor is 0.25.

a) What magnitude of force must the worker apply?

b) How much work is done on the crate by this force?

c) How much work is done by friction?

d) How much work is done by the normal force? By gravity?

7–5 In Exercise 7–4, suppose the worker pushes downward at an angle of 30.0° below the horizontal.

a) What magnitude of force must the worker apply to move the crate at constant speed?

b) How much work is done on the crate by this force when the crate is pushed a distance of 8.00 m?

c) How much work is done on the crate by friction during this displacement?

d) How much work is done by the normal force? By gravity?

7–6 The old oaken bucket that hangs in a well has a mass of 6.75 kg. We slowly pull it up a distance of 5.00 m by pulling horizontally on a rope passing over a pulley at the top of the well.

a) How much work do we do in pulling the bucket up?

b) How much work is done by the gravitational force acting on the bucket?

7–7 A 28.0-lb suitcase is pulled up a frictionless plane inclined at 30.0° to the horizontal by a force ***P*** with a magnitude of 18.0 lb and acting parallel to the plane. If the suitcase travels 15.0 ft along the incline, calculate

a) the work done on the suitcase by the force ***P***,

b) the work done by the gravity force,

c) the work done by the normal force,

d) the total work done on the suitcase.

7–8 An 8.00-kg package slides 2.00 m down a surface that is inclined at 53.0° below the horizontal. The coefficient of kinetic friction between the package and the surface is $\mu_k = 0.40$. Calculate

a) the work done by friction on the package,

b) the work done by gravity,

c) the work done by the normal force,

d) the total work done on the package.

Section 7–3 Work Done by a Varying Force

7–9 The end of a spring with force constant k is at $x = 0$ when no force is applied to it.

a) In terms of x_1 and k, how much force must be applied to the end of the spring to stretch it to $x = x_1$?

b) To stretch it to $x = x_2$?

c) How much work is done by the force that stretches the end of the spring from x_1 to x_2?

7–10 A force of 80.0 N is observed to stretch a certain spring a distance of 0.400 m beyond its unstretched length.

a) What magnitude of force is required to stretch the spring 0.100 m beyond its unstretched length? To compress the spring 0.200 m?

b) How much work must be done to stretch the spring 0.100 m beyond its unstretched length? How much work to compress the spring 0.200 m from its unstretched length?

7–11 A force in the positive x-direction acts on a refrigerator with a mass of 90.0 kg. The magnitude of the force varies with the x-coordinate of the refrigerator according to the equation $F = (45.0\ N \cdot m^{-1})x$. How much work does this force do when the refrigerator moves from $x_1 = 2.0$ m to $x_2 = 8.0$ m?

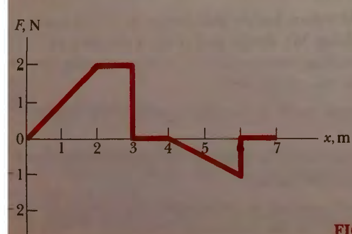


FIGURE 7–13

7–12 A force ***F*** that is parallel to the x-axis acts on a block of ice. The magnitude of the force varies with the x-coordinate of the block as shown in Fig. 7–13. Calculate the work done on the block of ice by the force ***F*** when the block moves from $x = 0$ to $x = 7.0$ m.

Section 7–4 Work and Kinetic Energy

7–13

a) Compute the kinetic energy of a 1200-kg automobile traveling at 20 $km \cdot hr^{-1}$.

b) By what factor does the kinetic energy increase if the speed is doubled?

7–14 Compute the kinetic energy, in joules, of a 12.0-g rifle bullet traveling at 250 $m \cdot s^{-1}$.

7–15 A baseball pitcher is throwing a fast ball, which has a speed (leaving his hand) of 42.0 $m \cdot s^{-1}$. The mass of the baseball is 0.180 kg. How much work has the pitcher done on the ball in throwing it?

7–16 A television set with a mass of 1.40 slugs is initially at rest on a frictionless horizontal surface. It is then pulled 4.0 ft by a horizontal force of magnitude 25.0 lb. Use the work–energy relation (Eq. 7–8) to find its final speed.

7–17 A little red wagon with a mass of 4.60 kg moves in a straight line on a frictionless horizontal surface. It has an initial speed of 10.0 $m \cdot s^{-1}$ and then is pulled 4.0 m by a force with a magnitude of 18.0 N in the direction of the initial velocity.

a) Use the work–energy relation to calculate the wagon's final speed.

b) Calculate the acceleration produced by the force. Use this acceleration in the kinematic relations of Chapter 2 to calculate the wagon's final speed. Compare this result to that obtained in part (a).

7–18 A sled with a mass of 8.00 kg moves in a straight line on a frictionless horizontal surface. At one point in its path its speed is 4.00 $m \cdot s^{-1}$, and after it has traveled 9.00 m its speed is 7.00 $m \cdot s^{-1}$ in the same direction. Use the work–energy relation to find the magnitude of the force acting on the sled, assuming that this force is constant and that it acts in the direction of the motion of the sled.

7–19 A force with magnitude 30.0 N acts on a 1.20-kg soccer ball moving initially in the direction of the force with a speed of 4.00 $m \cdot s^{-1}$. Over what distance must the force act to change the ball's speed to 6.00 $m \cdot s^{-1}$?

7–20 A small block with a mass of 0.0500 kg is attached to a cord passing through a hole in a frictionless horizontal surface, as in Fig. 7–14. The block is originally revolving at a distance of 0.200 m from the hole with a speed of 0.70 $m \cdot s^{-1}$. The cord is then pulled from below, shortening the radius of the circle in which tal area to 0.366 m^2. What then must her power output be to maintain a speed of 14.0 m·s^{-1}?

c) For the situation in part (b), what power output is required to maintain a speed of 7.0 m·s^{-1}? Note the great drop in power requirement when the speed is only halved. (See "The Aerodynamics of Human-Powered Land Vehicles," *Scientific American* December 1983. The article discusses aerodynamic speed limitations for a wide variety of human-powered vehicles.)

Problems

7–55 A projectile with mass m is fired from a gun with a muzzle velocity of magnitude v_0 at an angle of θ above the horizontal. Neglecting air resistance and using energy methods, find the maximum height attained by the projectile.

7–56 The system of Fig. 7–19 is released from rest with the 12.0-kg block 3.00 m above the floor. Use the principle of conservation of energy to find the speed with which the block strikes the floor. Neglect friction and the inertia of the pulley.

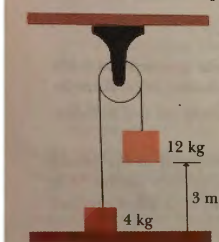


FIGURE 7–19

7–57 A meter stick, pivoted about a horizontal axis through its center, has a metal clamp with a mass of 3.00 kg attached to one end and a second clamp with a mass of 1.00 kg attached to the other. The mass of the meter stick can be neglected. The system is released from rest with the stick horizontal. What is the speed of each clamp as the stick swings through a vertical position?

7–58 A car in an amusement park ride rolls without friction around the loop-the-loop track shown in Fig. 7–20. It starts from rest at point A at a height h above the bottom of the loop.

a) What is the minimum value of h (in terms of R) such that the car moves around the loop without falling off at the top (point B)?

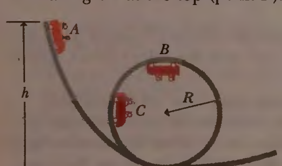


FIGURE 7–20

b) If $h = 2.75R$ and $R = 25.0$ m, compute the speed, radial acceleration, and tangential acceleration of the passengers when the car is at point C, which is at the end of a horizontal diameter. Show these acceleration components in a diagram, approximately to scale.

7–59 A man with a mass of 90.0 kg sits on a platform suspended from a moveable pulley as shown in Fig. 7–21 and raises himself at constant speed by a rope passing over a fixed pulley. The platform and the pulleys have negligible mass. Assuming no friction losses, find

a) the force the man must exert;

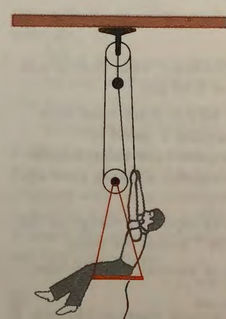


FIGURE 7–21

b) the increase in his energy when he raises himself 2.00 m. Answer by calculating his increase in potential energy and also by computing the product of the force on the rope and the length of the rope passing through his hands.

7–60 A skier starts at the top of a very large frictionless spherical snowball, with a very small initial velocity, and skis straight down the side. At what point does she lose contact with the snowball and fly off at a tangent? That is, at the instant when she loses contact with the snowball, what angle does a radial line from the center of the snowball to the skier make with the vertical?

7–61 A small block of ice with a mass of 0.550 kg is placed against a horizontal compressed spring mounted on a horizontal tabletop that is 1.90 m above the floor. The spring has a force constant $k = 2940$ N·m^{-1} and is