

7 Figure 7-21a shows four situations in which a horizontal force acts on the same block, which is initially at rest. The force magnitudes are  $F_2 = F_4 = 2F_1 = 2F_3$ . The horizontal component  $v_x$  of the block's velocity is shown in Fig. 7-21b for the four situations. (a) Which plot in Fig. 7-21b best corresponds to which force in Fig. 7-21a? (b) Which of the plots in Fig. 7-21c (for kinetic energy  $K$  versus time  $t$ ) best corresponds to which plot in Fig. 7-21b?

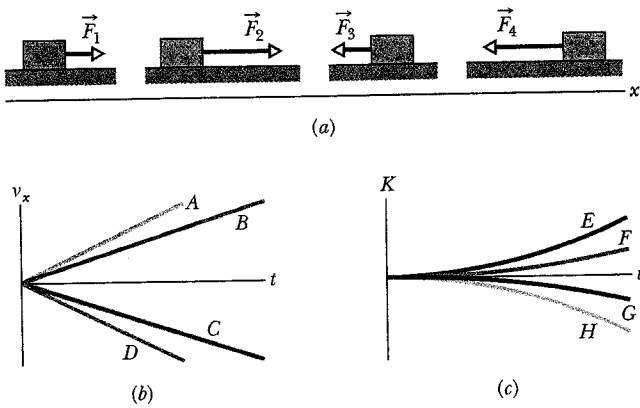


Fig. 7-21 Question 7.

- 8 Spring A is stiffer than spring B ( $k_A > k_B$ ). The spring force of which spring does more work if the springs are compressed (a) the same distance and (b) by the same applied force?
- 9 A glob of slime is launched or dropped from the edge of

a cliff. Which of the graphs in Fig. 7-22 could possibly show how the kinetic energy of the glob changes during its flight?

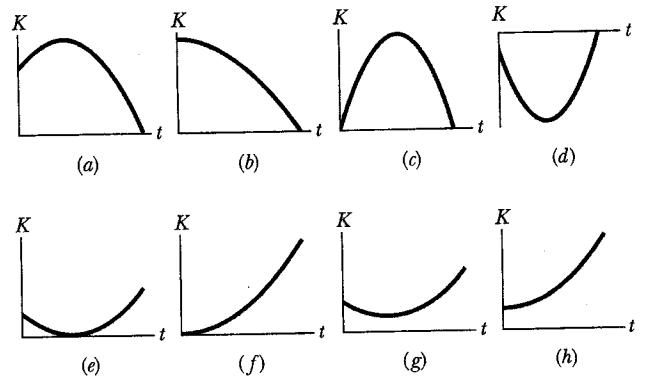


Fig. 7-22 Question 9.

- 10 Figure 7-23 gives the  $x$  component  $F_x$  of a force that can act on a particle. If the particle begins at rest at  $x = 0$ , what is its coordinate when it has (a) its greatest kinetic energy, (b) its greatest speed, and (c) zero speed? (d) What is the particle's direction of travel after it reaches  $x = 6$  m?

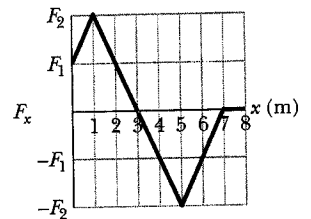


Fig. 7-23 Question 10.

## Problems

- SSM** Solution is in the Student Solutions Manual.  
**WWW** Solution is at <http://www.wiley.com/college/halliday>  
**ILW** Interactive LearningWare solution is at <http://www.wiley.com/college/halliday>  
 • • • Number of dots indicates level of problem difficulty.

### sec. 7-3 Kinetic Energy

- 1 If a Saturn V rocket with an Apollo spacecraft attached had a combined mass of  $2.9 \times 10^5$  kg and reached a speed of 11.2 km/s, how much kinetic energy would it then have?
- 2 On August 10, 1972, a large meteorite skipped across the atmosphere above the western United States and western Canada, much like a stone skipped across water. The accompanying fireball was so bright that it could be seen in the daytime sky and was brighter than the usual meteorite trail (Fig. 7-24). The meteorite's mass was about  $4 \times 10^6$  kg; its speed was about 15 km/s. Had it entered the atmosphere vertically, it would have hit Earth's surface with about the same speed. (a) Calculate the meteorite's loss of kinetic energy (in joules) that would have been associated with the vertical impact. (b) Express the energy as a multiple of the explosive energy of 1 megaton of TNT, which is  $4.2 \times 10^{15}$  J. (c) The energy associated with the atomic bomb explosion over Hiroshima was equivalent to 13 kilotons of TNT. To how many Hiroshima bombs would the meteorite impact have been equivalent?
- 3 A proton (mass  $m = 1.67 \times 10^{-27}$  kg) is being accelerated along a straight line at  $3.6 \times 10^{15}$  m/s<sup>2</sup> in a machine. If the

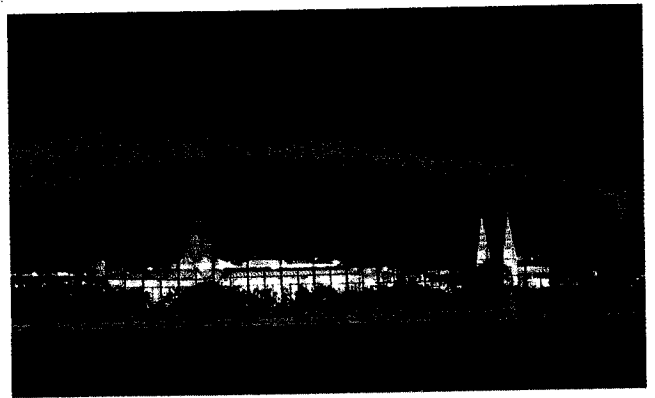


Fig. 7-24 Problem 2. A daytime meteorite trail.

proton has an initial speed of  $2.4 \times 10^7$  m/s and travels 3.5 cm, what then is (a) its speed and (b) the increase in its kinetic energy? **SSM**

- 4 A bead with mass  $1.8 \times 10^{-2}$  kg is moving along a wire in the positive direction of an  $x$  axis. Beginning at time  $t = 0$ , when the bead passes through  $x = 0$  with speed 12 m/s, a constant force acts on the bead. Figure 7-25 indicates the

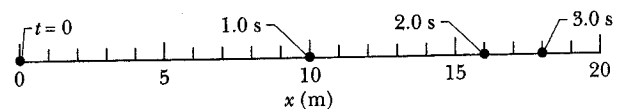


Fig. 7-25 Problem 4.

bead's position at times  $t = 0, 1.0, 2.0,$  and  $3.0$  s. The bead momentarily stops at  $t = 3.0$  s. What is the kinetic energy of the bead at  $t = 10$  s?

••5 A father racing his son has half the kinetic energy of the son, who has half the mass of the father. The father speeds up by  $1.0$  m/s and then has the same kinetic energy as the son. What are the original speeds of (a) the father and (b) the son?

### sec. 7-5 Work and Kinetic Energy

•6 The only force acting on a  $2.0$  kg canister that is moving in an  $xy$  plane has a magnitude of  $5.0$  N. The canister initially has a velocity of  $4.0$  m/s in the positive  $x$  direction and some time later has a velocity of  $6.0$  m/s in the positive  $y$  direction. How much work is done on the canister by the  $5.0$  N force during this time?

•7 A coin slides over a frictionless plane and across an  $xy$  coordinate system from the origin to a point with  $xy$  coordinates  $(3.0$  m,  $4.0$  m) while a constant force acts on it. The force has magnitude  $2.0$  N and is directed at a counterclockwise angle of  $100^\circ$  from the positive direction of the  $x$  axis. How much work is done by the force on the coin during the displacement?

•8 A floating ice block is pushed through a displacement  $\vec{d} = (15$  m) $\hat{i} - (12$  m) $\hat{j}$  along a straight embankment by rushing water, which exerts a force  $\vec{F} = (210$  N) $\hat{i} - (150$  N) $\hat{j}$  on the block. How much work does the force do on the block during the displacement?

••9 A  $3.0$  kg body is at rest on a frictionless horizontal air track when a constant horizontal force  $\vec{F}$  acting in the positive direction of an  $x$  axis along the track is applied to the body. A stroboscopic graph of the position of the body as it slides to the right is shown in Fig. 7-26. The force  $\vec{F}$  is applied to the body at  $t = 0$ , and the graph records the position of the body at  $0.50$  s intervals. How much work is done on the body by the applied force  $\vec{F}$  between  $t = 0$  and  $t = 2.0$  s?

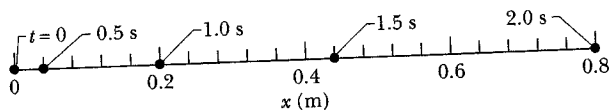


Fig. 7-26 Problem 9.

••10 An  $8.0$  kg object is moving in the positive direction of an  $x$  axis. When it passes through  $x = 0$ , a constant force directed along the axis begins to act on it. Figure 7-27 gives its kinetic energy  $K$  versus position  $x$  as it moves from  $x = 0$  to  $x = 5.0$  m. The force continues to act. What is  $v$  when the object moves back through  $x = -3.0$  m?

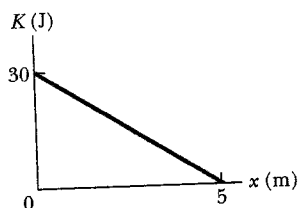


Fig. 7-27 Problem 10.

••11 A luge and its rider, with a total mass of  $85$  kg, emerge from a downhill track onto a horizontal straight track with an initial speed of  $37$  m/s. If a force slows them to a stop at a constant rate of  $2.0$  m/s<sup>2</sup>, (a) what magnitude  $F$  is required for the force, (b) what distance  $d$  do they travel while slowing, and (c) what work  $W$  is done on them by the force? What are (d)  $F$ , (e)  $d$ , and (f)  $W$  if they, instead, slow at  $4.0$  m/s<sup>2</sup>? **WWW**

••12 A can of bolts and nuts is pushed  $2.00$  m along an  $x$  axis by a broom along the greasy (frictionless) floor of a car repair shop in a version of shuffleboard. Figure 7-28 gives the work  $W$  done on the can by the constant horizontal force from the broom, versus the can's position  $x$ . (a) What is the magnitude of that force? (b) If the can had an initial kinetic energy of  $3.00$  J, moving in the positive direction of the  $x$  axis, what is its kinetic energy at the end of the  $2.00$  m?

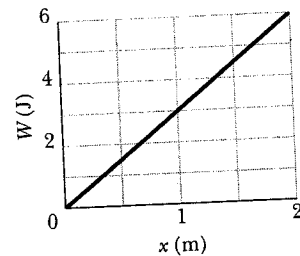


Fig. 7-28 Problem 12.

••13 Figure 7-29 shows three forces applied to a trunk that moves leftward by  $3.00$  m over a frictionless floor. The force magnitudes are  $F_1 = 5.00$  N,  $F_2 = 9.00$  N, and  $F_3 = 3.00$  N, and the indicated angle is  $\theta = 60.0^\circ$ . During the displacement, (a) what is the net work done on the trunk by the three forces and (b) does the kinetic energy of the trunk increase or decrease? **SSM**

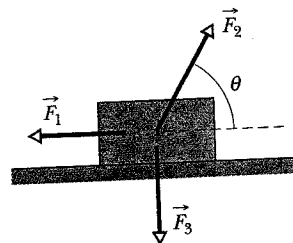


Fig. 7-29 Problem 13.

••14 Figure 7-30 shows an overhead view of three horizontal forces acting on a cargo canister that was initially stationary but now moves across a frictionless floor. The force magnitudes are  $F_1 = 3.00$  N,  $F_2 = 4.00$  N, and  $F_3 = 10.0$  N, and the indicated angles are  $\theta_2 = 50.0^\circ$  and  $\theta_3 = 35.0^\circ$ . What is the net work done on the canister by the three forces during the first  $4.00$  m of displacement?

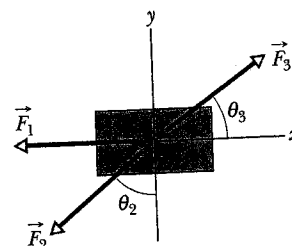


Fig. 7-30 Problem 14.

••15 A  $12.0$  N force with a fixed orientation does work on a particle as the particle moves through displacement  $\vec{d} = (2.00\hat{i} - 4.00\hat{j} + 3.00\hat{k})$  m. What is the angle between the force and the displacement if the change in the particle's kinetic energy is (a)  $+30.0$  J and (b)  $-30.0$  J?

### sec. 7-6 Work Done by the Gravitational Force

•16 (a) In 1975 the roof of Montreal's Velodrome, with a weight of  $360$  kN, was lifted by  $10$  cm so that it could be centered. How much work was done on the roof by the forces making the lift? (b) In 1960 a Tampa, Florida, mother reportedly raised one end of a car that had fallen onto her son when a jack failed. If her panic lift effectively raised  $4000$  N (about  $\frac{1}{4}$  of the car's weight) by  $5.0$  cm, how much work did her force do on the car?

•17 A helicopter lifts a  $72$  kg astronaut  $15$  m vertically from the ocean by means of a cable. The acceleration of the astronaut is  $g/10$ . How much work is done on the astronaut by (a) the force from the helicopter and (b) the gravitational force on her? Just before she reaches the helicopter, what are her (c) kinetic energy and (d) speed? **SSM WWW**

••18 In Fig. 7-31, a horizontal force  $\vec{F}_a$  of magnitude 20.0 N is applied to a 3.00 kg psychology book as the book slides a distance  $d = 0.500$  m up a frictionless ramp at angle  $\theta = 30.0^\circ$ . (a) During the displacement, what is the net work done on the book by  $\vec{F}_a$ , the gravitational force on the book, and the normal force on the book? (b) If the book has zero kinetic energy at the start of the displacement, what is its speed at the end of the displacement?

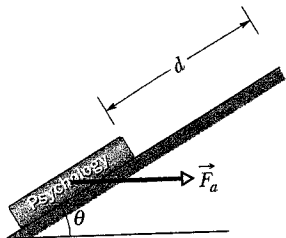


Fig. 7-31 Problem 18.

••19 A cord is used to vertically lower an initially stationary block of mass  $M$  at a constant downward acceleration of  $g/4$ . When the block has fallen a distance  $d$ , find (a) the work done by the cord's force on the block, (b) the work done by the gravitational force on the block, (c) the kinetic energy of the block, and (d) the speed of the block. **SSM**

••20 In Fig. 7-32, a constant force  $\vec{F}_a$  of magnitude 82.0 N is applied to a 3.00 kg shoe box at angle  $\phi = 53.0^\circ$ , causing the box to move up a frictionless ramp at constant speed. How much work is done on the box by  $\vec{F}_a$  when the box has moved through vertical distance  $h = 0.150$  m?

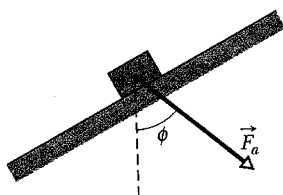


Fig. 7-32 Problem 20.

••21 In Fig. 7-33, a block of ice slides down a frictionless ramp at angle  $\theta = 50^\circ$  while an ice worker pulls on the block (via a rope) with a force  $\vec{F}_r$  that has a magnitude of 50 N and is directed up the ramp. As the block slides through distance  $d = 0.50$  m along the ramp, its kinetic energy increases by 80 J. How much greater would its kinetic energy have been if the rope had not been attached to the block?

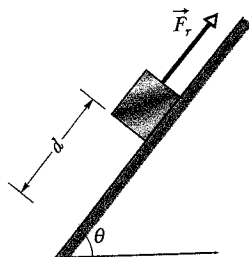


Fig. 7-33 Problem 21.

••22 A cave rescue team lifts an injured spelunker directly upward and out of a sinkhole by means of a motor-driven cable. The lift is performed in three stages, each requiring a vertical distance of 10.0 m: (a) the initially stationary spelunker is accelerated to a speed of 5.00 m/s; (b) he is then lifted at the constant speed of 5.00 m/s; (c) finally he is decelerated to zero speed. How much work is done on the 80.0 kg rescuee by the force lifting him during each stage?

•••23 In Fig. 7-34, a 0.250 kg block of cheese lies on the floor of a 900 kg elevator cab that is being pulled upward by a cable through distance  $d_1 = 2.40$  m and then through distance  $d_2 = 10.5$  m. (a) Through  $d_1$ , if the normal force on the block from the floor has constant magnitude  $F_N = 3.00$  N, how much work is done on the cab by the force from the cable? (b) Through  $d_2$ , if the

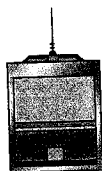


Fig. 7-34 Problem 23.

work done on the cab by the (constant) force from the cable is 92.61 kJ, what is the magnitude of  $F_N$ ?

**sec. 7-7 Work Done by a Spring Force**

•24 During spring semester at MIT, residents of the parallel buildings of the East Campus dorms battle one another with large catapults that are made with surgical hose mounted on a window frame. A balloon filled with dyed water is placed in a pouch attached to the hose, which is then stretched through the width of the room. Assume that the stretching of the hose obeys Hooke's law with a spring constant of 100 N/m. If the hose is stretched by 5.00 m and then released, how much work does the force from the hose do on the balloon in the pouch by the time the hose reaches its relaxed length?

•25 In Fig. 7-11, we must apply a force of magnitude 80 N to hold the block stationary at  $x = -2.0$  cm. From that position, we then slowly move the block so that our force does +4.0 J of work on the spring-block system; the block is then again stationary. What is the block's position? (*Hint:* There are two answers.)

•26 A spring and block are in the arrangement of Fig. 7-11. When the block is pulled out to  $x = +4.0$  cm, we must apply a force of magnitude 360 N to hold it there. We pull the block to  $x = 11$  cm and then release it. How much work does the spring do on the block when the block moves from  $x_i = +5.0$  cm to (a)  $x = +3.0$  cm, (b)  $x = -3.0$  cm, (c)  $x = -5.0$  cm, and (d)  $x = -9.0$  cm?

••27 Figure 7-35 gives spring force  $F_x$  versus position  $x$  for the spring-block arrangement of Fig. 7-11. We pull the block out to  $x = 12$  cm and then release it. How much work does the spring do on the block when the block moves from  $x_i = +8.0$  cm to (a)  $x = +5.0$  cm, (b)  $x = -5.0$  cm, (c)  $x = -8.0$  cm, and (d)  $x = -10.0$  cm?

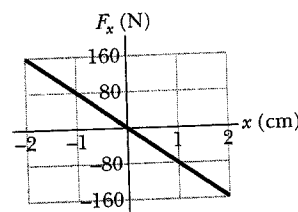


Fig. 7-35 Problem 27.

••28 In the arrangement of Fig. 7-11, we gradually pull the block from  $x = 0$  to  $x = +3.0$  cm, where it is stationary. Figure 7-36 gives the work that our force does on the block. We then pull the block out to  $x = +5.0$  cm and release it from rest. How much work does the spring do on the block

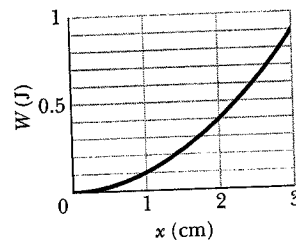


Fig. 7-36 Problem 28.

when the block moves from  $x_i = +5.0$  cm to (a)  $x = +4.0$  cm, (b)  $x = -2.0$  cm, and (c)  $x = -5.0$  cm?

••29 The only force acting on a 2.0 kg body as it moves along a positive  $x$  axis has an  $x$  component  $F_x = -6x$  N, with  $x$  in meters. The velocity of the body at  $x = 3.0$  m is 8.0 m/s. (a) What is the velocity of the body at  $x = 4.0$  m? (b) At what positive value of  $x$  will the body have a velocity of 5.0 m/s? **SSM WWW**

•••30 The block in Fig. 7-11a lies on a horizontal frictionless surface, and the spring constant is 50 N/m. Initially, the spring is at its relaxed length and the block is stationary at position  $x = 0$ . Then an applied force with a constant magnitude of

3.0 N pulls the block in the positive direction of the  $x$  axis, stretching the spring until the block stops. When that stopping point is reached, what are (a) the position of the block, (b) the work that has been done on the block by the applied force, and (c) the work that has been done on the block by the spring force? During the block's displacement, what are (d) the block's position when its kinetic energy is maximum and (e) the value of that maximum kinetic energy?

### sec. 7-8 Work Done by a General Variable Force

•31 A 10 kg brick moves along an  $x$  axis. Its acceleration as a function of its position is shown in Fig. 7-37. What is the net work performed on the brick by the force causing the acceleration as the brick moves from  $x = 0$  to  $x = 8.0$  m? **ILW**

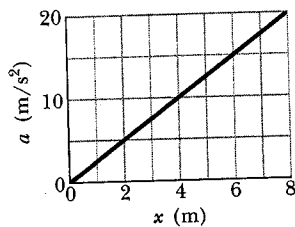


Fig. 7-37 Problem 31.

•32 A 5.0 kg block moves in a straight line on a horizontal frictionless surface under the influence of a force that varies with position as shown in Fig. 7-38. How much work is done by the force as the block moves from the origin to  $x = 8.0$  m?

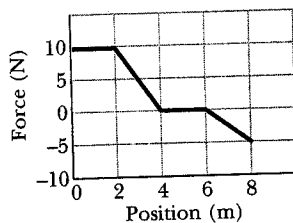


Fig. 7-38 Problem 32.

•33 The force on a particle is directed along an  $x$  axis and given by  $F = F_0(x/x_0 - 1)$ . Find the work done by the force in moving the particle from  $x = 0$  to  $x = 2x_0$  by (a) plotting  $F(x)$  and measuring the work from the graph and (b) integrating  $F(x)$ . **SSM WWW**

•34 A can of sardines is made to move along an  $x$  axis from  $x = 0.25$  m to  $x = 1.25$  m by a force with a magnitude given by  $F = \exp(-4x^2)$ , with  $x$  in meters and  $F$  in newtons. (Here  $\exp$  is the exponential function.) How much work is done on the can by the force?

•35 A single force acts on a 3.0 kg particle-like object in such a way that the position of the object as a function of time is given by  $x = 3.0t - 4.0t^2 + 1.0t^3$ , with  $x$  in meters and  $t$  in seconds. Find the work done on the object by the force from  $t = 0$  to  $t = 4.0$  s.

•36 A 1.5 kg block is initially at rest on a horizontal frictionless surface when a horizontal force along an  $x$  axis is applied to the block. The force is given by  $\vec{F}(x) = (2.5 - x^2)\hat{i}$  N, where  $x$  is in meters and the initial position of the block is  $x = 0$ . (a) What is the kinetic energy of the block as it passes through  $x = 2.0$  m? (b) What is the maximum kinetic energy of the block between  $x = 0$  and  $x = 2.0$  m?

•37 Figure 7-39 gives the acceleration of a 2.00 kg particle as an applied force  $\vec{F}_a$  moves it from rest along an  $x$  axis from  $x = 0$  to  $x = 9.0$  m. How much work has the force done on the particle when the particle reaches (a)  $x = 4.0$  m, (b)  $x =$

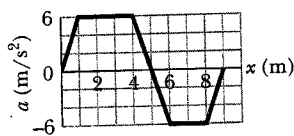


Fig. 7-39 Problem 37.

7.0 m, and (c)  $x = 9.0$  m? What is the particle's speed and direction of travel when it reaches (d)  $x = 4.0$  m, (e)  $x = 7.0$  m, and (f)  $x = 9.0$  m?

•38 A force  $\vec{F} = (cx - 3.00x^2)\hat{i}$  acts on a particle as the particle moves along an  $x$  axis, with  $\vec{F}$  in newtons,  $x$  in meters, and  $c$  a constant. At  $x = 0$ , the particle's kinetic energy is 20.0 J; at  $x = 3.00$  m, it is 11.0 J. Find  $c$ .

•39 Figure 7-40 shows a cord attached to a cart that can slide along a frictionless horizontal rail aligned along an  $x$  axis. The left end of the cord is pulled over a pulley, of negligible mass and friction and at cord height  $h = 1.20$  m, so the cart slides from  $x_1 = 3.00$  m to  $x_2 = 1.00$  m. During the move, the tension in the cord is a constant 25.0 N. What is the change in the kinetic energy of the cart during the move?

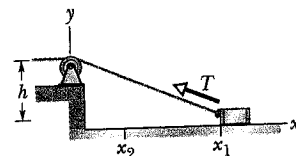


Fig. 7-40 Problem 39.

### sec. 7-9 Power

•40 The loaded cab of an elevator has a mass of  $3.0 \times 10^3$  kg and moves 210 m up the shaft in 23 s at constant speed. At what average rate does the force from the cable do work on the cab?

•41 A 100 kg block is pulled at a constant speed of 5.0 m/s across a horizontal floor by an applied force of 122 N directed  $37^\circ$  above the horizontal. What is the rate at which the force does work on the block? **SSM ILW**

•42 A skier is pulled by a tow rope up a frictionless ski slope that makes an angle of  $12^\circ$  with the horizontal. The rope moves parallel to the slope with a constant speed of 1.0 m/s. The force of the rope does 900 J of work on the skier as the skier moves a distance of 8.0 m up the incline. (a) If the rope moved with a constant speed of 2.0 m/s, how much work would the force of the rope do on the skier as the skier moved a distance of 8.0 m up the incline? At what rate is the force of the rope doing work on the skier when the rope moves with a speed of (b) 1.0 m/s and (c) 2.0 m/s?

•43 A force of 5.0 N acts on a 15 kg body initially at rest. Compute the work done by the force in (a) the first, (b) the second, and (c) the third seconds and (d) the instantaneous power due to the force at the end of the third second. **SSM**

•44 (a) At a certain instant, a particle-like object is acted on by a force  $\vec{F} = (4.0 \text{ N})\hat{i} - (2.0 \text{ N})\hat{j} + (9.0 \text{ N})\hat{k}$  while the object's velocity is  $\vec{v} = -(2.0 \text{ m/s})\hat{i} + (4.0 \text{ m/s})\hat{k}$ . What is the instantaneous rate at which the force does work on the object? (b) At some other time, the velocity consists of only a  $y$  component. If the force is unchanged and the instantaneous power is  $-12$  W, what is the velocity of the object just then?

•45 A fully loaded, slow-moving freight elevator has a cab with a total mass of 1200 kg, which is required to travel upward 54 m in 3.0 min, starting and ending at rest. The elevator's counterweight has a mass of only 950 kg, and so the elevator motor must help. What average power is required of the force the motor exerts on the cab via the cable? **SSM**

•46 A 0.30 kg ladle sliding on a horizontal frictionless surface is attached to one end of a horizontal spring ( $k = 500$  N/m) whose other end is fixed. The ladle has a kinetic energy of 10 J as it passes through its equilibrium position (the point at which the spring force is zero). (a) At what rate is the spring doing work on the ladle as the ladle passes through its

equilibrium position? (b) At what rate is the spring doing work on the ladle when the spring is compressed 0.10 m and the ladle is moving away from the equilibrium position?

••47 A machine carries a 4.0 kg package from an initial position of  $\vec{d}_i = (0.50 \text{ m})\hat{i} + (0.75 \text{ m})\hat{j} + (0.20 \text{ m})\hat{k}$  at  $t = 0$  to a final position of  $\vec{d}_f = (7.50 \text{ m})\hat{i} + (12.0 \text{ m})\hat{j} + (7.20 \text{ m})\hat{k}$  at  $t = 12 \text{ s}$ . The constant force applied by the machine on the package is  $\vec{F} = (2.00 \text{ N})\hat{i} + (4.00 \text{ N})\hat{j} + (6.00 \text{ N})\hat{k}$ . For that displacement, find (a) the work done on the package by the machine's force and (b) the average power of the machine's force on the package.

•••48 A force  $\vec{F} = (3.00 \text{ N})\hat{i} + (7.00 \text{ N})\hat{j} + (7.00 \text{ N})\hat{k}$  acts on a 2.00 kg mobile object that moves from an initial position of  $\vec{d}_i = (3.00 \text{ m})\hat{i} - (2.00 \text{ m})\hat{j} + (5.00 \text{ m})\hat{k}$  to a final position of  $\vec{d}_f = -(5.00 \text{ m})\hat{i} + (4.00 \text{ m})\hat{j} + (7.00 \text{ m})\hat{k}$  in 4.00 s. Find (a) the work done on the object by the force in the 4.00 s interval, (b) the average power due to the force during that interval, and (c) the angle between vectors  $\vec{d}_i$  and  $\vec{d}_f$ .

### Additional Problems

49 The only force acting on a 2.0 kg body as the body moves along an  $x$  axis varies as shown in Fig. 7-41. The velocity of the body at  $x = 0$  is 4.0 m/s. (a) What is the kinetic energy of the body at  $x = 3.0 \text{ m}$ ? (b) At what value of  $x$  will the body have a kinetic energy of 8.0 J? (c) What is the maximum kinetic energy of the body between  $x = 0$  and  $x = 5.0 \text{ m}$ ?

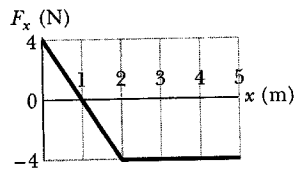


Fig. 7-41 Problem 49.

50 A 250 g block is dropped onto a relaxed vertical spring that has a spring constant of  $k = 2.5 \text{ N/cm}$  (Fig. 7-42). The block becomes attached to the spring and compresses the spring and compresses the spring 12 cm before momentarily stopping. While the spring is being compressed, what work is done on the block by (a) the gravitational force on it and (b) the spring force? (c) What is the speed of the block just before it hits the spring? (Assume that friction is negligible.) (d) If the speed at impact is doubled, what is the maximum compression of the spring?

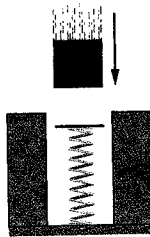


Fig. 7-42 Problem 50.

51 A 45 kg block of ice slides down a frictionless incline 1.5 m long and 0.91 m high. A worker pushes up against the ice, parallel to the incline, so that the block slides down at constant speed. (a) Find the magnitude of the worker's force. How much work is done on the block by (b) the worker's force, (c) the gravitational force on the block, (d) the normal force on the block from the surface of the incline, and (e) the net force on the block?

52 To pull a 50 kg crate across a horizontal frictionless floor, a worker applies a force of 210 N, directed  $20^\circ$  above the horizontal. As the crate moves 3.0 m, what work is done on the crate by (a) the worker's force, (b) the gravitational force on the crate, and (c) the normal force on the crate from the floor? (d) What is the total work done on the crate?

53 A force  $\vec{F}_a$  is applied to a bead as the bead is moved along a straight wire through displacement  $+5.0 \text{ cm}$ . The magnitude

of  $\vec{F}_a$  is set at a certain value, but the angle  $\phi$  between  $\vec{F}_a$  and the bead's displacement can be chosen. Figure 7-43 gives the work  $W$  done by  $\vec{F}_a$  on the bead for a range of  $\phi$  values. How much work is done by  $\vec{F}_a$  if  $\phi$  is (a)  $64^\circ$  and (b)  $147^\circ$ ?

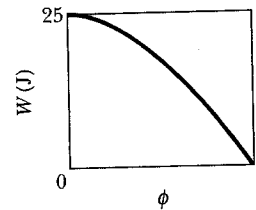


Fig. 7-43 Problem 53.

54 In Fig. 7-44a, a 2.0 N force is applied to a 4.0 kg block at a downward angle  $\theta$  as the block moves rightward through 1.0 m across a frictionless floor. Find an expression for the speed  $v_f$  of the block at the end of that distance if the block's initial velocity is (a) 0 and (b) 1.0 m/s to the right. (c) The situation in Fig. 7-44b is similar in that the block is initially moving at 1.0 m/s to the right, but now the 2.0 N force is directed downward to the left. Find an expression for the speed  $v_f$  of the block at the end of the 1.0 m distance. (d) Graph all three expressions for  $v_f$  versus downward angle  $\theta$  for  $\theta = 0^\circ$  to  $\theta = 90^\circ$ . Interpret the graphs.

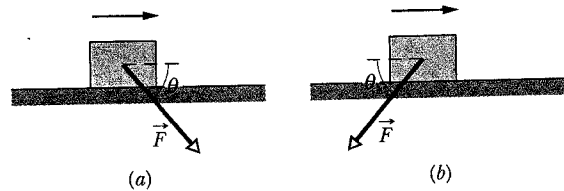


Fig. 7-44 Problem 54.

55 A 2.0 kg lunchbox is sent sliding over a frictionless surface, in the positive direction of an  $x$  axis along the surface. Beginning at time  $t = 0$ , a steady wind pushes on the lunchbox in the negative direction of the  $x$  axis. Figure 7-45 shows the position  $x$  of the lunchbox as a function of time  $t$  as the wind pushes on the lunchbox. From the graph, estimate the kinetic energy of the lunchbox at (a)  $t = 1.0 \text{ s}$  and (b)  $t = 5.0 \text{ s}$ . (c) How much work does the force from the wind do on the lunchbox from  $t = 1.0 \text{ s}$  to  $t = 5.0 \text{ s}$ ?

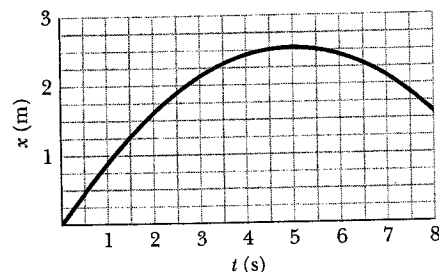


Fig. 7-45 Problem 55.

56 A force  $\vec{F} = (4.0 \text{ N})\hat{i} + c\hat{j}$  acts on a particle as the particle goes through displacement  $\vec{d} = (3.0 \text{ m})\hat{i} - (2.0 \text{ m})\hat{j}$ . (Other forces also act on the particle.) What is  $c$  if the work done on the particle by force  $\vec{F}$  is (a) 0, (b) 17 J, and (c)  $-18 \text{ J}$ ?

57 Figure 7-46 shows a cold package of hot dogs sliding rightward across a frictionless floor through a distance  $d = 20.0 \text{ cm}$  while three forces act on the package. Two of them are horizontal and have the magnitudes  $F_1 = 5.00 \text{ N}$  and  $F_2 = 1.00 \text{ N}$ ; the third is angled down by  $\theta = 60.0^\circ$  and has the magnitude  $F_3 = 4.00 \text{ N}$ . (a) For the 20.0 cm displacement, what is the net

work done on the package by the three applied forces, the gravitational force on the package, and the normal force on the package? (b) If the package has a mass of 2.0 kg and an initial kinetic energy of 0, what is its speed at the end of the displacement?

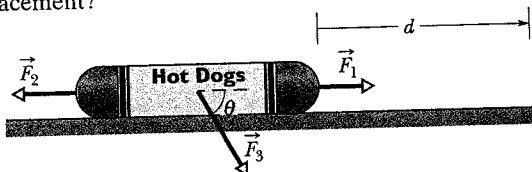


Fig. 7-46 Problem 57.

58 A force  $\vec{F}$  in the positive direction of an  $x$  axis acts on an object moving along the axis. If the magnitude of the force is  $F = 10e^{-x/2.0}$  N, with  $x$  in meters, find the work done by  $\vec{F}$  as the object moves from  $x = 0$  to  $x = 2.0$  m by (a) plotting  $F(x)$  and estimating the area under the curve and (b) integrating to find the work analytically.

59 To push a 25.0 kg crate up a frictionless incline, angled at  $25.0^\circ$  to the horizontal, a worker exerts a force of 209 N parallel to the incline. As the crate slides 1.50 m, how much work is done on the crate by (a) the worker's applied force, (b) the gravitational force on the crate, and (c) the normal force exerted by the incline on the crate? (d) What is the total work done on the crate?

60 A force  $\vec{F} = (3.0\hat{i} + 7.0\hat{j} + 7.0\hat{k})$  N acts on a 2.00 kg object that moves in 4.0 s from an initial position  $\vec{d}_i = (3.0\hat{i} - 2.0\hat{j} + 5.0\hat{k})$  m to a final position  $\vec{d}_f = (-5.0\hat{i} + 4.0\hat{j} + 7.0\hat{k})$  m. Find (a) the work done on the object by the force in that time interval, (b) the average power due to the force during that time interval, and (c) the angle between vectors  $\vec{d}_i$  and  $\vec{d}_f$ .

61 In Fig. 7-11a, a block of mass  $m$  lies on a horizontal frictionless surface and is attached to one end of a horizontal spring (spring constant  $k$ ) whose other end is fixed. The block is initially at rest at the position where the spring is unstretched ( $x = 0$ ) when a constant horizontal force  $\vec{F}$  in the positive direction of the  $x$  axis is applied to it. A plot of the resulting kinetic energy of the block versus its position  $x$  is shown in Fig. 7-47. (a) What is the magnitude of  $\vec{F}$ ? (b) What is the value of  $k$ ?

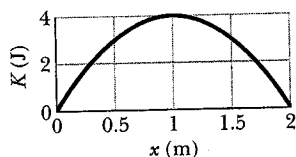


Fig. 7-47 Problem 61.

62 A constant force of magnitude 10 N makes an angle of  $150^\circ$  (measured counterclockwise) with the positive  $x$  direction as it acts on a 2.0 kg object moving in an  $xy$  plane. How much work is done on the object by the force as the object moves from the origin to the point having position vector  $(2.0\text{ m})\hat{i} - (4.0\text{ m})\hat{j}$ ?

63 In Fig. 7-48, a cord runs around two massless, frictionless pulleys. A canister with mass  $m = 20$  kg hangs from

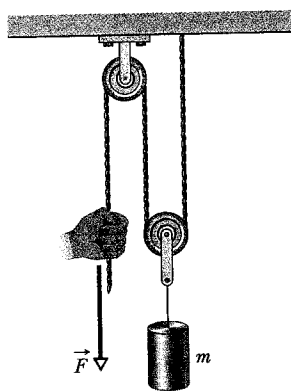


Fig. 7-48 Problem 63.

one pulley, and you exert a force  $\vec{F}$  on the free end of the cord. (a) What must be the magnitude of  $\vec{F}$  if you are to lift the canister at a constant speed? (b) To lift the canister by 2.0 cm, how far must you pull the free end of the cord? During that lift, what is the work done on the canister by (c) your force (via the cord) and (d) the gravitational force? (Hint: When a cord loops around a pulley as shown, it pulls on the pulley with a net force that is twice the tension in the cord.)

64 An initially stationary 2.0 kg object accelerates horizontally and uniformly to a speed of 10 m/s in 3.0 s. (a) In that 3.0 s interval, how much work is done on the object by the force accelerating it? What is the instantaneous power due to that force (b) at the end of the interval and (c) at the end of the first half of the interval?

65 What work is done by a force  $\vec{F} = (2x\text{ N})\hat{i} + (3\text{ N})\hat{j}$ , with  $x$  in meters, that moves a particle from a position  $\vec{r}_i = (2\text{ m})\hat{i} + (3\text{ m})\hat{j}$  to a position  $\vec{r}_f = -(4\text{ m})\hat{i} - (3\text{ m})\hat{j}$ ?

66 If a ski lift raises 100 passengers averaging 660 N in weight to a height of 150 m in 60.0 s, at constant speed, what average power is required of the force making the lift?

67 Boxes are transported from one location to another in a warehouse by means of a conveyor belt that moves with a constant speed of 0.50 m/s. At a certain location the conveyor belt moves for 2.0 m up an incline that makes an angle of  $10^\circ$  with the horizontal, then for 2.0 m horizontally, and finally for 2.0 m down an incline that makes an angle of  $10^\circ$  with the horizontal. Assume that a 2.0 kg box rides on the belt without slipping. At what rate is the force of the conveyor belt doing work on the box as the box moves (a) up the  $10^\circ$  incline, (b) horizontally, and (c) down the  $10^\circ$  incline?

68 An iceboat is at rest on a frictionless frozen lake when a sudden wind exerts a constant force of 200 N, toward the east, on the boat. Due to the angle of the sail, the wind causes the boat to slide in a straight line for a distance of 8.0 m in a direction  $20^\circ$  north of east. What is the kinetic energy of the iceboat at the end of that 8.0 m?

69 A frightened child is restrained by her mother as the child slides down a frictionless playground slide. If the force on the child from the mother is 100 N up the slide, the child's kinetic energy increases by 30 J as she moves down the slide a distance of 1.8 m. (a) How much work is done on the child by the gravitational force during the 1.8 m descent? (b) If the child is not restrained by her mother, how much will the child's kinetic energy increase as she comes down the slide that same distance of 1.8 m?

70 A 230 kg crate hangs from the end of a rope of length  $L = 12.0$  m. You push horizontally on the crate with a varying force  $\vec{F}$  to move it distance  $d = 4.00$  m to the side (Fig. 7-49). (a) What is the magnitude of  $\vec{F}$  when the crate is in this final position? During the crate's displacement, what are (b) the total work done on it, (c) the work done by the gravitational force on the crate, and (d) the work done by the pull on the crate from the rope? (e) Knowing that the crate is motionless before and after its dis-

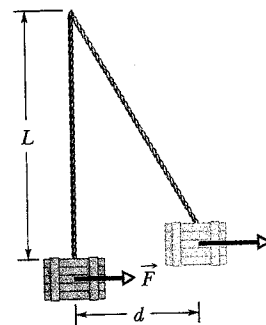


Fig. 7-49 Problem 70.

placement, use the answers to (b), (c), and (d) to find the work your force  $\vec{F}$  does on the crate. (f) Why is the work of your force not equal to the product of the horizontal displacement and the answer to (a)?

**71** A spring with a pointer attached is hanging next to a scale marked in millimeters. Three different packages are hung from the spring, in turn, as shown in Fig. 7-50. (a) Which mark on the scale will the pointer indicate when no package is hung from the spring? (b) What is the weight  $W$  of the third package?

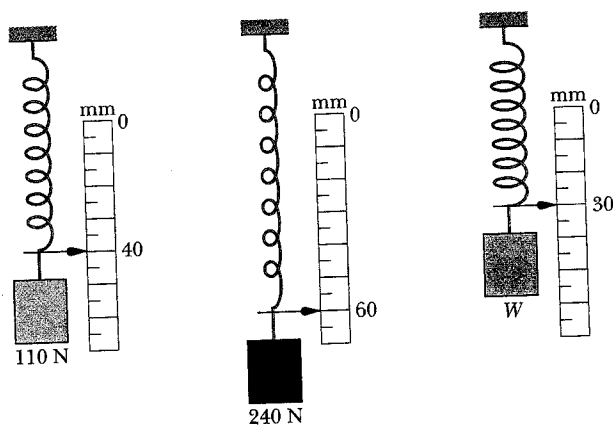


Fig. 7-50 Problem 71.

**72** A particle moves along a straight path through displacement  $\vec{d} = (8 \text{ m})\hat{i} + c\hat{j}$  while force  $\vec{F} = (2 \text{ N})\hat{i} - (4 \text{ N})\hat{j}$  acts on it. (Other forces also act on the particle.) What is the value of  $c$  if the work done by  $\vec{F}$  on the particle is (a) zero, (b) positive, and (c) negative?

**73** An elevator cab has a mass of 4500 kg and can carry a maximum load of 1800 kg. If the cab is moving upward at full load at 3.80 m/s, what power is required of the force moving the cab to maintain that speed?

**74** As a particle moves along an  $x$  axis, a force in the positive direction of the axis acts on it. Figure 7-51 shows the magnitude  $F$  of the force versus position  $x$  of the particle. The curve is given by  $F = a/x^2$ , with  $a = 9.0 \text{ N} \cdot \text{m}^2$ . Find the work done on the particle by the force as the particle moves from  $x = 1.0 \text{ m}$  to  $x = 3.0 \text{ m}$  by (a) estimating the work from the graph and (b) integrating the force function.

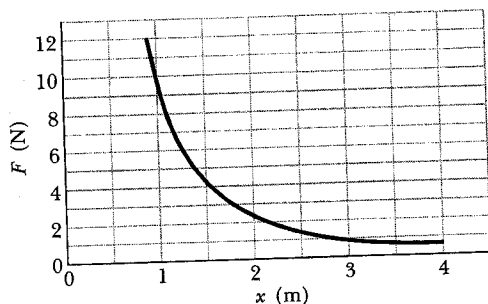


Fig. 7-51 Problem 74.

**75** A CD case slides along a floor in the positive direction of an  $x$  axis while an applied force  $\vec{F}_a$  acts on the case. The force is directed along the  $x$  axis and has the  $x$  component  $F_{ax} =$

$9x - 3x^2$ , with  $x$  in meters and  $F_{ax}$  in newtons. The case starts at rest at the position  $x = 0$ , and it moves until it is again at rest. (a) Plot the work  $\vec{F}_a$  does on the case as a function of  $x$ . (b) At what position is the work maximum, and (c) what is that maximum value? (d) At what position has the work decreased to zero? (e) At what position is the case again at rest?

**76 Numerical integration.** A breadbox is made to move along an  $x$  axis from  $x = 0.15 \text{ m}$  to  $x = 1.20 \text{ m}$  by a force with a magnitude given by  $F = \exp(-2x^2)$ , with  $x$  in meters and  $F$  in newtons. (Here  $\exp$  is the exponential function.) How much work is done on the breadbox by the force?

**77** A horse pulls a cart with a force of 40 lb at an angle of  $30^\circ$  above the horizontal and moves along at a speed of 6.0 mi/h. (a) How much work does the force do in 10 min? (b) What is the average power (in horsepower) of the force?

**78** A 50 kg ice-skater is moving toward the east across a frictionless frozen lake with a constant velocity when the constant force from a sudden wind pushes on the skater toward the west. A plot of position  $x$  versus time  $t$  for the skater's motion is shown in Fig. 7-52, where  $t = 0$  is taken to be the instant the wind starts to blow and the positive direction of the  $x$  axis is toward the east. (a) What is the kinetic energy of the ice-skater at  $t = 0$ ? (b) How much work does the force of the wind do on the ice-skater between  $t = 0$  and  $t = 3.0 \text{ s}$ ?

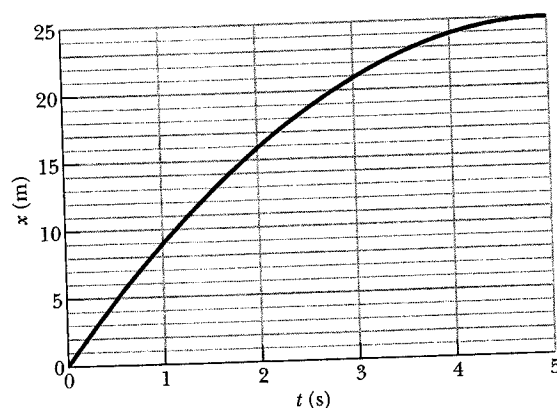


Fig. 7-52 Problem 78.

**79** An explosion at ground level leaves a crater with a diameter that is proportional to the energy of the explosion raised to the  $\frac{1}{3}$  power; an explosion of 1 megaton of TNT leaves a crater with a 1 km diameter. Below Lake Huron in Michigan there appears to be an ancient impact crater with a 50 km diameter. What was the kinetic energy associated with that impact, in terms of (a) megatons of TNT (1 megaton yields  $4.2 \times 10^{15} \text{ J}$ ) and (b) Hiroshima bomb equivalents (13 kilotons of TNT each)? (Ancient meteorite or comet impacts may have significantly altered Earth's climate and contributed to the extinction of the dinosaurs and other life-forms.)

**80** If a car of mass 1200 kg is moving along a highway at 120 km/h, what is the car's kinetic energy as determined by someone standing alongside the highway?

#### On-Line Simulation Problems

The website <http://www.wiley.com/college/halliday> has simulation problems about this chapter.