sec. 7-3 Kinetic Energy

•1 SSM A proton (mass $m = 1.67 \times 10^{-27}$ kg) is being accelerated along a straight line at 3.6×10^{15} m/s^2 in a machine. If the proton has an initial speed of 2.4×10^7 m/s and travels 3.5 cm, what then is (a) its speed and (b) the increase in its kinetic energy?

Answer:

(a) 2.9×10^7 m/s; (b) 2.1×10^{-13} J

•2 If a Saturn V rocket with an Apollo spacecraft attached had a combined mass of 2.9×10^5 kg and reached a speed of 11.2 km/s, how much kinetic energy would it then have?

•3 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. The meteorite's mass was about 4×10^6 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 4.2×10^{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?

Answer:

(a) 5×10^{14} J; (b) 0.1 megaton TNT; (c) 8 bombs

••4 A bead with mass 1.8×10^{-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 7-22 indicates the bead's position at these four times: $t_0 = 0$, $t_1 = 1.0$ s, $t_2 = 2.0$ s, and $t_3 = 3.0$ s. The bead momentarily stops at $t = 3.0$ s. What is the kinetic energy of the bead at $t = 10$ s?

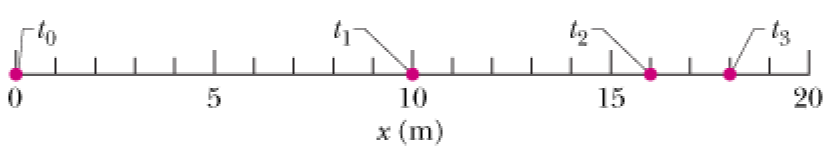

Figure 7-22 Problem 4.

••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?

Answer:

(a) 2.4 m/s; (b) 4.8 m/s

••6 A force $\vec{F}_a$ is applied to a bead as the bead is moved along a straight wire through displacement

+5.0 cm. The magnitude of $\vec{F}$ is set at a certain value, but the angle between $\vec{F}$ and the bead's displacement can be chosen. Figure 7-23 gives the work W done by $\vec{F}$ on the bead for a range of values; W_0 = 25 J. How much work is done by $\vec{F}$ if is (a) 64° and (b) 147°?

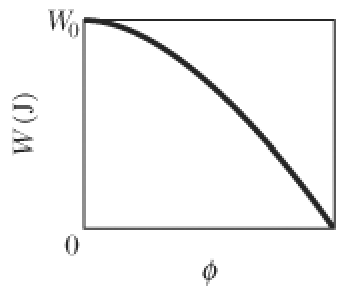

Figure 7-23 Problem 6.

sec. 7-5 Work and Kinetic Energy

•7 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. 7-24. 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?

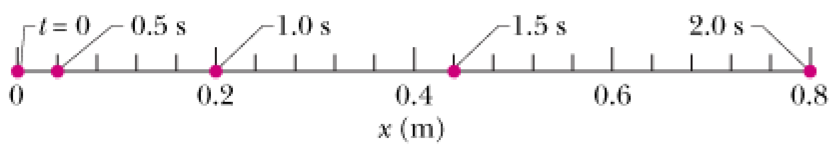

Figure 7-24 Problem 7.

Answer:

0.96 J

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

•9 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?

Answer:

20 J

•10 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° from the positive direction of the x axis. How much work is done by the force on the coin during the displacement?

••11 A 12.0 N force with a fixed orientation does work on a particle as the particle moves through the three-dimensional 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?

Answer:

(a) 62.3°; (b) 118°

••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 7-25 gives the work *W* done on the can by the constant horizontal force from the broom, versus the can's position *x*. The scale of the figure's vertical axis is set by W_s = 6.0 J. (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?

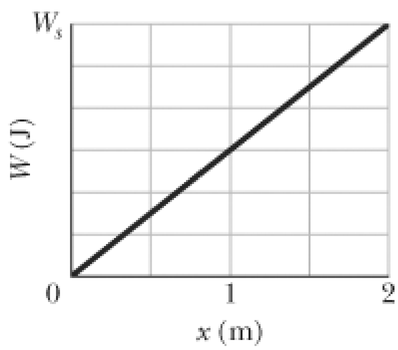

Figure 7-25 Problem 12.

••13 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^2, (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^2?

Answer:

(a) 1.7×10^2 N; (b) 3.4×10^2 m; (c) $- 5.8 \times 10^4$ J; (d) 3.4×10^2 N; (e) 1.7×10^2 m; (f) $- 5.8 \times 10^4$ J

••14 GO Figure 7-26 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 θ_2 = 50.0° and θ_3 = 35.0°. What is the net work done on the canister by the three forces during the first 4.00 m of displacement?

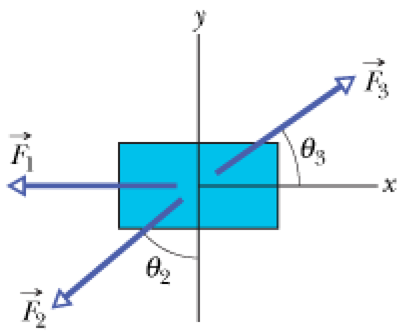

Figure 7-26 Problem 14.

••15 GO Figure 7-27 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 θ = 60.0°. 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?

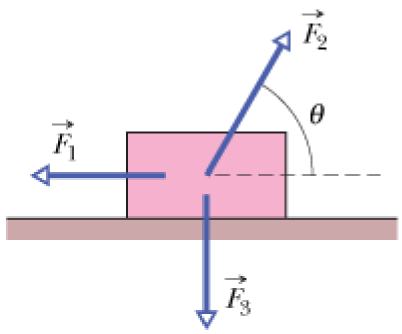

Figure 7-27 Problem 15.

Answer:

(a) 1.50 J; (b) increases

••16 GO 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 7-28 gives its kinetic energy *K* versus position *x* as it moves from *x* = 0 to *x* = 5.0 m; K_0 = 30.0 J. The force continues to act. What is *v* when the object moves back through *x* = -3.0 m?

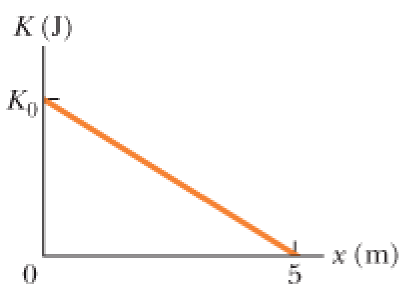

Figure 7-28 Problem 16.

sec. 7-6 Work Done by the Gravitational Force

•17 SSM WWW 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?

Answer:

(a) 12 kJ; (b) - 11 kJ; (c) 1.1 kJ; (d) 5.4 m/s

•18 (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?

••19 In Fig. 7-29, a block of ice slides down a frictionless ramp at angle θ = 50° 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?

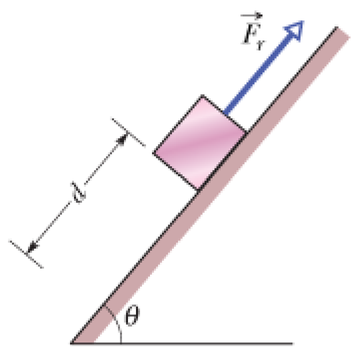

Figure 7-29 Problem 19.

Answer:

25 J

••20 A block is sent up a frictionless ramp along which an *x* axis extends upward. Figure 7-30 gives the kinetic energy of the block as a function of position *x*; the scale of the figure's vertical axis is set by K_s = 40.0 J. If the block's initial speed is 4.00 m/s, what is the normal force on the block?

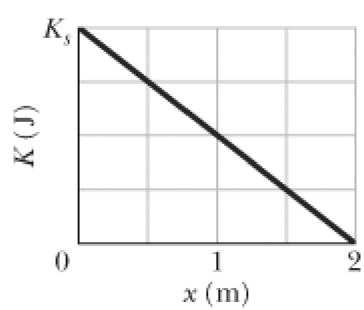

Figure 7-30 Problem 20.

••21 SSM 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.

Answer:

(a) $-3Mgd/4$; (b) Mgd; (c) $Mgd/4$; (d) $(gd/2)^{0.5}$

••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. 7-31, a constant force $\vec{F}_a$ of magnitude 82.0 N is applied to a 3.00 kg shoe box at angle = 53.0°, 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?

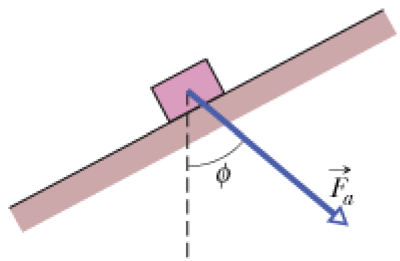

Figure 7-31 Problem 23.

Answer:

4.41 J

••24 GO In Fig. 7-32, 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 θ = 30.0°. (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?

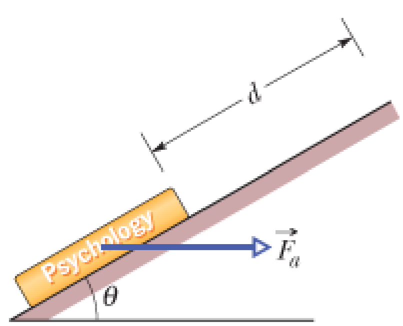

Figure 7-32 Problem 24.

•••25 GO In Fig. 7-33, 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 work done on the cab by the (constant) force from the cable is 92.61 kJ, what is the magnitude of F_N?

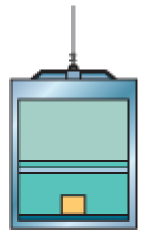

Figure 7-33 Problem 25.

Answer:

(a) 25.9 kJ; (b) 2.45 N

sec. 7-7 Work Done by a Spring Force

•26 In Fig. 7-9, 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.)

•27 A spring and block are in the arrangement of Fig. 7-9. 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 as 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?

Answer:

(a) 7.2 J; (b) 7.2 J; (c) 0; (d) - 25 J

•28 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?

••29 In the arrangement of Fig. 7-9, we gradually pull the block from x = 0 to x = +3.0 cm, where it is stationary. Figure 7-34 gives the work that our force does on the block. The scale of the figure's vertical axis is set by W_s = 1.0 J. 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 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?

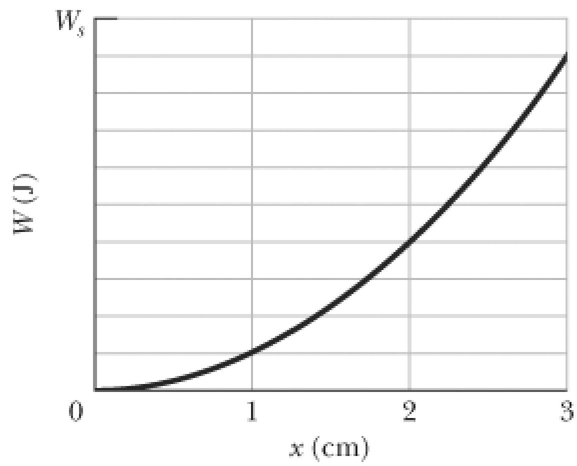

Figure 7-34 Problem 29.

Answer:

(a) 0.90 J; (b) 2.1 J; (c) 0

••30 In Fig. 7-9*a*, 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. 7-35. The scale of the figure's vertical axis is set by $K_s = 4.0$ J. (a) What is the magnitude of $\vec{F}$? (b) What is the value of *k*?

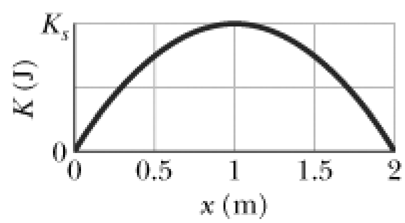

Figure 7-35 Problem 30.

••31 SSM WWW 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 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?

Answer:

(a) 6.6 m/s; (b) 4.7 m

••32 Figure 7-36 gives spring force F_x versus position *x* for the spring–block arrangement of Fig. 7-9. The scale is set by $F_s = 160.0$ N. We release the block at $x = 12$ cm. 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?

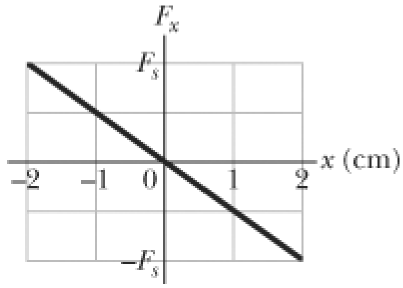

Figure 7-36 Problem 32.

•••33The block in Fig. 7-9*a* 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?

Answer:

(a) 0.12 m; (b) 0.36 J; (c) - 0.36 J; (d) 0.060 m; (e) 0.090 J

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

•34 ILW A 10 kg brick moves along an *x* axis. Its acceleration as a function of its position is shown in Fig. 7-37. The scale of the figure's vertical axis is set by $a_s = 20.0\ \text{m/s}^2$. 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?

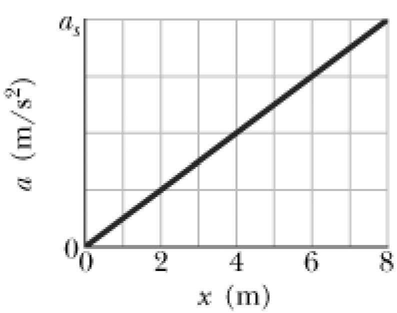

Figure 7-37 Problem 34.

•35 SSM WWW 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 $F(x)$.

Answer:

(a) 0; (b) 0

•36A 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.

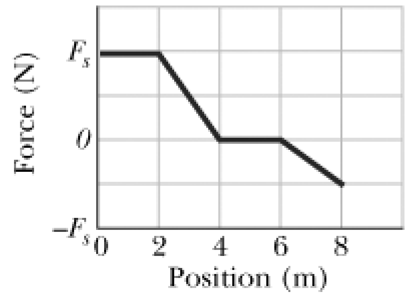

Figure 7-38 Problem 36.

The scale of the figure's vertical axis is set by F_s = 10.0 N. How much work is done by the force as the block moves from the origin to x = 8.0 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. The scale of the figure's vertical axis is set by a_s = 6.0 m/s^2. How much work has the force done on the particle when the particle reaches (a) x = 4.0 m, (b) x = 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?

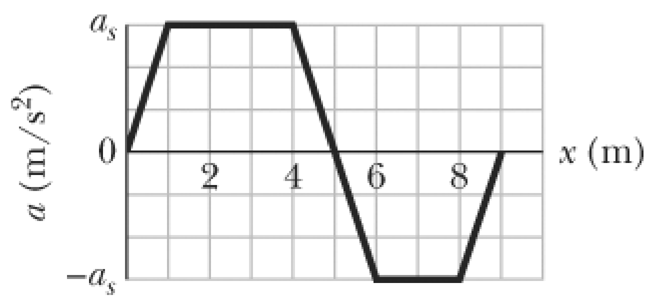

Figure 7-39 Problem 37.

Answer:

(a) 42 J; (b) 30 J; (c) 12 J; (d) 6.5 m/s, + x axis; (e) 5.5 m/s, + x axis; (f) 3.5 m/s, + x axis

••38 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 $\vec{F}(x) = (2.5 - x^2)\hat{\mathrm{i}}$ 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?

••39 GO A force $\vec{F} = (cx - 3.00x^2)\hat{\mathrm{i}}$ 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.

Answer:

4.00 N/m

••40 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?

••41 A single force acts on a 3.0 kg particle-like object whose position 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.

Answer:

5.3×10^2 J

•••42 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?

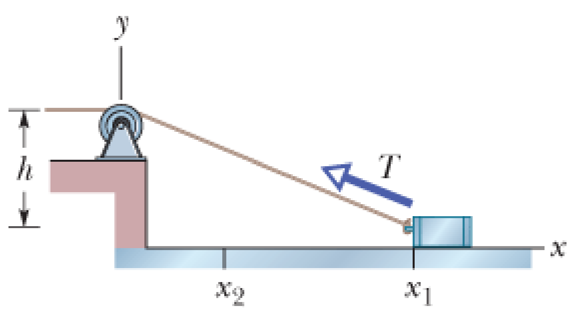

Figure 7-40 Problem 42.

sec. 7-9 Power

•43 SSM 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.

Answer:

(a) 0.83 J; (b) 2.5 J; (c) 4.2 J; (d) 5.0 W

•44 A skier is pulled by a towrope up a frictionless ski slope that makes an angle of 12° 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?

•45 SSM ILW 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° above the horizontal. What is the rate at which the force does work on the block?

Answer:

4.9×10^2 W

•46 The loaded cab of an elevator has a mass of 3.0×10^3 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?

••47A machine carries a 4.0 kg package from an initial position of $\vec{d}_i = (0.50\,\text{m})\hat{\text{i}} + (0.75\,\text{m})\hat{\text{j}} + (0.20\,\text{m})\hat{\text{k}}$ at $t = 0$ to a final position of $\vec{d}_f = (7.50\,\text{m})\hat{\text{i}} + (12.0\,\text{m})\hat{\text{j}} + (7.20\,\text{m})\hat{\text{k}}$ at $t = 12$ s. The constant force applied by the machine on the package is $\vec{F} = (2.00\,\text{N})\hat{\text{i}} + (4.00\,\text{N})\hat{\text{j}} + (6.00\,\text{N})\hat{\text{k}}$. 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.

Answer:

(a) 1.0×10^2 J; (b) 8.4 W

••48A 0.30 kg ladle sliding on a horizontal frictionless surface is attached to one end of a horizontal spring (k = 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?

••49 SSM 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 counter-weight 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?

Answer:

7.4×10^2 W

••50(a) At a certain instant, a particle-like object is acted on by a force $\vec{F} = (4.0\,\text{N})\hat{\text{i}} - (2.0\,\text{N})\hat{\text{j}} + (9.0\,\text{N})\hat{\text{k}}$ while the object's velocity is $\vec{v} = -(2.0\,\text{m/s})\hat{\text{i}} + (4.0\,\text{m/s})\hat{\text{k}}$. 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?

••51 A force $\vec{F} = (3.00\,\text{N})\hat{\text{i}} + (7.00\,\text{N})\hat{\text{j}} + (7.00\,\text{N})\hat{\text{k}}$ acts on a 2.00 kg mobile object that moves from an initial position of $\vec{d}_i = (3.00\,\text{m})\hat{\text{i}} - (2.00\,\text{m})\hat{\text{j}} + (5.00\,\text{m})\hat{\text{k}}$ to a final position of $\vec{d}_f = -(5.00\,\text{m})\hat{\text{i}} + (4.00\,\text{m})\hat{\text{j}} + (7.00\,\text{m})\hat{\text{k}}$ 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 $\vec{d}_f$.

Answer:

(a) 32.0 J; (b) 8.00 W; (c) 78.2°

•••52A funny car accelerates from rest through a measured track distance in time T with the engine operating at a constant power P. If the track crew can increase the engine power by a differential amount dP, what is the change in the time required for the run?

Additional Problems

53 Figure 7-41 shows a cold package of hot dogs sliding right-ward across a frictionless floor through a distance d = 20.0 cm while three forces act on the package. Two of them are horizontal and have the magnitudes F_1 = 5.00 N and F_2 = 1.00 N; the third is angled down by θ = 60.0° and has the magnitude F_3 = 4.00 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?

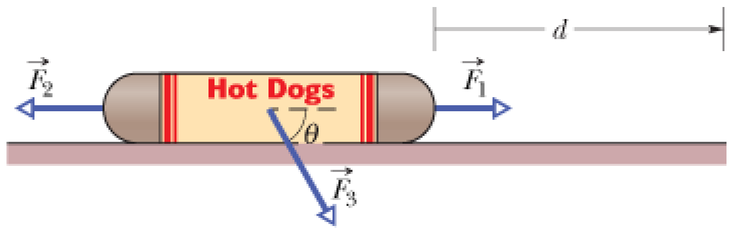

Figure 7-41 Problem 53.

Answer:

(a) 1.20 J; (b) 1.10 m/s

54 The only force acting on a 2.0 kg body as the body moves along an x axis varies as shown in Fig. 7-42. The scale of the figure's vertical axis is set by F_s = 4.0 N. 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 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 m?

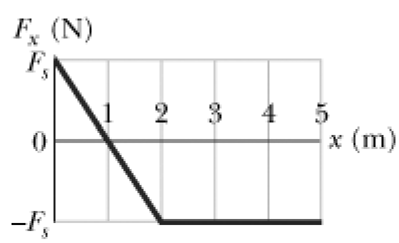

Figure 7-42 Problem 54.

55 SSM A horse pulls a cart with a force of 40 lb at an angle of 30° 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?

Answer:

(a) 1.8×10^5 ft · lb; (b) 0.55 hp

56 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?

57 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. 7-43). (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 displacement, 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)?

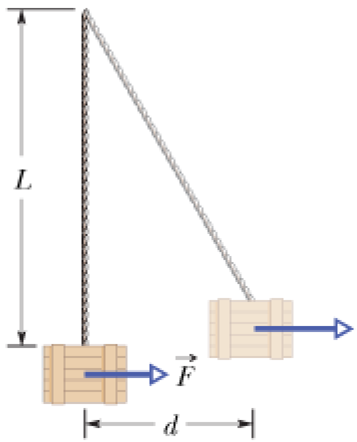

Figure 7-43 Problem 57.

Answer:

(a) 797 N; (b) 0; (c) - 1.55 kJ; (d) 0; (e) 1.55 kJ; (f) *F* varies during displacement

58To pull a 50 kg crate across a horizontal frictionless floor, a worker applies a force of 210 N, directed 20° 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?

59 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 4.2×10^{15} 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.)

Answer:

(a) 1×10^5 megatons TNT; (b) 1×10^7 bombs

60A 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?

61

How much 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 to a position $\vec{r_i} = (2\text{ m})\hat{i} + (3\text{ m})\hat{j}$ to a position $\vec{r_f} = -(4\text{ m})\hat{i} - (3\text{ m})\hat{j}$?

Answer:

- 6 J

62 A 250 g block is dropped onto a relaxed vertical spring that has a spring constant of k = 2.5 N/cm (Fig. 7-44). The block becomes attached to 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?

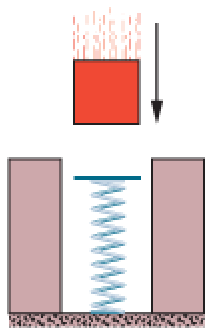

Figure 7-44 Problem 62.

63 SSM To push a 25.0 kg crate up a frictionless incline, angled at 25.0° 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?

Answer:

(a) 314 J; (b) - 155 J; (c) 0; (d) 158 J

64 Boxes are transported from one location to another in a ware-house 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° with the horizontal, then for 2.0 m horizontally, and finally for 2.0 m down an incline that makes an angle of 10° 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° incline, (b) horizontally, and (c) down the 10° incline?

65 In Fig. 7-45, a cord runs around two massless, frictionless pulleys. A canister with mass m = 20 kg hangs from 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.)

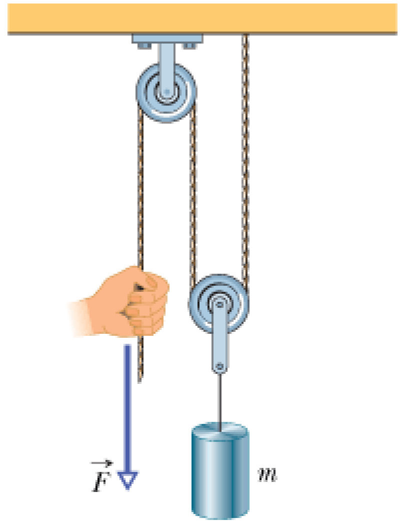

Figure 7-45 Problem 65.

Answer:

(a) 98 N; (b) 4.0 cm; (c) 3.9 J; (d) - 3.9 J

66If 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?

67 SSM 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. 7-46. (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?

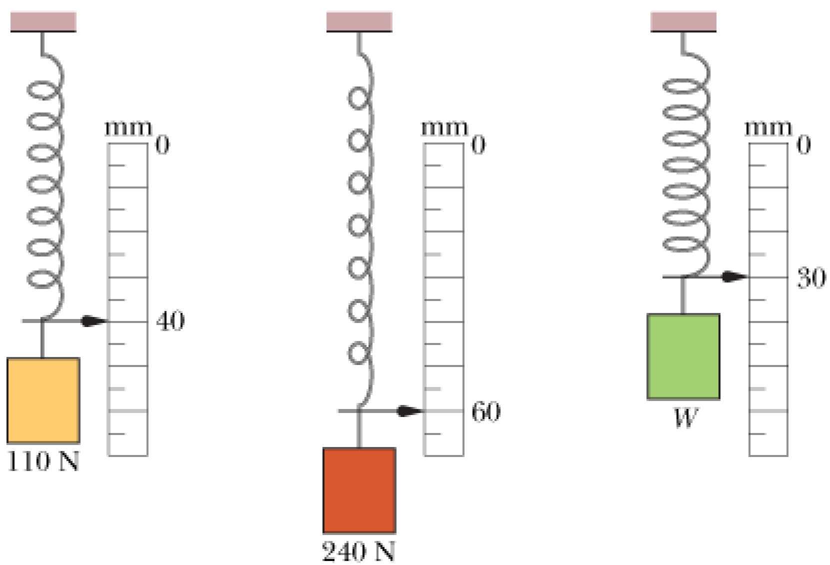

Figure 7-46 Problem 67.

Answer:

(a) 23 mm; (b) 45 N

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° north of east. What is the kinetic energy of the iceboat at the end of that 8.0 m?

69 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?

Answer:

165 kW

70 A force $\vec{F} = (4.0\,\mathrm{N})\hat{\mathrm{i}} + c\hat{\mathrm{j}}$ acts on a particle as the particle goes through displacement $\vec{d} = (3.0\,\mathrm{m})\hat{\mathrm{i}} - (2.0\,\mathrm{m})\hat{\mathrm{j}}$. (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 J?

71 A constant force of magnitude 10 N makes an angle of 150° (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 $(2.0\,\mathrm{m})\hat{\mathrm{i}} - (4.0\,\mathrm{m})\hat{\mathrm{j}}$?

Answer:

- 37 J

72 In Fig. 7-47*a*, a 2.0 N force is applied to a 4.0 kg block at a downward angle θ 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. 7-47*b* 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 θ for θ = 0° to θ = 90°. Interpret the graphs.

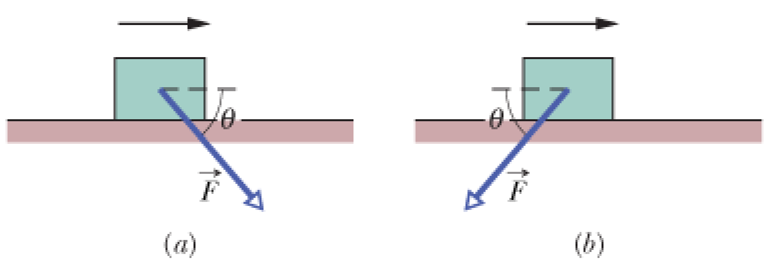

Figure 7-47 Problem 72.

73 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.

Answer:

(a) 13 J; (b) 13 J

74 A particle moves along a straight path through displacement $\vec{d} = (8\,\text{m})\hat{\text{i}} + c\hat{\text{j}}$ while force $\vec{F} = (2\,\text{N})\hat{\text{i}} - (4\,\text{N})\hat{\text{j}}$ 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?

75 SSM 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?

Answer:

235 kW

76 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?

77 As a particle moves along an x axis, a force in the positive direction of the axis acts on it. Figure 7-48 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 $x = 1.0$ m to $x = 3.0$ m by (a) estimating the work from the graph and (b) integrating the force function.

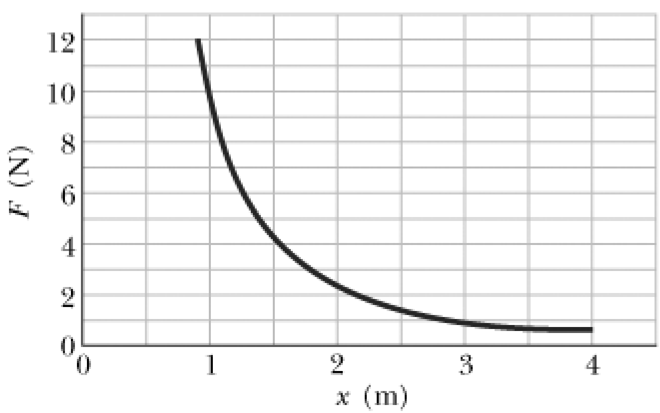

Figure 7-48 Problem 77.

Answer:

(a) 6 J; (b) 6.0 J

78 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?

79 SSM 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 7-49 shows the position x of the lunchbox as a function of time t as the wind pushes on the lunch-box. From the graph, estimate the kinetic energy of the lunchbox at (a) $t = 1.0$ s and (b) $t = 5.0$ s. (c) How much work does the force from the wind do on the lunchbox from $t = 1.0$ s to $t = 5.0$ s?

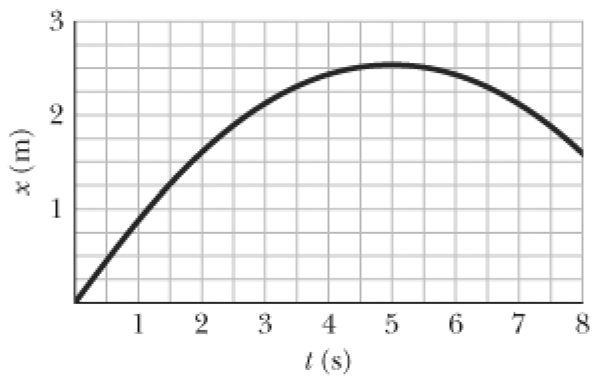

Figure 7-49 Problem 79.

Answer:

(a) 0.6 J; (b) 0; (c) - 0.6 J

80 *Numerical integration*. A breadbox is made to move along an x axis from $x = 0.15$ m to $x = 1.20$ 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?

sec. 8-4 Determining Potential Energy Values

•1 SSM What is the spring constant of a spring that stores 25 J of elastic potential energy when compressed by 7.5 cm?

Answer:

89 N/cm

•2 In Fig. 8-27, a single frictionless roller-coaster car of mass m = 825 kg tops the first hill with speed v_0 = 17.0 m/s at height h = 42.0 m. How much work does the gravitational force do on the car from that point to (a) point A, (b) point B, and (c) point C? If the gravitational potential energy of the car–Earth system is taken to be zero at C, what is its value when the car is at (d) B and (e) A? (f) If mass m were doubled, would the change in the gravitational potential energy of the system between points A and B increase, decrease, or remain the same?

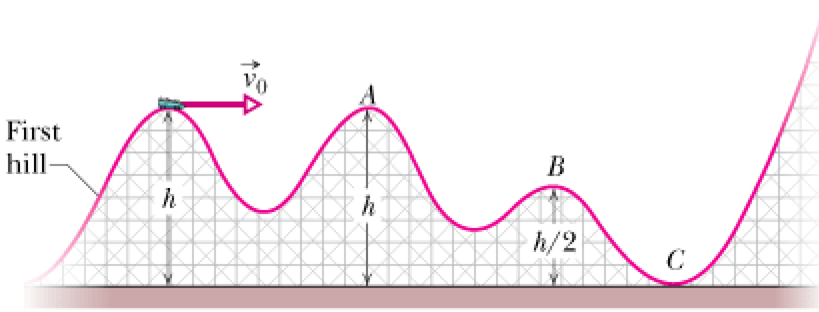

Figure 8-27 Problems 2 and 9.

•3 You drop a 2.00 kg book to a friend who stands on the ground at distance D = 10.0 m below. If your friend's outstretched hands are at distance d = 1.50 m above the ground (Fig. 8-28), (a) how much work W_g does the gravitational force do on the book as it drops to her hands? (b) What is the change ΔU in the gravitational potential energy of the book–Earth system during the drop? If the gravitational potential energy U of that system is taken to be zero at ground level, what is U(c) when the book is released and (d) when it reaches her hands? Now take U to be 100 J at ground level and again find (e) W_g, (f) ΔU, (g) U at the release point, and (h) U at her hands.

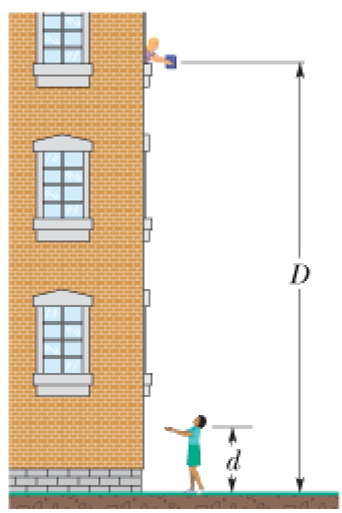

Figure 8-28 Problems 3 and 10.

Answer:

(a) 167 J; (b) - 167 J; (c) 196 J; (d) 29 J; (e) 167 J; (f) - 167 J; (g) 296 J; (h) 129 J

•4 Figure 8-29 shows a ball with mass m = 0.341 kg attached to the end of a thin rod with length L = 0.452 m and negligible mass. The other end of the rod is pivoted so that the ball can move in a vertical circle. The rod is held horizontally as shown and then given enough of a downward push to cause the ball to swing down and around and just reach the vertically up position, with zero speed there. How much work is done on the ball by the gravitational force from the initial point to (a) the lowest point, (b) the highest point, and (c) the point on the right level with the initial point? If the gravitational potential energy of the ball–Earth system is taken to be zero at the initial point, what is it when the ball reaches (d) the lowest point, (e) the highest point, and (f) the point on the right level with the initial point? (g) Suppose the rod were pushed harder so that the ball passed through the highest point with a nonzero speed. Would ΔU_g from the lowest point to the highest point then be greater than, less than, or the same as it was when the ball stopped at the highest point?

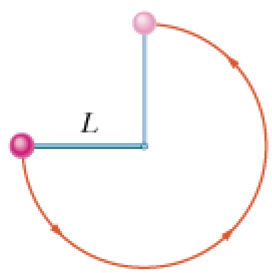

Figure 8-29 Problems 4 and 14.

•5 SSM In Fig. 8-30, a 2.00 g ice flake is released from the edge of a hemispherical bowl whose radius r is 22.0 cm. The flake–bowl contact is frictionless. (a) How much work is done on the flake by the gravitational force during the flake's descent to the bottom of the bowl? (b) What is the change in the potential energy of the flake–Earth system during that descent? (c) If that potential energy is taken to be zero at the bottom of the bowl, what is its value when the flake is released? (d) If, instead, the potential energy is taken to be zero at the release point, what is its value when the flake reaches the bottom of the bowl? (e) If the mass of the flake were doubled, would the magnitudes of the answers to (a) through (d) increase, decrease, or remain the same?

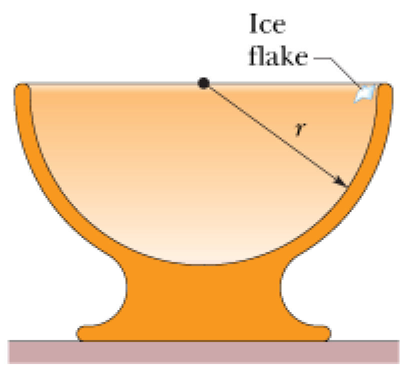

Figure 8-30 Problems 5 and 11.

Answer:

(a) 4.31 mJ; (b) - 4.31 mJ; (c) 4.31 mJ; (d) - 4.31 mJ; (e) all increase

••6 In Fig. 8-31, a small block of mass m = 0.032 kg can slide along the frictionless loop-the-loop, with loop radius R = 12 cm. The block is released from rest at point P, at height $h = 5.0R$ above the bottom of the loop. How much work does the gravitational force do on the block as the block travels from point P to (a) point Q and (b) the top of the loop? If the gravitational potential energy of the block–Earth system is taken to be zero at the bottom of the loop, what is that potential energy when the block is (c) at point P, (d) at point Q, and (e) at the top of the loop? (f) If, instead of merely being released, the block is given some initial speed downward along the track, do the answers to (a) through (e) increase, decrease, or remain the same?

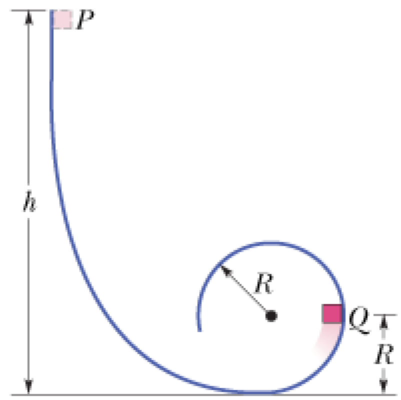

Figure 8-31 Problems 6 and 17.

••7 Figure 8-32 shows a thin rod, of length L = 2.00 m and negligible mass, that can pivot about one end to rotate in a vertical circle. A ball of mass m = 5.00 kg is attached to the other end. The rod is pulled aside to angle θ_0 = 30.0° and released with initial velocity $\vec{v}_0 = 0$. As the ball descends to its lowest point, (a) how much work does the gravitational force do on it and (b) what is the change in the gravitational potential energy of the ball–Earth system? (c) If the gravitational potential energy is taken to be zero at the lowest point, what is its value just as the ball is released? (d) Do the magnitudes of the answers to (a) through (c) increase, decrease, or remain the same if angle θ_0 is increased?

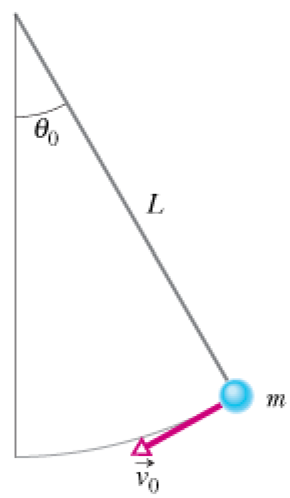

Figure 8-32 Problems 7, 18, and 21.

Answer:

(a) 13.1 J; (b) - 13.1 J; (c) 13.1 J; (d) all increase

••8A 1.50 kg snowball is fired from a cliff 12.5 m high. The snowball's initial velocity is 14.0 m/s, directed 41.0° above the horizontal. (a) How much work is done on the snowball by the gravitational force during its flight to the flat ground below the cliff? (b) What is the change in the gravitational potential energy of the snowball–Earth system during the flight? (c) If that gravitational potential energy is taken to be zero at the height of the cliff, what is its value when the snowball reaches the ground?

sec. 8-5 Conservation of Mechanical Energy

•9 GO In Problem 2, what is the speed of the car at (a) point *A*, (b) point *B*, and (c) point *C*? (d) How high will the car go on the last hill, which is too high for it to cross? (e) If we substitute a second car with twice the mass, what then are the answers to (a) through (d)?

Answer:

(a) 17.0 m/s; (b) 26.5 m/s; (c) 33.4 m/s; (d) 56.7 m; (e) all the same

•10(a) In Problem 3, what is the speed of the book when it reaches the hands? (b) If we substituted a second book with twice the mass, what would its speed be? (c) If, instead, the book were thrown down, would the answer to (a) increase, decrease, or remain the same?

•11 SSM WWW (a) In Problem 5, what is the speed of the flake when it reaches the bottom of the bowl? (b) If we substituted a second flake with twice the mass, what would its speed be? (c) If, instead, we gave the flake an initial downward speed along the bowl, would the answer to (a) increase, decrease, or remain the same?

Answer:

(a) 2.08 m/s; (b) 2.08 m/s; (c) increase

•12(a) In Problem 8, using energy techniques rather than the techniques of Chapter 4, find the speed of the snowball as it reaches the ground below the cliff. What is that speed (b) if the launch angle is changed to 41.0° *below* the horizontal and (c) if the mass is changed to 2.50 kg?

•13 SSM A 5.0 g marble is fired vertically upward using a spring gun. The spring must be compressed 8.0 cm if the marble is to just reach a target 20 m above the marble's position on the compressed spring. (a) What is the change ΔU_g in the gravitational potential energy of the marble–Earth system during the 20 m ascent? (b) What is the change ΔU_s in the elastic potential energy of the spring during its launch of the marble? (c) What is the spring constant of the spring?

Answer:

(a) 0.98 J; (b) - 0.98 J; (c) 3.1 N/cm

•14(a) In Problem 4, what initial speed must be given the ball so that it reaches the vertically upward position with zero speed? What then is its speed at (b) the lowest point and (c) the point on the right at which the ball is level with the initial point? (d) If the ball's mass were doubled, would the answers to (a) through (c) increase, decrease, or remain the same?

•15 SSM In Fig. 8-33, a runaway truck with failed brakes is moving downgrade at 130 km/h just before the driver steers the truck up a frictionless emergency escape ramp with an inclination of θ

= 15°. The truck's mass is 1.2×10^4 kg. (a) What minimum length L must the ramp have if the truck is to stop (momentarily) along it? (Assume the truck is a particle, and justify that assumption.) Does the minimum length L increase, decrease, or remain the same if (b) the truck's mass is decreased and (c) its speed is decreased?

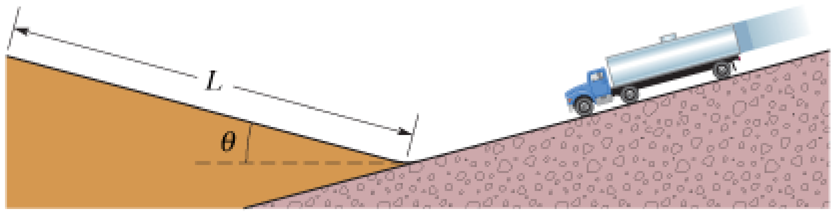

Figure 8-33 Problem 15.

Answer:

(a) 2.6×10^2 m; (b) same; (c) decrease

••16A 700 g block is released from rest at height h_0 above a vertical spring with spring constant k = 400 N/m and negligible mass. The block sticks to the spring and momentarily stops after compressing the spring 19.0 cm. How much work is done (a) by the block on the spring and (b) by the spring on the block? (c) What is the value of h_0? (d) If the block were released from height $2.00h_0$ above the spring, what would be the maximum compression of the spring?

••17 In Problem 6, what are the magnitudes of (a) the horizontal component and (b) the vertical component of the *net* force acting on the block at point Q? (c) At what height h should the block be released from rest so that it is on the verge of losing contact with the track at the top of the loop? (*On the verge of losing contact* means that the normal force on the block from the track has just then become zero.) (d) Graph the magnitude of the normal force on the block at the top of the loop versus initial height h, for the range h = 0 to h = 6R.

Answer:

(a) 2.5 N; (b) 0.31 N; (c) 30 cm

••18(a) In Problem 7, what is the speed of the ball at the lowest point? (b) Does the speed increase, decrease, or remain the same if the mass is increased?

••19 GO Figure 8-34 shows an 8.00 kg stone at rest on a spring. The spring is compressed 10.0 cm by the stone. (a) What is the spring constant? (b) The stone is pushed down an additional 30.0 cm and released. What is the elastic potential energy of the compressed spring just before that release? (c) What is the change in the gravitational potential energy of the stone–Earth system when the stone moves from the release point to its maximum height? (d) What is that maximum height, measured from the release point?

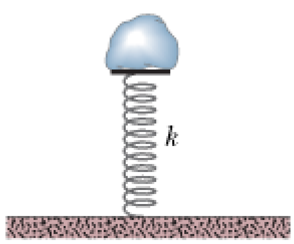

Figure 8-34 Problem 19.

Answer:

(a) 784 N/m; (b) 62.7 J; (c) 62.7 J; (d) 80.0 cm

••20 GO A pendulum consists of a 2.0 kg stone swinging on a 4.0 m string of negligible mass. The stone has a speed of 8.0 m/s when it passes its lowest point. (a) What is the speed when the string is at 60° to the vertical? (b) What is the greatest angle with the vertical that the string will reach during the stone's motion? (c) If the potential energy of the pendulum–Earth system is taken to be zero at the stone's lowest point, what is the total mechanical energy of the system?

••21 Figure 8-32 shows a pendulum of length L = 1.25 m. Its bob (which effectively has all the mass) has speed v_0 when the cord makes an angle θ_0 = 40.0° with the vertical. (a) What is the speed of the bob when it is in its lowest position if v_0 = 8.00 m/s? What is the least value that v_0 can have if the pendulum is to swing down and then up (b) to a horizontal position, and (c) to a vertical position with the cord remaining straight? (d) Do the answers to (b) and (c) increase, decrease, or remain the same if θ_0 is increased by a few degrees?

Answer:

(a) 8.35 m/s; (b) 4.33 m/s; (c) 7.45 m/s; (d) both decrease

••22 A 60 kg skier starts from rest at height H = 20 m above the end of a ski-jump ramp (Fig. 8-35) and leaves the ramp at angle θ = 28°. Neglect the effects of air resistance and assume the ramp is frictionless. (a) What is the maximum height h of his jump above the end of the ramp? (b) If he increased his weight by putting on a backpack, would h then be greater, less, or the same?

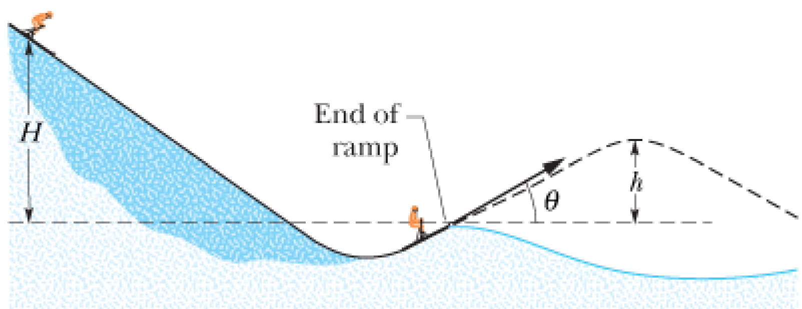

Figure 8-35 Problem 22.

••23 ILW The string in Fig. 8-36 is L = 120 cm long, has a ball attached to one end, and is fixed at its other end. The distance d from the fixed end to a fixed peg at point P is 75.0 cm. When the initially stationary ball is released with the string horizontal as shown, it will swing along the dashed arc. What is its speed when it reaches (a) its lowest point and (b) its highest point after the string catches on the peg?

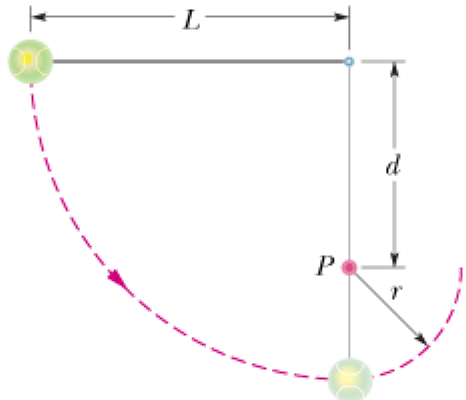

Figure 8-36 Problems 23 and 70.

Answer:

(a) 4.85 m/s; (b) 2.42 m/s

••24A block of mass m = 2.0 kg is dropped from height h = 40 cm onto a spring of spring constant k = 1960 N/m (Fig. 8-37). Find the maximum distance the spring is compressed.

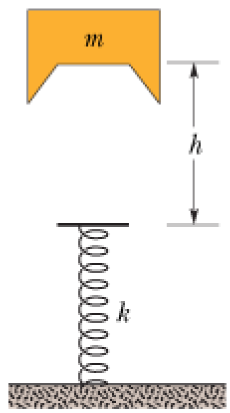

Figure 8-37 Problem 24.

••25
At t = 0 a 1.0 kg ball is thrown from a tall tower with $\vec{v} = (18\text{ m/s})\hat{i} + (24\text{ m/s})\hat{j}$. What is ΔU of the ball–Earth system between t = 0 and t = 6.0 s (still free fall)?

Answer:

-3.2×10^2 J

••26
A conservative force $\vec{F} = (6.0x - 12)\hat{i}$N, where x is in meters, acts on a particle moving along an x axis. The potential energy U associated with this force is assigned a value of 27 J at x = 0. (a) Write an expression for U as a function of x, with U in joules and x in meters. (b) What is the maximum positive potential energy? At what (c) negative value and (d) positive value of x is the potential energy equal to zero?

••27Tarzan, who weighs 688 N, swings from a cliff at the end of a vine 18 m long (Fig. 8-38). From the top of the cliff to the bottom of the swing, he descends by 3.2 m. The vine will break if the force on it exceeds 950 N. (a) Does the vine break? (b) If no, what is the greatest force on it during the swing? If yes, at what angle with the vertical does it break?

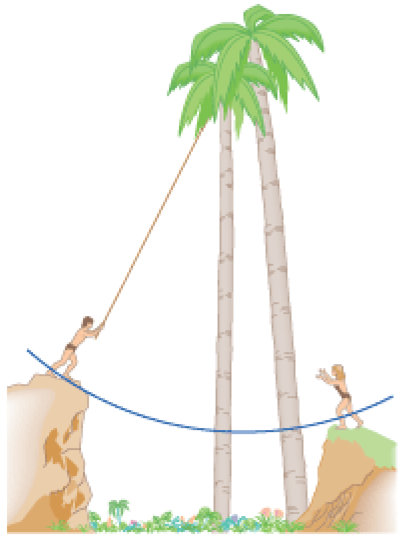

Figure 8-38 Problem 27.

Answer:

(a) no; (b) 9.3×10^2 N

••**28**Figure 8-39*a* applies to the spring in a cork gun (Fig. 8-39*b*); it shows the spring force as a function of the stretch or compression of the spring. The spring is compressed by 5.5 cm and used to propel a 3.8 g cork from the gun. (a) What is the speed of the cork if it is released as the spring passes through its relaxed position? (b) Suppose, instead, that the cork sticks to the spring and stretches it 1.5 cm before separation occurs. What now is the speed of the cork at the time of release?

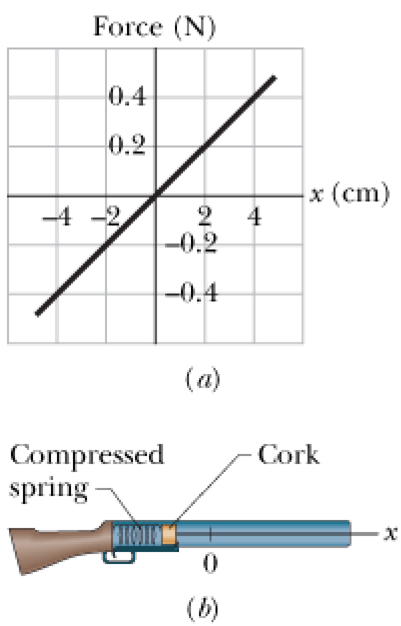

Figure 8-39 Problem 28.

••29 SSM WWW In Fig. 8-40, a block of mass $m = 12$ kg is released from rest on a frictionless incline of angle $\theta = 30°$. Below the block is a spring that can be compressed 2.0 cm by a force of 270 N. The block momentarily stops when it compresses the spring by 5.5 cm. (a) How far does the block move down the incline from its rest position to this stopping point? (b) What is the speed of the block just as it touches the spring?

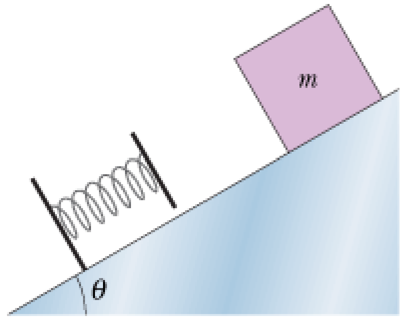

Figure 8-40 Problems 29 and 35.

Answer:

(a) 35 cm; (b) 1.7 m/s

••30 GO A 2.0 kg breadbox on a frictionless incline of angle $\theta = 40°$ is connected, by a cord that runs over a pulley, to a light spring of spring constant $k = 120$ N/m, as shown in Fig. 8-41. The box is released from rest when the spring is unstretched. Assume that the pulley is massless and frictionless. (a) What is the speed of the box when it has moved 10 cm down the incline? (b) How far down the incline from its point of release does the box slide before momentarily stopping, and what are the (c) magnitude and (d) direction (up or down the incline) of the box's acceleration at the instant the box momentarily stops?

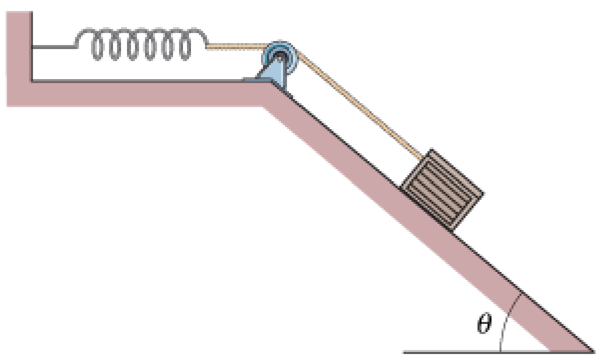

Figure 8-41 Problem 30.

••31 ILW A block with mass $m = 2.00$ kg is placed against a spring on a frictionless incline with angle $\theta = 30.0°$ (Fig. 8-42). (The block is not attached to the spring.) The spring, with spring constant $k = 19.6$ N/cm, is compressed 20.0 cm and then released. (a) What is the elastic potential energy of the compressed spring? (b) What is the change in the gravitational potential energy of the block–Earth system as the block moves from the release point to its highest point on the incline? (c) How far along the incline is the highest point from the release point?

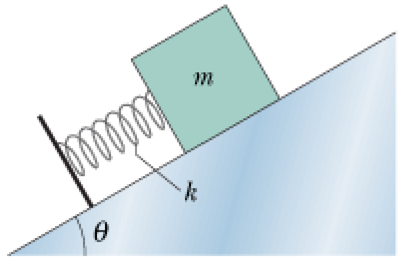

Figure 8-42 Problem 31.

Answer:

(a) 39.2 J; (b) 39.2 J; (c) 4.00 m

••32 In Fig. 8-43, a chain is held on a frictionless table with one-fourth of its length hanging over the edge. If the chain has length L = 28 cm and mass m = 0.012 kg, how much work is required to pull the hanging part back onto the table?

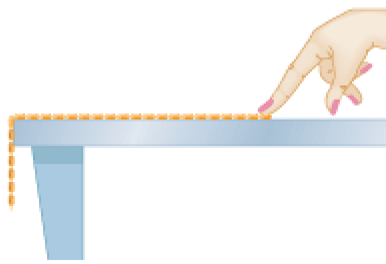

Figure 8-43 Problem 32.

•••33 GO In Fig. 8-44, a spring with k = 170 N/m is at the top of a frictionless incline of angle θ = 37.0°. The lower end of the incline is distance D = 1.00 m from the end of the spring, which is at its relaxed length. A 2.00 kg canister is pushed against the spring until the spring is compressed 0.200 m and released from rest. (a) What is the speed of the canister at the instant the spring returns to its relaxed length (which is when the canister loses contact with the spring)? (b) What is the speed of the canister when it reaches the lower end of the incline?

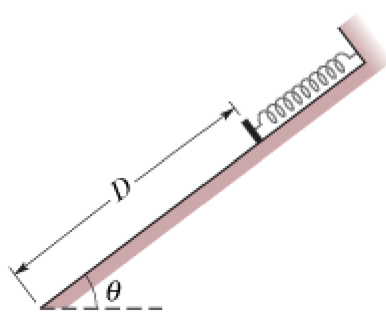

Figure 8-44 Problem 33.

Answer:

(a) 2.40 m/s; (b) 4.19 m/s

•••34 GO A boy is initially seated on the top of a hemispherical ice mound of radius R = 13.8 m. He begins to slide down the ice, with a negligible initial speed (Fig. 8-45). Approximate the ice as being frictionless. At what height does the boy lose contact with the ice?

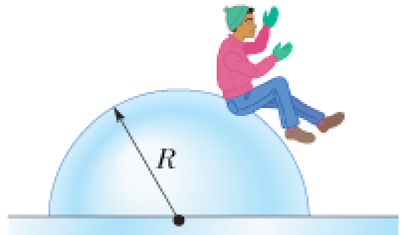

Figure 8-45 Problem 34.

•••35In Fig. 8-40, a block of mass m = 3.20 kg slides from rest a distance d down a frictionless incline at angle θ = 30.0° where it runs into a spring of spring constant 431 N/m. When the block momentarily stops, it has compressed the spring by 21.0 cm. What are (a) distance d and (b) the distance between the point of the first block–spring contact and the point where the block's speed is greatest?

Answer:

(a) 39.6 cm; (b) 3.64 cm

•••36 GO Two children are playing a game in which they try to hit a small box on the floor with a marble fired from a spring-loaded gun that is mounted on a table. The target box is horizontal distance D = 2.20 m from the edge of the table; see Fig. 8-46. Bobby compresses the spring 1.10 cm, but the center of the marble falls 27.0 cm short of the center of the box. How far should Rhoda compress the spring to score a direct hit? Assume that neither the spring nor the ball encounters friction in the gun.

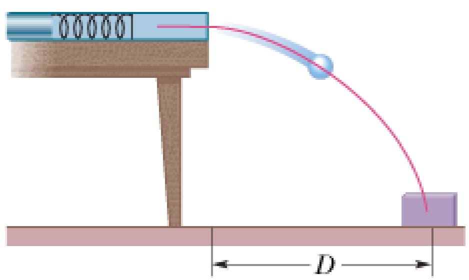

Figure 8-46 Problem 36.

•••37A uniform cord of length 25 cm and mass 15 g is initially stuck to a ceiling. Later, it hangs vertically from the ceiling with only one end still stuck. What is the change in the gravitational potential energy of the cord with this change in orientation? (*Hint:* Consider a differential slice of the cord and then use integral calculus.)

Answer:

- 18 mJ

sec. 8-6 Reading a Potential Energy Curve

••38Figure 8-47 shows a plot of potential energy U versus position x of a 0.200 kg particle that can travel only along an x axis under the influence of a conservative force. The graph has these values U_A = 9.00 J, U_C = 20.00 J:, and U_D = 24.00 J. The particle is released at the point where U forms a “potential hill” of “height” U_B = 12.00 J, with kinetic energy 4.00 J. What is the speed of the particle at (a) x = 3.5 m and (b) x = 6.5 m? What is the position of the turning point on (c) the right side and (d) the left side?

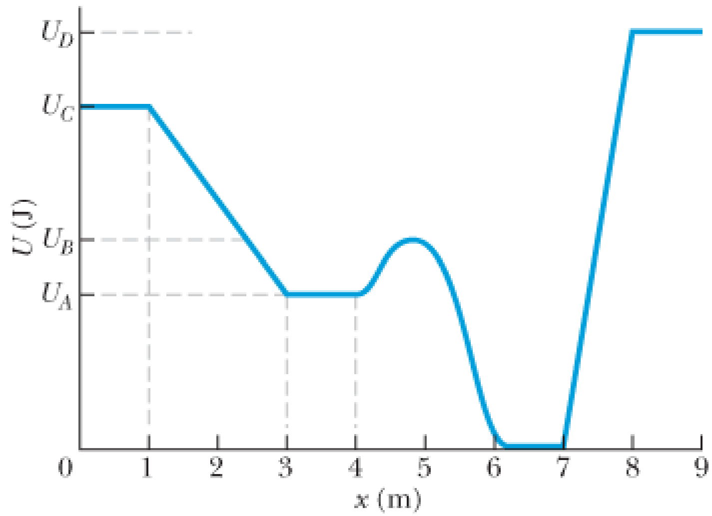

Figure 8-47 Problem 38.

••39 GO Figure 8-48 shows a plot of potential energy U versus position x of a 0.90 kg particle that can travel only along an x axis. (Nonconservative forces are not involved.) Three values are and U_A = 15.0 J, U_B = 35.0 J, U_C = 45.0 J. The particle is released at x = 4.5 m with an initial speed of 7.0 m/s, headed in the negative x direction. (a) If the particle can reach x = 1.0 m, what is its speed there, and if it cannot, what is its turning point? What are the (b) magnitude and (c) direction of the force on the particle as it begins to move to the left of x = 4.0 m? Suppose, instead, the particle is headed in the positive x direction when it is released at x = 4.5 m at speed 7.0 m/s. (d) If the particle can reach x = 7.0 m, what is its speed there, and if it cannot, what is its turning point? What are the (e) magnitude and (f) direction of the force on the particle as it begins to move to the right of x = 5.0 m?

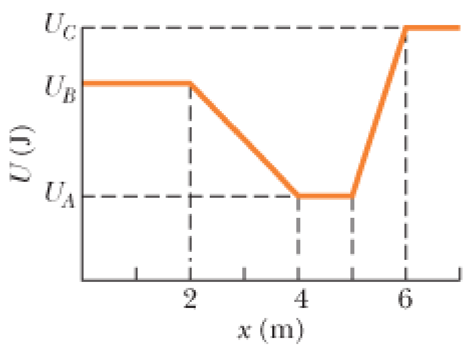

Figure 8-48 Problem 39.

Answer:

(a) 2.1 m/s; (b) 10 N; (c) + x direction; (d) 5.7 m; (e) 30 N; (f) - x direction

••40 The potential energy of a diatomic molecule (a two-atom system like H_2 or O_2) is given by

$$U = \frac{A}{r^{12}} - \frac{B}{r^6},$$

where r is the separation of the two atoms of the molecule and A and B are positive constants. This potential energy is associated with the force that binds the two atoms together. (a) Find the *equilibrium separation*—that is, the distance between the atoms at which the force on each atom is zero. Is the force repulsive (the atoms are pushed apart) or attractive (they are pulled together) if their separation is (b) smaller and (c) larger than the equilibrium separation?

•••41 A single conservative force $F(x)$ acts on a 1.0 kg particle that moves along an x axis. The potential energy $U(x)$ associated with $F(x)$ is given by

$$U(x) = -4x\,e^{-x/4}\ \text{J},$$

where x is in meters. At $x = 5.0$ m the particle has a kinetic energy of 2.0 J. (a) What is the mechanical energy of the system? (b) Make a plot of $U(x)$ as a function of x for $0 \le x \le 10$ m, and on the same graph draw the line that represents the mechanical energy of the system. Use part (b) to determine (c) the least value of x the particle can reach and (d) the greatest value of x the particle can reach. Use part (b) to determine (e) the maximum kinetic energy of the particle and (f) the value of x at which it occurs. (g) Determine an expression in newtons and meters for $F(x)$ as a function of x. (h) For what (finite) value of x does $F(x) = 0$?

Answer:

(a) - 3.7 J; (c) 1.3 m; (d) 9.1 m; (e) 2.2 J; (f) 4.0 m; (g) $(4 - x)e^{-x/4}$; (h) 4.0 m

sec. 8-7 Work Done on a System by an External Force

•42 A worker pushed a 27 kg block 9.2 m along a level floor at constant speed with a force directed 32° below the horizontal. If the coefficient of kinetic friction between block and floor was 0.20, what were (a) the work done by the worker's force and (b) the increase in thermal energy of the block–floor system?

•43 A collie drags its bed box across a floor by applying a horizontal force of 8.0 N. The kinetic frictional force acting on the box has magnitude 5.0 N. As the box is dragged through 0.70 m along the way, what are (a) the work done by the collie's applied force and (b) the increase in thermal energy of the bed and floor?

Answer:

(a) 5.6 J; (b) 3.5 J

••44 A horizontal force of magnitude 35.0 N pushes a block of mass 4.00 kg across a floor where the coefficient of kinetic friction is 0.600. (a) How much work is done by that applied force on the block–floor system when the block slides through a displacement of 3.00 m across the floor? (b) During that displacement, the thermal energy of the block increases by 40.0 J. What is the increase in thermal energy of the floor? (c) What is the increase in the kinetic energy of the block?

••45 SSM A rope is used to pull a 3.57 kg block at constant speed 4.06 m along a horizontal floor. The force on the block from the rope is 7.68 N and directed 15.0° above the horizontal. What are (a) the work done by the rope's force, (b) the increase in thermal energy of the block–floor system, and (c) the coefficient of kinetic friction between the block and floor?

Answer:

(a) 30.1 J; (b) 30.1 J; (c) 0.225

sec. 8-8 Conservation of Energy

•46An outfielder throws a baseball with an initial speed of 81.8 mi/h. Just before an infielder catches the ball at the same level, the ball's speed is 110 ft/s. In foot-pounds, by how much is the mechanical energy of the ball–Earth system reduced because of air drag? (The weight of a baseball is 9.0 oz.)

•47A 75 g Frisbee is thrown from a point 1.1 m above the ground with a speed of 12 m/s. When it has reached a height of 2.1 m, its speed is 10.5 m/s. What was the reduction in E_{mec} of the Frisbee–Earth system because of air drag?

Answer:

0.53 J

•48In Fig. 8-49, a block slides down an incline. As it moves from point *A* to point *B*, which are 5.0 m apart, force $\vec{F}$ acts on the block, with magnitude 2.0 N and directed down the incline. The magnitude of the frictional force acting on the block is 10 N. If the kinetic energy of the block increases by 35 J between *A* and *B*, how much work is done on the block by the gravitational force as the block moves from *A* to *B*?

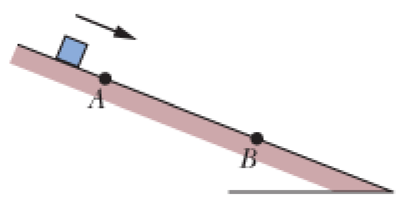

Figure 8-49 Problems 48 and 71.

•49 SSM ILW A 25 kg bear slides, from rest, 12 m down a lodge-pole pine tree, moving with a speed of 5.6 m/s just before hitting the ground. (a) What change occurs in the gravitational potential energy of the bear–Earth system during the slide? (b) What is the kinetic energy of the bear just before hitting the ground? (c) What is the average frictional force that acts on the sliding bear?

Answer:

(a) - 2.9 kJ; (b) 3.9×10^2 J; (c) 2.1×10^2 N

•50 A 60 kg skier leaves the end of a ski-jump ramp with a velocity of 24 m/s directed 25° above the horizontal. Suppose that as a result of air drag the skier returns to the ground with a speed of 22 m/s, landing 14 m vertically below the end of the ramp. From the launch to the return to the ground, by how much is the mechanical energy of the skier–Earth system reduced because of air drag?

•51During a rockslide, a 520 kg rock slides from rest down a hillside that is 500 m long and 300 m high. The coefficient of kinetic friction between the rock and the hill surface is 0.25. (a) If the gravitational potential energy *U* of the rock–Earth system is zero at the bottom of the hill, what is the value of *U* just before the slide? (b) How much energy is transferred to thermal energy during the slide? (c) What is the kinetic energy of the rock as it reaches the bottom of the hill? (d) What is its speed then?

Answer:

(a) 1.5 MJ; (b) 0.51 MJ; (c) 1.0 MJ; (d) 63 m/s

••52A large fake cookie sliding on a horizontal surface is attached to one end of a horizontal spring with spring constant k = 400 N/m; the other end of the spring is fixed in place. The cookie has a kinetic energy of 20.0 J as it passes through the spring's equilibrium position. As the cookie slides, a frictional force of magnitude 10.0 N acts on it. (a) How far will the cookie slide from the equilibrium position before coming momentarily to rest? (b) What will be the kinetic energy of the cookie as it slides back through the equilibrium position?

••53 GO In Fig. 8-50, a 3.5 kg block is accelerated from rest by a compressed spring of spring constant 640 N/m. The block leaves the spring at the spring's relaxed length and then travels over a horizontal floor with a coefficient of kinetic friction μ_k = 0.25. The frictional force stops the block in distance D = 7.8 m. What are (a) the increase in the thermal energy of the block–floor system, (b) the maximum kinetic energy of the block, and (c) the original compression distance of the spring?

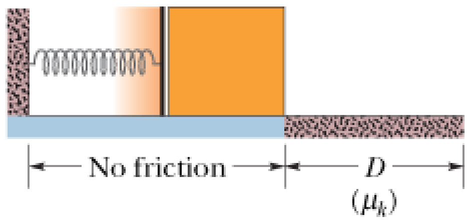

Figure 8-50 Problem 53.

Answer:

(a) 67 J; (b) 67 J; (c) 46 cm

••54 A child whose weight is 267 N slides down a 6.1 m playground slide that makes an angle of 20° with the horizontal. The coefficient of kinetic friction between slide and child is 0.10. (a) How much energy is transferred to thermal energy? (b) If she starts at the top with a speed of 0.457 m/s, what is her speed at the bottom?

••55 ILW In Fig. 8-51, a block of mass m = 2.5 kg slides head on into a spring of spring constant k = 320 N/m. When the block stops, it has compressed the spring by 7.5 cm. The coefficient of kinetic friction between block and floor is 0.25. While the block is in contact with the spring and being brought to rest, what are (a) the work done by the spring force and (b) the increase in thermal energy of the block–floor system? (c) What is the block's speed just as it reaches the spring?

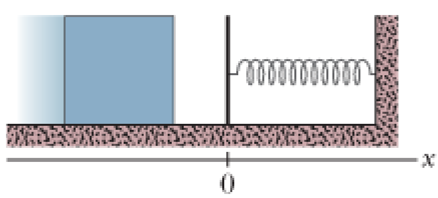

Figure 8-51 Problem 55.

Answer:

(a) - 0.90 J; (b) 0.46 J; (c) 1.0 m/s

••56 You push a 2.0 kg block against a horizontal spring, compressing the spring by 15 cm. Then you release the block, and the spring sends it sliding across a tabletop. It stops 75 cm from where you released it. The spring constant is 200 N/m. What is the block–table coefficient of kinetic friction?

••57 In Fig. 8-52, a block slides along a track from one level to a higher level after passing through an intermediate valley. The track is frictionless until the block reaches the higher level. There a frictional force stops the block in a distance *d*. The block's initial speed v_0 is 6.0 m/s, the height difference *h* is 1.1 m, and μ_k is 0.60. Find *d*.

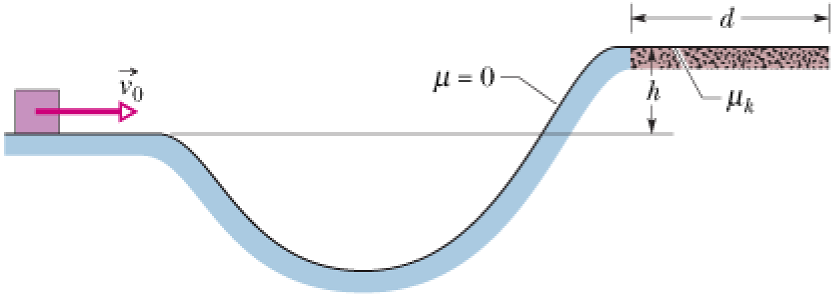

Figure 8-52 Problem 57.

Answer:

1.2 m

••58A cookie jar is moving up a 40° incline. At a point 55 cm from the bottom of the incline (measured along the incline), the jar has a speed of 1.4 m/s. The coefficient of kinetic friction between jar and incline is 0.15. (a) How much farther up the incline will the jar move? (b) How fast will it be going when it has slid back to the bottom of the incline? (c) Do the answers to (a) and (b) increase, decrease, or remain the same if we decrease the coefficient of kinetic friction (but do not change the given speed or location)?

••59A stone with a weight of 5.29 N is launched vertically from ground level with an initial speed of 20.0 m/s, and the air drag on it is 0.265 N throughout the flight. What are (a) the maximum height reached by the stone and (b) its speed just before it hits the ground?

Answer:

(a) 19.4 m; (b) 19.0 m/s

••60A 4.0 kg bundle starts up a 30° incline with 128 J of kinetic energy. How far will it slide up the incline if the coefficient of kinetic friction between bundle and incline is 0.30?

••61 When a click beetle is upside down on its back, it jumps upward by suddenly arching its back, transferring energy stored in a muscle to mechanical energy. This launching mechanism produces an audible click, giving the beetle its name. Videotape of a certain click-beetle jump shows that a beetle of mass $m = 4.0 \times 10^{-6}$ kg moved directly upward by 0.77 mm during the launch and then to a maximum height of $h = 0.30$ m. During the launch, what are the average magnitudes of (a) the external force on the beetle's back from the floor and (b) the acceleration of the beetle in terms of *g*?

Answer:

(a) 1.5×10^{-2} N; (b) $(3.8 \times 10^{2})g$

•••62 In Fig. 8-53, a block slides along a path that is without friction until the block reaches the section of length $L = 0.75$ m, which begins at height $h = 2.0$ m on a ramp of angle $\theta = 30°$. In that section, the coefficient of kinetic friction is 0.40. The block passes through point *A* with a speed of 8.0 m/s. If the block can reach point *B* (where the friction ends), what is its speed there, and if it cannot, what is its greatest height above *A*?

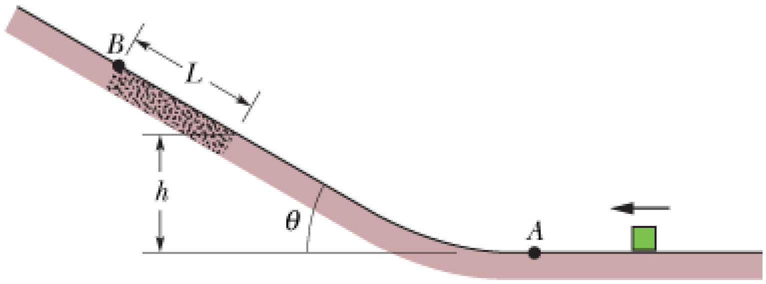

Figure 8-53 Problem 62.

•••63The cable of the 1800 kg elevator cab in Fig. 8-54 snaps when the cab is at rest at the first floor, where the cab bottom is a distance $d = 3.7$ m above a spring of spring constant $k = 0.15$ MN/m. A safety device clamps the cab against guide rails so that a constant frictional force of 4.4 kN opposes the cab's motion. (a) Find the speed of the cab just before it hits the spring. (b) Find the maximum distance x that the spring is compressed (the frictional force still acts during this compression). (c) Find the distance that the cab will bounce back up the shaft. (d) Using conservation of energy, find the approximate total distance that the cab will move before coming to rest. (Assume that the frictional force on the cab is negligible when the cab is stationary.)

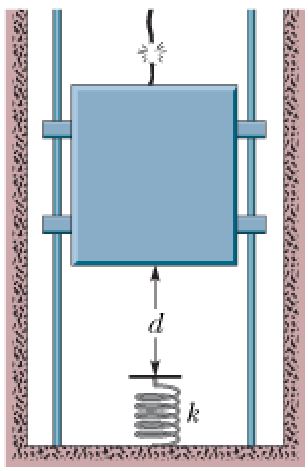

Figure 8-54 Problem 63.

Answer:

(a) 7.4 m/s; (b) 90 cm; (c) 2.8 m; (d) 15 m

•••64In Fig. 8-55, a block is released from rest at height $d = 40$ cm and slides down a frictionless ramp and onto a first plateau, which has length d and where the coefficient of kinetic friction is 0.50. If the block is still moving, it then slides down a second frictionless ramp through height $d/2$ and onto a lower plateau, which has length $d/2$ and where the coefficient of kinetic friction is again 0.50. If the block is still moving, it then slides up a frictionless ramp until it (momentarily) stops. Where does the block stop? If its final stop is on a plateau, state which one and give the distance L from the left edge of that plateau. If the block reaches the ramp, give the height H above the lower plateau where it momentarily stops.

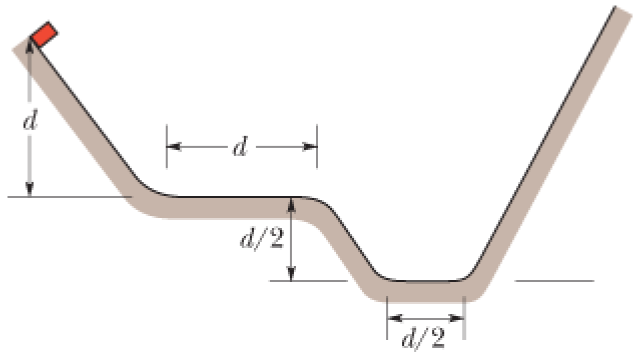

Figure 8-55 Problem 64.

•••65A particle can slide along a track with elevated ends and a flat central part, as shown in Fig. 8-56. The flat part has length L = 40 cm. The curved portions of the track are frictionless, but for the flat part the coefficient of kinetic friction is μ_k = 0.20. The particle is released from rest at point *A*, which is at height $h = L/2$. How far from the left edge of the flat part does the particle finally stop?

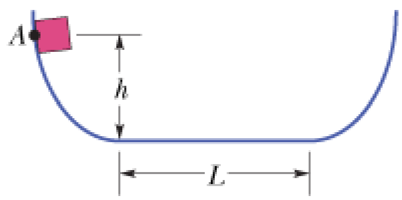

Figure 8-56 Problem 65.

Answer:

20 cm

Additional Problems

66A 3.2 kg sloth hangs 3.0 m above the ground. (a) What is the gravitational potential energy of the sloth–Earth system if we take the reference point $y = 0$ to be at the ground? If the sloth drops to the ground and air drag on it is assumed to be negligible, what are the (b) kinetic energy and (c) speed of the sloth just before it reaches the ground?

67 SSM A spring (k = 200 N/m) is fixed at the top of a frictionless plane inclined at angle $\theta = 40°$ (Fig. 8-57). A 1.0 kg block is projected up the plane, from an initial position that is distance d = 0.60 m from the end of the relaxed spring, with an initial kinetic energy of 16 J. (a) What is the kinetic energy of the block at the instant it has compressed the spring 0.20 m? (b) With what kinetic energy must the block be projected up the plane if it is to stop momentarily when it has compressed the spring by 0.40 m?

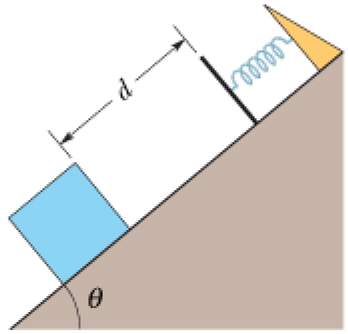

Figure 8-57 Problem 67.

Answer:

(a) 7.0 J; (b) 22 J

68From the edge of a cliff, a 0.55 kg projectile is launched with an initial kinetic energy of 1550 J. The projectile's maximum upward displacement from the launch point is +140 m. What are the (a) horizontal and (b) vertical components of its launch velocity? (c) At the instant the vertical component of its velocity is 65 m/s, what is its vertical displacement from the launch point?

69 SSM In Fig. 8-58, the pulley has negligible mass, and both it and the inclined plane are frictionless. Block *A* has a mass of 1.0 kg, block *B* has a mass of 2.0 kg, and angle θ is 30°. If the blocks are released from rest with the connecting cord taut, what is their total kinetic energy when block *B* has fallen 25 cm?

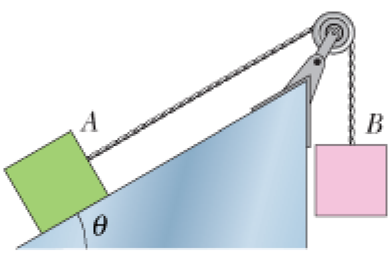

Figure 8-58 Problem 69.

Answer:

3.7 J

70In Fig. 8-36, the string is L = 120 cm long, has a ball attached to one end, and is fixed at its other end. A fixed peg is at point *P*. Released from rest, the ball swings down until the string catches on the peg; then the ball swings up, around the peg. If the ball is to swing completely around the peg, what value must distance *d* exceed? (*Hint:* The ball must still be moving at the top of its swing. Do you see why?)

71 SSM In Fig. 8-49, a block is sent sliding down a frictionless ramp. Its speeds at points *A* and *B* are 2.00 m/s and 2.60 m/s, respectively. Next, it is again sent sliding down the ramp, but this time its speed at point *A* is 4.00 m/s. What then is its speed at point *B*?

Answer:

4.33 m/s

72 Two snowy peaks are at heights $H = 850$ m and $h = 750$ m above the valley between them. A ski run extends between the peaks, with a total length of 3.2 km and an average slope of $\theta = 30°$ (Fig. 8-59). (a) A skier starts from rest at the top of the higher peak. At what speed will he arrive at the top of the lower peak if he coasts without using ski poles? Ignore friction. (b) Approximately what coefficient of kinetic friction between snow and skis would make him stop just at the top of the lower peak?

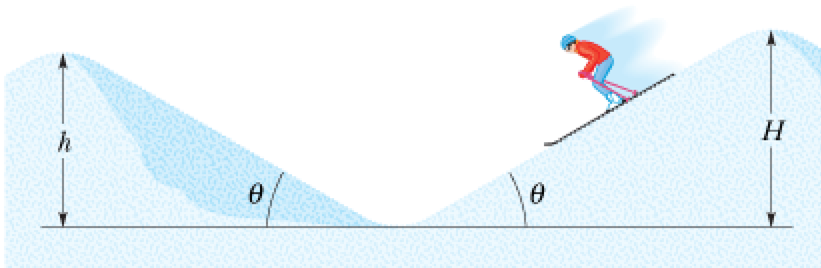

Figure 8-59 Problem 72.

73 SSM The temperature of a plastic cube is monitored while the cube is pushed 3.0 m across a floor at constant speed by a horizontal force of 15 N. The thermal energy of the cube increases by 20 J. What is the increase in the thermal energy of the floor along which the cube slides?

Answer:

25 J

74 A skier weighing 600 N goes over a frictionless circular hill of radius $R = 20$ m (Fig. 8-60). Assume that the effects of air resistance on the skier are negligible. As she comes up the hill, her speed is 8.0 m/s at point B, at angle $\theta = 20°$. (a) What is her speed at the hilltop (point A) if she coasts without using her poles? (b) What minimum speed can she have at B and still coast to the hilltop? (c) Do the answers to these two questions increase, decrease, or remain the same if the skier weighs 700 N instead of 600 N?

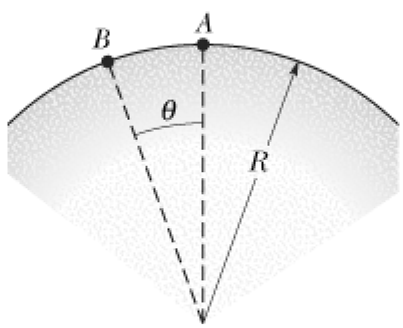

Figure 8-60 Problem 74.

75 SSM To form a pendulum, a 0.092 kg ball is attached to one end of a rod of length 0.62 m and negligible mass, and the other end of the rod is mounted on a pivot. The rod is rotated until it is straight up, and then it is released from rest so that it swings down around the pivot. When the ball reaches its lowest point, what are (a) its speed and (b) the tension in the rod? Next, the rod is rotated until it is horizontal, and then it is again released from rest. (c) At what angle from the vertical does the tension in the rod equal the weight of the ball? (d) If the mass of the ball is increased, does the answer to (c) increase, decrease, or remain the same?

Answer:

(a) 4.9 m/s; (b) 4.5 N; (c) 71°; (d) same

76 We move a particle along an x axis, first outward from x = 1.0 m to x = 4.0 m and then back to x = 1.0 m, while an external force acts on it. That force is directed along the x axis, and its x component can have different values for the outward trip and for the return trip. Here are the values (in newtons) for four situations, where x is in meters:

Outward	Inward
(a) +3.0	-3.0
(b) +5.0	+5.0
(c) +2.0x	-2.0x
(d) +3.0x^2	+3.0x^2

Find the net work done on the particle by the external force *for the round trip* for each of the four situations. (e) For which, if any, is the external force conservative?

77 SSM A conservative force $F(x)$ acts on a 2.0 kg particle that moves along an x axis. The potential energy $U(x)$ associated with $F(x)$ is graphed in Fig. 8-61. When the particle is at x = 2.0 m, its velocity is -1.5 m/s. What are the (a) magnitude and (b) direction of $F(x)$ at this position? Between what positions on the (c) left and (d) right does the particle move? (e) What is the particle's speed at x = 7.0 m?

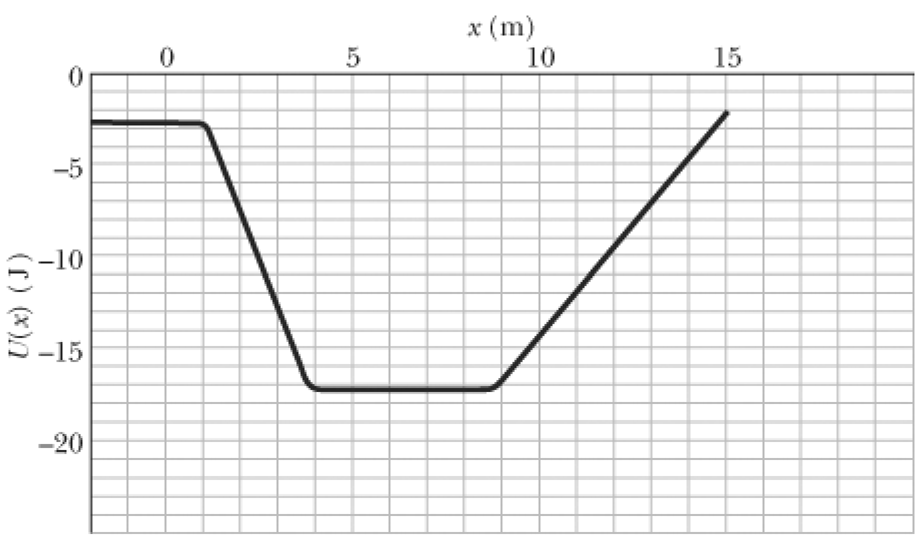

Figure 8-61 Problem 77.

Answer:

(a) 4.8 N; (b) + x direction; (c) 1.5 m; (d) 13.5 m; (e) 3.5 m/s

78 At a certain factory, 300 kg crates are dropped vertically from a packing machine onto a conveyor belt moving at 1.20 m/s (Fig. 8-62). (A motor maintains the belt's constant speed.) The coefficient of kinetic friction between the belt and each crate is 0.400. After a short time, slipping between the

belt and the crate ceases, and the crate then moves along with the belt. For the period of time during which the crate is being brought to rest relative to the belt, calculate, for a coordinate system at rest in the factory, (a) the kinetic energy supplied to the crate, (b) the magnitude of the kinetic frictional force acting on the crate, and (c) the energy supplied by the motor. (d) Explain why answers (a) and (c) differ.

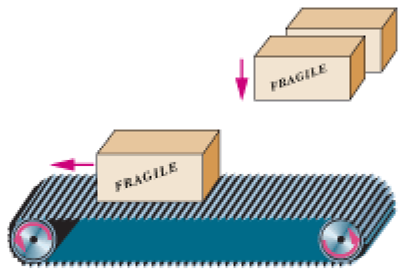

Figure 8-62 Problem 78.

79 SSM A 1500 kg car begins sliding down a 5.0° inclined road with a speed of 30 km/h. The engine is turned off, and the only forces acting on the car are a net frictional force from the road and the gravitational force. After the car has traveled 50 m along the road, its speed is 40 km/h. (a) How much is the mechanical energy of the car reduced because of the net frictional force? (b) What is the magnitude of that net frictional force?

Answer:

(a) 24 kJ; (b) 4.7×10^2 N

80In Fig. 8-63, a 1400 kg block of granite is pulled up an incline at a constant speed of 1.34 m/s by a cable and winch. The indicated distances are d_1 = 40 m and d_2 = 30 m. The coefficient of kinetic friction between the block and the incline is 0.40. What is the power due to the force applied to the block by the cable?

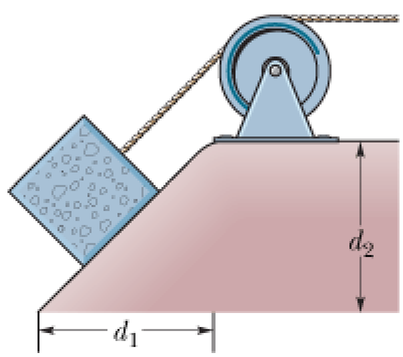

Figure 8-63 Problem 80.

81A particle can move along only an x axis, where conservative forces act on it (Fig. 8-64 and the following table). The particle is released at x = 5.00 m with a kinetic energy of K = 14.0 J and a potential energy of U 0. If its motion is in the negative direction of the x axis, what are its (a) K and (b)U at x = 2.00 m and its (c) K and (d) U at x = 0? If its motion is in the positive direction of the x axis, what are its (e)K and (f) U at x = 11.0 m, its (g) K and (h) U at x= 12.0 m, and its (i) K and (j) U at x = 13.0 m? (k) Plot $U(x)$ versus x for the range x = 0 to x = 13.0 m.

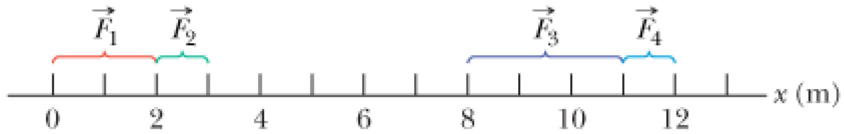

Figure 8-64 Problem 81 and 82.

Next, the particle is released from rest at $x = 0$. What are (l) its kinetic energy at $x = 5.0$ m and (m) the maximum positive position x_{max} it reaches? (n) What does the particle do after it reaches x_{max}?

Range	Force
0 to 2.00 m	$\vec{F}_1 = +(3.00\,\text{N})\hat{i}$
2.00 m to 3.00 m	$\vec{F}_2 = +(5.00\,\text{N})\hat{i}$
3.00 m to 8.00 m	$F = 0$
8.00 m to 11.0 m	$\vec{F}_3 = -(4.00\,\text{N})\hat{i}$
11.0 m to 12.0 m	$\vec{F}_4 = -(1.00\,\text{N})\hat{i}$
12.0 m to 15.0 m	$F = 0$

Answer:

(a) 5.00 J; (b) 9.00 J; (c) 11.0 J; (d) 3.00 J; (e) 12.0 J; (f) 2.00 J; (g) 13.0 J; (h) 1.00 J; (i) 13.0 J; (j) 1.00 J; (l) 11.0 J; (m) 10.8 m; (n) It returns to $x = 0$ and stops.

82 For the arrangement of forces in Problem 81, a 2.00 kg particle is released at $x = 5.00$ m with an initial velocity of 3.45 m/s in the negative direction of the x axis. (a) If the particle can reach $x = 0$ m, what is its speed there, and if it cannot, what is its turning point? Suppose, instead, the particle is headed in the positive x direction when it is released at $x = 5.00$ m at speed 3.45 m/s. (b) If the particle can reach $x = 13.0$ m, what is its speed there, and if it cannot, what is its turning point?

83 SSM A 15 kg block is accelerated at 2.0 m/s^2 along a horizontal frictionless surface, with the speed increasing from 10 m/s to 30 m/s. What are (a) the change in the block's mechanical energy and (b) the average rate at which energy is transferred to the block? What is the instantaneous rate of that transfer when the block's speed is (c) 10 m/s and (d) 30 m/s?

Answer:

(a) 6.0 kJ; (b) 6.0×10^2 W; (c) 3.0×10^2 W; (d) 9.0×10^2 W

84 A certain spring is found *not* to conform to Hooke's law. The force (in newtons) it exerts when stretched a distance x (in meters) is found to have magnitude $52.8x + 38.4x^2$ in the direction opposing the stretch. (a) Compute the work required to stretch the spring from $x = 0.500$ m to $x = 1.00$ m. (b) With one end of the spring fixed, a particle of mass 2.17 kg is attached to the other end of the spring when it is stretched by an amount $x = 1.00$ m. If the particle is then released from rest, what is its speed at the instant the stretch in the spring is $x = 0.500$ m? (c) Is the force exerted by the spring conservative or nonconservative? Explain.

85 SSM Each second, 1200 m^3 of water passes over a waterfall 100 m high. Three-fourths of the kinetic energy gained by the water in falling is transferred to electrical energy by a hydroelectric generator. At what rate does the generator produce electrical energy? (The mass of 1 m^3 of water is 1000 kg.)

Answer:

880 MW

86 GO In Fig. 8-65, a small block is sent through point *A* with a speed of 7.0 m/s. Its path is without friction until it reaches the section of length L = 12 m, where the coefficient of kinetic friction is 0.70. The indicated heights are h_1 = 6.0 m and h_2 = 2.0 m. What are the speeds of the block at (a) point *B* and (b) point *C*? (c) Does the block reach point *D*? If so, what is its speed there; if not, how far through the section of friction does it travel?

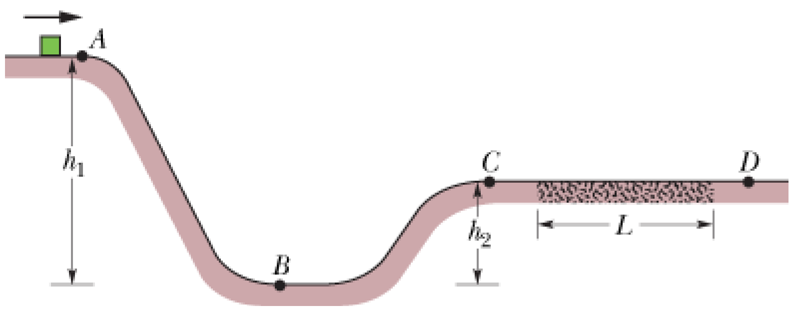

Figure 8-65 Problem 86.

87 SSM A massless rigid rod of length *L* has a ball of mass *m* attached to one end (Fig. 8-66). The other end is pivoted in such a way that the ball will move in a vertical circle. First, assume that there is no friction at the pivot. The system is launched downward from the horizontal position *A* with initial speed v_0. The ball just barely reaches point *D* and then stops. (a) Derive an expression for v_0 in terms of *L*, *m*, and *g*. (b) What is the tension in the rod when the ball passes through *B*? (c) A little grit is placed on the pivot to increase the friction there. Then the ball just barely reaches *C* when launched from *A* with the same speed as before. What is the decrease in the mechanical energy during this motion? (d) What is the decrease in the mechanical energy by the time the ball finally comes to rest at *B* after several oscillations?

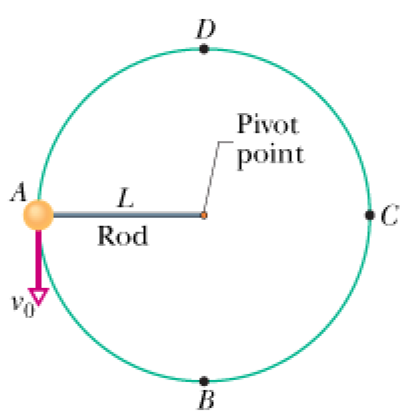

Figure 8-66 Problem 87.

Answer:

(a) $v_0 = (2gL)^{0.5}$; (b) $5mg$; (c) $- mgL$; (d) $- 2mgL$

88 A 1.50 kg water balloon is shot straight up with an initial speed of 3.00 m/s. (a) What is the kinetic energy of the balloon just as it is launched? (b) How much work does the gravitational force do on the balloon during the balloon's full ascent? (c) What is the change in the gravitational potential energy of the balloon–Earth system during the full ascent? (d) If the gravitational potential energy is taken to be zero at the launch point, what is its value when the balloon reaches its maximum height? (e) If, instead, the gravitational potential energy is taken to be zero at the maximum height, what is its value at the launch point? (f) What is the maximum height?

89 A 2.50 kg beverage can is thrown directly downward from a height of 4.00 m, with an initial speed of 3.00 m/s. The air drag on the can is negligible. What is the kinetic energy of the can (a) as it reaches the ground at the end of its fall and (b) when it is halfway to the ground? What are (c) the kinetic energy of the can and (d) the gravitational potential energy of the can–Earth system 0.200 s before the can reaches the ground? For the latter, take the reference point $y = 0$ to be at the ground.

Answer:

(a) 109 J; (b) 60.3 J; (c) 68.2 J; (d) 41.0 J

90 A constant horizontal force moves a 50 kg trunk 6.0 m up a 30° incline at constant speed. The coefficient of kinetic friction between the trunk and the incline is 0.20. What are (a) the work done by the applied force and (b) the increase in the thermal energy of the trunk and incline?

91 Two blocks, of masses $M = 2.0$ kg and $2M$, are connected to a spring of spring constant $k = 200$ N/m that has one end fixed, as shown in Fig. 8-67. The horizontal surface and the pulley are frictionless, and the pulley has negligible mass. The blocks are released from rest with the spring relaxed. (a) What is the combined kinetic energy of the two blocks when the hanging block has fallen 0.090 m? (b) What is the kinetic energy of the hanging block when it has fallen that 0.090 m? (c) What maximum distance does the hanging block fall before momentarily stopping?

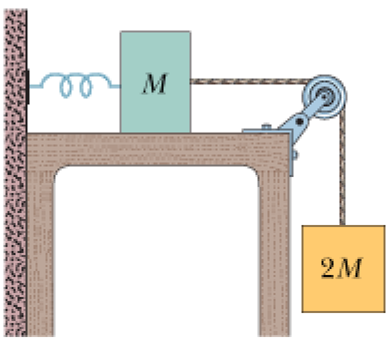

Figure 8-67 Problem 91.

Answer:

(a) 2.7 J; (b) 1.8 J; (c) 0.39 m

92 A volcanic ash flow is moving across horizontal ground when it encounters a 10° upslope. The front of the flow then travels 920 m up the slope before stopping. Assume that the gases entrapped in the flow lift the flow and thus make the frictional force from the ground negligible; assume also that the mechanical energy of the front of the flow is conserved. What was the initial speed of the front of the flow?

93 A playground slide is in the form of an arc of a circle that has a radius of 12 m. The maximum height of the slide is $h = 4.0$ m, and the ground is tangent to the circle (Fig. 8-68). A 25 kg child starts from rest at the top of the slide and has a speed of 6.2 m/s at the bottom. (a) What is the length of the slide? (b) What average frictional force acts on the child over this distance? If, instead of the ground, a vertical line through the *top of the slide* is tangent to the circle, what are (c) the length of the slide and (d) the average frictional force on the child?

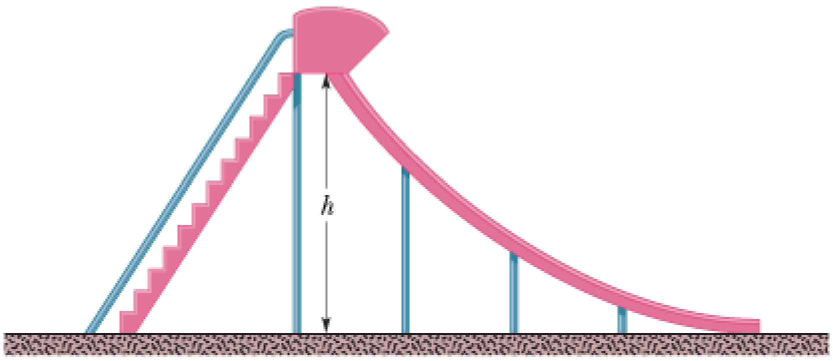

Figure 8-68 Problem 93.

Answer:

(a) 10 m; (b) 49 N; (c) 4.1 m; (d) 1.2×10^2 N

94 The luxury liner *Queen Elizabeth 2* has a diesel-electric power plant with a maximum power of 92 MW at a cruising speed of 32.5 knots. What forward force is exerted on the ship at this speed? (1 knot = 1.852 km/h.)

95 A factory worker accidentally releases a 180 kg crate that was being held at rest at the top of a ramp that is 3.7 m long and inclined at 39° to the horizontal. The coefficient of kinetic friction between the crate and the ramp, and between the crate and the horizontal factory floor, is 0.28. (a) How fast is the crate moving as it reaches the bottom of the ramp? (b) How far will it subsequently slide across the floor? (Assume that the crate's kinetic energy does not change as it moves from the ramp onto the floor.) (c) Do the answers to (a) and (b) increase, decrease, or remain the same if we halve the mass of the crate?

Answer:

(a) 5.5 m/s; (b) 5.4 m; (c) same

96 If a 70 kg baseball player steals home by sliding into the plate with an initial speed of 10 m/s just as he hits the ground, (a) what is the decrease in the player's kinetic energy and (b) what is the increase in the thermal energy of his body and the ground along which he slides?

97 A 0.50 kg banana is thrown directly upward with an initial speed of 4.00 m/s and reaches a maximum height of 0.80 m. What change does air drag cause in the mechanical energy of the banana–Earth system during the ascent?

Answer:

80 mJ

98 A metal tool is sharpened by being held against the rim of a wheel on a grinding machine by a force of 180 N. The frictional forces between the rim and the tool grind off small pieces of the tool. The wheel has a radius of 20.0 cm and rotates at 2.50 rev/s. The coefficient of kinetic friction between the wheel and the tool is 0.320. At what rate is energy being transferred from the motor driving the wheel to the thermal energy of the wheel and tool and to the kinetic energy of the material thrown from the tool?

99 A swimmer moves through the water at an average speed of 0.22 m/s. The average drag force is 110 N. What average power is required of the swimmer?

Answer:

24 W

100 An automobile with passengers has weight 16 400 N and is moving at 113 km/h when the driver brakes, sliding to a stop. The frictional force on the wheels from the road has a magnitude of 8230 N. Find the stopping distance.

101 A 0.63 kg ball thrown directly upward with an initial speed of 14 m/s reaches a maximum height of 8.1 m. What is the change in the mechanical energy of the ball–Earth system during the ascent of the ball to that maximum height?

Answer:

- 12 J

102 The summit of Mount Everest is 8850 m above sea level. (a) How much energy would a 90 kg climber expend against the gravitational force on him in climbing to the summit from sea level? (b) How many candy bars, at 1.25 MJ per bar, would supply an energy equivalent to this? Your answer should suggest that work done against the gravitational force is a very small part of the energy expended in climbing a mountain.

103 A sprinter who weighs 670 N runs the first 7.0 m of a race in 1.6 s, starting from rest and accelerating uniformly. What are the sprinter's (a) speed and (b) kinetic energy at the end of the 1.6 s? (c) What average power does the sprinter generate during the 1.6 s interval?

Answer:

(a) 8.8 m/s; (b) 2.6 kJ; (c) 1.6 kW

104 A 20 kg object is acted on by a conservative force given by $F = -3.0x - 5.0x^2$, with F in newtons and x in meters. Take the potential energy associated with the force to be zero when the object is at $x = 0$. (a) What is the potential energy of the system associated with the force when the object is at $x = 2.0$ m? (b) If the object has a velocity of 4.0 m/s in the negative direction of the x axis when it is at $x = 5.0$ m, what is its speed when it passes through the origin? (c) What are the answers to (a) and (b) if the potential energy of the system is taken to be -8.0 J when the object is at $x = 0$?

105 A machine pulls a 40 kg trunk 2.0 m up a 40° ramp at constant velocity, with the machine's force on the trunk directed parallel to the ramp. The coefficient of kinetic friction between the trunk and the ramp is 0.40. What are (a) the work done on the trunk by the machine's force and (b) the increase in thermal energy of the trunk and the ramp?

Answer:

(a) 7.4×10^2 J; (b) 2.4×10^2 J

106 The spring in the muzzle of a child's spring gun has a spring constant of 700 N/m. To shoot a ball from the gun, first the spring is compressed and then the ball is placed on it. The gun's trigger then releases the spring, which pushes the ball through the muzzle. The ball leaves the spring just as it leaves the outer end of the muzzle. When the gun is inclined upward by 30° to the horizontal, a 57 g ball is shot to a maximum height of 1.83 m above the gun's muzzle. Assume air drag on the ball is negligible. (a) At what speed does the spring launch the ball? (b) Assuming that friction on the ball within the gun can be neglected, find the spring's initial compression distance.

107 The only force acting on a particle is conservative force $\vec{F}$. If the particle is at point *A*, the potential energy of the system associated with $\vec{F}$ and the particle is 40 J. If the particle moves from point *A* to point *B*, the work done on the particle by $\vec{F}$ is +25 J. What is the potential energy of the system with the particle at *B*?

Answer:

15 J

108 In 1981, Daniel Goodwin climbed 443 m up the *exterior* of the Sears Building in Chicago using suction cups and metal clips. (a) Approximate his mass and then compute how much energy he had to transfer from biomechanical (internal) energy to the gravitational potential energy of the Earth–Goodwin system to lift himself to that height. (b) How much energy would he have had to transfer if he had, instead, taken the stairs inside the building (to the same height)?

109 A 60.0 kg circus performer slides 4.00 m down a pole to the circus floor, starting from rest. What is the kinetic energy of the performer as she reaches the floor if the frictional force on her from the pole (a) is negligible (she will be hurt) and (b) has a magnitude of 500 N?

Answer:

(a) 2.35×10^3 J; (b) 352 J

110 A 5.0 kg block is projected at 5.0 m/s up a plane that is inclined at 30° with the horizontal. How far up along the plane does the block go (a) if the plane is frictionless and (b) if the coefficient of kinetic friction between the block and the plane is 0.40? (c) In the latter case, what is the increase in thermal energy of block and plane during the block's ascent? (d) If the block then slides back down against the frictional force, what is the block's speed when it reaches the original projection point?

111 A 9.40 kg projectile is fired vertically upward. Air drag decreases the mechanical energy of the projectile–Earth system by 68.0 kJ during the projectile's ascent. How much higher would the projectile have gone were air drag negligible?

Answer:

738 m

112 A 70.0 kg man jumping from a window lands in an elevated fire rescue net 11.0 m below the window. He momentarily stops when he has stretched the net by 1.50 m. Assuming that mechanical energy is conserved during this process and that the net functions like an ideal spring, find the elastic potential energy of the net when it is stretched by 1.50 m.

113 A 30 g bullet moving a horizontal velocity of 500 m/s comes to a stop 12 cm within a solid wall. (a) What is the change in the bullet's mechanical energy? (b) What is the magnitude of the average force from the wall stopping it?

Answer:

(a) - 3.8 kJ; (b) 31 kN

114 A 1500 kg car starts from rest on a horizontal road and gains a speed of 72 km/h in 30 s. (a) What is its kinetic energy at the end of the 30 s? (b) What is the average power required of the car during the 30 s interval? (c) What is the instantaneous power at the end of the 30 s interval, assuming that the acceleration is constant?

115 A 1.50 kg snowball is shot upward at an angle of 34.0° to the horizontal with an initial speed of 20.0 m/s. (a) What is its initial kinetic energy? (b) By how much does the gravitational potential energy of the snowball–Earth system change as the snowball moves from the launch point to the point of maximum height? (c) What is that maximum height?

Answer:

(a) 300 J; (b) 93.8 J; (c) 6.38 m

116 A 68 kg sky diver falls at a constant terminal speed of 59 m/s. (a) At what rate is the gravitational potential energy of the Earth–sky diver system being reduced? (b) At what rate is the system's mechanical energy being reduced?

117 A 20 kg block on a horizontal surface is attached to a horizontal spring of spring constant k = 4.0 kN/m. The block is pulled to the right so that the spring is stretched 10 cm beyond its relaxed length, and the block is then released from rest. The frictional force between the sliding block and the surface has a magnitude of 80 N. (a) What is the kinetic energy of the block when it has moved 2.0 cm from its point of release? (b) What is the kinetic energy of the block when it first slides back through the point at which the spring is relaxed? (c) What is the maximum kinetic energy attained by the block as it slides from its point of release to the point at which the spring is relaxed?

Answer:

(a) 5.6 J; (b) 12 J; (c) 13 J

118 Resistance to the motion of an automobile consists of road friction, which is almost independent of speed, and air drag, which is proportional to speed-squared. For a certain car with a weight of 12 000 N, the total resistant force F is given by $F = 300 + 1.8v^2$, with F in newtons and v in meters per second. Calculate the power (in horsepower) required to accelerate the car at 0.92 m/s^2 when the speed is 80 km/h.

119 SSM A 50 g ball is thrown from a window with an initial velocity of 8.0 m/s at an angle of 30° above the horizontal. Using energy methods, determine (a) the kinetic energy of the ball at the top of its flight and (b) its speed when it is 3.0 m below the window. Does the answer to (b) depend on either (c) the mass of the ball or (d) the initial angle?

Answer:

(a) 1.2 J; (b) 11 m/s; (c) no; (d) no

120 A spring with a spring constant of 3200 N/m is initially stretched until the elastic potential energy of the spring is 1.44 J. (U = 0 for the relaxed spring.) What is ΔU if the initial stretch is changed to (a) a stretch of 2.0 cm, (b) a compression of 2.0 cm, and (c) a compression of 4.0 cm?

121 A locomotive with a power capability of 1.5 MW can accelerate a train from a speed of 10 m/s to 25 m/s in 6.0 min. (a) Calculate the mass of the train. Find (b) the speed of the train and (c) the force accelerating the train as functions of time (in seconds) during the 6.0 min interval. (d) Find the distance moved by the train during the interval.

Answer:

(a) 2.1×10^6 kg; (b) $(100 + 1.5t)^{0.5}$ m/s; (c) $(1.5 \times 10^6)/(100 + 1.5t)^{0.5}$ N; (d) 6.7 km

122 SSM A 0.42 kg shuffleboard disk is initially at rest when a player uses a cue to increase its speed to 4.2 m/s at constant acceleration. The acceleration takes place over a 2.0 m distance, at the end of which the cue loses contact with the disk. Then the disk slides an additional 12 m before stopping. Assume that the shuffle-board court is level and that the force of friction on the disk is constant. What is the increase in the thermal energy of the disk–court system (a) for that additional 12 m and (b) for the entire 14 m distance? (c) How much work is done on the disk by the cue?