6.8 OTHER FORMS OF ENERGY AND THE CONSERVATION OF ENERGY The principle of conservation of energy states that energy cannot be created or destroyed but can only be transformed from one form to another.

6.9 WORK DONE BY A VARIABLE FORCE The work done by a variable force of magnitude $F$ in moving an object through a displacement of magnitude $s$ is equal to the area under the graph of $F \cos \theta$ versus $s$. The angle $\theta$ is the angle between the force and displacement vectors.

Use Self-Assessment Test 6.3 to evaluate your understanding of Sections 6.6–6.9.

CONCEPTUAL QUESTIONS

1. Two forces $\vec{F}_1$ and $\vec{F}_2$ are acting on the box shown in the drawing, causing the box to move across the floor. The two force vectors are drawn to scale. Which force does more work? Justify your answer.

2. A box is being moved with a velocity $\vec{v}$ by a force $\vec{F}$ (parallel to $\vec{v}$) along a level horizontal floor. The normal force is $\vec{F}_n$, the kinetic frictional force is $\vec{F}_k$, and the weight of the box is $mg$. Decide which forces do positive, zero, or negative work. Provide a reason for each of your answers.

3. A force does positive work on a particle that has a displacement pointing in the $+x$ direction. This same force does negative work on a particle that has a displacement pointing in the $+y$ direction. In what quadrant does the force lie? Account for your answer.

4. A sailboat is moving at a constant velocity. (a) Is work being done by a net external force acting on the boat? Explain. (b) Recognizing that the wind propels the boat forward and the water resists the boat's motion, what does your answer in part (a) imply about the work done by the wind's force compared to the work done by the water's resistive force?

5. A ball has a speed of 15 m/s. Only one external force acts on the ball. After this force acts, the speed of the ball is 7 m/s. Has the force done positive, negative, or zero work? Explain.

6. A slow-moving car may have more kinetic energy than a fast-moving motorcycle. How is this possible?

7. A net external force acts on a particle. This net force is not zero. Is this sufficient information to conclude that (a) the velocity of the particle changes, (b) the kinetic energy of the particle changes, and (c) the speed of the particle changes? Give your reasoning in each case.

8. The speed of a particle doubles and then doubles again because a net external force acts on it. Does the net force do more work during the first or the second doubling? Justify your answer.

9. A shopping bag is hanging straight down from your hand as you walk across a horizontal floor at a constant velocity. (a) Does the force that your hand exerts on the bag's handle do any work? Explain. (b) Does this force do any work while you are riding up an escalator at a constant velocity? Give a reason for your answer.

10. In a simulation on earth, an astronaut in his space suit climbs up a vertical ladder. On the moon, the same astronaut makes the same climb. In which case does the gravitational potential energy of the astronaut change by a greater amount? Account for your answer.

11. A net external nonconservative force does positive work on a particle, and both its kinetic and potential energies change. What, if anything, can you conclude about (a) the change in the particle's total mechanical energy and (b) the individual changes in the kinetic and potential energies? Justify your answers.

12. Suppose the total mechanical energy of an object is conserved. (a) If the kinetic energy decreases, what must be true about the gravitational potential energy? (b) If the potential energy decreases, what must be true about the kinetic energy? (c) If the kinetic energy does not change, what must be true about the potential energy?

13. In Example 10 the Steel Dragon starts with a speed of 3.0 m/s at the top of the drop and attains a speed of 42.9 m/s when it reaches the bottom. If the roller coaster were to then start up an identical hill, would its speed be 3.0 m/s at the top of this hill? Assume that friction is negligible. Explain your answer in terms of energy concepts.

14. A person is riding on a Ferris wheel. When the wheel makes one complete turn, is the net work done by the gravitational force positive, negative, or zero? Justify your answer.

15. Consider the following two situations in which the retarding effects of friction and air resistance are negligible. Car A approaches a hill. The driver turns off the engine at the bottom of the hill, and the car coasts up the hill. Car B, its engine running, is driven up the hill at a constant speed. Which situation is an example of the principle of conservation of mechanical energy? Provide a reason for your answer.

16. A trapeze artist, starting from rest, swings downward on the bar, lets go at the bottom of the swing, and falls freely to the net. An assistant, standing on the same platform as the trapeze artist, jumps from rest straight downward. Friction and air resistance are negligible. (a) On which person, if either, does gravity do the greatest amount of work? Explain. (b) Who, if either, strikes the net with a greater speed? Why?

17. The drawing shows an empty fuel tank about to be released by three different jet planes. At the moment of release, each plane has the same speed and each tank is at the same height above the ground. However,
the directions of travel are different. In the absence of air resistance, do the tanks have different speeds when they hit the ground? If so, which tank has the largest speed and which has the smallest speed? Explain.

18. Is it correct to conclude that one engine is doing twice the work of another just because it is generating twice the power? Explain, neglecting friction and taking into account the time of operation of the engines.

Section 6.1 Work Done by a Constant Force

1. The brakes of a truck cause it to slow down by applying a retarding force of $3.0 \times 10^3$ N to the truck over a distance of 850 m. What is the work done by this force on the truck? Is the work positive or negative? Why?

2. A cable lifts a 1200-kg elevator at a constant velocity for a distance of 35 m. What is the work done by (a) the tension in the cable and (b) the elevator’s weight?

3. A 75.0-kg man is riding an escalator in a shopping mall. The escalator moves the man at a constant velocity from ground level to the floor above, a vertical height of 4.60 m. What is the work done on the man by (a) the gravitational force and (b) the escalator?

4. A person pulls a toboggan for a distance of 35.0 m along the snow with a rope directed 25.0° above the snow. The tension in the rope is 94.0 N. (a) How much work is done on the toboggan by the tension force? (b) How much work is done if the same tension is directed parallel to the snow?

5. During a tug-of-war, team A pulls on team B by applying a force of 1100 N to the rope between them. How much work does team A do if they pull team B toward them a distance of 2.0 m?

6. Consult Interactive LearningWare 6.1 at www.wiley.com/college/cutnell for background pertinent to this problem. The drawing shows a plane diving toward the ground and then climbing back upward. During each of these motions, the lift force $L$ acts perpendicular to the displacement $s$, which has the same magnitude, $1.7 \times 10^3$ m, in each case. The engines of the plane exert a thrust $T$, which points in the direction of the displacement and has the same magnitude during the dive and the climb. The weight $W$ of the plane has a magnitude of $5.9 \times 10^4$ N. In both motions, net work is performed due to the combined action of the forces $L$, $T$, and $W$. (a) Is more net work done during the dive or the climb? Explain. (b) Find the difference between the net work done during the dive and the climb.

7. A person pushes a 16.0-kg shopping cart at a constant velocity for a distance of 22.0 m. She pushes in a direction $29.0^\circ$ below the horizontal. A 48.0-N frictional force opposes the motion of the cart. (a) What is the magnitude of the force that the shopper exerts? Determine the work done by (b) the pushing force, (c) the frictional force, and (d) the gravitational force.

8. A $1.00 \times 10^2$-kg crate is being pushed across a horizontal floor by a force $\vec{F}$ that makes an angle of $30.0^\circ$ below the horizontal. The coefficient of kinetic friction is 0.200. What should be the magnitude of $\vec{F}$, so that the net work done by it and the kinetic frictional force is zero?

9. A husband and wife take turns pulling their child in a wagon along a horizontal sidewalk. Each exerts a constant force and pulls the wagon through the same displacement. They do the same amount of work, but the husband’s pulling force is directed $58^\circ$ above the horizontal, and the wife’s pulling force is directed $38^\circ$ above the horizontal. The husband pulls with a force whose magnitude is 67 N. What is the magnitude of the pulling force exerted by his wife?

10. A 55-kg box is being pushed a distance of 7.0 m across the floor by a force $\vec{F}$ whose magnitude is 150 N. The force $\vec{F}$ is parallel to the displacement of the box. The coefficient of kinetic friction is 0.25. Determine the work done on the box by each of the four forces that act on the box. Be sure to include the proper plus or minus sign for the work done by each force.

11. A 1200-kg car is being driven up a 5.0° hill. The frictional force is directed opposite to the motion of the car and has a magnitude of $f = 524$ N. A force $\vec{F}$ is applied to the car by the road and propels the car forward. In addition to these two forces, two other forces act on the car: its weight $\vec{W}$ and the normal force $\vec{N}$, directed perpendicular to the road surface. The length of the road up the hill is 290 m. What should be the magnitude of $\vec{F}$, so that the net work done by all the forces acting on the car is $+150$ kJ?

Section 6.2 The Work–Energy Theorem and Kinetic Energy

12. Refer to Concept Simulation 6.1 at www.wiley.com/college/cutnell for a review of the concepts with which this problem deals. A 0.075-kg arrow is fired horizontally. The bowstring exerts an average force of 65 N on the arrow over a distance of 0.90 m. With what speed does the arrow leave the bow?

13. Two cars, A and B, are traveling with the same speed of 40.0 m/s, each having started from rest. Car A has a mass of $1.20 \times 10^3$ kg, and car B has a mass of $2.00 \times 10^3$ kg. Compared to the work required to bring car A up to speed, how much additional work is required to bring car B up to speed?

14. A fighter jet is launched from an aircraft carrier with the aid of its own engines and a steam-powered catapult. The thrust of its engines is $2.3 \times 10^5$ N. In being launched from rest it moves through a distance of 87 m and has a kinetic energy of $4.5 \times 10^7$ J at lift-off. What is the work done on the jet by the catapult?

15. When a 0.045-kg golf ball takes off after being hit, its speed is 41 m/s. (a) How much work is done on the ball by the club? (b) Assume that the force of the golf club acts parallel to the motion of the ball and that the club is in contact with the ball for a distance
of 0.010 m. Ignore the weight of the ball and determine the average force applied to the ball by the club.

16. As background for this problem, review Conceptual Example 6. A 7420-kg satellite has an elliptical orbit, as in Figure 6.9b. The point on the orbit that is farthest from the earth is called the **apogee** and is at the far right side of the drawing. The point on the orbit that is closest to the earth is called the **perigee** and is at the left side of the drawing. Suppose that the speed of the satellite is 2820 m/s at the apogee and 8450 m/s at the perigee. Find the work done by the gravitational force when the satellite moves from (a) the apogee to the perigee and (b) the perigee to the apogee.

17. **ssm** The hammer throw is a track-and-field event in which a 7.3-kg ball (the "hammer"), starting from rest, is whirled around in a circle several times and released. It then moves upward on the familiar curving path of projectile motion. In one throw, the hammer is given a speed of 29 m/s. For comparison, a .22 caliber bullet has a mass of 2.6 g and, starting from rest, exits the barrel of a gun with a speed of 410 m/s. Determine the work done to launch the motion of (a) the hammer and (b) the bullet.

18. **Multiple-Concept Example 4** and **Interactive LearningWare 6.2 at w.w.y.e.m.com/college/cutnell** review the concepts that are important in this problem. A 5.0 \( \times 10^4 \) kg space probe is traveling at a speed of 11600 m/s through deep space. Retrorocotors are fired along the line of motion to reduce the probe's speed. The retrorocotors generate a force of 4.0 \( \times 10^3 \) N over a distance of 2500 km. What is the final speed of the probe?

19. **ssm** A sled is being pulled across a horizontal patch of snow. Friction is negligible. The pulling force points in the same direction as the sled's displacement, which is along the \(+x\) axis. As a result, the kinetic energy of the sled increases by 38%. By what percentage would the sled's kinetic energy have increased if this force had pointed 62° above the \(+x\) axis?

20. The concepts in this problem are similar to those in Multiple-Concept Example 4, except that the force doing the work in this problem is the tension in the cable. A rescue helicopter lifts a 79-kg person straight up by means of a cable. The person has an upward acceleration of 0.70 m/s² and is lifted from rest through a distance of 11 m. (a) What is the tension in the cable? (b) How much work is done by (b) the tension in the cable and (c) the person's weight? (d) Use the work–energy theorem and find the final speed of the person.

21. **ssm** A 6200-kg satellite is in a circular earth orbit that has a radius of 3.3 \( \times 10^7 \) m. A net external force must act on the satellite to make it change to a circular orbit that has a radius of 7.0 \( \times 10^7 \) m. What work must the net external force do?

22. **Interactive LearningWare 6.3 at w.w.y.e.m.com/college/cutnell** for a review of the concepts on which this problem is based. A gymnast is swinging on a high bar. The distance between his waist and the bar is 1.1 m, as the drawing shows. At the top of the swing, his speed is momentarily zero. Ignoring friction and treating the gymnast as if all of his mass is located at his waist, find his speed at the bottom of the swing.
33. Interactive Solution 6.33 at www.wiley.com/college/cutnell presents a model for solving this problem. A slingshot fires a pebble from the top of a building at a speed of 14.0 m/s. The building is 31.0 m tall. Ignoring air resistance, find the speed with which the pebble strikes the ground when the pebble is fired (a) horizontally, (b) vertically straight up, and (c) vertically straight down.

34. The skateboarder in the drawing starts down the left side of the ramp with an initial speed of 5.4 m/s. If nonconservative forces, such as kinetic friction and air resistance, are negligible, what would be the height $h$ of the highest point reached by the skateboarder on the right side of the ramp?

35. A 2.00-kg rock is released from rest at a height of 20.0 m. Ignore air resistance and determine the kinetic energy, gravitational potential energy, and total mechanical energy at each of the following heights: 20.0, 10.0, and 0 m.

36. Consult Conceptual Example 9 in preparation for this problem. Interactive LearningWare 6.3 at www.wiley.com/college/cutnell also provides useful background. The drawing shows a person who, starting from rest at the top of a cliff, swings down at the end of a rope, releases it, and falls into the water below. There are two paths by which the person can enter the water. Suppose he enters the water at a speed of 13.0 m/s via path 1. How fast is he moving on path 2 when he releases the rope at a height of 5.20 m above the water? Ignore the effects of air resistance.

37. A 47.0-g golf ball is driven from the tee with an initial speed of 52.0 m/s and rises to a height of 24.6 m. (a) Neglect air resistance and determine the kinetic energy of the ball at its highest point. (b) What is its speed when it is 8.0 m below its highest point?

38. The drawing shows a skateboarder moving at 5.4 m/s along a horizontal section of a track that is slanted upward by 48° above the horizontal at its end, which is 0.40 m above the ground. When she leaves the track, she follows the characteristic path of projectile motion. Ignoring friction and air resistance, find the maximum height $H$ to which she rises above the end of the track.

39. Review Interactive Solution 6.39 at www.wiley.com/college/cutnell for background on this problem. A wrecking ball swings at the end of a 12.0-m cable on a vertical circular arc. The crane operator manages to give the ball a speed of 5.00 m/s as the ball passes through the lowest point of its swing and then gives the ball no further assistance. Friction and air resistance are negligible. What speed $\gamma$ does the ball have when the cable makes an angle of 20.0° with respect to the vertical?

40. A particle, starting from point A in the drawing, is projected down the curved runway. Upon leaving the runway at point B, the particle is traveling straight upward and reaches a height of 4.00 m above the floor before falling back down. Ignoring friction and air resistance, find the speed of the particle at point A.

41. Two pole-vaulters just clear the bar at the same height. The first lands at a speed of 8.90 m/s, and the second lands at a speed of 9.00 m/s. The first vaulter clears the bar at a speed of 1.00 m/s. Ignore air resistance and friction and determine the speed at which the second vaulter clears the bar.

42. A skier starts from rest at the top of a hill. The skier coasts down the hill and up a second hill, as the drawing illustrates. The crest of the second hill is circular, with a radius of $r = 36$ m. Neglect friction and air resistance. What must be the height $h$ of the first hill so that the skier just loses contact with the snow at the crest of the second hill?

43. Conceptual Example 9 provides background for this problem. A swing is made from a rope that will tolerate a maximum tension of $8.00 \times 10^3$ N without breaking. Initially, the swing hangs vertically. The swing is then pulled back at an angle of 60.0° with respect to the vertical and released from rest. What is the mass of the heaviest person who can ride the swing?
44. A person starts from rest at the top of a large frictionless spherical surface, and slides into the water below (see the drawing). At what angle $\theta$ does the person leave the surface? (Hint: When the person leaves the surface, the normal force is zero.)

Section 6.6 Nonconservative Forces and the Work-Energy Theorem

45. A $5.00 \times 10^2$-kg hot-air balloon takes off from rest at the surface of the earth. The nonconservative wind and lift forces take the balloon up, doing $+9.70 \times 10^4$ J of work on the balloon in the process. At what height above the surface of the earth does the balloon have a speed of $8.00$ m/s?

46. The surfer in the photo is catching a wave. Suppose she starts at the top of the wave with a speed of $1.4$ m/s and moves down the wave until her speed increases to $9.5$ m/s. The drop in her vertical height is $2.7$ m. If her mass is $59$ kg, how much work is done by the (nonconservative) force of the wave?

47. A roller coaster (375 kg) moves from $A$ (5.00 m above the ground) to $B$ (20.0 m above the ground). Two nonconservative forces are present: friction does $-2.00 \times 10^4$ J of work on the car, and a chain mechanism does $+3.00 \times 10^4$ J of work to help the car up a long climb. What is the change in the car's kinetic energy, $\Delta KE = KE_f - KE_i$, from $A$ to $B$?

48. One of the new events in the 2002 Winter Olympics was the sport of skeleton (see the photo). Starting at the top of a steep, icy track, a rider jumps onto a sled (known as a skeleton) and proceeds—belly down and head first—to slide down the track. The track has fifteen turns and drops 104 m in elevation from top to bottom. (a) In the absence of nonconservative forces, such as friction and air resistance, what would be the speed of a rider at the bottom of the track? Assume that the speed of the rider at the beginning of the run is relatively small and can be ignored. (b) In reality, the best riders reach the bottom with a speed of $35.8$ m/s (about $80$ mph). How much work is done on an $86.0$-kg rider and skeleton by nonconservative forces?

49. The (nonconservative) force propelling a $1.50 \times 10^3$-kg car up a mountain road does $4.70 \times 10^6$ J of work on the car. The car starts from rest at sea level and has a speed of $27.0$ m/s at an altitude of $2.00 \times 10^6$ m above sea level. Obtain the work done on the car by the combined forces of friction and air resistance, both of which are nonconservative forces.

50. In attempting to pass the puck to a teammate, a hockey player gives it an initial speed of $1.7$ m/s. However, this speed is inadequate to compensate for the kinetic friction between the puck and the ice. As a result, the puck travels only one-half the distance between the players before sliding to a halt. What minimum initial speed should the puck have been given so that it reached the teammate, assuming that the same force of kinetic friction acted on the puck everywhere between the two players?

51. Refer to Interactive Solution 6.51 for a review of the approach taken in problems such as this one. A $67.0$-kg person jumps from rest off a $3.00$-m-high tower straight down into the water. Neglect air resistance during the descent. She comes to rest $1.10$ m under the surface of the water. Determine the magnitude of the average force that the water exerts on the diver. This force is nonconservative.

52. A pitcher throws a $0.140$-kg baseball, and it approaches the bat at a speed of $40.0$ m/s. The bat does $W_{\text{bat}} = 70.0$ J of work on the ball in hitting it. Ignoring air resistance, determine the speed of the ball after the ball leaves the bat and is $25.0$ m above the point of impact.

53. At a carnival, you can try to ring a bell by striking a target with a $9.00$-kg hammer. In response, a $0.400$-kg metal piece is sent upward toward the bell, which is $5.00$ m above. Suppose that $25.0\%$ of the hammer's kinetic energy is used to do the work of sending the metal piece upward. How fast must the hammer be moving when it strikes the target so that the bell just barely rings?

54. A $3.00$-kg model rocket is launched straight up. It reaches a maximum height of $1.00 \times 10^2$ m above where its engine cuts out, even though air resistance performs $-8.00 \times 10^2$ J of work on the rocket. What would have been this height if there were no air resistance?

Section 6.7 Power

55. One kilowatt-hour (kWh) is the amount of work or energy generated when one kilowatt of power is supplied for a time of one hour. A kilowatt-hour is the unit of energy used by power companies when figuring your electric bill. Determine the number of joules of energy in one kilowatt-hour.

56. Bicyclists in the Tour de France do enormous amounts of work during a race. For example, the average power per kilogram generated by Lance Armstrong ($m = 75.0$ kg) is $6.50$ W per kilogram of his body mass. (a) How much work does he do during a 135-km race in which his average speed is $12.0$ m/s? (b) Often, the work done is expressed in nutritional Calories rather than in joules. Express the work done in part (a) in terms of nutritional Calories, noting that 1 joule $= 2.389 \times 10^{-4}$ nutritional Calories.

57. Interactive Solution 6.57 at www.wiley.com/college/cutnell offers a model for solving this problem. A car accelerates uniformly from rest to $20.0$ m/s in $5.6$ s along a level stretch of road. Ignoring friction, determine the average power required to accelerate the car if (a) the weight of the car is $9.0 \times 10^3$ N, and (b) the weight of the car is $1.4 \times 10^4$ N.

58. You are trying to lose weight by working out on a rowing machine. Each time you pull the rowing bar (which simulates the "oars") toward you, it moves a distance of 1.2 m in a time of 1.5 s. The readout on the display indicates that the average power you are producing is $82$ W. What is the magnitude of the force that you exert on the handle?

59. Multiple-Concept Example 13 presents useful background for this problem. The cheetah is one of the fastest-accelerating animals, because it can go from rest to $27$ m/s (about $60$ mph) in $4.0$ s. If its
mass is 110 kg, determine the average power developed by the cheetah during the acceleration phase of its motion. Express your answer in (a) watts and (b) horsepower.

60. A motorcycle (mass of cycle plus rider = 2.50 \times 10^2 kg) is traveling at a steady speed of 20.0 m/s. The force of air resistance acting on the cycle and rider is 2.00 \times 10^2 N. Find the power necessary to sustain this speed if (a) the road is level and (b) the road is sloped upward at 37.0° with respect to the horizontal.

61. ssm The motor of a ski boat generates an average power of 7.50 \times 10^4 W when the boat is moving at a constant speed of 12 m/s. When the boat is pulling a skier at the same speed, the engine must generate an average power of 8.30 \times 10^4 W. What is the tension in the tow rope that is pulling the skier?

62. A 1900-kg car experiences a combined force of air resistance and friction that has the same magnitude whether the car goes up or down a hill at 27 m/s. Going up a hill, the car's engine needs to produce 47 hp more power to sustain the constant velocity than it does going down the same hill. At what angle is the hill inclined above the horizontal?

Section 6.9 Work Done by a Variable Force

63. ssm The drawing shows the force-versus-displacement graph for two different bows. These graphs give the force that an archer must apply to draw the bowstring. (a) For which bow is more work required to draw the bow fully from \( s = 0 \) to \( s = 0.50 \) m? Give your reasoning. (b) Estimate the additional work required for the bow identified in part (a) compared to the other bow.

64. Review Example 14, in which the work done in drawing the bowstring in Figure 6.22 from \( s = 0 \) to \( s = 0.500 \) m is determined.

**ADDITIONAL PROBLEMS**

68. A water skier, moving at a speed of 9.30 m/s, is being pulled by a tow rope that makes an angle of 37.0° with respect to the velocity of the boat (see the drawing). The tow rope is parallel to the water.

In part b of the figure, the force component \( F \cos \theta \) reaches a maximum at \( s = 0.306 \) m. Find the percentage of the total work that is done when the bowstring is moved (a) from \( s = 0 \) to 0.306 m and (b) from \( s = 0.306 \) to 0.500 m.

65. The graph shows the net external force component \( F \cos \theta \) along the displacement as a function of the magnitude \( s \) of the displacement. The graph applies to a 65-kg ice skater. How much work does the net force component do on the skater from (a) 0 to 3.0 m and (b) 3.0 m to 6.0 m? (c) If the initial speed of the skater is 1.5 m/s when \( s = 0 \) m, what is the speed when \( s = 6.0 \) m?

66. The graph shows how the force component \( F \cos \theta \) along the displacement varies with the magnitude \( s \) of the displacement. Find the work done by the force. (Hint: Recall how the area of a triangle is related to the triangle's base and height.)

67. A net external force is applied to a 6.00-kg object that is initially at rest. The net force component along the displacement of the object varies with the magnitude of the displacement as shown in the drawing. (a) How much work is done by the net force? (b) What is the speed of the object at \( s = 20.0 \) m?

The skier is moving in the same direction as the boat. If the tension in the tow rope is 135 N, determine the work that it does in 12.0 s.

69. ssm A pole-vaulter approaches the takeoff point at a speed of 9.00 m/s. Assuming that only this speed determines the height to which he can rise, find the maximum height at which the vaulter can clear the bar.

70. A projectile of mass 0.750 kg is shot straight up with an initial speed of 18.0 m/s. (a) How high would it go if there were no air friction? (b) If the projectile rises to a maximum height of only 11.8 m, determine the magnitude of the average force due to air resistance.

71. ssm Suppose in Figure 6.2 that \(+1.10 \times 10^3 \) J of work are done by the force \( F \) (magnitude = 30.0 N) in moving the suitcase a distance of 50.0 m. At what angle \( \theta \) is the force oriented with respect to the ground?

72. When an 81.0-kg adult uses a spiral staircase to climb to the second floor of his house, his gravitational potential energy increases by \( 2.00 \times 10^3 \) J. By how much does the potential energy
of an 18.0-kg child increase when the child climbs a normal staircase to the second floor?

*73. A $2.40 \times 10^3$-N force is pulling an 85.0-kg refrigerator across a horizontal surface. The force acts at an angle of 20.0° above the surface. The coefficient of kinetic friction is 0.200, and the refrigerator moves a distance of 8.00 m. Find (a) the work done by the pulling force, and (b) the work done by the kinetic frictional force.

*74. In 2.0 minutes, a ski lift raises four skiers at constant speed to a height of 140 m. The average mass of each skier is 65 kg. What is the average power provided by the tension in the cable pulling the lift?

*75. Interactive Solution 6.75 at www.wiley.com/college/cutnell offers help in modeling this problem. A basketball of mass 0.60 kg is dropped from rest from a height of 1.05 m. It rebounds to a height of 0.57 m. (a) How much mechanical energy was lost during the collision with the floor? (b) A basketball player dribbles the ball from a height of 1.05 m by exerting a constant downward force on it for a distance of 0.180 m. In dribbling, the player compensates for the mechanical energy lost each bounce. If the ball now returns to a height of 1.05 m, what is the magnitude of the force?

*76. A 63-kg skier coasts up a snow-covered hill that makes an angle of 25° with the horizontal. The initial speed of the skier is 6.6 m/s. After coasting a distance of 1.9 m up the slope, the speed of the skier is 4.4 m/s. (a) Find the work done by the kinetic frictional force that acts on the skis. (b) What is the magnitude of the kinetic frictional force?

*77. smm A water slide is constructed so that swimmers, starting from rest at the top of the slide, leave the end of the slide traveling horizontally. As the drawing shows, one person hits the water 5.00 m from the end of the slide in a time of 0.500 s after leaving the slide. Ignoring friction and air resistance, find the height $H$ in the drawing.

**78. The drawing shows a version of the loop-the-loop trick for a small car. If the car is given an initial speed of 4.0 m/s, what is the largest value that the radius $r$ can have if the car is to remain in contact with the circular track at all times?

**79. ssm www A truck is traveling at 11.1 m/s down a hill when the brakes on all four wheels lock. The hill makes an angle of 15° with respect to the horizontal. The coefficient of kinetic friction between the tires and the road is 0.750. How far does the truck skid before coming to a stop?

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### CONCEPTS & CALCULATIONS

Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. The Concept Questions involve little or no mathematics. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

#### 80. Concept Questions
You are moving into an apartment and take the elevator to the 6th floor. Does the force exerted on you by the elevator do positive or negative work when the elevator (a) goes up and (b) goes down? Explain your answers.

**Problem** Suppose your weight is 685 N and that of your belongings is 915 N. (a) Determine the work done by the elevator in lifting you and your belongings up to the 6th floor (15.2 m) at a constant velocity. (b) How much work does the elevator do on you alone (without belongings) on the downward trip, which is also made at a constant velocity? Check to see that your answers are consistent with your answers to the Concept Questions.

#### 81. Concept Questions
An asteroid is moving along a straight line. A force acts along the displacement of the asteroid and slows it down. (a) Is the direction of the force the same as or opposite to the direction of the displacement of the asteroid? Why? (b) Does the force do positive, negative, or zero work? Justify your answer. (c) What type of energy is changing as the object slows down? (d) What is the relationship between the work done by this force and the change in the object's energy?

**Problem** The asteroid has a mass of $4.5 \times 10^4$ kg, and the force causes its speed to change from 7100 to 5500 m/s. (a) What is the work done by the force? (b) If the asteroid slows down over a distance of $1.8 \times 10^4$ m, determine the magnitude of the force. Verify that your answers are consistent with the answers to the Concept Questions.

#### 82. Concept Questions
The drawing shows two boxes resting on frictionless ramps. One box is relatively light and sits on a steep ramp. The other box is heavier and rests on a ramp that is less steep. The boxes are released from rest at A and allowed to slide down the ramps. Which box, if either, has (a) the greater speed and (b) the greater kinetic energy at B? Provide a reason for each answer.

**Problem** The two boxes have masses of 11 and 44 kg. If A and B are 4.5 and 1.5 m, respectively, above the ground, determine the speed of (a) the lighter box and (b) the heavier box when each reaches B. (c) What is the ratio of the kinetic energy of the heavier box to that of the lighter box at B? Be sure that your answers are consistent with your answers to the Concept Questions.
83. **Concept Questions** A student, starting from rest, slides down a water slide. On the way down, a kinetic frictional force (a nonconservative force) acts on her. (a) Does the kinetic frictional force do positive, negative, or zero work? Provide a reason for your answer. (b) Does the total mechanical energy of the student increase, decrease, or remain the same as she descends the slide? Why? (c) If the kinetic frictional force does work, how is this work related to the change in the total mechanical energy of the student?

**Problem** The student has a mass of 83.0 kg and the height of the water slide is 11.8 m. If the kinetic frictional force does $-6.50 \times 10^3$ J of work, how fast is the student going at the bottom of the slide?

84. **Concept Questions** A helicopter, starting from rest, accelerates straight up from the roof of a hospital. The lifting force does work in raising the helicopter. (a) What type(s) of energy is (are) changing? Is each type increasing or decreasing? Why? (b) How is (are) the type(s) of energy that is (are) changing related to the work done by the lifting force? (c) If you want to determine the average power generated by the lifting force, what other variable besides the work must be known?

**Problem** An 810-kg helicopter rises from rest to a speed of 7.0 m/s in a time of 3.5 s. During this time it climbs to a height of 8.2 m. What is the average power generated by the lifting force?

85. **Concept Questions** A water-skier is being pulled by a tow rope attached to a boat. As the driver pushes the throttle forward, the skier accelerates. (a) What type of energy is changing? (b) Is the work being done by the net external force acting on the skier positive, zero, or negative? Why? (c) How is this work related to the change in the energy of the skier?

**Problem** A 70.3-kg water-skier has an initial speed of 6.10 m/s. Later, the speed increases to 11.3 m/s. Determine the work done by the net external force acting on the skier.

86. **Concept Questions** Under the influence of its drive force, a snowmobile is moving at a constant velocity along a horizontal patch of snow. When the drive force is shut off, the snowmobile coasts to a halt. (a) During the coasting phase, what is the net external force acting on the snowmobile? (b) How does the work $W$ done by the net external force depend on the magnitude and direction of the net force and on the displacement of the snowmobile? (c) What is the net force acting on the snowmobile during the constant-velocity phase? Explain. (d) The work-energy theorem is given by $W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ (Equation 6.3), where $W$ is the work done by the net external force acting on the snowmobile, $m$ is its mass, and $v_f$ and $v_i$ are, respectively, its final and initial speeds. Suppose the net external force, $m$, and $v_f$ and $v_i$ are known. By using only the work-energy theorem, can one determine the time $t$ it takes for the snowmobile to coast to a halt?

**Problem** The snowmobile and its rider have a mass of 136 kg. Under the influence of a drive force of 205 N, it is moving at a constant velocity, whose magnitude is 5.50 m/s. Its drive force is shut off. Find (a) the distance in which the snowmobile coasts to a halt and (b) the time required to do so.

87. **Concept Questions** The drawing shows two frictionless inclines that begin at ground level ($h = 0$ m) and slope upward at the same angle $\theta$. One track is longer than the other, however. Identical blocks are projected up each track with the same initial speed $v_0$. On the longer track the block slides upward until it reaches a maximum height $H$ above the ground. On the shorter track the block slides upward, flies off the end of the track at a height $H_1$ above the ground, and then follows the familiar parabolic trajectory of projectile motion. At the highest point of this trajectory, the block is a height $H_2$ above the end of the track. The initial total mechanical energy of each block is the same and is all kinetic energy. (a) When the block on the longer track reaches its maximum height, is its final total mechanical energy all kinetic energy, all potential energy, or some of each? Explain. (b) When the block on the shorter track reaches the top of its trajectory after leaving the track, is its final total mechanical energy all kinetic energy, all potential energy, or some of each? Justify your answer. (c) Which is the greater height above the ground: $H$ or $H_1 + H_2$? Why?

**Problem** The initial speed of each block is $v_0 = 7.00$ m/s, and each incline slopes upward at an angle of $\theta = 50.0^\circ$. The block on the shorter track leaves the track at a height of $H_1 = 1.25$ m above the ground. Find (a) the height $H$ for the block on the longer track and (b) the total height $H_1 + H_2$ for the block on the shorter track. Verify that your answers are consistent with your answers to the Concept Questions.

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**Diagram:**

- Longer track
- Shorter track