Section 6.1 Work

1. 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 luggage carrier a distance of 50.0 m. At what angle θ is the force oriented with respect to the ground?

2. The cable of a large crane applies a force of 2.2×10^4 N to a demolition ball as it lifts the ball vertically upward a distance of 7.6 m. (a) How much work does this force do on the ball? (b) Is the work positive or negative? Explain.

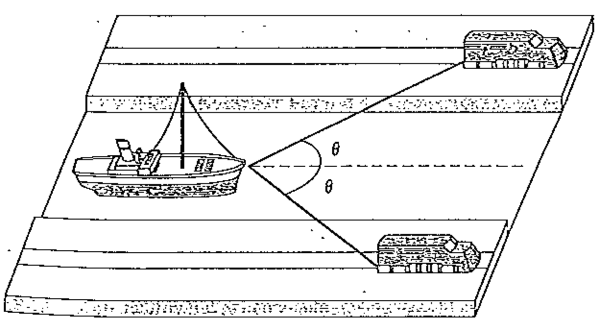
3. A tow rope, oriented parallel to the water, pulls a water-skier for a distance of 86 m. The work done by the tension in the rope is 1.9×10^4 J. Find the magnitude of the tension.

4. When spring arrives, a woman packs her winter clothes in a box and lifts it at a constant velocity to the top shelf of her closet, a distance of 1.8 m above the floor. The clothes weigh 150 N. How much work does she do in lifting the clothes?

5. 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?

6. You are moving into an apartment at the beginning of the semester. Your weight is 685 N and that of your belongings is 915 N. (a) How much work does the elevator do in lifting you and your belongings up five stories (15.2 m) at a constant velocity? (b) How much work does the elevator do on you (without belongings) on the downward trip, which is also made at a constant velocity? Be sure you include the correct sign for the work.

7. The drawing shows a boat being pulled by two locomotives through a canal of length 2.00 km. The tension in each cable is 5.00×10^3 N, and $\theta = 20.0°$. What is the net work done on the boat by the two locomotives?



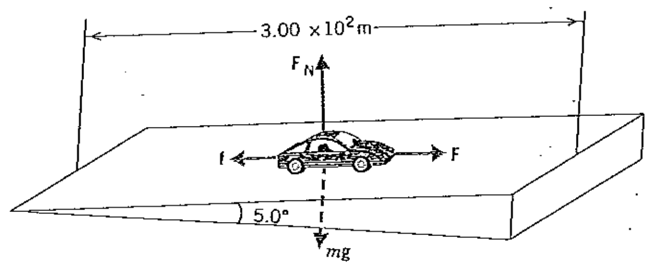
8. As preparation for this problem, review Conceptual Example 3. Suppose that both the hills in this example slope 21° above the horizontal and that the mass of the bicycle and rider is 86 kg. What is the work done by the combined weight of the bicycle and its rider when the cyclist (a) coasts 180 m down one hill and (b) pumps 75 m up the other? Pay particular attention to determining the angle θ in parts *a* and *b* of Figure 6.4.

*9. A person is refinishing an antique walnut table. In the process of sanding the tabletop, the sandpaper is rubbed back and forth 30 times, each time moving a total back-and-forth distance of 0.60 m. The sandpaper is pressed against the tabletop with a normal force of 1.5 N, and the coefficient of kinetic friction between the sandpaper and the table is 0.85. How much work is done by the kinetic frictional force during the sanding process?

*10. A 2.40×10^2-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.

*11. A 1.00×10^2-kg crate is being pulled across a horizontal floor by a force **P** that makes an angle of 30.0° above the horizontal. The coefficient of kinetic friction is 0.200. What should be the magnitude of **P**, so that the net work done by it and the kinetic frictional force is zero?

12. A 1200-kg car is being driven up a 5.0° hill, as the drawing illustrates. The frictional force is directed opposite to the motion of the car and has a magnitude of $f = 5.0 \times 10^2$ N. The force **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 **W**, and the normal force $\mathbf{F}_N$ directed perpendicular to the road surface. The length of the road up the hill is 3.0×10^2 m. What should be the magnitude of **F**, so that the net work done by all the forces acting on the car is +150 000 J? *(See Solved Problem 1 for a related problem.)*



Section 6.2 The Work–Energy Theorem and Kinetic Energy

13. A water-skier whose mass is 70.3 kg has an initial speed of 6.10 m/s. Later, the speed of the skier is 11.3 m/s. Determine the work done by the net force acting on the skier.

14. 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?

15. A 65.0-kg jogger is running at a speed of 5.30 m/s. (a) What is the kinetic energy of the jogger? (b) How much work is done by the net force that accelerates the jogger to 5.30 m/s from rest?

16. A pitcher hurls a 0.25-kg softball. The ball starts from rest and leaves the pitcher's hand at a speed of 25 m/s. How much work is done on the softball by the hurler's arm?

17. As background for this problem, review Conceptual Example 7. A satellite has an elliptical orbit, as in Figure 6.9*b*. 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 far 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 and that the mass of the satellite is 7420 kg. 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.

18. A 1.20×10^3-kg automobile coasts through a 50.0-m-long snowdrift that has been blown onto the road. The automobile has a speed of 20.0 m/s as it approaches the drift and emerges with a speed of 8.00 m/s. Find the average net force acting on the car in the drift. Relative to the displacement of the car, what is the direction of this net force?

19. A 5.0×10^4-kg space probe is traveling at a speed of 11 000 m/s through deep space. Retrorockets are fired along the line of motion to reduce the probe's speed. The retrorockets generate a force of 4.0×10^5 N over a distance of 2500 km. What is the final speed of the probe?

20. 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.

***21.** The head of a sledge hammer weighs 22 N and is moving at a speed of 7.6 m/s when it strikes a stake. The stake moves 0.025 m into the ground in response. Assume that forty percent of the hammer's kinetic energy is converted into the initial kinetic energy of the stake. Apply the work–energy theorem to the stake, and obtain the average resistive force applied to the stake by the ground.

***22.** The speed of a hockey puck decreases from 45.00 to 44.67 m/s in coasting 16 m across the ice. Find the coefficient of kinetic friction between the puck and the ice.

***23.** A power boat of mass 480 kg is cruising at a constant speed of 8.9 m/s. The propeller provides a drive force of 760 N. The driver of the boat shuts off the engine, and the boat coasts to a halt. Assume—contrary to fact—that the resistive force due to the water is constant, independent of the boat's speed. (a) How far does the boat coast? (b) How much time does it take for the boat to come to rest after the engine is turned off?

***24.** In screeching to a halt, a car leaves skid marks that are 65 m long. The coefficient of kinetic friction between the tires and the road is $\mu_k = 0.71$. How fast was the car going before the driver applied the brakes?

***25.** A wind-driven iceboat has a mass of 4.00×10^2 kg. The boat starts from rest and reaches a speed of 16.0 m/s after traveling a distance of 60.0 m. The coefficient of kinetic friction between the ice and the runners of the boat is 0.100. Determine the work done on the boat by the wind.

****26.** The model airplane in Figure 5.7 is flying at a speed of 22 m/s on a horizontal circle of radius 16 m. The mass of the plane is 0.90 kg. The person holding the guideline pulls it in until the radius of the circle becomes 14 m. The plane speeds up, and the tension in the guideline becomes four times greater. What is the net work done on the plane?

Section 6.3 Gravitational Potential Energy

27. Relative to the ground, what is the gravitational potential energy of a 55.0-kg person who is at the top of the Sears Tower, a height of 443 m above the ground?

28. A 0.15-kg ball is thrown 9.0 m straight up. (a) Find the work done by the gravitational force. Be sure to include the correct sign. (b) What is the change ($\Delta PE = PE_f - PE_0$) in the gravitational potential energy?

29. A shot-putter puts a shot (weight = 71.1 N) that leaves his hand at a distance of 1.52 m above the ground. (a) Find the work done by the gravitational force when the shot has risen to a height of 2.13 m above the ground. Include the correct sign for the work. (b) Determine the change ($\Delta PE = PE_f - PE_0$) in the gravitational potential energy of the shot.

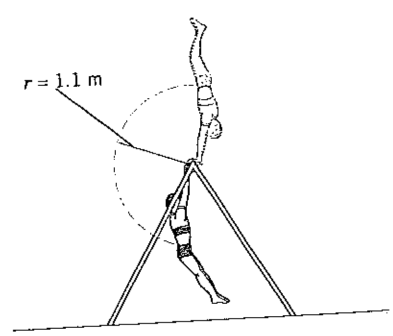
30. A pole-vaulter just clears the bar at 5.80 m and falls back to the ground. The change in the vaulter's potential energy is -3.70×10^3 J. What is his weight?

31. A 75.0-kg skier rides a 2830-m-long lift to the top of a mountain. The lift makes an angle of 14.6° with the horizontal. What is the change in the skier's gravitational potential energy?

32. The longest escalator in the world is in Hong Kong and has a length of 227 m. A 52.0-kg person rides the escalator from bottom to top, and her gravitational potential energy changes by 5.86×10^4 J. What is the angle of the escalator above the horizontal?

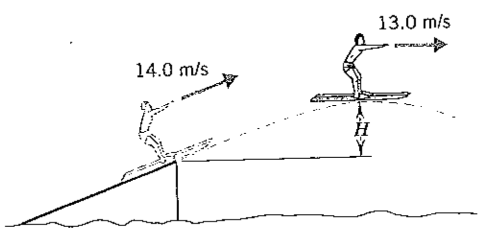
Section 6.5 The Conservation of Mechanical Energy

33. 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. Ignore friction and find the speed of his waist at the bottom of the swing.



34. A pole-vaulter approaches the takeoff point at a sp 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.

35. A water-skier lets go of the tow rope upon leaving the end of a jump ramp at a speed of 14.0 m/s. As the drawing indicates, the skier has a speed of 13.0 m/s at the highest point of the jump. Ignoring air resistance, determine the skier's height H above the *top of the ramp* at the highest point.



36. 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, 15.0, 10.0, 5.00, and 0 m.

37. A 48-kg person is sled-riding down a hill that is 4.6 m high. Starting at the top with a speed of 3.1 m/s, the sled reaches the bottom with a speed of 7.6 m/s. Determine the difference $(E_f - E_0)$ between the final and initial total mechanical energies. State whether the total mechanical energy has been conserved, and if it has not been conserved, give a likely reason why not.

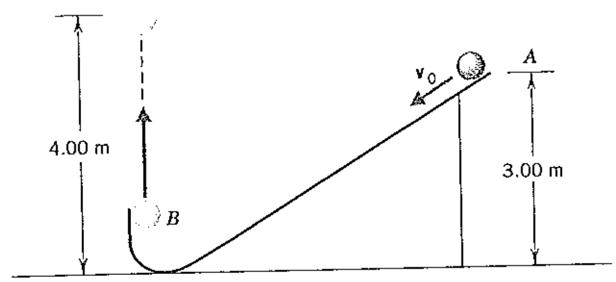
38. Before starting this problem, review Conceptual Example 11, which discusses the situations shown in Figure 6.18*a* and *b*. In this figure the two people start from rest at the top of the same cliff and enter the water via different paths. Suppose the person in part *a* of the figure lets go of the rope when he is 5.20 m above the water and enters the water at a speed of 13.0 m/s. If the person in part *b* of the drawing also lets go of the rope when he is 5.20 m above the water, how fast is he moving at that instant?

39. In Venezuela, the waterfall known as Angel Falls includes a section where the water drops through a vertical distance of 807 m. If the water crests the top of the falls with negligible speed, how fast would it be traveling at the bottom if air resistance were negligible?

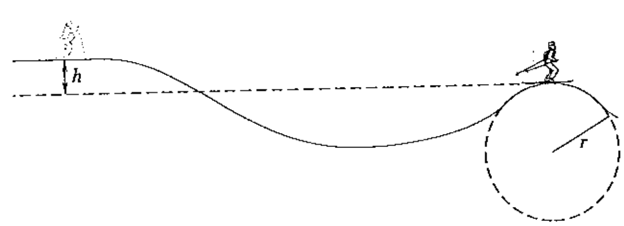
40. A cyclist approaches the bottom of a gradual hill at a speed of 11 m/s. The hill is 5.0 m high, and the cyclist estimates that she is going fast enough to coast up and over it without peddling. Ignoring air resistance and friction, find the speed at which the cyclist crests the hill.

*41. A grappling hook, attached to a 1.5-m rope, is whirled in a circle that lies in the vertical plane. The hook is whirled at a constant rate of three revolutions per second. In the absence of air resistance, to what maximum height can the hook be cast?

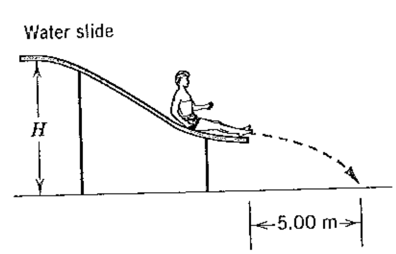
*42. A very small metal ball, starting from point A in the drawing, is projected down the curved runway. Upon leaving the runway at point B, the ball is traveling straight upward and reaches a height of 4.00 m above the floor before falling back down. Ignoring friction and air resistance, find the speed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



*43. 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?

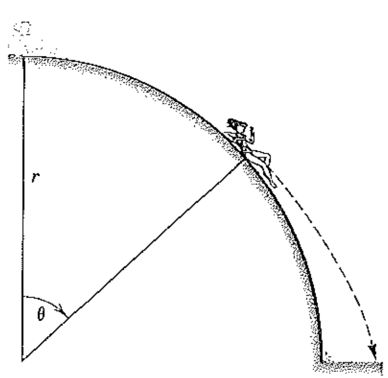


*44. A water slide is constructed so that swimmers, starting from rest at the top of the slide, leave the end of the slide traveling horizontally. As the drawing shows, one person is observed to hit the water 5.00 m from the end of the slide in a time of 0.500 s after leaving the slide. Ignoring friction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



**45. A swing is made from a rope that will tolerate a maximum tension of 8.00×10^2 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?

**46. A person starts from rest at the top of a large spherical surface, and slides into the water below (see the drawing). At what angle θ 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

47. A basketball player makes a jump shot. The 0.600-kg ball is released at a height of 2.00 m above the floor with a speed of 7.20 m/s. The ball goes through the net 3.00 m above the floor at a speed of 4.20 m/s. What is the work done on the ball by air resistance, a nonconservative force?

48. A group of students is white-water rafting down a river. The mass of the raft and occupants is 945 kg. The raft enters the rapids with a speed of 2.25 m/s and then drops through a vertical distance of 20.0 m before exiting the rapids. Resistive forces act on the raft during the descent and do -1.60×10^5 J of work. What is the exit speed of the raft?

49. 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 -2.00×10^4 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, $\Delta KE = KE_f - KE_0$, from A to B?

50. A 74.0-kg student, starting from rest, slides down a 11.8-m-high water slide. On the way down, friction (a nonconservative force) does -5.60×10^3 J of work on him. How fast is he going at the bottom of the slide?

51. A 55.0-kg skateboarder starts out with a speed of 1.80 m/s. He does +80.0 J of work on himself by pushing with his feet against the ground. In addition, friction does -265 J of work on him. In both cases, the forces doing the work are nonconservative. The final speed of the skateboarder is 6.00 m/s. (a) Calculate the change ($\Delta PE = PE_f - PE_0$) in the gravitational potential energy. (b) How much has the vertical height of the skater changed, and is the skater above or below the starting point?

52. A 5.00×10^2-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?

*53. A gymnast is bouncing on a trampoline. On the upward part of the motion, the mat of the trampoline pushes on the gymnast with a nonconservative force over a distance of 0.300 m. After leaving the mat, the 55.0-kg gymnast rises into the air for an additional 2.00 m before falling back down. What average force does the mat exert on the gymnast?

*54. A basketball of mass 0.60 kg is dropped from rest from a height of 1.22 m. It rebounds to a height of 0.69 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 1.22 m by exerting a constant downward force on it for a distance of 0.13 m. In dribbling, the player compensates for the mechanical energy lost during each bounce. If the ball now returns to a height of 1.22 m, what is the magnitude of the force?

*55. Review Conceptual Example 15 as background for this problem. In part (b) of the example twice as much work is done sliding the crate up the ramp in method 2 as is done lifting the crate straight up into the van. Assuming the coefficient of kinetic friction between the crate and the ramp to be $\mu_k = 0.60$, find the angle at which the ramp slopes upward.

*56. 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 (nonconservative) 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?

**57. A 3.00-kg model rocket is launched vertically straight up with sufficient initial speed to reach a maximum height of 1.00×10^2 m, even though air resistance (a nonconservative force) performs -8.00×10^2 J of work on the rocket. How high would the rocket have gone without air resistance?

Section 6.7 Power

58. A person is making homemade ice cream. She exerts a force of magnitude 22 N on the free end of the crank handle, and this end moves in a circular path of radius 0.28 m. The force is always applied parallel to the motion of the handle. If the handle is turned once every 1.3 s, what is the average power being expended?

59. The floors in a typical house are separated by a vertical distance of approximately 2.4 m. A student (weight = 440 N)

climbs the stairs between floors. Find the average power necessary to accomplish this, if the stairs are climbed in (a) 10.0 s and (b) 2.0 s.

60. 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.

61. A 3.00×10^2-kg piano is being lifted at a steady speed from ground level straight up to an apartment 10.0 m above the ground. The crane that is doing the lifting produces a steady power of 4.00×10^2 W. How much time does it take to lift the piano?

*62. A car accelerates uniformly from rest to 29 m/s in 12 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 1.2×10^4 N, and (b) if the weight of the car is 1.6×10^4 N.

*63. A 73-kg sprinter, starting from rest, reaches a speed of 7.0 m/s in 1.8 s, with a negligible effect due to air resistance. The sprinter then runs the remainder of the race at a steady speed of 7.0 m/s under the influence of a 35-N force due to air resistance. What is the average power needed (a) to accelerate the runner and (b) to sustain the steady speed at which most of the race is run?

*64. The motor of a ski boat generates an average power of 7.50×10^4 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 8.30×10^4 W. What is the tension in the tow rope that is pulling the skier?

**65. A motorcycle (mass of cycle plus rider = 2.50×10^2 kg) is traveling at a steady speed of 20.0 m/s over a 1.00-km stretch of road. The force of air resistance acting on the cycle and rider is 2.00×10^2 N. Find the power necessary to sustain this speed if (a) the road is level and (b) if the road is sloped upward at 37.0° with respect to the horizontal.

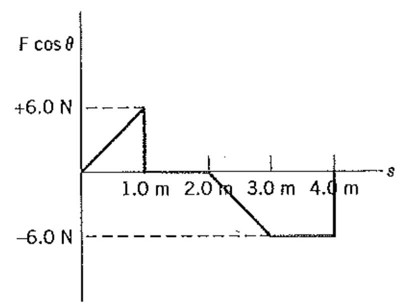
**66. A 1.20×10^3-kg car has a speed of 11.0 m/s at the bottom and a speed of 23.0 m/s at the top of a hill that makes an angle of 5.00° with respect to the horizontal. The length of the hill is 1.50 km, and the force of friction opposing the car's motion has a magnitude of 6.00×10^2 N. Determine the average power required to accelerate the car up the hill.

Section *6.9 Work Done by a Variable Force

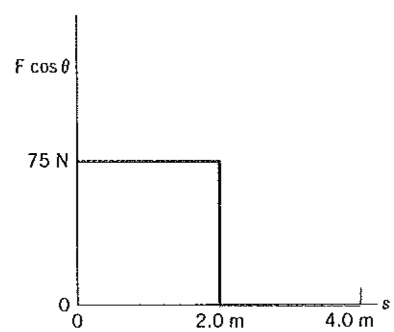
67. Using the procedure discussed in Example 17, estimate the work done in Figure 6.22*b* when the bowstring is pulled back a distance of 0.500 m. Each square in the graph has the same area as a square in Figure 6.24*b*, namely, 0.250 J.

68. Using the data in Figure 6.24*b*, estimate the work needed to draw back the bowstring from 0.278 to 0.500 m.

69. The force component along the displacement varies with the magnitude of the displacement, as shown in the graph. Find the work done by the force in the interval from (a) 0 to 1.0 m, (b) 1.0 to 2.0 m, and (c) 2.0 to 4.0 m. *(Note: In the last interval the force component is negative, so the work is negative.)*



70. The graph shows the force component along the displacement of a 75-kg ice skater as a function of the magnitude of the displacement. How much work is done on the skater from (a) 0 to 2.0 m and (b) 2.0 to 4.0 m? (c) If the initial speed of the skater is 2.5 m/s when $s = 0$, what is the speed when $s = 4.0$ m?



71. A force is applied to a 6.00-kg object that is initially at rest. The 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 force? (b) What is the speed of the object at $s = 20.0$ m?