

We mentioned in Example 6–15 that only part of the energy output of a car engine reaches the wheels. Not only is some energy wasted in getting from the engine to the wheels, in the engine itself much of the input energy (from the gasoline) does not do useful work. An important characteristic of all engines is their overall *efficiency* e , defined as the ratio of the useful power output of the engine, P_{out} , to the power input, P_{in} :

$$\text{Efficiency} \quad e = \frac{P_{\text{out}}}{P_{\text{in}}}.$$

The efficiency is always less than 1.0 because no engine can create energy, and no engine can even transform energy from one form to another without some energy going to friction, thermal energy, and other nonuseful forms of energy. For example, an automobile engine converts chemical energy released in the burning of gasoline into mechanical energy that moves the pistons and eventually the wheels. But nearly 85% of the input energy is “wasted” as thermal energy that goes into the cooling system or out the exhaust pipe, plus friction in the moving parts. Thus car engines are roughly only about 15% efficient. We will discuss efficiency in detail in Chapter 15.

Summary

Work is done on an object by a force when the object moves through a distance d . If the direction of a constant force F makes an angle θ with the direction of motion, the work done by this force is

$$W = Fd \cos \theta. \quad (6-1)$$

Energy can be defined as the ability to do work. In SI units, work and energy are measured in **joules** ($1 \text{ J} = 1 \text{ N} \cdot \text{m}$).

Kinetic energy (KE) is energy of motion. An object of mass m and speed v has translational kinetic energy

$$\text{KE} = \frac{1}{2}mv^2. \quad (6-3)$$

Potential energy (PE) is energy associated with forces that depend on the position or configuration of objects. Gravitational potential energy is

$$\text{PE}_{\text{grav}} = mgy, \quad (6-6)$$

where y is the height of the object of mass m above an arbitrary reference point. Elastic potential energy is given by

$$\text{elastic PE} = \frac{1}{2}kx^2 \quad (6-9)$$

for a stretched or compressed spring, where x is the displacement from the unstretched position and k is the spring stiffness constant. Other potential energies include chemical,

electrical, and nuclear energy. The change in potential energy when an object changes position is equal to the external work needed to take the object from one position to the other.

The **work-energy principle** states that the *net* work done on an object (by the *net* force) equals the change in kinetic energy of that object:

$$W_{\text{net}} = \Delta \text{KE} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2. \quad (6-2, 6-4)$$

The **law of conservation of energy** states that energy can be transformed from one type to another, but the total energy remains constant. It is valid even when friction is present, since the heat generated can be considered a form of energy transfer. When only *conservative forces* act, the total mechanical energy is conserved:

$$\text{KE} + \text{PE} = \text{constant}.$$

When nonconservative forces such as friction act, then

$$W_{\text{NC}} = \Delta \text{KE} + \Delta \text{PE}, \quad (6-10)$$

where W_{NC} is the work done by nonconservative forces.

Power is defined as the rate at which work is done, or the rate at which energy is transformed. The SI unit of power is the **watt** ($1 \text{ W} = 1 \text{ J/s}$).

Questions

- In what ways is the word “work” as used in everyday language the same as that defined in physics? In what ways is it different? Give examples of both.
- Can a centripetal force ever do work on an object? Explain.
- Can the normal force on an object ever do work? Explain.
- A woman swimming upstream is not moving with respect to the shore. Is she doing any work? If she stops swimming and merely floats, is work done on her?
- Is the work done by kinetic friction forces always negative? [*Hint*: Consider what happens to the dishes when you pull a tablecloth out from under them.]
- Why is it tiring to push hard against a solid wall even though you are doing no work?
- You have two springs that are identical except that spring 1 is stiffer than spring 2 ($k_1 > k_2$). On which spring is more work done (a) if they are stretched using the same force, (b) if they are stretched the same distance?

8. A hand exerts a constant horizontal force on a block that is free to slide on a frictionless surface (Fig. 6–30). The block starts from rest at point A, and by the time it has traveled a distance d to point B it is traveling with speed v_B . When the block has traveled another distance d to point C, will its speed be greater than, less than, or equal to $2v_B$? Explain your reasoning.

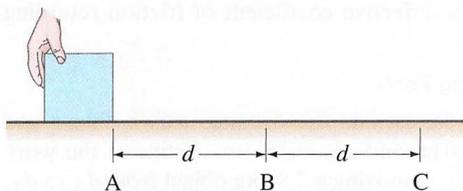


FIGURE 6–30
Question 8.

9. By approximately how much does your gravitational potential energy change when you jump as high as you can?
10. In Fig. 6–31, water balloons are tossed from the roof of a building, all with the same speed but with different launch angles. Which one has the highest speed on impact? Ignore air resistance.

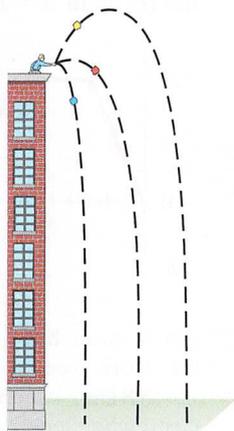


FIGURE 6–31
Question 10.

11. A pendulum is launched from a point that is a height h above its lowest point in two different ways (Fig. 6–32). During both launches, the pendulum is given an initial speed of 3.0 m/s . On the first launch, the initial velocity of the pendulum is directed upward along the trajectory, and on the second launch it is directed downward along the trajectory. Which launch will cause it to swing the largest angle from the equilibrium position? Explain.

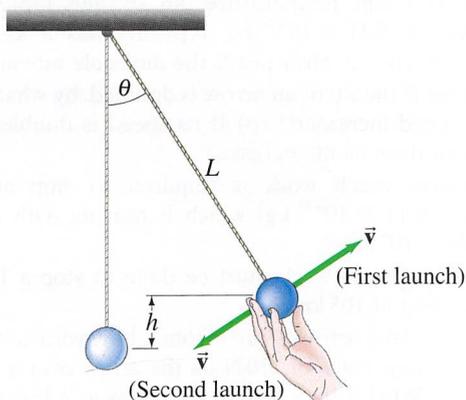


FIGURE 6–32 Question 11.

12. A coil spring of mass m rests upright on a table. If you compress the spring by pressing down with your hand and then release it, can the spring leave the table? Explain, using the law of conservation of energy.

13. A bowling ball is hung from the ceiling by a steel wire (Fig. 6–33). The instructor pulls the ball back and stands against the wall with the ball against his nose. To avoid injury the instructor is supposed to release the ball without pushing it. Why?

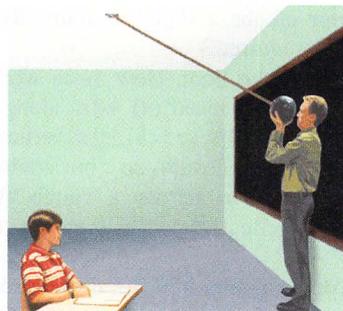


FIGURE 6–33
Question 13.

14. What happens to the gravitational potential energy when water at the top of a waterfall falls to the pool below?
15. Describe the energy transformations when a child hops around on a pogo stick.
16. Describe the energy transformations that take place when a skier starts skiing down a hill, but after a time is brought to rest by striking a snowdrift.
17. A child on a sled (total mass m) starts from rest at the top of a hill of height h and slides down. Does the velocity at the bottom depend on the angle of the hill if (a) it is icy and there is no friction, and (b) there is friction (deep snow)?
18. Seasoned hikers prefer to step over a fallen log in their path rather than stepping on top and jumping down on the other side. Explain.
19. Two identical arrows, one with twice the speed of the other, are fired into a bale of hay. Assuming the hay exerts a constant frictional force on the arrows, the faster arrow will penetrate how much farther than the slower arrow? Explain.
20. Analyze the motion of a simple swinging pendulum in terms of energy, (a) ignoring friction, and (b) taking friction into account. Explain why a grandfather clock has to be wound up.
21. When a “superball” is dropped, can it rebound to a height greater than its original height? Explain.
22. Suppose you lift a suitcase from the floor to a table. The work you do on the suitcase depends on which of the following: (a) whether you lift it straight up or along a more complicated path, (b) the time it takes, (c) the height of the table, and (d) the weight of the suitcase?
23. Repeat Question 22 for the *power* needed rather than the work.
24. Why is it easier to climb a mountain via a zigzag trail than to climb straight up?
25. Recall from Chapter 4, Example 4–14, that you can use a pulley and ropes to decrease the force needed to raise a heavy load (see Fig. 6–34). But for every meter the load is raised, how much rope must be pulled up? Account for this, using energy concepts.

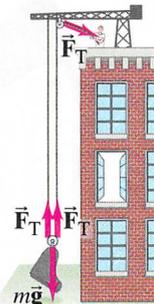


FIGURE 6–34
Question 25.

Problems

6-1 Work, Constant Force

- (I) How much work is done by the gravitational force when a 265-kg pile driver falls 2.80 m?
- (I) A 65.0-kg firefighter climbs a flight of stairs 20.0 m high. How much work is required?
- (I) A 1300-N crate rests on the floor. How much work is required to move it at constant speed (a) 4.0 m along the floor against a friction force of 230 N, and (b) 4.0 m vertically?
- (I) How much work did the movers do (horizontally) pushing a 160-kg crate 10.3 m across a rough floor without acceleration, if the effective coefficient of friction was 0.50?
- (II) A box of mass 5.0 kg is accelerated from rest across a floor at a rate of 2.0 m/s^2 for 7.0 s. Find the net work done on the box.
- (II) Eight books, each 4.3 cm thick with mass 1.7 kg, lie flat on a table. How much work is required to stack them one on top of another?
- (II) A lever such as that shown in Fig. 6-35 can be used to lift objects we might not otherwise be able to lift. Show that the ratio of output force, F_O , to input force, F_I , is related to the lengths l_I and l_O from the pivot point by $F_O/F_I = l_I/l_O$ (ignoring friction and the mass of the lever), given that the work output equals work input.

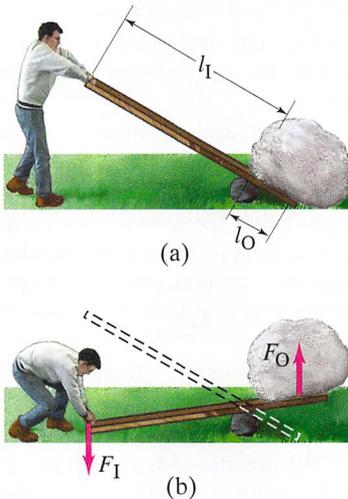


FIGURE 6-35
Problem 7.
A simple lever.

- (II) A 330-kg piano slides 3.6 m down a 28° incline and is kept from accelerating by a man who is pushing back on it *parallel to the incline* (Fig. 6-36). The effective coefficient of kinetic friction is 0.40. Calculate: (a) the force exerted by the man, (b) the work done by the man on the piano, (c) the work done by the friction force, (d) the work done by the force of gravity, and (e) the net work done on the piano.

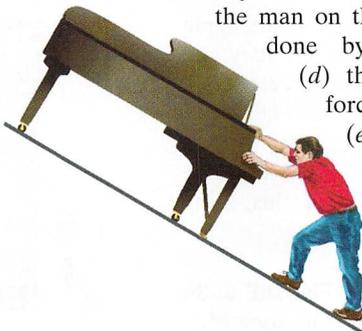


FIGURE 6-36
Problem 8.

- (II) (a) Find the force required to give a helicopter of mass M an acceleration of $0.10g$ upward. (b) Find the work done by this force as the helicopter moves a distance h upward.
- (II) What is the minimum work needed to push a 950-kg car 810 m up along a 9.0° incline? (a) Ignore friction. (b) Assume the effective coefficient of friction retarding the car is 0.25.

* 6-2 Work, Varying Force

- (II) In Fig. 6-6a, assume the distance axis is linear and that $d_A = 10.0 \text{ m}$ and $d_B = 35.0 \text{ m}$. Estimate the work done by force F in moving a 2.80-kg object from d_A to d_B .
- (II) The force on an object, acting along the x axis, varies as shown in Fig. 6-37. Determine the work done by this force to move the object (a) from $x = 0.0$ to $x = 10.0 \text{ m}$, and (b) from $x = 0.0$ to $x = 15.0 \text{ m}$.

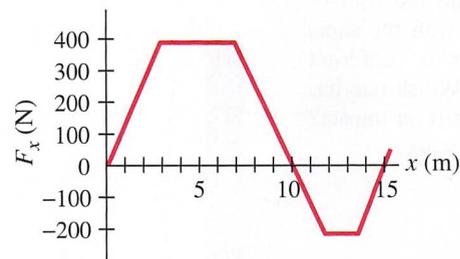


FIGURE 6-37
Problem 12.

- (II) A spring has $k = 88 \text{ N/m}$. Use a graph to determine the work needed to stretch it from $x = 3.8 \text{ cm}$ to $x = 5.8 \text{ cm}$, where x is the displacement from its unstretched length.
- (II) The net force exerted on a particle acts in the $+x$ direction. Its magnitude increases linearly from zero at $x = 0$, to 24.0 N at $x = 3.0 \text{ m}$. It remains constant at 24.0 N from $x = 3.0 \text{ m}$ to $x = 8.0 \text{ m}$, and then decreases linearly to zero at $x = 13.0 \text{ m}$. Determine the work done to move the particle from $x = 0$ to $x = 13.0 \text{ m}$ graphically by determining the area under the F_x vs. x graph.

6-3 Kinetic Energy; Work-Energy Principle

- (I) At room temperature, an oxygen molecule, with mass of $5.31 \times 10^{-26} \text{ kg}$, typically has a KE of about $6.21 \times 10^{-21} \text{ J}$. How fast is the molecule moving?
- (I) (a) If the KE of an arrow is doubled, by what factor has its speed increased? (b) If its speed is doubled, by what factor does its KE increase?
- (I) How much work is required to stop an electron ($m = 9.11 \times 10^{-31} \text{ kg}$) which is moving with a speed of $1.90 \times 10^6 \text{ m/s}$?
- (I) How much work must be done to stop a 1250-kg car traveling at 105 km/h?
- (II) An 88-g arrow is fired from a bow whose string exerts an average force of 110 N on the arrow over a distance of 78 cm. What is the speed of the arrow as it leaves the bow?
- (II) A baseball ($m = 140 \text{ g}$) traveling 32 m/s moves a fielder's glove backward 25 cm when the ball is caught. What was the average force exerted by the ball on the glove?
- (II) If the speed of a car is increased by 50%, by what factor will its minimum braking distance be increased, assuming all else is the same? Ignore the driver's reaction time.

22. (II) At an accident scene on a level road, investigators measure a car's skid mark to be 88 m long. The accident occurred on a rainy day, and the coefficient of kinetic friction was estimated to be 0.42. Use these data to determine the speed of the car when the driver slammed on (and locked) the brakes. (Why does the car's mass not matter?)
23. (II) A softball having a mass of 0.25 kg is pitched at 95 km/h. By the time it reaches the plate, it may have slowed by 10%. Neglecting gravity, estimate the average force of air resistance during a pitch, if the distance between the plate and the pitcher is about 15 m.
24. (II) How high will a 1.85-kg rock go if thrown straight up by someone who does 80.0 J of work on it? Neglect air resistance.
25. (III) A 285-kg load is lifted 22.0 m vertically with an acceleration $a = 0.160 g$ by a single cable. Determine (a) the tension in the cable, (b) the net work done on the load, (c) the work done by the cable on the load, (d) the work done by gravity on the load, and (e) the final speed of the load assuming it started from rest.

6-4 and 6-5 Potential Energy

26. (I) A spring has a spring stiffness constant, k , of 440 N/m. How much must this spring be stretched to store 25 J of potential energy?
27. (I) A 7.0-kg monkey swings from one branch to another 1.2 m higher. What is the change in potential energy?
28. (I) By how much does the gravitational potential energy of a 64-kg pole vaulter change if his center of mass rises about 4.0 m during the jump?
29. (II) A 1200-kg car rolling on a horizontal surface has speed $v = 65$ km/h when it strikes a horizontal coiled spring and is brought to rest in a distance of 2.2 m. What is the spring stiffness constant of the spring?
30. (II) A 1.60-m tall person lifts a 2.10-kg book from the ground so it is 2.20 m above the ground. What is the potential energy of the book relative to (a) the ground, and (b) the top of the person's head? (c) How is the work done by the person related to the answers in parts (a) and (b)?
31. (II) A 55-kg hiker starts at an elevation of 1600 m and climbs to the top of a 3300-m peak. (a) What is the hiker's change in potential energy? (b) What is the minimum work required of the hiker? (c) Can the actual work done be more than this? Explain why.
32. (II) A spring with $k = 53$ N/m hangs vertically next to a ruler. The end of the spring is next to the 15-cm mark on the ruler. If a 2.5-kg mass is now attached to the end of the spring, where will the end of the spring line up with the ruler marks?

6-6 and 6-7 Conservation of Mechanical Energy

33. (I) Jane, looking for Tarzan, is running at top speed (5.3 m/s) and grabs a vine hanging vertically from a tall tree in the jungle. How high can she swing upward? Does the length of the vine affect your answer?
34. (I) A novice skier, starting from rest, slides down a frictionless 35.0° incline whose vertical height is 185 m. How fast is she going when she reaches the bottom?
35. (I) A sled is initially given a shove up a frictionless 28.0° incline. It reaches a maximum vertical height 1.35 m higher than where it started. What was its initial speed?

36. (II) In the high jump, Fran's kinetic energy is transformed into gravitational potential energy without the aid of a pole. With what minimum speed must Fran leave the ground in order to lift her center of mass 2.10 m and cross the bar with a speed of 0.70 m/s?
37. (II) A 65-kg trampoline artist jumps vertically upward from the top of a platform with a speed of 5.0 m/s. (a) How fast is he going as he lands on the trampoline, 3.0 m below (Fig. 6-38)? (b) If the trampoline behaves like a spring with spring stiffness constant 6.2×10^4 N/m, how far does he depress it?

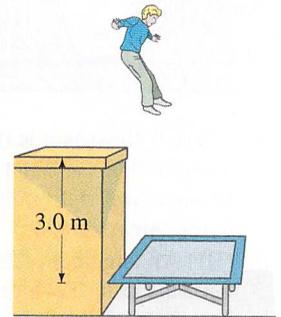


FIGURE 6-38
Problem 37.

38. (II) A projectile is fired at an upward angle of 45.0° from the top of a 265-m cliff with a speed of 185 m/s. What will be its speed when it strikes the ground below? (Use conservation of energy.)
39. (II) A vertical spring (ignore its mass), whose spring stiffness constant is 950 N/m, is attached to a table and is compressed down 0.150 m. (a) What upward speed can it give to a 0.30-kg ball when released? (b) How high above its original position (spring compressed) will the ball fly?
40. (II) A block of mass m slides without friction along the looped track shown in Fig. 6-39. If the block is to remain on the track, even at the top of the circle (whose radius is r), from what minimum height h must it be released?

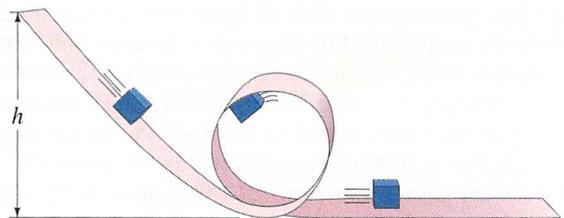


FIGURE 6-39 Problems 40 and 75.

41. (II) A block of mass m is attached to the end of a spring (spring stiffness constant k), Fig. 6-40. The block is given an initial displacement x_0 , after which it oscillates back and forth. Write a formula for the total mechanical energy (ignore friction and the mass of the spring) in terms of x_0 , position x , and speed v .

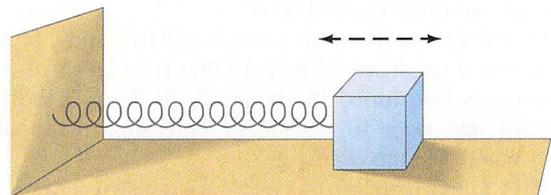


FIGURE 6-40 Problems 41, 55, and 56.

42. (II) A 62-kg bungee jumper jumps from a bridge. She is tied to a bungee cord whose unstretched length is 12 m, and falls a total of 31 m. (a) Calculate the spring stiffness constant k of the bungee cord, assuming Hooke's law applies. (b) Calculate the maximum acceleration she experiences.

43. (II) The roller-coaster car shown in Fig. 6–41 is dragged up to point 1 where it is released from rest. Assuming no friction, calculate the speed at points 2, 3, and 4.

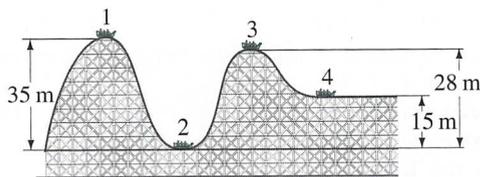


FIGURE 6–41
Problems 43
and 53.

44. (II) A 0.40-kg ball is thrown with a speed of 12 m/s at an angle of 33° . (a) What is its speed at its highest point, and (b) how high does it go? (Use conservation of energy, and ignore air resistance.)
45. (III) An engineer is designing a spring to be placed at the bottom of an elevator shaft. If the elevator cable should break when the elevator is at a height h above the top of the spring, calculate the value that the spring stiffness constant k should have so that passengers undergo an acceleration of no more than $5.0g$ when brought to rest. Let M be the total mass of the elevator and passengers.
46. (III) A cyclist intends to cycle up a 7.8° hill whose vertical height is 150 m. Assuming the mass of bicycle plus cyclist is 75 kg, (a) calculate how much work must be done against gravity. (b) If each complete revolution of the pedals moves the bike 5.1 m along its path, calculate the average force that must be exerted on the pedals tangent to their circular path. Neglect work done by friction and other losses. The pedals turn in a circle of diameter 36 cm.

6–8 and 6–9 Law of Conservation of Energy

47. (I) Two railroad cars, each of mass 7650 kg and traveling 95 km/h in opposite directions, collide head-on and come to rest. How much thermal energy is produced in this collision?
48. (II) A 21.7-kg child descends a slide 3.5 m high and reaches the bottom with a speed of 2.2 m/s. How much thermal energy due to friction was generated in this process?
49. (II) A ski starts from rest and slides down a 22° incline 75 m long. (a) If the coefficient of friction is 0.090, what is the ski's speed at the base of the incline? (b) If the snow is level at the foot of the incline and has the same coefficient of friction, how far will the ski travel along the level? Use energy methods.
50. (II) A 145-g baseball is dropped from a tree 13.0 m above the ground. (a) With what speed would it hit the ground if air resistance could be ignored? (b) If it actually hits the ground with a speed of 8.00 m/s, what is the average force of air resistance exerted on it?
51. (II) You drop a ball from a height of 2.0 m, and it bounces back to a height of 1.5 m. (a) What fraction of its initial energy is lost during the bounce? (b) What is the ball's speed just as it leaves the ground after the bounce? (c) Where did the energy go?
52. (II) A 110-kg crate, starting from rest, is pulled across a floor with a constant horizontal force of 350 N. For the first 15 m the floor is frictionless, and for the next 15 m the coefficient of friction is 0.30. What is the final speed of the crate?
53. (II) Suppose the roller coaster in Fig. 6–41 passes point 1 with a speed of 1.70 m/s. If the average force of friction is equal to one-fifth of its weight, with what speed will it reach point 2? The distance traveled is 45.0 m.
54. (II) A skier traveling 12.0 m/s reaches the foot of a steady upward 18.0° incline and glides 12.2 m up along this slope before coming to rest. What was the average coefficient of friction?
55. (III) A 0.620-kg wood block is firmly attached to a very light horizontal spring ($k = 180 \text{ N/m}$) as shown in Fig. 6–40. It is noted that the block-spring system, when compressed 5.0 cm and released, stretches out 2.3 cm beyond the equilibrium position before stopping and turning back. What is the coefficient of kinetic friction between the block and the table?
56. (III) A 280-g wood block is firmly attached to a very light horizontal spring, Fig. 6–40. The block can slide along a table where the coefficient of friction is 0.30. A force of 22 N compresses the spring 18 cm. If the spring is released from this position, how far beyond its equilibrium position will it stretch at its first maximum extension?
57. (III) Early test flights for the space shuttle used a "glider" (mass of 980 kg including pilot) that was launched horizontally at 500 km/h from a height of 3500 m. The glider eventually landed at a speed of 200 km/h. (a) What would its landing speed have been in the absence of air resistance? (b) What was the average force of air resistance exerted on it if it came in at a constant glide of 10° to the Earth?

6–10 Power

58. (I) How long will it take a 1750-W motor to lift a 315-kg piano to a sixth-story window 16.0 m above?
59. (I) If a car generates 18 hp when traveling at a steady 88 km/h, what must be the average force exerted on the car due to friction and air resistance?
60. (I) A 1400-kg sports car accelerates from rest to 95 km/h in 7.4 s. What is the average power delivered by the engine?
61. (I) (a) Show that one British horsepower (550 ft·lb/s) is equal to 746 W. (b) What is the horsepower rating of a 75-W lightbulb?
62. (II) Electric energy units are often expressed in the form of "kilowatt-hours." (a) Show that one kilowatt-hour (kWh) is equal to $3.6 \times 10^6 \text{ J}$. (b) If a typical family of four uses electric energy at an average rate of 520 W, how many kWh would their electric bill be for one month, and (c) how many joules would this be? (d) At a cost of \$0.12 per kWh, what would their monthly bill be in dollars? Does the monthly bill depend on the *rate* at which they use the electric energy?
63. (II) A driver notices that her 1150-kg car slows down from 85 km/h to 65 km/h in about 6.0 s on the level when it is in neutral. Approximately what power (watts and hp) is needed to keep the car traveling at a constant 75 km/h?
64. (II) How much work can a 3.0-hp motor do in 1.0 h?
65. (II) A shot-putter accelerates a 7.3-kg shot from rest to 14 m/s. If this motion takes 1.5 s, what average power was developed?
66. (II) A pump is to lift 18.0 kg of water per minute through a height of 3.60 m. What output rating (watts) should the pump motor have?
67. (II) During a workout, the football players at State U. ran up the stadium stairs in 66 s. The stairs are 140 m long and inclined at an angle of 32° . If a typical player has a mass of 95 kg, estimate the average power output on the way up. Ignore friction and air resistance.

68. (II) How fast must a cyclist climb a 6.0° hill to maintain a power output of 0.25 hp? Neglect work done by friction, and assume the mass of cyclist plus bicycle is 68 kg.
69. (II) A 1200-kg car has a maximum power output of 120 hp. How steep a hill can it climb at a constant speed of 75 km/h if the frictional forces add up to 650 N?
70. (II) What minimum horsepower must a motor have to be able to drag a 310-kg box along a level floor at a speed of 1.20 m/s if the coefficient of friction is 0.45?
71. (III) A bicyclist coasts down a 7.0° hill at a steady speed of 5.0 m/s. Assuming a total mass of 75 kg (bicycle plus rider), what must be the cyclist's power output to climb the same hill at the same speed?

General Problems

72. Designers of today's cars have built "5 mi/h (8 km/h) bumpers" that are designed to compress and rebound elastically without any physical damage at speeds below 8 km/h. If the material of the bumpers permanently deforms after a compression of 1.5 cm, but remains like an elastic spring up to that point, what must the effective spring stiffness constant of the bumper be, assuming the car has a mass of 1300 kg and is tested by ramming into a solid wall?
73. In a certain library the first shelf is 10.0 cm off the ground, and the remaining four shelves are each spaced 30.0 cm above the previous one. If the average book has a mass of 1.5 kg with a height of 21 cm, and an average shelf holds 25 books, how much work is required to fill all the shelves, assuming the books are all laying flat on the floor to start?
74. A film of Jesse Owens's famous long jump (Fig. 6-42) in the 1936 Olympics shows that his center of mass rose 1.1 m from launch point to the top of the arc. What minimum speed did he need at launch if he was traveling at 6.5 m/s at the top of the arc?



FIGURE 6-42
Problem 74.

75. The block of mass m sliding without friction along the looped track shown in Fig. 6-39 is to remain on the track at all times, even at the very top of the loop of radius r . (a) In terms of the given quantities, determine the minimum release height h (as in Problem 40). Next, if the actual release height is $2h$, calculate (b) the normal force exerted by the track at the bottom of the loop, (c) the normal force exerted by the track at the top of the loop, and (d) the normal force exerted by the track after the block exits the loop onto the flat section.
76. An airplane pilot fell 370 m after jumping from an aircraft without his parachute opening. He landed in a snowbank, creating a crater 1.1 m deep, but survived with only minor injuries. Assuming the pilot's mass was 78 kg and his terminal velocity was 35 m/s, estimate (a) the work done by the snow in bringing him to rest; (b) the average force exerted on him by the snow to stop him; and (c) the work done on him by air resistance as he fell.

77. A ball is attached to a horizontal cord of length L whose other end is fixed (Fig. 6-43). (a) If the ball is released, what will be its speed at the lowest point of its path? (b) A peg is located a distance h directly below the point of attachment of the cord. If $h = 0.80L$, what will be the speed of the ball when it reaches the top of its circular path about the peg?

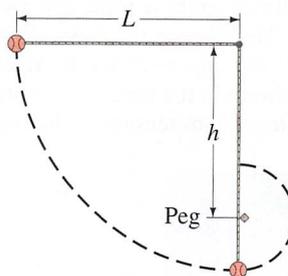


FIGURE 6-43
Problem 77.

78. A 65-kg hiker climbs to the top of a 3700-m-high mountain. The climb is made in 5.0 h starting at an elevation of 2300 m. Calculate (a) the work done by the hiker against gravity, (b) the average power output in watts and in horsepower, and (c) assuming the body is 15% efficient, what rate of energy input was required.
79. An elevator cable breaks when a 920-kg elevator is 28 m above a huge spring ($k = 2.2 \times 10^5$ N/m) at the bottom of the shaft. Calculate (a) the work done by gravity on the elevator before it hits the spring, (b) the speed of the elevator just before striking the spring, and (c) the amount the spring compresses (note that work is done by both the spring and gravity in this part).
80. Squaw Valley ski area in California claims that its lifts can move 47,000 people per hour. If the average lift carries people about 200 m (vertically) higher, estimate the power needed.
81. Water flows ($v \approx 0$) over a dam at the rate of 650 kg/s and falls vertically 81 m before striking the turbine blades. Calculate (a) the speed of the water just before striking the turbine blades (neglect air resistance), and (b) the rate at which mechanical energy is transferred to the turbine blades, assuming 58% efficiency.
82. Show that on a roller coaster with a circular vertical loop (Fig. 6-44), the difference in your apparent weight at the top of the circular loop and the bottom of the circular loop is $6g$'s—that is, six times your weight. Ignore friction. Show also that as long as your speed is above the minimum needed, this answer doesn't depend on the size of the loop or how fast you go through it.

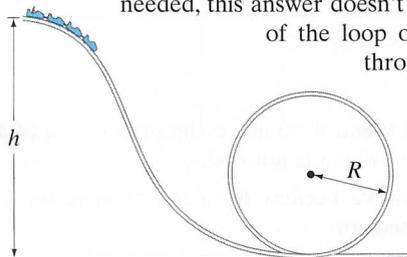


FIGURE 6-44
Problem 82.

83. (a) If the human body could convert a candy bar directly into work, how high could an 82-kg man climb a ladder if he were fueled by one bar ($= 1100 \text{ kJ}$)? (b) If the man then jumped off the ladder, what will be his speed when he reaches the bottom?
84. A projectile is fired at an upward angle of 45.0° from the top of a 165-m cliff with a speed of 175 m/s. What will be its speed when it strikes the ground below? (Use conservation of energy and neglect air resistance.)
85. If you stand on a bathroom scale, the spring inside the scale compresses 0.60 mm, and it tells you your weight is 710 N. Now if you jump on the scale from a height of 1.0 m, what does the scale read at its peak?
86. A 65-kg student runs at 5.0 m/s, grabs a rope, and swings out over a lake (Fig. 6–45). He releases the rope when his velocity is zero. (a) What is the angle θ when he releases the rope? (b) What is the tension in the rope just before he releases it? (c) What is the maximum tension in the rope?
90. A 6.0-kg block is pushed 8.0 m up a rough 37° inclined plane by a horizontal force of 75 N. If the initial speed of the block is 2.2 m/s up the plane and a constant kinetic friction force of 25 N opposes the motion, calculate (a) the initial kinetic energy of the block; (b) the work done by the 75-N force; (c) the work done by the friction force; (d) the work done by gravity; (e) the work done by the normal force; (f) the final kinetic energy of the block.
91. If a 1500-kg car can accelerate from 35 km/h to 55 km/h in 3.2 s, how long will it take to accelerate from 55 km/h to 75 km/h? Assume the power stays the same, and neglect frictional losses.
92. In a common test for cardiac function (the “stress test”), the patient walks on an inclined treadmill (Fig. 6–46). Estimate the power required from a 75-kg patient when the treadmill is sloping at an angle of 15° and the velocity is 3.3 km/h. (How does this power compare to the power rating of a lightbulb?)

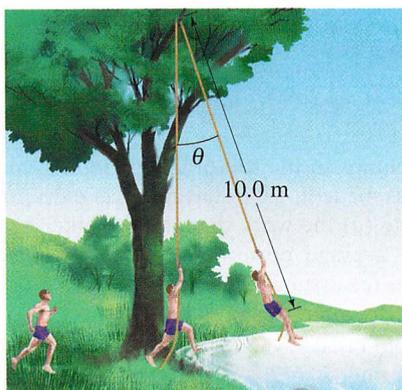


FIGURE 6–45
Problem 86.

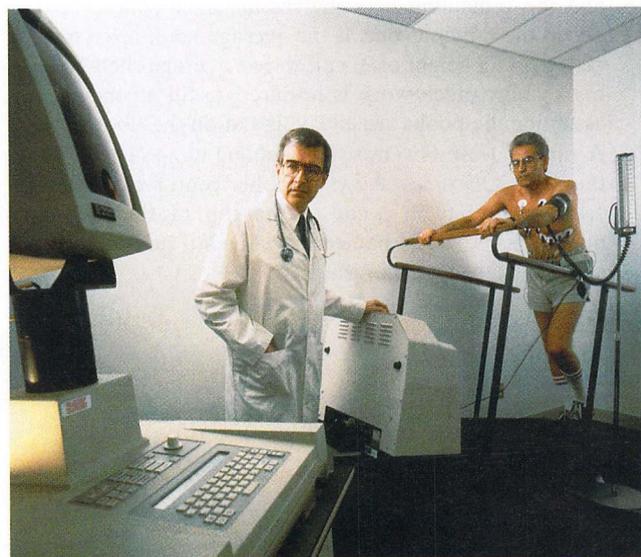


FIGURE 6–46 Problem 92.

87. In the rope climb, a 72-kg athlete climbs a vertical distance of 5.0 m in 9.0 s. What minimum power output was used to accomplish this feat?
88. Some electric-power companies use water to store energy. Water is pumped by reversible turbine pumps from a low to a high reservoir. To store the energy produced in 1.0 hour by a 120-MW ($120 \times 10^6 \text{ W}$) electric-power plant, how many cubic meters of water will have to be pumped from the lower to the upper reservoir? Assume the upper reservoir is 520 m above the lower and we can neglect the small change in depths within each. Water has a mass of 1000 kg for every 1.0 m^3 .
89. A spring with spring stiffness constant k is cut in half. What is the spring stiffness constant for each of the two resulting springs?
93. (a) If a volcano spews a 500-kg rock vertically upward a distance of 500 m, what was its velocity when it left the volcano? (b) If the volcano spews the equivalent of 1000 rocks of this size every minute, what is its power output?
94. Water falls onto a water wheel from a height of 2.0 m at a rate of 95 kg/s. (a) If this water wheel is set up to provide electricity output, what is its maximum power output? (b) What is the speed of the water as it hits the wheel?

Answers to Exercises

- A: (c).
 B: No, because the speed v would be the square root of a negative number, which is not real.
 C: It is nonconservative, because for a conservative force $W = 0$ in a round trip.

- D: $W_{\text{net}} = \Delta KE$, where $W_{\text{net}} = mg(y_1 - y_2)$ and $\Delta KE = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2$. Then $v_2^2 = 2g(y_1 - y_2)$.
 E: Equal speeds.