WORK & ENERGY - REVIEW QUESTIONS

REVIEWING CONCEPTS

1. In what units is work measured?
2. A satellite orbits Earth in a circular orbit. Does Earth's gravity do any work on the satellite?
3. An object slides at constant speed on a frictionless surface. What forces act on the object? What work is done?
4. Define work and power.
5. What is a watt equivalent to in terms of kg, m, and s?
6. Is it possible to get more work out of a machine than you put in?
7. How are the pedals of a bicycle a simple machine?

APPLYING CONCEPTS

1. Which requires more work, carrying a 420-N knapsack up a 200 m high hill or carrying a 210-N knapsack up a 400 m high hill? Why?
2. You slowly lift a box of books from the floor and put it on a table. Earth's gravity exerts a force, magnitude *mg*, downward, and you exert a force, magnitude *mg*, upward. The two forces have equal magnitude and opposite direction. It appears no work is done, but you know you did work. Explain what work is done.
3. Guy has to get a piano onto a 2.0 m high platform. He can use a 3.0 m long, frictionless ramp or a 4.0 m long, frictionless ramp. Which ramp will Guy use if he wants to do the least amount of work?
4. Grace has an after-school job carrying cartons of new copy paper up a flight of stairs, and then carrying used paper back down the stairs. The mass of the paper does not change. Grace's physics teacher suggests that Grace does no work all day, so she should not be paid. In what sense is the physics teacher correct? What arrangement of payments might Grace make to ensure compensation?

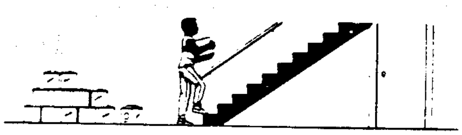

FIGURE 10–15.

5. Grace now carries the copy paper boxes down a level, 15.0 m long hall. Is Grace working now? Explain.
6. Two people of the same mass climb the same flight of stairs. The first person climbs the stairs in 25 s; the second person takes 35 s.
   a. Which person does more work? Explain your answer.
   b. Which person produces more power? Explain your answer.
7. How can one increase the ideal mechanical advantage of a machine?
8. A claw hammer is used to pull a nail from a piece of wood. How can you place your hand on the handle and locate the nail in the claw to make the effort force as small as possible?
9. How could you increase the mechanical advantage of a wedge without changing the ideal mechanical advantage?

PROBLEMS

.1 Work and Energy

1. Lee pushes horizontally with a 80-N force on a 20-kg mass 10 m across a floor. Calculate the amount of work Lee did.
2. The third floor of a house is 8.0 m above street level. How much work is needed to move a 150-kg refrigerator to the third floor?
3. Stan does 176 J of work lifting himself 0.300 m. What is Stan's mass?
4. A crane lifts a 2.25×10^3-N bucket containing 1.15 m^3 of soil (density = 2.00×10^3 kg/m^3) to a height of 7.50 m. Calculate the work the crane performs.
5. The graph in Figure 10–16 shows the force needed to stretch a spring. Find the work needed to stretch it from 0.12 m to 0.28 m.

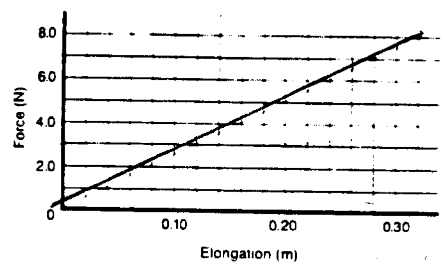

FIGURE 10–16. Use with Problems 5 and 6.

▶ **6.** In Figure 10–16, the magnitude of the force necessary to stretch a spring is plotted against the distance the spring is stretched.

a. Calculate the slope of the graph and show that

$$F = kd,$$

where $k = 25$ N/m.

b. Find the amount of work done in stretching the spring from 0.00 m to 0.20 m by calculating the area under the curve from 0.00 m to 0.20 m in Figure 10–16.

c. Show that the answer to part **b** can be calculated using the formula

$$W = \frac{1}{2}kd^2,$$

where W is the work, $k = 25$ N/m (the slope of the graph), and d is the distance the spring is stretched (0.20 m).

▶ **7.** John pushes a crate across the floor of a factory with a horizontal force. The roughness of the floor changes, and John must exert a force of 20 N for 5 m, then 35 N for 12 m, then 10 N for 8 m.

a. Draw a graph of force as a function of distance.

b. Find the work John does pushing the crate.

8. Sally applies a horizontal force of 462 N with a rope to drag a wooden crate across a floor with a constant speed. The rope tied to the crate is pulled at an angle of 56.0°.

a. How much force is exerted by the rope on the crate?

b. What work is done by Sally if the crate is moved 24.5 m?

c. What work is done by the floor through force of friction between the floor and the crate?

9. Mike pulls a sled across level snow with a force of 225 N along a rope that is 35.0° above the horizontal. If the sled moved a distance of 65.3 m, how much work did Mike do?

10. An 845-N sled is pulled a distance of 185 m. The task requires 1.20×10^4 J of work and is done by pulling on a rope with a force of 125 N. At what angle is the rope held?

11. Karen has a mass of 57.0 kg and she rides the up escalator at Woodley Park Station of the Washington D.C. Metro. Karen rode a distance of 65 m, the longest escalator in the free world. How much work did the escalator do on Karen if it has an inclination of 30°?

12. Chris carried a carton of milk, weight 10.0 N, along a level hall to the kitchen, a distance of 3.50 m. How much work did Chris do?

13. A student librarian picks up a 22-N book from the floor to a height of 1.25 m. He carries the book 8.0 m to the stacks and places the book on a shelf that is 0.35 m high. How much work does he do on the book?

▶ **14.** Pete slides a crate up a ramp at an angle of 30.0° by exerting a 225-N force parallel to the ramp. The crate moves at constant speed. The coefficient of friction is 0.28. How much work has been done when the crate is raised a vertical distance of 1.15 m?

▶ **15.** A 4200-N piano is to be slid up a 3.5-m frictionless plank that makes an angle of 30.0° with the horizontal. Calculate the work done in sliding the piano up the plank.

▶ **16.** A 60-kg crate is slid up an inclined ramp 2.0 m long onto a platform 1.0 m above floor level. A 400-N force, parallel to the ramp, is needed to slide the crate up the ramp at a constant speed.

a. How much work is done in sliding the crate up the ramp?

b. How much work would be done if the crate were simply lifted straight up from the floor to the platform?

17. Brutus, a champion weightlifter, raises 240 kg a distance of 2.35 m.

a. How much work is done by Brutus lifting the weights?

b. How much work is done holding the weights above his head?

c. How much work is done lowering them back to the ground?

d. Does Brutus do work if the weights are let go and fall back to the ground?

e. If Brutus completes the lift in 2.5 s, how much power is developed?

18. A force of 300 N is used to push a 145-kg mass 30.0 m horizontally in 3.00 s.

a. Calculate the work done on the mass.

b. Calculate the power.

19. Robin pushes a wheelbarrow by exerting a 145-N force horizontally. Robin moves it 60.0 m at a constant speed for 25.0 s.

a. What power does Robin develop?

b. If Robin moves the wheelbarrow twice as fast, how much power is developed?

▶ **20.** Use the graph in Figure 10–17.

a. Calculate the work done to pull the object 7.0 m.

b. Calculate the power if the work were done in 2.0 s.

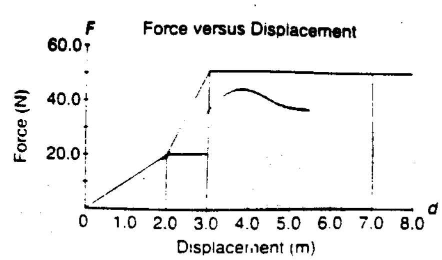

FIGURE 10–17. Use with Problem 20.

▶ **21.** In 35.0 s, a pump delivers 0.550 dm^3 of oil into barrels on a platform 25.0 m above the pump intake pipe. The density of the oil is 0.820 g/cm^3.

a. Calculate the work done by the pump.

b. Calculate the power produced by the pump.

22. A horizontal force of 805 N is needed to drag a crate across a horizontal floor with a constant speed. Pete drags the crate using a rope held at an angle of 32°.

a. What force does Pete exert on the rope?

b. How much work does Pete do on the crate when moving it 22 m?

c. If Pete completes the job in 8.0 s, what power is developed?

23. Wayne pulls a 305-N sled along a snowy path using a rope that makes a 45.0° angle with the ground. Wayne pulls with a force of 42.3 N. The sled moves 16 m in 3.0 s. What is Wayne's power?

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APPLYING CONCEPTS

1. A compact car and a semi-truck are both traveling at the same velocity. Which has more kinetic energy?
2. Sally and Lisa have identical compact cars. Sally drives on the freeway with a greater speed than Lisa. Which car has more kinetic energy?
3. Sally and Lisa have identical compact cars. Sally is northbound on the freeway and Lisa is southbound with the same speed. Which car has more kinetic energy?
4. Is it possible to exert a force and yet not cause a change in kinetic energy?
5. Two bodies of unequal mass each have the same kinetic energy and are moving in the same direction. If the same retarding force is applied to each, how will the stopping distances of the bodies compare?
6. If you drop a tennis ball onto a concrete floor, it will bounce back farther than if you drop it on a rug. Where does the lost energy go when it strikes the rug?
7. Most earth satellites follow an elliptical path rather than a circular path around Earth. The PE increases when the satellite moves farther from Earth. According to energy conservation, does a satellite have its greatest speed when it is closest to or farthest from Earth?
8. In mountainous areas, road designers build escape ramps to help trucks with failed brakes stop. These escape ramps are usually roads made of loose gravel that go uphill. Describe changes in forms of energy when a fast-moving truck uses one of these escape ramps.
9. If two identical bowling balls are raised to the same height, one on Earth and the other on the moon, which has the larger potential energy relative to the surface of the bodies?
10. Roads seldom go straight up a mountain but wind around and go up gradually. Explain.
11. What will be the kinetic energy of an arrow shot from a bow having a potential energy of 50 J?
12. Two pendulums are swinging side by side. At the bottom of the swing, the speed of one pendulum bob is twice the speed of the other. Compare the heights to which the two bobs rise at the ends of their swings.
13. In a baseball game, two pop-ups are hit in succession. The second rises twice as high as the first. Compare the speeds of the two balls when they leave the bat.
14. Two identical balls are thrown from the top of a cliff, each with the same speed. One is thrown straight down, the other straight up. How do the speeds and the kinetic energies of the balls compare as they strike the ground?
15. A ball is dropped from the top of a tall building and reaches terminal velocity as it falls. Will the potential energy of the ball upon release equal the kinetic energy it has when striking the ground? Explain.
16. According to Einstein's equation $E_o = mc^2$, does the rock-Earth system have more or less mass when the rock is lifted high above Earth than when the same rock is on Earth's surface?

PROBLEMS

11.1 Energy in Its Many Forms

Unless otherwise directed, assume air resistance is negligible.

1. A 1600-kg car travels at a speed of 12.5 m/s. What is its kinetic energy?
2. A racing car has a mass of 1500 kg. What is its kinetic energy if it has a speed of 108 km/h?
3. Sally has a mass of 45 kg and is moving with a speed of 10.0 m/s.
   - **a.** Find Sally's kinetic energy.
   - **b.** Sally's speed changes to 5.0 m/s. Now what is her kinetic energy?
   - **c.** What is the ratio of the kinetic energies in **a** and **b**? Explain the ratio.
4. Shawn and his bike have a total mass of 45.0 kg. Shawn rides his bike 1.80 km in 10.0 min at a constant velocity. What is Shawn's kinetic energy?

▶ 5. It is not uncommon during the service of a professional tennis player for the racquet to exert an average force of 150.0 N on the ball. If the ball has a mass of 0.060 kg and is in contact with the strings of the racquet for 0.030 s, what is the kinetic energy of the ball as it leaves the racquet? Assume the ball starts from rest.

▶ 6. Pam has a mass of 40.0 kg and she is at rest on smooth, level, frictionless ice. Pam straps on a rocket pack. The rocket supplies a constant force for 22.0 m and Pam acquires a speed of 62.0 m/s.
   - **a.** What is the magnitude of the force?
   - **b.** What is Pam's final kinetic energy?

7. Sally and Lisa have a mass of 45 kg and they are moving together with a speed of 10.0 m/s.
   - **a.** What is their combined kinetic energy?
   - **b.** What is the ratio of their combined mass to Sally's mass?
   - **c.** What is the ratio of their combined kinetic energy to Sally's kinetic energy. Explain.
8. In the 1950s, an experimental train that had a mass of 2.50×10^4 kg was powered across level track by a jet engine that produced a thrust of 5.00×10^5 N for a distance of 500 m.
   - **a.** Find the work done on the train.
   - **b.** Find the change in kinetic energy.
   - **c.** Find the final kinetic energy of the train if it started from rest.
   - **d.** Find the final speed of the train if there was no friction.
9. A 14 700-N car is traveling at 25 m/s. The brakes are suddenly applied and the car slides to a stop. The average braking force between the tires and the road is 7100 N. How far will the car slide once the brakes are applied?
10. A 15.0-kg cart is moving with a velocity of 7.50 m/s down a level hallway. A constant force of −10.0 N acts on the cart and its velocity becomes 3.20 m/s.
    - **a.** What is the change in kinetic energy of the cart?
    - **b.** How much work was done on the cart?
    - **c.** How far did the cart move while the force acted?

▶ 11. A 2.00×10^3-kg car has a speed of 12.0 m/s. The car then hits a tree. The tree doesn't move and the car comes to rest.
   - **a.** Find the change in kinetic energy of the car.

b. Find the amount of work done in pushing in the front of the car.
c. Find the size of the force that pushed the front of the car in 50.0 cm.

12. How much potential energy does Tim, mass 60.0 kg, gain when he climbs a gymnasium rope a distance of 3.5 m?
13. A 6.4-kg bowling ball is lifted 2.1 m into a storage rack. Calculate the increase in the ball's potential energy.
14. Mary weighs 500 N and she walks down a flight of stairs to a level 5.50 m below her starting point. What is the change in Mary's potential energy?
15. A weightlifter raises a 180-kg barbell to a height of 1.95 m. What is the increase in the barbell's potential energy?
16. A 10.0-kg test rocket is fired vertically from Cape Canaveral. Its fuel gives it a kinetic energy of 1960 J by the time the rocket motor burns all of the fuel. What additional height will the rocket rise?
17. Ace raised a 12.0-N physics book from a table 75 cm above the floor to a shelf, 2.15 m above the floor. What was the change in potential energy?
18. A hallway display of energy is constructed. People are told that to do 1.00 J of work, they should pull on a rope that lifts a block 1.00 m. What should be the mass of the block?
▶ 19. A constant net force of 410 N, up, is applied to a stone that weighs 32 N. The upward force is applied through a distance of 2.0 m, and the stone is then released. To what height, from the point of release, will the stone rise?

11.2 Conservation of Energy

20. A 98-N sack of grain is hoisted to a storage room 50 m above the ground floor of a grain elevator.
    a. How much work was required?
    b. What is the potential energy of the sack of grain at this height?
    c. The rope being used to lift the sack of grain breaks just as the sack reaches the storage room. What kinetic energy does the sack have just before it strikes the ground floor?
21. A 20-kg rock is on the edge of a 100-m cliff.
    a. What potential energy does the rock possess relative to the base of the cliff?
    b. The rock falls from the cliff. What is its kinetic energy just before it strikes the ground?
    c. What speed does the rock have as it strikes the ground?
22. An archer puts a 0.30-kg arrow to the bowstring. An average force of 201 N is exerted to draw the string back 1.3 m.
    a. Assuming no frictional loss, with what speed does the arrow leave the bow?
    b. If the arrow is shot straight up, how high does it rise?
23. A 2.0-kg rock initially at rest loses 400 J of potential energy while falling to the ground.
    a. Calculate the kinetic energy that the rock gains while falling.
    b. What is the rock's speed just before it strikes the ground?
24. Betty weighs 420 N and she is sitting on a playground swing seat that hangs 0.40 m above the ground. Tom pulls the swing back and releases it when the seat is 1.00 m above the ground.
    a. How fast is Betty moving when the swing passes through its lowest position?
    b. If Betty moves through the lowest point at 2.0 m/s, how much work was done on the swing by friction?
25. Bill throws a 10.0-g ball straight down from a height of 2.0 m. The ball strikes the floor at a speed of 7.5 m/s. What was the initial speed of the ball?
26. Magen's mass is 28 kg. She climbs the 4.8-m ladder of a slide, and reaches a velocity of 3.2 m/s at the bottom of the slide. How much work was done by friction on Magen?
27. A physics book, mass unknown, is dropped 4.50 m. What speed does the book have just before it hits the ground?
28. A 30.0-kg gun is standing on a frictionless surface. The gun fires a 50.0-g bullet with a muzzle velocity of 310 m/s.
    a. Calculate the momenta of the bullet and the gun after the gun was fired.
    b. Calculate the kinetic energy of both the bullet and the gun just after firing.
29. A railroad car with a mass of 5.0×10^5 kg collides with a stationary railroad car of equal mass. After the collision, the two cars lock together and move off at 4.0 m/s.
    a. Before the collision, the first railroad car was moving at 8.0 m/s. What was its momentum?
    b. What is the total momentum of the two cars after the collision?
    c. Find the kinetic energies of the two cars before and after the collision.
    d. Account for the loss of kinetic energy.
30. From what height would a compact car have to be dropped to have the same kinetic energy that it has when being driven at 100 km/h?
▶ 31. A golf ball, mass 0.046 kg, rests on a tee. It is struck by a golf club with an effective mass of 0.220 kg and a speed of 44 m/s. Assuming the collision is elastic, find the speed of the ball when it leaves the tee.
32. A steel ball has a mass of 4.0 kg and rolls along a smooth, level surface at 62 m/s.
    a. Find its kinetic energy.
    b. At first, the ball was at rest on the surface. A constant force acted on it through a distance of 22 m to give it the speed of 62 m/s. What was the magnitude of the force?
33. Show that $W = KE_f - KE_i$ if an object is not originally at rest. Use the equation relating initial and final velocity with constant acceleration and distance.