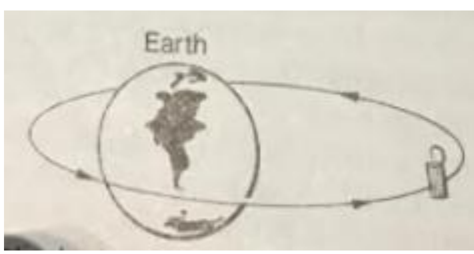
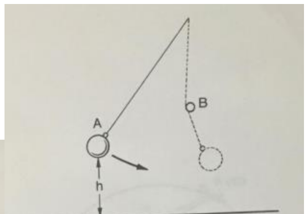
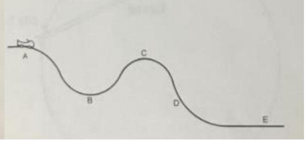
Discussion

1. Give an example of a situation in which:
   (a) a force is acting but there is no motion and therefore no work done.
   (b) a force is acting, but the displacement is perpendicular to the force and therefore no work is done.
   (c) there is motion, but since no force is acting to cause the motion, no work is done.
2. Suppose you have a contest in your class to see who can develop the most power in climbing a flight of stairs. Describe the physical characteristics of the person who would have the best chance of winning the contest.
3. When friction causes a moving object to slow down, it is doing negative work on the object. Explain why the work done by friction is viewed in this way.
4. A pendulum is drawn aside so that the centre of the bob is at position A as shown. A horizontal rod is positioned at B so that when the pendulum is released the string catches at B forcing the bob to swing in an arc which has a smaller radius. How will the height to which the bob swings on the right side of B compare to h? Explain your answer.
5. An engineer uses a single car to test the roller coaster track, shown in the diagram in the margin . In answering the following questions, assume that friction can be ignored and the speed at A is 0. In each case, give a reason for your answer.
   (a) Where is the gravitational potential energy the greatest?
   (b) Where is the kinetic energy the greatest?
   (c) Where is the speed the greatest?
   (d) Give a written description of what happens to the speed of the car as it rolls from A to B and so on to E.
6. Most satellites circle the Earth in elliptical orbits so that they are not always the same distance from the Earth. (An ellipse is an oval shape.) A satellite in a stable elliptical orbit has a total







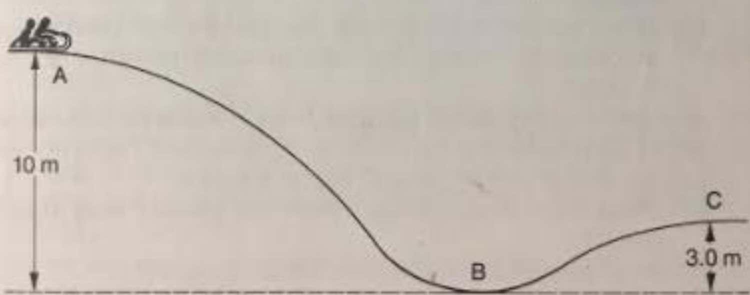
mechanical energy which remains constant. At what point in the orbit would the speed of the satellite be greatest? At what point would it be least? Explain your reasoning.

7. Explain why it is impossible to have a motor that is 100% efficient.
8. Utility companies must take many factors into consideration when designing power plants that convert the gravitational potential energy of water into electricity. To generate the maximum amount of electricity at Niagara Falls, for example, all of the water should be diverted through turbines instead of letting some of it go over the falls. List several reasons why this is not done.
9. Suppose you are a planner for a Canadian electrical utility company. You wish to build a hydro-electric power plant. Describe briefly the main factors you would have to consider in selecting a site for such a development.
10. The use of more flexible poles in pole vaulting has resulted in athletes being able to jump higher. By consulting the appropriate sources, estimate to what extent improved technology has affected the heights jumped by pole vaulters. Document your estimate with quotations from the references you have consulted.
11. One suggestion that has been made for efficient travel between two cities some distance apart is to link them with a straight tunnel bored through the Earth itself. Passengers would then travel through a portion of the Earth's core rather than travel along the circumference. Using energy relationships, explain why this approach should greatly decrease the fuel required to get from one city to the other.
12. When the speed of an object doubles, by what factor does its kinetic energy change?
13. Two balls with the same mass, one of wood and the other a ping-pong ball partly filled with sand, are rolled along a desk. The wooden ball rolls along nicely, but the ping-pong ball stops in a few centimetres. What happened to its kinetic energy? Was the kinetic energy changed to heat energy by the force of friction between the ball and the desk? Explain your answer.
14. Derive an expression for the speed v acquired by a mass m allowed to fall freely from rest through a height h at a location where the gravitational field strength is g. Assume that air resistance can be ignored.
15. A 60 kg man and a 40 kg girl sit on identical swings. They are then each given a push so that in both cases the swings move through the same angle from the vertical. How will their speeds compare as they swing through the bottom of the cycle? Explain your answer.

Use $g = 9.80$ N/kg.
Assume applied forces act horizontally unless stated otherwise.

16. Calculate the work done by a 0.47 N force pushing a pencil 0.26 m.
17. Calculate the work done by a 0.47 N force pushing a 0.026 kg pencil 0.26 m against a force of friction of 0.23 N.
18. Calculate the work done by a 2.4 N force pushing a 400 g sandwich across a table 0.75 m wide.
19. How far will a mother push a 20.0 kg baby carriage, using a force of 62 N, while she does 2920 J of work?
20. How much work must be done to lift a 20 kg sack of potatoes vertically 6.5 m?
21. If a small motor does 520 J of work to move a toy car 260 m, what force does it exert?
22. A girl pushes her little brother on his sled with a force of 300 N for 750 m. How much work does she do if the force of friction acting on the sled is (a) 200 N, (b) 300 N?
23. A 75.0 kg man pushes on a 500 000 t wall for 250 s but it does not move. How much work does he do on the wall?
24. A boy on a bicycle drags a wagon full of newspapers at 0.80 m/s for 30 min using a force of 40 N. How much work has the boy done?
25. A power mower does 9.00×10^{5} J of work in 0.500 h. What power does it develop?
26. How long would it take a 500 W electric motor to do 1.50×10^{5} J of work?
27. How much work can a 22 kW car engine do in 60 s
    (a) if it is 100% efficient? (b) if it is 30% efficient?
28. A force of 5.0 N moves a 6.0 kg object along a rough floor at a constant speed of 2.5 m/s.
    (a) How much work is done in 25 s by the force?
    (b) What power is being developed?
    (c) What force of friction is acting on the object?
29. The motor for an elevator can produce 2200 W of power. The elevator has a mass of 1100 kg complete with contents. At what constant speed will the elevator rise?
30. A 1500 kg car accelerates uniformly from rest to a speed of 100 km/h in 10.0 s.
    (a) What is the car's acceleration?
    (b) What is the car's displacement?
    (c) How much work is done on the car during this 10 s interval?
    (d) What average power is required to produce this motion?
31. A chair lift takes skiers to the top of a mountain that is 300 m high. The average mass of a skier complete with equipment is 80 kg. The chair lift can deliver three skiers to the top of the mountain every 30 s.
    (a) Determine the power required to carry out this task. (Assume the skiers join the lift at full speed.)
    (b) If friction increases the power required by 25%, what power must the motors running the lift be able to deliver?
32. What is the gravitational potential energy of a 61.2 kg person standing on the roof of a 10-storey building relative to each of the following levels? (Each storey is 2.50 m high.)
    (a) the tenth floor
    (b) the sixth floor
    (c) the first floor
33. A 10 000 kg airplane lands, descending a vertical distance of 10 km while travelling 100 km measured along the ground. What is the plane's loss of potential energy?
34. A coconut falls out of a tree 12.0 m above the ground and hits a bystander 1.80 m tall on top of the head. It bounces back up 0.50 m before falling to the ground. If the mass of the coconut is 2.00 kg, calculate the potential energy of the coconut relative to the ground at each of the following times.
    (a) while it is still in the tree
    (b) when it hits the bystander on the head
    (c) when it bounces up to its maximum height
    (d) when it lands on the ground
    (e) when it rolls into a groundhog hole and falls 2.50 m to the bottom of the hole
35. Engineers have long dreamed of harnessing the tides in the Bay of Fundy. Although in places the difference between high tide and low tide can be as much as 17 m, the average change in height for the entire bay is about 4.0 m. The bay has the same area as a rectangle that is about 300 km long and 65 km wide. Water has a density of 1000 kg/m^3.
    (a) Calculate the volume of water and the mass of water that flows out of the bay between high tide and low tide.
    (b) Determine the loss in gravitational potential energy when the water flows out of the bay. Assume that the decrease in gravitational potential energy is equal to that of the mass calculated in (a) being lowered a distance of 2.0 m.
    (c) If half the gravitational potential energy lost when the tide flows out could be converted to electricity over a 6 h period, determine the amount of electrical power that would be generated.
36. Calculate the kinetic energy of a 45 g golf ball travelling at:
    (a) 20 m/s (b) 60 m/s

37. How fast must a 1000 kg car be moving to have a kinetic energy of:
   (a) 2.0×10^3 J? (b) 2.0×10^5 J? (c) 1.0 kW · h?
38. How high would you have to lift a 1000 kg car to give it a potential energy of:
   (a) 2.0×10^3 J? (b) 2.00×10^5 J? (c) 1.00 kW · h?
39. A 50 kg cyclist on a 10 kg bicycle speeds up from 5.0 m/s to 10.0 m/s.
   (a) What was the total kinetic energy before accelerating?
   (b) What was the total kinetic energy after accelerating?
   (c) How much work was done to increase the kinetic energy of the cyclist?
   (d) Is it more work to speed up from 0 to 5.0 m/s than from 5.0 to 10.0 m/s?
40. At the moment when a shotputter releases a 5.00 kg shot, the shot is 2.00 m above the ground and travelling at 15.0 m/s. It reaches a maximum height of 8.00 m above the ground and then falls to the ground. Assume that air resistance is negligible.
   (a) What was the potential energy of the shot as it left the hand, relative to the ground?
   (b) What was the kinetic energy of the shot as it left the hand?
   (c) What was the total mechanical energy of the shot as it left the hand?
   (d) What was the total mechanical energy of the shot as it reached its maximum height?
   (e) What was the potential energy of the shot at its maximum height?
   (f) What was the kinetic energy of the shot at its maximum height?
   (g) What was the kinetic energy of the shot just as it struck the ground?
41.



Some children go tobogganing on an icy hill. They start from rest at the top of the hill as shown in the diagram. The toboggan and children have a combined mass of 90 kg. If friction is small enough to be ignored, determine:
   (a) the total mechanical energy of the toboggan at A.
   (b) the speed of the toboggan at B.
   (c) the speed of the toboggan at C.
42. A boy fires a 60 g pebble with his slingshot. The pebble leaves the slingshot at 35 m/s.
   (a) How high above the slingshot will the pebble rise if it is fired straight up?
   (b) If the pebble is fired so that it goes in an arc and has a speed of 10 m/s at its maximum height, what will the maximum height be?
   (c) At what speed would an 80 g pebble have to be fired to reach the same height as the pebble in (a)? Assume that the 80 g pebble is also fired straight up.
43. A high jumper of mass 55 kg wishes to jump over a bar 1.8 m above the ground. Her centre of mass is located 1.0 m above the ground. (We can imagine that all of her mass is located at this point for calculation purposes.)
   (a) If she wishes to clear the bar while travelling at a speed of 0.4 m/s, how fast must she be travelling the instant her feet leave the ground?
   (b) She lands on her back on a foam pad that is 40 cm thick. At what speed will she be travelling when she first makes contact with the pad?
   (c) Shortly after she lands she will be at rest. What has happened to the mechanical energy she had moments earlier?
44. A child of mass *m* slides down a slide 5.0 m high. The child's speed at the bottom of the slide is 3.0 m/s.
   (a) What percent of the mechanical energy that the child had at the top of the slide has not been converted to kinetic energy?
   (b) What feature of the slide determines the percentage of mechanical energy that is converted to other forms of energy?
45. A rodeo rider is riding a bucking bronco when he is thrown off. At the instant he leaves the horse he is located 1.6 m above the ground and is moving straight up at 4.0 m/s.
   (a) What maximum height above the ground does the rider reach?
   (b) At what speed will the rider hit the ground?
46. It is estimated that one kilogram of body fat will provide 3.8×10^7 J of energy. A 60 kg mountain climber decides to climb a mountain 4000 m high.

(a) How much work does the climber do against gravity in climbing to the top of the mountain?

(b) If the body's efficiency in converting energy stored as fat to mechanical energy is 25%, determine the amount of fat the climber will use up in providing the energy required to work against gravity.

47. Canadians use energy at an average rate of about 2 kW. (This figure includes energy used outside the home.) On a bright sunny day, the solar energy striking a horizontal surface provides power at a rate of 200 W/m^2. If a solar collector can capture 20% of the energy striking it, how large a collector in square metres is required to supply the energy requirements of a family of five during the daylight hours of a sunny day?

Work, Power, and Energy

16. 0.12 J
17. 0.12 J
18. 1.8 J
19. 47 m
20. 1.3×10^3 J
21. 2.00 N
22. (a) 2.25×10^5 J
    (b) 2.25×10^5 J
23. 0
24. 5.8×10^4 J
25. 500 W
26. 300 s
27. (a) 1.3×10^6 J
    (b) 3.9×10^5 J
28. (a) 3.1×10^2 J
    (b) 12 W
    (c) 5.0 N
29. 0.204 m/s
30. (a) 2.78 m/s^2
    (b) 139 m
    (c) 5.80×10^5 J
    (d) 5.80×10^4 W
31. (a) 2.35×10^4 W
    (b) 2.94×10^4 W
32. (a) 1.50×10^3 J
    (b) 7.5×10^3 J
    (c) 1.50×10^4 J
33. -9.80×10^8 J
34. (a) 235 J
    (b) 35.3 J
    (c) 45.1 J
    (d) 0
    (e) −49.0 J
35. (a) 7.8×10^{10} m^3
    7.8×10^{13} kg
    (b) 1.53×10^{15} J
    (c) 3.5×10^2 W
36. (a) 9.0 J
    (b) 81 J
37. (a) 2.0 m/s
    (b) 20 m/s
    (c) 85 m/s
38. (a) 0.20 m
    (b) 20.4 m
    (c) 367 m
39. (a) 7.5×10^2 J
    (b) 3.0×10^3 J
    (c) 2.3×10^3 J
40. (a) 98.0 J
    (b) 563 J
    (c) 661 J
    (d) 661 J
    (e) 269 J
    (f) 392 J
    (g) 661 J
41. (a) 8.8×10^3 J
    (b) 14 m/s
    (c) 12 m/s
42. (a) 63 m
    (b) 58 m
    (c) 35 m/s
43. (a) 4.0 m/s
    (b) 5.3 m/s
44. (a) 91%
45. (a) 2.4 m
    (b) 6.9 m/s
46. (a) 2.4×10^6 J
    (b) 0.25 kg
47. 250 m^2