EXERCISES

Conceptual Questions

1. Holding your physics book steady in your outstretched arm seems like a lot of work. Explain why it is not considered work in physics.

2. A golf ball and a football have the same kinetic energy. Which ball has the greater momentum? Explain.

3. What does a negative area under a force-versus-displacement graph represent?

4. How is an object different as a result of having work done on it?

5. Explain how energy is transferred when a diver jumps on a spring diving board, then dives into the pool.

6. Use unit analysis to show that the units work out in the equation $E_k = \frac{1}{2}mv^2$.

7. Explain what is meant by $-\Delta E_e = \Delta E_k$.

8. Can an object have different amounts of gravitational potential energy if it remains at the same elevation?

9. Explain the difference between an elastic collision and an inelastic collision. Give an example of each.

10. Can an object have momentum without having any kinetic energy? Is the reverse possible? Explain.

Problems

5.2 Work

11. How much work is required to
    a) tow a boat with a force of 4000 N for 5.0 m?
    b) kick a football with a force of 570 N over a distance of 8.0 cm?
    c) accelerate an electron from rest to 1.6×10^8 m/s ($m_e = 9.1 \times 10^{-31}$ kg)?

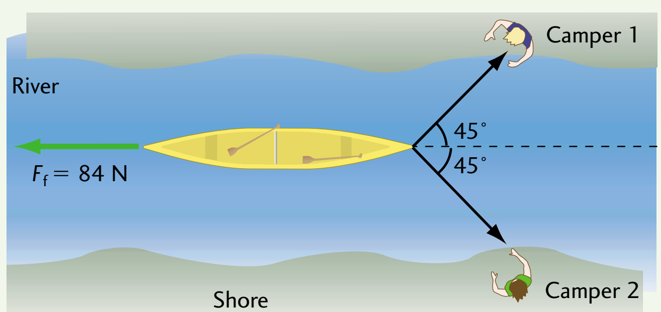
12. How much work is done pushing a wheelbarrow full of cement 5.3 m [forward] if a force of 500 N is applied
    a) horizontally?
    b) 20° above the horizontal?
    c) 20° from the vertical?

13. Jake the deliveryman pushes a box up a ramp, exerting a force of 350 N. He walks on the ramp, pushing the box for 25.0 m. If the box has a mass of 50.0 kg, what is the height of the ramp and the angle it makes with the horizontal? Ignore friction.

14. A snowplough diverts snow from the road to the ditch (an average movement of 5.0 m of snow at an average speed of 10.0 m/s). The density of the fresh snow is 254 kg/m^3 and the average depth is 35.0 cm. Assume that a lane of traffic is 4.0 m wide. If the snowplough clears a road that is 8.0 km long, how much work did it do on the snow?

15. Two campers pull a canoe, as illustrated in Figure 5.42. If the force of friction on the canoe is 84 N, how much work must each camper do to keep the canoe in the middle of the river for a displacement of 50 m?

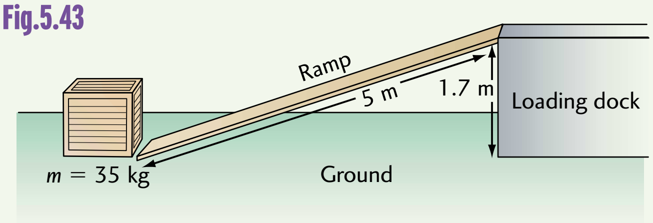
Fig.5.42



16. Calculate the amount of work done by a hammer thrower if an 8.0-kg hammer attached to a 1.3-m-long rope is rotated horizontally above the thrower's head. The hammer thrower holds the rope with a tension of 300 N.

17. Explain what is meant by –350 J. Give an example.

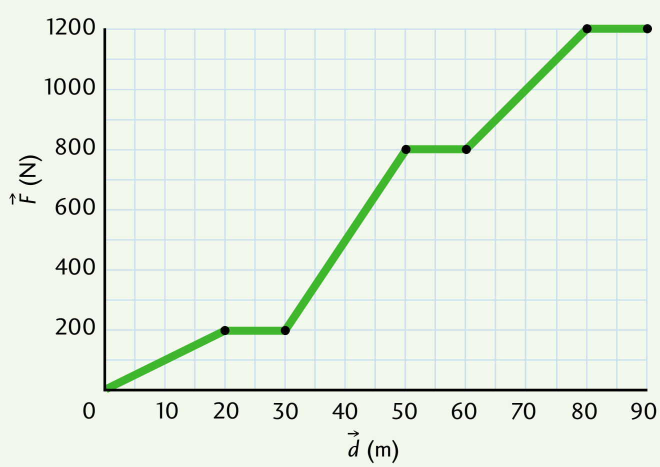
Fig.5.43



18. A 35-kg box needs to be lifted to the top of a loading dock, which is also accessible by ramp. The ramp is 5.0 m long and has a vertical height of 1.7 m.
    a) What minimum force is required to lift the box straight up onto the loading dock?
    b) What minimum amount of work is required to lift the crate straight up onto the loading dock?
    c) What force is required to push the crate up the ramp such that the amount of work is the same as in b)? Assume no friction.

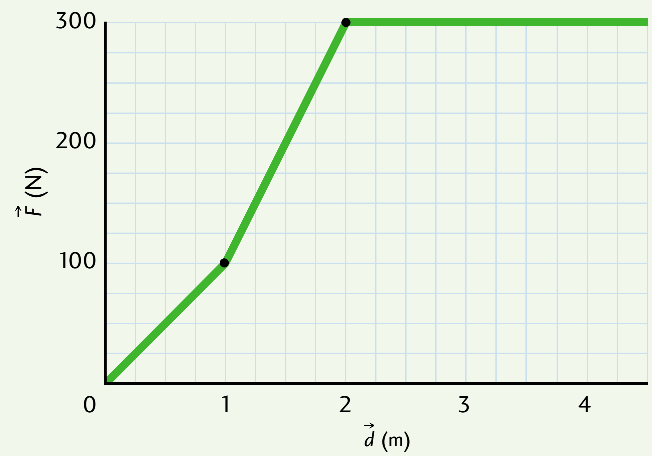
19. Calculate the work done on a 50-kg wakeboard enthusiast who experiences the horizontal force indicated on the graph in Figure 5.44.

Fig.5.44



20. A lawn tractor pulls a 120-kg wagon along a frictionless surface with a horizontal force given by the graph in Figure 5.45.
    a) How much work is done in moving the wagon 4.0 m?
    b) How is the wagon different as a result of the force applied?
    c) Calculate the speed of the wagon at a distance of 4.0 m from the start.

Fig.5.45



5.3 Kinetic Energy

21. Calculate the kinetic energy of
    a) a 45-kg sprinter running at 10 m/s.
    b) a 2.0-g fly buzzing around your head every second. (Assume your head has a radius of 10 cm.)
    c) a 15 000-kg army tank charging forward at 100 km/h.

22. A fish swimming horizontally and nibbling the end of your barbless hook has a kinetic energy of 450 J. You notice that 5.0 m of line is released every 2.0 s. Calculate the mass of the fish.

23. Calculate the velocity of a 1.2-kg falling star (meteorite) with 5.5×10^8 J of energy.

24. A 15-kg mass is released from rest at a height of 200 m. If air resistance is negligible, determine the kinetic energy of the mass after it has fallen 199 m.

25. Using unit analysis, show that $p = \sqrt{2mE_k}$ is correct.

26. What percentage of the speed of light is the speed of an electron with 5.0 keV of kinetic energy? ($m_e = 9.1 \times 10^{-31}$ kg, $1 \text{ eV} = 1.6 \times 10^{-19}$ J)

27. A 15-g bullet strikes a metal plate on an armoured car at a speed of 350 m/s. The bullet penetrates the armour 3.3 mm before coming to a stop.
   a) Calculate the average net force acting on the bullet while it is in the metal.
   b) Calculate the average force exerted on the metal by the bullet.

28. Figure 5.46 represents the horizontal force on a 1.5-kg trolley as it moves 3.0 m along a straight and level path. If the trolley starts from rest, calculate its kinetic energy and velocity after each metre of its motion.

Fig.5.46

29. Calculate the momentum of a 5.0-kg briefcase with a kinetic energy of 3.0×10^2 J.

30. A thin 200-g arrow moving horizontally at 125 m/s strikes a 1.0-kg apple, initially at rest. The arrow pierces the apple in a negligible time, emerging from it with a velocity of 100 m/s, and causing the apple to slide forward 3.0 m before coming to a standstill.
   a) What is the apple's velocity just after the arrow exits?
   b) What is the maximum kinetic energy of the apple?
   c) Is this collision elastic? Explain.
   d) What is the average frictional force stopping the apple?

5.4 Gravitational Potential Energy

31. Calculate the gravitational potential energy of
   a) a 2.0-kg physics textbook sitting on your desk 1.3 m above the floor.
   b) a 50-g egg dropped from the top of a 3.0-m-high chicken coup.
   c) a 200-kg air glider flying 469 m above the ground.
   d) a 5000-kg car parked on the road.

32. A forklift requires a force of 4410 N to lift a roll of steel 3.5 m.
   a) What is the mass of the steel?
   b) How much work is required to lift the steel?

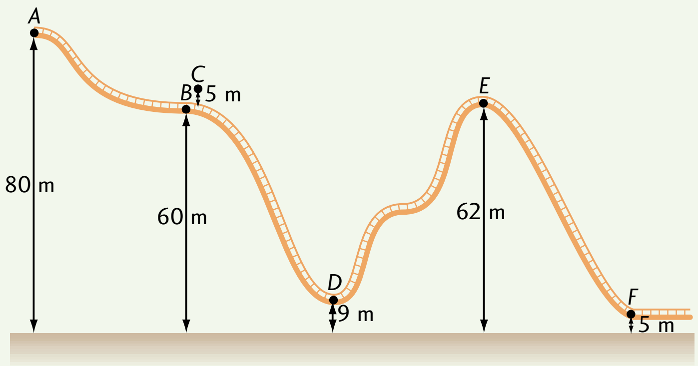
33. A rodeo rider is 1.8 m off the ground when on a bull. The bull suddenly throws the rider straight up at a velocity of 4.7 m/s. With what velocity will the rider land on the ground?

34. A 3.0-kg ball is dropped from a height of 0.80 m onto a vertical spring with a force constant of 1200 N/m. What is the maximum compression of the spring?

35. A ping-pong ball with a mass of 5.0 g is dropped from a height of 2.0 m. The ball loses 20% of its kinetic energy with each bounce. How many bounces would it take for the ping-pong ball to lose just over half of its original height?

36. A 1000-kg roller coaster car starts from rest at point A on a frictionless track, shown in Figure 5.47.

Fig.5.47



a) At which point on the track is the car's gravitational potential energy the greatest? the least?
b) What is the car's maximum speed?
c) What is the speed of the roller coaster car at point E?
d) What constant braking force would have to be applied to bring the coaster car at point F to a stop in 5.0 m?

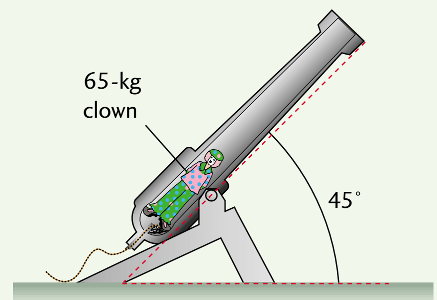
37. A slingshot with a force constant of 890 N/m is used to propel a primitive 10 005-kg starship in deep space by releasing a 5.0-kg block of ice into space. How much should the slingshot be pulled in order to increase the ship's speed by 5.0 m/s?

38. A toy rifle shoots a spring of mass 0.008 kg and with a spring constant of 350 N/m. You wish to hit a target horizontally a distance of 15 m away by pointing the rifle 45° above the horizontal. How far should you extend the spring in order to reach the target?

39. Newton was lying down in an apple orchard when an apple struck his stomach. It then bounced straight back up, having lost 15% of its kinetic energy in the collision. How high did it rise on the first bounce if it dropped from a branch 2.0 m high?

40. A human cannon (Figure 5.48) has a spring constant of 35 000 N/m. The spring can be extended up to 4.5 m. How far (horizontally) would a 65-kg clown be fired if the cannon is pointed upward at 45° to the horizontal?

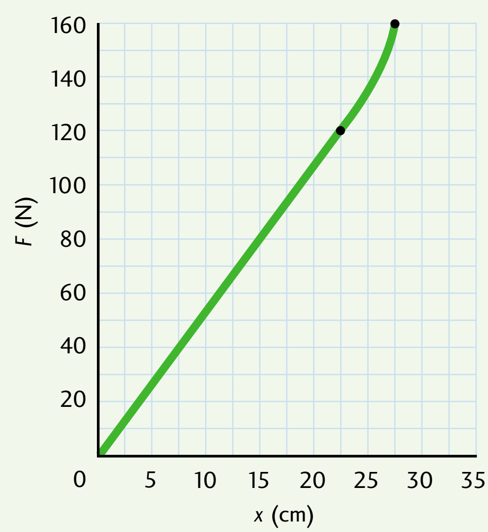
Fig.5.48



5.5 Elastic Potential Energy and Hooke's Law

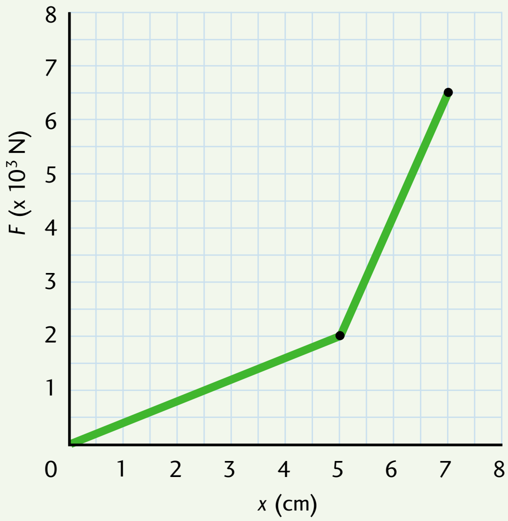
41. Determine the spring constant for the elastic band represented in Figure 5.49.

Fig.5.49



42. A spring that obeys Hooke's law has the following *F*-versus-*x* graph (Figure 5.50). How much work is required to stretch the spring
a) 5.0 cm?
b) 7.0 cm?

Fig.5.50



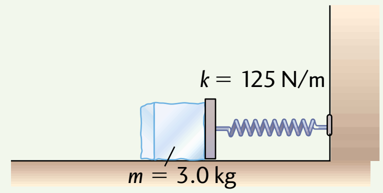
43. A toy gun has its spring compressed 3.0 cm by a 50-g projectile. The spring constant was measured at 400 N/m. Calculate the velocity of the projectile if it is launched horizontally.

44. A large bungee cord is used to propel a jet of mass 2.5×10^3 kg horizontally off an aircraft carrier. The rubber band is pulled back 35 m and released such that the jet takes off at 95 m/s. What is the spring constant of the rubber band?

45. A small truck is equipped with a rear bumper that has a spring constant of 8×10^5 N/m. The bumper can be compressed up to 15 cm without causing damage to the truck. What is the maximum velocity with which a solid 1000-kg car can collide with the bumper without causing damage to the truck?

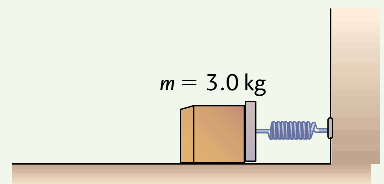
46. Figure 5.51 shows a 3.0-kg block of ice held against a spring with a force constant of 125 N/m. The spring is compressed by 12 cm. The ice is released across a horizontal plank with a coefficient of friction of 0.10.
 a) Calculate the velocity of the ice just as it leaves the spring. Assume the friction between the plank and the ice is negligible until the moment when the ice leaves the spring.
 b) Determine the distance the ice travels after it leaves the spring.

Fig.5.51



47. A spring with a force constant of 350 N/m (Figure 5.52) is compressed 12 cm by a 3.0-kg mass. How fast is the mass moving after only 10 cm of the spring is released?

Fig.5.52



48. What minimum force will compress a spring 15 cm if the spring constant is 4000 N/m?

49. A mattress manufacturer estimates that 20 springs are required to comfortably support a 100-kg person. When supporting the person, the 20 springs are compressed 3.5 cm. Calculate the spring constant for one spring.

50. A bungee cord needs to transfer 2.0×10^6 J of energy. A 10-kg mass extends the bungee cord 1.3 m. What is the maximum extension of the bungee cord?

5.6 Power

51. A 60-W light bulb is left on for 3 days, 8 hours, and 15 minutes. How much energy is used? Express this value in kWh as well.

52. a) A crane lifts a 3500-kg crate from the ground to a height of 13.4 m. If the lift takes 23 s and the crane's mechanical systems are 46% efficient, then what power must the engine provide?
 b) Convert the value in part a) to horsepower.

53. Suppose that your home uses 9.4 kWh of power in one day and you would like to replace that energy by riding a bicycle generator for 4 h. Using energy transfer theory, explain the physical condition (comfortable, exhausted, dead, etc.) you would be in at the end of the ride.

54. An elevator in a large hotel has a mass of 4400 kg. The maximum passenger load is 2200 kg. Suppose the speed of the elevator is 2.4 m/s.
   a) What is the average power required of the lifting device?
   b) Compare your answer in a) with some other power value in your daily experience.
   c) What would be the power consequence of counterweighing the elevator with a steel mass of 4400 kg?

55. A cyclist coasts down a 7.2° hill at a steady speed of 10.0 km/h. If the total mass of the bike and rider is 75.0 kg, what power output must the rider have to climb the hill at the same speed?

5.7 Elastic and Inelastic Collisions

56. Derive the expression $v_{2_f} = v_{1_o}\left(\frac{2m_1}{m_1 + m_2}\right)$ for two objects involved in an elastic collision, where the first object is initially at rest.

57. A 15-kg object, moving at 3.0 m/s, collides elastically (head-on) with a 3.0-kg object, initially at rest.
   a) What is the velocity of each object after collision?
   b) How much energy was transferred to the smaller object?

58. A 35-g sparrow, travelling at 8.0 m/s with its beak open, swallows a 2.0-g mosquito, travelling in the opposite direction at 12 m/s. Calculate the velocity of the sparrow and mosquito just after collision.

59. A 3.2-kg dynamics cart, moving to the right at 2.2 m/s, has a spring attached to one end. The cart collides with another cart of equal mass, initially at rest. After the collision, the first cart continues to move in the same direction at 1.1 m/s.
   a) Calculate the total momentum and the total kinetic energy before the collision.
   b) Find the final velocity of the second cart.
   c) Calculate the total amount of kinetic energy after the collision.
   d) Is this collision elastic? Explain.

60. A 15-g bullet travelling at 375 m/s penetrates a 2.5-kg stationary block of wood sitting on a frictionless surface. If the bullet emerges at 300 m/s, find the final velocity of the block.

61. A totally elastic, head-on collision occurs between object A, with a mass of $6m$, and object B, with a mass of $10m$. Object A is moving at 5 m/s [E], while object B is moving at 3 m/s [W]. Calculate the velocity of each mass after the collision.

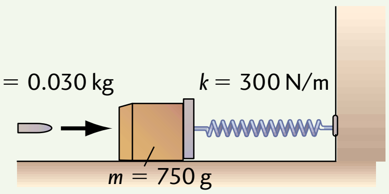
62. An elastic collision occurs on an air track between a moving mass m_1 and a stationary mass m_2. If the initial velocity of m_1 is 5 m/s and $m_1 = 3m_2$,
   a) calculate the velocity of the first mass after the interaction.
   b) calculate the velocity of the second mass after the interaction.

63. A 750-g block of wood is attached to a spring with $k = 300$ N/m, as shown in Figure 5.53. A 0.030-kg bullet is fired into the block, and the spring compresses 10.2 cm.

a) Calculate the velocity of the bullet before the collision.

b) Is this collision elastic or inelastic? Explain.

Fig.5.53

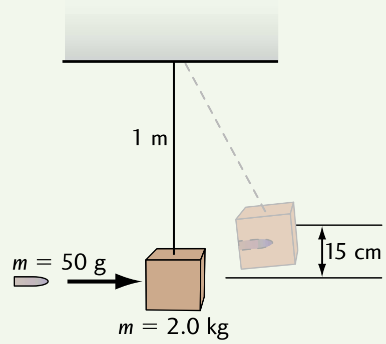


64. As part of a forensic experiment, a 50-g bullet is fired horizontally into a 2.0-kg wooden pendulum, as illustrated in Figure 5.54. The pendulum with the bullet imbedded in it rises 15 cm vertically from its initial position.

a) Calculate the velocity of the block and bullet just after the collision.

b) What is the velocity of the bullet just before impact?

Fig.5.54



65. A glancing elastic collision occurs between a cue ball and the eight ball. Both balls have the same mass and the eight ball is initially at rest. Prove that the angle between the velocity of the cue ball and the eight ball after collision is 90°.