1. Refer to Example Problem 1 to solve the following problem.
   a. If the hockey player exerted twice as much force, 9.00 N, on the puck, how would the puck’s change in kinetic energy be affected?
   Because $W = Fd$ and $\Delta KE = W$, doubling the force would double the work, which would double the change in kinetic energy to 1.35 J.
   b. If the player exerted a 9.00 N-force, but the stick was in contact with the puck for only half the distance, 0.075 m, what would be the change in kinetic energy?
   Because $W = Fd$, halving the distance would cut the work in half, which also would cut the change in kinetic energy in half, to 0.68 J.

2. Together, two students exert a force of 825 N in pushing a car a distance of 35 m.
   a. How much work do the students do on the car?
   \[ W = Fd = (825 \text{ N})(35 \text{ m}) = 2.9 \times 10^4 \text{ J} \]
   b. If the force was doubled, how much work would they do pushing the car the same distance?
   \[ W = Fd = (2)(825 \text{ N})(35 \text{ m}) = 5.8 \times 10^4 \text{ J} \text{ which is twice as much work} \]

3. A rock climber wears a 7.5-kg backpack while scaling a cliff. After 30.0 min, the climber is 8.2 m above the starting point.
   a. How much work does the climber do on the backpack?
   \[ W = Fd = mgd = (7.5 \text{ kg})(9.80 \text{ m/s}^2)(8.2 \text{ m}) = 6.0 \times 10^2 \text{ J} \]
   b. If the climber weighs 645 N, how much work does she do lifting herself and the backpack?
   \[ W = Fd + 6.0 \times 10^2 \text{ J} = (645 \text{ N})(8.2 \text{ m}) + 6.0 \times 10^2 \text{ J} = 5.9 \times 10^3 \text{ J} \]
   c. What is the average power developed by the climber?
   \[ P = \frac{W}{t} = \frac{(5.9 \times 10^3 \text{ J})}{(30.0 \text{ min})(60 \text{ s})} = 3.3 \text{ W} \]

4. If the sailor in Example Problem 2 pulled with the same force, and along the same distance, but at an angle of 50.0°, how much work would he do?
   \[ W = Fd \cos \theta = (255 \text{ N})(30.0 \text{ m})(\cos 50.0°) = 4.92 \times 10^3 \text{ J} \]

5. Two people lift a heavy box a distance of 15 m. They use ropes, each of which makes an angle of 15° with the vertical. Each person exerts a force of 225 N. How much work do they do?
   \[ W = Fd \cos \theta = (2)(225 \text{ N})(15 \text{ m})(\cos 15°) = 6.5 \times 10^3 \text{ J} \]
6. An airplane passenger carries a 215-N suitcase up the stairs, a displacement of 4.20 m vertically, and 4.60 m horizontally.

a. How much work does the passenger do?
   Since gravity acts vertically, only the vertical displacement needs to be considered.
   \[ W = Fd = (215 \text{ N})(4.20 \text{ m}) = 903 \text{ J} \]

b. The same passenger carries the same suitcase back down the same set of stairs. How much work does the passenger do now?
   Force is upward, but vertical displacement is downward, so
   \[ W = Fd \cos \theta = \frac{mgd \cos \theta}{t} = \frac{(13 \text{ kg})(9.80 \text{ m/s}^2)(275 \text{ m})}{(\cos 115^\circ)} = -1.5 \times 10^4 \text{ J} \]

7. A rope is used to pull a metal box a distance of 15.0 m across the floor. The rope is held at an angle of 46.0° with the floor, and a force of 628 N is applied to the rope. How much work does the force on the rope do?
   \[ W = Fd \cos \theta = \frac{(628 \text{ N})(15.0 \text{ m})(\cos 46.0^\circ)}{t} = 6.54 \times 10^3 \text{ J} \]

8. A bicycle rider pushes a bicycle that has a mass of 13 kg up a steep hill. The incline is 25° and the road is 275 m long, as shown in Figure 10-4. The rider pushes the bike parallel to the road with a force of 25 N.

   a. How much work does the rider do on the bike?
      Force and displacement are in the same direction.
      \[ W = Fd = (25 \text{ N})(275 \text{ m}) = 6.9 \times 10^3 \text{ J} \]

   b. How much work is done by the force of gravity on the bike?
      The force is downward (−90°), and the displacement is 25° above the horizontal or 115° from the force.
      \[ W = mgd \cos \theta = \frac{mgd}{t} = \frac{(13 \text{ kg})(9.80 \text{ m/s}^2)(275 \text{ m})}{(\cos 115^\circ)} = 1.5 \times 10^4 \text{ J} \]

9. A box that weighs 575 N is lifted a distance of 20.0 m straight up by a cable attached to a motor. The job is done in 10.0 s. What power is developed by the motor in W and kW?
   \[ P = \frac{W}{t} = \frac{Fd}{t} = \frac{(575 \text{ N})(20.0 \text{ m})}{10.0 \text{ s}} = 1.15 \times 10^3 \text{ W} = 1.15 \text{ kW} \]

10. You push a wheelbarrow a distance of 60.0 m at a constant speed for 25.0 s, by exerting a 145-N force horizontally.

   a. What power do you develop?
      \[ P = \frac{W}{t} = \frac{Fd}{t} = \frac{(145 \text{ N})(60.0 \text{ m})}{25.0 \text{ s}} = 348 \text{ W} \]

   b. If you move the wheelbarrow twice as fast, how much power is developed?
      \[ t \text{ is halved, so } P \text{ is doubled to } 696 \text{ W} \]

11. What power does a pump develop to lift 35 L of water per minute from a depth of 110 m? (1 L of water has a mass of 1.00 kg.)

   \[ P = \frac{W}{t} = \frac{mgd}{t} = \left( \frac{m}{t} \right) gd \]
   where \( \frac{m}{t} = (35 \text{ L/min})(1.00 \text{ kg/L}) \)

   Thus,
   \[ P = \left( \frac{m}{t} \right) gd = (35 \text{ L/min})(1.00 \text{ kg/L})(9.80 \text{ m/s}^2)(110 \text{ m})(1 \text{ min}/60\text{s}) = 0.63 \text{ kW} \]
Chapter 10 continued

12. An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35 s. How much force does the motor exert?

\[ P = \frac{W}{t} = \frac{Fd}{t} \]

\[ F = \frac{Pt}{d} = \frac{(65 \times 10^3 \text{ W})(35 \text{ s})}{17.5 \text{ m}} \]

\[ = 1.3 \times 10^5 \text{ N} \]

13. A winch designed to be mounted on a truck, as shown in Figure 10-7, is advertised as being able to exert a 6.8 \times 10^3 \text{-N} force and to develop a power of 0.30 kW. How long would it take the truck and the winch to pull an object 15 m?

\[ P = \frac{W}{t} = \frac{Fd}{t} \]

\[ t = \frac{Fd}{P} = \frac{(6.8 \times 10^3 \text{ N})(15 \text{ m})}{(0.30 \times 10^3 \text{ W})} = 340 \text{ s} \]

\[ = 5.7 \text{ min} \]

14. Your car has stalled and you need to push it. You notice as the car gets going that you need less and less force to keep it going. Suppose that for the first 15 m, your force decreased at a constant rate from 210.0 N to 40.0 N. How much work did you do on the car? Draw a force-displacement graph to represent the work done during this period.

The work done is the area of the trapezoid under the solid line:

\[ W = \frac{1}{2} d(F_1 + F_2) \]

\[ = \frac{1}{2}(15 \text{ m})(210.0 \text{ N} + 40.0 \text{ N}) \]

\[ = 1.9 \times 10^3 \text{ J} \]

Section Review

10.1 Energy and Work pages 257–265

15. Work Murimi pushes a 20-kg mass 10 m across a floor with a horizontal force of 80 N. Calculate the amount of work done by Murimi.

\[ W = Fd = (80 \text{ N})(10 \text{ m}) = 8 \times 10^2 \text{ J} \]

The mass is not important to this problem.

16. Work A mover loads a 185-kg refrigerator into a moving van by pushing it up a 10.0-m, friction-free ramp at an angle of inclination of 11.0°. How much work is done by the mover?

\[ y = (10.0 \text{ m})(\sin 11.0°) \]

\[ = 1.91 \text{ m} \]

\[ W = Fd = mgd \sin \theta \]

\[ = (185 \text{ kg})(9.80 \text{ m/s}^2)(10.0 \text{ m})(\sin 11.0°) \]

\[ = 3.46 \times 10^3 \text{ J} \]

17. Work and Power Does the work required to lift a book to a high shelf depend on how fast you raise it? Does the power required to lift the book depend on how fast you raise it? Explain.

No, work is not a function of time. However, power is a function of time, so the power required to lift the book does depend on how fast you raise it.
18. **Power** An elevator lifts a total mass of $1.1 \times 10^3$ kg a distance of 40.0 m in 12.5 s. How much power does the elevator generate?

\[
P = \frac{W}{t} = \frac{F \cdot d}{t} = \frac{m \cdot g \cdot d}{t}
\]

\[
= \frac{(1.1 \times 10^3 \text{ kg})(9.80 \text{ m/s}^2)(40.0 \text{ m})}{12.5 \text{ s}}
\]

\[
= 3.4 \times 10^4 \text{ W}
\]

19. **Work** A 0.180-kg ball falls 2.5 m. How much work does the force of gravity do on the ball?

\[
W = F_g \cdot d = m \cdot g \cdot d
\]

\[
= (0.180 \text{ kg})(9.80 \text{ m/s}^2)(2.5 \text{ m})
\]

\[
= 4.4 \text{ J}
\]

20. **Mass** A forklift raises a box 1.2 m and does 7.0 kJ of work on it. What is the mass of the box?

\[
W = F \cdot d = m \cdot g \cdot d
\]

so \[
m = \frac{W}{g \cdot d} = \frac{7.0 \times 10^3 \text{ J}}{(9.80 \text{ m/s}^2)(1.2 \text{ m})}
\]

\[
= 6.0 \times 10^2 \text{ kg}
\]

21. **Work** You and a friend each carry identical boxes from the first floor of a building to a room located on the second floor, farther down the hall. You choose to carry the box first up the stairs, and then down the hall to the room. Your friend carries it down the hall on the first floor, then up a different stairwell to the second floor. Who does more work?

Both do the same amount of work. Only the height lifted and the vertical force exerted count.

22. **Work and Kinetic Energy** If the work done on an object doubles its kinetic energy, does it double its velocity? If not, by what ratio does it change the velocity?

Kinetic energy is proportional to the square of the velocity, so doubling the energy doubles the square of the velocity. The velocity increases by a factor of the square root of 2, or 1.4.

23. **Critical Thinking** Explain how to find the change in energy of a system if three agents exert forces on the system at once.

Since work is the change in kinetic energy, calculate the work done by each force. The work can be positive, negative, or zero, depending on the relative angles of the force and displacement of the object. The sum of the three works is the change in energy of the system.

24. If the gear radius in the bicycle in Example Problem 4 is doubled, while the force exerted on the chain and the distance the wheel rim moves remain the same, what quantities change, and by how much?

\[
IMA = \frac{r_e}{r_s} = \frac{8.00 \text{ cm}}{35.6 \text{ cm}} = 0.225 \text{ (doubled)}
\]

\[
MA = \frac{F_r}{F_e} = \frac{(IMA)(F_e)}{(IMA)(F_e)}
\]

\[
= (0.214)(155 \text{ N})
\]

\[
= 33.2 \text{ N}
\]

\[
IMA = \frac{d_e}{d_r}
\]

so \[
d_e = (IMA)(d_r)
\]

\[
= (0.225)(14.0 \text{ cm})
\]

\[
= 3.15 \text{ cm}
\]

25. A sledgehammer is used to drive a wedge into a log to split it. When the wedge is driven 0.20 m into the log, the log is separated a distance of 5.0 cm. A force of $1.7 \times 10^4 \text{ N}$ is needed to split the log, and the sledgehammer exerts a force of $1.1 \times 10^4 \text{ N}$.

a. What is the $IMA$ of the wedge?

\[
IMA = \frac{d_e}{d_r} = \frac{(0.20 \text{ m})}{(0.050 \text{ m})} = 4.0
\]
Chapter 10 continued

b. What is the MA of the wedge?

\[ MA = \frac{F_r}{F_e} = \frac{(1.7 \times 10^4 \text{ N})}{(1.1 \times 10^4 \text{ N})} = 1.5 \]

c. Calculate the efficiency of the wedge as a machine.

\[ \eta = \frac{MA}{IMA} \times 100 = \frac{1.5}{4.0} \times 100 = 38\% \]

26. A worker uses a pulley system to raise a 24.0-kg carton 16.5 m, as shown in Figure 10-14. A force of 129 N is exerted, and the rope is pulled 33.0 m.

\[ \text{Figure 10-14} \]

a. What is the MA of the pulley system?

\[ MA = \frac{F_r}{F_e} = \frac{mg}{F_e} = \frac{(24.0 \text{ kg})(9.80 \text{ m/s}^2)}{129 \text{ N}} = 1.82 \]

b. What is the efficiency of the system?

\[ \eta = \frac{(MA)}{IMA} \times 100 = \frac{(MA)(100)}{d_e} \]

\[ = \frac{(1.82)(16.5 \text{ m})(100)}{33.0 \text{ m}} = 91.0\% \]

27. You exert a force of 225 N on a lever to raise a 1.25 \times 10^3 \text{ N} rock a distance of 13 cm. If the efficiency of the lever is 88.7 percent, how far did you move your end of the lever?

\[ \text{efficiency} = \frac{W_o}{W_i} \times 100 = \frac{F_r d_r}{F_e d_e} \times 100 \]

\[ \text{So } d_e = \frac{F_e d_e (100)}{F_r (\text{efficiency})} = \frac{(1.25 \times 10^3 \text{ N})(0.13 \text{ m})(100)}{(225 \text{ N})(88.7)} = 0.81 \text{ m} \]

28. A winch has a crank with a 45-cm radius. A rope is wrapped around a drum with a 7.5-cm radius. One revolution of the crank turns the drum one revolution.

a. What is the ideal mechanical advantage of this machine?

\[ IMA = \frac{d_e}{d_r} = \frac{(2\pi)45 \text{ cm}}{(2\pi)7.5 \text{ cm}} = 6.0 \]

b. If, due to friction, the machine is only 75 percent efficient, how much force would have to be exerted on the handle of the crank to exert 750 N of force on the rope?

\[ \text{efficiency} = \left(\frac{IMA}{IMA}\right) \times 100 = \frac{F_r}{(F_e)(IMA)} \times 100 \]

\[ \text{so } F_e = \frac{(F_r)(100)}{(\text{efficiency})(IMA)} = \frac{(750 \text{ N})(100)}{(75)(6.0)} = 1.7 \times 10^2 \text{ N} \]
29. Simple Machines Classify the tools below as a lever, a wheel and axle, an inclined plane, a wedge, or a pulley.
   a. screwdriver
      wheel and axle
   b. pliers
      lever
   c. chisel
      wedge
   d. nail puller
      lever

30. IMA A worker is testing a multiple pulley system to estimate the heaviest object that he could lift. The largest downward force he could exert is equal to his weight, 875 N. When the worker moves the rope 1.5 m, the object moves 0.25 m. What is the heaviest object that he could lift?

   \[
   IMA = \frac{d_e}{d_r} = \frac{(3)(2\pi r)}{2\pi r} \\
   = \frac{(3)(2\pi)(45 \text{ cm})}{(2\pi)(7.5 \text{ cm})} \\
   = 18
   \]

32. Efficiency Suppose you increase the efficiency of a simple machine. Do the MA and IMA increase, decrease, or remain the same? Either MA increases while IMA remains the same, or IMA decreases while MA remains the same, or MA increases while IMA decreases.

33. Critical Thinking The mechanical advantage of a multi-gear bicycle is changed by moving the chain to a suitable rear gear.

   a. To start out, you must accelerate the bicycle, so you want to have the bicycle exert the greatest possible force. Should you choose a small or large gear?
      large, to increase IMA

   b. As you reach your traveling speed, you want to rotate the pedals as few times as possible. Should you choose a small or large gear?
      Small, because less chain travel, hence few pedal revolutions, will be required per wheel revolution.

   c. Many bicycles also let you choose the size of the front gear. If you want even more force to accelerate while climbing a hill, would you move to a larger or smaller front gear?
      smaller, to increase pedal-front gear IMA because

Chapter 10 continued

Chapter Assessment

Concept Mapping

34. Create a concept map using the following terms: force, displacement, direction of motion, work, change in kinetic energy.

Mastering Concepts

35. In what units is work measured? (10.1) joules

36. Suppose a satellite revolves around Earth in a circular orbit. Does Earth’s gravity do any work on the satellite? (10.1)

No, the force of gravity is directed toward Earth and is perpendicular to the direction of displacement of the satellite.

37. An object slides at constant speed on a frictionless surface. What forces act on the object? What work is done by each force? (10.1)

Only gravity and an upward, normal force act on the object. No work is done because the displacement is perpendicular to these forces. There is no force in the direction of displacement because the object is sliding at a constant speed.

38. Define work and power. (10.1)

Work is the product of force and the distance over which an object is moved in the direction of the force. Power is the time rate at which work is done.

39. What is a watt equivalent to in terms of kilograms, meters, and seconds? (10.1)

\[ W = \frac{J}{s} = \frac{N \cdot m}{s} = \frac{(kg \cdot m/s^2) \cdot m}{s} = \frac{kg \cdot m^2}{s^3} \]

40. Is it possible to get more work out of a machine than you put into it? (10.2)

No, efficiency is less than or equal to 100%.

41. Explain how the pedals of a bicycle are a simple machine. (10.2)

Pedals transfer force from the rider to the bike through a wheel and axle.

Applying Concepts

42. Which requires more work, carrying a 420-N backpack up a 200-m-high hill or carrying a 210-N backpack up a 400-m-high hill? Why?

Each requires the same amount of work because force times distance is the same.

43. Lifting 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 magnitudes and opposite directions. It appears that no work is done, but you know that you did work. Explain what work was done.

You do positive work on the box because the force and motion are in the same direction. Gravity does negative work on the box because the force of gravity is opposite to the direction of motion. The work done by you and by gravity are separate and do not cancel each other.

44. You have an after-school job carrying cartons of new copy paper up a flight of stairs, and then carrying recycled paper back down the stairs. The mass of the paper does not
change. Your physics teacher says that you do not work all day, so you should not be paid. In what sense is the physics teacher correct? What arrangement of payments might you make to ensure that you are properly compensated?

The net work is zero. Carrying the carton upstairs requires positive work; carrying it back down is negative work. The work done in both cases is equal and opposite because the distances are equal and opposite. The student might arrange the payments on the basis of the time it takes to carry paper, whether up or down, not on the basis of work done.

45. You carry the cartons of copy paper down the stairs, and then along a 15-m-long hallway. Are you working now? Explain.

No, the force on the box is up and the displacement is down the hall. They are perpendicular and no work is done.

46. Climbing Stairs Two people of the same mass climb the same flight of stairs. The first person climbs the stairs in 25 s; the second person does so in 35 s.

a. Which person does more work? Explain your answer.

Both people are doing the same amount of work because they both are climbing the same flight of stairs and they have the same mass.

b. Which person produces more power? Explain your answer.

The person who climbs in 25 s expends more power, as less time is needed to cover the distance.

47. Show that power delivered can be written as $P = F \cos \theta$.

$P = \frac{W}{t}$, but $W = Fd \cos \theta$

so, $P = \frac{Fd \cos \theta}{t}$

because $v = \frac{d}{t}$

$P = Fv \cos \theta$

48. How can you increase the ideal mechanical advantage of a machine?

Increase the ratio of $d_e/d_i$ to increase the IMA of a machine.

49. Wedge How can you increase the mechanical advantage of a wedge without changing its ideal mechanical advantage?

Reduce friction as much as possible to reduce the resistance force.

50. Orbits Explain why a planet orbiting the Sun does not violate the work-energy theorem.

Assuming a circular orbit, the force due to gravity is perpendicular to the direction of motion. This means the work done is zero. Hence, there is no change in kinetic energy of the planet, so it does not speed up or slow down. This is true for a circular orbit.

51. Claw Hammer A claw hammer is used to pull a nail from a piece of wood, as shown in Figure 10-16. Where should you place your hand on the handle and where should the nail be located in the claw to make the effort force as small as possible?

Your hand should be as far from the head as possible to make $d_e$ as large as possible. The nail should be as close to the head as possible to make $d_i$ as small as possible.
Mastering Problems

10.1 Energy and Work
pages 278–280

Level 1

52. The third floor of a house is 8 m above street level. How much work is needed to move a 150-kg refrigerator to the third floor?

\[ W = Fd = mgd \]

\[ = (150 \text{ kg})(9.80 \text{ m/s}^2)(8 \text{ m}) \]

\[ = 1 \times 10^4 \text{ J} \]

53. Haloke does 176 J of work lifting himself 0.30 m. What is Haloke’s mass?

\[ W = Fd = mgd; \text{ therefore,} \]

\[ m = \frac{W}{gd} = \frac{176 \text{ J}}{(9.80 \text{ m/s}^2)(0.300 \text{ m})} \]

\[ = 59.9 \text{ kg} \]

54. Football After scoring a touchdown, an 84.0-kg wide receiver celebrates by leaping 1.20 m off the ground. How much work was done by the wide receiver in the celebration?

\[ W = Fd = mgd \]

\[ = (84.0 \text{ kg})(9.80 \text{ m/s}^2)(1.20 \text{ m}) \]

\[ = 988 \text{ J} \]

55. Tug-of-War During a tug-of-war, team A does 2.20×10^5 J of work in pulling team B 8.00 m. What force was team A exerting?

\[ W = Fd, \text{ so} \]

\[ F = \frac{W}{d} = \frac{2.20 \times 10^5 \text{ J}}{8.00 \text{ m}} = 2.75 \times 10^4 \text{ N} \]

56. To keep a car traveling at a constant velocity, a 551-N force is needed to balance frictional forces. How much work is done against friction by the car as it travels from Columbus to Cincinnati, a distance of 161 km?

\[ W = Fd = (551 \text{ N})(1.61 \times 10^5 \text{ m}) \]

\[ = 8.87 \times 10^7 \text{ J} \]

57. Cycling A cyclist exerts a force of 15.0 N as he rides a bike 251 m in 30.0 s. How much power does the cyclist develop?

\[ P = \frac{W}{t} = \frac{Fd}{t} \]

\[ = \frac{(15.0 \text{ N})(2.51 \text{ m})}{30.0 \text{ s}} \]

\[ = 126 \text{ W} \]

58. A student librarian lifts a 2.2-kg 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 above the floor. How much work does he do on the book?

Only the net vertical displacement counts.

\[ W = Fd = mgd \]

\[ = (2.2 \text{ kg})(9.80 \text{ m/s}^2)(0.35 \text{ m}) \]

\[ = 7.5 \text{ J} \]

59. A force of 300.0 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.

\[ W = Fd = (300.0 \text{ N})(30.0 \text{ m}) \]

\[ = 9.00 \times 10^3 \text{ J} \]

\[ = 9.00 \text{ kJ} \]

b. Calculate the power developed.

\[ P = \frac{W}{t} = \frac{9.00 \times 10^3 \text{ J}}{3.00 \text{ s}} \]

\[ = 3.00 \times 10^3 \text{ W} \]

\[ = 3.00 \text{ kW} \]

Level 2

60. Wagon A wagon is pulled by a force of 38.0 N exerted on the handle at an angle of 42.0° with the horizontal. If the wagon is pulled in a circle of radius 25.0 m, how much work is done?

\[ W = Fd \cos \theta \]

\[ = (38.0 \text{ N})(2\pi)(25.0 \text{ m})(\cos 42.0°) \]

\[ = 4.44 \times 10^3 \text{ J} \]

61. Lawn Mower Shani is pushing a lawn mower with a force of 88.0 N along a handle that makes an angle of 41.0° with the horizontal. How much work is done by...
Shani in moving the lawn mower 1.2 km to mow the yard?

\[ W = Fd \cos \theta \]
\[ = (88.0 \text{ N})(1.2 \times 10^3 \text{ m})(\cos 41.0^\circ) \]
\[ = 8.0 \times 10^4 \text{ J} \]

62. A 17.0-kg crate is to be pulled a distance of 20.0 m, requiring 1210 J of work to be done. If the job is done by attaching a rope and pulling with a force of 75.0 N, at what angle is the rope held?

\[ W = Fd \cos \theta \]
\[ \theta = \cos^{-1}\left(\frac{W}{Fd}\right) \]
\[ = \cos^{-1}\left(\frac{1210 \text{ J}}{(75.0 \text{ N})(20.0 \text{ m})}\right) \]
\[ = 36.2^\circ \]

63. **Lawn Tractor** A 120-kg lawn tractor, shown in Figure 10-17, goes up a 21° incline that is 12.0 m long in 2.5 s. Calculate the power that is developed by the tractor.

\[ P = \frac{W}{t} = \frac{F d \sin \theta}{t} = \frac{mg d \sin \theta}{t} \]
\[ = \frac{(120 \text{ kg})(9.80 \text{ m/s}^2)(12.0 \text{ m})(\sin 21^\circ)}{2.5 \text{ s}} \]
\[ = 2.0 \times 10^3 \text{ W} = 2.0 \text{ kW} \]

64. You slide 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 a constant speed. The coefficient of friction is 0.28. How much work did you do on the crate as it was raised a vertical distance of 1.15 m?

*F and d are parallel so*

\[ W = Fd = F \left(\frac{h}{\sin \theta}\right) \]

\[ = \frac{(225 \text{ N})(1.15 \text{ m})}{\sin 30.0^\circ} \]
\[ = 518 \text{ J} \]

65. **Piano** A 4.2 \times 10^3-\text{N} piano is to be slid up a 3.5-m frictionless plank at a constant speed. The plank makes an angle of 30.0° with the horizontal. Calculate the work done by the person sliding the piano up the plank.

The force parallel to the plane is given by

\[ F_\parallel = F \sin \theta \]

so \[ W = F_\parallel d = Fd \sin \theta \]
\[ W = (4200 \text{ N})(3.5 \text{ m})(\sin 30.0^\circ) \]
\[ = 7.4 \times 10^3 \text{ J} \]

66. **Sled** Diego pulls a 4.5-kg sled across level snow with a force of 225 N on a rope that is 35.0° above the horizontal, as shown in Figure 10-18. If the sled moves a distance of 65.3 m, how much work does Diego do?

\[ W = Fd \cos \theta \]
\[ = (225 \text{ N})(65.3 \text{ m})(\cos 35.0^\circ) \]
\[ = 1.20 \times 10^4 \text{ J} \]

67. **Escalator** Sau-Lan has a mass of 52 kg. She rides up the escalator at Ocean Park in Hong Kong. This is the world’s longest escalator, with a length of 227 m and an average inclination of 31°. How much work does the escalator do on Sau-Lan?

\[ W = F d \sin \theta = mgd \sin \theta \]
\[ = (52 \text{ kg})(9.80 \text{ m/s}^2)(227 \text{ m})(\sin 31^\circ) \]
\[ = 6.0 \times 10^4 \text{ J} \]

68. **Lawn Roller** A lawn roller is pushed across a lawn by a force of 115 N along the direction of the handle, which is 22.5°
Chapter 10 continued

above the horizontal. If 64.6 W of power is developed for 90.0 s, what distance is the roller pushed?

\[ P = \frac{W}{t} = \frac{F \cdot d \cdot \cos \theta}{t} \]

so,

\[ d = \frac{P \cdot t}{F \cdot \cos \theta} \]

\[ = \frac{(64.6 \text{ W})(90.0 \text{ s})}{(115 \text{ N})(\cos 22.5^\circ)} \]

\[ = 54.7 \text{ m} \]

69. 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, and 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.

\[ W = F_1d_1 + F_2d_2 + F_3d_3 \]

\[ = (20 \text{ N})(5 \text{ m}) + (35 \text{ N})(12 \text{ m}) + (10 \text{ N})(8 \text{ m}) \]

\[ = 600 \text{ J} \]

70. Maricruz slides a 60.0-kg crate up an inclined ramp that is 2.0-m long and attached to a platform 1.0 m above floor level, as shown in Figure 10-19. A 400.0-N force, parallel to the ramp, is needed to slide the crate up the ramp at a constant speed.

\[ W = Fd = (400.0 \text{ N})(2.0 \text{ m}) = 8.0 \times 10^2 \text{ J} \]

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

\[ W = Fd = mgd \]

\[ = (60.0 \text{ kg})(9.80 \text{ m/s}^2)(1.0 \text{ m}) \]

\[ = 5.9 \times 10^2 \text{ J} \]

71. Boat Engine An engine moves a boat through the water at a constant speed of 15 m/s. The engine must exert a force of 6.0 kN to balance the force that the water exerts against the hull. What power does the engine develop?

\[ P = \frac{W}{t} = \frac{F \cdot V}{t} = F \cdot V \]

\[ = (6.0 \times 10^3 \text{ N})(15 \text{ m/s}) \]

\[ = 9.0 \times 10^4 \text{ W} = 9.0 \times 10^1 \text{ kW} \]

Level 3

72. In Figure 10-20, the magnitude of the force necessary to stretch a spring is plotted against the distance the spring is stretched.
Chapter 10 continued

73. Use the graph in Figure 10-20 to find the work needed to stretch the spring from 0.12 m to 0.28 m.

Add the areas of the triangle and rectangle. The area of the triangle is:

\[
\frac{1}{2}bh = \frac{1}{2}(0.28 \text{ m} - 0.12 \text{ m})(7.00 \text{ N} - 3.00 \text{ N})
\]

\[
= 0.32 \text{ J}
\]

The area of the rectangle is:

\[
bh = (0.28 \text{ m} - 0.12 \text{ m})(3.00 \text{ N} - 0.00 \text{ N})
\]

\[
= 0.48 \text{ J}
\]

Total work is 0.32 J + 0.48 J = 0.80 J

74. A worker pushes a crate weighing 93 N up an inclined plane. The worker pushes the crate horizontally, parallel to the ground, as illustrated in Figure 10-21.

- **Figure 10-21**

a. The worker exerts a force of 85 N. How much work does he do?

**Displacement in direction of force is 4.0 m,**

so \( W = Fd = (85 \text{ N})(4.0 \text{ m}) \)

\[= 3.4 \times 10^2 \text{ J} \]

b. How much work is done by gravity?

(Be careful with the signs you use.)

**Displacement in direction of force is -3.0 m,**

so \( W = Fd = (93 \text{ N})(-3.0 \text{ m}) \)

\[= -2.8 \times 10^2 \text{ J} \]

c. The coefficient of friction is \( \mu = 0.20 \). How much work is done by friction?

(Be careful with the signs you use.)

\[ W = \mu F_N d = \mu(F_{\text{you, up}} + F_{\text{g, down}})d \]

\[= 0.20(85 \text{ N})(\sin \theta) +
(93 \text{ N})(\cos \theta)(-5.0 \text{ m}) \]

\[= 0.20(85 \text{ N})(3.0 \text{ m}) +
(93 \text{ N})(4.0 \text{ m}) \]

\[= -1.3 \times 10^2 \text{ J (work done against friction)} \]

75. **Oil Pump** In 35.0 s, a pump delivers 0.550 m³ of oil into barrels on a platform 25.0 m above the intake pipe. The oil's density is 0.820 g/cm³.
Chapter 10 continued

76. Conveyor Belt A 12.0-m-long conveyor belt, inclined at 30.0°, is used to transport bundles of newspapers from the mail room up to the cargo bay to be loaded onto delivery trucks. Each newspaper has a mass of 1.0 kg, and there are 25 newspapers per bundle. Determine the power that the conveyor develops if it delivers 15 bundles per minute.

\[ P = \frac{W}{t} = \frac{1.10 \times 10^5 \text{ J}}{35.0 \text{ s}} \]
\[ = 3.14 \times 10^3 \text{ W} = 3.14 \text{ kW} \]

77. A car is driven at a constant speed of 76 km/h down a road. The car’s engine delivers 48 kW of power. Calculate the average force that is resisting the motion of the car.

\[ P = \frac{W}{t} = \frac{Fd}{t} = Fv \]

so \( F = \frac{P}{v} \)

\[ = \frac{48,000 \text{ W}}{\left( \frac{76 \text{ km}}{1 \text{ h}} \right) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right)} \]
\[ = 2.3 \times 10^3 \text{ N} \]

78. The graph in Figure 10-22 shows the force and displacement of an object being pulled.

\[
\begin{align*}
\text{Force (N)} & \quad \text{Displacement (m)} \\
\hline
0.0 & 2.0 & 4.0 & 6.0 \\
20.0 & 40.0 & 60.0 & 80.0 \\
\end{align*}
\]

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

Find the area under the curve (see graph):

- 0.0 to 2.0 m:
  \[ \frac{1}{2} (20.0 \text{ N})(2.0 \text{ m}) = 2.0 \times 10^1 \text{ J} \]
- 2.0 m to 3.0 m:
  \[ \frac{1}{2} (30.0 \text{ N})(1.0 \text{ m}) + (20 \text{ N})(1.0 \text{ m}) = 35 \text{ J} \]
- 3.0 m to 7.0 m:
  \[ (50.0 \text{ N})(4.0 \text{ m}) = 2.0 \times 10^2 \text{ J} \]

Total work:

\[ 2.0 \times 10^1 \text{ J} + 35 \text{ J} + 2.0 \times 10^2 \text{ J} \]
\[ = 2.6 \times 10^2 \text{ J} \]

b. Calculate the power that would be developed if the work was done in 2.0 s.

\[ P = \frac{W}{t} = \frac{2.6 \times 10^2 \text{ J}}{2.0 \text{ s}} = 1.3 \times 10^2 \text{ W} \]
81. A pulley system lifts a 1345-N weight a distance of 0.975 m. Paul pulls the rope a distance of 3.90 m, exerting a force of 375 N.

a. What is the ideal mechanical advantage of the system?

\[IMA = \frac{d_e}{d_r} = \frac{3.90 \text{ m}}{0.975 \text{ m}} = 4.00\]

b. What is the mechanical advantage?

\[MA = \frac{F_r}{F_e} = \frac{1345 \text{ N}}{375 \text{ N}} = 3.59\]

c. How efficient is the system?

\[\text{efficiency} = \frac{MA}{IMA} \times 100 = \frac{3.59}{4.00} \times 100 = 89.8\%\]

82. A force of 1.4 N is exerted through a distance of 40.0 cm on a rope in a pulley system to lift a 0.50-kg mass 10.0 cm. Calculate the following.

a. the MA

\[MA = \frac{F_r}{F_e} = \frac{mg}{F_e} = \frac{(0.50 \text{ kg})(9.80 \text{ m/s}^2)}{1.4 \text{ N}} = 3.5\]

b. the IMA

\[IMA = \frac{d_e}{d_r} = \frac{40.0 \text{ cm}}{10.0 \text{ cm}} = 4.00\]

c. the efficiency

\[\text{efficiency} = \frac{MA}{IMA} \times 100 = \frac{3.5}{4.00} \times 100 = 88\%\]

83. A student exerts a force of 250 N on a lever, through a distance of 1.6 m, as he lifts a 150-kg crate. If the efficiency of the lever is 90.0 percent, how far is the crate lifted?

\[e = 90 = \frac{MA}{IMA} \times 100 = \frac{F_r}{F_e} \times 100\]

\[= \frac{F_r d_f}{F_e d_e} \times 100\]
Chapter 10 continued

so, \( d_r = \frac{eF_e d_e}{100F_r} = \frac{eF_e d_e}{100mg} \)

\[ = \frac{(90.0)(250 \text{ N})(1.6 \text{ m})}{(100)(150 \text{ kg})(9.80 \text{ m/s}^2)} \]

\[ = 0.24 \text{ m} \]

Level 2

84. What work is required to lift a 215-kg mass a distance of 5.65 m, using a machine that is 72.5 percent efficient?

\[ e = \frac{W_o}{W_i} \times 100 \]

\[ = \frac{F_r d_r}{W_i} \times 100 \]

\[ = \frac{mgd_r}{W_i} \times 100 \]

\[ W_i = \frac{mgd_r}{e} \times 100 \]

\[ = \frac{(215 \text{ kg})(9.80 \text{ m/s}^2)(5.65 \text{ m})(100)}{72.5} \]

\[ = 1.64 \times 10^4 \text{ J} \]

85. The ramp in Figure 10-23 is 18 m long and 4.5 m high.

**Figure 10-23**

a. What force, parallel to the ramp \( (F_A) \), is required to slide a 25-kg box at constant speed to the top of the ramp if friction is disregarded?

\[ W = F_g d = mgh \]

\[ \text{so } F = \frac{F_g}{d} = \frac{mgh}{d} \]

\[ = \frac{(25 \text{ kg})(9.80 \text{ m/s}^2)(4.5 \text{ m})}{18 \text{ m}} \]

\[ = 61 \text{ N} \]

b. What is the IMA of the ramp?

\[ IMA = \frac{d_r}{d_f} = \frac{18 \text{ m}}{4.5 \text{ m}} = 4.0 \]

c. What are the real \( MA \) and the efficiency of the ramp if a parallel force of 75 N is actually required?

\[ MA = \frac{F_r}{F_e} = \frac{(mg)(9.80 \text{ m/s}^2)}{75 \text{ N}} = 3.3 \]

\[ \text{efficiency} = \frac{MA}{IMA} \times 100 \]

\[ = \frac{3.3}{4.0} \times 100 = 82\% \]

86. Bicycle Luisa pedals a bicycle with a gear radius of 5.00 cm and a wheel radius of 38.6 cm, as shown in Figure 10-24. If the wheel revolves once, what is the length of the chain that was used?

\[ d = 2\pi r = 2\pi(5.00 \text{ cm}) = 31.4 \text{ cm} \]

**Figure 10-24**

Level 3

87. Crane A motor with an efficiency of 88 percent operates a crane with an efficiency of 42 percent. If the power supplied to the motor is 5.5 kW, with what constant speed does the crane lift a 410-kg crate of machine parts?

\[ \text{Total efficiency} = (88\%)(42\%) = 37\% \]

\[ \text{Useful Power} = (5.5 \text{ kW})(37\%) \]

\[ = 2.0 \text{ kW} \]

\[ = 2.0 \times 10^3 \text{ W} \]
Chapter 10 continued

\[ P = \frac{W}{t} = \frac{F_d d}{t} = F(d) = F_v \]

\[ v = \frac{P}{F_g} = \frac{P}{mg} = \frac{2.0 \times 10^3 W}{(410 \text{ kg})(9.80 \text{ m/s}^2)} \]

\[ = 0.50 \text{ m/s} \]

88. A compound machine is constructed by attaching a lever to a pulley system. Consider an ideal compound machine consisting of a lever with an IMA of 3.0 and a pulley system with an IMA of 2.0.

a. Show that the IMA of this compound machine is 6.0.

\[ W_{i1} = W_{o1} = W_{i2} = W_{o2} \]

\[ F_{e1}d_{e1} = F_{r2}d_{r2} \]

For the compound machine

\[ IMA_c = \frac{d_{e1}}{d_{r2}} \]

\[ \frac{d_{e1}}{d_{r1}} = IMA_1 \quad \text{and} \quad \frac{d_{e2}}{d_{r2}} = IMA_2 \]

\[ d_{r1} = d_{e2} \]

\[ \frac{d_{e1}}{IMA_1} = d_{r1} = d_{e2} = (IMA_2)(d_{r2}) \]

\[ d_{e1} = (IMA_1)(IMA_2)(d_{r2}) \]

\[ d_{r2} = IMA_c = (IMA_1)(IMA_2) \]

\[ = (3.0)(2.0) = 6.0 \]

b. If the compound machine is 60.0 percent efficient, how much effort must be applied to the lever to lift a 540-N box?

\[ e = \frac{MA}{IMA} \times 100 = \frac{F_e}{IMA} \times 100 \]

\[ = \frac{(F_e)(100)}{(IMA)(IMA)} \]

So \( F_e = \frac{(F_e)(100)}{(e)(IMA)} \)

\[ = \frac{(540 \text{ N})(100)}{(60.0)(6.0)} = 150 \text{ N} \]

c. If you move the effort side of the lever 12.0 cm, how far is the box lifted?

\[ d_{e1} = IMA_c \]

\[ d_{r2} = \frac{d_{e1}}{IMA_c} = \frac{12.0 \text{ cm}}{6.0} = 2.0 \text{ cm} \]

Mixed Review

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Level 1

89. Ramps Isra has to get a piano onto a 2.0-m-high platform. She can use a 3.0-m-long frictionless ramp or a 4.0-m-long frictionless ramp. Which ramp should Isra use if she wants to do the least amount of work? Either ramp: only the vertical distance is important. If Isra used a longer ramp, she would require less force. The work done would be the same.

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

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

\[ W = Fd = mgd \]

\[ = (240 \text{ kg})(9.80 \text{ m/s}^2)(2.35 \text{ m}) \]

\[ = 5.5 \times 10^3 \text{ J} \]

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

\[ d = 0, \text{ so no work} \]

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

\[ d \text{ is opposite of motion in part a, so } W \text{ is also the opposite, } -5.5 \times 10^3 \text{ J}. \]

d. Does Brutus do work if he lets go of the weights and they fall back to the ground? No. He exerts no force, so he does no work, positive or negative.

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

\[ P = \frac{W}{t} = \frac{5.5 \times 10^3 \text{ J}}{2.5 \text{ s}} = 2.2 \text{ kW} \]
91. A horizontal force of 805 N is needed to drag a crate across a horizontal floor with a constant speed. You drag the crate using a rope held at an angle of 32°.
   a. What force do you exert on the rope?
   \[ F_x = F \cos \theta \]
   \[ F = \frac{F_x}{\cos \theta} = \frac{805 \text{ N}}{\cos 32^\circ} \]
   \[ = 9.5 \times 10^2 \text{ N} \]
   b. How much work do you do on the crate if you move it 22 m?
   \[ W = F_x d = (805 \text{ N})(22 \text{ m}) \]
   \[ = 1.8 \times 10^4 \text{ J} \]
   c. If you complete the job in 8.0 s, what power is developed?
   \[ P = \frac{W}{t} = \frac{1.8 \times 10^4 \text{ J}}{8.0 \text{ s}} = 2.2 \text{ kW} \]

92. Dolly and Ramp A mover’s dolly is used to transport a refrigerator up a ramp into a house. The refrigerator has a mass of 115 kg. The ramp is 2.10 m long and rises 0.850 m. The mover pulls the dolly with a force of 496 N up the ramp. The dolly and ramp constitute a machine.
   a. What work does the mover do?
   \[ W_I = F d = (496 \text{ N})(2.10 \text{ m}) \]
   \[ = 1.04 \times 10^3 \text{ J} \]
   b. What is the work done on the refrigerator by the machine?
   \[ d = \text{height raised} = 0.850 \text{ m} \]
   \[ W_O = F g d = mgd \]
   \[ = (115 \text{ kg})(9.80 \text{ m/s}^2)(0.850 \text{ m}) \]
   \[ = 958 \text{ J} \]
   c. What is the efficiency of the machine?
   \[ \text{efficiency} = \frac{W_O}{W_I} \times 100 \]
   \[ = \frac{958 \text{ J}}{1.04 \times 10^3 \text{ J}} \times 100 \]
   \[ = 92.1\% \]

93. Sally does 11.4 kJ of work dragging a wooden crate 25.0 m across a floor at a constant speed. The rope makes an angle of 48.0° with the horizontal.
   a. How much force does the rope exert on the crate?
   \[ W = Fd \cos \theta \]
   \[ F = \frac{W}{d \cos \theta} = \frac{11,400 \text{ J}}{(25.0 \text{ m})(\cos 48.0^\circ)} \]
   \[ = 681 \text{ N} \]
   b. What is the force of friction acting on the crate?
   The crate moves with constant speed, so the force of friction equals the horizontal component of the force of the rope.
   \[ F_f = F_x = F \cos \theta \]
   \[ = (681 \text{ N})(\cos 48.0^\circ) \]
   \[ = 456 \text{ N}, \text{ opposite to the direction of motion} \]
   c. What work is done by the floor through the force of friction between the floor and the crate?
   Force and displacement are in opposite directions, so
   \[ W = -Fd = -(456 \text{ N})(25.0 \text{ m}) \]
   \[ = -1.14 \times 10^4 \text{ J} \]
   (Because no net forces act on the crate, the work done on the crate must be equal in magnitude but opposite in sign to the energy Sally expends: \(-1.14 \times 10^4 \text{ J}\))

94. Sledding An 845-N sled is pulled a distance of 185 m. The task requires \(1.20 \times 10^4 \text{ J}\) of work and is done by pulling on a rope with a force of 125 N. At what angle is the rope held?
   \[ W = Fd \cos \theta, \text{ so} \]
   \[ \theta = \cos^{-1} \left( \frac{W}{Fd} \right) = \cos^{-1} \left( \frac{1.20 \times 10^4 \text{ J}}{(125 \text{ N})(185 \text{ m})} \right) \]
   \[ = 58.7^\circ \]
An electric winch pulls a 875-N crate up a 15° incline at 0.25 m/s. The coefficient of friction between the crate and incline is 0.45.

**a.** What power does the winch develop?

Work is done on the crate by the winch, gravity, and friction. Because the kinetic energy of the crate does not change, the sum of the three works is equal to zero.

Therefore,

\[ W_{\text{winch}} = W_{\text{friction}} + W_{\text{gravity}} \]

or,

\[ P_{\text{winch}} = P_{\text{friction}} + P_{\text{gravity}} \]

\[
= \frac{\mu F_N d}{t} + \frac{F_g d}{t}
\]

\[
= \frac{\mu F_N (d)}{t} + F_g \frac{(d)}{t}
\]

\[
= \mu F_N v + F_g v
\]

\[
= (0.45)(875 \, \text{N})(\cos 15°)
\]

\[
(0.25 \, \text{m/s}) +
\]

\[
(875 \, \text{N})(0.25 \, \text{m/s})
\]

\[ = 3.1 \times 10^2 \, \text{W} \]

**b.** If the winch is 85 percent efficient, what is the electrical power that must be delivered to the winch?

\[ e = \frac{W_o}{W_i} = \frac{P_o}{P_i} \]

so,

\[ P_i = \frac{P_o}{e} \]

\[
= \frac{3.1 \times 10^2 \, \text{W}}{0.85}
\]

\[ = 3.6 \times 10^2 \, \text{W} \]

**Thinking Critically**

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**96.** Analyze and Conclude You work at a store, carrying boxes to a storage loft that is 12 m above the ground. You have 30 boxes with a total mass of 150 kg that must be moved as quickly as possible, so you consider carrying more than one up at a time. If you try to move too many at once, you know that you will go very slowly, resting often. If you carry only one box at a time, most of the energy will go into raising your own body. The power (in watts) that your body can develop over a long time depends on the mass that you carry, as shown in Figure 10-25. This is an example of a power curve that applies to machines as well as to people. Find the number of boxes to carry on each trip that would minimize the time required. What time would you spend doing the job? Ignore the time needed to go back down the stairs and to lift and lower each box.

The work has to be done the same,

\[ W = F_g d = mgd \]

\[ = (150 \, \text{kg})(9.80 \, \text{m/s}^2)(12 \, \text{m}) \]

\[ = 1.76 \times 10^4 \, \text{J} \]

From the graph, the maximum power is 25 W at 15 kg. Since the mass per box is 150 kg / 30 boxes = 5 kg, this represents three boxes.

\[ P = \frac{W}{t} \]

\[ = \frac{1.76 \times 10^4 \, \text{J}}{25 \, \text{W}} \]

\[ = 7.0 \times 10^2 \, \text{s} \]

\[ = 12 \, \text{min} \]

**97.** Apply Concepts A sprinter of mass 75 kg runs the 50.0-m dash in 8.50 s. Assume that the sprinter’s acceleration is constant throughout the race.

**a.** What is the average power of the sprinter over the 50.0 m?
Apply Concepts

The sprinter in the previous problem runs the 50.0-m dash in the same time, 8.50 s. However, this time the sprinter accelerates in the first second and runs the rest of the race at a constant velocity.

a. Calculate the average power produced for that first second.

Distance first second +
Distance rest of race = 50.0 m

d_1 = d_i + v_it + \frac{1}{2}at^2

d_i = v_i = 0 so

\[ d_1 = \frac{1}{2}a(t_1)^2 + v_i(t_2) = 50.0 \text{ m} \]

b. What is the maximum power generated by the sprinter?

Power increases linearly from zero, since the velocity increases linearly as shown by

\[ P = \frac{W}{t} = \frac{Fd}{t} = \frac{mad}{t} = Fv. \]

Therefore

\[ P_{\text{ave}} = \frac{\text{mad}}{t} \]

Therefore

\[ P_{\text{ave}} = 1.2 \times 10^3 \text{ W} \]

c. Make a quantitative graph of power versus time for the entire race.

98. Apply Concepts

The sprinter now generates?

\[ \text{Final velocity:} \]

\[ v_f = v_i + at \]

\[ v_i = 0 \text{ so} \]

\[ v_f = at = a(t_1) \]

Therefore,

\[ d_f = \frac{1}{2}at_1^2 + at_1t_2 \]

\[ a = \frac{d_f}{\frac{1}{2}t_1^2 + t_1t_2} \]

= \frac{50.0 \text{ m}}{\frac{1}{2}(1.00 \text{ s})^2 + (1.00 \text{ s})(7.50 \text{ s})}

= 6.25 \text{ m/s}^2

For the first second:

\[ d = \frac{1}{2}at^2 = \left(\frac{1}{2}\right)(6.25 \text{ m/s}^2)(1.00 \text{ s})^2 \]

= 3.12 \text{ m}

From Problem 97,

\[ P = \frac{mad}{t} \]

\[ P_{\text{ave}} = \frac{(75 \text{ kg})(6.25 \text{ m/s}^2)(3.12 \text{ m})}{1.00 \text{ s}} \]

= 1.5 \times 10^3 \text{ W}

b. What is the maximum power that the sprinter now generates?

\[ P_{\text{max}} = 2P_{\text{ave}} = 3.0 \times 10^3 \text{ W} \]

Writing in Physics

page 282

99. Just as a bicycle is a compound machine, so is an automobile. Find the efficiencies of the component parts of the power train (engine, transmission, wheels, and tires). Explore possible improvements in each of these efficiencies.

The overall efficiency is 15–30 percent. The transmission’s efficiency is about 90 percent. Rolling friction in the tires is about 1 percent (ratio of pushing force to weight moved). The largest gain is possible in the engine.
100. The terms force, work, power, and energy often mean the same thing in everyday use. Obtain examples from advertisements, print media, radio, and television that illustrate meanings for these terms that differ from those used in physics. **Answers will vary. Some examples include**, the company Consumers’ Power changed its name to Consumers’ Energy without changing its product, natural gas. "It’s not just energy, it’s power!" has appeared in the popular press.

**Cumulative Review**

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101. You are helping your grandmother with some gardening and have filled a garbage can with weeds and soil. Now you have to move the garbage can across the yard and realize it is so heavy that you will need to push it, rather than lift it. If the can has a mass of 24 kg, the coefficient of kinetic friction between the can’s bottom and the muddy grass is 0.27, and the static coefficient of friction between those same surfaces is 0.35, how hard do you have to push horizontally to get the can to just start moving? (Chapter 5)

\[ F_{\text{you on can}} = F_{\text{friction}} = \mu_s F_N = \mu_s mg \]
\[ = (0.35)(24 \text{ kg})(9.80 \text{ m/s}^2) \]
\[ = 82 \text{ N} \]

102. **Baseball** If a major league pitcher throws a fastball horizontally at a speed of 40.3 m/s (90 mph) and it travels 18.4 m (60 ft, 6 in), how far has it dropped by the time it crosses home plate? (Chapter 6)

\[ d_{\text{y}} = d_{\text{y}} + v_{iy}t + \frac{1}{2}gt^2 \]
\[ d_{\text{y}} = v_{iy} = 0 \]
so \[ d_{\text{y}} = \frac{1}{2}gt^2 \]
\[ = \left(\frac{1}{2}\right)(9.80 \text{ m/s}^2)(0.457 \text{ s})^2 \]
\[ = 1.02 \text{ m} \]

103. People sometimes say that the Moon stays in its orbit because the "centrifugal force just balances the centripetal force, giving no net force." Explain why this idea is wrong. (Chapter 8)

There is only one force on the moon, the gravitational force of Earth’s mass on it. This net force gives it an acceleration which is its centripetal acceleration toward Earth’s center.

**Challenge Problem**

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An electric pump pulls water at a rate of 0.25 m$^3$/s from a well that is 25 m deep. The water leaves the pump at a speed of 8.5 m/s.
1. What power is needed to lift the water to the surface?

   The work done in lifting is \( F \cdot g \cdot d = m \cdot g \cdot d \). Therefore, the power is

   \[
   P_{\text{lift}} = \frac{W}{t} = \frac{F \cdot g \cdot d}{t} = \frac{m \cdot g \cdot d}{t} \\
   = \frac{(0.25 \text{ m}^3)(1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(25 \text{ m})}{1.0 \text{ s}} \\
   = 6.1 \times 10^4 \text{ W} \\
   = 61 \text{ kW}
   \]

2. What power is needed to increase the pump’s kinetic energy?

   The work done in increasing the pump’s kinetic energy is \( \frac{1}{2} m v^2 \).

   Therefore, \( P = \frac{W}{t} = \frac{\Delta KE}{t} = \frac{\frac{1}{2} m v^2}{t} = \frac{m v^2}{2t} \)

   \[
   = \frac{(0.25 \text{ m}^3)(1.00 \times 10^3 \text{ kg/m}^3)(8.5 \text{ m/s})^2}{2(1.0 \text{ s})} \\
   = 9.0 \times 10^3 \text{ W} = 9.0 \text{ kW}
   \]

3. If the pump’s efficiency is 80 percent, how much power must be delivered to the pump?

   \[
   e = \frac{W_o}{W_i} \times 100 = \frac{W_o}{t} \times 100 = \frac{P_o}{P_i} \times 100 \text{ so,}
   \]

   \[
   P_i = \frac{P_o}{e} \times 100 = \frac{9.0 \times 10^3 \text{ W}}{80} \times 100 \\
   = 1.1 \times 10^4 \text{ W} \\
   = 11 \text{ kW}
   \]