Chapter 5: Work, Energy, Power, and Society

Mini Investigation: Pizza Pan Half-Pipe, page 221

A. The final positions are slightly less than the initial positions of the marble in each case. Increasing the initial height of the marble does not affect the difference between the initial and final positions of the marble.
B. Since energy is not being added to the system, the potential energy the marble has before it is released gets translated into kinetic energy of movement. The amount of energy of the marble at the initial position and finally position should be the same but it is not. The difference in the final position of the marble could be due to friction.

Section 5.1: Work

Tutorial 1 Practice, page 223

1. Given: Choose right as positive.
$m = 0.50$ kg; $v_i = +3.0$ m/s; $\Delta t = 2.0$ s;
$a = +1.2$ m/s^2; $F_f = 0$ N
Required: F_a; Δd; W
(a) The force exerted by the string on the cart:
Analysis: $F_{net} = ma$
Solution:

$$\begin{aligned} F_{net} &= ma \\ F_a - F_f &= ma \\ F_a - 0 &= (0.50 \text{ kg})(1.2 \text{ m/s}^2) \\ &= 0.6 \text{ kg•m/s}^2 \\ &= 0.6 \text{ N} \\ F_a &= 0.60 \text{ N} \end{aligned}$$

Statement: The string exerts a force of 0.60 N on the cart.
(b) The displacement of the cart:
Analysis: $\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$
Solution: First, find v_2.

$$\begin{aligned} a &= \frac{v_2 - v_1}{\Delta t} \\ v_2 &= a\Delta t + v_1 \\ &= \left(1.2 \frac{\text{m}}{\text{s}^{\not 2}}\right)(2.0 \not\text{s}) + 3.0 \text{ m/s} \\ &= 2.4 \text{ m/s} + 3.0 \text{ m/s} \\ &= 5.4 \text{ m/s} \end{aligned}$$

Then, find Δd.

$$\begin{aligned} \Delta d &= \left(\frac{v_1 + v_2}{2}\right)\Delta t \\ &= \left(\frac{3.1 \frac{\text{m}}{\not\text{s}} + 5.4 \frac{\text{m}}{\not\text{s}}}{2}\right)(2.0 \not\text{s}) \end{aligned}$$

$\Delta d = 8.4$ m
Statement: The displacement of the cart is 8.4 m.
(c) The mechanical work done by the string on the cart:
Analysis: $W = F\Delta d$
Solution:

$$\begin{aligned} W &= F\Delta d \\ &= (0.60 \text{ N})(8.4 \text{ m}) \\ &= 5.04 \text{ N•m} \\ &= 5.04 \text{ J} \\ W &= 5.0 \text{ J} \end{aligned}$$

$$\begin{aligned} W &= F\Delta d \\ &= (0.60 \text{ N})(8.4 \text{ m}) \\ &= 5.04 \text{ N•m} \\ &= 5.04 \text{ J} \\ W &= 5.0 \text{ J} \end{aligned}$$

Statement: The mechanical work done by the string on the cart is 5.0 J.

Tutorial 2 Practice, page 225

1. Given: $F = 125$ N; $\theta = 40.0°$; $\Delta d = 12.0$ m
Required: W
Analysis: $W = F_a(\cos \theta)\Delta d$
Solution:

$$\begin{aligned} W &= F(\cos \theta)\Delta d \\ &= (125 \text{ N})(\cos 40.0°)(12.0 \text{ m}) \\ &= 1149 \text{ N•m} \\ &= 1149 \text{ J} \\ W &= 1.15 \times 10^3 \text{ J, or } 1.15 \text{ kJ} \end{aligned}$$

Statement: The person does 1.15×10^3 J, or 1.15 kJ, of mechanical work on the lawnmower.
2. Solution: Both the work done by the normal force and the work done by gravity are zero. Both of these forces are perpendicular to the direction of motion and therefore do no work on the toboggan.
Statement: The work done by the normal force and the work done by gravity are zero.

Tutorial 3 Practice, page 226

1. (a) Since the brick wall does not move while the student is leaning on it, there is no acceleration. If there is no acceleration, there is no net force. Therefore, no work is done.
(b) Since the space probe is coasting at a constant velocity toward the planet, there is no net force acting on it. Therefore, there is no work done on it.
(c) A textbook sitting on a shelf experiences no motion. Since there is no motion, there is no work being done.

Tutorial 4 Practice, page 227

1. Given: $F_a = 4.5$ N; $F_f = 2.8$ N; $\Delta d = 1.3$ m
Required: W_{net}
Analysis: $W = F\Delta d$
Solution:

$$\begin{aligned} W_{net} &= W_a + W_f \\ &= F_a(\cos 0°)\Delta d + F_f(\cos 180°)\Delta d \\ &= (4.5\text{ N})(1)(1.3\text{ m}) + (2.8\text{ N})(-1)(1.3\text{ m}) \\ &= 5.85\text{ N}\bullet\text{m} - 3.64\text{ N}\bullet\text{m} \\ &= 2.21\text{ N}\bullet\text{m} \\ W_{net} &= 2.21\text{ J} \end{aligned}$$

Statement: The net work done on the bowl is 2.2 J.
2. Given: Choose up as positive.
$m = 450$ kg; $\Delta d = +12$ m; $g = 9.8$ N/kg
Required: W
Analysis:

$$W = F\Delta d$$
$$F_a = F_g$$
$$F_g = mg$$

Solution: Find F_g.

$$\begin{aligned} F_g &= mg \\ &= (450\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right) \\ &= 4410\text{ N} \\ F_a &= 44.10\text{ N} \end{aligned}$$

$$\begin{aligned} W_a &= F_a(\cos\ 0°)\Delta d \\ &= (4410\text{ N})(12\text{ m}) \\ &= 52\ 920\text{ N}\bullet\text{m} \\ &= 52.92\text{ kJ} \\ W_a &= 53\text{ kJ} \end{aligned}$$

Statement: The mechanical work done by the crane is 53 kJ.

Mini Investigation: Human Work, page 228

Answers may vary. Sample answers.
A. The amount of work I did to lift the book was 14.11 J. The amount of work I did to lift the shoe was 3.92 J. It took 10.2 J more to lift the book.
B. Since the shoe is lighter than the book, the shoe should take less work to lift. The book's mass is three times the mass of the shoe. To lift the shoe, I predicted it would take one-third the amount of work to lift the book. My prediction was fairly accurate.
C. Given: $W_{shoe} = 14.11$ J; $F_{g\ shoe} = 4.9$ N
Required: Δd
Analysis: $W = F\,\Delta d$
Solution:

$$\begin{aligned} W &= F\Delta d \\ \Delta d &= \frac{W}{F} \\ &= \frac{14.11\text{ J}}{4.9\text{ N}} \\ &= 2.88\text{ m} \\ \Delta d &= 2.9\text{ m} \end{aligned}$$

Statement: In order for the work to lift the shoe to equal the work to lift the book, the shoe must be lifted 2.9 m.

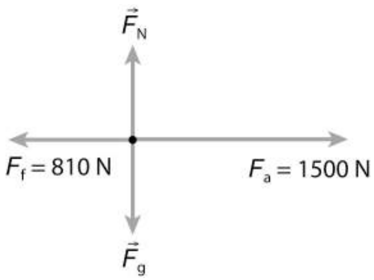
Section 5.1 Questions, page 229

1. Given: Choose the direction of motion to be positive.
$F = 25.0$ N; $\Delta d = 13.0$ m
Required: W
Analysis: $W = F\Delta d$
Solution:

$$\begin{aligned} W &= F\Delta d \\ &= (25.0\text{ N})(13.0\text{ m}) \\ &= 325\text{ N}\bullet\text{m} \\ W &= 325\text{ J} \end{aligned}$$

Statement: The work done by the applied force is 325 J.

2.



Given: $F_a = 1500$ N; $\theta_a = 0°$ (acting forwards); $F_f = 810$ N; $\theta_f = 180°$ (acting backwards); $\Delta d = 12$ m

Required: W_a; W_f; W_N; W_g

Analysis: $W = F(\cos\theta)\Delta d$

(a) The work done by the tow truck force on the car:

Solution:
$$\begin{aligned} W_a &= F_a(\cos\ \theta_a)\Delta d \\ &= (1500\text{ N})\ (\cos 0°)\ (12\text{ m}) \\ &= 18\ 000\text{ N•m} \\ W_a &= 18\text{ kJ} \end{aligned}$$

Statement: The work done by the force of the tow truck on the car is 18 kJ.

(b) The work done by the force of friction:

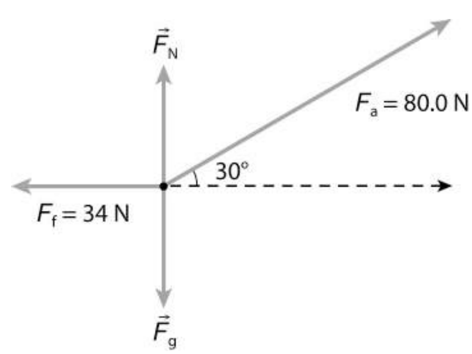
Solution:
$$\begin{aligned} W_f &= F_f(\cos\theta_f)\Delta d \\ &= (810\text{ N})(\cos 180°)(12\text{ m}) \\ &= -9720\text{ N•m} \\ &= -9720\text{ J} \\ W_f &= -9.7\text{ kJ} \end{aligned}$$

Statement: The work done by the force of friction is –9.7 kJ.

(c) The work done by the normal force is 0 J, since the normal force acts perpendicular to the direction of motion. (cos 90° = 0)

(d) The work done by the force of gravity is 0 J, since gravity acts perpendicular to the direction of motion. (cos 90° = 0)

3.



Given: $F_a = 80.0$ N; $\theta_a = 30.0°$; $F_f = 34$ N; $\theta_f =$ 180° (acting backwards); $\Delta d = 12$ m

Required: W_a; W_T

Analysis: $W = F(\cos\theta)\Delta d$; $W_T = W_a + W_f$

(a) The mechanical work done by the child on the wagon:

Solution:
$$\begin{aligned} W_a &= F_a(\cos\theta_a)\Delta d \\ &= (80.0\text{ N})(\cos 30.0°)(12\text{ m}) \\ &= 831.4\text{ N•m} \\ &= 831.4\text{ J} \\ W_a &= 830\text{ J} \end{aligned}$$

Statement: The mechanical work done by the child on the wagon is 830 J.

(b) The total work done on the wagon:

Solution:
$$\begin{aligned} W_T &= W_a + W_f \\ &= 831.4\text{ J} + F_f(\cos\theta_f)\Delta d \\ &= 831.4\text{ J} + (34\text{ N})(\cos 180°)(12\text{ m}) \\ &= 831.4\text{ N•m} - 408\text{ N•m} \\ &= 423.4\text{ N•m} \\ &= 423.4\text{ J} \\ W_T &= 420\text{ J} \end{aligned}$$

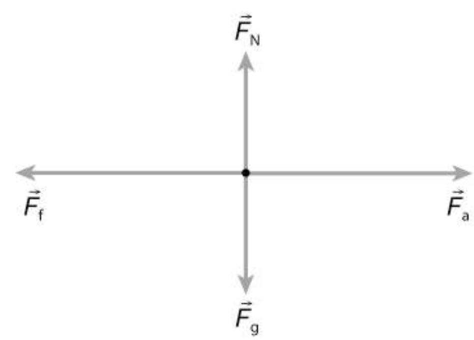
Statement: The total work done on the wagon is 420 J.

4. Given: $W_a = 250$ J; $\theta_a = 0°$; $\Delta d = 12$ m; $\theta_f = 180°$ (acting backwards)

Required: F_a; F_f; W_f

Analysis: $W = F(\cos\theta)\Delta d$

(a)



(b) The tension in the rope:

Solution:
$$\begin{aligned} W_a &= F_a(\cos\theta)\Delta d \\ F_a &= \frac{W_a}{(\cos\theta_a)\Delta d} \\ &= \frac{250\text{ J}}{(\cos 0°)(12\text{ m})} \\ &= 20.83\text{ J/m} \\ &= 20.83\text{ N} \\ F_a &= 21\text{ N} \end{aligned}$$

Statement: The tension in the rope is 21 N.

(c) Since the box is moving at a constant velocity, the forces acting on the box are balanced (the tension in the rope is balanced by the frictional force, and gravity is balanced by the normal force). Therefore, the force of friction is –21 N. There is also no net work done since the velocity of the box remains constant. Therefore, the work done by the force of friction is –250 J.

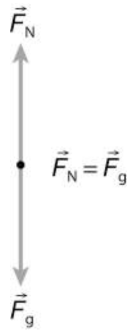
5. Given: Choose the direction up as positive.
m = 62 kg; $\theta_N = 0°$; v = +4.0 m/s; $\theta_g = 180°$;
Δt = 5.0 s; g = 9.8 N/kg

Required: W_N; W_g

Analysis:

$$W = F(\cos\theta)\Delta d$$
$$d = v\Delta t$$
$$F_g = mg$$

(a)



(b) The work done by the normal force on the person:

Solution:

$$\begin{aligned} W_N &= F_N(\cos\theta_N)\Delta d \\ &= (mg)(\cos\theta_N)(v\Delta t) \\ &= (62\ \text{kg})\left(9.8\ \frac{\text{N}}{\text{kg}}\right)(\cos 0°)\left(+4.0\ \frac{\text{m}}{\text{s}}\right)(5.0\ \text{s}) \\ &= 12\ 152\ \text{N•m} \\ &= 12\ 152\ \text{J} \\ W_N &= 12\ \text{kJ} \end{aligned}$$

Statement: The work done by the normal force on the person is 12 kJ.

(c) The work done by the force of gravity on the person: Since the elevator is moving at a constant velocity, the forces are balanced. The work done by the force of gravity on the person is –12 kJ, since gravity is opposing motion.

(d) If the direction of the elevator were reversed, then the work done by gravity would be +12 kJ, and the work done by the normal force would be –12 kJ. This is due to the fact that the angles would be reversed: $\theta_g = 0°$ and $\theta_N = 180°$.

6. Given: F vs. Δd graph; Δd = 0.5 m

Required: W

Analysis: W = area under F vs. Δd graph

Solution:

$$\begin{aligned} W &= \text{area under } F\Delta d \text{ graph (rectangle)} \\ &= bh \\ &= (0.5\ \text{m})(4\ \text{N}) \\ &= 2.0\ \text{N•m} \\ &= 2.0\ \text{J} \\ W &= 2\ \text{J} \end{aligned}$$

Statement: The work done on the cart by the force sensor is 2 J.

7. Given: m = 2.0 kg; $\theta_a = 0°$; v_i = 0.0 m/s;
$\theta_g = 180°$; a = 2.2 m/s^2; g = 9.8 N/kg; Δt = 3.0 s

Required: Δd; W_a; W_g; W_T; F_{net}; W_{net}

Analysis:

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$v_f = at + v_i$$
$$F_g = mg$$
$$W = F(\cos\theta)\Delta d$$
$$F_{net} = ma$$

(a) The displacement of the bucket:

Solution:

$$\begin{aligned} \Delta d &= \left(\frac{v_i + (at + v_i)}{2}\right)\Delta t \\ &= \left(\frac{0\ \frac{\text{m}}{\text{s}} + \left(2.2\ \frac{\text{m}}{\text{s}^2}\right)(3.0\ \text{s}) + 0\ \frac{\text{m}}{\text{s}}}{2}\right)3.0\ \text{s} \\ &= \left(\frac{6.6\ \frac{\text{m}}{\text{s}}}{2}\right)3.0\ \text{s} \\ \Delta d &= 9.9\ \text{m} \end{aligned}$$

Statement: The displacement of the bucket is 9.9 m.

(b) The work done by gravity and the work done by the rope:

Solution:

$$
\begin{aligned}
W_g &= F_g(\cos\theta)\,\Delta d \\
&= (mg)(\cos\theta)(\Delta d) \\
&= (2.0\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(\cos 180°)(9.9\ \text{m}) \\
&= -194.0\ \text{N•m} \\
&= -194.0\ \text{J} \\
W_g &= -190\ \text{J}
\end{aligned}
$$

To find W_a, calculate F_a.

$$
\begin{aligned}
F_{net} &= ma \\
F_a - F_g &= ma \\
F_a &= ma + mg \\
&= (2.0\ \text{kg})(2.2\ \text{m/s}^2) + (2.0\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right) \\
&= 4.4\ \text{kg•m/s}^2 + 19.6\ \text{N} \\
F_a &= 24.0\ \text{N}
\end{aligned}
$$

$$
\begin{aligned}
W_a &= F_a\left(\cos\theta_a\right)\Delta d \\
&= (24.0\ \text{N})(\cos 0°)(9.9\ \text{m}) \\
&= 237.6\ \text{N•m} \\
&= 237.6\ \text{J} \\
W_a &= 240\ \text{J}
\end{aligned}
$$

Statement: The work done by gravity is –190 J, and the work done by the rope is 240 J.

(c) The total mechanical work done on the bucket:

Solution:

$$
\begin{aligned}
W_T &= W_a + W_g \\
&= 237.6\ \text{J} - 194.0\ \text{J} \\
&= 43.6\ \text{J} \\
W_T &= 44\ \text{J}
\end{aligned}
$$

Statement: The total mechanical work done on the bucket is 44 J.

(d) The net force acting on the bucket and the mechanical work done by the net force:

Solution:

$$
\begin{aligned}
F_{net} &= ma \\
&= (2.0\ \text{kg})(2.2\ \text{m/s}^2) \\
&= 4.40\ \frac{\text{kg•m}}{\text{s}^2} \\
&= 4.40\ \text{N} \\
F_{net} &= 4.4\ \text{N}
\end{aligned}
$$

$$
\begin{aligned}
W_{net} &= F_{net}\left(\cos\theta_{net}\right)\Delta d \\
&= (4.40\ \text{N})(\cos 0°)(9.9\ \text{m}) \\
&= 43.56\ \text{N•m} \\
&= 43.56\ \text{J} \\
W_{net} &= 44\ \text{J}
\end{aligned}
$$

Statement: The net force acting on the bucket is 4.4 N. The mechanical work done by the net force is 44 J. This is the same value calculated in (c).

8. (a) No mechanical work is done on a box sitting on a shelf. The box is not moving, so the net force is zero. If the net force is zero, then the work done is also zero.

(b) If an employee pulls on the box with a horizontal force and nothing happens, then no mechanical work is done. Since nothing happens, the displacement is zero. If the displacement is zero, then the work done is also zero.

(c) Initially, work is done on the box to get it moving. However, once the box is sliding down the frictionless rollers, the box is moving at a constant velocity. If the velocity is constant, then there is no acceleration. If there is no acceleration, the net force is zero. If the net force is zero, then the work done is also zero.

9. Given: F vs. Δd graph
Required: W_A; W_B; W_C; W_T
Analysis: W = area under F vs. Δd graph;
$W_T = W_A + W_B + W_C$
(a) The work done by the spring in sections A, B, and C:
Solution:

$$\begin{aligned} W_A &= \text{area under } F\Delta d \text{ graph (rectangle A)} \\ &= bh \\ &= (2\text{ m})(5\text{ N}) \\ &= 10\text{ N}\bullet\text{m} \\ W_A &= 10\text{ J} \end{aligned}$$

$$\begin{aligned} W_B &= \text{area under } F\Delta d \text{ graph (triangle B)} \\ &= \frac{bh}{2} \\ &= \frac{(1\text{ m})(5\text{ N})}{2} \\ &= 2.5\text{ N}\bullet\text{m} \\ W_B &= 2.5\text{ J} \end{aligned}$$

$$\begin{aligned} W_C &= \text{area under } F\Delta d \text{ graph (triangle C)} \\ &= \frac{bh}{2} \\ &= \frac{(1\text{ m})(-5\text{ N})}{2} \\ &= -2.5\text{ N}\bullet\text{m} \\ W_C &= -2.5\text{ J} \end{aligned}$$

Statement: The work done by the spring in sections A, B, and C is, respectively, 10 J, 2.5 J, and –2.5 J.

(b) The total work done by the spring:
Solution:

$$\begin{aligned} W_T &= W_A + W_B + W_C \\ &= 10\text{ J} + 2.5\text{ J} - 2.5\text{ J} \\ W_T &= 10\text{ J} \end{aligned}$$

Statement: The total work done by the spring is 10 J.
(c) The work done in section C must be negative because the force is negative. It is applied in the direction opposite to that of the motion.
10. The total work done on one object by another can be calculated by using the mechanical work equation, $W = F(\cos\theta)\Delta d$ or by calculating the area under the force vs. displacement graph.
11. (a) If a force is perpendicular to the displacement, then the angle is 90º. The cosine of 90º is zero, so the product of $F(\cos\theta)\Delta d$ is also zero.
(b) If a force acts opposite to the displacement, then the angle is 180º. The cosine of 180º is –1, so the product of $F(\cos\theta)\Delta d$ is also negative.

Section 5.2: Energy

Tutorial 1 Practice, page 231

1. Given: m = 70.0 kg; v = 12 m/s
Required: E_k
Analysis: $E_k = \frac{1}{2}mv^2$
Solution:

$$\begin{aligned} E_k &= \frac{mv^2}{2} \\ &= \frac{(70.0\text{ kg})(12\text{ m/s})^2}{2} \\ &= 5040\ \frac{\text{kg•m}^2}{\text{s}^2} \\ &= 5040\text{ J} \\ E_k &= 5.0\text{ kJ} \end{aligned}$$

Statement: The kinetic energy of the runner is 5.0 kJ.

2. Given: E_k = 4.2 J; v = 5.0 m/s
Required: m
Analysis: $E_k = \frac{1}{2}mv^2$
Solution:

$$\begin{aligned} E_k &= \frac{mv^2}{2} \\ m &= \frac{2E_k}{v^2} \\ &= \frac{2(4.2\text{ J})}{(5.0\text{ m/s})^2} \\ &= 0.336\ \frac{\text{J•s}^2}{\text{m}^2} \\ &= 0.336\text{ kg} \\ m &= 0.34\text{ kg} \end{aligned}$$

Statement: The mass of the cart is 0.34 kg.

3. Given: E_k = 30.0 J; m = 150 g = 0.15 kg
Required: v
Analysis: $E_k = \frac{1}{2}mv^2$
Solution:

$$\begin{aligned} E_k &= \frac{mv^2}{2} \\ v &= \sqrt{\frac{2E_k}{m}} \\ &= \sqrt{\frac{2(30.0\text{ J})}{0.15\text{ kg}}} \\ v &= 20\text{ m/s} \end{aligned}$$

Statement: The speed of the bird is 20 m/s (correct to two significant digits).

Tutorial 2 Practice, page 232

1. Given: m =1300 kg; v_i = 0 m/s; v_f = 14 m/s; Δd = 82 m
Required: W; F_{net}
Analysis: $W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$; $W_{net} = F_{net}\Delta d$

(a) Net work done on the car:
Solution:

$$\begin{aligned} W_{net} &= \frac{mv_f^2}{2} - \frac{mv_i^2}{2} \\ &= \frac{(1300\text{ kg})(14\text{ m/s})^2}{2} - \frac{(1300\text{ kg})(0\text{ m/s})^2}{2} \\ &= 127\ 400\ \frac{\text{kg•m}^2}{\text{s}^2} - 0 \\ &= 127\ 400\text{ J} \\ &= 127.4\text{ kJ} \\ W_{net} &= 130\text{ kJ} \end{aligned}$$

Statement: The net work done on the car is 130 kJ.

(b) Net force acting on the car:
Solution:

$$\begin{aligned} W_{net} &= F_{net}\Delta d \\ F_{net} &= \frac{W_{net}}{\Delta d} \\ &= \frac{127\ 400\text{ J}}{82\text{ m}} \\ &= 1553.6\text{ J/m} \\ &= 1554\text{ N} \\ F_{net} &= 1.6\times10^3\text{ N} \end{aligned}$$

Statement: The net force acting on the car is 1.6×10^3 N.

2. Given: m = 52 kg; v_i = 11 m/s; v_f = 0 m/s; Δd = 8.0 m
Required: F_{net}
Analysis: $W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$; $W_{net} = F_{net}\Delta d$

(a) The net force on the skater:
Solution:

$$\begin{aligned} W_{net} &= \frac{mv_f^2}{2} - \frac{mv_i^2}{2} \\ &= \frac{(52\text{ kg})(0\text{ m/s})^2}{2} - \frac{(52\text{ kg})(11\text{ m/s})^2}{2} \\ &= 0\ \frac{\text{kg•m}^2}{\text{s}^2} - 3146\ \frac{\text{kg•m}^2}{\text{s}^2} \\ &= -3146\text{ J} \\ W_{net} &= -3.146\text{ kJ} \end{aligned}$$

$$W_{net} = F_{net}\Delta d$$
$$F_{net} = \frac{W_{net}}{\Delta d}$$
$$= \frac{-3146 \text{ J}}{8.0 \text{ m}}$$
$$= -393.2 \text{ J/m}$$
$$= -393.2 \text{ N}$$
$$F_{net} = -3.9 \times 10^2 \text{ N}$$

Statement: The net force on the skater is -3.9×10^2 N.

(b) The net work done on the skater must be negative for these two reasons. First, the object is slowing down and losing kinetic energy. Since the change in kinetic energy is negative, the net work done must be negative. Second, the force of friction is causing the skater to slow down. Friction always acts in the direction opposing motion. Since the force and motion are in opposite directions, the net work done is negative. The net force works in a backwards direction.

Tutorial 3 Practice, page 234

1. Given: m = 58 kg; h_{top} = 6.0 m; $h_{landing}$ = 3.0 m; h_{ground} = 0 m; g = 9.8 N/kg; Ground is reference level for height.

Required: $E_{g\ top}$; $E_{g\ landing}$; $E_{g\ ground}$

Analysis: $E_g = mgh$

(a) Gravitational potential energy at top, landing, and ground level:

Solution:

$$E_{g\ top} = mgh_{top}$$
$$= (58 \cancel{\text{kg}})\left(9.8 \frac{\text{N}}{\cancel{\text{kg}}}\right)(6.0 \text{ m})$$
$$= 3410.4 \text{ N•m}$$
$$= 3410.4 \text{ J}$$
$$E_{g\ top} = 3400 \text{ J}$$

$$E_{g\ landing} = mgh_{landing}$$
$$= (58 \cancel{\text{kg}})\left(9.8 \frac{\text{N}}{\cancel{\text{kg}}}\right)(3.0 \text{ m})$$
$$= 1705.2 \text{ N•m}$$
$$= 1705.2 \text{ J}$$
$$E_{g\ landing} = 1700 \text{ J}$$

$$E_{g\ bottom} = mgh_{bottom}$$
$$= (58 \cancel{\text{kg}})\left(9.8 \frac{\text{N}}{\cancel{\text{kg}}}\right)(0 \text{ m})$$
$$E_{g\ bottom} = 0 \text{ J}$$

Statement: The gravitational potential energy at the top, landing, and bottom of stairs is, respectively, 3400 J, 1700 J, and 0 J.

(b) As you go down a flight of stairs, the gravitational potential energy decreases. As you climb a flight of stairs, the gravitational potential energy increases.

Section 5.2 Questions, page 235

1. Given: m = 610 kg; E_k = 40.0 kJ = 40 000 J

Required: v

Analysis: $E_k = \frac{1}{2}mv^2$

Solution: $E_k = \frac{1}{2}mv^2$

$$v = \sqrt{\frac{2E_k}{m}}$$
$$= \sqrt{\frac{2(40\ 000 \text{ J})}{610 \text{ kg}}}$$
$$= 11.45 \text{ m/s}$$
$$v = 11 \text{ m/s}$$

Statement: The speed of the bobsleigh is 11 m/s.

2. Given: m = 0.160 kg; v_i = 0 m/s; v_f = 22 m/s; Δd = 1.2 m

Required: E_k; F_{net}

Analysis:

$$E_k = \frac{1}{2}mv^2$$
$$F_{net} = ma$$
$$v_f^2 = v_i^2 + 2a\Delta d$$
$$W_{net} = E_{kf} - E_{ki}$$
$$W_{net} = F_{net}\Delta d$$

(a) The final kinetic energy of the puck:

Solution: $E_k = \frac{1}{2}mv^2$

$$= \frac{1}{2}(0.160 \text{ kg})(22 \text{ m/s})^2$$
$$= 38.72 \frac{\text{kg•m}^2}{\text{s}^2}$$
$$= 38.72 \text{ J}$$
$$E_k = 39 \text{ J}$$

Statement: The final kinetic energy of the puck is 39 J.

(b) The average net force on the puck using two different methods:
Solution:
Method 1:
Step 1. Calculate the acceleration using kinematics.

$$v_f^2 = v_i^2 + 2a\Delta d$$
$$a = \frac{v_f^2 - v_i^2}{2\Delta d} = \frac{(22\text{ m/s})^2 - (0\text{ m/s})^2}{(2)(1.2\text{ m})} = \frac{484\text{ m}^{\not{2}}/\text{s}^2}{2.4\not{\text{m}}}$$
$$a = 201.7\text{ m/s}^2$$

Step 2. Calculate the net force using Newton's second law of motion.

$$F_{net} = ma = (0.160\text{ kg})(201.7\text{ m/s}^2) = 32.27\ \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2} = 32.27\text{ N}$$
$$F_{net} = 32\text{ N}$$

Method 2:
Step 1. Calculate the net work done on the puck by calculating the change in kinetic energy.

$$W_{net} = \Delta E_k = E_{kf} - E_{ki} = 38.72\text{ J} - 0\text{ J}$$
$$W_{net} = 38.72\text{ J}$$

Step 2. Use the net work formula to calculate the net force.

$$W_{net} = F_{net}\Delta d$$
$$F_{net} = \frac{W_{net}}{\Delta d} = \frac{38.72\text{ J}}{1.2\text{ m}} = 32.27\text{ J/m}$$
$$F_{net} = 32\text{ N}$$

Statement: Using two different methods, the average net force on the puck is 32 N.

3. Given: m = 42 kg; v_i = 0 m/s; h_A = 16.0 m; h_D = 0 m; g = 9.8 N/kg
Required: E_{gA}; h_B; h_C; E_{gD}
Analysis: $E_g = mgh$
(a) The gravitational potential energy of the person at position A:
Solution:

$$E_{gA} = mgh_A = (42\not{\text{kg}})\left(9.8\ \frac{\text{N}}{\not{\text{kg}}}\right)(16.0\text{ m}) = 6585.6\text{ N}\bullet\text{m} = 6585.6\text{ J}$$
$$E_{gA} = 6.6\text{ kJ}$$

Statement: The gravitational potential energy of the person at position A is 6.6 kJ.
(b) The height above the ground of the person at position B:
Given: E_{gB} = 4500 J
Solution:

$$E_{gB} = mgh_B$$
$$h_B = \frac{E_{gB}}{mg} = \frac{4500\text{ J}}{(42\not{\text{kg}})\left(9.8\ \frac{\text{N}}{\not{\text{kg}}}\right)} = 10.93\text{ J/N}$$
$$h_B = 11\text{ m}$$

Statement: The height above the ground of the person at position B is 11 m.
(c) The height above the ground of the person at position C:
Given: $\Delta E_{g(\text{A to C})} = -4900$ J
Solution:
Step 1: Calculate the gravitational potential energy at position C.

$$\Delta E_{g(\text{A to C})} = E_{gC} - E_{gA}$$
$$E_{gC} = \Delta E_{g(\text{A to C})} + E_{gA} = -4900\text{ J} + 6585.6\text{ J}$$
$$E_{gC} = 1685.6\text{ J}$$

Step 2: Calculate the height at position C.

$$E_{gC} = mgh_C$$

$$h_C = \frac{E_{gC}}{mg}$$

$$= \frac{1685.6 \text{ J}}{(42 \not{\text{kg}})\left(9.8 \dfrac{\text{N}}{\not{\text{kg}}}\right)}$$

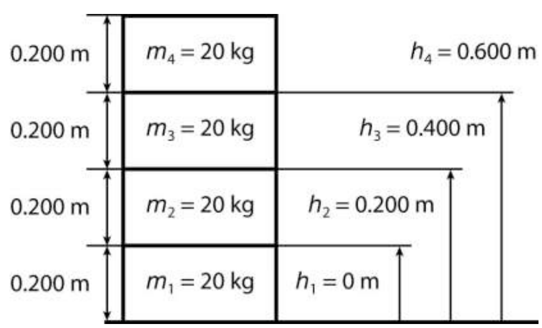
$$= 4.09 \text{ J/N}$$

$$h_C = 4.1 \text{ m}$$

Statement: At position C, the person is 4.1 m high.

(d) The person's gravitational potential energy at ground level at D: The person is at the ground level, which has been used as the reference level for gravitational potential energy. Therefore, the person's height is 0 m. So the gravitational potential energy at position D is 0 J.

4. Given: $m_{\text{block}} = 2.0$ kg; $g = 9.8$ N/kg;
$h_{\text{block}} = 20.0$ cm $= 0.200$ m; One row has 10 blocks.
$m_{\text{row}} = 10 \times m_{\text{block}} = 10 \times 2.0 \text{ kg} = 20 \text{ kg}$
There are 4 rows in total.
$m_1 = m_2 = m_3 = m_4 = m = 20$ kg; $h_{\text{row 1}} = 0$ m;
$h_{\text{row 2}} = 0.200$ m; $h_{\text{row 3}} = 0.400$ m; $h_{\text{row 4}} = 0.600$ m



Required: E_{gT}

Analysis: $E_g = mgh$;
$E_{gT} = E_{\text{row 1}} + E_{\text{row 2}} + E_{\text{row 3}} + E_{\text{row 4}}$

Solution:

$$E_{gT} = E_{\text{row 1}} + E_{\text{row 2}} + E_{\text{row 3}} + E_{\text{row 4}}$$

$$= m_1gh_1 + m_2gh_2 + m_3gh_3 + m_4gh_4$$

$$= (20 \not{\text{kg}})\left(9.8 \frac{\text{N}}{\not{\text{kg}}}\right)(0.200 \text{ m} + 0.400 \text{ m} + 0.600 \text{ m})$$

$$= 235.2 \text{ N}\bullet\text{m}$$

$$= 235.2 \text{ J}$$

$$E_{gT} = 240 \text{ J}$$

Statement: When the blocks are set in place, the gravitational potential energy stored in the wall is 240 J.

5. As the height of the basketball increases, its speed decreases, the kinetic energy decreases, and the gravitational potential energy increases. When the ball reaches its maximum height, it temporarily stops. Here, its gravitational potential energy is at the maximum and its kinetic energy is zero. As the ball begins to fall toward the ground, its speed increases so its kinetic energy increases, and its height decreases so its gravitational potential energy decreases. As it hits the floor, where the height is zero, the gravitational potential energy is zero and the speed and kinetic energy are at a maximum (and equal to its original value).

6. As the people in the drop tower ride are slowly pulled to the top,

- negative work is done on the people by gravity (acts in the direction opposite of motion)
- positive work is done on the people by the chains lifting the car (acts in the direction of motion)
- their gravitational potential energy increases because their height increases
- their kinetic energy remains constant if they are pulled up at a constant velocity

When the riders reach the top,

- their kinetic energy is zero because they are temporarily stopped
- their gravitational energy is at a maximum because they are at their highest point

Immediately after the riders are released,

- there is positive work done on the people by gravity (acts in the direction of motion)
- their gravitational potential energy decreases because their height decreases
- their kinetic energy increases as they speed up on the way down

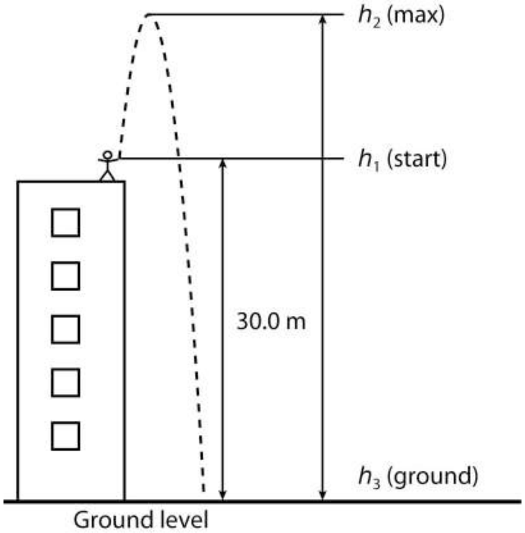
As the riders are safely slowed at the bottom by the braking system,

- there is positive work done on the people by gravity (acts in the direction of motion)
- there is negative work done on the people by the braking system (acts in the direction opposite of motion)
- their kinetic energy decreases as the braking system slows them down
- their gravitational potential energy decreases because their height decreases

Section 5.3: Types of Energy and the Law of Conservation of Energy

Tutorial 1 Practice, page 241

1. Given: m = 0.20 kg; h_1 = 30.0 m; v_1 = 22.0 m/s; h_3 = 0 m; g = 9.8 N/kg;
Ground is reference level for height.



Required: E_m, total energy of the ball at start (h_1); h_2 (maximum height); v_2, velocity at h_2 (maximum height); v_3, velocity at h_3 (ground level);

Analysis: E_m = constant; $E_g = mgh$; $E_k = \frac{1}{2}mv^2$;

$E_m = E_g + E_k$

(a) The total energy of the ball at start (h_1):

Solution:

$$\begin{aligned} E_m &= E_g + E_k \\ &= mgh_1 + \frac{mv_1^2}{2} \\ &= (0.20\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(30.0\ \text{m}) \\ &\quad + \frac{(0.20\ \text{kg})(22.0\ \text{m/s})^2}{2} \\ &= 58.8\ \text{N•m} + 48.4\ \frac{\text{kg•m}^2}{\text{s}^2} \\ &= 58.8\ \text{J} + 48.4\ \text{J} \\ &= 107.2\ \text{J} \\ E_m &= 110\ \text{J} \end{aligned}$$

Statement: The total energy of the ball at the start was 110 J.

(b) Total energy of ball at its maximum height (h_2):

Solution: At its maximum height, the upward velocity of the ball is zero (v_2 = 0 m/s) because it has temporarily stopped before it begins falling to the ground. However, the total energy of the ball remains constant.

$$\begin{aligned} E_m &= E_g + E_k \\ &= mgh_2 + \frac{mv_2^2}{2} \\ E_m &= mgh_2 + 0 \\ E_m &= mgh_2 \\ h_2 &= \frac{E_m}{mg} \\ &= \frac{107.2\ \text{J}}{(0.20\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)} \\ &= 54.69\ \text{m} \\ h_2 &= 55\ \text{m} \end{aligned}$$

Statement: The upward velocity of the ball at the maximum height is 0 m/s. The maximum height of the ball occurs at the upward point where its velocity is 0 m/s. This point occurs at 55 m.

(c) Velocity of the ball when it hits the ground (h_3):

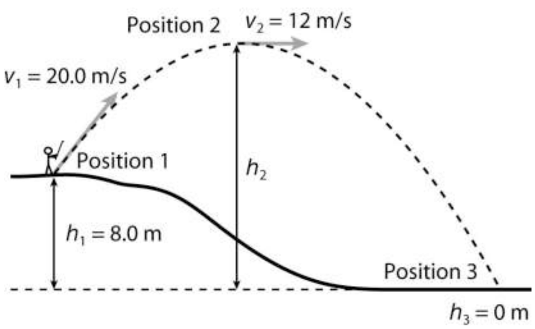
Solution: At ground level, the height of the ball is zero (h_3 = 0 m). At this point, its gravitational potential energy is also zero. However, the total energy of the ball remains constant.

$$\begin{aligned} E_m &= E_g + E_k \\ &= mgh_3 + \frac{mv_3^2}{2} \\ &= 0 + \frac{mv_3^2}{2} \\ E_m &= \frac{mv_3^2}{2} \\ v_3 &= \sqrt{\frac{2E_m}{m}} \\ &= \sqrt{\frac{2(107.2\ \text{J})}{0.20\ \text{kg}}} \\ &= \sqrt{1072\ \text{J/kg}} \\ &= 32.74\ \text{m/s} \\ v_3 &= 33\ \text{m/s} \end{aligned}$$

Statement: The velocity of the ball is 33 m/s as it hits the ground.

Section 5.3 Questions, page 241

1. (a) At the top of the building, the ball has gravitational energy. As it falls, the energy is converted to kinetic energy.
(b) Chemical energy is stored in the archer's arm. Elastic energy is stored in the bow and bowstring. As the arrow is released, both types of energy are converted to kinetic energy and transferred to the arrow.
(c) Chemical energy is stored in the fireworks. When the fireworks are lit, the chemical energy is converted to radiant energy (light), sound energy, and thermal energy (heat).
(d) Electrical energy (moving electrons) is transferred to the bulb with it is turned on. The electrical energy is converted to radiant energy (light) and thermal energy (heat).
(e) Chemical energy is stored in the gasoline. When the lawnmower is turned on, the chemical energy is converted to kinetic energy (moving parts), sound energy, thermal energy (heat), and electrical energy (spark plug).
2. Given: m = 45.9 g = 0.0459 kg; h_1 = 8.0 m; v_1 = 20.0 m/s; v_2 = 12 m/s; g = 9.8 N/kg; h_3 = 0 m



Required: E_m; h_2; v_3
Analysis: $E_m = E_k + E_g$; $E_k = \frac{1}{2} mv^2$; $E_g = mgh$; E_m = constant
(a) The total mechanical energy at the start (at position 1):
Solution:

$$\begin{aligned}E_m &= E_k + E_g \\ &= \frac{1}{2}mv^2 + mgh \\ &= \frac{1}{2}(0.0459\text{ kg})(20.0\text{ m/s})^2 \\ &\quad + (0.0459\text{ kg})\left(9.8\ \frac{\text{N}}{\text{kg}}\right)(8.0\text{ m}) \\ &= 9.18\ \frac{\text{kg•m}^2}{\text{s}^2} + 3.60\text{ N•m} \\ &= 12.78\text{ J} \\ E_m &= 13\text{ J}\end{aligned}$$

Statement: The total mechanical energy of the ball at the start is 13 J.
(b) The maximum height of the ball above the green (at position 2):
Solution:

$$\begin{aligned}E_m &= E_k + E_g \\ &= \frac{1}{2}mv^2 + mgh_2 \\ mgh_2 &= E_m - \frac{1}{2}mv^2 \\ h_2 &= \frac{2E_m - mv^2}{2mg} \\ &= \frac{2(12.78\text{ J}) - (0.0459\text{ kg})(12\text{ m/s})^2}{2(0.0459\text{ kg})\left(9.8\ \frac{\text{N}}{\text{kg}}\right)} \\ &= 21.06\text{ m} \\ h_2 &= 21\text{ m}\end{aligned}$$

Statement: The maximum height of the ball above the green is 21 m.
(c) The speed of the ball when it strikes the green (at position 3):
Solution:

$$\begin{aligned}E_m &= E_k + E_g \\ &= \frac{1}{2}mv_3^2 + mgh_3 \\ &= \frac{1}{2}mv_3^2 + 0 \\ v_3 &= \sqrt{\frac{2E_m}{m}} \\ &= \sqrt{\frac{2(12.78\text{ J})}{0.0459\text{ kg}}} \\ &= 23.60\text{ m/s} \\ v_3 &= 24\text{ m/s}\end{aligned}$$

Statement: The speed of the ball when it strikes the green is 24 m/s.

3. Given: position 1 = top of first hill; position 2 = top of loop; v_1 = 0 m/s; v_2 = 10.0 m/s; h_2 = 16 m; g = 9.8 N/kg

Required: h_1, height of first hill

Analysis: $E_m = E_k + E_g$; $E_k = \frac{1}{2}mv^2$; $E_g = mgh$; E_m = constant

Solution:

$$E_{m1} = E_{m2}$$
$$E_{k1} + E_{g1} = E_{k2} + E_{g2}$$
$$\frac{1}{2}\cancel{m}v_1^2 + \cancel{m}gh_1 = \frac{1}{2}\cancel{m}v_2^2 + \cancel{m}gh_2$$
$$v_1 = 0 \text{ m/s}$$
$$gh_1 = \frac{1}{2}v_2^2 + gh_2$$
$$2gh_1 = v_2^2 + 2gh_2$$
$$h_1 = \frac{v_2^2 + 2gh_2}{2g}$$
$$h_1 = \frac{(10.0 \text{ m/s})^2 + 2(9.8 \text{ N/kg})(16 \text{ m})}{2(9.8 \text{ N/kg})}$$
$$= 21.10 \text{ m}$$
$$h_1 = 21 \text{ m}$$

Statement: The minimum height of the first hill must be 21 m.

4. (a) Given: v_i = 0 m/s; $v_f = v$

Solution:

$$v_f^2 = v_i^2 + 2a\Delta d$$
$$v^2 = 0 + 2a\Delta d$$
$$v^2 = 2a\Delta d$$

(b) Given: $v^2 = 2a\Delta d$; $E_k = \frac{1}{2}mv^2$

Solution:

$$E_k = \frac{mv^2}{2}$$
$$= \frac{m(\cancel{2}a\Delta d)}{\cancel{2}}$$
$$= ma\Delta d$$
$$= F_{net}\Delta d$$
$$E_k = W_{net}$$

Statement: This result shows that the final kinetic energy of an object is equal to the net work done on the object if it starts at rest.

Section 5.4: Efficiency, Energy Sources, and Energy Conservation

Tutorial 1 Practice, page 243

1. Given: E_{in} = 5200 J; m = 50.0 kg; h = 4.0 m; g = 9.8 N/kg
Required: efficiency
Analysis: $E_g = mgh$; $E_{out} = E_g$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

Solution:

$$\begin{aligned} E_g &= mgh \\ &= (50.0\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(4.0\ \text{m}) \\ E_g &= 1960\ \text{J} \\ E_{out} &= 1960\ \text{J} \end{aligned}$$

$$\begin{aligned} \text{efficiency} &= \frac{E_{out}}{E_{in}} \times 100\ \% \\ &= \frac{1960\ \cancel{\text{J}}}{5200\ \cancel{\text{J}}} \times 100\ \% \\ &= 37.69\ \% \\ \text{efficiency} &= 38\ \% \end{aligned}$$

Statement: The efficiency of the forklift is 38 %.

2. Given: m = 1250 kg; h = 1.8 m; F_a = 5500 N; Δd = 12.6 m
Required: E_{out}; E_{in}; efficiency
Analysis: $E_g = mgh$; $E_{out} = E_g$; $W = F\Delta d$; $W = E_{in}$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

(a) E_g, amount of useful energy produced:
Solution:

$$\begin{aligned} E_g &= mgh \\ &= (1250\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(1.8\ \text{m}) \\ &= 22\ 050\ \text{N•m} \\ &= 22\ 050\ \text{J} \\ E_g &= 22\ \text{kJ} \end{aligned}$$

Statement: The amount of useful energy produced is 22 kJ.

(b) E_{in}, amount of energy used to pull the car from the ditch:
Solution:

$$\begin{aligned} W &= F\Delta d \\ &= (5500\ \text{N})(12.6\ \text{m}) \\ &= 69\ 300\ \text{N•m} \\ &= 69\ 300\ \text{J} \\ W &= 69\ \text{kJ} \\ E_{in} &= 69\ \text{kJ} \end{aligned}$$

Statement: The amount of energy used to pull the car from the ditch is 69 kJ.

(c) The percent efficiency:
Solution:

$$\begin{aligned} \text{efficiency} &= \frac{E_{out}}{E_{in}} \times 100\ \% \\ &= \frac{22\ 050\ \cancel{\text{J}}}{69\ 300\ \cancel{\text{J}}} \times 100\ \% \\ &= 31.82\ \% \\ \text{efficiency} &= 32\ \% \end{aligned}$$

Statement: The efficiency is 32 %. In any process, there is always some energy lost to friction, which is converted to thermal energy. Therefore, the percent efficiency is less than 100 %.

Section 5.4 Questions, page 249

1. Given: m = 54 kg; v_i = 0 m/s; v_f = 11 m/s; efficiency = 85 %
Required: E_{in}
Analysis: $E_{out} = \Delta E_k$; $E_k = \frac{1}{2}mv^2$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

Solution:

$$\begin{aligned} E_{out} &= \Delta E_k \\ &= E_{kf} - E_{ki} \\ &= \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \\ &= \frac{1}{2}(54\ \text{kg})(11\ \text{m/s})^2 - 0 \\ &= 3267\ \frac{\text{kg•m}^2}{\text{s}^2} \\ E_{out} &= 3267\ \text{J} \end{aligned}$$

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

$$\begin{aligned} E_{in} &= \frac{E_{out} \times 100\ \%}{\text{efficiency}} \\ &= \frac{3267\ \text{J} \times 100\ \%}{85\ \%} \\ &= 3843.5\ \text{J} \\ E_{in} &= 3800\ \text{J} \end{aligned}$$

Statement: The athlete provided an energy of 3800 J.

2. (a) The efficiency of the skier:

Given: $v_i = 0$ m/s; $h_i = 65$ m; $v_f = 23$ m/s; $h_f = 0$ m; $g = 9.8$ N/kg

Required: efficiency

Analysis: $E_{in} = E_g$; $E_{out} = \Delta E_k$; $E_g = mgh$; $E_k = \frac{1}{2}mv^2$; $\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$

Solution:

$$\begin{aligned} \text{efficiency} &= \frac{E_{out}}{E_{in}} \times 100\ \% \\ &= \frac{E_k}{E_g} \times 100\ \% \\ &= \frac{\frac{1}{2}\cancel{m}v_f^2}{\cancel{m}gh} \times 100\ \% \\ &= \frac{v_f^2}{2gh} \times 100\ \% \\ &= \frac{(23\ \text{m/s})^2 \times 100\ \%}{2(9.8\ \text{N/kg})(65\ \text{m})} \\ &= 41.52\ \% \\ \text{efficiency} &= 42\ \% \end{aligned}$$

Statement: The efficiency of the skier is 42 %.

(b) Both the kinetic energy and gravitational energy are proportional to the mass, so the mass of the skier can be divided out. Therefore, the mass of the skier travelling down the slope does not affect the efficiency of the skis.

3. Given: $E_{in} = 65$ J (from the golf club); efficiency = 20 %; $m = 46$ g = 0.046 kg

Required: v_i

Analysis: $E_k = \frac{1}{2}mv_i^2$; $E_{out} = E_k$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

Solution:

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

$$\begin{aligned} E_{out} &= \frac{\text{efficiency} \times E_{in}}{100\ \%} \\ &= \frac{20\ \% \times 65\ \text{J}}{100\ \%} \\ E_{out} &= 13\ \text{J} \end{aligned}$$

$$\begin{aligned} E_k &= \frac{1}{2}mv_i^2 \\ v_i &= \sqrt{\frac{2E_k}{m}} \\ &= \sqrt{\frac{2E_{out}}{m}} \\ &= \sqrt{\frac{2\ (13\ \text{J})}{0.046\ \text{kg}}} \\ &= 23.77\ \text{m/s} \\ v_i &= 24\ \text{m/s} \end{aligned}$$

Statement: The initial speed of the ball after being struck is 24 m/s.

4. Answers may vary. Sample answers:

(a) Some advantages of non-renewable energy resources are that they are relatively inexpensive, easy to access, easy to store, and easy to transport. Some disadvantages are that they will run out eventually and they contribute to pollution, the greenhouse effect, and acid rain.

(b) Some advantages of renewable energy resources are that they last forever and have low emissions and pollutants. Some disadvantages are the high costs for start-up and maintenance and that the energy they provide is not consistent.

5.

	Nuclear power plants	**Hydroelectric power plants**
efficiency	30 % to 40 %	80 %
method of generating electricity	thermal energy produced by nuclear reaction heats water and creates steam to turn turbines and generators	falling or moving water turns turbines and generators
energy transformations	nuclear energy is converted to electrical energy	kinetic energy (moving water) is converted to electrical energy
environmental impact	produces radioactive waste; entirely safe method of disposing of spent nuclear fuel unknown at present	damming rivers may flood land and disrupt ecosystems

6. Answers may vary. Sample answer:
Fossil fuels should not be considered a renewable energy source because the time span needed to generate the fuels from the decaying matter is millions of years. This is well beyond the lifespan of our current civilization, so these fuels cannot be renewed through natural processes in time for our current generation to benefit from them.

7. Passive solar design is used strictly for heating and cooling purposes. The radiant energy from the Sun is converted to thermal energy, which can be used to heat spaces. Some designs place deciduous trees on the side of the building that gets the most sunlight. In the winter, when deciduous trees lose their leaves, the Sun's energy enters the building and heats the interior spaces. In the summer, when the trees have their leaves, the leaves shade the interior spaces from sunlight so that they remain cooler.
Photovoltaic cells, or solar cells, use light-sensitive materials to convert the Sun's radiant energy directly to electrical energy. The solar cells create an electric current when the Sun shines on them. This electric current can be used immediately for lighting and running appliances, or the solar cells can be connected to batteries to store the energy for use during the night or on cloudy days.

Section 5.5: Power

Tutorial 1 Practice, page 251

1. Given: $P = 0.50$ kW $= 5.0 \times 10^2$ W; $W = 1200$ J

Required: Δt

Analysis: $P = \dfrac{W}{\Delta t}$

Solution:

$$\begin{aligned} P &= \frac{W}{\Delta t} \\ \Delta t &= \frac{W}{P} \\ &= \frac{1200\text{ J}}{500\text{ W}} \\ &= 2.4\text{ J/W} \\ \Delta t &= 2.4\text{ s} \end{aligned}$$

Statement: It would take the motor 2.4 s to do 1200 J of work.

2. Given: $m = 55$ kg; $h_{start} = 850$ m; $h_{finish} = 2400$ m; $g = 9.8$ N/kg

$$\begin{aligned} \Delta t &= 3\text{ h} \\ &= 3\text{ h} \times \frac{60\text{ min}}{1\text{ h}} \times \frac{60\text{ s}}{1\text{ min}} \end{aligned}$$

$\Delta t = 1.08 \times 10^4$ s (one extra digit carried)

Assume heights and time are accurate to two significant digits.

Required: P

Analysis:

$$\begin{aligned} E &= mgh \\ P &= \frac{\Delta E}{\Delta t} \\ &= \frac{E_{\text{g finish}} - E_{\text{g start}}}{\Delta t} \\ &= \frac{mgh_{\text{finish}} - mgh_{\text{start}}}{\Delta t} \end{aligned}$$

Solution:

$$\begin{aligned} P &= \frac{mgh_{\text{finish}} - mgh_{\text{start}}}{\Delta t} \\ &= \frac{(55\text{ kg})\left(9.8\frac{\text{N}}{\text{kg}}\right)(2400\text{ m}) - (55\text{ kg})\left(9.8\frac{\text{N}}{\text{kg}}\right)(850\text{ m})}{1.08 \times 10^4\text{ s}} \\ &= 77.36\ \frac{\text{N}\bullet\text{m}}{\text{s}} \\ &= 77.36\text{ W} \\ P &= 77\text{ W} \end{aligned}$$

Statement: The average power of the climber is 77 W.

3. Given: $m = 60.0$ kg; $v_i = 0$ m/s; $v_f = 12$ m/s; $\Delta t = 6.0$ s

Required: P

Analysis: $E_k = \dfrac{mv^2}{2}$; $P = \dfrac{\Delta E}{\Delta t}$

Solution:

$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ &= \frac{E_{\text{k (finish)}} - E_{\text{k (start)}}}{\Delta t} \\ &= \frac{\frac{mv_f^2}{2} - \frac{mv_i^2}{2}}{\Delta t} \\ &= \frac{mv_f^2}{2\Delta t} - 0 \\ &= \frac{(60.0\text{ kg})(12\text{ m/s})^2}{2(6.0\text{ s})} \\ &= 720\text{ J/s} \\ P &= 720\text{ W} \end{aligned}$$

Statement: The person's power is 720 W.

Mini Investigation: Human Power, page 251

A. Answers may vary. Sample answer:

Given: $m = 63$ kg; $\Delta d = 2.00$ m; $\Delta t = 9.0$ s; $g = 9.8$ m/s^2

Required: P

Analysis: $P = \dfrac{\Delta E}{\Delta t}$; $F_g = mgh$

Solution:

$$\begin{aligned} \Delta E &= F_f - F_i \\ &= mgh - 0 \\ \Delta E &= mgh \end{aligned}$$

$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ &= \frac{mgh}{\Delta t} \\ &= \frac{mg\Delta d}{\Delta t} \\ &= \frac{(63\text{ kg})(9.8\text{ m/s})(2.0\text{ m})}{9.0\text{ s}} \\ &= 1.4 \times 10^2\text{ W} \end{aligned}$$

Statement: The average power produced by walking slowly is 1.4×10^2 W.

B. Given: m = 63 kg; Δd = 2.00 m; Δt = 5.5 s; g = 9.8 m/s^2

Required: P

Analysis: $P = \dfrac{\Delta E}{\Delta t}$; $F_g = mgh$

Solution: From A:

$$P = \frac{mg\Delta d}{\Delta t}$$
$$= \frac{(63 \text{ kg})(9.8 \text{ m/s})(2.0 \text{ m})}{5.5 \text{ s}}$$
$$= 2.2 \times 10^2 \text{ W}$$

Statement: The average power produced by walking slowly is 2.2×10^2 W.

C. My partner's power was greater when walking up the stairs quickly because he had to exert more energy to walk more quickly.

D. Answers may vary. Sample answer:
If you assume the 100 W bulb is on for approximately 5 s before it gets hot, the power it uses is 1.1×10^2 W. Walking quickly produces the most power because you needs lots of energy to for a quick speed. You need energy to power your muscles. In a bulb, you need power (electricity) to heat a very small, thin metal filament for light. This amount of power you would need is very small relative to your leg muscles.

Tutorial 2 Practice, page 252

1. Given: P = 3100 MW = 3.1×10^9 W;

$$\Delta t = 1 \text{ day}$$
$$= 1\cancel{\text{day}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}} \times \frac{60 \text{ s}}{1\ \cancel{\text{min}}}$$
$$\Delta t = 86\ 400 \text{ s}$$

Required: ΔE

Analysis: $P = \dfrac{\Delta E}{\Delta t}$

Solution: $P = \dfrac{\Delta E}{\Delta t}$

$$\Delta E = P\Delta t$$
$$= (3.1 \times 10^9 \text{ W})(86\ 400 \text{ s})$$
$$= 2.678 \times 10^{14} \text{ W•s}$$
$$= 2.678 \times 10^{14} \text{ J}$$
$$= 2.678 \times 10^8 \text{ MJ}$$
$$\Delta E = 2.7 \times 10^8 \text{ MJ}$$

Statement: The generating station can produce 2.7×10^8 MJ of energy in one day.

Tutorial 3 Practice, page 253

1. Given: $P_{\text{incand}} = \dfrac{100 \text{ W}}{\cancel{\text{bulb}}} \times 20\ \cancel{\text{bulbs}}$

$$= 2000 \text{ W}$$
$$P_{\text{incand}} = 2.0 \text{ kW}$$

P_{CFL} = 23 W/bulb; rate = 6.0¢/kWh;

$$\Delta t = 1\ \cancel{\text{year}} \times \frac{365\ \cancel{\text{days}}}{1\ \cancel{\text{year}}} \times \frac{12 \text{ h}}{1\ \cancel{\text{day}}}$$
$$\Delta t = 4380 \text{ h}$$

Assume two significant digits in power rating.

Required: ΔE, total energy; total cost; savings using CFLs

Analysis: $P = \dfrac{\Delta E}{\Delta t}$; cost = $\Delta E \times$ rate

(a) The total amount of energy used by all the bulbs in the year:

Solution:

$$P = \frac{\Delta E}{\Delta t}$$
$$\Delta E = P\Delta t$$
$$= (2.0 \text{ kW})(4380 \text{ h})$$
$$\Delta E = 8760 \text{ kWh}$$

Statement: The total amount of energy used by all the bulbs is 8800 kWh.

(b) Cost of lighting the store for the year:

Solution:

$$\text{cost} = \Delta E \times \text{rate}$$
$$= (8760\ \cancel{\text{kWh}})\left(6.0 \frac{¢}{\cancel{\text{kWh}}}\right)$$
$$= 52\ 560¢$$
$$= \$525.60$$
$$\text{cost} = \$530$$

Statement: It costs $530 to light the store for the year.

(c) Money saved by using CFLs instead of incandescent bulbs:

Solution: This can be solved by using a simple ratio to compare the costs based on the power of the two types of bulbs. The difference in costs is the savings.

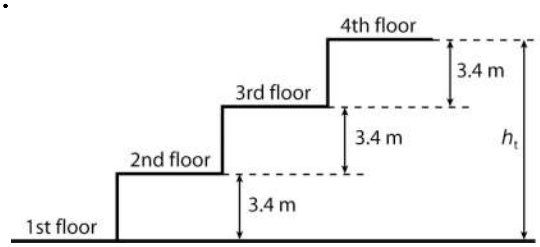
$$\frac{\text{cost}_{\text{CFL}}}{\text{cost}_{\text{incand}}} = \frac{P_{\text{CFL}}}{P_{\text{incand}}}$$
$$\text{cost}_{\text{CFL}} = \text{cost}_{\text{incand}} \times \frac{P_{\text{CFL}}}{P_{\text{incand}}}$$
$$= \$525.60 \times \frac{23 \text{ W}}{100 \text{ W}}$$
$$\text{cost}_{\text{CFL}} = \$120.89$$

$$\begin{aligned}\text{savings} &= \text{cost}_{\text{incand}} - \text{cost}_{\text{CFL}} \\ &= \$525.60 - \$120.89 \\ &= \$404.71\end{aligned}$$
$\text{savings} = \$400$

Statement: Using CFLs creates a total savings of \$400 (correct to two significant digits) for the year.

Section 5.5 Questions, page 254

1.



Given: m = 54 kg; h_{floor} = 3.4 m; g = 9.8 N/kg; h_{ground} = 0 m; Δt = 32 s

Required: E_g; P

Analysis: $E_g = mgh$; $P = \dfrac{W}{\Delta t}$; $W = \Delta E_g$;

$\Delta E_g = E_{\text{g at top}} - E_{\text{g at ground}}$; $h_{\text{Total}} = 3 \times h_{\text{floor}}$

(a) Gravitational potential energy at the top of the climb:

Solution:

$$\begin{aligned}\Delta E_g &= E_{\text{g at top}} - E_{\text{g at ground}} \\ &= mgh_{\text{Total}} - mgh_{\text{at ground}} \\ &= mg(3h_{\text{floor}}) - 0 \\ &= (54 \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(3)(3.4\ \text{m}) \\ &= 5397.8\ \text{N}\bullet\text{m}\end{aligned}$$
$\Delta E_g = 5400$ J

Statement: The person's gravitational energy at the top is 5400 J.

(b) The power of the person for the climb:

Solution:

$$\begin{aligned}P &= \frac{W}{\Delta t} \\ &= \frac{E_g}{\Delta t} \\ &= \frac{5397.8\ \text{J}}{32\ \text{s}} \\ &= 168.7\ \text{J/s}\end{aligned}$$
$P = 170$ W

Statement: The person's power output is 170 W.

(c) If a lighter person climbed the stairs in the same amount of time, the power output would be lower. Since the person's mass is lower, the amount of gravitational energy acquired would be lower (gravitational energy is proportional to mass). Then less work would be done in the same amount of time and a lower power output would result.

2. Given: m = 65 kg; g = 9.8 N/kg; h_{top} = 5.0 m; h_{ground} = 0 m; v = 1.4 m/s

Required: Δt; P

Analysis: $v = \dfrac{\Delta d}{\Delta t}$; $P = \dfrac{W}{\Delta t}$; $W = \Delta E_g$;

$\Delta E_g = E_{\text{g at top}} - E_{\text{g at ground}}$; $E_g = mgh$

(a) The time it takes the student to climb the rope and the student's power:

Solution:

$$\begin{aligned}v &= \frac{\Delta d}{\Delta t} \\ \Delta t &= \frac{\Delta d}{v} \\ &= \frac{5.0\ \cancel{\text{m}}}{1.4\ \cancel{\text{m}}/\text{s}} \\ &= 3.57\ \text{s}\end{aligned}$$
$\Delta t = 3.6$ s

$$\begin{aligned}\Delta E_g &= E_{\text{g at top}} - E_{\text{g at ground}} \\ &= mgh_{\text{Total}} - mgh_{\text{ground}} \\ &= (65 \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)(5.0\ \text{m}) - 0 \\ &= 3185\ \text{N}\bullet\text{m}\end{aligned}$$
$\Delta E_g = 3185$ J

$$\begin{aligned}P &= \frac{W_{\text{net}}}{\Delta t} \\ &= \frac{\Delta E_g}{\Delta t} \\ &= \frac{3185\ \text{J}}{3.57\ \text{s}} \\ &= 892.2\ \text{J/s} \\ &= 892.2\ \text{W}\end{aligned}$$
$P = 890$ W

Statement: It takes 3.6 s for the student to climb the rope and the student's power is 890 W.

(b) The student's power without finding the time:
Solution:

$$\begin{aligned} P &= \frac{W_{net}}{\Delta t} \\ &= \frac{\Delta E_g}{\Delta t} \\ &= \frac{mgh}{\Delta t}\ (h = \Delta d) \\ &= \frac{mg\Delta d}{\Delta t}\left(v = \frac{\Delta d}{\Delta t}\right) \\ &= mgv \\ &= (65\ \cancel{\text{kg}})\left(9.8\ \frac{\text{N}}{\cancel{\text{kg}}}\right)\left(1.4\ \frac{\text{m}}{\text{s}}\right) \\ &= 891.8\ \frac{\text{N}\bullet\text{m}}{\text{s}} \\ &= 891.8\ \text{J/s} \\ P &= 890\ \text{W} \end{aligned}$$

Statement: The student's power is 890 W. Since the height climbed is the distance travelled at a constant speed, the simple kinematics formula can be substituted into the equation, as shown above.

3. (a) In order to calculate power, the amount of work done and the time taken is needed. In this case, you could measure the time taken (in seconds) for the mass to be lifted at a constant speed. Knowing the mass of the object (in kilograms), you could calculate the change in gravitational energy of the object using $E_g = mgh$, which is equivalent to the work done on the object. Then using the power formula, $P = \frac{W_{net}}{\Delta t}$, the power could be calculated. (In this case, since the speed is constant, there is no change in kinetic energy so no corresponding work done to change it.)

(b) In this case, since the speed is no longer constant, there is a change in kinetic energy and some corresponding work done to change the speed. As the object is being pulled up, both its gravitational and kinetic energy increase. In order to calculate the student's power in this case, the change in gravitational energy and the change in kinetic energy must be taken into account. The change in gravitational energy is calculated in the same way as in part (a). In order to calculate the change in kinetic energy, we must find the object's final speed and use the equation $E_k = \frac{1}{2} mv^2$ to calculate the additional work done. The power can then be calculated by finding the total work done (add ΔE_g and ΔE_k) and the total time taken using $P = \frac{W_{net}}{\Delta t}$.

4. (a) The amount of solar energy transformed into electrical energy each day:
Given: P_{panel} = 600 W; number of panels = 10; Δt = 4.5 h
Required: E_{Total}
Analysis: $P_{Total} = \frac{\Delta E_{Total}}{\Delta t}$ P_{Total}; $P_{Total} = 10\ P_{panel}$
Solution:

$$\begin{aligned} P_{Total} &= \frac{\Delta E_{Total}}{\Delta t} \\ \Delta E_{Total} &= P_{Total}\,\Delta t \\ &= (10P_{panel})\Delta t \\ &= (10)(600\ \text{W})(4.5\ \text{h}) \\ &= 27\ 000\ \text{Wh} \\ \Delta E_{Total} &= 27\ \text{kWh (in one day)} \end{aligned}$$

Statement: The solar panels will produce 27 kWh of energy in one day.

(b) The amount of money saved in a year on the electrical energy bill:
Given: E_{day} = 27 kWh; Δt = 365 days; rate = 5.5¢/kWh
Required: cost savings
Analysis: $E_{year} = E_{day} \times$ 365 days/year;
cost savings = rate × E_{year}
Solution:

$$\begin{aligned} E_{year} &= E_{day} \times \frac{365\ \text{days}}{\text{year}} \\ &= \frac{27\ \text{kWh}}{\cancel{\text{day}}} \times \frac{365\ \cancel{\text{days}}}{\text{year}} \\ E_{year} &= 9855\ \text{kWh/year} \end{aligned}$$

$$\begin{aligned} \text{cost savings} &= \text{rate} \times \text{energy} \\ &= \left(5.5\ \frac{¢}{\cancel{\text{kWh}}}\right)\left(9855\ \frac{\cancel{\text{kWh}}}{\text{year}}\right) \\ &= 54\ 202.5\ ¢/\text{year} \\ &= \$542.03/\text{year} \\ \text{cost savings} &= \$540\ /\ \text{year} \end{aligned}$$

Statement: This family will save $540 per year in electrical energy costs.

(c) Given: number of persons, $n = 5$; consumption, $E = 2$ kWh/person/day
Required: energy consumption of family in one day, E_{family}
Analysis: $E_{\text{family}} = E \times n$
Solution: In one day,

$$\begin{aligned} E_{\text{family}} &= E \times n \\ &= (2)\frac{\text{kWh}}{\cancel{\text{person}}} \times 5\ \cancel{\text{persons}} \\ &= 10\ \text{kWh} \end{aligned}$$

The solar panels produce 27 kWh per day, which is more than enough to supply the family's needs.
Statement: The family should not have to buy additional electricity. They could sell the excess energy back to their energy supplier on full-production days. (However, on cloudy days, when the solar panels are not creating electrical energy, they would still need to purchase energy from the supplier.)

5. Given: 1 kW
Required: Show 1 kW = 3.6 MJ.
Analysis: Covert hours to seconds. Convert watts to joules. Convert kilowatt hours to Joules. Convert joules to megajoules.
Solution:

$$1\ \text{kW} = 1000\ \text{W}$$

$$\begin{aligned} 1\ \text{kWh} &= 1000\ \text{Wh} \\ &= 1000\text{W}\cancel{\text{h}} \times \frac{3600\ \text{s}}{1\ \cancel{\text{h}}} \\ &= 3\ 600\ 000\ \text{Ws} \end{aligned}$$

$$1\ \text{W} = 1\ \text{J/s}$$

$$\begin{aligned} 1\ \text{kWh} &= 3\ 600\ 000\ \frac{\text{J}}{\cancel{\text{s}}}\cancel{\text{s}} \\ &= 3\ 600\ 000\ \text{J} \end{aligned}$$

$$1\ 000\ 000\ \text{J} = 1\ \text{MJ}$$

$$1\ \text{kWh} = 3.6\ \text{MJ}$$

Statement: This shows 1 kW = 3.6 MJ.

Chapter 5 Review, pages 262–267

Knowledge

1. (d)
2. (c)
3. (a)
4. (b)
5. (c)
6. False. Mechanical work is calculated by multiplying the magnitude of a force times the *displacement of the object to which* it is applied.
7. True
8. False. Gravitational energy is a form of *potential* energy.
9. False. Energy, work, and time are scalar quantities, *which means that power can also be described as a scalar quantity.*
10. (a) (iii)
(b) (iv)
(c) (ii)
(d) (i)
11. Work equals force multiplied by displacement.
12. No work was done on the tree because there was no displacement.
13. Thermal energy is a measure of the kinetic energy of atoms and molecules.
14. Given: m = 60.0 kg; v = 40.0 m/s
Required: E_k
Analysis: $E_k = \frac{mv^2}{2}$
Solution:

$$\begin{aligned} E_k &= \frac{mv^2}{2} \\ &= \frac{(60.0\text{ kg})(40.0\text{ m/s})^2}{2} \\ &= 48\ 000\ \frac{\text{kg•m}^2}{\text{s}^2} \\ &= 48\ 000\text{ J} \\ E_k &= 48\text{ kJ} \end{aligned}$$

Statement: The skydiver's kinetic energy is 48 kJ.
15. The term m is mass in kilograms, g is the acceleration due to gravity (9.8 m/s^2), and h is height in metres.
16. The potential energy of the apple as it hangs from the tree is transformed into kinetic energy as it falls to the ground.
17. The two types of electrical energy are static electricity and current electricity.
18. Architects may take advantage of the Sun's position in the sky to design buildings to best use the Sun's energy to heat a building. They may place windows on the south-facing side of the building, or orient the building so that one wall faces the Sun. These considerations are called passive solar design.
19. Answers may vary. Sample answer: Efficiency is a ratio comparing the energy output to the energy input. It is expressed as a percentage.
20. Nuclear power plants take advantage of nuclear fission.
21. Fossil fuels are called fossil fuels because they are the decayed and compressed remains of prehistoric plants and animals that lived between 100 million and 600 million years ago.
22. The unit commonly used to measure the energy rating of an electrical appliance is the kilowatt hour (kWh).
23. Energy is the capacity to do work, and power is the rate at which energy is transformed or the rate at which work is done.

Understanding

24. Answers may vary. Sample answers:
(a) No work is done on a wheelbarrow full of soil when it is pushed forward horizontally at constant velocity on a frictionless surface.
(b) Pushing a wheelbarrow full of soil with increasing speed and pushing a wheelbarrow uphill both do work.
25. Sample answer: I would multiply the force exerted on the handle by cos 30°.
26. Given: m = 2100 kg; v_i = 0; a = 2.6 m/s^2; Δt = 4.0 s
Required: W
Analysis: $\Delta d = v_i t + \frac{1}{2}at^2$; $F_{net} = ma$; $W = F\Delta d$
Solution:

$$\begin{aligned} \Delta d &= v_i t + \frac{1}{2}at^2 \\ &= 0 + \frac{1}{2}\left(2.6\ \frac{\text{m}}{\cancel{\text{s}^2}}\right)(4.0\ \cancel{\text{s}^2}) \\ \Delta d &= 20.8\text{ m (one extra digit carried)} \end{aligned}$$

$$\begin{aligned} F &= ma \\ &= (2000\text{ kg})(2.6\text{ m/s}^2) \\ &= 5460\ \frac{\text{kg•m}}{\text{s}^2} \\ F &= 5460\text{ N} \end{aligned}$$

$W = F\Delta d$

$= (5460\text{ N})(20.8\text{ m})$

$= 133\,568\text{ N}\bullet\text{m}$

$W = 110\text{ kJ}$

Statement: The car has done 110 kJ of work.

27. Answers may vary. Sample answer:
As the roller coaster speeds up when it goes down a slope, potential energy is transformed into kinetic energy. As the roller coaster slows down when it goes up a slope, kinetic energy is transformed into potential energy.

28. (a) The velocity of the object increases.

(b) The kinetic energy of the object increases.

29. Given: m = 1900 kg; v_i = 25.0 m/s; v_f = 15.0 m/s; Δt = 6.25 s

Required: W

Analysis: $a = \dfrac{v_f - v_i}{\Delta t}$; $F_{net} = ma$; $W = F\Delta d$

Solution:

$$a = \frac{v_f - v_i}{\Delta t}$$
$$= \frac{15.0\text{ m/s} - 25.0\text{ m/s}}{6.25\text{ s}}$$
$$a = -1.60\text{ m/s}^2$$

$$F_{net} = ma$$
$$= (1900\text{ kg})(-1.6\text{ m/s}^2)$$
$$= -3040\text{ kg}\bullet\text{m/s}^2$$
$$F = -3040\text{ N}$$

$$d = \left(\frac{v_f + v_i}{2}\right)\Delta t$$
$$= \left(\frac{15.0\ \frac{\text{m}}{\cancel{\text{s}}} + 25.0\ \frac{\text{m}}{\cancel{\text{s}}}}{2}\right)(6.25\ \cancel{\text{s}})$$
$$d = 125\text{ m}$$

$$W = F\Delta d$$
$$= (-3040\text{ N})(125\text{ m})$$
$$= -380\,000\text{ N}\bullet\text{m}$$
$$W = -380\text{ kJ}$$

Statement: The amount of work done on the car was 380 kJ in the opposite direction of motion.

30. Given: m = 68 kg; h = 320 m; v = 1.5 m/s; g = 9.8 m/s^2

Required: E_m

Analysis: $E_m = E_k + E_g$; $E_k = \dfrac{1}{2}mv^2$; $E_g = mgh$

Solution:

$$E_m = E_k + E_g$$
$$= \frac{mv^2}{2} + mgh$$
$$= \frac{(68\text{ kg})(1.5\text{ m/s})^2}{2} + (68\text{ kg})(9.8\text{ m/s}^2)(320\text{ m})$$
$$= 76.5\ \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2} + 213\,248\ \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2}$$
$$= 213\,324.5\ \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2}$$
$$= 213\,324.5\text{ J}$$
$$E_m = 210\text{ kJ}$$

Statement: The total mechanical energy of the rock climber is 210 kJ.

31. Given: m = 2600 kg; F_f = 8200 N; g = 9.8 m/s^2

$$v_i = \frac{72\ \cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{\cancel{\text{km}}} \times \frac{\cancel{\text{h}}}{3600\text{ s}}$$
$$v_i = 20\text{ m/s}$$

Required: Δt

Analysis: $W = E_{k\text{ final}} - E_{k\text{ initial}}$; $W = F\Delta d$

Solution:

$$W = E_{k\text{ final}} - E_{k\text{ initial}}$$
$$= 0 - \frac{mv_i^2}{2}$$
$$= -\frac{(2600\text{ kg})(20\text{ m/s})^2}{2}$$
$$= 520\,000\ \frac{\text{kg}\bullet\text{m}^2}{\text{s}^2}$$
$$W = 520\text{ kJ}$$

$$W = F\Delta d$$
$$\Delta d = \frac{W}{F}$$
$$= \frac{520\,000\text{ J}}{8200\text{ N}}$$
$$= 63.4\text{ m}$$
$$\Delta d = 63\text{ m}$$

Statement: It takes 63 m for the truck to stop.

32. Answers may vary. Sample answer:
The potential energy of the water raised behind the dam is transformed into kinetic energy as it falls toward the turbine. Kinetic energy is transferred to the turbine, and the turbine transforms the kinetic energy into electrical energy.

33. Answers may vary. Sample answers:
(a) The grass converts radiant (solar) energy into chemical energy and converts chemical energy into mechanical energy to grow.
(b) Mechanical energy from the vibrating string transfers into sound energy throughout the air.
(c) The stuntman starts with gravitational potential energy, which is converted into kinetic energy as he falls. Then the kinetic energy from the stuntman is transferred into elastic energy in the springs of the trampoline.
(d) Solar (radiant) energy is transferred into thermal energy on the asphalt.

34. Given: m = 73 kg; Δd = 120 m; $v_i = 0$; g = 9.8 m/s^2
Required: v_f
Analysis: Use the lower position just before the bungee catches as the reference level for height. Assume that the jumper starts from rest.
$E_{top} = E_{bottom}$; $E_{k\ top} + E_{g\ top} = E_{k\ bottom} + E_{g\ bottom}$
Solution:

$$\begin{aligned}
E_{top} &= E_{bot} \\
E_{k\ top} + E_{g\ top} &= E_{k\ bottom} + E_{g\ bottom} \\
\frac{1}{2}mv_i^2 + mgh_{top} &= \frac{1}{2}mv_f^2 + mgh_{bottom} \\
0 + \cancel{m}gh_{top} &= \frac{1}{2}\cancel{m}v_f^2 + 0 \\
v_f^2 &= 2gh_{top} \\
v_f &= \sqrt{2gh_{top}} \\
&= \sqrt{2(9.8\ \text{m/s}^2)(120\ \text{m})} \\
&= \sqrt{2352\ \text{m}^2/\text{s}^2} \\
&= 48.49\ \text{m/s} \\
v_f &= 48\ \text{m/s}
\end{aligned}$$

Statement: The speed of the jumper just before the bungee catches is 48 m/s.

35. (a) The energy transformations that take place in a light bulb are as follows: electrical energy is converted to radiant energy and thermal energy.
(b) Incandescent light bulbs are inefficient at producing radiant energy but efficient at producing thermal energy. They typically transform only about 5 % of the electrical energy into radiant energy. The remaining 95 % is transformed into thermal energy. Fluorescent and compact fluorescent lamps (CFLs) are more efficient at producing radiant energy. These types of lamps can transform up to 25 % of the electrical energy into radiant energy.

36. Answers may vary. Sample answers:
(a) A renewable energy resource is one that is replenished continuously in a short amount of time or is available in inexhaustible quantities. Wood is an example of a renewable energy resource.
(b) A non-renewable energy resource is one that is available in finite, dwindling quantities or is replenished over very long time periods. Oil is an example of a non-renewable energy resource.

37. Given: h = 55 m; efficiency = 50.0 %; g = 9.8 N/m
Required: v_f
Analysis: efficiency $= \frac{E_k}{E_g}$; $E_k = \frac{1}{2}mv^2$; $E_g = mgh$
Solution:

$$\begin{aligned}
\text{efficiency} &= \frac{E_k}{E_g} \\
\frac{E_k}{E_g} &= 0.50 \\
\frac{\frac{mv_f^2}{2}}{mgh} &= 0.50 \\
\frac{mv_f^2}{2} &= 0.50\ mgh \\
v_f &= \sqrt{\frac{2(0.50\ \cancel{m}gh)}{\cancel{m}}} \\
&= \sqrt{2(0.50)\left(9.8\ \frac{\text{N}}{\cancel{\text{m}}}\right)(55\ \cancel{\text{m}})} \\
&= 23.2\ \text{m/s} \\
v_f &= 23\ \text{m/s}
\end{aligned}$$

Statement: The velocity of the roller coaster at the bottom of the first low point is 23 m/s.

38. (a) Given: efficiency = 17.0 %; E_{out} = 252 J
Required: E_{in}

Analysis: $\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$

Solution: The energy input to produce 252 J of light energy:

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$
$$E_{in} = \frac{E_{out}}{\text{efficiency}} \times 100\ \%$$
$$= \frac{252\ \text{J}}{17.0\ \cancel{\%}} \times 100\ \cancel{\%}$$
$$= 1482.3\ \text{J}$$
$$E_{in} = 1480\ \text{J}$$

Statement: The energy input required is 1480 J.
(b) The waste energy is thermal energy.
Given: E_{in} = 1482.3 J; E_{out} = 252 J
Required: E_{waste}
Analysis: $E_{in} = E_{out} + E_{waste}$
Solution:

$$E_{in} = E_{out} + E_{waste}$$
$$E_{waste} = E_{in} - E_{out}$$
$$= 1482.3\ \text{J} - 252\ \text{J}$$
$$= 1230.3\ \text{J}$$
$$E_{waste} = 1230\ \text{J}$$

Statement: A total of 1230 J would be wasted.
39. Given: efficiency = 12 %; F = 18 000 N; v = 21 m/s; Δd = 450 m
Required: E_{in}
Analysis: The energy output of the car is equal to the work done: $E_{out} = W$; $E_{out} = F\Delta d$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

Solution:

$$E_{out} = W$$
$$= F\Delta d$$
$$= (18\ 000\ \text{N})(450\ \text{m})$$
$$= 8\ 100\ 000\ \text{N•m}$$
$$E_{out} = 8.1\ \text{MJ}$$

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$
$$E_{in} = \frac{E_{out}}{\text{efficiency}} \times 100\ \%$$
$$= \frac{8\ 100\ 000\ \text{J}}{12\ \cancel{\%}} \times 100\ \cancel{\%}$$
$$= 67\ 500\ 000\ \text{J}$$
$$E_{in} = 68\ \text{MJ}$$

Statement: The amount of chemical energy needed to move the car is 68 MJ.
40. Table 1

Energy source	Renewable or non-renewable?
biofuel	**renewable**
coal	**non-renewable**
geothermal	**renewable**
hydroelectric	**renewable**
natural gas	**non-renewable**
nuclear	**non-renewable**
oil	**non-renewable**
solar	**renewable**
wind	**renewable**
wood	**renewable**

41. Answers may vary. Sample answers:
(a) Hydroelectric. Flowing water has gravitational (potential) energy. As the water falls, the potential energy is converted to kinetic energy. This kinetic energy is captured in the hydroelectric plant, and converted to electrical energy.
(b) Tidal. Water on Earth has potential energy because of the Moon's gravity. As the water moves toward the Moon, the potential (gravitational) energy is converted to kinetic energy. This is captured by turbine and converted to electrical energy. Water's potential energy also gets converted to kinetic energy as the water falls to low tide.
(c) Geothermal. Matter deep inside the Earth has a great deal of thermal energy. This can be used directly to heat buildings on the Earth's surface or used to heat water. As the water boils, the thermal energy is converted to kinetic energy, which is captured by a turbine and converted to electrical energy.
(d) Wind. Moving air (wind) has kinetic energy. This is converted to electrical energy.

42. Given: $W = 600.0$ N; $h = 3.0$ m; $\Delta t = 5.0$ s
Required: P
Analysis: $W = F\Delta d$; $P = \frac{W}{\Delta t}$
Solution:

$$W = F\Delta d$$

$$\begin{aligned} P &= \frac{W}{\Delta t} \\ &= \frac{F\Delta d}{\Delta t} \\ &= \frac{(600.0\ \text{N})(3.0\ \text{m})}{5.0\ \text{s}} \\ &= 360\ \frac{\text{N}\bullet\text{m}}{\text{s}} \\ P &= 360\ \text{W} \end{aligned}$$

Statement: The man's power is 360 W.

43. Given: $F = 120$ N; $\Delta d = 6.0$ m; $\Delta t = 2.0$ s
Required: P
Analysis: $W = F\Delta d$; $P = \frac{W}{\Delta t}$
Solution:

$$\begin{aligned} W &= F\Delta d \\ &= (120\ \text{N})(6.0\ \text{m}) \\ &= 720\ \text{N}\bullet\text{m} \\ W &= 720\ \text{J} \end{aligned}$$

$$\begin{aligned} P &= \frac{W}{\Delta t} \\ &= \frac{720\ \text{J}}{2.0\ \text{s}} \\ &= 360\ \text{J/s} \\ P &= 360\ \text{W} \end{aligned}$$

Statement: The girl's power is 360 W.

44. Given: $P = 4.0 \times 10^5$ W;
$\Delta t = 0.70$ ms $= 0.70 \times 10^{-3}$ s;
$\Delta d = 1.4$ cm $= 1.4 \times 10^{-2}$ m;
$m = 145$ g $= 145 \times 10^{-3}$ kg
Required: F_{net}; a_{avg}
Analysis: $P = \frac{E}{\Delta t}$; $E = \frac{F}{\Delta d}$; $F_{net} = ma$
Solution:

$$P = \frac{E}{\Delta t}$$

$$E = F_{net}\Delta d$$

$$P = \frac{F_{net}\Delta d}{\Delta t}$$

$$\begin{aligned} F_{net} &= \frac{P\Delta t}{\Delta d} \\ &= \frac{(4.0\times10^5\ \text{W})(0.70\times10^{-3}\ \text{s})}{1.4\ \times10^{-2}\,\text{m}} \\ &= 20\ 000\ \frac{\text{W}\bullet\text{s}}{\text{m}} \\ &= 20\ 000\ \text{N} \\ F_{net} &= 2.0\times10^4\ \text{N} \end{aligned}$$

$$F_{net} = ma$$

$$\begin{aligned} a &= \frac{F_{net}}{m} \\ &= \frac{20\ 000\ \text{N}}{145\times10^{-3}\ \text{kg}} \\ &= 137\ 931\ \text{N/kg} \\ &= 137\ 931\ \text{m/s}^2 \\ a &= 1.4\times10^5\ \text{m/s}^2 \end{aligned}$$

Statement: The net force applied to the ball is 2.0×10^4 N, and the average acceleration is 1.4×10^5 m/s^2.

Analysis and Application

45. Answers may vary. Sample answer:
A waiter carrying a tray of food over his head across a room and travelling at a constant velocity.

46. Answers may vary. Sample answers:
(a) Posing as a still model for portrait painting is paid as work, but is not work since the model does not move any distance. Carrying bags of cement is paid as work, but is not work in the sense that the force on the bags of cement is perpendicular to the direction of motion.
(b) Digging holes with a shovel is work in both senses because soil is being lifted against the force of gravity and is gaining potential energy. Throwing cement bags onto a truck is work because the force is in the same direction as the displacement and the bags are gaining kinetic energy as they accelerate.

47. Given: $h = 2.2$ m; $F = 98$ N; $m = 10.0$ kg; $g = 9.8$ m/s^2
Required: W_{man}; $W_{gravity}$; W_{net}
Analysis: $W = F\Delta d$; $W_g = mgh$
(a) The work done by the man lifting the box:
Solution:

$$\begin{aligned} W &= F_{net}\Delta d \\ &= (98\ \text{N})(2.2\ \text{m}) \\ &= 215.6\ \text{N}\bullet\text{m} \\ W &= 220\ \text{J} \end{aligned}$$

Statement: The work done by the man lifting the box was 220 J.

(b) The work done by gravity:

Solution:

$$\begin{aligned}W_g &= mgh\\ &= (10\text{ kg})(-9.8\text{ m/s}^2)(2.2\text{ m})\\ &= -215.6\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}\\ &= -215.6\text{ J}\\ W_g &= -220\text{ J}\end{aligned}$$

Statement: The work done by gravity was –220 J.

(c) The net work done on the box:

Solution:

$$\begin{aligned}W_{net} &= W_{man} + W_g\\ &= 215.6\text{ J} + (-215.6\text{ J})\\ W_{net} &= 0\text{ J}\end{aligned}$$

Statement: The work done on the box was 0 J.

(d) Yes, it is possible to know the net work done on the box without knowing the mass or the force exerted. Since you are told that the man moves the box at a constant velocity, then the net force on the box must be zero. If the net force is zero, then the net work must also be zero.

48. Given: m = 155 kg; F = 1910 N; h = 2.80 m; g = 9.8 m/s^2

Required: F_{net}; F-d graph

Analysis: the net force acting on the weight when lifted is $F_{net} = F_{lift} - F_g$; the net force acting on the weight when dropped is $F_{net} = ma = mg$

(i) The net force acting on the weight for the lift:

Solution:

$$\begin{aligned}F_{net} &= F_{lift} - F_g\\ &= F_{lift} - mg\\ &= 1910\text{ N} - (155\text{ kg})(9.8\text{ m/s}^2)\\ &= 391.0\text{ N}\\ F_{net} &= 3.9\times10^2\text{ N}\end{aligned}$$

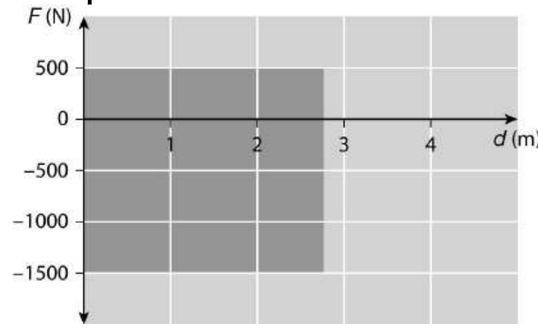
(ii) The net force acting on the weight for the drop:

Solution:

$$\begin{aligned}F_{net} &= F_g\\ &= mg\\ &= (155\text{ kg})(9.8\text{ m/s}^2)\\ &= 1519\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}\\ &= 1519\text{ N}\\ F_{net} &= 1.5\times10^3\text{ N}\end{aligned}$$

Statement: The net force acting on the weight for the lift is 3.0×10^2 N and the net force acting on the weight for the drop is 1.5×10^3 N.

***F-d* Graph:**



49. Given: m = 0.50 kg; h = 22 m; g = 9.8 m/s^2

Required: E_g; E_k; v_f

Analysis: $E_g = mgh$; $E_k = \frac{mv^2}{2}$

(a) Initial potential energy of the rock:

Solution:

$$\begin{aligned}E_g &= mgh\\ &= (0.50\text{ kg})(9.8\text{ m/s}^2)(22\text{ m})\\ &= 107.8\text{ J}\\ E_g &= 110\text{ J}\end{aligned}$$

Statement: The initial potential energy of the rock is 110 J.

(b) The kinetic energy of the rock just before it hits the water:

Solution:

$$\begin{aligned}E_{bottom} &= E_{top}\\ E_{g\ final} + E_{k\ final} &= E_{g\ final} + E_{k\ initial}\\ 0 + E_{k\ final} &= E_{g\ final} + 0\\ E_{k\ final} &= E_{g\ final}\\ E_{k\ final} &= 110\text{ J}\end{aligned}$$

Statement: The kinetic energy of the rock just before it hits the water is 110 J.

(c) The final speed of the rock:

Solution:

$$\begin{aligned}E_{k\ final} &= E_{g\ initial}\\ \frac{\cancel{m}v_f^2}{2} &= \cancel{m}gh\\ v_f &= \sqrt{2gh}\\ &= \sqrt{2(9.8\text{ m/s}^2)(22\text{ m})}\\ &= 20.7\text{ m/s}\\ v_f &= 21\text{ m/s}\end{aligned}$$

Statement: The final speed of the rock is 21 m/s.

50. Given: $m = 1800$ kg; $h_{initial} = 450$ m; $v_i = 42$ m/s; $v_f = 64$ m/s; $\Delta h = 120$ m; $g = 9.8$ m/s^2

Required: $E_{g\ initial}$; $E_{g\ final}$; $E_{k\ initial}$; $E_{k\ final}$; W_{total}

Analysis: $E_{g\ initial} = mgh$; $E_k = \frac{mv^2}{2}$;

$W = E_{k\ final} - E_{k\ initial}$

(a) Initial and final potential energy:

Solution:

$$E_{g\ initial} = mgh$$
$$= (1800\ \text{kg})(9.8\ \text{m/s}^2)(450\ \text{m})$$
$$= 7\ 938\ 000\ \frac{\text{kg•m}^2}{\text{s}^2}$$
$$E_{g\ initial} = 7.9 \times 10^6\ \text{J, or } 7.9\ \text{MJ}$$

$$E_{g\ final} = mgh_{final}$$
$$E_{g\ final} = (1800\ \text{kg})(9.8\ \text{m/s}^2)(450\ \text{m} - 120\ \text{m})$$
$$= 5\ 821\ 200\ \text{J}$$
$$E_{g\ final} = 5.8 \times 10^6\ \text{J, or } 5.8\ \text{MJ}$$

Statement: The initial potential energy of the plane is 7.9×10^6 J, or 7.9 MJ. The final potential energy of the plane is 5.8×10^6 J, or 5.8 MJ.

(b) Initial and final kinetic energy:

Solution:

$$E_{k\ initial} = \frac{mv_i^2}{2}$$
$$= \frac{(1800\ \text{kg})(42\ \text{m/s})^2}{2}$$
$$= 1\ 587\ 600\ \frac{\text{kg•m}^2}{\text{s}^2}$$
$$E_{k\ initial} = 1.6 \times 10^6\ \text{J, or } 1.6\ \text{MJ}$$

$$E_{k\ final} = \frac{mv_f^2}{2}$$
$$= \frac{(1800\ \text{kg})(64\ \text{m/s})^2}{2}$$
$$= 3\ 686\ 400\ \frac{\text{kg•m}^2}{\text{s}^2}$$
$$E_{k\ final} = 3.7 \times 10^6\ \text{J, or } 3.7\ \text{MJ}$$

Statement: The initial kinetic energy of the plane is 1.6×10^6 J, or 1.6 MJ. The final kinetic energy of the plane is 3.7×10^6 J, or 3.7 MJ.

(c) The total work done on the plane:

Solution:

$$W = E_{k\ final} - E_{k\ initial}$$
$$= 3.7\ \text{MJ} - 1.6\ \text{MJ}$$
$$W = 2.1\ \text{MJ}$$

Statement: The total work done on the plane is 2.1 MJ.

51. Answers may vary. Sample answers:

(a) The engine did work when the car accelerated to pass the other car because the kinetic energy was increasing. The engine did work when the car went up the hill because the gravitational potential energy was increasing.

(b) When the car accelerated to pass, chemical energy in the fuel was being converted into kinetic energy. When the car went up the hill, chemical energy in the fuel was being converted into potential energy.

(c) When travelling at a constant speed on a flat highway, chemical energy was being converted into thermal energy because of friction and waste heat from the engine. When the car coasted down the hill, gravitational potential energy was being converted into kinetic energy.

52. Answers may vary. Sample answers:

(a) Solar cells and photosynthesis operate on solar energy, which is virtually inexhaustible. Fossil fuels are finite and exhaustible.

(b) Plants (biofuels) are replaced in a matter of months or years, but fossil fuels take millions of years to form.

53. Given: $m = 11$ kg; $F_{friction} = 86$ N; $d = 22$ m

Required: F_{min}; ΔE; efficiency

Analysis: $E = W$; $W = F\Delta d$;

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

(a) Solution: The minimal force needed would be the force to overcome $F_{friction}$ of 86 N: $F_{min} = 86$ N

(b) Minimum amount of energy:

Solution:

$$\Delta E = W$$
$$W = F\Delta d$$
$$\Delta E = F\Delta d$$
$$= (86\ \text{N})(22\ \text{m})$$
$$= 1892\ \text{J}$$
$$\Delta E = 1900\ \text{J}$$

Statement: The minimum amount of energy is 1900 J.

(c) The man's efficiency: The output energy or work done is only the minimum work required to push against friction.
Solution:

$$\begin{aligned}\text{efficiency} &= \frac{E_{\text{out}}}{E_{\text{in}}} \times 100\ \% \\ &= \frac{1892\ \cancel{\text{J}}}{2180\ \cancel{\text{J}}} \times 100\ \% \\ &= 86.7\ \% \\ \text{efficiency} &= 87\ \%\end{aligned}$$

Statement: The man's efficiency is 87 %.

54. Answers may vary. Sample answers:
(a) In the summer, when the Sun is high, the porch roof shades the interior and reduces the need for air conditioning. In the winter, when the Sun is low, the rays can pass under the porch roof and help heat the interior.
(b) Deciduous trees shade the house in summer and cool it, and when they lose their leaves in the winter, they allow sunlight to help warm the house. Evergreen trees shade the house all year long.

55. Answers may vary. Sample answers:
(a)

$$\begin{aligned}\text{efficiency} &= \frac{E_{\text{k}}}{E_{\text{p}}} \times 100\ \% \\ &= \frac{\frac{\cancel{m}v^2}{2}}{\cancel{m}gh} \times 100\ \% \\ \text{efficiency} &= \frac{v^2}{2gh} \times 100\ \%\end{aligned}$$

Mass is not needed because it cancels out.
(b) Given: $v_{\text{f}} = 5.0$ m/s; $h = 3.0$ m; $g = 9.8$ m/s^2
Required: efficiency
Analysis: $\text{efficiency} = \frac{v^2}{2gh} \times 100\ \%$
Solution:

$$\begin{aligned}\text{efficiency} &= \frac{v^2}{2gh} \times 100\ \% \\ &= \frac{\left(5.0\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)^{\cancel{2}}}{2\left(9.8\ \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)(3.0\ \cancel{\text{m}})} \times 100\ \% \\ &= 42.5\ \% \\ \text{efficiency} &= 43\ \%\end{aligned}$$

Statement: The efficiency of the energy transformation is 43 %.

(c) One factor that contributes to loss of efficiency is the friction that occurs between the slide and the slider's clothing. Friction transforms the kinetic energy into thermal energy.
(d) Potential energy was converted to thermal energy.
(e) potential energy = kinetic energy + thermal energy
(f) The law of conservation of energy was not violated because the loss of mechanical energy was equal to the thermal energy released into the surroundings.

56. Answers may vary. Sample answer:
Three ways I could conserve electrical energy are as follows: taking quick showers instead of long baths, not blow drying my hair, and turning off the computer when I am not using it.

57. Note: After the first printing, one decimal place was added to each given value in this question. The correct answer is still 95 J.
Given: efficiency = 5.0 %; $P = 100.0$ W; $t = 1.0$ h
Required: E_{waste}
Analysis: $W = P\Delta t$; $\text{efficiency} = \frac{E_{\text{out}}}{E_{\text{in}}} \times 100\ \%$
Solution:

$$\begin{aligned}W &= P\Delta t \\ &= 100.0\ \text{W} \times 1.0\ \text{h} \\ W &= 100.0\ \text{J}\ \ \text{(two extra digits carried)}\end{aligned}$$

$$\begin{aligned}E_{\text{waste}} &= (0.95)(100.0\ \text{J}) \\ E_{\text{waste}} &= 95\ \text{J}\end{aligned}$$

Statement: The amount of waste thermal energy is 95 J.

58. Answers may vary. Sample answers:
(a) Nuclear energy is converted into thermal energy, which is converted into mechanical energy. The mechanical energy is converted into electrical energy.
(b) Two disadvantages of using nuclear power as a source of electrical energy are as follows: The water used to cool the nuclear power plant can cause thermal pollution in streams when it is released. Radioactive waste remains hazardous for thousands of years and is very difficult to store safely.

59. (a) Given: P = 1275 W = 1.275 kW; rate of electricity = 5¢/kWh;

$$\Delta t = 2 \text{ min} = 2 \text{ min} \times \frac{1 \text{ h}}{60 \text{ min}} = 0.03 \text{ h}$$

Required: cost of heating a cup of soup

Analysis: $P = \frac{\Delta E}{\Delta t}$;

cost = number of kilowatt hours × rate

Solution:

$$P = \frac{\Delta E}{\Delta t}$$

$$\Delta E = P\Delta t = 1.275 \text{ kW} \times 0.03 \text{ h} = 0.038 \text{ kWh}$$

$$\Delta E = 0.04 \text{ kWh}$$

$$\text{cost} = \Delta E \times \text{rate} = 0.038 \text{ kWh}\left(5 \frac{¢}{\text{kWh}}\right) = 0.19 ¢$$

$$\text{cost} = 0.2 ¢$$

Statement: The cost of heating a cup of soup is 0.2¢.

(b) Answers may vary. Sample answer: "Hidden" costs of heating the cup of soup in the microwave are as follows: the cost of manufacturing the microwave oven and the environmental damage caused by generating the electricity using fossil fuels.

60. Answers may vary. Sample answer: Plants transform radiant energy from the Sun into chemical energy, which is converted into another form of chemical energy when the plant food is eaten and stored in a person's cells. The person's muscles convert the chemical energy into kinetic energy, which is converted into electrical and then chemical energy and stored in the batteries of the radio. This chemical energy is converted into electrical energy, which is then converted into sound energy.

61. Answers may vary. Sample answers:

(a) Sunlight is converted into chemical energy in plants, which can be processed to make biofuels. The Sun causes uneven heating of the Earth, which causes winds to blow. The kinetic energy of wind is transformed into electrical energy by wind turbines.

(b) Tidal energy has gravitational energy as its source.

(c) Both coal and oil store chemical energy that was originally stored in plants. The plants transformed solar energy by photosynthesis.

(d) Plants store energy in a matter of months or years, so the energy is renewable and can be replenished with the growth of a plant. Fossil fuels are non-renewable because they are used in energy transforming processes and so these fuels cannot be replenished.

62. Answers may vary. Sample answers:

(a) Biofuels are combustible gases or liquids manufactured by processing plants. This fuel can be transported as easily as gasoline, so it can be used anywhere, but its most efficient use would be near the location the plants were grown.

(b) Geothermal energy is energy from Earth, such as hot springs. Geothermal heat can be used to produce steam, which is used to generate electricity. Its most practical use is near geothermal vents, which are mostly in British Columbia.

(c) Tidal power harnesses the kinetic energy of the rising and falling ocean surface, so its most practical use is along the ocean coastlines.

(d) Wind is used to turn electrical generators powered by wind turbines. Wind power is most practical in the windiest parts of Canada, including the Plains and the North.

63. Given: m = 610 kg; v_i = 0 m/s; v_f = 14 m/s; t = 1.1 s

Required: d; ΔE; P

Analysis: $d = \frac{v_f + v_i}{2}\Delta t$; $E_k = \frac{mv^2}{2}$; $P = \frac{\Delta E}{\Delta t}$

(a) The distance required by the horse:

Solution:

$$d = \left(\frac{v_f + v_i}{2}\right)\Delta t = \left(\frac{14 \frac{\text{m}}{\text{s}} + 0 \frac{\text{m}}{\text{s}}}{2}\right)(1.1 \text{ s})$$

$$d = 7.7 \text{ m}$$

Statement: The distance required by the horse is 7.7 m.

(b) The minimum amount of energy required:
Solution:

$$\Delta E = E_{\text{k final}} - E_{\text{k initial}}$$
$$= \frac{mv_{\text{final}}^2}{2} - 0$$
$$= \frac{(610\text{ kg})(14\text{ m/s})^2}{2}$$
$$= 59\ 780\text{ J}$$
$$\Delta E = 6.0 \times 10^4\text{ J}$$

Statement: The minimum amount of energy required by the horse is 6.0×10^4 J.
(c) The horse's power:
Solution:

$$P = \frac{\Delta E}{\Delta t}$$
$$= \frac{59\ 780\text{ J}}{1.1\text{ s}}$$
$$= 54\ 345.4\text{ J/s}$$
$$P = 54\ 000\text{ W, or } 54\text{ kW}$$

Statement: The horse's power is 54 kW.
64. Given: $P = 3.0 \times 10^2$ W; efficiency = 92 %; t = 4.0 s; m = 78 kg

$$v_{\text{i}} = 21\ \frac{\text{km}}{\text{h}}$$
$$= 21\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} \times \frac{1000\text{ m}}{\cancel{\text{km}}}$$
$$= 5.83\text{ m/s}$$

Required: v_{f}

Analysis: $P = \frac{\Delta E}{\Delta t}$; efficiency $= \frac{E_{\text{out}}}{E_{\text{in}}} \times 100\ \%$;

$$E_{\text{k}} = \frac{mv^2}{2}$$

Solution:

$$\Delta E_{\text{in}} = P\Delta t$$
$$= (3.0 \times 10^2\text{ W})(4.0\text{ s})$$
$$= 1200\text{ W/s}$$
$$\Delta E_{\text{in}} = 1200\text{ J}$$

$$\text{efficiency} = \frac{\Delta E_{\text{out}}}{\Delta E_{\text{in}}} \times 100\%$$
$$\Delta E_{\text{out}} = \frac{(\text{efficiency})(E_{\text{in}})}{100\%}$$
$$= \frac{(92\ \cancel{\%})(1200\text{ J})}{100\ \cancel{\%}}$$
$$\Delta E_{\text{out}} = 1104\text{ J}$$

$$\Delta E_{\text{out}} = \frac{mv_{\text{f}}^2}{2} - \frac{mv_{\text{i}}^2}{2}$$
$$\frac{mv_{\text{f}}^2}{2} = \Delta E_{\text{out}} + \frac{mv_{\text{i}}^2}{2}$$
$$v_{\text{f}}^2 = \frac{2\Delta E_{\text{out}}}{m} + v_{\text{i}}^2$$
$$v_{\text{f}} = \sqrt{\frac{2\Delta E_{\text{out}}}{m} + v_{\text{i}}^2}$$
$$v_{\text{f}} = \sqrt{\frac{2(1104\text{ J})}{78\text{ kg}} + (5.83\text{ m/s})^2}$$
$$v_{\text{f}} = 7.9\text{ m/s}$$

Statement: The cyclist will be travelling at 7.9 m/s.

Evaluation

65. Answers may vary. Sample answers:
(a) Fossil fuels should be phased out and replaced with wind power everywhere. Geothermal and solar energy could be used in the places where they are most practical.
(b) Fossil fuels cause more pollution and release greenhouse gases, which contribute to climate change. Fossil fuels are not renewable and are in shorter supply than nuclear fuels.
(c) Wind power is practical for most parts of Ontario and has relatively little environmental impact. The source is inexhaustible.
(d) Solar power is not a practical alternative in most parts of Ontario because of short winter daylight hours. Burning biofuels and wood releases greenhouse gases.
66. Answers may vary. Sample answers:
(a) Advantages: Photovoltaic cells are an inexhaustible source of energy, and the operation of the cells causes no waste products. Disadvantages: Solar cells only work when the Sun is shining. Electricity must be transmitted from the source.
(b) The manufacture of photovoltaic cells uses energy and produces waste that must be disposed of. Materials must be shipped by highway and by train. Energy is lost during transmission, which is often from remote desert locations.
(c) Canada's energy needs are greatest in winter when energy is needed for heating. This is also the time of year when solar energy is least available because of Canada's latitude. Solar energy would be most useful in southern Canada and in areas with little cloud cover, like the central Plains.

Reflect on Your Learning

67. Answers may vary. Sample answer:
I learned that some energy transformations were not as efficient as I thought they would be, for example, photosynthesis. I also learned that others, for example, bicycles, are much more efficient than I thought.

68. Answers may vary. Sample answer:
(a) I still wonder why no work is done when you hold a heavy object stationary in the air. It feels like work.
(b) I can read the textbook again on the work and look at the examples of work and try to figure out why my example from part (a) is not an example of work. By comparing the different factors in each example, I should be able figure it out.

69. Answers may vary. Sample answer:
Yes. I used to believe that all renewable energy sources were more environmental friendly than non-renewable energy sources. I now know that renewable energy sources can have negative environmental consequences, too. For example burning wood releases carbon dioxide (a greenhouse gas) into the atmosphere.

70. Answers may vary. Sample answers:
(a) Thermal energy can be considered potential energy because it can give substances the ability to do work. For example, when enough heat is added to water it can become vaporized and can be used to turn generators, and the heat that is added to the air in hot-air balloons causes them to lift off.
(b) Nuclear energy can be considered potential energy because it does not directly create kinetic or electrical energy, but can give off large amounts of heat, which can then be used to turn generators. An example would be a nuclear power plant.
(c) Chemical energy can be considered potential energy because it has the ability to be converted to mechanical energy and do work. An example would be gasoline. Gasoline alone does not do anything, but when ignited it can power a car.

Research

71. Answers may vary. Students should define and describe the oil sands, discuss its advantages and disadvantages in terms of cost, practicality, and environmental impact; and compare it to other energy sources.

72. Answers may vary. Students should describe hydroelectric power, identify areas of Canada where hydroelectric power is currently providing power, and discuss environmental advantages and disadvantages, such as altering the flow of rivers. Reports should also include discussion of the possibilities of expanding Canadian hydroelectric power.

73. Answers may vary. Students should describe how energy-efficient appliances minimize waste heat loss. They should also describe ways to prevent heat loss and gain to houses, such as installing double-glazed windows, improving home insulation, and using passive solar architecture.

74. Answers may vary. Students should describe how animals create and use bioluminescence. The main uses include mating and hunting. Bioluminescence is close to 100 % efficient. Students may include information about genetic sequencing and how the principles of bioluminescence have been adapted in genetic research and other areas.

75. Answers may vary. Some suggested topics are: rechargeable batteries, the flywheel storage capabilities of cars, and compressed air storage. The page should describe the basics of how the technology works and its applications and limitations.