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Practice Problems

Example Problem B1.1

1. $v = \dfrac{\Delta d}{\Delta t}$

$= \dfrac{4.0 \times 10^6 \text{ m}}{3.6 \times 10^4 \text{s}}$

$= 1.1 \times 10^2 \dfrac{\text{m}}{\text{s}}$

2. $v = \dfrac{\Delta d}{\Delta t}$ so $\Delta t = \dfrac{\Delta d}{v}$

$= \dfrac{4.00 \times 10^7 \text{ m}}{694 \dfrac{\text{m}}{\text{s}}}$

$= 5.76 \text{ x } 10^4 \text{ s}$

3. $v = \dfrac{\Delta d}{\Delta t}$

$\Delta d = v\Delta t$

$= \left(6.9 \dfrac{\text{m}}{\text{s}}\right)(4.0 \text{ s})$

$= 28 \text{ m}$

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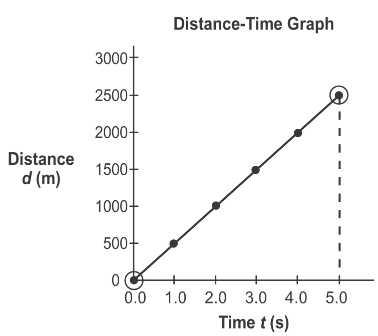
Practice Problem

Example Problem B1.2

4. a)



b) slope $= \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{2480 \text{ m} - 0 \text{ m}}{5.0 \text{ s} - 0.0 \text{ s}}$

$= \dfrac{2480 \text{ m}}{5.0 \text{ s}}$

$= 496 \text{ m/s}$

$= 5.0 \text{ x } 10^2 \text{ m/s}$

c) Since slope = m/s, it represents average speed.

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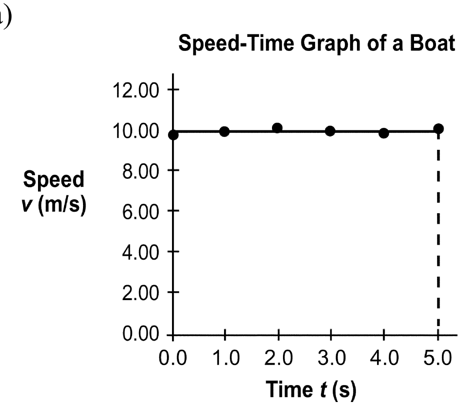
Practice Problem

Example Problem B1.3

5. a)



b) slope $= \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{10.1 \dfrac{\text{m}}{\text{s}} - 10.1 \dfrac{\text{m}}{\text{s}}}{5.0 \text{ s} - 0.0 \text{ s}}$

$= \dfrac{0.0 \dfrac{\text{m}}{\text{s}}}{5.0 \text{ s}}$

$= 0 \dfrac{\text{m}}{\text{s}^2}$

A slope of 0.0 (or 0) indicates uniform motion.

c) area = length x width

$= (v)(\Delta t)$

$= (10.1 \dfrac{\text{m}}{\text{s}})(5.0 \text{ s})$

$= 50 \text{ m}$

The area represents the distance travelled.

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B1.1 Check and Reflect

1. An object is in motion if an imaginary line joining the object to a reference point changes in length or direction.
2. An object in uniform motion travels at a constant rate of motion in a straight line.
3. Quantitative studies of uniform motion involve formulas and graphs.
4. a) slope of a distance–time graph = speed
   b) slope of a speed–time graph = change in speed during a time interval

c) area under the line of a speed–time graph = distance travelled

5. The first segment indicates uniform motion with a constant speed and the second segment indicates an object at rest.
6. The two segments indicate uniform motion but the first segment indicates a faster speed.
7. Electricity flowing through a wire most closely resembles uniform motion because it flows at a constant rate. Situations (a) and (b) are increasing in speed as they fall.

8. $$v = \frac{\Delta d}{\Delta t} = \frac{50.0 \text{ m}}{12.0 \text{ s}} = 4.17 \frac{\text{m}}{\text{s}}$$

9. $$\Delta t = \frac{\Delta d}{v} = \frac{45.0 \text{ m}}{30.0 \frac{\text{m}}{\text{s}}} = 1.50 \text{ s}$$

10. $$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t = \left(990 \frac{\text{km}}{\text{h}}\right)(4.10 \text{ h}) = 4.06 \times 10^3 \text{ km}$$

11. $$\Delta t = \frac{\Delta d}{v} = \frac{30.0 \text{ km}}{6.00 \frac{\text{km}}{\text{h}}} = 5.00 \text{ h}$$

12. a) $$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{d_f - d_i}{t_f - t_i} = \frac{10 \text{ m} - 0 \text{ m}}{2.0 \text{ s} - 0 \text{ s}} = 5 \text{ m/s}$$

b) The slope represents the speed of the object.

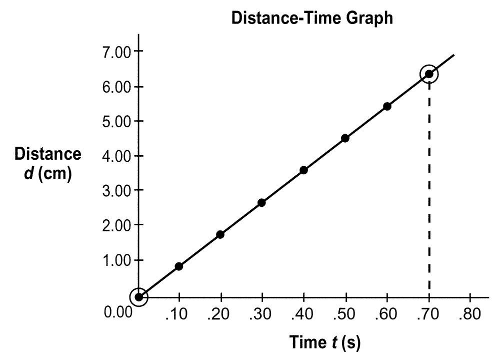
13. a) 0 m/s^2

b) The slope represents the change in the object's speed.

14. a)

Time t (s)	Distance d (cm)
0.00	0.00
0.10	0.79
0.20	1.68
0.30	2.56
0.40	3.55
0.50	4.46
0.60	5.33
0.70	6.24

b)



c) $$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{6.24 \text{ cm} - 0.00 \text{ cm}}{0.70 \text{ s} - 0.00 \text{ s}} = \frac{6.24 \text{ cm}}{0.70 \text{ s}} = 9.0 \frac{\text{cm}}{\text{s}}$$

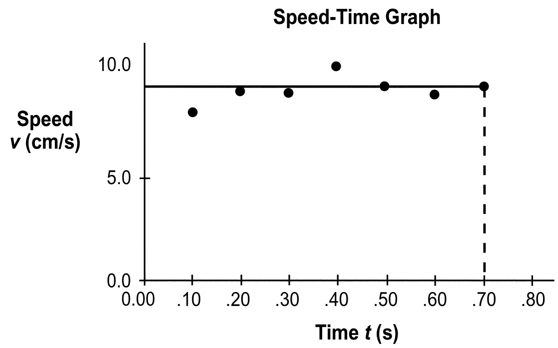
d) Because slope = $\frac{\Delta d}{\Delta t}$, it gives you the speed.

15. a)

Time t (s)	Speed v (cm/s)
0.10	7.9
0.20	8.9
0.30	8.8
0.40	9.9
0.50	9.1
0.60	8.7
0.70	9.1

Note: For uniform motion, the average speed or velocity during a time interval is equal to the speed or velocity at any instant of the time interval. Thus, the average speed or velocity during the time interval is the speed or velocity at the end of the time interval. For motion with uniform acceleration, the average speed or velocity for a time interval is equal to the instantaneous speed or velocity at the midpoint of the time interval.

b)



c) area = length x width = $v\Delta t$

$= (8.9\ \frac{\text{cm}}{\text{s}})(0.70\ \text{s})$

$= 6.3$ cm

d) Because area = $v\Delta t$, it gives the distance travelled.

16. $\Delta d = \Delta d_1 + \Delta d_2$
$= 15.0\ \text{m} + 12.0\ \text{m}$
$= 27.0\ \text{m}$

$\Delta t = \Delta t_1 + \Delta t_2$
$= 5.00\ \text{s} + 10.00\ \text{s}$
$= 15.00\ \text{s}$

$$v = \frac{\Delta d}{\Delta t} = \frac{27.0\ \text{m}}{15.00\ \text{s}} = 1.80\ \text{m/s}$$

17. $\Delta d_1 = v\Delta t$
$= (2.00\ \frac{\text{m}}{\text{s}})(10.00\ \text{s})$
$= 20.00\ \text{m}$

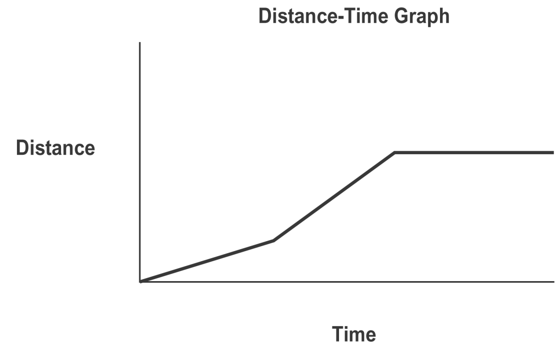
$\Delta d_2 = v\Delta t$
$= (1.50\ \frac{\text{m}}{\text{s}})(8.00\ \text{s})$
$= 12.00\ \text{m}$

$\Delta d = \Delta d_1 + \Delta d_2$
$= 20.00\ \text{m} + 12.0\ \text{m}$
$= 32.0\ \text{m}$

$\Delta t = \Delta t_1 + \Delta t_2$
$= 10.00\ \text{s} + 8.00\ \text{s}$
$= 18.00\ \text{s}$

$$v = \frac{\Delta d}{\Delta t} = \frac{32.0\ \text{m}}{18.00\ \text{s}} = 1.78\ \text{m/s}$$

18. Students' answers will vary but resemble the graph below:



19. Uniform motion can occur only when all forces acting on an object are balanced. This is difficult to achieve in everyday situations because forces such as friction and wind resistance tend to slow a moving object down.

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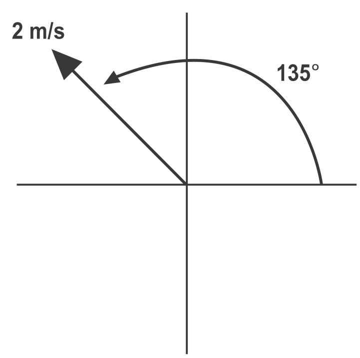
Practice Problem

Example Problem B1.4

6.



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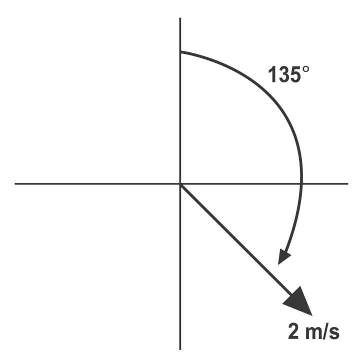
Practice Problem

Example Problem B1.5

7.



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Practice Problems

Example Problem B1.6

8. a) $\Delta\vec{d} = \Delta\vec{d}_1 + \Delta\vec{d}_2$
$= 10.0\text{ m [E]} + 12.0\text{ m [E]}$
$= 22.0\text{ m [E]}$

b) $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$
$= \dfrac{22.0\text{ m[E]}}{15.00\text{ s}}$
$= 1.47\dfrac{\text{m}}{\text{s}}\text{[E]}$

9. $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$
$\Delta\vec{d} = \vec{v}\Delta t$
$= (8.00\ \dfrac{\text{m}}{\text{s}}\ \text{[N]})(14.0\text{ s})$
$= 112\text{ m [N]}$

10. $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$
$\Delta t = \dfrac{\Delta\vec{d}}{\vec{v}}$
$= \dfrac{-400\text{ km[W]}}{-900\ \dfrac{\text{km}}{\text{h}}\ \text{[W]}}$
$= 0.444\text{ h}$

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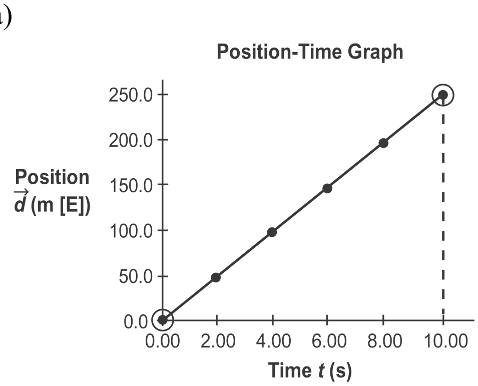
Practice Problem

Example Problem B1.7

11. a)



b) slope $= \dfrac{\vec{d}_f - \vec{d}_i}{t_f - t_i}$
$= \dfrac{250.0\text{ m[E]} - 0.0\text{ m[E]}}{10.0\text{ s} - 0.0\text{ s}}$
$= \dfrac{250.0\text{ m[E]}}{10.0\text{ s}}$
$= 25.0\ \dfrac{\text{m}}{\text{s}}\text{[E]}$

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B1.2 Check and Reflect

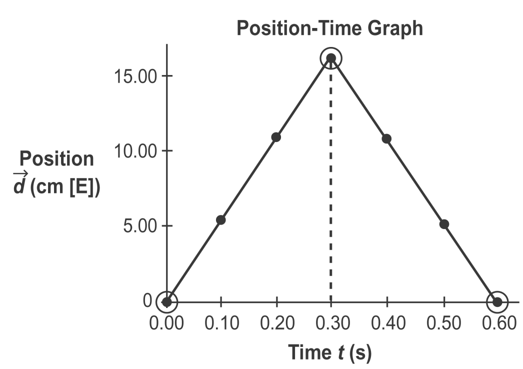
1. A scalar quantity indicates only magnitude, and a vector quantity shows magnitude and direction.
2. Scalar quantities are d, v, t.
Vector quantities are $\vec{d}$, $\vec{v}$.
3. Vector 1 = [60°]
Vector 2 = [215°]
4. Vector 1 = [30°]
Vector 2 = [245°]
5. a) $\Delta d = \Delta d_1 + \Delta d_2$
$= 10.0\text{ m} + 15.0\text{ m}$
$= 25.0\text{ m}$

b) $\Delta\vec{d} = \Delta\vec{d}_1 + \Delta\vec{d}_2$
$= (\Delta 10.0\text{ m [S]}) + (15.0\text{ m [N]})$
$= 5.0\text{ m [N]}$

c) $v = \dfrac{\Delta d}{\Delta t}$
$= \dfrac{25.0\text{ m}}{16.00\text{ s}}$
$= 1.56\dfrac{\text{m}}{\text{s}}$

d) $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$
$= \dfrac{5.0\text{ m[N]}}{16.00\text{ s}}$
$= 0.313\ \dfrac{\text{m}}{\text{s}}\ \text{[N]}$

6. a)



b) $\text{slope}_1 = \dfrac{\text{rise}}{\text{run}}$

$$= \frac{15.74 \text{ cm [E]} - 0.00 \text{ cm}}{0.30 \text{ s} - 0.00 \text{ s}}$$

$$= \frac{15.74 \text{ cm [E]}}{0.30 \text{ s}}$$

$$= 52 \ \frac{\text{cm}}{\text{s}} \ \text{[E]}$$

$\text{slope}_2 = \dfrac{\text{rise}}{\text{run}}$

$$= \frac{0.00 \text{ cm} - 15.74 \text{ cm [W]}}{0.60 \text{ s} - 0.30 \text{ s}}$$

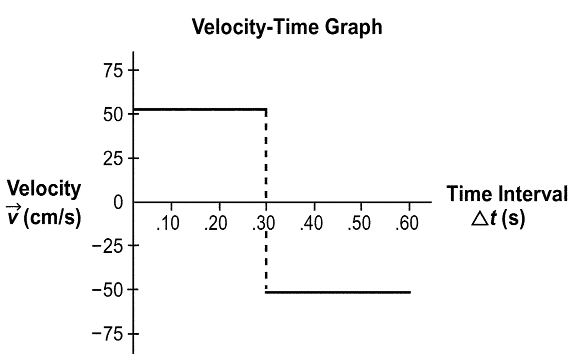
$$= \frac{-15.74 \text{ cm [W]}}{0.30 \text{ s}}$$

$$= -52 \ \frac{\text{cm}}{\text{s}} \ \text{[W]}$$

Because slope $= \dfrac{\Delta \vec{d}}{\Delta t}$, it gives you the velocity, because $\vec{v} = \dfrac{\Delta \vec{d}}{\Delta t}$.

7.

Time Interval Δt (s)	Velocity $\vec{v}$ (cm/s)
0.00 – 0.10	52 [E]
0.10 – 0.20	52 [E]
0.20 – 0.30	52 [E]
0.30 – 0.40	52 [W]
0.40 – 0.50	52 [W]
0.50 – 0.60	52 [W]

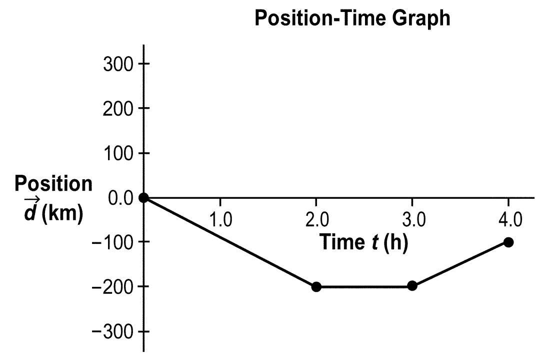


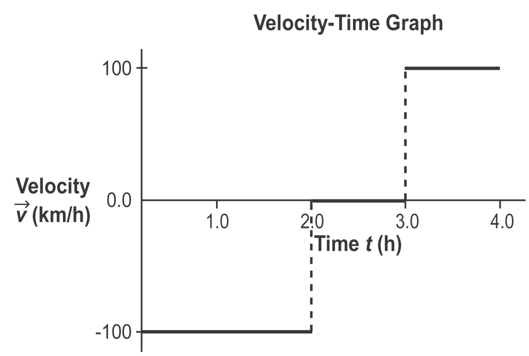
This problem is an example of motion in two directions. A graph of velocity as a function of time, in this case, will yield lines above and below the x-axis. Make sure that the values of the velocities are plotted at the midpoints in time. For any object undergoing uniform acceleration, the average velocity determined during a time interval (e.g., 0.0 s to 0.1 s) using $\vec{v} = \Delta \vec{d} / \Delta t$ is the instantaneous velocity at the midpoint in the time interval (e.g., 0.05 s). Also make sure that the lines, drawn above and below the x-axis are extrapolated to the end of the time intervals.

a) The slope of each part of the graph is a straight line, so the motion is uniform.

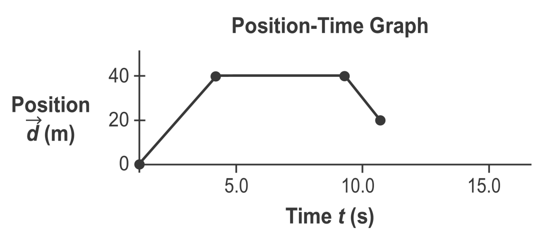
b) Uniform motion in different directions is positive or negative.

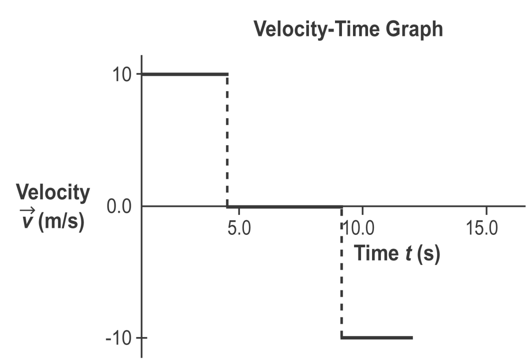
8. a)





b)





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Practice Problems

Example Problem B1.8

12. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$= \frac{50\frac{m}{s}[\text{upward}] - 0\frac{m}{s}}{4.00\,s}$

$= \frac{50\frac{m}{s}[\text{upward}]}{4.00\,s}$

$= 13\ \frac{m}{s^2}[\text{upward}]$

The shuttle craft's acceleration is 13 $\frac{m}{s^2}$ [upward].

13. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$= \frac{0.0\frac{m}{s} - 25.0\frac{m}{s}}{0.500\,s}$

$= \frac{-25.0\frac{m}{s}}{0.500\,s}$

$= -50.0\ \frac{m}{s^2}$

The magnitude of the ball's acceleration is 50.0 $\frac{m}{s^2}$. (The ball's acceleration is −50.0 $\frac{m}{s^2}$.)

14. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$= \frac{0.0\frac{m}{s} - 10.0\frac{m}{s}}{0.0300\,s}$

$= \frac{-10.0\frac{m}{s}}{0.0300\,s}$

$= -333\ \frac{m}{s^2}$

The magnitude of the puck's acceleration is 333 $\frac{m}{s^2}$.

(The puck's acceleration is −333 $\frac{m}{s^2}$.)

15. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$= \frac{5.00\frac{m}{s}[E] - 15.0\ \frac{m}{s}[E]}{4.00\,s}$

$= \frac{-10.0\ \frac{m}{s}\ [E]}{4.00\,s}$

$= -2.50\ \frac{m}{s^2}[E]$

The car's acceleration is −2.50 $\frac{m}{s^2}$ [E].

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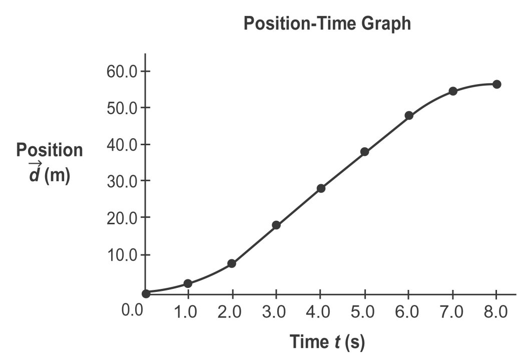
Practice Problem

Example Problem B1.9

16. a)



b) i) accelerated motion because line is a curve
ii) uniform motion because line is straight
iii) accelerated motion because line is a curve

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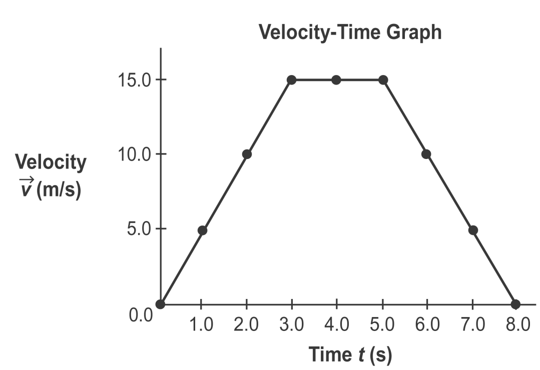
Practice Problem

Example Problem B1.10

17. a)



b) i) A straight line with a positive slope is positive acceleration.
ii) A straight horizontal line is uniform motion.
iii) A straight line with a negative slope is negative acceleration.

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B1.3 Check and Reflect

1. a) Positive (speeding-up in a positive direction)
   b) Negative (slowing-down in a positive direction)
   c) Negative (speeding-up in a negative direction)
   d) Positive (slowing-down in a negative direction)
2. It could be speeding-up in a negative direction
3. a) It could be speeding-up in a positive direction.
   b) It could be slowing-down in a positive direction.
4. a) $\Delta t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

   b) $\vec{v}_f = \vec{v} + \vec{a}\Delta t$

5. $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$= \frac{0\frac{m}{s} - 15\frac{m}{s}\text{ [N]}}{3.0\text{ s}}$$

$$= -5.0\ \frac{m}{s^2}\text{ [N]}$$

The acceleration of the bus is $-5.0\ \frac{m}{s^2}$ [N].

6. $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$= \frac{(-40.0\ \frac{m}{s}\text{ [W]}) - (-25.0\ \frac{m}{s}\text{ [W]})}{4.00\text{ s}}$$

$$= \frac{-15.0\frac{m}{s}\text{ [W]}}{4.00\text{ s}}$$

$$= -3.75\ \frac{m}{s^2}\text{ [W]}$$

The acceleration of the car is $-3.75\ \frac{m}{s^2}$ [W].

7. $a = \dfrac{v_f - v_i}{\Delta t}$

$$= \frac{1.50\ \frac{m}{s} - 2.00\ \frac{m}{s}}{2.00\text{ s}}$$

$$= -0.250\ \frac{m}{s^2}$$

The magnitude of the ball's acceleration is $0.250\ \frac{m}{s^2}$.

(The ball's acceleration is $-0.250\ \frac{m}{s^2}$.)

8. $\vec{v}_f = \vec{v}_i\ (\vec{a}\ \Delta t)$

$$= (1.30\ \frac{m}{s^2}\text{ [N]})(6.00\text{ s})$$

$$= 7.80\ \frac{m}{s^2}\text{ [N]}$$

The final velocity of the object is $7.80\ \frac{m}{s^2}$ [N].

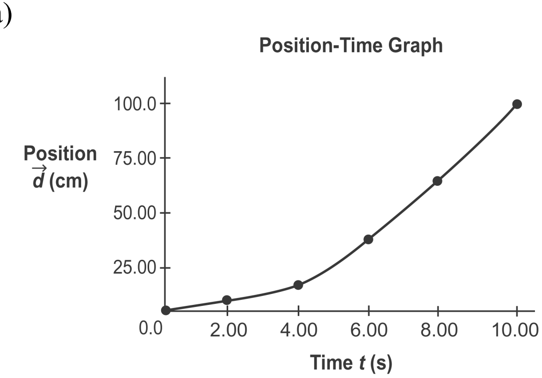
9. $\Delta t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

$$= \frac{(-49.1\frac{m}{s}\text{ [down]}) - 0.0\ \frac{m}{s}}{-9.81\ \frac{m}{s^2}}$$

$= 5.01$ s

It will take –5.01 s for the object to reach a final velocity of –49.1 m/s downward.

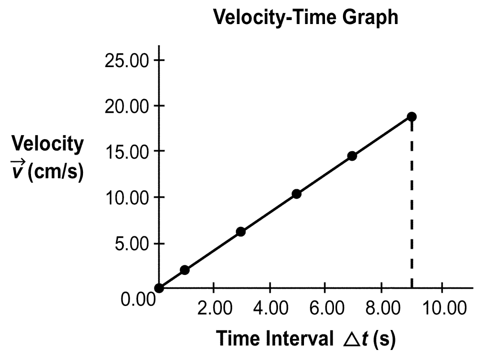
10. a)



A curved line has an increasing slope so it indicates accelerated motion.

b)

Time Interval Δt (s)	Velocity $\vec{v}$ (cm/s)
0.00 – 2.00	2.00
2.00 – 4.00	6.00
4.00 – 6.00	10.00
6.00 – 8.00	14.00
8.00 – 10.00	18.00



Note: For uniform motion, the average speed or velocity during a time interval is equal to the speed or velocity at any instant of the time interval. Thus, the average speed or velocity during the time interval is the speed or velocity at the end of the time interval. For motion with uniform acceleration, the average speed or velocity for a time interval is equal to the instantaneous speed or velocity at the midpoint of the time interval.

c) $\text{slope} = \frac{\text{rise}}{\text{run}}$

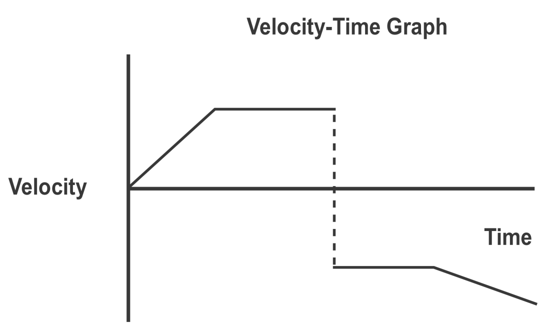
$$= \frac{18.00\,\frac{\text{m}}{\text{s}}}{9.00\,\text{s}}$$

$$= 2.00\ \frac{\text{m}}{\text{s}^2}$$

d) i) Displacement could just be read from the vertical axis of the position-time graph.
ii) Displacement could be determined by finding the area under a velocity-time graph.

11. a) i) speeding-up in a positive direction
ii) uniform motion in a positive direction
iii) uniform motion in a negative direction
iv) speeding-up in a negative direction

b)



12. You could measure the starting speed (v_i) the final speed (v_f) in a time interval (At) and determine acceleration using:

$$a = \frac{v_f - v_i}{\Delta t}$$

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Practice Problems

Example Problem B1.11

18. $W = Fd$
$$= (6.50\times10^3\ \text{N})(150\ \text{m})$$
$$= 9.75\times10^5\ \text{J}$$

19. $W = Fd$
$$F = \frac{W}{d}$$
$$= \frac{2.2\times10^4\ \text{J}}{9.5\ \text{m}}$$
$$= \frac{2.2\times10^4}{9.5}\frac{\frac{\text{kg}\cdot\text{m}\cdot\cancel{\text{m}}}{\text{s}^2}}{\cancel{\text{m}}}$$
$$= 2.3\times10^3\ \text{N}$$

Example Problem B1.12

20. $\Delta E = W$
$= 2.2 \text{ x } 10^4$ J

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B1.4 Check and Reflect

1. A force is a push or a pull on an object. For example, a force of 10 N is required to pull a wagon.
2. If work is done on an object, the object must gain energy.
3. Force is required to do work on an object ($W = Fd$), and the object will gain energy equivalent to the work done ($\Delta E = W$).
4. $1\,\text{N} = 1\frac{\text{kg}\cdot\text{m}}{\text{s}^2}$
5. a) There is no motion.
b) The force and the movement are not in the same direction.
c) Gravity is applying the force on the ball. There is no force being applied by the student.
6. a) $W = Fd$
$= (98.0\,\text{N})(1.50\,\text{m})$
$= 147\,\text{J}$
b) $W = Fd$
$= (25.0\text{ N})(2.00\text{ m})$
$= 50.0$ J
c) $W = Fd$
$= (2.00\text{ N})(0.100\text{ m})$
$= 0.200$ J

The cat does no work in carrying the kitten. Work is only done when the cat lifts the kitten against the force of gravity.

7. $F = \frac{W}{d}$

$= \frac{43.0\ \text{J}}{3.20\ \text{m}}$

$= 13.4\ \text{N}$

8. $d = \frac{W}{F}$

$= \frac{2.00 \times 10^4\ \text{J}}{1.20 \times 10^3\ \text{N}}$

$= 16.7\ \text{m}$

9. $W = Fd$

$= (30.0\ \text{N})(1.30\ \text{m})$

$= 39.0\ \text{J}$

This is a work input, because this is the work that the person did to move the object.

10. a) $W = \text{area under the line}$

$= \text{length} \times \text{width}$

$= Fd$

$= (50\ \text{N})(100\ \text{m})$

$= 5.0 \times 10^3\ \text{J}$

b) The area under the line represents the work done.

11. Yes, your heart does work because it applies a force to move blood through a distance.

12. He is not doing any work in holding the barbell above his head. For work to be done, not only must a force be applied but the object must also move through a distance. In this case, there is no movement while he is holding the barbell above his head. He is, however, doing work when he lifts the barbell from the floor to a position above his head.

13. The force of gravity is a pull because gravity pulls all objects toward the centre of mass or the centre of Earth. A rock in the air will be pulled towards the centre of Earth, not pushed out into space.

14. An object in straight-line motion should continue in motion at a uniform speed in a straight line, unless a force acts on it. Since there is negligible friction in space, there is really no opposing force on the craft so it will continue moving in uniform motion.

B1.0 Section Review

Knowledge

1. Uniform motion is motion at a constant rate in a straight line, while accelerated motion is changing motion.
2. Average velocity is a vector quantity so direction must be specified.
3. The speedometer only measures magnitude of motion or speed.
4. slope = $\frac{\Delta d}{\Delta t}$

   = speed
5. a) scalar
   b) vector
   c) scalar
   d) vector
   e) scalar
6. a) uniform motion
   b) accelerated motion
7. $\Delta W = \Delta E$
8. $\Delta E = W$

   $= 15.0\ \text{J}$

Applications

9. $v = \frac{\Delta d}{\Delta t}$

$= \frac{23.0\ \text{m}}{14.2\ \text{s}}$

$= 1.62\ \frac{\text{m}}{\text{s}}$

10. $v = \frac{\Delta d}{\Delta t}$

$\Delta d = v\Delta t$

$= (5.30\ \frac{\text{m}}{\text{s}})(55.0\ \text{s})$

$= 292\ \text{m}$

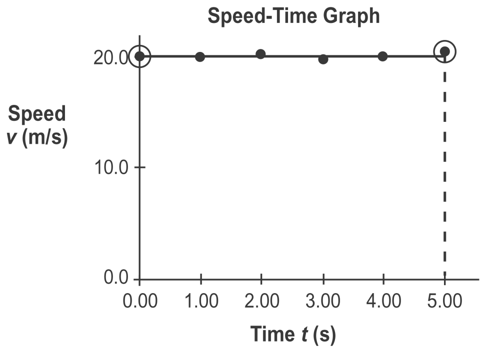
11. $v = \frac{\Delta d}{\Delta t}$

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

$= \frac{4200\ \text{km}}{800\ \frac{\text{km}}{\text{s}}}$

$= 5.25\ \text{h}$

12. a)



b) $\text{slope} = \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{20.0\frac{\text{m}}{\text{s}} - 20.0\frac{\text{m}}{\text{s}}}{5.00\,\text{s}}$

$= \dfrac{0\frac{\text{m}}{\text{s}}}{5.00\,\text{s}}$

$= 0.00\ \dfrac{\text{m}}{\text{s}^2}$

The slope represents acceleration.

c) area = length x width

$= (20.0\ \frac{\text{m}}{\text{s}})(5.00\ \text{s})$

= 100 m

Because area = $v\Delta t$ and $v\Delta t = \Delta d$, the area represents the distance travelled.

13. a) $\Delta d = \Delta d_1 + \Delta d_2$

= 2.0 m + 5.0 m

= 7.0 m

b) $\Delta \vec{d} = \Delta \vec{d}_1 + \Delta \vec{d}_2$

= (2.0 m [E]) + (–5.0 m [W])

= −3.0 m [W]

14. a) vector A = 75º

vector B = 140º

b) vector A = 15º

vector B = 310º

15. a) $\Delta d = \Delta d_1 + \Delta d_2$

= 500 m + 300 m

= 800 m

b) $\Delta \vec{d} = \Delta \vec{d}_1 + \Delta \vec{d}_2$

= (500 m [N]) + (–300 m [S])

= 200 m [N]

c) $v = \dfrac{\Delta d}{\Delta t}$

$= \dfrac{800\ \text{m}}{250\ \text{s}}$

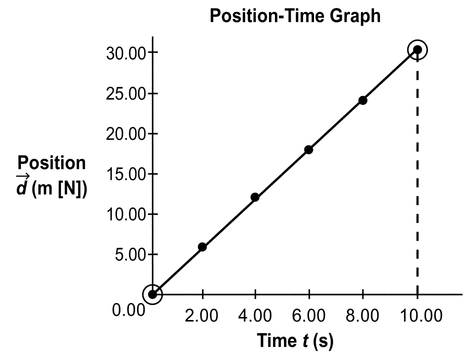
$= 3.20\ \dfrac{\text{m}}{\text{s}}$

d) $\vec{v} = \dfrac{\Delta \vec{d}}{\Delta t}$

$= \dfrac{200\,\text{m[N]}}{250\,\text{s}}$

= 0.800 m/s [N]

16. a)



b) $\text{slope} = \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{30.00\ \text{m} - 0.00\ \text{m}}{10.00\ \text{s} - 0.00\ \text{s}}$

= 3.00 m/s

Because the slope = $\dfrac{\Delta \vec{d}}{\Delta t}$, which equals $\vec{v}$, the slope represents the velocity.

17. $a = \dfrac{v_f - v_i}{\Delta t}$

$= \dfrac{4.50\frac{\text{m}}{\text{s}} - 0\ \frac{\text{m}}{\text{s}}}{8.00\ \text{s}}$

$= .563\ \dfrac{\text{m}}{\text{s}^2}$

18. $\vec{v}_f = \vec{v}_i + \vec{a}\ \Delta t$

$= (-3.00\ \frac{\text{m}}{\text{s}^2}\ [\text{W}])(4.00\ \text{s})$

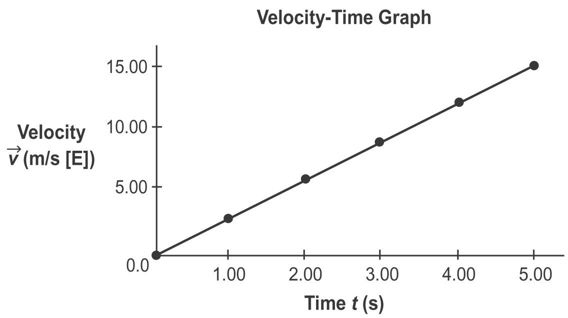
$= -12.0\ \dfrac{\text{m}}{\text{s}}\ [\text{W}]$

19. $t = \dfrac{v_f - v_i}{\vec{a}}$

$= \dfrac{(4.00\frac{\text{m}}{\text{s}}\ [\text{N}]) - (2.50\ \frac{\text{m}}{\text{s}}\ [\text{N}])}{0.500\ \frac{\text{m}}{\text{s}^2}\ [\text{N}]}$

= 3.00 s

20. a)



b) A positive slope indicates positive acceleration.

21. $F = F_1 + F_2$
$= -10$ N [W] + 30 N [E]
$= 20$ N [E]

22. $W = Fd$
$= (15.0 \text{ N})(40.0 \text{ m})$
$= 600$ J

23. $W = Fd$
$= (35.0 \text{ N})(3.0 \text{ N})$
$= 1.1 \times 10^2$ J
$\Delta E = W$
$= 1.1 \times 10^2$ J

24. $W = Fd$

$$F = \frac{W}{d}$$
$$= \frac{350 \text{ J}}{10.0 \text{ m}}$$
$$= 35.0 \text{ N}$$

Extensions

25. a) No. Displacement could only equal distance travelled.
b) Yes. For example, an object travelling 10 [E], then 10 [W] travels a distance of 20 m but the displacement is 0.

26. Yes. For example, an object travelling 2.0 m [E] for 1.0 s, then 2.0 m [W] for 1.0 s has an average speed of 2.0 m/s but an average velocity of 0.

27. $\Delta \vec{d}_1 = \vec{v}\,\Delta t$

$$= (100 \frac{\text{km}}{\text{h}} \text{ [E]})(3.00 \text{ h})$$
$$= 300 \text{ km [E]}$$

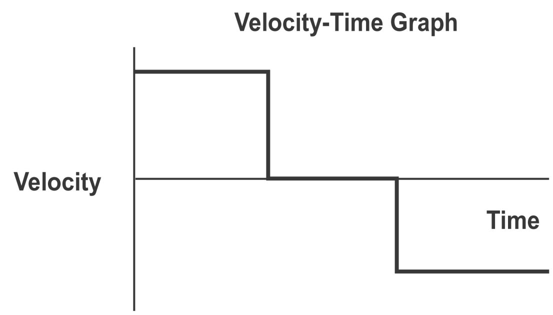
$\Delta \vec{d}_2 = \vec{v}\,\Delta t$

$$= (110 \frac{\text{km}}{\text{h}} \text{ [E]})(1.00 \text{ h})$$
$$= 110 \text{ km [E]}$$

$\Delta \vec{d}_t = \Delta \vec{d}_1 + \Delta \vec{d}_2$
$= 410$ km [E]

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$
$$= \frac{410 \text{ km[E]}}{4.00 \text{ h}}$$
$$= 103 \text{ km/h [E]}$$

28. a) Upward-sloping straight line: uniform motion in a positive direction
Horizontal line: Rest
Downward-sloping straight line: uniform motion in a negative direction
b)



29. a) Yes, because frictional forces will slow the car down.
b) No, because there are minimal frictional forces in space. As the spacecraft nears a planet, however, the gravitational forces will act on it.

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B2.1 Check and Reflect

1. Faraday discovered that magnetism can produce electricity.
2. a) Oersted's experiment was a primitive electric motor. As an electric current flowed in a wire, it produced a magnetic field that surrounded the wire. Electrical energy produces magnetic energy. When this wire is placed in another external magnetic field, the wire will move.
b) Faraday invented the first electric generator. Magnetism produces electricity. When a wire cuts a magnetic field it produces an electric current.
c) Seebeck invented a thermo-electric device. Heat can be converted to electricity. When two strips of different metals of different temperatures are attached at a junction, the thermal energy flows between the two metals through the junction, and a current is produced in the metal strips.
d) Edison invented the light bulb. Electricity is converted to light energy.

e) Volta invented the battery. The chemical reaction between two different types of metals in contact with one another can produce an electric current.

3. a) electromagnets
   b) electric generators
   c) thermo-electric devices; students are unlikely to be able to identify specific applications (e.g., portable refrigerators, night-vision goggles)
   d) light bulbs
   e) batteries for all kinds of devices
4. Nuclear fusion is the fusing of the nuclei of two smaller atoms to form a larger nucleus, and nuclear fission is the breaking up of a larger nucleus to form two smaller nuclei. In both reactions, a large amount of energy is released. Another difference is that nuclear fusion releases much more energy than nuclear fission does. A similarity between the two reactions is that they both involve a nuclear change.
5. Early scientists thought that the Sun's energy came from chemical energy of burning substances. This theory was not accepted because the Sun waould have burned up completely in about 5000 years.
6. Energy from the Sun comes from nuclear fusion reactions. Hydrogen nuclei fuse and in the process produce large amounts of energy.
7. The ancient Greeks had difficulty defining energy because it could not be seen. It can only be observed when it does something.
8. They thought that a quantity called *vis viva* or a "living force" was transmitted through the balls and caused the ball on the other side to rise.
9. a) Sadi Carnot discovered that the transformation of heat into mechanical energy could occur only when heat flows from a hot to a cold object; in the process some heat is always lost.
   b) James Young correctly suggested that mechanical energy combined kinetic energy and potential energy, and that mechanical energy was related to the work a system can do.
   c) Joseph Black suggested that heat was a fluid called "caloric" that flowed from hot to cold objects.
   d) Count Rumford was the first to suggest that heat and mechanical energy were related.
10. The moving block of wood swinging toward the motionless block has kinetic energy. When it strikes the stationary block, it loses its kinetic energy, which is converted to thermal energy in the stationary block. This increase in thermal energy causes the block's temperature to rise. The manipulated variable is the kinetic energy of the first block, and the responding variable is the thermal energy of the other block. If the swinging block were released from a greater height, it would have more kinetic energy and thus there would be a greater transfer of energy during the collision and the temperature of the second block should rise higher.
11. Students' answers will vary, but may include examples of potential (gravitational, electric, or chemical), kinetic, chemical, electric, heat, light, radiant, or magnetic energy.
12. a) chemical energy
    b) radiant or light energy
    c) kinetic energy
    d) electric energy
    e) radiant energy
    f) potential energy
    g) magnetic energy
13. a) Students' answers will vary. Example: A battery requires energy from a chemical reaction in the battery to produce electricity.
    b) Students' answers will vary. Example: A solar panel requires light energy to produce electricity.
    c) Students' answers will vary. Example: A thermal imaging sheet or infrared film requires heat energy.
    d) Students' answers will vary. Example: A TV requires electrical energy to work.
    e) Students' answers will vary. Example: A compass requires magnetic energy to work.
14. a) Students' answers will vary. Example: A fuel cell produces chemical energy.
    b) Students' answers will vary. Example: A light bulb produces light energy.
    c) Students' answers will vary. Example: A toaster produces heat.
    d) Students' answers will vary. Example s: A generator will produce electrical energy.
    e) Students' answers will vary. Example: An electromagnet will produce magnetic energy.
15. Students' answers will vary. Example: If sound is a form of energy, then it should be easily converted to other forms of energy. For example, a sound wave, carrying sound energy from a tuning fork, can be received by a microphone. The microphone changes the sound energy to electrical energy in the form of a current that can then be displayed as waveforms of the sound on an oscilloscope. Alternatively, a struck tuning fork could be placed in water. The waves produced in the water are produced by the sound energy from the tuning fork.

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Practice Problem

Example Problem B2.1

1. $E_{p(grav)} = mgh$
$= (25.0 \text{ kg})(9.81 \text{ m/s}^2)(4.00 \text{ m})$
$= 981 \text{ J}$

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Practice Problems

Example Problem B2.2

2. $E_{p(grav)} = mgh$

$$h = \frac{E_{p(grav)}}{mg}$$

$$= \frac{47.0 \text{ J}}{(0.800 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)}$$

$= 5.99 \text{ m}$

3. $E_{p(grav)} = mgh$

$$m = \frac{E_{p(grav)}}{gh}$$

$$= \frac{1.47 \times 10^3 \text{ J}}{\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(3.00 \text{ m})}$$

$= 49.9 \text{ kg}$

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B2.2 Check and Reflect

1. Potential energy is not obvious because it is stored energy. It is only evident when it transforms into another form of energy.
2. a) elastic potential energy
b) gravitational potential energy
c) elastic potential energy
d) gravitational potential energy
e) chemical potential energy
3. Kinetic energy is energy due to the motion of an object, and potential energy is due to the state or position of the object. Also, potential energy is stored energy but kinetic energy cannot be stored.
4. a) $W = Fd$
$W = (32.0 \text{ N})(3.00 \text{ m})$
$W = 96.0 \text{ J}$
b) $W = E_p = 96.0 \text{ J}$

5. $$F = \frac{W}{d}$$
$$= \frac{155 \text{ J}}{1.20 \text{ m}}$$
$= 129 \text{ N}$

6. $$h = \frac{E_p}{mg}$$
$$= \frac{800 \text{ J}}{(55.0 \text{ kg})(9.81 \text{ m/s}^2)}$$
$= 1.48 \text{ m}$

7. $E_p = W = Fd$
$= (500 \text{ N})(0.750 \text{ m})$
$= 375 \text{ J}$

8. $$F = \frac{E_p}{d}$$
$$= \frac{320 \text{ J}}{0.100 \text{ m}}$$
$= 3.20 \times 10^3 \text{ N}$

9. $E_p = mgh$
$= (60.0 \text{ kg})(9.81 \text{ m/s}^2)(3.50 \text{ m})$
$= 2.06 \text{ x } 10^3 \text{ J}$

10. To increase the elastic potential energy of a spring, you could stretch or compress a spring a greater distance. Students may also mention that you could change the type of spring to one with greater or less tension.
11. Potential energy is calculated relative to a reference point where the potential energy is 0. Relative to the surface of Earth, an object would have a potential energy of 0. However, relative to the centre of Earth, the object still has gravitational potential energy because it could potentially fall down a mine shaft farther toward the centre of Earth.

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Practice Problems

Example Problems B2.3, B2.4

4. $$E_k = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(9.11 \times 10^{-31} \text{ kg})\left(2.00 \times 10^5 \frac{\text{m}}{\text{s}}\right)^2$$
$= 1.82 \text{ x } 10^{-20} \text{ J}$

5. $E_k = \frac{1}{2}mv^2$

$m = \frac{2E_k}{v^2}$

$= \frac{2(18\text{ J})}{\left(2.2\frac{\text{m}}{\text{s}}\right)^2}$

$= 7.4\text{ kg}$

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Practice Problems

Example Problem B2.5

6. $E_k = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_k}{m}}$

$= \sqrt{\frac{2(304\text{ J})}{0.300\text{ kg}}}$

$= 45.0\ \frac{\text{m}}{\text{s}}$

7. $E_k = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_k}{m}}$

$= \sqrt{\frac{2(18\text{ J})}{7.4\text{ kg}}}$

$= 2.2\text{ m/s}$

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B2.3 Check and Reflect

1. Kinetic energy is associated with the motion of an object.
2. The mass and the speed of the object determine its kinetic energy as described in the formula $E_k = \frac{1}{2}mv^2$.
3. $1\text{ J} = 1\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$
4. a) On the way down, the kinetic energy of the mass gradually increases, until it is half-way down. From the half-way point, the kinetic energy gradually decreases to zero. On the way back up, the kinetic energy increases until the half-way point. From there up, it gradually decreases to zero.

   b) i) A gain in kinetic energy can only be the result of conversion from another form of energy. In this case, elastic potential energy in the spring is converted to kinetic energy.

   ii) A loss on kinetic energy indicates that kinetic energy is converted to some other form of energy; in this case, potential energy.

5. a) $E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}(0.500\text{ kg})(12.0\text{ m/s})^2$

$= 36.0\text{ J}$

b) $E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}(75.0\text{ kg})(40\text{ m/s})^2$

$= 6.00 \text{ x } 10^4\text{ J}$

c) $E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}(4.00 \text{ x } 10^{-3}\text{ kg})(140\text{ m/s})^2$

$= 39.2\text{ J}$

6. $E_k = \frac{1}{2}mv^2$

$m = \frac{2E_k}{v^2}$

$= \frac{2(57.6\text{ J})}{\left(2.40\ \frac{\text{m}}{\text{s}}\right)^2}$

$= \frac{115.2\ \frac{\text{kg}\cdot\cancel{\text{m}^2}}{\cancel{\text{s}^2}}}{5.76\ \frac{\cancel{\text{m}^2}}{\cancel{\text{s}^2}}}$

$= 20.0\text{ kg}$

7. a) $E_{ki} = \frac{1}{2}mv^2$

$v_i = \sqrt{\frac{2E_{ki}}{m}}$

$= \sqrt{\frac{2(320\text{ J})}{40.0\text{ kg}}}$

$= \sqrt{\frac{640\ \frac{\cancel{\text{kg}}\cdot\text{m}^2}{\text{s}^2}}{40.0\ \cancel{\text{kg}}}}$

$= 4.00\ \frac{\text{m}}{\text{s}}$

b) $E_{K_f} = \frac{1}{2}mv^2$

$v_f = \sqrt{\frac{2E_{K_f}}{m}}$

$= \sqrt{\frac{2(400\ \text{J})}{40.0\ \text{kg}}}$

$= \sqrt{\frac{800\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}}{40.0\ \text{kg}}}$

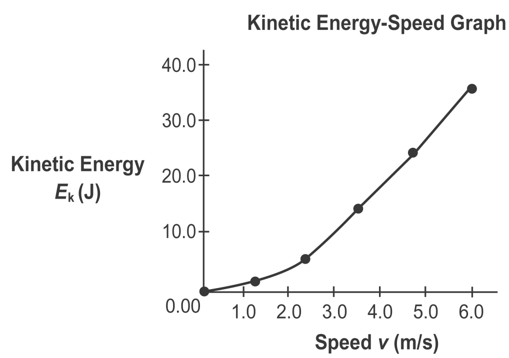
$= 4.47\ \frac{\text{m}}{\text{s}}$

Therefore, $\Delta v = v_f - \Delta v_i$

$= 4.47\ \frac{\text{m}}{\text{s}} - 4.00\ \frac{\text{m}}{\text{s}}$

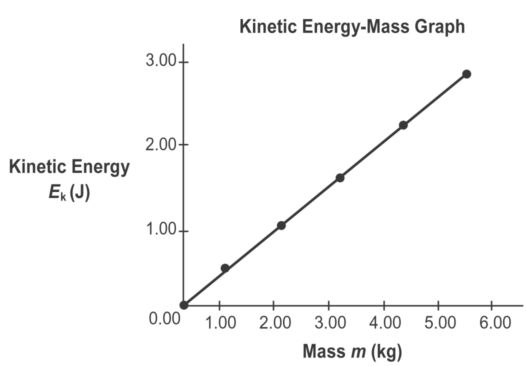
$= 0.470\ \frac{\text{m}}{\text{s}}$

8. a)



b) The graph shows that kinetic energy varies directly with the square of the speed.

9. a)



b) The graph shows that kinetic energy varies directly with mass.

10. a) Since $E_k = \frac{1}{2}mv^2$

then $E_k \propto m$

$\frac{E_{k1}}{E_{k2}} = \frac{m_1}{m_2}$

$E_{k2} = \frac{E_{k1}\cdot m_2}{m_1}$

$= \frac{(40.0\ \text{J})(2)}{1}$

$= 80.0\ \text{J}$

b) Since $E_k = \frac{1}{2}mv^2$

then $E_k \propto v^2$

$\frac{E_{k1}}{E_{k2}} = \frac{v_1^2}{v_2^2}$

$E_{k2} = \frac{E_{k1}\cdot v_2^2}{v_1^2}$

$= \frac{(40.0\ \text{J})(2)^2}{1^2}$

$= 160\ \text{J}$

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Practice Problems

Example Problem B2.6

8. $E_m = E_k + E_{p(grav)}$

$= \frac{1}{2}mv^2 + mgh$

$= \frac{1}{2}(0.300\ kg)\left(8.00\ \frac{m}{s}\right)^2 + (0.300\ kg)(9.81\ m/s^2)(30.0\ m)$

$= 9.60\ \text{J} + 88.29\ \text{J}$

$= 97.9\ \text{J}$

9. $E_m = E_k + E_{p(grav)}$

$E_{p(grav)} = E_m - E_k$

$= E_m - \frac{1}{2}mv^2$

$= 3.00\times10^3\ \text{J} - \frac{1}{2}(55.0\ \text{kg})\left(8.33\ \frac{\text{m}}{\text{s}}\right)^2$

$= 3.00\times10^3\ \text{J} - 1.91\times10^3\ \text{J}$

$= 1.09\ \text{x}\ 10^3\ \text{J}$

10. $E_m = E_k + E_{p(grav)}$

$E_k = E_m - E_{p(grav)}$

$= E_m - mgh$

$= 1.88\times10^3\ \text{J} - (2.00\ \text{kg})\left(9.81\frac{\text{m}}{\text{s}^2}\right)(50.0\ \text{m})$

$= 1.88\times10^3\ \text{J} - 981\ \text{J}$

$= 899\ \text{J}$

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Practice Problems

Example Problem B2.7

11. $E_{\text{k}_{\text{(bottom)}}} = E_{\text{p(grav)}_{\text{(top)}}}$

$$\frac{1}{2}mv^2 = mgh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2\left(9.81\frac{\text{m}}{\text{s}^2}\right)(12.0\text{ m})}$$

$$= 15.3\frac{\text{m}}{\text{s}}$$

12. $E_{\text{p(grav)}_{\text{(top)}}} = E_{\text{k}_{\text{(bottom)}}}$

$$mgh = \frac{1}{2}mv^2$$

$$h = \frac{1}{2}\left(\frac{v^2}{g}\right)$$

$$= \frac{\left(1.60\frac{\text{m}}{\text{s}}\right)^2}{2\left(9.81\frac{\text{m}}{\text{s}^2}\right)}$$

$$= 0.130\text{ m}$$

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Practice Problems

Example Problem B2.9

13. $E_\text{m} = E_{\text{p(grav)}} + E_\text{k}$

$$E_{\text{p(grav)}} = E_\text{m} - E_\text{k}$$

$$= E_\text{m} - \frac{1}{2}mv^2$$

$$= 0.481\text{ J} - \frac{1}{2}(0.020\text{ kg})\left(4.10\ \frac{\text{m}}{\text{s}}\right)^2$$

$$= 0.481\text{ J} - 0.168\text{ J}$$

$$= 0.313\text{ J}$$

14. E_m —> E_k

Therefore E_k = .491 J

Since $E_\text{k} = \frac{1}{2}mv^2$

$$v = \sqrt{\frac{2E_\text{K}}{m}}$$

$$= \sqrt{\frac{2(0.491\text{ J})}{0.500\text{ kg}}}$$

$$= \sqrt{\frac{2(.491\ \frac{\cancel{\text{kg}}\cdot\text{m}^2}{\text{s}^2})}{.500\ \cancel{\text{kg}}}}$$

$$= 1.40\ \frac{\text{m}}{\text{s}}$$

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B2.4 Check and Reflect

1. Mechanical energy is the sum of the kinetic and potential energy of an object at any given time.
2. a) The moment the ball leaves the kicker's foot, the ball has kinetic energy.
   b) Halfway to its highest point, it has kinetic and potential energy.
   c) At its highest point, it has potential energy and kinetic energy.
   d) The kinetic and gravitational potential energy are equal when the ball is halfway up or down its vertical arc.
   e) The kinetic energy is lowest at the top of the arc.
   f) The gravitational potential energy is lowest at the bottom of the arc.
   g) The mechanical energy is the same anywhere in the arc after the ball leaves the foot of the punter.
3. The law of conservation of energy states that the total amount of energy in a given situation remains constant.
4. a) As the height increases, the gravitational potential energy increases directly, and as the ball falls there is a corresponding loss of gravitational potential energy.
   b) As the height increases, the kinetic energy decreases directly, and as the ball falls there is a corresponding increase in kinetic energy.
   c) As the height increases, the mechanical energy remains constant.
5. a) $W = Fd$
   W = (40.0 N)(0.100 m)
   W = 4.00 J
   b) The work is stored as elastic potential energy in the spring.
   c) The elastic potential energy in the spring is converted to kinetic energy in the ball.
   d) The ball will have 4.00 J of kinetic energy the instant the ball leaves the spring.

e) $v = \sqrt{\frac{2E_k}{m}}$

$= \sqrt{\frac{2(4.00 \text{ J})}{1.00 \times 10^{-2} \text{ kg}}}$

$= 28.3$ m/s

f) The ball will gain 4.00 J of gravitational potential energy.

g) $h = \frac{E_p}{mg}$

$= \frac{4.00 \text{ J}}{(1.00 \times 10^{-2} \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)}$

$= 40.8$ m

6. $E_{k(bottom)} = E_{k(top)}$

$1/2mv^2 = mgh$

$v = \sqrt{2gh}$

$= \sqrt{2(9.81 \frac{\text{m}}{\text{s}^2})(.910 \text{ m})}$

$= 4.23$ m/s

7. $E_m = E_k + E_{p(grav)}$

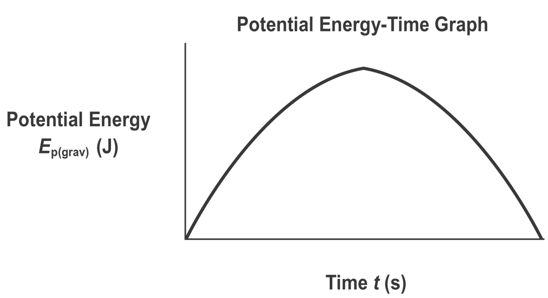
$= 1/2mv^2 + mgh$

$= 1/2(0.300 \text{ kg})(1.50 \text{ m/s})^2 + (0.300 \text{ kg})(9.81 \text{ m/s}^2)(1.30 \text{ m})$

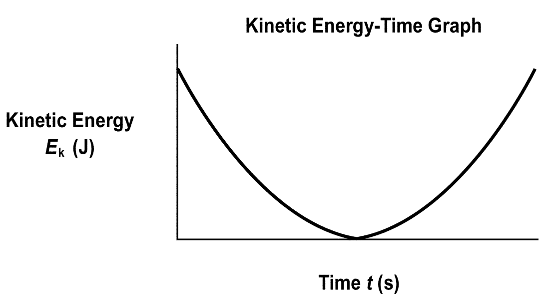
$= 0.3375 \text{ J} + 3.8259$

$= 4.16$ J

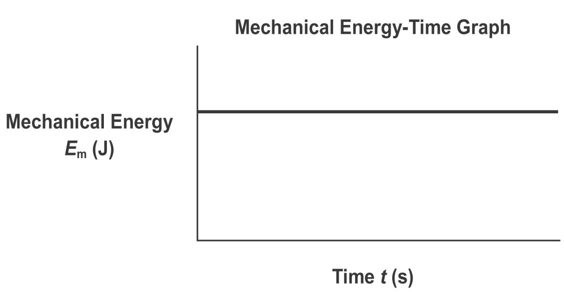
8. a)



b)



c)



9. a) $E_{p(grav)} = mgh$

$= (2.00 \text{ kg})(9.81 \text{ m/s}^2)(1.50 \text{ m})$

$= 29.4$ J

b) $E_{p(grav)} = E_k$

Therefore $E_k = 29.4$ J

Since $E_k = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_k}{m}}$

$= \sqrt{\frac{2(29.4 \text{ J})}{2.00 \text{ kg}}}$

$= \sqrt{\frac{2(29.4 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2})}{2.00 \text{ kg}}}$

$= 5.42$ m/s

c) i) maximum gravitational potential energy: top of the arc

ii) maximum kinetic energy: bottom of the arc

iii) maximum mechanical energy: throughout the arc

10. It will lose some kinetic energy to friction in the air.

11. a) upper line: object's mechanical energy is increasing

middle line: object has constant mechanical energy

bottom line: object's mechanical energy is decreasing

b) The top line is impossible unless new energy is added to the system.

Student Book page 195

B2.5 Check and Reflect

1. Flowing water from a dam or river has kinetic energy. When the water strikes the turbines in a power plant, the kinetic energy is transformed to mechanical energy in the rotating turbines. The rotation of the turbine turns a coil of wire in a magnetic field, and the mechanical energy is converted into electrical energy in the generator.
2. The burning of coal in a combustion chamber converts chemical energy to heat. The heat is used to produce steam that is directed towards the turbines. From this point, the processes of energy transformation are the same as in question 1.
3. a) In a hydro-electric power station, heat is only produced wherever there is friction, and the greatest source of heat due to friction comes from the rotating turbines in the generator.

b) In a coal-burning power station, the greatest loss of heat occurs in the combustion chambers, where fuel is burned to heat water to produce steam.

4. In a coal-burning power station, there is a combustion chamber to burn the fuel that heats the water to produce steam. In any combustion process, the majority of the heat is lost in the venting of exhaust gases. Also, as the steam travels through the piping, it cools and condenses, losing a lot of heat to the surroundings. In hydro-electric generating stations, heat is not required to produce electricity. Heat is only produced through friction, which can be controlled.
5. Nuclear energy → heat → mechanical energy → electrical energy
6. Solar cells are similar to batteries because the positive and negative layers in a solar cell are similar to the positive and negative terminals in a battery.
7. Students' answers will vary, but may include:
   light bulbs: electricity to light
   speakers: electricity to sound
   radiators: heat to radiant energy
   electric clocks: electricity to mechanical energy
8. a) Nuclear energy is converted to radiant energy in the Sun. Radiant energy travels to Earth and is stored as chemical potential energy in plants through the process of photosynthesis. The stored chemical energy in plants, in the form of fossil fuels, is combusted in a generating station to produce heat. The heat produces steam, which turns turbines, converting heat energy into mechanical energy. The mechanical energy in the rotating turbines produces electricity. The electricity transmitted to your home is converted into heat in the heating pad.
   b) Nuclear energy is converted to radiant energy in the Sun. Radiant energy travels to Earth and is stored as chemical potential energy in plants through the process of photosynthesis. The stored chemical energy in plants, in the form of the fossil fuel gasoline, is combusted in the engine to produce mechanical energy and heat.
   c) Nuclear energy is converted to radiant energy in the Sun. Radiant energy travels to Earth and is stored as chemical potential energy in plants through the process of photosynthesis. The stored chemical energy in plants is digested by the horse, which converts the stored chemical potential energy through the process of respiration into mechanical energy and heat.
9. a) Students' answers will vary. One example is: When you go outside, you can detect many forms of energy, including heat, light, sound, radiant, mechanical (kinetic and potential), magnetic, electrical, and nuclear.
   b) Students' answers will vary. One example is: The chemical potential energy in oil, gas, and coal, formed when plants converted radiant energy from the Sun to chemical energy through the process of photosynthesis. It has been stored for millions of years.
   c) Students' answers will vary. One example is: Light energy is converted to electric energy in solar cells.
10. As the barbell falls, it is changing its position and is in motion. Both of these are evidence that an energy conversion has taken place. Students may also mention that when the barbell hits the floor, it makes a loud noise, which is also evidence of an energy conversion.
11. Heat involves the motion of atoms within a substance, and motion is kinetic energy, which is part of mechanical energy.

Student Book pages 196–197

B2.0 Section Review

Knowledge

1. Students' answers may vary but could include heat, electrical, kinetic, potential, light, sound, nuclear, radiant, or magnetic energy.
2. Energy is defined as the ability to do work.
3. Thermodynamics is a study of the interrelationships between heat, work, and energy.
4. The principle of thermodynamics developed from the study of heat was that heat flows from hot to cold objects.
5. Nuclear fusion is the combining of two smaller nuclei to produce a larger nucleus, while nuclear fission is the breaking down of a larger nucleus into two smaller nuclei.
6. The reaction in the Sun is nuclear fusion of smaller hydrogen atoms into larger helium atoms.
7. Kinetic energy is the motion of an object, and potential energy is the position of the object.
8. a) Students' answers will vary. One example is: An object is rolling along the surface of Earth.
   b) Students' answers will vary. One example is: An object is held above the surface of Earth without moving.
   c) Students' answers will vary. One example is: An object is moving above the surface of Earth.
9. Potential energy becomes useful when it is converted to another form of energy that does work on an object.

10. Mechanical energy involves both potential and kinetic energy.
11. The mass of an object is a measure of the inertia of the object, measured in kilograms, while the weight of an object is a measure of the gravitational force on the object, and is measured in newtons. Mass is constant, while the weight varies with gravity.
12. Chemical energy is energy stored in the bonds of molecules. It is released during a chemical reaction.
13. a) The person has maximum kinetic energy at the beginning of the leap.
    b) The person has minimum kinetic energy at the top of the leap.
    c) The person has maximum gravitational potential energy at the top of the leap.
    d) The person has minimum gravitational potential energy at the start of the leap.
    e) The gravitational potential energy equals the kinetic energy at the halfway point of the person's rise into the air.
14. a) Students' answers will vary. One example is: When a moving ball with kinetic energy collides with a wall, some kinetic energy is lost to heat in the collision.
    b) Students' answers will vary. One example is: Striking a tuning fork on a table converts mechanical energy to sound energy.
    c) Students' answers will vary. One example is: The mechanical energy of a generator produces electricity, which can be converted to light.
    d) Students' answers will vary. One example is: The mechanical energy of a generator produces electricity.
15. The byproducts of a hydrogen fuel cell are water and oxygen.

Applications

16. They could not explain why the ball on the other side rose to nearly the same height. Some scientists suggested that the first ball had a *vis viva* or living force that was transmitted through the balls and caused the ball on the other side to rise.
17. Young thought that mechanical energy was related to the work a system could do.
18. Students' answers will vary but may include the following:
    chemical: battery
    light: light bulb
    thermal: toaster
    radiant: fireplace
    electric: generator
    kinetic: engine
    sound: stereo
19. Students' answers will vary but may include the following:
    chemical: leaves of trees
    light: Sun
    thermal: fire
    radiant: Sun
    electricity: electric eel
    kinetic: river
    sound: buzzing of a bee
20. $W = Fd$
    $= (30.0\text{ N})(1.50\text{ m})$
    $= 45.0\text{ J}$
21. $E_p = mgh$
    $= (1.00\text{ kg})(9.81\text{ m/s}^2)(1.00\text{ m})$
    $= 9.81\text{ J}$
22. The work done and the energy gained are not equal because energy is lost to friction as the block slides up the inclined plane.
23. There was 800 J of elastic potential energy stored in the springboard.
24. The assumption was that all the elastic potential energy was converted to gravitational potential energy. No energy was lost to heat.
25. $$v = \sqrt{\frac{2E_k}{m}}$$
    $$= \sqrt{\frac{2(800\text{ J})}{50.0\text{ kg}}}$$
    $$= 5.7\text{ m/s}$$
26. The assumption was that all the potential energy was converted to kinetic energy.
27. Students' answers will vary but may include the following: Digestion in your small intestine converts the stored chemical energy in food to heat and energy for cells, which can then be transformed into mechanical energy when the muscles in your vocal cords move to produce sound. In this example, chemical potential energy is converted to mechanical energy that, in turn, is converted to sound.
28. Students' answers may vary but could include the following:
    a) chemical to light: the burning of phosphorus produces a strong light
    b) light to chemical: photosynthesis converts light energy to stored chemical energy
    c) kinetic to heat: a moving object produces friction which produces heat
    d) heat to kinetic: heating air causes air molecules to vibrate faster
    e) electric to magnetic: electric energy is converted to magnetic energy in an electromagnet

f) magnetic to electrical: a generator converts magnetic energy to electrical energy

29. Solar cells are used to produce electricity on space stations because they convert light directly to electricity. Since they have no moving parts and don't involve chemical reactions, they never need maintenance or recharging.
30. As the ice cube melts, there is a change in temperature and shape, and as the ice cube slides down, there is a change in motion. These changes are evidence of energy conversions.

Extensions

31. Students' answers will vary. One example could be projecting an object into the air using a coiled spring or stretched elastic. Students would have to measure the height to which the object rises to determine the potential energy. They would then compare it to the kinetic energy given to the object from the initial, stored elastic potential energy through the work done to stretch the elastic. The manipulated variable would be the amount the spring was compressed or the elastic stretched. The responding variable would be the height to which the object rises.
32. A drop of water in a cloud has potential energy due to its position relative to the surface of Earth and it also has kinetic energy because it is moving. A drop of water on a still lake does not have these energies.
33. Yes. Earth has gravitational potential energy relative to the gravitational pull of the Sun. It also has kinetic energy because it is in motion around the Sun.
34. A scientist would consider the development of the hydrogen fuel cell as an energy source to be an important innovation because it involves a reaction in which electricity can be produced quite effectively with no recharging necessary. An environmentalist would consider it to be an important innovation because the only waste products are water and oxygen, both of which are beneficial to the environment.
35. Students' answers will vary but may resemble the following. We must develop a source of energy which will not be harmful to the environment, can be used to provide the necessary energy for all of society's needs, and can be easily accessible in all parts of the world. For example, electricity produced from hydrogen fuel cells or solar cells should be developed.

Student Book page 205

B3.1 Check and Reflect

1. Thermodynamics is the study of the interrelationships between heat, work, and energy.
2. The first law of thermodynamics states that the total energy, including heat, in a system and its surroundings must remain constant.
3. Work is the movement of matter from one place to another and heat is the transfer of thermal energy from one location to another.
4. a) 1st law of thermodynamics
   b) 2nd law of thermodynamics
   c) 1st law of thermodynamics
5. A heat engine converts heat into mechanical energy and a heat pump uses mechanical energy to transfer heat. Students may provide a variety of answers. For example, an automobile engine is a heat engine; a refrigerator is a heat pump.
6. A perpetual motion machine is able to transfer all the energy input into mechanical energy output with no loss of energy to the surroundings.
7. The second law of thermodynamics states that heat flows naturally from hot objects to cold objects and, in the process, some heat is lost to the surroundings. Some of this energy can be converted to mechanical energy
8. Two sticks rubbed together is positive work because work is done by the surroundings on a system.
9. When water condenses on a cold glass, heat is flowing from the warmer water vapour in the air to the cooler glass. As the water vapour cools, it condenses.
10. a) The first law of thermodynamics: Heat in a system and its surroundings remains constant. Heat cannot be created so you cannot get something for nothing.
    b) The second law of thermodynamics: When heat flows from hot to cold, some, but not all, of this heat can be used to do work. So you will never come close to getting the same amount of work output as the amount of heat put into a system.
    c) The second law of thermodynamics: Heat naturally flows from hot to cold, not from cold to hot. A rock will never naturally jump into the air.
11. No. The refrigerator is a heat pump. It uses mechanical energy to transfer heat from a hot object to a cold object. If you leave the refrigerator door open, the refrigerator will operate at a greater rate in attempting to cool the interior. And in the process, it will transfer

thermal energy to the room making the room even hotter.

12. A perpetual motion machine attempts to convert one type of energy to another type of energy with 100% efficiency and so no energy would be lost to the surroundings. A Rube Goldberg machine just converts energy from one type to another with no regard for efficiency.

Student Book page 214

B3.2 Check and Reflect

1. Hero's steam engine was considered a toy because it did not perform any useful purpose.
2. By the 1600s, many European countries had cut down most of their forests. Since wood was the primary source of energy, they had to switch to coal. One of the problems in coal mining is that the mine shafts slowly fill with water. The water had to be extracted with pumps. A machine had to be developed that would operate the pumps continuously and provide more power. Thus the evolution of the steam engine began.
3. One discovery was the tremendous force created by a vacuum, and the other discovery was that water increases its volume by 1300 times when converted to steam.
4. The first attempts to create gunpowder explosions in a chamber to move a piston were considered too dangerous, so inventors concentrated on developing relatively safer technologies using steam. The internal combustion engine was developed as a way of improving on steam engines, which could not be used on roads. Another reason was that gasoline had not yet been discovered as a fuel source.
5. Watt considered Newcomen's engine inefficient because the water was heated to produce steam and was cooled to create a vacuum in the same chamber. To produce steam again, the chamber had to be reheated. Watt considered this to be a waste of energy. He designed a separate chamber in which to cool the steam, thus the heating chamber always remained hot.
6. Students could provide one of the following answers. Watt's engine:
   - had a separate chamber to condense the steam.
   - had double-acting pistons, so that the downward as well as the upward stroke produced power.
   - converted the back-and-forth motion of the piston into rotary motion.
7. The advantages of steam engines were that they were easy to build and easy to maintain. Two disadvantages were that they were very large and very inefficient.
8. Daimler designed an internal combustion engine powered by gasoline rather than coal gas. This was an improvement because gasoline burns hotter than coal gas and provides more energy.
9. The intake valve allows for the injection of the fuel into the combustion chamber, and the exhaust valve expels the waste gases from combustion.
10. a) Papin designed the first heat engine in which heat was used to do work. The heat created steam that was used to drive a piston forward in a tube. As the steam cooled, a vacuum was created, and atmospheric pressure pushed the piston back.
    b) Newcomen devised a pump that used a beam pivoted at its centre. Steam pressure would cause the beam to tilt one way, and by condensing the steam the beam would tilt the other way. The tilting of the beam, back and forth, would cause a rod to move up and down, drawing water up a pipe.
    c) Watt devised a steam engine with a separate condenser to cool the steam. This greatly improved the efficiency of the steam engine as the boiler chamber always remained hot.
11. Student diagrams should resemble Figure B3.11 on page 206 of the student book. The diagram should show that the pressure created by the steam moves the piston up. When the steam condenses, a partial vacuum is created, and the piston is pushed back down by atmospheric pressure.
12. The internal combustion engine delivered more power and was much smaller than the steam engine. Also, it did not need a separate boiler to create the heat needed to do the work.
13. a) minivan: piston
    b) 747: turbine
    c) propeller airplane: piston
    d) propeller boat: piston
    e) lawn mower: piston
    f) motorcycle: piston
14. a) Students' answers will vary but could include: a gas-powered lawnmower, a gas powered weed-eater, a gas-powered generator.
    b) Students' answers will vary but could include: a twirling water sprinkler, any fan with an electric motor.

Student Book page 216

Practice Problem

Example Problem B3.1

1. $$\% \text{ efficiency} = \frac{E_{\text{m (useful output)}}}{E_{\text{m (total input)}}} \times 100\%$$
$$= \frac{1.96 \times 10^4 \text{ J}}{5.61 \times 10^4 \text{ J}} \times 100\%$$
$$= 34.9\%$$

Student Book page 217

Practice Problems

Example Problem B3.2

2. $$\% \text{ efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100$$
$$\text{efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}}$$
$$E_{\text{m(useful output)}} = \text{efficiency} \times E_{\text{m(total input)}}$$
$$= (0.85)(15 \text{ J})$$
$$= 13 \text{ J}$$

Example Problem B3.3

3. $$\% \text{ efficiency} = \frac{\text{heat}_{\text{useful output}}}{\text{heat}_{\text{total input}}} \times 100\%$$
$$= \frac{125 \text{J}}{4.00 \times 10^3 \text{ J}} \times 100\%$$
$$= 3.13\%$$

Student Book page 220

B3.3 Check and Reflect

1. Heat is usually the wasted energy during an energy transfer or transformation.
2. The exhaust system or the cooling/heating systems consume the most energy.
3. Efficiency is how well a device produces useful energy outputs compared to the total energy input.
4. A steam engine is more efficient than a gas or diesel engine.
5. a) Input: 1000 J
   b) Output: 800 J
   c) Useful work: 800 J
   d) Wasted energy: 200 J
   e) $$\text{percent efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100\%$$
   $$= \frac{800 \text{ J}}{1000 \text{ J}} \times 100\%$$
   $$= 80\%$$
6. Students' answers will vary. This is one example: Thermal energy is useful when it is used to heat a home or food. It is considered wasted energy when it is a product of an energy transformation, such as the combustion of fuel in an engine, to produce mechanical energy or movement.
7. $$\text{percent efficiency} = \frac{\text{Work}_{\text{useful output}}}{\text{Work}_{\text{total input}}} \times 100\%$$
$$= \frac{2.30 \times 10^3 \text{ J}}{3.50 \times 10^3 \text{ J}} \times 100$$
$$= 65.7\%$$
8. $$\text{Work}_{\text{useful output}} = \text{efficiency} \times \text{Work}_{\text{total input}}$$
$$= (0.350)(1.20 \times 10^4 \text{ J})$$
$$= 4.20 \times 10^3 \text{ J}$$
9. $$E_{\text{m(total input)}} = \frac{E_{\text{m(useful output)}}}{\text{efficiency}}$$
$$\text{Work}_{\text{total input}} = \frac{mgh}{\text{efficiency}}$$
$$= \frac{(2.00 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m})}{0.350}$$
$$= 2.80 \text{ x } 10^5 \text{ J}$$
10. The work input would be how much energy you consume in doing the work input and the work output would be how much energy the skateboard gains in terms of mechanical energy.
11. A perpetual motion machine is nearly 100% efficient while an internal combustion engine is only about 15% efficient.
12. A perpetual motion machine is much more efficient than a Rube Goldberg machine.

Student Book page 227

B3.4 Check and Reflect

1. Students' answers will vary but could include the following:
   Solar: solar cell, fossil fuel, biomass, or biogas
   Non-solar: nuclear, geothermal, tidal
2. The ultimate source of energy in the Sun is a nuclear fusion reaction where hydrogen nuclei fuse to form a heavier helium nucleus.
3. Biomass is any organic matter, such as wood, crop residues, seaweed, algae, and animal wastes.

4. Cogeneration is the process of using waste energy from one process to power a second process.
5. Sustainable: any process that supplies the needs of today's society without compromising the needs of future generations.
6. Fossil fuels are considered indirect solar energy sources because they were formed from the process of photosynthesis, which involves solar energy, in plants millions of years ago.
7. Photosynthesis converts solar energy to stored chemical energy directly. A windmill relies on solar energy to heat Earth's surface air first, creating convection currents of air, which then turn the turbines of a windmill.
8. Biomass is considered renewable because it can be replaced in a relatively short period of time.
9. The three factors are: an increasing population, an increasing demand for energy, and the reliance on non-renewable sources of energy.
10. An energy crisis happens when the reserves of available energy sources are depleted.
11. Two short-term solutions are to search for new reserves of fossil fuels and reduce the rate of consumption of existing fossil fuel reserves.
12. The most practical solution is to use our available non-renewable energy sources more efficiently, and to search for new, more sustainable energy sources.
13. Students' answers will vary, but should include some of the following.
    Costs of developing thermal power stations:
    - Fossil fuels cannot be replaced.
    - Combustion results in thermal pollution in the air.
    - Combustion results in emissions of harmful gases.
    - Fossil fuels are needed for the production of other materials such as fertilizers and chemicals.
    - Reserves are dwindling, which leads to global uncertainties and political unrest.

    Benefits of developing thermal power stations:
    - Fossil fuels are accessible in many places in the world.
    - Fossil fuels can be transported in large quantities via tanker or pipeline.
    - Fossil fuels can be transformed into other forms of energy through a relatively simple process of combustion.
    - Fossil fuels store a great deal of chemical potential energy.
    - Fossil fuels are affordable as an energy supply.
14. Students' answers will vary but could include the following:
    Advantages of a "user pay" tax:
    - The cost will fall only on the users and not the rest of society.
    - The tax will lead to increased conservation of energy.
    - The tax will force users to become more efficient.

    Disadvantages:
    - The tax will increase the cost of energy.
    - The tax would be difficult to administer and monitor.
    - The tax does not solve the problem of an energy crisis.

Student Book pages 228

B3.0 Section Review

Knowledge

1. Heat is converted to mechanical energy in a heat engine.
2. Heat flows naturally from hot objects to cold objects. In the process of heat transfer, some energy is always lost to heat.
3. In a perpetual motion machine, no energy is lost to the surroundings during energy transfers in the device.
4. When you form a snowball, heat is flowing from your hands to the snow.
5. A thermo-electric converter has two strips of different metals joined at a junction. When the two strips are at different temperatures, heat flows from the warmer metal to the colder one. This flow of heat creates an electrical current that can be converted to mechanical energy in the motor.
6. Animals, wind, and moving water were used to operate pre-industrial simple machines.
7. Students' answers will vary but could include the following:
   Benefits of non-renewable energy sources:
   - easily obtainable
   - found in almost all places in the world
   - transportable in large quantities relatively cheaply

   Costs of non-renewable energy sources:
   - harmful because of combustion products
   - wasteful of thermal energy
   - not sustainable
8. Southern Alberta has strong and steady winds due to the prevailing westerlies over the Rocky Mountains.

Applications

9. Students' answers will vary but may be similar to the following. A light bulb converts electrical

energy to light energy but most of the electrical energy is lost as heat. The heat and the light produced must equal the amount of input electricity.

10. Assuming that the floor does not absorb any of the energy from either ball, the steel ball will rise higher because it does not deform as much as the rubber ball when it hits the floor. But as the rubber ball deforms, its kinetic energy is converted to elastic potential energy, and during the deformation, energy is lost to heat. This is an application of the first law of thermodynamics.
11. This violates the first law of thermodynamics. You can never get more out of a system than you put in. Energy can never be created.
12. Hydro generation can be up to 75% efficient while thermal generation is only up to 15% efficient because in thermal generating stations, most of the energy from combustion is lost to heat. This is the waste energy. The useful energy is only the amount of electrical energy produced.
13. A 25% efficiency means that only one quarter of the total energy input is converted to useful energy output.
14. a) heat output = efficiency x heat input
    = (0.35)(1000 J)
    = 350 J
    = 3.5×10^2 J
    b) The rest of the energy is wasted in the form of heat.
15. The energy crisis is the depletion of our energy sources.
16. The current solution is to try to find new reserves of non-renewable sources of energy, conserve energy, and try to become more efficient.
17. Students' answer will vary but could include the following:
    a) Residential sector: better insulation of homes
    b) Commercial sector: energy-efficient office equipment
    c) Industrial sector: more efficient machines and cogeneration where possible
    d) Transportation sector: more fuel-efficient vehicles or rail
18. Increasing energy conservation and energy efficiency means we use less non-renewable energy but we are still using them up.
19. A better solution to the energy crisis is to develop a new source of energy that is renewable.
20. Alberta power plants use non-renewable energy sources because there are large reserves of coal located near the thermal generating stations. They don't use wood because wood would have to be transported from great distances, depending on the location of the cutting areas.

Extensions

21. Because cold air falls, the cold air from the freezer compartment was used to cool food in lower compartments.
22. They are related because the greater the efficiency, the less energy is used so more is conserved.
23. It can be made more efficient by installing better insulation on the hot-water heater, lowering the temperature of the hot water, and installing more efficient burners or elements.
24. Electric car motors do not have as much power as internal combustion engines and electric batteries run down too quickly.
25. To an environmentalist the term "sustainable development" means developing energy sources other than fossil fuels that will ensure a safe environment and an energy supply for future generations. To an oil industry employee, the term "sustainable development" means discovering new reserves for future generations.

Student pages 232–237

Unit B Review

Vocabulary

1. acceleration: change in velocity during a specific time interval
   cogeneration: using the waste energy from one process to power another process
   efficiency: the ratio of the useful energy output to the total energy input
   energy: the ability to do work
   first law of thermodynamics: the total amount of energy, including heat, in a system and its surroundings always remains constant
   force: a push or pull
   heat: the transfer of thermal energy
   kinetic energy: energy due to the motion of an object
   law of conservation of energy: energy can never be created nor destroyed but can be converted from one form to another.
   potential energy: energy due to the position of an object relative to another object (e.g., gravitational potential energy results from an object's position relative to Earth's surface)
   second law of thermodynamics: heat flows naturally from hot to cold objects and in the process can be made to do work; during this process some energy is always lost as heat

sustainable: processes that will not compromise future generations
system: set of interconnected parts; in studies of work and energy transfers, object or objects involved in a transfer
uniform motion: travel at a constant rate of motion in a straight line
velocity: speed and direction of an object
work: a force moving an object through a distance

Knowledge

B1.0

2. Students' answers will vary for the examples given in parentheses below.
   a) scalar (10 m)
   b) vector (10 m [E])
   c) scalar (10 m/s)
   d) vector (10 m/s [E])
   e) vector (10 m/s^2 [E])
   f) scalar (10 J)
   g) scalar (10 J)
   h) vector (10 N [E])
3. You must measure the distance travelled and the time in which the distance was travelled.
4. Acceleration is the rate of change in speed. It may be speeding up or slowing down. Uniform motion is motion in which the object maintains the same speed over a time interval.
5. a) If a force is applied in the same direction as the motion, then the object will speed up.
   b) If a force is applied in the opposite direction to the motion, then the object will slow down.
6. Work is done on an object when a force moves an object through a distance. The force and the distance moved must be in the same direction.
7. If you carry an object while moving forward, the force applied on the object is vertical to overcome the gravitational force on the object, while the distance travelled is horizontal.
8. $W = Fd$
   $= (20.0\text{ N})(1.30\text{ m})$
   $= 26.0\text{ J}$

B2.0

9. $1\text{ J} = 1\ \dfrac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$
10. Kinetic energy is energy due to the motion of an object.
11. Gravitational and elastic are two forms of potential energy.
12. The weight of an object is the force necessary to move an object against the opposing force of gravity. If an object is lifted vertically, then this force is equivalent to the weight, and the distance the object moves vertically determines the work done on an object.
13. If you stretch the elastic more, it has more elastic potential energy. This transforms into more kinetic energy in the rock, so the rock will have a greater speed.
14. Kinetic energy is greatest at the time that the rock leaves the catapult. The gravitational potential energy is greatest at the highest point the rock reaches.
15. Students' answers will vary but could include the following:
    a) Solar energy is converted to electrical energy in a solar cell.
    b) Light energy is converted to stored chemical energy in plants through photosynthesis.
    c) Chemical energy in a battery is converted to electrical energy.
16. Solar energy is converted to electrical energy.
17. Hydro-electric power stations do not involve combustion of fuels. This combustion results in a large loss of heat to the surroundings. So hydro is more efficient.
18. When you turn a page, chemical energy within the cells of your body is converted to the mechanical energy of your muscles that cause your hand to move. The mechanical energy from your hand does work in turning the page and thus gives the page mechanical energy.

B3.0

19. A heat engine uses heat to produce mechanical energy, and a heat pump uses mechanical energy to transfer heat. Students' examples will vary but could include: a jet engine is a heat engine, and an air conditioner is a heat pump.
20. They both stipulate that in any conversion to other types of energy, energy must be conserved.
21. Students' answers may vary but could include the following. A hot-water heater uses heat to heat up water. It illustrates the first law of thermodynamics because not all the heat that is put into the system heats up the water. Some of the heat will be lost to the surroundings.
22. If heat were added to a perpetual motion machine, all the heat should be completely transformed into mechanical energy with no heat lost to other forms of energy.
23. They both describe the behaviour of heat in transfers or transformations.
24. Students' answers will vary but may include the following. In the home, heat flows into a thermostat causing the metal strip to expand and

in the expansion, the strip moves, indicating a gain in mechanical energy.

25. Students' drawings should resemble Figure B3.14 on page 208 of the student book. A boiler produced steam that forced a piston up a cylinder. When cold water was sprayed on the outside of the cylinder, the steam would condense, and the piston would move back down the cylinder. The piston rod was connected to a pivoting beam, which in turn was connected to the mine pump. The up-and-down motion of the piston drove the pump.
26. A Watt engine uses steam power to drive a piston, while the internal combustion engine uses the gases produced from the combustion of fuels to drive a piston. An internal combustion engine produces much more heat than a steam engine.
27. Coal is formed from plants that used solar energy in the process of photosynthesis millions of years ago.
28. Students' answers will vary but could include the following. Gas furnaces, gas stoves, gas water heaters, etc., could all be converted to electrical devices. The electricity supplied to the home could come from hydro-electric or wind power stations.
29. Cogeneration is a process of using waste energy from one process to power another process. In some schools, water is heated to supply the hot water necessary for showers, etc. Once used, this hot water could be piped throughout the school to heat the building.

Applications

30. The three lines on the graphs should all be straight lines. The line with the steeper slope depicts the faster car, the line with the shallower slope depicts the slower car, and a horizontal line depicts the car at rest.

31. $\Delta t = \dfrac{\Delta d}{v}$

$= \dfrac{180 \text{ km}}{90.0 \text{ km/h}}$

$= 2.00 \text{ h}$

32. a) $\Delta d = \Delta d_1 + \Delta d_2$

$= 10.0 \text{ m} + 10.0 \text{ m}$

$= 20.0 \text{ m}$

b) $\Delta \vec{d} = \Delta \vec{d}_1 + \Delta \vec{d}_2$

$= \Delta 10.0 \text{ m [down]} + 10.0 \text{ m [up]}$

$= 0 \text{ m}$

c) $v = \dfrac{\Delta d}{\Delta t}$

$= \dfrac{20.0 \text{ m}}{4.00 \text{ s}}$

$= 5.0 \text{ m/s}$

d) $\vec{v} = \dfrac{\Delta \vec{d}}{\Delta t}$

$= \dfrac{0 \text{ m}}{4.00 \text{ s}}$

$= 0.0 \text{ m/s}$

33. $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$= \dfrac{50 \frac{\text{m}}{\text{s}} [\text{N}] - 0 \frac{\text{m}}{\text{s}}}{6.00 \text{ s}}$

$= 8.33 \text{ m/s}^2 \text{ [N]}$

34. $W = Fd$

$= (6.0 \text{ N})(0.33 \text{ m})$

$= 2.0 \text{ J}$

35. The chain and the sign are pulling forces, while the beam is a pushing force on the ring.

36. $W = Fd$

$= (100 \text{ N})(5.00 \text{ m})$

$= 500 \text{ J}$

37. By storing the water in high towers, the water gains the necessary gravitational potential energy to flow through the water system in the community.
38. The object gains kinetic energy because of its motion, but does not gain any gravitational potential energy.

39. $E_k = \dfrac{1}{2} m v^2$

$E_k = \dfrac{1}{2} (0.00230 \text{ kg})(2.50 \text{ m/s})^2$

$= 7.19 \times 10^{-3} J$

40. $v = \sqrt{\dfrac{2E_k}{m}}$

$= \sqrt{\dfrac{2(4.00 \times 10^5 J}{2.00 \times 10^3 kg}}$

$= 20.0 \text{ m/s}$

41. $E_p = mgh$

$= (0.400 \text{ kg})(9.81 \text{ m/s}^2)(500 \text{ m})$

$= 1.96 \text{ x } 10^3 \text{ J}$

42. $h = \dfrac{E_{p(grav)}}{mg}$

$= \dfrac{7.90 \times 10^5 J}{800 N}$

$= 988 \text{ m}$

43. $E_p = mgh$

$= (750 \text{ N})(15.0 \text{ m})$

$= 1.13 \times 10^4 \text{ J}$

E_p is converted from E_k ,
therefore $E_k = 1.13 \times 10^4$ J

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{2(1.13\times10^4 \text{ J})\left(\frac{750 \text{ N}}{9.81\frac{\text{m}}{\text{s}^2}}\right)}$$

$= 17.2$ m/s

44. i) a) This is gravitational potential energy
b) When the water in the reservoir is allowed to flow downhill, the gravitational potential energy can be made to move some device, converting the potential energy into kinetic energy.
c) This potential energy can be converted to electrical energy, as in a hydro-electric power station.

ii) a) The rocket has chemical potential energy.
b) When the chemical reaction occurs, the rocket will rise into the air.
c) The chemical potential energy was first converted into kinetic energy, which in turn was converted into gravitational potential energy.

iii) a) The toy gun has elastic potential energy.
b) When released, the elastic potential energy can move the dart.
c) The elastic potential energy is converted first to kinetic energy.

45. a) The initial source of energy is chemical potential energy. It is potential energy because it is stored energy.
b) The battery is still functional after a long period because the chemical reaction inside the battery does not occur unless there is a drain of the energy.
c) The stored chemical energy is converted to electrical energy.

46. $E_k = \frac{1}{2}mv^2$

$$= \frac{1}{2}(0.300 \text{ kg})\left[\left(747\frac{\text{km}}{\text{h}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\right]^2$$

$= 6.46 \times 10^3$ J

But E_k is converted to E_p,
therefore $E_p = 6.46 \times 10^3$ J

$$h = \frac{E_{p(grav)}}{mg}$$

$$h = \frac{6.46\times10^3 \text{ J}}{(0.300 \text{ kg})(9.81 \text{ m/s}^2)}$$

$= 2.19 \times 10^3$ m

47. Step 1: Find the work done in lifting the object to a height.
Step 2: Equate the work done W_{done} with E_p, which equals E_k.
Step 3: Once you know the E_k you can determine the speed.

48. Step 1: Determine the E_k.
Step 2: Equate the E_k with E_p.
Step 3: Once you know the E_p, you can determine the height. You must ignore friction.

49. Students' answers will vary but could be the following. Energy is used to heat water in a hot-water tank and the only purpose for the hot water in most homes is for washing. Once used, this waste hot water could be piped throughout the home for heating.

50. Mechanical energy in the movement of the match is first converted to heat to ignite the match. This initial heat is then converted to chemical energy due to combustion, and the chemical energy is then converted to heat and light energy.

51. The extra energy will be stored as chemical potential energy in the form of fat.

52. a) You cannot have an efficiency of over 100% because, according to the first law of thermodynamics, the energy in a system and its surroundings must remain constant. To have an efficiency of over 100%, energy would have to be created, which is impossible.
b) ii) A steam engine can extract heat from a combustion reaction and use it to heat steam, and the steam can then be used to do work.
iii) Only a hypothetical perpetual motion machine can convert mechanical energy to mechanical energy with no loss.

53. $$\text{percent efficiency} = \frac{\text{useful energy output}}{\text{total heat input}} \times 100\%$$

$$= \frac{350 \text{ J}}{1000 \text{ J}} \times 100\%$$

$= 35.0\%$

54. $$\text{work}_{input} = \frac{\text{work}_{output}}{\text{efficiency}}$$

$\text{work}_{output} = Fd$

$= 400 \text{ N} \times 3.50 \text{ m}$

$= 1400 \text{ J}$

$$\text{work}_{\text{input}} = \frac{\text{work}_{\text{output}}}{\text{efficiency}}$$
$$= \frac{1400\ \text{J}}{0.15}$$
$$= 9.33 \times 10^3\ \text{J}$$

55. a) The surroundings are the air and blankets that surround the hot-water bottle.
b) It is a closed system because energy is transferred to the surroundings, not matter.
c) It would then be an open system, since there is an exchange of both matter and energy
56. If energy from the Sun originated from the combustion of matter, then the Sun should have burned out after about 1000 years.
57. a) Combustion chamber, turbine, generator
b) Combustion chamber: Heat energy is produced which can be useful in heating water to steam and wasted through the exhaust system.
Turbine: The energy in the steam can be useful in rotating the turbines and wasted in friction and lost heat.
Generator: The mechanical energy of the rotating turbine in a magnetic coil can produce useful electrical energy and wasted in energy lost to friction.
58. Waste heat from the combustion chamber and from the steam in the turbines can be recycled and used to heat the power plant. There is not much energy to recover from the generator itself.
59.

	Risk	Benefit	Sustainability
Wood	Produces a lot of waste ash and polluting gases	Cheap and easy to obtain	Sustainable since it can be replaced in a relatively short time
Coal	Produces a lot of waste ash and polluting gases	Cheap and burns hotter	Not sustainable but there are still large supplies remaining
Gas	Only produces polluting gases	Cheap and cleaner burning	Not sustainable and only small supplies remaining

60. A pump system must be devised to keep the warm water tank constantly filled with warm water and the cold water tank filled with cold water. However, very powerful pumps must be used if water is to be pumped through great distances. Secondly, the flow of energy from the hot tank to the cold tank is necessary to turn the turbines that drive the propeller. However, the force of the flow of energy will not be powerful enough to turn a turbine to rotate a propeller.

Extensions

61. Students' answers may vary but they are likely to include the example in the student book: steam engines. In trying to develop better systems to pump water, steam engines were developed to move the piston back and forth to pump water.
62. For every new development in a technology, there is a scientific principle to explain its operation. Technologies are always being developed to exploit scientific principles.
63. Students' answers may vary, but one example may be the following. The most important technology has been the internal combustion engine. Efficient engines have resulted in modern industrialized societies that are totally reliant on this technology.
64. Students' answers will vary but could include the following:
a) Heat can produce steam that, in a steam engine, is used to propel a vehicle.
b) Heat can produce the combustion of gases that, in a rocket engine, may propel a rocket upwards, changing the rocket's position.
c) Heat from a stove element can increase the temperature of a pot on the stove.
65. Hot-water heaters are usually the most inefficient energy consumers in the home. Possible ways to improve efficiency would be:
- Improve the tank's insulation.
- Turn down the temperature of water.
- Use an electric heating element rather than a gas-powered element.
66. Initially, the object has kinetic energy. As the object rises, the kinetic energy is converted to potential energy. At the highest point in its rise, it only has potential energy. The mechanical energy involves both potential and kinetic energy, and each can convert into the other, so in this situation the mechanical energy remains constant.
67. Total $E_p = mgh$ (at the top)
$= (0.0100\ \text{kg})(9.81\ \text{m/s}^2)(1.30\ \text{m})$
$= 0.128\ \text{J}$
At the point that the $E_k = E_p$, the $E_{p(grav)} = \dfrac{0.128\ \text{J}}{2} = 0.0638\ \text{J}$

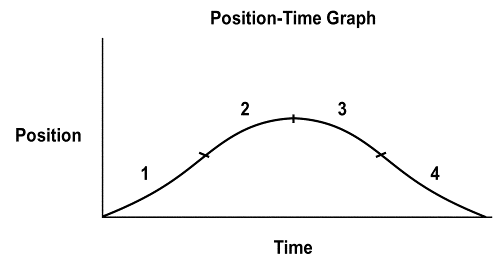
$$h = \frac{E_{p(grav)}}{mg}$$
$$= \frac{0.0638\ \text{J}}{(0.0100\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}$$
$$= 0.650\ \text{m}$$

At this height, both the kinetic and potential energy are equal.

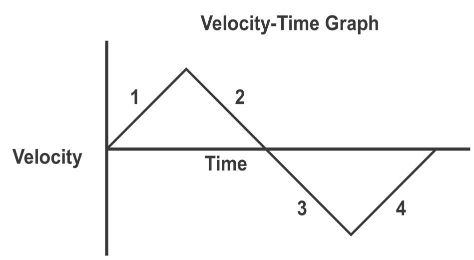
68. Work is done on the object against gravity so energy is transferred (the bone gains potential energy) in both cases.
69. The pendulum's potential energy will be less on the moon because the force of gravity is less on the moon. Consequently, the kinetic energy will also be less because potential energy is converted to kinetic energy.
70. a) Hydro-electric stations should be located near fast moving water, coal-burning or gas-burning stations should be located near fossil fuel deposits, and nuclear stations should ideally be located wherever it is difficult to locate the other types of stations.
    b) They all generate electricity and they all are potentially harmful to the environment.
    c) Coal- and gas-burning plants use chemical combustion reactions to produce heat while nuclear plants use nuclear fission reactions to produce heat. Also, nuclear plants are much more complex in design.
    d) Hydro-electric stations are the most efficient, followed by thermal, and then nuclear power stations.
71. A superconductor can be considered a perpetual motion machine because it can transform energy without any energy loss.
72. Students' answers will vary but may include the following: Hot water used for washing could circulate through the house to heat the home.
73. Since the government is concerned with the welfare of society as a whole then their chief concern should be the effects of energy sources on the environment.
74. A new energy source would affect every technology in the home. For example, all the appliances that run on electricity would have to be replaced. Also, all the machines that run on fuel would have to be replaced. However, if the new energy source was used to generate electricity, then only the appliances running on fuel would have to be changed.

Skills Practice

75. a) Students should measure distance carefully on page 236 of the student book.
    b) The distance-time graph should be a straight line with a positive slope of 7.5×10^{-3} m/s
    c) The object is exhibiting uniform motion.
    d) The slope is 7.5×10^{-3} m/s.
    e) The value represents the average speed of the object.
    f) An upward curve would show that the object is accelerating.
76. a) Students should use the distances measured in question 75.
    b) The speed-time graph should have a horizontal straight line. Note: For any object undergoing uniform acceleration, the average speed determined during a time interval (e.g., 0.0 s to 0.1s) using $v = \Delta d/\Delta t$ is the instantaneous speed at the midpoint in the time interval (e.g., 0.05 s).
    c) It represents uniform motion.
    d) If the object was accelerating, the speed-time graph would show a straight line with a positive slope.
    e) The line of best fit has a slope of 0.
    f) The slope represents the acceleration.
    g) area = length × width
       $= (7.0\text{ s})(7.5\times10^{-3}\text{ m/s})$
       $= 5.3\times10^{-2}\text{ m}$
    h) The area represents the total distance travelled.
77. $W = Fd$ = area under the line
    = 1/2(5.0 m)(10.0 N)
    = 25 J
78. a)



    b) 1. speeding up — positive direction
       2. slowing down — positive direction
       3. speeding up — negative direction
       4. slowing down — negative direction
    c)



79. The water could be pumped through hollow bamboo. A problem to be overcome is developing a pump. You would also have to overcome the problem of the height that the water has to be pumped. You could use a windmill to power the pump. To overcome the height problem, you may have to pump the water up in steps.

Self Assessment

80. Drawing conclusions is extremely important in assessing the success of the investigation or the research. The validity of the conclusion depends on how well the investigation or the research was done and how well the researcher interpreted the results.
81. Students' answers will vary but students should show an interest in the topics they have encountered.
82. Students' answers will vary, but should reflect the content of the unit.
83. The concept of energy was difficult to develop because energy is an abstract phenomenon that can only be observed during a transformation or a conversion when something is done. Technology was vital to the concept of energy, because the technologies allowed scientists to analyze the behaviour of energy, mostly in the form of heat.
84. Students' answers will vary but students should indicate what they personally can do to help conserve energy and so protect the environment.