Unit B Changes in Motion

Chapter 1: Describing Motion

Practice, page 169

1. **a.**

$$\Delta d = 40 \text{ km} \quad \Delta t = 0.5 \text{ h} \quad v = ?$$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{40 \text{ km}}{0.5 \text{ h}} \\ &= 8 \times 10^1 \text{ km/h} \end{aligned}$$

The average speed of the motorist is 8×10^1 km/h.

b.

$$\Delta d = 40 \text{ km} \quad \Delta t = 10.0 \text{ h} \quad v = ?$$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{40 \text{ km}}{10.0 \text{ h}} \\ &= 4.0 \text{ km/h} \end{aligned}$$

The average speed of the pioneer is 4.0 km/h.

c.

$$\Delta d = 40 \text{ km} \quad \Delta t = 9.0 \text{ h} \quad v = ?$$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{40 \text{ km}}{9.0 \text{ h}} \\ &= 4.4 \text{ km/h} \end{aligned}$$

The average speed of the hunters is 4.4 km/h.

2. **a.** The cyclists stopped for approximately 20 min.

b.

$$\begin{aligned} \Delta d &= 40 \text{ km} \\ \Delta t &= 2.5 \text{ h} + 0.5 \text{ h} \\ &= 3.0 \text{ h} \\ v &= ? \end{aligned}$$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{40 \text{ km}}{3.0 \text{ h}} \\ &= 13 \text{ km/h} \end{aligned}$$

The cyclists' average speed would be 13 km/h.

3. The motorist completed the journey with a constant speed because the graph is a straight line.

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4. All of these objects show non-uniform motion. In each case, speed is not constant and motion is not in a straight line.

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5. **a.** The scalar quantities are those that have magnitude (or size) only, not direction. These quantities are illustrated in the thermometer, the cereal box (mass of food in grams), the soup can (volume of soup in millilitres), the sign showing the distances to Gunn and Edmonton, the radio display (frequency in megahertz), and the VCR display (time in minutes).

b. The items that do not show scalars all include direction. This includes the highway sign with arrows and the Highway 33 marker.

c. Answers will vary. Sample statements containing a scalar quantity are as follows:

- The temperature tomorrow will be 21°C.
- During a winter storm, 15 cm of snow fell.
- A song on a CD is 3 minutes 45 seconds long.
- A house has 100 m^2 of floor area.

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6. $\Delta d = 20.5 \text{ km}$
$\Delta t = 2.5 \text{ h}$
$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{20.5 \text{ km}}{2.5 \text{ h}} = 8.2 \text{ km/h}$$

Convert the average speed into metres per second.

$$v = 8.2 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} = 2.3 \text{ m/s}$$

David's average speed was 8.2 km/h or 2.3 m/s.

7. $\Delta d = 20.6 \cancel{\text{km}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = 2.06 \times 10^4 \text{ m}$

$\Delta t = 1.0 \cancel{\text{min}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}} = 60 \text{ s}$

$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{2.06 \times 10^4 \text{ m}}{60 \text{ s}} = 343 \text{ m/s}$$

Note: Sometimes, it is preferable to do the conversions first.

The speed of sound is 343 m/s.

8. $\Delta d = 80 \text{ m}$
$\Delta t = 12.2 \text{ s}$
$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{80 \text{ m}}{12.2 \text{ s}} = 6.557\,377\,049 \text{ m/s} = 6.6 \text{ m/s}$$

Convert average speed into kilometres per hour.

$$v = 6.557\,377\,049 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} \times \frac{3600 \cancel{\text{s}}}{1 \text{ h}} = 24 \text{ km/h}$$

Note: Conversions are done with the unrounded value.

Kelsey's average speed was 6.6 m/s or 24 km/h.

1.1 Questions, page 173

Knowledge

1. **a.** Uniform motion is motion in a straight line at a constant speed.
   b. Non-uniform motion is motion with a change in speed, direction, or both.
   c. Instantaneous speed is speed at an instant of time.
   d. A scalar quantity is a quantity consisting of magnitude only, not direction.
   e. A conversion factor is a fraction used to convert one set of units into another.

2. **a.**
$$90.0\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}} = 5400\ \text{s} = 5.40 \times 10^{3}\ \text{s}$$

   b.
$$30\ \text{days} \times \frac{24\ \text{h}}{1\ \text{day}} \times \frac{3600\ \text{s}}{1\ \text{h}} = 2\ 592\ 000\ \text{s} = 2.6 \times 10^{6}\ \text{s}$$

   c.
$$17\ \text{years} \times \frac{365.25\ \text{days}}{1\ \text{year}} \times \frac{24\ \text{h}}{1\ \text{day}} \times \frac{3600\ \text{s}}{1\ \text{h}} = 536\ 479\ 200\ \text{s} = 5.4 \times 10^{8}\ \text{s}$$

3. **a.**
$$628\ \mu\text{m} \times \frac{1\times10^{-6}\ \text{m}}{1\ \mu\text{m}} = 6.28\times10^{-4}\ \text{m}$$

   b.
$$1.3\ \text{mm} \times \frac{1\times10^{-3}\ \text{m}}{1\ \text{mm}} = 1.3\times10^{-3}\ \text{m}$$

   c.
$$85.5\ \text{cm} \times \frac{1\times10^{-2}\ \text{m}}{1\ \text{cm}} = 0.855\ \text{m}$$

   d.
$$285\ \text{km} \times \frac{1000\ \text{m}}{1\ \text{km}} = 285\ 000\ \text{m} = 2.85\times10^{5}\ \text{m}$$

Applying Concepts

4. **a.** The car is demonstrating uniform motion.

   b. The speedometer displays the instantaneous speed of the vehicle. If the vehicle's cruise control is working properly, the speed should not change; it should remain constant.

   c. $\Delta d = 250\ \text{m}$
   $\Delta t = 10.0\ \text{s}$
   $v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{250\ \text{m}}{10.0\ \text{s}} = 25.0\ \text{m/s} = 25.0\ \frac{\text{m}}{\text{s}} \times \frac{1\ \text{km}}{1000\ \text{m}} \times \frac{3600\ \text{s}}{1\ \text{h}} = 90.0\ \text{km/h}$$

   The average speed of the car is 90.0 km/h.

   d. When an object is travelling with uniform motion, the average speed and the instantaneous speed are the same.

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9. **a.**

$$v = 30\,\frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 8.\overline{3}\ \text{m/s}$$
$$\Delta t = 2.0\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t = (8.\overline{3}\ \text{m/s})(2.0\ \text{s}) = 17\ \text{m}$$

Dana would travel 17 m.

b.

$$v = 50\,\frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 13.\overline{8}\ \text{m/s}$$
$$\Delta t = 2.0\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t = (13.\overline{8}\ \text{m/s})(2.0\ \text{s}) = 28\ \text{m}$$

Dana would travel 28 m.

c.

$$v = 80\,\frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 22.\overline{2}\ \text{m/s}$$
$$\Delta t = 2.0\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t = (22.\overline{2}\ \text{m/s})(2.0\ \text{s}) = 44\ \text{m}$$

Dana would travel 44 m.

d.

$$v = 110\,\frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 30.\overline{5}\ \text{m/s}$$
$$\Delta t = 2.0\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t = (30.\overline{5}\ \text{m/s})(2.0\ \text{s}) = 61\ \text{m}$$

Dana would travel 61 m.

10. Speed limits do not indicate the speed you should travel. A speed limit is the maximum speed you can safely travel under ideal conditions. Travelling in excess of a speed limit is very dangerous because your vehicle will travel further if you are momentarily distracted. This leaves less distance between you and any potential hazard and, therefore, less time to react to the hazard.

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11. $v = 95\text{ km/h}$

$\Delta d = 439\text{ km}$

$\Delta t = ?$

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

$$\Delta t = \frac{\Delta d}{v} = \frac{439\text{ km}}{95\text{ km/h}} = 4.6\text{ h}$$

It will take 4.6 h to drive from Edmonton to Fort McMurray.

12. $v = 30\text{ km/h}$

$\Delta d = 5000\text{ km}$

$\Delta t = ?$

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

$$\Delta t = \frac{\Delta d}{v} = \frac{5000\text{ km}}{30\text{ km/h}} = 166.\overline{6}\ \cancel{\text{h}} \times \frac{1\text{ d}}{24\ \cancel{\text{h}}} = 6.9\text{ d}$$

← Convert hours to days (d).

It will take a tuna 6.9 d to cross the Atlantic Ocean.

13. $v = 25\text{ mm/year}$

$$= 25\frac{\cancel{\text{mm}}}{\cancel{\text{year}}} \times \frac{1\text{ m}}{1000\ \cancel{\text{mm}}} \times \frac{1\ \cancel{\text{year}}}{365.25\ \cancel{\text{d}}} \times \frac{1\ \cancel{\text{d}}}{24\text{ h}}$$

$$= 2.851\,927\,903 \times 10^{-6}\text{ m/h}$$

$\Delta d = 5.0 \times 10^{-5}\text{ m}$

$\Delta t = ?$

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

$$\Delta t = \frac{\Delta d}{v} = \frac{5.0 \times 10^{-5}\text{ m}}{2.851\,927\,903 \times 10^{-6}\text{ m/h}} = 18\text{ h}$$

It will take 18 h before Nova Scotia is a “hair’s breadth” farther from England.

1.2 Questions, pages 177 and 178

Knowledge

1.

Technological Advancement	Unintended Problems Created
improvements to soundproofing and suspension systems of vehicles	Drivers can become so comfortable that they forget about the hazards associated with travelling at highway speeds.
introduction of HID headlights	Drivers of oncoming vehicles face new hazards due to the excessively glaring light from HID headlights.

2. **a.** Write the formula for average speed.

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

Multiply both sides by elapsed time, Δt.

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

Rewrite the equation so distance is on the left side.

$$\Delta d = v\Delta t$$

b. Write the formula for average speed.

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

Multiply both sides by elapsed time, Δt.

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

Divide both sides by average speed, v.

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

Applying Concepts

3.

Initial Problem	Technology Initially Designed to Solve Problem	Unintended Problems Created	Refinements That Addressed Unintended Problems
Drivers of early automobiles had to wear goggles to protect their eyes as they drove their "horseless carriages."	A glass shield, initially called a windscreen, built from thick, tempered glass designed not to break is installed.	In a collision, striking your head on such a heavily built windscreen could be fatal.	Modern windshields are made with safety glass designed to break safely.
Even though drivers and passengers use seat belts, occupants can still be seriously injured if they collide with the dashboard and windshield.	Air bags are installed in the dashboards as safety devices.	A child sitting in the passenger seat could be injured or killed by the air bag after it is deployed.	The next generation of air bags are equipped with sensors in the seat of the vehicle to detect the mass of the occupant. This information is used to control the deployment of the air bag.

4. a.

$$\Delta d = 500 \text{ m} + 500 \text{ m} = 1000 \text{ m}$$

$\Delta t = 74.75 \text{ s}$

$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{1000 \text{ m}}{74.75 \text{ s}} = 13.377\ 926\ 42 \text{ m/s} = 13.38 \text{ m/s}$$

Convert metres per second into kilometres per hour.

$$v = 13.377\ 926\ 42 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} \times \frac{3600 \cancel{\text{s}}}{1 \text{ h}} = 48.16 \text{ km/h}$$

Catriona's average speed was 13.38 m/s or 48.16 km/h.

b. The competitors travel with non-uniform motion when they are not travelling in a straight line, which occurs on the turns. They also travel with non-uniform motion when their speed changes, which occurs whenever they speed up or slow down on the straight sections of the track.

c. $v = 13.377\ 926\ 42 \text{ m/s}$

$\Delta t = 0.15 \text{ s}$

$\Delta d = ?$

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

$$\Delta d = v\Delta t = (13.377\ 926\ 42 \text{ m/s})(0.15 \text{ s}) = 2.0 \text{ m}$$

Catriona Le May Doan travels 2.0 m in 0.15 s.

d. $v = 13.377\ 926\ 42 \text{ m/s}$

$\Delta d = 400 \text{ m}$

$\Delta t = ?$

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

$$\Delta t = \frac{\Delta d}{v} = \frac{400 \text{ m}}{13.377\ 926\ 42 \text{ m/s}} = 29.9 \text{ s}$$

The difference in the times is mainly due to the fact that the extremely low friction of ice skates allows the athlete to glide at a higher speed between strides. Runners do not have this advantage.

Practice, page 180

14. a. $\vec{d} = 2.5 \text{ km}[\text{N}]$ or $+2.5 \text{ km}$

b. $\vec{d} = 0.3 \text{ km}[\text{N}]$ or $+0.3 \text{ km}$

c. $\vec{d} = 8.5 \text{ km}[\text{S}]$ or -8.5 km

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15. **a.** $\Delta\vec{d} = 7.5\ \text{km}[\text{N}]$ or $+7.5\ \text{km}$

b. $\Delta\vec{d} = 13.5\ \text{km}[\text{N}]$ or $+13.5\ \text{km}$

c. $\Delta\vec{d} = 5.0\ \text{km}[\text{S}]$ or $-5.0\ \text{km}$

d.
$$\begin{aligned}\Delta\vec{d} &= \Delta\vec{d}_{\text{BC to MC}} + \Delta\vec{d}_{\text{MC to TB}}\\ &= 8.6\ \text{km}[\text{N}] + 6.1\ \text{km}[\text{S}]\\ &= (+8.6\ \text{km}) + (-6.1\ \text{km})\\ &= +2.5\ \text{km or } 2.5\ \text{km}[\text{N}]\end{aligned}$$

16. The answers to question 14.a. and question 15.d. are identical. In both cases $\Delta\vec{d} = 2.5\ \text{km}[\text{N}]$. The middle portion did not make any difference. Therefore, you can conclude that displacement depends only on the starting point and the ending point.

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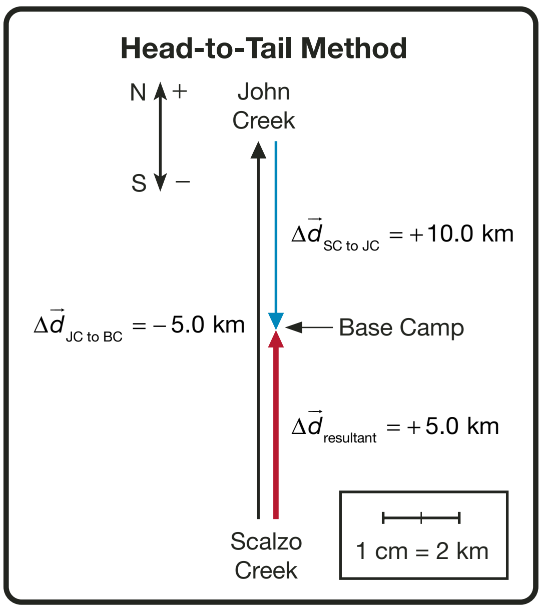
17. **a.** **Scalzo Creek to John Creek**

$\Delta\vec{d}_{\text{SC to JC}} = 10.0\ \text{km}[\text{N}]$ or $+10.0\ \text{km}$

John Creek to Base Camp

$\Delta\vec{d}_{\text{JC to BC}} = 5.0\ \text{km}[\text{S}]$ or $-5.0\ \text{km}$

b.



The resultant displacement is 5.0 km[N].

c.
$$\begin{aligned}\Delta\vec{d}_{\text{resultant}} &= \Delta\vec{d}_{\text{SC to JC}} + \Delta\vec{d}_{\text{JC to BC}}\\ &= (+10.0\ \text{km}) + (-5.0\ \text{km})\\ &= +5.0\ \text{km}\end{aligned}$$

The resultant displacement is 5.0 km[N].

d. $\Delta d = 10.0 \text{ km} + 5.0 \text{ km}$
$= 15.0 \text{ km}$
$\Delta t = 2.5 \text{ h} + 3.0 \text{ h} + 1.5 \text{ h}$
$= 7.0 \text{ h}$
$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{15.0 \text{ km}}{7.0 \text{ h}} = 2.1 \text{ km/h}$$

Remember: Distance is not a vector. So, the negative sign due to direction is not included.

The average speed for the entire journey is 2.1 km/h.

e. $\Delta \vec{d} = +5.0 \text{ km}$
$\Delta t = 7.0 \text{ h}$
$\vec{v} = ?$

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+5.0 \text{ km}}{7.0 \text{ h}} = +0.71 \text{ km/h}$$

The average velocity of the entire journey is $0.71 \text{ km/h}[\text{N}]$.

18. $\vec{v} = 4.0 \text{ km/h}[\text{S}]$
$= -4.0 \text{ km/h}$
$\Delta t = 2.75 \text{ h}$
$\Delta \vec{d} = ?$

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$
$$\Delta \vec{d} = \vec{v}\Delta t = (-4.0 \text{ km/h})(2.75 \text{ h}) = -11 \text{ km}$$

Melissa and Usha were 11 km [S] of the Terry Brook crossing. According to Figure B1.15, they ended up at the Nick Brook crossing.

1.3 Questions, page 185

Knowledge

1. **a.** Position is the distance and direction of a location relative to a reference point. For example, the position of Edmonton is about 294 km north of Calgary.

   b. Displacement is the change in position between two locations and includes direction. For example, if you drove from Calgary to Edmonton and then back to Red Deer, the displacement of you and your vehicle would be 145 km [N].

   c. A vector is a quantity with magnitude and direction. Examples include position, displacement, and velocity.

   d. A sign convention is an agreement about which direction is positive and which is negative. For example, it is common to represent north as the positive direction and south as the negative direction.

   e. Average velocity is a vector quantity describing a change in position over a specified time. It is the displacement divided by the elapsed time. If a motorist travelled from Edmonton to Calgary in 3.5 h, the average velocity would be 294 km [S] ÷ 3.5 h = 84 km/h [S].

Applying Concepts

2. The scale in Figure B1.19 is 1 cm = 3 km. Therefore, you must multiply each measurement by 3 to obtain the displacement in kilometres.

a. $\vec{d} = 18.0\ \text{km}[\text{W}]$ or $-18.0\ \text{km}$

b. $\vec{d} = 21.0\ \text{km}[\text{E}]$ or $+21.0\ \text{km}$

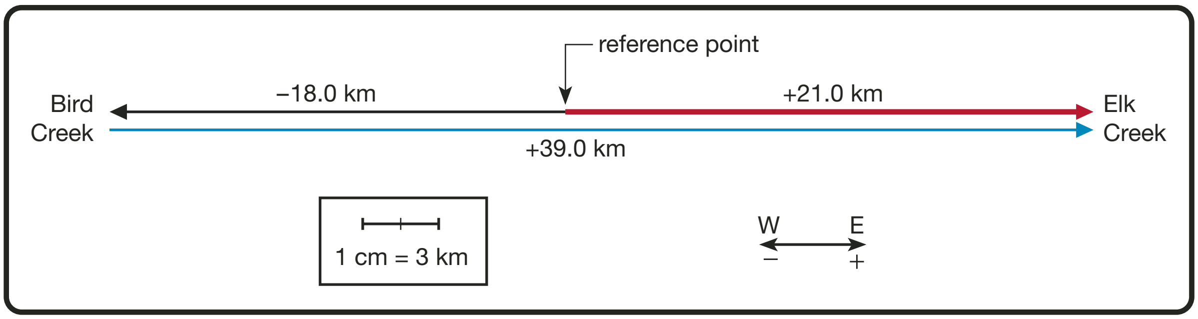
c. $\vec{d} = 9.0\ \text{km}[\text{W}]$ or $-9.0\ \text{km}$

d. $\vec{d} = 12.0\ \text{km}[\text{E}]$ or $+12.0\ \text{km}$

3. a.

$$\begin{aligned}\Delta\vec{d}_{\text{resultant}} &= \Delta\vec{d}_{\text{RP to BC}} + \Delta\vec{d}_{\text{BC to EC}}\\ &= (18.0\ \text{km}[\text{W}]) + (39.0\ \text{km}[\text{E}])\\ &= (-18.0\ \text{km}) + (+39.0\ \text{km})\\ &= +21.0\ \text{km}\end{aligned}$$

Head-to-Tail Method



Terry's resultant displacement is 21.0 km[E].

b. **Average Speed**

$$\begin{aligned}\Delta d &= 18.0\ \text{km} + 39.0\ \text{km}\\ &= 57.0\ \text{km}\\ \Delta t &= 0.75\ \text{h} + 0.25\ \text{h} + 2.00\ \text{h}\\ &= 3.00\ \text{h}\\ v &= ?\end{aligned}$$

$$\begin{aligned}v &= \frac{\Delta d}{\Delta t}\\ &= \frac{57.0\ \text{km}}{3.0\ \text{h}}\\ &= 19.0\ \text{km/h}\end{aligned}$$

Average Velocity

$$\begin{aligned}\Delta\vec{d} &= +21.0\ \text{km}\\ \Delta t &= 3.00\ \text{h}\\ \vec{v} &= ?\end{aligned}$$

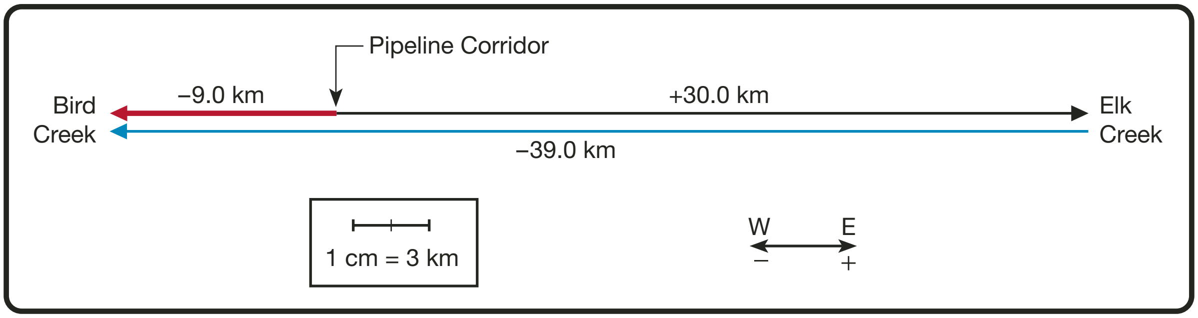
$$\begin{aligned}\vec{v} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+21.0\ \text{km}}{3.00\ \text{h}}\\ &= +7.00\ \text{km/h}\end{aligned}$$

Terry's average speed was 19.0 km/h, and his average velocity was 7.00 km/h[E].

4. a. $\Delta\vec{d}_{\text{resultant}} = \Delta\vec{d}_{\text{PC to EC}} + \Delta\vec{d}_{\text{EC to BC}}$

$$= (30.0 \text{ km}[\text{E}]) + (-39.0 \text{ km}[\text{W}])$$
$$= (30.0 \text{ km}) + (-39.0 \text{ km})$$
$$= -9.0 \text{ km}$$

Head-to-Tail Method



Monica's resultant displacement is 9.0 km [W].

b. Average Speed

$\Delta d = 30.0 \text{ km} + 39.0 \text{ km}$
$= 69.0 \text{ km}$

$\Delta t = 1.75 \text{ h} + 0.75 \text{ h} + 2.5 \text{ h}$
$= 5.0 \text{ h}$

$v = ?$

$$v = \frac{\Delta d}{\Delta t} = \frac{69.0 \text{ km}}{5.0 \text{ h}} = 14 \text{ km/h}$$

Average Velocity

$\Delta\vec{d} = -9.0 \text{ km}$

$\Delta t = 5.0 \text{ h}$

$\vec{v} = ?$

$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{-9.0 \text{ km}}{5.0 \text{ h}} = -1.8 \text{ km/h}$$

Monica's average speed was 14 km/h, and her average velocity was 1.8 km/h [W].

5. a. $\vec{v} = 24.0 \text{ km/h}[\text{E}]$
$= +24.0 \text{ km/h}$

$\Delta t = 30.0 \text{ min}$
$= 0.500 \text{ h}$

$\Delta\vec{d} = ?$

$$v = \frac{\Delta\vec{d}}{\Delta t}$$
$$\Delta\vec{d} = \vec{v}\Delta t$$
$$= (+24.0 \text{ km/h})(0.500 \text{ h})$$
$$= +12.0 \text{ km}$$

The snowmobiler is 12.0 km [E] after 30.0 min.

b. The snowmobiler is at the point where Lake Trail meets the snowmobile trail.

Practice, page 187

19. The computer model is expensive to create, but it probably saves money in the long run because of the expense of doing many trials with actual eyeballs (likely animal eyeballs from slaughterhouses, as human eyeballs obtained from organ donors are used for other purposes). The computer model also has the advantage of being a great time-saver because the experimenter can literally type in a new set of conditions to test and, in just a couple of minutes, the computer can run the trial and print out all the important data. It would take much longer to change a variable and run a new trial using actual eyeballs.

Practice, page 187

20. The structures within the eye that are the focus of microsurgery are very small and quite delicate. A microscope, therefore, is an essential tool to guide the surgeon's instruments.

Practice, page 191

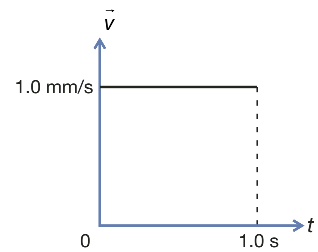
21. **a.** Using the graph, the average velocity would be determined by calculating the slope over the time interval $t = 0$ to $t = 1.0$ s.

b.

$$\begin{aligned} \text{slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{+1.0\ \text{mm} - 0}{1.0\ \text{s} - 0} \\ &= +1.0\ \text{mm/s} \end{aligned}$$

The average velocity over the time interval $t = 0$ s to $t = 1.0$ s is $+1.0$ mm/s.

c.



22. **a.** This portion of the graph is a curved line. Because uniform motion is described by a sloping straight line, you can conclude that this part of the graph does not describe uniform motion.

b. The curve indicates that the robot arm travels a shorter distance in each time interval than it did in the previous time interval. This implies that the robot arm is slowing down.

1.4 Questions, pages 192 and 193

Knowledge

1. **a.** The slope of a position-time graph is average velocity.
b. The area under a velocity-time graph is displacement.
c. Changing metres per second into kilometres per hour requires using a conversion factor.
d. A measurement that has both magnitude and direction is called a vector.

Applying Concepts

2. **a.** A hand-control system needs to be precise and reliable. The system should also not require excessive effort to operate or distract the driver. In short, the hand-control system needs to be very user friendly—suiting the needs of the persons with disabilities using the system.

b. When people who use a wheelchair drive to a mall or store, they are often driving a larger vehicle that can accommodate the wheelchair, such as a full-size van. This wider vehicle needs a wider parking stall. Once the vehicle is parked, additional room is required along the side of the parking space for getting into the wheelchair. Given all the extra effort required to get the wheelchair out of the vehicle and then to get into the wheelchair, it only seems fair to provide the shortest possible route to the entrance.

3. a. Position–Time I shows the tool starting at 0.2 mm and moving to 1.6 mm in 9.0 s. Since the line is straight with a positive slope, the motion is uniform and directed to the right.

Position–Time II shows the tool starting at 2.0 mm and moving to −3.0 mm in 4.5 s. Since the line is straight with a negative slope, the motion is uniform and directed to the left.

Position–Time III shows the tool starting at −0.2 mm and moving to −1.4 mm in 9.0 s. Since the line is straight with a negative slope, the motion is uniform and directed to the left.

Position–Time IV shows the tool starting at −0.6 mm and moving to 0.8 mm in 8.0 s. Since the line is straight with a positive slope, the motion is uniform and directed to the right.

b. Position–Time I

$$\begin{aligned}\text{average velocity} &= \text{slope}\\ \vec{v} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{(+1.6\text{ mm})-(+0.2\text{ mm})}{9.0\text{ s}-0}\\ &= +0.16\text{ mm/s}\end{aligned}$$

Position–Time II

$$\begin{aligned}\text{average velocity} &= \text{slope}\\ \vec{v} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{(-3.0\text{ mm})-(+2.0\text{ mm})}{4.5\text{ s}-0}\\ &= -1.1\text{ mm/s}\end{aligned}$$

Position–Time III

$$\begin{aligned}\text{average velocity} &= \text{slope}\\ \vec{v} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{(-1.4\text{ mm})-(-0.2\text{ mm})}{9.0\text{ s}-0}\\ &= -0.13\text{ mm/s}\end{aligned}$$

Position–Time IV

$$\begin{aligned}\text{average velocity} &= \text{slope}\\ \vec{v} &= \frac{\text{rise}}{\text{run}}\\ &= \frac{(+0.8\text{ mm})-(-0.6\text{ mm})}{8.0\text{ s}-0}\\ &= +0.18\text{ mm/s}\end{aligned}$$

4. a. Velocity–Time I shows the tool moving with a constant velocity of −1.6 mm/s for a total of 7.0 s. Because the velocity is negative, the tool is moving to the left.

Velocity–Time II shows the tool moving with a constant velocity of +1.2 mm/s for a total of 16.0 s. Because the velocity is positive, the tool is moving to the right.

Velocity–Time III shows the tool moving with a constant velocity of 0 for a total of 18.0 s. Because the velocity is zero, the tool is not moving left or right; it is at rest.

Velocity–Time IV shows the tool moving with a constant velocity of −0.65 mm/s for a total of 8.0 s. Because the velocity is negative, the tool is moving to the left.

b. Velocity–Time I

displacement = area under graph

$$\begin{aligned}\Delta\vec{d} &= l \times w \\ &= (-1.6\ \text{mm/s})(7.0\ \text{s}) \\ &= -11\ \text{mm}\end{aligned}$$

Velocity–Time II

displacement = area under graph

$$\begin{aligned}\Delta\vec{d} &= l \times w \\ &= (+1.2\ \text{mm/s})(16.0\ \text{s}) \\ &= 19\ \text{mm}\end{aligned}$$

Velocity–Time III

displacement = area under graph

$$\begin{aligned}\Delta\vec{d} &= l \times w \\ &= (0)(18.0\ \text{s}) \\ &= 0\end{aligned}$$

Velocity–Time IV

displacement = area under graph

$$\begin{aligned}\Delta\vec{d} &= l \times w \\ &= (-0.65\ \text{mm/s})(8.0\ \text{s}) \\ &= -5.2\ \text{mm}\end{aligned}$$

Practice, page 195

23. a. velocity = slope

$$\begin{aligned} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{100\ \text{m} - 40\ \text{m}}{14.0\ \text{s} - 8.0\ \text{s}} \\ &= 10\ \text{m/s}\end{aligned}$$

b. displacement = area under graph

$$\begin{aligned} &= l \times w \\ &= (10\ \text{m/s})(14.0\ \text{s} - 8.0\ \text{s}) \\ &= (10\ \text{m/s})(6.0\ \text{s}) \\ &= 60\ \text{m}\end{aligned}$$

Practice, page 199

24. a. acceleration = slope

$$\begin{aligned}\vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{180\ \text{mm/s} - 30\ \text{mm/s}}{18.0\ \text{s} - 0} \\ &= 8.3\ \text{mm/s}^2\end{aligned}$$

b. acceleration = slope

$$\begin{aligned}\vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{17\ \text{cm/s} - 0}{6.0\ \text{s} - 1.5\ \text{s}} \\ &= 3.8\ \text{cm/s}^2\end{aligned}$$

c. acceleration = slope

$$\begin{aligned}\vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{6.5\ \text{m/s} - 1.0\ \text{m/s}}{2.0\ \text{s} - 0} \\ &= 2.8\ \text{m/s}^2\end{aligned}$$

d. acceleration = slope

$$\begin{aligned}\vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{40\ \text{cm/s} - 0}{14.0\ \text{s} - 3.0\ \text{s}} \\ &= 3.6\ \text{cm/s}^2\end{aligned}$$

Practice, page 200

25. Since solving for time involves dividing final velocity by acceleration, the vector notation is dropped.

$v_{\mathrm{i}} = 0$

$\Delta d = 400 \text{ m}$

$a = 30.8 \text{ m/s}^2$

$$v_{\mathrm{f}} = 500 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1.0 \cancel{\text{h}}}{3600 \text{ s}} = 138.\bar{8} \text{ m/s}$$

$\Delta t = ?$

$$a = \frac{v_{\mathrm{f}} - v_{\mathrm{i}}}{\Delta t}$$

$$\Delta t = \frac{v_{\mathrm{f}} - v_{\mathrm{i}}}{a} = \frac{138.\bar{8} \text{ m/s} - 0}{30.8 \text{ m/s}^2} = 4.51 \text{ s}$$

It took the dragster 4.51 s to reach its top speed.

Practice, page 203

26. $\vec{a} = 2.20 \text{ m/s}^2$

$\Delta t = 36.0 \text{ s}$

$\vec{v}_{\mathrm{i}} = 0$

$\vec{v}_{\mathrm{f}} = ?$

$$\vec{a} = \frac{\vec{v}_{\mathrm{f}} - \vec{v}_{\mathrm{i}}}{\Delta t}$$

$$\vec{a} = \frac{\vec{v}_{\mathrm{f}}}{\Delta t} \quad \leftarrow v_{\mathrm{i}} = 0$$

$$\begin{aligned} \vec{v}_{\mathrm{f}} &= \vec{a}\Delta t \\ &= \left(2.20 \text{ m/s}^2\right)(36.0 \text{ s}) \\ &= 79.2 \text{ m/s} \\ &= 79.2 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} \times \frac{3600 \cancel{\text{s}}}{1 \text{ h}} \\ &= 285 \text{ km/h} \end{aligned}$$

The jet's take-off speed is 285 km/h.

27. **a.** acceleration = slope

$$\begin{aligned} \vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{(-15.0 \text{ m/s}) - (-3.0 \text{ m/s})}{18.0 \text{ s} - 0} \\ &= -0.667 \text{ m/s}^2 \end{aligned}$$

b. acceleration = slope

$$\begin{aligned} \vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{(-4.0 \text{ cm/s}) - (+3.0 \text{ cm/s})}{10.0 \text{ s} - 0} \\ &= -0.70 \text{ cm/s}^2 \end{aligned}$$

c. acceleration = slope

$$\begin{aligned} \vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{(+1 \text{ mm/s}) - (+18 \text{ mm/s})}{30.0 \text{ s} - 4.0 \text{ s}} \\ &= -0.65 \text{ mm/s}^2 \end{aligned}$$

d. acceleration = slope

$$\begin{aligned} \vec{a} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{(+4.5 \text{ m/s}) - (-4.0 \text{ m/s})}{16.0 \text{ s} - 0} \\ &= +0.53 \text{ m/s}^2 \end{aligned}$$

28. $v_i = 100 \text{ km/h}[\text{N}]$

$= +100 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}}$

$= 27.\overline{7} \text{ m/s}$

$\vec{v}_f = 0$

$\Delta t = 5.0 \text{ s}$

$\vec{a} = ?$

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

$$\vec{a} = \frac{-\vec{v}_i}{\Delta t} \leftarrow v_f = 0$$

$$= \frac{-(27.\overline{7} \text{ m/s})}{5.0 \text{ s}}$$

$$= -5.6 \text{ m/s}^2$$

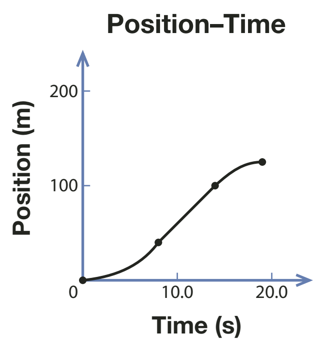
The vehicle is accelerating at 5.6 m/s^2 [S].

29. There are many possible answers to this question. One possibility is that driving near the edge of the roof of a five-storey building would be a new hazard that would demand maximum attention and concentration on the driver's part. The hazards of driving on a road are more familiar; and even though these hazards are just as dangerous, familiarity sometimes breeds complacency.

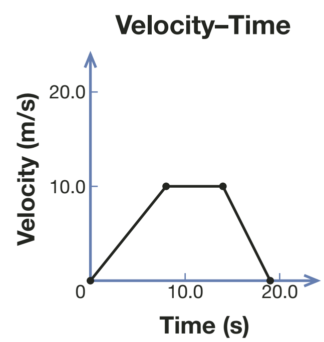
1.5 Questions, page 204

Knowledge

1. a. and b.



2. a. and b.



Applying Concepts

3. a. acceleration = slope

$$\vec{a} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{10.0 \text{ m/s} - 0}{8.0 \text{ s} - 0}$$

$$= 1.3 \text{ m/s}^2$$

The car accelerates at 1.3 m/s^2 in the first 8.0 s.

b. acceleration = slope

$$\vec{a} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{0 - 10.0 \text{ m/s}}{19.0 \text{ s} - 14.0 \text{ s}}$$

$$= -2.0 \text{ m/s}^2$$

The car accelerates at -2.0 m/s^2 in the last 5.0 s.

c. displacement = area of triangle

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}bh\\ &= \frac{1}{2}(8.0\ \text{s})(10.0\ \text{m/s})\\ &= 40\ \text{m}\end{aligned}$$

This calculation confirms that the displacement in the first 8.0 s is 40 m.

d. displacement = area of triangle

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}bh\\ &= \frac{1}{2}(5.0\ \text{s})(10.0\ \text{m/s})\\ &= 25\ \text{m}\end{aligned}$$

This calculation confirms that the displacement in the last 5.0 s is 25 m.

Practice, page 206

30. The first lane you enter is called the acceleration lane because this is the space designated for vehicles to accelerate from a lower velocity to the higher velocity of the vehicles already travelling on the highway.

31. a.

$$\begin{aligned}\vec{v}_{\text{i}} &= +15.0\ \text{m/s}\\ &= +15.0\frac{\cancel{\text{m}}}{\cancel{\text{s}}}\times\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\times\frac{3600\ \cancel{\text{s}}}{1\ \text{h}}\\ &= +54.0\ \text{km/h}\end{aligned}$$

$$\begin{aligned}\vec{v}_{\text{f}} &= +30.0\ \text{m/s}\\ &= +30.0\frac{\cancel{\text{m}}}{\cancel{\text{s}}}\times\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\times\frac{3600\ \cancel{\text{s}}}{1\ \text{h}}\\ &= +108\ \text{km/h}\end{aligned}$$

b. $v_{\text{i}} = 15.0\ \text{m/s}$
$v_{\text{f}} = 30.0\ \text{m/s}$
$\Delta t = 5.0\ \text{s}$
$a = ?$

$$\begin{aligned}a &= \frac{v_{\text{f}} - v_{\text{i}}}{\Delta t}\\ &= \frac{30.0\ \text{m/s} - 15.0\ \text{m/s}}{5.0\ \text{s}}\\ &= 3.0\ \text{m/s}^2\end{aligned}$$

The magnitude of the acceleration is $3.0\ \text{m/s}^2$.

c. The acceleration corresponds to the slope of the velocity–time graph. If the acceleration value is less, the slope value is also less. This means that the underpowered vehicle would take longer to increase its velocity from +54.0 km/h to +108 km/h.

d. Vehicles with lower acceleration values will take longer and will, therefore, travel a greater distance as they speed up to reach the highway velocity. The lane must be long enough to accommodate these slower vehicles.

Practice, page 208

32. Let east be the positive direction.

$$\vec{v}_i = 65.0\ \text{km/h}[\text{E}]$$
$$= +65.0 \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= +18.0\bar{5}\ \text{m/s}$$
$$\vec{v}_f = 100.0\ \text{km/h}[\text{E}]$$
$$= +100.0 \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= +27.\bar{7}\ \text{m/s}$$
$$\Delta t = 4.0\ \text{s}$$
$$\Delta\vec{d} = ?$$

$$\Delta\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)\Delta t$$
$$= \left[\frac{(+18.0\bar{5}\ \text{m/s}) + (+27.\bar{7}\ \text{m/s})}{2}\right](4.0\ \text{s})$$
$$= +91.7\ \text{m}$$

The displacement of the car is 91.7 m[E].

Practice, page 209

33. **a.** Since solving for time involves dividing displacement by a velocity, the vector notation is dropped.

$$v_i = 14.5\ \text{m/s}[\text{up}]$$
$$= +14.5\ \text{m/s}$$
$$\Delta d = 10.7\ \text{m}[\text{up}]$$
$$= +10.7\ \text{m}$$
$$v_f = 0$$
$$\Delta t = ?$$

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$\Delta d = \left(\frac{v_i}{2}\right)\Delta t \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{2\Delta d}{v_i}$$
$$= \frac{2(+10.7\ \text{m})}{(+14.5\ \text{m/s})}$$
$$= 1.48\ \text{s}$$

It took 1.48 s for the ball to travel from the player's arms to the ceiling.

b. Since solving for time involves dividing velocity by acceleration, the vector notation is dropped.

$$a = 9.81\ \text{m/s}^2[\text{down}]$$
$$= -9.81\ \text{m/s}^2$$
$$v_i = 14.5\ \text{m/s}[\text{up}]$$
$$= +14.5\ \text{m/s}$$
$$v_f = 0$$
$$\Delta t = ?$$

$$a = \frac{v_f - v_i}{\Delta t}$$
$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{-v_i}{a}$$
$$= \frac{-(14.5\ \text{m/s})}{(-9.81\ \text{m/s}^2)}$$
$$= 1.48\ \text{s}$$

It took 1.48 s for the ball to travel from the player's arms to the ceiling.

Practice, page 211

34. Let east be the positive direction.

$$\vec{v}_{\text{i}} = 63\ \text{km/h}[\text{E}]$$
$$= +63\frac{\cancel{\text{km}}}{\cancel{\text{h}}}\times\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\times\frac{1\ \cancel{\text{h}}}{3600\ \text{s}}$$
$$= +17.5\ \text{m/s}$$
$$\vec{a} = 1.0\ \text{m/s}^2[\text{E}]$$
$$= +1.0\ \text{m/s}^2$$
$$\Delta t = 9.0\ \text{s}$$
$$\Delta\vec{d} = ?$$

$$\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$= (+17.5\ \text{m/s})(9.0\ \text{s}) + \frac{1}{2}(+1.0\ \text{m/s}^2)(9.0\ \text{s})^2$$
$$= +2.0\times10^2\ \text{m}$$

The vehicle travelled 2.0×10^2 m[E].

35. $$\vec{v}_{\text{i}} = +84\frac{\cancel{\text{km}}}{\cancel{\text{h}}}\times\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\times\frac{1\ \cancel{\text{h}}}{3600\ \text{s}}$$
$$= +23.\bar{3}\ \text{m/s}$$
$$\vec{a} = -4.5\ \text{m/s}^2$$
$$\Delta t = 5.0\ \text{s}$$
$$\Delta\vec{d} = ?$$

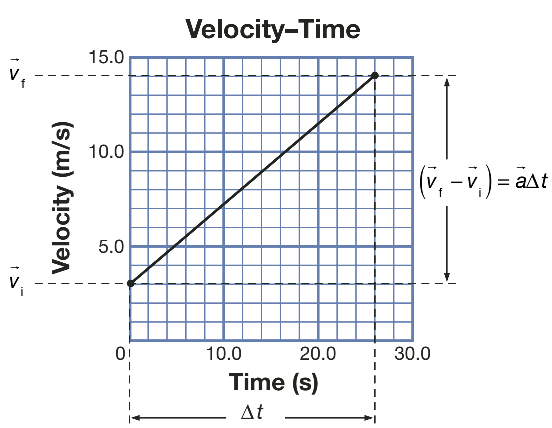
$$\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$= (+23.\bar{3}\ \text{m/s})(5.0\ \text{s}) + \frac{1}{2}(-4.5\ \text{m/s}^2)(5.0\ \text{s})^2$$
$$= +60\ \text{m}$$

The displacement of the vehicle during the 5.0-s interval is 60 m, in the original direction.

1.6 Questions, pages 212 and 213

Knowledge

1.



2. a. displacement = area under graph

$$\Delta\vec{d} = l \times w$$
$$= (\text{average velocity})(\text{time interval})$$
$$= \left(\frac{\vec{v}_{\text{i}} + \vec{v}_{\text{f}}}{2}\right)\Delta t$$

b. displacement = area under graph

$$\Delta\vec{d} = \text{area of rectangle} + \text{area of triangle}$$
$$= (l \times w) + \frac{1}{2}(b \times h)$$
$$= \vec{v}_{\text{i}}\Delta t + \frac{1}{2}(\Delta t)(\vec{a}\Delta t)$$
$$= \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$

Applying Concepts

3. a.

$$\vec{v}_{\text{i}} = +95.0\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\,\cancel{\text{km}}} \times \frac{1\,\cancel{\text{h}}}{3600\text{ s}}$$
$$= +26.3\bar{8}\text{ m/s}$$
$$\vec{v}_{\text{f}} = +50.0\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\,\cancel{\text{km}}} \times \frac{1\,\cancel{\text{h}}}{3600\text{ s}}$$
$$= +13.\bar{8}\text{ m/s}$$
$$\Delta t = 5.00\text{ s}$$
$$\vec{a} = ?$$

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$$
$$= \frac{(+13.\bar{8}\text{ m/s}) - (+26.3\bar{8}\text{ m/s})}{5.00\text{ s}}$$
$$= -2.50\text{ m/s}^2$$

The vehicle decelerates at 2.50 m/s^2.

b.

$$\vec{v}_{\text{i}} = +26.3\bar{8}\text{ m/s}$$
$$\vec{v}_{\text{f}} = +13.\bar{8}\text{ m/s}$$
$$\Delta t = 5.00\text{ s}$$
$$\Delta\vec{d} = ?$$

$$\Delta\vec{d} = \left(\frac{\vec{v}_{\text{i}} + \vec{v}_{\text{f}}}{2}\right)\Delta t$$
$$= \left[\frac{(+26.3\bar{8}\text{ m/s}) + (+13.\bar{8}\text{ m/s})}{2}\right](5.00\text{ s})$$
$$= +101\text{ m}$$

The displacement of the vehicle during the 5.00-s interval is 101 m, in the original direction.

c.

$$\vec{v}_{\text{i}} = +26.3\bar{8}\text{ m/s}$$
$$\vec{a} = -2.50\text{ m/s}^2$$
$$\Delta t = 5.00\text{ s}$$
$$\Delta\vec{d} = ?$$

$$\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$= (+26.3\bar{8}\text{ m/s})(5.00\text{ s}) + \frac{1}{2}(-2.50\text{ m/s}^2)(5.00\text{ s})^2$$
$$= +101\text{ m}$$

The displacement during the 5.00-s interval is 101 m, in the original direction.

d. The values are the same. The answers suggest that the deceleration lane should be at least 101 m long.

e. $\vec{v}_{\text{i}} = +26.3\overline{8}\ \text{m/s},\ \vec{v}_{\text{f}} = +13.\overline{8}\ \text{m/s},\ \vec{a} = -1.50\ \text{m/s}^2,\ \Delta\vec{d} = ?$

Since the displacement equations require a value for time, this becomes a two-step process.

First, solve for Δt. (Drop the vector notation.)

$$a = \frac{v_{\text{f}} - v_{\text{i}}}{\Delta t}$$

$$\begin{aligned}\Delta t &= \frac{v_{\text{f}} - v_{\text{i}}}{a} \\ &= \frac{(+13.\overline{8}\ \text{m/s}) - (+26.3\overline{8}\ \text{m/s})}{-1.50\ \text{m/s}^2} \\ &= 8.3\overline{3}\ \text{s}\end{aligned}$$

Now, solve for $\Delta\vec{d}$.

$$\begin{aligned}\Delta\vec{d} &= \left(\frac{\vec{v}_{\text{i}} + \vec{v}_{\text{f}}}{2}\right)\Delta t \\ &= \frac{(+26.3\overline{8}\ \text{m/s}) + (+13.\overline{8}\ \text{m/s})}{2}(8.3\overline{3}\ \text{s}) \\ &= +168\ \text{m}\end{aligned}$$

The displacement during the time interval is 168 m, in the original direction.

f. The acceleration lane has to be sufficiently long to accommodate a range of vehicles under a variety of circumstances. Since vehicles that can only manage an acceleration of $-1.5\ \text{m/s}^2$ require a lane of at least 168 m, it makes sense to have the deceleration lane at least 170 m long.

4. a. Since solving for time involves dividing displacement by acceleration, the vector notation is dropped.

During the second half of its path, the ball has a downward, or negative, displacement. Also, its initial speed is 0 at its maximum height.

$\Delta d = -18.5\ \text{m}$

$v_{\text{i}} = 0$

$a = -9.81\ \text{m/s}^2$

$\Delta t = ?$

$$\Delta d = v_{\text{i}}\Delta t + \frac{1}{2}a(\Delta t)^2$$

$$\Delta d = \frac{1}{2}a\Delta t^2 \quad \leftarrow v_{\text{i}} = 0$$

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(-18.5\ \text{m})}{-9.81\ \text{m/s}^2}} \\ &= 1.942\ 076\ 613\ \text{s} \\ &= 1.94\ \text{s}\end{aligned}$$

It took the ball 1.94 s to travel this distance.

b. The acceleration that causes the ball to speed up from the top of its path to the release point is the same acceleration that causes the ball to slow down between leaving the bat and reaching the top of its path. In both cases, the acceleration is $9.81\ \text{m/s}^2$, directed straight down. So the time to reach its highest point should be the same as the time to fall back down. Therefore, the time is 1.94 s.

c. During the first half of its path, the ball has an upward, or positive, displacement.

$$\Delta\vec{d} = +18.5\ \text{m}$$
$$\vec{a} = -9.81\ \text{m/s}^2$$
$$\Delta t = 1.942\ 076\ 613\ \text{s}$$
$$\vec{v}_\text{f} = 0$$
$$\vec{v}_\text{i} = ?$$

$$\vec{a} = \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}$$
$$\vec{a} = \frac{-\vec{v}_\text{i}}{\Delta t} \quad \leftarrow \vec{v}_\text{f} = 0$$
$$-\vec{v}_\text{i} = \vec{a}\Delta t$$
$$\vec{v}_\text{i} = -\vec{a}\Delta t \quad \leftarrow \text{Multiply both sides by } -1.$$
$$= -\left(-9.81\ \text{m/s}^2\right)\left(1.942\ 076\ 613\ \text{s}\right)$$
$$= +19.1\ \text{m/s}$$

The initial velocity of the ball immediately after it left the bat is 19.1 m/s [up].

Practice, page 214

36. a. Since the solution involves dividing displacement by acceleration, the vector notation is dropped.

$$\Delta d = -22.5\ \text{cm}$$
$$= -0.225\ \text{m}$$
$$v_\text{i} = 0$$
$$a = -9.81\ \text{m/s}^2$$
$$\Delta t = ?$$

$$\Delta d = v_\text{i}\Delta t + \frac{1}{2}a\left(\Delta t\right)^2$$
$$\Delta d = \frac{1}{2}a\left(\Delta t\right)^2 \quad \leftarrow v_\text{i} = 0$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2\left(-0.225\ \text{m}\right)}{-9.81\ \text{m/s}^2}}$$
$$= 0.214\ \text{s}$$

The metre-stick fell for 0.214 s.

b. The person's reaction time is equal to the length of time that the metre-stick fell, which is 0.214 s.

c. The reaction time of a driver can be affected by any combination of the following factors:

- fatigue
- the influence of drugs or alcohol
- distractions caused by a cellphone, drinking coffee, looking for a CD, etc.

Practice, page 215

37. Braking distance is dependent upon the value of the deceleration for a vehicle on a given roadway. It follows that when drivers first encounter appreciable amounts of snow on a roadway, the deceleration values are decreased and the braking distances are increased. Unless the driver makes a conscious effort to anticipate these changes, the vehicle will have a longer braking distance and the possibility of having a collision will increase.

Another factor is that many drivers face the first snowfall of the winter driving season without installing winter tires on their vehicles. Winter tires are specially designed to improve traction on snow and ice.

Practice, page 216

38. a. Vector notation is dropped since solving for time involves dividing velocity by acceleration and since the question is asking for distance (a scalar).

Determine the reaction distance.

$$v = 100\,\frac{\text{km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{3600\text{ s}}$$
$$= 27.\overline{7}\text{ m/s}$$
$$\Delta t = 1.50\text{ s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t$$
$$= (27.\overline{7}\text{ m/s})(1.50\text{ s})$$
$$= 41.\overline{6}\text{ m}$$
$$= 41.7\text{ m}$$

The reaction distance is 41.7 m.

Determine the braking distance.

$v_i = 27.\overline{7}$ m/s, $v_f = 0$, $a = -5.85$ m/s^2, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$
$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{-v_i}{a}$$
$$= \frac{-(27.\overline{7}\text{ m/s})}{(-5.85\text{ m/s}^2)}$$
$$= 4.748\,338\,082\text{ s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$= \left(\frac{27.\overline{7}\text{ m/s} + 0}{2}\right)(4.748\,338\,082\text{ s})$$
$$= 65.949\,140\,02\text{ m}$$
$$= 65.9\text{ m}$$

The braking distance is 65.9 m.

Determine the stopping distance.

$$\Delta d_{\text{stopping}} = \Delta d_{\text{reaction}} + \Delta d_{\text{braking}}$$
$$= 41.\overline{6}\text{ m} + 65.949\,140\,02\text{ m}$$
$$= 108\text{ m}$$

The minimum stopping distance is 108 m.

b. The vector notation is dropped since solving for time involves dividing velocity by acceleration and since the question is asking for distance (a scalar).

Determine the reaction distance.

$$v = 80.0\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\,\cancel{\text{km}}} \times \frac{1\,\cancel{\text{h}}}{3600\text{ s}}$$
$$= 22.\overline{2}\text{ m/s}$$
$$\Delta t = 1.50\text{ s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t$$
$$= (22.\overline{2}\text{ m/s})(1.50\text{ s})$$
$$= 33.\overline{3}\text{ m}$$
$$= 33.3\text{ m}$$

The reaction distance is 33.3 m.

Determine the braking distance.

$v_i = 22.\overline{2}$ m/s, $v_f = 0$, $a = -5.85\text{ m/s}^2$, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$
$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{-v_i}{a}$$
$$= \frac{-(22.\overline{2}\text{ m/s})}{(-5.85\text{ m/s}^2)}$$
$$= 3.798\,670\,465\text{ s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$= \left(\frac{22.\overline{2}\text{ m/s} + 0}{2}\right)(3.798\,670\,465\text{ s})$$
$$= 42.207\,449\,61\text{ m}$$
$$= 42.2\text{ m}$$

The braking distance is 42.2 m.

Determine the stopping distance.

$$\Delta d_{\text{stopping}} = \Delta d_{\text{reaction}} + \Delta d_{\text{braking}}$$
$$= 33.\overline{3}\text{ m} + 42.207\,449\,61\text{ m}$$
$$= 75.5\text{ m}$$

The minimum stopping distance is 75.5 m.

Practice, page 218

39. **a.** Determine the reaction distance.

$$v = 70\ \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 19.\overline{4}\ \text{m/s}$$
$$\Delta t = 1.50\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t$$
$$= (19.\overline{4}\ \text{m/s})(1.50\ \text{s})$$
$$= 29.1\overline{6}\ \text{m}$$
$$= 29\ \text{m}$$

Calculate the braking distance.

$v_i = 19.\overline{4}$ m/s, $v_f = 0$, $a = -5.85$ m/s^2, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$
$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{-v_i}{a}$$
$$= \frac{-(19.\overline{4}\ \text{m/s})}{-5.85\ \text{m/s}^2}$$
$$= 3.323\ 836\ 657\ \text{s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$= \left(\frac{19.\overline{4}\ \text{m/s} + 0}{2}\right)(3.323\ 836\ 657\ \text{s})$$
$$= 32.315\ 078\ 61\ \text{m}$$

Determine the stopping distance.

$$\Delta d_{\text{stopping}} = \Delta d_{\text{reaction}} + \Delta d_{\text{braking}}$$
$$= 29.1\overline{6}\ \text{m} + 32.315\ 078\ \text{m}$$
$$= 61.481\ 745\ 28\ \text{m}$$
$$= 61\ \text{m}$$

The length of the area of no return is equal to the stopping distance, 61 m.

Determine the time it takes to travel through the area of no return.

$v = 19.\overline{4}$ m/s

$\Delta d = 61.481\ 745\ 28$ m

$\Delta t = ?$

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

$$\begin{aligned}\Delta t &= \frac{\Delta d}{v} \\ &= \frac{61.481\ 745\ 28\ \text{m}}{19.\overline{4}\ \text{m/s}} \\ &= 3.2\ \text{s}\end{aligned}$$

The minimum time interval for a yellow light in a 70-km/h zone is 3.2 s.

b. Determine the reaction distance.

$$\begin{aligned}v &= 90\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} \\ &= 25\ \text{m/s}\end{aligned}$$

$\Delta t = 1.50$ s

$\Delta d = ?$

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

$$\begin{aligned}\Delta d &= v\Delta t \\ &= (25\ \text{m/s})(1.50\ \text{s}) \\ &= 37.5\ \text{m}\end{aligned}$$

Determine the braking distance.

$v_i = 25$ m/s, $v_f = 0$, $a = -5.85$ m/s^2, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop the vehicle.

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

$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$

$$\begin{aligned}\Delta t &= \frac{-v_i}{a} \\ &= \frac{-(25\ \text{m/s})}{(-5.85\ \text{m/s}^2)} \\ &= 4.273\ 504\ 274\ \text{s}\end{aligned}$$

Next, determine the braking distance.

$$\begin{aligned}\Delta d &= \left(\frac{v_i + v_f}{2}\right)\Delta t \\ &= \left(\frac{25\ \text{m/s} + 0}{2}\right)(4.273\ 504\ 274\ \text{s}) \\ &= 53.418\ 803\ 42\ \text{m}\end{aligned}$$

Determine the stopping distance.

$$\begin{aligned}\Delta d_{\text{stopping}} &= \Delta d_{\text{reaction}} + \Delta d_{\text{braking}} \\ &= 37.5 \text{ m} + 53.418\ 803\ 42 \text{ m} \\ &= 90.918\ 803\ 42 \text{ m} \\ &= 91 \text{ m}\end{aligned}$$

The length of the area of no return is equal to the stopping distance, 91 m.

Determine the time it takes to travel through the area of no return.

$v = 25$ m/s
$\Delta d = 90.918\ 803\ 42$ m
$\Delta t = ?$

$$\begin{aligned}v &= \frac{\Delta d}{\Delta t} \\ \Delta t &= \frac{\Delta d}{v} \\ &= \frac{90.918\ 803\ 42 \text{ m}}{25 \text{ m/s}} \\ &= 3.6 \text{ s}\end{aligned}$$

The minimum time interval for a yellow light in a 90-km/h zone is 3.6 s.

40. As the speed limits increase, the minimum time interval for the yellow lights increases.

41. The yellow light is a signal to warn motorists that the traffic light is about to turn red. If a motorist approaches the intersection at a higher speed, more time is needed to safely stop the vehicle.

42. An intersection is already a hazardous area because so much is happening in a very small space. To approach an intersection at a higher speed makes it even more dangerous. One reason for this is that the driver will now have less time to respond to an unexpected hazard that enters the intersection because the vehicle will reach the intersection sooner.

The fact that the vehicle reaches the intersection sooner also makes the situation more dangerous for everyone else in the area of the intersection because all of these people also have less time to react. This includes other drivers and pedestrians.

1.7 Questions, page 220

Knowledge

1. The typical reaction time for most drivers is **1.5 s**.

2. When a vehicle is travelling through the reaction distance, it is travelling with uniform motion.

3. When a vehicle is travelling through the braking distance, it is travelling with decelerated or negative accelerated motion.

Applying Concepts

Note that vector notation is dropped throughout questions 4, 5, and 6.

4. **a.**

$$v = 105 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}}$$
$$= 29.1\overline{6} \text{ m/s}$$
$$\Delta t = 1.50 \text{ s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t$$
$$= (29.1\overline{6} \text{ m/s})(1.50 \text{ s})$$
$$= 43.75 \text{ m}$$
$$= 43.8 \text{ m}$$

The reaction distance is 43.8 m.

b. $v_i = 29.1\overline{6}$ m/s, $v_f = 0$, $a = -5.85$ m/s^2, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$
$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$
$$\Delta t = \frac{-v_i}{a}$$
$$= \frac{-(29.1\overline{6} \text{ m/s})}{-5.85 \text{ m/s}^2}$$
$$= 4.985\ 754\ 986 \text{ s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$
$$= \left(\frac{29.1\overline{6} \text{ m/s} + 0}{2}\right)(4.985\ 754\ 986 \text{ s})$$
$$= 72.708\ 926\ 88 \text{ m}$$

The braking distance is 72.7 m.

c.

$$\Delta d_{\text{stopping}} = \Delta d_{\text{reacting}} + \Delta d_{\text{braking}}$$
$$= 43.75 \text{ m} + 72.708\ 926\ 88 \text{ m}$$
$$= 116 \text{ m}$$

The stopping distance is 116 m.

d. Determine the reaction distance.

$v = 29.1\overline{6}\ \text{m/s}$

$\Delta t = 3.00\ \text{s}$

$\Delta d = ?$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ \Delta d &= v\Delta t \\ &= \left(29.1\overline{6}\ \text{m/s}\right)\left(3.00\ \text{s}\right) \\ &= 87.5\ \text{m} \end{aligned}$$

The reaction distance is 87.5 m.

The braking distance is unchanged at 72.7 m; therefore, the new stopping distance can be determined as follows:

$$\begin{aligned} \Delta d_{\text{stopping}} &= \Delta d_{\text{reacting}} + \Delta d_{\text{braking}} \\ &= 87.5\ \text{m} + 72.708\,926\,88\ \text{m} \\ &= 160\ \text{m} \end{aligned}$$

The stopping distance for this vehicle is 160 m.

e. As the calculation in question 4.d. demonstrates, if the reaction time increases to 3.00 s due to the influence of drugs or alcohol, the vehicle will travel 87.5 m before the driver even begins to touch the brake pedal. The total increase in stopping distance is an additional 44 m, which means that the driver's chances of avoiding the hazard have been greatly reduced.

Other distractions could include using a cellphone, adjusting the controls on the stereo or radio, eating, drinking, or reading a map.

f. The reaction time is the same as in question 4.a., so the reaction distance is also the same, 43.75 m (unrounded value).

Determine the new braking distance.

$v_i = 29.1\overline{6}\ \text{m/s},\ v_f = 0,\ a = -2.50\ \text{m/s}^2,\ \Delta t = ?,\ \Delta d = ?$

First, determine the time it takes to stop the vehicle.

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

$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$

$$\begin{aligned} \Delta t &= \frac{-v_i}{a} \\ &= \frac{-\left(29.1\overline{6}\ \text{m/s}\right)}{\left(-2.50\ \text{m/s}^2\right)} \\ &= 11.\overline{6}\ \text{s} \end{aligned}$$

Next, determine the braking distance.

$$\begin{aligned}\Delta d &= \left(\frac{v_{\text{i}} + v_{\text{f}}}{2}\right)\Delta t \\ &= \left(\frac{29.1\bar{6}\ \text{m/s} + 0}{2}\right)\left(11.\bar{6}\ \text{s}\right) \\ &= 170.13\bar{8} \\ &= 170\ \text{m}\end{aligned}$$

The braking distance has increased to 170 m.

Determine the new stopping distance.

$$\begin{aligned}\Delta d_{\text{stopping}} &= \Delta d_{\text{reacting}} + \Delta d_{\text{braking}} \\ &= 43.75\ \text{m} + 170.13\bar{8}\ \text{m} \\ &= 214\ \text{m}\end{aligned}$$

The new stopping distance is 214 m.

g. If a speed limit represents the maximum speed under ideal conditions, then it makes sense that the speed should be lower when the conditions become less than ideal. The answer to question 5.f. illustrates that changing the condition of the roadway has a dramatic effect on stopping distance. Under these conditions, it is crucial that a driver reduces the speed of the vehicle to allow for the extra time and distance needed to come to a full stop.

Practice, page 222

43. In order for a driver to brake and turn safely, there must be sufficient traction between the tires and the road. In other words, the force of friction between the tires and the road must be adequate. Sand is spread on the road to increase the frictional forces between the tires and the road.

Practice, page 222

44. A large transport truck travelling on a highway has a much larger mass than a passenger vehicle. This means that the transport truck will need a greater stopping distance and more time to slow down than other vehicles with less mass. This is why the drivers of these trucks try to leave an adequate space between themselves and the vehicles they are following on the highway. If a passenger vehicle were to enter this space prior to the truck driver needing to execute an emergency stop, there would no longer be the necessary stopping distance and a collision could occur between the truck and the passenger vehicle. If this happened, it could injure the driver of the truck but more likely the occupants of the passenger vehicle.

Practice, page 226

45. **a.** Consider the direction of the initial velocity to be the positive direction for this question. Since the braking force acts to oppose the motion, the direction of the net force will be considered to be negative.

$\vec{F}_{\text{net}} = -6500 \text{ N}$

$m = 2920 \text{ kg}$

$\vec{a} = ?$

$$\begin{aligned}
\vec{F}_{\text{net}} &= m\vec{a} \\
\vec{a} &= \frac{\vec{F}_{\text{net}}}{m} \\
&= \frac{-6500 \text{ N}}{(2920 \text{ kg})} \\
&= -2.226\ 027\ 397 \text{ m/s}^2 \\
&= -2.226 \text{ m/s}^2
\end{aligned}$$

The rate of deceleration is 2.226 m/s².

b.

$$\begin{aligned}
v_{\text{i}} &= 70.0 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} \\
&= 19.\overline{4} \text{ m/s}
\end{aligned}$$

$v_{\text{f}} = 0$

$a = -2.226\ 027\ 397 \text{ m/s}^2$

$\Delta t = ?$

$\Delta d = ?$

First, determine the time it takes to stop.

$$\begin{aligned}
a &= \frac{v_{\text{f}} - v_{\text{i}}}{\Delta t} \\
a &= \frac{-v_{\text{i}}}{\Delta t} \quad \leftarrow v_{\text{f}} = 0 \\
\Delta t &= \frac{-v_{\text{i}}}{a} \\
&= \frac{-\left(19.\overline{4} \text{ m/s}\right)}{\left(-2.226\ 027\ 397 \text{ m/s}^2\right)} \\
&= 8.735\ 042\ 735 \text{ s}
\end{aligned}$$

Next, determine the braking distance.

$$\begin{aligned}
\Delta d &= \left(\frac{v_{\text{i}} + v_{\text{f}}}{2}\right)\Delta t \\
&= \left(\frac{19.\overline{4} \text{ m/s} + 0}{2}\right)(8.735\ 042\ 735 \text{ s}) \\
&= 84.9 \text{ m}
\end{aligned}$$

The braking distance is 84.9 m.

c.

$\vec{F}_{\text{net}} = -6500 \text{ N}$

$$\begin{aligned}
m &= 2920 \text{ kg} + 1250 \text{ kg} \\
&= 4170 \text{ kg}
\end{aligned}$$

$\vec{a} = ?$

$$\begin{aligned}
\vec{F}_{\text{net}} &= m\vec{a} \\
\vec{a} &= \frac{\vec{F}_{\text{net}}}{m} \\
&= \frac{-6500 \text{ N}}{4170 \text{ kg}} \\
&= -1.558\ 752\ 998 \text{ m/s}^2 \\
&= -1.559 \text{ m/s}^2
\end{aligned}$$

The deceleration is -1.559 m/s².

d. $v_i = 19.\overline{4}$ m/s, $v_f = 0$, $a = -1.558\ 752\ 998$ m/s^2, $\Delta t = ?$, $\Delta d = ?$

First, determine the time it takes to stop.

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

$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$

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

$$= \frac{-(19.\overline{4}\text{ m/s})}{(-1.558\ 752\ 998\text{ m/s}^2)}$$

$$= 12.474\ 358\ 97\text{ s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$

$$= \left(\frac{19.\overline{4}\text{ m/s} + 0}{2}\right)(12.474\ 358\ 97\text{ s})$$

$$= 121\text{ m}$$

The braking distance is 121 m.

e. The massive load on the trailer reduces the deceleration of the trailer. Given that the farmer still has to come to a stop, he should reduce his velocity and allow more time and distance for braking.

46. As the previous parts of question 45 illustrate, increasing the mass of a trailer reduces the ability of the vehicle pulling that trailer to decelerate. It makes sense that very large trailers should be equipped with additional brakes controlled by the driver to assist in the deceleration process.

1.8 Questions, page 227

Knowledge

1. a. The sled with the single rider will experience the greater deceleration.

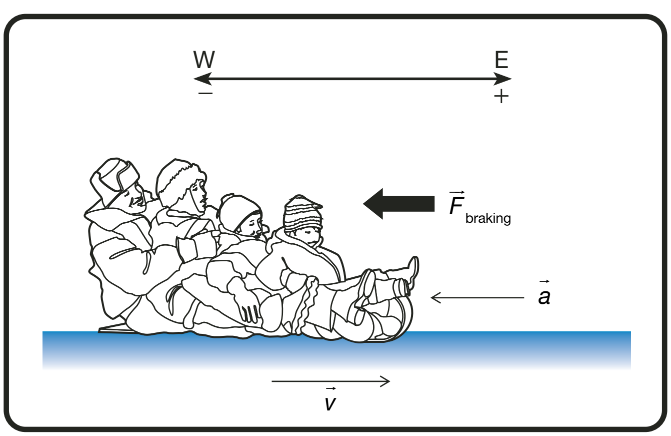
b. Newton's second law states that as the mass increases, the rate of acceleration decreases for a given net force. Since the sled with the two riders had more mass, it should have the lower rate of deceleration.

2. a. The toboggan with all four riders providing the braking force will experience the greater deceleration.

b. Newton's second law states that as the net force increases, the rate of deceleration decreases for a given mass. Since the toboggan with all four riders braking would be subjected to greater braking forces, this toboggan would experience the greater deceleration.

Applying Concepts

3. a.



b. $\vec{v}_i = 6.0 \text{ m/s}[\text{E}]$
$= +6.0 \text{ m/s}$
$\vec{v}_f = 0$
$\Delta t = 3.0 \text{ s}$
$\vec{a} = ?$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{-\vec{v}_i}{\Delta t} \leftarrow \vec{v}_f = 0$$
$$= \frac{(+6.0 \text{ m/s})}{3.0 \text{ s}}$$
$$= -2.0 \text{ m/s}^2$$

The acceleration is 2.0 m/s^2 [W].

c. The braking force is the net force.

$m = 185 \text{ kg}$
$\vec{a} = -2.0 \text{ m/s}^2$
$\vec{F}_{\text{braking}} = ?$

$$\vec{F}_{\text{braking}} = m\vec{a}$$
$$= (185 \text{ kg})(-2.0 \text{ m/s}^2)$$
$$= -3.7 \times 10^2 \text{ kg•m/s}^2$$

The braking force is 3.7×10^2 N [W].

4. a. Let south be the positive direction. Since the sled is travelling south, the braking force must oppose the motion of the sled and be directed to the north.

The braking force is the net force.

$\vec{F}_{\text{braking}} = 225 \text{ N}[\text{N}]$
$= -225 \text{ N}$
$m = 55 \text{ kg}$
$\vec{a} = ?$

$$\vec{F}_{\text{braking}} = m\bar{a}$$
$$\vec{a} = \frac{\vec{F}_{\text{braking}}}{m}$$
$$= \frac{-225 \text{ N}}{55 \text{ kg}}$$
$$= -4.\overline{09} \text{ m/s}^2$$
$$= -4.1 \text{ m/s}^2$$

The acceleration is 4.1 m/s^2 [N].

b. $\vec{a} = -4.\overline{09} \text{ m/s}^2$
$\Delta t = 2.5 \text{ s}$
$\vec{v}_f = 0$
$\vec{v}_i = ?$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$\vec{a} = \frac{-\vec{v}_i}{\Delta t} \leftarrow \vec{v}_f = 0$$
$$\vec{a}\Delta t = -\vec{v}_i$$
$$v_i = -\vec{a}\Delta t$$
$$= -(-4.\overline{09} \text{ m/s}^2)(2.5 \text{ s})$$
$$= +10 \text{ m/s}$$

Prior to the brakes being applied, the sled was travelling 10 m/s [S].

Practice, page 233

47. A player with a large mass will have a lot of inertia. In other words, a player with a large mass will have a strong tendency to resist changes in his or her state of motion; so, once this player began running toward the end zone, the other team would have difficulty stopping him or her.

48. **a.** Newton's first law predicts that the passenger who is in motion prior to the collision with the barrier will continue to be in motion after the collision. So, even though the vehicle stops, the passenger will tend to keep going.

b. It is important to eventually stop the passenger. Newton's first law states that, in the absence of a net force, an object in motion will tend to maintain its velocity. Seat belts and air bags are designed to provide a net force on the passenger to allow the passenger to safely come to a stop. Without seat belts and air bags, the net force on the passenger would be provided by objects like the steering wheel, dashboard, and windshield acting on the passenger's head and rib cage.

49. **a.** In this diagram, both the head and body will be accelerated forward due to the net force applied by the seat and the head restraint.

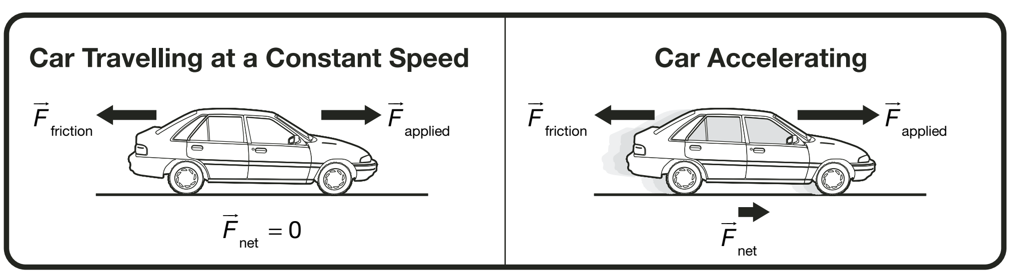
b. Newton's first law states that in the absence of a net force, an object at rest will tend to remain at rest. If there is no force acting on the head, because the head restraint is too low, the head will tend to remain at rest. However, there is a force acting on the rest of the body because the seat is able to push on it. This means that the part of the body below the neck will accelerate forward, while the head will remain at rest.

c. The tissues in the neck become hyperextended as the body accelerates forward from under a stationary head. Eventually, the neck tissues reach the limit of their extension and cause the head to be pulled forward with the rest of the body. Unfortunately, by this point, the acceleration of the body has already passed its maximum value, so the head tends to continue forward moving past the body. This again causes hyperextension in other parts of the neck's tissues. In this scenario, the head moves very much like the end of a whip.

1.9 Questions, page 234

Knowledge

1.



2. The diagram of the car moving with uniform motion represents Newton's first law. Newton's first law explains why objects tend to maintain their velocity, which is what the car is doing in this case.

The diagram of the car accelerating represents Newton's second law. Newton's second law explains that objects will accelerate in the direction of a net force.

Applying Concepts

3. **a.** $\vec{F}_{a} = 1200\ \text{N}[\text{S}]$ $\quad \vec{F}_{f} = 375\ \text{N}[\text{N}]$ $\quad m = 224\ \text{kg}$ $\quad \vec{a} = ?$

$= +1200\ \text{N}$ $\quad = -375\ \text{N}$

First, determine the net force.

$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_{a} + \vec{F}_{f}\\ &= (+1200\ \text{N}) + (-375\ \text{N})\\ &= +825\ \text{N}\end{aligned}$$

Next, determine the acceleration.

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\begin{aligned}\vec{a} &= \frac{\vec{F}_{\text{net}}}{m}\\ &= \frac{+825\ \text{N}}{224\ \text{kg}}\\ &= +3.683\ 035\ 714\ \text{m/s}^2\\ &= +3.68\ \text{m/s}^2\end{aligned}$$

The acceleration is $3.68\ \text{m/s}^2$ [S].

b. Since solving for time involves dividing velocity by acceleration, the vector notation is dropped.

$$v_{i} = 0$$

$$\begin{aligned}v_{f} &= 65.0\ \text{km/h}[\text{S}]\\ &= +65.0\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}}\\ &= 18.0\overline{5}\ \text{m/s}\end{aligned}$$

$$a = 3.683\ 035\ 714\ \text{m/s}^2$$

$$\Delta t = ?$$

$$a = \frac{v_{f} - v_{i}}{\Delta t}$$

$$a = \frac{v_{f}}{\Delta t} \leftarrow \vec{v}_{i} = 0$$

$$\begin{aligned}\Delta t &= \frac{v_{f}}{a}\\ &= \frac{18.0\overline{5}\ \text{m/s}}{3.683\ \text{m/s}^2}\\ &= 4.90\ \text{s}\end{aligned}$$

It takes 4.90 s for the motorcycle to accelerate from rest to 65.0 km/h [S].

4. Each of these driving suggestions relates to Newton's first law of motion. When a motorcyclist carries a passenger, the mass of the whole vehicle increases significantly. This means that the vehicle has more inertia and, therefore, will tend to have a greater resistance to changes in its state of motion. It follows that cornering, decelerating to a stop, and executing emergency braking manoeuvres will all become more difficult because the bike will tend to have a greater resistance to each of these changes in motion.