Strategy
Use the equation for acceleration.

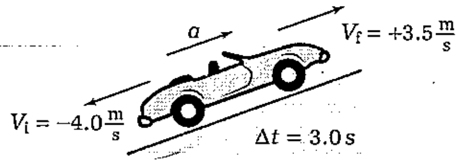
Calculations

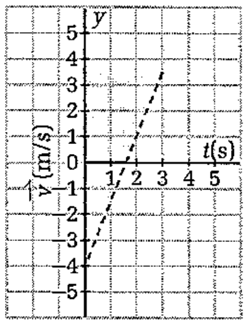
$$a = \frac{v_f - v_i}{\Delta t}$$
$$= \frac{+38\ \frac{m}{s} - \left(+6.0\ \frac{m}{s}\right)}{4.0\ s}$$
$$= +8.0\ \frac{m}{s^2}$$

The Indy race car's acceleration is $+8.0\ m/s^2$.

Validate
The units in the answer were m/s^2, which is correct for acceleration. The average acceleration is positive, since the velocity of the Indy car was increasing while travelling in the positive direction.

7. **Frame the Problem**
- Sketch and label a diagram of the motion.





- The equations of motion apply to the problem, since the acceleration was constant.

Identify the Goal
The car's acceleration once the driver got it started

Variables and Constants

Involved in the problem		Known	Unknown
v_i	a	$v_i = -4.0\ \frac{m}{s}$	a
v_f	Δt	$v_f = +3.5\ \frac{m}{s}$	
		$\Delta t = 3.0\ s$	

Strategy
- Use the equation for acceleration.
- Let uphill be the positive direction.

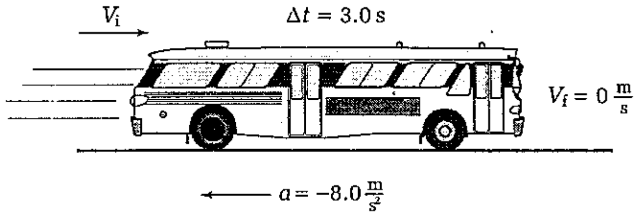
Calculations

$$a = \frac{v_f - v_i}{\Delta t}$$
$$= \frac{+3.5\ \frac{m}{s} - \left(-4.0\ \frac{m}{s}\right)}{3.0\ s}$$
$$= \frac{7.5\ \frac{m}{s}}{3.0\ s}$$
$$= +2.5\ \frac{m}{s^2}$$

The car's acceleration once the driver got it started was $2.5\ m/s^2$ [uphill].

Validate
The units in the answer were m/s^2, which is correct for acceleration. The acceleration is positive, since the velocity of the Indy car was increasing uphill.

8. **Frame the Problem**
   - Sketch and label a diagram of the motion.



- The equations of motion apply to the problem, since the acceleration was constant.
- The final velocity of the bus will be zero.

Identify the Goal
The velocity the bus was travelling when the brakes were applied

Variables and Constants

Involved in the problem		Known		Unknown
v_i	a	$a = -8.0\ \frac{m}{s}$	$v_f = 0.0\ \frac{m}{s}$	v_i
v_f	Δt	$\Delta t = 3.0$ s		

Strategy	Calculations
Select the equation that relates the initial velocity to the final velocity, acceleration, and time interval.	$v_i = v_f - a\Delta t$
All of the needed quantities are known, so substitute them into the equation.	$v_i = 0.0\ \frac{m}{s} - (-8.0\ \frac{m}{s^2})(3.0\ (s)$
Simplify.	$v_i = +24\ \frac{m}{s}$

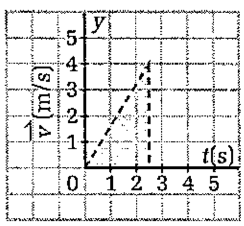
The bus was travelling at +24 m/s^2 when the brakes were applied.

Validate
The units in the answer were m/s^2, which is correct for velocity. The initial velocity was positive, which is correct.

Practice Problem Solutions

Student Textbook page 84

9. **Frame the Problem**
   - Make a diagram of the motion of the field hockey player that includes the known variables.



- The equations of motion apply to the problem, since the acceleration was constant.

Identify the Goal
(a) The distance she travelled
(b) Her acceleration

Variables and Constants

Involved in the problem		Known	Unknown
v_i	a	$v_i = 0.0\ \frac{m}{s}$	Δd
v_f	Δt	$v_f = 4.0\ \frac{m}{s}$	a
Δd		$\Delta t = 2.5$ s	

Strategy

Use the equation of motion that relates time, initial velocity, and final velocity to displacement.

All of the needed quantities are known, so substitute them into the equation. Simplify.

Calculations

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

$$\Delta d = \left(\frac{0.0\ \frac{m}{s} + 4.0\ \frac{m}{s}}{2.0}\right)(2.5\ s)$$

$$\Delta d = 2.0\ \frac{m}{s}(2.5\ s)$$

$$\Delta d = 5.0\ m$$

(a) The distance was 5.0 m.

Use the information to find the acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t}$$

$$a = \frac{4.0\ \frac{m}{s} - 0.0\ \frac{m}{s}}{2.5\ s}$$

$$a = \frac{4.0\ \frac{m}{s}}{2.5\ s}$$

$$a = 1.6\ \frac{m}{s^2}$$

(b) Her acceleration is 1.6 m/s^2.

Validate

The units for displacement are metres and metres per second for acceleration, which are correct. Both displacement and acceleration are positive, as they should be.

10. Frame the Problem

- Let time zero be the moment that Michael begins to accelerate.
- At time zero, Michael is 75 m behind Robert and will thus must run 75 m further than Robert in order to catch up with him.
- When Michael catches up to Robert, they will have run for the same amount of time.
- Michael is travelling with uniform acceleration. Thus, the equation of motion that relates displacement, initial velocity, acceleration, and time interval describes Michael's motion.
- Robert travels with constant velocity or uniform motion. Robert's motion can therefore be described by using the equation that defines velocity.

Identify the Goal

Length of time it will take Michael to catch up with Robert in the race

Variables and Constants

Involved in the problem		Known	Unknown
$\Delta d_R + 75$ m	Δt	$a_M = 0.15\ \frac{m}{s^2}$	Δt
Δd_M	v_R	$v_{M(i)} = 3.8\ \frac{m}{s}$	Δd_M
$v_{M(i)}$		$v_R = 4.2\ \frac{m}{s}$	$\Delta d_R + 75$ m
a_M			

Strategy
Write a mathematical equation that states that the distance Michael runs is equal to the distance Robert runs during the time interval, plus the 75 m Michael has to make up.

Calculations

$\Delta d_M = \Delta d_R + 75\ \text{m}$

$v_M\Delta t + \frac{1}{2}a_M\Delta t^2 = 75\ \text{m} + v_R\Delta t$

Substitute the equation that defines the velocity for Robert for Δd_R. Substitute the equation of motion that relates displacement, initial velocity, acceleration, and the time interval for Michael for Δd_M.

$3.8\ \frac{\text{m}}{\text{s}}\Delta t + \frac{1}{2}(0.15\ \frac{\text{m}}{\text{s}^2})\Delta t^2 = 75\ \text{m} + 4.2\ \frac{\text{m}}{\text{s}}\Delta t$

$3.8\ \frac{\text{m}}{\text{s}}\Delta t + (0.075\ \frac{\text{m}}{\text{s}^2})\Delta t^2 = 75\ \text{m} + 4.2\ \frac{\text{m}}{\text{s}}\Delta t$

The time interval from time zero is the same for the two runners when Michael catches up with Robert. Solve for Δt, the unknown, after substituting the known values into the equations.

$3.8\ \frac{\text{m}}{\text{s}}\Delta t - 4.2\ \frac{\text{m}}{\text{s}}\Delta t + (0.075\ \frac{\text{m}}{\text{s}^2})\Delta t^2 - 75 = 0$

$-0.4\ \frac{\text{m}}{\text{s}}\Delta t + (0.075\ \frac{\text{m}}{\text{s}^2})\Delta t^2 - 75 = 0$

$(0.075\ \frac{\text{m}}{\text{s}^2})\Delta t^2 - 0.4\ \frac{\text{m}}{\text{s}}\Delta t - 75 = 0$

Use the quadratic formula to solve for Δt, since it cannot be easily factored.

$\Delta t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\Delta t = \frac{-(-0.4) \pm \sqrt{(-0.4)^2 - 4(0.075)(-75)}}{2(0.075)}$

$\Delta t = \frac{0.4 \pm \sqrt{0.16 + 22.5}}{0.15}$

$\Delta t = \frac{0.4 \pm \sqrt{22.66}}{0.15}$

$= \frac{0.4 \pm \sqrt{4.76}}{0.15}$

Exclude −29.07, since a negative time has no meaning in this situation.

$\Delta t = \frac{0.4 + 4.76}{0.15}$ $\quad$ $\Delta t = \frac{0.4 - 4.76}{0.15}$

$\Delta t = \frac{5.16}{0.15}$ $\quad$ $\Delta t = \frac{-4.36}{0.15}$

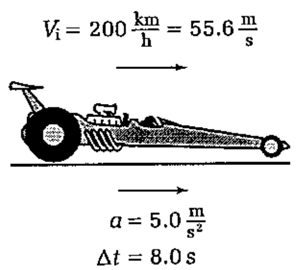
$\therefore \Delta t = 34.4\ \text{s}$ $\quad$ $\therefore \Delta t = -29.07\ \text{s}$

It will take Michael 34 s to catch Robert.

Validate
The time is positive, and it seems to be reasonable.

11. Frame the Problem

- Sketch and label the situation.



- Since the acceleration of the race car is constant, the equation of motion that relates displacement, initial velocity, acceleration, and time interval describes its motion.

Identify the Goal
How far the car has travelled (its displacement) after 8 s

Variables and Constants

Involved in the problem		Known	Unknown
v_i	a	$v_i = 200\ \frac{km}{h}$	Δd
Δd	Δt	$\Delta t = 8.0$ s	
		$a = 5.0\ \frac{m}{s^2}$	

Strategy

First, convert 200 km/h to m/s, since acceleration and time are given in these units.

Calculations

$$\frac{200\ km}{h} \times \frac{1\ h}{3600\ s} \times \frac{1000\ m}{1\ km} = 55.6\ \frac{m}{s}$$

Select the equation of motion that relates the unknown variable, Δd, to the three known variables, a, v_i, and Δt.

$$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$$

All of the needed quantities are known, so substitute them into the equation.

$$\Delta d = 55.6\ \frac{m}{s}(8.0\ s) + \frac{1}{2}(5.0\ \frac{m}{s^2})(8.0\ s)^2$$

Simplify.

$$\Delta d = 444.8\ m + 160\ m$$

$$\Delta d = 604.8\ m = 605\ m$$

$$\Delta d = 604.8\ m = 600\ m$$

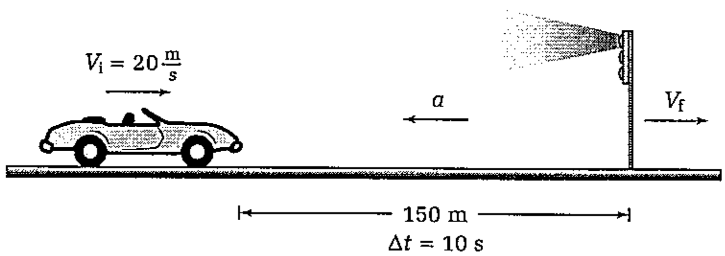
The race car travelled 6.0×10^2 m during the 8.0 s time interval.

Validate

The units cancelled to give metres for displacement, which is correct, and the displacement seems to be reasonable.

12. Frame the Problem

- Sketch and label the diagram of motion.



- The motorist must slow down and cover the 150 m in 10 s without stopping, and continue travelling when the light turns green.
- Since the acceleration of the car is constant, the equation of motion that relates to acceleration, displacement, initial velocity, and time interval describes the motion.

Identify the Goal

(a) The acceleration of the car

(b) The speed of the car just as it passes the green light

Variables and Constants

Involved in the problem		Known	Unknown
v_i	a	$v_i = 20\ \frac{m}{s}$	a
v_f	Δt	$\Delta d = 150$ m	v_f
Δd		$\Delta t = 10$ s	

Strategy
Select the equation of motion that relates the unknown variable, acceleration, to the three known variables, time, initial velocity, and displacement. Substitute and simplify.

Calculations
Rearrange $\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t$ to solve for a:

$a = \frac{2\Delta d}{\Delta t^2} - \frac{2v_i}{\Delta t}$

$a = \frac{2(150\ \text{m})}{10\text{s}} - \frac{2(20)\ \frac{\text{m}}{\text{s}}}{10\ \text{s}}$

$a = \frac{300\ \text{m}}{100\ \text{s}^2} - \frac{40\ \frac{\text{m}}{\text{s}}}{10\ \text{s}}$

$a = 30\ \frac{\text{m}}{\text{s}^2} - 40\ \frac{\text{m}}{\text{s}^2}$

$a = 10\ \frac{\text{m}}{\text{s}^2}$

(a) The motorist's acceleration is $-10\ \text{m/s}^2$.

Select the equation that relates final velocity to the initial velocity, acceleration, and time interval.

$v_f = v_i + a\Delta t$

All of the needed quantities are known, so substitute them into the equation.

$v_f = 20\ \frac{\text{m}}{\text{s}} + (-1\ \frac{\text{m}}{\text{s}^2})10\ \text{s}$

$v_f = 20\ \frac{\text{m}}{\text{s}} + -10\ \frac{\text{m}}{\text{s}}$

Simplify.

$v_f = 10\ \frac{\text{m}}{\text{s}}$

(b) The final velocity of the car just as it passes the green light is 10 m/s.

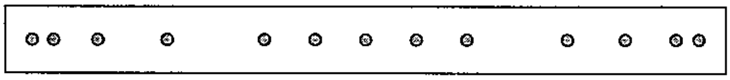
Validate
The negative value of the acceleration indicated the motorist slowed down to a reasonable final velocity of 10 m/s.

Solutions for Problems for Understanding

Student Textbook pages 86–87

15. **(a)** A car is moving in the frame of reference of the road.
(b) A car is at rest in the frame of reference of the trailer.

16.



17. **(a)** The total distance is 17 km ($d = 5.0\ \text{km} + 12\ \text{km}$).
(b) Their displacement is 7 km[S].
(c) To get back to their starting point, the displacement would be 7 km[N].

18. The cyclist travels 25 km[W].

$\Delta t = 1.2\ \cancel{\text{h}} \times \frac{3600\ \text{s}}{1\ \cancel{\text{h}}} = 4320\ \text{s}$

$\vec{\Delta d} = \vec{v}_{ave}\Delta t$

$= 5.9\ \frac{\text{m}}{\cancel{\text{s}}}[\text{W}](4320\ \cancel{\text{s}})$

$= 25\,488\ \text{m[W]}$

$= 25.488\ \text{km[W]}$

19. **(a)** The displacement of the canoeist is 0.4 km[downstream].
Let downstream be positive and upstream be negative.

Practice Problems

Student Textbook page 45

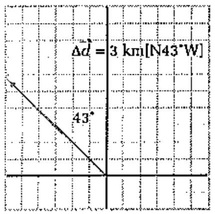
All solutions for Practice Problems are in the *Solutions Manual*.

2.2 Section Review Answers

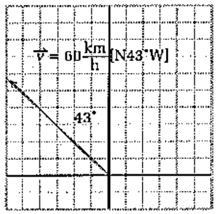
Student Textbook page 46

1. K/U Four scalar quantities are time, mass, speed, and distance. Five vector quantities are position, displacement, velocity, acceleration, and force.
2. (a) K/U "Time" refers to one instant. "Time interval" means the period of time between two instants and is given by $\Delta t = t_f - t_i$.
   (b) K/U Position, displacement, and distance are all measures of length and have a magnitude. Position and displacement have a direction, whereas distance does not have a direction.
   (c) K/U Both measure the speed at which an object is travelling. Speed is a scalar quantity, and velocity is a vector quantity. Velocity has magnitude, unit, and direction, while speed has magnitude and unit only.
3. K/U After $365\frac{1}{4}$ days, Earth returns to its initial position in its orbit around the Sun, and thus its displacement is zero.
4. MC For example, "The displacement of my house to the school is $\Delta\vec{d}$ = 1.4 km[S69°W]."
5. C Refer to the scale drawings below.

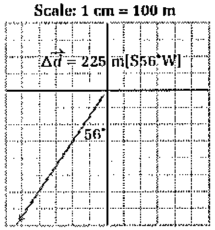
(a) Scale: 1 cm = 2 km



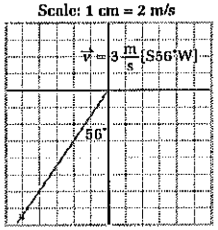
Scale: 1 cm = 20 km/h



(b) Scale: 1 cm = 100 m



Scale: 1 cm = 2 m/s



(c) Scale: 1 cm = 25 km

$\Delta\vec{d}$ = 100 m[W]

Scale: 1 cm = 1 m/s

$6.0\frac{km}{h}[W] = 1.67\frac{m}{s}[W]$

$\vec{v} = 1.67\frac{m}{s}[W]$

6. (a) K/U 4.4 m[W23°N]
   (b) K/U 4.4 mm[E23°S]
   (c) K/U 1.4 m[W32°N]
   (d) K/U 1.4 m[E32°S]

2.3 Constant, Average, and Instantaneous Velocity

Student Textbook pages 47–60

In uniform motion, the velocity is constant. In non-uniform motion, the velocity changes. The average velocity is the velocity between two points on a position-time graph and may be unreasonable if the direction changes between the two points. The instantaneous velocity is actually an average velocity between two points where the time interval is so small that it approaches zero.

Constant Velocity

Student Textbook pages 47–49

Physics Background

The only way to be certain that an object has constant velocity is to have continuous data indicating that the same velocity is being maintained during each time interval.

Teaching Strategy

Brainstorm situations in which students believe velocity is constant. Discuss the reasons why it might or might not be constant.

Quick Lab

Maintaining a Constant Pace

Student Textbook page 50
Approximate Time Required: 30 min

Teaching Tip

Have students practise pulling the tape at a constant speed before the actual timer run.

Answers to Analyze and Conclude Questions

1. Answers will vary.
2. Answers will vary.

Answers to Apply and Extend Questions

3. (a) No, there is not enough data. The student may have stopped, slowed down, or speeded up during the trip.
   (b) You have data for several instants in time, but no data for displacements. Therefore, you cannot determine whether the dog's velocity was constant.
   (c) Without continuous data, you cannot be certain that the swimmer's velocity is constant.

Phase	Time (seconds)	Position (metres [up]) $\vec{d}$	Time Interval (seconds)	Displacement (metres) $\Delta\vec{d} = \vec{d_2} - \vec{d_1}$	Average velocity (m/s) $\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$
1 engine on	0	0	1	10	5
	2	10	3	30	15
	4	40	5	50	25
	6	90	7	70	35
	8	160	9	60	30
2 engine off (rising)	10	220	11	20	10
	12	240	13	–20	–10
3 engine off (falling)	14	220	15	–60	–30
	16	160	17	–68	–34
4 parachute opens	18	92	19	–44	–22
	20	48	21	–20	–10
	22	28	23	–8	–4
5 terminal velocity	24	20	25	–8	–4
	26	12	27	–8	–4
	28	4	29	–4	–2
	30	0			

Math Link

Student Textbook page 55

The definition of the trigonometric function, "tangent," is the side of a right triangle opposite the angle in question divided by the adjacent side. If the opposite side is vertical and the adjacent side is horizontal, the value of the tangent of the angle is the slope of the hypotenuse of the triangle. This definition is exactly how you find the slope of a line that is tangent to a curve.

1. **Phase 1:** The thrust force of the rocket engine causes the rocket to travel with a uniform acceleration of 5 m/s^2 [up].
Phase 2: The engine is off, so the only force acting on the rocket is the downward force of gravity, which causes the rocket to slow its ascent and eventually stop rising.
Phase 3: The rocket has reached it maximum height and at this point its velocity is zero. The rocket then falls downward with a free-fall acceleration of $-9.81 m/s^2$, causing its downward velocity to increase.
Phase 4: The parachute opens as the rocket is still falling downward, but the parachute causes the rocket's downward velocity to decrease.
Phase 5: The rocket has reached terminal velocity and is no longer accelerating, and thus continues to travel downward at a constant velocity until it lands.
2. When the velocity-time graph passes through zero, the position-time graph is at its maximum. The slope of the position-time graph is zero. The rocket has reached a maximum height and is stopped for a split second, making the velocity at this point zero.
3. The velocity-time graph is a straight horizontal line when the velocity is constant. In this case, the rocket is in terminal velocity.
4. All of the values are very close or the same. The average velocity-time graph consists of straight-line sloping sections and not an irregular curve, implying that the position of the rocket between intervals is not changing haphazardly. The instantaneous velocity is actually close to or the same as the object's average velocity between the intervals in question.

Time (s)	Instantaneous velocity	Average velocity
7	35 m/s	35 m/s
13	–10 m/s	–10 m/s
21	–9.6 m/s	–10 m/s
25	–4 m/s	–4 m/s

5. A straight line on a position-time graph indicates that motion is uniform. In this case, the rocket is accelerating (non-uniform motion) for most of its flight, indicating that the points should be joined by a curve.

Assessment and Evaluation

Feature	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Categories	Learning Skills
Quick Lab: Rocket Motion, page 59	*Understanding Basic Concepts* ■ [FM 1.01] define and describe concepts and units related to force and motion *Developing Skills of Inquiry and Communication* ■ [FM 2.03] interpret patterns and trends in data by means of graphs drawn by hand or by computer, and infer or calculate linear and non-linear relationships among variables	■ Assessment Checklist 5: Learning Skills ■ Assessment Checklist 6: Using Math in Science (see "Assessment and Evaluation" in the front matter of *Teacher's Resource* CD-ROM)	■ Knowledge and Understanding ■ Inquiry ■ Communication ■ Making Connections	■ Works independently ■ Organization ■ Initiative

Practice Problems

Student Textbook pages 57–58

All solutions for Practice Problems are in the *Solutions Manual.*

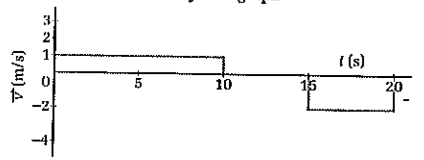
2.3 Section Review Answers

Student Textbook page 60

1. **(a)** Ⓒ Driving downtown in rush hour will involve changes in direction and frequent changes in speed, so it is non-uniform motion.
(b) Ⓒ Whenever an object starts or stops, its velocity changes, making the motion non-uniform.
(c) Ⓒ The pendulum changes direction and speed as it swings in its cycle; therefore, it experiences non-uniform motion.
(d) Ⓒ A ball rolling down a ramp experiences an increase in velocity and, thus, non-uniform motion.
(e) Ⓒ The merry-go-round rotation implies change in direction and, thus, non-uniform motion.

2. The velocity-time graph is shown below.

Velocity-time graph



3. (a) C The slope of a position-time graph is the velocity.
(b) C The slope of a velocity-time graph is the acceleration.
(c) C Average velocity is equal to the slope of the straight line joining two points on a position-time graph. Instantaneous velocity is the value approached by the average velocity as the time interval approaches zero. It is obtained by finding the slope of the tangent at a moment in time on a position-time graph. If the position-time graph consists of a straight sloping line, then the instantaneous velocity is equal to the average velocity and it is called "constant velocity."
(d) C A tangent line is drawn to find the instantaneous velocity at a specific point of time on a position-time graph. To calculate this velocity, you must find the slope of the tangent. The time interval is the run between any two points selected on the tangent line.
(e) C A negative time would occur before the instant that the stopwatch or clock was started.
(f) C When an object is in free fall, it reaches a velocity at which the acceleration becomes zero due to air resistance. The object then falls at a constant velocity called "terminal velocity." Terminal velocity is the velocity at which the downward pull of gravity is balanced by the equal and upward opposing force of air resistance for a falling object.
(g) C m/s and km/h are both speed or velocity units; 1 m/s is equal to 3.6 km/h, as shown by the following unit conversion analysis.

Convert $\frac{1\ \text{m}}{\text{s}}$ to $\frac{\text{km}}{\text{h}}$: $\frac{1\ \text{m}}{\text{s}} \times \frac{60\ \text{s}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{h}} \frac{1\ \text{km}}{1000\ \text{m}} = 3.6\frac{\text{km}}{\text{h}}$

4. MC Answers will vary. Generally, physicists deal more with concrete phenomena that involve observations gathered by the senses, while mathematicians generally deal with abstract concepts that might or might not have any concrete equivalent or application.

5. MC Determine Δt for the girl Δt_G to complete the two laps running at a speed of x m/s. $\Delta t_G = \frac{\Delta d}{x}$.

Determine Δt_B, the total time for the boy to complete the two laps, running at different speeds.

The boy runs the first lap at a speed of $(x - 2)$ m/s, and the second lap at a speed of $(x + 2)$ m/s.

$$\Delta t_B = \frac{\frac{\Delta d}{2}}{(x-2)} + \frac{\frac{\Delta d}{2}}{(x+2)}$$

$$\Delta t_B = \frac{(x+2)\frac{\Delta d}{2} + (x-2)\frac{\Delta d}{2}}{(x-2)(x+2)}$$

$$\Delta t_B = \frac{\frac{\Delta d}{2}[(x+2)+(x-2)]}{(x-2)(x+2)}$$

$$\Delta t_B = \frac{\frac{\Delta d}{2}(2x)}{x^2-4}$$

$$\therefore \Delta t_B = \frac{\Delta dx}{x^2-4}$$

Find the ratio of the girl's time to the boy's time to complete the two laps.

$$\frac{\Delta t_G}{\Delta t_B} = \frac{\frac{\Delta d}{x}}{\frac{\Delta dx}{x^2-4}}$$

$$\frac{\Delta t_G}{\Delta t_B} = \left(\frac{\Delta d}{x}\right)\left(\frac{x^2-4}{\Delta dx}\right)$$

$$\therefore \frac{\Delta t_G}{\Delta t_B} = \frac{x^2-4}{x^2}$$

The girl will take 4 s less than the boy to complete the two laps around the track.

6. K/U

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

$$v = \frac{\Delta d \times \frac{1}{2}}{\Delta t \times 3}$$

$$v = \frac{1\Delta d}{6\Delta t}$$

The velocity changes by a factor of $\frac{1}{6}$.

2.4 Acceleration

Student Textbook pages 61–70

This section builds on the understanding of acceleration that students gained in Grade 10. The relationship between acceleration and velocity vectors is analyzed. Constant, average, and instantaneous acceleration of objects are studied. Objects falling in air might not accelerate at 9.81 m/s^2 because of their shape. Investigation 2-A will consider this problem.

Direction of Acceleration Vectors

Student Textbook pages 61–63

Physics Background

The direction of an acceleration vector is in the same direction as the change in velocity. The acceleration vector of an object is in the direction of the force or push you would have to exert to cause the change in velocity.

Teaching Strategies

- Refer to BLM 2-6, Fill in the Graph/Skill Builder.
- Ask students to brainstorm situations in which they have experienced accelerated motion and explain how their velocity changed.

9. Air friction would produce a decrease in the value of g, causing objects to fall at a slower rate.
10. The precision and accuracy of the measuring instruments could introduce error.
11. Students might not have been as accurate as possible while measuring the distance between dots, making the velocity and then the acceleration determination erroneous. Make sure the timer frequency is adjusted properly, and use new carbon discs. Make sure the recording tape falls freely through the timer.
12. The shape of the object might affect its free-fall properties. Objects that are not streamlined and have flat shapes might be slowed down by drag forces.

Answer to Apply and Extend Question

13. You could use the same equipment as in the above investigation to test objects of the same mass but with different shapes. Oval streamlined shapes would be the most aerodynamic, due to a low drag coefficient.

Assessment and Evaluation

Feature	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Categories	Learning Skills
Investigation 2-A: Acceleration Due to Gravity, pages 68–69	*Understanding Basic Concepts* ■ [FM 1.05] analyze and describe the gravitational force acting on an object near, and at a distance from the surface of Earth *Developing Skills of Inquiry and Communication.* ■ [FM 2.01] design and carry out an experiment to identify specific variables that affect motion ■ [SPH V.02] select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., collect data accurately, using stopwatches, photogates, or data loggers)	■ Assessment Checklist 2: Laboratory Report ■ Assessment Checklist 6: Using Math in Science ■ Rubric for Investigation 2-A (see "Assessment and Evaluation" in the front matter of *Teacher's Resource CD-ROM*)	■ Knowledge and Understanding ■ Inquiry ■ Communication ■ Making Connections	■ Teamwork ■ Organization ■ Initiative

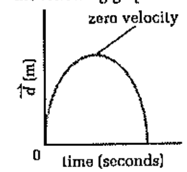
2.4 Section Review Answers

Student Textbook page 70

1. (a) (I) Barb and Al are walking together during the following time periods: 17.5 s to 27 s, 35 s to 48 s, 54 s to 69 s, 72.5 s to 81 s.
   (b) (I) Al and Barb meet at 12 s, 32.5 s, 50 s, and 62.5 s.
   (c) (I) Al and Barb are facing each other during the following time periods: 0 s to 12 s, 27 s to 32.5 s, and 48.5 s to 50 s.
   (d) (I) The following table indicates Al walked faster at 0.84 m/s, since he walked a greater total distance over the same time period.

Al's total distance travelled (m)	Al's average walking speed (m/s)	Barb's total distance travelled (m)	Barb's average walking speed (m/s)
2 to 20 = 18 20 to 6 = 14 6 to 18 = 12 18 − 2 = 16 2 − 10 = 8	$v = \frac{d_{total}}{\Delta t_{total}}$ $v = \frac{68\ m}{81\ s}$	20 to 6 = 14 6 to 16 = 10 16 to 8 = 8 8 to 12 = 4	$v = \frac{d_{total}}{\Delta t_{total}}$ $v = \frac{36\ m}{81\ s}$
Total = 68 m	v = 0.84 m/s	Total = 36 m	v = 0.44 m/s

2. (a) (K/U) A constant acceleration means that the velocity of an object changes uniformly for equal time intervals. A non-uniform acceleration implies the velocity of an object is changing by a different amount (unequally) for equal time intervals. Non-uniform acceleration also means that the acceleration is changing with time.
   (b) (K/U) Average acceleration for an interval of time is equal to the slope of the line joining the two points on a velocity-time graph. Instantaneous acceleration is the value approached by the average acceleration as the time interval approaches zero. The average acceleration is equal to the instantaneous acceleration if the velocity-time graph is a straight line.
3. (a) (C) A tangent line is drawn to find the instantaneous acceleration at a specific point of time on a velocity-time graph. To calculate the acceleration, you must find the slope of the tangent. The time interval is the run between any two points selected on the tangent line.
   (b) (C) "Negative acceleration" means that the acceleration vector points in the negative direction, according to the chosen frame of reference. "Deceleration" is a non-technical term that means "slowing down."
   (c) (C) m/s are units for velocity, and m/s^2 are units for acceleration. Acceleration is defined as the change in velocity during a time interval. You can express the units as "metres per second, every second." Thus, a change in velocity (m/s) gives its acceleration (m/s^2).
4. (K/U) The direction of an acceleration vector is obtained by subtracting the initial velocity vector from the final velocity vector ($\vec{a} = \vec{v_f} - \vec{v_i}$). Join the vectors tail to tail and the resultant is a vector joining the head of the $\vec{v_i}$ vector to the head of the $\vec{v_f}$ vector.
5. (a) (K/U) An object is increasing in speed in a certain direction.
   (b) (K/U) An object is decreasing in speed, moving in a certain direction.
6. (I) The velocity is zero when the ball is at the top of its path. There is no point on the following graph where the acceleration is zero.



7. (I) The top left-hand graph in the textbook represents constant positive acceleration. The top right-hand graph represents constant negative velocity and, thus, no acceleration. The bottom left-hand graph represents constant velocity and, thus, no acceleration. The bottom right-hand graph represents increasing negative acceleration (non-uniform acceleration).

Assessment and Evaluation

Feature	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Categories	Learning Skills
Investigation 2-B: Stop on a Dime, page 78	*Understanding Basic Concepts* ■ [FM 1.01] define and describe concepts and units related to force and motion ■ [FM 1.02] describe and explain different kinds of motion, and apply quantitatively the relationships among displacement, velocity, and acceleration in specific contexts	■ Assessment Checklist 1: Designing an Experiment ■ Assessment Checklist 4: Performance Task Group Assessment ■ Rubric for Investigation 2-B (see "Assessment and Evaluation" in the front matter of *Teacher's Resource CD-ROM*)	■ Knowledge and Understanding ■ Inquiry ■ Communication ■ Making Connections	■ Teamwork ■ Organization ■ Initiative

Practice Problems

Student Textbook pages 84

All solutions for Practice Problems are in the *Solutions Manual*.

2.5 Section Review Answers

Student Textbook page 84

1. K/U Kinematics is the study of the description of motion.
2. MC The 6.9 s reading is not exact. The reading would be an over-measurement, since it will take additional time for the sound of the splash to reach the buddies' ears. To minimize the timing error, the buddies must visually observe and measure the time interval from when the stone is released to when it hits the water in the river below.
3. C The following are examples of possible answers.
   (a) C A marble starting from rest at the top of a ramp reaches a speed of 3.4 m/s [down] at the bottom of the ramp, in a time of 1.5 s. Calculate the acceleration of the marble.
   (b) C A car starts at rest and begins to roll down a hill. After 5.0 s, the car has reached a velocity of 4.5 m/s. How far did the car roll?
   (c) C An astronaut drops an instrument initially at rest from the edge of a cliff on a planet in the solar system. It takes 4.0 s for the instrument to fall 29.6 m. Calculate the acceleration due to gravity on this planet, and identify the planet.

Chapter 2 Review Answers

Student Textbook pages 85–87

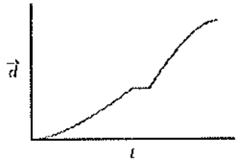
Knowledge and Understanding

1. (a) Kinematics is the study of the description of motion without regard to its causes.
   (b) Dynamics is the study of the causes (forces or other agents) of motion.
   (c) Mechanics is the study of motion and includes both kinematics and dynamics.
   (d) Velocity is the rate of change of displacement.
   (e) Acceleration is the rate of change of velocity.
   (f) The frame of reference is the location or position with which the motion of an object is compared. The selected coordinate system is at rest in the frame of reference.
   (g) The centre of mass is the point on an object where all of the mass appears to be concentrated when analyzing the motion of the object.
   (h) A vector is a quantity that contains a magnitude, unit, and direction, such as position and acceleration.
   (i) A scalar is a quantity that contains a magnitude and unit only, such as speed and distance.
2. Movies, videos, and cartoons are actually still frames in which the positions of objects change a small amount from frame to frame. The frame rate is so fast that our eyes perceive that the objects are moving.
3. (a) The average velocity is equal to the slope of the straight line joining two points on a position-time graph. The instantaneous velocity is the value approached by the average velocity as the time interval approaches zero. It is obtained by finding the slope of the tangent at a moment in time on a position-time graph.
   (b) Average acceleration for an interval of time is equal to the slope of the line joining the two points on a velocity-time graph. Instantaneous acceleration is the value approached by the average acceleration as the time interval approaches zero. It is obtained by finding the slope of the tangent at a moment in time on a velocity-time graph.
4. The application of a changing force on an object could produce a non-uniform acceleration. A constant force such as gravity would cause a uniform acceleration.
5. The area under a curve requires that you make narrow time interval columns, otherwise it will not be accurate. Refer to Figure 2.27 on page 76 in the student textbook. The areas of each individual column are then added, to obtain the total area under the curve.
6. Position is the location of an object relative to the origin of the selected coordinate system. Displacement is the change in position of an object.
7. When an object is accelerating, the velocity is changing every second. For example, if an object is accelerating at 5 m/s^2, the velocity is changing, increasing by 5 m/s every second.
8. Some applications of acceleration are the accelerometer, a device used to measure acceleration; the design of runways, where planes speed up or slow down; spacecraft and all vehicles undergoing rapid velocity changes; parachutes and braking systems designed to slow down objects, anti-gravity suits, etc.
9. A negative area under a velocity-time graph means the object is moving in the negative direction. For example, if east is defined as the positive direction, the object would be moving west.

Inquiry

10. **(a)** The spacing between each dot is increasing with each time interval.
(b) Assuming that the cart was moving in the positive direction, the spacing between each dot would be decreasing with each time interval.
(c) The spacing between each dot is the same at each time interval.
(d) There is no spacing between dots (one big dot).

11. The displacement and velocity-time graphs of the student on rollerblades follow.



Communication

12. A car's speedometer measures the rotation of the drive shaft, which is converted into km/h on a dial or digital display. This is the physical quantity of speed.

Making Connections

13. Refer to the Ontario Ministry of Transportation and the Transport Canada Internet sites listed in the Unit Resources section of this *Teacher's Resource.*

14. Students' answers will vary.

Problems for Understanding

All solutions for Problems for Understanding are in the *Solutions Manual.*

Notes