Chapter 1 Investigations

Investigation 1.2.1: Watch Your Speed, page 46

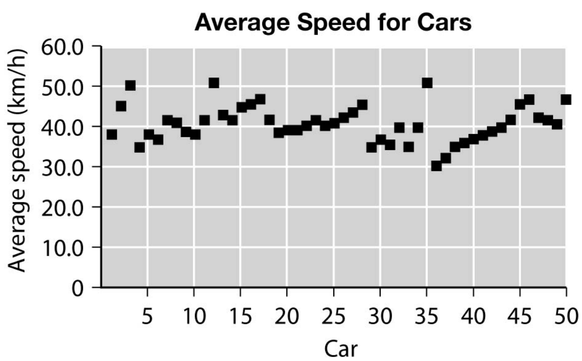
Analyze and Evaluate

Answers may vary. Sample answers:

(a)

$$\begin{aligned} v_{\text{av}} &= \frac{\Delta d}{\Delta t} \\ &= \frac{20\ \cancel{\text{m}}}{1.6\ \text{s}}\left(\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\right) \\ &= \frac{2\ \text{km}}{160\ \cancel{\text{s}}}\left(\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\ \text{h}}\right) \\ v_{\text{av}} &= 45\ \text{km/h} \end{aligned}$$

(b)



(c) There may have been measurement errors when we were timing the cars, and not every car was timed because the stopwatch wasn't always ready.
(d) To reduce uncertainty, I would have more than one person timing the same car to avoid measuring errors.

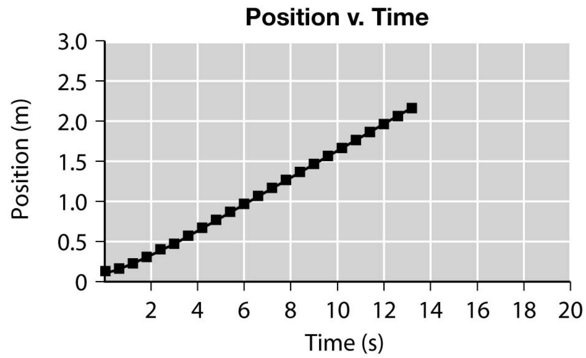
Apply and Extend

(e) There were too many speeders in our study. Since there is already a sign telling drivers the speed limit is 40 km/h, there should be something else to slow down the drivers. The city should install a speed bump, or have police in the area ticketing speeders.

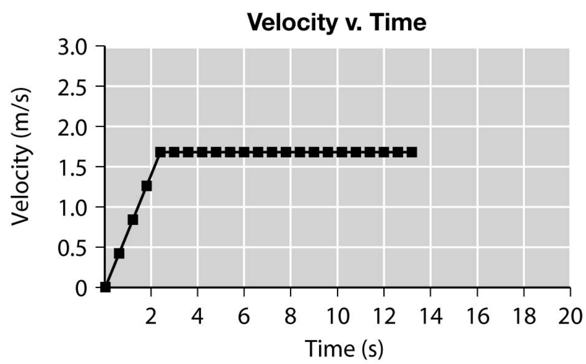
Investigation 1.4.1: Uniform Velocity, pages 47–48

Analyze and Evaluate

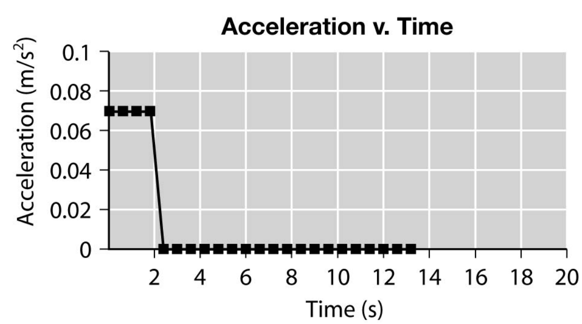
Note: Questions (a) and (b) were switched after the first printing. The following answers reflect this change.
Answers may vary. Sample answers:
(a) The graph of car position versus time is linear. As time increases, the position of the car increases. The graph has a vertical intercept value of 0.15 m at 0 s.



The graph of car velocity and time is an increasing straight line from 0 s to 2.4 s. The graph is a straight line from 2.4 s meaning that the slope is zero. The graph has a vertical intercept value of 0 m/s at 0 s.



The graph of car acceleration and time is a straight horizontal line from 0 s to 2.8 s, then a straight, decreasing line from 1.8 s to 2.4 s. Then the graph is a straight line from 2.4 s onward meaning the slope is zero. The graph has a vertical intercept value of 0.072 m/s^2 at 0 s and a horizontal intercept value of 2.4 s and onward.



(b) The relationship between time and position is linear. The relationship between velocity and time is non-linear. The relationship between acceleration and time is non-linear.

(c) The position-time graph describes uniform motion. The velocity-time graph describes non-uniform motion. The acceleration-time graph describes non-uniform motion.

(d) $$\text{slope}_{\text{position-time}} = \frac{1.99\text{ m} - 1.48\text{ m}}{12\text{ s} - 9\text{ s}} = \frac{0.51\text{ m}}{3\text{ s}}$$

$$\text{slope}_{\text{position-time}} = 0.17\text{ m/s}$$

The slope of the position-time graph is the same value as the velocity of the car from 2.4 s and onward.

(e) $$\text{slope}_{\text{velocity-time1}} = \frac{0.17\text{ m/s} - 0\text{ m/s}}{2.4\text{ s} - 0\text{ s}} = \frac{0.17\text{ m/s}}{2.4\text{ s}}$$

$$\text{slope}_{\text{velocity-time1}} = 0.071\text{ m/s}^2$$

The slope of the velocity-time graph from 0 s to 2.4 s is the same value as the acceleration of the car from 0 s to 2.4 s.

$$\text{slope}_{\text{velocity-time2}} = \frac{0.17\text{ m/s} - 0.17\text{ m/s}}{13.2\text{ s} - 2.4\text{ s}} = \frac{0.0\text{ m/s}}{10.8\text{ s}}$$

$$\text{slope}_{\text{velocity-time2}} = 0.0\text{ m/s}^2$$

The slope of the velocity-time graph from 2.4 s onward is the same value as the acceleration of the car from 2.4 s onward.

The point where the velocity becomes a constant value is shown by the decreasing linear portion of the acceleration-time graph.

(f)

Time (s)	**Equation** $\Delta\vec{d} = \vec{v}_i\,\Delta t + \frac{1}{2}\Delta\vec{v}_f\,\Delta t$	**Displacement** (m [forward])
0.0		0.0
0.6	$\Delta\vec{d} = \left(0.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(0.6\ \cancel{\text{s}}) + \frac{1}{2}\left(0.04\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(0.6\ \cancel{\text{s}})$	0.012
1.2	$\Delta\vec{d} = \left(0.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(1.2\ \cancel{\text{s}}) + \frac{1}{2}\left(0.09\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(1.2\ \cancel{\text{s}})$	0.054
1.8	$\Delta\vec{d} = \left(0.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(1.8\ \cancel{\text{s}}) + \frac{1}{2}\left(0.13\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forwards}]\right)(1.8\ \cancel{\text{s}})$	0.117
2.4	…	0.204
3.0	…	0.255
3.6	…	0.306
4.2	…	0.357
4.8	…	0.408
5.4	…	0.459
6.0	…	0.510
6.6	…	0.561
7.2	…	0.612
7.8	…	0.663
8.4	…	0.714
9.0	…	0.765
9.6	…	0.816
10.2	…	0.867
10.8	…	0.918
11.4	…	0.969
12.0	…	1.020
12.6	…	1.071
13.2	…	1.122
Total		**12.78**

The total area under the velocity-time graph is approximately equal to the final position of the car at 13 m.

(g) Students should list any causes of uncertainty in their measurements. Another source of error could be that the motion sensor was not calibrated correctly.
(h) Students should outline improvements for their procedure to reduce uncertainty, including testing the motion sensor prior to the investigation.

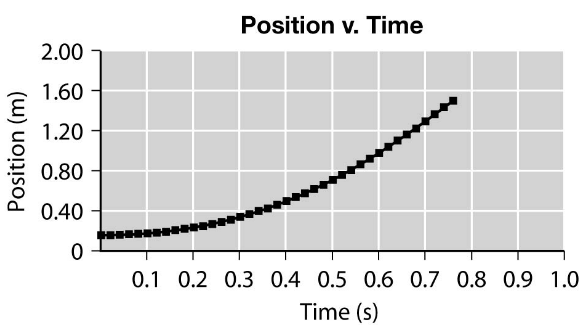
Apply and Extend

(i) It is possible to determine the toy car's average speed by dividing the distance it travels by the time it takes.
(j) Some cameras use sensors to determine the distance to the object being photographed in order to focus correctly. The sensors on a camera do not have the same precision as the motion sensor for the experiment since it is just a minor feature of the camera.

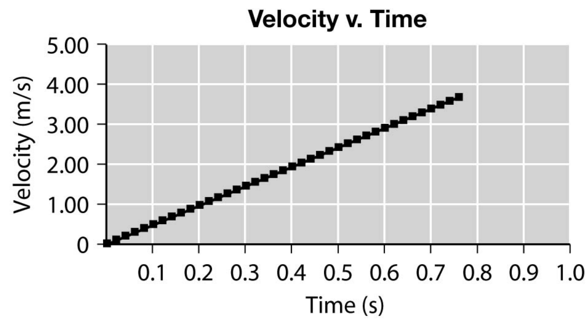
Investigation 1.4.2: Motion Down a Ramp, page 49

Analyze and Evaluate

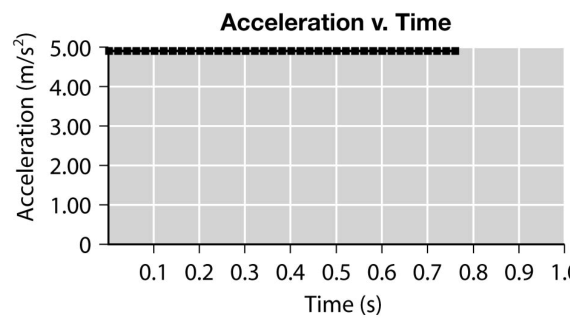
(a) The graph of PVC pipe position versus time is a curve. As time increases, the position of the car increases. The graph has a vertical intercept value of 0.15 m at 0 s.



The graph of PVC pipe velocity and time is an increasing straight line from 0 s onward. The graph has a vertical intercept value of 0 m/s at 0 s.



The graph of PVC pipe acceleration and time is a straight horizontal line from 0 s onward. The graph has a vertical intercept value of 4.90 m/s^2 at 0 s.



(b) The relationship between position and time is non-linear. The relationship between velocity and time is linear. The relationship between acceleration and time is linear.
(c) The position-time graph describes non-uniform motion. The velocity-time graph describes uniform motion. The acceleration-time graph describes the uniform motion.

(d)
$$\text{slope}_{\text{velocity-time}} = \frac{0.98\ \text{m/s} - 0.00\ \text{m/s}}{0.20\ \text{s} - 0\ \text{s}}$$
$$= \frac{0.98\ \text{m/s}}{0.20\ \text{s}}$$
$$\text{slope}_{\text{velocity-time}} = 4.9\ \text{m/s}^2$$

The slope of the velocity-time graph is the same value as the acceleration of the PVC pipe.

(e)

Time (s)	**Equation** $\vec{v} = (\Delta \vec{a})(\Delta t)$		**Velocity** (m/s) [downward]
0.0	$\vec{v} = \left(4.9\ \frac{\text{m}}{\text{s}^{\not 2}}\ [\text{downward}]\right)(0\ \not\text{s})$		0.00
0.02	$\vec{v} = \left(4.9\ \frac{\text{m}}{\text{s}^{\not 2}}\ [\text{downward}]\right)(0.02\ \not\text{s})$		0.098
Time (s)	**Velocity** (m/s) [downward]	**Time** (s)	**Velocity** (m/s) [downward]
0.04	0.196	0.40	1.960
0.06	0.294	0.42	2.058
0.08	0.392	0.44	2.156
0.10	0.490	0.46	2.254
0.12	0.588	0.48	2.352
0.14	0.686	0.50	2.450
0.16	0.784	0.52	2.548
0.18	0.882	0.54	2.646
0.20	0.980	0.56	2.744
0.22	1.078	0.58	2.842
0.24	1.176	0.60	2.940
0.26	1.274	0.62	3.038
0.28	1.372	0.64	3.136
0.30	1.470	0.66	3.234
0.32	1.568	0.68	3.332
0.34	1.666	0.70	3.430
0.36	1.764	0.72	3.528
0.38	1.862		
Total			**65.268**

The area under the acceleration-time graph is about 20 times greater than the final velocity of the PVC pipe. The final velocity of the PVC pipe was 3.63 m/s [downward].

(f) Answers may vary. Students should list any causes of uncertainty in their measurements. Another source of error could be that the motion sensor was not calibrated correctly.
(g) Answers may vary. Students should outline improvements for their procedure to reduce uncertainty, including testing the motion sensor prior to the investigation.

Apply and Extend

(h) Answers may vary depending on the brands and models of remote control vehicles used.
(i) Answers may vary depending on the force used to push the PVC pipe up the ramp.
(j) Answers may vary. Sample answer:
Hi Sis,
Most wooden coasters that I've seen always take you up a climb at the beginning, then the rest of the ride you're being pushed along by gravity or momentum from a drop. That means that the most exciting stuff is usually around the start of the ride because you can drop from a greater height and get faster speeds. By the end, the drops are shorter and the ride slows down a lot.

Chapter 1 Review, pages 52–57

Note: Question 5 was modified after the first printing:
"Which of the following describes a line drawn to a specific scale with an arrow head?"
The correct answer is still (a).

Knowledge

1. (b)
2. (c)
3. (d)
4. (d)
5. (a)
6. (c)
7. (a)
8. (d)
9. (c)
10. False. *Direction* is the line an object moves along from a particular starting point.
11. False. A *vector* is a quantity that has a magnitude and also direction.
12. True
13. False. Vectors are added by joining them tip to *tail*.
14. False. The difference between speed and velocity is that speed is a *scalar* while velocity is a *vector*.
15. True
16. False. Motion in a straight line but with a varying speed is considered motion with *non-uniform* velocity.
17. False. The slope of a velocity–time graph gives the *average acceleration* of an object.
18. True
19. Note: After the first printing, option (d) was changed to "uniform velocity." The answer below is still correct.
(a) (v)
(b) (i)
(c) (vi)
(d) (ii)
(e) (iii)
(f) (iv)
20. Velocity is a vector while speed is a scalar. Average velocity is calculated by dividing the total displacement (also a vector) by the total time for that displacement. Average speed is calculated by dividing the total distance (also a scalar) by the total time for that distance.
21. If an object has a negative acceleration, it is accelerating in the direction opposite to the direction it is travelling. The negative acceleration causes the object to slow down and, if it continues, to speed up in the opposite direction.

Understanding

Note: Figure 1 was modified after the first printing. The distance between home and school was changed to 750 m (was 75 m). The answers below reflect this change.

22. Given: $\vec{d}_{\text{initial}} = 0\text{ m}$; $\vec{d}_{\text{final}} = 2000\text{ m [W]}$

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 2000\text{ m [W]} - 0\text{ m}\\ \Delta\vec{d}_{\text{T}} &= 2000\text{ m [W]}\end{aligned}$$

Statement: Your displacement would be 2000 m [W].

23. Given: $\vec{d}_{\text{initial}} = 750\text{ m [E]}$; $\vec{d}_{\text{final}} = 2500\text{ m [E]}$

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 2500\text{ m [E]} - 750\text{ m [E]}\\ \Delta\vec{d}_{\text{T}} &= 1750\text{ m [E]}\end{aligned}$$

Statement: Your displacement would be 1750 m [E].

24. Given: $\vec{d}_{\text{initial}} = 2000\text{ m [W]}$; $\vec{d}_{\text{final}} = 2500\text{ m [E]}$

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 2500\text{ m [E]} - 2000\text{ m [W]}\\ &= 2500\text{ m [E]} + 2000\text{ m [E]}\\ \Delta\vec{d}_{\text{T}} &= 4500\text{ m [E]}\end{aligned}$$

Statement: Your displacement would be 4500 m [E].

25. Given: $\vec{d}_{\text{initial}} = 750\text{ m [E]}$; $\vec{d}_{\text{final}} = 0\text{ m}$ (ignore the detail about the market because displacement only involves initial and final positions)

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 0\text{ m} - 750\text{ m [E]}\\ &= 0\text{ m} + 750\text{ m [W]}\\ \Delta\vec{d}_{\text{T}} &= 750\text{ m [W]}\end{aligned}$$

Statement: Your displacement would be 750 m [W].

26. Given: $\vec{d}_{\text{inital}}$ = 76 km [W]; $\vec{d}_{\text{final}}$ = 54 km [E]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 54\text{ km [E]} - 76\text{ km [W]}\\ &= 54\text{ km [E]} + 76\text{ km [E]}\\ \Delta\vec{d}_{\text{T}} &= 130\text{ km [E]}\end{aligned}$$

Statement: The car's displacement is 130 km [E].

27. Given: Δd = 250 m; Δt = 4.0 s

Required: v_{av}

Analysis: $v_{\text{av}} = \frac{\Delta d}{\Delta t}$

Solution:
$$\begin{aligned}v_{\text{av}} &= \frac{\Delta d}{\Delta t}\\ &= \frac{250\text{ m}}{4.0\text{ s}}\\ v_{\text{av}} &= 63\text{ m/s}\end{aligned}$$

Statement: The race car's average speed is 63 m/s.

28. Given: v_{av} = 15 m/s; Δt = 3.0 s

Required: Δd

Analysis: $v_{\text{av}} = \frac{\Delta d}{\Delta t}$

$\Delta d = v_{\text{av}}\,\Delta t$

Solution:
$$\begin{aligned}\Delta d &= v_{\text{av}}\,\Delta t\\ &= \left(15\ \frac{\text{m}}{\cancel{\text{s}}}\right)\left(3.0\ \cancel{\text{s}}\right)\\ \Delta d &= 45\text{ m}\end{aligned}$$

Statement: The baseball will go 45 m in 3.0 s.

29. Given: $\Delta\vec{d}$ = 310 m [S]; Δt = 8.0 s

Required: $\vec{v}_{\text{av}}$

Analysis: $\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{v}_{\text{av}} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{310\text{ m [S]}}{8.0\text{ s}}\\ \vec{v}_{\text{av}} &= 39\text{ m/s [S]}\end{aligned}$$

Statement: The average velocity of the bird is 39 m/s [S].

30. Given: $\vec{d}_{\text{inital}}$ = 45 km [W]; $\vec{d}_{\text{final}}$ = 15 km [E]; Δt = 1.2 h

Required: $\vec{v}_{\text{av}}$

Analysis: $\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$

$\vec{v}_{\text{av}} = \frac{\vec{d}_{\text{final}} - \vec{d}_{\text{initial}}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{v}_{\text{av}} &= \frac{\vec{d}_{\text{final}} - \vec{d}_{\text{initial}}}{\Delta t}\\ &= \frac{15\text{ km [E]} - 45\text{ km [W]}}{1.2\text{ h}}\\ &= \frac{15\text{ km [E]} + 45\text{ km [E]}}{1.2\text{ h}}\\ &= \left(\frac{60\ \cancel{\text{km}}\ \text{[E]}}{1.2\text{ h}}\right)\left(\frac{1000\text{ m}}{1\ \cancel{\text{km}}}\right)\\ &= \left(\frac{60\ 000\text{ m [E]}}{1.2\ \cancel{\text{h}}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\text{ s}}\right)\\ \vec{v}_{\text{av}} &= 14\text{ m/s [E]}\end{aligned}$$

Statement: The velocity of the car is 14 m/s [E].

31. Given: $\Delta\vec{d}$ = 2400 m [W]; $\vec{v}_{\text{av}}$ = 9.0 m/s [W]

Required: Δt

Analysis: $\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$

$\Delta t = \frac{\Delta\vec{d}}{\vec{v}_{\text{av}}}$

Solution:
$$\begin{aligned}\Delta t &= \frac{\Delta\vec{d}}{\vec{v}_{\text{av}}}\\ &= \frac{2400\ \cancel{\text{m}}\ \text{[W]}}{9.0\ \frac{\cancel{\text{m}}}{\text{s}}\ \text{[W]}}\\ \Delta t &= 2.7\times10^{2}\text{ s}\end{aligned}$$

Statement: The bird is in flight for 2.7×10^2 s or 270 s.

32. Given: v_{av} = 251 km/h; Δt = 14.3 s

Required: Δd

Analysis: $v_{\text{av}} = \frac{\Delta d}{\Delta t}$

$\Delta d = v_{\text{av}}\,\Delta t$

Solution:
$$\begin{aligned}\Delta d &= v_{\text{av}}\,\Delta t\\ &= \left(251\ \frac{\text{km}}{\cancel{\text{h}}}\right)\left(14.3\ \cancel{\text{s}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \cancel{\text{s}}}\right)\\ \Delta d &= 0.997\text{ km}\end{aligned}$$

Statement: The length of the track is 0.997 km or 997 m.

33. (a) The position–time graph is a straight line, so the slope is the same at every point. Since the slope gives the velocity, the object has uniform velocity.

(b) The slope of the position–time graph is negative, so the velocity is negative. The slope is constant, so the velocity is constant.

34. (a) The position–time graph is curved downward, so the object has non-uniform velocity. In the first half of the time, the displacement is more than twice the displacement in the second half of the time.

(b) The slope at all points of the position–time graph is positive, so the velocity is always positive. The slope is decreasing, so the velocity must also be decreasing or slowing down.

35. Given: $\vec{v}_i = 0$ m/s; $\vec{v}_f = 5.0$ m/s [E]; $\Delta t = 1.25$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta \vec{v}}{\Delta t} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution:

$$\vec{a}_{av} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} = \frac{5.0\text{ m/s [E]} - 0\text{ m/s}}{1.25\text{ s}} = \frac{5.0\text{ m/s [E]}}{1.25\text{ s}}$$

$$\vec{a}_{av} = 4.0\text{ m/s}^2\text{ [E]}$$

Statement: The average acceleration of the runner is 4.0 m/s^2 [E].

36. Given: $\vec{v}_i = 0$ m/s; $\vec{a}_{av} = 6.25$ m/s^2 [W]; $\Delta t = 2.0$ s

Required: $\vec{v}_f$

Analysis:

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

$$\vec{a}_{av}\,\Delta t = \vec{v}_f - \vec{v}_i$$

$$\vec{v}_f = \vec{v}_i + \vec{a}_{av}\,\Delta t$$

Solution:

$$\vec{v}_f = \vec{v}_i + \vec{a}_{av}\,\Delta t = 0\text{ m/s} + \left(6.25\ \frac{\text{m}}{\cancel{\text{s}^2}}\text{ [W]}\right)(2.0\text{ s})$$

$$\vec{v}_f = 13\text{ m/s [W]}$$

Statement: The final velocity of the horse is 13 m/s [W].

37. Given: $v_i = 0$ m/s; $v_f = 343$ m/s; $a_{av} = 1.25 \times 10^5$ m/s^2

Required: Δt

Analysis:

$$a_{av} = \frac{v_f - v_i}{\Delta t}$$

$$\Delta t = \frac{v_f - v_i}{a_{av}}$$

Solution:

$$\Delta t = \frac{v_f - v_i}{a_{av}} = \frac{343\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}} - 0\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{1.25\times10^5\ \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}}$$

$$\Delta t = 2.74\times10^{-3}\text{ s}$$

Statement: The acceleration will take 2.74×10^{-3} s or 2.74 ms.

38. Given: $\vec{v}_i = 180$ km/h [S]; $\vec{a}_{av} = 8.2$ m/s^2 [N]; $\Delta t = 3.2$ s

Required: $\vec{v}_f$

Analysis:

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

$$\vec{a}_{av}\,\Delta t = \vec{v}_f - \vec{v}_i$$

$$\vec{v}_f = \vec{v}_i + \vec{a}_{av}\,\Delta t$$

Solution:

$$\vec{v}_f = \vec{v}_i + \vec{a}_{av}\,\Delta t$$

$$= 180\text{ km/h [S]} + \left(8.2\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\text{ [N]}\right)(3.2\ \cancel{\text{s}})$$

$$= 180\text{ km/h [S]} + 26.24\text{ m/s [N]}$$

$$= 180\text{ km/h [S]} + \left(-26.24\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\text{ [S]}\right)\left(\frac{1\text{ km}}{1000\ \cancel{\text{m}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\text{ h}}\right)\left(\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right)$$

$$\vec{v}_f = 86\text{ km/h [S]}$$

Statement: The velocity of the car is 86 km/h [S] when it makes the turn.

39. Given: $a_{av} = 1.8$ m/s^2; $\Delta t = 2.4$ s; $v_f = 10.2$ m/s

Required: v_i

Analysis:

$$a_{av} = \frac{v_f - v_i}{\Delta t}$$

$$a_{av}\,\Delta t = v_f - v_i$$

$$v_i = v_f - a_{av}\,\Delta t$$

Solution:

$$v_i = v_f - a_{av}\,\Delta t = 10.2\text{ m/s} - \left(1.8\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(2.4\text{ s})$$

$$v_i = 5.9\text{ m/s}$$

Statement: The student's initial speed was 5.9 m/s.

40. Given: b = 4.0 s; h = 2.0 m/s [E]; l = 4.0 s; w = 2.0 m/s [E]

Required: $\Delta\vec{d}$

Analysis: Use the area under the graph to determine the position at t = 4.0 s:

$\Delta\vec{d} = A_{\text{triangle}} + A_{\text{rectangle}}$

Solution:

$$\begin{aligned}\Delta\vec{d} &= A_{\text{triangle}} + A_{\text{rectangle}}\\ &= \frac{1}{2}bh + lw\\ &= \frac{1}{2}(4.0\ \cancel{\text{s}})\left(2.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{E}]\right) + (4.0\ \cancel{\text{s}})\left(2.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{E}]\right)\\ &= 4.0\text{ m [E]} + 8.0\text{ m [E]}\\ \Delta\vec{d} &= 12\text{ m [E]}\end{aligned}$$

Statement: The object has travelled 12 m [E] after 4.0 s.

41. Given: $\vec{v}_{\text{i}}$ = 4.0 m/s [W]; $\vec{a}_{\text{av}}$ = 1.0 m/s^2 [W]; Δt = 3.0 s

Required: $\Delta\vec{d}$

Analysis: $\Delta\vec{d} = \vec{v}_{\text{i}}\,\Delta t + \frac{1}{2}\vec{a}_{\text{av}}\,\Delta t^2$

Solution:

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_{\text{i}}\,\Delta t + \frac{1}{2}\vec{a}_{\text{av}}\,\Delta t^2\\ &= \left(4.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{W}]\right)(3.0\ \cancel{\text{s}}) + \frac{1}{2}\left(1.0\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{W}]\right)(3.0\ \cancel{\text{s}})^2\\ &= 12\text{ m [W]} + 4.5\text{ m [W]}\\ \Delta\vec{d} &= 17\text{ m [W]}\end{aligned}$$

Statement: The displacement of the object is 17 m [W].

42. (a) Equation 4 $\left(v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d\right)$ should be used to find the final velocity because it includes the variables Δd, a_{av}, v_{f}, and v_{i}, and excludes time.

(b) Given: v_{i} = 3.0 m/s; Δd = 6.0 m; a = 0.80 m/s^2

Required: v_{f}

Analysis:

$$\begin{aligned}v_{\text{f}}^2 &= v_{\text{i}}^2 + 2a\Delta d\\ v_{\text{f}} &= \sqrt{v_{\text{i}}^2 + 2a\Delta d}\end{aligned}$$

Solution:

$$\begin{aligned}v_{\text{f}} &= \sqrt{v_{\text{i}}^2 + 2a\Delta d}\\ &= \sqrt{\left(3.0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(0.80\ \frac{\text{m}}{\text{s}^2}\right)(6.0\text{ m})}\\ v_{\text{f}} &= 4.3\text{ m/s}\end{aligned}$$

Statement: The final velocity of the ball is 4.3 m/s [down].

43. (a) Given: $\vec{v}_{\text{i}}$ = 0 m/s; $\Delta\vec{d}$ = 10.0 m [down]; $\vec{a} = \vec{g}$ = 9.8 m/s^2 [down]

Required: Δt

Analysis:

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_{\text{i}}\,\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2\\ &= (0\text{ m/s})\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2\\ (\Delta t)^2 &= \frac{2\Delta\vec{d}}{\vec{a}}\\ \Delta t &= \sqrt{\frac{2\Delta\vec{d}}{\vec{a}}}\end{aligned}$$

Solution:

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta\vec{d}}{\vec{a}}}\\ &= \sqrt{\frac{2(10.0\ \cancel{\text{m}})}{\left(9.8\ \frac{\cancel{\text{m}}}{\text{s}^2}\right)}}\\ \Delta t &= 1.4\text{ s}\end{aligned}$$

Statement: The ball takes 1.4 s to fall 10.0 m.

(b) Given: $\vec{v}_{\text{i}}$ = 0 m/s; $\Delta\vec{d}$ = 10.0 m [down]; $\vec{a} = \vec{g}$ = 9.8 m/s^2 [down]

Required: $\vec{v}_{\text{f}}$

Analysis:

$$\begin{aligned}v_{\text{f}}^2 &= v_{\text{i}}^2 + 2a\Delta d\\ v_{\text{f}} &= \sqrt{v_{\text{i}}^2 + 2a\Delta d}\end{aligned}$$

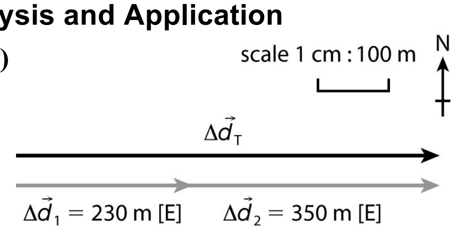
Solution:

$$\begin{aligned}v_{\text{f}} &= \sqrt{v_{\text{i}}^2 + 2a\Delta d}\\ &= \sqrt{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(10.0\text{ m})}\\ v_{\text{f}} &= 14\text{ m/s}\end{aligned}$$

Statement: The final velocity of the ball is 14 m/s [down].

Analysis and Application

44. (a)



(b) Given: $\Delta\vec{d}_1$ = 230 m [E]; $\Delta\vec{d}_2$ = 350 m [E]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution (algebraic):

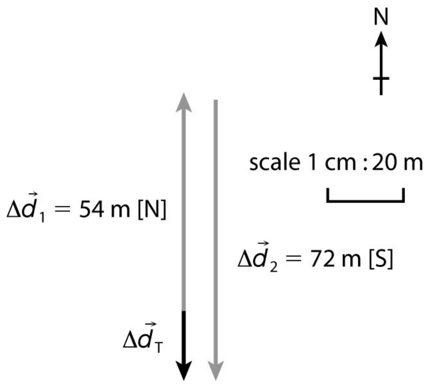
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 230\text{ m [E]} + 350\text{ m [E]}\\ \Delta\vec{d}_{\text{T}} &= 580\text{ m [E]}\end{aligned}$$

Solution (scale diagram):
This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [E].

$\Delta\vec{d}_T$ measures 5.8 cm in length, so using the scale of 1 cm : 100 m, the actual magnitude of $\Delta\vec{d}_T$ is 580 m [E].

Statement: The car's total displacement is 580 m [E].

45. (a)



(b) Given: $\Delta\vec{d}_1 = 54$ m [N]; $\Delta\vec{d}_2 = 72$ m [S]

Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution (algebraic):
$$\begin{aligned}\Delta\vec{d}_T &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 54\text{ m [N]} + 72\text{ m [S]}\\ &= -54\text{ m [S]} + 72\text{ m [S]}\\ \Delta\vec{d}_T &= 18\text{ m [S]}\end{aligned}$$

Solution (scale diagram):
This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [S].

$\Delta\vec{d}_T$ measures 0.9 cm in length, so using the scale of 1 cm : 20 m, the actual magnitude of $\Delta\vec{d}_T$ is 18 m [S].

Statement: The eagle's total displacement is 18 m [S].

46. Given: $\vec{d}_{\text{inital}} = 4.0$ m [E]; $\vec{d}_{\text{final}} = 16$ m [E]; $\Delta t = 6.0$ s

Required: $\vec{v}_{\text{av}}$

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\vec{v}_{\text{av}} = \frac{\vec{d}_{\text{final}} - \vec{d}_{\text{initial}}}{\Delta t}$$

Solution:
$$\begin{aligned}\vec{v}_{\text{av}} &= \frac{\vec{d}_{\text{final}} - \vec{d}_{\text{initial}}}{\Delta t}\\ &= \frac{16\text{ m [E]} - 4.0\text{ m [E]}}{6.0\text{ s}}\\ \vec{v}_{\text{av}} &= 2.0\text{ m/s [E]}\end{aligned}$$

Statement: The average velocity of the object is 2.0 m/s [E].

47. Given: $\vec{d}_1 = 250$ m [N]; $\vec{d}_2 = 750$ m [N]; $t_1 = 15$ s; $t_2 = 36$ s

Required: $\vec{v}_{\text{av}}$

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\vec{v}_{\text{av}} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$$

Solution:
$$\begin{aligned}\vec{v}_{\text{av}} &= \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}\\ &= \frac{750\text{ m [N]} - 250\text{ m [N]}}{36\text{ s} - 15\text{ s}}\\ &= \frac{500\text{ m [N]}}{21\text{ s}}\\ \vec{v}_{\text{av}} &= 24\text{ m/s [N]}\end{aligned}$$

Statement: The average velocity of the car between the checkpoints is 24 m/s [N].

48. Given: $\vec{d}_1 = 320$ m [E]; $\vec{d}_2 = 140$ m [W]; $t_1 = 25$ s; $t_2 = 49$ s

Required: $\vec{v}_{\text{av}}$

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\vec{v}_{\text{av}} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$$

Solution:
$$\begin{aligned}\vec{v}_{\text{av}} &= \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}\\ &= \frac{140\text{ m [W]} - 320\text{ m [E]}}{49\text{ s} - 25\text{ s}}\\ &= \frac{140\text{ m [W]} + 320\text{ m [W]}}{24\text{ s}}\\ \vec{v}_{\text{av}} &= 19\text{ m/s [W]}\end{aligned}$$

Statement: The average velocity of the racer between the checkpoints is 19 m/s [W].

49. Given: $\vec{d}_1$ = 450 km [W]; $\vec{d}_2$ = 920 km [W]; $\vec{v}_{av}$ = 40.0 km/h [W]

Required: Δt

Analysis: $\vec{v}_{av} = \dfrac{\Delta \vec{d}}{\Delta t}$

$$\vec{v}_{av} = \frac{\vec{d}_2 - \vec{d}_1}{\Delta t}$$

$$\Delta t = \frac{\vec{d}_2 - \vec{d}_1}{\vec{v}_{av}}$$

Solution: $\Delta t = \dfrac{\vec{d}_2 - \vec{d}_1}{\vec{v}_{av}}$

$$= \frac{920\ \cancel{\text{km}}\ [\text{W}] - 450\ \cancel{\text{km}}\ [\text{W}]}{40.0\ \dfrac{\cancel{\text{km}}}{\text{h}}\ [\text{W}]}$$

$$\Delta t = 12\ \text{h}$$

Statement: It will take the train 12 h to travel between the two stations.

50. Given: $\vec{d}_1$ = 4.5 km [S]; $\vec{d}_2$ = 2.5 km [N]; v_{av} = 9.7 m/s

Required: Δt

Analysis: $\vec{v}_{av} = \dfrac{\Delta \vec{d}}{\Delta t}$

$$\vec{v}_{av} = \frac{\vec{d}_2 - \vec{d}_1}{\Delta t}$$

$$\Delta t = \frac{\vec{d}_2 - \vec{d}_1}{\vec{v}_{av}}$$

Solution: $\Delta t = \dfrac{\vec{d}_2 - \vec{d}_1}{\vec{v}_{av}}$

$$= \frac{2.5\ \text{km [N]} - 4.5\ \text{km [S]}}{9.7\ \text{m/s}}$$

$$= \frac{2.5\ \text{km [N]} + 4.5\ \text{km [N]}}{9.7\ \text{m/s}}$$

$$= \frac{7.0\ \cancel{\text{km}}\ [\text{N}]}{9.7\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}}}}\left(\frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \text{min}}{60\ \cancel{\text{s}}}\right)$$

$$\Delta t = 12\ \text{min}$$

Statement: The trip will take him 12 min.

51. Given: v_i = 1.0 m/s; v_f = 7.6 m/s; Δt = 0.8 s

Required: $\vec{a}_{av}$

Analysis: $a_{av} = \dfrac{v_f - v_i}{\Delta t}$

Solution: $a_{av} = \dfrac{v_f - v_i}{\Delta t}$

$$= \frac{7.6\ \text{m/s} - 1.0\ \text{m/s}}{0.8\ \text{s}}$$

$$a_{av} = 8.3\ \text{m/s}^2$$

Statement: The acceleration of the deer is 8.3 m/s^2.

52. Given: $\vec{v}_i$ = 7.0 m/s [W]; $\vec{v}_f$ = 12.1 m/s [W]; $\vec{a}_{av}$ = 3.9 m/s^2 [W]

Required: Δt

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

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

Solution: $\Delta t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}_{av}}$

$$= \frac{12.1\ \text{m/s [W]} - 7.0\ \text{m/s [W]}}{3.9\ \text{m/s}^2\ [\text{W}]}$$

$$= \frac{5.1\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}}}\ [\text{W}]}{3.9\ \dfrac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\ [\text{W}]}$$

$$\Delta t = 1.3\ \text{s}$$

Statement: It takes 1.3 s for the motorcycle to accelerate.

53. Given: $\vec{v}_i$ = 32.0 m/s [down]; $\vec{v}_f$ = 24.0 m/s [up]; Δt = 5.30 s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$= \frac{24.0\ \text{m/s [up]} - 32.0\ \text{m/s [down]}}{5.30\ \text{s}}$$

$$= \frac{24.0\ \text{m/s [up]} + 32.0\ \text{m/s [up]}}{5.30\ \text{s}}$$

$$\vec{a}_{av} = 10.6\ \text{m/s}^2\ [\text{up}]$$

Statement: The average acceleration of the bungee jumper is 10.6 m/s^2 [up].

54. Given: $\vec{v}_i$ = 4.3 m/s [W]; $\vec{v}_f$ = 2.5 m/s [E]; Δt = 7.2 s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{av} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ &= \frac{2.5 \text{ m/s [E]} - 4.3 \text{ m/s [W]}}{7.2 \text{ s}} \\ &= \frac{2.5 \text{ m/s [E]} + 4.3 \text{ m/s [E]}}{7.2 \text{ s}} \\ \vec{a}_{av} &= 0.94 \text{ m/s}^2 \text{ [E]}\end{aligned}$$

Statement: The average acceleration of the balloon is 0.94 m/s^2 [E].

55. (a) 0 s to 3.0 s:

Given: $\Delta\vec{v}$ = 1.0 m/s [E]; Δt = 3.0 s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{av} &= \frac{\Delta\vec{v}}{\Delta t} \\ &= \frac{1.0 \text{ m/s [E]}}{3.0 \text{ s}} \\ \vec{a}_{av} &= 0.33 \text{ m/s}^2 \text{ [E]}\end{aligned}$$

Statement: The average acceleration from 0 s to 3.0 s is 0.33 m/s^2 [E].

3.5 s to 5.0 s:

Given: $\Delta\vec{v}$ = 0.0 m/s; Δt = 1.5 s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{av} &= \frac{\Delta\vec{v}}{\Delta t} \\ &= \frac{0.0 \text{ m/s}}{1.5 \text{ s}} \\ \vec{a}_{av} &= 0.0 \text{ m/s}^2\end{aligned}$$

Statement: The average acceleration from 3.5 s to 5.0 s is 0.0 m/s^2.

(b) Given: b_1 = 3.0 s; b_2 = 2.0 s; h = 1.0 m/s [W]; l = 2.0 s

Required: $\Delta\vec{d}$

Analysis: $\Delta\vec{d} = A_{\text{triangle 1}} + A_{\text{rectangle}} + A_{\text{triangle 2}}$

Solution:
$$\begin{aligned}\Delta\vec{d} &= A_{\text{triangle 1}} + A_{\text{rectangle}} + A_{\text{triangle 2}} \\ &= \frac{1}{2}b_1h + lh + \frac{1}{2}b_2h \\ &= \frac{1}{2}(3.0 \not{s})\left(1.0 \frac{\text{m}}{\not{s}} \text{ [E]}\right) + (2.0 \not{s})\left(1.0 \frac{\text{m}}{\not{s}} \text{ [E]}\right) \\ &\quad + \frac{1}{2}(2.0 \not{s})\left(1.0 \frac{\text{m}}{\not{s}} \text{ [E]}\right) \\ &= 1.5 \text{ m [E]} + 2.0 \text{ m [E]} + 1.0 \text{ m [E]} \\ \Delta\vec{d} &= 4.5 \text{ m [E]}\end{aligned}$$

Statement: The ball has travelled 4.5 m [E] after 7.0 s.

56. (a) Given: l = 3.0 s; h = 4.5 m/s^2 [S]

Required: $\Delta\vec{v}$

Analysis: $\Delta\vec{v} = A_{\text{rectangle}}$

Solution:
$$\begin{aligned}\Delta\vec{v} &= A_{\text{rectangle}} \\ &= lh \\ &= (3.0 \not{s})\left(4.5 \frac{\text{m}}{\text{s}^{\not{2}}} \text{ [S]}\right) \\ \Delta\vec{v} &= 14 \text{ m/s [S]}\end{aligned}$$

Statement: The velocity has increased by 14 m/s [S] from 2.0 s to 5.0 s.

(b) Given: $\vec{v}_i$ = 6.0 m/s [S]; $\Delta\vec{v}$ = 14 m/s [S]

Required: $\vec{v}_f$

Analysis: $\vec{v}_f = \vec{v}_i + \Delta\vec{v}$

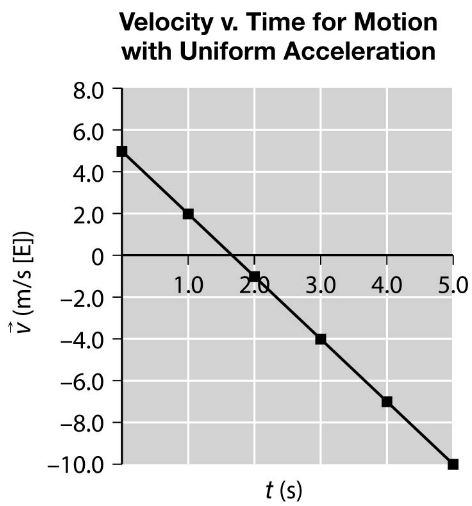
Solution:
$$\begin{aligned}\vec{v}_f &= \vec{v}_i + \Delta\vec{v} \\ &= 6.0 \text{ m/s [S]} + 14 \text{ m/s [S]} \\ \vec{v}_f &= 20 \text{ m/s [S]}\end{aligned}$$

Statement: The final velocity of the object is 20 m/s [S].

57. (a)

Time (s)	Acceleration (m/s [W])	Equation $\vec{v} = \vec{v}_i + \vec{a}\Delta t$	Velocity (m/s [W])
0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(0.0 \not{s})$	5.0
1.0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(1.0 \not{s})$	2.0
2.0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(2.0 \not{s})$	–1.0
3.0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(3.0 \not{s})$	–4.0
4.0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(4.0 \not{s})$	–7.0
5.0	–3.0	$\vec{v} = 5.0 \text{ m/s [E]} + \left(-3.0 \frac{\text{m}}{\text{s}^{\not 2}} \text{[E]}\right)(5.0 \not{s})$	–10.0

(b)



58. (a) Reading from the graph, at t = 3.0 s, $\vec{d}$ = –2.5 m [E], so the object is –2.5 m [E].

(b) Given: t = 2.0 s; position–time graph

Required: $\vec{v}_{inst}$

Analysis: $\vec{v}_{inst}$ is equal to the slope, m, of the tangent to the curve at t = 2.0 s, so $m = \frac{\Delta\vec{d}}{\Delta t}$.

By placing a ruler along the curve in Figure 8 at t = 2.0 s, I can picture the tangent. The tangent has a rise of about –5 m [E] over a run of 5.0 s.

Solution:
$$m = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{-5 \text{ m [E]}}{5.0 \text{ s}}$$
$$\vec{v}_{inst} = -1 \text{ m/s [E]}$$

Statement: The instantaneous velocity of the object at 2.0 s is –1 m/s [E].

(c) Given: $\Delta\vec{d}$ = –6 m [E]; Δt = 4.0 s

Required: $\vec{v}_{av}$

Analysis: $\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$

Solution:
$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{-6 \text{ m [E]}}{4.0 \text{ s}}$$
$$\vec{v}_{av} = -1.5 \text{ m/s [E]}$$

Statement: The average velocity of the object over the time interval from 1.0 s to 5.0 s is –1.5 m/s [E].

59. (a) Given: v_i = 160 km/h; v_f = 0 m/s; a = 11.0 m/s^2

Required: Δt

Analysis: $v_f = v_i + a_{av}\Delta t$
$$\Delta t = \frac{v_f - v_i}{a_{av}}$$

Solution: Convert v_i to metres per second:
$$v_i = \left(-160 \frac{\not{\text{km}}}{\not{\text{h}}}\right)\left(\frac{1000 \text{ m}}{1 \not{\text{km}}}\right)\left(\frac{1 \not{\text{h}}}{60 \not{\text{min}}}\right)\left(\frac{1 \not{\text{min}}}{60 \text{ s}}\right)$$
$$v_i = 44.44 \text{ m/s}$$

$$\Delta t = \frac{v_f - v_i}{a_{av}}$$
$$= \frac{0 \text{ km/h} - 44.44 \text{ m/s}}{-11.0 \text{ m/s}^2} \text{ (two extra digits carried)}$$
$$= \frac{-44.44 \frac{\cancel{m}}{\cancel{s}}}{11.0 \frac{\cancel{m}}{s^{\cancel{2}}}}$$
$$\Delta t = 4.0 \text{ s}$$

Statement: The car takes 4.0 s to stop.

(b) Given: v_i = 44.44 m/s; v_f = 0 m/s; a = 11.0 m/s^2

Required: Δd

Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

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

Solution:

$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{(0 \text{ m/s})^2 - (44.44 \text{ m/s})^2}{2(-11.0 \text{ m/s}^2)} \text{(two extra digits carried)}$$
$$= \frac{-1975 \frac{m^{\cancel{2}}}{\cancel{s^2}}}{-22.0 \frac{\cancel{m}}{\cancel{s^2}}}$$
$$\Delta d = 90 \text{ m}$$

Statement: The car travels 90 m when braking.

60. Given: v_i = 5.5 m/s; v_f = 9.0 m/s; Δd = 32 m

Required: a

Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

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

Solution: $a = \dfrac{v_f^2 - v_i^2}{2\Delta d}$

$$= \frac{(9.0 \text{ m/s})^2 - (5.5 \text{ m/s})^2}{2(32 \text{ m})}$$
$$= \frac{50.75 \frac{m^{\cancel{2}}}{s^2}}{-64 \text{ m}}$$
$$\Delta d = 0.79 \text{ m/s}^2$$

Statement: The sailboat is accelerating at a rate of 0.79 m/s^2.

61. (a) Given: v_i = 52 km/h; a_{av} = 2.0 m/s^2; Δt = 7.2 s

Required: $\Delta \vec{d}$

Analysis: $\Delta \vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}_{av} \Delta t^2$

Solution: Convert v_i to metres per second:

$$v_i = \left(52 \frac{\cancel{km}}{\cancel{h}}\right)\left(\frac{1000 \text{ m}}{1 \cancel{km}}\right)\left(\frac{1 \cancel{h}}{60 \cancel{min}}\right)\left(\frac{1 \cancel{min}}{60 \text{ s}}\right)$$
$$v_i = 14.44 \text{ m/s}$$
$$\Delta d = v_i \Delta t + \frac{1}{2}a_{av} \Delta t^2$$
$$= \left(14.44 \frac{\text{m}}{\cancel{s}}\right)(7.2 \cancel{s}) + \frac{1}{2}\left(2.0 \frac{\text{m}}{\cancel{s^2}}\right)(7.2 \cancel{s})^2 \text{ (two extra digits carried}$$
$$\Delta d = 1.6 \times 10^2 \text{ m}$$

Statement: The displacement of the van is 160 m or 1.6 × 10^2 m.

(b) Given: v_i = 14.44 m/s; a = 2.0 m/s^2; Δt = 7.2 s

Required: v_f

Analysis: $v_f = v_i + a\Delta t$

Solution:

$$v_f = v_i + a\Delta t$$
$$= 14.44 \frac{\text{m}}{\text{s}} + \left(2.0 \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(7.2 \cancel{s}) \text{ (two extra digits carried)}$$
$$= \left(28.84 \frac{\cancel{m}}{\cancel{s}}\right)\left(\frac{1 \text{ km}}{1000 \cancel{m}}\right)\left(\frac{60 \cancel{s}}{1 \cancel{min}}\right)\left(\frac{60 \cancel{min}}{1 \text{ h}}\right)$$
$$\vec{v}_f = 1.0 \times 10^2 \text{ km/h}$$

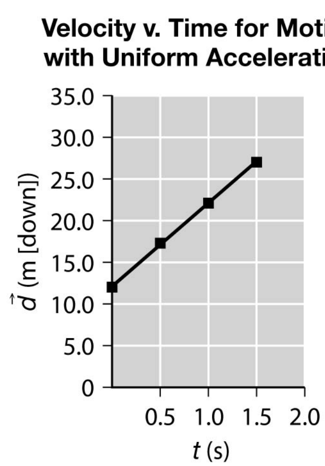
Statement: The van's final velocity is 100 km/h or 1.0 × 10^2 km/h [forward].

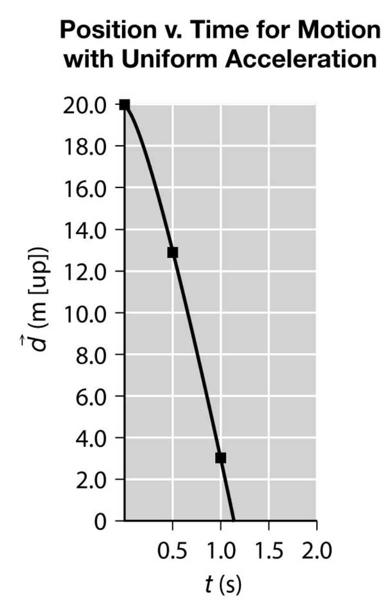
62. (a) Step 1: Create a table of values to calculate the velocity and position at each time until the rock hits the water.

Given: $\vec{v}_i$ = 12 m/s [down]; $\Delta\vec{d}$ = 20 m [down]; $\vec{a} = \vec{g}$ = 9.8 m/s^2 [down]

Time (s)	**Equation** $\vec{v} = \vec{v}_i + \vec{a}\Delta t$	**Velocity** (m/s [down])	**Equation** $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$	**Position** (m [down])
0.0	$\vec{v} = 12\ \frac{\text{m}}{\text{s}}\ [\text{down}] + \left(9.8\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\ [\text{down}]\right)(0.0\ \cancel{\text{s}})$	12	$\Delta\vec{d} = \left(12\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{down}]\right)(0.0\ \cancel{\text{s}}) + \frac{1}{2}\left(9.8\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{down}]\right)(0.0\ \cancel{\text{s}})^2$	0.0
0.5	$\vec{v} = 12\ \frac{\text{m}}{\text{s}}\ [\text{down}] + \left(9.8\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\ [\text{down}]\right)(0.5\ \cancel{\text{s}})$	17	$\Delta\vec{d} = \left(12\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{down}]\right)(0.5\ \cancel{\text{s}}) + \frac{1}{2}\left(9.8\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{down}]\right)(0.5\ \cancel{\text{s}})^2$	7.2
1.0	$\vec{v} = 12\ \frac{\text{m}}{\text{s}}\ [\text{down}] + \left(9.8\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\ [\text{down}]\right)(1.0\ \cancel{\text{s}})$	22	$\Delta\vec{d} = \left(12\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{down}]\right)(1.0\ \cancel{\text{s}}) + \frac{1}{2}\left(9.8\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{down}]\right)(1.0\ \cancel{\text{s}})^2$	17
1.5	$\vec{v} = 12\ \frac{\text{m}}{\text{s}}\ [\text{down}] + \left(9.8\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\ [\text{down}]\right)(1.5\ \cancel{\text{s}})$	27	$\Delta\vec{d} = \left(12\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{down}]\right)(1.5\ \cancel{\text{s}}) + \frac{1}{2}\left(9.8\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{down}]\right)(1.5\ \cancel{\text{s}})^2$	29

Step 2: Use these values to create velocity–time and position–time graphs.

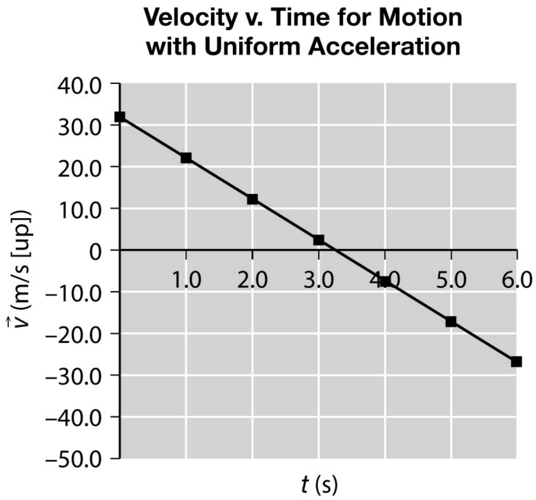


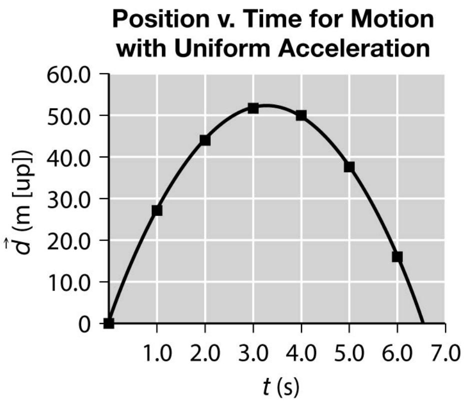


(b) Step 1: Create a table of values to calculate the velocity and position at each time until the ball hits the ground.
Given: $\vec{v}_i = 32$ m/s [up]; $\vec{a} = \vec{g} = -9.8$ m/s^2 [up]

Time (s)	Equation $\vec{v} = \vec{v}_i + \vec{a}\Delta t$	Velocity $\vec{v}$ (m/s [up])	Equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$	Position $\Delta\vec{d}$ (m [up])
0.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(0.0\ \cancel{s})$	32	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(0.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(0.0\ \cancel{s})^2$	0.0
1.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(1.0\ \cancel{s})$	22	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(1.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(1.0\ \cancel{s})^2$	27
2.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(2.0\ \cancel{s})$	12	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(2.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(2.0\ \cancel{s})^2$	44
3.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(3.0\ \cancel{s})$	3	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(3.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(3.0\ \cancel{s})^2$	52
4.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(4.0\ \cancel{s})$	–7	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(4.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(4.0\ \cancel{s})^2$	50
5.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(5.0\ \cancel{s})$	–17	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(5.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(5.0\ \cancel{s})^2$	38
6.0	$\vec{v} = 32\ \frac{m}{s}\ [up] + \left(-9.8\ \frac{m}{s^{\cancel{2}}}\ [up]\right)(6.0\ \cancel{s})$	–27	$\Delta\vec{d} = \left(32\ \frac{m}{\cancel{s}}\ [up]\right)(6.0\ \cancel{s}) + \frac{1}{2}\left(-9.8\ \frac{m}{\cancel{s^2}}\ [up]\right)(6.0\ \cancel{s})^2$	16

Step 2: Use these values to create velocity–time and position–time graphs.





63. Given: $\vec{v}_i = 10.0$ m/s [down]; $\Delta t = 2.1$ s;

$\vec{a} = \vec{g} = 9.8 \text{ m/s}^2$ [down]

Required: $\Delta\vec{d}$

Analysis: $\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

Solution:

$$\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$

$$= \left(10.0 \frac{\text{m}}{\cancel{\text{s}}} \text{ [down]}\right)(2.1 \cancel{\text{s}}) + \frac{1}{2}\left(9.8 \frac{\text{m}}{\cancel{\text{s}^2}} \text{ [down]}\right)(2.1 \cancel{\text{s}})^2$$

$\Delta\vec{d} = 43$ m [down]

Statement: The bridge is 43 m high.

64. (a) Given: $\vec{v}_i = 22$ m/s [up]; $\vec{v}_f = 0.0$ m/s;

$\vec{a} = \vec{g} = 9.8 \text{ m/s}^2$ [down]

Required: Δd

Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

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

Solution:

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

$$= \frac{\left(0 \frac{\text{m}}{\text{s}}\right)^2 - \left(22 \frac{\text{m}}{\text{s}}\right)^2}{2\left(-9.8 \frac{\text{m}}{\text{s}^2}\right)}$$

$$= \frac{-484 \frac{\text{m}^{\cancel{2}}}{\cancel{\text{s}^2}}}{-19.6 \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}}$$

$\Delta d = 25$ m

Statement: The baseball will reach a maximum height of 25 m.

(b) Given: $\vec{v}_i = 80.0$ m/s [up]; $\vec{v}_f = 0.0$ m/s;

$\vec{a} = \vec{g} = 9.8 \text{ m/s}^2$ [down]

Required: Δt

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

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

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

$$= \frac{0 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} - 22 \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{\left(-9.8 \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\right)}$$

$\Delta t = 2.245$ s (two extra digits carried)

It will take the ball the same amount of time to reach the maximum height as it will to return to the baseball player.

2(2.245 s) = 4.5 s

Statement: The ball is in the air for 4.5 s.

Evaluation

65. Answers may vary. Sample answers:

(a)

Trial	**Time** (s)	**Equation** $\vec{v} = \frac{\Delta d}{\Delta t}$	**Velocity** (m/s [down])
1	0.49	$\frac{1.0 \text{ m}}{0.49 \text{ s}}$	2.0
2	0.50	$\frac{1.0 \text{ m}}{0.50 \text{ s}}$	2.0
3	0.47	$\frac{1.0 \text{ m}}{0.47 \text{ s}}$	2.1

(b)

Trial	**Time** (s)	**Equation** $\vec{v} = \frac{\Delta d}{\Delta t}$	**Velocity** (m/s [down])
1	0.60	$\frac{2.0 \text{ m}}{0.60 \text{ s}}$	3.3
2	0.64	$\frac{2.0 \text{ m}}{0.64 \text{ s}}$	3.1
3	0.65	$\frac{2.0 \text{ m}}{0.65 \text{ s}}$	3.1

The 2.0 m distance gives the fastest average velocity. This is what should be expected, because there is more time for the pencil to accelerate and travel at a faster velocity.

66. Graph (a) is a curve getting steeper as time increases. Graph (b) is also a curve getting steeper as time increases. The magnitude of the displacement in graph (b) is more than 10 m greater than in graph (a), so graph (b) has the greater average velocity (magnitude). So, graph (b) must also have the greater acceleration in magnitude.

67. (a) For 0 s to 2.0 s:

Given: $\Delta\vec{v} = 4.0$ m/s [S]; $\Delta t = 2.0$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t} = \frac{4.0 \text{ m/s [S]}}{2.0 \text{ s}}$$
$$\vec{a}_{av} = 2.0 \text{ m/s}^2 \text{ [S]}$$

Statement: The average acceleration from 0 s to 2.0 s is 2.0 m/s^2 [S].

For 3.0 s to 6.0 s:

Given: $\Delta\vec{v} = -9.0$ m/s [S]; $\Delta t = 3.0$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t} = \frac{-9.0 \text{ m/s [S]}}{3.0 \text{ s}}$$
$$\vec{a}_{av} = -3.0 \text{ m/s}^2 \text{ [S]}$$

Statement: The average acceleration from 3.0 s to 6.0 s is –3.0 m/s^2 [S].

(b) Since velocity is a vector, it has direction. So a negative velocity is the same as a positive velocity in the opposite direction, which means the object is moving in the opposite direction. The velocity of this object is negative from 5.0 s to 8.0 s.

(c) (i) The velocity is positive between 0 s and 5.0 s, and the slope is negative from 3.0 s to 5.0 s. Since the slope of a velocity–time graph gives the acceleration, the object has positive velocity and negative acceleration from 3.0 s to 5.0 s.

(ii) The velocity is negative between 5.0 s and 8.0 s, and the slope is positive from 7.0 s to 8.0 s. Since the slope of a velocity–time graph gives the acceleration, the object has negative velocity and positive acceleration from 7.0 s to 8.0 s.

(iii) Since the slope of a velocity–time graph gives the acceleration, the object has zero acceleration from 6.0 s to 7.0 s, when the graph is flat.

(d) Normally, to determine the distance or displacement from a velocity–time graph, you would calculate the area under the graph. Since the graph goes below the *x*-axis (when the object stops and moves in the opposite direction), you would have to calculate the area between the graph and the *x*-axis to determine the total distance. Since some of the movement was back towards the starting point, to find the position or displacement, you would have to subtract the distance travelled north from the distance travelled south. To do so, subtract the area above the graph when the velocity is negative from the area below the graph when velocity is positive.

(e) The velocity is positive between 0 s and 5.0 s and the graph forms a triangle with b = 5.0 s and h = 6.0 m/s:

$$A_{\text{triangle}} = \frac{1}{2}bh$$
$$= \frac{1}{2}(5.0\ \cancel{\text{s}})\left(6.0\ \frac{\text{m}}{\cancel{\text{s}}}\right)$$
$$A_{\text{triangle}} = 15\text{ m}$$

The velocity is negative between 5.0 s and 8.0 s and the graph forms a trapezoid with b_1 = 3.0 s, b_2 = 1.0 s, and h = 3.0 m/s:

$$A_{\text{trapezoid}} = \left(\frac{b_1 + b_2}{2}\right)h$$
$$= \left(\frac{3.0\ \cancel{\text{s}} + 1.0\ \cancel{\text{s}}}{2}\right)\left(3.0\ \frac{\text{m}}{\cancel{\text{s}}}\right)$$
$$A_{\text{triangle}} = 6\text{ m}$$

The total distance travelled is 15 m + 6 m = 21 m. The position relative to the starting point is 15 m [S] + 6 m [N] = 9 m [S].

68. (a) The slope of a position–time graph gives the velocity. Since the slope is 0 m/s at t = 1.0 s and t = 5.0 s, those are the times when the instantaneous velocity of the object is zero.

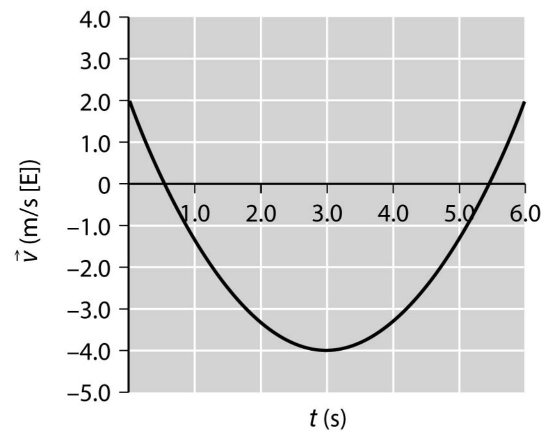
(b) The slope of a velocity–time graph gives the acceleration. That means that the instantaneous acceleration is zero whenever the slope of the graph is flat.

(c) Answers may vary. Sample answer:
Using a ruler to approximate the instantaneous velocity from the graph, I can see the following:

- the slope is positive and decreasing from 0 s to 1.0 s
- the slope is negative and decreasing from 1.0 s to 3.0 s
- the slope is negative and increasing from 3.0 s to 5.0 s
- the slope is positive and increasing from 5.0 s to 6.0 s

The velocity–time graph for the object would look similar to this:

Velocity v. Time for Figure 11



The slope of the velocity–time graph is zero at t = 3.0 s, so the instantaneous acceleration of the object is zero at t = 3.0 s.

(d) At t = 3.0 s in the position–time graph, the slope reaches its maximum steepness and starts levelling out again. You could say that the graph changes from arching down to arching up.

Reflect on Your Learning

69. (a) When considering acceleration–time graphs, the area underneath the line or curve gives the velocity of an object. If the acceleration of an object is not constant, than the velocity–time graph would not look like a straight line. It could be curved, be non-linear line segments, or a combination of the two.

(b) The units of the slope in an acceleration–time graph would be written as $\text{m/s}^2/\text{s}$ or m/s^3. The slope shows how quickly the acceleration is changing.

Research

70. Answers may vary. Students' answers should follow along the guides of the questions given. They should try to focus on how the device worked or any special techniques that were used and the mathematics behind it.

71. Answers may vary.

(a) Students' answers will likely mention the cheetah as being the fastest land animal, but that its speed cannot be maintained for a very long time. Other animals mentioned might include the pronghorn or the wildebeest.

(b) Students will likely mention the peregrine falcon as being the fastest bird but only in a dive. Other birds mentioned might include the albatross or the swift.

(c) Students' answers will likely include the sailfish and a description of how it gets its name and how it can reach the speeds it does.

72. Answers may vary. Students' answers should include the world records for both land and flight speeds, and give estimates on how fast the average space shuttle rocket can travel. They may include a brief history of each or the propulsion technologies that are used.

73. Answers may vary. Each runner's starting block is connected to an electronic false start system and the control room that signals the start of the race. Any sign of acceleration by a runner before the starting device has gone off is detected by the officials and immediately stops the race.

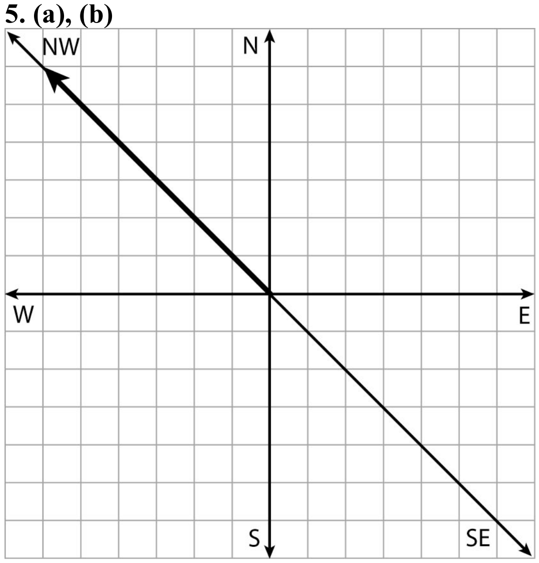
Chapter 1 Self-Quiz, page 51

1. (d)
2. (a)
3. (b)
4. (b)
5. (c)
6. (b)
7. (c)
8. (d)
9. False. Position is the distance *and direction* of an object from a particular reference point.
10. True
11. False. The displacement of an object is found by *subtracting* the start position *from* the end position.
12. False. The average *velocity* of an object in motion is its total displacement divided by the total time taken for the motion.
13. False. Motion with *non-uniform* velocity is called accelerated motion.
14. True
15. False. Instantaneous velocity is the velocity of an object *at a specific instant in time*.
16. False. The area under an acceleration-time graph gives the *change* in velocity of that time period.
17. True

Unit 1: Kinematics

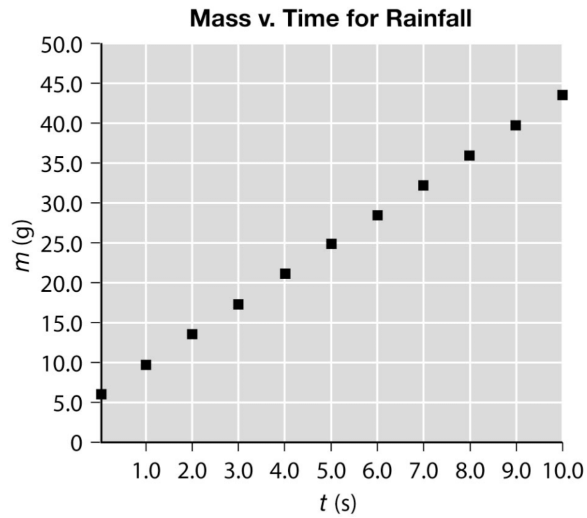
Are You Ready?, pages 4–5

1. Answers may vary. Sample answer:
The car starts to move with a jerk, then speeds up until it reaches a constant speed. There is a braking motion when the car slows down and everybody moves forward in their seats a little. When the car turns, the passengers are pushed to the side.
2. The elevator starts moving up, getting faster until it reaches a constant speed. Then it slows down and comes to a stop at the tenth floor.
3. (a) Distance can be described in metres (m) or any scale factor of them such as centimetres (cm) or kilometres (km).
(b) Time can be described in seconds (s), minutes (min), or hours (h).
(c) Speed can be described in metres per second (m/s) or kilometres per hour (km/h).
4. Answers may vary. Sample answer:
(a) If I worked with a partner, we could each mark the maximum distance travelled forward and backward, then measure between them. To measure time, we could use a stopwatch for one swing back and forth.
(b) Each swing might be slightly wider or narrower, and the time might not be the same for each swing.
(c) We could time 10 swings and divide the total time by 10 to get the average amount of time per swing.
5. (a), (b)



6. At the start, $t = 0$ s, the mass of water in the can was 6.0 g. Every second for the next 10 s, the mass increased by 3.7 g.

7. (a)



(b) The data forms a straight a line, so the equation for the data is linear: $m = at + b$. Since the mass at $t = 0$ s is 6.0 g, the constant value, b, is 6.0. Since the mass increases by 3.7 g every second, the value of a is 3.7. The equation to represent the data is:
$m = 3.7t + 6.0$
(i) The graph shows all the points arranged in a straight line from (0, 6.0) to (10, 43.0). As time increases, mass increases.
(ii) I can pick any two data points to determine the slope by dividing the rise by the run. For example, using (0, 6.0) and (10, 43.0):

$$\begin{aligned} \text{slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{\Delta m}{\Delta t} \\ &= \frac{43.0\text{ g} - 6.0\text{ g}}{10\text{ s} - 0\text{ s}} \\ &= \frac{37.0\text{ g}}{10\text{ s}} \\ \text{slope} &= 3.7\text{ g/s} \end{aligned}$$

The slope is 3.7 g/s.
(iii) The slope describes how many more grams of water there are in the can each second.
(iv) If the rainfall continued at the same intensity, it would be valid to extrapolate beyond $t = 10$ s.
(v) Substitute $t = 5.38$ s into $m = 3.7t + 6.0$:

$$\begin{aligned} m &= 3.7t + 6.0 \\ &= 3.7(5.38) + 6.0 \\ m &= 25.9 \end{aligned}$$

At $t = 5.38$ s, the mass of water in the can is 25.9 g.

8.

Solve for ...	Equation	Answer
a	$F = ma$	$\boldsymbol{a = \dfrac{F}{m}}$
t	$v = \dfrac{d}{t}$	$\boldsymbol{t = \dfrac{d}{v}}$
T	$PV = nRT$	$\boldsymbol{T = \dfrac{PV}{nR}}$
b	$y = mx + b$	$\boldsymbol{b = y - mx}$
t	$d = \left(\dfrac{v_f + v_i}{2}\right)t$	$\boldsymbol{t = \dfrac{2d}{v_f + v_i}}$
a	$d = v_i t + \dfrac{1}{2}at^2$	$\boldsymbol{a = 2\dfrac{d - v_i t}{t^2}}$
D	$AB = \dfrac{CD}{E}$	$\boldsymbol{D = \dfrac{ABE}{C}}$
v_f	$v_f^2 = v_i^2 + 2ad$	$\boldsymbol{v_f = \sqrt{v_f^{\,2} + 2ad}}$
J	$J = \dfrac{(4.0\times10^{10})(3.0\times10^{4})^8}{2.0\times10^{-15}}$	$\boldsymbol{J = 1.3 \times 10^{61}}$

9. (a) Given: a = 10 m; b = 15 m; right triangle

Required: x

Analysis: $x^2 = a^2 + b^2$

$x = \sqrt{a^2 + b^2}$

Solution: $x = \sqrt{a^2 + b^2}$

$= \sqrt{(10\text{ m})^2 + (15\text{ m})^2}$

$= \sqrt{100\text{ m}^2 + 225\text{ m}^2}$

$x = 18\text{ m}$

Statement: The length of x is 18 m.

(b) Given: a = 7.0 m; c = 25 m; right triangle

Required: y

Analysis: $c^2 = a^2 + y^2$

$y = \sqrt{c^2 - a^2}$

Solution: $y = \sqrt{c^2 - a^2}$

$= \sqrt{(25\text{ m})^2 - (7.0\text{ m})^2}$

$= \sqrt{625\text{ m}^2 - 49\text{ m}^2}$

$y = 24\text{ m}$

Statement: The length of y is 24 m.

(c) Given: a = 25 m; c = 30 m; right triangle

Required: z

Analysis: $c^2 = a^2 + z^2$

$z = \sqrt{c^2 - a^2}$

Solution: $z = \sqrt{c^2 - a^2}$

$= \sqrt{(30\text{ m})^2 - (25\text{ m})^2}$

$= \sqrt{900\text{ m}^2 - 625\text{ m}^2}$

$z = 17\text{ m}$

Statement: The length of z is 17 m.

10. (a) Given: adjacent = 10 m; opposite = 15 m; right triangle

Required: θ

Analysis: $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

$\theta = \tan^{-1}\left(\dfrac{\text{opposite}}{\text{adjacent}}\right)$

Solution: $\theta = \tan^{-1}\left(\dfrac{\text{opposite}}{\text{adjacent}}\right)$

$= \tan^{-1}\left(\dfrac{15\ \cancel{\text{m}}}{10\ \cancel{\text{m}}}\right)$

$\theta = 56°$

Statement: The value of θ is 56°.

(b) Given: hypotenuse = 25 m; adjacent = 7.0 m; right triangle

Required: φ

Analysis: $\cos\varphi = \dfrac{\text{adjacent}}{\text{hypotenuse}}$

$\varphi = \cos^{-1}\left(\dfrac{\text{adjacent}}{\text{hypotenuse}}\right)$

Solution: $\varphi = \cos^{-1}\left(\dfrac{\text{adjacent}}{\text{hypotenuse}}\right)$

$= \cos^{-1}\left(\dfrac{7.0\ \cancel{\text{m}}}{25\ \cancel{\text{m}}}\right)$

$\varphi = 74°$

Statement: The value of φ is 74°.

(c) Given: hypotenuse = 30 m; opposite = 25 m; right triangle

Required: α

Analysis: $\sin\alpha = \dfrac{\text{opposite}}{\text{hypotenuse}}$

$\alpha = \sin^{-1}\left(\dfrac{\text{opposite}}{\text{hypotenuse}}\right)$

Solution: $\alpha = \sin^{-1}\left(\dfrac{\text{opposite}}{\text{hypotenuse}}\right)$

$= \sin^{-1}\left(\dfrac{25\ \cancel{\text{m}}}{30\ \cancel{\text{m}}}\right)$

$\alpha = 56°$

Statement: The value of α is 56°.

11. (a) Let x be the length in kilometres; multiply by fractions that equal 1 to convert the units:

$$x = \left(45\ 963\ \cancel{\text{cm}}\right)\left(\frac{1\ \cancel{\text{m}}}{100\ \cancel{\text{cm}}}\right)\left(\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\right)$$

$x = 0.459\ 63\ \text{km}$

The robin has flown 0.459 63 km.

(b) Let x be the speed in metres per second; multiply by fractions that equal 1 to convert the units:

$$x = \left(82\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \text{s}}\right)$$

$x = 23\ \text{m/s}$

The speed of the car is 23 m/s.

(c) Let x be the speed in kilometres per hour; multiply by fractions that equal 1 to convert the units:

$$x = \left(27.78\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\right)\left(\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\ \text{h}}\right)$$

$x = 100.0\ \text{km/h}$

The speed of the baseball pitch is 100.0 km/h.

(d) Let x be the time in seconds; multiply by fractions that equal 1 to convert the units:

$$x = \left(365.24\ \cancel{\text{days}}\right)\left(\frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right)\left(\frac{60\ \text{s}}{1\ \cancel{\text{min}}}\right)$$

$x = 3.1557 \times 10^7\ \text{s}$

There are 3.1557×10^7 s in a calendar year.

12. (a) Given: adjacent = 20 m; $\theta = 20°$; right triangle

Required: a (hypotenuse); b (opposite)

Analysis:
$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{\text{adjacent}}{a}$$
$$a = \frac{\text{adjacent}}{\cos\theta}$$
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{b}{\text{adjacent}}$$
$$b = \text{adjacent}(\tan\theta)$$

Solution:
$$a = \frac{\text{adjacent}}{\cos\theta} = \frac{20\ \text{m}}{\cos 20°}$$
$$a = 21\ \text{m}$$

$$b = \text{adjacent}(\tan\theta) = (20\ \text{m})(\tan 20°)$$
$$b = 7.3\ \text{m}$$

Statement: The length of the hypotenuse is 21 m and the length of the side opposite the angle is 7.3 m.

(b) Given: hypotenuse = 30 m; $\theta = 40°$; right triangle

Required: c (adjacent); d (opposite)

Analysis:
$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{\text{c}}{\text{hypotenuse}}$$
$$c = \text{hypotenuse}(\cos\theta)$$
$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{d}{\text{hypotenuse}}$$
$$d = \text{hypotenuse}(\sin\theta)$$

Solution:
$$c = \text{hypotenuse}(\cos\theta) = (30\ \text{m})(\cos 40°)$$
$$c = 23\ \text{m}$$

$$d = \text{hypotenuse}(\sin\theta) = (30\ \text{m})(\sin 40°)$$
$$d = 19\ \text{m}$$

Statement: The length of the side adjacent to the angle is 23 m and the length of the side opposite the angle is 19 m.

(c) Given: opposite = 40 m; $\theta = 35°$; right triangle

Required: e (adjacent); f (hypotenuse)

Analysis:
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{\text{opposite}}{e}$$
$$e = \frac{\text{opposite}}{\tan\theta}$$
$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{\text{adjacent}}{f}$$
$$f = \frac{\text{adjacent}}{\sin\theta}$$

Solution: $e = \frac{\text{opposite}}{\tan\theta}$

$= \frac{40\text{ m}}{\tan 35°}$

$e = 57\text{ m}$

$f = \frac{\text{opposite}}{\sin\theta}$

$= \frac{40\text{ m}}{\sin 35°}$

$f = 70\text{ m}$

Statement: The length of the side adjacent to the angle is 57 m and the length of the hypotenuse is 70 m.

13. (a) Distance increases the higher you go along the vertical axis. Since the point for object 1 is the highest at $t = 5$ s, object 1 has travelled the farthest at that time.

(b) Use a ruler to determine how far along the vertical axis each point is at $t = 3$ s. Object 1 has travelled 12 m, object 2 has travelled 7.5 m, and object 3 has travelled 6 m.

(c) Given: Figure 3

Required: slope of each line

Analysis:

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

Solution:

Object 1: $\text{slope} = \frac{20\text{ m}}{5\text{ s}}$

$= 4\text{ m/s}$

Object 2: $\text{slope} = \frac{12\text{ m}}{5\text{ s}}$

$= 2.4\text{ m/s}$

Object 3: $\text{slope} = \frac{10\text{ m}}{5\text{ s}}$

$= 2\text{ m/s}$

Statement: Object 1 line has a slope of 4 m/s, object two line has slope of 2.4 m/s, and object 3 line has a slope of 2 m/s.

UNIT 1

Kinematics

OVERALL EXPECTATIONS

- analyze technologies that apply concepts related to kinematics, and assess the technologies' social and environmental impact
- investigate, in qualitative and quantitative terms, linear motion with uniform and non-uniform velocity, and solve related problems
- demonstrate an understanding of linear motion with uniform and non-uniform velocity

BIG IDEAS

- Motion involves a change in the position of an object over time.
- Motion can be described using mathematical relationships.
- Many technologies that apply concepts related to kinematics have societal and environmental implications.

UNIT TASK **PREVIEW**

The challenge in this Unit Task is to design and construct a bean bag launcher. You will need to calibrate the launcher to fire accurately at various target distances. You will compete with your classmates to construct the most accurate launcher. The Unit Task is described in detail on page 96. As you work through the unit, look for Unit Task Bookmarks to see how information in the section relates to the Unit Task.

FOCUS ON **STSE**

SPORTS IN MOTION

The interactions among Science, Technology, Society, and the Environment (STSE) make physics relevant to our lives in a million different ways. Sports are just one example. In Canada, hockey is more than just a game. For many, it's an obsession! Hockey is an exciting, fast-paced sport. You can watch players skate down the ice to score the next goal, a defenceman skillfully deflecting the puck out of the opposition player's control, or a goaltender making a difficult glove save. Speed is a critical part of the game, from racing to get to the puck to firing a shot past the goaltender.

Imagine hockey or any other sport without motion and speed—it would not be nearly as entertaining. The rapid acceleration of the puck during a slapshot, the way that a skilled player can rapidly change his or her speed and direction of motion—these high-speed actions are what make a hockey game so exciting. In other sports, motion and speed are just as important for the athlete as for the enjoyment of the fans. You can clearly see the skill of professional athletes in the precision control of a long soccer pass, or of a basketball as it sails through the air in a perfect jumpshot. There is a direct link between how objects move and the level of excitement we experience while watching or playing our favourite sports.

Questions

1. Consider your favourite sport.
   (a) What kinds of motions are required to play this sport? Describe these motions in your own words.
   (b) Describe the type(s) of motion that must be avoided to be successful in your favourite sport.

2. (a) List any advances in technology that have helped to make professionals in your favourite sport more successful.
   (b) How have these advances in technology helped to improve the athlete's speed or motion? Explain your reasoning.
   (c) Research one advance in technology that has helped to make athletes in your favourite sport more successful. Write a paragraph describing how this technology works.

3. How can a better understanding of motion help a participant in your favourite sport avoid injury?

4. What type of protective equipment is required in your favourite sport? Is there any equipment that might help to make your favourite sport safer? How does this equipment affect an athlete's motion?

5. Research how the use of protective equipment in your favourite sport has changed throughout its history. Discuss your findings with a partner.

CONCEPTS

- motion
- Cartesian coordinate system
- Pythagorean theorem
- slope of a straight line

SKILLS

- plotting a line graph on a Cartesian coordinate system
- analyzing graphs
- using and converting SI units
- solving an algebraic equation for an unknown variable
- using trigonometry to solve right triangles
- using a protractor and a centimetre ruler precisely
- effectively using a scientific calculator and a spreadsheet
- researching and collecting information
- planning and conducting investigations
- communicating scientific information clearly and accurately

Concepts Review

1. Recall the last time you rode in a car. Describe the different types of motion that the vehicle underwent throughout the trip. C
2. An elevator is initially at rest on the second floor of a building. A person on the tenth floor pushes the down button for the elevator. Describe the motion of the elevator as it moves from the second floor to the tenth floor. C
3. What units are used to describe the following: K/U
   (a) distance
   (b) time
   (c) speed
4. You are at the park watching a younger sibling swing back and forth on the swing set. K/U
   (a) Describe how you could measure the distance travelled and the time taken as your sibling swings back and forth.
   (b) What sources of uncertainty exist in this experiment?
   (c) How could you modify your experiment to reduce the uncertainty?
5. (a) Draw a Cartesian coordinate system. Mark and label the compass directions north, south, east, and west on your diagram. Then, mark and label the directions northwest and southeast on your diagram.
   (b) Draw a line 4 cm long, starting at the origin of your Cartesian coordinate system and pointing northwest. T/I
6. A tin can is placed outside just as it starts to rain. **Table 1** contains measurements of the mass of water in the can taken at time intervals of 1 s. Describe the information provided in Table 1. T/I

Table 1 Mass–Time Rainfall Data

t (s)	*m* (g)
0	6.0
1	9.7
2	13.4
3	17.1
4	20.8
5	24.5
6	28.2
7	31.9
8	35.6
9	39.3
10	43.0

Skills Review

7. (a) Plot a graph of mass versus time using the data in Table 1. Plot time on the horizontal axis.
   (b) Determine an equation to represent the data. Then answer the following questions:
   (i) Describe the graph. What is the relationship between mass and time?
   (ii) Write an equation to determine the slope of the line on the graph, and provide a value for the slope, including the correct units.
   (iii) What information does the slope provide?
   (iv) Would it be valid to extrapolate this graph for another 10 s?
   (v) Using the equation of the graph, determine the mass of water in the can at 5.38 s. T/I C A

8. Copy and complete **Table 2**. T/I

Table 2

Solve for …	Equation	Answer
a	$F = ma$	
t	$v = \frac{d}{t}$	
T	$PV = nRT$	
b	$y = mx + b$	
t	$d = \left(\frac{v_f + v_i}{2}\right)t$	
a	$d = v_i t + \frac{1}{2}at^2$	
D	$AB = \frac{CD}{E}$	
v_f	$v_f^2 = v_i^2 + 2ad$	
J	$J = \frac{(4.0 \times 10^{10})(3.0 \times 10^4)^8}{2.0 \times 10^{-15}}$	

9. Use the Pythagorean theorem to determine the length of the unknown side in each right triangle shown in **Figure 1**. T/I

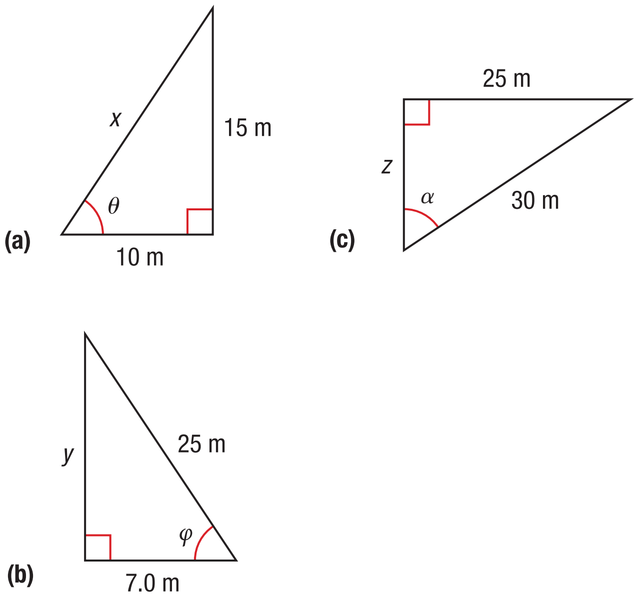


Figure 1

10. Determine the value of each angle in the triangles in Question 9. T/I
(a) θ
(b) φ
(c) α

11. (a) A robin flies a distance of 45 963 cm. How far has it flown in kilometres?
(b) What is the speed in metres per second of a car that is travelling at 82 km/h?
(c) What is the speed in kilometres per hour of a 27.78 m/s baseball pitch?
(d) How many seconds are there in a calendar year, given that a calendar year has 365.24 days in it? T/I

12. Determine each unknown length in **Figure 2**. K/U

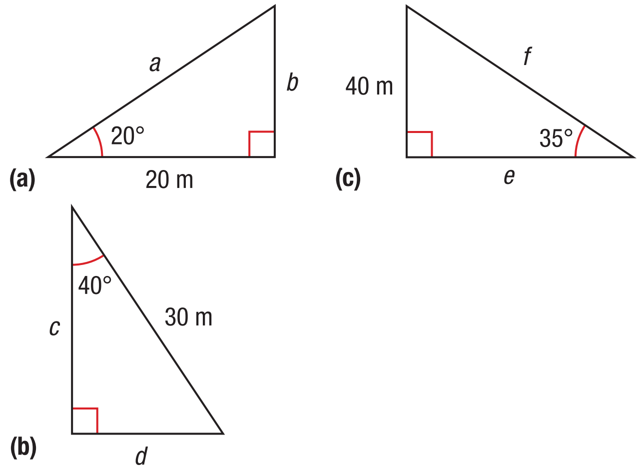


Figure 2

13. The three lines on the distance–time graph in **Figure 3** represent the motion of three objects. T/I
(a) Which object has travelled farthest at time $t = 5$ s?
(b) How far has each object travelled at time $t = 3$ s?
(c) What is the slope of each line?

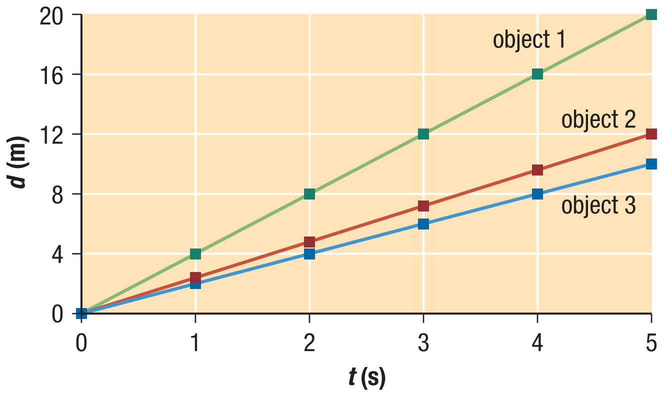


Figure 3

CAREER PATHWAYS PREVIEW

Throughout this unit you will see Career Links in the margins. These links mention careers that are relevant to Kinematics. On the Chapter Summary page at the end of each chapter, you will find a Career Pathways feature that shows you the educational requirements of the careers. There are also some career-related questions for you to research.