Chapter 2

One-Dimensional Kinematics

Exercises

2-1 (a) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{4.00\times10^2 \text{ m}}{43.2 \text{ s}} = 9.26 \text{ m/s}$

(b) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{18.8 \text{ cm}}{0.119 \text{ ms}} = \dfrac{0.118 \text{ m}}{1.19\times10^{-4} \text{ s}} = 1.58\times10^3 \text{ m/s}$

(c) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{2\pi r}{\Delta t} = \dfrac{2\pi(3.84\times10^8 \text{ m})}{(27.3 \text{ d})(24 \text{ h/d})(3600 \text{ s/h})} = 1.02\times10^3 \text{ m/s}$

(d) $\text{speed}_{\text{av, slow}} = \dfrac{d}{\Delta t} = \dfrac{9.0 \text{ m}}{(36 \text{ h})(3600 \text{ s/h})} = 6.9\times10^{-5} \text{ m/s}$

$\text{speed}_{\text{av, fast}} = \dfrac{d}{\Delta t} = \dfrac{9.0 \text{ m}}{(12 \text{ h})(3600 \text{ s/h})} = 2.1\times10^{-4} \text{ m/s}$

Thus, the range of speeds is from 6.9×10^{-5} m/s to 2.1×10^{-4} m/s.

2-2 (a) $\Delta t = \dfrac{d}{\text{speed}_{\text{av}}} = \dfrac{1.50\times10^{11} \text{ m}}{3.00\times10^8 \text{ m/s}} = 5.00\times10^2 \text{ s}$

(b) $\Delta t = \dfrac{d}{\text{speed}_{\text{av}}} = \dfrac{2(3.84\times10^8 \text{ m})}{3.00\times10^8 \text{ m/s}} = 2.56 \text{ s}$

2-3 (a) $d = \text{speed}_{\text{av}}(\Delta t)$

(b) LHS: [d] = L; RHS: $[\text{speed}_{\text{av}}][\Delta t] = \dfrac{\text{L}}{\text{T}} \times \text{T} = \text{L}$

Thus, the equation is dimensionally correct.

2-4 (a) $d = \text{speed}_{\text{av}}(\Delta t) = (344\ \text{m/s})(0.0350\ \text{s}) = 12.0\ \text{m}$

(b) $d = \text{speed}_{\text{av}}(\Delta t) = \left(1.74\ \dfrac{\text{km}}{\text{h}}\right)(60.0\ \text{h}) = 1.04\times10^{2}\ \text{km}\times\dfrac{10^{3}\ \text{m}}{\text{km}} = 1.04\times10^{5}\ \text{m}$

(c) $d = \text{speed}_{\text{av}}(\Delta t) =$ (6.14 km/h)(144 h) = 884 km

(d) $d = \text{speed}_{\text{av}}(\Delta t) =$ (575 km/h)(1.25 h) = 7.19×10^{2} km

2-5 (a) uniform motion (b) The object is speeding up.(c) The object is slowing down.

2-6 Assume a person can take about 2 steps/s, with each step covering about 1 m; thus the average fast walking speed would be about 2 m/s.

$$\Delta t = \frac{d}{\text{speed}_{\text{av}}} \approx \frac{1\times10^{4}\ \text{m}}{2\ \text{m/s}} \approx 5\times10^{3}\ \text{s, or about 1.4 h}$$

Hence, the range of answers would be about 1 h to 2 h.

2-7 vector quantity; the velocity (both the speed and the direction) of the wind

2-8 (a) if motion is in one direction with no reversals of direction of motion

(b) yes, if an object reverses its direction of motion

(c) No; at most, the displacement's magnitude equals the distance (as in (a)).

2-9 (a) Speed (instantaneous) indicates how fast an object is moving; it is a scalar quantity. Velocity is a vector quantity; it is similar to speed in that at any time the magnitude of velocity equals the speed, but velocity also includes direction.

(b) The motion must be in one direction with no reversals of direction of motion.

2-10 (a) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{2\times 12\text{ km}}{0.80\text{ h}} = 3.0\times 10^{1}\text{ km/h}$

(b) $v_{\text{av}} = \dfrac{\Delta x}{\Delta t} = \dfrac{0\text{ km}}{0.80\text{ h}} = 0\text{ km/h}$

(c) The average speed is a scalar quantity that involves the total distance travelled (24 km), whereas the average velocity is a vector quantity that involves displacement at the end of the elapsed time, in this case 0 km.

2-11 (a) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{0.46\text{ m} + 0.84\text{ m} + 0.12\text{ m}}{2.5\text{ s}} = 0.57\text{ m/s}$

(b) $\Delta x = x_1 + x_2 + x_3 = 0.46\text{ m} - 0.84\text{ m} + 0.12\text{ m} = -0.26\text{ m}$

(c) $v_{\text{av}} = \dfrac{\Delta x}{\Delta t} = \dfrac{-0.26\text{ m}}{2.5\text{ s}} = -0.10\text{ m/s}$

2-12 (a) $\text{speed}_{av} = \dfrac{d}{\Delta t} = \dfrac{40\text{ m}}{4.0\text{ s}} = 1.0\times 10^{1}\text{ m/s}$

$\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{40\text{ m}}{8.0\text{ s}} = 5.0\text{ m/s}$

(b) $v_{\text{av}} = \dfrac{\Delta x}{\Delta t} = \dfrac{45\text{ m} - 40\text{ m}}{2.0\text{ s}} = 2.5\text{ m/s west}$

$v_{\text{av}} = \dfrac{\Delta x}{\Delta t} = \dfrac{0\text{ m} - 50\text{ m}}{4.0\text{ s}} = -12.5\text{ m/s west} = 13\text{ m/s east}$

$v_{\text{av}} = \dfrac{\Delta x}{\Delta t} = \dfrac{0\text{ m} - 0\text{ m}}{16\text{ s}} = 0\text{ m/s}$

(c) The instantaneous speed is the magnitude of the instantaneous velocity, or the slope of the line on the graph.

At 6.0 s: $\text{speed}_{\text{inst}} = m = \dfrac{\Delta x}{\Delta t} = \dfrac{0 \text{ m}}{2.0 \text{ s}} = 0 \text{ m/s}$

At 10 s: $\text{speed}_{\text{inst}} = m = \dfrac{\Delta x}{\Delta t} = \dfrac{50 \text{ m} - 40 \text{ m}}{4.0 \text{ s}} = 2.5 \text{ m/s}$

(d) $v = m = \dfrac{\Delta x}{\Delta t} = \dfrac{0 \text{ m} - 50 \text{ m west}}{16 \text{ s} - 12 \text{ s}} = -13 \text{ m/s west or } 13 \text{ m/s east}$

2-13 $\Delta x = v_{\text{av}} \Delta t = (28 \text{ m/s forward})(0.20 \text{ s}) = 5.6 \text{ m forward}$

2-14 $\Delta t = \dfrac{\Delta x}{v_{\text{av}}} = \dfrac{2.4\times10^3 \text{ m} - 7.2\times10^2 \text{ m}}{8.5 \text{ m/s}} = 2.0\times10^2 \text{ s}$

2-15 (a) The object is moving west away from the origin ($x = 0$) with constant velocity, then the velocity increases during a very short time interval and the object continues west with a larger constant velocity. Finally, the velocity is reduced to zero (during a very short time interval) and the object stays at one position, west of the initial starting position.

(b) The object begins at a position that is east of the origin ($x = 0$) and travels toward the origin (i.e., westward) with a velocity that has a continually decreasing magnitude; the object eventually reaches the origin.

(c) The object begins at a position south of the origin ($x = 0$) and travels northward at a constant velocity, eventually passing and going beyond the origin.

2-16 Area = lw=(25 m/s northward)(0.30 s) = 7.5 m northward

The area represents the displacement between 0.0 s and 0.30 s.

2-17 Answers will vary because it is difficult to draw the tangents and determine their slopes on the small graph.

(a) $v_{2.5\text{ s}} = m_{2.5\text{ s}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \approx \frac{0\text{ cm} - (-18\text{ cm south})}{5.1\text{ s} - 2.5\text{ s}} \approx 6.9\text{ cm/s south}$

(b) $v_{4.5\text{ s}} = m_{4.5\text{ s}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \approx \frac{20\text{ cm south} - 0\text{ cm}}{5.2\text{ s} - 3.9\text{ s}} \approx 15\text{ cm/s south}$

(c) At 6.0 s the line on the graph is horizontal, so the slope is zero, which means that v is also zero.

2-18 (a), (b), and (d)

2-19 (a) constant southward velocity (b) increasing southward velocity (c) decreasing southward velocity

2-20 Yes, a car that is travelling west and slowing down has a westward velocity but an eastward acceleration.

2-21 (a) $|a_{\text{av}}| = \frac{|\Delta v|}{\Delta t} = \frac{34.2\text{ m/s}}{58.5\text{ s}} = 0.585\text{ m/s}^2$

(b) $|a_{\text{av}}| = \frac{|\Delta v|}{\Delta t} = \frac{341\text{ m/s}}{9.45\text{ s}} = 36.1\text{ m/s}^2$

2-22 $a_{av} = \dfrac{v_2 - v_1}{\Delta t} = \dfrac{0 \text{ m/s} - 42.8 \text{ m/s east}}{3.12 \times 10^{-2} \text{ s}} = -1.37 \times 10^3 \text{ m/s}^2 \text{ east} = 1.37 \times 10^3 \text{ m/s}^2 \text{ west}$

2-23 (a) $a_{av} = \dfrac{v_2 - v_1}{\Delta t} = \dfrac{1.12 \times 10^3 \text{ km/h east} - 1.65 \times 10^3 \text{ km/h east}}{345 \text{ s}} = 1.54 \text{ km/h/s west}$

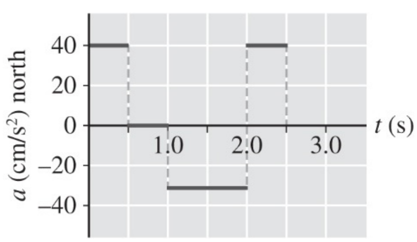
(b) $1.54 \dfrac{\text{km/h}}{\text{s}} = 1.54 \dfrac{\text{km/h}}{\text{s}} \times \dfrac{10^3 \text{ m}}{1 \text{ km}} \times \dfrac{1 \text{ h}}{3600 \text{ s}} = 0.427 \text{ m/s}^2$

Thus, the average acceleration is 0.427 m/s² west.

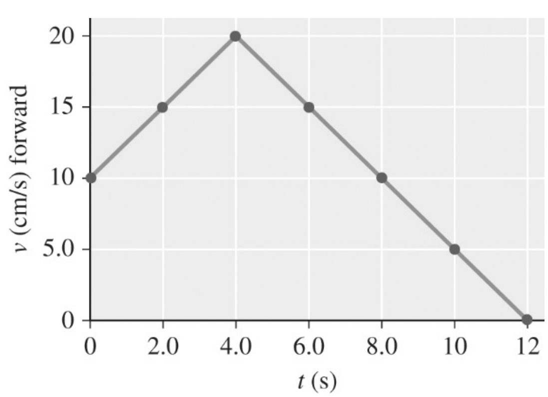
2-24 The slopes of the four line segments on the graph indicate the acceleration for the different time intervals. For example, the first slope is:

$$a = m = \frac{v_2 - v_1}{\Delta t} = \frac{40 \text{ cm/s north} - 20 \text{ cm/s north}}{0.5 \text{ s}} = 40 \text{ cm/s}^2 \text{ north}$$

The required *a-t* graph is shown below.



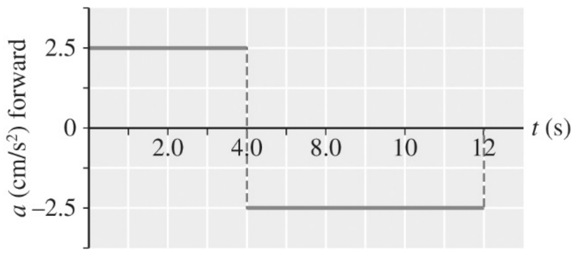
2-25 (a) The *v-t* graph is shown below.



(b) $a_1 = m_1 = \dfrac{\Delta v}{\Delta t} = \dfrac{20\text{ cm forward} - 10\text{ cm/s forward}}{4.0\text{ s} - 0.0\text{ s}} = 2.5\text{ cm/s}^2\text{ forward}$

$a_2 = m_2 = \dfrac{\Delta v}{\Delta t} = \dfrac{0\text{ cm/s} - 20\text{ cm/s forward}}{12\text{ s} - 4.0\text{ s}} = -2.5\text{ cm/s}^2\text{ forward}$

(c) The required *a*-*t* graph is shown below.



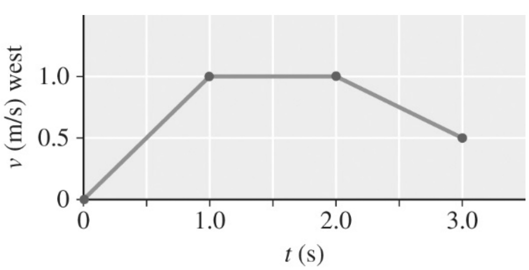
2-26 From $a = \dfrac{\Delta v}{\Delta t}$, $\Delta v = a\Delta t$

$\Delta v_1 = a_1\Delta t = (1.0\text{ m/s}^2\text{ west})(1.0\text{ s} - 0\text{ s}) = 1.0\text{ m/s west}$

$\Delta v_2 = a_2\Delta t = 0$

$\Delta v_3 = a_3\Delta t = (-0.5\text{ m/s}^2\text{ west})(3.0\text{ s} - 2.0\text{ s}) = -0.5\text{ m/s west}$

The resulting velocity–time graph is shown below.



2-27 during constant acceleration

2-28 (a) The object speeds up from rest with a continually decreasing acceleration; after reaching a maximum velocity, the object slows down with constant acceleration until it comes to rest.

(b) The object undergoes constant positive acceleration, followed by constant negative acceleration (of smaller magnitude but for a greater time period than the positive acceleration).

(c) The object undergoes increasing positive acceleration, followed by constant positive acceleration for a greater amount of time than the increasing acceleration.

2-29 Since the four variables involved are $a,\ v_0,\ \Delta x,$ and $t,$ the equation required is Eqn. 2-9.

2-30 LHS: $\left[v^2 - v_0^2\right] = \left(\frac{\text{L}}{\text{T}}\right)^2$; RHS: $[a][\Delta x] = \frac{\text{L}}{\text{T}^2} \times \text{L} = \frac{\text{L}^2}{\text{T}^2}$

Thus, the equation is dimensionally correct.

2-31 From $x = x_0 + \frac{1}{2}(v_0 + v)\,t$,

$$2\Delta x = (v_0 + v)\,t$$
$$\therefore t = \frac{2\Delta x}{v_0 + v}$$

2-32 Eqn. 2-8 is $x = x_0 + \frac{1}{2}(v_0 + v)\,t$, or $\Delta x = \frac{1}{2}(v_0 + v)\,t$.

The total area under the line on the graph is the sum of the area of the rectangle (A_1) and the area of the triangle (A_2).

$$A_1 + A_2 = lw + \tfrac{1}{2}bh$$
$$= v_0 t + \tfrac{1}{2}(v - v_0)t$$
$$= v_0 t + \tfrac{1}{2}vt - \tfrac{1}{2}vt$$
$$= \tfrac{1}{2}(vt + v_0 t)$$
$$= \tfrac{1}{2}(v + v_0)t = \Delta x$$

This is the same as Eqn. 2-8.

2-33 Given: v_0 = +12.3 m/s; a = –2.6 m/s^2; t = 1.5 s. Find v.

Using Eqn. 2-7: $v = v_0 + at = +12.3\ \text{m/s} + (-2.6\ \text{m/s}^2)(1.5\ \text{s}) = +8.4\ \text{m/s}$

2-34 Given: v_0 = +41 m/s; v = –45 m/s; $t = 2.0 \times 10^{-3}$ s. Find a.

From $v = v_0 + at$, $a = \dfrac{v - v_0}{t} = \dfrac{-45\ \text{m/s} - 41\ \text{m/s}}{2.0\times10^{-3}\ \text{s}} = -4.3\times10^4\ \text{m/s}^2$

Thus, the acceleration is 4.3×10^4 m/s^2 in a direction opposite to the ball's initial velocity.

2-35 Given: v_0 = 0 m/s; a = +2.4 m/s^2; t = 3.3 s.

(a) Find Δx. Using Eqn. 2-9:

$$\Delta x = v_0 t + \tfrac{1}{2}at^2 = 0 + \tfrac{1}{2}(2.4\ \text{m/s}^2)(3.3\ \text{s}) = 13\ \text{m}$$

(b) Find v. Using Eqn. 2-7:

$$v = v_0 + at = 0 + (2.4\ \text{m/s}^2)(3.3\ \text{s}) = 7.9\ \text{m/s}$$

2-36 Given: $v_0 = 40$ km/h; $v = 100$ km/h; $t = 36$ s.

(a) $$36\ \text{s} \times \frac{1\ \text{h}}{3600\ \text{s}} = 1.0 \times 10^{-2}\ \text{h}$$

(b) $$\Delta x = \tfrac{1}{2}(v_0 + v)\,t = \tfrac{1}{2}(40\ \text{km/h} + 100\ \text{km/h})(1.0 \times 10^{-2}\ \text{h}) = 7.0 \times 10^{-1}\ \text{km}$$

(c) $$a = \frac{v - v_0}{t} = \frac{100\ \text{km/h forward} - 40\ \text{km/h forward}}{36\ \text{s}} = 1.7\ \text{(km/h)/s forward}$$

Therefore, the magnitude of the acceleration is 1.7 (km/h)/s.

2-37 Given: $v_0 = 2.28 \times 10^2$ m/s forward; $a = 62.5$ m/s^2 forward; $\Delta x = 1.86$ km forward, or 1.86×10^3 m forward. Find v.

$$v^2 - v_0^2 = 2a(x - x_0)$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$v = \pm\sqrt{(2.28 \times 10^2\ \text{m/s})^2 + 2(65\ \text{m/s}^2)(1.86 \times 10^3\ \text{m})}$$

$$= \pm 533\ \text{m/s}$$

Only the positive root applies, so the speed is 533 m/s.

2-38 We know that $v = 0$ m/s and Δx is measureable. We can use Eqn. 2-10 to find the acceleration if we can estimate the initial speed needed to slide the device a distance of, say, 50 cm. A test of hand movement reveals a speed of about 1 m/s. Thus, with $v_0 = 1$ m/s, $v = 0$ m/s, and $\Delta x = 0.50$ m, we can find a.

From $v^2 - v_0^2 = 2a(x - x_0)$,

$$a = \frac{v^2 - v_0^2}{2\Delta x} \approx \frac{0 - (1\ \text{m/s})^2}{2(0.5\ \text{m})} \approx -1\ \text{m/s}^2$$

So the estimated acceleration is 1 m/s^2 in a direction opposite to the initial motion.

2-39 Given: $a = 0.040\ \text{m/s}^2$; $t = 225$ s; $\Delta x = 4.0$ km $= 4.0 \times 10^3$ m. Find v_0.

$$\Delta x = v_0 t + \tfrac{1}{2}at^2, \quad \therefore v_0 t = \Delta x - \tfrac{1}{2}at^2$$

$$\therefore v_0 = \frac{\Delta x - \frac{1}{2}at^2}{t} = \frac{4.0\times10^3\ \text{m} - \frac{1}{2}(0.040\ \text{m/s}^2)(225\ \text{s})^2}{225\ \text{s}} = 13\ \text{m/s}$$

2-40 Given: $v_0 = 6.74 \times 10^7$ m/s west; $v = 2.38 \times 10^7$ m/s west; $\Delta x = 0.485$ m west.

(a) Find t.

$$\Delta x = \tfrac{1}{2}\left(v_0 + v\right)t$$

$$\therefore t = \frac{2\Delta x}{v_0 + v} = \frac{2(0.485\ \text{m})}{6.74\times10^7\ \text{m/s} + 2.38\times10^7\ \text{m/s}} = 1.06\times10^{-8}\ \text{s}$$

(b) Find a.

$$a = \frac{v - v_0}{t} = \frac{2.38\times10^7\ \text{m/s} - 6.74\times10^7\ \text{m/s}}{1.0636\times10^{-8}\ \text{s}} = 4.10\times10^{15}\ \text{m/s}^2\text{east}$$

2-41 (a) same magnitude, opposite direction (b) same (c) zero (d) 9.8 m/s^2 down at all points

2-42 In all cases, $v_0 = 0$ m/s, $a = g = 9.8\ \text{m/s}^2$, and we choose downward to be positive.

(a) From $v^2 = v_0^2 + 2a(\Delta y)$

$$v = \sqrt{v_0^2 + 2a(\Delta y)} = \sqrt{0 + 2(9.8\ \text{m/s}^2)(55\ \text{m})} = 33\ \text{m/s}$$

(b) From $v^2 = v_0^2 + 2a(\Delta y)$

$$\Delta y = \frac{v^2 - v_0^2}{2a} = \frac{(27\ \text{m/s})^2 - (0\ \text{m/s})^2}{2(9.8\ \text{m/s})^2} = 37\ \text{m}$$

(c) $v = v_0 + at = 0\ \text{m/s} + 9.8\ \text{m/s}^2(2.4\ \text{s}) = 24\ \text{m/s}$

2-43 Given: $v_0 = 0$ m/s, $a = g = 9.8$ m/s^2, and we choose downward to be positive. (Only one of the possible methods of solving the problem is shown here.)

At 1.0 s, the distance fallen is:

$$\Delta y = v_0 t + \tfrac{1}{2} at^2 = 0 + \tfrac{1}{2}(9.8 \text{ m/s}^2)(1.0 \text{ s})^2 = 4.9 \text{ m}$$

At 2.0 s, the distance fallen from the initial position is:

$$\Delta y = v_0 t + \tfrac{1}{2} at^2 = 0 + \tfrac{1}{2}(9.8 \text{ m/s}^2)(2.0 \text{ s})^2 = 19.6 \text{ m}$$

From 1.0 s to 2.0 s, the distance fallen is 19.6 m – 4.9 m = 14.7 m, which is 3 × 4.9 m.

2-44 Choose upward to be positive: $a = -g = -9.8$ m/s^2; $v = v_{top} = 0$ m/s; $t_{upward} = (4.2 \text{ s})/2 = 2.1$ s.

(a) From $v = v_0 + at$

$$v_0 = v - at = 0 \text{ m/s} - (-9.8 \text{ m/s}^2)(2.1 \text{ s}) = +21 \text{ m/s, i.e., 21 m/s upward}$$

(b) One possible solution is:

$$\Delta y = v_0 t + \tfrac{1}{2} at^2 = (20.58 \text{ m/s})(2.1 \text{ s}) + \tfrac{1}{2}(-9.8 \text{ m/s}^2)(2.1 \text{ s})^2 = 22 \text{ m}$$

2-45 Let downward be positive: $a = +g = +9.8$ m/s^2; $v_0 = -2.1$ m/s; $t = 3.8$ s.

(a) $\Delta y = v_0 t + \tfrac{1}{2} at^2 = (-2.1 \text{ m/s})(3.8 \text{ s}) + \tfrac{1}{2}(+9.8 \text{ m/s}^2)(3.8 \text{ s})^2 = 63 \text{ m}$

(b) $v = v_0 + at = -2.1 \text{ m/s} + 9.8 \text{ m/s}^2 (3.8 \text{ s}) = 35 \text{ m/s}$

2-46 (a) Let upward be positive: $a = -g$ (at each location); $v = v_{top} = 0$ m/s. Find Δy.

From $v^2 - v_0^2 = 2a\,\Delta y$, $\Delta y = \dfrac{v^2 - v_0^2}{2a}$

In London: $\Delta y = \dfrac{v^2 - v_0^2}{2a} = \dfrac{0\text{ m}^2/\text{s}^2 - (5.112\text{ m/s})^2}{2(-9.823\text{ m/s}^2)} = 1.330\text{ m}$

In Denver: $\Delta y = \dfrac{v^2 - v_0^2}{2a} = \dfrac{0\text{ m}^2/\text{s}^2 - (5.112\text{ m/s})^2}{2(-9.796\text{ m/s}^2)} = 1.334\text{ m}$

(b) London is near sea level, while Denver is at a higher elevation in the mountains, where g is slightly lower.

2-47 Let downward be positive: $v_0 = 0$ m/s; $t = 1.7$ s; $\Delta y = +2.3$ m.

(a) $\Delta y = v_0 t + \frac{1}{2}at^2 = 0\text{ m} + \frac{1}{2}at^2$

$\therefore a = \dfrac{2\Delta y}{t^2} = \dfrac{2(2.3\text{ m})}{(1.7\text{ s})^2} = +1.6\text{ m/s}^2$

(b) $\dfrac{g}{a_{\text{Moon}}} = \dfrac{9.8\text{ m/s}^2}{1.59\text{ m/s}^2} = 6.2{:}1$

2-48 Given: $t = 60$ s; $a = 5\,|g| = 5 \times 9.8\text{ m/s}^2 = 49\text{ m/s}^2$; $v_0 = 0$ m/s.

$v = v_0 + at = 0\text{ m/s} + 49\text{ m/s}^2(60\text{ s}) = 2.9 \times 10^3\ \dfrac{\text{m}}{\text{s}} \times \dfrac{1\text{ km}}{10^3\text{ m}} \times \dfrac{3600\text{ s}}{\text{h}} = 1.1 \times 10^4\text{ km/h}$

2-49 Let upward be positive: $a = -g = -9.8\text{ m/s}^2$.

(a) The ball rose for (2.6 s)/2 = 1.3 s, at which instant $v = 0$ m/s.

(b) From $v = v_0 + at$,

$v_0 = v - at = 0\text{ m/s} - (-9.8\text{ m/s}^2)(1.3\text{ s}) = 13\text{ m/s upward}$

(c) On Mars, $a = -g = (0.38)(-9.8\text{ m/s}^2) = -3.72\text{ m/s}^2$

From $v = v_0 + at$,

$$t = \frac{v - v_0}{a} = \frac{0\text{ m/s} - (12.7\text{ m/s})}{-3.72\text{ m/s}^2} = 3.4\text{ s}$$

Thus, the total time is 2(3.4 s) = 6.8 s.

2-50 Let $+y$ be downward: $a = +g = 9.8\text{ m/s}^2$; $\Delta y = +0.80$ m; $t = 0.087$ s. Since both v and v_0 are unknown, we must first find v_0.

From $\Delta y = v_0 t + \frac{1}{2}at^2$:

$$v_0 = \frac{\Delta y - \frac{1}{2}at^2}{t} = \frac{0.80\text{ m} - \frac{1}{2}(9.8\text{ m/s}^2)(0.087\text{ s})^2}{0.087\text{ s}} = 8.77\text{ m/s}$$

Now $v = v_0 + at = 8.77\text{ m/s} + 9.8\text{ m/s}^2(0.087\text{ s}) = 9.6\text{ m/s}$

2-51 Let $+y$ be downward. Then $a = +g = 9.8\text{ m/s}^2$; $v_0 = +14$ m/s; $y_0 = 0$ m and $y = +21$ m, so $\Delta y = +21$ m. Find t.

From $\Delta y = v_0 t + \frac{1}{2}at^2$

$$\frac{1}{2}at^2 + v_0 t - \Delta y = 0$$

$$\frac{1}{2}(9.8\text{ m/s}^2)(t^2) + 14\text{ m/s}(t) - 21\text{ m} = 0$$

$$4.9\text{ m/s}^2(t^2) + 14\text{ m/s}(t) - 21\text{ m} = 0$$

Now applying the quadratic formula with b = +14, a = +4.9, c = –21 and omitting units for convenience:

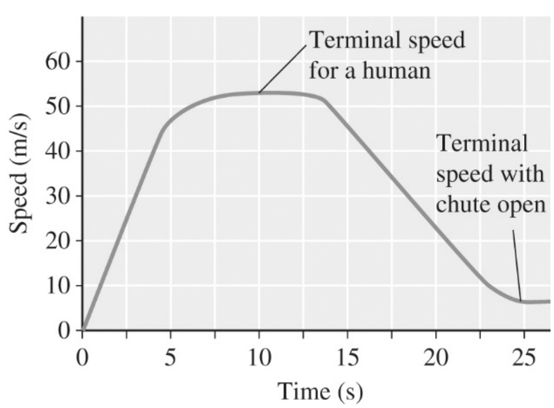
$$t = \frac{-b \pm \sqrt{b^2 - 4\,ac}}{2a}$$

$$= \frac{-14 \pm \sqrt{(14)^2 - 4(4.9)(-21)}}{2(4.9)}$$

$$= 1.1 \text{ s or } -3.9 \text{ s}$$

Thus, the stone reaches the water at 1.1 s. The second root of the solution (–3.9 s) corresponds to the stone being at water level 3.9 s *before* it arrives at y_0 = 0 m. At this time of –3.9 s, it is travelling upward (perhaps having been thrown upward by someone on a raft), then it goes up past the bridge and starts coming down again, passing the bridge at t = 0 s with a downward velocity of magnitude 14 m/s. So this second stone was at y_0 = 0 m at t = 0 s with a downward velocity of magnitude 14 m/s, and it was at water level two times.

2-52 According to Table 2-4, the jumper will have a terminal speed of about 50 m/s before opening the parachute, and then about 10 m/s or less afterward. The initial slope of the speed–time graph should be about 9.8 m/s^2.



CHAPTER REVIEW

Multiple-Choice Questions

2-53 (d)

2-54 (a)

2-55 (b)

2-56 (d)

2-57 (b)

Review Questions and Problems

2-58 $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{(304.29\times10^3\ \text{m})\div69}{84.118\ \text{s}} = 52.426\ \text{m/s}$

2-59 (a) $d = \text{speed}_{\text{av}}(\Delta t) = (25\ \text{m/s})(2.0\ \text{s}) = 5.0\times10^1\ \text{m}$

(b) One car length is about 3 to 5 m, so 5.0×10^1 m is about 10 to 17 car lengths.

2-60 $\Delta t_1 = \dfrac{d}{\text{speed}_{\text{av}}} = \dfrac{18.0\ \text{km}}{115\ \text{km/h}} = 0.157\ \text{h}$

$\Delta t_2 = \dfrac{d}{\text{speed}_{\text{av}}} = \dfrac{18.0\ \text{km}}{90.0\ \text{km/h}} = 0.200\ \text{h}$

The time difference is (0.200 h – 0.157 h) × 60 min/h = 2.6 min.

2-61 No; jogger 1 is travelling at a constant speed that is larger than the (constant) speed of jogger 2.

2-62 (a) Let d_{TOT} be the total distance travelled.

$$\begin{aligned} d_{\text{TOT}} &= d_1 + d_2 \\ &= \text{speed}_{\text{av},1}(\Delta t_1) + \text{speed}_{\text{av},2}(\Delta t_2) \\ &= (80\text{ km/h})(0.50\text{ h}) + (60\text{ km/h})(1.5\text{ h}) \\ &= 1.3\times10^2\text{ km} \end{aligned}$$

(b) $$\text{speed}_{\text{av}} = \frac{d_{\text{TOT}}}{t_{\text{TOT}}} = \frac{1.3\times10^2\text{ km}}{2.0\text{ h}} = 65\text{ km/h}$$

2-63 (a) Let Δt_{TOT} be the total time.

$$\begin{aligned} \Delta t_{\text{TOT}} &= \Delta t_1 + \Delta t_2 \\ &= \frac{d_1}{\text{speed}_{\text{av},1}} + \frac{d_2}{\text{speed}_{\text{av},2}} \\ &= \frac{1.6\times10^3\text{ m}}{24\text{ m/s}} + \frac{1.2\times10^3\text{ m}}{18\text{ m/s}} \\ &= 1.3\times10^2\text{ s} \end{aligned}$$

(b) $$\text{speed}_{\text{av}} = \frac{d_{\text{TOT}}}{t_{\text{TOT}}} = \frac{2.8\times10^3\text{ m}}{1.33\times10^2\text{ s}} = 21\text{ m/s}$$

2-64 Given: $v = c = 3.0 \times 10^8$ m/s; $d_{\text{TOT}} = 2(4.8 \times 10^7\text{ m}) = 9.6 \times 10^7$ m.

$$\Delta t_{\text{TOT}} = 0.55\text{ s} + \frac{d_{\text{TOT}}}{\text{speed}_{\text{av}}} = 0.55\text{ s} + \frac{9.6\times10^7\text{ m}}{3.0\times10^8\text{ s}} = 0.55\text{ s} + 0.32\text{ s} = 0.87\text{ s}$$

2-65 The person who takes 12 s to run 100 m is running at an average speed of

$\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{100 \text{ m}}{12 \text{ s}} = 8.3 \text{ m/s}.$ Since the faster runner takes only 10 s to run 100 m, the slower runner will have run $d = \text{speed}_{\text{av}}(\Delta t) = (8.3 \text{ m/s})(10 \text{ s}) = 83 \text{ m},$ so is now 17 m behind the faster runner.

2-66 (a) $\text{speed}_{\text{av}} = \dfrac{d}{\Delta t} = \dfrac{2\pi r}{\Delta t} = \dfrac{2(\pi)(1.1\times10^{11} \text{ m})}{2.1\times10^{7} \text{ s}} = 3.3\times10^{4} \text{ m/s}\left(\dfrac{3600 \text{ s/h}}{1000 \text{ m/km}}\right) = 1.2\times10^{5} \text{ km/h}$

(b) The displacement has a magnitude of $2(r) = 2.2 \times 10^{11}$ m, and takes half the time to complete half the orbit. The magnitude of the average velocity is:

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{2.2\times10^{11} \text{ m}}{1.05\times10^{7} \text{ s}} = 2.1\times10^{4} \text{ m/s}$$

(c) After one complete revolution, the displacement is zero, so the average velocity is also zero.

2-67 (a) They are equal. (b) They are equal. (c) The magnitude of the instantaneous velocity equals the instantaneous speed.

2-68 (a) $\text{speed}_{\text{av}} = \dfrac{d_{\text{TOT}}}{\Delta t_{\text{TOT}}} = \dfrac{1100 \text{ km} + 2800 \text{ km}}{2.2 \text{ h} + 1.0 \text{ h} + 3.1 \text{ h}} = 6.2\times10^{2} \text{ km/h} = 1.7\times10^{2} \text{ m/s}$

(b) $\text{speed}_{\text{av}} = \dfrac{d_{\text{TOT}}}{\Delta t_{\text{AIR}}} = \dfrac{3900 \text{ km}}{5.3 \text{ h}} = 7.4\times10^{2} \text{ km/h} = 2.0 \times 10^{2} \text{ m/s}$

(c) $v_{\text{av}} = \dfrac{\Delta x}{\Delta t_{\text{TOT}}} = \dfrac{1700 \text{ km east}}{6.3 \text{ h}} = 2.7\times10^{2} \text{ km/h east} = 75 \text{ m/s east}$

2-69 (a) $d_1 = \text{speed}_{\text{av},1}(\Delta t_1) = (42\text{ m/s})(0.44\text{ s}) = 18.48\text{ m or }18\text{ m}$

(b) Let d_2 be the distance the ball travels from the batter to the fielder.

$d_2 = \text{speed}_{\text{av},2}(\Delta t_2) = (48\text{ m/s})(1.9\text{ s}) = 91.2\text{ m}$

For the entire motion:

$$\text{speed}_{\text{av}} = \frac{d_{\text{TOT}}}{\Delta t_{\text{TOT}}} = \frac{18.48\text{ m} + 91.2\text{ m}}{0.44\text{ s} + 1.9\text{ s}} = 47\text{ m/s}$$

(c) $$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{91.2\text{ m} - 18.48\text{ m}}{0.44\text{ s} + 1.9\text{ s}} = 31\text{ m/s}$$

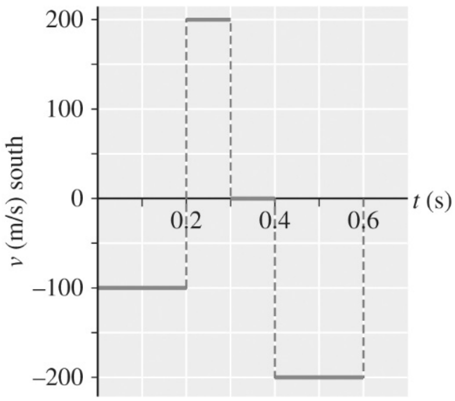
2-70 The motion begins from a position that is opposite in direction to the motion; for 2 time units there is uniform motion in the positive direction; for the next time unit there is uniform motion at a slow speed in the negative direction; for the final time unit there is uniform motion at a high speed in the negative direction, ending at the position that had occurred at 1 time unit.

2-71 The slope of a line on a position–time graph indicates the velocity. If the line is curved, the slope of the tangent to the curve at a particular instant indicates the velocity at that instant.

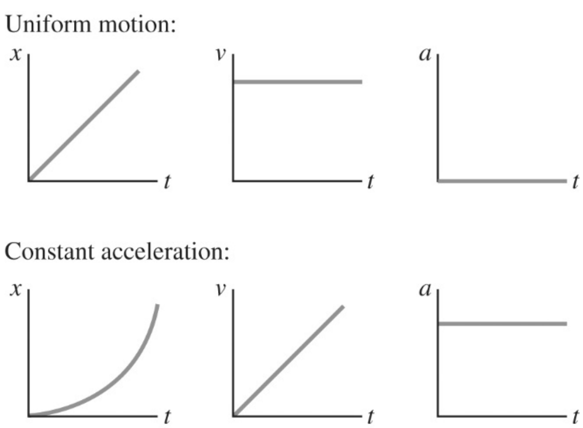
2-72 (a) The area under the line (or curve) on a velocity–time graph indicates the displacement.

(b) The slope of the line on a velocity–time graph indicates the acceleration.

2-73



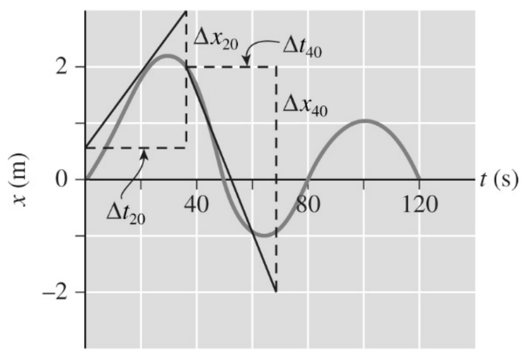
2-74 Uniform motion is motion at a constant velocity, in other words at a constant speed in one direction. Constant acceleration (in one dimension) is motion with a uniformly changing velocity, in other words a uniformly changing speed in a single direction. The graphs are shown below.



2-75 (a) 30 s, 65 s, 100 s

(b) positive: 0–30 s, 65–100 s; negative: 30–65 s, 100–120 s

(c) Tangents at 20 s and 40 s are drawn and their slopes are calculated.



$$m_{20} = \frac{\Delta x}{\Delta t} \approx \frac{2.4\text{ m}}{35\text{ s}} \approx 6.9\times10^{-2}\text{ m/s}$$

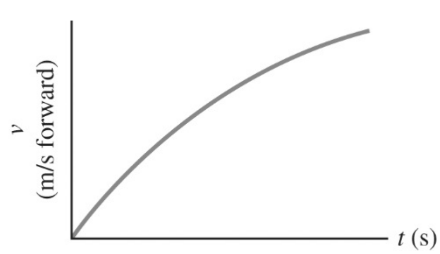
$$m_{40} = \frac{\Delta x}{\Delta t} \approx \frac{-4.0\text{ m}}{30\text{ s}} \approx -1.3\times10^{-1}\text{ m/s}$$

2-76 At the top of the path of a ball thrown vertically upward, the ball is instantaneously at rest (i.e., has zero speed), but it has non-zero acceleration (9.8 m/s^2 downward).

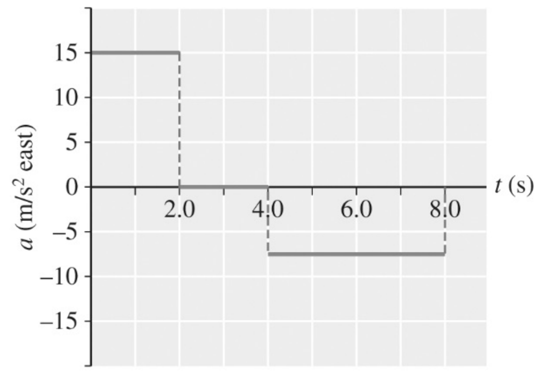
2-77 (c) The acceleration is shown as westerly, and the eastward velocity vectors are becoming smaller as the dog moves toward the east.

2-78 (a) Runner is moving south and is speeding up. (b) Runner is moving south and is slowing down. (c) Runner is moving north and is slowing down. (d) Runner is moving north and is speeding up.

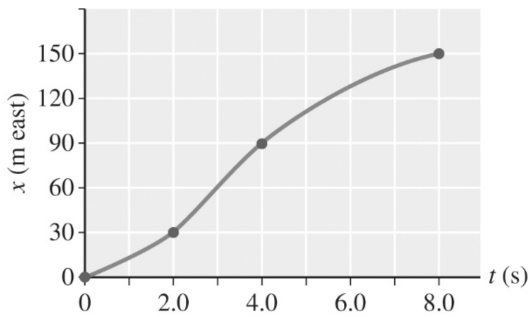
2-79



2-80



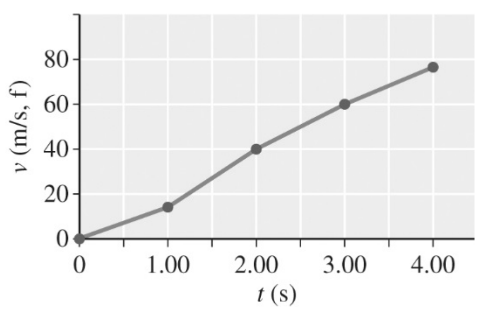
(a)



(b)

2-81 Let "f" represent the forward direction.

(a)

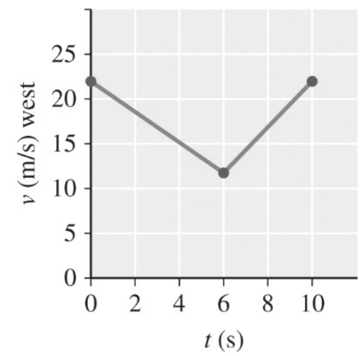


(b) $$a_{\text{av, greatest}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{38.8 \text{ m/s, f} - 14.4 \text{ m/s, f}}{2.00 \text{ s} - 1.00 \text{ s}} = 24.4 \text{ m/s}^2, \text{ f}$$

$$a_{\text{av, least}} = \frac{v_1 - v_0}{t_1 - t_0} = \frac{14.4 \text{ m/s, f} - 0}{1.00 \text{ s} - 0} = 14.4 \text{ m/s}^2, \text{ f}$$

(c) $$|a_{\text{av}}| = \frac{v_4 - v_0}{t_4 - t_0} = \frac{74.2 \text{ m/s} - 0 \text{ m/s}}{4.00 \text{ s}} = 18.6 \text{ m/s}^2$$

2-82 (a)



(b) The displacement equals the area under the line segments on the *v*-*t* graph:

$A_1 = lw + \frac{1}{2}bh = (12\text{ m/s west})(6\text{ s}) + \frac{1}{2}(10\text{ m/s west})(6\text{ s}) = 102\text{ m west}$

$A_2 = lw + \frac{1}{2}bh = (12\text{ m/s west})(4\text{ s}) + \frac{1}{2}(10\text{ m/s west})(4\text{ s}) = 68\text{ m west}$

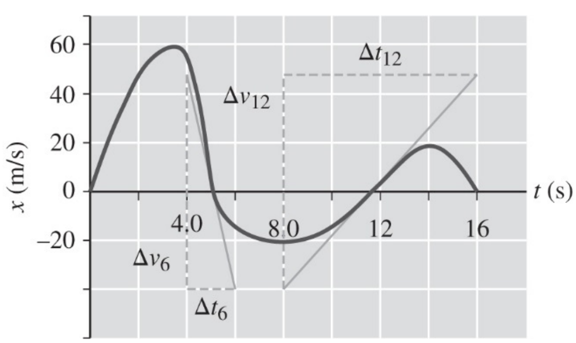
Thus, the total displacement is 102 m west + 68 m west = 1.7×10^2 m west.

2-83 (a) 0.0 s, 6.0 s, 12 s

(b) 4.0 s, 8.0 s, 14 s

(c) 4.0–8.0 s, 14–16 s

(d) Tangents are drawn at 6.0 s and 12 s, then their slopes are calculated.



$$m_{6.0} = \frac{\Delta v_{6.0}}{\Delta t_{6.0}} \approx \frac{-90\text{ m/s south}}{2.6\text{ s}} \approx -35\text{ m/s}^2 \text{ south or } +35\text{ m/s}^2 \text{ north}$$

$$m_{12} = \frac{\Delta v_{12}}{\Delta t_{12}} \approx \frac{+80\text{ m/s south}}{6.7\text{ s}} \approx 12\text{ m/s}^2 \text{ south}$$

2-84 Given: $v_0 = 0$ m/s; $\Delta x = 15$ m; $t = 1.2$ s.

(a) $\Delta x = v_0 t + \frac{1}{2}at^2 = \frac{1}{2}at^2$

$$\therefore a = \frac{2\Delta x}{t^2} = \frac{2(15\text{ m})}{(1.2\text{ s})^2} = 21\text{ m/s}^2$$

(b) $v = v_0 + at = 0 + (21\text{ m/s}^2)(1.2\text{ s}) = 25\text{ m/s}$

(c) $\dfrac{21\text{ m/s}^2}{(9.8\text{ m/s}^2)/g} = 2.1g$

2-85 When a ball is tossed vertically upward, at the top of the flight it reverses directions but its acceleration remains 9.8 m/s^2 downward.

2-86 Given: $v_0 = 4.0$ km/h = 1.1 m/s; $v = 33$ km/h = 9.2 m/s; $t = 33$ s.

$$\Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}(1.1\text{ m/s} + 9.2\text{ m/s})(33\text{ s}) = 1.7 \times 10^2\text{ m}$$

2-87 (a) starting from rest, a positive constant acceleration of relatively high magnitude; uniform motion; negative constant acceleration with low magnitude; negative constant acceleration with high magnitude

(b) starting with a fairly high forward velocity; negative constant acceleration eventually coming to a stop and then reversing direction with the same constant acceleration

(c) constant positive acceleration followed by uniformly diminishing positive acceleration

2-88 Given: $v_0 = 0$ m/s; $v = 25$ cm/s; $\Delta x = 2.0$ cm f, where f = forward.

(a) With $v = 0$ m/s, $v^2 = v_0^2 + 2a(\Delta x) = 2a(\Delta x)$:

$$\therefore a = \frac{v^2}{2\Delta x} = \frac{(25\text{ cm/s f})^2}{2(2.0\text{ cm f})} = 1.6\times10^2\text{ cm/s}^2\text{ f}$$

(b) With $v = 0$ m/s, $\Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}vt$:

$$\therefore t = \frac{2\Delta x}{v} = \frac{2(2.0\text{ cm})}{25\text{ cm/s}} = 0.16\text{ s}$$

2-89 Given: $a = 1.6$ m/s^2; $\Delta x = 2.0 \times 10^2$ m.

(a) With $v_0 = 0$ m/s, $\Delta y = v_0 t + \frac{1}{2}at^2 = \frac{1}{2}at^2$

$$\therefore t^2 = \frac{2\Delta x}{a} \text{ and } t = \sqrt{\frac{2\Delta x}{a}} = \sqrt{\frac{2(2.0\times10^2\text{ m})}{1.6\text{ m/s}^2}} = 16\text{ s}$$

(b) From $\Delta y = v_0 t + \frac{1}{2}at^2$:

$$\tfrac{1}{2}at^2 + v_0 t - \Delta y = 0$$

$$\tfrac{1}{2}(1.6\text{ m/s}^2)(t^2) + 8.0\text{ m/s}(t) - 2.0\times10^2\text{ m} = 0$$

$$0.8\text{ m/s}^2(t^2) + 8.0\text{ m/s}(t) - 2.0\times10^2\text{ m} = 0$$

Now applying the quadratic formula with $b = +8.0$, $a = +0.8$, $c = -2.0 \times 10^2$, and omitting units for convenience:

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

$$= \frac{-8.0 \pm \sqrt{(8.0)^2 - 4(0.8)(-2.0\times10^2)}}{2(0.8)}$$

$$= 12\text{ s (the only positive root)}$$

2-90 Only the first runner has to accelerate from rest; the remaining three runners are able to receive the baton transferred in the relay while running at nearly full speed. Practice helps improve a smooth, efficient baton transfer at a high speed.

2-91 In all cases, the distance is found using the data on the graph applied to the equation $d = \text{speed}_{\text{av}}t$. Two samples are provided here, the first and last calculations:

$d_{\text{initial}} = \text{speed}_{\text{av, i}}t = (0.80 \text{ s})(14 \text{ m/s}) = 11 \text{ m}$

$d_{\text{final}} = \text{speed}_{\text{av, f}}t = (3.0 \text{ s})(33 \text{ m/s}) = 99 \text{ m}$

With no alcohol the distances are: 11 m; 20 m; 26 m.

With 3 bottles consumed the distances are: 17 m; 30 m; 40 m.

With 5 bottles consumed the distances are: 42 m; 75 m; 99 m.

2-92 Let $+y$ be upward; then $a = -g = -9.8 \text{ m/s}^2$; $v = 0$ m/s; $\Delta y = +1.9$ m.

From $v^2 = v_0^2 + 2a\Delta y$:

$v_o{}^2 = v^2 - 2a\Delta y$

$\therefore v_o = \sqrt{v^2 - 2a\Delta y} = \sqrt{0 \text{ m}^2/\text{s}^2 - 2(-9.8 \text{ m/s}^2)(1.9 \text{ m})} = 6.1 \text{ m/s upward}$

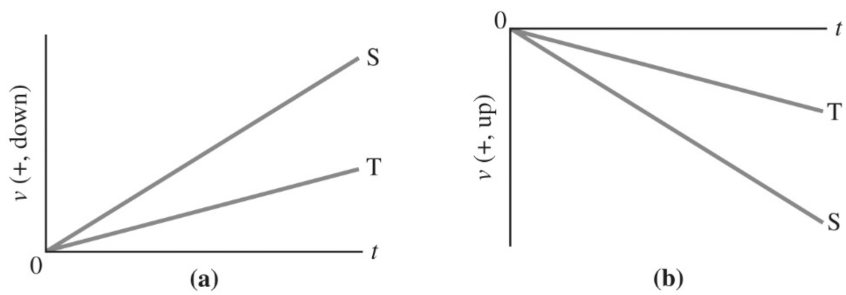
2-93 Given: $a = 30g = 30(9.8 \text{ m/s}^2) = 2.9 \times 10^2 \text{ m/s}^2$; $v_0 = 0$ m/s; $v = 0.1 \times 3.00 \times 10^8 \text{ m/s} = 3.00 \times 10^7$ m/s.

From $v = v_0 + at$:

$$t = \frac{v - v_0}{a} = \frac{3.0\times10^7 \text{ m/s} - 0 \text{ m/s}}{2.9\times10^2 \text{ m/s}^2} = 1.0\times10^5 \text{ s} = \frac{1.0\times10^5 \text{ s}}{3600 \text{ s/h}} = 28 \text{ h}$$

2-94 Since air resistance can be neglected, we can apply the constant acceleration equations. In the equation $v^2 = v_0^2 + 2a\Delta y$, a and Δy are the same for the stone as it rises and then falls. Also, the velocity at the top of the flight (v for the rising stone and v_0 for the falling stone) is zero. So the initial velocity of the rising stone equals the final velocity of the falling stone at the reference point (in this case the railing).

2-95 Refer to the graphs below, where S represents the steel ball and T represents the tennis ball.



2-96 (C); neglecting air resistance, the motion of a ball going up and then down under the influence of gravity is symmetric.

2-97 Let +y be downward, then $a = +g = +9.8\text{ m/s}^2$; $v_0 = -17\text{ m/s}$; $\Delta y = -5.2\text{ m}$.

From $\Delta y = v_0 t + \frac{1}{2}at^2$:

$$\tfrac{1}{2}at^2 + v_0 t - \Delta y = 0$$
$$\tfrac{1}{2}(9.8\text{ m/s}^2)(t^2) + (-17\text{ m/s})(t) - (-5.2\text{ m}) = 0$$
$$4.9\text{ m/s}^2(t^2) - 17\text{ m/s}(t) + 5.2\text{ m} = 0$$

Now applying the quadratic formula with $b = -17$, $a = +4.9$, $c = +5.2$, and omitting units for convenience:

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

$$= \frac{17 \pm \sqrt{(-17)^2 - 4(4.9)(5.2)}}{2(4.9)}$$

$$= 0.34 \text{ s and } 3.1 \text{ s}$$

Thus, the ball will pass the camera at 0.34 s and at 3.1 s.

Applying Your Knowledge

2-98 Assume that the maximum running speed of the amateur player is about v_0 = 8 m/s and that the person can come to a stop in a distance of about 1 m. With v = 0 m/s:

From $v^2 - v_0^2 = 2a\left(\Delta x\right)$:

$$a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{0 \text{ m}^2/\text{s}^2 - (8 \text{ m/s})^2}{2(1 \text{ m})} = -32 \text{ m/s}^2 = 3.3g$$

Thus, at an estimated acceleration of magnitude about 3g, the patient is advised not to play tennis at this stage.

2-99 $\text{speed}_{\text{av}} = \frac{d}{\Delta t} = \frac{1.0 \text{ km}}{38 \text{ s}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 95 \text{ km/h}$

2-100 The distance travelled by the sonar signal is

$d = \text{speed}_{\text{sound}}(\Delta t_{\text{sound}}) = (350 \text{ m/s})(3.40 \text{ s}) = 1.19 \times 10^3 \text{ m}$

700 m of this 1190 m was travelled by the sonar signal as it travelled *toward* the cliff. This means that when the 3.4 s have elapsed, the sound has travelled a distance of (1190 m – 700 m) = 490 m *away* from the cliff to be detected by helicopter. Therefore,

the helicopter has moved forward by (700 m – 490 m) = 210 m. Hence, the helicopter's speed is:

$$\text{speed}_{\text{H}} = \frac{d_{\text{H}}}{\Delta t_{\text{H}}} = \frac{2.1 \times 10^2 \text{ m}}{3.40 \text{ s}} = 62 \text{ m/s}$$

2-101 (a) According to the graph, A and B have the same velocity at 0.0 s and 45 s when the lines on the graph intersect.

(b) Applying the hint, at some unknown time t:

$$\text{area}_{\text{A}} = \text{area}_{\text{B}}$$

$$\tfrac{1}{2} b_{\text{A}} h_{\text{A}} + l_{\text{A}} w_{\text{A}} = \tfrac{1}{2} b_{\text{B}} h_{\text{B}} + l_{\text{B}} w_{\text{B}}$$

$$0.5(30 \text{ s})(15 \text{ m/s}) + (15 \text{ m/s})(t - 30 \text{ s}) = 0.5(60 \text{ s})(20 \text{ m/s}) + (20 \text{ m/s})(t - 60 \text{ s})$$

$$225 \text{ m} + 15 \text{ m/s } t - 450 \text{ m} = 600 \text{ m} + 20 \text{ m/s } t - 1200 \text{ m}$$

$$375 \text{ m} = 5 \text{ m/s } t$$

$$t = 75 \text{ s}$$

(c) The data for either A or B can be used. The distance travelled is equal to the area under the line up to 75 s:

$$\begin{aligned} \text{area}_{\text{B}} &= \tfrac{1}{2} b_{\text{B}} h_{\text{B}} + l_{\text{B}} w_{\text{B}} \\ &= 0.5(60 \text{ s})(20 \text{ m/s}) + (15 \text{ s})(20 \text{ m/s}) \\ &= 9.0 \times 10^2 \text{ m} \end{aligned}$$

2-102 Let F be the fish and B be the barracuda and define the initial position as $x_0 = 0$ m, so $\Delta x = x - x_0 = x$. Then $v_{0,\text{B}} = 0$ m/s; v_{F} = constant = 18 m/s; $a_{\text{B}} = 2.2 \text{ m/s}^2$.

(a) B catches F at time t, so we can equate t_{F} and t_{B}.

$$t_F = t_B$$

$$\frac{x_F}{\text{speed}_F} = \sqrt{\frac{2x_B}{a_P}}$$

$$\frac{x_F}{18\ \text{m/s}} = \sqrt{\frac{2x_B}{2.2\ \text{m/s}^2}}$$

Squaring both sides of the equation and using x for the distance travelled since B and F have travelled the same distance when B catches F:

$$\frac{x^2}{324\ \text{m}^2/\text{s}^2} = \frac{2x}{2.2\ \text{m/s}^2}$$

$$x = \frac{2(324\ \text{m}^2/\text{s}^2)}{2.2\ \text{m/s}^2}$$

$$= 2.9 \times 10^2\ \text{m}$$

(b) At time t the distances travelled are equal. Using the fish, $x_F = \text{speed}_F t$

$$\therefore t = \frac{x_F}{\text{speed}_F} = \frac{2.94 \times 10^2\ \text{m}}{18\ \text{m/s}} = 16\ \text{s}$$

2-103 Let $+y$ be downward, then $a = +g = +9.8\ \text{m/s}^2$; $v_0 = 0$ m/s; $\Delta y_1 = 0.50$ m.

(a) From $\Delta y_1 = v_0 t + \frac{1}{2}at^2 = \frac{1}{2}at^2$

$$t_{0.50\ \text{m}} = \sqrt{\frac{2\Delta y_1}{a}} = \sqrt{\frac{2(0.50\ \text{m})}{9.8\ \text{m/s}^2}} = 0.32\ \text{s}$$

(b) Various ways can be used to solve this problem. One way is to solve for the times to fall 5.8 m and 5.3 m and subtract.

$$t_{5.8\ \text{m}} - t_{5.3\ \text{m}} = \sqrt{\frac{2\Delta y_3}{a}} - \sqrt{\frac{2\Delta y_2}{a}} = \sqrt{\frac{2(5.8\ \text{m})}{9.8\ \text{m/s}^2}} - \sqrt{\frac{2(5.3\ \text{m})}{9.8\ \text{m/s}^2}} = 0.048\ \text{s}$$

(c) The vaulter takes almost (0.32 s / 0.048 s) = 7 times as long to travel first 50 cm as the final 50 cm, thus appearing to be in "slow motion" at the top of the vault.

2-104 (a) $\dfrac{77\text{ m/s}^2}{(9.8\text{ m/s}^2)/g}=7.9g \quad \dfrac{2.2\times10^2\text{ m/s}^2}{(9.8\text{ m/s}^2)/g}=22g$

(b) We must assume that the negative acceleration is uniform or constant. Thus, a = -2.2×10^2 m/s^2; $t = 1.2\times10^{-2}$ s; v = 0 m/s; Δx = ?

From $v = v_0 + at$:

$v_0 = v - at = 0\text{ m/s} - (-2.2\times10^2\text{ m/s}^2)(1.2\times10^{-2}\text{ s}) = 2.6\text{ m/s}$

Now $\Delta x = \left(\dfrac{v_0+v}{2}\right)t = \left(\dfrac{2.64\text{ m/s} + 0\text{ m/s}}{2}\right)(1.2\times10^{-2}\text{ s}) = 1.6\times10^{-2}\text{ m} = 1.6\text{ cm}$

(c) Teens may still be growing so their muscles and bones are not as strong as they will be later. Also, it is possible safety equipment is not as protective as the (potentially more expensive) equipment used by professional athletes.

2-105 One way to solve this problem is to draw a v-t graph of the motion, calculate the area on the graph, and equate it to 100 m to find the maximum (constant) speed, which can then be used to find the acceleration.

$$A_{\text{triangle}} + A_{\text{rectangle}} = 100\text{ m}$$

$$\tfrac{1}{2}bh + lw = 100\text{ m}$$

$$\tfrac{1}{2}v(4.00\text{ s}) + v(6.00\text{ s}) = 100\text{ m}$$

$$v(8.00\text{ s}) = 100\text{ m}$$

$$v = 12.5\text{ m/s}$$

$$a = \frac{v - v_0}{t} = \frac{12.5 \text{ m/s} - 0 \text{ m/s}}{4.00 \text{ s}} = 3.13 \text{ m/s}^2$$

Thus, the magnitude of the acceleration is 3.13 m/s^2.

2-106 (a) A *v*-*t* graph of the motion, like the first graph shown in (b) below, could be used to analyze the motion. However, we will use equations, first involving constant acceleration and then constant speed. Let Δy be the distance fallen from rest while experiencing a constant acceleration under free fall of 9.8 m/s^2 downward, reaching a final speed of 3.0×10^1 m/s.

From $v^2 = v_0{}^2 + 2a(\Delta y)$, we have $\Delta y = \frac{v^2 - v_0{}^2}{2a} = \frac{(3.0\times 10^1 \text{ m/s})^2 - 0}{2(9.8 \text{ m/s}^2)} = 46 \text{ m}$

For the last 1.5 s at the constant speed, the distance fallen is

$$y = v_{av} t = (3.0\times 10^1 \text{ m/s})(1.5 \text{ s}) = 45 \text{ m}$$

Thus, the height from which the ball is dropped is 46 m + 45 m = 91 m.

(b) The ball experiences air resistance as soon as it begins its downward motion, so its acceleration is not constant at 9.8 m/s^2. The graphs are shown below.