1. Once the arrow has left the bow, it has a constant downward acceleration equal to the free-fall acceleration, \( g \). Taking upward as the positive direction, the elapsed time required for the velocity to change from an initial value of 15.0 m/s upward \((v_0 = +15.0 \text{ m/s})\) to a value of 8.00 m/s downward \((v_f = -8.00 \text{ m/s})\) is given by

\[
\Delta t = \frac{\Delta v}{a} = \frac{v_f - v_0}{-g} = \frac{-8.00 \text{ m/s} - (+15.0 \text{ m/s})}{-9.80 \text{ m/s}^2} = 2.35 \text{ s}
\]

Thus, the correct choice is (d).

2. The maximum height (where \( v = 0 \)) reached by a freely falling object shot upward with an initial velocity \( v_0 = +225 \text{ m/s} \) is found from \( v^2 = v_0^2 + 2a(\Delta y) \) as

\[
(\Delta y)_{\text{max}} = \frac{0 - (v_0)^2}{2(-g)} = \frac{0 - (225 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 2.58 \times 10^3 \text{ m}
\]

Thus, the projectile will be at the \( \Delta y = 6.20 \times 10^2 \text{ m} \) level twice, once on the way upward and once coming back down. The elapsed time when it passes this level coming downward can be found by using \( \Delta y = v_0t - \frac{1}{2}gt^2 \) and obtaining the largest of the two solutions to the resulting quadratic equation:

\[
6.20 \times 10^2 \text{ m} = (225 \text{ m/s})t - \frac{1}{2}(9.80 \text{ m/s}^2)t^2
\]

or

\[
(4.90 \text{ m/s}^2)t^2 - (225 \text{ m/s})t + 6.20 \times 10^2 \text{ m} = 0
\]

The quadratic formula yields

\[
t = \frac{-(-225 \text{ m/s}) \pm \sqrt{(-225 \text{ m/s})^2 - 4(4.90 \text{ m/s}^2)(6.20 \times 10^2 \text{ m})}}{2(4.90 \text{ m/s}^2)}
\]

with solutions of \( t = 43.0 \text{ s} \) and \( t = 2.94 \text{ s} \). The projectile is at a height of \( 6.20 \times 10^2 \text{ m} \) and coming downward at the largest of these two elapsed times, so the correct choice is seen to be (e).

3. The derivation of the equations of kinematics for an object moving in one dimension (Equations 2.6, 2.9, and 2.10 in the textbook) was based on the assumption that the object had a constant acceleration. Thus, (b) is the correct answer. An object having constant acceleration would have constant velocity only if that acceleration had a value of zero, so (a) is not a necessary condition. The speed (magnitude of the velocity) will increase in time only in cases when the velocity is in the same direction as the constant acceleration, so (c) is not a correct response. An object projected straight upward into the air has a constant acceleration. Yet its position (altitude) does not always increase in time (it eventually starts to fall back downward) nor is its velocity always directed downward (the direction of the constant acceleration). Thus, neither (d) nor (e) can be correct.
4. The bowling pin has a constant downward acceleration \((a = -g = -9.80 \text{ m/s}^2)\) while in flight. The velocity of the pin is directed upward on the upward part of its flight and is directed downward as it falls back toward the juggler’s hand. Thus, only (d) is a true statement.

5. The initial velocity of the car is \(v_0 = 0\) and the velocity at time \(t\) is \(v\). The constant acceleration is therefore given by \(a = \frac{\Delta v}{\Delta t} = \frac{(v - v_0)}{t} = \frac{(v - 0)}{t} = \frac{v}{t}\) and the average velocity of the car is \(\overline{v} = \frac{v + v_0}{2} = \frac{(v + 0)}{2} = \frac{v}{2}\). The distance traveled in time \(t\) is \(\Delta x = \overline{v}t = \frac{vt}{2}\). In the special case where \(a = 0\) (and hence \(v = v_0 = 0\)), we see that statements (a), (b), (c), and (d) are all correct. However, in the general case \((a \neq 0, \text{ and hence } v \neq 0)\) only statements (b) and (c) are true. Statement (e) is not true in either case.

6. We take downward as the positive direction with \(y = 0\) and \(t = 0\) at the top of the cliff. The freely falling pebble then has \(v_0 = 0\) and \(a = g = +9.8 \text{ m/s}^2\). The displacement of the pebble at \(t = 1.0\) s is given: \(y_1 = 4.9\) m. The displacement of the pebble at \(t = 3.0\) s is found from

\[
y_3 = v_0t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(9.8 \text{ m/s}^2)(3.0\text{ s})^2 = 44 \text{ m}
\]

The distance fallen in the 2.0 s interval from \(t = 1.0\) s to \(t = 3.0\) s is then

\[
\Delta y = y_3 - y_1 = 44 \text{ m} - 4.9 \text{ m} = 39 \text{ m}
\]

and choice (c) is seen to be the correct answer.

8. The elevator starts from rest (\(v_0 = 0\)) and reaches a speed of \(v = 6 \text{ m/s}\) after undergoing a displacement of \(\Delta y = 30 \text{ m}\). The acceleration may be found using the kinematics equation \(v^2 = v_0^2 + 2\alpha(\Delta y)\) as

\[
a = \frac{v^2 - v_0^2}{2(\Delta y)} = \frac{(6 \text{ m/s})^2 - 0}{2(30 \text{ m})} = 0.6 \text{ m/s}^2
\]

Thus, the correct choice is (c).

11. At ground level, the displacement of the rock from its launch point is \(\Delta y = -h\), where \(h\) is the height of the tower and upward has been chosen as the positive direction. From \(v^2 = v_0^2 + 2\alpha(\Delta y)\), the speed of the rock just before hitting the ground is found to be

\[
|v| = \sqrt{v_0^2 + 2\alpha(\Delta y)} = \sqrt{v_0^2 + 2(-g)(-h)} = \sqrt{(12 \text{ m/s})^2 + 2(9.8 \text{ m/s}^2)(40.0 \text{ m})} = 30 \text{ m/s}
\]

Choice (b) is therefore the correct response to this question.

2. Yes. Zero velocity means that the object is at rest. If the object also has zero acceleration, the velocity is not changing and the object will continue to be at rest.
4. No. They can be used only when the acceleration is constant. Yes. Zero is a constant.

2.1 We assume that you are approximately 2 m tall and that the nerve impulse travels at uniform speed. The elapsed time is then

$$\Delta t = \frac{\Delta x}{v} = \frac{2 \text{ m}}{100 \text{ m/s}} = 2 \times 10^{-2} \text{ s} = 0.02 \text{ s}$$

2.2 At constant speed, \( c = 3 \times 10^8 \text{ m/s} \), the distance light travels in 0.1 s is

$$\Delta x = c(\Delta t) = (3 \times 10^8 \text{ m/s})(0.1 \text{ s}) = (3 \times 10^7 \text{ m})(\frac{1 \text{ mi}}{1.609 \text{ km}})(\frac{1 \text{ km}}{10^3 \text{ m}}) = 2 \times 10^4 \text{ mi}$$

Comparing this to the diameter of the Earth, \( D_E \), we find

$$\frac{\Delta x}{D_E} = \frac{\Delta x}{2R_E} = \frac{3.0 \times 10^7 \text{ m}^2}{2(6.38 \times 10^6 \text{ m}^2)} = 2.4 \text{ (with } R_E \text{ is Earth's radius)}$$

2.3 Distances traveled between pairs of cities are

- \( \Delta x_1 = v_1(\Delta t_1) = (80.0 \text{ km/h})(0.500 \text{ h}) = 40.0 \text{ km} \)
- \( \Delta x_2 = v_2(\Delta t_2) = (100 \text{ km/h})(0.200 \text{ h}) = 20.0 \text{ km} \)
- \( \Delta x_3 = v_3(\Delta t_3) = (40.0 \text{ km/h})(0.750 \text{ h}) = 30.0 \text{ km} \)

Thus, the total distance traveled is \( \Delta x = (40.0 + 20.0 + 30.0) \text{ km} = 90.0 \text{ km} \), and the elapsed time is \( \Delta t = 0.500 \text{ h} + 0.200 \text{ h} + 0.750 \text{ h} + 0.250 \text{ h} = 1.70 \text{ h} \).

(a) \( v = \frac{\Delta x}{\Delta t} = \frac{90.0 \text{ km}}{1.70 \text{ h}} = 52.9 \text{ km/h} \)

(b) \( \Delta x = 90.0 \text{ km} \) (see above)

2.7 (a) Displacement = \( \Delta x = (85.0 \text{ km/h})(35.0 \text{ min}) \left( \frac{1 \text{ h}}{60.0 \text{ min}} \right) + 130 \text{ km} = 180 \text{ km} \)

(b) The total elapsed time is

$$\Delta t = (35.0 \text{ min} + 15.0 \text{ min}) \left( \frac{1 \text{ h}}{60.0 \text{ min}} \right) + 2.00 \text{ h} = 2.84 \text{ h}$$

so,

$$\overline{v} = \frac{\Delta x}{\Delta t} = \frac{180 \text{ km}}{2.84 \text{ h}} = 63.4 \text{ km/h}$$
2.9 The instantaneous velocity at any time is the slope of the $x$ vs. $t$ graph at that time. We compute this slope by using two points on a straight segment of the curve, one point on each side of the point of interest.

(a) $v_{t=0.5s} = \frac{x_{t=0.5s} - x_{t=0s}}{1.0 \text{ s} - 0} = \frac{4.0 \text{ m}}{1.0 \text{ s}} = 4.0 \text{ m/s}$

(b) $v_{t=2.0s} = \frac{x_{t=2.5s} - x_{t=1.0s}}{2.5 \text{ s} - 1.0 \text{ s}} = \frac{-6.0 \text{ m}}{1.5 \text{ s}} = -4.0 \text{ m/s}$

(c) $v_{t=0.0s} = \frac{x_{t=4.0s} - x_{t=2.5s}}{4.0 \text{ s} - 2.5 \text{ s}} = \frac{0}{1.5 \text{ s}} = 0$

(d) $v_{t=4.5s} = \frac{x_{t=5.0s} - x_{t=4.0s}}{5.0 \text{ s} - 4.0 \text{ s}} = \frac{+2.0 \text{ m}}{1.0 \text{ s}} = 2.0 \text{ m/s}$
2.21 The average speed during a time interval is

\[ \bar{v} = \frac{\text{distance traveled}}{\Delta t} \]

During any quarter mile segment, the distance traveled is

\[ \Delta x = \frac{1 \text{ mi}}{4} \left( \frac{5280 \text{ ft}}{1 \text{ mi}} \right) = 1320 \text{ ft} \]

(a) During the first quarter mile segment, Secretariat’s average speed was

\[ \bar{v}_1 = \frac{1320 \text{ ft}}{25.2 \text{ s}} = 52.4 \text{ ft/s} \]

During the second quarter mile segment,

\[ \bar{v}_2 = \frac{1320 \text{ ft}}{24.0 \text{ s}} = 55.0 \text{ ft/s} \]

For the third quarter mile of the race,

\[ \bar{v}_3 = \frac{1320 \text{ ft}}{23.8 \text{ s}} = 55.5 \text{ ft/s} \]

For the fourth final quarter mile,

\[ \bar{v}_4 = \frac{1320 \text{ ft}}{23.2 \text{ s}} = 56.9 \text{ ft/s} \]

and during the final quarter mile,

\[ \bar{v}_5 = \frac{1320 \text{ ft}}{23.0 \text{ s}} = 57.4 \text{ ft/s} \]

(b) Assuming that \( v_{\text{final}} = \bar{v}_5 \) and recognizing that \( v_0 = 0 \), the average acceleration for the entire race was

\[ a = \frac{v_{\text{final}} - v_0}{\text{total elapsed time}} = \frac{57.4 \text{ ft/s} - 0}{(25.2 + 24.0 + 23.8 + 23.2 + 23.0) \text{ s}} = 0.481 \text{ ft/s}^2 \]

2.23 From \( a = \Delta v / \Delta t \), we have \( \Delta t = \frac{\Delta v}{a} = \frac{(60 - 55) \text{ mi/h}}{0.60 \text{ m/s}^2} \left( \frac{0.447 \text{ m/s}}{1 \text{ mi/h}} \right) = 3.7 \text{ s} \).
2.24 (a) From \( t = 0 \) to \( t = 5.0 \) s,
\[
\overline{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{-8.0 \text{ m/s} - (-8.0 \text{ m/s})}{5.0 \text{ s} - 0} = 0
\]
From \( t = 0 \) to \( t = 15 \) s,
\[
\overline{a} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{15 \text{ s} - 5.0 \text{ s}} = 1.6 \text{ m/s}^2
\]
and from \( t = 0 \) to \( t = 20 \) s,
\[
\overline{a} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{20 \text{ s} - 0} = 0.80 \text{ m/s}^2
\]

(b) At any instant, the instantaneous acceleration equals the slope of the line tangent to the \( v \) vs. \( t \) graph at that point in time. At \( t = 2.0 \) s, the slope of the tangent line to the curve is \( 0 \).
At \( t = 10 \) s, the slope of the tangent line is \( 1.6 \text{ m/s}^2 \), and at \( t = 18 \) s, the slope of the tangent line is \( 0 \).

2.29 (a) \( \Delta x = v_{av} (\Delta t) = (v + v_0 / 2) \Delta t \) becomes 40.0 m = \( \left( \frac{2.80 \text{ m/s} + v_0}{2} \right) \) (8.50 s),
which yields \( v_0 = \frac{2}{8.50 \text{ s}} (40.0 \text{ m}) - 2.80 \text{ m/s} = 6.61 \text{ m/s} \)

(b) \( a = \frac{v - v_0}{\Delta t} = \frac{2.80 \text{ m/s} - 6.61 \text{ m/s}}{8.50 \text{ s}} = -0.448 \text{ m/s}^2 \)
2.32 (a) The time for the truck to reach 20 m/s, starting from rest, is found from $v = v_0 + at$:

$$t_{\text{speed}} = \frac{v - v_0}{a} = \frac{20 \ m/s - 0}{2.0 \ m/s^2} = 10 \ s$$

The total time for the trip is $t_{\text{total}} = t_{\text{speed}} + t_{\text{constant}} + t_{\text{braking}} = 10 \ s + 20 \ s + 5.0 \ s = 35 \ s$.

(b) The distance traveled during the first 10 s is

$$\left(\Delta x\right)_{\text{speed}} = \overline{v}_{\text{speed}} \cdot t_{\text{speed}} = \left(\frac{v + v_0}{2}\right) \cdot t_{\text{speed}} = \left(\frac{20 \ m/s + 0}{2}\right)(10 \ s) = 100 \ m$$

The distance traveled during the next 20 s (with $a = 0$) is

$$\left(\Delta x\right)_{\text{constant}} = v \cdot t_{\text{constant}} = (20 \ m/s)(20 \ s) = 400 \ m$$

The distance traveled in the last 5.0 s is

$$\left(\Delta x\right)_{\text{braking}} = \overline{v}_{\text{braking}} \cdot t_{\text{braking}} = \left(\frac{v_t + v}{2}\right) \cdot t_{\text{braking}} = \left(\frac{0 + 20 \ m/s}{2}\right)(5.0 \ s) = 50 \ m$$

The total displacement is then

$$\left(\Delta x\right)_{\text{total}} = \left(\Delta x\right)_{\text{speed}} + \left(\Delta x\right)_{\text{constant}} + \left(\Delta x\right)_{\text{braking}} = 100 \ m + 400 \ m + 50 \ m = 550 \ m$$

and the average velocity for the entire trip is

$$\overline{v}_{\text{up}} = \frac{(\Delta x)_{\text{total}}}{t_{\text{total}}} = \frac{550 \ m}{35 \ s} = 16 \ m/s$$
2.45  (a) From $v^2 = v_0^2 + 2a(\Delta y)$ with $v = 0$, we have

$$\Delta y_{\text{max}} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (25.0 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 31.9 \text{ m}$$

(b) The time to reach the highest point is

$$t_{wp} = \frac{v - v_0}{a} = \frac{0 - 25.0 \text{ m/s}}{-9.80 \text{ m/s}^2} = 2.55 \text{ s}$$

(c) The time required for the ball to fall 31.9 m, starting from rest, is found from

$$\Delta y = (0)t + \frac{1}{2}at^2 \text{ as } t = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-31.9 \text{ m})}{-9.80 \text{ m/s}^2}} = 2.55 \text{ s}$$

(d) The velocity of the ball when it returns to the original level (2.55 s after it starts to fall from rest) is

$$v = v_0 + at = 0 + (-9.80 \text{ m/s}^2)(2.55 \text{ s}) = -25.0 \text{ m/s}$$
(a) After 2.00 s, the velocity of the mailbag is

\[ v_{\text{bag}} = v_0 + at = -1.50 \text{ m/s} + \left(-9.80 \text{ m/s}^2\right)(2.00 \text{ s}) = -21.1 \text{ m/s} \]

The negative sign tells that the bag is moving downward and the magnitude of the velocity gives the speed as \(21.1 \text{ m/s}\).

(b) The displacement of the mailbag after 2.00 s is

\[ (\Delta y)_{\text{bag}} = \left(\frac{v + v_0}{2}\right)t = \left[\frac{-21.1 \text{ m/s} + (-1.50 \text{ m/s})}{2}\right](2.00 \text{ s}) = -22.6 \text{ m} \]

During this time, the helicopter, moving downward with constant velocity, undergoes a displacement of

\[ (\Delta y)_{\text{copter}} = v_0t + \frac{1}{2}at^2 = (-1.5 \text{ m/s})(2.00 \text{ s}) + 0 = -3.00 \text{ m} \]

The distance separating the package and the helicopter at this time is then

\[ d = \left| (\Delta y)_p - (\Delta y)_h \right| = |-22.6 \text{ m} - (-3.00 \text{ m})| = | -19.6 \text{ m} | = 19.6 \text{ m} \]

(c) Here, \( (v_0)_{\text{bag}} = (v_0)_{\text{copter}} = +1.50 \text{ m/s} \) and \( a_{\text{bag}} = -9.80 \text{ m/s}^2 \) while \( a_{\text{copter}} = 0 \). After 2.00 s, the velocity of the mailbag is

\[ v_{\text{bag}} = 1.50 \text{ m/s} + \left(-9.80 \text{ m/s}^2\right)(2.00 \text{ s}) = -18.1 \text{ m/s} \]

and its speed is

\[ |v_{\text{bag}}| = 18.1 \text{ m/s} \]

In this case, the displacement of the helicopter during the 2.00 s interval is

\[ (\Delta y)_{\text{copter}} = (+1.50 \text{ m/s})(2.00 \text{ s}) + 0 = +3.00 \text{ m} \]

Meanwhile, the mailbag has a displacement of

\[ (\Delta y)_{\text{bag}} = \left(\frac{v_{\text{bag}} + v_0}{2}\right)t = \left[\frac{-18.1 \text{ m/s} + 1.50 \text{ m/s}}{2}\right](2.00 \text{ s}) = -16.6 \text{ m} \]

The distance separating the package and the helicopter at this time is then

\[ d = \left| (\Delta y)_p - (\Delta y)_h \right| = |-16.6 \text{ m} - (+3.00 \text{ m})| = | -19.6 \text{ m} | = 19.6 \text{ m} \]