# CHAPTER 2: Describing Motion: Kinematics in One Dimension

## Solutions to Problems

1. The average speed is given by:

$$v = d/\Delta t = 235\text{ km}/3.25\text{ h} = \boxed{72.3\text{ km/h}}.$$

2. The time of travel can be found by rearranging the average speed equation.

$$v = d/\Delta t \rightarrow \Delta t = d/v = (15\text{ km})/(25\text{ km/h}) = \boxed{0.60\text{ h}} = 36\text{ min}$$

3. The distance of travel (displacement) can be found by rearranging the average speed equation. Also note that the units of the velocity and the time are not the same, so the speed units will be converted.

$$v = \frac{d}{\Delta t} \rightarrow d = v\Delta t = (110\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)(2.0\text{ s}) = 0.061\text{ km} = \boxed{61\text{ m}}$$

4. (*a*) $35\text{ mi/h} = (35\text{ mi/h})(1.61\text{ km/mi}) = \boxed{56\text{ km/h}}$

(*b*) $35\text{ mi/h} = (35\text{ mi/h})(1610\text{ m/mi})(1\text{ h}/3600\text{ s}) = \boxed{16\text{ m/s}}$

(*c*) $35\text{ mi/h} = (35\text{ mi/h})(5280\text{ ft/mi})(1\text{ h}/3600\text{ s}) = \boxed{51\text{ ft/s}}$

5. The average velocity is given by $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{-4.2\text{ cm} - 3.4\text{ cm}}{6.1\text{ s} - 3.0\text{ s}} = \frac{-7.6\text{ cm}}{3.1\text{ s}} = \boxed{-2.5\text{ cm/s}}$.

6. The average velocity is given by $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{8.5\text{ cm} - 3.4\text{ cm}}{4.5\text{ s} - (-2.0\text{ s})} = \frac{5.1\text{ cm}}{6.5\text{ s}} = \boxed{0.78\text{ cm/s}}$.

The average speed cannot be calculated. To calculate the average speed, we would need to know the actual distance traveled, and it is not given.

7. The time for the first part of the trip is calculated from the initial speed and the first distance.

$$\text{ave speed}_1 = v_1 = \frac{d_1}{\Delta t_1} \rightarrow \Delta t_1 = \frac{d_1}{v_1} = \frac{130\text{ km}}{95\text{ km/h}} = 1.37\text{ h} = 82\text{ min}$$

The time for the second part of the trip is therefore

$$\Delta t_2 = \Delta t_{tot} - \Delta t_1 = 3.33\text{ h} - 1.37\text{ h} = 1.96\text{ h} = 118\text{ min}$$

The distance for the second part of the trip is calculated from the average speed for that part of the trip and the time for that part of the trip.

$$\text{ave speed}_2 = v_2 = \frac{d_2}{\Delta t_2} \rightarrow d_2 = v_2 \Delta t_2 = (65\,\text{km/h})(1.96\,\text{h}) = 127.5\,\text{km} = 1.3 \times 10^2\,\text{km}$$

(*a*) The total distance is then $d_{total} = d_1 + d_2 = 130\,\text{km} + 127.5\,\text{km} = 257.5\,\text{km} \approx \boxed{2.6 \times 10^2\,\text{km}}$

(*b*) The average speed is NOT the average of the two speeds. Use the definition of average speed.

$$\text{ave speed} = \frac{d_{total}}{\Delta t_{total}} = \frac{257.5\,\text{km}}{3.33\,\text{h}} = \boxed{77\,\text{km/h}}$$

8. The speed of sound is intimated in the problem as 1 mile per 5 seconds. The speed is calculated by:

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \left(\frac{1\,\text{mi}}{5\,\text{s}}\right)\left(\frac{1610\,\text{m}}{1\,\text{mi}}\right) = \boxed{300\,\text{m/s}}.$$

Note that only 1 significant figure is given, (5 sec), and so only 1 significant figure is justified in the result.

$\boxed{9.}$ The distance traveled is 2.0 miles $(8\,\text{laps} \times 0.25\,\text{mi/lap})$. The displacement is 0 because the ending point is the same as the starting point.

(*a*) Average speed = $\frac{d}{\Delta t} = \frac{2.0\,\text{mi}}{12.5\,\text{min}} = \left(\frac{2\,\text{mi}}{12.5\,\text{min}}\right)\left(\frac{1610\,\text{m}}{1\,\text{mi}}\right)\left(\frac{1\,\text{min}}{60\,\text{s}}\right) = \boxed{4.3\,\text{m/s}}$

(*b*) Average velocity = $\bar{v} = \Delta x / \Delta t = \boxed{0\,\text{m/s}}$

10. The distance traveled is $116\,\text{km} + \frac{1}{2}(116\,\text{km}) = 174\,\text{km}$, and the displacement is $116\,\text{km} - \frac{1}{2}(116\,\text{km}) = 58\,\text{km}$. The total time is 14.0 s + 4.8 s = 18.8 s.

(*a*) Average speed = $\frac{d}{\Delta t} = \frac{174\,\text{m}}{18.8\,\text{s}} = \boxed{9.26\,\text{m/s}}$

(*b*) Average velocity = $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{58\,\text{m}}{18.8\,\text{s}} = \boxed{3.1\,\text{m/s}}$

11. Since the locomotives have the same speed, they each travel half the distance, 4.25 km. Find the time of travel from the average speed.

$$\text{ave speed} = v = \frac{d}{\Delta t} \rightarrow \Delta t = \frac{d}{v} = \frac{4.25\,\text{km}}{95\,\text{km/h}} = 0.0447\,\text{h}\left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 2.68\,\text{min} \cong \boxed{2.7\,\text{min}}$$

12. Both objects will have the same time of travel. If the truck travels a distance $d_{truck}$, then the distance the car travels will be $d_{car} = d_{truck} + 110\,\text{m}$. Using the equation for average speed, $v = d/\Delta t$, solve for time, and equate the two times.

$$\Delta t = \frac{d_{truck}}{v_{truck}} = \frac{d_{car}}{v_{car}} \qquad \frac{d_{truck}}{75\,\text{km/h}} = \frac{d_{truck} + 110\,\text{m}}{88\,\text{km/h}}$$

Solving for $d_{truck}$ gives $d_{truck} = (110\,\text{m})\dfrac{(75\,\text{km/h})}{(88\,\text{km/h} - 75\,\text{km/h})} = 634.6\,\text{m}$.

The time of travel is

$$\Delta t = \frac{d_{truck}}{v_{truck}} = \left(\frac{634.6\,\text{m}}{75000\,\text{m/h}}\right)\left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 0.5077\,\text{min} = 30.46\,\text{s} = \boxed{3.0\times10^{1}\,\text{s}}.$$

Also note that $\Delta t = \dfrac{d_{car}}{v_{car}} = \left(\dfrac{634.6\,\text{m} + 110\,\text{m}}{88000\,\text{m/h}}\right)\left(\dfrac{60\,\text{min}}{1\,\text{h}}\right) = 0.5077\,\text{min} = 30.46\,\text{s}$.

ALTERNATE SOLUTION:

The speed of the car relative to the truck is $88\,\text{km/h} - 75\,\text{km/h} = 13\,\text{km/h}$. In the reference frame of the truck, the car must travel 110 m to catch it.

$$\Delta t = \frac{0.11\,\text{km}}{13\,\text{km/h}}\left(\frac{3600\,\text{s}}{1\,\text{h}}\right) = 30.46\,\text{s}$$

13. The average speed for each segment of the trip is given by $v = \dfrac{d}{\Delta t}$, so $\Delta t = \dfrac{d}{v}$ for each segment.

For the first segment, $\Delta t_1 = \dfrac{d_1}{v_1} = \dfrac{3100\,\text{km}}{790\,\text{km/h}} = 3.924\,\text{h}$.

For the second segment, $\Delta t_2 = \dfrac{d_2}{v_2} = \dfrac{2800\,\text{km}}{990\,\text{km/h}} = 2.828\,\text{h}$.

Thus the total time is $\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 3.924\,\text{h} + 2.828\,\text{h} = 6.752\,\text{h} \approx \boxed{6.8\,\text{h}}$.

The average speed of the plane for the entire trip is

$$v = \frac{d_{tot}}{\Delta t_{tot}} = \frac{3100\,\text{km} + 2800\,\text{km}}{6.752\,\text{h}} = 873.8 \approx \boxed{8.7\times10^{2}\,\text{km/h}}.$$

14. The distance traveled is 500 km (250 km outgoing, 250 km return, keep 2 significant figures). The displacement $(\Delta x)$ is 0 because the ending point is the same as the starting point.

(*a*) To find the average speed, we need the distance traveled (500 km) and the total time elapsed.

During the outgoing portion, $v_1 = \frac{d_1}{\Delta t_1}$ and so $\Delta t_1 = \frac{d_1}{v_1} = \frac{250\text{ km}}{95\text{ km/h}} = 2.632\text{ h}$. During the return portion, $v_2 = \frac{d_2}{\Delta t_2}$, and so $\Delta t_2 = \frac{d_2}{v_2} = \frac{250\text{ km}}{55\text{ km/h}} = 4.545\text{ h}$. Thus the total time, including lunch, is $\Delta t_{total} = \Delta t_1 + \Delta t_{lunch} + \Delta t_2 = 8.177\text{ h}$. Average speed $= \frac{d_{total}}{\Delta t_{total}} = \frac{500\text{ km}}{8.177\text{ h}} = \boxed{61\text{ km/h}}$.

(*b*) Average velocity = $\boxed{\bar{v} = \Delta x/\Delta t = 0}$

15. The average speed of sound is given by $v = d/\Delta t$, and so the time for the sound to travel from the end of the lane back to the bowler is $\Delta t_{sound} = \frac{d}{v_{sound}} = \frac{16.5\text{ m}}{340\text{ m/s}} = 4.85 \times 10^{-2}\text{ s}$. Thus the time for the ball to travel from the bowler to the end of the lane is given by $\Delta t_{ball} = \Delta t_{total} - \Delta t_{sound} = 2.50\text{ s} - 4.85 \times 10^{-2}\text{ s} = 2.4515\text{ s}$. And so the speed of the ball is:

$$v_{ball} = \frac{d}{\Delta t_{ball}} = \frac{16.5\text{ m}}{2.4515\text{ s}} = \boxed{6.73\text{ m/s}}.$$

16. The average acceleration is given by

$$a = \frac{\Delta v}{\Delta t} = \frac{95\text{ km/h} - 0\text{ km/h}}{6.2\text{ s}} = \frac{(95\text{ km/h})\left(\frac{1\text{ m/s}}{3.6\text{ km/h}}\right)}{6.2\text{ s}} = \boxed{4.3\text{ m/s}^2}.$$

17. (*a*) The average acceleration of the sprinter is $a = \frac{\Delta v}{\Delta t} = \frac{10.0\text{ m/s} - 0.0\text{ m/s}}{1.35\text{ s}} = \boxed{7.41\text{ m/s}^2}$.

(*b*) $a = (7.41\text{ m/s}^2)\left(\frac{1\text{ km}}{1000\text{ m}}\right)\left(\frac{3600\text{ s}}{1\text{ h}}\right)^2 = \boxed{9.60 \times 10^4\text{ km/h}^2}$

$\boxed{18.}$ The time can be found from the average acceleration, $a = \frac{\Delta v}{\Delta t}$.

$$\Delta t = \frac{\Delta v}{a} = \frac{110\text{ km/h} - 80\text{ km/h}}{1.6\text{ m/s}^2} = \frac{(30\text{ km/h})\left(\frac{1\text{ m/s}}{3.6\text{ km/h}}\right)}{1.6\text{ m/s}^2} = 5.208\text{ s} \approx \boxed{5\text{ s}}$$

19. The initial velocity of the car is the average speed of the car before it accelerates.

$$v=\frac{d}{\Delta t}=\frac{110\text{ m}}{5.0\text{ s}}=22\text{ m/s}=v_0$$

The final speed is $v=0$, and the time to stop is 4.0 s. Use Eq. 2-11a to find the acceleration.

$$v=v_0+at \rightarrow$$

$$a=\frac{v-v_0}{t}=\frac{0-22\text{ m/s}}{4.0\text{ s}}=\boxed{-5.5\text{ m/s}^2}=\left(-5.5\text{ m/s}^2\right)\left(\frac{1g}{9.80\text{ m/s}^2}\right)=\boxed{-0.56g\text{'s}}$$

20. To estimate the velocity, find the average velocity over each time interval, and assume that the car had that velocity at the midpoint of the time interval. To estimate the acceleration, find the average acceleration over each time interval, and assume that the car had that acceleration at the midpoint of the time interval. A sample of each calculation is shown.

Table of Calculations

| $t$(s) | $x$(m) |
|---|---|
| 0.00 | 0.00 |
| 0.25 | 0.11 |
| 0.50 | 0.46 |
| 0.75 | 1.06 |
| 1.00 | 1.94 |
| 1.50 | 4.62 |
| 2.00 | 8.55 |
| 2.50 | 13.79 |
| 3.00 | 20.36 |
| 3.50 | 28.31 |
| 4.00 | 37.65 |
| 4.50 | 48.37 |
| 5.00 | 60.30 |
| 5.50 | 73.26 |
| 6.00 | 87.16 |

| $t$(s) | $v$ (m/s) |
|---|---|
| 0.00 | 0.00 |
| 0.125 | 0.44 |
| 0.375 | 1.40 |
| 0.625 | 2.40 |
| 0.875 | 3.52 |
| 1.25 | 5.36 |
| 1.75 | 7.86 |
| 2.25 | 10.48 |
| 2.75 | 13.14 |
| 3.25 | 15.90 |
| 3.75 | 18.68 |
| 4.25 | 21.44 |
| 4.75 | 23.86 |
| 5.25 | 25.92 |
| 5.75 | 27.80 |

| $t$(s) | $a$(m/s$^2$) |
|---|---|
| 0.063 | 3.52 |
| 0.25 | 3.84 |
| 0.50 | 4.00 |
| 0.75 | 4.48 |
| 1.06 | 4.91 |
| 1.50 | 5.00 |
| 2.00 | 5.24 |
| 2.50 | 5.32 |
| 3.00 | 5.52 |
| 3.50 | 5.56 |
| 4.00 | 5.52 |
| 4.50 | 4.84 |
| 5.00 | 4.12 |
| 5.50 | 3.76 |

From 2.00 s to 2.50 s, for average velocity:

$$t_{mid}=\frac{2.50\text{ s}+2.00\text{ s}}{2}=2.25\text{ s}$$

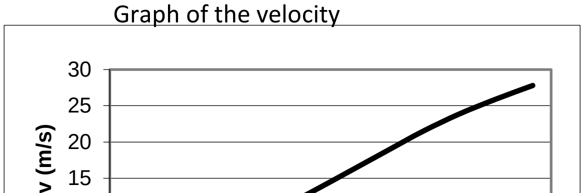
$$v=\frac{\Delta x}{\Delta t}=\frac{13.79\text{ m}-8.55\text{ m}}{2.50\text{ s}-2.00\text{ s}}=\frac{5.24\text{ m}}{0.50\text{ s}}=10.48\text{ m/s}$$

From 2.25 s to 2.75 s, for average acceleration:

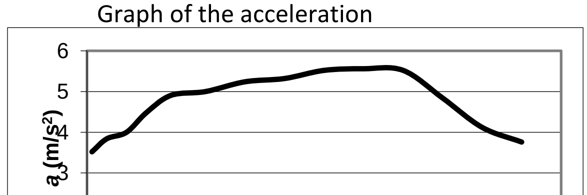
$$t_{mid}=\frac{2.25\text{ s}+2.75\text{ s}}{2}=2.50\text{ s}$$

$$\bar{a}=\frac{\Delta v}{\Delta t}=\frac{13.14\text{ m/s}-10.48\text{ m/s}}{2.75\text{ s}-2.25\text{ s}}=\frac{2.66\text{ m/s}}{0.50\text{ s}}=5.32\text{ m/s}^2$$

Graph of the velocity




Graph of the acceleration



21. By definition, the acceleration is $a = \frac{v - v_0}{t} = \frac{25\,\text{m/s} - 13\,\text{m/s}}{6.0\,\text{s}} = \boxed{2.0\,\text{m/s}^2}$.

The distance of travel can be found from Eq. 2-11b.

$$x - x_0 = v_0 t + \tfrac{1}{2} a t^2 = (13\,\text{m/s})(6.0\,\text{s}) + \tfrac{1}{2}\left(2.0\,\text{m/s}^2\right)(6.0\,\text{s})^2 = \boxed{114\,\text{m}}$$

22. The acceleration can be found from Eq. (2-11c).

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (23\,\text{m/s})^2}{2(85\,\text{m})} = \boxed{-3.1\,\text{m/s}^2}.$$

23. Assume that the plane starts from rest. The runway distance is found by solving Eq. 2-11c for $x - x_0$.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; x - x_0 = \frac{v^2 - v_0^2}{2a} = \frac{(33\,\text{m/s})^2 - 0}{2\left(3.0\,\text{m/s}^2\right)} = \boxed{1.8 \times 10^2\,\text{m}}$$

24. The sprinter starts from rest. The average acceleration is found from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(11.5\,\text{m/s})^2 - 0}{2(15.0\,\text{m})} = 4.408\,\text{m/s}^2 \approx \boxed{4.41\,\text{m/s}^2}.$$

The elapsed time is found by solving Eq. 2-11a for time.

$$v = v_0 + at \;\rightarrow\; t = \frac{v - v_0}{a} = \frac{11.5\,\text{m/s} - 0}{4.408\,\text{m/s}^2} = \boxed{2.61\,\text{s}}$$

25. The words "slowing down uniformly" implies that the car has a constant acceleration. The distance of travel is found form combining Eqs. 2-7 and 2-8.

$$x - x_0 = \frac{v_0 + v}{2} t = \left( \frac{21.0\,\text{m/s} + 0\,\text{m/s}}{2} \right) (6.00\,\text{sec}) = \boxed{63.0\,\text{m}}.$$

$\boxed{26.}$ The final velocity of the car is zero. The initial velocity is found from Eq. 2-11c with $v = 0$ and solving for $v_0$.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; v_0 = \sqrt{v^2 - 2a(x - x_0)} = \sqrt{0 - 2(-7.00\,\text{m/s}^2)(92\,\text{m})} = \boxed{36\,\text{m/s}}$$

27. The final velocity of the driver is zero. The acceleration is found from Eq. 2-11c with $v = 0$ and solving for $a$.

$$a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - \left[ (85\,\text{km/h}) \left( \frac{1\,\text{m/s}}{3.6\,\text{km/h}} \right) \right]^2}{2(0.80\,\text{m})} = -348.4\,\text{m/s}^2 \approx \boxed{-3.5 \times 10^2\,\text{m/s}^2}$$

Converting to "$g$'s": $a = \dfrac{-3.484 \times 10^2\,\text{m/s}^2}{(9.8\,\text{m/s}^2)/g} = \boxed{-36\,g\text{s}}$.

28. The origin is the location of the car at the beginning of the reaction time. The initial speed of the car is $(95\,\text{km/h}) \left( \frac{1\,\text{m/s}}{3.6\,\text{km/h}} \right) = 26.39\,\text{m/s}$. The location where the brakes are applied is found from the equation for motion at constant velocity: $x_0 = v_0 t_R = (26.39\,\text{m/s})(1.0\,\text{s}) = 26.39\,\text{m}$. This is now the starting location for the application of the brakes. In each case, the final speed is 0.

(*a*) Solve Eq. 2-11c for the final location.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; x = x_0 + \frac{v^2 - v_0^2}{2a} = 26.39\,\text{m} + \frac{0 - (26.39\,\text{m/s})^2}{2(-4.0\,\text{m/s}^2)} = \boxed{113\,\text{m}}$$

(*b*) Solve Eq. 2-11c for the final location with the second acceleration.

$$x = x_0 + \frac{v^2 - v_0^2}{2a} = 26.39\,\text{m} + \frac{0 - (26.39\,\text{m/s})^2}{2(-8.0\,\text{m/s}^2)} = \boxed{70\,\text{m}}$$

29. The origin is the location of the car at the beginning of the reaction time. The location where the brakes are applied is found from the equation for motion at constant velocity: $x_0 = v_0 t_R$

This is the starting location for the application of the brakes. Solve Eq. 2-11c for the final location of the car, with $v = 0$.

$$x = x_0 + \frac{v^2 - v_0^2}{2a} = v_0 t_R - \frac{v_0^2}{2a}$$

30. The critical condition is that the total distance covered by the passing car and the approaching car must be less than 400 m so that they do not collide. The passing car has a total displacement composed of several individual parts. These are: i) the 10 m of clear room at the rear of the truck, ii) the 20 m length of the truck, iii) the 10 m of clear room at the front of the truck, and iv) the distance the truck travels. Since the truck travels at a speed of $v = 25\,\text{m/s}$, the truck will have a displacement of $\Delta x_{\text{truck}} = (25\,\text{m/s})t$. Thus the total displacement of the car during passing is $\Delta x_{\substack{\text{passing}\\ \text{car}}} = 40\,\text{m} + (25\,\text{m/s})t$.

To express the motion of the car, we choose the origin to be at the location of the passing car when the decision to pass is made. For the passing car, we have an initial velocity of $v_0 = 25\,\text{m/s}$ and an acceleration of $a = 1.0\,\text{m/s}^2$. Find $\Delta x_{\substack{\text{passing}\\ \text{car}}}$ from Eq. 2-11b.

$$\Delta x_{\substack{\text{passing}\\ \text{car}}} = x_c - x_0 = v_0 t + \tfrac{1}{2} a t = (25\,\text{m/s})t + \tfrac{1}{2}(1.0\,\text{m/s}^2)t^2$$

Set the two expressions for $\Delta x_{\substack{\text{passing}\\ \text{car}}}$ equal to each other in order to find the time required to pass.

$$40\,\text{m} + (25\,\text{m/s})t_{\text{pass}} = (25\,\text{m/s})t_{\text{pass}} + \tfrac{1}{2}(1.0\,\text{m/s}^2)t_{\text{pass}}^2 \rightarrow 40\,\text{m} = \tfrac{1}{2}(1.0\,\text{m/s}^2)t_{\text{pass}}^2 \rightarrow$$
$$t_{\text{pass}} = \sqrt{80\,\text{s}^2} = 8.94\,\text{s}$$

Calculate the displacements of the two cars during this time.

$$\Delta x_{\substack{\text{passing}\\ \text{car}}} = 40\,\text{m} + (25\,\text{m/s})(8.94\,\text{s}) = 264\,\text{m}$$
$$\Delta x_{\substack{\text{approaching}\\ \text{car}}} = v_{\substack{\text{approaching}\\ \text{car}}} t = (25\,\text{m/s})(8.94\,\text{s}) = 224\,\text{m}$$

Thus the two cars together have covered a total distance of 488 m, which is more than allowed.

$$\boxed{\text{The car should not pass.}}$$

31. During the final part of the race, the runner must have a displacement of 1100 m in a time of 180 s (3 min). Assume that the starting speed for the final part is the same as the average speed thus far.

Average speed = $\dfrac{d}{\Delta t} = \dfrac{8900\,\text{m}}{(27 \times 60)\,\text{s}} = 5.494\,\text{m/s} = v_0$

The runner will accomplish this by accelerating from speed $v_0$ to speed *v* for $t$ seconds, covering a distance $d_1$, and then running at a constant speed of *v* for $(180 - t)$ seconds, covering a distance $d_2$. We have these relationships:

$$v = v_o + at \qquad d_1 = v_o t + \tfrac{1}{2}at^2 \qquad d_2 = v(180 - t) = (v_0 + at)(180 - t)$$

$$1100\,\text{m} = d_1 + d_2 = v_o t + \tfrac{1}{2}at^2 + (v_0 + at)(180 - t) \;\rightarrow\; 1100\,\text{m} = 180v_0 + 180at - \tfrac{1}{2}at^2 \;\rightarrow$$

$$1100\,\text{m} = (180\,\text{s})(5.494\,\text{m/s}) + (180\,\text{s})(0.2\,\text{m/s}^2)t - \tfrac{1}{2}(0.2\,\text{m/s}^2)t^2$$

$$0.1t^2 - 36t + 111 = 0 \qquad t = 357\,\text{s},\ 3.11\,\text{s}$$

Since we must have $t < 180\,\text{s}$, the solution is $t = 3.1\,\text{s}$.

32. The car's initial speed is $v_o = (45\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 12.5\,\text{m/s}$.

Case I: trying to stop. The constraint is, with the braking deceleration of the car $\left(a = -5.8\,\text{m/s}^2\right)$, can the car stop in a 28 m displacement? The 2.0 seconds has no relation to this part of the problem. Using equation (2-11c), the distance traveled during braking is

$$(x - x_0) = \frac{v^2 - v_0^2}{2a} = \frac{0 - (12.5\,\text{m/s})^2}{2(-5.8\,\text{m/s}^2)} = 13.5\,\text{m} \quad \boxed{\text{She can stop the car in time.}}$$

Case II: crossing the intersection. The constraint is, with the acceleration of the car $\left[a = \left(\dfrac{65\,\text{km/h} - 45\,\text{km/h}}{6.0\,\text{s}}\right)\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 0.9259\,\text{m/s}^2\right]$, can she get through the intersection (travel 43 meters) in the 2.0 seconds before the light turns red? Using equation (2.11b), the distance traveled during the 2.0 sec is

$$(x - x_0) = v_0 t + \tfrac{1}{2}at^2 = (12.5\,\text{m/s})(2.0\,\text{s}) + \tfrac{1}{2}(0.927\,\text{m/s}^2)(2.0\,\text{s})^2 = 26.9\,\text{m}.$$

$\boxed{\text{She should stop.}}$

33. Choose downward to be the positive direction, and take $y_0 = 0$ at the top of the cliff. The initial velocity is $v_0 = 0$, and the acceleration is $a = 9.80\,\text{m/s}^2$. The displacement is found from equation (2-11b), with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; y - 0 = 0 + \tfrac{1}{2}(9.80\,\text{m/s}^2)(3.25\,\text{s})^2 \;\rightarrow\; y = \boxed{51.8\,\text{m}}$$

34. Choose downward to be the positive direction. The initial velocity is $v_0 = 0$, the final velocity is $v = (85\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 23.61\,\text{m/s}$, and the acceleration is $a = 9.80\,\text{m/s}^2$. The time can be found by solving Eq. 2-11a for the time.

$$v = v_0 + at \;\rightarrow\; t = \frac{v - v_0}{a} = \frac{23.61\,\text{m/s} - 0}{9.80\,\text{m/s}^2} = \boxed{2.4\,\text{s}}$$

35. Choose downward to be the positive direction, and take $y_0 = 0$ to be at the top of the Empire State Building. The initial velocity is $v_0 = 0$, and the acceleration is $a = 9.80\,\text{m/s}^2$.

(*a*) The elapsed time can be found from Eq. 2-11b, with *x* replaced by *y*.

$$y-y_0=v_0t+\tfrac{1}{2}at^2 \quad\rightarrow\quad t=\sqrt{\frac{2y}{a}}=\sqrt{\frac{2(380\,\text{m})}{9.80\,\text{m/s}^2}}=8.806\,\text{s}\approx\boxed{8.8\,\text{s}}\,.$$

(*b*) The final velocity can be found from equation (2-11a).

$$v=v_0+at=0+\left(9.80\,\text{m/s}^2\right)\left(8.806\,\text{s}\right)=\boxed{86\,\text{m/s}}$$

36. Choose upward to be the positive direction, and take $y_0=0$ to be at the height where the ball was hit. For the upward path, $v_0=22\,\text{m/s}$, $v=0$ at the top of the path, and $a=-9.80\,\text{m/s}^2$.

(*a*) The displacement can be found from Eq. 2-11c, with *x* replaced by *y*.

$$v^2=v_0^2+2a(y-y_0) \quad\rightarrow\quad y=y_0+\frac{v^2-v_0^2}{2a}=0+\frac{0-(22\,\text{m/s})^2}{2\left(-9.80\,\text{m/s}^2\right)}=\boxed{25\,\text{m}}$$

(*b*) The time of flight can be found from Eq. 2-11b, with *x* replaced by *y*, using a displacement of 0 for the displacement of the ball returning to the height from which it was hit.

$$y=y_0+v_0t+\tfrac{1}{2}at^2=0 \quad\rightarrow\quad t\left(v_0+\tfrac{1}{2}at\right)=0 \quad\rightarrow\quad t=0,\ t=\frac{2v_0}{-a}=\frac{2(22\,\text{m/s})}{-9.80\,\text{m/s}^2}=\boxed{4.5\,\text{s}}$$

The result of $t = 0$ s is the time for the original displacement of zero (when the ball was hit), and the result of $t = 4.5$ s is the time to return to the original displacement. Thus the answer is $t = 4.5$ seconds.

37. Choose upward to be the positive direction, and take $y_0=0$ to be the height from which the ball was thrown. The acceleration is $a=-9.80\,\text{m/s}^2$. The displacement upon catching the ball is 0, assuming it was caught at the same height from which it was thrown. The starting speed can be found from Eq. 2-11b, with *x* replaced by *y*.

$$y=y_0+v_0t+\tfrac{1}{2}at^2=0 \quad\rightarrow$$

$$v_0=\frac{y-y_0-\tfrac{1}{2}at^2}{t}=-\tfrac{1}{2}at=-\tfrac{1}{2}\left(-9.80\,\text{m/s}^2\right)\left(3.0\,\text{s}\right)=14.7\,\text{m/s}\approx\boxed{15\,\text{m/s}}$$

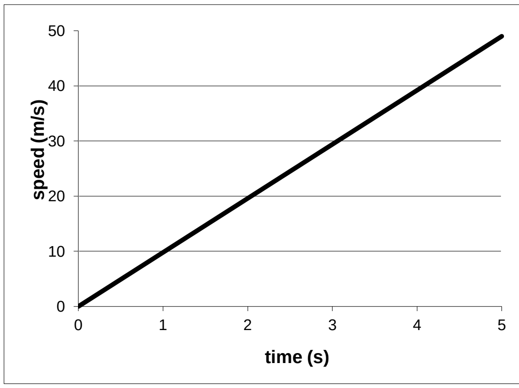
The height can be calculated from Eq. 2-11c, with a final velocity of $v=0$ at the top of the path.

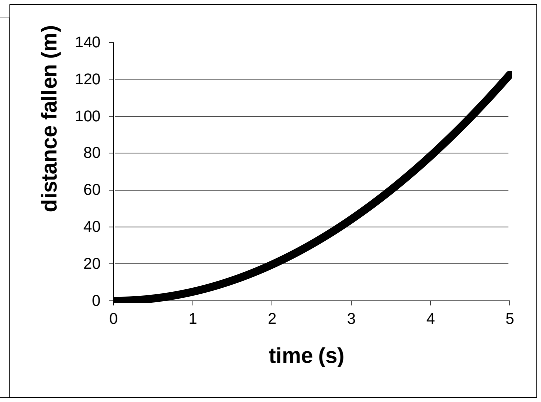
$$v^2=v_0^2+2a(y-y_0) \quad\rightarrow\quad y=y_0+\frac{v^2-v_0^2}{2a}=0+\frac{0-(14.7\,\text{m/s})^2}{2\left(-9.8\,\text{m/s}^2\right)}=\boxed{11\,\text{m}}$$

38. Choose downward to be the positive direction, and take $y_0=0$ to be at the height where the object was released. The initial velocity is $v_0=0$, and the acceleration is $a=9.80\,\text{m/s}^2$.

(*a*) The speed of the object will be given by Eq. 2-11a with $v_0=0$, and so $v=at=\left(9.80\,\text{m/s}^2\right)t$. This is the equation of a straight line passing through the origin with a slope of $9.80\,\text{m/s}^2$.

(*b*) The distance fallen will be given by equation (2-11b) with $v_0 = 0$, and so $y = y_0 + v_0 t + \frac{1}{2}at^2 = 0 + 0 + \left(4.90\,\text{m/s}^2\right)t^2$. This is the equation of a parabola, centered on the t-axis, opening upward.




39. Choose downward to be the positive direction, and take $y_0 = 0$ to be the height where the object was released. The initial velocity is $v_0 = -5.20\,\text{m/s}^2$, the acceleration is $a = 9.80\,\text{m/s}^2$, and the displacement of the package will be $y = 125\,\text{m}$. The time to reach the ground can be found from Eq. 2-11b, with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; t^2 + \frac{2v_0}{a}t - \frac{2y}{a} = 0 \;\rightarrow\; t^2 + \frac{2(-5.2\,\text{m/s})}{9.80\,\text{m/s}^2}t - \frac{2(125\,\text{m})}{9.80\,\text{m/s}^2} = 0 \;\rightarrow$$
$$t = 5.61\,\text{s},\; -4.55\,\text{s}$$

The correct time is the positive answer, $\boxed{t = 5.61\,\text{s}}$.

40. Choose downward to be the positive direction, and take $y_0 = 0$ to be the height from which the object is released. The initial velocity is $v_0 = 0$, the acceleration is $a = g$. Then we can calculate the position as a function of time from Eq. 2-11b, with *x* replaced by *y*, as $y(t) = \frac{1}{2}gt^2$. At the end of each second, the position would be as follows:

$$y(0) = 0; \quad y(1) = \tfrac{1}{2}g; \quad y(2) = \tfrac{1}{2}g(2)^2 = 4y(1); \quad y(3) = \tfrac{1}{2}g(3)^2 = 9y(1)$$

The distance traveled during each second can be found by subtracting two adjacent position values from the above list.

$$d(1) = y(1) - y(0) = y(1); \quad d(2) = y(2) - y(1) = 3y(1); \quad d(3) = y(3) - y(2) = 5y(1)$$

We could do this in general.

$$y(n) = \tfrac{1}{2}gn^2 \qquad y(n+1) = \tfrac{1}{2}g(n+1)^2$$
$$d(n+1) = y(n+1) - y(n) = \tfrac{1}{2}g(n+1)^2 - \tfrac{1}{2}gn^2 = \tfrac{1}{2}g\left((n+1)^2 - n^2\right)$$
$$= \tfrac{1}{2}g\left(n^2 + 2n + 1 - n^2\right) = \tfrac{1}{2}g(2n+1)$$

The value of $(2n+1)$ is always odd, in the sequence $\boxed{1, 3, 5, 7, \ldots}$

41. Choose upward to be the positive direction, and take $y_0 = 0$ to be the height from which the ball is thrown. The initial velocity is $v_0$, the acceleration is $a = -g$, and the final location for the round trip is $y = 0$. The velocity under those conditions can be found from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 - v_0^2 = 2ay = 0 \;\rightarrow\; v^2 = v_0^2 \;\rightarrow\; \boxed{v = \pm v_0}$$

The two results represent two different velocities for the same displacement of 0. The positive sign $(v = v_0)$ is the initial velocity, when the ball is moving upwards, and the negative sign $(v = -v_0)$ is the final velocity, when the ball is moving downwards. Both of these velocities have the same magnitude, and so the ball has the same speed at the end of its flight as at the beginning.

42. Choose upward to be the positive direction, and $y_0 = 0$ to be the height from which the stone is thrown. We have $v_0 = 18.0\,\text{m/s}$, $a = -9.80\,\text{m/s}^2$, and $y - y_0 = 11.0\,\text{m}$.

(*a*) The velocity can be found from Eq, 2-11c, with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0) = 0 \;\rightarrow$$
$$v = \pm\sqrt{v_0^2 + 2ay} = \pm\sqrt{(18.0\,\text{m/s})^2 + 2(-9.80\,\text{m/s}^2)(11.0\,\text{m})} = \pm 10.4\,\text{m/s}$$

Thus the speed is $\boxed{|v| = 10.4\,\text{m/s}}$

(*b*) The time to reach that height can be found from equation (2-11b).

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; t^2 + \frac{2(18.0\,\text{m/s})}{-9.80\,\text{m/s}^2}t + \frac{2(-11.0\,\text{m})}{-9.80\,\text{m/s}^2} = 0 \;\rightarrow$$
$$t^2 - 3.673t + 2.245 = 0 \;\rightarrow\; \boxed{t = 2.90\,\text{s},\, 0.775\,\text{s}}$$

(*c*) $\boxed{\text{There are two times at which the object reaches that height}}$ – once on the way up $(t = 0.775\,\text{s})$,

and once on the way down $(t = 2.90\,\text{s})$.

43. The 10-cm (100 mm) apple has a diameter of about 6 mm as measured in the photograph. Thus any distances measured from the picture need to be multiplied by 100 / 6. Choose the downward direction to be positive. Choose $y_0 = 0$ to be stem of the apple on the THIRD image from the top of the picture. It is the first picture in which the stem of the apple is visible. The velocity of the apple at that position is not 0, but it is not known either. Call it $v_0$. We will choose that the time at that point is $t = 0$, and we call the time interval from one picture to the next to be $T$. The acceleration of the apple is $a = g = 9.8\,\text{m/s}^2$.

The 3rd picture after the $t=0$ picture (the first one that is not overlapping with another image) has the stem 16.5 mm from the origin of coordinates, at a time of $t=3T$. The actual position would be found by

$$y_1=(16.5\,\text{mm})(100/6)=275\,\text{mm}=0.275\,\text{m}.$$

The 6th picture after the $t=0$ picture (the next to last one in the picture) has the stem 42 mm from the origin of coordinates, at a time of $t=6T$. The actual position would be found by

$$y_2=(42\,\text{mm})(100/6)=700\,\text{mm}=0.70\,\text{m}.$$

Now we have two sets of position-time data, relative to the origin. Both of those sets of position-time data must satisfy equation Eq. 2-11b.

$$\begin{aligned} y_1&=y_0+v_0t_1+\tfrac{1}{2}at_1^2 \;\rightarrow\; 0.275=3v_0T+\tfrac{1}{2}g(3T)^2 \\ y_2&=y_0+v_0t_2+\tfrac{1}{2}at_2^2 \;\rightarrow\; 0.70=6v_0T+\tfrac{1}{2}g(6T)^2 \end{aligned}$$

Multiply the first equation by 2, and then subtract it from the second equation to eliminate the dependence on $v_0$. The resulting equation can be solved for $T$.

$$\left.\begin{aligned} 0.55\,\text{m}&=6v_0T+9gT^2 \\ 0.70\,\text{m}&=6v_0T+18gT^2 \end{aligned}\right\} \rightarrow 0.15\,\text{m}=9gT^2 \rightarrow T=\sqrt{\frac{0.15\,\text{m}}{9(9.8\,\text{m/s}^2)}}=\boxed{4.1\times10^{-2}\,\text{s}}$$

This is equivalent to $\dfrac{1\,\text{flash}}{T}=\dfrac{1\,\text{flash}}{4.1\times10^{-2}\,\text{s}}=\boxed{24\,\text{flashes per second}}$.

44. Choose downward to be the positive direction, and $y_0=0$ to be the height from which the stone is dropped. Call the location of the top of the window $y_w$, and the time for the stone to fall from release to the top of the window is $t_w$. Since the stone is dropped from rest, using Eq. 2-11b with *y* substituting for *x*, we have $y_w=y_0+v_0t+\tfrac{1}{2}at^2=0+0+\tfrac{1}{2}gt_w^2$. The location of the bottom of the window is $y_w+2.2\,\text{m}$, and the time for the stone to fall from release to the bottom of the window is $t_w+0.28\,\text{s}$. Since the stone is dropped from rest, using Eq. 2-11b, we have $y_w+2.2\,\text{m}=y_0+v_0+\tfrac{1}{2}at^2=0+0+\tfrac{1}{2}g(t_w+0.28\,\text{s})^2$. Substituting the first expression for $y_w$ into the second one.

$$\tfrac{1}{2}gt_w^2+2.2\,\text{m}=\tfrac{1}{2}g(t_w+0.28\,\text{s})^2 \rightarrow t_w=0.662\,\text{s}$$

Use this time in the first equation.

$$y_w=\tfrac{1}{2}gt_w^2=\tfrac{1}{2}(9.8\,\text{m/s}^2)(0.662\,\text{s})^2=\boxed{2.1\,\text{m}}.$$

45. For the falling rock, choose downward to be the positive direction, and $y_0=0$ to be the height from which the stone is dropped. The initial velocity is $v_0=0\,\text{m/s}$, the acceleration is $a=g$, the

displacement is $y=H$, and the time of fall is $t_1$. Using Eq. 2-11b with *y* substituting for *x*, we have $H=y_0+v_0t+\frac{1}{2}t^2=0+0+\frac{1}{2}gt_1^2$.

For the sound wave, use the constant speed equation that $v_s=\frac{d}{\Delta t}=\frac{H}{T-t_1}$, which can be rearranged

to give $t_1=T-\frac{H}{v_s}$, where $T=3.2\text{ s}$ is the total time elapsed from dropping the rock to hearing the sound. Insert this expression for $t_1$ into the equation for *H*, and solve for *H*.

$$H=\tfrac{1}{2}g\left(T-\frac{H}{v_s}\right)^2 \rightarrow \frac{g}{2v_s^2}H^2-\left(\frac{gT}{v_s}+1\right)H+\tfrac{1}{2}gT^2=0 \rightarrow$$
$$4.239\times10^{-5}H^2-1.092H+50.18=0 \rightarrow H=46.0\text{ m}, 2.57\times10^4\text{ m}$$

If the larger answer is used in $t_1=T-\frac{H}{v_s}$, a negative time of fall results, and so the physically correct answer is $\boxed{H=46\text{ m}}$.

46. Choose upward to be the positive direction, and $y_0=0$ to be the location of the nozzle. The initial velocity is $v_0$, the acceleration is $a=-9.8\text{ m/s}^2$, the final location is $y=-1.5\text{ m}$, and the time of flight is $t=2.0\text{ s}$. Using Eq. 2-11b and substituting *y* for *x* gives the following.

$$y=y_0+v_0t+\tfrac{1}{2}at^2 \rightarrow v_0=\frac{y-\frac{1}{2}at^2}{t}=\frac{-1.5\text{ m}-\frac{1}{2}\left(-9.8\text{ m/s}^2\right)(2.0\text{ s})^2}{2.0\text{ s}}=\boxed{9.1\text{ m/s}}$$

$\boxed{47.}$ Choose downward to be the positive direction, and $y_0=0$ to be at the top of the cliff. The initial velocity is $v_0=-12.0\text{ m/s}$, the acceleration is $a=9.80\text{ m/s}^2$, and the final location is $y=70.0\text{ m}$.

(*a*) Using Eq. 2-11b and substituting *y* for *x*, we have

$$y=y_0+v_0t+\tfrac{1}{2}at^2 \rightarrow \left(4.9\text{ m/s}^2\right)t^2-(12.0\text{ m/s})t-70\text{ m}=0 \rightarrow t=-2.749\text{ s}, 5.198\text{ s}.$$

The positive answer is the physical answer: $\boxed{t=5.20\text{ s}}$.

(*b*) Using Eq. 2-11a, we have $v=v_0+at=-12.0\text{ m/s}+\left(9.80\text{ m/s}^2\right)(5.198\text{ s})=\boxed{38.9\text{ m/s}}$.

(*c*) The total distance traveled will be the distance up plus the distance down. The distance down will be 70 m more than the distance up. To find the distance up, use the fact that the speed at the top of the path will be 0. Then using Eq. 2-11c:

$$v^2=v_0^2+2a(y-y_0) \rightarrow y=y_0+\frac{v^2-v_0^2}{2a}=0+\frac{0-(-12.0\text{ m/s})^2}{2\left(9.80\text{ m/s}^2\right)}=-7.35\text{ m}.$$

Thus the distance up is 7.35 m, the distance down is 77.35 m, and the total distance traveled is $\boxed{84.7\text{ m}}$.

48. Choose upward to be the positive direction, and $y_0 = 0$ to be the level from which the ball was thrown. The initial velocity is $v_0$, the instantaneous velocity is $v = 13\,\text{m/s}$, the acceleration is $a = -9.80\,\text{m/s}^2$, and the location of the window is $y = 28\,\text{m}$.

(*a*) Using Eq. 2-11c and substituting *y* for *x*, we have

$$v^2 = v_0^2 + 2a(y - y_0) \;\rightarrow$$
$$v_0 = \pm\sqrt{v^2 - 2a(y - y_0)} = \pm\sqrt{(13\,\text{m/s})^2 - 2(-9.8\,\text{m/s}^2)(28\,\text{m})} = \boxed{27\,\text{m/s}}$$

Choose the positive value because the initial direction is upward.

(*b*) At the top of its path, the velocity will be 0, and so we can use the initial velocity as found above, along with Eq. 2-11c.

$$v^2 = v_0^2 + 2a(y - y_0) \;\rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (27\,\text{m/s})^2}{2(-9.8\,\text{m/s}^2)} = \boxed{37\,\text{m}}$$

(*c*) We want the time elapsed from throwing (speed $v_0 = 27\,\text{m/s}$) to reaching the window (speed $v = 13\,\text{m/s}$). Using Eq. 2-11a, we have:

$$v = v_0 + at \;\rightarrow t = \frac{v - v_0}{a} = \frac{13\,\text{m/s} - 27\,\text{m/s}}{-9.80\,\text{m/s}^2} = \boxed{1.4\,\text{s}}.$$

(*d*) We want the time elapsed from the window (speed $v_0 = 13\,\text{m/s}$) to reaching the street (speed $v = -27\,\text{m/s}$). Using Eq. 2-11a, we have:

$$v = v_0 + at \;\rightarrow t = \frac{v - v_0}{a} = \frac{-27\,\text{m/s} - 13\,\text{m/s}}{-9.80\,\text{m/s}^2} = \boxed{4.1\,\text{s}}.$$

49. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The greatest velocity is found at the highest point on the graph, which is at $\boxed{t \approx 48\,\text{s}}$.

(*b*) The indication of a constant velocity on a velocity-time graph is a slope of 0, which occurs from

$\boxed{t = 90\,\text{s to } t \approx 108\,\text{s}}$.

(*c*) The indication of a constant acceleration on a velocity-time graph is a constant slope, which occurs from $\boxed{t = 0\,\text{s to } t \approx 38\,\text{s}}$, again from $\boxed{t \approx 65\,\text{s to } t \approx 83\,\text{s}}$, and again from $\boxed{t = 90\,\text{s to } t \approx 108\,\text{s}}$.

(*d*) The magnitude of the acceleration is greatest when the magnitude of the slope is greatest, which occurs from $\boxed{t \approx 65\,\text{s to } t \approx 83\,\text{s}}$.

50. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The instantaneous velocity is given by the slope of the tangent line to the curve. At $t = 10.0\,\text{s}$,

the slope is approximately $v(10) \approx \frac{3\,\text{m} - 0}{10.0\,\text{s} - 0} = \boxed{0.3\,\text{m/s}}$.

(*b*) At $t = 30.0\,\text{s}$, the slope of the tangent line to the curve, and thus the instantaneous velocity, is

approximately $v(30) \approx \frac{22\,\text{m} - 8\,\text{m}}{35\,\text{s} - 25\,\text{s}} = \boxed{1.4\,\text{m/s}}$.

(*c*) The average velocity is given by $\bar{v} = \frac{x(5)\,\text{m} - x(0)\,\text{m}}{5.0\,\text{s} - 0\,\text{s}} = \frac{1.5\,\text{m} - 0}{5.0\,\text{s}} = \boxed{.30\,\text{m/s}}$.

(*d*) The average velocity is given by $\bar{v} = \frac{x(30)\,\text{m} - x(25)\,\text{m}}{30.0\,\text{s} - 25.0\,\text{s}} = \frac{16\,\text{m} - 9\,\text{m}}{5.0\,\text{s}} = \boxed{1.4\,\text{m/s}}$.

(*e*) The average velocity is given by $\bar{v} = \frac{x(50)\,\text{m} - x(40)\,\text{m}}{50.0\,\text{s} - 40.0\,\text{s}} = \frac{10\,\text{m} - 19.5\,\text{m}}{10.0\,\text{s}} = \boxed{-0.95\,\text{m/s}}$.

51. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The indication of a constant velocity on a position-time graph is a constant slope, which occurs

from $\boxed{t = 0\,\text{s to } t \approx 18\,\text{s}}$.

(*b*) The greatest velocity will occur when the slope is the highest positive value, which occurs at

about $\boxed{t = 27\,\text{s}}$.

(*c*) The indication of a 0 velocity on a position-time graph is a slope of 0, which occurs at about

from $\boxed{t = 38\,\text{s}}$.

(*d*) $\boxed{\text{The object moves in both directions.}}$ When the slope is positive, from $t = 0\,\text{s}$ to $t = 38\,\text{s}$,

the object is moving in the positive direction. When the slope is negative, from $t = 38\,\text{s}$ to $t = 50\,\text{s}$, the object is moving in the negative direction.

52. Slightly different answers may be obtained since the data comes from reading the graph. We assume

that the short, nearly horizontal portions of the graph are the times that shifting is occurring, and those times are not counted as being "in" a certain gear.

($a$) The average acceleration in 2nd gear is given by $a_2 = \frac{\Delta v_2}{\Delta t_2} = \frac{24\,\text{m/s} - 14\,\text{m/s}}{8\,\text{s} - 4\,\text{s}} = \boxed{2.5\,\text{m/s}^2}$.

The average acceleration in 4th gear is given by $a_4 = \frac{\Delta v_4}{\Delta t_4} = \frac{44\,\text{m/s} - 37\,\text{m/s}}{27\,\text{s} - 16\,\text{s}} = \boxed{0.64\,\text{m/s}^2}$.

($b$) The distance traveled can be determined from a velocity-time graph by calculating the area between the graph and the $v = 0$ axis, bounded by the times under consideration. For this case, we will approximate the area as a rectangle.

$$\text{height} = \bar{v} = \frac{v_f + v_0}{2} = \frac{44\,\text{m/s} + 37\,\text{m/s}}{2} = 40.5\,\text{m/s} \qquad \text{width} = \Delta t = 27\,\text{s} - 16\,\text{s} = 11\,\text{s}$$

Thus the distance traveled is $d = \bar{v}\Delta t = (40.5\,\text{m/s})(11\,\text{s}) = \boxed{450\,\text{m}}$.

53. Slightly different answers may be obtained since the data comes from reading the graph. We assume that the short, nearly horizontal portions of the graph are the times that shifting is occurring, and those times are not counted as being "in" a certain gear.

($a$) The average acceleration in first gear is given by $a = \frac{\Delta v}{\Delta t} = \frac{14\,\text{m/s} - 0\,\text{m/s}}{4\,\text{s} - 0\,\text{s}} = \boxed{4\,\text{m/s}^2}$.

($b$) The average acceleration in third gear is given by $a = \frac{\Delta v}{\Delta t} = \frac{37\,\text{m/s} - 24\,\text{m/s}}{14\,\text{s} - 9\,\text{s}} = \boxed{3\,\text{m/s}^2}$.

($c$) The average acceleration in fifth gear is given by $a = \frac{\Delta v}{\Delta t} = \frac{52\,\text{m/s} - 44\,\text{m/s}}{50\,\text{s} - 27\,\text{s}} = \boxed{0.35\,\text{m/s}^2}$.

($d$) The average acceleration through the first four gears is given by

$$a = \frac{\Delta v}{\Delta t} = \frac{44\,\text{m/s} - 0\,\text{m/s}}{27\,\text{s} - 0\,\text{s}} = \boxed{1.6\,\text{m/s}^2}.$$

54. Slightly different answers may be obtained since the data comes from reading the graph.

($a$) To estimate the distance the object traveled during the first minute, we need to find the area under the graph, from $t$ = 0 s to $t$ = 60 s. Each "block" of the graph represents an "area" of $\Delta x = (10\,\text{m/s})(10\,\text{s}) = 100\,\text{m}$. By counting and estimating, there are about 17.5 blocks under the 1st minute of the graph, and so the distance traveled during the 1st minute is about $\boxed{1750\,\text{m}}$.

($b$) For the second minute, there are about 5 blocks under the graph, and so the distance traveled during the second minute is about $\boxed{500\,\text{m}}$.

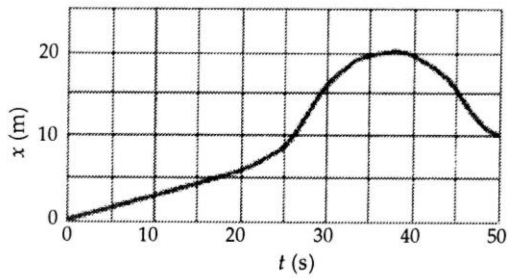
Alternatively, average accelerations can be estimated for various portions of the graph, and then the uniform acceleration equations may be applied. For instance, for part (*a*), break the motion up into two segments, from 0 to 50 seconds and then from 50 to 60 seconds.

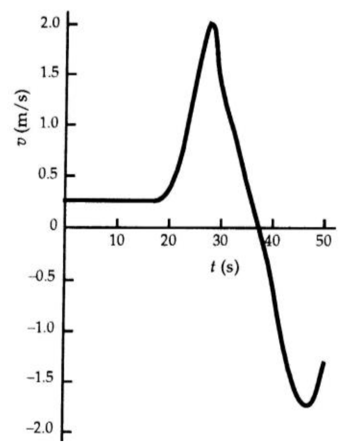
(*a*) t = 0 to 50: $a_1 = \frac{\Delta v}{\Delta t} = \frac{38\,\text{m/s} - 14\,\text{m/s}}{50\,\text{s} - 0\,\text{s}} = 0.48\,\text{m/s}^2$

$$d_1 = v_{01}t_1 + \tfrac{1}{2}a_1t_1^2 = (14\,\text{m/s})(50\,\text{s}) + \tfrac{1}{2}(0.48\,\text{m/s}^2)(50\,\text{s})^2 = 1300\,\text{m}$$
$$a_2 = \frac{\Delta v}{\Delta t} = \frac{31\,\text{m/s} - 38\,\text{m/s}}{60\,\text{s} - 50\,\text{s}} = -0.70\,\text{m/s}^2$$
$$d_2 = v_{02}t_2 + \tfrac{1}{2}a_2t_2^2 = (38\,\text{m/s})(10\,\text{s}) + \tfrac{1}{2}(-0.70\,\text{m/s}^2)(10\,\text{s})^2 = 345\,\text{m}$$
$$d_1 + d_2 = 1645\,\text{m}$$

55. The *v* vs. *t* graph is found by taking the slope of the *x* vs. *t* graph.

Both graphs are shown here.




56. (*a*) During the interval from A to B, it is **moving in the negative direction**, because its displacement is negative.

(*b*) During the interval from A to B, it is **speeding up**, because the magnitude of its slope is increasing (changing from less steep to more steep).

(*c*) During the interval from A to B, **the acceleration is negative**, because the graph is concave downward, indicating that the slope is getting more negative, and thus the acceleration is negative.

(*d*) During the interval from D to E, it is $\boxed{\text{moving in the positive direction}}$, because the displacement is positive.

(*e*) During the interval from D to E, it is $\boxed{\text{speeding up}}$, because the magnitude of its slope is increasing (changing from less steep to more steep).

(*f*) During the interval from D to E, $\boxed{\text{the acceleration is positive}}$, because the graph is concave upward, indicating the slope is getting more positive, and thus the acceleration is positive.

(*g*) During the interval from C to D, $\boxed{\text{the object is not moving in either direction}}$.

$\boxed{\text{The velocity and acceleration are both 0.}}$

57. (*a*) For the free-falling part of the motion, choose downward to be the positive direction, and $y_0 = 0$ to be the height from which the person jumped. The initial velocity is $v_0 = 0$, acceleration is $a = 9.80\,\text{m/s}^2$, and the location of the net is $y = 15.0\,\text{m}$. Find the speed upon reaching the net from Eq. (2-11c) with *x* replaced by *y.*

$$v^2 = v_0^2 + 2a(y - y_{()}) \rightarrow v = \pm\sqrt{0 + 2a(y-0)} = \pm\sqrt{2(9.80\,\text{m/s}^2)(15.0\,\text{m})} = 17.1\,\text{m/s}$$

The positive root is selected since the person is moving downward.

For the net-stretching part of the motion, choose downward to be the positive direction, and $y_0 = 15.0\,\text{m}$ to be the height at which the person first contacts the net. The initial velocity is $v_0 = 17.1\,\text{m/s}$, the final velocity is $v = 0$, and the location at the stretched position is $y = 16.0\,\text{m}$. Find the acceleration from Eq. (2-11c) with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow a = \frac{v^2 - v_0^2}{2(y - y_0)} = \frac{0^2 - (17.1\,\text{m/s})^2}{2(1.0\,\text{m})} = \boxed{-150\,\text{m/s}^2}$$

(*b*) For the acceleration to be smaller, in the above equation we see that the displacement would have to be larger. This means that the net should be $\boxed{\text{"loosened"}}$.

58. Choose the upward direction to be positive, and $y_0 = 0$ to be the level from which the object was thrown. The initial velocity is $v_0$ and the velocity at the top of the path is $v = 0\,\text{m/s}$. The height at the top of the path can be found from Eq. (2-11c) with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow y - y_0 = \frac{-v_0^2}{2a}.$$

From this we see that the displacement is inversely proportional to the acceleration, and so if the acceleration is reduced by a factor of 6 by going to the Moon, and the initial velocity is unchanged, the $\boxed{\text{displacement increases by a factor of 6}}$.

59. The initial velocity of the car is $v_0 = (100\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 27.8\,\text{m/s}$. Choose $x_0 = 0$ to be location at which the deceleration begins. We have $v = 0\,\text{m/s}$ and $a = -30g = -294\,\text{m/s}^2$. Find the displacement from Eq. (2-11c).

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow x = x_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (27.8\,\text{m/s})^2}{2(-2.94\times10^2\,\text{m/s}^2)} = 1.31\,\text{m} \approx \boxed{1.3\,\text{m}}$$

60. Choose downward to be the positive direction, and $y_0 = 0$ to be at the height of the bridge. Agent Bond has an initial velocity of $v_0 = 0$, an acceleration of $a = g$, and will have a displacement of $y = 12\,\text{m} - 1.5\,\text{m} = 10.5\,\text{m}$. Find the time of fall from Eq. 2-11b with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \rightarrow t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(10.5\,\text{m})}{9.80\,\text{m/s}^2}} = 1.464\,\text{s}$$

If the truck is approaching with $v = 25\,\text{m/s}$, then he needs to jump when the truck is a distance away given by $d = vt = (25\,\text{m/s})(1.464\,\text{s}) = 36.6\,\text{m}$. Convert this distance into "poles".

$$d = (36.60\,\text{m})(1\,\text{pole}/25\,\text{m}) = 1.46\,\text{poles}$$

So he should jump when the truck is about $\boxed{1.5\,\text{poles}}$ away from the bridge.

61. (*a*) Choose downward to be the positive direction, and $y_0 = 0$ to be the level from which the car was dropped. The initial velocity is $v_0 = 0$, the final location is $y = H$, and the acceleration is $a = g$. Find the final velocity from Eq. 2-11c, replacing *x* with *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow v = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{2gH}.$$

The speed is the magnitude of the velocity, $\boxed{v = \sqrt{2gH}}$.

(*b*) Solving the above equation for the height, we have that $H = \frac{v^2}{2g}$. Thus for a collision of

$$v = (60\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 16.67\,\text{m/s},$$ the corresponding height is:

$$H = \frac{v^2}{2g} = \frac{(16.67\,\text{m/s})^2}{2(9.80\,\text{m/s}^2)} = 14.17\,\text{m} \approx \boxed{14\,\text{m}}.$$

(*c*) For a collision of $v=(100\text{km/h})\left(\frac{1\text{m/s}}{3.6\text{km/h}}\right)=27.78\text{m/s}$, the corresponding height is:

$$H=\frac{v^2}{2g}=\frac{(27.78\text{m/s})^2}{2(9.80\text{m/s}^2)}=39.37\text{m}\approx\boxed{39\text{m}}.$$

62. The average speed is the distance divided by the time.

$$v=\frac{d}{t}=\left(\frac{1\times10^9\text{ km}}{1\text{y}}\right)\left(\frac{1\text{y}}{365\text{d}}\right)\left(\frac{1\text{d}}{24\text{h}}\right)=1.142\times10^5\text{ km/h}\approx\boxed{1\times10^5\text{ km/h}}$$

63. Use the information for the first 180 m to find the acceleration, and the information for the full motion to find the final velocity. For the first segment, the train has $v_0=0\text{m/s}$, $v_1=25\text{m/s}$, and a displacement of $x_1-x_0=180\text{m}$. Find the acceleration from Eq. 2-11c.

$$v_1^2=v_0^2+2a(x_1-x_0)\ \rightarrow a=\frac{v_1^2-v_0^2}{2(x_1-x_0)}=\frac{(25\text{m/s})^2-0}{2(180\text{m})}=1.736\text{m/s}^2$$

Find the speed of the train after it has traveled the total distance (total displacement of $x_2-x_0=275\text{m}$) using Eq. 2-11c.

$$v_2^2=v_0^2+2a(x_2-x_0)\ \rightarrow v_2=\sqrt{v_0^2+2a(x_2-x_0)}=\sqrt{2(1.736\text{m/s}^2)(275\text{m})}=\boxed{31\text{m/s}}.$$

64. For the motion in the air, choose downward to be the positive direction, and $y_0=0$ to be at the height of the diving board. Then diver has $v_0=0$, (assuming the diver does not jump upward or downward), $a=g=9.8\text{m/s}^2$, and $y=4.0\text{m}$ when reaching the surface of the water. Find the diver's speed at the water's surface from Eq. 2-11c, with *x* replaced by *y*.

$$v^2=v_0^2+2a(y-y_0)x\ \rightarrow v=\pm\sqrt{v_0^2+2a(y-y_0)}=\sqrt{0+2(9.8\text{m/s}^2)(4.0\text{m})}=8.85\text{m/s}$$

For the motion in the water, again choose down to be positive, but redefine $y_0=0$ to be at the surface of the water. For this motion, $v_0=8.85\text{m/s}$, $v=0$, and $y-y_0=2.0\text{m}$. Find the acceleration from Eq. 2-11c, with *x* replaced by *y*.

$$v^2=v_0^2+2a(y-y_0)\ \rightarrow a=\frac{v^2-v_0^2}{2(y-y_0)x}=\frac{0-(8.85\text{m/s})^2}{2(2.0\text{m})}=-19.6\text{m/s}^2\approx\boxed{-20\text{m/s}^2}$$

The negative sign indicates that the acceleration is directed upwards.

65. This problem can be analyzed as a series of three one-dimensional motions: the acceleration phase, the constant speed phase, and the deceleration phase. The maximum speed of the train is:

$$(90\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right)=25\,\text{m/s}.$$

In the acceleration phase, the initial velocity is $v_0=0\,\text{m/s}$, the acceleration is $a=1.1\,\text{m/s}^2$, and the final velocity is $v=25\,\text{m/s}$. Find the elapsed time for the acceleration phase from Eq. 2-11a.

$$v=v_0+at \;\rightarrow\; t_{\text{acc}}=\frac{v-v_0}{a}=\frac{25\,\text{m/s}-0}{1.1\,\text{m/s}^2}=22.73\,\text{s}.$$

Find the displacement during the acceleration phase from Eq. 2-11b.

$$(x-x_0)_{\text{acc}}=v_0t+\tfrac{1}{2}at^2=0+\tfrac{1}{2}\left(1.1\,\text{m/s}^2\right)(22.73\,\text{s})^2=284\,\text{m}.$$

In the deceleration phase, the initial velocity is $v_0=25\,\text{m/s}$, the acceleration is $a=-2.0\,\text{m/s}^2$, and the final velocity is $v=0\,\text{m/s}$. Find the elapsed time for the deceleration phase from equation Eq. 2-11a.

$$v=v_0+at \;\rightarrow\; t_{\text{dec}}=\frac{v-v_0}{a}=\frac{0-25\,\text{m/s}}{-2.0\,\text{m/s}^2}=12.5\,\text{s}.$$

Find the distance traveled during the deceleration phase from Eq. 2-11b.

$$(x-x_0)_{\text{dec}}=v_0t+\tfrac{1}{2}at^2=(25\,\text{m/s})(12.5\,\text{s})+\tfrac{1}{2}\left(-2.0\,\text{m/s}^2\right)(12.5\,\text{s})^2=156\,\text{m}.$$

The total elapsed time and distance traveled for the acceleration / deceleration phases are:

$$t_{\text{acc}}+t_{\text{dec}}=22.7\,\text{s}+12.5\,\text{s}=35.2\,\text{s}$$
$$(x-x_0)_{\text{acc}}+(x-x_0)_{\text{dec}}=284\,\text{m}+156\,\text{m}=440\,\text{m}$$

(*a*) If the stations are spaced 1.80 km = 1800 m apart, then there is a total of $\frac{9000\,\text{m}}{1800\,\text{m}}=5$ inter-station segments. A train making the entire trip would thus have a total of 5 inter-station segments and 4 stops of 20 s each at the intermediate stations. Since 440 m is traveled during acceleration and deceleration, 1360 m of each segment is traveled at an average speed of $v=25\,\text{m/s}$. The time for that 1360 m is given by $d=vt \;\rightarrow\; t_{\substack{\text{constant}\\\text{speed}}}=\frac{d}{v}=\frac{1360\,\text{m}}{25\,\text{m/s}}=54.4\,\text{s}.$

Thus a total inter-station segment will take 35.2 s + 54.4 s = 89.6 s. With 5 inter-station segments of 89.6 s each, and 4 stops of 20 s each, the total time is given by:

$$t_{0.8\,\text{km}}=5(89.6\,\text{s})+4(20\,\text{s})=528\,\text{s}=\boxed{8.8\,\text{min}}.$$

(*b*) If the stations are spaced 3.0 km =3000 m apart, then there is a total of $\frac{9000\,\text{m}}{3000\,\text{m}}=3$ inter-station segments. A train making the entire trip would thus have a total of 3 inter-station segments and 2 stops of 20 s each at the intermediate stations. Since 440 m is traveled during acceleration and deceleration, 2560 m of each segment is traveled at an average speed of $v=25\,\text{m/s}$. The time for that 2560 m is given by $d=vt \;\rightarrow\; t=\frac{d}{v}=\frac{2560\,\text{m}}{25\,\text{m/s}}=102.4\,\text{s}.$

Thus a total inter-station segment will take 35.2 s + 102.4 s = 137.6 s. With 3 inter-station segments of 137.6 s each, and 2 stops of 20 s each, the total time is

$$t_{3.0\,\mathrm{km}} = 3(137.6\,\mathrm{s}) + 2(20\,\mathrm{s}) = 453\,\mathrm{s} = \boxed{7.5\,\mathrm{min}}.$$

66. Choose downward to be the positive direction, and $y_0 = 0$ to be at the start of the pelican's dive.

The pelican has an initial velocity is $v_0 = 0$ and an acceleration of $a = g$, and a final location of $y = 16.0\,\mathrm{m}$. Find the total time of the pelican's dive from Eq. 2-11b, with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \rightarrow y = 0 + 0 + \tfrac{1}{2}at^2 \rightarrow t_{\mathrm{dive}} = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(16.0\,\mathrm{m})}{9.80\,\mathrm{m/s^2}}} = 1.81\,\mathrm{s}.$$

The fish can take evasive action if he sees the pelican at a time of 1.81 s – 0.20 s = 1.61 s into the dive. Find the location of the pelican at that time from Eq. 2-11b.

$$y = y_0 + v_0 t + \tfrac{1}{2}at = 0 + 0 + \tfrac{1}{2}(9.80\,\mathrm{m/s^2})(1.61\,\mathrm{s})^2 = 12.7\,\mathrm{m}$$

Thus the fish must spot the pelican at a minimum height from the surface of the water of $16.0\,\mathrm{m} - 12.7\,\mathrm{m} = \boxed{3.3\,\mathrm{m}}$.

67. First consider the "uphill lie", in which the ball is being putted down the hill. Choose $x_0 = 0$ to be the ball's original location, and the direction of the ball's travel as the positive direction. The final velocity of the ball is $v = 0\,\mathrm{m/s}$, the acceleration of the ball is $a = -2.0\,\mathrm{m/s^2}$, and the displacement of the ball will be $x - x_0 = 6.0\,\mathrm{m}$ for the first case, and $x - x_0 = 8.0\,\mathrm{m}$ for the second case. Find the initial velocity of the ball from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow v_0 = \sqrt{v^2 - 2a(x - x_0)} = \begin{cases} \sqrt{0 - 2(-2.0\,\mathrm{m/s^2})(6.0\,\mathrm{m})} = 4.9\,\mathrm{m/s} \\ \sqrt{0 - 2(-2.0\,\mathrm{m/s^2})(8.0\,\mathrm{m})} = 5.7\,\mathrm{m/s} \end{cases}$$

The range of acceptable velocities for the uphill lie is $\boxed{4.9\,\mathrm{m/s} \text{ to } 5.7\,\mathrm{m/s}}$, with a spread of 0.8 m/s.

Now consider the "downhill lie", in which the ball is being putted up the hill. Use a very similar set-up for the problem, with the basic difference being that the acceleration of the ball is now $a = -3.0\,\mathrm{m/s^2}$. Find the initial velocity of the ball from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow v_0 = \sqrt{v^2 - 2a(x - x_0)} = \begin{cases} \sqrt{0 - 2(-3.0\,\mathrm{m/s^2})(6.0\,\mathrm{m})} = 6.0\,\mathrm{m/s} \\ \sqrt{0 - 2(-3.0\,\mathrm{m/s^2})(8.0\,\mathrm{m})} = 6.9\,\mathrm{m/s} \end{cases}$$

The range of acceptable velocities for the downhill lie is $\boxed{6.0\,\mathrm{m/s} \text{ to } 6.9\,\mathrm{m/s}}$, with a spread of 0.9 m/s.

Because the range of acceptable velocities is smaller for putting down the hill, more control in putting is necessary, and so the downhill putt is more difficult.

68. (*a*) The train's constant speed is $v_{\text{train}} = 6.0\,\text{m/s}$, and the location of the empty box car as a function of time is given by $x_{\text{train}} = v_{\text{train}}t = (6.0\,\text{m/s})t$. The fugitive has $v_0 = 0\,\text{m/s}$ and $a = 4.0\,\text{m/s}^2$ until his final speed is $8.0\,\text{m/s}$. The elapsed time during acceleration is $t_{\text{acc}} = \frac{v - v_0}{a} = \frac{8.0\,\text{m/s}}{4.0\,\text{m/s}^2} = 2.0\,\text{s}$. Let the origin be the location of the fugitive when he starts to run. The first possibility to consider is, "Can the fugitive catch the train before he reaches his maximum speed?" During the fugitive's acceleration, his location as a function of time is given by $x_{\text{fugitive}} = x_0 + v_0t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}\left(4.0\,\text{m/s}^2\right)t^2$. For him to catch the train, we must have $x_{\text{train}} = x_{\text{fugitive}} \rightarrow (6.0\,\text{m/s})t = \frac{1}{2}\left(4.0\,\text{m/s}^2\right)t^2$. The solutions of this are $t = 0\,\text{s}, 3\,\text{s}$. Thus the fugitive cannot catch the car during his 2.0 s of acceleration.

Now the equation of motion of the fugitive changes. After the 2.0 s acceleration, he runs with a constant speed of $8.0\,\text{m/s}$. Thus his location is now given (for times $t > 2\,\text{s}$) by the following.

$$x_{\text{fugitive}} = \tfrac{1}{2}\left(4.0\,\text{m/s}^2\right)(2.0\,\text{s})^2 + (8.0\,\text{m/s})(t - 2.0\,\text{s}) = (8.0\,\text{m/s})t - 8.0\,\text{m}.$$

So now, for the fugitive to catch the train, we again set the locations equal.

$$x_{\text{train}} = x_{\text{fugitive}} \rightarrow (6.0\,\text{m/s})t = (8.0\,\text{m/s})t - 8.0\,\text{m} \rightarrow t = \boxed{4.0\,\text{s}}$$

(*b*) The distance traveled to reach the box car is given by

$$x_{\text{fugitive}}(t = 4.0\,\text{s}) = (8.0\,\text{m/s})(4.0\,\text{s}) - 8.0\,\text{m} = \boxed{24\,\text{m}}.$$

69. Choose downward to be the positive direction, and $y_0 = 0$ to be at the roof from which the stones are dropped. The first stone has an initial velocity of $v_0 = 0$ and an acceleration of $a = g$. Eqs. 2-11a and 2-11b (with *x* replaced by *y*) give the velocity and location, respectively, of the first stone as a function of time.

$$v = v_0 + at \rightarrow v_1 = gt_1 \qquad y = y_0 + v_0t + \tfrac{1}{2}at^2 \rightarrow y_1 = \tfrac{1}{2}gt_1^2.$$

The second stone has the same initial conditions, but its elapsed time $t - 1.50\,\text{s}$, and so has velocity and location equations as follows.

$$v_2 = g(t_1 - 1.50\,\text{s}) \qquad y_2 = \tfrac{1}{2}g(t_1 - 1.50\,\text{s})^2$$

The second stone reaches a speed of $v_2 = 12.0\,\text{m/s}$ at a time given by

$$t_1 = 1.50\,\text{s} + \frac{v_2}{g} = 1.50\,\text{s} + \frac{12.0\,\text{m/s}}{9.80\,\text{m/s}^2} = 2.72\,\text{s}.$$

The location of the first stone at that time is

$$y_1 = \tfrac{1}{2}gt_1^2 = \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)(2.72\,\text{s})^2 = 36.4\,\text{m}.$$

The location of the second stone at that time is

$$y_2 = \tfrac{1}{2}g(t_1 - 1.50\,\text{s})^2 = \tfrac{1}{2}(9.80\,\text{m/s}^2)(2.72 - 1.50\,\text{s})^2 = 7.35\,\text{m}.$$

Thus the distance between the two stones is $y_1 - y_2 = 36.4\,\text{m} - 7.35\,\text{m} = \boxed{29.0\,\text{m}}$.

70. To find the average speed for the entire race, we must take the total distance divided by the total time. If one lap is a distance of $L$, then the total distance will be $10L$. The time elapsed at a given constant speed is given by $t = d/v$, so the time for the first 9 laps would be $t_1 = \dfrac{9L}{198.0\,\text{km/h}}$, and the time for the last lap would be $t_2 = L/v_2$, where $v_2$ is the average speed for the last lap. Write an expression for the average speed for the entire race, and then solve for $v_2$.

$$v = \frac{d_{\text{total}}}{t_1 + t_2} = \frac{10L}{\dfrac{9L}{198.0\,\text{km/h}} + \dfrac{L}{v_2}} = 200.0\,\text{km/h} \;\rightarrow$$

$$v_2 = \frac{1}{\dfrac{10}{200.0\,\text{km/h}} - \dfrac{9}{198.0\,\text{km/h}}} = \boxed{220.0\,\text{km/h}}$$

71. The initial velocity is $v_0 = (18\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 5.0\,\text{m/s}$. The final velocity is $v_0 = (75\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 20.83\,\text{m/s}$. The displacement is $x - x_0 = 4.0\,\text{km} = 4000\,\text{m}$. Find the average acceleration from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(20.83\,\text{m/s})^2 - (5.0\,\text{m/s})^2}{2(4000\,\text{m})} = \boxed{5.1\times10^{-2}\,\text{m/s}^2}$$

72. Assume that $y_0 = 0$ for each child is the level at which the child loses contact with the trampoline surface. Choose upward to be the positive direction.

(*a*) The second child has $v_{02} = 5.0\,\text{m/s}$, $a = -g = -9.8\,\text{m/s}^2$, and $v = 0\,\text{m/s}$ at the maximum height position. Find the child's maximum height from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 = v_{02}^2 + 2a(y_2 - y_0) \;\rightarrow\; y_2 = y_0 + \frac{v^2 - v_{02}^2}{2a} = 0 + \frac{0 - (5.0\,\text{m/s})^2}{2(-9.8\,\text{m/s}^2)} = 1.276\,\text{m} \approx \boxed{1.3\,\text{m}}$$

(*b*) Since the first child can bounce up to one-and-a-half times higher than the second child, the first child can bounce up to a height of $1.5(1.276\,\text{m}) = 1.913\,\text{m} = y_1 - y_0$. Eq. 2-11c is again used to find the initial speed of the first child.

$$v^2 = v_{01}^2 + 2a(y_1 - y_0) \rightarrow$$
$$v_{01} = \pm\sqrt{v^2 - 2a(y_1 - y_0)} = \sqrt{0 - 2(-9.8\,\mathrm{m/s^2})(1.913\,\mathrm{m})} = 6.124\,\mathrm{m/s} \approx \boxed{6.1\,\mathrm{m/s}}$$

The positive root was chosen since the child was initially moving upward.

(*c*) To find the time that the first child was in the air, use Eq. 2-11b with a total displacement of 0, since the child returns to the original position.

$$y = y_0 + v_{01}t_1 + \tfrac{1}{2}at_1^2 \rightarrow 0 = (6.124\,\mathrm{m/s})t_1 + \tfrac{1}{2}(-9.8\,\mathrm{m/s^2})t_1^2 \rightarrow t_1 = 0\,\mathrm{s},\ 1.2497\,\mathrm{s}$$

The time of 0 s corresponds to the time the child started the jump, so the correct answer is $\boxed{1.2\,\mathrm{s}}$.

73. For the car to pass the train, the car must travel the length of the train AND the distance the train travels. The distance the car travels can thus be written as either $d_{car} = v_{car}t = (95\,\mathrm{km/h})t$ or $d_{car} = L_{train} + v_{train}t = 1.10\,\mathrm{km} + (75\,\mathrm{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

$$(95\,\mathrm{km/h})t = 1.10\,\mathrm{km} + (75\,\mathrm{km/h})t \rightarrow t = \frac{1.10\,\mathrm{km}}{20\,\mathrm{km/h}} = 0.055\,\mathrm{h} = \boxed{3.3\,\mathrm{min}}$$

The distance the car travels during this time is $d = (95\,\mathrm{km/h})(0.055\,\mathrm{h}) = 5.225\,\mathrm{km} \approx \boxed{5.2\,\mathrm{km}}$.

If the train is traveling the opposite direction from the car, then the car must travel the length of the train MINUS the distance the train travels. Thus the distance the car travels can be written as either $d_{car} = (95\,\mathrm{km/h})t$ or $d_{car} = 1.10\,\mathrm{km} - (75\,\mathrm{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

$$(95\,\mathrm{km/h})t = 1.10\,\mathrm{km} - (75\,\mathrm{km/h})t \rightarrow t = \frac{1.10\,\mathrm{km}}{170\,\mathrm{km/h}} = 6.47\times10^{-3}\,\mathrm{h} = \boxed{23.3\,\mathrm{s}}$$

The distance the car travels during this time is $d = (95\,\mathrm{km/h})(6.47\times10^{-3}\,\mathrm{h}) = \boxed{0.61\,\mathrm{km}}$.

74. For the baseball, $v_0 = 0$, $x - x_0 = 3.5\,\mathrm{m}$, and the final speed of the baseball (during the throwing motion ) is $v = 44\,\mathrm{m/s}$. The acceleration is found from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(44\,\mathrm{m/s})^2 - 0}{2(3.5\,\mathrm{m})} = \boxed{280\,\mathrm{m/s^2}}$$

75. (*a*) Choose upward to be the positive direction, and $y_0 = 0$ at the ground. The rocket has $v_0 = 0$, $a = 3.2\,\mathrm{m/s^2}$, and $y = 1200\,\mathrm{m}$ when it runs out of fuel. Find the velocity of the rocket when it runs out of fuel from Eq 2-11c, with *x* replaced by *y*.

$$v_{1200\,m}^2 = v_0^2 + 2a(y - y_0) \rightarrow$$
$$v_{1200\,m} = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{0 + 2(3.2\,m/s^2)(1200\,m)} = 87.64\,m/s \approx \boxed{88\,m/s}$$

The positive root is chosen since the rocket is moving upwards when it runs out of fuel.

(*b*) The time to reach the 1200 m location can be found from equation (2-11a).

$$v_{1200\,m} = v_0 + at_{1200\,m} \rightarrow t_{1200\,m} = \frac{v_{1200\,m} - v_0}{a} = \frac{87.64\,m/s - 0}{3.2\,m/s^2} = 27.39\,s \approx \boxed{27\,s}$$

(*c*) For this part of the problem, the rocket will have an initial velocity $v_0 = 87.64\,m/s$, an acceleration of $a = -9.8\,m/s^2$, and a final velocity of $v = 0$ at its maximum altitude. The altitude reached from the out-of-fuel point can be found from equation (2-11c).

$$v^2 = v_{1200\,m}^2 + 2a(y - 1200\,m) \rightarrow$$
$$y_{max} = 1200\,m + \frac{0 - v_{1200\,m}^2}{2a} = 1200\,m + \frac{-(87.64\,m/s)^2}{2(-9.8\,m/s^2)} = 1200\,m + 390\,m = \boxed{1590\,m}$$

(*d*) The time for the "coasting" portion of the flight can be found from Eq. 2-11a.

$$v = v_{1200\,m} + at_{coast} \rightarrow t_{coast} = \frac{v - v_0}{a} = \frac{0 - 87.64\,m/s}{-9.8\,m/s^2} = 8.94\,s$$

Thus the total time to reach the maximum altitude is $t = 27\,s + 8.94\,s \approx \boxed{36\,s}$.

(*e*) For this part of the problem, the rocket has $v_0 = 0\,m/s$, $a = -9.8\,m/s^2$, and a displacement of $-1600\,m$ (it falls from a height of 1600 m to the ground). Find the velocity upon reaching the Earth from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow$$
$$v = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{0 + 2(-9.80\,m/s^2)(-1600\,m)} = \boxed{-177\,m/s}$$

The negative root was chosen because the rocket is moving downward, which is the negative direction.

(*f*) The time for the rocket to fall back to the Earth is found from Eq. 2-11a.

$$v = v_0 + at \rightarrow t_{fall} = \frac{v - v_0}{a} = \frac{-177\,m/s - 0}{-9.80\,m/s^2} = 18.1\,s$$

Thus the total time for the entire flight is $t = 36\,s + 18.1\,s = \boxed{54\,s}$.

76. The speed limit is $50\,km/h\left(\frac{1\,m/s}{3.6\,km/h}\right) = 13.89\,m/s$.

(*a*) For your motion, you would need to travel $(10 + 15 + 50 + 15 + 70)\,m = 160\,m$ to get through the third light. The time to travel the 160 m is found using the distance and the constant speed.

$$d=vt \;\rightarrow\; t=\frac{d}{v}=\frac{160\,\mathrm{m}}{13.89\,\mathrm{m/s}}=11.52\,\mathrm{s}$$

$\boxed{\text{Yes}}$, you can make it through all three lights without stopping.

(*b*) The second car needs to travel 150 m before the third light turns red. This car accelerates from $v_0=0\,\mathrm{m/s}$ to a maximum of $v=13.89\,\mathrm{m/s}$ with $a=2.0\,\mathrm{m/s^2}$. Use Eq. 2-11a to determine the duration of that acceleration.

$$v=v_0+at \;\rightarrow\; t_{acc}=\frac{v-v_0}{a}=\frac{13.89\,\mathrm{m/s}-0\,\mathrm{m/s}}{2.0\,\mathrm{m/s^2}}=6.94\,\mathrm{s}$$

The distance traveled during that time is found from Eq. 2-11b.

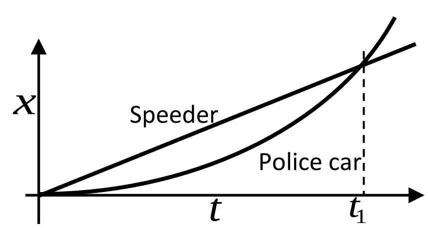
$$\left(x-x_0\right)_{acc}=v_0t_{acc}+\tfrac{1}{2}at_{acc}^2=0+\tfrac{1}{2}\left(2.0\,\mathrm{m/s^2}\right)\left(6.94\,\mathrm{s}\right)^2=48.2\,\mathrm{m}.$$

Since 6.94 sec have elapsed, there are 13 – 6.94 = 6.06 sec remaining to clear the intersection. The car travels another 6 seconds at a speed of 13.89 m/s, covering a distance of $d_{\substack{\text{constant}\\\text{speed}}}=vt=(13.89\,\mathrm{m/s})(6.06\,\mathrm{s})=84.2\,\mathrm{m}$. Thus the total distance is 48.2 m + 84.2 m = 132.4 m. $\boxed{\text{No}}$, the car cannot make it through all three lights without stopping.

77. Take the origin to be the location where the speeder passes the police car. The speeder's constant speed is $v_{speeder}=\left(120\,\mathrm{km/h}\right)\left(\frac{1\,\mathrm{m/s}}{3.6\,\mathrm{km/h}}\right)=33.3\,\mathrm{m/s}$, and the location of the speeder as a function of time is given by $x_{speeder}=v_{speeder}t_{speeder}=\left(33.3\,\mathrm{m/s}\right)t_{speeder}$. The police car has an initial velocity of $v_0=0\,\mathrm{m/s}$ and a constant acceleration of $a_{police}$. The location of the police car as a function of time is given by Eq. 2-11b.

$$x_{police}=v_0t+\tfrac{1}{2}at^2=\tfrac{1}{2}a_{police}t_{police}^2.$$

(*a*) The position vs. time graphs would qualitatively look like the graph shown here.




(*b*) The time to overtake the speeder occurs when the speeder has gone a distance of 750 m. The time is found using the speeder's equation from above.

$$750\,\mathrm{m}=\left(33.3\,\mathrm{m/s}\right)t_{speeder} \;\rightarrow\; t_{speeder}=\frac{750\,\mathrm{m}}{33.3\,\mathrm{m/s}}=22.5\,\mathrm{s}\approx\boxed{23\,\mathrm{s}}$$

(*c*) The police car's acceleration can be calculated knowing that the police car also had gone a distance of 750 m in a time of 22.5 s.

$$750\,\mathrm{m}=\tfrac{1}{2}a_p\left(22.5\,\mathrm{s}\right)^2 \;\rightarrow\; a_p=\frac{2\left(750\,\mathrm{m}\right)}{\left(22.5\,\mathrm{s}\right)^2}=2.96\,\mathrm{m/s^2}\approx\boxed{3.0\,\mathrm{m/s^2}}$$

(*d*) The speed of the police car at the overtaking point can be found from Eq. 2-11a.

$$v = v_0 + at = 0 + (2.96\ \mathrm{m/s^2})(22.5\ \mathrm{s}) = 66.67\ \mathrm{m/s} \approx \boxed{67\ \mathrm{m/s}}$$

Note that this is exactly twice the speed of the speeder.

78. Choose downward to be the positive direction, and the origin to be at the roof of the building from which the stones were dropped. The first stone has $y_0 = 0$, $v_0 = 0$, a final location of $y = H$ (as yet unknown), and $a = g$. If the time for the first stone to reach the ground is $t_1$, then Eq. 2-11c gives the following, replacing *x* with *y*:

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \ \rightarrow\ H = \tfrac{1}{2}(9.80\ \mathrm{m/s^2})t_1^2.$$

The second stone has $v_0 = 25.0\ \mathrm{m/s}$, $y_0 = 0$, a final location of $y = H$, and $a = g$. The time for the second stone to reach the ground is $t_1 - 2.00\ \mathrm{s}$, and so Eq. 2-11c for the second stone is

$$H = (25.0\ \mathrm{m/s})(t_1 - 2.00) + \tfrac{1}{2}(9.80\ \mathrm{m/s^2})(t_1 - 2.00)^2.$$

(*a*) Set the two expressions for $H$ equal to each other, and solve for $t_1$.

$$\tfrac{1}{2}(9.80\ \mathrm{m/s^2})t_1^2 = (25.0\ \mathrm{m/s})(t_1 - 2) + \tfrac{1}{2}(9.80\ \mathrm{m/s^2})(t_1 - 2)^2 \ \rightarrow\ t_1 = \boxed{5.63\ \mathrm{s}}$$

(*b*) The building height is given by $H = \tfrac{1}{2}gt_1^2 = \tfrac{1}{2}(9.80\ \mathrm{m/s^2})(5.63\ \mathrm{s})^2 = \boxed{155\ \mathrm{m}}$.

(*c*) The speed of the stones is found using Eq. 2-11a.

$$\#1:\ v = v_0 + at = gt_1 = (9.80\ \mathrm{m/s^2})(5.63\ \mathrm{s}) = \boxed{55.2\ \mathrm{m/s}}$$
$$\#2:\ v = v_0 + at = v_0 + g(t_1 - 2) = 25.0\ \mathrm{m/s} + (9.80\ \mathrm{m/s^2})(3.63\ \mathrm{s}) = \boxed{60.6\ \mathrm{m/s}}$$

79. Choose upward to be the positive direction, and the origin to be at ground level. The initial velocity of the first stone is $v_{0A} = 11.0\ \mathrm{m/s}$, and the acceleration of both stones is $a = -9.80\ \mathrm{m/s^2}$. The starting location is $y_{0A} = H_A$, and it takes 4.5 s for the stone to reach the final location $y = 0$. Use Eq. 2-11b (with *x* replaced by *y*) to find a value for $H_A$.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \ \rightarrow\ 0 = H_A + (11.0\ \mathrm{m/s})(4.5\ \mathrm{s}) - \tfrac{1}{2}(9.80\ \mathrm{m/s^2})(4.5\ \mathrm{s})^2 \ \rightarrow$$
$$H_A = 49.7\ \mathrm{m}$$

Assume that the 12th floor balcony is three times higher above the ground than the 4th floor balcony. Thus the height of 4th floor balcony is $\tfrac{1}{3}(49.7\ \mathrm{m}) = 16.6\ \mathrm{m}$. So for the second stone, $y_{0B} = 16.6\ \mathrm{m}$, and it takes 4.5 s for the stone to reach the final location $y = 0$. Use Eq. 2-11b to find the starting velocity, $v_{0B}$.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \ \rightarrow\ 0 = 16.6\ \mathrm{m} + v_{0B}(4.5\ \mathrm{s}) - \tfrac{1}{2}(9.80\ \mathrm{m/s^2})(4.5\ \mathrm{s})^2 \ \rightarrow$$
$$v_{0B} = \boxed{18\ \mathrm{m/s}}$$

80. Choose downward to be the positive direction, and the origin to be at the location of the plane. The parachutist has $v_0 = 0$, $a = g = 9.8\,\text{m/s}^2$, and will have $y - y_0 = 2850\,\text{m}$ when she pulls the ripcord. Eq. 2-11b, with *x* replaced by *y*, is used to find the time when she pulls the ripcord.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; t = \sqrt{2(y - y_0)/a} = \sqrt{2(2850\,\text{m})/(9.80\,\text{m/s}^2)} = \boxed{24.1\,\text{s}}$$

The speed is found from Eq. 2-11a.

$$v = v_0 + at = 0 + (9.80\,\text{m/s}^2)(24.1\,\text{s}) = 236\,\text{m/s} \cong \boxed{2.3\times10^2\,\text{m/s}} = 850\,\text{km/h}$$

81. The speed of the conveyor belt is given by $d = v\Delta t \rightarrow v = \dfrac{d}{\Delta t} = \dfrac{1.1\,\text{m}}{2.5\,\text{min}} = \boxed{0.44\,\text{m/min}}$. The rate of burger production, assuming the spacing given is center to center, can be found as $\left(\dfrac{1\,\text{burger}}{0.15\,\text{m}}\right)\left(\dfrac{0.44\,\text{m}}{1\,\text{min}}\right) = \boxed{2.9\,\dfrac{\text{burgers}}{\text{min}}}$.

82. Choose upward to be the positive direction, and the origin to be at the level where the ball was thrown. The velocity at the top of the ball's path will be $v = 0$, and the ball will have an acceleration of $a = -g$. If the maximum height that the ball reaches is $y = H$, then the relationship between the initial velocity and the maximum height can be found from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \;\rightarrow\; 0 = v_0^2 + 2(-g)H \;\rightarrow\; H = v_0^2/2g.$$

We are told that $v_{0\,\text{Bill}} = 1.5 v_{0\,\text{Joe}}$, so $\dfrac{H_{\text{Bill}}}{H_{\text{Joe}}} = \dfrac{(v_{0\,\text{Bill}})^2/2g}{(v_{0\,\text{Joe}})^2/2g} = \dfrac{(v_{0\,\text{Bill}})^2}{(v_{0\,\text{Joe}})^2} = 1.5^2 = 2.25 \approx \boxed{2.3}$.

83. As shown in problem 41, the speed with which the ball was thrown upward is the same as its speed on returning to the ground. From the symmetry of the two motions (both motions have speed = 0 at top, have same distance traveled and have same acceleration), the time for the ball to rise is 1.2 s. Choose upward to be the positive direction, and the origin to be at the level where the ball was thrown. For the ball, $v = 0$ at the top of the motion, and $a = -g$. Find the initial velocity from Eq. 2-11a.

$$v = v_0 + at \;\rightarrow\; v_0 = v - at = 0 - (-9.80\,\text{m/s}^2)(1.2\,\text{s}) = \boxed{12\,\text{m/s}}$$

84. Choose downward to be the positive direction, and the origin to be at the top of the building. The barometer has $y_0 = 0$, $v_0 = 0$, and $a = g = 9.8\,\text{m/s}^2$. Use Eq. 2-11b to find the height of the building, with *x* replaced by *y*.

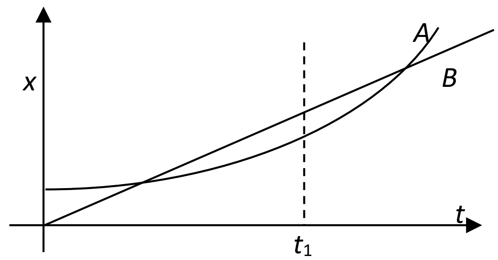
$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 = 0 + 0 + \tfrac{1}{2}(9.8\,\text{m/s}^2)t^2$$

$$y_{t=2.0} = \tfrac{1}{2}(9.8\,\text{m/s}^2)(2.0\,\text{s})^2 = 20\,\text{m} \qquad y_{t=2.3} = \tfrac{1}{2}(9.8\,\text{m/s}^2)(2.3\,\text{s})^2 = 26\,\text{m}$$

The difference in the estimates is $\boxed{6\text{m}}$.

The intent of the method was probably to use the change in air pressure between the ground level and the top of the building to find the height of the building. The very small difference in time measurements, which could be due to human reaction time, makes a 6 m difference in the height. This could be as much as 2 floors in error.

85. (*a*) The two bicycles will have the same velocity at any time when the instantaneous slopes of their $x$ vs. $t$ graphs are the same. That occurs near the time $t_1$ as marked on the graph.




(*b*) Bicycle A has the larger acceleration, because its graph is concave upward, indicating a positive acceleration. Bicycle B has no acceleration because its graph has a constant slope.

(*c*) The bicycles are passing each other at the times when the two graphs cross, because they both have the same position at that time. The graph with the steepest slope is the faster bicycle, and so is the one that is passing at that instant. So at the first crossing, bicycle B is passing bicycle A. At the second crossing, bicycle A is passing bicycle B.

(*d*) Bicycle B has the highest instantaneous velocity at all times until the time $t_{1.}$, where both graphs have the same slope. For all times after $t_1$, bicycle A has the highest instantaneous velocity. The largest instantaneous velocity is for bicycle A at the latest time shown on the graph.

(*e*) The bicycles appear to have the same average velocity. If the starting point of the graph for a particular bicycle is connected to the ending point with a straight line, the slope of that line is the average velocity. Both appear to have the same slope for that "average" line.