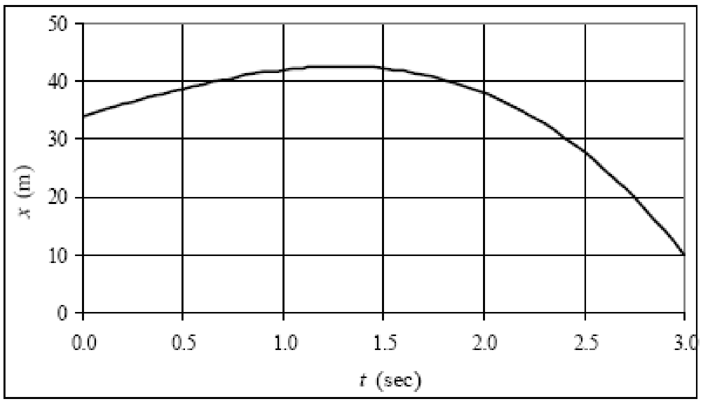
3. The average velocity is given by Eq. 2.2.

$$\overline{v} = \frac{\Delta x}{\Delta t} = \frac{8.5\,\text{cm} - 4.3\,\text{cm}}{4.5\,\text{s} - (-2.0\,\text{s})} = \frac{4.2\,\text{cm}}{6.5\,\text{s}} = \boxed{0.65\,\text{cm/s}}$$

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. We only have the displacement.

8. (*a*)



The spreadsheet used for this problem can be found on the Media Manager, with filename "PSE4_ISM_CH02.XLS", on tab "Problem 2.8a".

(*b*) The average velocity is the displacement divided by the elapsed time.

$$\overline{v} = \frac{x(3.0) - x(0.0)}{3.0\,\text{s} - 0.0\,\text{s}} = \frac{\left[34 + 10(3.0) - 2(3.0)^3\right]\text{m} - (34\,\text{m})}{3.0\,\text{s}} = \boxed{-8.0\,\text{m/s}}$$

(*c*) The instantaneous velocity is given by the derivative of the position function.

$$v = \frac{dx}{dt} = \left(10 - 6t^2\right)\text{m/s} \qquad 10 - 6t^2 = 0 \;\rightarrow\; t = \sqrt{\frac{5}{3}}\,\text{s} = \boxed{1.3\,\text{s}}$$

This can be seen from the graph as the "highest" point on the graph.

18. 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 $d_{car} = v_{car}t = (95\,\text{km/h})t$ or $d_{car} = \ell_{train} + v_{train}t = 1.10\text{ km} + (75\,\text{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

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

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

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 $d_{car} = (95\,\text{km/h})t$ or $d_{car} = 1.10\text{ km} - (75\,\text{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

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

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

23. 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 $\boxed{t = 0\text{ s to } t \approx 42\text{ s}}$, 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 $\boxed{t \approx 65\text{ s to } t \approx 83\text{ s}}$.

30. The acceleration can be found from Eq. 2-12c.

$$v^2 = v_0^2 + 2a(x - x_0) \quad \rightarrow \quad a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (25\,\text{m/s})^2}{2(85\text{ m})} = \boxed{-3.7\,\text{m/s}^2}$$

52. 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. 2-12b, with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 = 0 \quad \rightarrow$$

$$v_0 = \frac{y - y_0 - \frac{1}{2}at^2}{t} = -\tfrac{1}{2}at = -\tfrac{1}{2}(-9.80\,\text{m/s}^2)(3.2\text{ s}) = 15.68\,\text{m/s} \approx \boxed{16\,\text{m/s}}$$

The height can be calculated from Eq. 2-12c, with a final velocity of $v = 0$ at the top of the path.

$$v^2 = v_0^2 + 2a(y - y_0) \quad \rightarrow \quad y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (15.68\,\text{m/s})^2}{2(-9.80\,\text{m/s}^2)} = 12.54\,\text{m} \approx \boxed{13\text{ m}}$$

55. 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 $v_0 = -5.10\,\text{m/s}$, the acceleration is $a = 9.80\,\text{m/s}^2$, and the displacement of the package will be $y = 105$ m. The time to reach the ground can be found from Eq. 2-12b, with x replaced by y.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad t^2 + \frac{2v_0}{a}t - \frac{2y}{a} = 0 \quad \rightarrow \quad t^2 + \frac{2(-5.10\,\text{m/s})}{9.80\,\text{m/s}^2}t - \frac{2(105\text{ m})}{9.80\,\text{m/s}^2} = 0 \quad \rightarrow$$

$$t = 5.18\,\text{s}\,,\ -4.14\,\text{s}$$

The correct time is the positive answer, $\boxed{t = 5.18\,\text{s}}$.

61. 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. 2-12b with y substituting for x, we have $y_w = y_0 + v_0 t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}gt_w^2$. 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 $t_w + 0.33\,\text{s}$. Since the stone is dropped from rest, using Eq. 2-12b, we have the following: $y_w + 2.2\text{ m} = y_0 + v_0 + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}g(t_w + 0.33\,\text{s})^2$. Substitute the first expression for y_w into the second expression.

$$\tfrac{1}{2}gt_w^2 + 2.2\text{ m} = \tfrac{1}{2}g(t_w + 0.33\text{ s})^2 \quad \rightarrow \quad t_w = 0.515\text{ s}$$

Use this time in the first equation to get the height above the top of the window from which the stone fell.

$$y_w = \tfrac{1}{2}gt_w^2 = \tfrac{1}{2}(9.80\,\text{m/s}^2)(0.515\text{ s})^2 = \boxed{1.3\,\text{m}}$$

72. (*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 $a = 9.80\,\mathrm{m/s^2}$, and the location of the net is $y = 15.0\,\mathrm{m}$. Find the speed upon reaching the net from Eq. 2-12c with *x* replaced by *y*.

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

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 $y_0 = 15.0\,\mathrm{m}$ to be the height at which the person first contacts the net. The initial velocity is $v_0 = 17.1\,\mathrm{m/s}$, the final velocity is $v = 0$, and the location at the stretched position is $y = 16.0\,\mathrm{m}$. . Find the acceleration from Eq. 2-12c with *x* replaced by *y*.

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

(*b*) For the acceleration to be smaller, in the above equation we see that the displacement should be larger. This means that the net should be "loosened".

81. Choose downward to be the positive direction, and $y_0 = 0$ to be at the top of the cliff. The initial velocity is $v_0 = -12.5\,\mathrm{m/s}$, the acceleration is $a = 9.80\,\mathrm{m/s^2}$, and the final location is $y = 75.0\,\mathrm{m}$.

(*a*) Using Eq. 2-12b and substituting *y* for *x*, we have the following.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \rightarrow \left(4.9\,\mathrm{m/s^2}\right)t^2 - \left(12.5\,\mathrm{m/s}\right)t - 75.0\ \mathrm{m} = 0 \rightarrow t = -2.839\,\mathrm{s}\ ,\ 5.390\,\mathrm{s}$$

The positive answer is the physical answer: $\boxed{t = 5.39\,\mathrm{s}}$.

(*b*) Using Eq. 2-12a, we have $v = v_0 + at = -12.5\,\mathrm{m/s} + \left(9.80\,\mathrm{m/s^2}\right)\left(5.390\,\mathrm{s}\right) = \boxed{40.3\,\mathrm{m/s}}$.

(*c*) The total distance traveled will be the distance up plus the distance down. The distance down will be 75.0 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. Using Eq. 2-12c we have the following.

$$v^2 = v_0^2 + 2a\left(y - y_0\right) \rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - \left(-12.5\,\mathrm{m/s}\right)^2}{2\left(9.80\,\mathrm{m/s^2}\right)} = -7.97\,\mathrm{m}$$

Thus the distance up is 7.97 m, the distance down is 82.97 m, and the total distance traveled is $\boxed{90.9\,\mathrm{m}}$.

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

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

(*d*) In the interval from D to E, it is **moving in the positive direction**, because the displacement is positive.

(*e*) In the interval from D to E, it is **speeding up**, because the magnitude of its slope is increasing (changing from less steep to more steep).

(*f*) In the interval from D to E, **the acceleration is positive**, because the graph is concave upward, indicating the slope is getting more positive, and thus the acceleration is positive.

(*g*) In the interval from C to D, **the object is not moving in either direction**.

The velocity and acceleration are both 0.