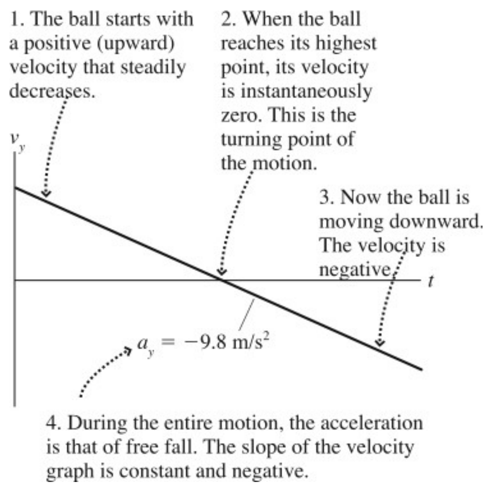
Physics 2A
Chapter 2 HW Solutions

Chapter 2
Conceptual Questions: 3, 9, 10, 13
Problems: 7, 14, 22, 27, 34, 37, 44, 59, 63, 67

Q2.3. Reason: Call "up" the positive direction (this choice is arbitrary, and you could do it the other way, but this is typically easier in cases like this). Also assume that there is no air resistance. This assumption is probably not true (unless the rock is thrown on the moon), but air resistance is a complication that will be addressed later, and for small heavy items like rocks no air resistance is a pretty good assumption if the rock isn't going too fast.
To be able to draw this graph without help demonstrates a good level of understanding of these concepts. The velocity graph will not go up and down as the rock does—that would be a graph of the position. Think carefully about the velocity of the rock at various points during the flight.

At the instant the rock leaves the hand it has a large positive (up) velocity, so the value on the graph at $t = 0$ needs to be a large positive number. The velocity decreases as the rock rises, but the velocity arrow would still point up. So the graph is still above the t axis, but decreasing. At the tippy-top the velocity is zero; that corresponds to a point on the graph where it crosses the t axis. Then as the rock descends with increasing velocity (in the negative, or down, direction), the graph continues below the t axis. It may not have been totally obvious before, but this graph will be a *straight line* with a negative slope.

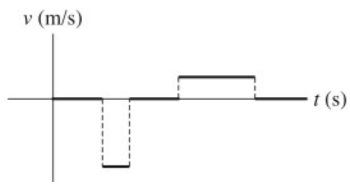


Assess: Make sure that the graph touches or crosses the t axis whenever the velocity is zero. In this case, that is only when it reaches to top of its trajectory and the velocity vector is changing direction from up to down.
It is also worth noting that this graph would be more complicated if we were to include the time at the beginning when the rock is being accelerated by the hand. Think about what that would entail.

Q2.9. Reason: **(a)** Sirius the dog starts at about 1 m west of a fire hydrant (the hydrant is the $x = 0$ m position) and walks toward the east at a constant speed, passing the hydrant at $t = 1.5$ s. At $t = 4$ s Sirius encounters his faithful friend Fido 2 m east of the hydrant and stops for a 6-second barking hello-and-smell. Remembering some important business, Sirius breaks off the conversation at $t = 10$ s and sprints back to the hydrant, where he stays for 4 s and then leisurely pads back to his starting point.
(b) Sirius is at rest during segments B (while chatting with Fido) and D (while at the hydrant). Notice that the graph is a horizontal line while Sirius is at rest.

(c) Sirius is moving to the right whenever x is increasing. That is only during segment A. Don't confuse something going right on the graph (such as segments C and E) with the object physically moving to the right (as in segment A). Just because t is increasing doesn't mean x is.
(d) The speed is the magnitude of the slope of the graph. Both segments C and E have negative slope, but C's slope is steeper, so Sirius has a greater speed during segment C than during segment E.
Assess: We stated our assumption (that the origin is at the hydrant) explicitly. During segments B and D time continues to increase but the position remains constant; this corresponds to zero velocity.

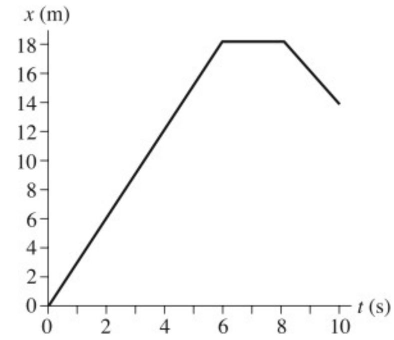
Q2.10. Reason: There are five different segments of the motion, since the lines on the position-versus-time graph have different slopes between five different time periods.
(a) During the first part of the motion, the position of the object, x, is constant. The line on the position-versus-time graph has zero slope since it is horizontal, so the velocity of the object is 0 m/s. The value of the position is positive, so the object is to the right of the origin.
During the second part of the motion, the line on the position-versus-time graph has a negative slope. This means the velocity of the object is negative. The line on the graph is straight, so the object moves with constant velocity. The object moves from a position to the right of the origin to a position to the left of the origin since the line goes below the time axis.
During the third part of the motion, the position-versus-time graph again has zero slope, so the object's velocity is again 0 m/s. The object stays at the same position throughout this part of the motion, which is on the left of the origin.
In the fourth part, the slope of the line on the graph is positive. The object has a positive velocity and is moving toward the right. Note that the magnitude of the slope here is less than the magnitude of the slope during the second part of the motion. The magnitude of the velocity during this part of the motion is less than the magnitude of the velocity during the second part of the motion. At the end of this time period the object ends up at the origin.
The object is at the origin, and stays at the origin during the final part of the motion. The slope of the line on the graph is zero, so the object has a velocity of 0 m/s.
(b) Referring to the velocities obtained in part **(a)**, the velocity-versus-time graph would look like the following diagram.



Assess: Velocity is given by the slope of lines on position-versus-time graphs. See Conceptual Example 2.1 and the discussion that follows.

Q2.13. Reason: **(a)** For the velocity to be constant, the velocity-versus-time graph must have zero slope. Looking at the graph, there are three time intervals where the graph has zero slope: segment A, segment D and segment F.
(b) For an object to be speeding up, the magnitude of the velocity of the object must be increasing. When the slope of the lines on the graph is nonzero, the object is accelerating and therefore changing speed.
Consider segment B. The velocity is positive while the slope of the line is negative. Since the velocity and acceleration are in opposite directions, the object is slowing down. At the start of segment B, we can see the velocity is +2 m/s, while at the end of segment B the velocity is 0 m/s.
During segment E the slope of the line is positive which indicates positive acceleration, but the velocity is negative. Since the acceleration and velocity are in opposite directions, the object is slowing here also. Looking at the graph at the beginning of segment E the velocity is –2 m/s, which has a magnitude of 2 m/s. At the end of segment E the velocity is 0 m/s, so the object has slowed down.
Consider segment C. Here the slope of the line is negative and the velocity is negative. The velocity and acceleration are in the same direction so the object is speeding up. The object is gaining velocity in the negative direction. At the beginning of that segment the velocity is 0 m/s, and at the end the velocity is –2 m/s, which has a magnitude of 2 m/s.
(c) In the analysis for part **(b)**, we found that the object is slowing down during segments B and E.
(d) An object standing still has zero velocity. The only time this is true on the graph is during segment F, where the line has zero slope, and is along $v = 0$ m/s.
(e) For an object to moving to the right, the convention is that the velocity is positive. In terms of the graph, positive values of velocity are above the time axis. The velocity is positive for segments A and B. The velocity must also be greater than zero. Segment F represents a velocity of 0 m/s.
Assess: Speed is the magnitude of the velocity vector. Compare to Conceptual Example 2.6 and also Question 2.2.

P2.7. Prepare: To get a position from a velocity graph we count the area under the curve.
Solve:
(a)



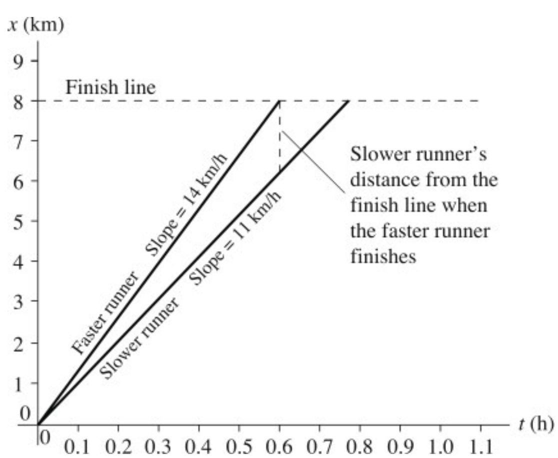
(b) We need to count the area under the velocity graph (area below the x-axis is subtracted). There are 18 m of area above the axis and 4 m of area below. $18\text{m} - 4\text{m} = 14\text{m}$.

Assess: These numbers seem reasonable; a mail carrier could back up 4 m. It is also important that the problem state what the position is at $t = 0$, or we wouldn't know how high to draw the position graph.

P2.14. Prepare: We'll do this problem in multiple steps. Rearrange Equation 1.1 to produce

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

Use this to compute the time the faster runner takes to finish the race; then use $\text{distance} = \text{speed} \times \text{time}$ to see how far the slower runner has gone in that amount of time. Finally, subtract that distance from the 8.00 km length of the race to find out how far the slower runner is from the finish line.



Solve: The faster runner finishes in

$$t = \frac{8.00\,\text{km}}{14.0\,\text{km/h}} = 0.571\,\text{h}$$

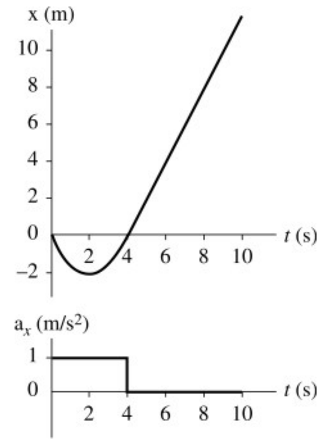
In that time the slower runner runs $d = (11.0\,\text{km/h}) \times (0.571\,\text{h}) = 6.29\,\text{km}$.

This leaves the slower runner $8.00\,\text{km} - 6.29\,\text{km} = 1.71\,\text{km}$ from the finish line as the faster runner crosses the line.

Assess: The slower runner will not even be in sight of the faster runner when the faster runner crosses the line.
We did not need to convert hours to seconds because the hours cancelled out of the last equation. Notice we kept 3 significant figures, as indicated by the original data.

P2.22. Prepare: Displacement is equal to the area under the velocity graph between t_i and t_f, and acceleration is the slope of the velocity-versus-time graph.

Solve: (a)



(b) From the acceleration versus t graph above, a_x at $t = 3.0$ s is +1 m/s².

P2.27. Prepare: Acceleration is the rate of change of velocity.

$$a_x = \frac{\Delta v_x}{\Delta t}$$

Where $\Delta v_x = 4.0\,\text{m/s}$ and $\Delta t = 0.11\text{s}$.

We will then use that acceleration in Equation 2.14 (a special case of Equation 2.12) to compute the displacement during the strike:

$$\Delta x = \frac{1}{2} a_x (\Delta t)^2$$

where we are justified in using the special case because $(v_x)_i = 0.0$ m/s.

Solve: (a)

$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{4.0\text{ m/s}}{0.11\text{ s}} = 36\text{ m/s}^2$$

(b)

$$\Delta x = \frac{1}{2} a_x (\Delta t)^2 = \frac{1}{2}(36\text{ m/s}^2)(0.11\text{ s})^2 = 0.22\text{ m}$$

Assess: The answer is remarkable but reasonable. The pike strikes quickly and so is able to move 0.22 m in 0.11 s, even starting from rest. The seconds squared cancel in the last equation.

P2.34. Prepare: Do this in two parts. First compute the distance traveled during the acceleration phase and what speed it reaches. Then compute the additional distance traveled at that constant speed.

Solve: During the acceleration phase, since $(v_x)_i = 0$

$$\Delta x = \frac{1}{2} a_x (\Delta t)^2 = \frac{1}{2}(250\text{ m/s}^2)(20\text{ ms})^2 = 0.05\text{ m} = 5.0\text{ cm}$$

We also compute the speed it attains.

$$v_x = a_x \Delta t = (250\text{ m/s}^2)(20\text{ ms}) = 5.0\text{ m/s}$$

Now the distance traveled at a constant speed of 5.0 m/s.

$$\Delta x = v_x \Delta t = (5.0\text{ m/s})(30\text{ ms}) = 0.15\text{ m} = 15\text{ cm}$$

Now add the two distances to get the total.

$$\Delta x_{\text{total}} = 5.0\ \text{cm} + 15\ \text{cm} = 20\ \text{cm}$$

Assess: A 20-cm-long tongue is impressive, but possible.

P2.37. Prepare: We will use the equation for constant acceleration to find out how far the sprinter travels during the acceleration phase. Use Equation 2.11 to find the acceleration.

$$v_x = a_x t_1 \qquad \text{where } v_0 = 0 \text{ and } t_0 = 0$$

$$a_x = \frac{v_x}{t_1} = \frac{11.2\ \text{m/s}}{2.14\ \text{s}} = 5.23\ \text{m/s}^2$$

Solve: The distance traveled during the acceleration phase will be

$$\Delta x = \frac{1}{2} a_x (\Delta t)^2$$
$$= \frac{1}{2}(5.23\ \text{m/s}^2)(2.14\ \text{s})^2$$
$$= 12.0\ \text{m}$$

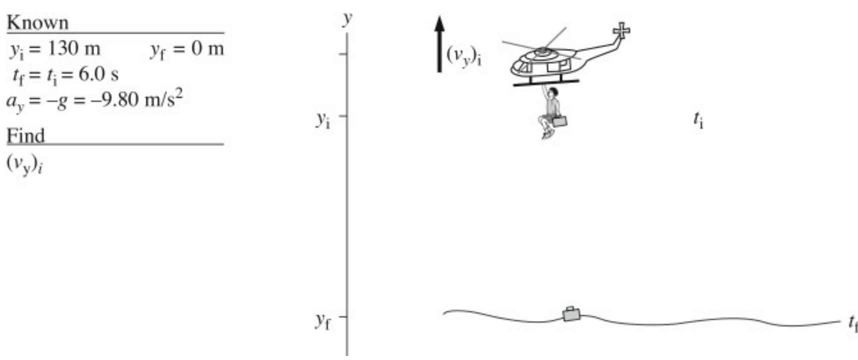
The distance left to go at constant velocity is $100\ \text{m} - 12.0\ \text{m} = 88.0\ \text{m}$. The time this takes at the top speed of 11.2 m/s is

$$\Delta t = \frac{\Delta x}{v_x} = \frac{88.0\ \text{m}}{11.2\ \text{m/s}} = 7.86\ \text{s}$$

The total time is $2.14\ \text{s} + 7.86\ \text{s} = 10.0\ \text{s}$.

Assess: This is indeed about the time it takes a world-class sprinter to run 100 m (the world record is a bit under 9.8 s). Compare the answer to this problem with the accelerations given in Problem 2.25 for Carl Lewis.

P2.44. Prepare: Since the villain is hanging on to the ladder as the helicopter is ascending, he and the briefcase are moving with the same upward velocity as the helicopter. We can calculate the initial velocity of the briefcase, which is equal to the upward velocity of the helicopter. See the following figure.



Solve: We can use Equation 2.12 here. We know the time it takes the briefcase to fall, its acceleration, and the distance it falls. Solving for $(v_y)_i \Delta t$,

$$(v_y)_i \Delta t = (y_f - y_i) - \frac{1}{2}(a_y)\Delta t^2 = -130\ \text{m} - \left[\frac{1}{2}(-9.80\ \text{m/s}^2)(6.0\ \text{s})^2\right] = 46\ \text{m}$$

Dividing by Δt to solve for $(v_y)_i$,

$$(v_x)_i = \frac{46\ \text{m}}{6.0\ \text{s}} = 7.7\ \text{m/s}$$

Assess: Note the placement of negative signs in the calculation. The initial velocity is positive, as expected for a helicopter ascending.

P2.59. **Prepare:** Fleas are amazing jumpers; they can jump several times their body height—something we cannot do. We assume constant acceleration so we can use the equations in Table 2.4. The last of the three relates the three variables we are concerned with in part **(a)**: speed, distance (which we know), and acceleration (which we want).

$$(v_y)_f^2 = (v_y)_i^2 + 2a_y\Delta y$$

In part **(b)** we use the first equation in Table 2.4 because it relates the initial and final velocities and the acceleration (which we know) with the time interval (which we want).

$$(v_y)_f = (v_y)_i + a_y\Delta t$$

Part **(c)** is about the phase of the jump *after* the flea reaches takeoff speed and leaves the ground. So now it is $(v_y)_i$, that is 1.0 m/s instead of $(v_y)_f$. And the acceleration is not the same as in part **(a)**—it is now $-g$ (with the positive direction up) since we are ignoring air resistance. We do not know the time it takes the flea to reach maximum height, so we employ the last equation in Table 2.4 again because we know everything in that equation except Δy.

Solve: **(a)** Use $(v_y)_i = 0.0\text{ m/s}$ and rearrange the last equation in Table 2.4.

$$a_y = \frac{(v_y)_f^2}{2\Delta y} = \frac{(1.0\text{ m/s})^2}{2(0.50\text{ mm})}\left(\frac{1000\text{ mm}}{1\text{ m}}\right) = 1000\text{ m/s}^2$$

(b) Having learned the acceleration from part (**a**) we can now rearrange the first equation in Table 2.4 to find the time it takes to reach takeoff speed. Again use $(v_y)_i = 0.0$ m/s.

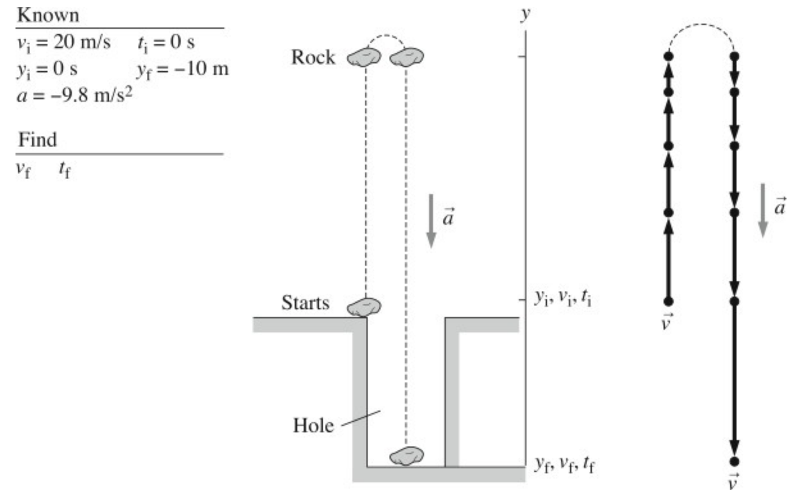
$$\Delta t = \frac{(v_y)_f}{a_y} = \frac{1.0\text{ m/s}}{1000\text{ m/s}^2} = .0010\text{ s}$$

(c) This time $(v_y)_f = 0.0\text{m/s}$ as the flea reaches the top of its trajectory. Rearrange the last equation in Table 2.4 to get

$$\Delta y = \frac{-\left(v_y\right)_i^2}{2a_y} = \frac{-(1.0\text{ m/s})^2}{2(-9.8\text{ m/s}^2)} = 0.051\text{ m} = 5.1\text{ cm}$$

Assess: Just over 5 cm is pretty good considering the size of a flea. It is about 10–20 times the size of a typical flea. Check carefully to see that each answer ends up in the appropriate units.
The height of the flea at the top will round to 5.2 cm above the ground if you include the 0.050 cm during the initial acceleration phase before the feet actually leave the ground.

P2.63. **Prepare:** A visual overview of the rock's motion that includes a pictorial representation, a motion diagram, and a list of values is shown below. We represent the rock's motion along the *y*-axis. As soon as the rock is tossed up, it falls freely and thus kinematic equations hold. The rock's acceleration is equal to the acceleration due to gravity that always acts vertically downward toward the center of the earth. The initial position of the rock is at the origin where $y_i = 0$, but the final position is below the origin at $y_f = -10$ m. Recall sign conventions which tell us that v_i is positive and a is negative.



Solve: **(a)** Substituting the known values into $y_f = y_i + v_i \Delta t + \frac{1}{2} a \Delta t^2$, we get

$$-10 \text{ m} = 0 \text{ m} + 20 \text{ (m/s)} t_f + \frac{1}{2}(-9.8 \text{ m/s}^2) t_f^2$$

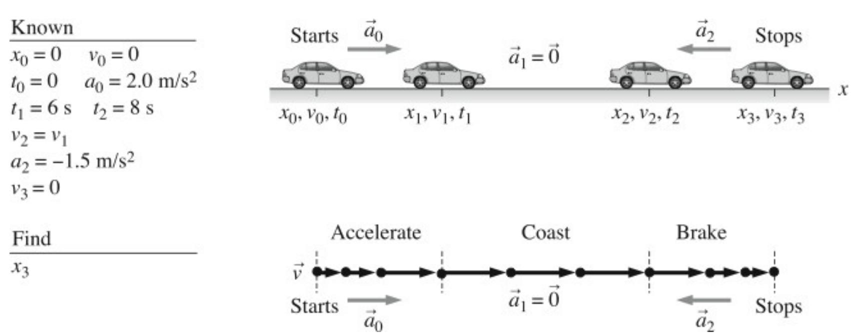
One of the roots of this equation is negative and is not physically relevant. The other root is t_f = 4.53 s which is the answer to part **(b)**. Using $v_f = v_i + a\Delta t$, we obtain

$$v_f = 20 \text{(m/s)} + (-9.8 \text{ m/s}^2)(4.53 \text{ s}) = -24 \text{ m/s}$$

(b) The time is 4.5 s.

Assess: A time of 4.5 s is a reasonable value. The rock's velocity as it hits the bottom of the hole has a negative sign because of its downward direction. The magnitude of 24 m/s compared to 20 m/s when the rock was tossed up is consistent with the fact that the rock travels an additional distance of 10 m into the hole.

P2.67. **Prepare:** A visual overview of car's motion that includes a pictorial representation, a motion diagram, and a list of values is shown below. We label the car's motion along the *x*-axis. This is a three-part problem. First the car accelerates, then it moves with a constant speed, and then it decelerates. The total displacement between the stop signs is equal to the sum of the three displacements, that is, $x_3 - x_0 = (x_3 - x_2) + (x_2 - x_1) + (x_1 - x_0)$.



Solve: First, the car accelerates:

$$v_1 = v_0 + a_0(t_1 - t_0) = 0 \text{ m/s} + (2.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s}) = 12 \text{ m/s}$$

$$x_1 = x_0 + v_0(t_1 - t_0) + \frac{1}{2}a_0(t_1 - t_0)^2 = 0 \text{ m} + \frac{1}{2}(2.0 \text{ m/s}^2)(6 \text{ s} - 0 \text{ s})^2 = 36 \text{ m}$$

Second, the car moves at v_1:

$$x_2 - x_1 = v_1(t_2 - t_1) + \frac{1}{2}a_1(t_2 - t_1)^2 = (12 \text{ m/s})(8 \text{ s} - 6 \text{ s}) + 0 \text{ m} = 24 \text{ m}$$

Third, the car decelerates:

$$v_3 = v_2 + a_2(t_3 - t_2) \Rightarrow 0\text{ m/s} = 12\text{ m/s} + (-1.5\text{ m/s}^2)(t_3 - t_2) \Rightarrow (t_3 - t_2) = 8\text{ s}$$

$$x_3 = x_2 + v_2(t_3 - t_2) + \frac{1}{2}a_2(t_3 - t_2)^2 \Rightarrow x_3 - x_2 = (12\text{ m/s})(8\text{ s}) + \frac{1}{2}(-1.5\text{ m/s}^2)(8\text{ s})^2 = 48\text{ m}$$

Thus, the total distance between stop signs is

$$x_3 - x_0 = (x_3 - x_2) + (x_2 - x_1) + (x_1 - x_0) = 48\text{ m} + 24\text{ m} + 36\text{ m} = 108\text{ m} \approx 110\text{ m}$$

Assess: A distance of approximately 360 ft in a time of around 16 s with an acceleration/deceleration is reasonable.