Chapter 2, Conceptual Questions

2.4. (a) At t = 1 s, the slope of the line for object A is greater than that for object B. Therefore, object A's speed is greater. (Both are positive slopes.)
(b) No, the speeds are never the same. Each has a constant speed (constant slope) and A's speed is always greater.

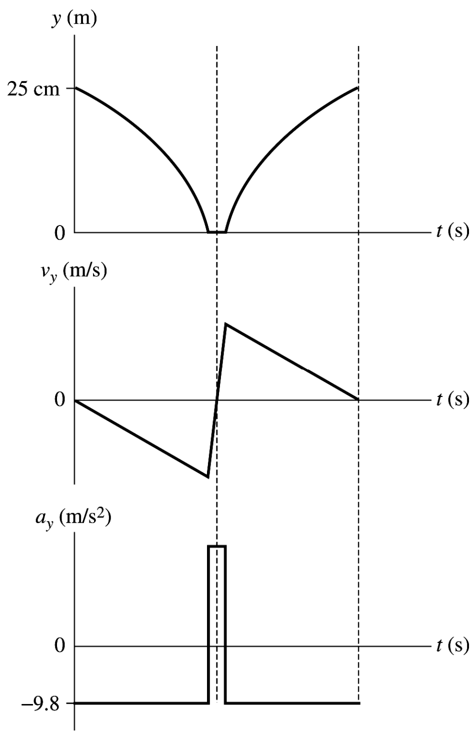
2.5. (a) A's speed is greater at t = 1 s. The slope of the tangent to B's curve at t = 1 s is smaller than the slope of A's line.
(b) A and B have the same speed at just before t = 3 s. At that time, the slope of the tangent to the curve representing B's motion is equal to the slope of the line representing A.

2.6. (a) B. The object is still moving, but the magnitude of the slope of the position-versus-time curve is smaller than at D.
(b) D. The slope is greatest at D.
(c) At points A, C, and E the slope of the curve is zero, so the object is not moving.
(d) At point D the slope is negative, so the object is moving to the left.

2.7. (a) The slope of the position-versus-time graph is greatest at D, so the object is moving fastest at this point.
(b) The slope is negative at points C, D, and E, meaning the object is moving to the left at these points.
(c) At point C the slope is increasing in magnitude (getting more negative), meaning that the object is speeding up to the left.
(d) At point B the object is not moving since the slope is zero. Before point B, the slope is positive, while after B it is negative, so the object is turning around at B.

2.8. (a) The positions of the third dots of both motion diagrams are the same, as are the sixth dots of both, so cars A and B are at the same locations at the time corresponding to dot 3 and again at that of dot 6.
(b) The spacing of dots 4 and 5 in both diagrams is the same, so the cars are traveling at the same speeds between times corresponding to dots 4 and 5.

2.14. The ball remains in contact with the floor for a small but noticeable amount of time. It is in free fall when not in contact with the floor. When it hits the floor, it is accelerated very rapidly in the upward direction as it bounces.



Chapter 2, Exercises and Problems

2.5. Model: The bicyclist is a particle.
Visualize: Please refer to Figure EX2.5.
Solve: The slope of the position-versus-time graph at every point gives the velocity at that point. The slope at $t = 10$ s is

$$v = \frac{\Delta s}{\Delta t} = \frac{100\text{ m} - 50\text{ m}}{20\text{ s}} = 2.5\text{ m/s}$$

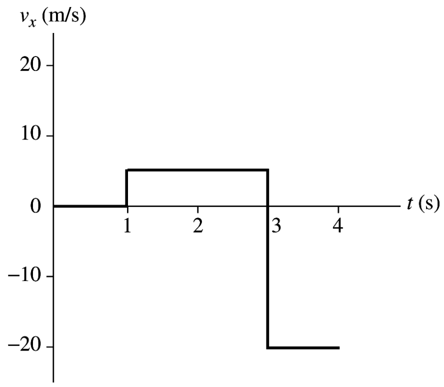
The slope at $t = 25$ s is

$$v = \frac{100\text{ m} - 100\text{ m}}{10\text{ s}} = 0\text{ m/s}$$

The slope at $t = 35$ s is

$$v = \frac{0\text{ m} - 100\text{ m}}{10\text{ s}} = -10\text{ m/s}$$

2.6. Visualize: Please refer to Figure EX2.6.
Solve: (a) We can obtain the values for the velocity-versus-time graph from the equation $v = \Delta s/\Delta t$.



(b) There is only one turning point. At $t = 3$ s the velocity changes from $+5$ m/s to -20 m/s, thus reversing the direction of motion. At $t = 1$ s, there is an abrupt change in motion from rest to $+5$ m/s, but there is no reversal in motion.

2.7. Visualize: Please refer to Figure EX2.7. The particle starts at $x_0 = 10$ m at $t_0 = 0$. Its velocity is initially in the
$-x$ direction. The speed decreases as time increases during the first second, is zero at $t = 1$ s, and then increases after the particle reverses direction.
Solve: (a) The particle reverses direction at $t = 1$ s, when v_x changes sign.
(b) Using the equation $x_f = x_0$ + area of the velocity graph between t_1 and t_f,

$$x_{2\text{ s}} = 10\text{ m} - \text{(area of triangle between 0 s and 1 s)} + \text{(area of triangle between 1 s and 2 s)}$$

$$= 10\text{ m} - \frac{1}{2}(4\text{ m/s})(1\text{ s}) + \frac{1}{2}(4\text{ m/s})(1\text{ s}) = 10\text{ m}$$

$$x_{3\text{ s}} = 10\text{ m} + \text{area of trapazoid between 2 s and 3 s}$$

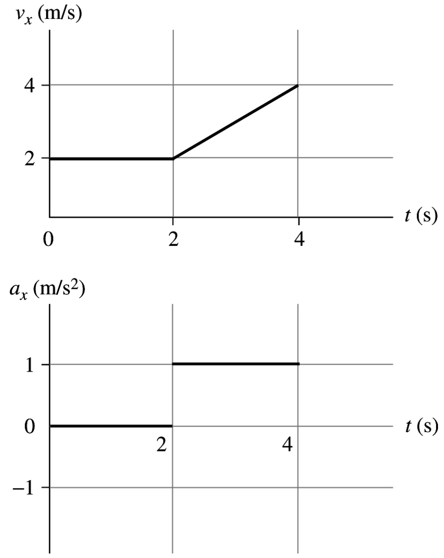
$$= 10\text{ m} + \frac{1}{2}(4\text{ m/s} + 8\text{ m/s})(3\text{ s} - 2\text{ s}) = 16\text{ m}$$

$$x_{4\text{ s}} = x_{3\text{ s}} + \text{area between 3 s and 4 s}$$

$$= 16\text{ m} + \frac{1}{2}(8\text{ m/s} + 12\text{ m/s})(1\text{ s}) = 26\text{ m}$$

2.8. Visualize: Please refer to Figure EX2.8.

Solve: A constant velocity from $t = 0$ s to $t = 2$ s means zero acceleration. On the other hand, a linear increase in velocity between $t = 2$ s and $t = 4$ s implies a constant positive acceleration.



2.11. Visualize: Please refer to Figure EX2.11.

Solve: **(a)** Using the equation

$$x_f = x_i + \text{area under the velocity-versus-time graph between } t_i \text{ and } t_f$$

we have

$$x(\text{at } t = 1\text{ s}) = x(\text{at } t = 0\text{ s}) + \text{area between } t = 0\text{ s and } t = 1\text{ s}$$

$$= 2.0\text{ m} + (4\text{ m/s})(1\text{ s}) = 6\text{ m}$$

Reading from the velocity-versus-time graph, $v_x(\text{at } t = 1\text{ s}) = 4$ m/s. Also, $a_x = \text{slope} = \Delta v/\Delta t = 0\text{ m/s}^2$.

(b) $x(\text{at } t = 3.0\text{ s}) = x(\text{at } t = 0\text{ s}) + \text{area between } t = 0\text{ s and } t = 3\text{ s}$

$$= 2.0\text{ m} + 4\text{ m/s}\times 2\text{ s} + 2\text{ m/s}\times 1\text{ s} + (1/2)\times 2\text{ m/s}\times 1\text{ s} = 13.0\text{ m}$$

Reading from the graph, $v_x(t = 3\text{ s}) = 2$ m/s. The acceleration is

$$a_x(t = 3\text{ s}) = \text{slope} = \frac{v_x(\text{at } t = 4\text{ s}) - v_x(\text{at } t = 2\text{ s})}{2\text{ s}} = -2\text{ m/s}^2$$

2.13. Model: We are using the particle model for the skater and the kinematics model of motion under constant acceleration.

Solve: Since we don't know the time of acceleration we will use

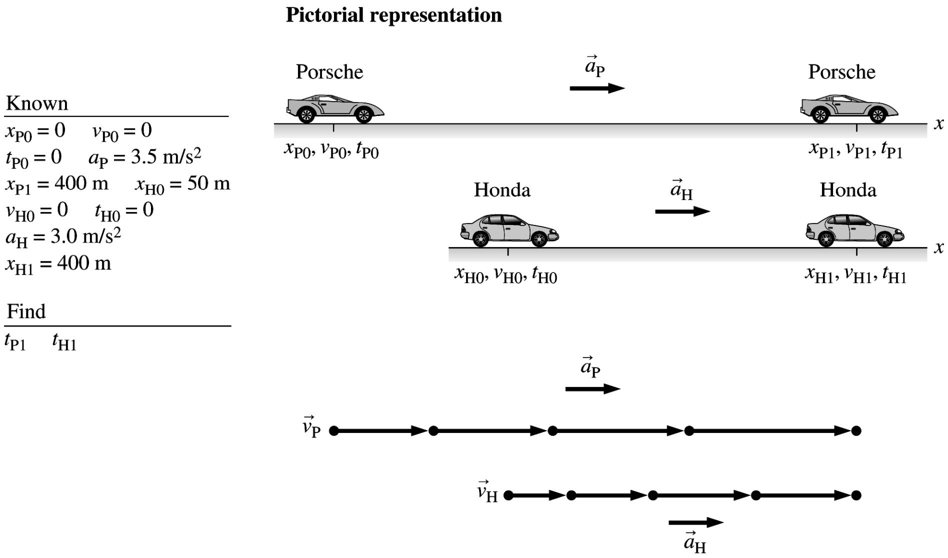
$$v_f^2 = v_i^2 + 2a(x_f - x_i)$$

$$\Rightarrow a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{(6.0\text{ m/s})^2 - (8.0\text{ m/s})^2}{2(5.0\text{ m})} = -2.8\text{ m/s}^2$$

Assess: A deceleration of 2.8 m/s^2 is reasonable.

2.14. Model: We are assuming both cars are particles.

Visualize:



Solve: The Porsche's time to finish the race is determined from the position equation

$$x_{P1} = x_{P0} + v_{P0}(t_{P1} - t_{P0}) + \frac{1}{2}a_P(t_{P1} - t_{P0})^2$$

$$\Rightarrow 400 \text{ m} = 0 \text{ m} + 0 \text{ m} + \frac{1}{2}(3.5 \text{ m/s}^2)(t_{P1} - 0 \text{ s})^2 \Rightarrow t_{P1} = 15.1 \text{ s}$$

The Honda's time to finish the race is obtained from Honda's position equation as

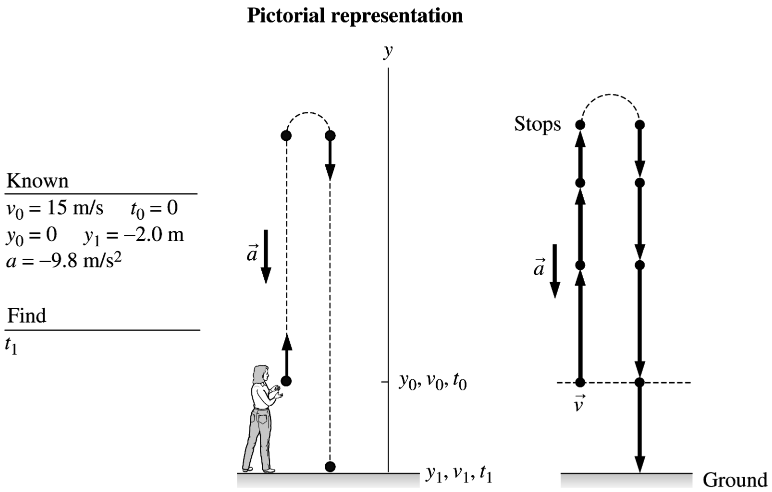
$$x_{H1} = x_{H0} + v_{H0}(t_{H1} - t_{H0}) + \frac{1}{2}a_{H0}(t_{H1} - t_{H0})^2$$

$$400 \text{ m} = 50 \text{ m} + 0 \text{ m} + \frac{1}{2}(3.0 \text{ m/s}^2)(t_{H1} - 0 \text{ s})^2 \Rightarrow t_{H1} = 15.3 \text{ s}$$

So, the Porsche wins.

2.17. **Model:** We represent the ball as a particle.

Visualize:



Solve: Once the ball leaves the student's hand, the ball undergoes free fall and its acceleration is equal to the acceleration due to gravity that always acts vertically downward toward the center of the earth. According to the constant-acceleration kinematic equations of motion

$$y_1 = y_0 + v_0 \Delta t + \frac{1}{2} a \Delta t^2$$

Substituting the known values

$$-2 \text{ m} = 0 \text{ m} + (15 \text{ m/s})t_1 + (1/2)(-9.8 \text{ m/s}^2)t_1^2$$

The solution of this quadratic equation gives $t_1 = 3.2$ s. The other root of this equation yields a negative value for t_1, which is not valid for this problem.

Assess: A time of 3.2 s is reasonable.

2.21. **Solve:** **(a)** The position $t = 2$ s is $x_{2\text{ s}} = [2(2)^2 - 2 + 1]$ m $= 7$ m.

(b) The velocity is the derivative $v = dx/dt$ and the velocity at $t = 2$ s is calculated as follows:

$$v = (4t - 1) \text{ m/s} \Rightarrow v_{2\text{ s}} = [4(2) - 1] \text{ m/s} = 7 \text{ m/s}$$

(c) The acceleration is the derivative $a = dv/dt$ and the acceleration at $t = 2$ s is calculated as follows:

$$a = (4) \text{ m/s}^2 \Rightarrow a_{2\text{ s}} = 4 \text{ m/s}^2$$

2.22. **Solve:** The formula for the particle's position along the x-axis is given by

$$x_f = x_i + \int_{t_i}^{t_f} v_x \, dt$$

Using the expression for v_x we get

$$x_f = x_i + \frac{2}{3}\left[t_f^3 - t_i^3\right] \qquad a_x = \frac{dv_x}{dt} = \frac{d}{dt}(2t^2 \text{ m/s}) = 4t \text{ m/s}^2$$

(a) The particle's position at $t = 1$ s is $x_{1\text{ s}} = 1 \text{ m} + \frac{2}{3} \text{ m} = \frac{5}{3}$ m.

(b) The particle's speed at $t = 1$ s is $v_{1\text{ s}} = 2$ m/s.

(c) The particle's acceleration at $t = 1$ s is $a_{1\text{ s}} = 4$ m/s^2.

2.23. Solve: The formula for the particle's velocity is given by

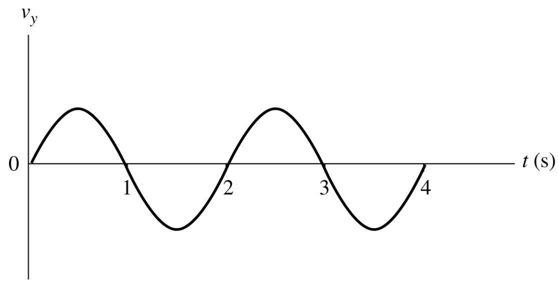
$$v_f = v_i + \text{area under the acceleration curve between } t_i \text{ and } t_f$$

For $t = 4$ s, we get

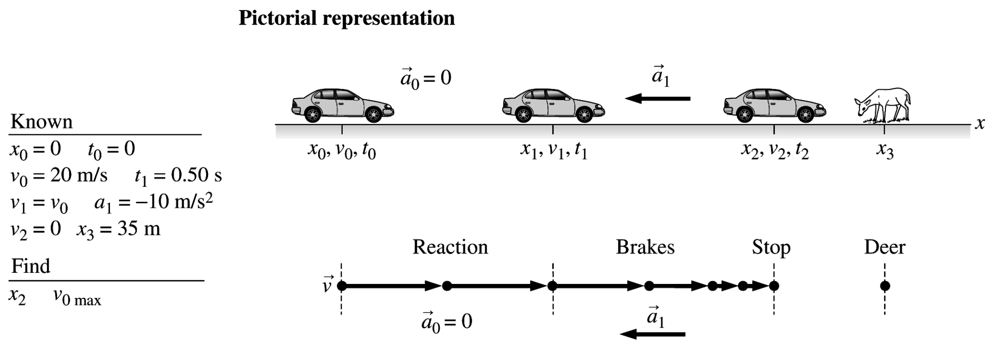
$$v_{4\text{ s}} = 8 \text{ m/s} + \frac{1}{2}(4 \text{ m/s}^2)4 \text{ s} = 16 \text{ m/s}$$

Assess: The acceleration is positive but decreases as a function of time. The initial velocity of 8.0 m/s will therefore increase. A value of 16 m/s is reasonable.

2.29. Visualize: Please refer to Figure P2.29.
Solve: **(a)** The velocity-versus-time graph is the derivative with respect to time of the distance-versus-time graph. The velocity is zero when the slope of the position-versus-time graph is zero, the velocity is most positive when the slope is most positive, and the velocity is most negative when the slope is most negative. The slope is zero at $t = 0$, 1 s, 2 s, 3 s, . . . ; the slope is most positive at $t = 0.5$ s, 2.5 s, . . ; and the slope is most negative at $t = 1.5$ s, 3.5 s, . . .
(b)



2.47. Model: We will use the particle model and the constant-acceleration kinematic equations.
Visualize:



Solve: **(a)** To find x_2, we first need to determine x_1. Using $x_1 = x_0 + v_0(t_1 - t_0)$, we get $x_1 = 0 \text{ m} + (20 \text{ m/s})(0.50 \text{ s} - 0 \text{ s}) = 10$ m. Now,

$$v_2^2 = v_1^2 + 2a_1(x_2 - x_1) \Rightarrow 0 \text{ m}^2/\text{s}^2 = (20 \text{ m/s})^2 + 2(-10 \text{ m/s}^2)(x_2 - 10 \text{ m}) \Rightarrow x_2 = 30 \text{ m}$$

The distance between you and the deer is $(x_3 - x_2)$ or $(35 \text{ m} - 30 \text{ m}) = 5$ m.
(b) Let us find $v_{0\text{ max}}$ such that $v_2 = 0$ m/s at $x_2 = x_3 = 35$ m. Using the following equation,

$$v_2^2 - v_{0\text{ max}}^2 = 2a_1(x_2 - x_1) \Rightarrow 0 \text{ m}^2/\text{s}^2 - v_{0\text{ max}}^2 = 2(-10 \text{ m/s}^2)(35 \text{ m} - x_1)$$

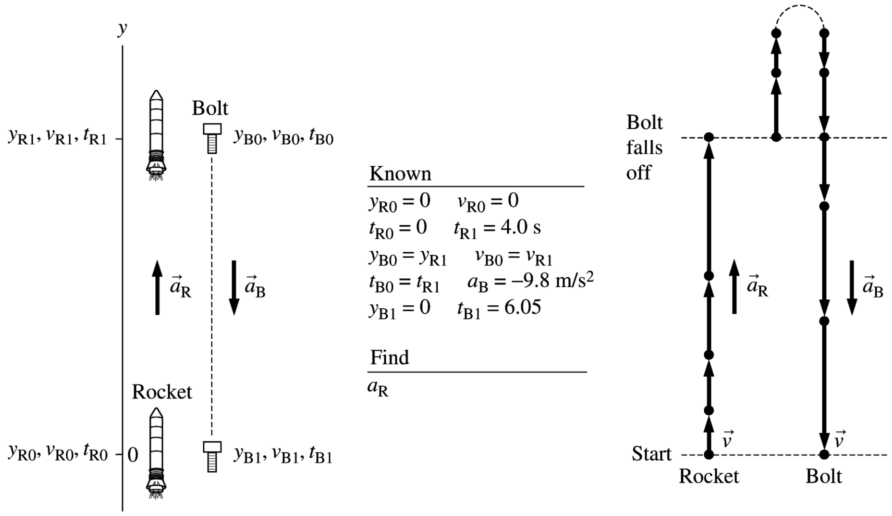
Also, $x_1 = x_0 + v_{0\text{ max}}(t_1 - t_0) = v_{0\text{ max}}(0.50 \text{ s} - 0 \text{ s}) = (0.50 \text{ s})v_{0\text{ max}}$. Substituting this expression for x_1 in the above equation yields

$$-v_{0\text{ max}}^2 = (-20 \text{ m/s}^2)[35 \text{ m} - (0.50 \text{ s})\, v_{0\text{ max}}] \Rightarrow v_{0\text{ max}}^2 + (10 \text{ m/s})v_{0\text{ max}} - 700 \text{ m}^2/\text{s}^2 = 0$$

The solution of this quadratic equation yields $v_{0\text{ max}} = 22$ m/s. (The other root is negative and unphysical for the present situation.)
Assess: An increase of speed from 20 m/s to 22 m/s is very reasonable for the car to cover an additional distance of 5 m with a reaction time of 0.50 s and a deceleration of 10 m/s^2.

2.77. Model: The rocket and the bolt will be represented as particles to investigate their motion.
Visualize:

Pictorial representation



The initial velocity of the bolt as it falls off the side of the rocket is the same as that of the rocket, that is, $v_{B0} = v_{R1}$ and it is positive since the rocket is moving upward. The bolt continues to move upward with a deceleration equal to $g = 9.8 \text{ m/s}^2$ before it comes to rest and begins its downward journey.

Solve: To find a_R we look first at the motion of the rocket:

$$y_{R1} = y_{R0} + v_{R0}(t_{R1} - t_{R0}) + \frac{1}{2}a_R(t_{R1} - t_{R0})^2$$
$$= 0 \text{ m} + 0 \text{ m/s} + \frac{1}{2}a_R(4.0 \text{ s} - 0 \text{ s})^2 = 8a_R$$

To find a_R we must determine the magnitude of y_{R1} or y_{B0}. Let us now look at the bolt's motion:

$$y_{B1} = y_{B0} + v_{B0}(t_{B1} - t_{B0}) + \frac{1}{2}a_B(t_{B1} - t_{B0})^2$$
$$0 = y_{R1} + v_{R1}(6.0 \text{ s} - 0 \text{ s}) + \frac{1}{2}(-9.8 \text{ m/s}^2)(6.0 \text{ s} - 0 \text{ s})^2$$
$$\Rightarrow y_{R1} = 176.4 \text{ m} - (6.0 \text{ s})\, v_{R1}$$

Since $v_{R1} = v_{R0} + a_R(t_{R1} - t_{R0}) = 0 \text{ m/s} + 4\,a_R = 4\,a_R$ the above equation for y_{R1} yields $y_{R1} = 176.4 - 6.0(4a_R)$. We know from the first part of the solution that $y_{R1} = 8a_R$. Therefore, $8a_R = 176.4 - 24.0a_R$ and hence $a_R = 5.5 \text{ m/s}^2$.