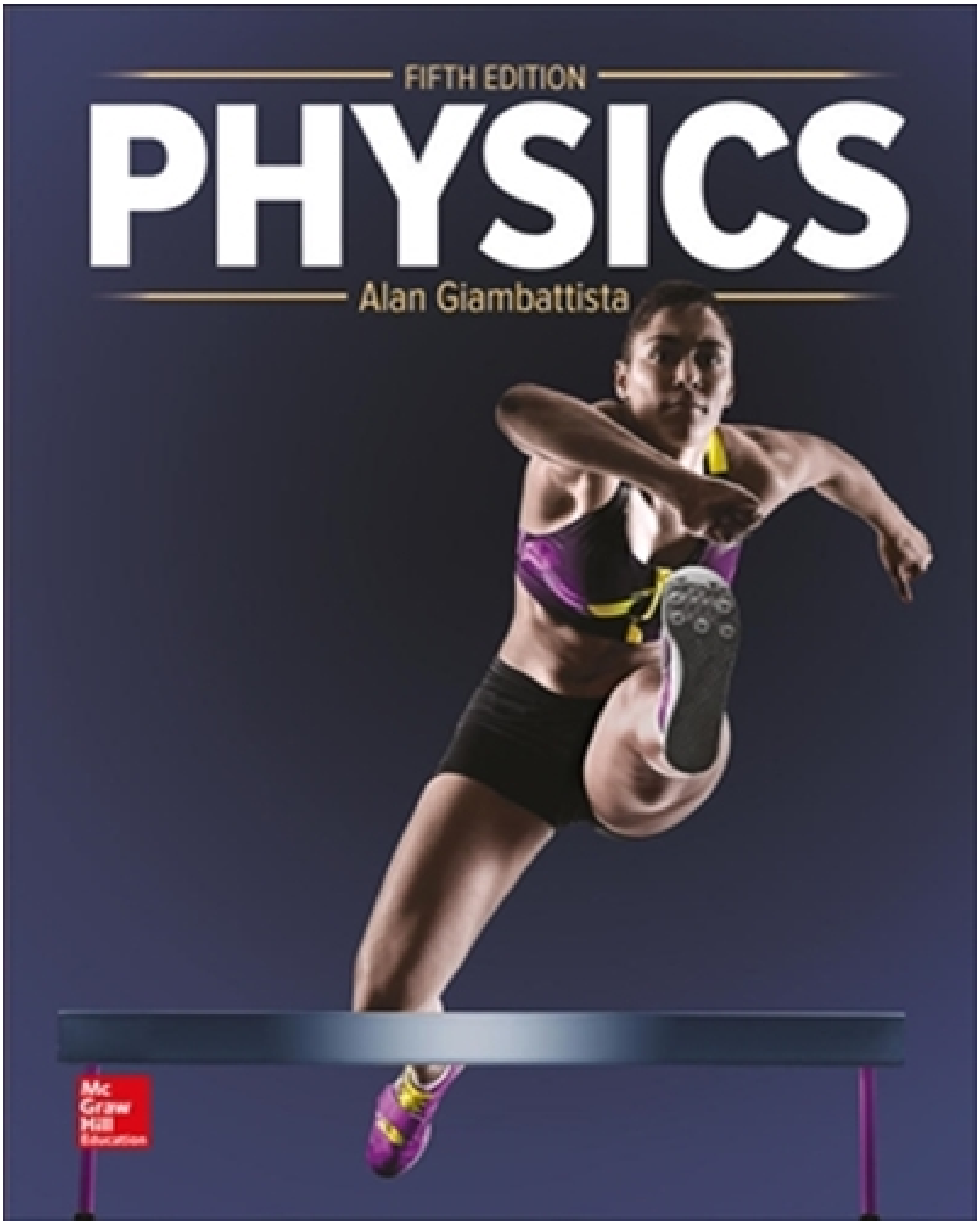
Solutions for Physics 5th Edition by Giambattista



Solutions

Chapter 2
MOTION ALONG A LINE

Conceptual Questions

1. Distance traveled is a scalar quantity equal to the total length of the path taken in moving from one point to another. Displacement is a vector quantity directed from the initial point towards the final point with a magnitude equal to the straight line distance between the two points. The magnitude of the displacement has no direction, and is always less than or equal to the total distance traveled.
2. The velocity of an object is a vector quantity equal to the displacement of the object per unit time interval. The speed of an object is a scalar quantity equal to the distance traveled by the object per unit time interval.
3. The area under the curve of a v_x versus time graph is equal to the *x*-component of the displacement.
4. The slope of a line tangent to a curve on a v_x versus time graph is equal to the *x*-component of the acceleration at the time corresponding to the point where the tangent line touches the curve.
5. The area under the curve of an a_x versus time graph is equal to the change in the *x*-component of the velocity.
6. The slope of a line tangent to a curve on a graph plotting the *x*-component of position versus time is equal to the *x*-component of the instantaneous velocity at the time corresponding to the point where the tangent line touches the curve.
7. The average velocity of an object is defined as the ratio of the displacement of the object during an interval of time to the length of the time interval. The instantaneous velocity of an object is obtained from the average velocity by using a time interval that approaches zero. An object can have different average velocities for different time intervals. However, the average velocity for one particular time interval has a unique value.
8. Yes, the instantaneous velocity of an object can be zero while the acceleration is nonzero. When you toss a ball straight up in the air, its acceleration is directed downward, with a magnitude of *g*, the entire time it’s in the air. Its velocity is zero at the highest point of its path, however. At previous times its acceleration is associated with its upward velocity decreasing. At later times the same acceleration describes the downward velocity increasing in magnitude. At the apex of the motion, the same acceleration describes the object's changing direction.
9. **(a)** $a_x > 0$ and $v_x < 0$ means you are moving south and slowing down.

   (b) $a_x = 0$ and $v_x < 0$ means you are moving south at a constant speed.

   (c) $a_x < 0$ and $v_x = 0$ means you are momentarily at rest as you change your direction of motion from north to south.

   (d) $a_x < 0$ and $v_x < 0$ means you are moving south and speeding up.

   (e) As can be seen from our answers above, it is not a good idea to use the term “negative acceleration” to mean slowing down. In parts (c) and (d), the acceleration is negative, but the bicycle is speeding up. Also, in part (a), the acceleration is positive, but the bicycle is slowing down.
10. At the highest point of the coin's motion, it is momentarily at rest, so its velocity is zero. Throughout the coin's motion, its acceleration is downward, with magnitude called *g*, the local free-fall acceleration or the local gravitational field. (We ignore air resistance for a coin much denser than air, not shaped like a parachute or potato chip, and moving slowly compared to sound.)
11. The balls cross paths at a height above *h*/2. From the top of its flight, the first ball moves relatively slowly and for the same time interval as the second ball, which has higher speeds in its motion from the moment it is released until it meets the first ball. The higher speed of the second ball means it moves over a greater distance than the first ball in the section of motion we consider.

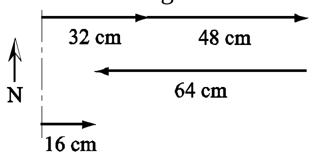
Multiple Choice Questions

1. (c) **2.** (d) **3.** (a) **4.** (b) **5.** (c) **6.** (a) **7.** (b) **8.** (a) **9.** (a) **10.** (c) **11.** (a) **12.** (a) **13.** (d) **14.** (c) **15.** (d) **16.** (a) **17.** (b) **18.** (a) **19.** (d) **20.** (c) **21.** + **22.** $+x$ **23.** $-x$ **24.** not changing **25.** – **26.** $+x$ **27.** – **28.** 0 **29.** $-x$ **30.** decreasing

Problems

1. **Strategy** Let east be the $+x$-direction.

   Solution Draw a vector diagram; then compute the sum of the three displacements.
   The vector diagram:

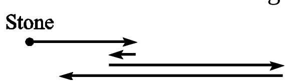


   The sum of the three displacements is $(32\text{ cm} + 48\text{ cm} - 64\text{ cm})$ east = $\boxed{16\text{ cm east}}$.

   Discussion. We would get the same physical answer if we chose west as the positive direction.

2. **Strategy** Let the positive direction be to the right. Make a vector diagram with the location of the stone as the starting point.

   Solution The vector diagram:



   Add the displacements.

$$\begin{aligned}\Delta\vec{\mathbf{r}} &= 4.0\text{ m right} + 1.0\text{ m left} + 6.5\text{ m right} + 8.3\text{ m left}\\ &= 4.0\text{ m right} - 1.0\text{ m right} + 6.5\text{ m right} - 8.3\text{ m right}\\ &= 1.2\text{ m right}\end{aligned}$$

   The squirrel's total displacement from his starting point is $\boxed{\text{1.2 m to the right of the starting point}}$.

3. Strategy Let east be the +x-direction.

Solution Compute the displacements; then find the total distance traveled.

(a) The runner's displacement from his starting point is

$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}}_f - \vec{\mathbf{r}}_i = 20 \text{ m west} - 60 \text{ m east} = 20 \text{ m west} + 60 \text{ m west} = \boxed{80 \text{ m west or } -80 \text{ m}}$.

(b) Since the runner is located 20 m west of the milestone, his displacement from the milestone is $\boxed{20 \text{ m west or } -20 \text{ m}}$.

(c) The runner's displacement from his starting point is

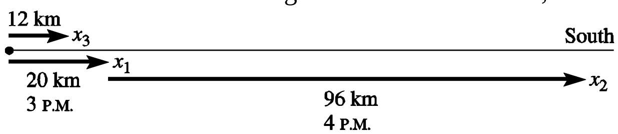
$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}}_f - \vec{\mathbf{r}}_i = 140 \text{ m east} - 60 \text{ m east} = \boxed{80 \text{ m east or } +80 \text{ m}}$.

(d) The runner first jogs $60 \text{ m} + 20 \text{ m} = 80 \text{ m}$; then he jogs $20 \text{ m} + 140 \text{ m} = 160 \text{ m}$. The total distance traveled is

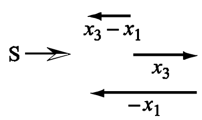
$80 \text{ m} + 160 \text{ m} = \boxed{240 \text{ m}}$.

4. Strategy Let south be the +x-direction.

Solution Draw vector diagrams for each situation; then find the displacements of the car.



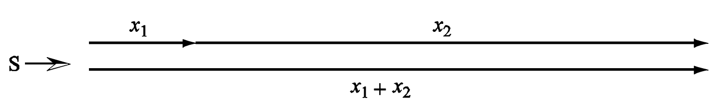
(a)



$x_3 - x_1 = 12 \text{ km} - 20 \text{ km} = -8 \text{ km}$

The displacement of the car between 3 P.M. and 6 P.M. is $\boxed{\text{8 km north of its position at 3 P.M.}}$

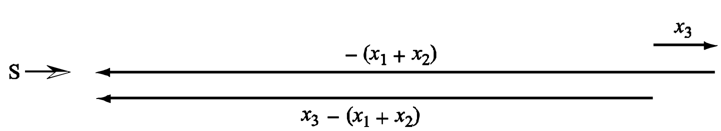
(b)



$x_1 + x_2 = 20 \text{ km} + 96 \text{ km} = 116 \text{ km}$

The displacement of the car from the starting point to the location at 4 P.M. is $\boxed{\text{116 km south of the starting point.}}$

(c)



$x_3 - (x_1 + x_2) = 12 \text{ km} - 116 \text{ km} = -104 \text{ km}$

The displacement of the car between 4 P.M. and 6 P.M. is $\boxed{\text{104 km north of its position at 4 P.M.}}$

5. Strategy Use the definition of average velocity.

Solution Find the average velocity of the train.

$$\vec{\mathbf{v}}_{av} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t} = \frac{10 \text{ km east} - 3 \text{ km east}}{3{:}28 - 3{:}14} = \frac{7 \text{ km east}}{14 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ h}} = \boxed{30 \text{ km/h east}}$$

Discussion. The values of $\vec{\mathbf{r}}$ depend on the choice of origin, but the values of $\Delta\vec{\mathbf{r}}$ and $\vec{\mathbf{v}}$ do not.

6. Strategy Use the definition of average velocity.

Solution Find the average velocity of the cyclist in meters per second.

$$\vec{\mathbf{v}}_{av} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t} = \frac{10.0 \text{ km east}}{11 \text{ min } 40 \text{ s}} = \frac{10.0\times10^3 \text{ m east}}{700 \text{ s}} = \boxed{14.3 \text{ m/s east}}$$

7. Strategy Since the swift flies in a single direction, use the definition of average speed and the fact that it flies due north. The conversion factor is 1 mi/h = 0.4470 m/s.

Solution Find the average velocity of the swift.

$$v_{av} = \frac{\Delta r}{\Delta t} = \frac{3.2\times10^3 \text{ m}}{32.8 \text{ s}} = 98 \text{ m/s} \text{ and } v_{av} = \frac{\Delta r}{\Delta t} = \frac{3.2\times10^3 \text{ m}}{32.8 \text{ s}} \times \frac{1 \text{ mi/h}}{0.4470 \text{ m/s}} = 220 \text{ mi/h}, \text{ so}$$

$$\vec{\mathbf{v}}_{av} = \boxed{98 \text{ m/s } (220 \text{ mi/h}) \text{ due north}}.$$

Discussion. We could have used the conversion factors 1 mi = 1609 m and 1 h = 3600 s.

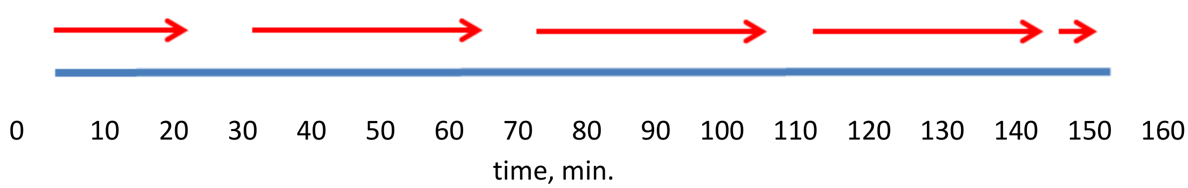
8. Strategy Jason never changes direction, so the direction of the average velocity is due west. Find the average speed by dividing the total distance traveled by the total time.

Solution The distance traveled during each leg of the trip is given by $\Delta x = v_{av}\Delta t$.

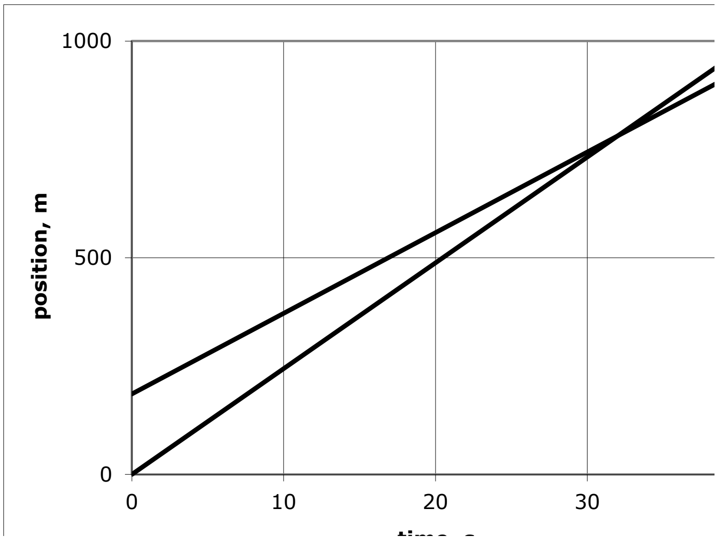
$$v_{av} = \frac{(35.0 \text{ mi/h})(0.500 \text{ h}) + (60.0 \text{ mi/h})(2.00 \text{ h}) + (25.0 \text{ mi/h})(10.0/60.0) \text{ h}}{0.500 \text{ h} + 2.00 \text{ h} + (10.0/60.0) \text{ h}} = 53.1 \text{ mi/h}$$

So, the average velocity is $\boxed{53.1 \text{ mi/h due west}}$.

Motion Diagram at 10 minute intervals:



9. Strategy When the Boxster catches the Scion, the displacement of the Boxster will be $\Delta r + 186$ m and the displacement for the Scion will be Δr. For both cars the Δt will be the same.



The steeper line represents the motion of the Boxster. The line that starts out on top is the Scion. On the graph it appears that the faster car overtakes in about 32 s. We can find a precise value algebraically:

Solution Find the time it takes for the Boxster to catch the Scion.

$v_{av} = \dfrac{\Delta r_{car}}{\Delta t}$, so for the Boxster, $v_{av,B} = \dfrac{\Delta r + 186\ \text{m}}{\Delta t}$ or $\Delta r = v_{av,B}\Delta t - 186\ \text{m}$.

For the Scion,

$v_{av,S} = \dfrac{\Delta r}{\Delta t}$, so $\Delta r = v_{av,S}\Delta t$.

Equate the two expressions for Δr.

$$v_{av,S}\Delta t = v_{av,B}\Delta t - 186\ \text{m}$$

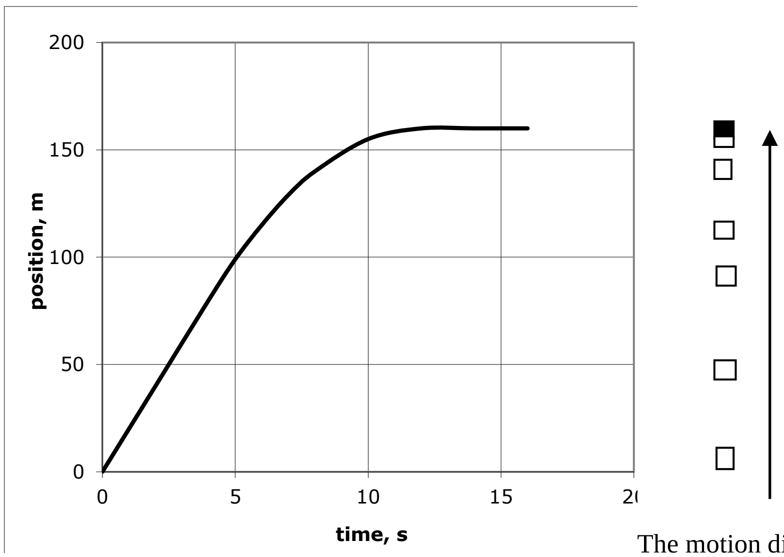
$$(v_{av,S} - v_{av,B})\Delta t = -186\ \text{m}$$

$$\Delta t = \frac{186\ \text{m}}{v_{av,B} - v_{av,S}} = \frac{186\ \text{m}}{24.4\ \text{m/s} - 18.6\ \text{m/s}} = \frac{186\ \text{m}}{5.8\ \text{m/s}} = \boxed{32\ \text{s}}$$

Discussion. The graph clearly shows the situation of the faster car overtaking the slower car, as the intersection of the two lines. The cars have the same position then. The graph complements the precise calculation we have done.

10. Strategy Use the area under the curve to find the displacement of the car.

Solution The displacement of the car is given by the area under the v_x vs. t curve. Under the curve, there are 16 squares and each square represents (5 m/s)(2 s) = 10 m. Therefore, the car moves $16(10\text{ m}) = \boxed{160\text{ m}}$.
Counting squares at 2-s intervals gives the motion diagram



The motion diagram is drawn beside the graph, with the same scale as the vertical position axis of the graph. It is to be read vertically upward. It shows positions at t = 0, 2 s, 4 s, 6, s, 8 s, 10 s, and, with the black box, at 12, 14, and 16 s.

11. **Strategy and Solution** Look at the slope or steepness of the line in each 1-s time interval. [4 to 5 s] has the biggest (and only) downward slope. [2 to 3 s] has zero slope. [0 to 1, 1 to 2, and 3 to 4 s] have gentle upward slopes and [5 to 6 s] has the steepest upward slope.

12. **Strategy and Solution** Look at the steepness of the line in each 1-s interval without regard for whether it is going up or down. The line from [2 to 3 s] is flat. [0 to 1, 1 to 2, and 3 to 4s] have gentle slopes. [5 to 6 s] is steeper and [4 to 5 s] is still closer to vertical.

Discussion. The answer to this question is just like the answer to question 12, about slope as a signed number, except for the placement in the ranking of the one down-sloping section (4 to 5 s). Instead of being placed as the smallest actual slope, it is now placed with the biggest absolute value of slope.

13. **Strategy and Solution** Look at the slope or steepness of the line in each 1-s time interval. [5 to 6 s] has the steepest upward slope. [0 to 1, 1 to 2, and 3 to 4 s] have gentle upward slopes. [2 to 3 s] has zero slope. [4 to 5 s] has the biggest (and only) downward slope.

14. Strategy Use the graph to answer the question. What color is George Washington's white horse?

Solution It starts at $x = 0$ at $t = 0$ and at $t = 3$ s is at $x = 20$ m, so it has moved $\boxed{20\text{ m}}$.

15. Strategy Set up ratios of speeds to distances.

Solution Use $v = \Delta x/\Delta t$, write it as $v/\Delta x = 1/\Delta t$, apply it to each object, set the expression for the baseball equal to that for the softball, and find the speed of the baseball v.

$$\frac{v}{60.5\text{ ft}} = \frac{65.0\text{ mi/h}}{43.0\text{ ft}},\quad \text{so}\quad v = \frac{65.0\text{ mi/h}}{43.0\text{ ft}}(60.5\text{ ft}) = \boxed{91.5\text{ mi/h}}.$$

16. (a) Strategy Use the area between the v_y vs. t curve and the x-axis to find the displacement of the elevator.

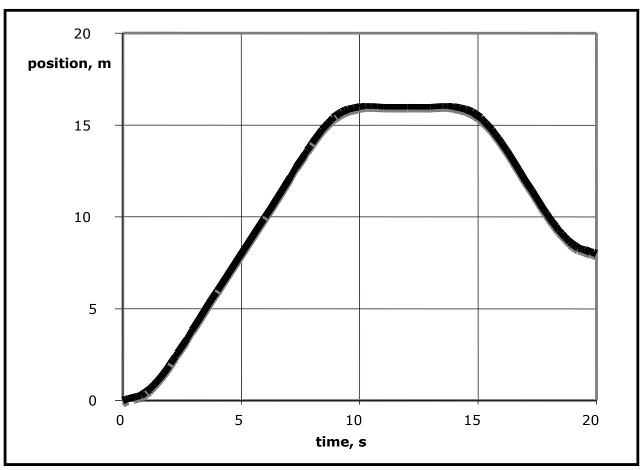
Solution From $t = 0$ s to $t = 10$ s, there are 8 squares. From $t = 14$ s to $t = 20$ s, there are 4 squares. Each square represents (1 m/s)(2 s) = 2 m. The displacement from $t = 14$ s to $t = 20$ s is negative $(v_y < 0)$. So the total displacement is $\Delta y = 8(2\text{ m}) + (-4)(2\text{ m}) = 8\text{ m}$, and the elevator is $\boxed{8\text{ m}}$ above its starting point.

(b) Strategy Use the slope of the curve to determine when the elevator reaches its highest point.

Solution The vertical velocity is positive for $t = 0$ s to $t = 10$ s. It is negative for $t = 14$ s to $t = 20$ s. It is zero for $t = 10$ s to $t = 14$ s. So the elevator reaches its highest location at $t = 10$ s and remains there until $t = 14$ s before it goes down. Thus, the elevator is at its highest location from $\boxed{t = 10\text{ s to } t = 14\text{ s}}$.

(c) Strategy and Solution.

The elevator starts from rest at the origin at time zero. It gains upward speed for 2 s, moves steadily upward at 2 m/s for 6 s, and slows to a stop in another 2 s. It stays at height 16 m above its starting point for 4 s, then gains speed moving down for 2 s, coasts steadily down at 2 m/s for 2 s, and comes to a stop at elevation 8 m in a final 2-s time interval.



(d)

17. Strategy Use vector subtraction to find the change in velocity.

Solution Find the change in velocity of the scooter.

$$\Delta\vec{\mathbf{v}} = \vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i = 15\text{ m/s west} - 12\text{ m/s east} = 15\text{ m/s west} - (-12\text{ m/s west}) = \boxed{27\text{ m/s west}}$$

Discussion. Thinking about a vector change, or a change that is larger than the original value, is a mental step that a normal person puts some effort into understanding.

18. Strategy Determine the maximum time allowed to complete the run.

Solution Massimo must take no more than $\Delta t = \Delta x/v = 1000\text{ m}/(4.0\text{ m/s}) = 250\text{ s}$ to complete the run. Since he ran the first 900 m is 250 s, $\boxed{\text{he cannot pass the test because he would have to run the last 100 m in 0 s}}$.

19. Strategy Use the definition of average velocity.

Solution Find the average velocities of the skater.

(a) $v_{\text{av},x} = \dfrac{\Delta x}{\Delta t} = \dfrac{6.0\text{ m} - 0}{4.0\text{ s}} = \boxed{1.5\text{ m/s}}$

(b) $v_{\text{av},x} = \dfrac{6.0\text{ m} - 0}{5.0\text{ s}} = \boxed{1.2\text{ m/s}}$

20. Strategy The slope of the x vs. t curve is equal to v_x. Use the definition of instantaneous velocity.

Solution Compute the instantaneous velocity at $t = 2.0$ s as the slope of the straight segment going through this point. $v_x = \dfrac{6.0\text{ m} - 4.0\text{ m}}{3.0\text{ s} - 1.0\text{ s}} = \boxed{1.0\text{ m/s}}$

Discussion. We made a free choice of any two points along the line segment passing through (2 s, 5 m).

21. Strategy The slope of each segment (between changes in the slope) of the graph is equal to the speed during that time period.

Solution Find the speed during each time period. Then, plot v_x as a function of time.

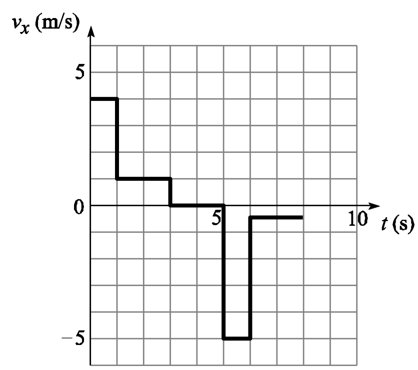
$0 < t < 1\text{ s: } v_x = \dfrac{4\text{ m}}{1\text{ s}} = 4\text{ m/s}$

$1 < t < 3\text{ s: } v_x = \dfrac{6\text{ m} - 4\text{ m}}{3\text{ s} - 1\text{ s}} = 1\text{ m/s}$

$3 < t < 5\text{ s: } v_x = \dfrac{6\text{ m} - 6\text{ m}}{5\text{ s} - 3\text{ s}} = 0\text{ m/s}$

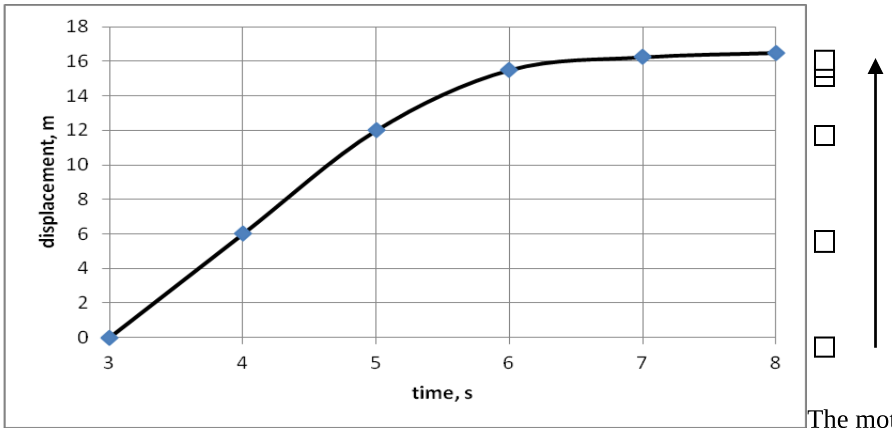
$5 < t < 6\text{ s: } v_x = \dfrac{1\text{ m} - 6\text{ m}}{6\text{ s} - 5\text{ s}} = -5\text{ m/s}$

$6 < t < 8\text{ s: } v_x = \dfrac{0\text{ m} - 1\text{ m}}{8\text{ s} - 6\text{ s}} = -0.5\text{ m/s}$



22. Strategy Use the area under the curve to find the displacement of the skateboard.

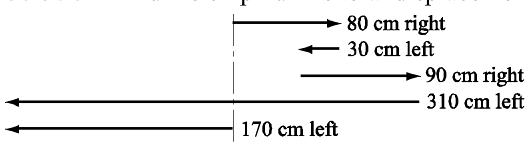
Solution The displacement of the skateboard is given by the area under the v vs. t curve. Under the curve for $t = 3.00$ s to $t = 8.00$ s, there are 16.5 squares and each square represents (1.0 m/s)(1.0 s) = 1.0 m; so the board moves $\boxed{16.5\text{ m}}$. Counting squares at 1-s intervals from 3 s to 8 s gives the motion diagram



The motion diagram is shown beside the graph, with the same scale as the vertical position axis of the graph. It is to be read vertically upward.

23. (a)Strategy Let the positive direction be to the right. Draw a diagram.

Solution Find the chipmunk's total displacement.



$80\text{ cm} - 30\text{ cm} + 90\text{ cm} - 310\text{ cm} = -170\text{ cm}$

The total displacement is $\boxed{170\text{ cm to the left}}$.

(b) Strategy The average speed is found by the dividing the total distance traveled by the elapsed time.

Solution Find the total distance traveled. $80\text{ cm} + 30\text{ cm} + 90\text{ cm} + 310\text{ cm} = 510\text{ cm}$

Find the average speed. $\dfrac{510\text{ cm}}{18\text{ s}} = \boxed{28\text{ cm/s}}$

(c) Strategy The average velocity is found by dividing the displacement by the elapsed time.

Solution Find the average velocity.

$$\vec{\mathbf{v}}_{\text{av}} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t} = \frac{170\text{ cm to the left}}{18\text{ s}} = \boxed{9.4\text{ cm/s to the left}}$$

24. Strategy The average speed is found by dividing the total distance traveled by the elapsed time.

(a) Solution Find the average speed for the first 10-km segment of the race.

$$v_1 = \frac{10.0\times10^3\text{ m}}{0.5689\text{ h}}\frac{1\text{ h}}{3600\text{ s}} = \frac{10.0\times10^3\text{ m}}{2048\text{ s}} = \boxed{4.88\text{ m/s}}$$

(b) Solution Find the average speed for the entire race.

$$v_{\text{av}} = \frac{42{,}195\text{ m}}{2.3939\text{ h}}\frac{1\text{ h}}{3600\text{ s}} = \frac{42{,}195\text{ m}}{8618\text{ s}} = \boxed{4.90\text{ m/s}}$$

25. Strategy Use the definition of average velocity. Find the time spent by each runner in completing her portion of the race.

Solution The times for each runner are given by $\Delta t = \Delta r/v$ as

$300.0\text{ m}\div 7.30\text{ m/s}=41.1\text{ s}$, $300.0\text{ m}\div 7.20\text{ m/s}=41.7\text{ s}$, and $100.0\text{ m}\div 7.80\text{ m/s}=12.8\text{ s}$. The net displacement of the baton is 100.0 m to the north, so the average velocity of the baton for the entire race is

$$\vec{\mathbf{v}}_{\text{av}}=\frac{\Delta\vec{\mathbf{r}}}{\Delta t}=\frac{100.0\text{ m north}}{41.1\text{ s}+41.7\text{ s}+12.8\text{ s}}=\boxed{1.05\text{ m/s to the north}}.$$

Discussion. Note the contrast in adding net displacement and total time. Time is not a vector.

26. Strategy. Use the definition of instantaneous speed as the magnitude of the slope of a tangent to a position-versus-time graph.
Solution. Pick out by eye the steepest slope of the graph in Figure 2.8 as at about 46 s. A tangent line drawn here passes through about (34 s, 15 km) and (46 s, –10 m/s) and (56 s, –30 m/s). We can choose any pair of these points to find its slope. For best precision we choose the two farthest apart:

$$|\vec{\mathbf{v}}_{\text{av}}|=\frac{|\Delta\vec{\mathbf{r}}|}{\Delta t}=\frac{|-30\text{ km}-15\text{ km}|}{56\text{ min}-34\text{ min}}=2.05\frac{\text{km}}{\text{min}}=2.05\frac{\text{km}}{\text{min}}\frac{60\text{ min}}{1\text{ h}}=\boxed{1.2\times10^2\text{ km/h}}.$$

27. Strategy Use $\Delta v=a\Delta t$ and solve for Δt.

Solution

$$\Delta t=\frac{\Delta v}{a}=\frac{22\text{ m/s}-0}{1.7\text{ m/s}^2}=\boxed{13\text{ s}}$$

28. Strategy Use the definition of average acceleration.

Solution

$$\vec{\mathbf{a}}_{\text{av}}=\frac{\Delta\vec{\mathbf{v}}}{\Delta t}=\frac{\vec{\mathbf{v}}_{\text{f}}-\vec{\mathbf{v}}_{\text{i}}}{\Delta t}$$
$$=\frac{0-28\text{ m/s in the direction of the car's travel}}{4.0\text{ s}}=\boxed{7.0\text{ m/s}^2\text{ in the direction opposite the car's velocity}}$$

29. Strategy Refer to the graph. The absolute value of the slope of a *v* versus *t* graph is equal to the magnitude of the acceleration. The steeper the slope up or down, the larger the magnitude.

Solution We see directly the steepest slope for the time interval between 5 and 6 s, then between 0 and 1 s, then between 1 and 3 s, then between 6 and 8 s, and zero slope between 3 and 5 s. For the instants of time that this problem asks about, the ranking in order of the magnitude of the acceleration, from largest to smallest, is

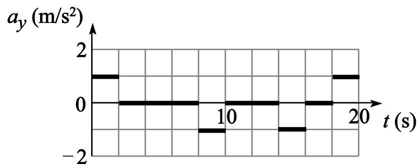
$\boxed{5.5\text{ s}, 0.5\text{ s}, 1.5\text{ s} = 2.5\text{ s}, 3.5\text{ s} = 4.5\text{ s}}$.

Discussion. We can calculate the magnitude of the acceleration at each instant by computing the magnitude of the slope of the tangent there, which is the slope of the segment of the graph passing through the point. This is easy to do by counting boxes, because each box is 1 s by 1 m/s.

t (s)	0.5	1.5	2.5	3.5	4.5	5.5
$|a|$ (m/s^2)	4	1	1	0	0	$|-5|=5$

Our ranking is confirmed.

30. Strategy The acceleration is equal to the value of the slope of the *v* versus *t* graph.
Solution Between 8 and 10 s, for example, we have $a=\Delta v/\Delta t=(0-2\text{ m/s})/2\text{ s}=-1\text{ m/s}^2$. The sketch of the acceleration of the elevator is shown.



31. Strategy Use the definition of average acceleration.

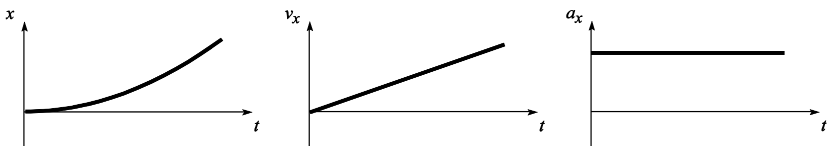
Solution Find the average acceleration of the airplane.

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{(35\ \text{m/s} - 0)}{8.0\ \text{s}} = 4.4\ \text{m/s}^2;\ \text{thus}\ \vec{\mathbf{a}}_{\text{av}} = \boxed{4.4\ \text{m/s}^2\ \text{forward}}.$$

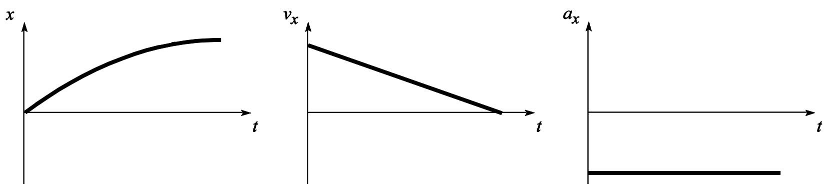
32. Strategy Use the definitions of position, velocity, and acceleration.

Solution Sketch graphs of $x(t)$, $v_x(t)$, and $a_x(t)$. Describe the motion in words.

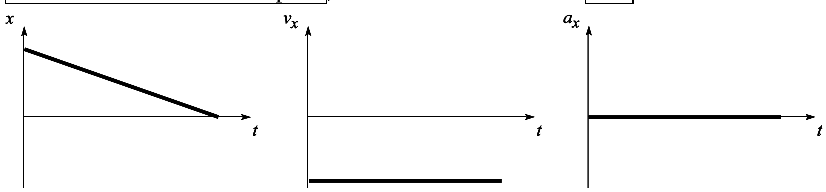
(a) Since the distance between the dots is increasing to the right, the motion of the object is to the right with increasing speed, and the acceleration is positive and to the right.



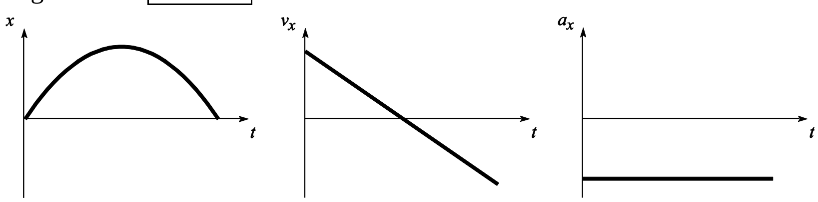
(b) Since the distance between the dots is decreasing to the right, the motion of the object is to the right with decreasing speed, and the acceleration is negative and to the left.



(c) Since the distance between the dots is the same and the motion is from right to left, the motion of the object is to the left with constant speed, and the acceleration is zero.

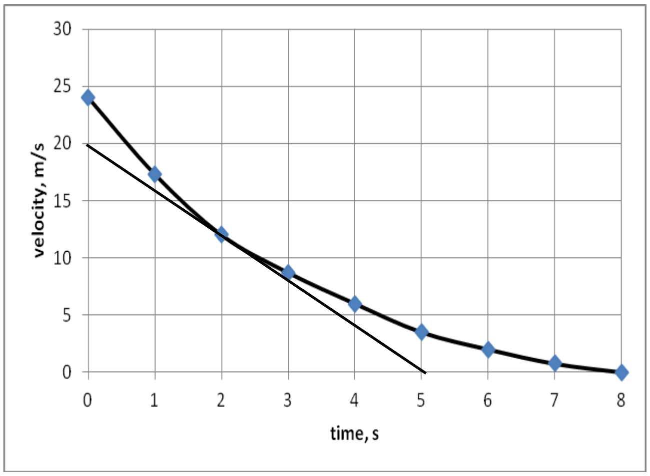


(d) The distance between the dots decreases from left to right; then increases from right to left. The object moves to the right with decreasing speed, turns around at point 4, and then moves to the left with increasing speed. Since the speed decreases when the object moves to the right and increases when it moves to the left, the acceleration is negative and to the left.



33. Strategy Follow the directions and note the contrast between average and instantaneous.

Solution



(a) The average acceleration over the zero-to-eight-second time interval is

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{0-24\text{ m/s}}{8\text{ s}-0} = -3.0\text{ m/s}^2 \quad \text{so} \quad \vec{\mathbf{a}}_{avg} = 3.0\text{ m/s}^2 \text{ away from the deer}$$

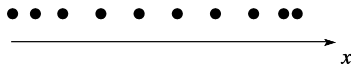
(b) We draw by eye a tangent line at $t = 2$ s and find its slope from two well-separated points:

$$a = \frac{\Delta v}{\Delta t} \approx \frac{0-20\text{ m/s}}{5\text{ s}-0} = -4.0\text{ m/s}^2 \quad \text{so} \quad \vec{\mathbf{a}} \approx 4.0\text{ m/s}^2 \text{ away from the deer}$$

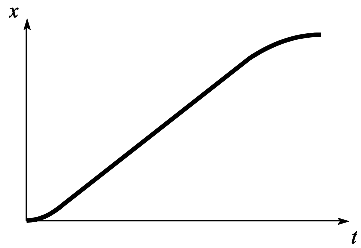
Discussion One way to estimate the uncertainty is to do an operation a few or several times, using different methods if possible, and see how much scatter shows up; or just to apply critical thinking in general. This applies to laboratory measurements and to sketching a tangent line. Here, if (0, 20 m/s) and (5 s, 0) are on the straight tangent line, the vertical-axis coordinate at $t = 2$ s should be 20 – 4(2) = 12 m/s. This agrees with the data table, so we have some confidence that answer (b) is accurate to two digits.

34. Strategy Consider (say) an 800-m race. For the motion diagram, the dots will be closer together at the beginning and at the end of the race than in the middle, to reflect the positive and negative accelerations—speeding up and slowing down. The dots can be evenly spaced for the middle of the race as the runner can be running with approximately constant speed. Use the definitions of displacement, velocity, and acceleration to sketch the graphs. (In a 100-m race, sprinters are taught to speed up all the way and to break the tape when they are moving faster than ever before, so there might be no constant-speed portion in the diagram or graphs.)

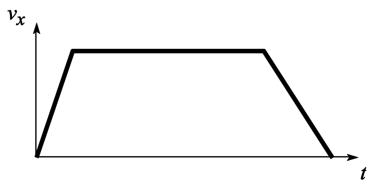
Solution Sketch the motion diagram.



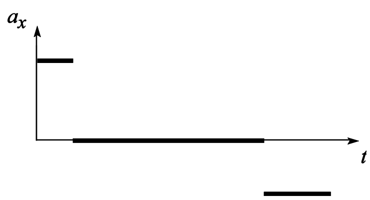
Sketch the graph of $x(t)$.



Sketch the graph of $v_x(t)$.



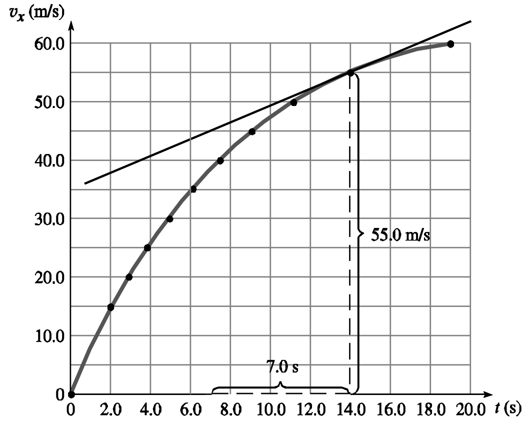
Sketch the graph of $a_x(t)$.



35. Strategy Use the definitions of instantaneous acceleration, displacement, and average velocity.

Solution

(a) We draw a line tangent to the point at $(14.0\text{ s},\ 55.0\text{ m/s})$.



It looks as if the tangent line passes through the point $(7.0\text{ s},\ 45.0\text{ m/s})$. Its slope is then

$$\vec{\mathbf{a}}_x = \frac{\Delta\vec{\mathbf{v}}_x}{\Delta t} = \frac{(55.0\ \text{m/s} - 45.0\ \text{m/s})\text{ in the }+x\text{-direction}}{14.0\text{ s} - 7.0\text{ s}} = \boxed{1.4\ \text{m/s}^2\text{ in the }+x\text{-direction}}$$

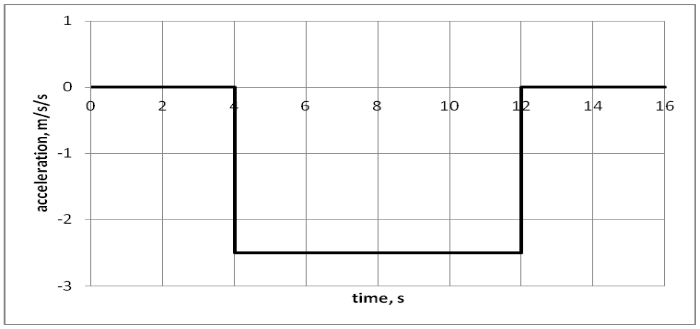
(b) The area under the v_x vs. t curve from t = 12.0 s to t = 16.0 s represents the displacement of the body. Each grid square represents $(10.0\text{ m/s})(1.0\text{ s}) = 1.0 \times 10^1\text{ m},$ and there are approximately 22 squares under the curve for t = 12.0 s to t = 16.0 s, so the car travels $\boxed{220\text{ m in the }+x\text{-direction}}$.

(c) $$\vec{\mathbf{v}}_{\text{av}} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t} = \frac{220\text{ m in the }+x\text{-direction}}{4.0\text{ s}} = \boxed{55\text{ m/s in the }+x\text{-direction}}$$

36. Strategy The magnitude of the acceleration is the absolute value of the slope of the graph at $t = 7.0$ s.

Solution We choose two well-separated points along the straight section of graph that passes through the $t = 7$ s point.

$$a_x = \left|\frac{\Delta v_x}{\Delta t}\right| = \left|\frac{0 - 20.0\ \text{m/s}}{12.0\ \text{s} - 4.0\ \text{s}}\right| = \boxed{2.5\ \text{m/s}^2}$$



37. (a) Strategy The acceleration a_x is equal to the slope of the v_x versus t graph. Use the definition of average acceleration.

Solution $a_{\text{av},x} = \frac{\Delta v_x}{\Delta t} = \frac{14\ \text{m/s} - 4\ \text{m/s}}{11\ \text{s} - 6\ \text{s}} = \boxed{2.0\ \text{m/s}^2}$

(b) Strategy For constant acceleration, $v_{\text{av},\,x} = (v_\text{f} + v_\text{i})/2.$

Solution $v_{\text{av},\,x} = \frac{14\ \text{m/s} + 4\ \text{m/s}}{2} = \boxed{9.0\ \text{m/s}}$

(c) Strategy $v_{\text{av},\,x} = \Delta x/\Delta t$ and Δx is the area under the graph in the figure. Find the area.

Solution Each square represents $(1.0\ \text{m/s})(1.0\ \text{s}) = 1.0\ \text{m}$ and there are 195 squares under the graph. So,

$v_{\text{av},\,x} = \frac{195(1.0\ \text{m})}{20.0\ \text{s}} = \boxed{9.8\ \text{m/s}}.$

(d) Strategy At $t = 10$ s, $v_x = 12$ m/s, and at $t = 15$ s, $v_x = 14$ m/s.

Solution $\Delta v_x = 14\ \text{m/s} - 12\ \text{m/s} = \boxed{2.0\ \text{m/s}}$

(e) Strategy The area under the v_x vs. t graph for $t = 10$ s to $t = 15$ s represents the displacement of the car.

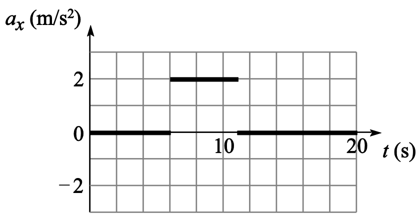
Solution Each square represents 1.0 m. There are 69 of these squares, so the car has traveled (1.0 m)(69) = $\boxed{69\ \text{m}}$.

Discussion For the section of motion from 6 to 11 s, the graph of v versus t is a single straight line, so a is constant, so a constant-acceleration equation like $v_{\text{av},\,x} = (v_\text{f} + v_\text{i})/2.$ is true. In part (e), for the section of motion from 10 to 15 s, the acceleration does not have a single constant value, so we cannot compute the correct value for Δx from $\Delta x = (v_\text{f} + v_\text{i})\,t/2.$ [Try it and see how the answer is tempting but wrong. That is also the reason that the calculation in part (b) does not give the answer to part (c).] On the other hand, we do not really have to count squares here. We can take the 10-to-15 s section of motion apart into two constant-a sections: from 10 s to 11 s with $\Delta x = (v_\text{f} + v_\text{i})\,t/2.$ = (13 m/s)(1 s) = 13 m and from 11 to 15 s with $\Delta x = vx\,\Delta t$ = (14 m/s)(4 s) = 56 m. Then the net displacement is 56 + 13 m = 69 m.

38. Strategy The acceleration a_x is equal to the slope of the v_x versus t graph.

Solution Sketch a graph of $a_x(t)$ for the car. The constant slope of the curve from $t = 6$ s to $t = 11$ s is

$$a_{\text{av},x} = \frac{\Delta v_x}{\Delta t} = \frac{14\ \text{m/s} - 4\ \text{m/s}}{11\ \text{s} - 6\ \text{s}} = \boxed{2.0\ \text{m/s}^2}.$$



39. Strategy The acceleration a_x is equal to the slope of the v_x versus t graph. The displacement is equal to the area under the curve.

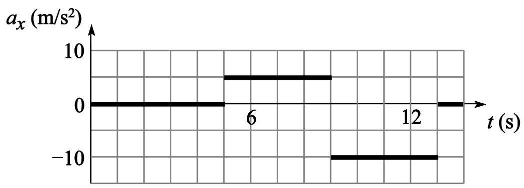
Solution

(a) a_x is the slope of the graph at $t = 11$ s.

$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{10.0\ \text{m/s} - 30.0\ \text{m/s}}{12.0\ \text{s} - 10.0\ \text{s}} = \boxed{-10\ \text{m/s}^2}$$

(b) Since v_x is staying constant, $a_x = \boxed{0}$ at $t = 3$ s.

(c) Sketch the acceleration using the v_x versus t graph.



(d) The area under the v_x vs. t curve from $t = 12$ s to $t = 14$ s represents the displacement of the body. Each square represents $(10.0\ \text{m/s})(1.0\ \text{s}) = 1.0 \times 10^1$ m, and there is $1/2$ square under the curve for $t = 12$ s to $t = 14$ s, so the car travels $\boxed{5.0\ \text{m}}$.

40. Strategy Use the idea of instantaneous acceleration as the slope of a tangent to a v-versus-t curve. Use the idea of displacement as area on a v-versus-t curve.

Solution. (a) The tangent line drawn at $t = 2$ s in Figure 2.15 appears to go through (0.5 s, –5 m/s) and (3.5 s, –2m/s). Its slope is then $a = \frac{-2-(-5)}{3.5-0.5}\frac{\text{m/s}}{\text{s}} = \boxed{+1.0\ \text{m/s}^2}$

(b) Method one: Think about cutting the shape bounded by the graph line and the axes out of plywood, turning it so that the velocity axis is horizontal, and homing in on a point on the v axis where the shape could be balanced, with as much weight of higher speeds on one side as of lower speeds on the other side. We estimate in this way that the average velocity is about –2 m/s.

Method two: There are about –9.7 rectangles of area between the graph line and the t axis and between $t = 0$ and $t = 10$ s. Each rectangle is (2 s)(1 m/s) = 2 m, so the stopping distance is about (–9.7)(2 m) = –19 m. Then the average velocity in the process is $v_{avg} = \Delta x/\Delta t = -19\ \text{m}/10\ \text{s} = -1.9$ m/s, We think of this estimate as more precise than that from method one, so we say the average speed is $\boxed{1.9\ \text{m/s}}$.

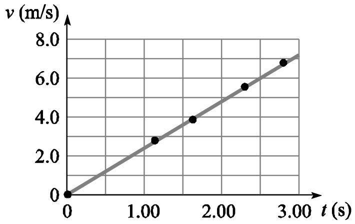
41. Strategy Since the time intervals are the same, a greater *change* in distance between each successive pairs of dots indicates a greater magnitude acceleration. If there is no change in distance between dots, the acceleration is zero.

Solution The distance between dots in (b) and (c) is constant; therefore, the accelerations are zero. The distance between dots in (a) and (d) is increasing, indicating a positive acceleration. The increase is greater for (a) than for (d); therefore, (a) represents a greater magnitude acceleration than (d). Ranking the motion diagrams in order of the magnitude of the acceleration, from greatest to lest, we have $\boxed{\text{(a), (d), (b) = (c)}}$.

Discussion. Start believing that a lot of information is packed into a motion diagram. Use a ruler to demonstrate what we state about the changes in distance between the dots.

42. (a) Strategy Plot the data on a v versus t graph. Draw a best-fit line.

Solution



(b) Strategy The slope of the graph gives the acceleration.

Solution The points appear to lie quite close to the single straight line drawn for comparison, so $\boxed{\text{yes}}$, it is plausible that the acceleration is constant. Compute the magnitude of the acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{7.2 \text{ m/s} - 0}{3.0 \text{ s} - 0} = 2.4 \text{ m/s}^2$$

The acceleration is $\boxed{2.4 \text{ m/s}^2 \text{ in the direction of motion}}$.

43. Strategy Use equations for motion with constant acceleration.

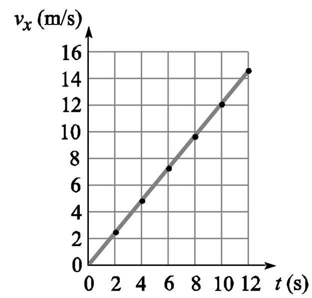
Solution (a) With v_{ix} = 200 m/s, v_{fx} =700 m/s, a_x = 9.0g = 882. m/s^2 we want Δt. We choose $v_{fx} - v_{ix} = a_x\Delta t$ to find $\Delta t = \frac{v_{fx} - v_{ix}}{a_x} = \frac{700 \text{ m/s} - 200 \text{ m/s}}{88.2 \text{ m/s}^2} = \boxed{5.7 \text{ s}}$

(b) With the same data we can find Δx from $v_{fx}^2 - v_{ix}^2 = 2a_x\Delta x$ thus:

$$\Delta x = \frac{v_{fx}^2 - v_{ix}^2}{2a_x} = \frac{(700 \text{ m/s})^2 - (200 \text{ m/s})^2}{2(88.2 \text{ m/s}^2)} = \boxed{2.6 \text{ km}}$$

44. (a) Strategy The graph will be a line with a slope of 1.20 m/s^2.

Solution $v_x = 0$ when $t = 0$. The graph is shown.



(b) Strategy Use Eq. (2-12).

Solution Find the distance the train traveled.

$$\Delta x = v_{ix}\Delta t + \frac{1}{2}a_x(\Delta t)^2 = (0)\Delta t + \frac{1}{2}a_x(\Delta t)^2 = \frac{1}{2}a_x(\Delta t)^2$$
$$= \frac{1}{2}(1.20 \text{ m/s}^2)(12.0 \text{ s})^2 = \boxed{86.4 \text{ m}}$$

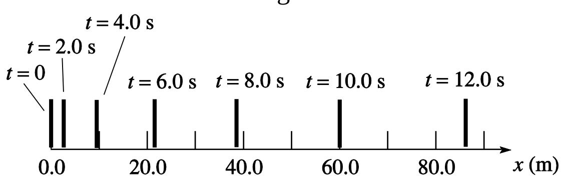
(c) Strategy Use Eq. (2-13).

Solution Find the final speed of the train.

$v_{fx} - v_{ix} = v_{fx} - 0 = a_x\Delta t$, so $v_{fx} = a_x\Delta t = (1.20 \text{ m/s}^2)(12.0 \text{ s}) = \boxed{14.4 \text{ m/s}}$.

(d) Strategy Refer to Figure 2.17, which shows various motion diagrams.

Solution The motion diagram is shown.

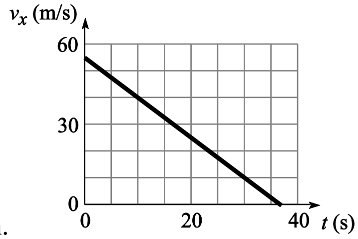


45. Strategy Relate the acceleration, speed, and distance using Eq. (2-13). Let southwest be the positive direction.

Solution Find the constant acceleration required to stop the airplane. The acceleration must be opposite to the direction of motion of the airplane, so the direction of the acceleration is (−southwest) = northeast. Use the acceleration for the slope of the $v_x(t)$ curve.

$$v_{fx}^2 - v_{ix}^2 = 2a_x\Delta x, \text{ so } a_x = \frac{v_{fx}^2 - v_{ix}^2}{2\Delta x} = \frac{0 - (55 \text{ m/s})^2}{2(1.0 \times 10^3 \text{ m})} = -1.5 \text{ m/s}^2.$$

Thus, the acceleration is $\boxed{1.5\ \text{m/s}^2\ \text{northeast}}$. The slope is $-1.5\ \text{m/s}^2$. The v_x-intercept is 55 m/s. Sketch the graph.



Discussion. Do a check: find the area under the curve as the area of a triangle and see if it comes out convincingly close to 1000 m. Note the terminology: A graph line is called a curve whether it is curved or straight or has corners. The "shape" of a graph is not a shape like a square or triangle. Instead, the shape of a graph can be described as flat, as straight and sloping up or down, as curved and starting from a positive or negative value with a positive or negative slope and concave up or concave down, or as a line with corners and sections that can individually be described.

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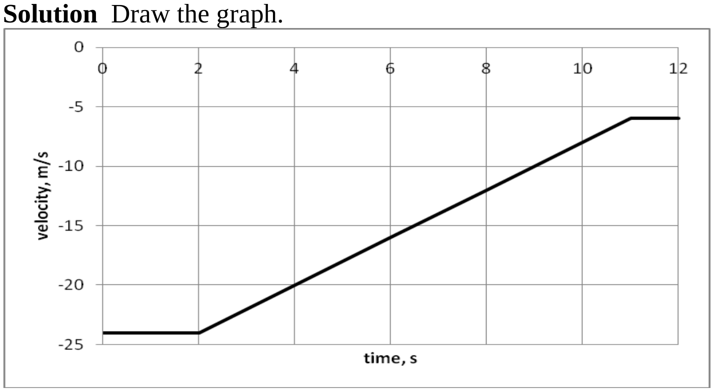
46. (a) Strategy Between 0 to 2 s the velocity is $-24.0\ \text{m/s}$, and between 11 and 12 s the velocity is $-6.0\ \text{m/s}$. Since the acceleration is constant between 2 and 11 s, draw a straight line between the two horizontal lines of constant speed.

Solution Draw the graph.



(b) Strategy Let north be the +*x*-direction. Use Eq. (2-9) to find the acceleration of the train between 2 and 11 s. Before 2 s and after 11 s the acceleration is zero.

Solution

$v_{fx} - v_{ix} = a_x \Delta t$, so $a_x = (v_{fx} - v_{ix})/\Delta t = (-6.00\ \text{m/s} - [-24.0\ \text{m/s}])/(9.00\ \text{s}) = +2.00\ \text{m/s}^2$.

The acceleration is $\boxed{2.00\ \text{m/s}^2\ \text{north}}$.

(c) Strategy We can use Eq. (2-12).

Solution Find the displacement of the train.

$\Delta x = v_{ix}\Delta t + \frac{1}{2}a_x(\Delta t)^2 = (-24.0\ \text{m/s})(9.00\ \text{s}) + \frac{1}{2}(+2.00\ \text{m/s}^2)(9.00\ \text{s})^2 = -135\ \text{m}$, meaning $\boxed{135\ \text{m south}}$

47. (a) Strategy For motion in a straight line, the magnitude of a constant acceleration is equal to the change in speed divided by the time elapsed.

Solution Find how long the airplane accelerated.

$a = \frac{\Delta v}{\Delta t}$, so $\Delta t = \frac{\Delta v}{a} = \frac{46.0\ \text{m/s} - 0}{5.00\ \text{m/s}^2} = \boxed{9.20\ \text{s}}$.

(b) Strategy Use Eq. (2-13).

Solution Find the distance the plane traveled along the runway.

$v_{fx}^2 - v_{ix}^2 = v_{fx}^2 - 0 = 2a_x\Delta x$, so $\Delta x = \frac{v_{fx}^2}{2a_x} = \frac{(46.0\ \text{m/s})^2}{2(5.00\ \text{m/s}^2)} = \boxed{212\ \text{m}}$.

48. Strategy Use Eq. (2-9) for (a) and Eq. (2-11) for (b). Let the "initial" point be at clock reading 10 s and the "final" point be at 12 s.

Solution

(a) Find the speed at 12.0 s.

$v_{fx} - v_{ix} = a_x\Delta t$, so $v_{fx} = a_x\Delta t + v_{ix} = (2.0\ \text{m/s}^2)(12.0\ \text{s} - 10.0\ \text{s}) + 1.0\ \text{m/s} = 4.0\ \text{m/s} + 1.0\ \text{m/s} = \boxed{5.0\ \text{m/s}}$.

(b) Find the distance traveled between $t = 10.0$ s and $t = 12.0$ s.

$\Delta x = \frac{1}{2}(v_{fx} + v_{ix})\Delta t = \frac{1}{2}(5.0\ \text{m/s} + 1.0\ \text{m/s})(12.0\ \text{s} - 10.0\ \text{s}) = \boxed{6.0\ \text{m}}$

49. Strategy Find the time it takes for the car to collide with the tractor (assuming it does) by setting the distance the car travels equal to that of the tractor plus the distance between them and solving for *t*. Use Eq. (2-12). Then, use the standard relationships for constant acceleration to answer the remaining questions.

Solution Solve for the time in Δx for car = Δx for tractor + 25 m

$(27.0\ \text{m/s})\Delta t + \frac{1}{2}(-7.00\ \text{m/s}^2)(\Delta t)^2 = (10.0\ \text{m/s})\Delta t + 25.0\ \text{m}$, so $0 = (3.50\ \text{m/s}^2)(\Delta t)^2 - (17.0\ \text{m/s})\Delta t + 25.0\ \text{m}$

and solving for *t* we get an imaginary value for the time. Therefore, $\boxed{\text{you won't hit the tractor}}$.
Find the distance the car requires to stop.

$\Delta x_\text{c} = (v_\text{fc}^2 - v_\text{ic}^2)/(2a) = [0 - (27.0\ \text{m/s})^2]/[2(-7.00\ \text{m/s}^2)] = \boxed{52.1\ \text{m}}$. Since the acceleration of the car is constant, the average speed of the car as it attempts to stop is $v_\text{c, av} = (v_\text{fc} + v_\text{ic})/2 = (0 + 27.0\ \text{m/s})/2 = 13.5\ \text{m/s}$. Thus, the time required for the car to stop is $\Delta t = \Delta x_\text{c}/v_\text{c, av} = (52.1\ \text{m})/(13.5\ \text{m/s}) = 3.86\ \text{s}$. The distance the tractor travels in this time is $\Delta x_\text{t} = v_\text{t}\Delta t = (10.0\ \text{m/s})(3.86\ \text{s}) = 38.6\ \text{m}$. Now, $38.6\ \text{m} + 25.0\ \text{m} = 63.6\ \text{m}$, which is $63.6\ \text{m} - 52.1\ \text{m} = \boxed{11.5\ \text{m}}$ beyond the stopping point of the car.

Discussion. You might give a convincing solution by assuming the car does not hit the tractor, finding the time interval and distance required to stop, and finding where the tractor is when the car comes to rest. Our method is good for variety and works even though the tractor is moving faster than the car during the last bit of the car's motion. The 11.5 m is not the minimum distance between the two, which occurs slightly earlier. Note that the same equation 2-12 describes the car with one set of numbers. The same equation containing an acceleration term describes the tractor with another set of numbers, even though the tractor is moving at constant speed. The set of equations for constant acceleration are all you need to describe constant-velocity motion, by substituting $a = 0$.

50. **(a) Strategy** Use Eq. (2-13) to find the constant acceleration of the sneeze.

Solution Find the acceleration of the sneeze as it moves the initial 0.25 cm.

$$v_{\text{fx}}^2 - v_{\text{ix}}^2 = 2a_x\Delta x,\text{ so } a_x = \frac{v_{\text{fx}}^2 - v_{\text{ix}}^2}{2\Delta x} = \frac{(44\text{ m/s})^2 - 0}{2(0.0025\text{ m})} = \boxed{3.9\times10^5\text{ m/s}^2}.$$

(b) Strategy Use Eq. (2-11) to find the time to travel the initial 0.25 cm; then use Eq. (2-12) to find the time to travel the remaining 1.75 cm.

Solution Find the time to travel the initial 0.25 cm.

$$\Delta x = \frac{1}{2}(v_{\text{fx}} + v_{\text{ix}})\Delta t,\text{ so } \Delta t = \frac{2\Delta x}{v_{\text{fx}} + v_{\text{ix}}} = \frac{2(0.0025\text{ cm})}{44\text{ m/s} + 0} = 1.1\times10^{-4}\text{ s} = 0.11\times10^{-3}\text{ s} = 0.11\text{ ms}.$$

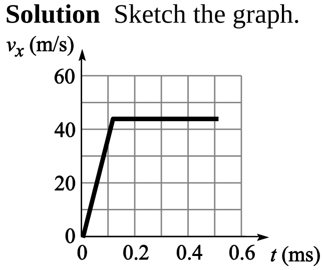
Find the time to travel the remaining 1.75 cm.

$$\Delta x = v_{ix}\Delta t + 0,\text{ so } \Delta t = \frac{\Delta x}{v_{ix}} = \frac{0.0175\text{ cm}}{44\text{ m/s}} = 4.0\times10^{-4}\text{ s} = 0.40\text{ ms}.$$

The time the sneeze takes to travel the 2.0-cm distance in the nose is 0.11 ms + 0.40 ms = $\boxed{0.51\text{ ms}}$.

(c) Strategy Use the information in parts (a) and (b) to graph $v_x(t)$.

Solution Sketch the graph.



51. **Strategy** Use Eq. (2-13).

Solution Find the distance the train travels in stopping.

$$\Delta x = \frac{v_{\text{fx}}{}^2 - v_{\text{ix}}{}^2}{2a_x} = \frac{0 - (26.8\text{ m/s})^2}{2(-1.52\text{ m/s}^2)} = 236\text{ m}$$

236 m > 184 m, so the answer is $\boxed{\text{no; it takes 236 m for the train to stop}}$.

52. (a) Strategy Use Eq. (2-13) and Newton's second law.

Solution Find the final speed of the electrons.

$v_{fx}^2 - v_{ix}^2 = v_{fx}^2 - 0 = 2a_x\Delta x = 2\Delta x$, so

$v_{fx} = \pm\sqrt{2a_x\Delta x} = \sqrt{2(7.03\times10^{13}\text{ m/s}^2)(0.020\text{ m})} = \boxed{1.7\times10^6\text{ m/s}}$. (Speed is always positive.)

(b) Strategy Use Eq. (2-12).

Solution Find the time it takes the electrons to travel the length of the tube.

$x = 0$ to 2.0 cm: $\Delta x_1 = v_{ix}\Delta t_1 + \frac{1}{2}a_x(\Delta t_1)^2 = 0 + \frac{1}{2}a_x(\Delta t_1)^2$, so $(\Delta t_1)^2 = \frac{2\Delta x_1}{a_x}$ or $\Delta t_1 = +\sqrt{\frac{2\Delta x_1}{a_x}}$.

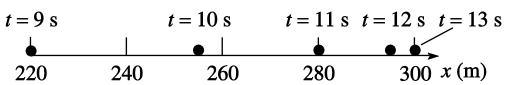
$x = 2.0$ cm to 47 cm: $\Delta x_2 = v_{fx}\Delta t_2$, so $\Delta t_2 = \frac{\Delta x_2}{v_{fx}}$.

Find the total time.

$$\Delta t = \Delta t_1 + \Delta t_2 = \sqrt{\frac{2\Delta x_1}{a_x}} + \frac{\Delta x_2}{v_{fx}} = \sqrt{\frac{2(0.020\text{ m})}{7.03\times10^{13}\text{ m/s}^2}} + \frac{0.45\text{ m}}{1.677\times10^6\text{ m/s}} = \boxed{290\text{ ns}}$$

53. Strategy Refer to the figure. Analyze graphically and algebraically. Each square represents (10 m/s)(1 s) = 10 m. Count squares to determine the distance traveled at each time.

Solution Sketch the motion diagram and describe the motion in words.



The x-coordinates are determined by choosing $x = 0$ at $t = 0$. At $t = 9.0$ s and $x = 220$ m, the object has its maximum speed of 40 m/s. From $t = 9.0$ s to $t = 13.0$ s, the speed of the object decreases at a constant rate until it reaches zero at $x = 300$ m.

Graphical analysis:
The displacement of the object is given by the area under the v_x vs. t curve between $t = 9.0$ s and $t = 13.0$ s. The area is a triangle, $A = \frac{1}{2}bh.$

$$\Delta x = \frac{1}{2}(13.0\text{ s} - 9.0\text{ s})(40\text{ m/s}) = 80\text{ m}$$

Algebraic solution:
Use the definition of average velocity.

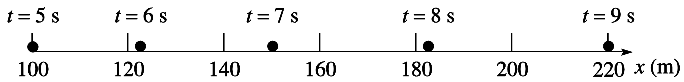
$$\Delta x = v_{av,x}\Delta t = \frac{v_{ix} + v_{fx}}{2}\Delta t = \frac{40\text{ m/s} + 0}{2}(13.0\text{ s} - 9.0\text{ s}) = 80\text{ m}$$

The object goes $\boxed{80\text{ m}}$.

Discussion The graph shows that the object has different accelerations over the intervals from 0 to 5 s, from 5 to 9 s, and from 9 to 13 s. If the problem had asked about displacement over a time interval from 3 to 12 s, for the algebraic solution we would have been required to figure out the answer in steps, adding distances for three different parts of this motion, because the acceleration does not have a single value between 3 s and 12 s.

54. Strategy Refer to the figure. Each square represents (10 m/s)(1 s) = 10 m. Count squares to determine the distance traveled at each time.

Solution Sketch the motion diagram and describe the motion in words.



The x-coordinates are determined by choosing $x = 0$ at $t = 0$. At $t = 5.0$ s and $x = 100$ m, the object's speed is 20 m/s. From $t = 5.0$ s to $t = 9.0$ s, the speed of the object increases at a constant rate until it reaches 40 m/s at $x = 220$ m.

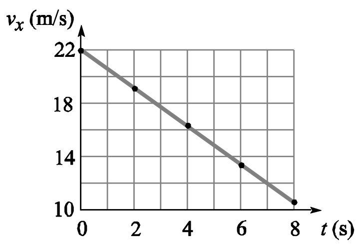
Find the slope of the graph to find the acceleration.

$$a_{\text{av},\,x} = \frac{40\ \text{m/s} - 20\ \text{m/s}}{9.0\ \text{s} - 5.0\ \text{s}} = 5.0\ \text{m/s}^2$$

The acceleration is $\boxed{5.0\ \text{m/s}^2 \text{ in the } +x\text{-direction}}$.

55. (a) Strategy The graph will be a line with a slope of $-1.40\ \text{m/s}^2$.

Solution $v_x = 22\ \text{m/s}$ when $t = 0$.



(b) Strategy Since the train slows down, the acceleration is negative. Use Eq. (2-9).

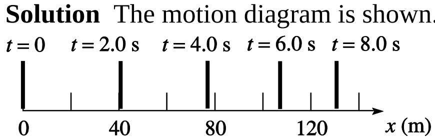
Solution $v_{\text{fx}} - v_{\text{ix}} = a_x\Delta t$, so $v_{\text{fx}} = v_{\text{ix}} + a_x\Delta t = 22\ \text{m/s} + (-1.4\ \text{m/s}^2)(8.0\ \text{s}) = \boxed{11\ \text{m/s}}$.

(c) Strategy Use Eq. (2-12) to find the distance the train traveled up the incline.

Solution $x_\text{f} = x_\text{i} + v_{\text{ix}}\Delta t + \frac{1}{2}a_x(\Delta t)^2 = 0 + (22\ \text{m/s})(8.0\ \text{s}) + \frac{1}{2}(-1.4\ \text{m/s}^2)(8.0\ \text{s})^2 = \boxed{130\ \text{m}}$

(d) Strategy Refer to Figure 2.17, which shows various motion diagrams.

Solution The motion diagram is shown.



56. Strategy Use Eq. (2-12).

Solution Solve for Δt using the quadratic formula.

$$\Delta y = v_{\text{iy}}\Delta t + \frac{1}{2}a_y(\Delta t)^2, \text{ so } \frac{1}{2}a_y(\Delta t)^2 + v_{\text{iy}}\Delta t - \Delta y = 0.$$

$$\Delta t = \frac{-v_{\text{iy}} \pm \sqrt{v_{\text{iy}}^2 + 2a_y\Delta y}}{a_y} = \frac{-3.00\ \text{m/s} \pm \sqrt{(3.00\ \text{m/s})^2 + 2(-9.80\ \text{m/s}^2)(-78.4\ \text{m})}}{-9.80\ \text{m/s}^2} = -3.71\ \text{s or } 4.32\ \text{s}$$

Since $\Delta t > 0$, the brick lands on the ground $\boxed{4.32\ \text{s}}$ after it is thrown from the roof.

57. Strategy Use Eq. (2-13).

Solution Find the final speed of the penny.

$v_{\text{fy}}{}^2 - v_{\text{iy}}{}^2 = v_{\text{fy}}{}^2 - 0 = -2g\Delta y$, so $v_{\text{fy}} = \pm\sqrt{-2g\Delta y} = -\sqrt{-2(9.80\text{ m/s}^2)(0\text{ m} - 369\text{ m})} = -85.0\text{ m/s}$.

Therefore, $\vec{\mathbf{v}} = \boxed{85.0\text{ m/s down}}$.

Discussion This is much less than the speed of a rifle bullet. If it hits a person on the head, I do not think it would necessarily cause serious harm. If you learned in a different physics course that the free-fall acceleration is 9.81 m/s^2, you used the value for the coast of Normandy (at sea level, 45° latitude). But g is 9.80 m/s^2 in New York, across most of the lower forty-eight United States, in southern Europe and China, and in great tracts of southern South America, Africa, and Australia.

58. **Strategy** If we ignore air resistance, the golf ball is in free fall. Use Eq. (2-12).

Solution

(a) Find the time it takes the golf ball to fall 12.0 m.

$v_{\text{iy}} = 0$, so $\Delta y = -\frac{1}{2}g(\Delta t)^2$ and $\Delta t = \sqrt{-\frac{2\Delta y}{g}} = \sqrt{\frac{-2(0 - 12.0\text{ m})}{9.80\text{ m/s}^2}} = \boxed{1.56\text{ s}}$.

(b) Find how far the golf ball would fall in $2\sqrt{\frac{-2(0-12.0\text{ m})}{9.80\text{ m/s}^2}} = 3.13\text{ s}$.

$\Delta y = -\frac{1}{2}g(\Delta t)^2 = -\frac{1}{2}(9.80\text{ m/s}^2)(3.13\text{ s})^2 = -48.0\text{ m}$, so the golf ball would fall through $\boxed{48.0\text{ m}}$.

59. **Strategy** The final speed is zero for the upward part of his free-fall flight. Use Eq. (2-13).

Solution Find the initial speed.

$v_{\text{fy}}{}^2 - v_{\text{iy}}{}^2 = 0 - v_{\text{iy}}{}^2 = -2g\Delta y$, so $v_{\text{iy}} = \sqrt{2g\Delta y} = \sqrt{2(9.80\text{ m/s}^2)(1.3\text{ m} - 0)} = \boxed{5.0\text{ m/s}}$.

60. **Strategy** The acceleration of the camera is given by $v_{y1}/\Delta t_1$, where $v_{y1} = 3.3\text{ m/s}$ and $\Delta t_1 = 2.0\text{ s}$. Use Eq. (2-12).

Solution After 4.0 s, the camera has fallen

$\Delta y = \frac{1}{2}a_y(\Delta t)^2 = \frac{1}{2}\left(\frac{v_{y1}}{\Delta t_1}\right)(\Delta t)^2 = \frac{3.3\text{ m/s}}{2(2.0\text{ s})}(4.0\text{ s})^2 = \boxed{13\text{ m}}$.

61. **Strategy** Use Eq. (2-12) to find the time it takes for the coin to reach the water. Then, find the time it takes the sound to reach Glenda's ear. Add these two times. Let $h = 7.00$ m.

Solution Find the time elapsed between the release of the coin and the hearing of the splash.

$h = v_{\text{iy}}\Delta t + \frac{1}{2}a_y(\Delta t)^2 = 0 + \frac{1}{2}g(\Delta t_1)^2$, so $\Delta t_1 = \sqrt{\frac{2h}{g}}$. Then $h = v_{\text{s}}\Delta t_2$, so $\Delta t_2 = \frac{h}{v_{\text{s}}}$.

Therefore, the time elapsed is $\Delta t = \Delta t_1 + \Delta t_2 = \sqrt{\frac{2h}{g}} + \frac{h}{v_{\text{s}}} = \sqrt{\frac{2(7.00\text{ m})}{9.80\text{ m/s}^2}} + \frac{7.00\text{ m}}{343\text{ m/s}} = \boxed{1.22\text{ s}}$.

Discussion Note the contrast: Sound is a wave, not an object with mass. So sound can behave as if it had infinite acceleration, immediately traveling off from its source at full speed. If you knew the time for a somewhat deeper well, could you find the depth? Suppose the time is 2.20 s and try it. Figure out how to get 22.3 m.

62. (a) Strategy The stone is instantaneously at rest at its maximum height. Use Eq. (2-13).

Solution Find the maximum height of the stone.

$$v_{fy}{}^2 - v_{iy}{}^2 = 0 - v_{iy}{}^2 = -2g\Delta y = -2g(y_f - y_i), \text{ so } y_f = y_i + \frac{v_{iy}{}^2}{2g} = 1.50\text{ m} + \frac{(19.6\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{21.1\text{ m}}.$$

(b) Strategy The stone is instantaneously at rest at its maximum height of 21.1 m. Use Eq. (2-12).

Solution Method one: Going up $21.1\text{ m} - 1.50\text{ m} = 19.6\text{ m}$ (to rest) takes the same time as falling down 19.6 m (from rest), so $\Delta y_{up} = \frac{1}{2}g(\Delta t_{up})^2$, or $\Delta t_{up} = \sqrt{2(19.6\text{ m})/(9.80\text{ m/s}^2)} = 2.00\text{ s}$. Falling 21.1 m from rest takes $\Delta t_{down} = \sqrt{2(21.1\text{ m})/(9.80\text{ m/s}^2)} = 2.08\text{ s}$. The total time elapsed is $2.00\text{ s} + 2.08\text{ s} = \boxed{4.08\text{ s}}$.

Method two: The velocity clearly reverses sign between the upward part of the flight and the downward part, but the acceleration is the same: 9.80 m/s² down. So we can describe the whole flight with one constant-acceleration equation. We use $\Delta y = v_{yi}t - (1/2)gt^2$, or $-1.50\text{ m} = 19.6\text{ m/s } t - 4.9\text{ m/s}^2\, t^2$. With the requirement $t > 0$ we transpose all the terms to the right-hand side and solve with the quadratic formula:

$$\Delta t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-19.6\text{ m/s}) + \sqrt{(-19.6\text{ m/s})^2 - 4(+4.90\text{ m/s}^2)(-1.50\text{ m})}}{+9.80\text{ m/s}^2} = \boxed{4.08\text{ s}}$$

63. Strategy Use Eqs. (2-12), (2-13), and (2-9). Let the +*y*-direction be down.

Solution (a) Without air resistance, the lead ball falls $\Delta y = \frac{1}{2}g(\Delta t)^2 = \frac{1}{2}(9.80\text{ m/s}^2)(3.0\text{ s})^2 = \boxed{44\text{ m}}$.

(b) The lead ball is initially at rest. Find the speed of the ball after it has fallen 2.5 m.

$$v_{fy}{}^2 - 0 = 2g\Delta y, \text{ so } v_{fy} = \sqrt{2g\Delta y} = \sqrt{2(9.80\text{ m/s}^2)(2.5\text{ m})} = \boxed{7.0\text{ m/s}}.$$

(c) After 3.0 s, the lead ball is falling at a speed of $v_y = 0 + g\Delta t = (9.80\text{ m/s}^2)(3.0\text{ s}) = \boxed{29\text{ m/s}}$.

(d) Find the change in height of the ball when $\Delta t = 2.42$ s.

$$\Delta y = v_{iy}\Delta t + \frac{1}{2}g(\Delta t)^2 = (4.80\text{ m/s})(2.42\text{ s}) + \frac{1}{2}(9.80\text{ m/s}^2)(2.42\text{ s})^2 = 17.1\text{ m}$$

The ball will be $\boxed{\text{17.1 m below the top of the tower}}$.

Discussion Do it yourself with the choice of the *y* direction pointing up. Prove that the physical meaning of all your answers is the same. Remember that a square root can be either positive or negative. The mass of the ball and the height of the tower are unnecessary for the solution.

64. Strategy Use Eq. (2-13). When the balloonist lets go of the sandbag, it is moving upward at 10.0 m/s.

Solution Find the sandbag's speed when it hits the ground.

$$v_{fy}{}^2 - v_{iy}{}^2 = -2g\Delta y, \text{ so } v_{fy} = \sqrt{v_{iy}{}^2 - 2g\Delta y} = \sqrt{(10.0\text{ m/s})^2 - 2(9.80\text{ m/s}^2)(-40.8\text{ m})} = \boxed{30.0\text{ m/s}}.$$

65. (a) Strategy Use Eq. (2-12) and the quadratic formula to find the time it takes the rock to reach Lois. Then, use Eq. (2-12) again to find Superman's required constant acceleration.

Solution Solve for Δt using the quadratic formula.

$$\Delta y = v_{iy}\Delta t + \frac{1}{2}a_y(\Delta t)^2, \text{ so } \frac{1}{2}a_y(\Delta t)^2 + v_{iy}\Delta t - \Delta y = 0.$$

$$\Delta t = \frac{-v_{iy} \pm \sqrt{v_{iy}^2 + 2a_y\Delta y}}{a_y} = \frac{-(-2.8\text{ m/s}) \pm \sqrt{(-2.8\text{ m/s})^2 + 2(-9.80\text{ m/s}^2)(-14.0\text{ m})}}{-9.80\text{ m/s}^2} = -2.00\text{ s or } 1.4286\text{ s}$$

Since $\Delta t > 0$, it takes 1.43 s for the rock to reach Lois. Find Superman's required acceleration.

$$\Delta x = v_{ix}\Delta t + \frac{1}{2}a_x(\Delta t)^2 = 0 + \frac{1}{2}a_x(\Delta t)^2 = \frac{1}{2}a_x(\Delta t)^2, \text{ so } a_x = \frac{2\Delta x}{(\Delta t)^2} = \frac{2(120\text{ m})}{(1.43\text{ s})^2} = 120\text{ m/s}^2.$$

The Man of Steel must accelerate at $\boxed{120\text{ m/s}^2\text{ toward Lois}}$ to intercept the rock just touching her hair, and bat it away (the rock, not the hair) to save her.

(b) Strategy Use Eq. (2-9).

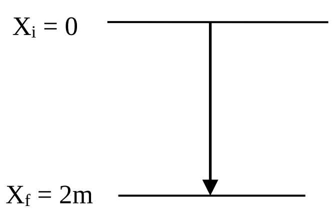
Solution Find Superman's speed when he reaches Lois.

$$v_x = 0 + a_x\Delta t = (120\text{ m/s}^2)(1.43\text{ s}) = \boxed{170\text{ m/s}}$$

Discussion The quadratic formula gets the units right. Is that surprising? The negative answer it gives actually has physical meaning: if Lois had thrown the rock up at the right high speed just 2.00 s before the start of the process we analyzed, the villain would not have had to touch the rock. It would have passed him moving down at 2.8 m/s and then reproduced precisely the same motion we considered.

66. Strategy If we ignore air resistance, the apple is in free fall. Use one of the equations of constant-acceleration motion.

Solution Solve for $v_{0.5}$



$$v_f^2 - v_i^2 = 2a(\Delta x)$$

$$v_f^2 - (0\tfrac{m}{s})^2 = 2(9.80\tfrac{m}{s^2})(2m - 0m)$$

$$v_f = 6.261\frac{m}{s}\ downward$$

$$v_{0.5} = \frac{1}{2}v_f = 3.1305\frac{m}{s}\ downward$$

$$v_{0.5}^2 - v_i^2 = 2a(x_{0.5} - x_i)$$

$$(3.1305\frac{m}{s})^2 - (0\frac{m}{s})^2 = 2(\frac{9.8m}{s^2})(x_{0.5} - 0m)$$

$$x_{0.5} = 0.5m$$

Therefore, $v_{0.5}$ occurs 0.5 m below the branch

67. Strategy The unknown time for the stone to fall distance d at constant acceleration, together with the unknown time for sound to return at constant speed, must add to 3.20 s. This gives an equation we hope to solve.

Solution The time for the sound of the rock hitting the bottom to reach you is $\Delta t_{\text{sound}} = d/v_s = d/(343\text{ m/s})$ The time for the rock, starting from rest, to fall to the bottom appears in

$$d = \frac{1}{2}g(\Delta t_r)^2 \quad \text{or} \quad \Delta t_r = \sqrt{2d/g} = (2/[9.80\text{ m/s}^2])^{1/2}\sqrt{d} = (0.4518\text{ s}/\sqrt{\text{m}})\sqrt{d}$$

The two times add to 3.20 s: $d/(343\text{ m/s}) + (0.4518\text{ s/m}^{1/2})d^{1/2} = 3.20\text{ s}$

$(0.002915\text{ s/m})(\sqrt{d})^2 + (0.4518\text{ s/m}^{1/2})\sqrt{d} - 3.20\text{ s} = 0$ Because $d = (\sqrt{d})^2$ we have a quadratic equation in the square root of d, which we can solve and then square the answer to find d itself. We want the smaller of the two values, as the larger corresponds to your thowing the stone upward so cleverly that it takes 3.20 s to reach the bottom of the well.

$$\sqrt{d} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-0.4518 \pm \sqrt{0.4518^2 - 4(0.002915)(-3.20)}}{2(0.002915)}\frac{\text{s/m}^{1/2}}{\text{s/m}} = \frac{-0.4518 + 0.4914}{2(0.002915)}\text{ m}^{1/2} = 6.79\text{ m}^{1/2}$$

So $d = 6.79^2\text{ m} = \boxed{46.0\text{ m}}$

68. (a) Strategy Use Eq. (2-12).

Solution Find the rocket's altitude when the engine fails.

$$\Delta y = 0 + \frac{1}{2}a(\Delta t_1)^2 = \frac{1}{2}(20.0\text{ m/s}^2)(50.0\text{ s})^2 = \boxed{25.0\text{ km}}$$

(b) Strategy Let $v_{iy} =$ the speed when the engine fails $= a\Delta t_1$; Then $v_y = v_{iy} - g\Delta t = 0$ at maximum height.

Solution Find the time elapsed from the engine failure to maximum height.

$$0 = v_{iy} - g\Delta t = a\Delta t_1 - g\Delta t, \text{ so } \Delta t = \frac{a}{g}\Delta t_1 = \frac{20.0\text{ m/s}^2}{9.80\text{ m/s}^2}(50.0\text{ s}) = 102\text{ s}.$$

The time to maximum height from lift off is $\Delta t + \Delta t_1 = 102\text{ s} + 50.0\text{ s} = \boxed{152\text{ s}}$.

(c) Strategy Use Eq. (2-12).

Solution Find the maximum height reached by the rocket.

$$y_f = y_i + v_{iy}\Delta t - \frac{1}{2}g(\Delta t)^2 = y_i + (a\Delta t_1)\left(\frac{a}{g}\Delta t_1\right) - \frac{1}{2}g\left(\frac{a}{g}\Delta t_1\right)^2 = y_i + \frac{a^2(\Delta t_1)^2}{g} - \frac{a^2(\Delta t_1)^2}{2g} = y_i + \frac{a^2(\Delta t_1)^2}{2g}$$

$$= 25.0\text{ km} + \frac{(20.0\text{ m/s}^2)^2(50.0\text{ s})^2}{2(9.80\text{ N/kg})} = \boxed{76.0\text{ km}}$$

(d) Strategy Use Eq. (2-13). For the downward motion $v_{iy} = 0$ at the maximum height.

Solution Find the final velocity.

$$v_{fy}{}^2 - v_{iy}{}^2 = v_{fy}{}^2 - 0 = 2a_y\Delta y = -2g\Delta y, \text{ so } v_{fy} = \sqrt{-2g\Delta y} = \sqrt{-2(9.80\text{ N/kg})(0 - 76.0\times10^3\text{ m})} = 1220\text{ m/s}.$$

Thus, $\vec{\mathbf{v}} = \boxed{1220\text{ m/s downward}}$.

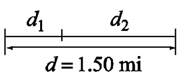
69. Strategy Each car has traveled the same distance Δx in the same time Δt when they meet.

Solution Using Eq. (2-12), we have Δx for police = Δx for speeder

$$\Delta x = v_i \Delta t + \frac{1}{2}a(\Delta t)^2 = 0 + \frac{1}{2}a(\Delta t)^2 = v\Delta t, \text{ so } \Delta t = \frac{2v}{a}.$$ The speed of the police car is $v_p = a\Delta t = a(2v/a) = \boxed{2v}$.

Discussion If it is a little hard for you to distinguish the knowns a and v from the unknown final speed of the police car, or to see just what we have done, then solve this problem: The speeder goes past at 34 m/s and the police car accelerates at 6.0 m/s². Find the police car's speed at the overtake point. Then go back and solve the symbolic problem with precisely the same steps.

70. Strategy $v_{1fx}{}^2 - v_{1ix}{}^2 = 2a_1 d_1$, where $a_1 = 10.0\ \text{ft/s}^2$ and d_1 is the distance from the start to the point of no return. $v_{2fx}{}^2 - v_{2ix}{}^2 = 2a_2 d_2$, where $a_2 = -7.00\ \text{ft/s}^2$ and d_2 is the distance from the point of no return to the end of the runway. The initial speed v_{1ix} and the final speed v_{2fx} are zero. The speed at the point of no return is $v_{1fx} = v_{2ix}$. Let $v_{1fx} = v_{2ix} = v$ for simplicity. Also, $d = d_1 + d_2$ is the length of the runway.



Solution From the strategy, we have $v^2 = 2a_1 d_1$ and $-v^2 = 2a_2 d_2 = 2a_2(d - d_1)$.

Eliminate v^2. by substitution.

$$2a_1 d_1 = 2a_2(d_1 - d)$$
$$a_1 d_1 = a_2 d_1 - a_2 d$$
$$(a_1 - a_2)d_1 = -a_2 d$$
$$d_1 = \frac{a_2}{a_2 - a_1}d = \frac{-7.00\ \text{ft/s}^2}{-7.00\ \text{ft/s}^2 - 10.0\ \text{ft/s}^2}(1.50\ \text{mi})\left(\frac{5280\ \text{ft}}{1\ \text{mi}}\right)$$
$$= \boxed{3260\ \text{ft from the starting end of the runway}}$$

Find the time to d_1 using Eq. (2-12).

$$d_1 = \frac{1}{2}a_1(\Delta t)^2, \text{ so } \Delta t = \sqrt{\frac{2d_1}{a_1}} = \sqrt{\frac{2(3260\ \text{ft})}{10.0\ \text{ft/s}^2}} = \boxed{25.5\ \text{s}}.$$

71. Strategy The average speed of the flower pot as it passes the student's window is very nearly equal to its instantaneous speed, so $v_{av,y} = \Delta y/\Delta t \approx v_y$.

Solution Determine the distance the flower pot fell to reach the speed v_y.

$$v_y^2 = 2gh, \text{ so } h = \frac{v_y^2}{2g} \approx \frac{1}{2g}\left(\frac{\Delta y}{\Delta t}\right)^2 = \frac{(1.0\ \text{m})^2}{2(9.80\ \text{m/s}^2)(0.051\ \text{s})^2} = 19.6\ \text{m}.$$

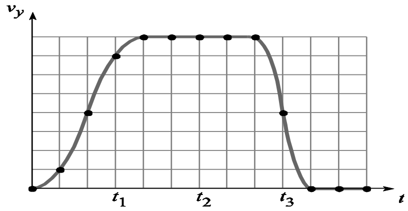
$$\frac{19.6\ \text{m}}{4.0\ \frac{\text{m}}{\text{floor}}} = 4.9\ \text{floors},$$ so the pot fell from the 4th floor + 4.9 floors = $\boxed{9\text{th}}$ floor.

72. Strategy Analyze the graph to answer each question about the motion of the elevator.

Solution (a) The area under the curve represents the change in velocity. Each space along the *t*-axis represents 2 s. $A_1 = \frac{1}{2}bh = \frac{1}{2}(8\text{ s})\left(0.2\text{ m/s}^2\right) = 0.8\text{ m/s}$ The elevator accelerates $(a_y > 0)$ to 0.8 m/s during the first 8 s. Then, the elevator travels at 0.8 m/s $(a_y = 0)$ for the next 8 s. $A_2 = \frac{1}{2}bh = \frac{1}{2}(4\text{ s})\left(-0.4\text{ m/s}^2\right) = -0.8\text{ m/s}$ The elevator slows down $(a_y < 0)$ until it comes to rest. Then, it sits for the next 4 s. So, the passenger has gone to a **higher** floor.

(b) Sketch the graph of v_y vs. *t* by plotting points at two-second intervals with v_y determined from the a_y vs. *t* graph. Each rectangle represents $(2\text{ s})(0.2\text{ m/s}^2) = 0.4\text{ m/s}$.

t (s)	v_y	*t* (s)	v_y
0	The elevator is at rest, so $v_y = 0$.	12	0.8 m/s
2	$1/4 \times (0.4\text{ m/s}) = 0.1\text{ m/s}$	14	0.8 m/s
4	$1(0.4\text{ m/s}) = 0.4\text{ m/s}$	16	0.8 m/s
6	$(1\ 3/4)(0.4\text{ m/s}) = 0.7\text{ m/s}$	18	$-1(0.4\text{ m/s}) + 0.8\text{ m/s} = 0.4\text{ m/s}$
8	$2(0.4\text{ m/s}) = 0.8\text{ m/s}$	20	$-1(0.4\text{ m/s}) + 0.4\text{ m/s} = 0$
10	0.8 m/s, since $a_y = 0$.	22	0, since $a_y = 0$



Each vertical space represents 0.1 m/s and each horizontal space is 2 s.

(c) The graph from part (b) shows that the velocity is nonnegative for $t \geq 0$, so the position of the elevator is always increasing in height until it stops.
Break the region under the graph from part (b) into six sections (blocks of time):

Section 1: $(0,\ 4\ \text{s})$ Section 2: $(4\ \text{s},\ 8\ \text{s})$ Section 3: $(8\ \text{s},\ 16\ \text{s})$

Section 4: $(16\ \text{s},\ 18\ \text{s})$ Section 5: $(18\ \text{s},\ 20\ \text{s})$ Section 6: $(20\ \text{s},\ 24\ \text{s})$

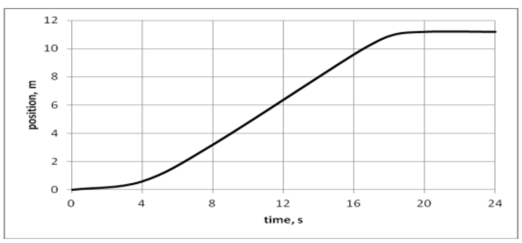
Find the approximate distance the elevator travels in each section by counting boxes under the curve, each of which represents displacement $(0.1\ \text{m/s})(2\ \text{s}) = 0.2\ \text{m}$.

Section 1:	Section 2:	Section 3:	Section 4:	Section 5:	Section 6:
3(0.2 m) = 0.6 m	13(0.2 m) = 2.6 m	32(0.2 m) = 6.4 m	6.5(0.2 m) = 1.3 m	1.5(0.2 m) = 0.3 m	0(0.2 m) = 0

Adding up the increments gives the position at the end of each time interval like this:

t, s	0	4	8	16	18	20	24
x, m	0	0.6	3.2	9.6	10.9	11.2	11.2

Plot points and draw a smooth curve.



73. (a) Strategy Use the definition of average speed.

Solution Find the average speed of the swimmer.

$$v_{\text{av}} = \frac{\Delta r}{\Delta t} = \frac{1500\ \text{m}}{14\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}} + 53\ \text{s}} = \boxed{1.7\ \text{m/s}}$$

(b) Strategy and Solution The swimmer pushes off from each end of the pool to raise his average speed.

74. (a) Strategy Use Eqs. (2-11) and (2-9) since the acceleration is constant.

Solution Find the distance traveled.

$$\Delta x = v_{\text{av},\,x}\Delta t = \frac{v_{fx}+v_{ix}}{2}\Delta t = \frac{27.3\ \text{m/s}+17.4\ \text{m/s}}{2}(10.0\ \text{s}) = \boxed{224\ \text{m}}.$$

(b) Strategy Use the definition of average acceleration.

Solution Find the magnitude of the acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{27.3\ \text{m/s}-17.4\ \text{m/s}}{10.0\ \text{s}} = \boxed{0.99\ \text{m/s}^2}$$

75. Strategy Use the definition of average acceleration.

Solution Compute the trout's average acceleration.

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{2\ \text{m/s}}{0.05\ \text{s}} = 40\ \text{m/s}^2,\ \text{so}\ \vec{\mathbf{a}}_{\text{av}} = \boxed{40\ \text{m/s}^2\ \text{in the direction of motion}}.$$

76. (a) Strategy Use the definition of average acceleration.

Solution Find the magnitude of the acceleration. $a = \dfrac{\Delta v}{\Delta t} = \dfrac{24\ \text{m/s}}{2.0\ \text{s}} = \boxed{12\ \text{m/s}^2}$

(b) Strategy Relate the distance traveled, acceleration, and time using Eq. (2-12).

Solution Find the distance traveled. $\Delta x = 0 + \dfrac{1}{2}a(\Delta t)^2 = \dfrac{1}{2}(12\ \text{m/s}^2)(2.0\ \text{s})^2 = \boxed{24\ \text{m}}$

(c) Strategy Use the definition of average acceleration.

Solution The magnitude of the acceleration of the runner is $a = \dfrac{\Delta v}{\Delta t} = \dfrac{6.0\ \text{m/s}}{2.0\ \text{s}} = \boxed{3.0\ \text{m/s}^2}$.

Find a_c / a_r. $\dfrac{a_c}{a_r} = \dfrac{12\ \text{m/s}^2}{3.0\ \text{m/s}^2} = \boxed{4.0}$

77. Strategy Use the definitions of average velocity and average acceleration.

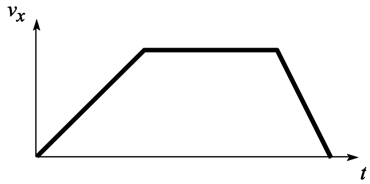
Solution (a) $\vec{\mathbf{v}}_{\text{av}} = \dfrac{\Delta\vec{\mathbf{y}}}{\Delta t} = \dfrac{160\times10^3\ \text{m up}}{(8.0\ \text{min})\left(\frac{60\ \text{s}}{1\ \text{min}}\right)} = \boxed{330\ \text{m/s up}}$

(b) $\vec{\mathbf{a}}_{\text{av}} = \dfrac{\Delta\vec{\mathbf{v}}}{\Delta t} = \dfrac{7600\ \text{m/s up} - 0}{(8.0\ \text{min})\left(\frac{60\ \text{s}}{1\ \text{min}}\right)} = \boxed{16\ \text{m/s}^2\ \text{up}}$

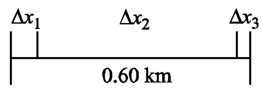
Discussion. *If* we made the additional assumption that the acceleration is constant, we could say that the average velocity is the velocity halfway through the motion in time, at the four-minute mark. But there are a couple of reasons that the acceleration might not be constant: The rocket body is always losing mass as it throws its exhaust out of its back end, and air resistance drops to a very low value at 160 km up.

78. Strategy Initially, the slope (and acceleration) is $+1.0\ \text{m/s}^2$, corresponding to the streetcar speeding up. Then, the slope (and acceleration) is zero for the streetcar moving with constant speed. Finally, the slope (and acceleration) is $-2.0\ \text{m/s}^2$, corresponding to the streetcar slowing to a stop. For the duration of the trip, use the standard relationships for constant acceleration motion, Eqs. (2-9) through (2-13).

Solution Sketch the graph of $v_x(t)$.



Compute the duration of the trip. Refer to the figure at right.



Find v_{x1}, the speed after 10.0 s.

$$\Delta v_{x1} = a_{x1}\Delta t_1 = (1.0\ \text{m/s}^2)(10.0\ \text{s}) = 10\ \text{m/s}$$

Find Δx_1, Δx_3, and Δt_3.

$$\Delta x_1 = \frac{1}{2}a_{x1}(\Delta t_1)^2 = \frac{1}{2}(1.0\ \text{m/s}^2)(10.0\ \text{s})^2 = 50\ \text{m}$$

$$\Delta x_3 = \frac{{v_{x3}}^2 - {v_{ix3}}^2}{2a_3} = \frac{0 - {v_{x1}}^2}{2a_3} = \frac{-(10\ \text{m/s})^2}{2(-2.0\ \text{m/s}^2)} = 25\ \text{m}$$

$$\Delta x_3 = v_{\text{av},x}\Delta t_3,\ \text{so}\ \Delta t_3 = \frac{\Delta x_3}{v_{\text{av}3}} = \frac{25\ \text{m}}{(10\ \text{m/s})/2} = 5.0\ \text{s}.$$

Find Δx_2.

$$\Delta x_2 = v_{x2}\Delta t_2 = v_{x1}\Delta t_2,\ \text{so}\ \Delta t_2 = \frac{\Delta x_2}{v_{x1}}.$$

Find the total time.

$$\Delta t = \Delta t_1 + \Delta t_2 + \Delta t_3 = \Delta t_1 + \frac{\Delta x_2}{v_{x1}} + \Delta t_3 = 10.0\ \text{s} + \frac{0.60\times 10^3\ \text{m} - 50\ \text{m} - 25\ \text{m}}{10\ \text{m/s}} + 5.0\ \text{s} = \boxed{68\ \text{s}}$$

79. (a) Strategy Use Eq. (2-13).

Solution Find the initial velocity of the stone by taking the "final" point at the window.

$v_{fy}{}^2 - v_{iy}{}^2 = 2a_y\Delta y$, so $v_{iy} = \pm\sqrt{v_{fy}{}^2 - 2a_y\Delta y} = \pm\sqrt{(-25.0\text{ m/s})^2 - 2(-9.80\text{ m/s}^2)(-16.0\text{ m})} = \pm 17.6\text{ m/s}$.

Since the stone was thrown vertically downward, its initial velocity was $\boxed{17.6\text{ m/s downward}}$.

(b) Strategy Use Eq. (2-12).

Solution Find the change in height of the stone, now taking the final point just before it hits the ground.

$$\Delta y = v_{iy}\Delta t + \frac{1}{2}a_y(\Delta t)^2 = (-17.647\text{ m/s})(3.00\text{ s}) + \frac{1}{2}(-9.80\text{ m/s}^2)(3.00\text{ s})^2 = -97.0\text{ m}$$

The height of the building is $\boxed{97.0\text{ m}}$.

80. Strategy The direction of the acceleration is opposite the direction of motion. Use Eq. (2-16).

Solution

(a) Find the magnitude of the acceleration.

$$v_{fx}{}^2 - v_{ix}{}^2 = 2a_x\Delta x,\text{ so } a_x = \frac{v_{fx}{}^2 - v_{ix}{}^2}{2\Delta x} = \frac{0-(29\text{ m/s})^2}{2(1.0\text{ m})} = -420\text{ m/s}^2.$$

So, $\vec{\mathbf{a}} = \boxed{420\text{ m/s}^2\text{ opposite the direction of motion}}$.

(b) Find the magnitude of the acceleration.

$$a_x = \frac{v_{fx}{}^2 - v_{ix}{}^2}{2\Delta x} = \frac{0-(29\text{ m/s})^2}{2(0.100\text{ m})} = -4200\text{ m/s}^2$$

So, $\vec{\mathbf{a}} = \boxed{4200\text{ m/s}^2\text{ opposite the direction of motion}}$.

81. Strategy Use the fact that distance traveled equals average rate times time elapsed.

Solution

(a) Marcella must run the whole distance in $t = \dfrac{1000\text{ m}}{3.33\text{ m/s}} = 300\text{ s}$. She ran the first 500 m in

$t_1 = \dfrac{500\text{ m}}{4.20\text{ m/s}} = 119\text{ s}$, so she must run the last 500 m in $t_2 = t - t_1 = \dfrac{1000\text{ m}}{3.33\text{ m/s}} - \dfrac{500\text{ m}}{4.20\text{ m/s}} = \boxed{181\text{ s}}$.

(b) Marcella's average speed for the last 500 m must be $v = \dfrac{d}{t_2} = \dfrac{500\text{ m}}{181\text{ s}} = \boxed{2.76\text{ m/s}}$.

Discussion Note that 3.33 is not halfway between 2.76 and 4.20. She ran with the latter two speeds for equal distances but not for equal times.

82. Strategy Use the definitions of displacement, average velocity, and average acceleration.

Solution

$$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}}_f - \vec{\mathbf{r}}_i = 185\text{ mi north} - 126\text{ mi north} = \boxed{59\text{ mi north}}$$

$$\vec{\mathbf{v}}_{av} = \frac{\Delta\vec{\mathbf{r}}}{\Delta t} = \frac{59\text{ mi north}}{37\text{ min}}\left(\frac{60\text{ min}}{1\text{ h}}\right) = \boxed{96\text{ mi/h north}}$$

$$\vec{\mathbf{a}}_{av} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t} = \frac{105.0\text{ mi/h north} - 112.0\text{ mi/h north}}{37\text{ min}} = \frac{-7.0\text{ mi/h north}}{37\text{ min}}\left(\frac{60\text{ min}}{1\text{ h}}\right) = \boxed{11\text{ mi/h}^2\text{ south}}$$

83. Strategy Use the graph to answer the questions. The slope of the graph represents the acceleration of the ball.

Solution

(a) The ball reaches its maximum height the first time $v_y = 0$, or at $t = \boxed{0.30\text{ s}}$.

(b) The time it takes for the ball to make the transition from its extreme negative velocity to its greatest positive velocity is the time that the ball is in contact with the floor.

$0.65\text{ s} - 0.60\text{ s} = \boxed{0.05\text{ s}}$

(c) Using Eq. (2-12) and the definition of average acceleration, we find that the maximum height of the ball is at the end of its first upward flight and is

$$\Delta y = v_{iy}\Delta t + \frac{1}{2}a_y(\Delta t)^2 = v_{iy}\Delta t + \frac{\Delta v_y}{2\Delta t}(\Delta t)^2 = (3.0\text{ m/s})(0.30\text{ s}) + \frac{0-3.0\text{ m/s}}{2}(0.30\text{ s}) = \boxed{0.45\text{ m}}.$$

(d) $a_y = \dfrac{\Delta v_y}{\Delta t} = \dfrac{-3.0\text{ m/s} - 3.0\text{ m/s}}{0.60\text{ s}} = -10\text{ m/s}^2$, so the acceleration is $\boxed{10\text{ m/s}^2\text{ down}}$.

(e) $a_{av} = \dfrac{\Delta v}{\Delta t} = \dfrac{3.0\text{ m/s} - (-3.0\text{ m/s})}{0.05\text{ s}} = 120\text{ m/s}^2$, so the acceleration is $\boxed{120\text{ m/s}^2\text{ up}}$.

84. (a) Strategy and Solution The intersection of the two curves indicates when the motorcycle and the police car are moving at the same speed. According to the graph, they are moving at the same speed at $\boxed{t = 11\text{ s}}$.

(b) Strategy and Solution The displacement of each vehicle is represented by the area under each curve. The answer is $\boxed{\text{no; the area under the police car curve is less than the area under the motorcycle curve.}}$

85. Strategy Analyze the graph to answer each question about the motion of the engine. The *x*-component of the engine's velocity is represented by the slope.

Solution

(a) $a_x < 0$ when the engine is moving in the $+x$-direction and slowing down, when it is moving in the $-x$-direction and speeding up, and when it is momentarily at rest and changing direction from positive to negative x. So at $\boxed{t_3 \text{ and } t_4}$ $a_x < 0$.

(b) $a_x = 0$ when the engine's speed is constant. This includes the cast of speed zero and constant. So, at $\boxed{t_0,\ t_2,\ t_5, \text{ and } t_7}$ $a_x = 0$.

(c) $a_x > 0$ when the engine is moving in the $+x$-direction and speeding up and when it is moving in the $-x$-direction and slowing down. So, at $\boxed{t_1 \text{ and } t_6}$ $a_x > 0$.

(d) $v_x = 0$ when the slope of the graph is zero. So, at $\boxed{t_0,\ t_3, \text{ and } t_7}$ $v_x = 0$.

(e) The speed is decreasing when a_x and v_x have opposite directions. So, at $\boxed{t_6}$ the speed is decreasing.

Discussion Is this surprisingly tough? Just below the given graph of x versus t sketch a graph of its slope v versus t. Whenever the x versus t graph line is curving, the engine possesses nonzero acceleration. When the graph line is "concave upward ∪," a is positive and when x versus t is "concave downward ∩" the acceleration is negative.

86. (a) Strategy Use the definition of average speed.

Solution For crossing a synapse $v_{av} = \dfrac{\Delta x}{\Delta t} = \dfrac{100\times 10^{-9}\text{ m}}{0.10\times 10^{-3}\text{ s}} = \boxed{1.0\text{ mm/s}}$

(b) Strategy Find the time it takes the pain signal to travel the length of a 1.0-m long neuron. Then, add the times of travel across synapses and neurons.

Solution $t_n = \dfrac{x}{v} = \dfrac{1.0\text{ m}}{100\text{ m/s}} = 10\text{ ms}$

Find the total time to reach the brain.

$$t_n + t_{syn} + t_n + t_{syn} = 2t_n + 2t_{syn} = 2(t_n + t_{syn}) = 2(10\text{ ms} + 0.10\text{ ms}) = \boxed{20\text{ ms}}$$

(c) Strategy Use the definition of average speed.

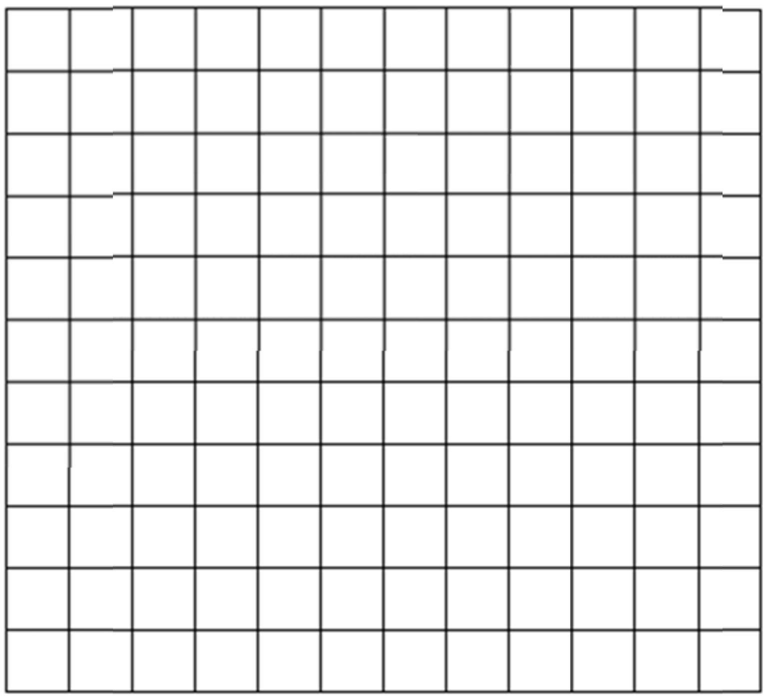
Solution $v_{av} = \dfrac{\Delta x}{\Delta t} = \dfrac{2.0\text{ m} + 2(100\times 10^{-9}\text{ m})}{20.2\times 10^{-3}\text{ s}} = \boxed{99\text{ m/s}}$

Chapter

Section .1

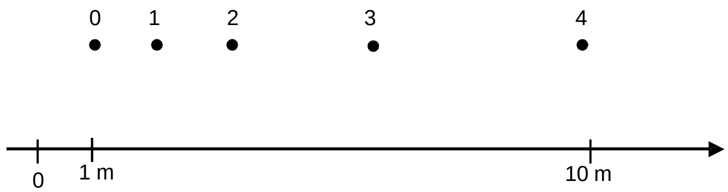
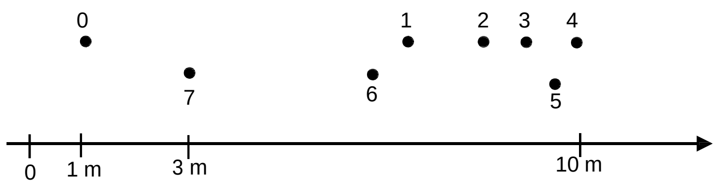
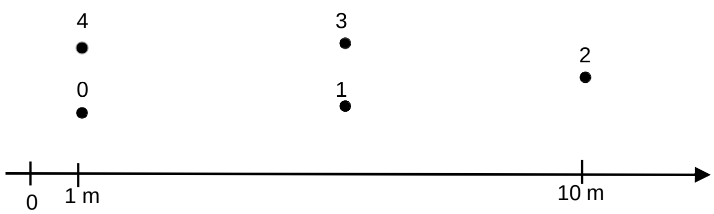
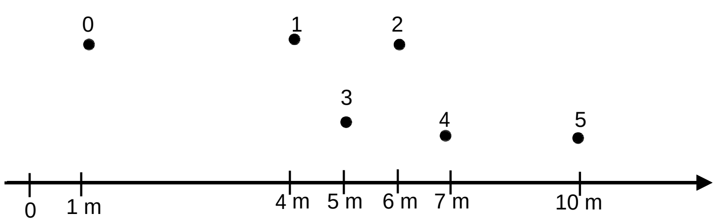
1. Displacement

A sailboat travels west for 3.0 km, then south for 6.0 km south, then 45° north of east for 7.0 km. Draw vector arrows on the grid below to illustrate the sum of the three displacements. Based on your sketch, what is the *approximate* magnitude and direction of the total displacement? One grid represents 1 km.



2. **Position and Displacement**

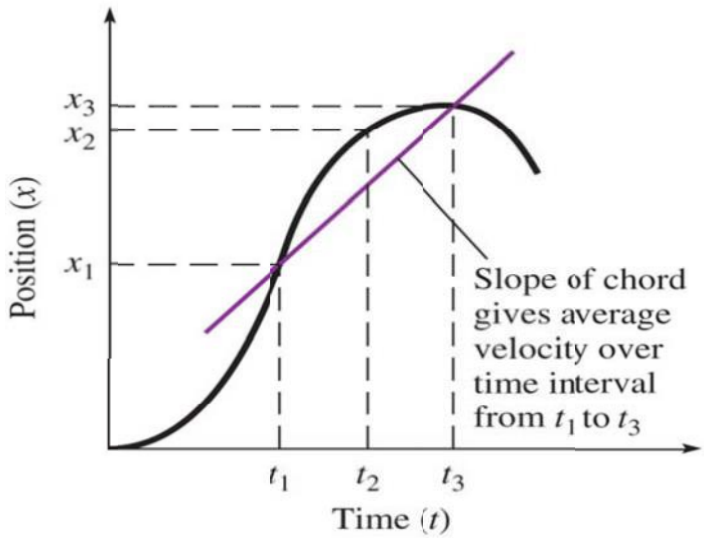
Motion diagrams for several objects in horizontal 1-D motion are shown below. Use the given scales to determine the distance traveled and the displacement for each case. Explain why or why not these numbers are different.

	Distance Traveled (m)	Displacement (m) Δx
		
		
		
		

Section .2

3. Speed and Velocity

The graph below shows the position of a train on an east-west track as a function of time. The +*x* direction is east. *[this is from Fig 3.11 in text]*

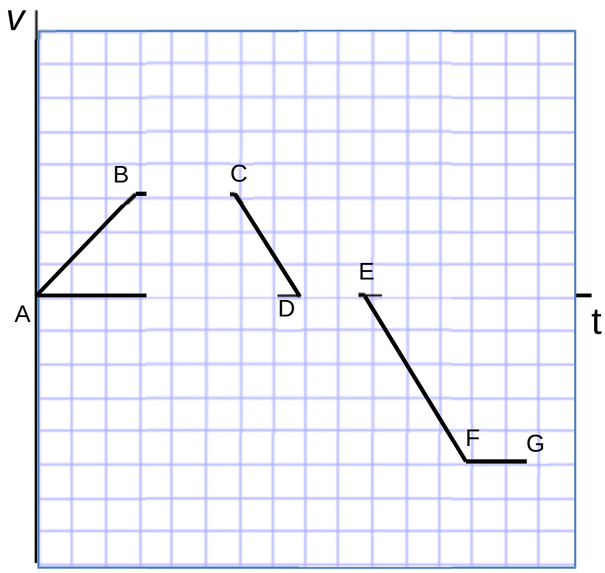


(a) Rank the instants t_1, t_2, t_3 in order of decreasing instantaneous speed. Explain your reasoning.

(b) During which of the time intervals ($0 < t < t_1$, $t_1 < t < t_2$, $t_2 < t < t_3$, and $t < t_3$), if any, is the train's speed increasing? During which time intervals is the train's speed decreasing? Explain.

(c) During which of the time intervals, if any, is the train moving west? Explain.

4. Consider the velocity vs. time Graph shown below of a car moving along a horizontal road. The positive x-direction is to th right, and asume that the car starts at x=0 at time t=0s. For the questions a) thru e) find the correct answer(s) from the list below.



a) During which segment(s) does the car speed up while moving to the right?

______

b) During which segement (s) does the car speed up while moving to the left?

______

c) During which segment(s) does the car slow down while moving to the right?

______

d) During which segement (s) does the car slow down while moving to the left?

______

e) During which segment dies the car travel at a constant velocity?.

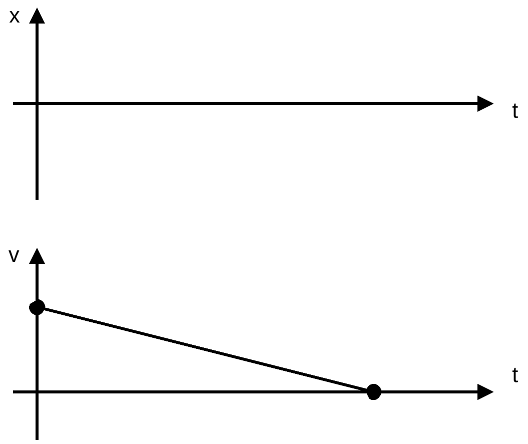
______

f) At which point (A, B, C, D, E, F, or G) is the car furthest from the origin (x=0)?

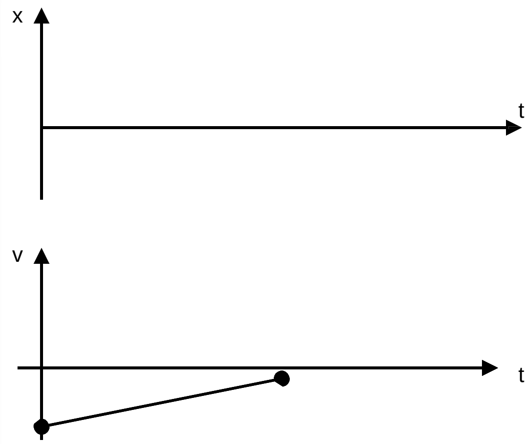
______

5. Velocity

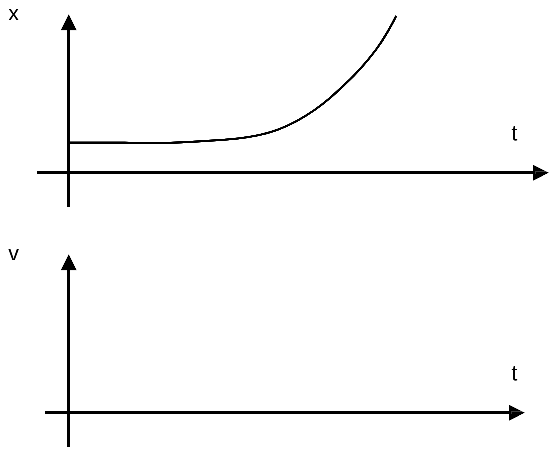
For each of the following cases construct the missing graph(s) and give a written description of the motion.



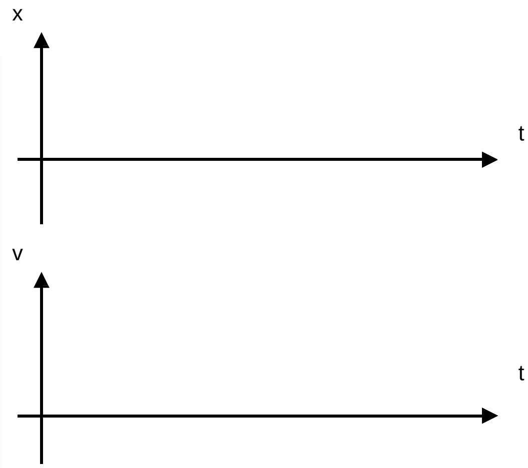
Description:



Description:



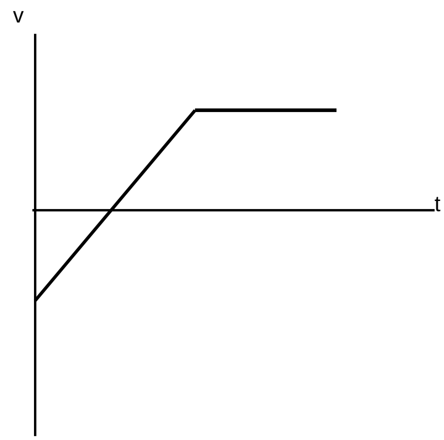
Description:



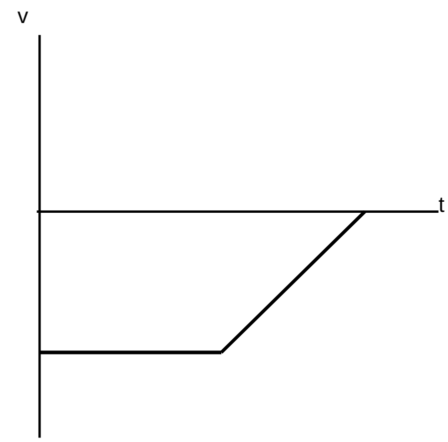
Description: Increasing negative velocity

6. Given below are two velocity-vs-time graphs. Draw the a-vs-t and x-vs-t graphs, given that at time t=0 the object was at x=0.

a)

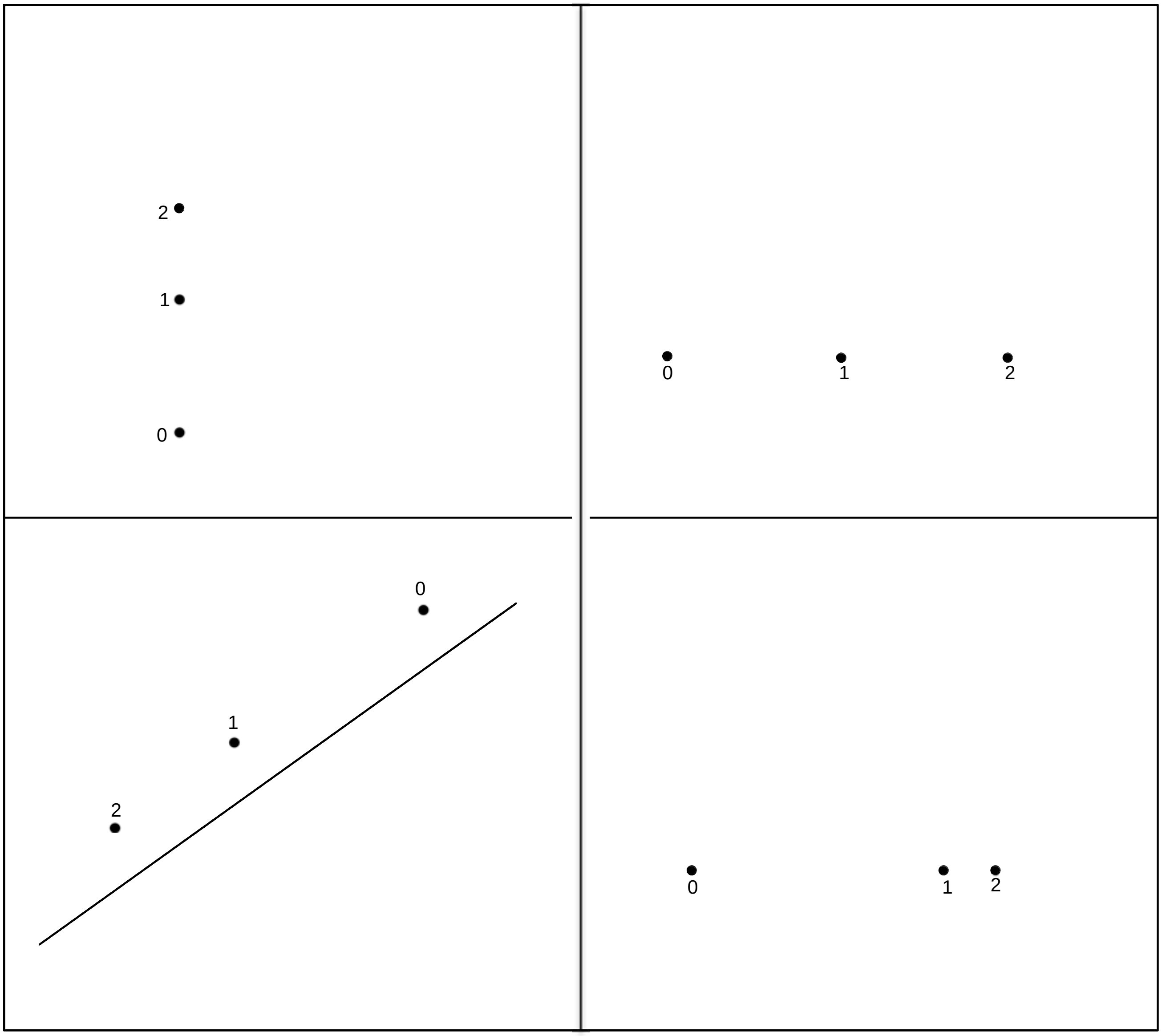


b)



7. Velocity - Average Velocity and Motion Diagrams

Partial motion diagrams for objects in 1-2D motion are shown below. Draw vectors for the initial velocity, final velocity, and acceleration on each diagram.

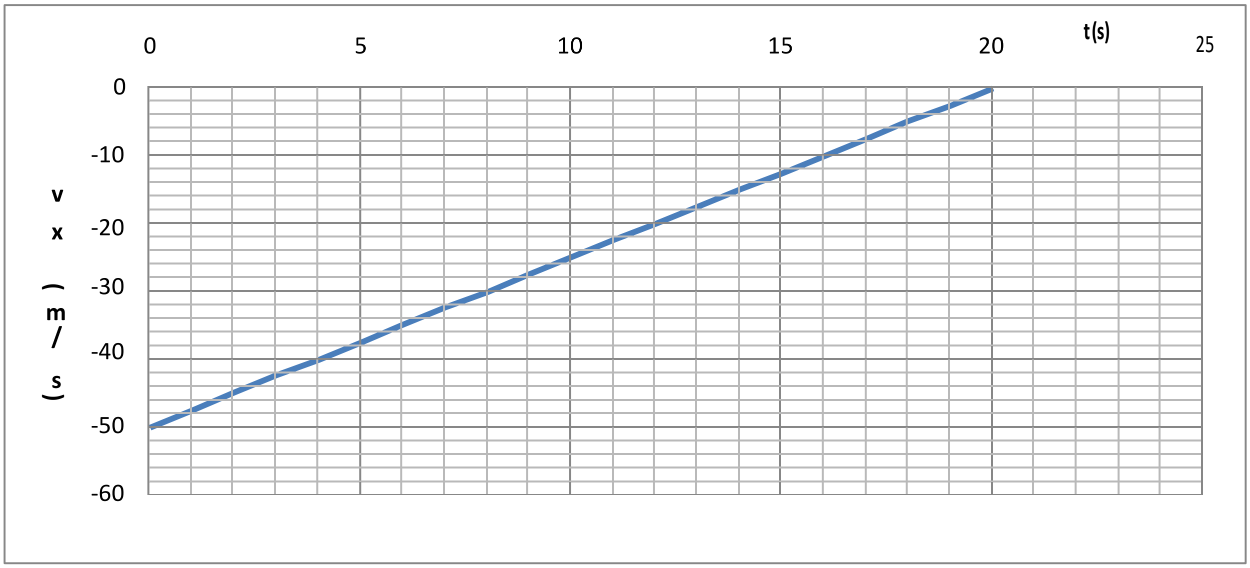


CLICK HERE TO ACCESS THE COMPLETE Solutions

Section 2.3

Problems to 1 : Representations of Motion . [each SC]

A train of mass 2×10^5 kg is moving on a straight track, braking to slow down as it approaches a station. The *x*-axis points south. The graph below shows the velocity v_x as a function of time.



.(a) Is the velocity north or south? Explain.

(b) Draw velocity vectors for the train at t = 0, 5 s, and 10 s.

. (a) Is the acceleration constant? Explain.

(b) Find the magnitude of the acceleration. Is the acceleration north or south? Explain.

(c) What is the net force acting on the train?

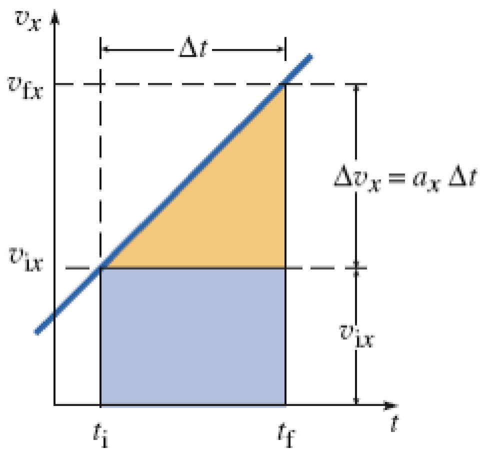
1 .(a) Is the displacement between t = 5 s and t = 10 s north or south? Explain.

(b) Show on the graph how you would calculate the displacement of the train between t = 5 s and t = 10 s. (No need to calculate the value; just represent the quantity visually.)

(c) Make a qualitative motion diagram for the train (i.e. a series of dots showing the train's position every 5 s). It's not necessary to calculate numerical values; just illustrate qualitatively what the motion is like.

1 . Graphical Representations of Motion

The graph below shows $v_x(t)$ for an airplane that is speeding up.



(a) Is the acceleration constant? Explain.

(b) Write an expression for the area of the shaded triangle above v_{ix} in terms of quantities specified on the graph.

(c) Write an expression for the area of the shaded rectangle above v_{ix} in terms of quantities specified on the graph.

(d) Write an expression for the sum of the areas of the triangle and rectangle. What quantity does the total area represent?

Section

Problems to : Motion Diagrams

For each of the motions below sketch a motion diagram as described in section . You may use a dot to represent the object in motion. First, establish a coordinate axis for each motion. Draw arrows to scale above each dot to represent the velocity vector. Indicate the acceleration direction for each constant-acceleration segment of the motion. (SC)

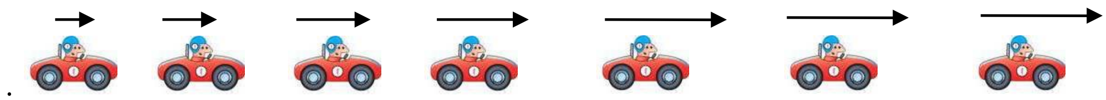
. A car is travelling at a constant speed of 35 mph when the driver sees a stop sign. The driver takes 5 seconds to start applying brakes and the car eventually comes to a stop at the stop sign.

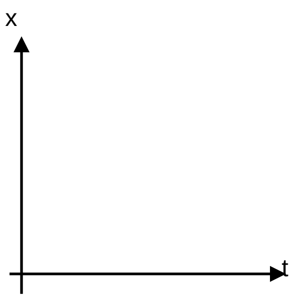
. In the 100-m dash, a runner begins from rest and accelerates at constant rate until the 60-m mark and then maintains her maximum speed until crossing the finish line.

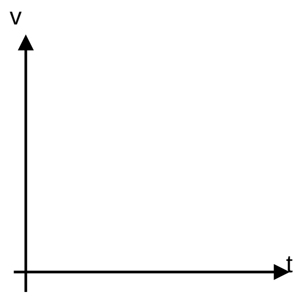
. You get into an elevator at the ground floor of a 50 story building and press the button for the 50^{th} floor. The elevator accelerates for 10 seconds, maintains the maximum speed for 60 seconds and then comes to a stop at the top floor.

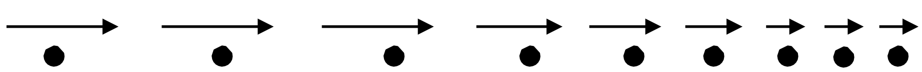
Problems & : Graphical Representations of Motion

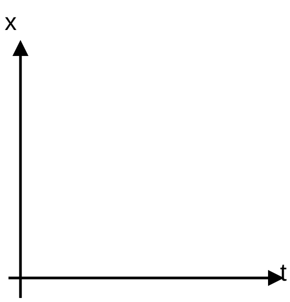
Draw position-vs-time and Velocity-vs-time graphs for the motions represented by the following motion diagrams.

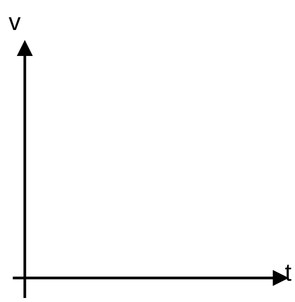












. Graphical Representations of Motion

You get on to an elevator on the 50th floor and press the button for the ground floor. The elevator speeds up until it reaches the maximum speed, and then maintains this speed for most of the decent. Finally it slows down and stop on the ground floor.

a. Draw the motion diagram for the elevator.

b. Draw velocity-vs-time graph and position-vs-time graph for the elevator.

Section

.   Kinematic Equations – Constant Force

Construct a physical situation involving 1-D horizontal motion of a point mass with a constant acceleration that is consistent with the following kinematic equations:

Case A:

$$625 \text{ m} = \tfrac{1}{2} (500\text{N} / 10 \text{ kg}) (5 \text{ sec})^2$$

Case B:

$$2600 \text{ m} = 50 \text{ m} + 5 \text{ m/s} (10 \text{ s}) + \tfrac{1}{2} (500\text{N} / 10 \text{ kg}) (10 \text{ sec})^2$$

Case C:

$$(20 \text{ m/s})^2 = 2 (1000 \text{ N} / 100 \text{ kg}) (20 \text{ m})$$

. Kinematic Equations – Constant Force

State the kinematic equation that would be used if given the following information:

Case A:

M, F_{net}, ⊗X, ⊗t, v_o

Case B:

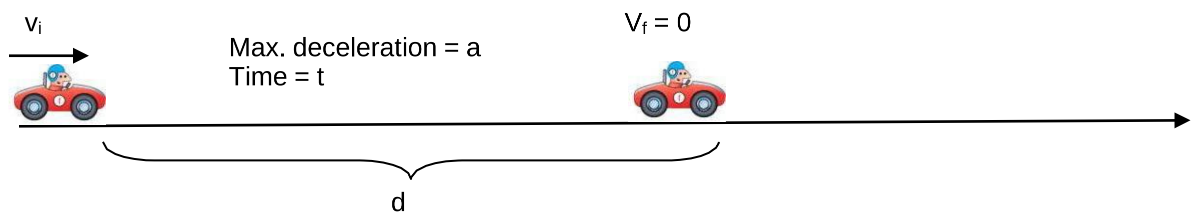
M, F_{net}, ⊗X, v_o, v_f

Case C:

M, F_{net}, v_o, v_f, ⊗t

. **Kinematics**

A car travelling at a constant speed of v_i can come to a stop in a minimum distance *d* in time t, given that the car has a maximum deceleration *a* when brakes are fully engaged.



Now suppose the same car (with the same maximum deceleration *a*) is traveling at an initial speed of $2v_i$, and has a minimum stopping distance *d'* in time *t'*. Using kinematic equations, find

a. The ratio $\frac{t'}{t}$

b. The ratio $\frac{d'}{d}$