2. Can an object have a varying speed if its velocity is constant? Can it have varying velocity if its speed is constant? If yes, give examples in each case.

2. If the velocity of an object is constant, the speed must also be constant. (A constant velocity means that the speed and direction are both constant.) If the speed of an object is constant, the velocity CAN vary. For example, a car traveling around a curve at constant speed has a varying velocity, since the direction of the velocity vector is changing.

14. Can an object have zero velocity and nonzero acceleration at the same time? Give examples.

14. Yes. For example, a rock thrown straight up in the air has a constant, nonzero acceleration due to gravity for its entire flight. However, at the highest point it momentarily has a zero velocity. A car, at the moment it starts moving from rest, has zero velocity and nonzero acceleration.

15. Can an object have zero acceleration and nonzero velocity at the same time? Give examples.

15. Yes. Anytime the velocity is constant, the acceleration is zero. For example, a car traveling at a constant 90 km/h in a straight line has nonzero velocity and zero acceleration.

18. Describe in words the motion plotted in Fig. 2–36 in terms of v, a, etc. [*Hint*: First try to duplicate the motion plotted by walking or moving your hand.]

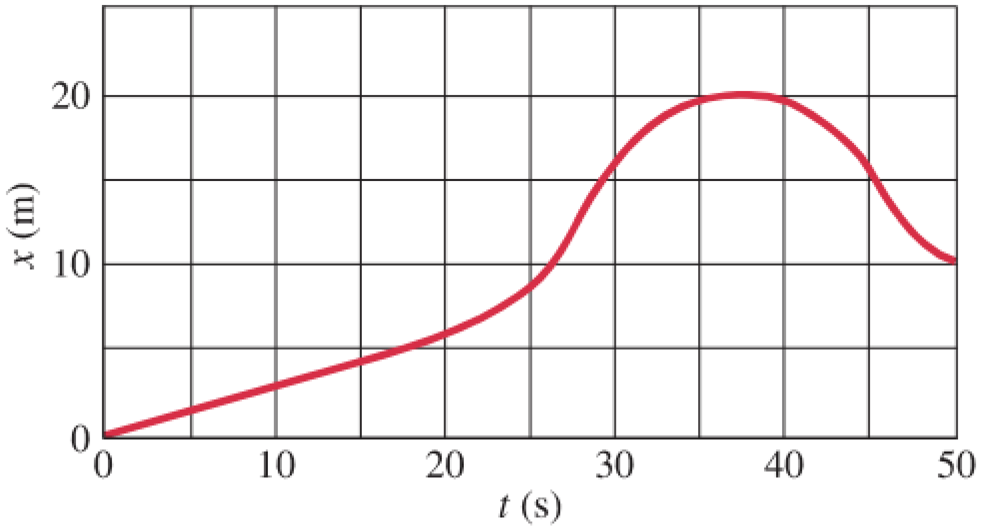


FIGURE 2–36 Question 18, Problems 9 and 86.

18. The slope of the position versus time curve is the velocity. The object starts at the origin with a constant velocity (and therefore zero acceleration), which it maintains for about 20 s. For the next 10 s, the positive curvature of the graph indicates the object has a positive acceleration; its speed is increasing. From 30 s to 45 s, the graph has a negative curvature; the object uniformly slows to a stop, changes direction, and then moves backwards with increasing speed. During this time interval its acceleration is negative, since the object is slowing down while traveling in the positive direction and then speeding up while traveling in the negative direction. For the final 5 s shown, the object continues moving in the negative direction but slows down, which gives it a positive acceleration. During the 50 s shown, the object travels from the origin to a point 20 m away, and then back 10 m to end up 10 m from the starting position.

19. Describe in words the motion of the object graphed in Fig. 2–37.

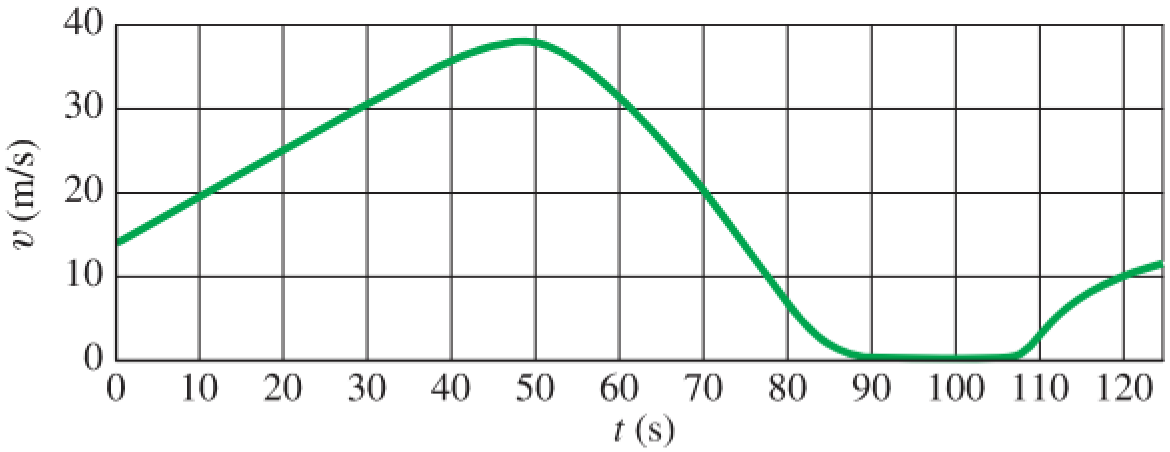


FIGURE 2–37 Question 19, Problem 23.

19. The object begins with a speed of 14 m/s and increases in speed with constant positive acceleration from $t = 0$ until $t = 45$ s. The acceleration then begins to decrease, goes to zero at $t = 50$ s, and then goes negative. The object slows down from $t = 50$ s to $t = 90$ s, and is at rest from $t = 90$ s to $t = 108$ s. At that point the acceleration becomes positive again and the velocity increases from $t = 108$ s to $t = 130$ s.

1. (I) If you are driving 110 km/h along a straight road and you look to the side for 2.0 s, how far do you travel during this inattentive period?

1. The distance of travel (displacement) can be found by rearranging Eq. 2-2 for the average velocity. Also note that the units of the velocity and the time are not the same, so the speed units will be converted.

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

4. (I) A rolling ball moves from $x_1 = 3.4\,\text{cm}$ to $x_2 = -4.2\,\text{cm}$ during the time from $t_1 = 3.0\,\text{s}$ to $t_2 = 5.1\,\text{s}$. What is its average velocity?

4. The average velocity is given by Eq. 2-2.

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{-4.2\,\text{cm} - 3.4\,\text{cm}}{5.1\,\text{s} - 3.0\,\text{s}} = \frac{-7.6\,\text{cm}}{2.1\,\text{s}} = \boxed{-3.6\,\text{cm/s}}$$

The negative sign indicates the direction.

6. (II) You are driving home from school steadily at 95 km/h for 130 km. It then begins to rain and you slow to 65 km/h. You arrive home after driving 3 hours and 20 minutes. (*a*) How far is your hometown from school? (*b*) What was your average speed?

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

$$\bar{v}_1 = \frac{\Delta x_1}{\Delta t_1} \rightarrow \Delta t_1 = \frac{\Delta x_1}{\bar{v}_1} = \frac{130\,\text{km}}{95\,\text{km/h}} = 1.37\,\text{h} = 82\,\text{min}$$

The time for the second part of the trip is now calculated.

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

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

$$\bar{v}_2 = \frac{\Delta x_2}{\Delta t_2} \rightarrow \Delta x_2 = \bar{v}_2\Delta t_2 = (65\,\text{km/h})(1.96\,\text{h}) = 127.5\,\text{km} = 1.3\times10^2\,\text{km}$$

(*a*) The total distance is then $\Delta x_{\text{total}} = \Delta x_1 + \Delta x_2 = 130\,\text{km} + 127.5\,\text{km} = 257.5\,\text{km} \approx \boxed{2.6\times10^2\,\text{km}}$.

(*b*) The average speed is NOT the average of the two speeds. Use the definition of average speed, Eq. 2-2.

$$\bar{v} = \frac{\Delta x_{\text{total}}}{\Delta t_{\text{total}}} = \frac{257.5\,\text{km}}{3.33\,\text{h}} = \boxed{77\,\text{km/h}}$$

11. (II) A car traveling 95 km/h is 110 m behind a truck traveling 75 km/h. How long will it take the car to reach the truck?

11. Both objects will have the same time of travel. If the truck travels a distance Δx_{truck}, then the distance the car travels will be $\Delta x_{car} = \Delta x_{truck} + 110\,\text{m}$. Use Eq. 2-2 for average speed, $\bar{v} = \Delta x/\Delta t$, solve for time, and equate the two times.

$$\Delta t = \frac{\Delta x_{truck}}{\bar{v}_{truck}} = \frac{\Delta x_{car}}{\bar{v}_{car}} \qquad \frac{\Delta x_{truck}}{75\ \text{km/h}} = \frac{\Delta x_{truck} + 110\ \text{m}}{95\ \text{km/h}}$$

Solving for Δx_{truck} gives $\Delta x_{truck} = (110\,\text{m})\dfrac{(75\,\text{km/h})}{(95\,\text{km/h} - 75\,\text{km/h})} = 412.5\,\text{m}$.

The time of travel is $\Delta t = \dfrac{\Delta x_{truck}}{\bar{v}_{truck}} = \left(\dfrac{412.5\,\text{m}}{75000\,\text{m/h}}\right)\left(\dfrac{60\,\text{min}}{1\,\text{h}}\right) = 0.33\,\text{min} = 19.8\,\text{s} = \boxed{2.0\times10^{1}\,\text{s}}$.

Also note that $\Delta t = \dfrac{\Delta x_{car}}{\bar{v}_{car}} = \left(\dfrac{412.5\,\text{m} + 110\,\text{m}}{95000\,\text{m/h}}\right)\left(\dfrac{60\,\text{min}}{1\,\text{h}}\right) = 0.33\,\text{min} = 20\,\text{s}$.

ALTERNATE SOLUTION:

The speed of the car relative to the truck is $95\,\text{km/h} - 75\,\text{km/h} = 20\,\text{km/h}$. In the reference frame of the truck, the car must travel 110 m to catch it.

$$\Delta t = \frac{0.11\ \text{km}}{20\,\text{km/h}}\left(\frac{3600\ \text{s}}{1\ \text{h}}\right) = 19.8\ \text{s}$$

16. (II) The position of a ball rolling in a straight line is given by $x = 2.0 - 3.6\,t + 1.1\,t^2$, where x is in meters and t in seconds. (*a*) Determine the position of the ball at $t = 1.0\,\text{s}$, $2.0\,\text{s}$, and $3.0\,\text{s}$. (*b*) What is the average velocity over the interval $t = 1.0\,\text{s}$ to $t = 3.0\,\text{s}$? (*c*) What is its instantaneous velocity at $t = 2.0\,\text{s}$ and at $t = 3.0\,\text{s}$?

16. We are given that $x(t) = 2.0\,\text{m} - (3.6\,\text{m/s})t + (1.1\,\text{m/s}^2)t^2$.

(*a*) $x(1.0\,\text{s}) = 2.0\,\text{m} - (3.6\,\text{m/s})(1.0\,\text{s}) + (1.1\,\text{m/s}^2)(1.0\,\text{s})^2 = \boxed{-0.5\,\text{m}}$

$x(2.0\,\text{s}) = 2.0\,\text{m} - (3.6\,\text{m/s})(2.0\,\text{s}) + (1.1\,\text{m/s}^2)(2.0\,\text{s})^2 = \boxed{-0.8\,\text{m}}$

$x(3.0\,\text{s}) = 2.0\,\text{m} - (3.6\,\text{m/s})(3.0\,\text{s}) + (1.1\,\text{m/s}^2)(3.0\,\text{s})^2 = \boxed{1.1\,\text{m}}$

(*b*) $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{1.1\text{m} - (-0.5\text{m})}{2.0\,\text{s}} = \boxed{0.80\,\text{m/s}}$

(*c*) The instantaneous velocity is given by $v(t) = \dfrac{dx(t)}{dt} = -3.6\,\text{m/s} + (2.2\,\text{m/s}^2)t$.

$v(2.0\,\text{s}) = -3.6\,\text{m/s} + (2.2\,\text{m/s}^2)(2.0\,\text{s}) = \boxed{0.8\,\text{m/s}}$

$v(3.0\,\text{s}) = -3.6\,\text{m/s} + (2.2\,\text{m/s}^2)(3.0\,\text{s}) = \boxed{3.0\,\text{m/s}}$

19. (III) A bowling ball traveling with constant speed hits the pins at the end of a bowling lane 16.5 m long. The bowler hears the sound of the ball hitting the pins 2.50 s after the ball is released from his hands. What is the speed of the ball, assuming the speed of sound is 340 m/s?

19. The average speed of sound is given by $v_{sound} = \Delta x/\Delta t$, and so the time for the sound to travel from the end of the lane back to the bowler is $\Delta t_{sound} = \dfrac{\Delta x}{v_{sound}} = \dfrac{16.5\ \text{m}}{340\ \text{m/s}} = 4.85\times10^{-2}\,\text{s}$. Thus the time for the ball to travel from the bowler to the end of the lane is given by $\Delta t_{ball} = \Delta t_{total} - \Delta t_{sound} = 2.50\,\text{s} - 4.85\times10^{-2}\,\text{s} = 2.4515\,\text{s}$. And so the speed of the ball is as follows.

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

22. (I) A sprinter accelerates from rest to 9.00 m/s in 1.28 s. What is her acceleration in (*a*) m/s^2; (*b*) km/h^2?

22. (*a*) The average acceleration of the sprinter is $\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{9.00\,\text{m/s} - 0.00\,\text{m/s}}{1.28\ \text{s}} = \boxed{7.03\,\text{m/s}^2}$.

(*b*) $$\bar{a} = \left(7.03\,\text{m/s}^2\right)\left(\frac{1\ \text{km}}{1000\ \text{m}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)^2 = \boxed{9.11\times10^4\ \text{km/h}^2}$$

25. (II) A car moving in a straight line starts at $x = 0$ at $t = 0$. It passes the point $x = 25.0\text{ m}$ with a speed of 11.0 m/s at $t = 3.00\text{ s}$. It passes the point $x = 385\text{ m}$ with a speed of 45.0 m/s at $t = 20.0\text{ s}$. Find (*a*) the average velocity and (*b*) the average acceleration between $t = 3.00\text{ s}$ and $t = 20.0\text{ s}$.

25. (*a*) $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{385\text{ m} - 25\text{ m}}{20.0\text{ s} - 3.0\text{ s}} = \boxed{21.2\text{ m/s}}$

(*b*) $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{45.0\text{ m/s} - 11.0\text{ m/s}}{20.0\text{ s} - 3.0\text{ s}} = \boxed{2.00\text{ m/s}^2}$

29. (II) The position of an object is given by $x = At + Bt^2$, where x is in meters and t is in seconds. (*a*) What are the units of A and B? (*b*) What is the acceleration as a function of time? (*c*) What are the velocity and acceleration at $t = 5.0\text{ s}$? (*d*) What is the velocity as a function of time if $x = At + Bt^{-3}$?

29. (*a*) Since the units of A times the units of t must equal meters, the units of A must be $\boxed{\text{m/s}}$.

Since the units of B times the units of t^2 must equal meters, the units of B must be $\boxed{\text{m/s}^2}$.

(*b*) The acceleration is the second derivative of the position function.

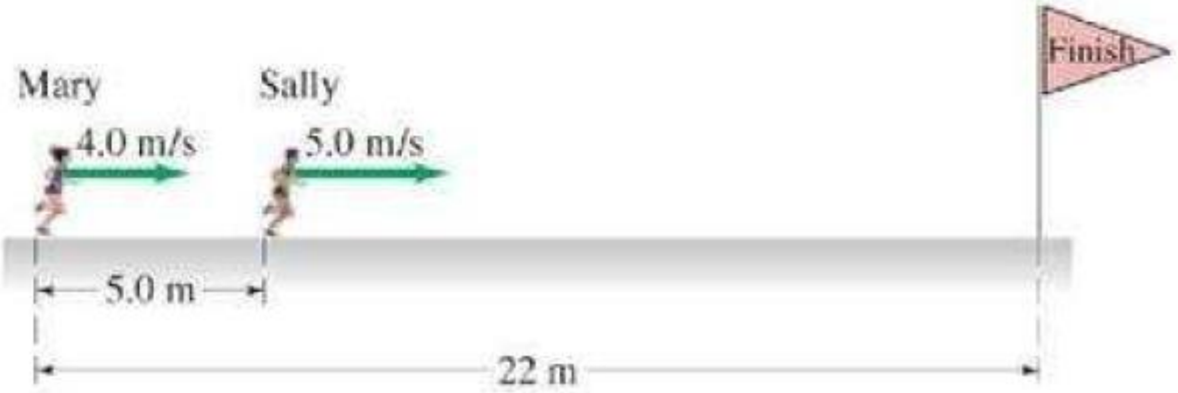
$$x = At + Bt^2 \rightarrow v = \frac{dx}{dt} = A + 2Bt \rightarrow a = \frac{d^2x}{dt^2} = \frac{dv}{dt} = \boxed{2B\text{ m/s}^2}$$

(*c*) $v = A + 2Bt \rightarrow v(5) = \boxed{(A + 10B)\text{ m/s}}$ $\quad a = \boxed{2B\text{ m/s}^2}$

(*d*) The velocity is the derivative of the position function.

$$x = At + Bt^{-3} \rightarrow v = \frac{dx}{dt} = \boxed{A - 3Bt^{-4}}$$

47. (III) Mary and Sally are in a foot race (Fig. 2–43). When Mary is 22 m from the finish line, she has a speed of 4.0 m/s and is 5.0 m behind Sally, who has a speed of 5.0 m/s. Sally thinks she has an easy win and so, during the remaining portion of the race, decelerates at a constant rate of $0.50\ \mathrm{m/s^2}$ to the finish line. What constant acceleration does Mary now need during the remaining portion of the race, if she wishes to cross the finish line side-by-side with Sally?



47. For the runners to cross the finish line side-by-side means they must both reach the finish line in the same amount of time from their current positions. Take Mary's current location as the origin. Use Eq. 2-12b.

For Sally: $22 = 5 + 5t + \tfrac{1}{2}(-.5)t^2 \rightarrow t^2 - 20t + 68 = 0 \rightarrow$

$$t = \frac{20 \pm \sqrt{20^2 - 4(68)}}{2} = 4.343\,\mathrm{s},\ 15.66\,\mathrm{s}$$

The first time is the time she first crosses the finish line, and so is the time to be used for the problem. Now find Mary's acceleration so that she crosses the finish line in that same amount of time.

For Mary: $22 = 0 + 4t + \tfrac{1}{2}at^2 \rightarrow a = \dfrac{22-4t}{\tfrac{1}{2}t^2} = \dfrac{22-4(4.343)}{\tfrac{1}{2}(4.343)^2} = \boxed{0.49\ \mathrm{m/s^2}}$

46. (III) A runner hopes to complete the 10,000-m run in less than 30.0 min. After running at constant speed for exactly 27.0 min, there are still 1100 m to go. The runner must then accelerate at $0.20\ \mathrm{m/s^2}$ for how many seconds in order to achieve the desired time?

46. During the final part of the race, the runner must have a displacement of 1100 m in a time of 180 s (3.0 min). Assume that the starting speed for the final part is the same as the average speed thus far.

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{8900\ \mathrm{m}}{(27\times 60)\ \mathrm{s}} = 5.494\ \mathrm{m/s} = v_0$$

The runner will accomplish this by accelerating from speed v_0 to speed v for t seconds, covering a distance d_1, and then running at a constant speed of v for $(180-t)$ seconds, covering a distance d_2. We have these relationships from Eq. 2-12a and Eq. 2-12b.

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

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

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

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

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

58. (II) A rocket rises vertically, from rest, with an acceleration of $3.2\ \mathrm{m/s^2}$ until it runs out of fuel at an altitude of 950 m. After this point, its acceleration is that of gravity, downward. (*a*) What is the velocity of the rocket when it runs out of fuel? (*b*) How long does it take to reach this point? (*c*) What maximum altitude does the rocket reach? (*d*) How much time (total) does it take to reach maximum altitude? (*e*) With what velocity does it strike the Earth? (*f*) How long (total) is it in the air?

58. (*a*) Choose upward to be the positive direction, and $y_0 = 0$ at the ground. The rocket has $v_0 = 0$, $a = 3.2\ \mathrm{m/s^2}$, and $y = 950\ \mathrm{m}$ when it runs out of fuel. Find the velocity of the rocket when it runs out of fuel from Eq 2-12c, with *x* replaced by *y*.

$$v_{950\ \mathrm{m}}^2 = v_0^2 + 2a(y - y_0) \rightarrow$$

$$v_{950\ \mathrm{m}} = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{0 + 2(3.2\ \mathrm{m/s^2})(950\ \mathrm{m})} = 77.97\ \mathrm{m/s} \approx \boxed{78\ \mathrm{m/s}}$$

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

(*b*) The time to reach the 950 m location can be found from Eq. 2-12a.

$$v_{950\ \mathrm{m}} = v_0 + at_{950\ \mathrm{m}} \rightarrow t_{950\ \mathrm{m}} = \frac{v_{950\ \mathrm{m}} - v_0}{a} = \frac{77.97\ \mathrm{m/s} - 0}{3.2\ \mathrm{m/s^2}} = 24.37\ \mathrm{s} \approx \boxed{24\ \mathrm{s}}$$

(*c*) For this part of the problem, the rocket will have an initial velocity $v_0 = 77.97\ \mathrm{m/s}$, an acceleration of $a = -9.80\ \mathrm{m/s^2}$, and a final velocity of $v = 0$ at its maximum altitude. The altitude reached from the out-of-fuel point can be found from Eq. 2-12c.

$$v^2 = v_{950\ \mathrm{m}}^2 + 2a(y - 950\ \mathrm{m}) \rightarrow$$

$$y_{\max} = 950\ \mathrm{m} + \frac{0 - v_{950\ \mathrm{m}}^2}{2a} = 950\ \mathrm{m} + \frac{-(77.97\ \mathrm{m/s})^2}{2(-9.80\ \mathrm{m/s^2})} = 950\ \mathrm{m} + 310\ \mathrm{m} = \boxed{1260\ \mathrm{m}}$$

(*d*) The time for the "coasting" portion of the flight can be found from Eq. 2-12a.

$$v = v_{950\text{ m}} + at_{\text{coast}} \quad \to \quad t_{\text{coast}} = \frac{v - v_0}{a} = \frac{0 - 77.97\text{ m/s}}{-9.80\text{ m/s}^2} = 7.96\text{ s}$$

Thus the total time to reach the maximum altitude is $t = 24.37\text{ s} + 7.96\text{ s} = 32.33\text{s} \approx \boxed{32\text{ s}}$.

(*e*) For the falling motion of the rocket, $v_0 = 0\text{ m/s}$, $a = -9.80\text{ m/s}^2$, and the displacement is -1260 m (it falls from a height of 1260 m to the ground). Find the velocity upon reaching the Earth from Eq. 2-12c.

$$v^2 = v_0^2 + 2a(y - y_0) \quad \to$$

$$v = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{0 + 2(-9.80\text{ m/s}^2)(-1260\text{ m})} = -157\text{ m/s} \approx \boxed{-160\text{ m/s}}$$

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

(*f*) The time for the rocket to fall back to the Earth is found from Eq. 2-12a.

$$v = v_0 + at \quad \to \quad t_{\text{fall}} = \frac{v - v_0}{a} = \frac{-157\text{ m/s} - 0}{-9.80\text{ m/s}^2} = 16.0\text{ s}$$

Thus the total time for the entire flight is $t = 32.33\text{ s} + 16.0\text{ s} = 48.33\text{s} \approx \boxed{48\text{s}}$. .

66. (III) A rock is thrown vertically upward with a speed of 12.0 m/s. Exactly 1.00 s later, a ball is thrown up vertically along the same path with a speed of 18.0 m/s. (*a*) At what time will they strike each other? (*b*) At what height will the collision occur? (*c*) Answer (*a*) and (*b*) assuming that the order is reversed: the ball is thrown 1.00 s before the rock.

66. (*a*) Choose up to be the positive direction. Let the throwing height of both objects be the $y = 0$ location, and so $y_0 = 0$ for both objects. The acceleration of both objects is $a = -g$. The equation of motion for the rock, using Eq. 2-12b, is $y_{rock} = y_0 + v_{0\,rock}t + \frac{1}{2}at^2 = v_{0\,rock}t - \frac{1}{2}gt^2$, where t is the time elapsed from the throwing of the rock. The equation of motion for the ball, being thrown 1.00 s later, is $y_{ball} = y_0 + v_{0\,ball}(t - 1.00\,s) + \frac{1}{2}a(t - 1.00\,s)^2 =$ $v_{0\,ball}(t - 1.00\,s) - \frac{1}{2}g(t - 1.00\,s)^2$. Set the two equations equal (meaning the two objects are at the same place) and solve for the time of the collision.

$$y_{rock} = y_{ball} \rightarrow v_{0\,rock}t - \tfrac{1}{2}gt^2 = v_{0\,ball}(t - 1.00\,s) - \tfrac{1}{2}g(t - 1.00\,s)^2 \rightarrow$$

$$(12.0\,m/s)t - \tfrac{1}{2}(9.80\,m/s^2)t^2 = (18.0\,m/s)(t - 1.00\,s) - \tfrac{1}{2}(9.80\,m/s^2)(t - 1.00\,s)^2 \rightarrow$$

$$(15.8\,m/s)t = (22.9\,m) \rightarrow t = \boxed{1.45\,s}$$

(*b*) Use the time for the collision to find the position of either object.

$$y_{rock} = v_{0\,rock}t - \tfrac{1}{2}gt^2 = (12.0\,m/s)(1.45\,s) - \tfrac{1}{2}(9.80\,m/s^2)(1.45\,s)^2 = \boxed{7.10\,m}$$

(c) Now the ball is thrown first, and so $y_{\text{ball}} = v_{0\text{ ball}}t - \frac{1}{2}gt^2$ and $y_{\text{rock}} = v_{0\text{ rock}}(t - 1.00\,\text{s}) - \frac{1}{2}g(t - 1.00\,\text{s})^2$. Again set the two equations equal to find the time of collision.

$$y_{\text{ball}} = y_{\text{rock}} \rightarrow v_{0\text{ ball}}t - \tfrac{1}{2}gt^2 = v_{0\text{ rock}}(t - 1.00\,\text{s}) - \tfrac{1}{2}g(t - 1.00\,\text{s})^2 \rightarrow$$

$$(18.0\,\text{m/s})t - \tfrac{1}{2}(9.80\,\text{m/s}^2)t^2 = (12.0\,\text{m/s})(t - 1.00\,\text{s}) - \tfrac{1}{2}(9.80\,\text{m/s}^2)(t - 1.00\,\text{s})^2 \rightarrow$$

$$(3.80\,\text{m/s})t = 16.9\,\text{m} \rightarrow t = 4.45\,\text{s}$$

But this answer can be deceptive. Where do the objects collide?

$$y_{\text{ball}} = v_{0\text{ ball}}t - \tfrac{1}{2}gt^2 = (18.0\,\text{m/s})(4.45\,\text{s}) - \tfrac{1}{2}(9.80\,\text{m/s}^2)(4.45\,\text{s})^2 = -16.9\,\text{m}$$

Thus, assuming they were thrown from ground level, they collide below ground level, which cannot happen. Thus $\boxed{\text{they never collide}}$.

*68. (III) The acceleration of a particle is given by $a = A\sqrt{t}$ where $A = 2.0\,\text{m/s}^{5/2}$. At $t = 0$, $v = 7.5\,\text{m/s}$ and $x = 0$. (a) What is the speed as a function of time? (b) What is the displacement as a function of time? (c) What are the acceleration, speed and displacement at $t = 5.0\,\text{s}$?

68. (a) The speed is the integral of the acceleration.

$$a = \frac{dv}{dt} \rightarrow dv = a\,dt \rightarrow dv = A\sqrt{t}\,dt \rightarrow \int_{v_0}^{v} dv = A\int_0^t \sqrt{t}\,dt \rightarrow$$

$$v - v_0 = \tfrac{2}{3}At^{3/2} \rightarrow v = v_0 + \tfrac{2}{3}At^{3/2} \rightarrow \boxed{v = 7.5\,\text{m/s} + \tfrac{2}{3}(2.0\,\text{m/s}^{5/2})t^{3/2}}$$

(*b*) The displacement is the integral of the velocity.

$$v = \frac{dx}{dt} \rightarrow dx = vdt \rightarrow dx = \left(v_0 + \tfrac{2}{3}At^{3/2}\right)dt \rightarrow$$

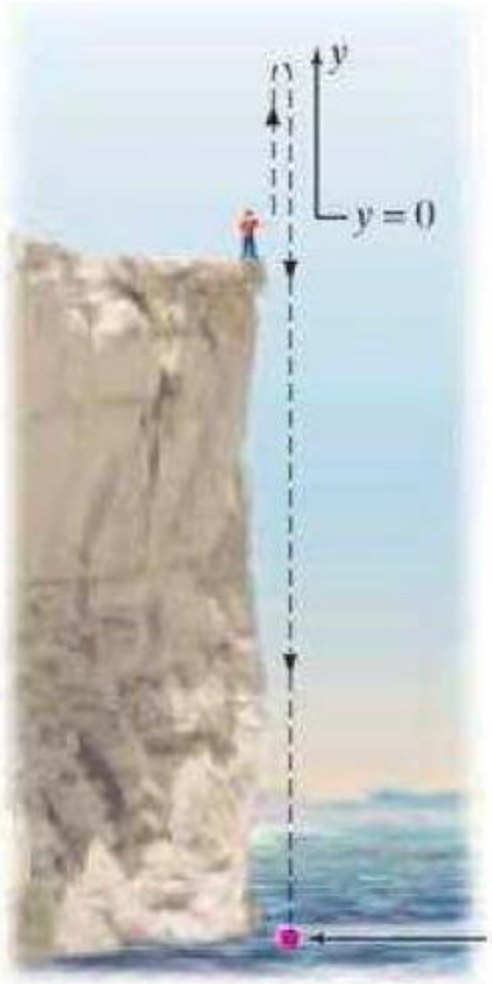
$$\int_{0\,\text{m}}^{x} dx = \int_0^t \left(v_0 + \tfrac{2}{3}At^{3/2}\right)dt \rightarrow x = v_0 t + \tfrac{2}{3}\tfrac{2}{5}At^{5/2} = \boxed{(7.5\,\text{m/s})t + \tfrac{4}{15}\left(2.0\,\text{m/s}^{5/2}\right)t^{5/2}}$$

(*c*) $a(t = 5.0\,\text{s}) = \left(2.0\,\text{m/s}^{5/2}\right)\sqrt{5.0\,\text{s}} = \boxed{4.5\,\text{m/s}^2}$

$$v(t = 5.0\,\text{s}) = 7.5\,\text{m/s} + \tfrac{2}{3}\left(2.0\,\text{m/s}^{5/2}\right)(5.0\,\text{s})^{3/2} = 22.41\,\text{m/s} \approx \boxed{22\,\text{m/s}}$$

$$x(t = 5.0\,\text{s}) = (7.5\,\text{m/s})(5.0\,\text{s}) + \tfrac{4}{15}\left(2.0\,\text{m/s}^{5/2}\right)(5.0\,\text{s})^{5/2} = 67.31\,\text{m} \approx \boxed{67\,\text{m}}$$

81. A stone is thrown vertically upward with a speed of 12.5 m/s from the edge of a cliff 75.0 m high (Fig. 2–49). (*a*) How much later does it reach the bottom of the cliff? (*b*) What is its speed just before hitting? (*c*) What total distance did it travel?



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

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

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

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

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

93. Figure 2–52 shows the position vs. time graph for two bicycles, A and B. (*a*) Is there any instant at which the two bicycles have the same velocity? (*b*) Which bicycle has the larger acceleration? (*c*) At which instant(s) are the bicycles passing each other? Which bicycle is passing the other? (*d*) Which bicycle has the highest instantaneous velocity? (*e*) Which bicycle has the higher average velocity?

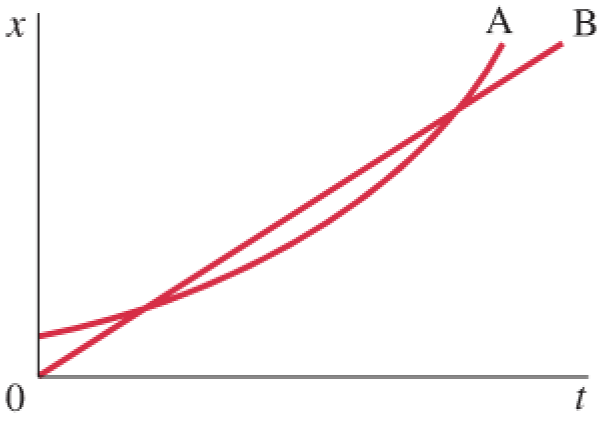
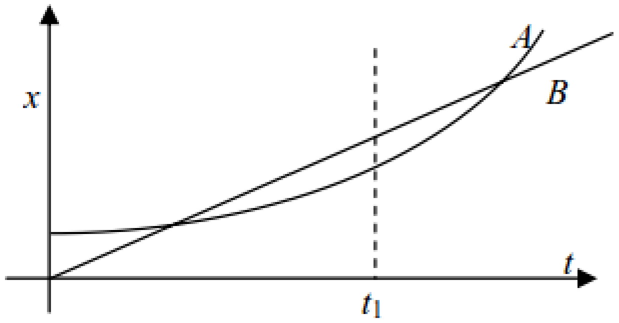


FIGURE 2–52 Problem 93.

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



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

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

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

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