40. **Graphs** A sprinter walks up to the starting blocks at a constant speed and positions herself for the start of the race. She waits until she hears the starting pistol go off, and then accelerates rapidly until she attains a constant velocity. She maintains this velocity until she crosses the finish line, and then she slows down to a walk, taking more time to slow down than she did to speed up at the beginning of the race. Sketch a velocity-time and a position-time graph to represent her motion. Draw them one above the other on the same time scale. Indicate on your \( p-t \) graph where the starting blocks and finish line are.

![Velocity-Time Graph](image)

41. **Critical Thinking** Describe how you could calculate the acceleration of an automobile. Specify the measuring instruments and the procedures that you would use.

*One person reads a stopwatch and calls out time intervals. Another person reads the speedometer at each time and records it. Plot speed versus time and find the slope.*

### Practice Problems

**3.3 Free Fall**

Pages 72–75

**page 74**

**42.** A construction worker accidentally drops a brick from a high scaffold.

a. What is the velocity of the brick after 4.0 s?

   *Say upward is the positive direction.*

   \[ v_f = v_i + at, \quad a = -g = -9.80 \text{ m/s}^2 \]

   \[ v_i = 0.0 \text{ m/s} + (-9.80 \text{ m/s}^2)(4.0 \text{ s}) \]

   \[ = -39 \text{ m/s when the upward direction is positive} \]

b. How far does the brick fall during this time?

   \[ s = v_i t + \frac{1}{2} at^2 \]

   \[ = 0 + \left(\frac{1}{2}\right)(-9.80 \text{ m/s}^2)(4.0 \text{ s})^2 \]

   \[ = -78 \text{ m} \]

   The brick falls 78 m.

43. Suppose for the previous problem you choose your coordinate system so that the opposite direction is positive.
Chapter 3 continued

a. What is the brick’s velocity after 4.0 s?

Now the positive direction is downward.

\[ v_f = v_i + at, \ a = g = 9.80 \text{ m/s}^2 \]

\[ v_f = 0.0 \text{ m/s} + (9.80 \text{ m/s}^2)(4.0 \text{ s}) \]

\[ = +39 \text{ m/s} \text{ when the downward direction is positive} \]

b. How far does the brick fall during this time?

\[ d = v_i t + \frac{1}{2}at^2, \ a = g = 9.80 \text{ m/s}^2 \]

\[ = (0.0 \text{ m/s})(4.0 \text{ s}) + \]

\[ \left(\frac{1}{2}\right)(9.80 \text{ m/s}^2)(4.0 \text{ s})^2 \]

\[ = +78 \text{ m} \]

The brick still falls 78 m.

44. A student drops a ball from a window 3.5 m above the sidewalk. How fast is it moving when it hits the sidewalk?

\[ v_f^2 = v_i^2 + 2ad, \ a = g \text{ and } v_i = 0 \]

so \[ v_f = \sqrt{2gd} \]

\[ = \sqrt{(2)(9.80 \text{ m/s}^2)(3.5 \text{ m})} \]

\[ = 8.3 \text{ m/s} \]

45. A tennis ball is thrown straight up with an initial speed of 22.5 m/s. It is caught at the same distance above the ground.

a. How high does the ball rise?

\[ a = -g, \text{ and at the maximum height, } v_f = 0 \]

\[ v_f^2 = v_i^2 + 2ad \text{ becomes} \]

\[ v_i^2 = 2gd \]

\[ d = \frac{v_i^2}{2g} = \frac{(22.5 \text{ m/s})^2}{(2)(9.80 \text{ m/s}^2)} = 25.8 \text{ m} \]

b. How long does the ball remain in the air? Hint: The time it takes the ball to rise equals the time it takes to fall.

Calculate time to rise using \[ v_f = v_i + at, \text{ with } a = -g \text{ and } v_f = 0 \]

\[ t = \frac{v_i}{g} = \frac{22.5 \text{ m/s}}{9.80 \text{ m/s}^2} = 2.30 \text{ s} \]

The time to fall equals the time to rise, so the time to remain in the air is

\[ t_{\text{air}} = 2t_{\text{rise}} = (2)(2.30 \text{ s}) = 4.60 \text{ s} \]

46. You decide to flip a coin to determine whether to do your physics or English homework first. The coin is flipped straight up.

a. If the coin reaches a high point of 0.25 m above where you released it, what was its initial speed?
\[ v_f^2 = v_i^2 + 2aΔd \]
\[ v_i = \sqrt{v_f^2 + 2gΔd} \text{ where } a = -g \]
and \( v_i = 0 \) at the height of the toss, so
\[ v_i = \sqrt{(0.0 \text{ m/s})^2 + (2)(9.80 \text{ m/s}^2)(0.25 \text{ m})} \]
\[ = 2.2 \text{ m/s} \]

b. If you catch it at the same height as you released it, how much time did it spend in the air?
\[ v_f = v_i + at \text{ where } a = -g \]
\[ v_i = 2.2 \text{ m/s and} \]
\[ v_f = -2.2 \text{ m/s} \]
\[ t = \frac{v_f - v_i}{-g} \]
\[ = \frac{-2.2 \text{ m/s} - 2.2 \text{ m/s}}{-9.80 \text{ m/s}^2} \]
\[ = 0.45 \text{ s} \]

**Section Review**

### 3.3 Free Fall

**pages 72–75**

**page 75**

47. **Maximum Height and Flight Time** Acceleration due to gravity on Mars is about one-third that on Earth. Suppose you throw a ball upward with the same velocity on Mars as on Earth.

a. How would the ball’s maximum height compare to that on Earth?
   At maximum height, \( v_f = 0 \),
   so \( d_f = \frac{v_i^2}{2g} \) or three times higher.

b. How would its flight time compare?
   Time is found from \( d_f = \frac{1}{2}gt_f^2 \), or
   \[ t_f = \sqrt{\frac{2d_f}{g}} \]
   Distance is multiplied by 3 and \( g \) is divided by 3,
   so the flight time would be three times as long.

48. **Velocity and Acceleration** Suppose you throw a ball straight up into the air. Describe the changes in the velocity of the ball. Describe the changes in the acceleration of the ball.