Section 3 Free Fall: Practice Problems

41. A construction worker accidentally drops a brick from a high scaffold.

a. What is the velocity of the brick after 4.0 s?
b. How far does the brick fall during this time?

SOLUTION:

a. Let upward be the positive direction.

$$v_f = v_i + at,\ a = -9.8\ \text{m/s}^2$$
$$v_f = 0.0\ \text{m/s} + (-9.8\ \text{m/s}^2)(4.0\ \text{s})$$
$$= -39\ \text{m/s} = 39\ \text{m/s downward}$$

b.

$$x = v_i t + \frac{1}{2} a t^2$$
$$= 0 + \left(\frac{1}{2}\right)(-9.8\ \text{m/s}^2)(4.0\ \text{s})^2$$
$$= -78\ \text{m}$$

The brick falls 78 m.

ANSWER:

a. Let upward be the positive direction.
v_f = 39 m/s downward
b. x = –78 m
The brick falls 78 m.

44. 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?
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.*

SOLUTION:

a.

$a = -g$

at the maximum height, $v_f = 0$

$v_f^2 = v_i^2 + 2ax$ becomes

$v_i^2 = 2gx$

$$x = \frac{v_i^2}{2g} = \frac{(22.5\ \text{m/s})^2}{(2)(9.8\ \text{m/s}^2)} = 26\ \text{m}$$

b.

Rise time:

$v_f = v_i + at$

but $a = -g$ and $v_f = 0$, so

$$t = \frac{v_i}{g} = \frac{22.5\ \text{m/s}}{9.8\ \text{m/s}^2} = 2.3\ \text{s}$$

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

$t_{air} = 2t_{rise} = (2)(2.3\ \text{s}) = 4.6\ \text{s}$

ANSWER:

a. x **= 26 m**
b. t **= 4.6 s**

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

a. What is the velocity of the coin at the top of its trajectory?
b. If the coin reaches a high point of 0.25 m above where you released it, what was its initial speed?
c. If you catch it at the same height as you released it, how much time did it spend in the air?

SOLUTION:

a. $v_{top} = 0$ **m/s;** $a_{top} = 9.8$ **m/s downward**

b.

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$v_i = \sqrt{v_f^2 + 2g\Delta x} \text{ where } a = -g$$

and $v_f = 0$ at the height of the toss.

$$v_i = \sqrt{2g\Delta x}$$

$$= \sqrt{(2)(9.8 \text{ m/s}^2)(0.25) \text{ m}}$$

$$= 2.2 \text{ m/s}$$

c.

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{-g} = \frac{-2.2 \text{ m/s} - 2.2 \text{ m/s}}{-9.8 \text{ m/s}^2}$$

$$= 0.45 \text{ s}$$

ANSWER:

a. $v_{top} = 0$ **m/s;** $a_{top} = 9.8$ **m/s downward**
b. $v_i = 2.2$ **m/s**
c. $t = 0.45$ **s**

Section 3 Free Fall: Review

47. **MAIN IDEA** Suppose you hold a book in one hand and a flat sheet of paper in another hand. You drop them both, and they fall to the ground. Explain why the falling book is a good example of free fall, but the paper is not.

SOLUTION:

Free fall is the motion of an object when gravity is the only significant force on it. The paper is significantly affected by the air, but the book is not.

ANSWER:

Free fall is the motion of an object when gravity is the only significant force on it. The paper is significantly affected by the air, but the book is not.

49. **Free-Fall Ride** Suppose a free-fall ride at an amusement park starts at rest and is in free fall. What is the velocity of the ride after 2.3 s? How far do people on the ride fall during the 2.3-s time period?

SOLUTION:

Let upward be the positive direction.

$$v_f = v_i + at$$
$$= (0 \text{ m/s}) + (-9.8 \text{ m/s}^2)(2.3 \text{ s})$$
$$= -23 \text{ m/s}$$
$$= 23 \text{ m/s downward}$$

$$x_f = x_i + v_i t + \frac{1}{2} at^2$$

where $x_i = 0$ m and $v_i = 0$ m/s, so

$$x_f = \frac{1}{2} at^2 = \frac{1}{2} (-9.8 \text{ m/s}^2)(2.3 \text{ s})^2$$
$$= -26 \text{ m}$$

The people fall 26 m during the 2.3-s time period.

ANSWER:

Let upward be the positive direction.

v_f = 23 m/s downward

x_f = −26 m

The people fall 26 m during the 2.3-s time period.

51. **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.

SOLUTION:

Velocity is reduced at a constant rate as the ball travels upward. At its highest point, velocity is zero. As the ball begins to drop, the velocity begins to increase in the negative direction. When it reaches the height from which it was initially released, the ball has the same speed it had upon release. The acceleration is constant throughout the ball's flight.

ANSWER:

Velocity is reduced at a constant rate as the ball travels upward. At its highest point, velocity is zero. As the ball begins to drop, the velocity begins to increase in the negative direction. When it reaches the height from which it was initially released, the ball has the same speed it had upon release. The acceleration is constant throughout the ball's flight.

Chapter Assessment
Section 3 Free Fall: Mastering Problems

72. A stone that starts at rest is in free fall for 8.0 s. (Level 1)

a. Calculate the stone's velocity after 8.0 s.
b. What is the stone's displacement during this time?

SOLUTION:

a. $v_f = v_i + at_f$ **where** $a = -9.8\ m/s^2$

$= 0.0\ m/s + (-9.8\ m/s^2)(8.0\ s)$
$= -78\ m/s$
$= 78\ m/s$ downward
b. Choose the coordinate system to have the origin where the stone is at rest and positive to be upward.

$$x_f = v_i t + \frac{1}{2} a t_f^2 \text{ where } a = -9.8\ m/s^2$$

$$= 0.0\ m - \left(\frac{1}{2}\right)(9.8\ m/s^2)(8.0\ s)^2$$

$$= -3.1 \times 10^2\ m$$

$= 3.1 \times 10^2$ m downward

ANSWER:

a. 78 m/s downward
b. 310 m downward

74. You throw a ball downward from a window at a speed of 2.0 m/s. How fast will it be moving when it hits the sidewalk 2.5 m below? (Level 2)

SOLUTION:

Choose a coordinate system with the positive direction downward and the origin at the point where the ball leaves your hand.

$$v_f^2 = v_i^2 + 2ax_f \text{ where } a = 9.8\ m/s^2$$

$$v_f = \sqrt{v_i^2 + 2ax_f} = \sqrt{(2.0\ m/s)^2 + (2)(9.8\ m/s^2)(2.5\ m)}$$

$$= 7.3\ m/s \text{ downward}$$

ANSWER:

Choose a coordinate system with the positive direction downward and the origin at the point where the ball leaves your hand.

$v_f = 7.3\ m/s$ downward

76. **Beanbag** You throw a beanbag in the air and catch it 2.2 s later at the same place at which you threw it. (Level 3)
a. How high did it go?
b. What was its initial velocity?

SOLUTION:

a. Choose a coordinate system with the upward direction positive. The time to reach the maximum height is half of the time in the air.

$$v_f = v_i + at_f \text{ where } a = -9.8 \text{ m/s}^2$$

$$v_i = v_f - at_f$$

$$= 0.0 \text{ m/s} - (-9.8 \text{ m/s}^2)(1.1 \text{ s})$$

$$= 10.78 \text{ m/s (Retain extra digits for the intermediate calculation.)}$$

$$x_f = x_i + v_i t_f + \frac{1}{2} a t_f^2 \text{ where } a = -9.8 \text{ m/s}^2$$

$$= 0.0 \text{ m} + (10.78 \text{ m/s})(1.1 \text{ s}) + \left(\frac{1}{2}\right)(-9.8 \text{ m/s}^2)(1.1 \text{ s})^2$$

$$= 5.9 \text{ m}$$

b.
v_i = 11 m/s upward

ANSWER:

a. Choose a coordinate system with the upward direction positive. The time to reach the maximum height is half of the time in the air.
v_i = 10.78 m/s
x_f = 5.9 m

b.
v_i = 11 m/s upward

Chapter Assessment: Mixed Review

88. **Bicycle** A bicycle accelerates from 0.0 m/s to 4.0 m/s in 4.0 s. What distance does it travel? (Level 1)

SOLUTION:

$$x_f = \bar{v} t_f = \frac{v_i + v_f}{2} t_f$$

$$= \frac{1}{2}(0.0 \text{ m/s} + 4.0 \text{ m/s})(4.0 \text{ s})$$

$$= 8.0 \text{ m}$$

ANSWER:
8.0 m

89. A weather balloon is floating at a constant height above Earth when it releases a pack of instruments. (Level 1)

a. If the pack hits the ground with a downward velocity of −73.5 m/s, how far did the pack fall?
b. Calculate the distance the ball has rolled at the end of 2.2 s.

SOLUTION:

a.

$$v_f^2 = v_i^2 + 2ax_f$$

$$x_f = \frac{v_f^2 + v_i^2}{2a}$$

$$= \frac{(-73.5\ \text{m/s})^2 - (0.00\ \text{m/s})^2}{(2)(-9.8\ \text{m/s}^2)}$$

$$= -2.8 \times 10^2\ \text{m}$$

$$= 2.8 \times 10^2\ \text{m downward}$$

b.

$$v_f = v_i + at_f \text{ where } a = -9.8\ \text{m/s}^2$$

$$t_f = \frac{v_f - v_i}{a}$$

$$= \frac{-73.5\ \text{m/s} - 0.00\ \text{m/s}}{-9.8\ \text{m/s}^2}$$

$$= 7.5\ \text{s}$$

ANSWER:

a. $x_f = 2.8 \times 10^2$ **m downward**

b. $t_f = 7.5$ **s**