Free fall

Objects moving under the influence of gravity alone are said to be in free fall.

The acceleration of such an object comes from the gravitational force exerted on the object by the Earth. The magnitude of the acceleration is determined by the mass of the Earth, the radius of the Earth, and a number called the universal gravitational constant.

At the Earth's surface, $\vec{g}$, the acceleration due to gravity, equals 9.8 m/s^2 and is directed down.

Free fall Example

You throw a ball straight up. It leaves your hand at 12.0 m/s.

(a) How high does it go?

(b) If, when the ball is on the way down, you catch it at the same height at which you let it go, how long was it in flight?

(c) How fast is it traveling when you catch it?

Can you answer any of these questions without doing any math?

Step 1: Get Organized

Draw a picture.

Show the origin.

Choose a positive direction.

Organize the data.

Parameter	Value
y_i	0
v_i	+12.0 m/s
a	-9.8 m/s^2

Constant-acceleration equations

$$v = v_i + at$$

$$y = y_i + v_i t + \frac{1}{2} a t^2$$

$$v^2 = v_i^2 + 2a(y - y_i)$$

$$y = y_i + \frac{1}{2}\left(v_i + v\right) t$$

Part (a)

How high does it go?

Define up to be the positive y-direction, and define the origin to be the point at which the ball leaves your hand.

At the very top of its flight, the ball has an instantaneous velocity of ____.

Part (a)

How high does it go?

Define up to be the positive y-direction, and define the origin to be the point at which the ball leaves your hand.

At the very top of its flight, the ball has an instantaneous velocity of zero. We can plug v = 0 and y_i = 0 into the equation:

$$v^2 = v_i^2 + 2a(y - y_i)$$

This gives:

$$y - y_i = \frac{v^2 - v_i^2}{2a} = \frac{0 - (12.0 \text{ m/s})^2}{2 \times (-9.8 \text{ m/s}^2)} = 7.35 \text{ m}$$

The ball goes 7.35 m high.

Part (b)

How long is the ball in flight?

Constant-acceleration equations

$$v = v_i + at$$

$$y = y_i + v_i t + \frac{1}{2}at^2$$

$$v^2 = v_i^2 + 2a(y - y_i)$$

$$y = y_i + \frac{1}{2}\left(v_i + v\right)t$$

Part (b)

How long is the ball in flight?

Method 1: While going up, if the ball passes through a particular height at a particular velocity, on its way down it will pass through that height at the same speed, with its velocity directed down rather than up. The down half of the trip is a mirror image of the up half. We could just figure out how long it takes to reach its maximum height, and then double that to

get the total time.

Part (b)

How long is the ball in flight?

Method 2: Use the fact that $y = 0$ when the ball comes down.

Use the equation $$y = y_i + v_i t + \frac{1}{2}at^2$$

This gives $$0 = 0 + v_i t + \frac{1}{2}at^2$$

Divide both sides by t $$0 = v_i + \frac{1}{2}at$$

Solve for t $$t = \frac{-2v_i}{a} = \frac{-2 \times (+12.0\ \text{m/s})}{-9.8\ \text{m/s}^2} = 2.45\ \text{s}$$