Chapter 3 - Part C
Motion Along a Straight Line

3-6 Free-Fall Acceleration

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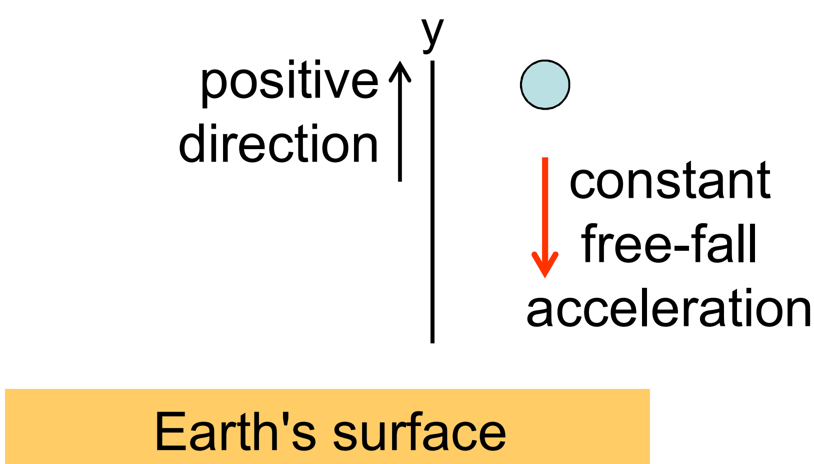
Free-fall

In the absence of the effects of air, all objects dropped or thrown near Earth's surface have a certain constant acceleration toward Earth. This acceleration is called free-fall acceleration and it is due to Earth's gravity.



$$a = -g = -9.8\ m/s^2$$

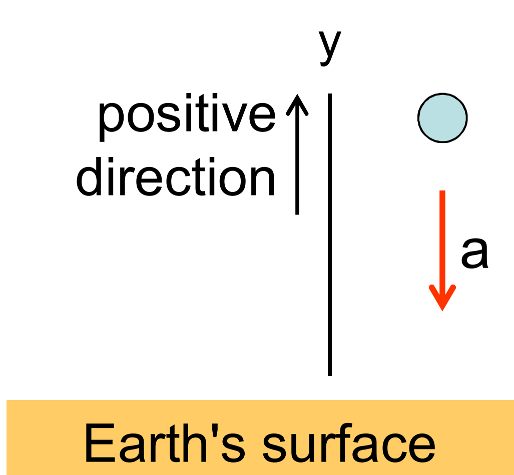
g is the magnitude of the free-fall acceleration.
g is always positive.
$g = 9.8\ m/s^2$.

The value of g varies slightly from place to place on Earth's surface. the value $g = 9.8\ m/s^2$ is accurate enough for our purposes in this course.

3-6 Free-Fall Acceleration
Formulas

Equations for free-fall = Equations for motion with constant acceleration

x	→	y
x_0	→	y_0
a	→	$-g$



$a = -g = -9.8 \text{ m/s}^2$

$$v = v_0 - g\,t$$

$$y - y_0 = v_0\,t - \frac{1}{2} g\,t^2$$

Basic equations

$$v^2 = v_0^2 - 2\,g\,(y - y_0)$$

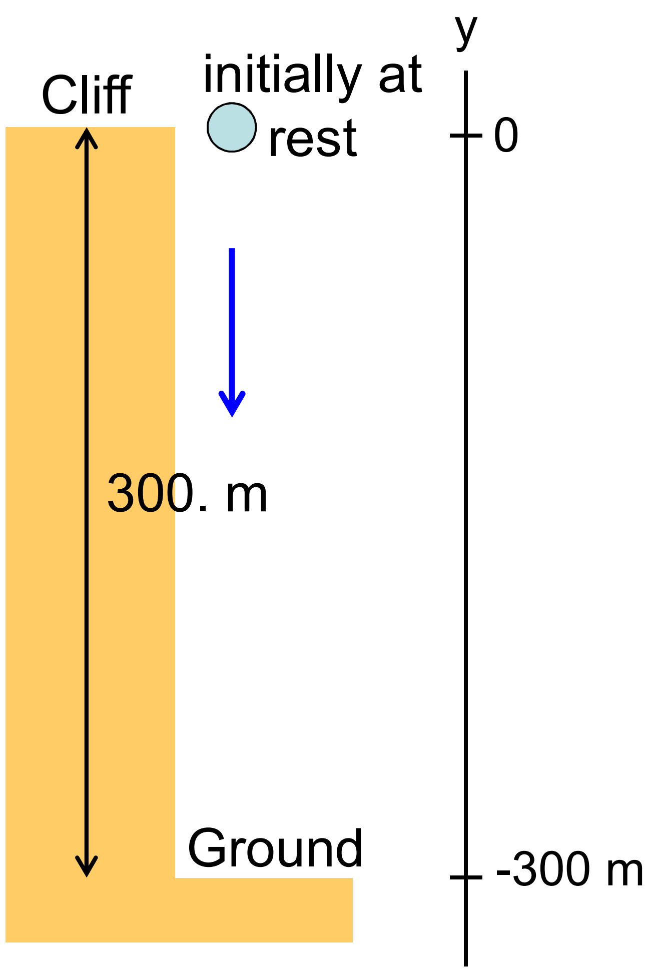
$$y - y_0 = \frac{1}{2}(v + v_0)\,t$$

$$y - y_0 = v\,t + \frac{1}{2} g\,t^2$$

$$v_{avg} = \frac{1}{2}(v + v_0)$$

Useful and can be derived from the two basic equations

3-6 Free-Fall Acceleration
Example



How long does the ball fall to reach the ground?

Solution

Since we know $y - y_0$ and v_0, we can use the following equation to find t

$$y - y_0 = v_0\, t - \frac{1}{2} g\, t^2$$

($y_0 = 0$, $v_0 = 0$)

Choose the origin of the y-axis at the cliff.

Initially at rest

$$y = -\frac{1}{2} g\, t^2$$

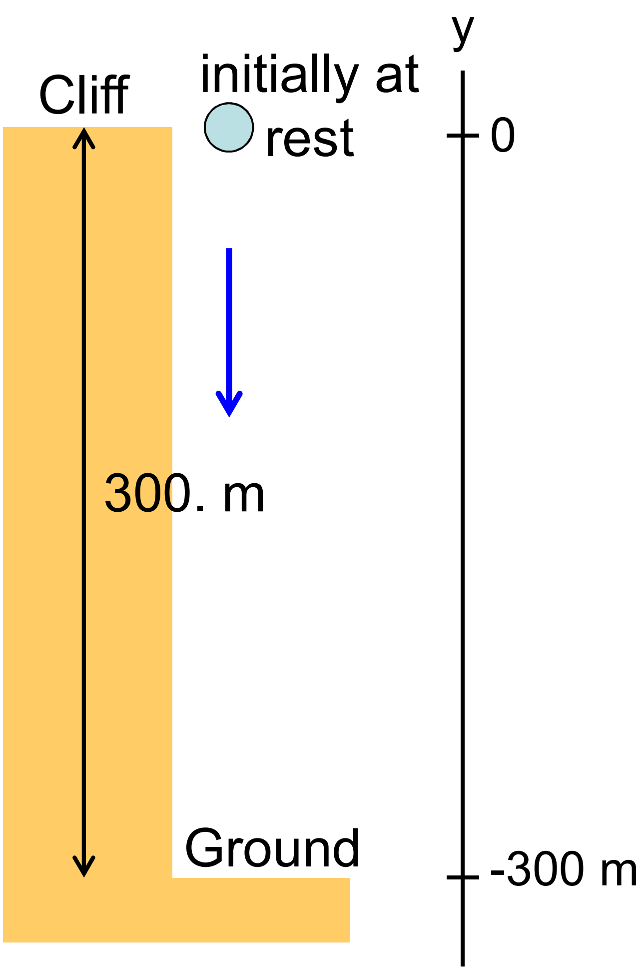
$$t^2 = -\frac{2\,y}{g}$$

$$t = \pm\sqrt{-\frac{2\,y}{g}} = \pm\sqrt{-\frac{2\,(-300\text{ m})}{9.80\text{ m/s}^2}} = \pm 7.82\text{ s}$$

Since the ball reaches the ground after t = 0, the negative answer is not valid.

$$t = 7.82\text{ s}$$

3-6 Free-Fall Acceleration
Example



What is the ball velocity when it hits the ground?

Solution

Since we know $y - y_0$ and v_0, we can use the following equation to find v

$$v^2 = v_0^2 - 2g(y - y_0)$$

with $v_0 = 0$ and $y_0 = 0$.

Choose the origin of the y-axis at the cliff.

Initially at rest

$$v^2 = -2gy$$

$$v = \pm\sqrt{-2gy} = \pm\sqrt{-2(-300\text{ m})(9.80\text{ m/s}^2)}$$

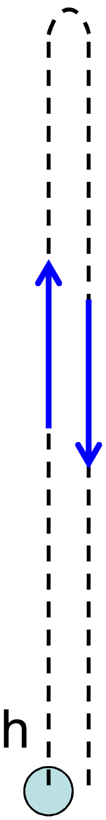
$$= \pm 76.7\text{ m/s}$$

Since the ball is moving in the negative direction, the positive answer is not valid.

$$v = -76.7\text{ m/s}$$

3-6 Free-Fall Acceleration

Example



Thrown up with initial velocity 15 m/s.

How long does the ball take to reach its maximum height?

Solution

Since we know v and v_0, we can use the following equation to find t

$$v = v_0 - g\,t$$

(v = 0)

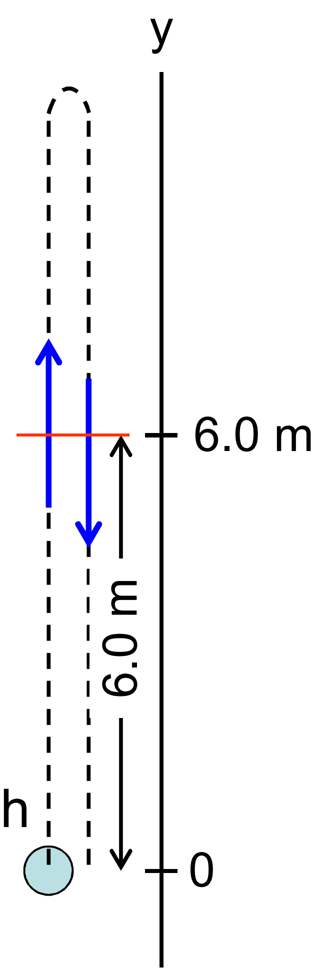
> At its maximum height, the ball is at rest → v = 0

$$0 = v_0 - g\,t$$

$$t = \frac{v_0}{g} = \frac{15\ \text{m/s}}{9.8\ \text{m/s}^2} = 1.5\ \text{s}$$

3-6 Free-Fall Acceleration

Example



Thrown up with initial velocity 15 m/s.

How long does the ball take to reach a point 6.0 m above its release point?

Solution

Since we know $y-y_0$ and v_0, we can use the following equation to find t

Choose the origin of the y-axis at the release point

$$y - y_0 = v_0 t - \frac{1}{2} g t^2 \quad (y_0 = 0)$$

$$y = v_0 t - \frac{1}{2} g t^2$$

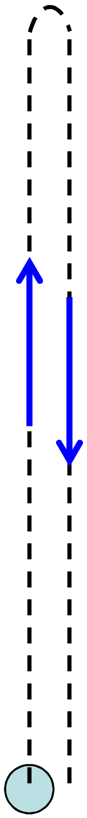
$$g t^2 - 2 v_0 t + 2 y = 0$$

$$t = \frac{2 v_0 \pm \sqrt{4 v_0^2 - 8 g y}}{2 g} = \frac{v_0 \pm \sqrt{v_0^2 - 2 g y}}{g}$$

$$= \frac{15 \text{ m/s} \pm \sqrt{(15 \text{ m/s})^2 - 2(9.8 \text{ m/s}^2)(6 \text{ m})}}{(9.8 \text{ m/s}^2)}$$

$$= \begin{cases} 0.47 \text{ s} & \text{The way up} \\ 2.6 \text{ s} & \text{The way down} \end{cases}$$

3-6 Free-Fall Acceleration
Checkpoint



What is the sign of the ball displacement for the ascent, from the release point to the highest point?

What is the sign of the ball displacement for the descent, from the highest point back to the release point?

What is the ball's acceleration at its highest point?

Solution

Positive

Negative

$a = -g = -9.8\ m/s^2$