Free-Falling Objects

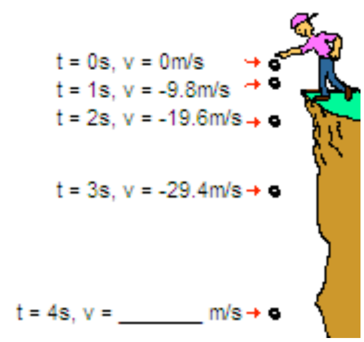
1. It is a well known fact that if you drop a feather and brick from the same height at the same time at the surface of the earth the brick will hit the ground first. However, in the absence of ______________________, like in outer space or in a vacuum, both the feather and the brick will hit the ground at the same time.

2. Free fall is…

3. All objects at the surface of the earth fall with a constant __________________ at the rate of ________ m/s^2. Gravity causes this acceleration which is directed towards the center of the earth. Therefore the variable ____ represents this constant acceleration.

4. We will call up the positive direction and down the negative direction. The acceleration due to gravity is (positive, negative). (Circle one)

5. Ramon drops a ball from the top of a cliff. What will the velocity of the ball be after 5 seconds? (Use the diagram to the right.)



Why are the velocities in the figure to the right negative?

6. Taylor tosses a tennis ball upward while serving.
a. While moving upward the ball will (move at a constant velocity, speed up, slow down).

b. At the highest point of the balls journey its velocity will be equal to _______.

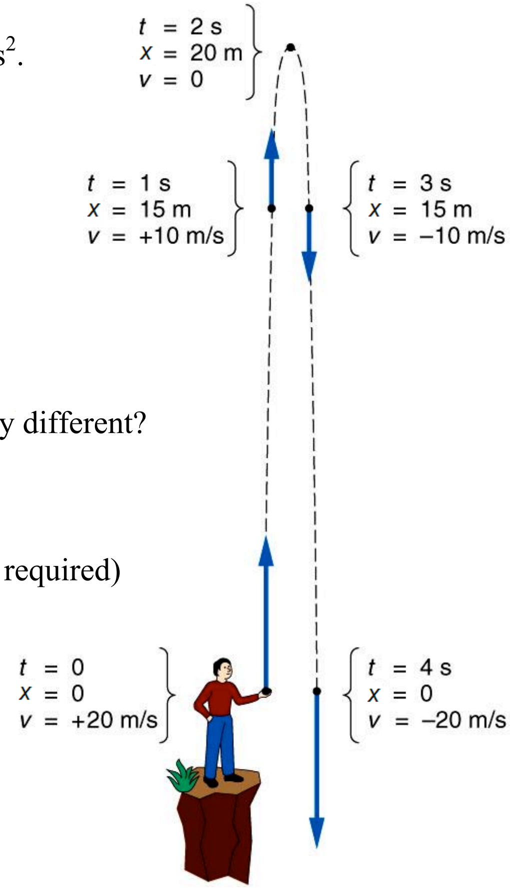
c. At the highest point of the balls journey its acceleration will be equal to _______.

d. While moving downward the ball will (move at a constant velocity, speed up, slow down).

7. Nick throws the ball upwards instead now with an initial velocity of +29.4m/s. What will the velocity of the ball be after 1s?

After 2s?

8. Look at the figure to the right to answer the following questions.



Note: the acceleration due to gravity, *g*, has been rounded to $-10 m/s^2$.

a. How long does it take the ball reach the highest point?

b. How long does it take the ball to fall from the highest point to the starting point?

c. Note the initial velocity of the ball. How is the final velocity different?

d. What is the acceleration of the ball after 2s? (no calculation required)

Conclusions for tossed objects:

1. The time it takes a tossed object to reach its highest point is equal to the time it takes the object to fall back to its starting point. (Ex: 2s up, 2s down)

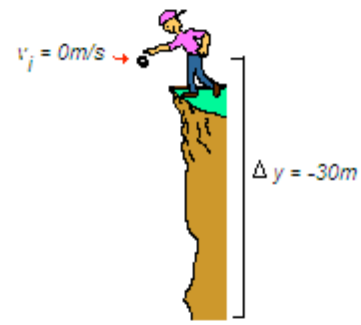
2. The initial velocity of an object is equivalent to the negative initial velocity when the object returns to the same starting position. (Ex: v = +20 m/s, v = -20m/s)

Using Kinematic Equations for Free Fall

Thus far we have used the kinematic equations for horizontal motion; however, they can also be used for vertical motion by replacing *x* (position for horizontal motion) with *y* (for vertical). The variable *g* will replace *a*.

Horizonal (Old)	Vertical (New)
$\Delta x = \frac{1}{2}(v_i + v_f)t$	$\Delta y = \frac{1}{2}(v_i + v_f)t$
$v_f = v_i + at$	$v_f = v_i + gt$
$\Delta x = v_i t + \frac{1}{2} a t^2$	$\Delta y = v_i t + \frac{1}{2} g t^2$
$v_f^2 = v_i^2 + 2a\Delta x$	$v_f^2 = v_i^2 + 2g\Delta y$

Example 1: Tim stands at the edge of a cliff that is 30m high and drops a penny. He wants to know how long it will take the penny to hit the water at the bottom of the cliff. Calculate this time. First draw a picture of the situation and label any givens. Do the calculation with your calculator to make sure you can do the calculation.



Givens:

$v_i = 0$ m/s (**any object dropped has an initial velocity of 0**)

$g = -9.8 m/s^2$ (this is a **given for ALL free fall problems** and it's always negative)

$\Delta y = -30m$ (the **height is negative** in this case because the ball moves downwards)

$\Delta t = ?$

$$\Delta y = v_i \Delta t + \frac{1}{2} g (\Delta t)^2$$

$$-30m = 0\,\Delta t + \frac{1}{2}(-9.8\ m/s^2)(\Delta t)^2$$

$$-30m = 0 + (-4.9\ m/s^2)(\Delta t)^2$$

The zero goes away so divide both sides by $-4.9\ m/s^2$.

$$6.12 = (\Delta t)^2$$

To undo the time squared take the square root of both sides.

$$\sqrt{6.12} = \Delta t$$

$$\boxed{2.47s = \Delta t}$$

Problem Solving

Directions: Your turn. Draw a picture for each problem and show all work.

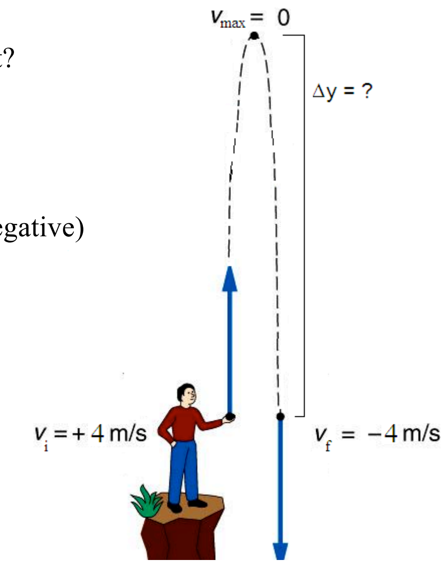
1. Kevin throws his calculator out of his living room window. The calculator has an initial velocity of -3m/s and the calculator takes 0.45s to hit the ground. (Remember: the acceleration due to gravity is a given in every problem even if it doesn't state it.)
   a. What will the final velocity of the calculator be right before it hits the ground? (Ans: -7.41m/s)
   b. How high is the window above the ground? (Ans: 2.34m)

2. Steve drops a stone into the water below.
   a. How high is the cliff if it takes 4.1 seconds to hit the water? (82.5m)
   b. What is the velocity of the stone when it hits the water? (-40.2 m/s)

3. Kendra is standing inside a vacuum chamber (there is no air inside). She drops a feather to see how long it will take to hit the ground. If she drops it from 2.5 m above the ground, then how long will it take? (0.71s)

Example 2: Tyler throws a baseball upwards with an initial velocity of 4m/s.

a. How long will it take the baseball to reach its maximum height? Draw the picture to the right and label known values.



Givens:

v_i = +4 m/s (it's positive because the ball moves up)

v_f = 0 (because the velocity at the maximum height is ALWAYS zero)

$g = -9.8 m/s^2$ (this is a given for ALL free fall problems and it's always negative)

Δt = ?

$v_f = v_i + g\Delta t$

$0 = 4m/s + (-9.8m/s^2)\ \Delta t$

Subtract 4m/s.

$-4m/s = (-9.8m/s^2)\ \Delta t$

Divide by $-9.8m/s^2$.

$0.41s = \Delta t$

b. What is the maximum height reached by the baseball?

Δy = ?

$\Delta y = \frac{1}{2}(v_i + v_f)\ \Delta t$

$\Delta y = \frac{1}{2}(4m/s + 0)\ (0.41s)$

$\Delta y = 0.82$ m

c. What is the total time that the ball is in the air?

Solution: Multiply the time for the first part by 2.

$\Delta t = 0.41s * 2$

$\Delta t = 0.82s$ (It is only coincidental that this equals the displacement.)

d. What is the velocity of the ball when it returns to its starting point?

Solution: Same as the initial velocity but in the negative direction.

$v_f = -4m/s$

PRACTICE:

1. Brent throws a football upward with an initial velocity of 20 m/s. (Refer to Example 2)
   a. How long will it take the football to reach its maximum height? (Ans: 2.04s)
   b. What is the maximum height reached by the baseball? (Ans: 20.4m)
   c. What is the total time the ball is in the air? (Ans: 4.08s)
   d. What will the velocity of the ball be when it returns to Brent's hands.

2. Acacia tosses a softball upward. The ball reaches a height of 6.5 m.

a. What will the velocity of the ball be when it strikes the ground? (-11.3 m/s)

b. What was velocity of the ball when it left her hand?

c. How long is the ball in the air? (2.3 s)