THE ACCELERATION OF GRAVITY

Free-falling object is an object that is falling under the sole influence of gravity. A free-falling object has an acceleration of 9.8 m/s/s, downward (on Earth). This numerical value for the acceleration of a free-falling object is such an important value that it is given a special name. It is known as the **acceleration of gravity** - the acceleration for any object moving under the sole influence of gravity. A matter of fact, this quantity known as the acceleration of gravity is such an important quantity that physicists have a special symbol to denote it - the symbol **g**. The numerical value for the acceleration of gravity is most accurately known as 9.8 m/s/s. There are slight variations in this numerical value that are dependent primarily upon on altitude. We will occasionally use the approximated value of 10 m/s/s. By so doing, we will be able to better focus on the conceptual nature of physics without too much of a sacrifice in numerical accuracy.

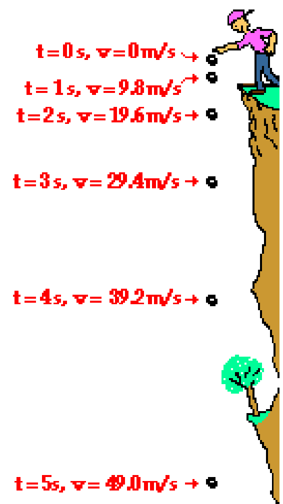
g = 9.8 m/s/s, downward (~ 10 m/s/s, downward)

Recall from an earlier lesson that acceleration is the rate at which an object changes its velocity. It is the ratio of velocity change to time between any two points in an object's path. To accelerate at 9.8 m/s/s means to change the velocity by 9.8 m/s each second.

$$a = \frac{\Delta v}{t} = \frac{-9.8 \text{ m/s}}{1 \text{ s}}$$

If the velocity and time for a free-falling object being dropped from a position of rest were tabulated, then one would note the following pattern.

Time (s)	Velocity (m/s)
0	0
1	- 9.8
2	- 19.6
3	- 29.4
4	- 39.2
5	- 49.0

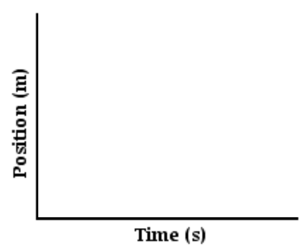


Observe that the velocity-time data above reveal that the object's velocity is changing by 9.8 m/s each consecutive second. That is, the free-falling object has an acceleration of approximately 9.8 m/s/s.

Another way to represent this acceleration of 9.8 m/s/s is to add numbers to our dot diagram that we saw earlier in this lesson. The velocity of the ball is seen to increase as depicted in the diagram at the right. (NOTE: The diagram is not drawn to scale - in two seconds, the object would drop considerably further than the distance from shoulder to toes.)

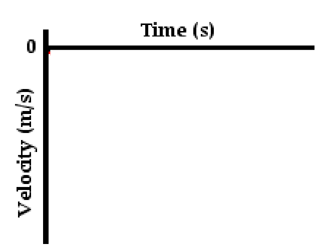
1. How would the graph of position vs. time look for a free falling object?

    a. What does the slope represent?



2. How would the graph of velocity vs. time look for a free falling object?

    a. What does the slope represent?



Free-falling objects are in a state of acceleration. Specifically, they are accelerating at a rate of 9.8 m/s/s. This is to say that the velocity of a free-falling object is changing by 9.8 m/s every second. If dropped from a position of rest, the object will be traveling 9.8 m/s (approximately 10 m/s) at the end of the first second, 19.6 m/s (approximately 20 m/s) at the end of the second second, 29.4 m/s (approximately 30 m/s) at the end of the third second, etc. Thus, the velocity of a free-falling object that has been dropped from a position of rest is dependent upon the time that it has fallen. The formula for determining the velocity of a falling object after a time of **t** seconds is

$$v_f = g \times t \qquad v_f = v_i + g \times t$$

(dropped from rest)

g is the acceleration of gravity. The value for g on Earth is 9.8 m/s/s. The above equation can be used to calculate the final velocity of the object after any given amount of time when dropped from rest.

The distance that a free-falling object has fallen from a position of rest is also dependent upon the time of fall. This distance can be computed by use of a formula; the distance fallen after a time of **t** seconds is given by the formula.

$$d = 0.5 * g * t^2$$

(dropped from rest)

<u>Applying Free Fall Concepts to Problem-Solving</u>

There are a few conceptual characteristics of free fall motion that will be of value when using the equations to analyze free fall motion. These concepts are described as follows:

- An object in free fall experiences an acceleration of -9.8 m/s/s. (The - sign indicates a downward acceleration.) Whether explicitly stated or not, the value of the acceleration in the kinematic equations is -9.8 m/s/s for any freely falling object.
- If an object is merely dropped (as opposed to being thrown) from an elevated height, then the initial velocity of the object is 0 m/s.
- If an object is projected upwards in a perfectly vertical direction, then it will slow down as it rises upward. The instant at which it reaches the peak of its trajectory, its velocity is 0 m/s. This value can be used as one of the motion parameters in the kinematic equations; for example, the final velocity (v_f) after traveling to the peak would be assigned a value of 0 m/s.
- If an object is projected upwards in a perfectly vertical direction, then the velocity at which it is projected is equal in magnitude and opposite in sign to the velocity that it has when it returns to the same height. That is, a ball projected vertically with an upward velocity of +30 m/s will have a downward velocity of -30 m/s when it returns to the same height.

Check Your Understanding

3. Upton Chuck is riding the Giant Drop at Great America. If Upton free falls for 2.60 seconds, what will be his final velocity and how far will he fall?

4. If Michael Jordan has a vertical leap of 1.29 m, then what is his takeoff speed and his hang time (total time to move upwards to the peak and then return to the ground)?

5. A baseball is popped straight up into the air and has a hang-time of 6.25 s. Determine the height to which the ball rises before it reaches its peak. (Hint: the time to rise to the peak is one-half the total hang-time.)

    a. Calculate its final velocity

    b. Draw a velocity vs. time graph