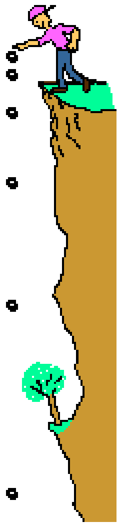
Name:________________________________

Group:______________________________

Freefall

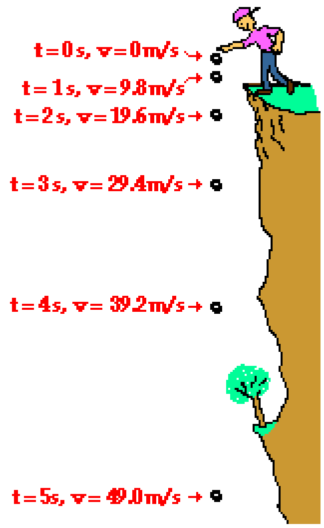
Freefall

A free falling object is an object that is falling under the sole influence of gravity. Any object that is being acted upon only by the force of gravity is said to be in a state of free fall.



There are **two** important motion characteristics that are true of free-falling objects:

- Free-falling objects do not encounter air resistance.
- All free-falling objects (on Earth) accelerate downwards at a rate of 9.8 m/s/s (often approximated at 10 m/s/s for calculations)



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

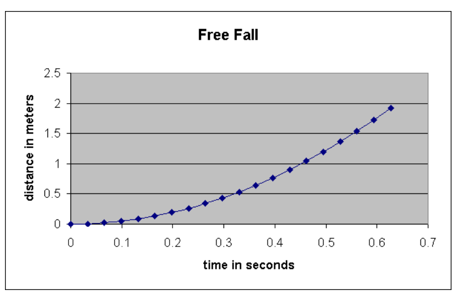
A free-falling object has an acceleration of 9.8 m/s/s, downward (on Earth). This numerical value for the acceleration of a free-falling object is such an important value that it is given a special name. It is known as the **acceleration of gravity** - the acceleration for any object moving under the sole influence of gravity. The acceleration of gravity is such an important quantity that physicists have a special symbol to denote it - the symbol **g**.

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.

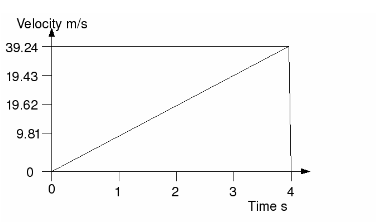
Representing Freefall in Graphs

Observe that the line on the graph curves. As learned earlier, a curved line on a position versus time graph signifies an accelerated motion. Since a free-falling object is undergoing an acceleration (g = 9.8 m/s/s), it would be expected that its position-time graph would be curved. A further look at the position-time graph reveals that the object starts with a small velocity (slow) and finishes with a large velocity (fast). Since the slope of any position vs. time graph is the velocity of the object ,the small initial slope indicates a small initial velocity and the large final slope indicates a large final velocity.

A position versus time graph for a free-falling object is shown to the right.



A velocity versus time graph for a free-falling object is shown below.



Observe that the line on the graph is a straight, diagonal line. As learned earlier, a diagonal line on a velocity versus time graph signifies an accelerated motion. Since a free-falling object is undergoing an acceleration (g = 9,8 m/s/s, downward), it would be expected that its velocity-time graph would be diagonal. A further look at the velocity-time graph reveals that the object starts with a zero velocity (as read from the graph) and finishes with a large velocity.

Falling with Air Resistance

As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. The actual amount of air resistance encountered by the object is dependent upon a variety of factors. To keep the topic simple, it can be said that the two most common factors that have a direct affect upon the amount of air resistance are the:

1) speed of the object and the
2) cross-sectional area of the object.

Increased speeds result in an increased amount of air resistance.

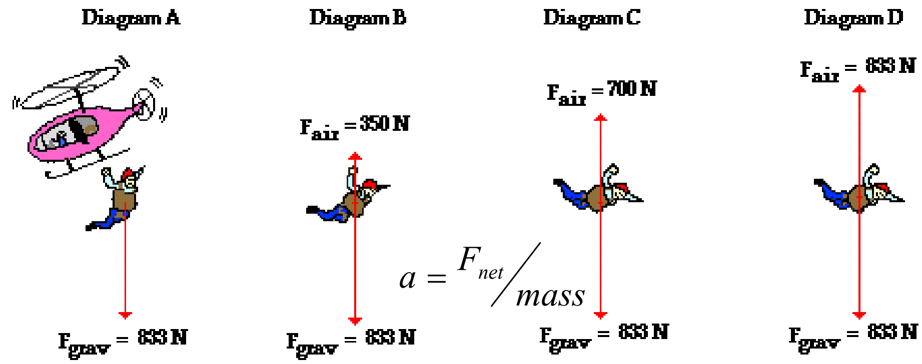
Increased cross-sectional areas result in an increased amount of air resistance.

Terminal Velocity

The fastest something can move because of the resistance it encounters.

Why does an object that encounters air resistance eventually reach a terminal velocity? To answer this questions, Newton's second law will be applied to the motion of a falling skydiver.

In the diagrams to the right, free-body diagrams showing the forces acting upon an 85-kg skydiver (equipment included) are shown. For each case, use the diagrams to determine the net force and acceleration of the skydiver at each instant in time.



$$a = F_{net}/mass$$

$$a = \frac{-833N}{85kg} = -9.8m/s^2$$

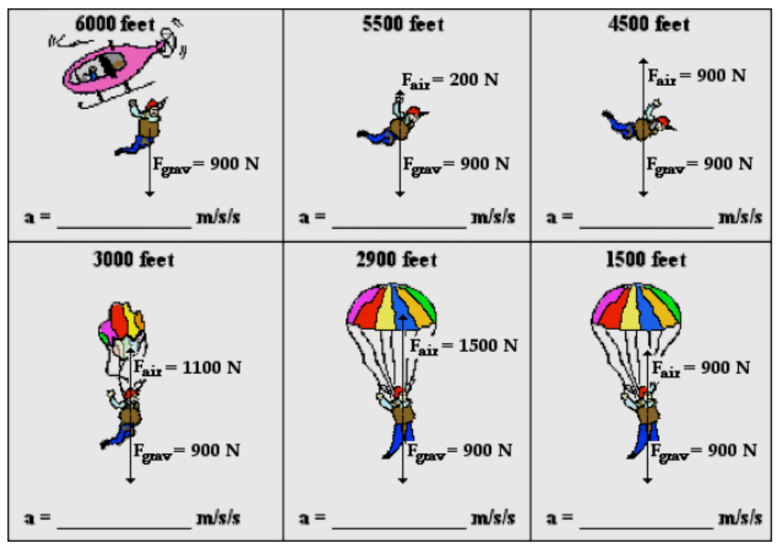
$$a = \frac{-833N + 350N}{85kg} = -5.7m/s^2$$

$$a = \frac{-833N + 700N}{85kg} = -1.6m/s^2$$

$$a = \frac{-833N + 833N}{85kg} = 0m/s^2$$

The diagrams illustrate a key principle. As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating. The object is said to have reached a **terminal velocity**. The change in velocity terminates as a result of the balance of forces. The velocity at which this happens is called the terminal velocity.

A 90-kg (approx.) skydiver jumps out of a helicopter at 6000 feet above the ground.
As he descends, the force of air resistance acting upon him continually changes.
For each diagram, apply Newton's second law (Fnet = m•a) to determine the acceleration value.



1. At which two altitudes has the skydiver reached terminal velocity?

2. At which altitude(s) is the skydiver in the state of speeding up?

3. At which altitude(s) is the skydiver in the state of slowing down?

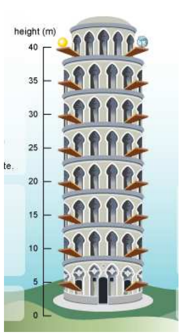
4. At 2900 feet, the skydiver is ___________. Choose two.
a. moving upward b. moving downward c. speeding up d. slowing down

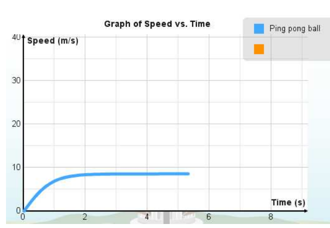
5. Explain why air resistance increases from 6000 feet to 4500 feet.

6. Explain why air resistance decreases from 3000 feet to 1500 feet.

Galileo dropped a ping pong ball and a golf ball off of the Tower of Pisa. Each of the balls have parachutes that can be deployed at any time.

Using your knowledge of freefall and graphs, answer the following questions.



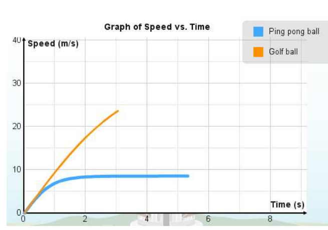


The Ping pong ball, only, was dropped.

1. What is the ball's terminal velocity?

The Ping pong ball, only, was dropped.

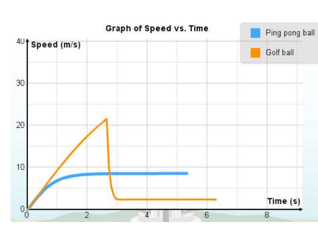
2. By inferring from the graph, what happened to the ping pong ball to change it's terminal velocity?



The Ping pong ball, and golf ball were both dropped.

3. Which has the greater terminal velocity?

4. Why



The Ping pong ball, and golf ball were both dropped.

5. By making inferences from the graph, what happened to the two balls after they were dropped?