Section 4: Free- Fall and Acceleration Due to Gravity

- **These notes are adapted from GBS Physics Homepage.**
- http://www.physicsclassroom.com/Class/index.cfm

Introduction to Free Fall

A free falling object is an object that is falling under the sole influence of gravity. Any object that is being acted upon only be 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 or 9.8 m/s^2

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 Big Misconception

The acceleration of a **free-falling object** on earth is the same for all free-falling objects regardless of how long they have been falling, or whether they were initially dropped from rest or thrown up into the air.

Yet such questions are often asked:

1. "Doesn't a more massive object accelerate at a greater rate than a less massive object?"
2. "Wouldn't an elephant free-fall faster than a mouse?"

These questions are reasonable and are probably based upon our personal observations of falling objects in the physical world. After all, nearly everyone has observed the difference in the rate of fall of a single piece of paper (or similar object) and a textbook. The two objects clearly travel to the ground at different rates - with the more massive book falling faster.

But, the answer to the question (doesn't a more massive object accelerate at a greater rate than a less massive object?) is absolutely not! That is, absolutely not if we are considering the specific type of falling motion known as free-fall.

Free-fall is the motion of objects that move under the sole influence of gravity; <u>**free-falling objects do not encounter air resistance**</u>. **More massive objects will only fall faster if there is an appreciable amount of air resistance present.**

Consider a skydiver. As he falls, he encounters the force of air resistance. The amount of air resistance acting on him is dependent upon two variables:

- His speed

As a skydiver falls, he accelerates downwards, gaining speed with each second. The increase in speed is accompanied by an increase in air resistance (as observed in the animation below). This force of air resistance counters the force of gravity. As the skydiver falls faster and faster, the amount of air resistance increases more and more until it approaches the magnitude of the force of gravity. Once the force of air resistance is as large as the force of gravity, a balance of forces is attained and **the skydiver no longer accelerates**. **The skydiver is said to have reached a terminal velocity.**

- His cross-sectional area

A skydiver in the spread eagle position encounters more air resistance than a skydiver who assumes the tuck position or who falls feet (or head) first. The greater cross-sectional area of a skydiver in the spread eagle position leads to a greater air resistance and a tendency to reach a slower terminal velocity. The importance of cross-sectional area to skydiving is also demonstrated by the use of a parachute. An open parachute increases the cross-sectional area of the falling skydiver and thus increases the amount of air resistance which he encounters. Once the parachute is opened, the air resistance overwhelms the downward force of gravity. The net force and the acceleration on the falling skydiver is upward. An upward net force on a downward falling object would cause that object to slow down. The skydiver thus slows down. As the speed decreases, the amount of air resistance also decreases until once more the skydiver reaches a terminal velocity.

So, in situations where air resistance is negligible, an object will fall with an acceleration of -9.8 m/s^2. Whether an object is dropped, thrown up in the air or thrown down, it will still experience an acceleration of -9.8 m/s^2.