Honors Freshman Physics **Newton's Laws of Motion, and non-freefall**

Galileo used inclined planes to determine the acceleration of falling objects and developed the concept that, without friction, a moving object on a flat plane would continue in a straight line forever at the same velocity -- Galileo called this "tendency" of matter **inertia**.

Inertia is a property of matter, the tendency of an object to remain in its current state of motion; the resistance of an object to a change in its velocity.

The amount of inertia an object has depends on how much matter it has, or its **mass**. Mass is simply a measure of how resistant on object is to changing its state of motion. Mass is also defined as the amount of matter in an object.

Galileo recognized that the reason a rolling cannonball eventually came to rest was due to a resistive **force** - **friction**. Since friction was always present in daily life it had been overlooked in previous explanations of motion.

Isaac Newton developed three laws of motion based on the overcoming of an object's inertia. In his **first law of motion** he states:

> Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

A force is simply a push or a pull. According to Newton's Law of Universal Gravitation, the force of **gravity** is the pull due to an object's mass and its **distance** from another mass. Near the earth's surface gravity accelerates the mass of an object at a rate of - 9.8 m/s^2 (which we call ***g***) towards the earth. The force called **weight** is the effect of gravity on an object's mass.

If there is no acceleration then the net force must be zero (balanced forces), this can happen if an object is (a) not moving, **static equilibrium**, or (b) moving at a constant velocity, **dynamic equilibrium**.

As you sit in your seat you have a net force of zero acting on you. If gravity is pulling down on you there must be a balancing force pushing back up on you, thereby resulting in no acceleration.

When you push a chair across the room at a constant velocity the chair slides over the floor. There is an opposing force of friction that must be balanced by your pushing force.

Friction is defined as the opposing force that results when surfaces slide or tend to slide past one another. This includes solids, liquids, and gases. Static friction is greater than sliding friction. For solids the speed and surface area have no effect on the friction, but in fluids friction is effected by **speed** and **surface area**. This is due to the total amount of fluid pushed aside by the object. Sort of like trying to walk through the hallways between classes, the faster you go the more people you encounter in a given time (more opposition) and the smaller you are the easier it is to avoid people (less opposition).

Newton's second law of motion relates the acceleration of an object to the "impressed force:"

> The alteration of motion is ever proportional to the motive force impressed: and is made in the direction of the right line in which that force is impressed[,and is inversely proportional to the mass of the object].

Write the equation you "discovered" during the lab.

With this in mind a force can also be defined as anything that can accelerate an object.

The force mentioned in the second law refers to a **net force**. A net force is the overall result of all forces that may be acting on an object.

This provides an explanation for why it is harder to push a heavy object than a light object.

Newton's third law of motion is probably the best recognized and the least understood:

> To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

The forces involved here are often referred to as action and reaction where the reaction does not exist without the action.

The misunderstanding of this law lies in the fact that the action force and the reaction force are acting on different objects, and therefore are not balancing forces that result in no acceleration.

This is why a rocket can accelerate in empty space.

Freefall is the situation when the only force (and net force) acting on an object is that of gravity, this is when the frictional forces in the atmosphere are negligible.

One of Galileo's observations was that during freefall the acceleration on any object is a constant value ***g***, regardless of the object's mass. This is easily proved with the help of Newton's second law of motion and the fact that the weight of an object is the force required to accelerate an object at ***g*.** If you were to find the weight of a 10 kg brick and the weight of a 20 kg brick you would find their respective weights to be related by a factor of two also. Plug this information into Newton's second law and solve for $\mathbf{a}_{10}$ and $\mathbf{a}_{20}$.

Basically the 20 kg brick has twice the inertia of the 10 kg brick and therefore requires twice the force, and always resulting in the same acceleration because of the equal ratios of force to mass. When observing differing mass objects in the classroom it is almost impossible to detect the effect of air resistance, but it is still there. The presence of the air resistance causes a lower net force pulling down on an object, but this net force is not constant.

This real life condition is known as **non-freefall.**

Recall that the size of the fluid friction force depends on surface area and velocity. The surface area can be changed, but does not always. However, the velocity is always changing when there is a net force, and as the velocity increases the force of air resistance increases. As a result the net force pulling down on the object becomes less until it equals zero, resulting in no acceleration and a **terminal velocity** for the remainder of the fall. As a rule, if two objects are dropped at the same time in a non-freefall situation, the first one to reach its terminal velocity will reach the ground last.