Lecture 5.

1. **Acceleration**

When an object's velocity changes, it accelerates. Acceleration shows the change in velocity in a unit time.

$$a = \frac{V_f - V_i}{t}$$

Velocity is measured in meters per second, m/s, so acceleration is measured in (m/s)/s, or m/s^2, which can be both positive and negative. A very interesting case - free fall acceleration or gravitational acceleration. A free-falling object is an object which is falling under the sole influence of gravity; such an object has an acceleration on Earth of 9.8 m/ s^2, downward. This numerical value for the acceleration of a free-falling object is such an important value that it has been given a special name. It is known as the **acceleration of gravity** – the acceleration for any object moving under the sole influence of gravity. As 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**.

$$g = 9.8 m / s^2$$

This value (known as the acceleration of gravity) 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 the question is often asked "Doesn't a massive object accelerate at a greater rate than a less massive object?" This question is a reasonable inquiry that is probably based upon personal observations made of falling objects in the physical world. After all, nearly everyone has observed the difference in 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 massive book falling faster.

The answer to the question (Doesn't a massive object accelerate at a greater rate than a less massive object?) is . . . absolutely not! That is, absolutely not, if you are considering the specific type of falling motion known as free-fall. Free-fall is the motion of objects under the sole influence of gravity; free-falling objects do not encounter air resistance. Massive objects will only fall faster than less massive objects if there is an appreciable amount of air resistance present.

2. Newton’s Laws

I. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

Newton's First Law states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force. It may be seen as a statement about inertia, that objects will remain in their state of motion unless a force acts to change the motion. Any change in motion involves an acceleration, and then Newton's Second Law applies; in fact, the First Law is just a special case of the Second Law for which the net external force is zero.

Newton's First Law contains implications about the fundamental symmetry of the universe in that a state of motion in a straight line must be just as "natural" as being at rest. If an object is at rest in one frame of reference, it will appear to be moving in a straight line to an observer in a reference frame which is moving by the object. There is no way to say which reference frame is "special", so all constant velocity reference frames must be equivalent.

II. The relationship between an object's mass *m*, its acceleration a, and the applied force *F* is *F* = *ma*. Acceleration and force are vectors (as indicated by their symbols being displayed in slant bold font); in this law the direction of the force vector is the same as the direction of the acceleration vector.

Newton's Second Law as stated below applies to a wide range of physical phenomena. It is applicable only if the force is the net external force. It does not apply directly to situations where the mass is changing, either from loss or gain of material, or because the object is traveling close to the speed of light where relativistic effects must be included. It does not apply directly on the very small scale of the atom where quantum mechanics must be used.

III. For every action there is an equal and opposite reaction.

All forces in the universe occur in equal but oppositely directed pairs. There are no isolated forces; for every external force that acts on an object there is a force of equal magnitude but opposite direction which acts back on the object which exerted that external force. In the case of internal forces, a force on one part of a system will be countered by a reaction force on another part of the system so that an isolated system cannot by any means exert a net force on the system as a whole. A system cannot "bootstrap" itself into motion with purely internal forces - to achieve a net force and acceleration, it must interact with an object external to itself. Newton's third law is one of the fundamental symmetry principles of the universe. Since we have no examples of it being violated in nature, it is a useful tool for analyzing situations which are somewhat counter-intuitive. For example, when a small truck collides head-on with a large truck, your intuition might tell you that the force on the small truck is larger. Not so!