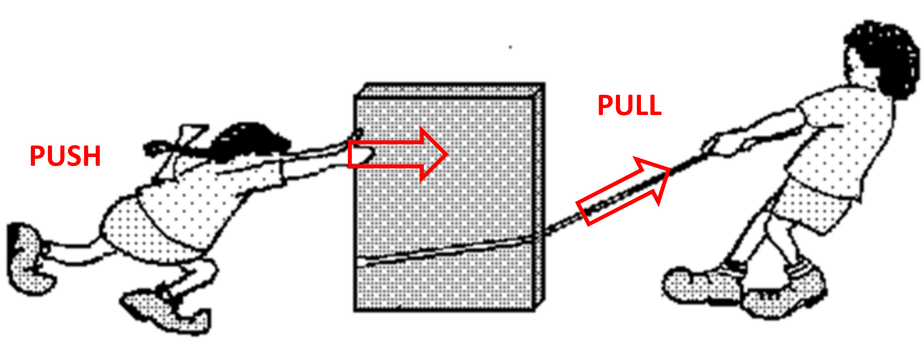
PHYS:1200 LECTURE 6 – MECHANICS (5)

In the previous lectures, we discussed the concept of acceleration (rate of change of velocity with time) and how, if the acceleration is known, it can be used to determine the future location and velocity of an object. We considered one case in particular- the acceleration of gravity that is produced by the gravitational attraction on the object by the earth. In this lecture we will discuss the general problem of how to determine the acceleration of an object. This is the subject called **dynamics.** We have also talked about the fact that accelerations are produced by forces acting on an object. Now we will discover how to analyze the forces acting on an object and how to calculate its acceleration. **The principle that relates forces and accelerations is Newton's Second Law of Motion**. Recall that Newton's First Law is simply Galileo's principle of inertia. We will find that the 2nd law actually incorporates the 1st law. In this lecture we will introduce the concept of **FORCE**, and in particular **NET FORCE.**

6-1. Forces.—The simplest type of force occurs when an object is pushed or pulled – these are examples of what we call **contact forces** which means that the agent exerting the force is actually touching the object that it is acting on. Another common example of a contact force is friction that occurs between an object and the surface on which it slides. Now it is possible, and typical, that more than one force might act on an object at the same time and these forces might act in different directions. For example, suppose two people are moving a large crate across the floor. One person pushes from behind and the other person pulls on a cord attached to the front of the object as shown below.



The red arrows represent the forces applied to the crate. The force exerted by the person on the left is in a direction to push the object to the right. The force applied by the person on the right is more complicated because it is applied at an angle so only part of this force acts to pull the object to the right. This example illustrates the fact that **not only is the strength of the force important but the direction** in which it is applied must also be taken into account. Force is a type of quantity that we call a **VECTOR—a quantity having both magnitude (strength) and direction.** In terms of the motion of an object what is important is what we call the **NET FORCE. The net force is a force quantity that takes into account both direction and strength of all the forces acting on an object.**

6-2. Newton's Second Law.—In simplest terms the 2nd law says that a force must be applied to an object to *change* its velocity. The rate of change of velocity with time is the acceleration. Now we are all aware of the concept of acceleration as it applies to say driving on a straight road. When you accelerate you increase the velocity of the car. When you apply the brakes, you decrease the velocity of the car. However, the direction of the change in velocity is also important – **velocity is a vector quantity**. When you make a turn, the direction of your velocity is changing even if you maintain the same speed while you are turning**. Any change in velocity either magnitude (speed) or direction means that the object is accelerating and according to Newton's 2nd law a net force is required to do this.**

The next question is exactly how much force is required to produce a certain acceleration of an object? **The amount of force necessary to produce a certain amount of acceleration of an object depends on the mass (inertia) of the object – the more massive the object is, the more force it takes to produce that acceleration.** This makes common sense—more force is needed to move a big object than a small object.

The quantitative statement of **Newton's 2nd law** is that the net force exerted on an object equals its mass multiplied by its acceleration:

Newton's Second Law $$F_{NET} = m\,a \qquad [1]$$

In equation [1], F is expressed in Newtons (N), m in kilograms (kg) and a in m/s^2.

There are other forms of Newton's 2^{nd} law that may be useful. For example, suppose the mass of an object is known as well as the magnitude of the net force acting on it. Then according to equation [1] its acceleration will be

Acceleration given the net force and mass: $$a = \frac{F_{NET}}{m} \quad [2]$$

An example of the application of equation [1] is given on slides **21 and 22.**

Example 6.1: A force F = 100 N is applied to move a box of mass m = 200 kg. A friction force f = 20 N opposes the motion. (a) What is the acceleration of the box? (b) What is the velocity of the box at t = 12 s?

Solution- (a) Net force = F_{NET} = 100 N – 20 N = 80 N, a = F_{NET}/m = 80 N/ 200 kg = 0.4 m/s^2

(b) v = a t = 0.4 m/s^2 x 12 s = 4.8 m/s

6-3. Mass and Weight.—We are now in a position to reconsider the acceleration of an object under free fall (gravity) and to show that Galileo's conclusion that the acceleration of a falling object is g, independent of its mass. Recall that the weight of an object of mass m (the gravitational pull of the earth on it) is W = m g. This formula is due to **Newton's universal law of gravitation**. Now let us combine W = m g with Newton's 2^{nd} law:

$$W = \cancel{m}\, g = \cancel{m}\, a \;\; \Rightarrow \;\; a = g \quad [3]$$

Therefore, **the acceleration of an object under gravity is exactly g**, the masses cancelled out, so all objects, **regardless of mass**, fall to earth with an acceleration g ≈ 10 m/s^2 (≈ means approximately equal to); Galileo was right!

Example 6.2: (a) What is the mass of an object that weighs 1000 N on Earth?

(b) What is the weight of this object on the moon where g_M = 1.6 m/s^2?

Solution-- (a) m = w_E/g = 1000 N/ (10 m/s^2) = 100 kg

(b) w_M = m g_M = 100 kg x 1.6 m/s^2 = 160 N.