

# GRAVITATION

## INTRODUCTION

- an object dropped from a height falls towards the earth.
- All the planets go around the Sun.
- The moon goes around the earth.

In all these cases, there must be some force acting on.

**Isaac Newton** could grasp that the same force is responsible for all these. This force is called the **gravitational force**.

## OUTLINE

- Gravitation
- Universal Law of Gravitation
- Motion under gravity
  - + Acceleration due to gravity
- Difference between mass and weight
- Thrust and Pressure
- Pressure in fluid
  - + Buoyancy
  - + Archimedes' Principle
  - + Density and Flotation

## GRAVITATION :-

\* The motion of the moon around the earth is due to the centripetal force. The **centripetal force** is provided by the force of attraction of the earth. If there were no such force, the moon would pursue a uniform straight line motion.

\* Newton concluded that not only does the earth attract an apple and the moon, but all objects in the universe attract each other. This force of attraction between objects is called the gravitational force.

## UNIVERSAL LAW OF GRAVITATION:-

Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. The force is along the line joining the centres of two objects.

$$F \propto M \times m \text{ ----- (i)}$$

$$F \propto 1/d^2 \text{ ----- (ii)}$$

Combining (i) and (ii)

$$F \propto M \times m / d^2$$

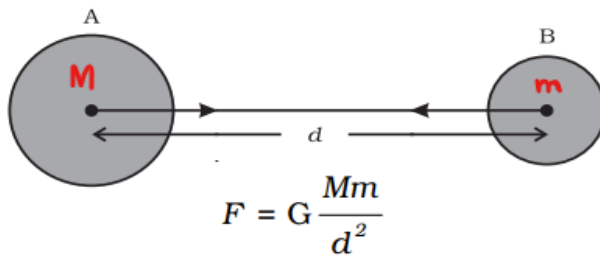
$$F = G (M \times m / d^2)$$

where G is the constant of proportionality and is called the universal gravitation constant.

-The SI unit of G is  $N m^2 kg^{-2}$

-The value of G was found out by Henry Cavendish by using a sensitive balance.

-The accepted value of G is  $6.673 \times 10^{-11} N m^2 kg^{-2}$  .



*The gravitational force between two uniform objects is directed along the line joining their centres.*

### **FREE FALL:-**

Whenever objects fall towards the earth under gravitational force alone, we say that the objects are in free fall.

Acceleration due to the earth's gravitational force is called the acceleration due to gravity.

-It is denoted by g.

-The unit of g is the same as that of acceleration, that is,  $m\ s^{-2}$ .

Since  $F = m\ g = G (M \times m / d^2)$

So,

$$g = GM/d^2$$

By putting the values of

$G = 6.7 \times 10^{-11}\ N\ m^2\ kg^{-2}$ ,

mass of the earth,  $M = 6 \times 10^{24}\ kg$ , and

radius of the earth,  $R = 6.4 \times 10^6\ m$ .

The value of g on earth is  $9.8\ m/s^{-2}$

(The earth is not a perfect sphere. As the radius of the earth increases from the poles to the equator, the value of g becomes greater at the poles than at the equator.)

All objects hollow or solid, big or small, will fall from a height at the same rate as g is independent of the mass of an object.

According to a story, Galileo dropped different objects from the top of the Leaning Tower of Pisa in Italy to prove the same.

As g is constant near the earth, all the equations for the uniformly accelerated motion of objects become valid with acceleration a replaced by g and displacement s by height h-

$$v = u + gt$$

$$h = ut + \frac{1}{2} gt^2$$

$$v^2 - u^2 = 2gh$$



### **MASS :-**

- the mass of an object is the measure of its inertia.
- it is the amount of matter present inside an object.
- it is constant and does not change from place to place.

### **WEIGHT:-**

The force of attraction of the earth on an object is known as the weight of the object.

$$W = m \times g$$

- SI unit of weight is newton (N).
- weight depends on its location.

\* Weight of an object on the moon =  $(1/6) \times$  its weight on the earth

### **THRUST AND PRESSURE :-**

- The force acting on an object perpendicular to the surface is called thrust.
- The thrust on unit area is called pressure.
- SI unit of pressure as  $N/m^2$  or  $N\ m^{-2}$  also called pascal, denoted as Pa.

### **PRESSURE IN FLUIDS :-**

- fluids have weight, so they also exert pressure on the base and walls of the container in which they are enclosed.
- **Pascals' Law** - Pressure exerted in any confined mass of fluid is transmitted undiminished in all directions.

### **BUOYANCY:-**

When an object is immersed completely or partially in a liquid/fluid an upward force is experienced by that object which is called Buoyancy.

- When gravitational pull is greater than upthrust buoyancy force it **sinks** other wise it **floats**.
- The magnitude of this buoyant force depends on the density of the fluid.
- The density of a substance is defined as the mass per unit volume. The unit of density is kilogram per metre cube ( $kg\ m^{-3}$ ).
- Objects of density less than that of a liquid **float** on the liquid. The objects of density greater than that of a liquid **sink** in the liquid.

### **Archimedes' Principle:-**

When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

### **Relative Density:-**

It is often convenient to express density of a substance in comparison with that of water. The relative density of a substance is the ratio of its density to that of water:

$$\text{Relative density} = \text{Density of a substance} / \text{Density of water}$$