GRAVITATION

Universal Law of Gravitation

According to Newton's universal law of gravitation, **every object in the universe attracts every other object with a force, which is**

(i) Directly proportional to the product of the masses of the objects and

(ii) Inversely proportional to the square of the distance between their centres.

$$G = \frac{F \times d^2}{M \times m}$$

The SI unit of G can be obtained by substituting the unit of force, distance and mass in equation (iii).

$$G = \frac{Nm^2}{\text{kg} \times \text{kg}}$$

$$G = Nm^2/\text{kg}^2 \quad \text{or} \quad G = \text{Nm}^2\,\text{kg}^{-2}$$

Newton's third law of motion (i.e., action and reaction are always equal and opposite) applies to gravitational force as well.

Kepler's Laws of Planetary Motion

1st Law: Every planet revolves around the Sun in an elliptical orbit, with the Sun situated at any one of the foci of the ellipse.

2nd Law: In the elliptical orbit of the planet, the line joining the centre of the planet to the centre of Sun sweeps out equal areas in equal intervals of time.

3rd Law: The Square of time period of revolution of a planet around the Sun is directly proportional to the cube of the semi-major axis or the elliptical orbit.

•Newton guessed the inverse square rule $\left(\text{i.e.}, F \propto \frac{1}{r^2}\right)$ using Kepler's third law of planetary motion, and assuming that orbits of planets around the Sun are circular.

Gravity is the phenomenon of attraction between Earth and any other body. Force of gravity, $F = \frac{G m M}{r^2}$

where M is mass of Earth and m is mass of the body at a distance r from the centre of Earth.

Relation between g and G

The relation between g and G is $g = \frac{GM}{R^2}$ where M is mass of Earth and R is radius of Earth. The value of g does not depend on mass of the body.

Three Equations of Motion under Gravity

$$v = u + gt$$

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

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

where u is initial velocity, v is final velocity after t second, h is the height covered in t second.

When a body is projected upwards, it undergoes retardation = $g = -9.8\ \text{m/s}^2$ and in free fall, the body has uniform acceleration $g = +9.8\ \text{m/s}^2$.

Mass and Weight

- **Mass of a body is the quantity of matter in the body.**
- **Weight of a body is the force with which the body is attracted towards the centre of the Earth.**

Thrust and Pressure

- Force acting normally or perpendicular to the surface is called **thrust.**
- **Pressure (*P*)** is the thrust **(*F*)** per unit area of the surface, i.e., ***P = F/A*.**
- The same force acting on a smaller area exerts a large pressure and a smaller pressure while acting on a larger area.

The **unit of pressure** is **pascal (Pa)** where 1 Pa = 1N/m^2.

Other units of pressure are (*i*) **bar** (*ii*) **millibar** (m bar) and (iii) **atm**

$$1 \text{ bar} = 10^5 \text{ Pa and } 1 \text{ m bar} = 10^2 \text{ Pa}$$

$$1 \text{ atmospheric pressure (1 atm)} = 1.013 \times 10^5 \text{ N/m}^2 = 1.013 \times 10^5 \text{ Pa}$$

$$= 101.3 \text{ k Pa} = 1.013 \text{ bar}$$

Density and Relative Density

Mass per unit volume of a substance is called its density, i.e.,

$$\text{density } (d) = \frac{\text{mass } (M)}{\text{volume } (V)}$$

The **SI unit** of density is kg/m^3 and its cgs unit is g/cm^3.

Density of a substance is one of its characteristic properties and it enables us to determine its purity.

Relative density of a substance is defined as the ratio of its density to that of water at 4°C. Being a ratio of two similar quantities, it has no unit.

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

Relative density of a substance is also defined as the ratio of the mass of the substance to the mass of an equal volume of water at 4°C.

Pascal's law states that the pressure applied at any place to an enclosed mass of a fluid is *transmitted equally in all directions* and it acts undiminished at every point of the fluid and on the walls of the container.