7 GRAVITATION

1 OMQ + 1 VSAQ + 1 SAQ [1 M + 2M + 4M = 7 M]

CONCEPTS & DEFINITIONS

1. In this chapter we study about (i) Kepler's laws (ii) Universal Law of Gravitation (iii) Escape speed (iv) Orbital speed (v) Satellites

2. Kepler's laws:

1. **Law of orbits:** All planets move in elliptical orbits with the sun situated at one of the foci.
2. **Law of areas:** The line that joins any planet to the sun sweeps equal areas in equal intervals of time.
3. **Law of periods :** The square of the time period of revolution of a planet is proportional to the cube of the semi-major axis of the ellipse traced out by the planet.

3. Universal law of Gravitation :

Statement: Every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

If m_1, m_2 are the masses of two particles and r is the distance between them, then the Gravitational Force of attraction between them is $F = \frac{Gm_1m_2}{r^2}$, Here G is the Universal Gravitational constant. **Value of G** $= 6.67 \times 10^{-11}$ N $m^2 kg^{-2}$ **SI unit of G :** N $m^2 kg^{-2}$

Dimensions of G : $G = \frac{Fr^2}{m_1m_2} \Rightarrow [G] = \frac{[MLT^{-2}]\times[L]^2}{[M]^2} = [M^{-1}L^3T^{-2}]$

4. Acceleration due to gravity (g) : The uniform acceleration produced in a freely falling body is known as Acceleration due to gravity (g)

Consider a body of mass 'm' on the surface of a Planet of mass M and radius R

According to Newton's Second law, the force acting on the body, $F = mg$ ....(1)

According to Universal law of gravitation, the force acting on the body $F = \frac{GMm}{R^2}$ .....(2)

From equations (1) & (2), $mg = \frac{GMm}{R^2} \Rightarrow g = \frac{GM}{R^2}$ which is Relation between 'g' and 'G'

Note : The value of 'g' depends on Mass , Radius ,Latitude and Shape of the Planet.

Acceleration due to gravity at Poles is greater than its value at Equator.

The value of 'g' is maximum on the Surface & decreases with increase in Height, Depth of the body.

5. Gravitational potential energy: The potential energy of a body arising out of the force of gravitation is called the gravitational potential energy.

The gravitational potential energy associated with two particles of masses m_1, m_2 separated by a distance r is given by $U = -\frac{Gm_1m_2}{r}$

6.1 Escape Velocity (v_e) : The minimum velocity with which a body must be projected, so as to enable it, to just over come the gravitational pull is known as 'Escape velocity'.

Formula : Escape velocity $v_e = \sqrt{2gR}$, g = acceleration due to gravity, R = radius of Planet

Note: i) Escape speed on the earth v_e = 11.2 km s^{-1}.

ii) Escape speed does not depend on the mass of the Projected body.

iii) Escape speed does not depend on the Angle of projection.

6.2 Orbital velocity (v_o) : The velocity required to put a Satellite into its orbit around the Earth.

Formula: Orbital velocity $v_o = \sqrt{gR}$

Note: Escape velocity = $\sqrt{2} \times$ Orbital velocity

7. Geostationary satellite: If the period of revolution of an artificial Satellite is equal to the period of rotation of earth then such a Satellite is called a Geostationary Satellite.

Note : Height of the Geostationary satellite h = 35,800 km, Orbital Radius = 42,250 km

8. Polar Satellite: The low altitude (500 to 800km) satellites, which go around the poles of the earth in a north-south direction are known as polar satellites. The time period of polar satellite is around 100 minutes.

Imp.Formulae

1. $F = \frac{Gm_1m_2}{r^2}$
2. $g = \frac{GM}{R^2}$
3. $g_h = g\left(1 - \frac{2h}{R}\right)$
4. $g_d = g\left(1 - \frac{d}{R}\right)$
5. $U = \frac{-Gm_1m_2}{r}$
6. Escape velocity $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$
7. Orbital velocity $v_0 = \sqrt{\frac{GM}{R}} = \sqrt{gR}$
8. $T = \frac{2\pi(R+h)}{v_0}$