CONCEPT MAP

Gravitation

Kepler's laws of planetary motion

1st Law : Every planet revolve around the sun in an elliptical orbit and sun is situated at the one of the focus of ellipse.

2nd Law : The radius vector drawn from the sun to planet sweeps out equal areas in equal intervals of time.

$$\frac{dA}{dt} = \frac{L}{2m} = \frac{1}{2}r^2\omega = \text{constant}$$

3rd Law : The square of the time period of revolution of a planet around the sun is directly proportional to the cube of semimajor axis of the elliptical orbit.
i.e., $T^2 \propto a^3$

Gravitational Constant (G) : It is equal to the force of attraction acting between two bodies each of unit mass, whose centres are placed unit distance apart. The value of G is the constant throughout the universe. It is a scalar quantity. The value of $G = 6.67 \times 10^{-11}\ N\,m^2\,kg^{-2}$.

Newton's law of gravitation

Newton's Law of Gravitation : It states that the gravitational force of attraction acting between two bodies of the universe is directly proportional to the product of their masses and is inversely proportional to the square of the distance between them,
i.e., $F = Gm_1m_2/r^2$;
where G is the universal gravitational constant.

Symbols Used

W = Weight of the object
m = mass of the object
g = acceleration due to gravity
R = radius of the earth
h = height from the surface of earth
d = depth from the surface of earth
T = time period of satellite
E = total energy of satellite
G = gravitational constant
v_e = escape velocity
v_p = velocity at perihelion
v_A = velocity at aphelion
r = radius of circular/elliptical orbit

Gravitational Field : It is the space around a material body in which its gravitational pull can be experienced.

Intensity of a gravitational field at a point located at distance r from the centre of the body of mass M is given by,

$$I = \frac{GM}{r^2}$$

Gravitational Potential : Gravitational potential, V at a point

$$= \frac{\text{work done}\,(W)}{\text{test mass}\,(m_0)} = \frac{-GM}{r}$$

Gravitational potential energy of two masses m_1 and m_2 separated by a distance r is given by

$$U = -\frac{Gm_1m_2}{r}$$

Gravity : It is the force of attraction exerted by earth towards its centre on a body on the surface of earth or $W = mg$

Acceleration due to gravity : It is the uniform acceleration produced by a freely falling body under the gravitational pull of the earth. i.e., $g = 9.8\ m\,s^{-2}$ at the surface of earth.

Earth Satellites : It is a body which is revolving continuously in an orbit around a comparatively much larger body.

Orbital Speed : It is the speed required to put the satellite into given orbit around earth.
Orbital speed of satellite, when it is revolving around earth at height h is given by

$$v_0 = R\sqrt{\frac{g}{R+h}}$$

Escape Speed : The escape speed on earth is defined as the minimum speed with which a body has to be projected vertically upwards from the surface of earth (or any other planet) so that it just crosses the gravitational field of earth (or of that planet) and never returns on its own.

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR} = 11.2\ m\,s^{-1}$$

Altitude : The value of g decreases with increase in height

- $g' = \dfrac{gR^2}{(R+h)^2}$ when $h << R$
- $g' = \left(1 - \dfrac{2h}{R}\right)$

Depth : The value of g decreases with increase in depth, d and becomes zero at the centre of earth

$$g' = g\left(1 - \frac{d}{R}\right)$$

Effect of rotation of earth :
$g' = g - \omega^2 R\cos^2\lambda$
g is maximum at the poles and minimum at the equator.

Geostationary satellite : A satellite which revolves around the earth with the same angular speed in the same direction as is done by the earth around its axis is called geostationary or geosynchronous satellite. The height of geostationary satellite is ≈ 36000 km and its orbital velocity = 3.1 km s^{-1}.

Polar satellite : It is that satellite which revolves in polar orbit around earth.