Subject : Physics

Class : XI **Kannada**

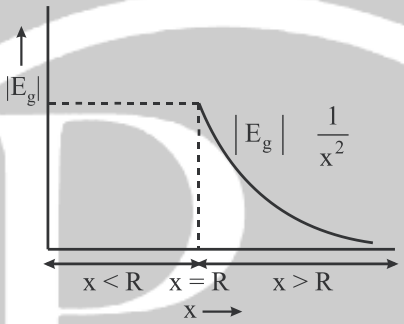
Gravitation

Newton's Universal Law of Gravitation



- Force of attraction between two point masses $F = \frac{Gm_1 m_2}{r^2}$ where $G = 6.67 \times 10^{-11}$ Nm^2/kg^2
- Directed along the line joining the point masses.
- It is a conservative force ⇒ mechanical energy will be conserved.
- It is a central force ⇒ angular momentum will be conserved

Gravitational Field due to Spherical Shell



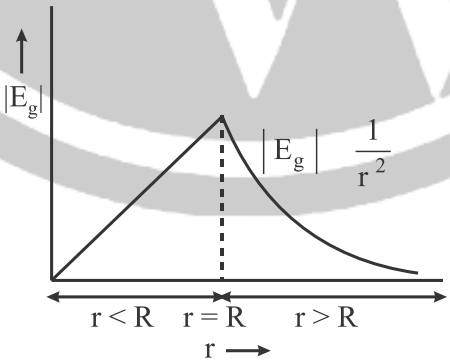
Outside region $E_g = \frac{GM}{r^2}$, where $x > R$

On the surface $E_g = \frac{GM}{R^2}$, where $x = R$

Inside Region $E_g = 0$, where $x < R$

Note : Direction always towards the centre of the sphere, radially inwards.

Gravitational Field Due to Solid Sphere



Outside Region $E_g = \frac{GM}{r^2}$, where $r > R$

On the surface $E_g = \frac{GM}{R^2}$, where $r = R$

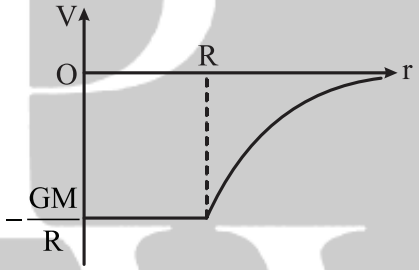
Inside Region $E_g = \frac{GMr}{R^3}$, where $r < R$

Gravity 'g'

- Acceleration due to gravity $g_s = \frac{GM}{R^2}$ (on the surface of earth)
- At height h, $g_h = \frac{GM}{(R+h)^2}$
- If $h << R$; $g_h \approx g_s\left(1-\frac{2h}{R}\right)$
- At depth d, $g_d = \frac{GM(R-d)}{R^3} = g_s\left(1-\frac{d}{R}\right)$
- Effect of rotation on g : $g' = g - \omega^2 R\cos^2\lambda$
  (Where λ is angle of latitude)

Gravitational Potential

- Due to point mass at a distance r $V = \frac{GM}{r}$
- Gravitational potential due to spherical shell Outside the shell $V = \frac{GM}{r}, r > R$ Inside /on the surface of the shell $V = \frac{GM}{R}, r < R$

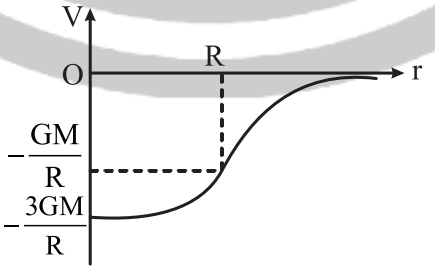


- Potential due to a solid sphere

  Outside Region $V = -\frac{GM}{r}, r > R$

  On the surface $V = -\frac{GM}{R}, r = R$

  Inside Region $V = -\frac{GM\left(3R^2 - r^2\right)}{2R^3}, r < R$



- Potential on the axis of a thin ring at a distance r from the centre

  $V = -\frac{GM}{\sqrt{R^2 + r^2}}$

Motion of a Satellite

- Escape velocity from a planet of mass M and radius R $V_e = \sqrt{\frac{2GM}{R}}$

- Orbital velocity of satellite (orbital radius r) $V_0 = \sqrt{\frac{GM}{r}} = \sqrt{\frac{GM}{(R+H)}}$
- For nearby satellite $V_0 = \sqrt{\frac{GM}{R}}\frac{V_e}{\sqrt{2}}$ Here V_e = escape velocity on earth surface.

Time Period of Satellite

$$T = \frac{2\pi r}{v} = \frac{2\pi r^{3/2}}{\sqrt{GM}}$$

Energies of a Satellite

Potential energy $U = -\frac{GMm}{r}$

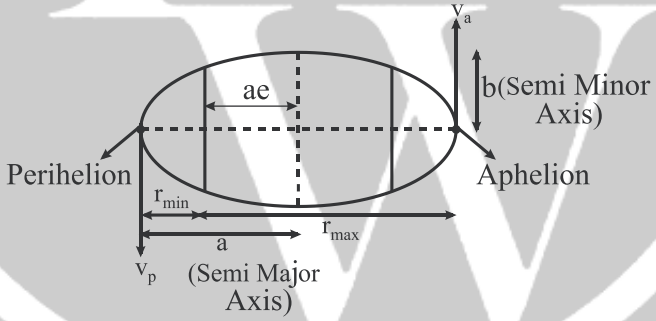
Kinetic energy $K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$

Mechanical energy $E = U + K = -\frac{GMm}{2r}$

Binding energy $BE = -E = \frac{GMm}{2r}$

Kepler's Laws

- 1st Law of orbitals: Path of a planet is elliptical with the sun at one of the focus.
- II[nd] Law of areas: Areal velocity $\frac{d\vec{A}}{dt} = constant = \frac{\vec{L}}{2m}$
- IIIrd Law of periods: $T^2 \propto a^3$ *or* $T^2 \propto \left(\frac{r_{max} + r_{min}}{2}\right)^3 \propto$ (mean radius)^3 for circular orbits $T^2 \propto R^3$



- $r_{max} = a(1+e)$
  $r_{min} = a(1-e)$
- $\frac{v_p}{v_a} = \frac{v_{max}}{v_{min}} = \frac{1+e}{1-e}$ (Where, e is eccentricity.)



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