(3) V due to a spherical shell.
(i) For \( r > R \), \( V = \frac{-GM}{r} \)
(ii) For \( r = R \), \( V = \frac{-GM}{R} \)
(iii) For \( r < R \), \( V = \frac{-GM}{R} \)

(4) V due to a ring
(i) At the centre \( V_C = -\frac{GM}{a} \)
(ii) At a point on its axis \( V_{axis} = \frac{GM}{a^2 + r^2} \)

(c) The gravitational P.E. of a point mass \( m \) at a distance \( r \) from the centre of the earth (where \( r > R \)) is given by the gravitational potential \( \Phi = \frac{GMm}{r} \). For \( r = R \), \( U = -\frac{GMm}{R} \) and if \( r = \infty \) then \( V_p = 0 \) at infinity.

This is the maximum value of \( V \).

Gravitational Potential (V)

(1) Due to a point mass at a distance \( r \), \( V = -\frac{GM}{r} \).

(2) V due to a uniform solid sphere.
For \( r > R \), \( V = -\frac{GM}{r} \).
For \( r = R \), \( V = -\frac{GM}{R} \).
At the centre, \( V = \frac{3GM}{2R} \).

Graph of \( V \) against \( r \).

Graph of \( I \) against \( r \).

Intensity due to a uniform circular ring

(i) At a point on the axis \( I = \frac{GMr}{(a^2 + x^2)^{3/2}} \)
(ii) At the centre of the ring \( I = 0 \)

(b) Gravitation Potential (V): If \( W \) is the work done in bringing a body of mass \( m_0 \) from infinity to a point \( P \) in the gravitational field without acceleration, then the gravitational potential at \( P = V_p = \frac{W}{mass} = \frac{W}{m_0} \). It is measured in J/kg or \( m^2/sec^2 \) and its dimensional formula is \( [V] = \left[ \frac{W}{m_0} \right] = \left[ \frac{M^1 L^2 T^{-2}}{M} \right] = [M^0 L^2 T^{-2}] \).

It is a scalar quantity.

- The gravitational potential at a point \( P \) at a distance \( r \) from the centre of the earth of radius \( R \) and mass \( M \), where \( r > R \), is given by \( V_p = -\frac{GM}{r} \).

Thus \( V_p \) is always negative. At the surface of the earth, \( r = R \).

\( \therefore \) \( V_p = -\frac{GM}{R} \) and if \( r = \infty \) then \( V_p = 0 \) at infinity.

This is the maximum value of \( V \).

Useful Points:

(i) Gravitational force is independent of the intervening medium. The ratio of the gravitational force to the electrostatic force between two electrons is of the order of \( 10^{39} \).

(ii) The escape velocity of a body from the surface of the earth is about 11.2 km/s, while for the moon escape velocity is about 2.38 km/s.