The Value of G was first Determined by?

Gravitation

- Claudius Ptolemy proposed 'Geocentric Theory'. According to this theory all planets including sun are revolving round the earth.
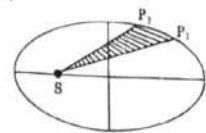- Copernicus proposed 'Heliocentric theory'. According this theory all planets including earth are revolving round the sun.
- **Kepler's Law of Planetary Motion:**
- i) **I law :** Every planet revolves round the sun in an elliptical orbit, with the sun lying at one focus of the ellipse. This is also called law of orbits.
- ii) **II Law:** The areal velocity of a planet round the sun is constant or every planet sweeps out equal areas in equal intervals of time.

Or, $\frac{dA}{dt}$ = constant. Where 'dA' is the area swept out by the planet in a time 'dt'.

i) The areal velocity is
$$\frac{dA}{dt} = \frac{1}{2} r^2\, \omega = \frac{1}{2} Rv.$$
$$\frac{dA}{dt} = \frac{1}{2}\frac{mr^2\omega}{m} = \frac{1}{2m} = \frac{L}{2m}.$$

- From the above equation $I\omega$ is constant. Therefore, Kepler's second law is a direct consequence of the law of conservation of angular momentum.
- According to Kepler's second law, when a planet is closest to the sun its speed is maximum and it is farthest from the sun its speed is minimum.
  L = mvr = constant;
  vr = constant $v_1 r_1 = v_2 r_2$
  If v_1, v_2 are the velocities of a planet when it is at distances r_1, r_2 from the sun respectively.

Kepler's third law (or) law of period:
- According to Kepler's third law the square of the period of revolution (T) of a planet round the sun is directly proportional to the cube of the semi major axis (R) of the elliptical orbit.
  $\therefore$ $T^2 \propto R^3$
- According to Kepler's third law as the distance of the planet from the sun increase, duration of the year of the planet increase.

Newton's Universal Law of Gravitation :
- Every body in universe attracts every other body with a force which is directly proportional to the product of the masses of the

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two bodies and inversely proportional to the square of the distance between them.

$$F = G\frac{m_1 m_2}{d^2}$$

- Where 'm_1' and 'm_2' are the masses of two bodies and 'd' is the distance between this centers and 'G' is the universal gravitational constant.
- i) The universal gravitational constant 'G' is the numericale qual to the force of attraction between two bodies of unit masses, separated by unit distance.
- ii) The value of
  $G = 6.67 \times 10^{-8}\ \frac{dyne-cm^2}{gm^2}$
  (C.G.S. system)
  $= 6.67 \times 10^{-11}\ \frac{newton-m^2}{kg^2}$
  (M.K.S system)
  The dimensional formula of G is $[M^{-1} L^3 T^{-2}]$
- iv) The value of G was first determined by Henry Cavendish.
- v) This force acts along the line joining the centers of the masses.
- vi) The gravitational force between two bodiesisindependent of the presence of the third body and the medium in which the bodies are situated.
- vii) The gravitational force between two bodies is action – reaction pair.
- viii) Gravitational force is conservation force work done by it is independent of the path.
- ❖ **Gravitational Intensity:**
- It is the gravitational force of attraction exerted by a body on unit mass. Gravitational intensity due to a mass 'M' at a distance 'r' from the center of mass is given by $E_g = \frac{GM}{r^2}$
- It is a vector quantity expressed in the units newton – kg^{-1}.
- ❖ **The gravitational force between two bodies are action – reaction pair.**
- If two bodies of masses m1 and m2 are separated by a distance d then the distance of the point where intensity of gravitational field is zero from m1 is $x = \frac{d}{\sqrt{\frac{m_2}{m_1}}+1}$
- ❖ **Gravitational Potential:**
- The amount of work done in bringing a unit mass from infinity to that point is called
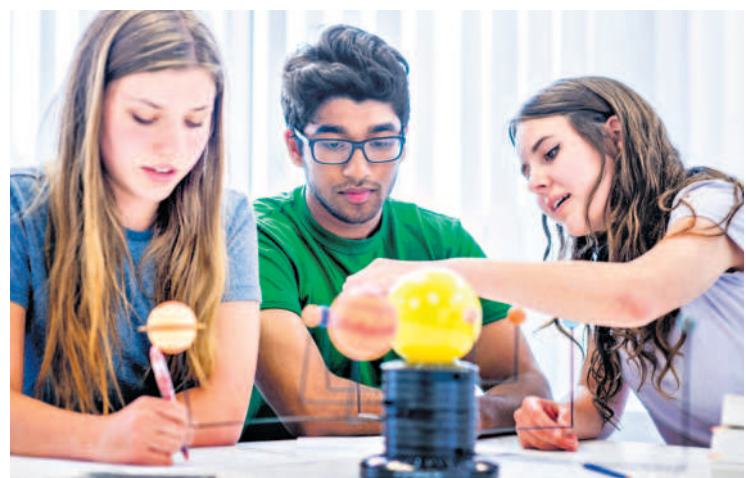
gravitational potential at the point.
- ❖ Gravitational Potential due to a mass 'M' at a distance 'r' is given by $V_G = -\frac{GM}{r}$
- ❖ ravitational Potential is a scalar quantity.
- ❖ Gravitational Potential is measured in J. kg^{-1}.
- ❖ Dimensional formula of gravitational potential is $L^2 T^{-2}$.
- ❖ **Gravitational Potential energy of a two body system :**
- The amount of work done in bringing the two bodies from infinity separation to the given separation is stored as potential energy.
- If 'm_1', 'm_2' are two masses separated by infinite distance the gravitational potential energy of the system when they are brought to a separation of 'r' is given by $U = -G\frac{m_1 m_2}{r}$
- [The negative sign indicates that the two bodies are attracting each other].
- If three particles of masses 'm_1', 'm2' and 'm3' are kept at three corners of a equilateral triangle of side 'd' then gravitational P.E. of the system is given by
  $U = -\frac{G}{d}(m_1 m_2 + m_2 m_3 + m_3 m_1)$
- If a body is kept on surface of the earth then then its gravitational
  $P.E. = -\frac{GMm}{R}$
  Where M = mass of the earth
  R = radius of the earth
- If a body is at a height h above surface of the earth then its gravitational $P.E. = -\frac{GMm}{R+h}$
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- If h <<R then W = mgh
- ❖ If a body is projected with

velocity v from surface of the earth so that it goes upto height nR from surface of the earth then
$$v = \sqrt{\frac{2ynR}{1+n}}$$

- ❖ **Acceleration due to gravity:**
The acceleration acquired by a freely falling body due to gravitational pull is called acceleration due to gravity. It is denoted by 'g'.
'g' is a vector quantity.
Units of 'g' :
(i) cm/sec^2 (C.G.S. system)
(ii) m/sec^2 (S.I. system)
- The dimensional formula of 'g' is $[M^0 L^1 T^2]$.
- The value of 'g' near the surface of the earth is equal to 9.8 m/ sec^2.
- The value of 'g' maximum as poles is (9.83 m/sec^2) and minimum at equator 9.78 m/sec^2.
- The value of 'g' is numerically equal to the force experienced by unit mass placed in the gravitational field, i.e., $g = GM/R^2$. where 'M' is the mass of the earth and 'R' is the radius of the earth.
Note: The mass of the earth can be estimated using the following formula $M = gR^2/G$. Its value is nearly equal to 6 x 10^{24} kg.
- i) If M_1, M_2 are the masses and R_1, R_2 are the radii of two planets then
  $\frac{g_1}{g_2} = \frac{M_1}{M_2} \times \frac{R_2^2}{R_1^2}$.
- The acceleration due to gravity (g) on a planet of radius R and density d is given by $g = 4/3\ \pi\ GRd$.
- If R_1, R_2 are radii and d_1, d_2 are the densities of two planets
  $\frac{g_1}{g_2} = \frac{R_1 d_1}{R_2 d_2}$
- iii) If a body is dropped from same height on two different planets then
- 1) Striking Velocity
  'v' $\alpha \sqrt{g}$
  $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2}}$

2) Time of descent
  't' $\alpha\ \frac{1}{\sqrt{g}}$
  $\therefore \frac{t_1}{t_2} = \sqrt{\frac{g_2}{g_1}}$

- iv) If a body weight on surface of earth is 'W' kg then its weight on surface of planet of mass M_1, radius R_1, density d1is given by
  $W_1 = W\left[\frac{m_1}{m} \times \frac{R^2}{R_1^2}\right]$
  $= w\left[\frac{R_1\, d_1}{Rd}\right]$

Where M = mass of the earth; R = radius of the earth; d = density of the earth
- The lines joining the places on the earth having same values of 'g' are called isogams.
- Gravity meter and Etvos gravity balance are used to measure changes in acceleration due to gravity.
- ❖ **Variation of 'g':**
- a) **Effect of altitude :** If 'g' is the acceleration due to gravity on the surface of the earth 'g' is the acceleration due to gravity at the height h above the surface of the earth.
  $g = \frac{GM}{R^2}$ and $g^1 = \frac{GM}{(R+h)^2}$
  Hence, $\frac{g_1}{g_2} = \frac{R^2}{(R+h)^2}$
- i) For small values of h,
  $g^1 = g\left(1 - \frac{2h}{R}\right)$ Thus as height increases the value of 'g' decreases.
- ii) At height h, $\frac{\Delta g}{g} \times 100$
  $= \frac{2h}{R} \times 100$
- ❖ The acceleration due to gravity becomes x % of its value on surface of the earth at height
  $= R\left[\frac{10}{\sqrt{x}} - 1\right]$
- ❖ Theheightwhere acceleration due to gravity is 1/x of that on surface of the earth h = R ($\sqrt{x}$-1)
- ❖ **Effect of depth:** If 'g' is acceleration due to gravity at the surface of the earth, 'g1' the acceleration due to gravity at a depth 'd' below the surface of the earth.
  $\frac{g^1}{g} = \left(1 - \frac{d}{R}\right)$
  $\therefore g^1 = g\left(1 - \frac{d}{R}\right)$

Thusas the depth 'd' increase, the acceleration due to gravity decreases.

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