Unit:- 5 :- Gravitation

Newton's law of Gravitation:-

"Every particle of matter in this universe attracts every other particle with a force which varies directly as the product of the masses of two particles and inversely as the square of distance between them."

* The force of attraction between any two bodies in the universe is known as the force of gravitation.
* This force is mutual and acts along the line joining the centre of the two bodies.

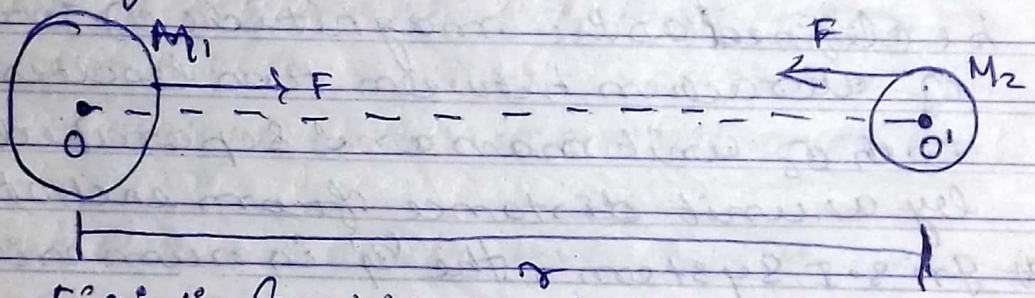


Fig:-1:- Gravitational attraction bet^n two bodies.

Consider two bodies of masses m_1 and m_2 as shown in figure (1). Let 'r' be the distance bet^n their centres and 'F' be the magnitude of force of attraction between them. According to the law of gravitation,

(i) $F \propto m_1 m_2$

(ii) $F \propto \frac{1}{r^2}$

Combining the above two factors we get,

$$F \propto \frac{M_1 M_2}{r^2}$$

$$\Rightarrow F = G \frac{M_1 M_2}{r^2} \quad \text{---} \quad (i)$$

where the proportionality constant G is known as universal constant of gravitation or gravitational constant.

Defination of G:-

Let $m_1 = m_2 = 1$ unit

$r = 1$ unit

then, from eq^n (i) we get;

$$F = G \cdot \frac{1 \times 1}{r^2} = G$$

or $G = F$.

* Thus, the gravitational constant may be defined as the magnitude of force of attraction between two bodies each of unit mass and separated by a unit distance from each other.
* In S.I System, the G is numerically equal to the force of attraction between two masses of 1kg each and placed at a distance of 1m from each other.
* In C.G.S System, the G is numerically equal to the force of attraction between two masses of 1g each and placed at a distance of 1cm from each other.

Units And Value of G:-

(i) S.I unit:- We know that,

$$F = G \times \frac{m_1 \cdot m_2}{r^2}$$

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

$$= \frac{N m^2}{kg^2}$$

Value of G in S.I System $= 6.67 \times 10^{-11} N m^2 kg^{-2}$

(ii) C.G.S unit :- We know that,

$$F = G \frac{M_1 m_2}{r^2}$$

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

$$= \text{dyne} \cdot \frac{cm^2}{gm^2}$$

value of G in C.G.S System $= 6.67 \times 10^{-8}$ dyne $cm^2 gm^{-2}$

Acceleration Due To Gravity :- (g)

- Gravity is a special case of gravitation in which one of the bodies is earth and the second body is either placed on earth or near it.
- Force Between earth and a body near it is called gravity.
- The acceleration produced by gravity is called acceleration due to gravity and is denoted by 'g'.

Relation bet^n g and G :-

We know that ; $F = mg$ — (ii)

Since the body is placed on the surface of the earth of mass 'M' or radius 'R', then according to Newton's law of Gravitation,

$$F = G \cdot \frac{Mm}{R^2} \quad \text{— (iii)}$$

Fig :- 2

From eqn (ii) and (iii) we have,

$$\therefore g = G\frac{Mm}{R^2}$$

$$\Rightarrow g = \frac{GM}{R^2} \quad \text{— (iv)}$$

Since, 'g' depends upon the mass and radius of the planet it is not a universal constant.

unit of g :-

S.I unit :- $\frac{M}{Sec^2}$ or $M \cdot Sec^{-2}$

C.G.S unit :- $\frac{CM}{Sec^2}$ or $cm \cdot Sec^{-2}$

Variation ~~Variation~~ of 'g' with altitude :-

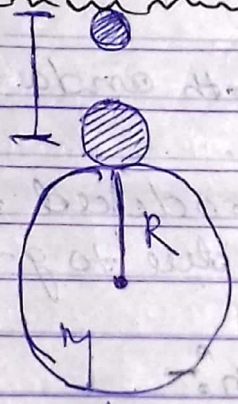


Fig :- 3 :- Effect of altitude on 'g'.

We know that on earth surface,

$$g = G\frac{M}{R^2} \quad \text{— (v)}$$

When the body is taken to a height 'h' above the surface of earth. The acceleration due to gravity is given by,

$$g' = G\frac{M}{(R+h)^2} \quad \text{— (vi)}$$

Since $R+h > R$, thus $g' < g$

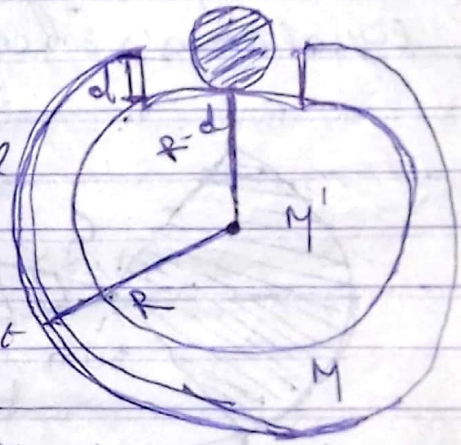
Thus from the above it is clear that the value of acceleration due to gravity decreases with increase in height above the earth surface.

Variation Of 'g' with depth :-

Acceleration due to gravity when a body is taken to a depth 'd' below the earth surface is :-

$$g' = \frac{G M'}{(R-d)^2} \quad \text{——— (viii)}$$

Where M' is the mass of the earth at a depth d' below the surface.



From mathematical calculation's it is observed that $g - g' \propto d$.

It is clear from the above that as 'd' increases g' must decrease. Thus, the value of acceleration due to gravity decreases as the depth increases.

Defination Of 'g' :-

Mass :- Mass is the amount of matter contained in a given body and doesn't varry in its geographical position on the earth surface.

Weight :- The weight of an object is a measure of the force exerted on the object by gravity and therefore the weight of the body will varry with its geographical position on the earth surface.

Keplers Law Of planetary Motion:-

First Law:- Law Of Elliptical Orbits:-

"A planet moves around the sun in an elliptical orbit with sun situated at one of its foci."

Second Law:- Law of Aerial velocity:-

"A planet moves around the sun in such a way that its aerial velocity is constant. i.e., the line joining the planet with sun sweeps equal area's in equal interval of time."

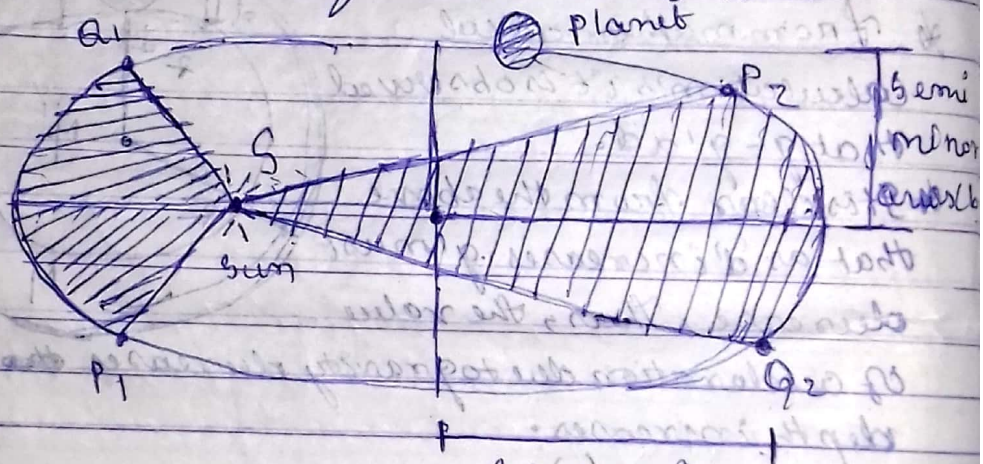


Fig:- 5:- Rotating of planet around the sun.

If 't' is the time taken by the planet to move from P_1 to Q_1 and also from P_2 to Q_2 then, Arc $(A_1) = Arc(A_2)$.

Third Law:- Law Of Time periods :- (Harmonic)

"A planet moves around the sun in such a way that the square of its time period is proportional to the cube of the semi-major axis of its elliptic orbit".

$\Rightarrow |T^2 \propto a^3| \quad \text{---(viii)}$

$g = 9.832 - 9.789.$