SUBJECT-ENGINEERING PHYSICS

SEMESTER-1ST & 2ND

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UNIT-5

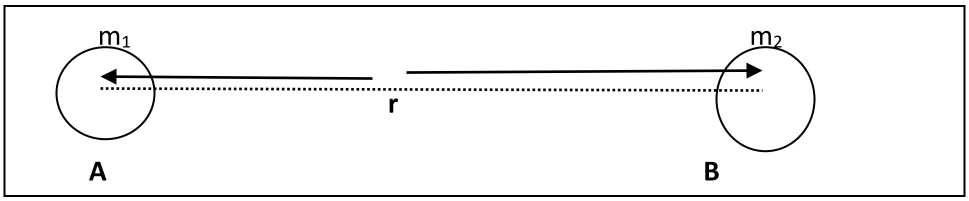
GRAVITATION

GRAVITATION-:

- It is a name given to the force of attraction between any two bodies in the universe.
- It was discovered by Newton in the year 1665, when he saw an apple falling down the tree.

NEWTON'S LAW OF GRAVITATION-:

STATEMENT- "Everybody in this universe attracts every other body with a force. The magnitude of this force is directly proportional to the product of their masses & is inversely proportional the square of distance between them."



- Consider two bodies of masses m_1 & m_2. Let 'r' be the distance between their centers & 'F' be the force of attraction between them.
- Mathematically, $F \propto m_1 m_2$ & $F \propto \frac{1}{r^2}$
- So, $F \propto \frac{m_1 m_2}{r^2}$

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

Where G is the constant of proportionality & is known as universal gravitational constant.

UNIVERSAL GRAVITATIONAL CONSTANT -:

From Newton's law of gravitation we know that

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

$$\boxed{G = \frac{Fr^2}{m_1 m_2}}$$

If $m_1 = m_2 = 1unit$ & $r = 1unit$

Then

$$G = F$$

- So, universal gravitational constant is defined as the force of attraction between two bodies of unit mass & separated by unit distance from each other.
  It is a scalar quantity.
- Its value is independent of nature & size of the bodies as well as the nature of the medium between the bodies.
- Its value is 6.67×10^{-11} Nm^2kg^{-2}.
- Its dimension is $[M^{-1} L^3 T^{-2}]$

GRAVITY -:

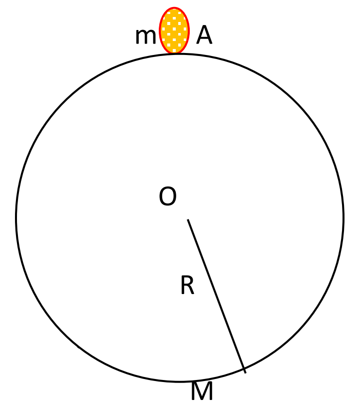
- It is a force of attraction exerted by earth towards its centre on a body lying on or near the surface of earth.
- It is a special case of gravitation & is also called earth's gravitational pull.
- The force with which a body is attracted towards the centre of earth is called its weight.

ACCELERATION DUE TO GRAVITY -:

- It is defined as the constant acceleration produced in a body when it falls freely under the effect of gravity alone.
- It is denoted by 'g'.
- S.I. unit is m/s^2 or N/kg.
- It is a vector quantity. Its direction is towards the centre of earth.
- Its value on the surface of earth is 9.8 m/s^2.
- Its dimension is $[M^0 L^1 T^{-2}]$

MASS	**WEIGHT**
1. It is the amount of matter contained in the body.	1. It is the force with which a body is attracted towards the centre of the earth.
2. It is a scalar quantity.	2. It is a vector quantity.
3. S.I. unit is kilogram(kg).	3. S.I. unit is newton(N).
4. Mass of a body is constant.	4. Weight of a body varies from place to place.
5. It is a fundamental physical quantity.	5. It is a derived physical quantity.
6. Mass of a body can never be equal to zero. .	6. Weight of a body is equal to zero at the centre of the earth.

RELATION BETWEEN g & G -:



Consider earth to be a spherical body of mass M & radius R with centre at O.

A body of mass m is placed at a point A on the surface of earth.

Let F be the gravitational force of attraction between the body & earth.

According to Newton's law of gravitation

$$F = G\frac{mM}{R^2} \quad \text{----------} \ (1)$$

Where G is the universal gravitational constant

From earth's gravitational pull, $F = mg$ --------- (2)

Equating equ (1) & equ (2) $mg = G\frac{mM}{R^2}$

$$\boxed{g = \frac{GM}{R^2}}$$

VARIATION OF g WITH HEIGHT & DEPTH -:

1. EFFECT OF ALTITUDE-:

Consider earth to be a spherical body of mass M & radius R with centre at O.
Let g is acceleration due to gravity at a point A which is on the surface of earth.
We know that

$$g = \frac{GM}{R^2}$$

Suppose g' is the acceleration due to gravity at a point B that is at a height h above the surface of earth.

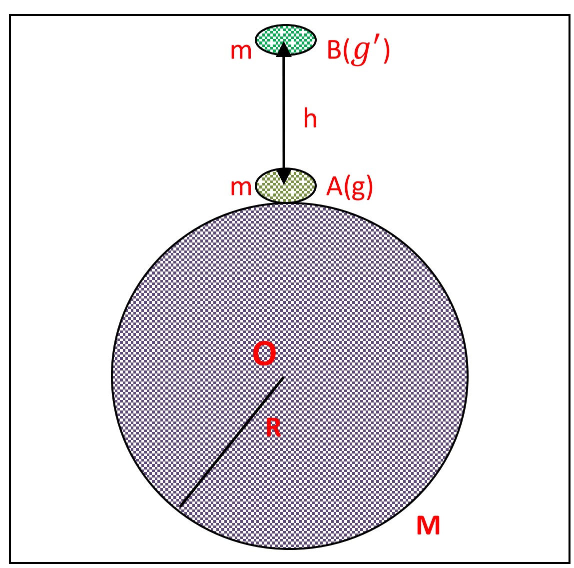
$$g' = \frac{GM}{(R+h)^2}$$

When $h \ll R$,

$$\boxed{g' = g\left(1 - \frac{2h}{R}\right)}$$

So,

$$\boxed{g' < g}$$



So the value of acceleration due to gravity decreases with increase in height.

2. EFFECT OF DEPTH -:

Consider earth to be a spherical body of mass M & radius R with centre at O. ρ is the uniform density of earth.

$$\rho = \frac{mass\ of\ earth}{volume\ of\ earth}$$

$$= \frac{M}{\frac{4}{3}\pi R^3}$$

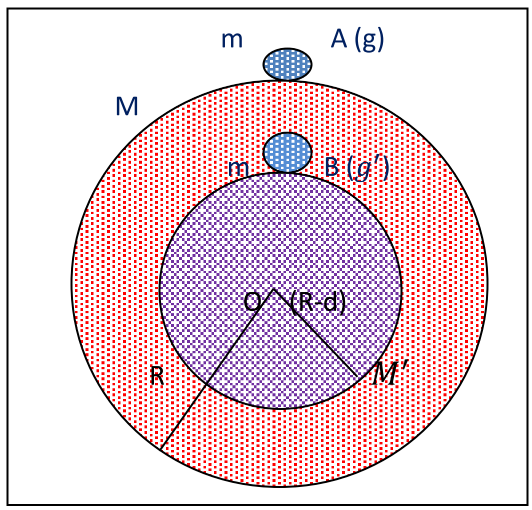
$$M = \frac{4}{3}\pi\rho R^3$$

Let g is the acceleration due to gravity at a point A which is on the surface of earth.

We know that

$$g = \frac{GM}{R^2}$$

Suppose g' is the acceleration due to gravity at a point B that is at a depth d below the surface of earth.



$$g' = \frac{GM'}{(R-d)^2}$$

Where, $\left[M' = \frac{4}{3}\pi\rho(R-d)^3\right]$

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

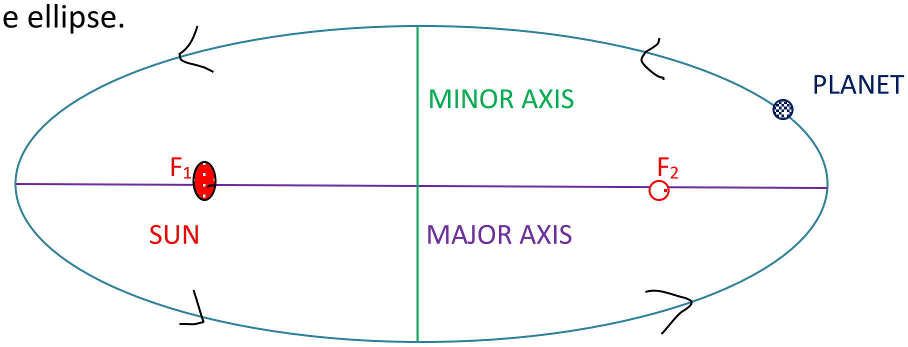
So, $$\boxed{g' < g}$$

So the value of acceleration due to gravity decreases with increase in depth.

KEPLER'S LAWS OF PLANATORY MOTION -:

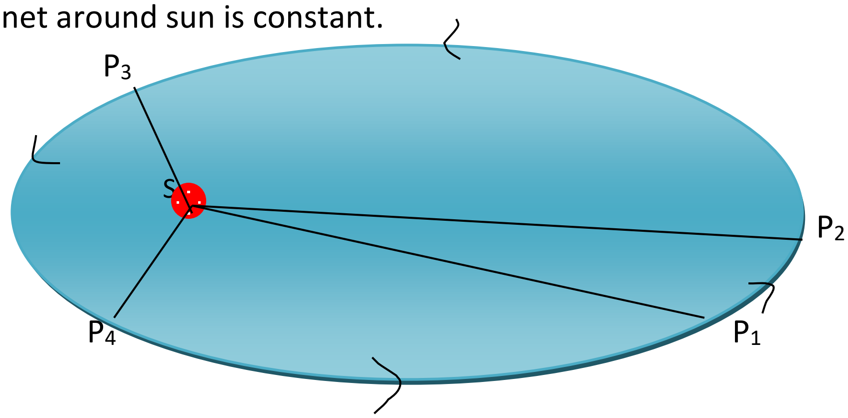
FIRST LAW (LAW OF ELLIPTICAL ORBIT) -:

Every planet revolves around sun in an elliptical orbit with sun situated at one of the foci of the ellipse.



SECOND LAW (LAW OF AREA) -:

A planet revolves around sun in such a way that the radius vector joining the planet to the sun sweeps out equal area in equal interval of time or the the areal velocity of the planet around sun is constant.



$$area\ of\ P_1SP_2 = area\ of\ P_3SP_4$$
$$(SP_1)(P_1P_2) = (SP_3)(P_3P_4)$$
$$since \quad SP_1 > SP_3$$
$$so \quad P_1P_2 < P_3P_4$$
$$or \quad \boxed{\frac{P_1P_2}{t} < \frac{P_3P_4}{t}}$$

$$\frac{P_1P_2}{t} = linear\ velocity\ of\ the\ planet\ at\ P_1$$
$$\frac{P_3P_4}{t} = linear\ velocity\ of\ the\ planet\ at\ P_3$$

So the orbital velocity of a planet around sun is not constant.

- So the linear velocity of the planet closer to the sun is greater than the linear velocity of planet when away from the sun.

THIRD LAW (LAW OF TIMEPERIOD) -:

A planet revolves around sun in such a way that the square of time period of revolution of a planet around sun is directly proportional to the cube of semi major axis of the ellipse.

$$\boxed{T^2\ \alpha\ R^3}$$ where,

$$T = time\ taken\ by\ the\ planet\ to\ go\ once\ around\ the\ sun$$
$$R = semi\ major\ axis\ of\ the\ ellipse$$

- So a planet situated at larger distance takes longer time to complete one revolution around sun as compared to the time taken by the planet situated nearer to the sun.