Gravitation

- The Phenomenon of attraction b/w any two objects in the Universe is called gravitation.

- Gravity — attractive force which is exerted by earth on any body.

Universal law of Gravitation.

m_1 A — B m_2, distance r

Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses & inversely proportional to the square of the distance between them.

$F \propto m_1 m_2$

$F \propto \frac{1}{r^2}$

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

G → Universal gravitational constant.

SI unit of G

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

$G = \frac{N \times m^2}{Kg^2}$

$G = 6.67 \times 10^{-11}\ Nm^2\ Kg^{-2}$

Universal gravitational Constant

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

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

$G = \frac{F \times (1m)^2}{1 kg \times 1 kg}$

$\boxed{G = F}$

Universal gravitational constant is numerically equal to the gravitational force of attraction between two bodies each of mass 1kg kept at unit distance from each other.

Why gravitational Constant (G) is known as Universal gravitational constant?

→ The value of G doesn't depend on mass of two bodies, distance b/w two bodies, nature, medium, shape / size.

Conditions

(i) When two objects each of 1kg and 1m apart.

1kg — 1m — 1kg

$F = G \frac{m_1 m_2}{r^2} = 6.67 \times 10^{-11} \frac{1 \times 1}{1} = 6.67 \times 10^{-11} N$

$= 0.000 \ldots 67 N$

(ii) ball m_1 — 1m — Train m_2

2kg, 5000 kg

force of Ball to Train $= G \frac{m_1 m_2}{r^2} = \frac{G\ 2 \times 5000}{(1)^2}$

$F = 10000 G N$

Force of Train to Ball $= \frac{G m_2 m_1}{r^2} = \frac{G.\ 5000 \times 2}{(1)^2}$

$= 10000 GN$

(iii) 1kg

earth mass $= 6 \times 10^{24}$ kg.

Radius of earth $= 6400 km$.

$= 6400 \times 1000$ m.

$= 6.4 \times 10^6 m$

$F_{AE} = \frac{6.67 \times 10^{-11} \times 1 \times 6 \times 10^{24}}{(6.4 \times 10^6)^2} = \boxed{9.8 N}$

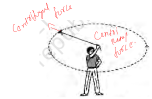
$F_{EA} = 9.8 N$

Newton's 2nd law of motion

$F = ma$.

✓ $a_{FA} = \frac{F}{m} = \frac{9.8}{1} = 9.8 ms^{-2}$

✓ $a_{AE} = \frac{F}{m} = \frac{9.8}{6 \times 10^{24} kg} = \boxed{1.63 \times 10^{-24} ms^{-2}}$



Before the thread is released, the stone moves in a circular path with a certain speed and changes direction at every point. The change in direction involves change in velocity or acceleration. The force that causes this acceleration and keeps the body moving along the circular path is acting towards the centre. This force is called the centripetal (meaning 'centre-seeking') force. In the absence of this

The motion of the moon around the earth is due to the centripetal force. The centripetal force is provided by the force of attraction of the earth. If there were no such force, the moon would pursue a uniform straight line motion.

m_1 3 time, m_2 $\frac{1}{2}$ time, r, $\frac{1}{3}$ times

$F_1 = \frac{G m_1 m_2}{r^2}$

$F_2 = \frac{G\ 3m_1 \frac{1}{2} m_2}{(\frac{r}{3})^2} = \frac{G\ 3 \times 9\ m_1 m_2}{2 \times r^2}$

$= \boxed{F_2 = \frac{27}{2} F_1}$

half / 6

1) Two particles A and B of mass m_1 and m_2 respectively are placed on same distance. If the mass of each of the two particles is doubled, keeping the distance b/w them unchanged, the gravitational force b/w them will be.

1) ✓ m_1 — r — m_2

$F_1 = \frac{G m_1 m_2}{r^2}$

2) $2m_1$ — r — $2m_2$

$F_2 = \frac{G\ 2m_1 2m_2}{r^2}$

$F_2 = \frac{G m_1 m_2}{r^2} 4$

$\boxed{F_2 = 4F_1}$

$$\boxed{F_2 = \frac{F_1}{4}}$$

$$\frac{1}{3}$$

$F_2 = \frac{G m_1 m_2}{(\frac{r}{2})^2}$

$F_2 = \frac{\ }{\frac{r^2}{4}}$

$\frac{r}{3}$

2) mass of sun is 2×10^{30} kg & mass of earth is 6×10^{24} kg. If the avg distance b/w the sun and the earth is 1.5×10^{8} km, Calculate the gravitational force b/w them.

$$F = \frac{Gm_1m_2}{r^2}$$

3) The gravitational force b/w two objects is F. If masses of both objects are halved w/o changing distance b/w them, gravitational force would become.

$$F_1 = \frac{Gm_1m_2}{d^2}$$

$$F_2 = \frac{G\left(\frac{m_1}{2}\right)\left(\frac{m_2}{2}\right)}{d^2} = \frac{Gm_1m_2}{d^2 \cdot 4} = \frac{F_1}{4}$$

$$F_2 = \frac{F_1}{4}$$

4) Gravitational force b/w two objects weighing 20 g and 15 g is is 150×10^{-10} N ?. Find distance b/w two objects.

Scientists → Arrangement of planets

Ptolemy	→ 140 AD	Geocentric theory	Earth is at center & all planets revolve around
Copernicus	→ 1543	Heliocentric theory — Sun at the center	
Tycho brahe	→ 1548	Tychonic system	Moon is at the center.
Galileo	→ 1609	Sun is at the center — Heliocentric theory	telescope

Kepler's law of planetary motion

He stated three laws which govern the motion of planets around the sun. These are known as Kepler's law of planetary motion.

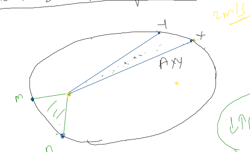
Circle – 1 center
1 Focus (radius are equal)

Ellipse → 2 center
Focus, Foci

Kepler's 1st law of motion

– Planets move in elliptical orbits around the sun, with the sun at one of two foci of the elliptical orbit.

Kepler's 2nd law of motion



$$\uparrow F = \frac{Gm_1m_2}{R^2} \uparrow\downarrow$$

✓ Each planet revolves around the sun in such a way that the line joining the planet to the sun sweeps over equal areas in equal intervals of time.

✓ A planet moves faster when it is closer to the sun & moves slowly when it is further away from the sun.

Kepler's 3rd law of motion

✓ The cube of the mean distance of a planet from the sun is directly proportional to the square of time, it takes to move around the sun.

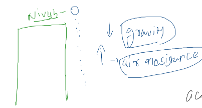
$r^3 \propto T^2$

$r^3 = \text{constant } T^2$

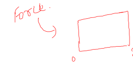
$r^3 / T^2 = \text{constant}$

r = mean distance of planet from the sun.
T = time period of the planet around the sun.

Free Fall and acceleration due to gravity (g)



The falling of a body (or object) from a height towards the earth under gravitational force of earth (with no other force acting on it), such a body is called Freely Falling body.



acc^n = change in velocity

$\uparrow F = ma \uparrow$

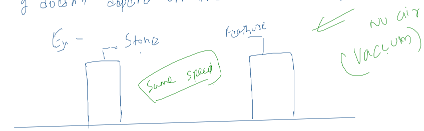
Acc^n due to gravity (g)

→ The uniform acc^n produced in a freely falling body due to gravitational force of the earth is known as acc^n due to gravity.

→ SI unit = $m s^{-2}$

→ g doesn't depend on the mass of the falling object.

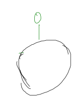
Eg –



Calculation of acc^n due to gravity

→ Force exerted by earth on the body

$F = GMm/R^2$ – (i)



This force by earth produces acc^n in the stone due to which stone moves downwards.

→ $F = m a$ – (ii)

$GMm/R^2 = m \times a$

$a = \frac{GMm}{m \cdot R^2}$

Here, $a = \frac{GM}{R^2}$

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

$$g = \frac{6.67\times10^{-11}\ Nm^2kg^{-2} \times 6\times10^{24}\ kg}{(6.4\times10^6)^2}$$

$$\boxed{g = 9.8\ ms^{-2}}$$