CHAPTER # 15

Date: 08-July-2025

08 [GRAVITATION]

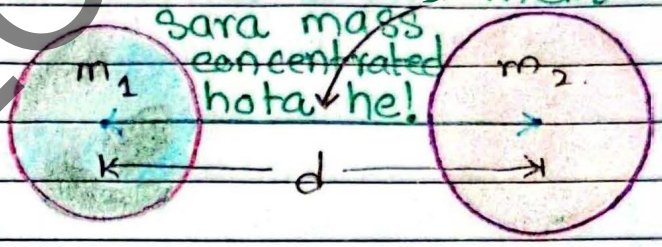
→ NEWTONS LAW OF GRAVITATION

⇒ Earth kissi bhi object ko jitni bhi force se attract krti he, wo object bhi earth ko utni hi force se attract krta he.

⇒ Basically, Gravitation is a mutual force, in which 2 objects apply force on one another

⇒ Gravitational forces are always attractive.

o Note:- koi bhi object apne centre (Radius) se attract krta he na k surface se. Bcz centre mein sara mass concentrated hota he!



Newton's research :-

According to newton Force applied is directly Proportional to the product of mass of both object and inversely proportional to the Square of distance between thier centres

Mathematically

i- $F \propto m_1 m_2$

ii- $F \propto \frac{1}{d^2}$

By Combining both eq. $F \propto \frac{m_1 m_2}{d^2}$

Value of G :- 6.67×10^{-11}

Unit " " :- Nm^2/kg^2

Dimension " " :- $[M^{-1} L^3 T^{-2}]$

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

Q) Why the value of Universal Gravitational Constant is small?

Because agr wo zyada ho ga tou Poori universe eik dosre se collapse haye gi / Squeeze ho gi

⇒ So actually Gravitational Constant Intensity of force determine krti

Date: 8/1

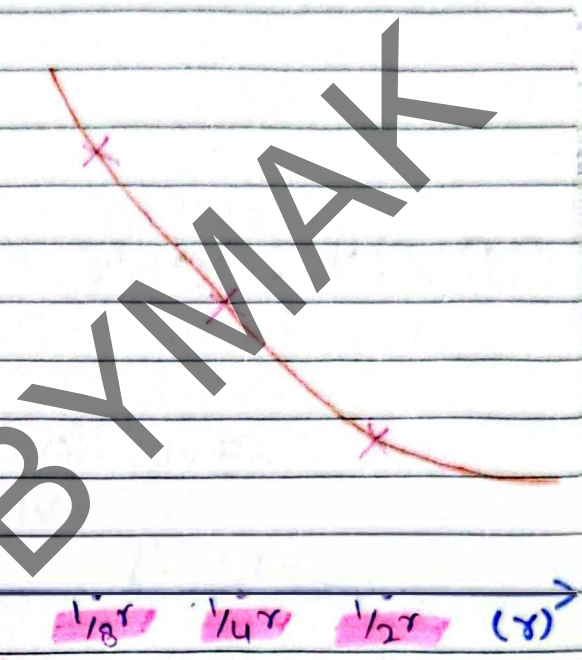
Q Why is the value of 'G' same every where?
Q If the 'd' gets reduced by 1/4 then the force is changed by :- [MDCAT / ECAT
Q Difference between 'g' and 'G'] - Home work
Q Is there any advantage of having the constant value of G?

Q (i) $r' = 1/3\, r$
(ii) $r' = 1/2\, r$
(iii) $r' = 1/8\, r$
(iv) $r' = 1/1.4\, r$
— Home work

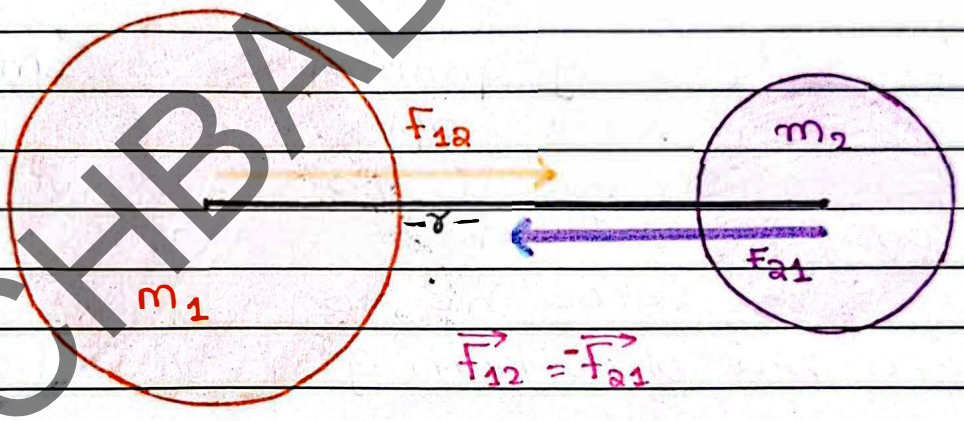
Universal Gravitational Constant (G)		Acceleration due to Gravity (g)
	DEFINITION	
A Constant Used to Calculate gravitational force b/w 2 masses		The acceleration an object feels due to Earths gravity.
	UNIT	
Nm^2/kg^2		m/s^2
	DIMENSIONS	
$[M^{-1}L^3T^{-2}]$		$[LT^{-2}]$
	VALUE	
$6.67 \times 10^{-11}\ Nm^2/kg^2$		$9.8\ m/s^2$

Date: 9/7

i-) $r' = \frac{1}{2}r$	ii-) $r' = \frac{1}{4}r$	iii-) $r' = \frac{1}{8}r$
$F' = G\cdot\frac{m_1m_2}{r^2}$	$F' = G\cdot\frac{m_1m_2}{r^2}$	$F' = G\frac{m_1m_2}{r^2}$
$F' = G\cdot\frac{m_1m_2}{(\frac{1}{2}r)^2}$	$F' = G\cdot\frac{m_1m_2}{(\frac{1}{4}r)^2}$	$F' = G\frac{m_1m_2}{(\frac{1}{8}r)^2}$
$F' = G\cdot\frac{m_1m_2}{\frac{1}{4}r^2}$	$F' = G\cdot\frac{m_1m_2}{\frac{1}{16}r^2}$	$F' = G\cdot\frac{m_1m_2}{\frac{1}{64}r^2}$
$F' = 4\times\left(G\cdot\frac{m_1m_2}{r^2}\right)$	$F = 16\times\left(G\cdot\frac{m_1m_2}{r^2}\right)$	$F' = 64\times\left[G\cdot\frac{m_1m_2}{r^2}\right]$
$F' = 4F$	$F' = 16F$	$F' = 64F$



Q Briefly Explain the newtons 3rd Law of motion in terms of Gravitation.



Acc to newtons Law of Gravitation, all objects attract each other, So m_1 exerts F_{12} on m_2, as a result m_2 exerts force F_{21} on m_1. Therefore this gravitational force demonstrate action and reaction pair. (Newtons 3rd law of motion is conser here)

ASSIGNMENT 15.1

DATA:-

M_e :- 6×10^{24} kg

M_m :- 7.4×10^{22} kg

r :- 3.84×10^{5} km

:- 3.84×10^{8} m

REQUIRED :-

$F_G = ?$

CALCULATIONS

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

$$F = \frac{(6.67 \times 10^{-11})(6 \times 10^{24})(7.4 \times 10^{22})}{(3.84 \times 10^{8})^2}$$

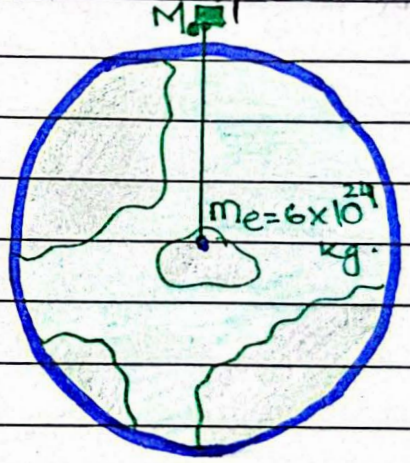
$$F = 2 \times 10^{20} \text{ N}$$

(MCQ)
Q In 1798 to measure gravitational force between 2 objects Henry Cavendish an, englishman used torsion balance apparatus. Note that Newton only worked on it however henry was the 1st one to use it.

15.2 GRAVITATIONAL FIELD STRENGTH

PRMZ

Newton ka 2nd law of motion kehta he k if we'll apply force, acceleration ho gi. ab Jo force apply ho rhi yahan wo gravitational force he, to acceleration bhi phir hum 'g' lein ge.



As, $F = ma$

So, $F_G = mg$

$$g = \frac{F_G \text{ (N)}}{m \text{ (kg)}} \quad (\because g = 9.8 \text{ ms}^{-2})$$

$$\text{N/kg} = \text{m/s}^2$$

$$\text{kg ms}^{-2}/\text{kg} = \text{ms}^{-2}$$

$$\text{ms}^{-2} = \text{ms}^{-2}$$

where 'g' is gravitational field strength (g.f.s) (g.f.s and gravitational acceleration. same hein)

Just for fun!

$\left(\frac{ac/b}{a}\right)$

$\left(\Rightarrow \frac{ac}{b} \times \frac{1}{a}\right)$

$\left(\Rightarrow \frac{c}{b}\right)$

$g = \frac{F_G}{m}$

$g = \frac{G m_0 m_E / r^2}{m_E}$ $\left(\because F_G = G\frac{m_1 m_2}{r^2}\right)$

$g = G\frac{m_0}{r^2}$ (As, 'G' is constant)

$g \propto \frac{m_0}{r^2}$

Conclusion:-
- $g \propto m_0$
- $g \propto 1/r^2$

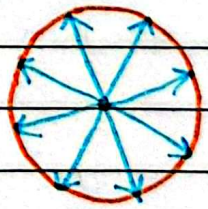
Question related:
Define GFS with the help of mathematical derivation and diagram.

GRAVITATIONAL FIELD LINES

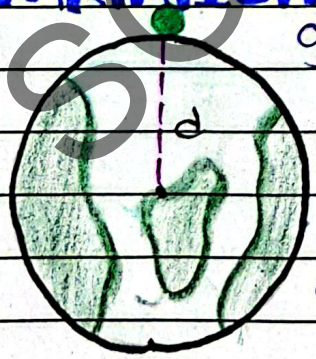
→ G.F.S inc. when the object moves towards centre
→ G.f.S dec. when the object moves against/away from the centre

Outside the sphere:-
When u are outside the sphere the G.f acts as if all the mass is concentrated in the centre of the sphere

Inside the sphere:-
When u are inside the sphere, due to point mass, the outer field is uniform.



VARIATION OF 'g' WITH ALTITUDE



$g = \frac{F_G}{m_0}$ $\left(F_G = G\frac{m_1 m_2}{r^2}\right)$

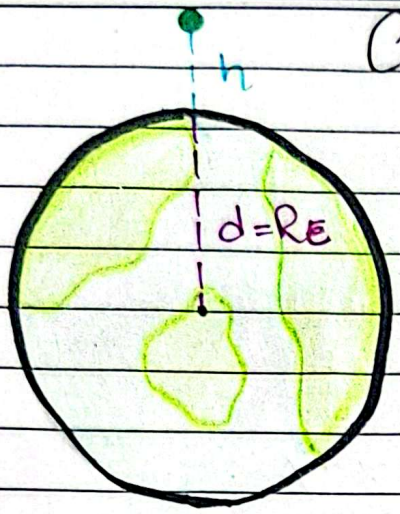
$g = G\frac{m_E m_0}{r^2 \cdot m_0}$

(a)

$g = G\cdot\frac{m_E}{r^2}$

Case 1:-
when, $d = r$
$(d)r = R_E$

Date: _____



Case # 02:- when, $r = R_E + h$

$$g = \frac{F_G}{m}$$

$$= G\frac{m_E m_0}{(r_E + h)^2} \Big/ m_0$$

$$= G \cdot \frac{m_E m_0}{(r_E + h)^2 \cdot m_0}$$

$$= G\frac{m_E}{(r_E + h)^2}$$

$$\left(F_G = G\frac{m_0 m_E}{r^2}\right)$$

MCQ RELATED

Q find the value of 'g' on the earth surface.

$$g_h' = \frac{G M_e}{(r_e + h)^2}$$

$$g_h' = \frac{G \cdot M_e}{(r_e + r_e)^2}$$

$$g_h' = \frac{G \cdot M_e}{(2r_e)^2}$$

$$g_h' = \frac{1}{4} \times \left[\frac{G \cdot M_e}{(r_e)^2}\right]$$

$$g_h' = \frac{1}{4} \times g' = \frac{g}{4} = \frac{9.8}{4}$$

$$g_h' = 2.45\ ms^{-2}$$

Just for fun :)

Q Calculate the value of 'g' through equation 'a'.

$$\rightarrow g = G\frac{M_E}{R_E}$$

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

$$g \approx 9.8\ ms^{-2}$$

$M_E = 6\times10^{24}\ kg$

$r_E = 6.4\times10^{6}\ m$

$G = 6.67\times10^{-11}\ Nm^2/kg$

Note :- Change in value of 'g' is noticed at long distances only.

ASSIGNMENT 15.2

Date: 11- July -2025

DATA

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

$R_E = 6.4 \times 10^6\ m$

$M_E = 6 \times 10^{24}\ kg$

$h = 35.7 \times 10^6\ m$

REQUIRED

$g_h = ?$

FORMULA

$$g_h = G\frac{M_e}{(R_e + h)^2}$$

CALCULATION

$$g_h = G\frac{M_e}{(R_e+h)^2} = (6.67 \times 10^{-11}) \times \frac{(6 \times 10^{24})}{((6.4 \times 10^6) + (35.7 \times 10^6))^2}$$

$$g_h = 2.3 \times 10^{-1}\ ms^{-1}.$$

Therefore, the value of 'g' at 35,700 km above earth is very low as compared to it value at the surface of earth.

ASSIGNMENT 15.3

DATA

$g_m = 1.6\ N/kg$

$M_{moon} = 7.3 \times 10^{22}\ kg$

$R_{moon} = ?$

FORMULA

$$g_m = G\frac{M_{moon}}{(R_{moon})^2}$$

CALCULATIONS:-

$$g_m = (6.67 \times 10^{-11}) \times \frac{7.3 \times 10^{22}}{(R_{moon})^2}$$

$$(R_{moon})^2 = \frac{(6.67 \times 10^{-11}) \times (7.3 \times 10^{22})}{1.6}$$

$$= 3.04 \times 10^{12}.$$

$$R_{moon} = \sqrt{3.04 \times 10^{12}}$$

$$= 1.74 \times 10^6\ m.$$

Therefore, the radius of moon is 1.74×10^6 m.

SATELLITES & ORBITS

Date: 14 July 2025

"A satellite is any object that orbits the Planet due to the force of gravity, maintaining a stable path around it"

Natural Satellite:- (Moon)

A natural body orbiting a planet, where the larger body's gravity dominates the system is called natural satellite.

6 Plantes possess natural Satellite

Artificial Satellites:-

Body orbiting a planet, Placed intentionally by humans.

'Majour Factor, playing key role in the story of satellites is 'Gravity'

Gravity actually holds the Satellite

Other than bk!!

- linear Velocity!
- $S = vt \Rightarrow v = \frac{S}{t}$
- $t = T$ (Time Period)
- $S = 2\pi r$ (Circumference)
- $V = \frac{2\pi r}{T}$ (along the tangent)
- Orbital Velocity!
- $\omega = \frac{2\pi r}{T}$
- $\omega = 2\pi \times {}^{1}/_{T}$
- $\left(f = {}^{1}/_{T}\right)$
- $\omega = 2\pi f$

When, Launching a Satellite, its initial velocity matters a lot. & Satellite launched at low speed attains circular or nearly circular trajectory. where as, when the satellite is launched at high speed, it attains elliptical path.

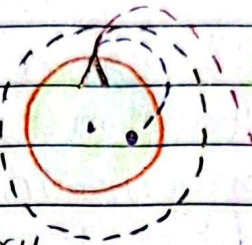
Note:-

0.1% error in launching of satellite can cause, the loss of Trillions of Dollars!

"CASES-Of-LAUNCHING-A-SATELLITE"

Date: 14th July-2025

1. ⇒If Satellite is launched at low velocity, then it will return back to the earth.
2. ⇒If the Satellite is launched at high velocity, then, it will attain a constant circular trajectory
3. ⇒If the Satellite is launched at extremely high velocity, also called as 'escape velocity' then it will escape from earth's gravitational field and would get lost somewhere in universe.



Role of Elon Musk!!

- Introduced Star Link which is sort of Satellite Internet.
- And Duniya k har kone mein os Internet ki sewice mille gi

~METHOD-OF-LAUNCHING-A-SATELLITE~

This methodology or tip was actually introduced by Sir Isaac Newton

"Launching the Satellite from high Altitude, along the tangent to earth's Surface"

The concept Newton gave was that 'If we launch a canon ball

Interesting info!!

- Space missions costs alot, At NASA b/w every 2 missions there is atleast gap of 2-6 months on average.
- Cost of Such missions is more or less $1.5 billion
- This is because every single mission requires a complex and carefully planned Process to ensure mission success!

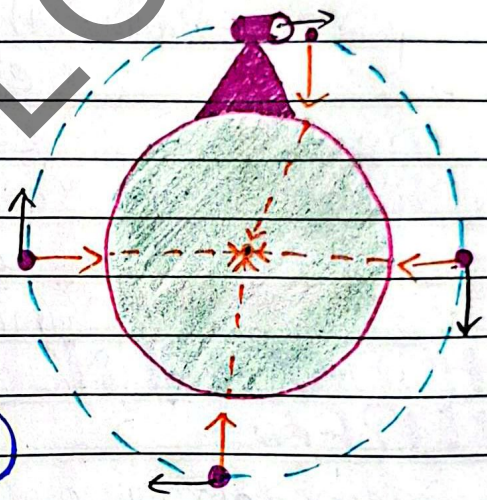
- Majour Space Missions are launched by .)America .)Russia .)China
- India is also an emerging country in this field

tangential to the surface of earth at orbital velocity then it will attain circular trajectory.

PKMZ story:-

Jab canon ball earth se max. distance cover ker le ga tou wo chahe ga k agay b wo along the tangent move kare. but, earth ki gravitational field os ko apni taraf attract krti he, is wajah se wo bechari ball na along tangent ja paati he na gravitational pull ki wajah se inwards, darmian mein stuck ho jaati he and maslehat k tehet circular path apt. kr leti he.

Agar $9.8\ ms^{-2}$ ki value micro seconds k liye b change ho jaaye tou ye sari satellites universe mein ghum jain gi.



QUESTIONS RELATED

Q:1 Why it is necessary to put satellite in right orbit?

So that the satellite revolves around the earth, otherwise either it will escape or return to the earth

Q:2 Why we put satellite in circular or nearly circular orbit?

Because it requires least energy.

Date: 14th July

Q:2 If we will give

Q:3 What will happen if the provided velocity is greater than orbital velocity?

① Satellite will break the orbit and escape out
② " " move in eliptical path.

Q:4 Explain how a satellite is launched in an orbit. What are necessary conditions?

- Tangential to the surface of earth
- Sufficient Altitude to reduce Air Resistance
- Correct tangential/orbital velocity (7.9 km/s)
- Direction (Initially vertical, later horizontal)
- Balance between Velocity & Gravity.

Q:5 Why Rocket isnt launched diagonally?

(i) Atmospheric resistance [Launching vertically first helps the rocket move quickly through the thickest part of the atmosphere, Avoiding DRAG and FUEL LOSS.]

(ii) Gravity Loss [Reduces time spent Fighting Gravity · Once high enough, rocket tilts - GRAVITY TURN - to reach orbital path.]

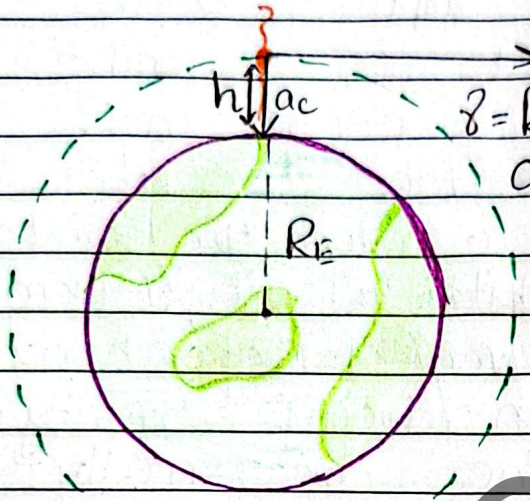
(iii) Efficient trajectory [first upward, then gradual turn to horizontal orbit path is the most fuel efficient Path.]

(iv) If the rocket is moving with high velocity, then it might cross the Earths gravitational field.

ORBITAL VELOCITY

Date: 15th July 25

'Velocity required by a Satellite to Orbit the Earth or any celestial body at any specific Altitude.'



$r = R_E + h$

$a_c = g$

Escape Velocity
Agr Satellite ko earth ki gravitational field ki range se bahar bhejna ho, tou jis velocity se launch krte hein wo escape velocity hoti he

LQs-

Q Derive Orbital Velocity for A.S?

A.S = Artificial Satellite

$\because a_c = \frac{V_o^2}{r_o}$

$r_o a_c = V_o^2$

$V_o^2 = r_o a_c$

$V_o^2 = r_o g$ — i

$V_o = \sqrt{r_o g}$ — ii

$\because g = G \frac{M_E}{(R_E+h)^2}$

$V_o = \sqrt{\frac{r_o G M_E}{(R_E+h)^2}}$

$r_o = (R_E + h)$

$\Rightarrow V_o = \sqrt{(R_E+h) \cdot \frac{G M_E}{(R_E+h)^2}}$

$$V_o = \sqrt{\frac{G M_E}{(R_E+h)}}$$

Date: _____

SQ 3-

Q On which factors the value of orbital velocity depends?

($V_o \propto \sqrt{M}$) (1) Mass of Planet

($V_o \propto 1/\sqrt{r}$) (2) Distance between Satellite and Planet

SLO Based

Q How the shape of Orbit of Artificial Satellite affects its speed?

When the satellite moves in elliptical path then its speed varies due to the variation in radius. However in circular orbit its speed remains constant.

Satellite close to gravitating body → Moves faster

Satellite away from gravitating body → Moves Slower

ASSIGNMENT 15.4

DATA

$h = 6.4 \times 10^6$ m

$R_E = 6.4 \times 10^6$ m

$M_E = 6 \times 10^{24}$ kg

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

FORMULA

$$V_o = \sqrt{G \frac{M_E}{R_E + h}}$$

CALCULATIONS

$$V_o = \sqrt{(6.67 \times 10^{-11}) \times \frac{(6 \times 10^{24})}{(6.4 \times 10^6 + 6.4 \times 10^6)}}$$

$V_o = 5562.15$ ms^{-1}

RESULT

Therefore, the orbital speed of satellite is 5562.15 ms^{-1}

"GEO STATIONARY SATELLITE"

"A Satellite which remains stationary above some point on earth"

(Also called as Geosynchronous Satellite)

Q Derive the expression for geostationary orbits.

Derivation:-

$$V_o = \sqrt{G\frac{M_e}{r}} \quad \text{— i}$$

As,

$$V = \frac{S}{t} = \frac{2\pi r_o}{T} \quad \text{— ii}$$

As both relations are of 'V' so, by comparing them:-

$$\Rightarrow \frac{2\pi r_o}{T} = \sqrt{G\frac{M_e}{r_o}}$$

Squaring both sides

$$\Rightarrow \left(\frac{2\pi r_o}{T}\right)^2 = \left(\sqrt{G\frac{M_E}{r_o}}\right)^2$$

$$\Rightarrow \frac{4\pi^2 r_o^2}{T^2} = G\frac{M_E}{r_o}$$

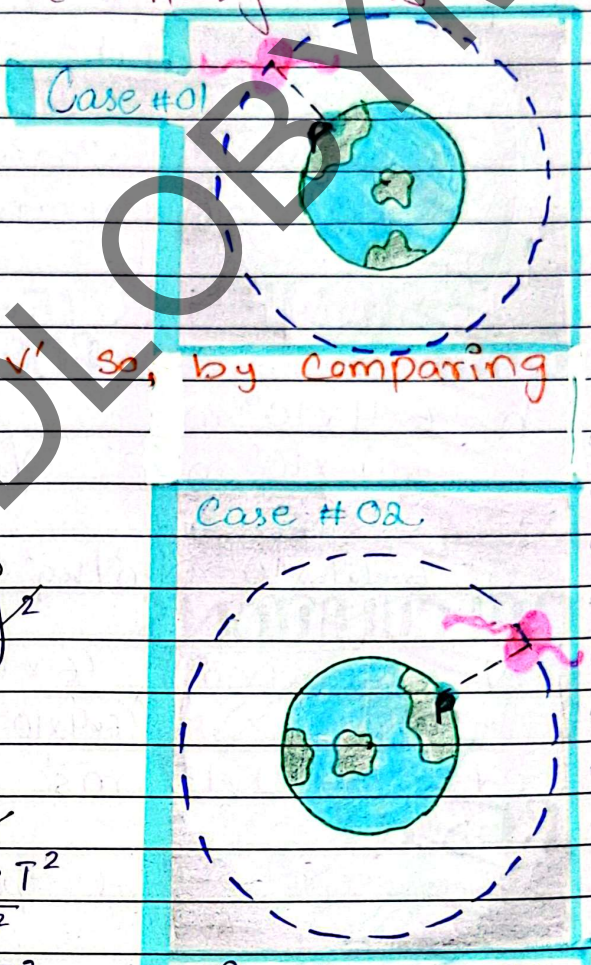
By Rearranging

$$\Rightarrow r_o^2 \times r_o = G\frac{M_E \times T^2}{4\pi^2}$$

$$\Rightarrow r_o^3 = G\frac{M_E \times T^2}{4\pi^2}$$

By Taking Cube root

$$\Rightarrow r_o = \left(G\frac{M_E \times T^2}{4\pi^2}\right)^{1/3}$$



QUESTIONS RELATED

Date: _____

LQ Derive value of 'r' and 'v' for an geo-stationary satellite.

Calculation of orbital radius for geo stationary satellite:- As,

$$r = \left(G \frac{M_E \times T^2}{4\pi^2}\right)^{1/3}$$

Therefore,

$$r = \left[\frac{(6.67\times10^{-11})(6\times10^{24})(3.14)^2}{4\times(3.14)^2}\right]^{1/3}$$

$$r = 4.23\times10^{7}\ m$$

Calculate the orbital speed of ge... satellite:- As,

$$V_o = \sqrt{\frac{G M_E}{r}}$$

Therefore,

$$V_o = \sqrt{\frac{(6.67\times10^{-11})(6\times10^{24})}{(4.23\times10^{7})}}$$

$$V_o = 3.076\times10^{3}\ m/s$$

Q find the orbital radius of earth around the sun.

$$r = \left[\frac{G M_E T^2}{4\pi^2}\right]^{1/3}$$

$$r = \left[\frac{(6.67\times10^{-11})(6\times10^{24})(3.2\times10^{7})^2}{4(3.14)^2}\right]^{1/3}$$

$$r = \left[\frac{(6.67\times10^{-11})(6\times10^{24})(3.2\times10^{7})^2}{4(3.14)^2}\right]^{1/3}$$

$$r = 218141905\,0\ m$$

$$r = 2.2\times10^{9}\ m$$

ASSIGNMENT 15.5

DATA

$G = 6.67\times10^{-11}$

$M_E = 6\times10^{24}$

$R_E = 6.4\times10^{3}$

$T = 24\ h = 86400\ s$

FORMULA

- $r = \left(G \frac{M_E \times T^2}{4\pi^2}\right)^{1/3}$
- $h = r - R_E$

REQUIRED

- $h = ?$

"CALCULATIONS"

$\therefore h = r - R_E$

$= 4.23\times10^{7} - 6.4\times10^{6}$

$= 3.589\times10^{7}\ m$

GRAVITATIONAL POTENTIAL

Date: 17th July 2025

Gravitational Potential is the work done per unit mass to bring a body from infinity to a point in gravitational field.

At infinity g = 0 or nearly 0

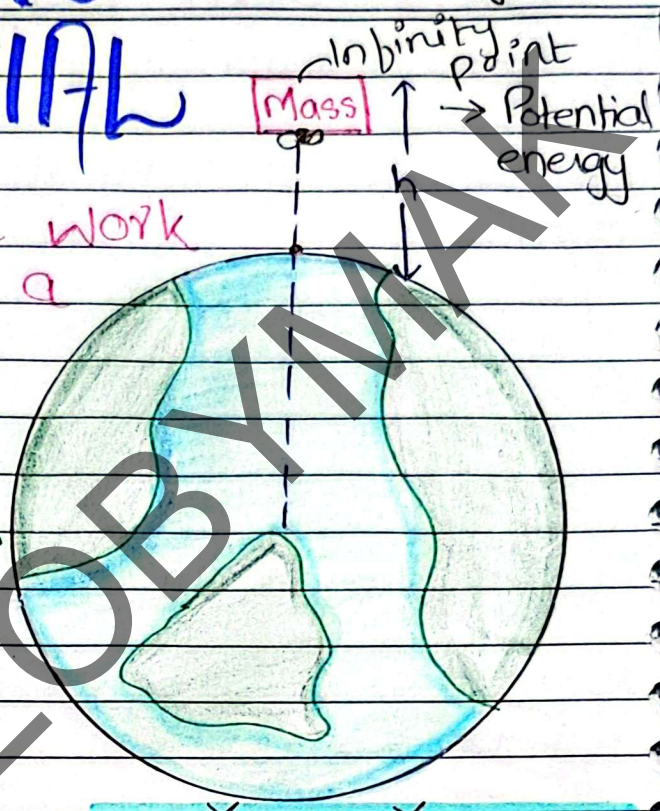


fig :- A

PKMZ

eik object ko surface of earth se utha ker eik infinity point tk le jain jahan gravity negligable ho wahan os object mein ya os mass mein kitna potential he os ko kehte hein Gravitational Point.

Q Differentiate between gravitational Potential and gravitational potential energy.

DERIVATION

18th July (LONG QUES)

Our goal is to find P.E from earths centre to infinity where g = 0

Since from work-Energy Principal

$\Delta P.E = W_{net}$ (i)

Point to Ponder!!

Q Why we use G.P?

x Here for Potential energy calculation we cant use formula P.E = mgh as it has some x limitations. Value of g decreases above the surface of earth continiously x So for that we use gravitational Potential

Date: 18th July 2025

Since the total work done is given by :-

$$W_T = W_1 + W_2 + W_3 + \ldots\ldots + W_{n-1} + W_{n-2} \quad \text{(ii)}$$

Now Calculating the work done :-

$W_1 = F \cdot d$

$W_1 = \vec{F}_{av} \cdot \vec{\Delta r}$ (F_{av} :- Because force is Variable

$W_1 = f_{av} \Delta r \cos\theta$ ($\theta = 180$)

$W_1 = f_{av} \Delta r \cos(180)$ ($\cos 180 = -1$)

$W_1 = -F_{av} \Delta r$ (iii) (here -ve sign shows opposite direction)

(As according to newton..)

$$F_{av} = G \frac{m_1 m_E}{r_{av}^2} \quad \text{(iv)}$$

(Putting eq (iv) in (iii) then,)

$$W_1 = -\left(G \frac{m_1 m_E}{r_{av}^2}\right) \cdot \Delta r \quad \text{(v)}$$

Since, the value of force changes by varying the distance between 2 masses, so we need to take the average force by considering 'r' distance.

Calculating for r_{av}^2 :- 21st July

$$r_{av} = \frac{R_E + r_1}{2} \quad (\because r_1 = R_E + \Delta r)$$

$$r_{av} = \frac{R_E + (R_E + \Delta r)}{2}$$

$$r_{av} = \frac{2R_E + \Delta r}{2} \Rightarrow r_{av} = \frac{2R_E}{2} + \frac{\Delta r}{2}$$

$$r_{av} = R_E + \frac{\Delta r}{2} \quad \text{x}$$

(By Sq. on b.s)^2

$$(r_{av})^2 = \left(R_E + \frac{\Delta r}{2}\right)^2$$

(as, $(a+b)^2 = a^2 + 2ab + b^2$)

Q Why are we taking average F.P (Force).

$F = G \frac{M_1 M_2}{r_{av}^2}$

We are considering Average force because force k formula mein sirf eik cheez variable he 'Radius' baqi sab constant hota he. So r ka effect atta he force par.

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$$(r_{av})^2 = (R_E)^2 + \left(\frac{\Delta r}{2}\right)^2 + 2(R_E)\left(\frac{\Delta r}{2}\right)$$

$$(r_{av})^2 = R_E^2 + \frac{\Delta r^2}{4} + R_E \cdot \Delta r$$

where, $\Delta r << R_E$

$$r_{av}^2 = R_E^2 + R_E \Delta r$$

$(\because r_1 = R_E + \Delta r) \Rightarrow (\Delta r = r_1 - R_E)$

$$(r_{av})^2 = R_E^2 + R_E (r_1 - R_E)$$

$$= R_E^2 + R_E r_1 - R_E^2$$

$$(r_{av})^2 = R_E r_1 \quad \text{— vi}$$

Note that !:
As, Δr is very small value therefore we neglect $\frac{\Delta r}{4}$

PKMZ JUGARH!!
No. 1: $-(G M_E m_1)$ is constant
No. 2: jaise W_1 k liye $\left(\frac{1}{R_E} - \frac{1}{r_1}\right)$ he, waise hi jon sa b W_n he, os k liye $\left(\frac{1}{R_E} - \frac{1}{r_n}\right)$ ho ga!
No. 3: Phir Wnet Per jak cancellation hogi!

(Now Putting equation (vi) in (v))

$$W_1 = -\left(G \frac{m_1 m_E}{r_1 R_E}\right) \cdot (\Delta r)$$

(As, $\Delta r = r_1 - R_E$)

$$W_1 = -\left(G \frac{m_1 m_E}{r_1 R_E}\right) \cdot (\Delta r) \Rightarrow -\left(G \frac{m_1 m_E}{r_1 R_E}\right) \cdot (r_1 - R_E)$$

$$W_1 = -(G \cdot m_1 m_E) \cdot \left(\frac{r_1}{r_1 R_E} - \frac{R_E}{r_1 R_E}\right)$$

$$W_1 = -(G \cdot m_1 m_E) \cdot \left(\frac{1}{R_E} - \frac{1}{r_1}\right) \quad \text{— (vii)}$$

Similarly ! from equation vii, we can write as,

$$\Rightarrow W_2 = -(G \cdot m_1 m_E) \cdot \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\Rightarrow W_n = -(G \cdot m_1 m_E) \cdot \left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

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Now Substituting values in equation (ii), then

$$W_{net} = -GM_1M_E\left[\left(\frac{1}{R_E}-\frac{1}{R_1}\right)+\left(\frac{1}{R_1}-\frac{1}{R_2}\right)+\dots+\left(\frac{1}{R_{n-2}}-\frac{1}{R_{n-1}}\right)+\left(\frac{1}{R_{n-1}}-\frac{1}{R_n}\right)\right]$$

$$= -GM_1M_E\left[\frac{1}{R_E}-\frac{1}{R_1}+\frac{1}{R_1}-\frac{1}{R_2}+\dots+\frac{1}{R_{n-2}}-\frac{1}{R_{n-1}}+\frac{1}{R_{n-1}}-\frac{1}{R_n}\right]$$

$$W_{net} = -GM_1M_E\left[\frac{1}{R_E}-\frac{1}{R_n}\right] \quad \text{— (viii)}$$

from equation (-i-) 22nd July 2025

$$W_{net} = \Delta P.E$$

(By Comparing eq. i and viii)

$$\Delta P.E = -GmM_E\left[\frac{1}{R_E}-\frac{1}{R_n}\right]$$

(But $R_n = \infty$)

$$\Delta P.E = -GmM_E\left[\frac{1}{R_E}-\frac{1}{\infty}\right]$$

$$\Delta P.E = -GmM_E\left[\frac{1}{R_E}-0\right] \quad (\because r = R_E + h)$$

$$U = \Delta P.E = -\frac{GmM_E}{r}$$ → Gravitational Potential energy at infinity

Any Number $= \frac{\infty}{0}$

Any no. $= \frac{0}{\infty}$

Let the no. = 1

$\frac{1}{\infty} = 0$

Absolute P.E :- (A.P.e)

The Amount of Work Done in moving a body from Earths Surface to a point at infinite distance where the value of g is negligible.

We are considering r, instead of R_E, bcz here we are taking it with reference to Absolute P.E

Potential Well

MAN IS TRAPPED IN GRAVITATIONAL W

Date:

So, therefore, the final equation is;-

$$U(r) = -G\frac{M_E m}{r}$$

(Absolute Potential) $(V) = \frac{\text{(Absolute Potential Energy)}}{m}$.

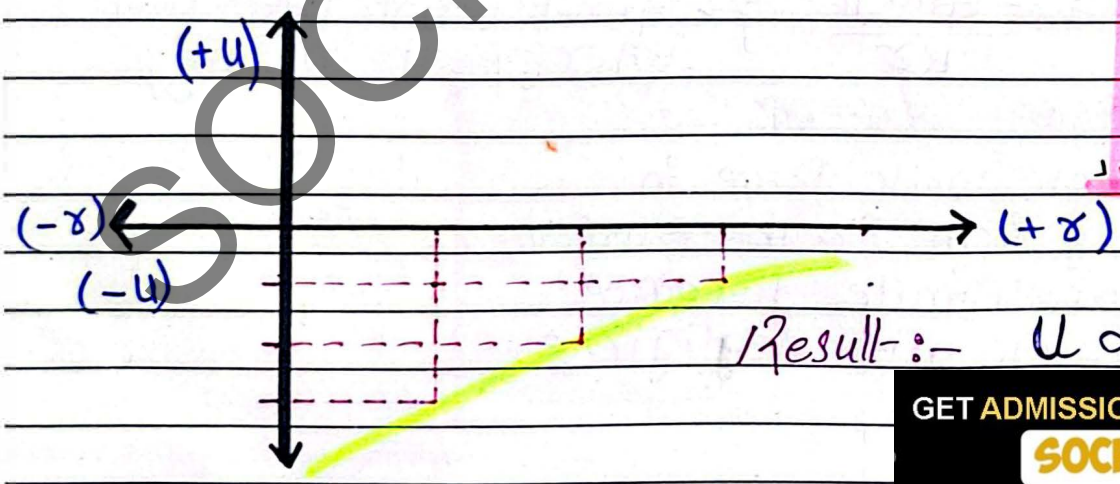
$$V = \frac{U}{m} = \frac{\left(-G\frac{M_E \cdot m}{r}\right)}{m}$$

$$V = -G\frac{M_E}{r}$$

Q Why P-E increases as we move upwards? (above the surface of earth)

$$U(r) = -G\frac{M_E m}{r}$$

$$-U(r) = G\frac{M_E \cdot m}{r}$$



Result:- $U \propto r$

QD/f between g.p.e and A.p.e

g.p.e, surface of earth per hoti, hum formula mein R_E use krte and for A.p.e, ye hota he at infinite point above surface of earth &. in formula we'll simply use r ($\because r = R_E + h$)

hum 'r' ko x-axis per lete and 'U' ko on Y-axis, because U is dependent on 'r'.

$$V = -\frac{GM_E}{r}$$

① $V_{(r)} = -\frac{GM_E}{r}$

$V_{(R_E)} = -\frac{(6.67\times10^{-11})(6\times10^{24})}{(6.4\times10^{6})}$

$V_{(R_E)} = -6.23\times10^{7}$ Nm/kg

② $V_{(2R_E)} = -\frac{GM_E}{2R_E}$

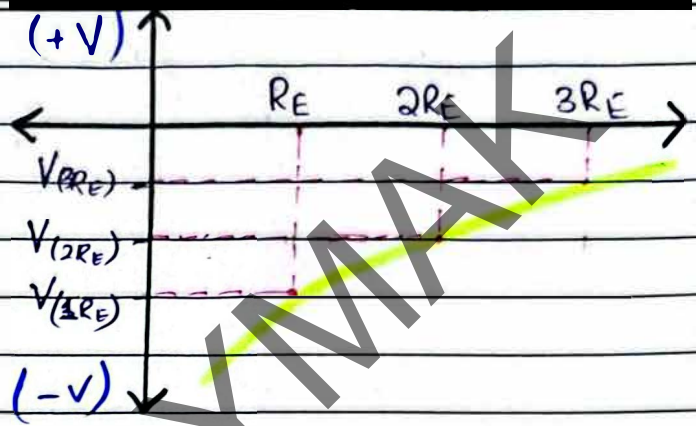
$V_{(R_E)} = -\frac{(6.67\times10^{-11})(6\times10^{24})}{2(6.4\times10^{6})}$

$V_{(2R_E)} = -3.13\times10^{7}$ Nm/kg

③ $V_{(3R_E)} = -\frac{GM_E}{3R_E}$

$= -\frac{(6.67\times10^{-11})(6\times10^{24})}{3(6.4\times10^{6})}$

$V_{(3R_E)} = 2.08\times10^{7}$ Nm/kg



Q Why Absolute potential energy increases with distance?

The original relation b/w A.P.E and 'r' is inverse, butttt!!

After putting -Ve sign, the inverse relation is further inverted and becomes 'Direct Relation'

PKMZ: Potential Well

Imagine, a ball, floating on the surface of water in a well. Now by applying some pulling force it moves upward. When the ball reachs at the upper surface of well, the gravity acting on it is negligable, and once it's out of the well, its at the infity point where no force is acting on it, and $g = 0$.

In the same way, when an object moves upward from the surface of earth, it is due to a 'Pulling' force, i.e. Gravitational Potential.