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Electromagnetism

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- Electrostatic
  - charge and electric field (electrostatic)
  - Gauss law
  - Capacitor
- Electrodynamic
  - Electric current
  - magnetic effect of current
  - Electro magnetic Induction
  - Alternating current.

Board → 50%
JEE → 30 to 35%

* **Electrostatic** mist :→
  - Electro → charge
  - static → something which does not change with time. or something which is at rest

* **charge** → Charge is a fundamental property of any material or matter which is responsible for all electrical phenomena (electrical force)
  - Charge एक Hero है जो स्थिर तो नहीं but इसकी activity स्थिर होती है। इसलिए हम इसे Superhero भी कह सकते है

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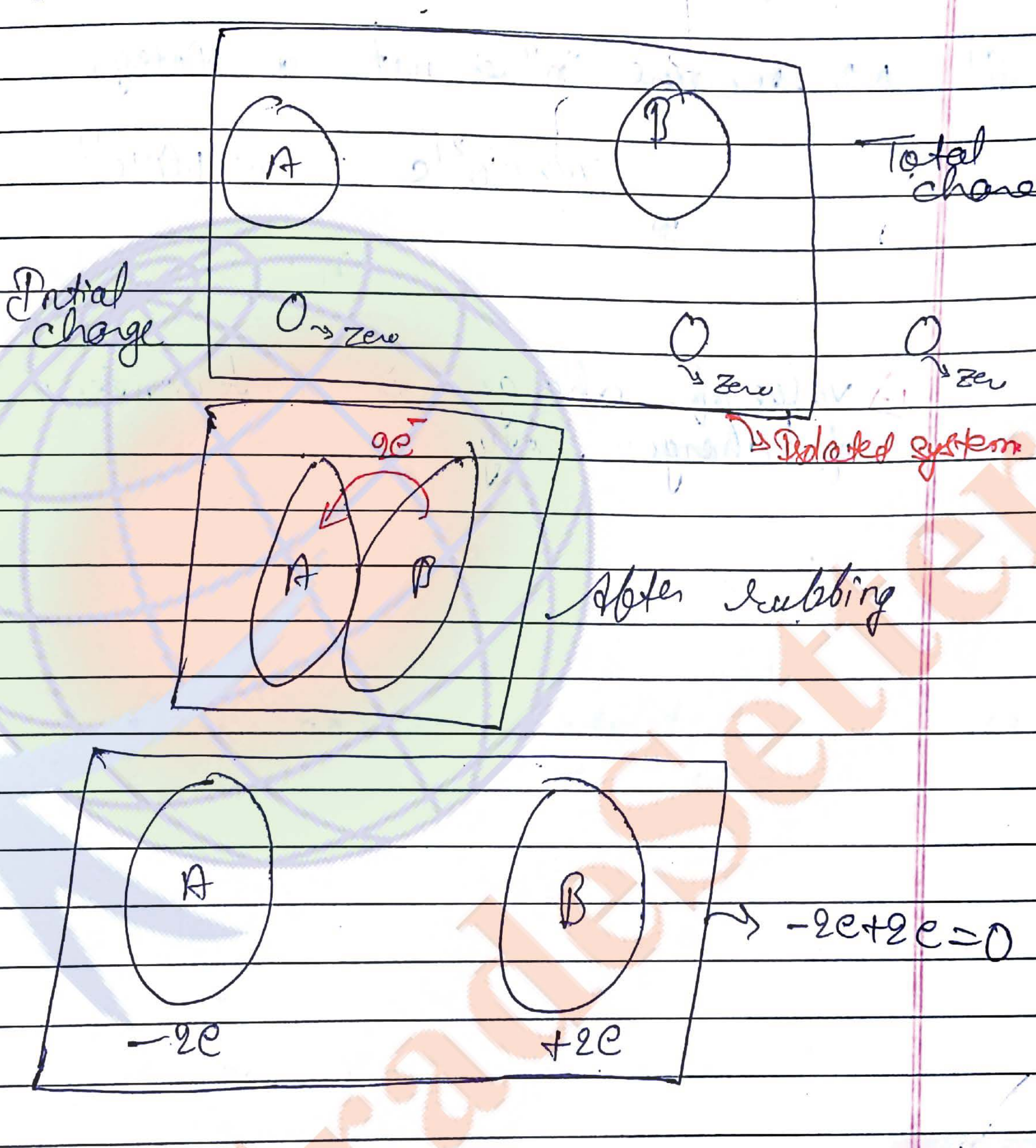
2.) In an Isolated system total charge of the system remain conserved or constant.



3.) charge is quantized.

Charge on any body is always Integral multiple of electronic charge ($e = 1.6 \times 10^{-19} C$)

$Q = \pm ne$

$n = 1, 2, 3 \ldots$

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Method of charging →

- Contact method
  - Friction method
  - Conduction method
- Induction method

1) Friction method :-

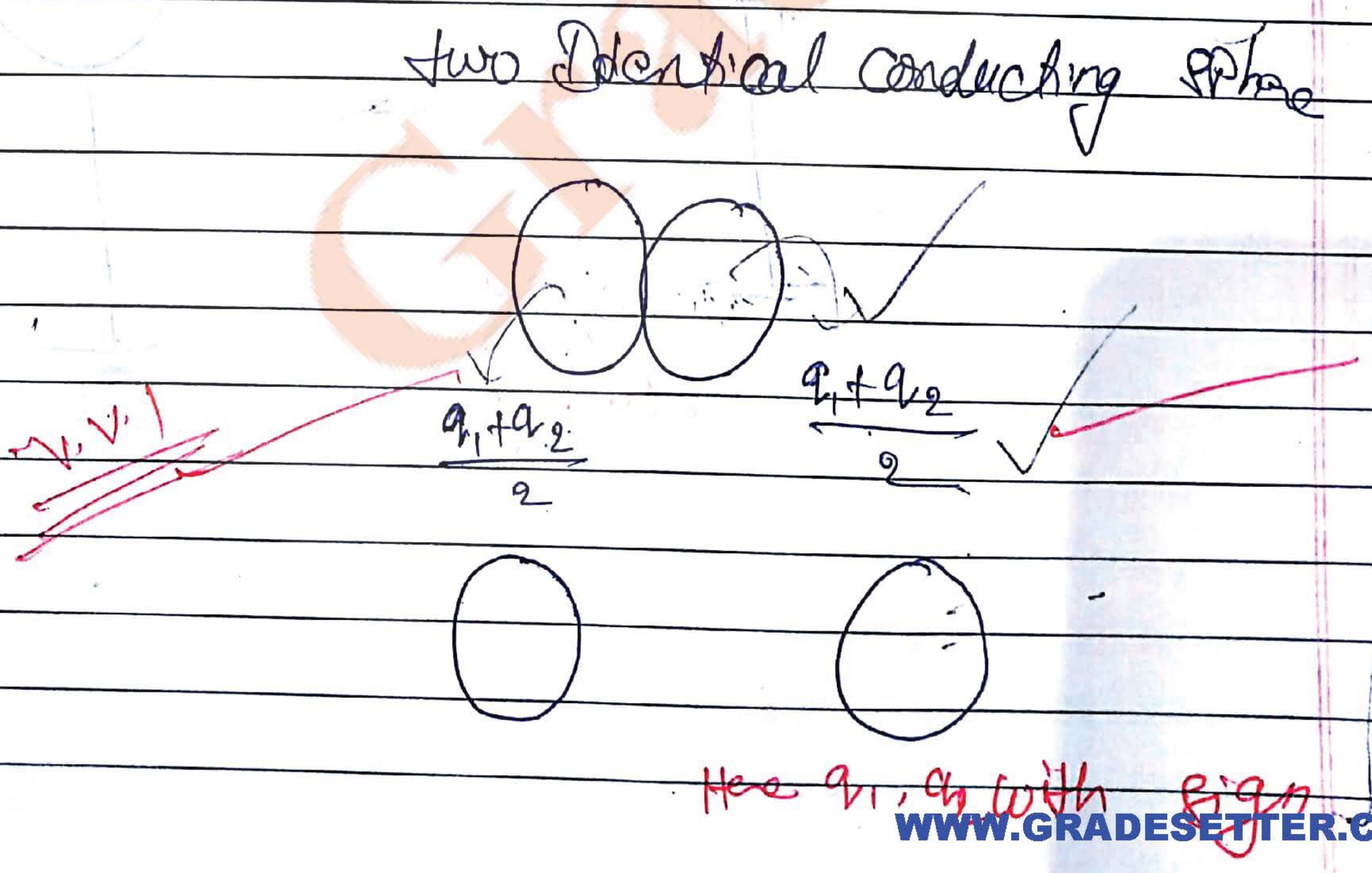
By this method equal and opposite charge come on both rubbed bodies.

11) Conduction method :-

When two conductor in which one should be charge are brought in contact then sharing (equal) of charge take place b/w them.



two identical conducting sphere



Here q_1, q_2 with sign

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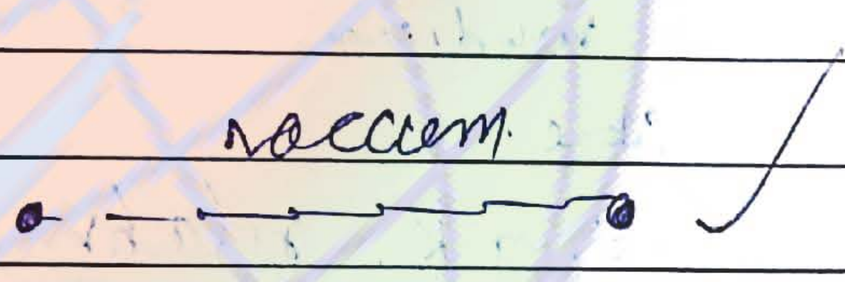
Coloumb law →

1) This law give the electrical force b/w two point charges.



2) This law is applicable only for point charges. but - Hence, to Integral calculus because with the help of that calculus we can determined force b/w large charge body.

3.) Physically point charge does not exist in nature actually it is electrostatic behavior which can be shown by any body on particular condition.



$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

Coloumb law

F = electric force b/w q_1 and q_2
r = seperation b/w point charges.
ε_0 = electrical permittivity of vaccum

→ Permit means permission

When q_1 and q_2 are in a medium rather than in vaccum then permitivity get change thus force b/w charges get change.

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Note

medium

q_1 ——————— q_2

C_m = Electrical Permittivity of medium

$$F_{medium} = \frac{1}{4\pi\varepsilon_m} \frac{q_1 q_2}{r^2}$$

Examine की चलाकी → examiner will not give "ε_m" directed of ε_m he given ε_r or K of medium.

Here

ε_r or K relative Permitivity of medium
or
Di-electric constant of medium

$\because$

$$\varepsilon_r = K = \frac{\varepsilon_m}{\varepsilon_0}$$

$\because$

$$\varepsilon_m = K \times \varepsilon_0 \text{ or } \varepsilon_r \times \varepsilon_0$$

$\because$

$$F_{medium} = \frac{1}{4\pi\varepsilon_0 K} \frac{q_1 q_2}{r^2}$$

Note! →

$$1 \leq K \leq \infty$$

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$K = 1 \Rightarrow$ In vaccum

$K = \infty \Rightarrow$ In metal or Conductor.

Note ➡

4) In vaccum force b/w charge particle is maximum

None

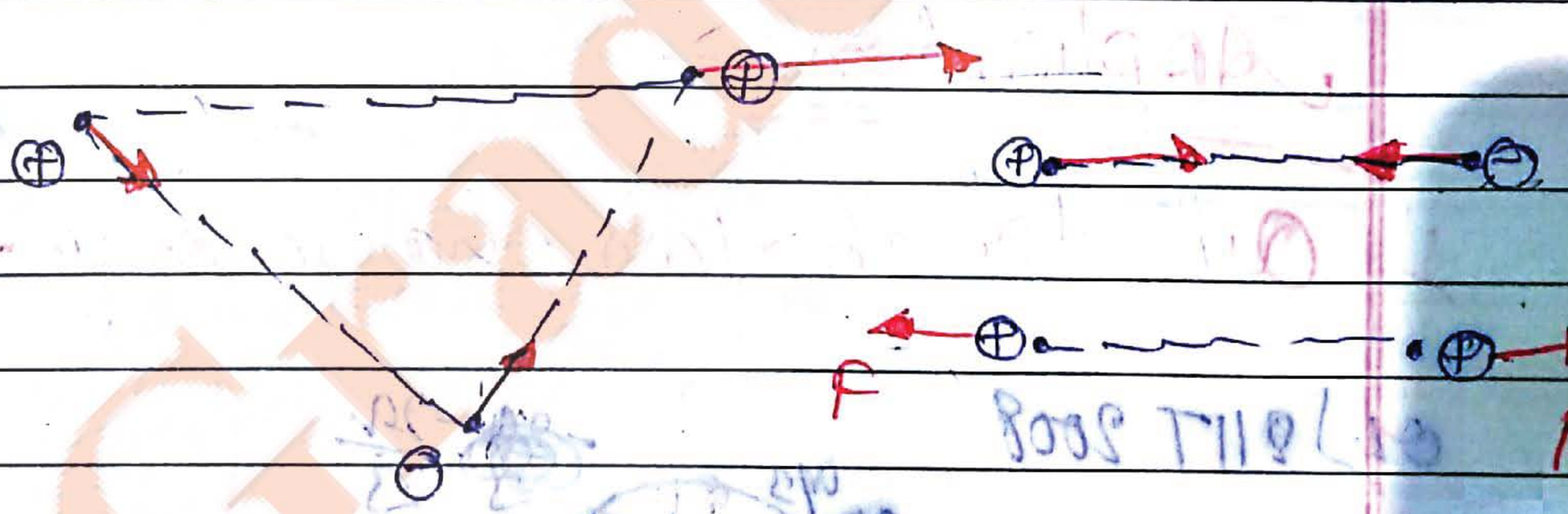
$\varepsilon_0 = 8.85 \times 10^{-12} C^2 m^{-2} N^{-1}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \, N m^2 C^{-2}$

eg! ⇒ 1 C ●---- 1m ----● 1 C

$F = 9 \times 10^9 \, N$

5) Direction of force is along the line joining point charges.



6) Electric force is a conservative force.

7) Electric force follows superposition Principle.

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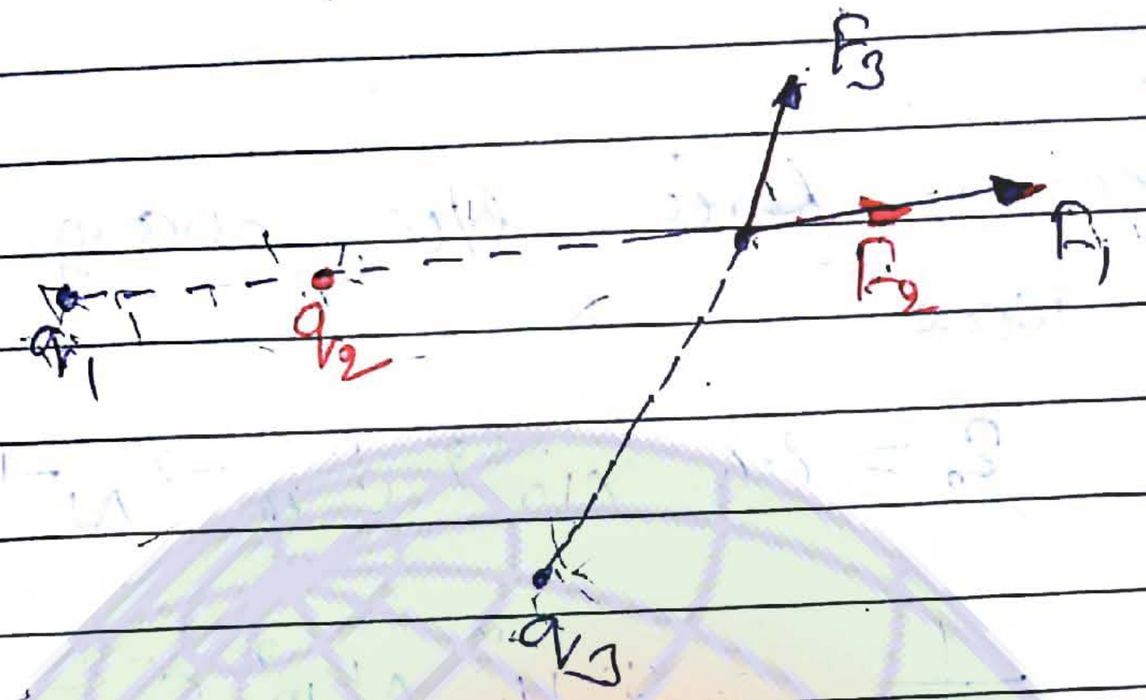
⑦ Superposition Principle →



1) Force b/w two charge particle does not change due to presence of any charge nearby two charges. ∴ but net force on any charge is vector sum of all the individual force acted by individual force.

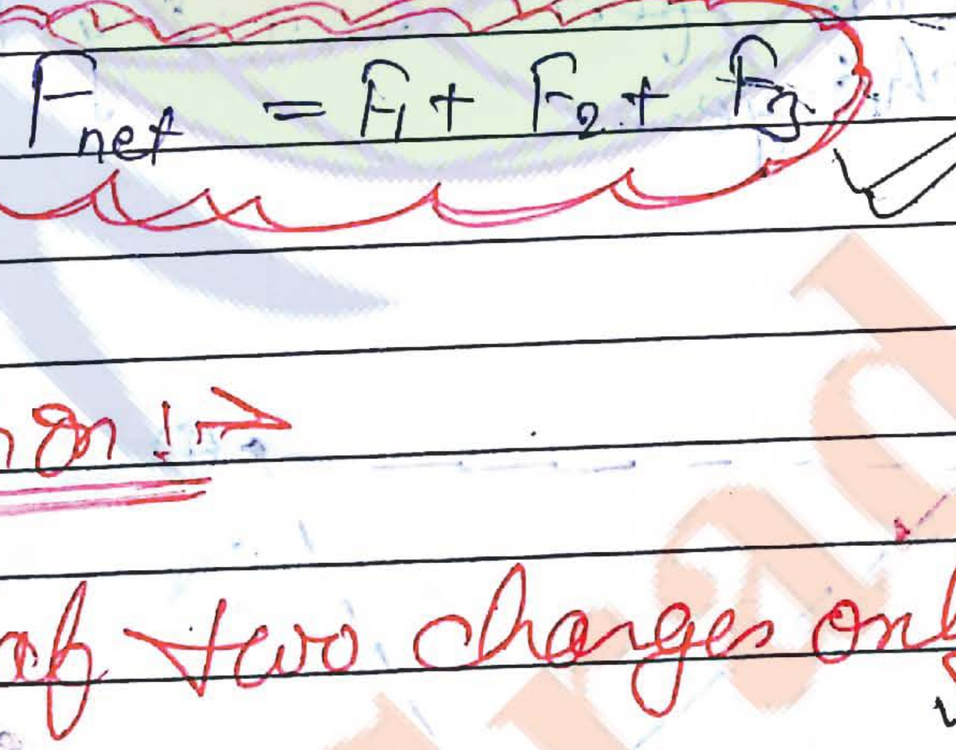
Note यहाँ पर हमारा है निष्कर्ष प्राप्त होते।

$$F_{net} = F_1 + F_2 + F_3$$

Application :→

1) Question of two charges only. →

04.) IIT 2008



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Electric field

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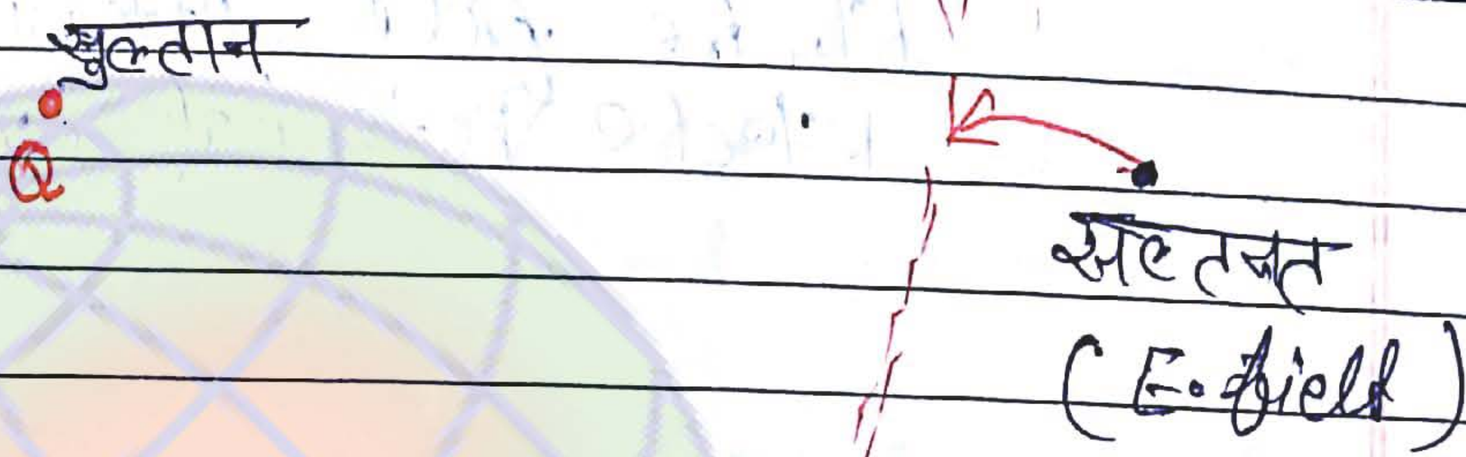
→ It is the region (क्षेत्र) in which the charge body experience electric force



i) • Every charge body, body creates or Produce electric field just like (चुम्बक)

ii) • Electric is a action at a distance force that means ~~to applied~~ no need to touch body to applied force.



(Q creat E. field and this E. field ~~Produce~~ apply force on q.)

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1 Quiz

(iii) To define any point in electric field two properties of electric field are required:-

a) Electric field Intensity (E) vector.
b) Electric Potential (V) scaler.

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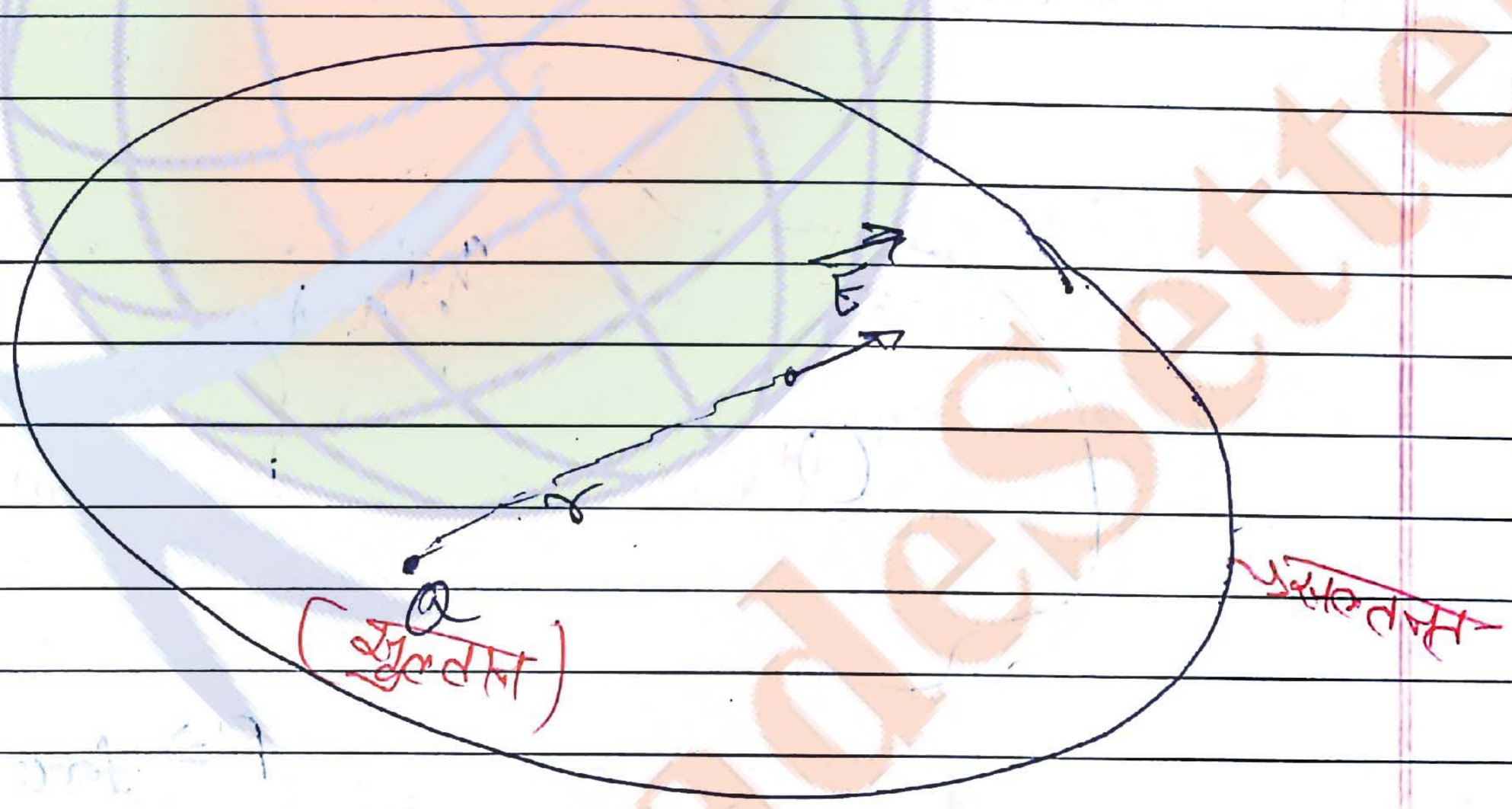
IIT 2018 mains

★ Electric field Intensity ⇒

Electric field Intensity at any point in a electric field is defined as electric force acting on a unit positive point charge if placed at that point.

i) electric field Intensity is (basically ह्रास of गिरी) test like force.



ii) If we know $\vec{E}$ at a point then we can determine force on any charge placed at that point.

$$F = qE$$ q without sign

$$\vec{F} = q\vec{E}$$ q with sign

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Application of formula $F = qE$

(*) Question of kinematics →

i) $S = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$v = u + at$

} + Projectile motion.

ii) Projectile motion →

iii) If a (इलाका + क्षेत्रफल) Region में Magnitude as well as direction of $\vec{E}$ is same at each point such क्षेत्रफल is known as Uniform electric field.

Ques 1.) Two charge particle "A" and "B" have mass but their charges are "q" and "4q" There two particles are released one by one in same uniform electric field (released from rest)
In time t_1 distance travelled by "A" is equal to q distance travel by "B" in time t_2. Determine $\frac{t_1}{t_2}$?

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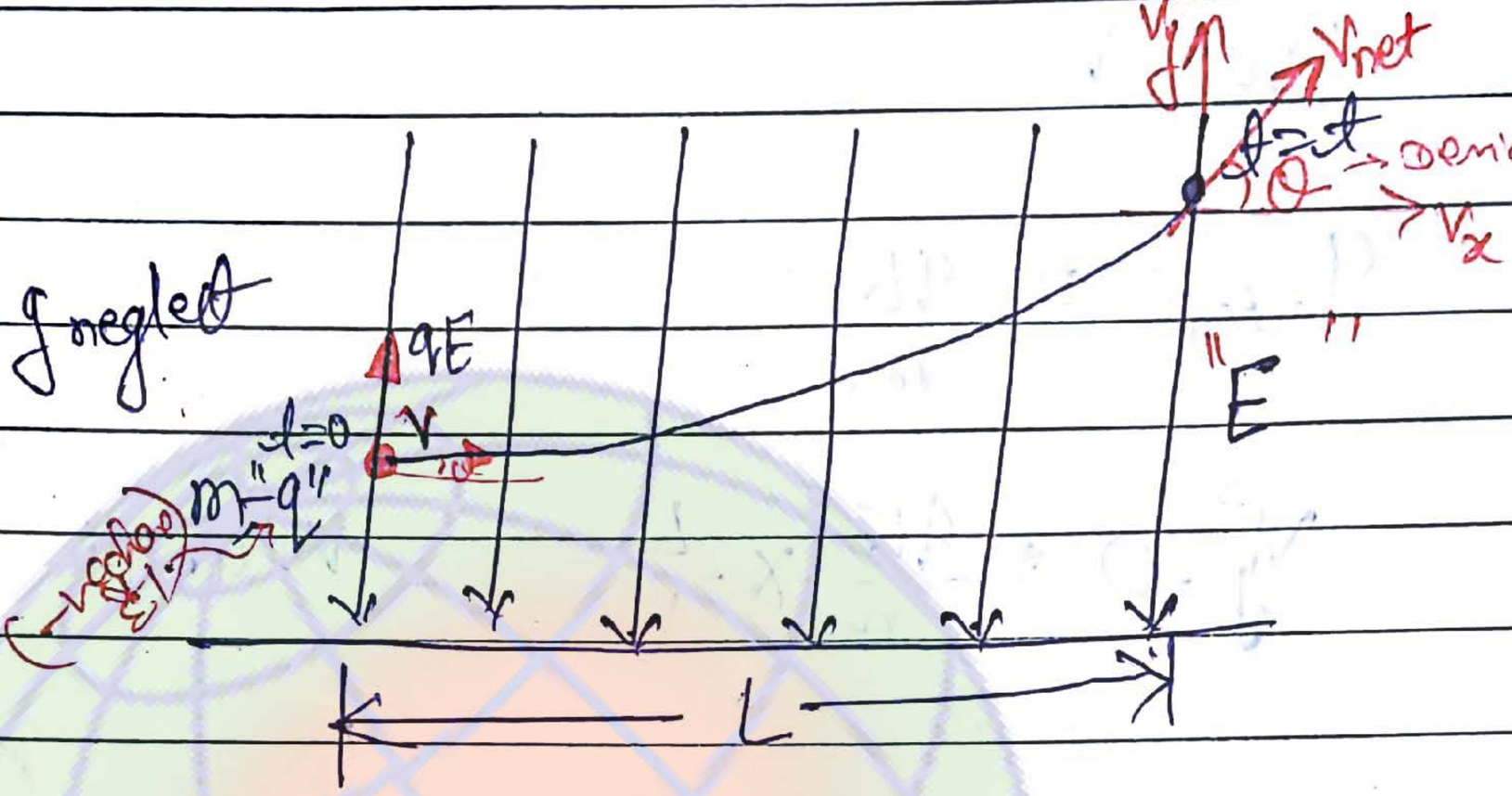
नोट:- -ve charge की force E के opp

दोनों में common time (t) है

Projectile motion →

eg:-



After how much time charge particle is able to exit the electric field

Sol:-

$S_{horizontal} = L$ → distance

$V_{initial} = V$

$a_{horizontal} = 0$ { चूँकी horizontal direction में कोई force नहीं लग रहा है। F=0 होने के लिए (F=ma) का 'a' भी zero होना होगा।

$S = ut + \frac{1}{2}at^2$

$L = Vt$

$$t = \frac{L}{V}$$

(ii) Determine the deviation of charge particle from it's initial direction of motion when it exit the electric field.

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Sol'n $\tan\theta = \frac{v_y}{v_x}$

$v_x = v$

$q_{vertical} = \frac{qE}{m}$

$v = u + at$

$v_y = 0 + \frac{qE}{m} \times \frac{L}{v}$

$v_y = \frac{qEL}{mv}$

$\tan\theta = \frac{qEL}{mv^2}$

(iii) Determine % change in kinetic energy of angle of deviation ($\theta = 60^\circ$)

Sol'n

$$\% \text{ change in K.E} = \frac{\frac{1}{2}mv_{net}^2 - \frac{1}{2}mv^2}{\frac{1}{2}mv^2} \times 100$$

$$\% \text{ change in K.E} = \frac{\text{final} - \text{initial}}{\text{initial}} \times 100$$

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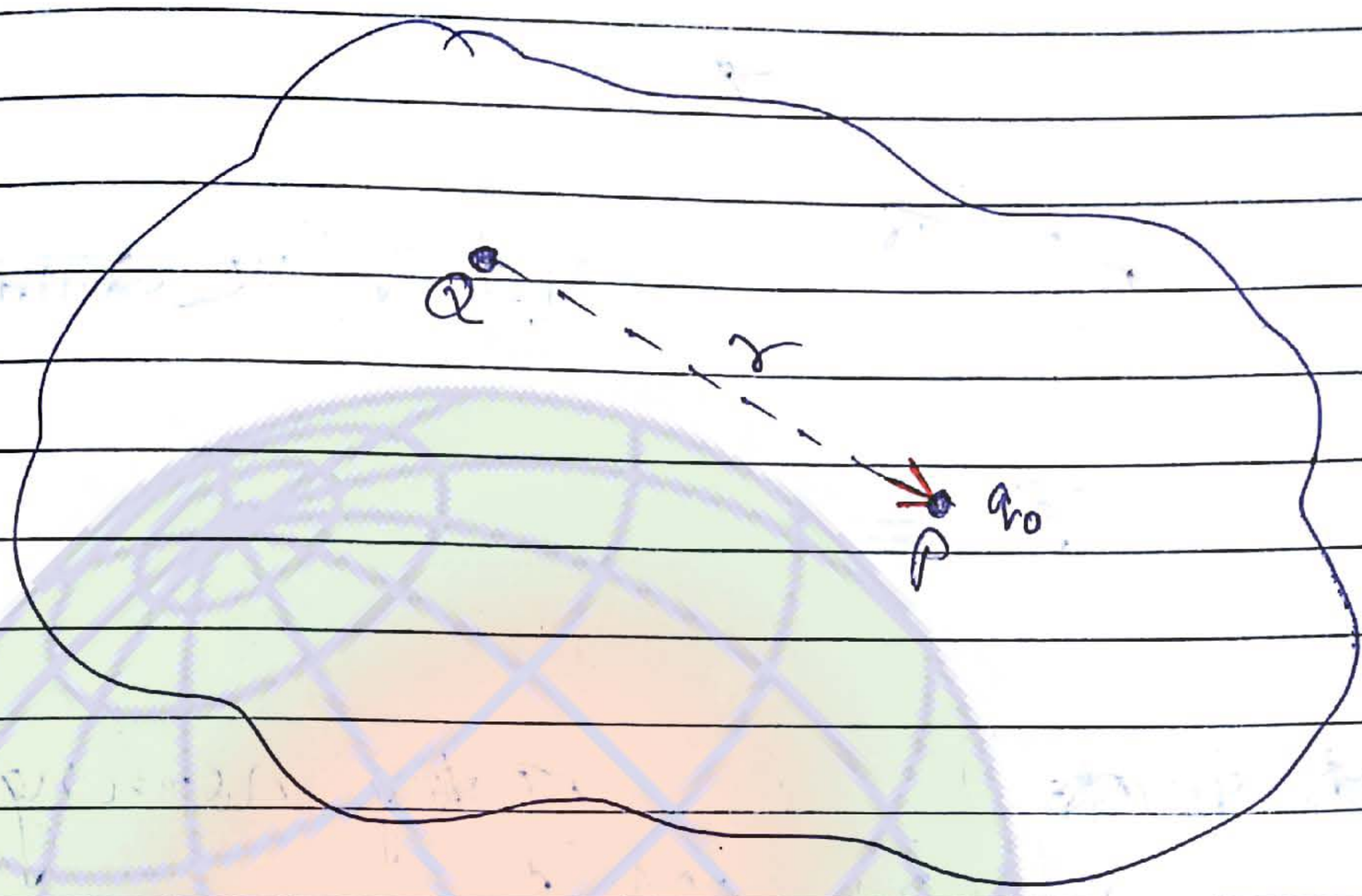
"E" due to Point charge (Sulton) Point charge



$$F = \frac{kQ \times q_0}{r^2}$$

$$E = \frac{F}{q_0} = \frac{kQ}{r^2}$$

$$\vec{F} = \frac{kQ\,q_0\,\vec{r}}{r^3}$$

for,

$$\vec{E} = \frac{kQ}{r^3}\vec{r}$$

(Q कुंज के सापेक्ष)

→ यह formula 3-D का सापेक्ष है।

→ This formula valid in 3-D only.

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Note:->



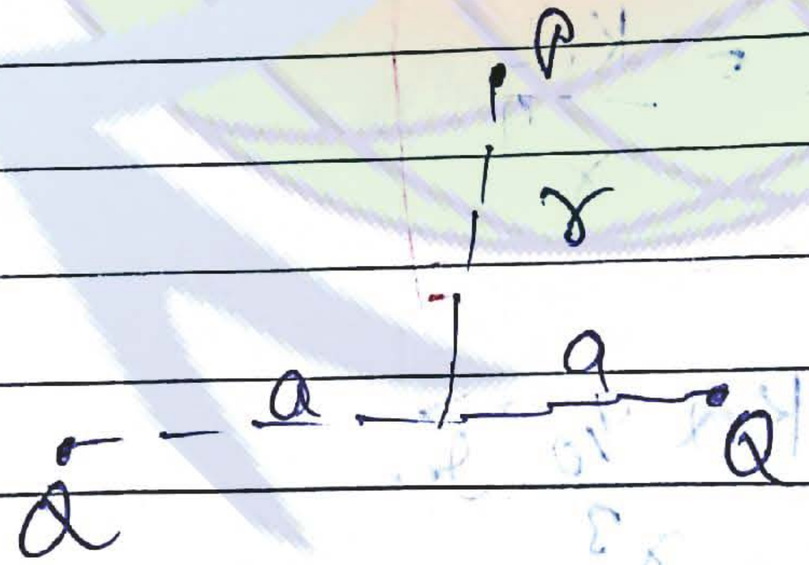
जुड़ी "P" पर बनानी है।

$\vec{E}$ = → electric field Intensity

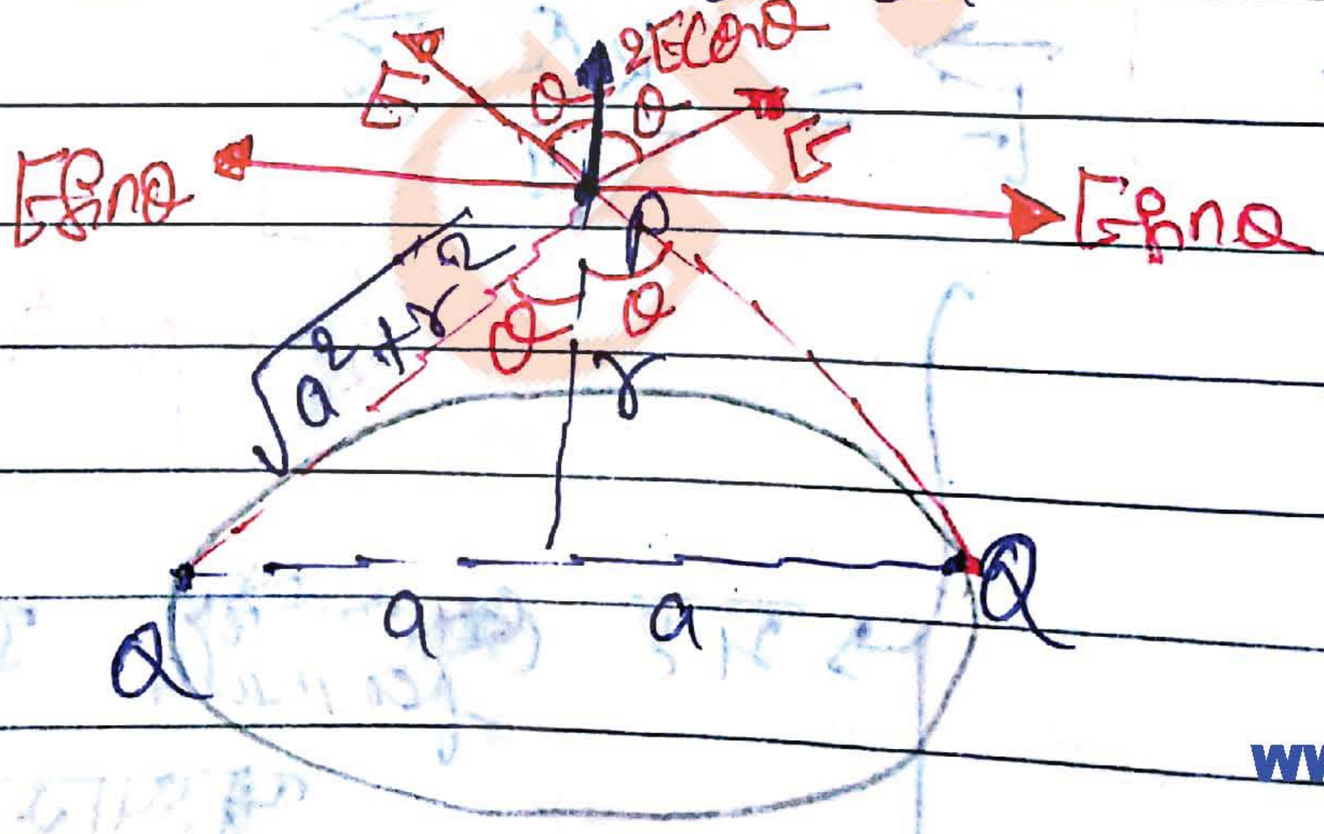
An "E" is nothing but electric field

Therefore it also follows "Superposition Principal"

Q.1



Determine "E" at "P".



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Electric Dipole →

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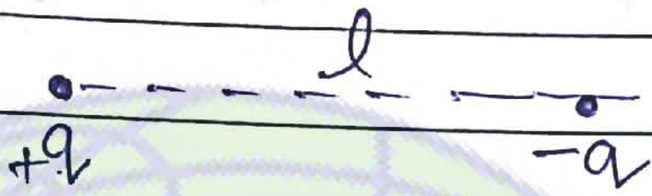
i) Electric dipole is a arrangement in which two equal and opposite charges are placed at certain separation.

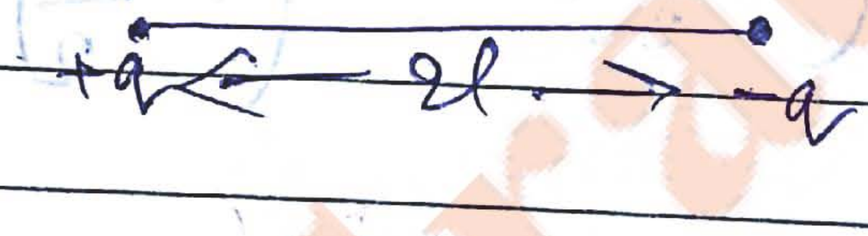


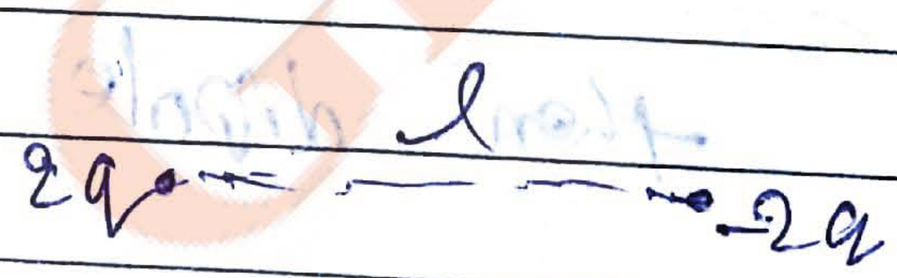
ii) Real life example of dipole →

H_2O, HF, NH_3



iii) To define any dipole, dipole moment is required





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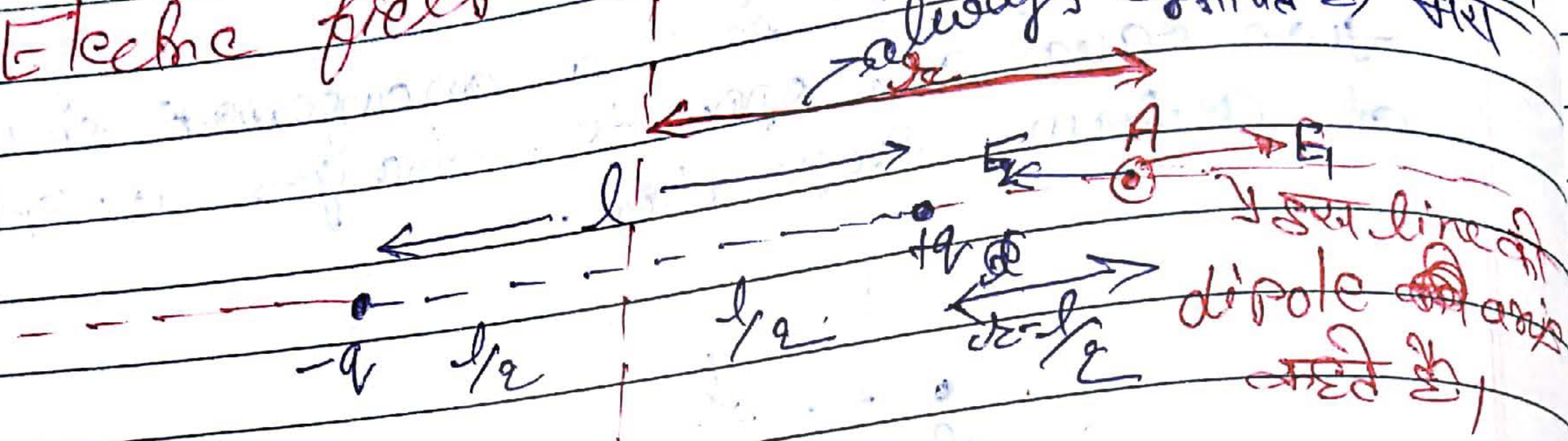
Electric field Intensity due to a dipole

always (हमेशा) ज्ञात होते है) न्यूटन प्रति



dipole axis

→ Equatorial axis.

E at any point on dipole axis ⟹

$\vec{E}_A$ ⇒ vector sum of E of charge "+q" and "−q".

$$= E_1 - E_2$$

$$= \frac{kq}{\left(r-\frac{l}{2}\right)^2} - \frac{kq}{\left(r+\frac{l}{2}\right)^2}$$

If $r >>>>>>>>>> l$

than dipole is short dipole

$$E_A = \frac{kq}{r^2}\left[\left(1-\frac{l}{2r}\right)^{-2} - \left(1+\frac{l}{2r}\right)^{-2}\right]$$

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Note:- In chemistry | In physics

$H^+ \quad Cl^-$ → इसका उल्टा है

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((Chemistry original concept वाला पढ़ें))

$$E_A = \frac{kq}{r^2}\left[1 + \frac{l}{r} - \left(1 - \frac{l}{r}\right)\right]$$

$$E_A = \frac{2kql}{r^3}$$

$\because P = ql$

$$E_A = \frac{2kP}{r^3}$$

$\because E \propto q \times l$

(4) Dipole moment:-

Dipole moment(P) = either charge × separation b/w charge.

$$P = ql$$

△ Dipole moment is a vector quantity it's direction is from "-ve" charge to "+ve" charge



$$P = ql$$

$$\vec{P} = q\vec{l}$$

Notes



$$\vec{P} = q(x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} +$$

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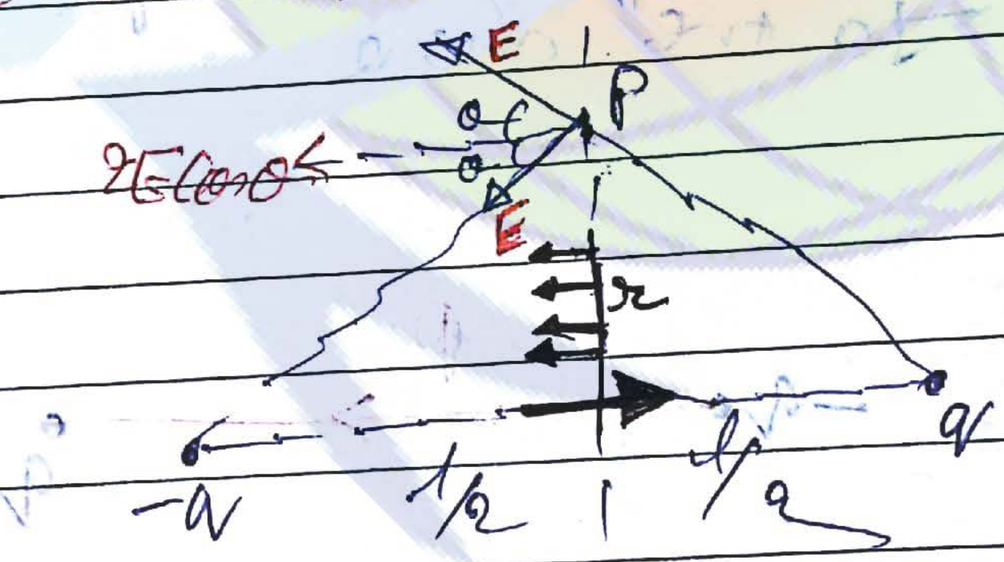
2) unit of dipole is coulomb-meter.

3) At the axis of dipole

$$E_{axis} = \frac{2KP}{r^3}$$ समाद रहें।

4) Imp. बात - At the axis of dipole direction "E" is in the direction of P (dipole) except at those point which lies b/w "-q" and "+q"

5) E at equitorial axis →



E at equitorial axis →

$$E = \frac{kq}{r^2 + \frac{l^2}{4}}$$

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$$\cos\theta = \frac{l}{2\left(r^2 + \frac{l^2}{4}\right)^{1/2}}$$

$$\vec{E}_{net} = 2E\cos\theta$$

$$= \frac{kql}{\left(r^2 + \frac{l^2}{4}\right)^{3/2}}$$

If $r >>>>>>>>>> l$

$$k = \frac{kql}{r^3}$$

$$\boxed{\vec{E}_{Equitorial\ axis} = \frac{kp}{r^3}}$$

$$\boxed{\vec{E}_{axis} = 2\ Equitorial\ axis}$$

Direction of "Equitorial axis" is "Parallel to "p"

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Electric Potential and energy and electric Potential →

I) Electric force is a conservative force and workdone by this force does not depend on the path followed by the particle or body workdone by the electric force depend on Initial and final Position.

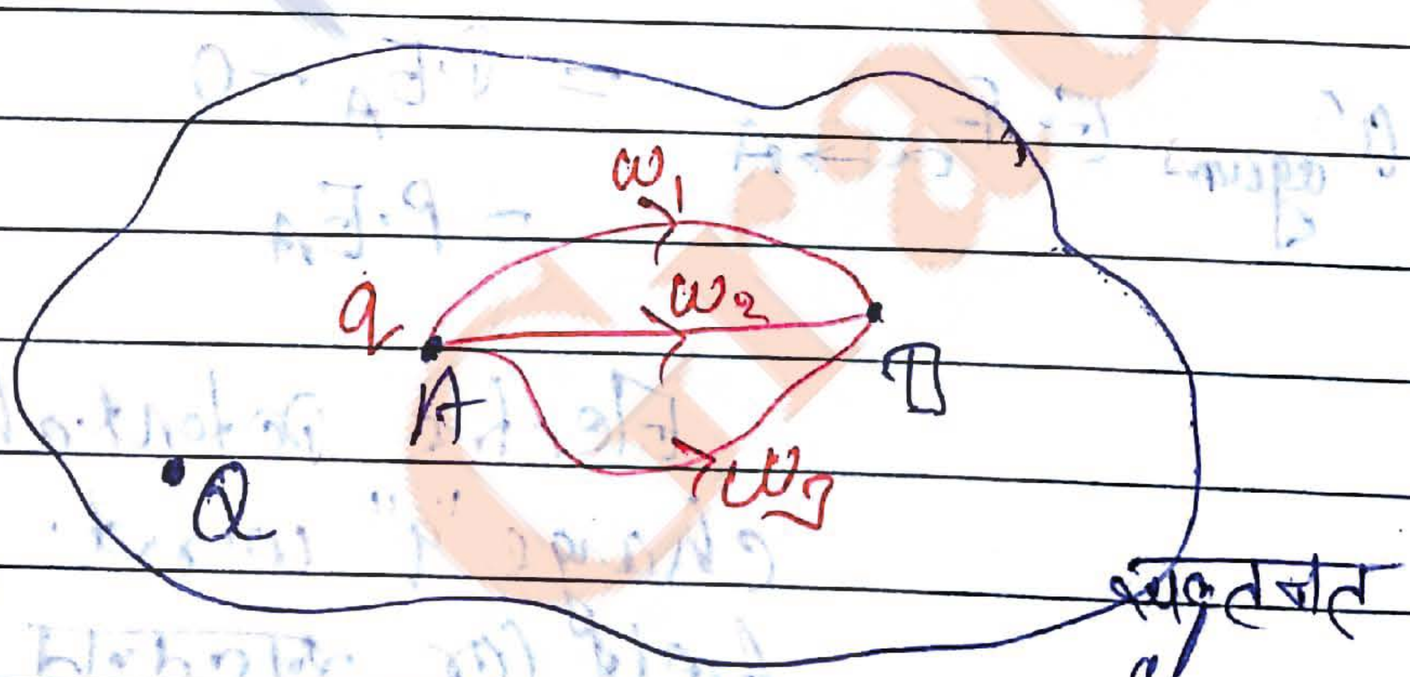
II) Workdone by electric force = − Workdone against E.P

III) Workdone against electric force is equal to

workdone against E.P = $(P.E_f - P.E_i)$

(electric potential energy change.)

IV) workdone by E.P = $-(P.E_f - P.E_i) = P.E_i - P.E_f$



$$w_1 = w_2 = w_3$$

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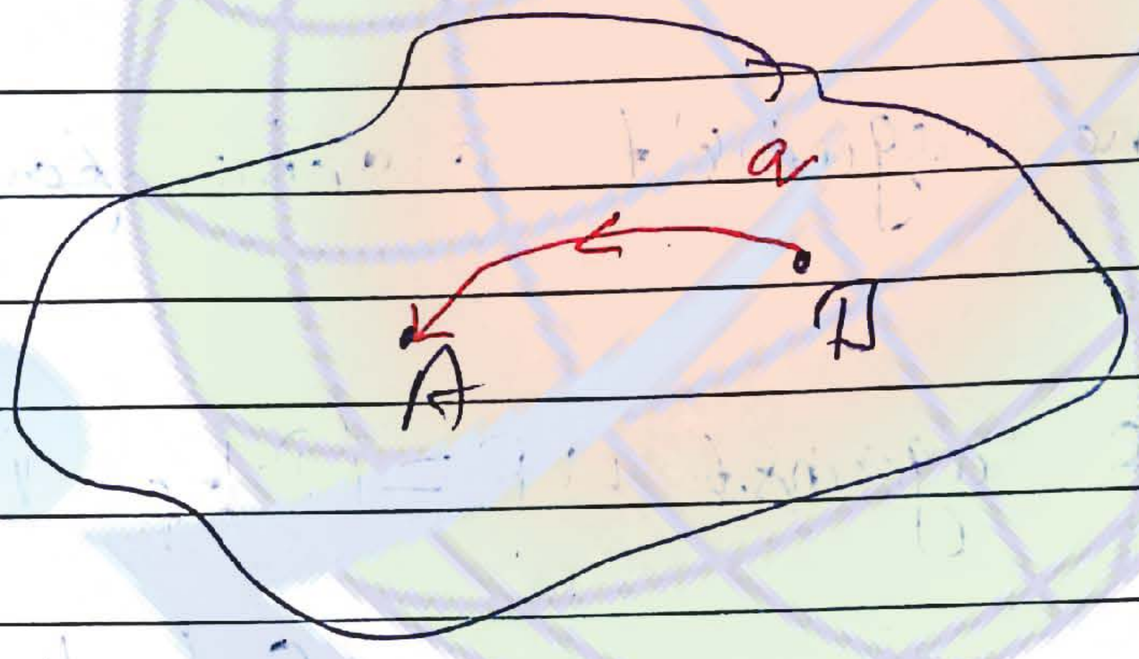
work done by electric force or electric field of those charges which are not moving but fixed at their position

v) Potential energy is a relative term and it need refrence to define Potential energy at any point.

Refrence of P.E is taken at Infinity

vi)

vii)



$W_{against} = E.P_{B \to A} = P.E_A - P.E_B$

$W_{against\ E.F_{\infty \to A}} = P.E_A - 0$

$= P.E_A$

Electric potential energy of charge "q" w.r.t. electric field (or charges) at point A

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vii) E Potential energy of charge "q" w.r.t E =
elecbe poten energy of charge "q" w.r.t E
is defined as:—
work done against elecbe field or elecbe
force in bringing charge "q" from Infinity
(Reference point) to the given point

viii) Elect potential energy can be +ve, -ve
or Zero.

ix) elecbe potential energy is a scalar quantity
and it's unit is Joule.

x) $W_{by\ E.F\ A\to B} = -W_{by\ E.F\ B\to A}$

$W_{agains\ E.F\ A\to B} = -W_{agains\ E.F\ B\to A}$

xi) Elecbe potential

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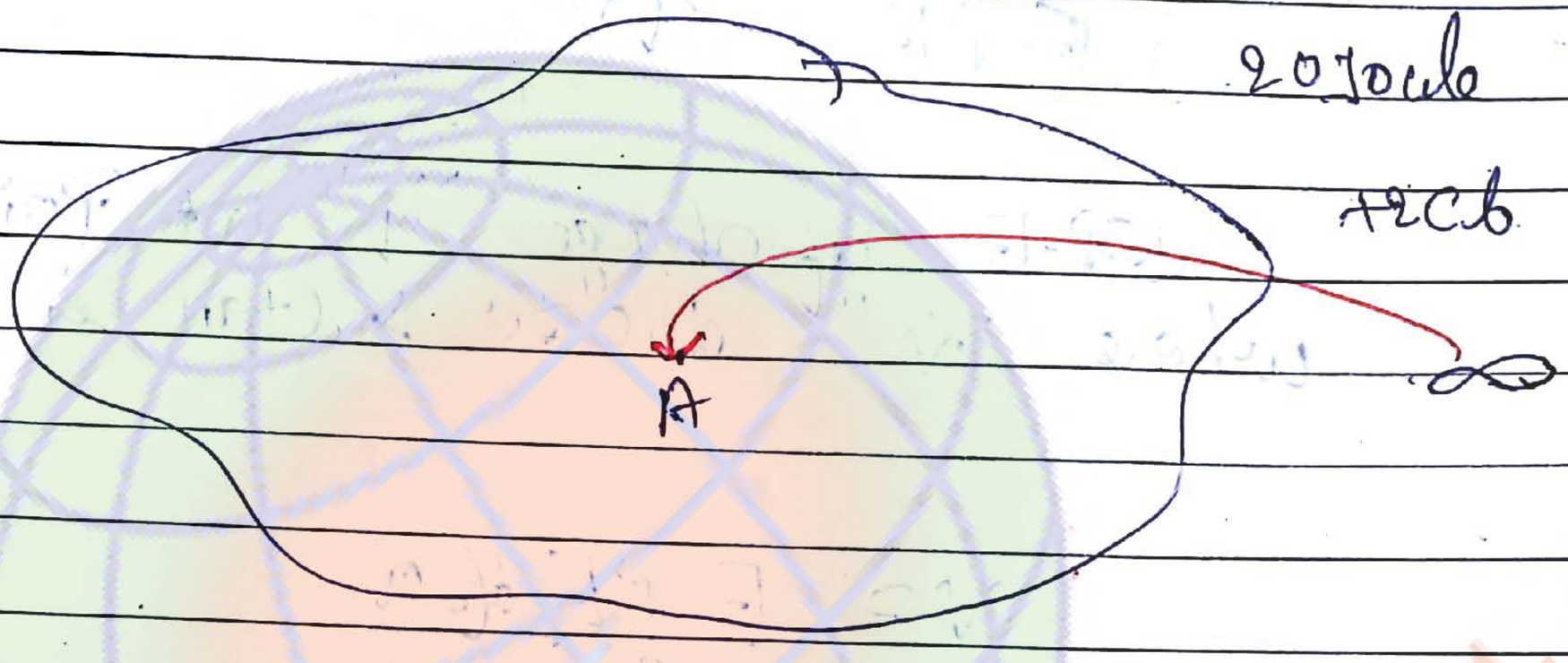
Electric Potential →

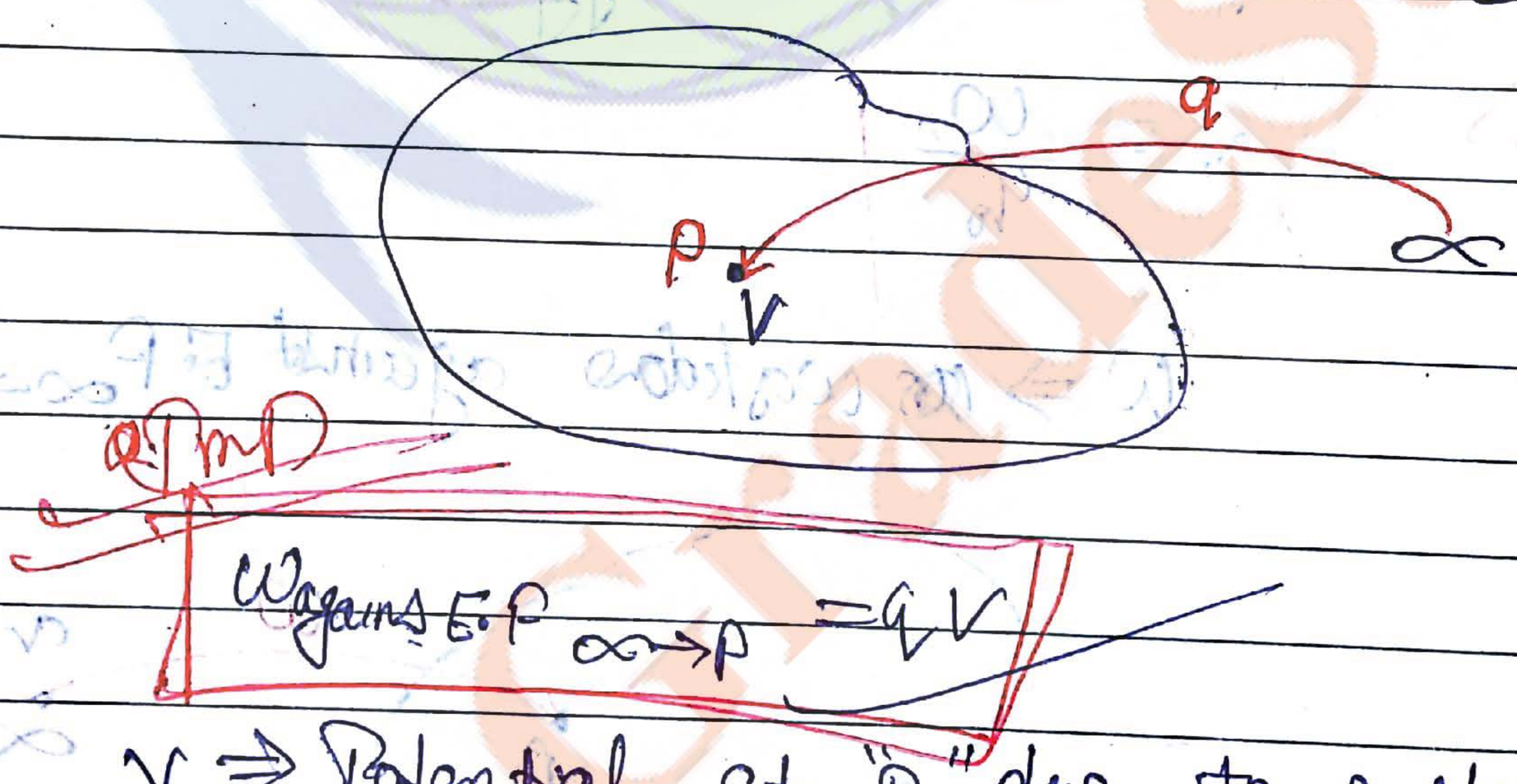
Electric potential at any given point is defined as :-

The workdone against E.F in bringing unit +ve charge from "∞" to that given point.



$W \propto q$

Electric Potential is just like ratio of workdone



V ⇒ Potential at "P" due to Sultanat of Sultan.

q ⇒ entering in Sultanat of Sultan from "∞"

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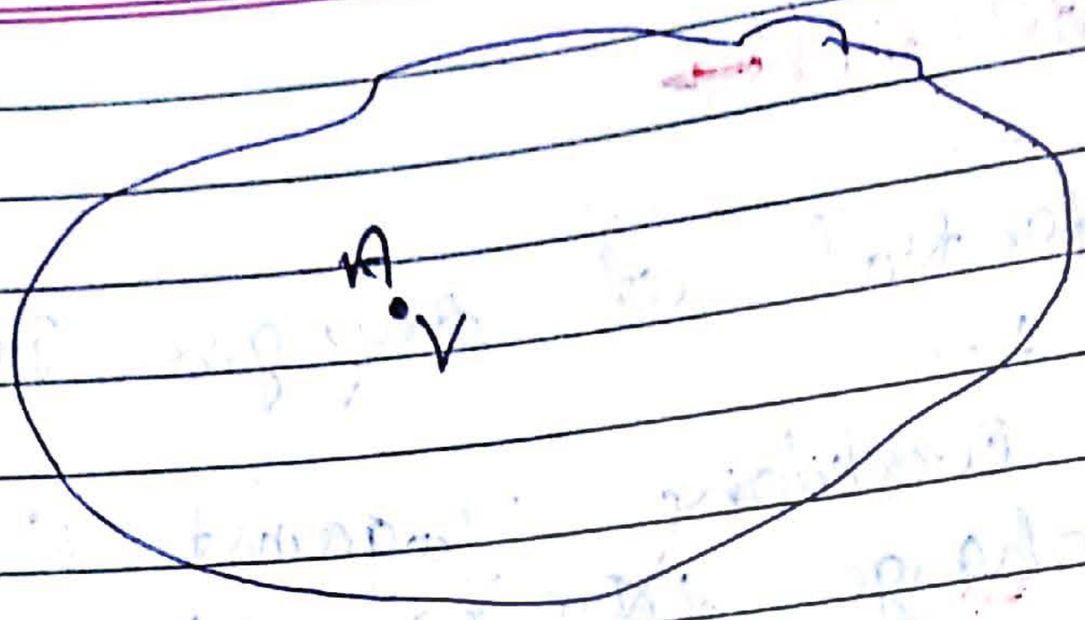


$$\vec{F} \cdot P \cdot \vec{E} = qV$$

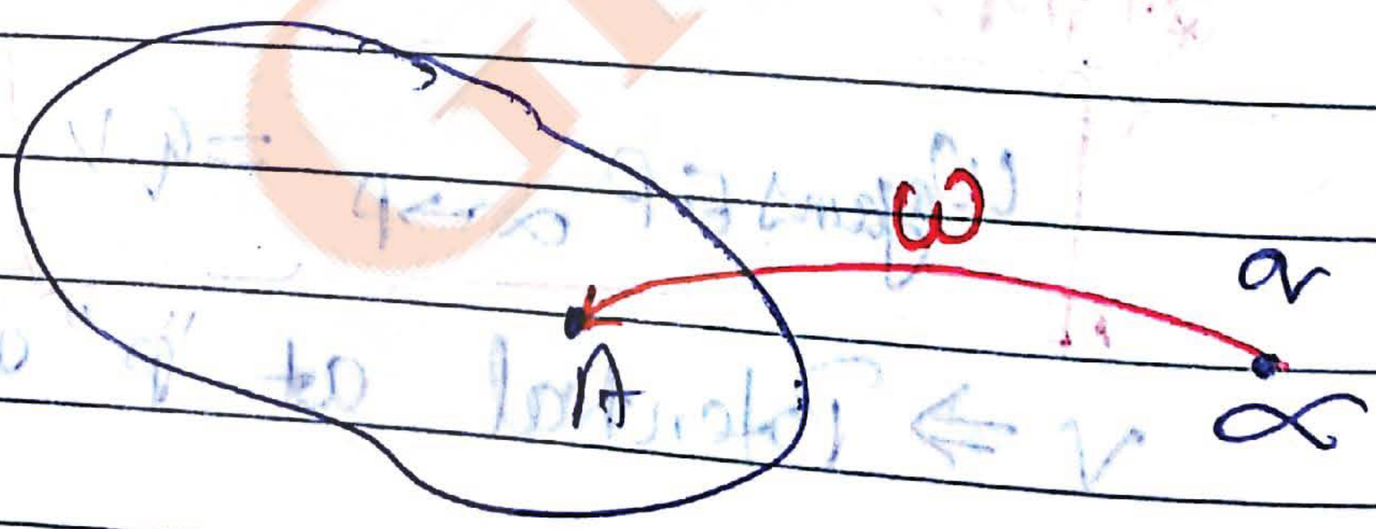
$\vec{F} \cdot P \cdot \vec{E}$ of charge "q" at Point "A" where "V" due to Sultan is known,

$$V = \frac{\int \vec{P}\vec{E} \cdot d\vec{a}}{q}$$

iii) electric potential is also defined as Potential energy per unit charge.

iv) $$V = \frac{W}{q_0}$$

W ⇒ work done against $\vec{E} \cdot F_{\infty \to A}$



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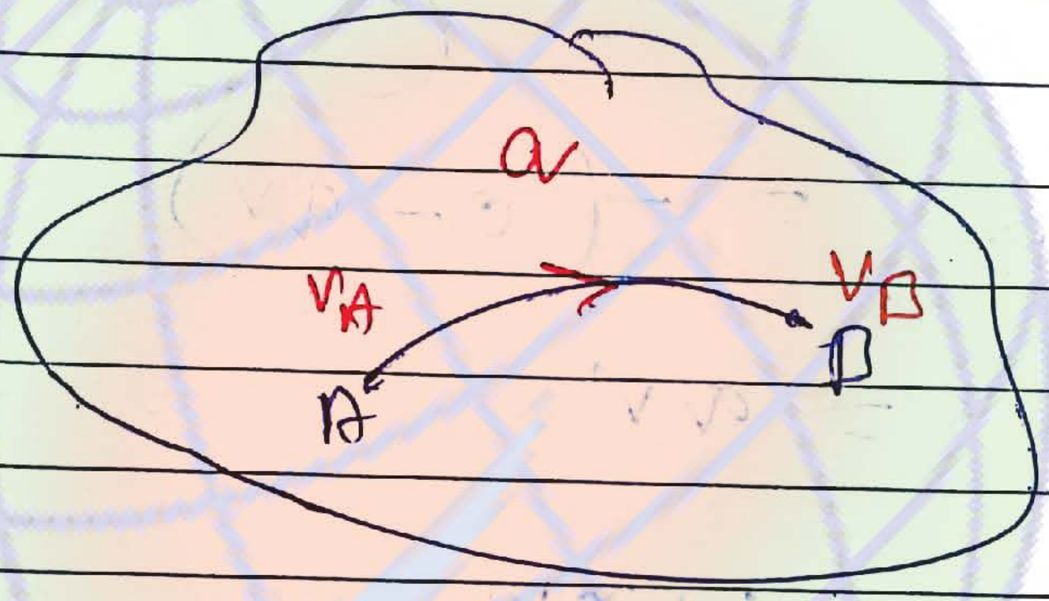
v) Potential is also a related term and it refrence is taken at "∞".

vi) Unit of Potential is volt.

vii) Potential can be +ve, -ve or Zero.

viii) In all formulas of EPE and workdone put q, V, W and EPE with sign in their sign are known to us.



$$W_{by\ F} = -(qV_B - qV_A)$$

$$= -q(V_B - V_A)$$

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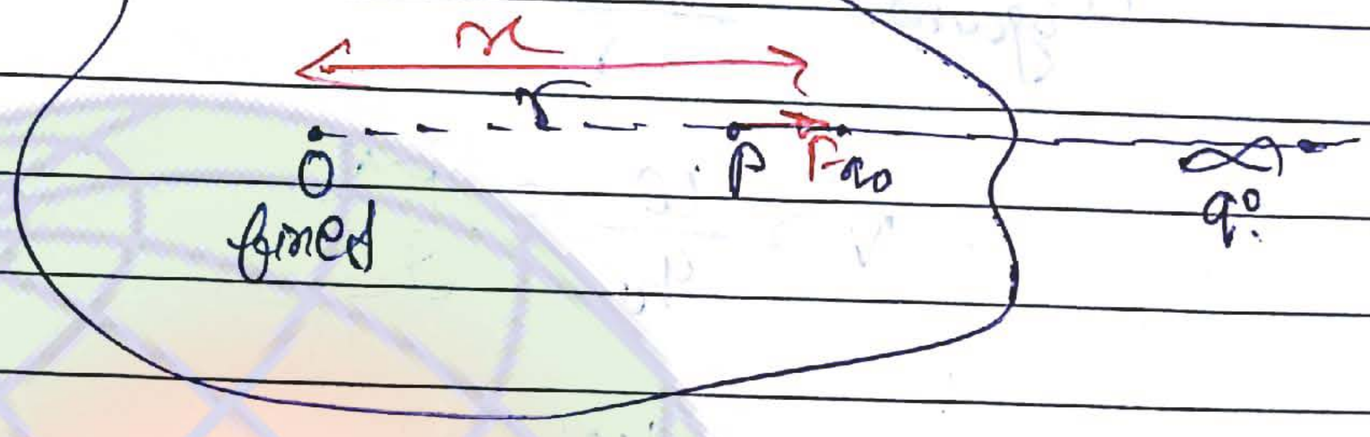
☆ Electric Potential due to Sulton :-

⇒ "V" due to Point charge →



W against E.F in bringing q_0 $\infty \rightarrow P = W$

$$V_P = \frac{W}{q_0}$$

W by E.F in bringing q_0 $P \rightarrow \infty = W$.

W against

Reversible

$$F = \frac{KQq_0}{x^2}$$

$$W_{by\ F} = \int_r^\infty F\,dx$$

$$W = KQxq_0 \int_r^\infty \frac{1}{x^2}\,dx$$

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$$= KQq_0 \left[\frac{-1}{r} \right]_r^\infty$$

$$W = \frac{KQq_0}{r}$$

$$W_{by\,ans} = \frac{KQq_0}{r}$$

$$V = \frac{W}{q_0} = \frac{KQ}{r}$$

$$\boxed{V = \frac{KQ}{r}}$$

K.K concept

Formula of Potential Put charge with sign

iv) Potential follows superposition theorem

vii) Net potential at any point is the scalar sum of potential's due to individual charges.

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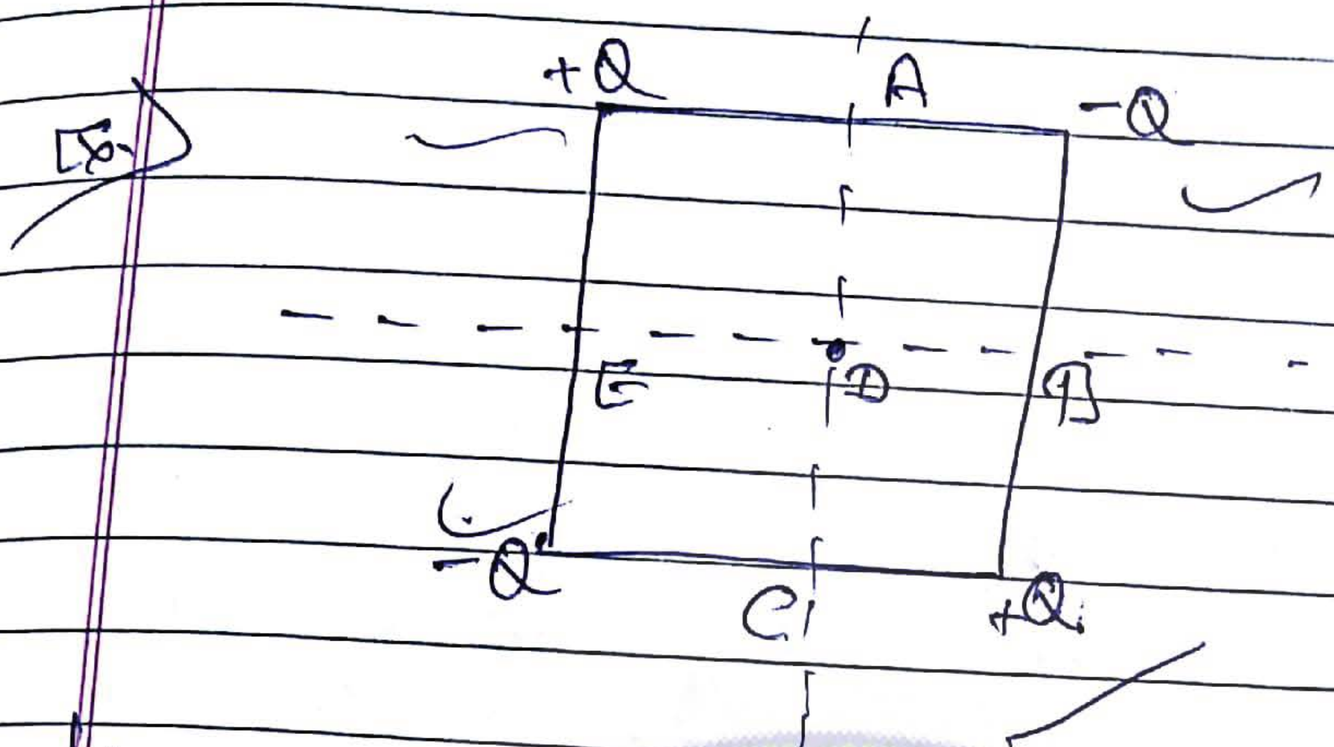

Sol^n

All all the five point's potential is zero

Ex) Regular polygon of N-side, $(N-1)$ same Q charge है, determine 'V' at centre from distance of each corner $\vec{r}_{centre} = r$

$$V = \frac{(N-1)Q}{r}$$

Potential निकालना ज्यादा आसान है "E" के निकालने से because Potential एक scalar quantity.

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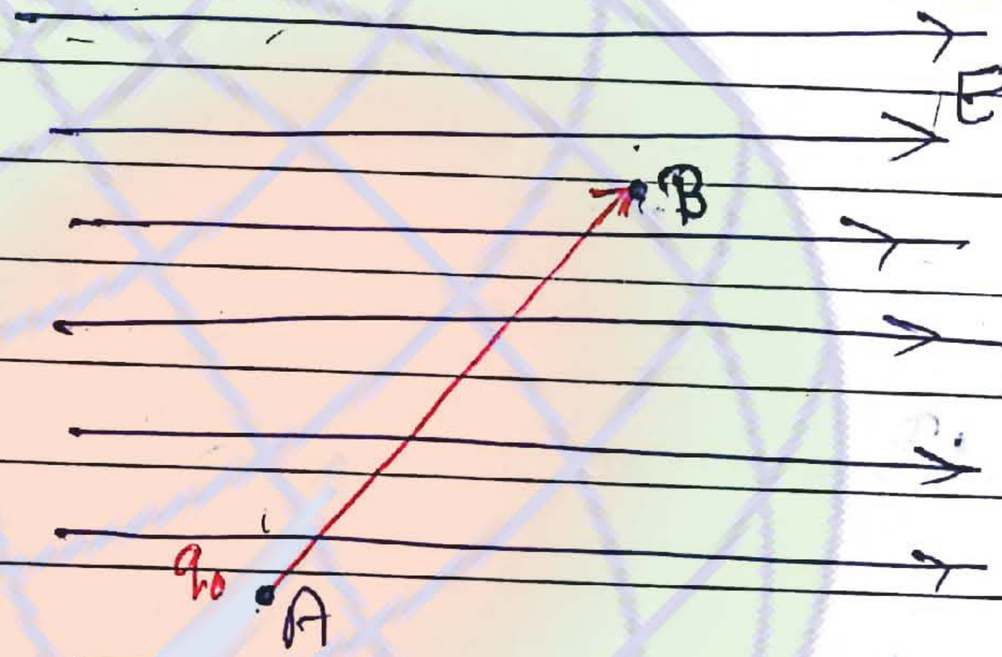
☆ Relationship b/w "E" and "V" ⇒

☆ Case 1st → Uniform "E"

Jb "E" ei know determinate of V or ΔV ⇒



$$W_{by\ \vec{E}\cdot\vec{F}\ q_0\ A\to B} = -\left(q_0 V_B - q_0 V_A\right)$$

$$\vec{F} = q_0\vec{E}$$

$$W_{by\ \vec{E}\cdot\vec{F}} = \vec{F}\cdot\vec{AB}$$

$$q_0\vec{E}\cdot\vec{AB} = -q_0\left(V_B - V_A\right)$$

$$V_B - V_A = -\vec{E}\cdot\vec{AB}$$

Attention (ww) ☆

अर्थात समान के L.H.S और R.H.S में ∫B, Reverse भी गया है।

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i) Potential does not change the direction perpendicular to "E".

ii) In the direction of "E" Potential decrease. where as the direction opposite to "E" Potential Increase

Ex(1) 

Ex(2) $\vec{E} = 2\hat{j} + 3\hat{j}$

$V_{at}(1,1,1) = 4\text{volt}$

$V_{at}(0,0,0) = ?$

Sol:

$V_D - V_A = ?$

(A) $V_{at}(1,1,1) = 4\text{volt}$

(B) $V(0,0,0) = ?$

$V_A - V_D = -\vec{E} \cdot \vec{BA}$

$4 - V_D = -(2\hat{i} + 3\hat{j}) \cdot (\hat{i} + \hat{j} + \hat{k})$

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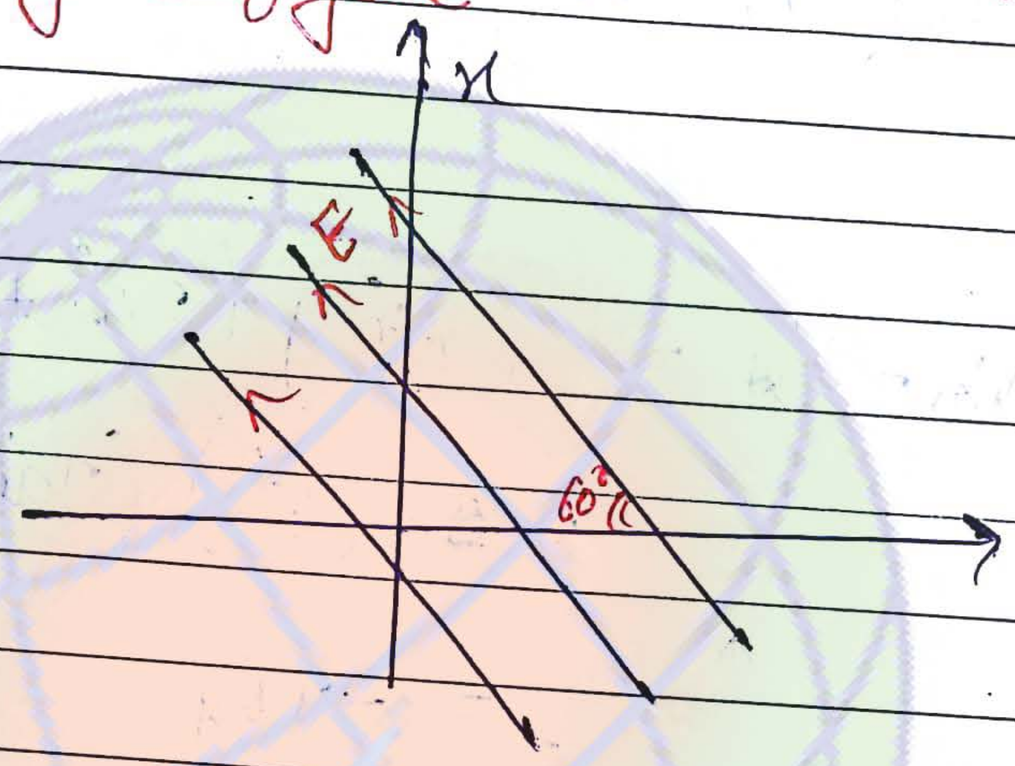
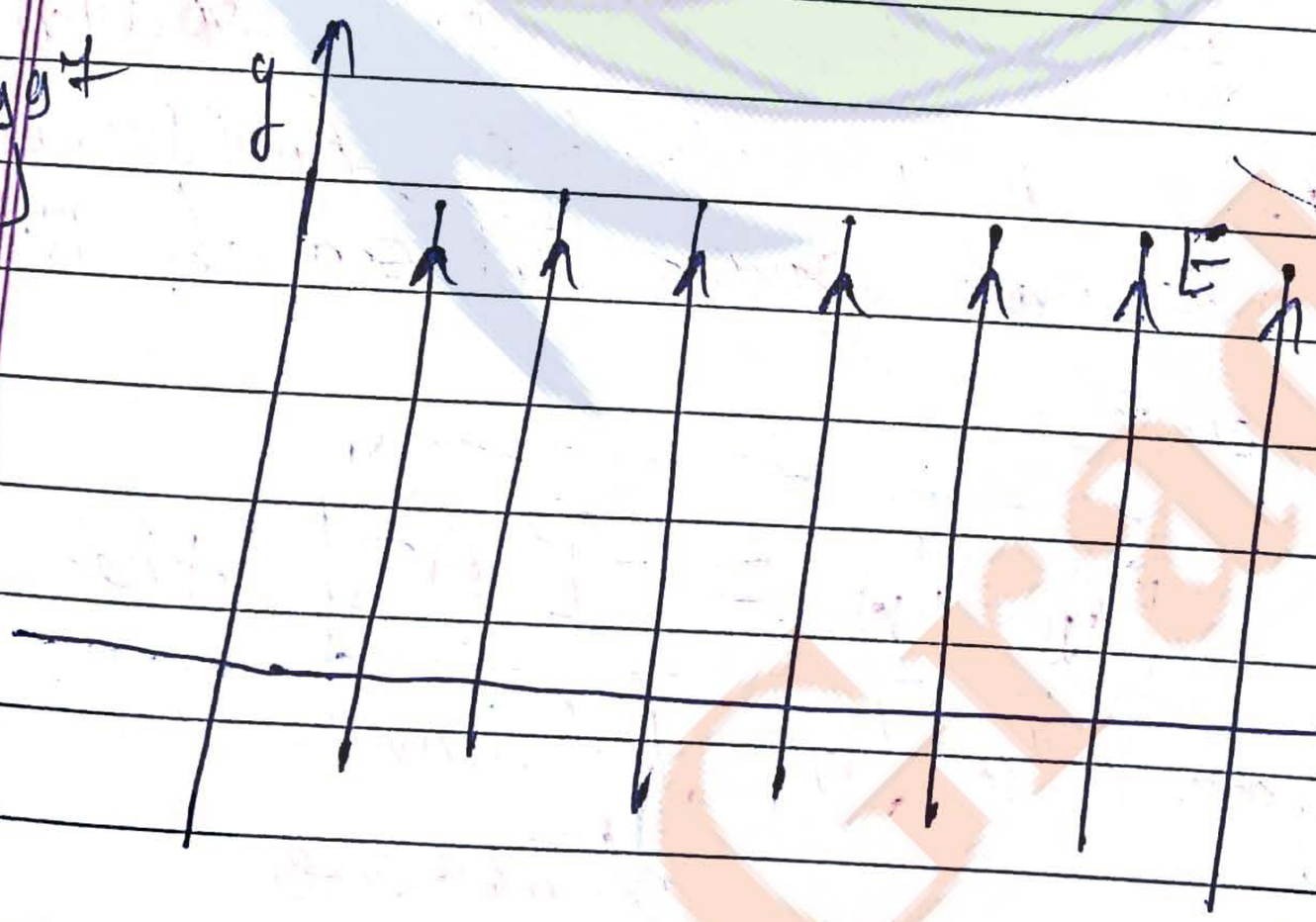
$$4 - V_D = -2 - 3$$

$$V_D = 4 + 2 + 3 = 9V$$

Ex: Examiner can give direction of "E" and it's magnitude by making a figure



we can write their "E" in form of vector or $(\hat{i}, \hat{j}, \text{or } \hat{k})$



Determine workdone by electric force in taking charge "q" from A to B, B to C and C to D

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☆ Determination of "E" when "V" is known for uniform E→

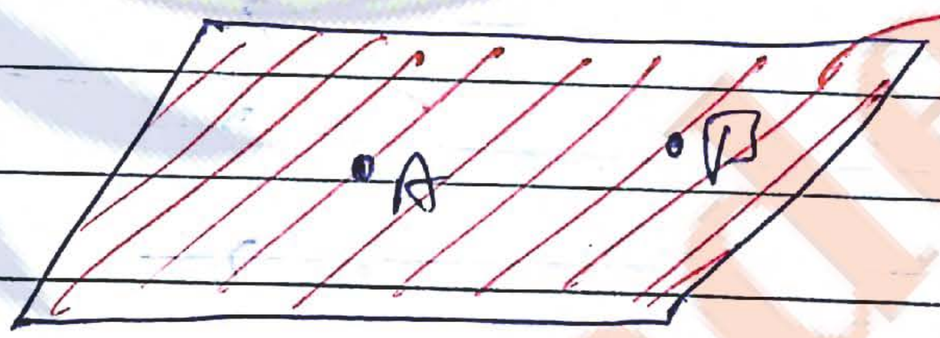
$$E = \frac{\Delta V}{d}$$

Here

d ⇒ distance b/w two equipotential surface.

ΔV ⇒ Potential difference b/w two equipotential surface

◎ Equipotential Surface → A hypothetical surface over which potential is same everywhere is known as equipotential surface.



$V_A = V_B$

1) Work done in moving any charge from one point to another point on equipotential surface is always zero → (by or against the E. Force)

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Electric flux (ϕ) → (flux is a scalar quantity)

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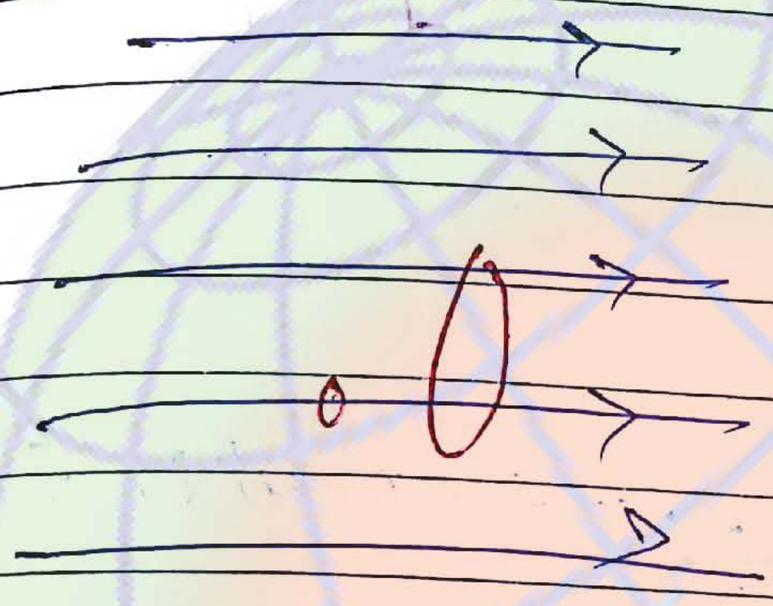
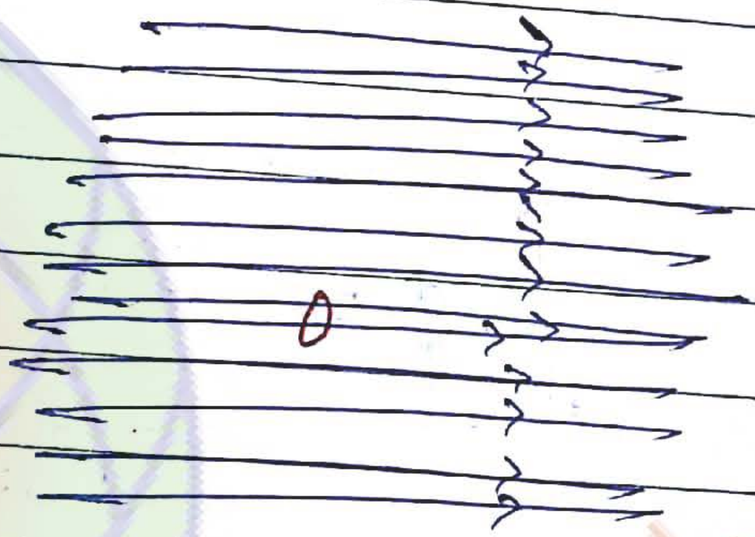
1) Electric flux is a quantity which is proportional to number of E.L.P passing through that surface. (No. of electric field lines passing through an area in the direction of area vector is known as electric flux.)

2) Higher the flux means higher the number of E.L.P passing through the surface

3)

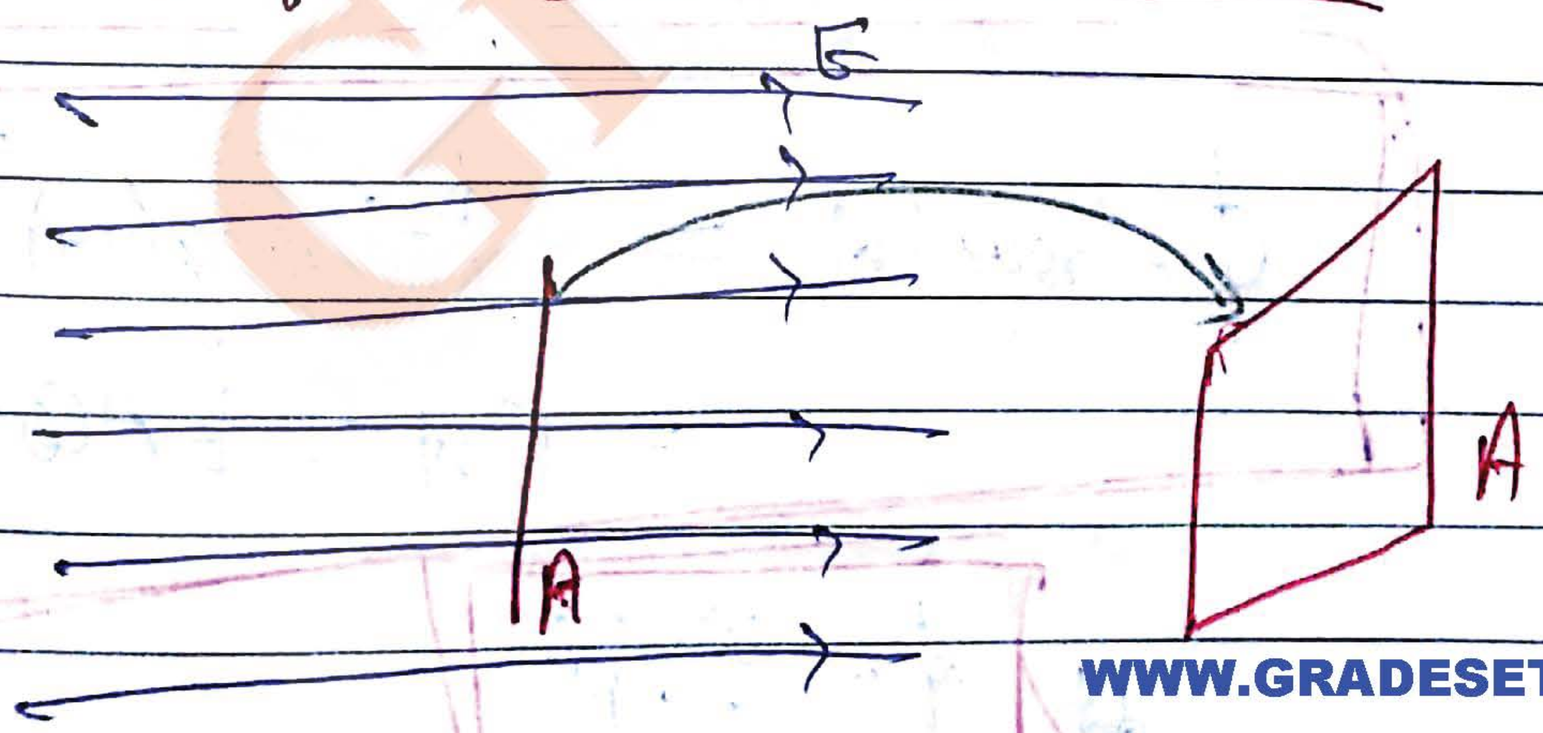




4) Flux depend on i) magnitude of $\vec{E}$ (electric field intensity), ii) Area of the surface, iii) orientation of surface

* Determination of Flux in uniform "E" →

Case 1st → Surface is Plane Surface →



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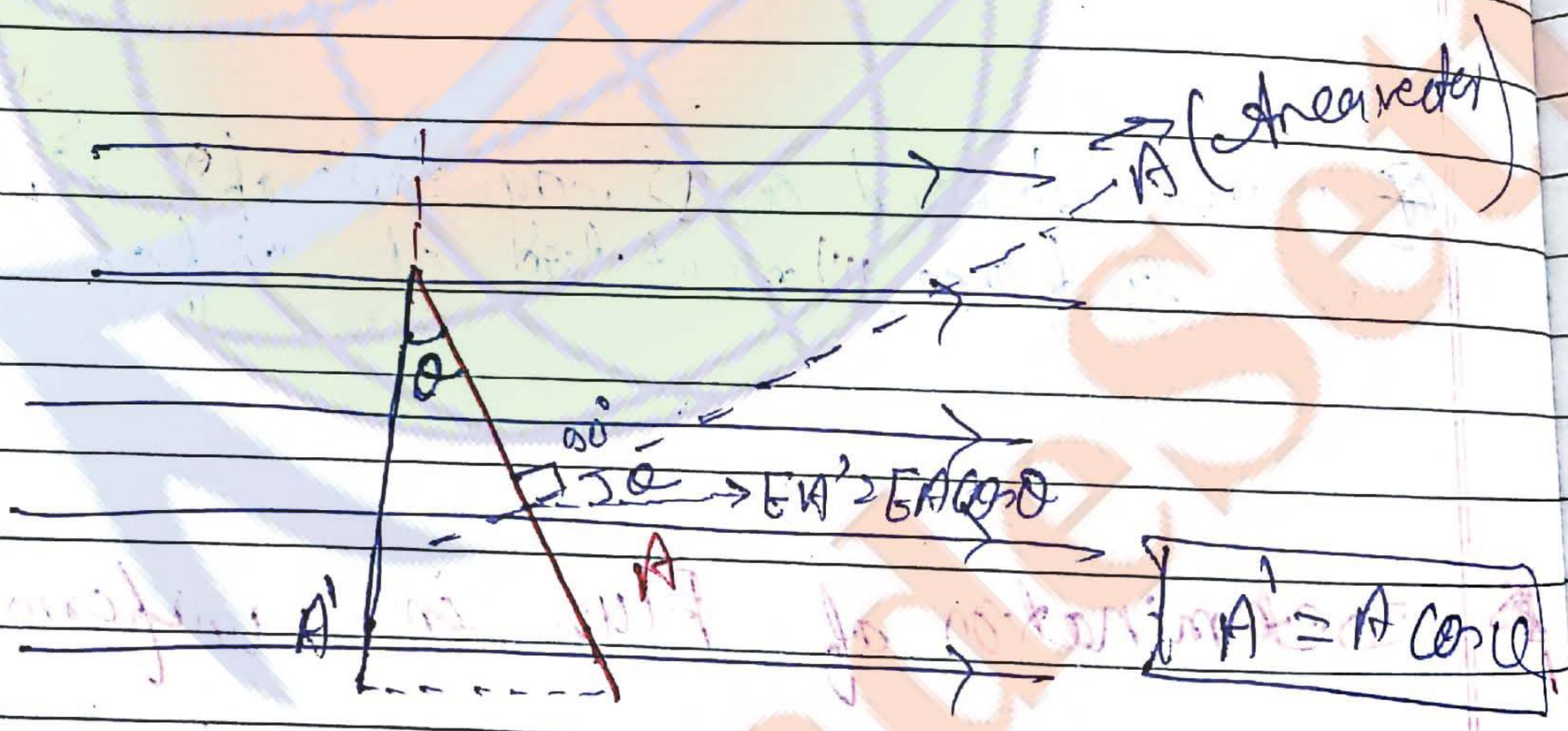
Numbe of lines passing through a E
unit area

No of lines passing through a E_A
unit area

ϕ

$\phi = EA$

when surface is normal to "E".



ϕ through A = ϕ through A'

$= EA' = EA\cos\theta$

$\phi = \vec{E} \cdot \vec{A}$

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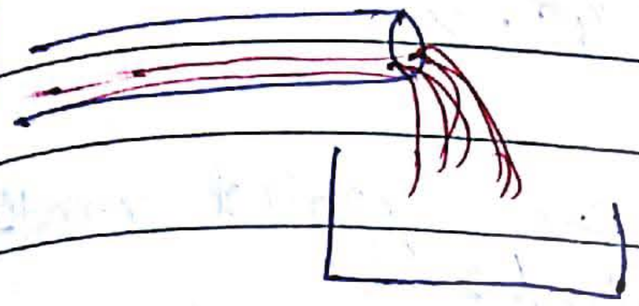
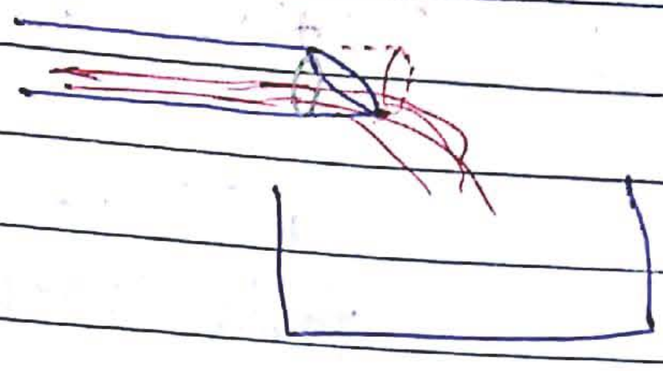
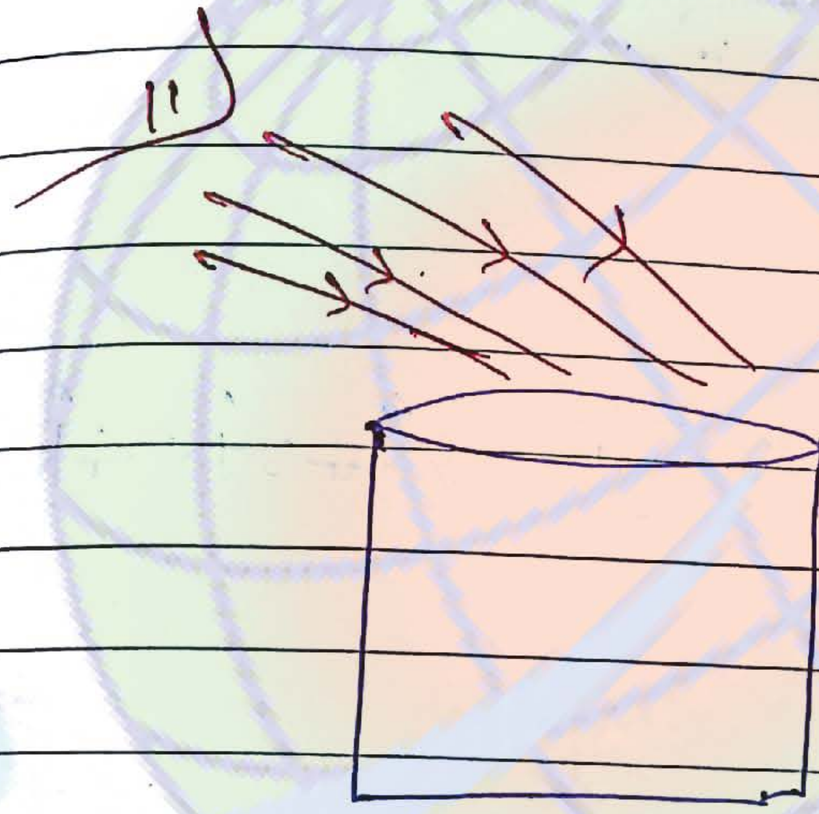
Notes → 1) flux सम्बन्धी





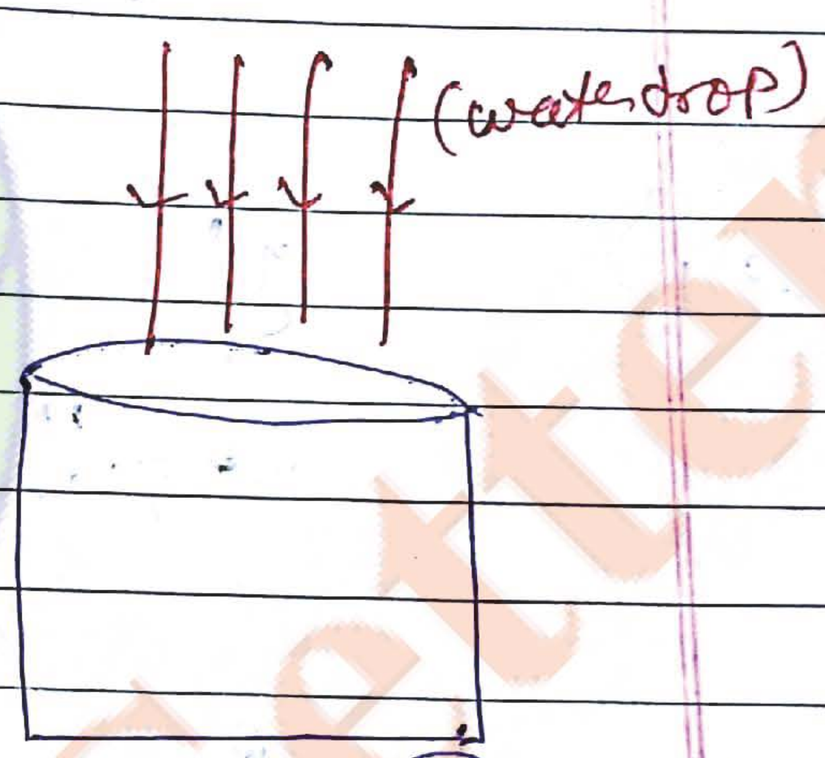
दोनों Core में ~~same~~ same पानी गिरेगा तो, दोनों Core में same flux.



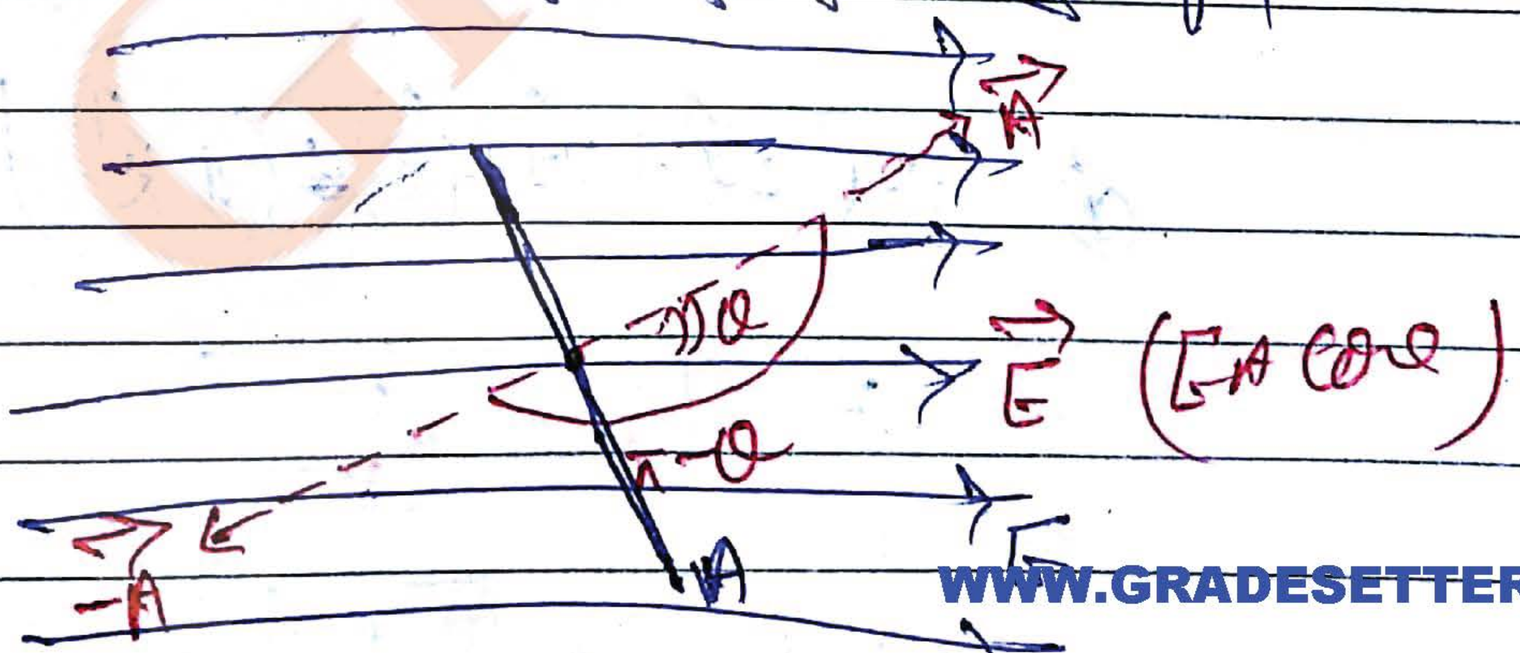
(2) Flux $\Phi = \vec{E} \cdot \vec{A}$

where,

$\vec{A}$ ⇒ Area vector is the vector whose magnitude is Area of surface and whose direction is ⊥ar to the surface



(पानी गिरने का तरीका)



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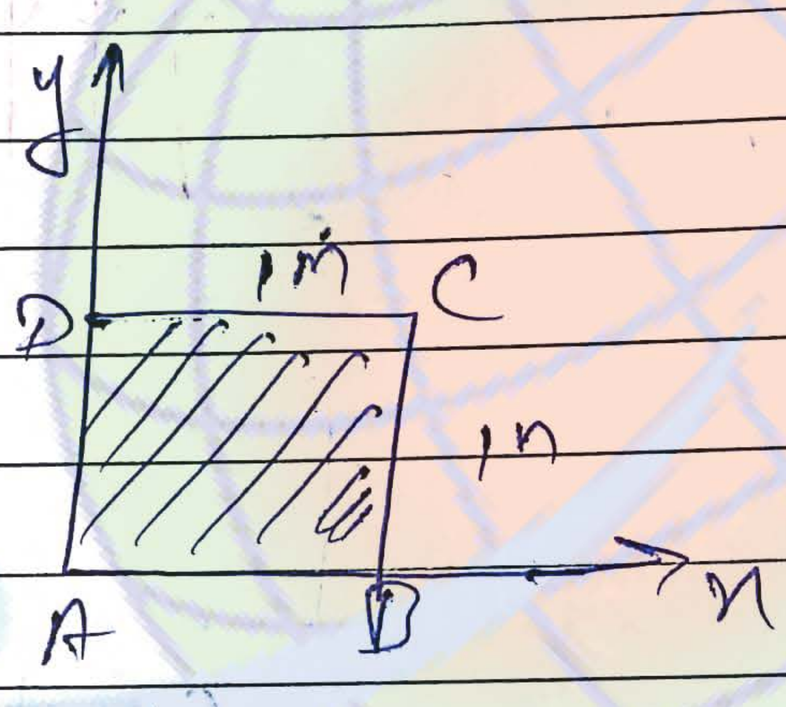
Here

1) ϕ = +ve (~~stands for~~)

means E.L.P are going on the side where $\vec{A}$ is taken.

2) ϕ = -ve

means E.L.P are going on the opposite side of $\vec{A}$.



$\vec{E} = 2\hat{i} + 3\hat{j} + 4\hat{k}$

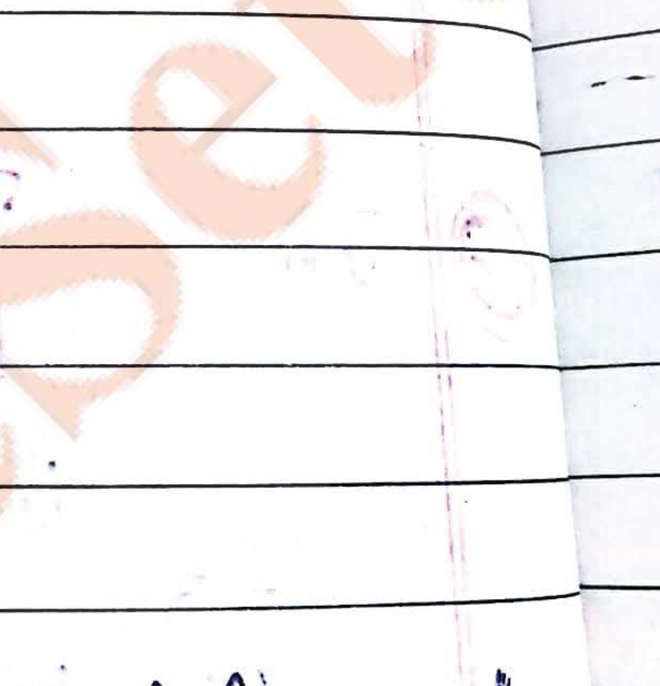
ϕ through ABCD = ?

$\phi = \vec{E} \cdot \vec{A}$

$\vec{A} = 1\hat{k}$ (Area vector surface ka 1 or hota hai)

$\phi = (2\hat{i} + 3\hat{j} + 4\hat{k}) \cdot (1\hat{k})$

$= 4$



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Concept of Equivalent plane

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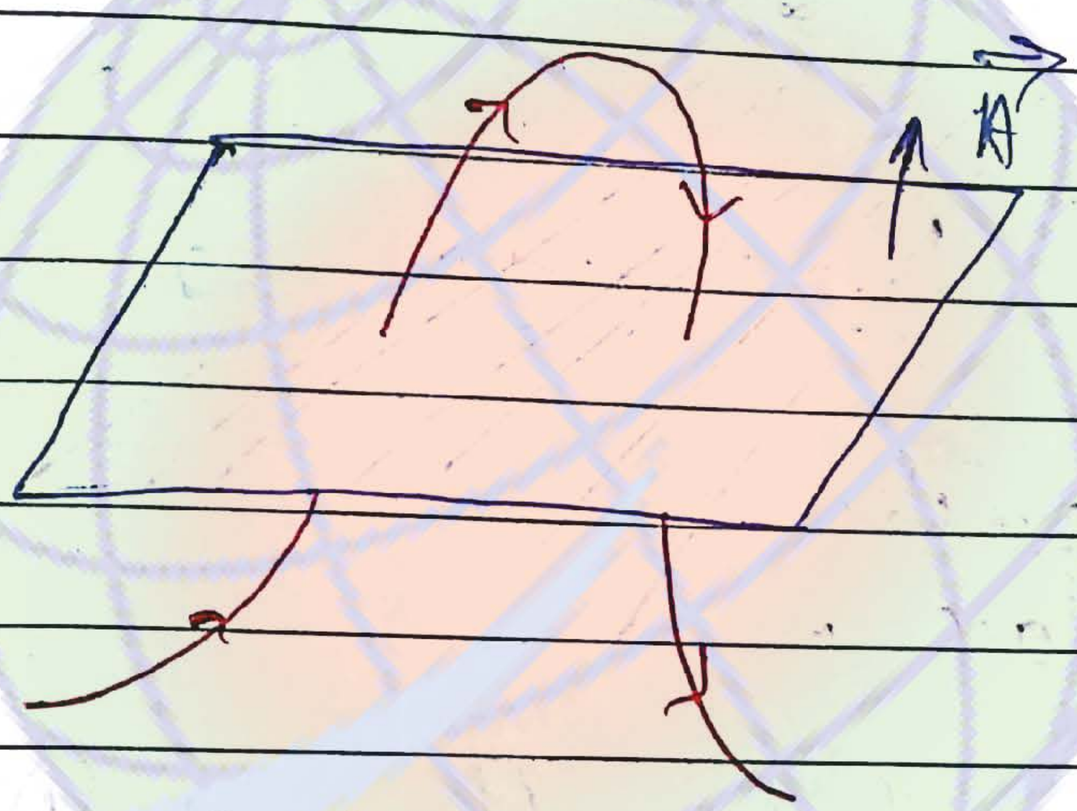
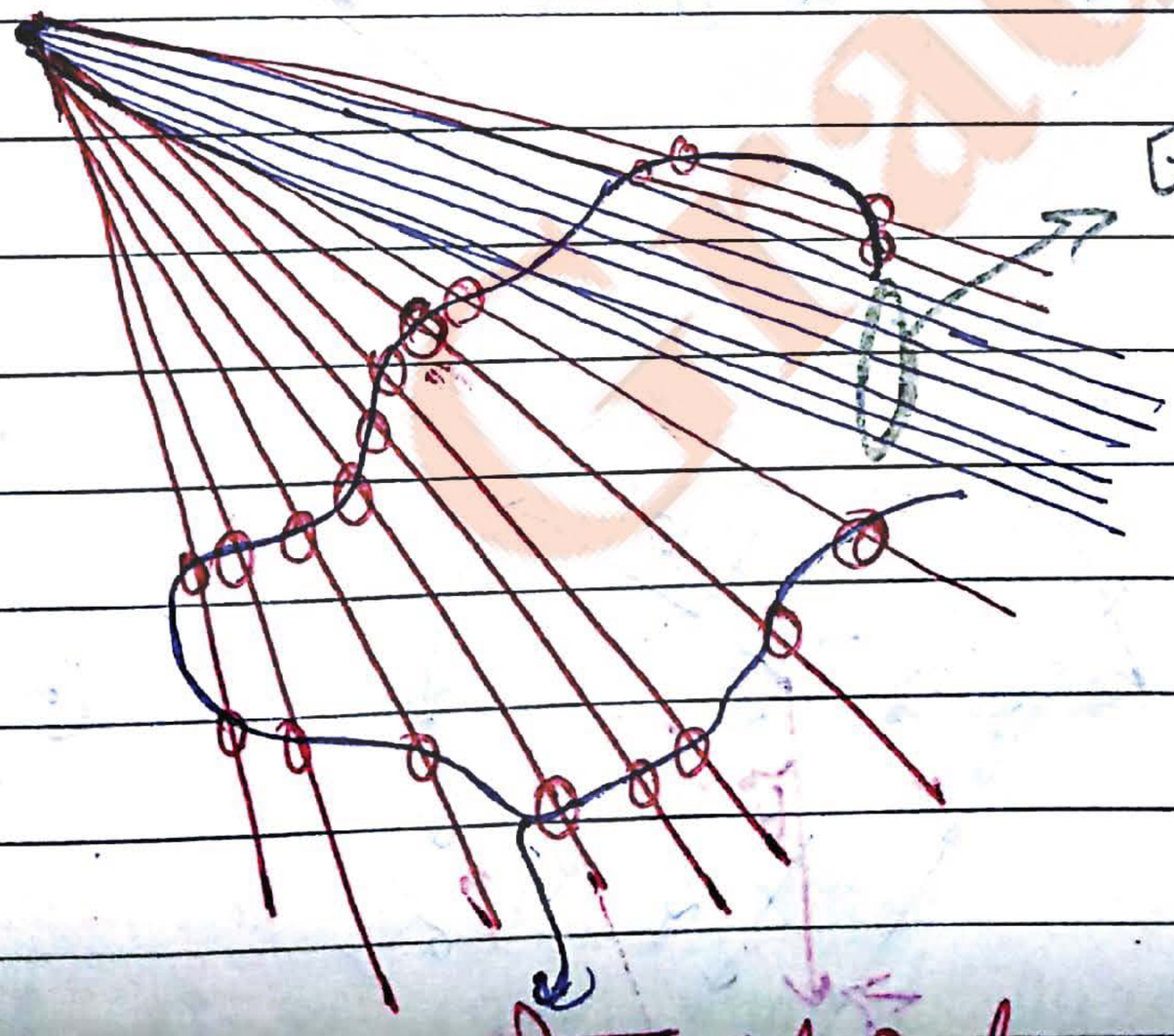
Dialogue ⇒
When an E.L.P passes through the surface two times or even number of times then flux due to that E.L.P through the surface is "Zero".



(flux is Zero)



Equivalent plane.



अभीष्ट सतह surface.

Note:⇒ Here अर्थात् जो Red Pen से E.L.P दिखाये है वह Surface है

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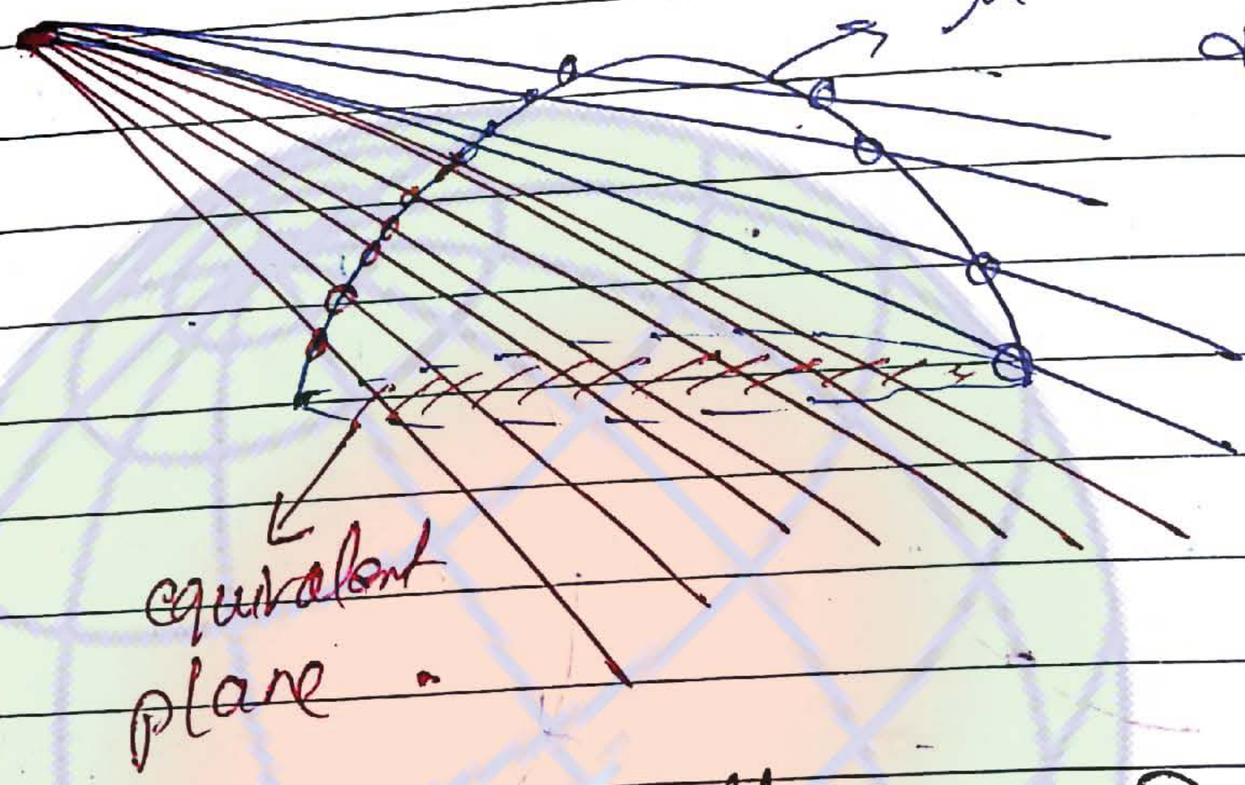
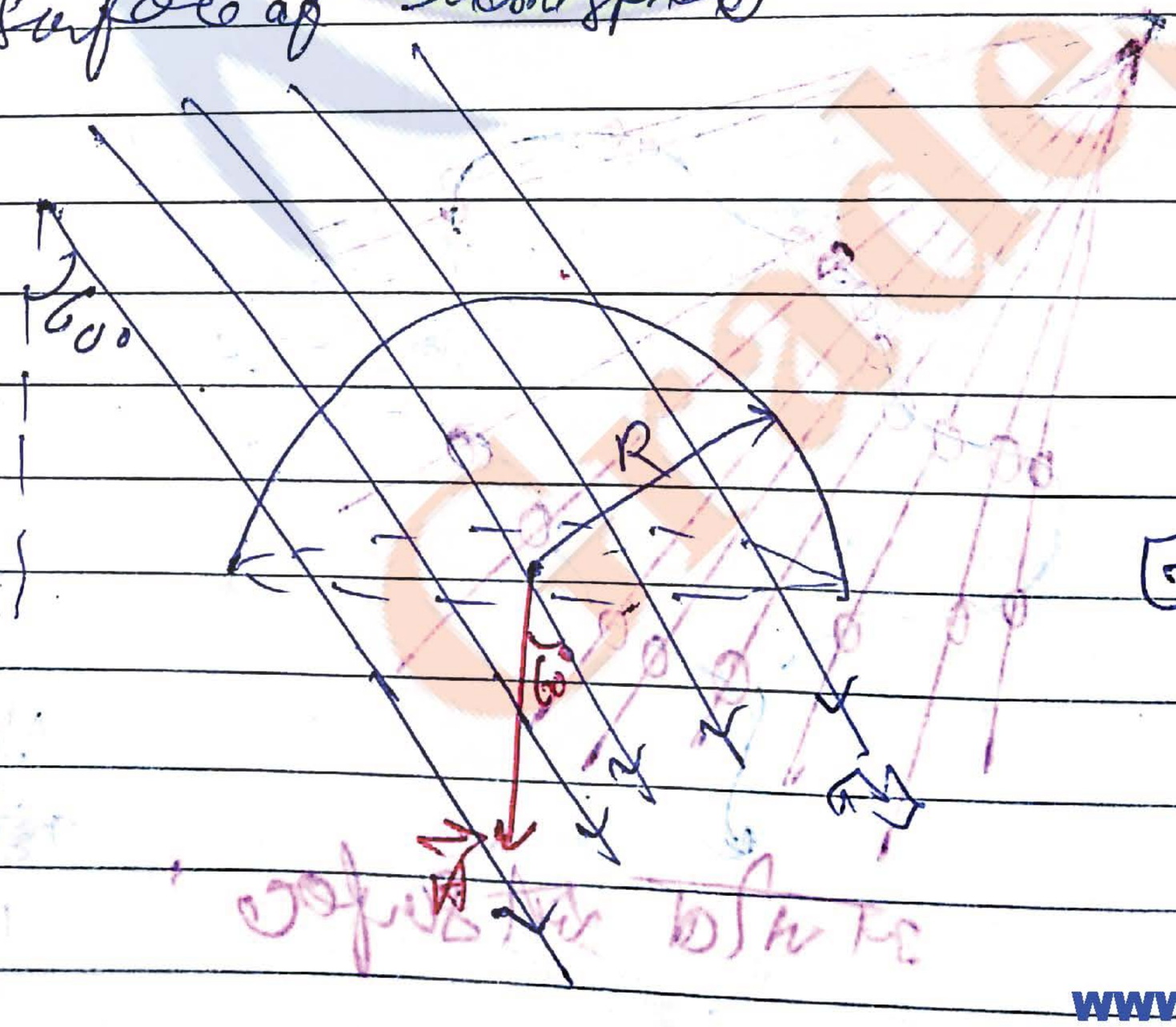
ϕ_{surface} = $\phi_{\text{through equivalent plane}}$.

Ex)



(*) value of electric flux is Independent of shape and is Zero surface.

Ex) Determine flux through the curved surface of hemisphere



$\phi = E A \cos 60°$

$= \frac{E}{2} \times \pi R^2$

$= \frac{E \pi R^2}{2}$

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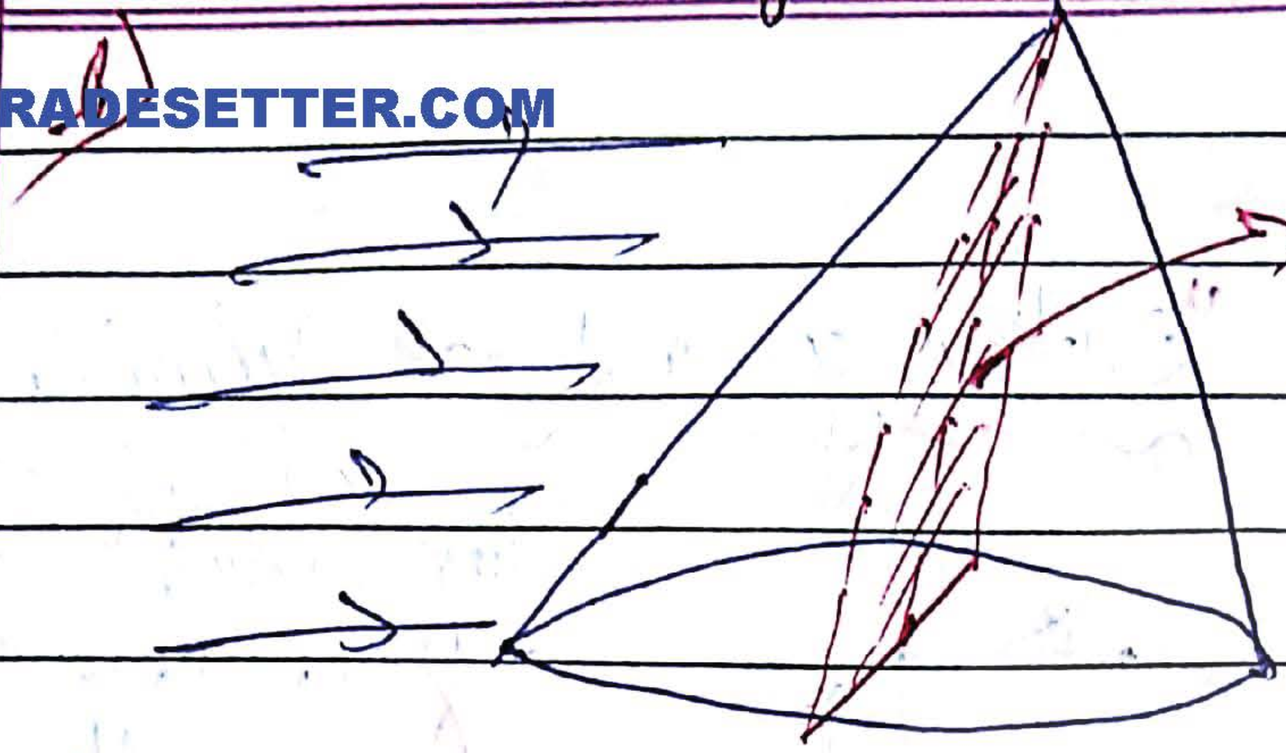
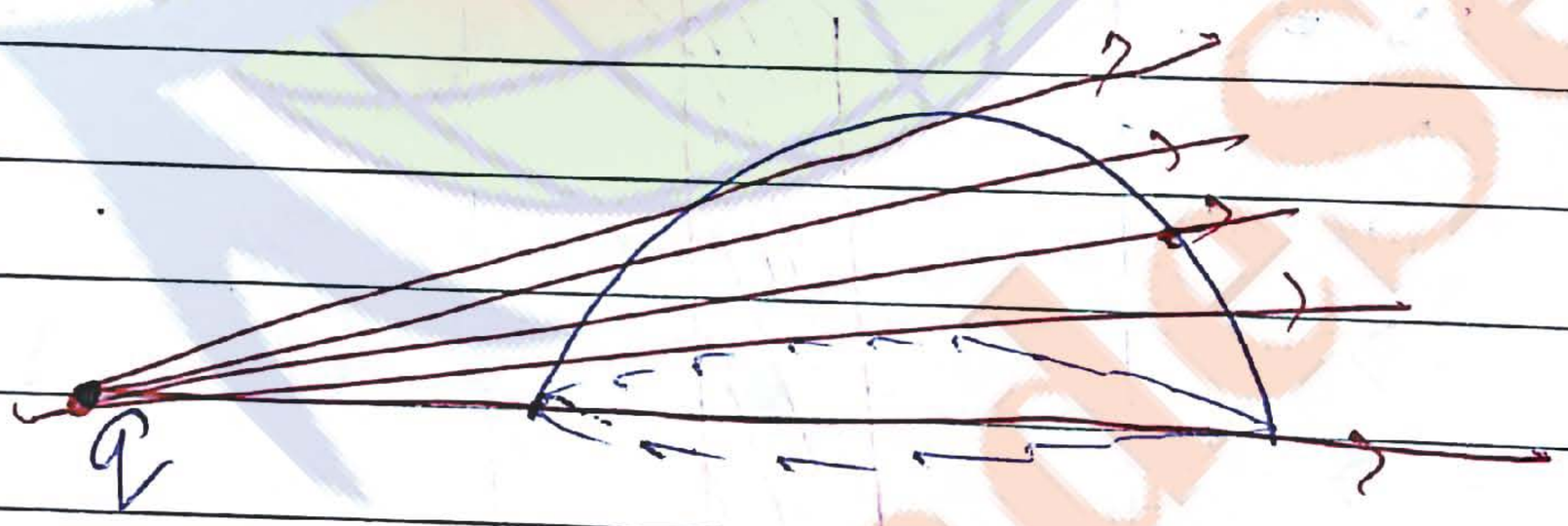


Plane से "ϕ" flux equivalent

Concept (GD Sir) →

★ flux through the plane due to a charge is zero if charge is present in that plane.

Q) Determine flux through Hemisphere.



(flux through hemisphere = flux through equivalent plane and charge q in equivalent plane)

Therefore flux through hemisphere is zero

⇒ flux of a constant vector through any closed surface is zero.

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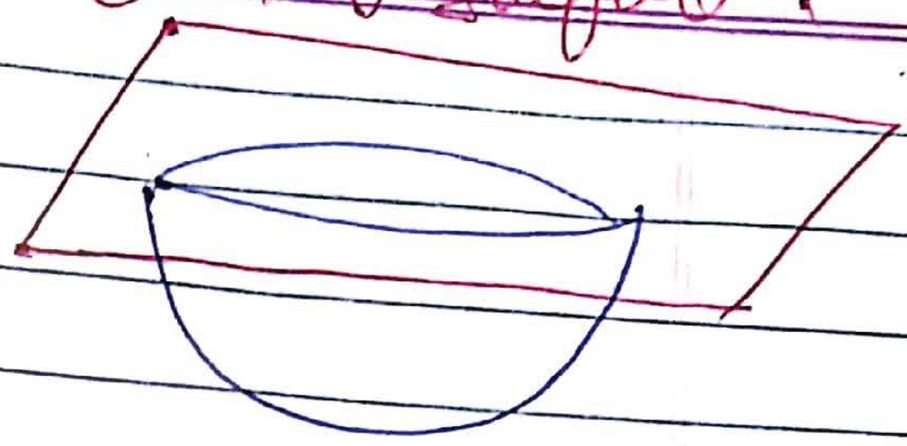
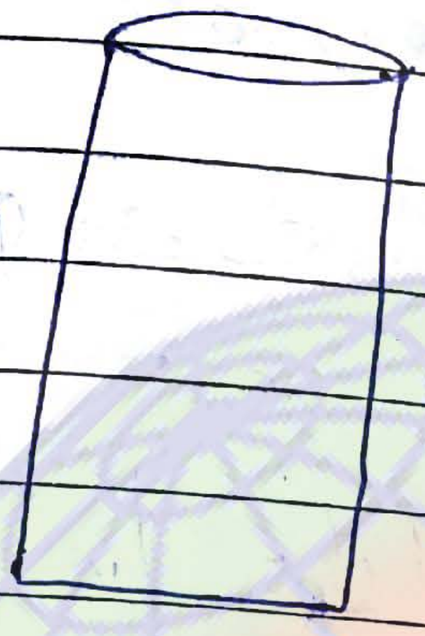
Open surface



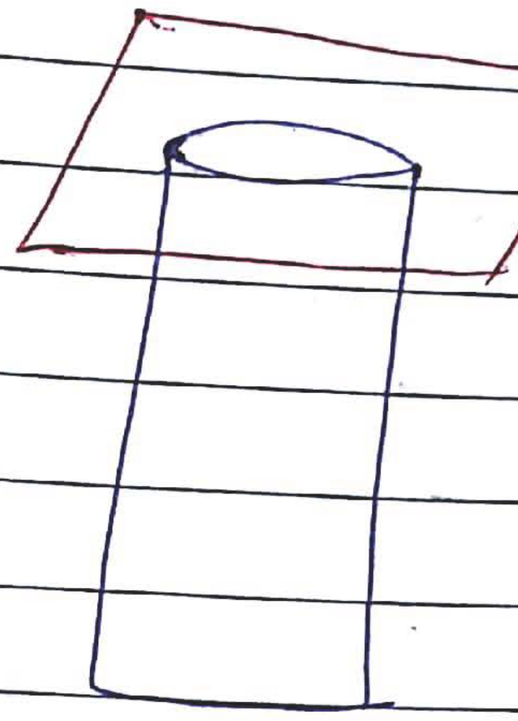
बेलन

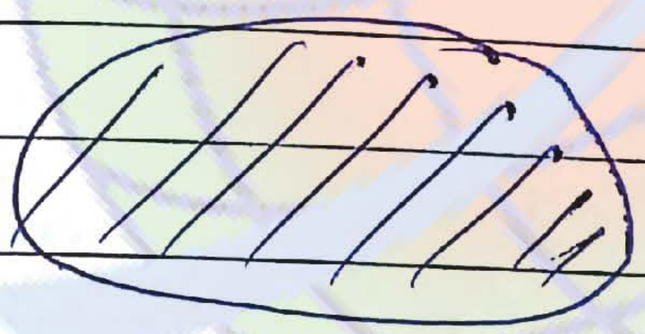
closed surface.



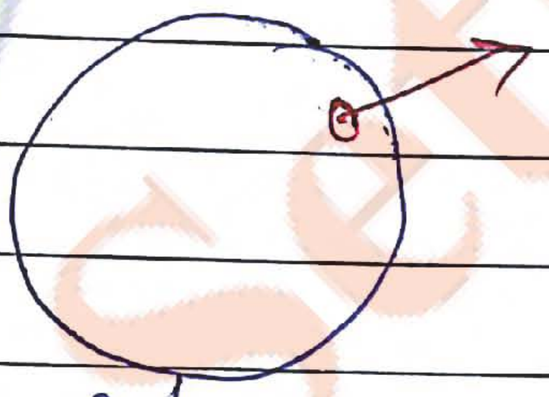


शंकु

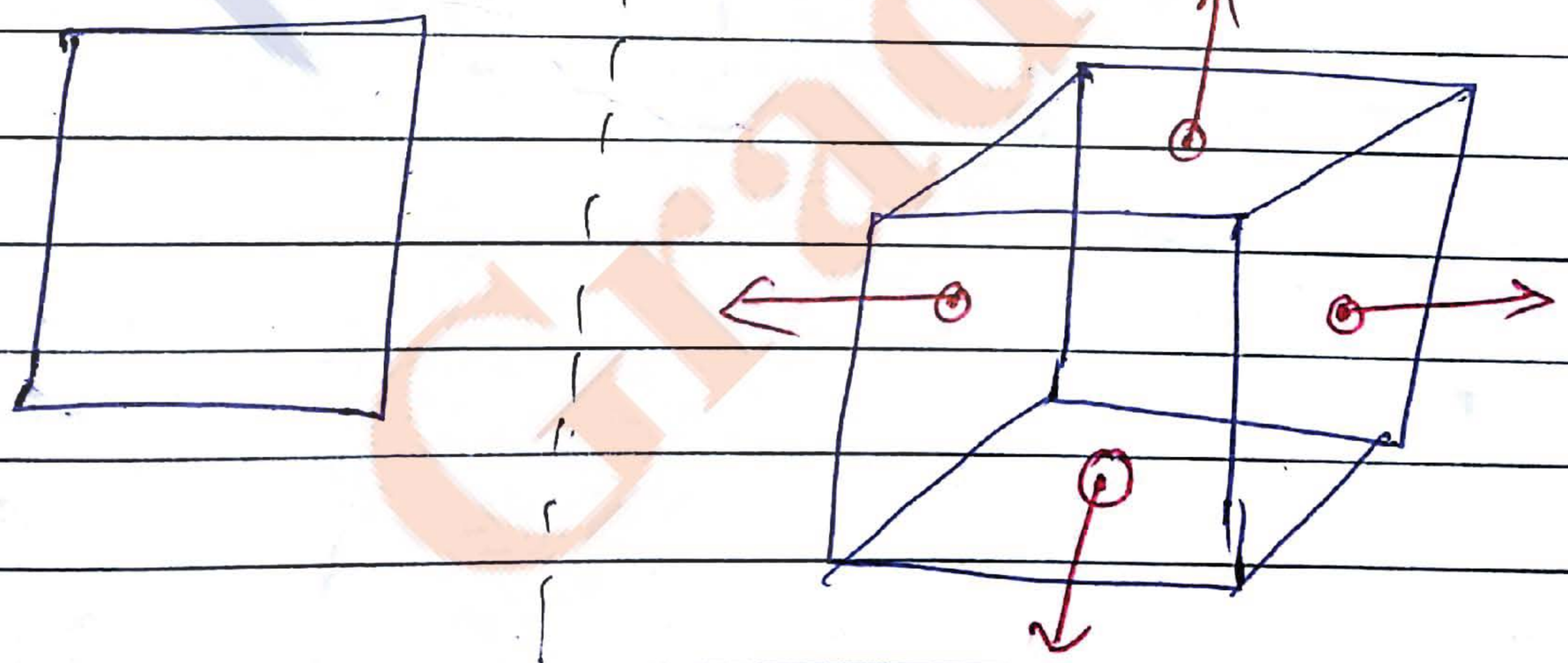




डिस्क



sphere.



⇓

closed surface consist of one or more than one surface

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which enclose certain Dis'de them
(जो अपनी दिशा बताती है)

ii) Enclosed surface area
vector is taken "outside"
of enclosed volume

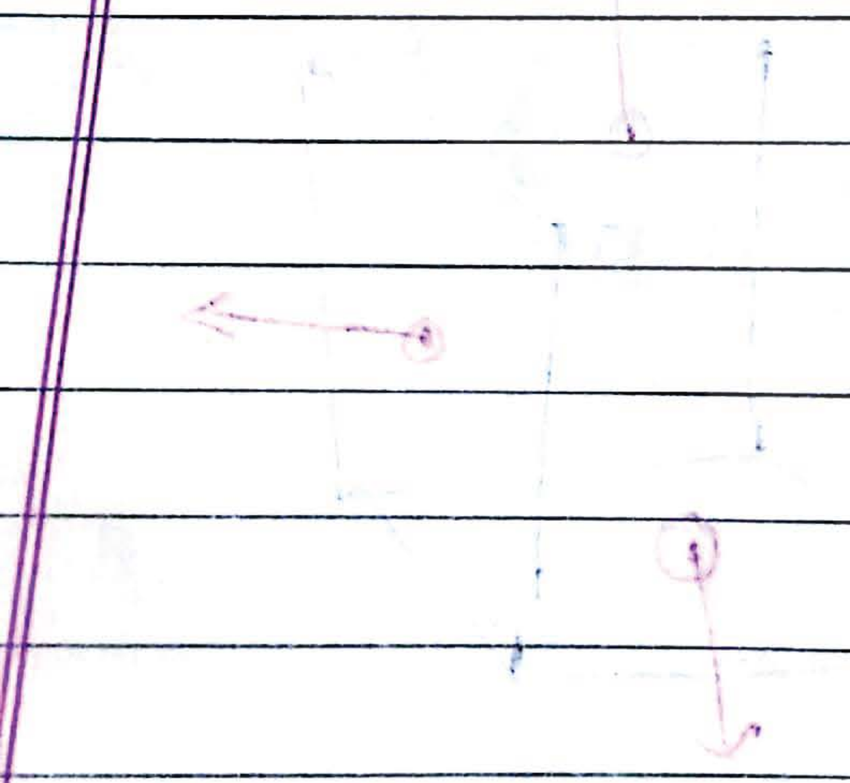
ii) ϕ = +ve $\Rightarrow \phi_{outward}$

ϕ = -ve $\Rightarrow \phi_{Inward}$

Total $\phi = \phi_{in} + \phi_{out}$

ϕ_{in} को -ve में लिखेंगे।

ϕ_{out} को +ve में लिखेंगे।



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Gauss law

Page No.
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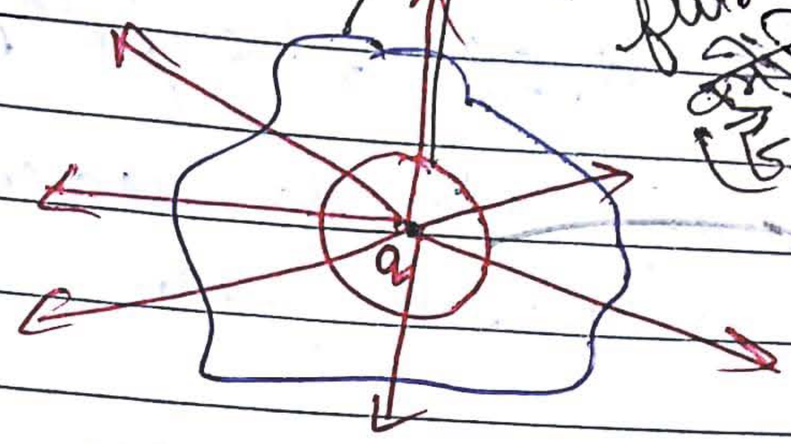
Note →

Definition →



Unsymmetrical shape/sphere का भी apply होता है।

flux same होगा जिस भी shape से दोनों से charge को पास करेंगे।

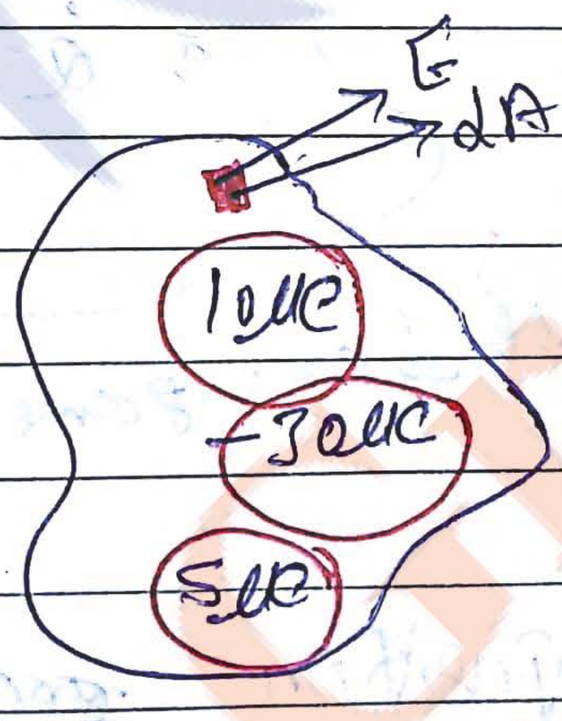
$\phi = \frac{q}{\varepsilon_0}$

1) According to gauss law → flux through any closed surface is given by the product of $\frac{1}{\varepsilon_0}$ and charge enclosed by that closed surface

$$\oint E \cdot dA = \frac{q_{enclosed}}{\varepsilon_0} = \phi_{total}$$

$\phi_{closed\ surface}$

Soln



10μC

20μC

$q_{enclosed} = 10 + 5 - 30$

$= -15\mu C$

$\phi = \frac{-15}{\varepsilon_0} \times 10^{-6}$

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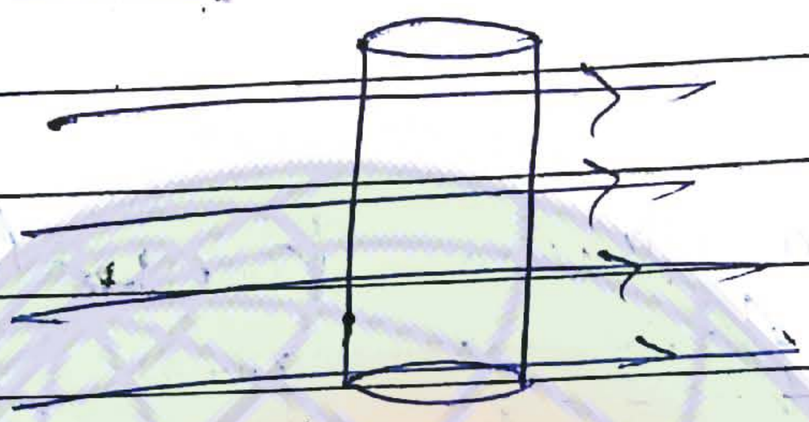
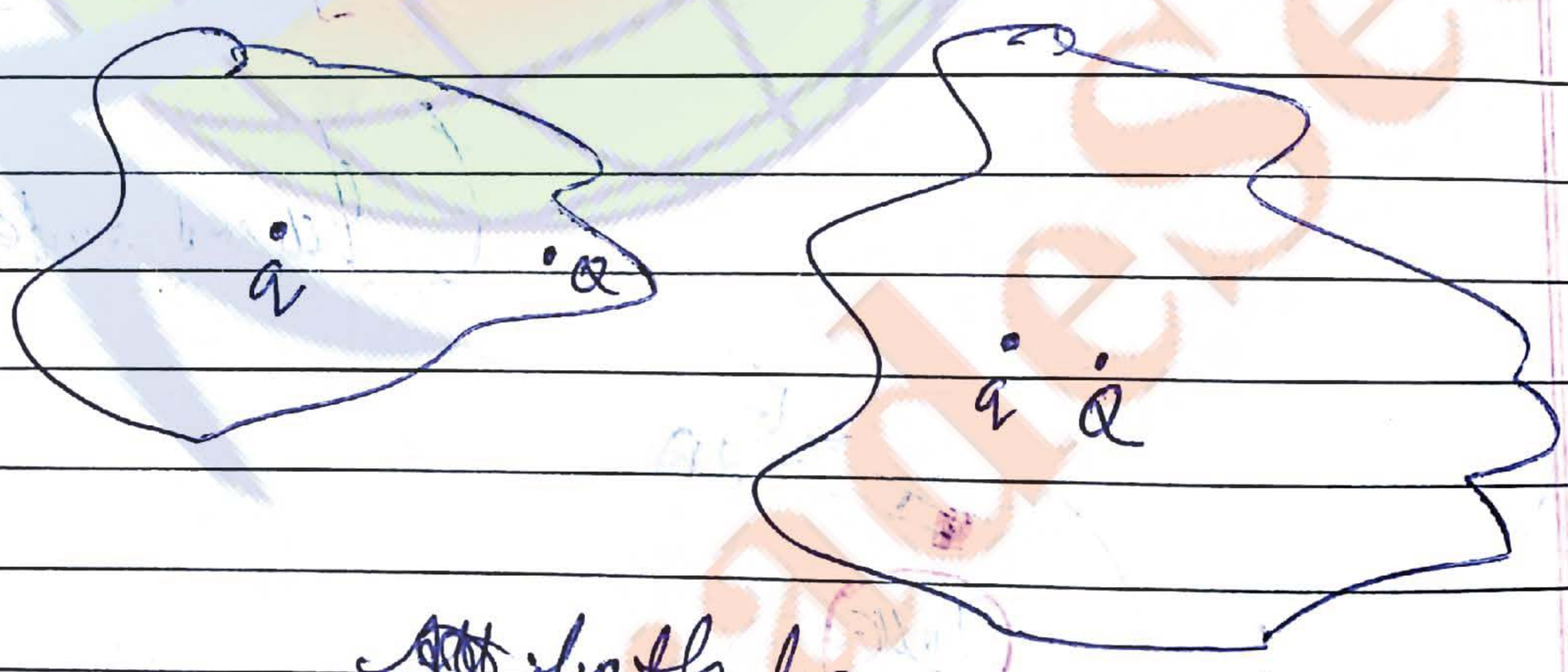
ii) In $\oint \vec{E} \cdot d\vec{A}$, E is electric field due to the charges present inside as well as out side of the closed surface.



iii) Flux through closed surface does not depend on shape and size of closed surface and relative position of charges inside closed surface.



both have same flux.

iv) By changing the position of charge or magnitude outside closed surface flux remain unchange. but electric field can be change.

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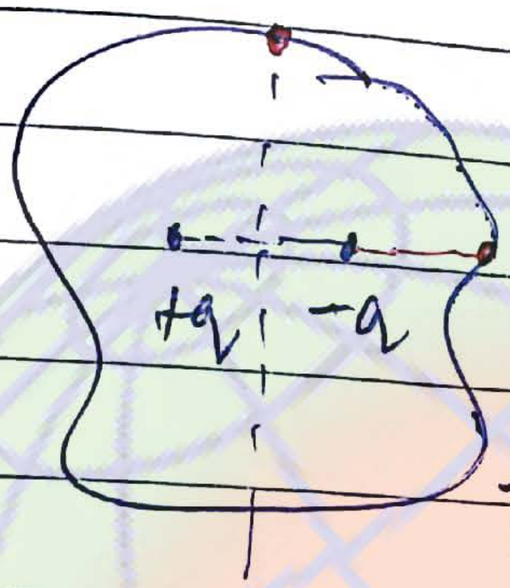
iii) If a flux through closed surface is zero it is not necessarily that E at the surface is zero

But if E is zero on the surface than flux must be zero.



माटे रखे → dipole के case में "E" मतो axis पर zero होता है, और ⊥ मन थी equitorial plane पर / अर्थात dipole के case में E, Infinity पर zero होता है)

flux is zero but E is not zero

iv) flux through closed surface depend on medium also.

(जाने से capacitor में क्या पड़ेगा)

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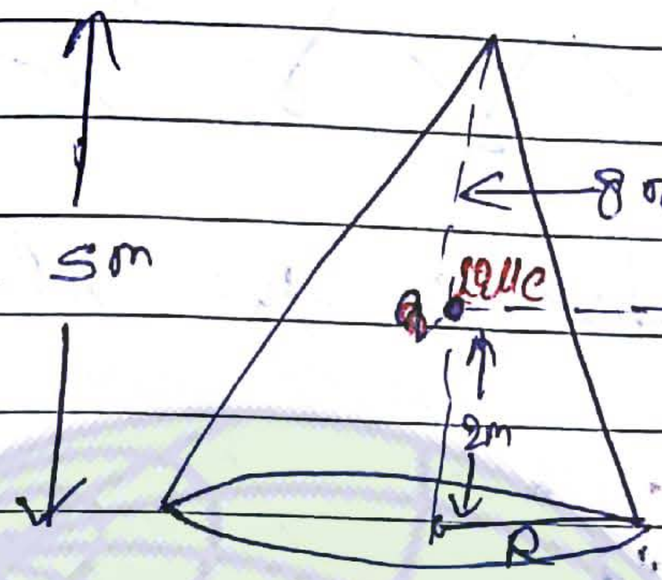
1) Determination of flux using gauss law →

Fig 1)

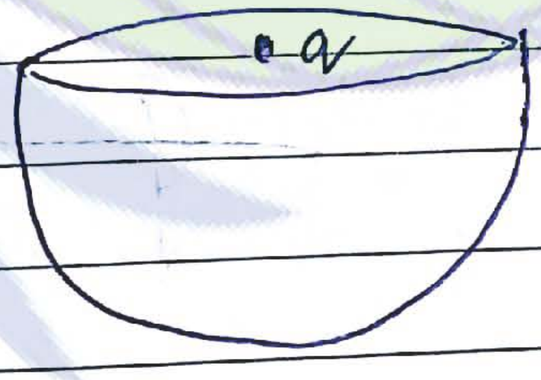


$R > 4m$

$$\phi_{through\ core} = \frac{10\mu C}{\varepsilon_0} - \frac{-10\times10^{-6}}{\varepsilon_0} C$$

↓
इसे तो सिर्फ Surface के अंदर का charge का दिए जो की एकवारय है जो तिरीनों को मदद्गार के लिए दिया गया है इसलिए आप सभी Student ऐसे Question एकवारय Point) से सतर्क रहें।

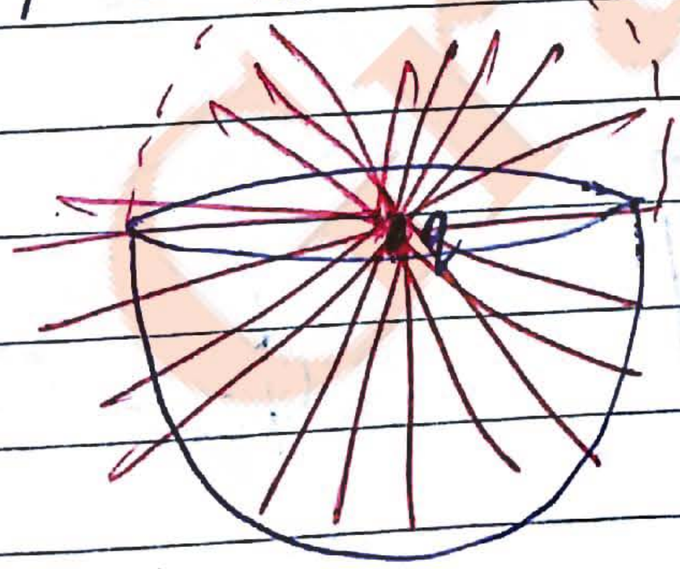
Fig 2)



open hemisphere

ϕ through curved surface of hemisphere ,

Fig



$$\phi_{sphere} = \frac{q}{\varepsilon_0}$$

$$\phi_{open\ hemisphere} = \frac{1}{2} \cdot \frac{q}{\varepsilon_0}$$

चूंकी gauss law सिर्फ closed surface के लिए Applicable है इसलिए सबसे पहले आप closed surface consider करें। A/q - "ϕ" find करें।

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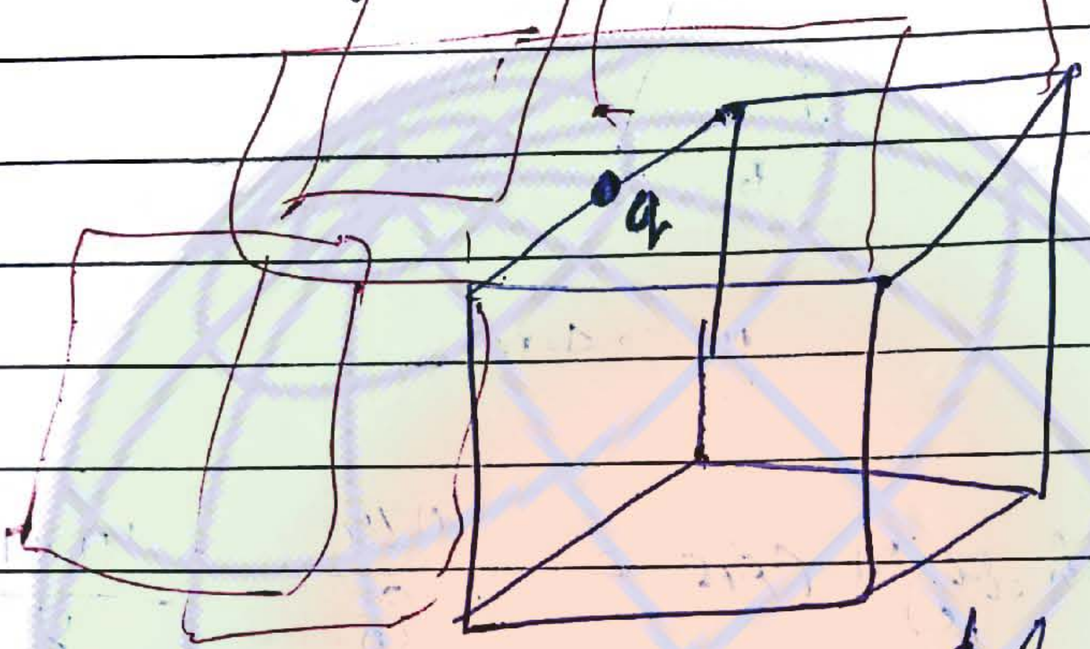
उ॰ ➡ एक charge पूरे ब्रह्मांड में स्थित है तो flux $\frac{q}{\varepsilon_0}$ देता है।

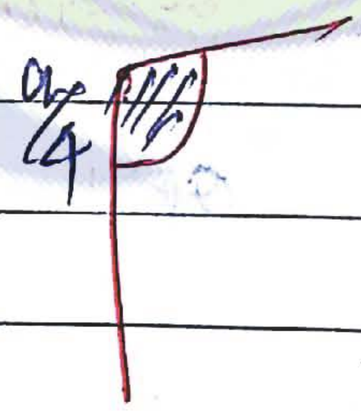
Q3. Determine flux through the cube

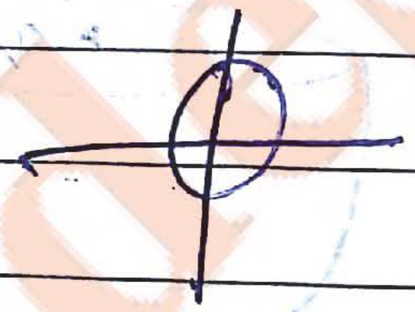


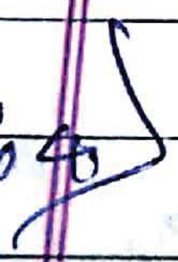
ϕ by cube (छड़ा) $= \frac{q}{\varepsilon_0}$

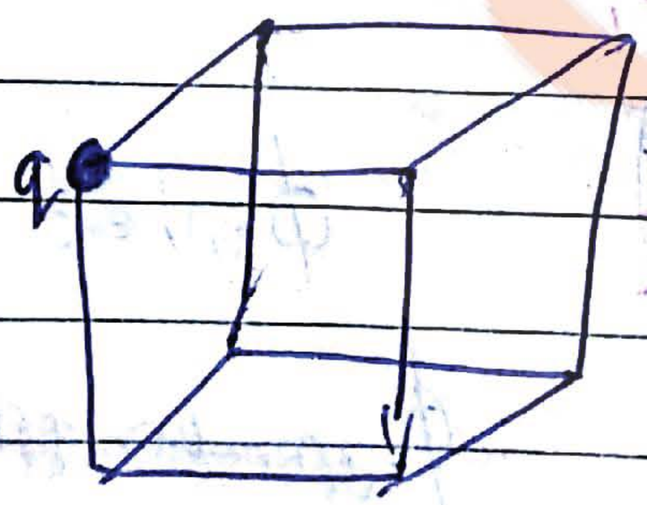
$\phi_{cube} = \frac{1}{4} \cdot \frac{q}{\varepsilon_0}$

Alt









$\phi_{cube} = \frac{1}{8} \cdot \frac{q}{\varepsilon_0}$

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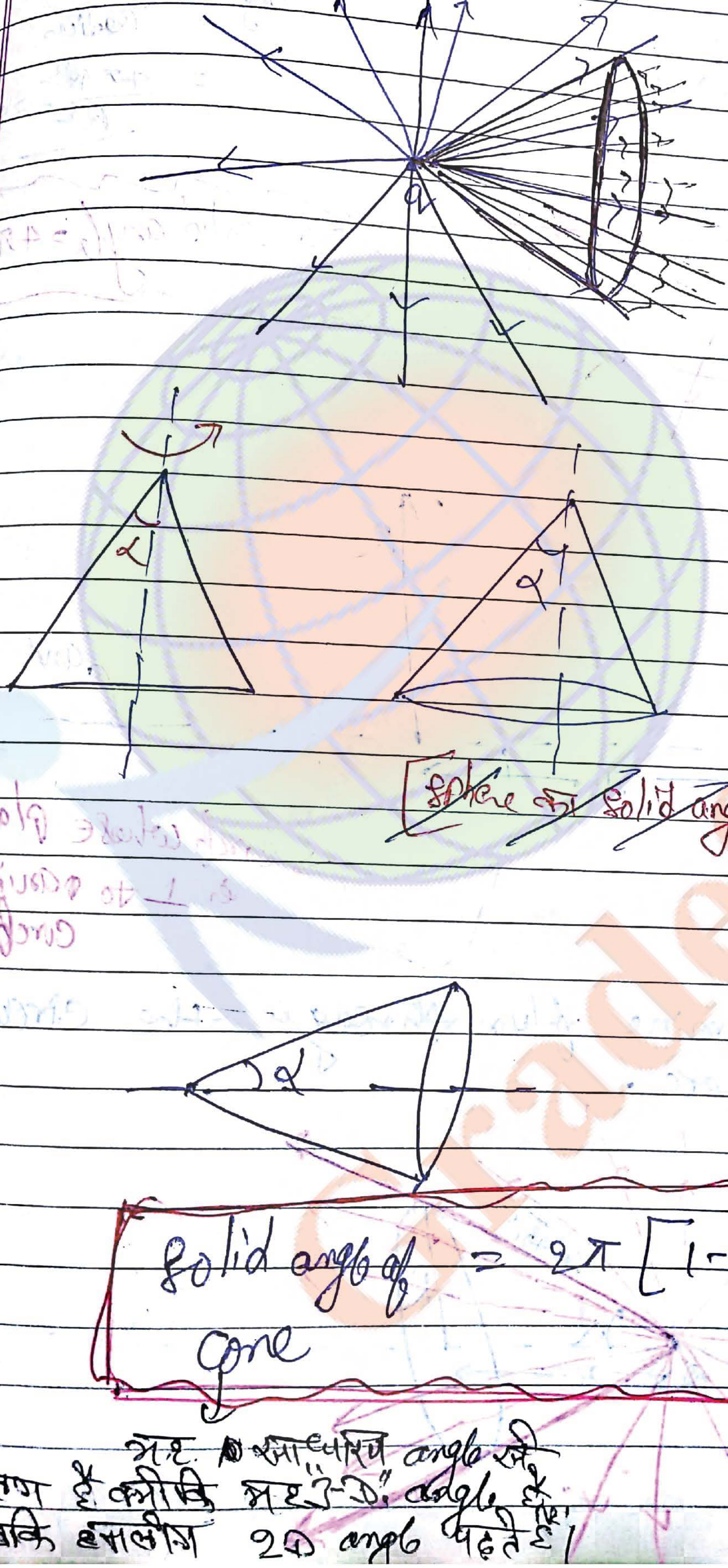
Concept of Solid Angle (घनिय कोण)

↳ It is basically a cone subtended by an area at the point of contact.



Point charge के लिए total flux पूरे ब्रह्मांड में "q" होता है $\frac{q}{\varepsilon_0}$

Sphere का Solid angle $= 4\pi$

$$\text{Solid angle of cone} = 2\pi[1-\cos\alpha]$$

where, α is the semi vertical angle of the cone

यह साधारण angle से अलग है क्योंकि यह 3-D angle है जबकि साधारण 2D angle पढ़ते हैं।

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