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BY

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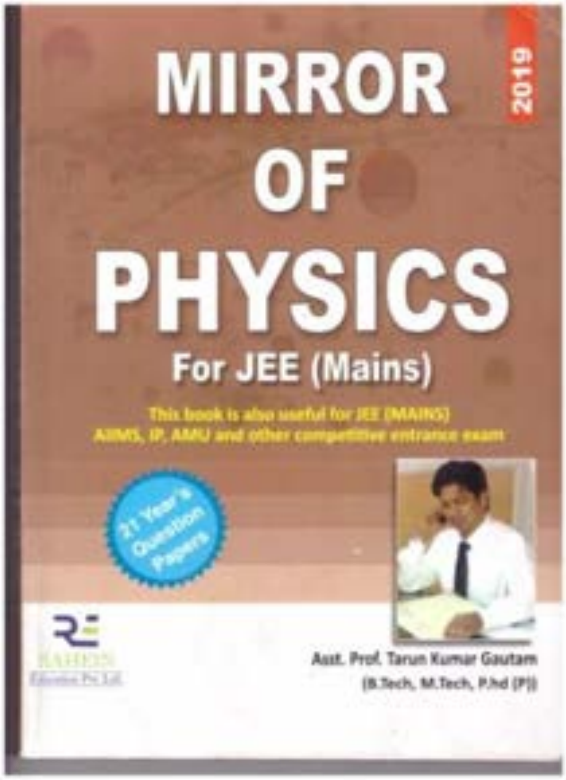
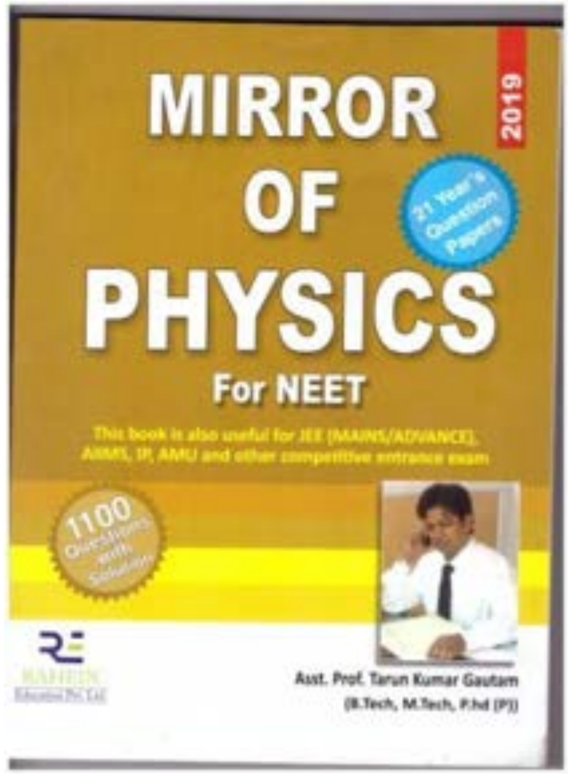
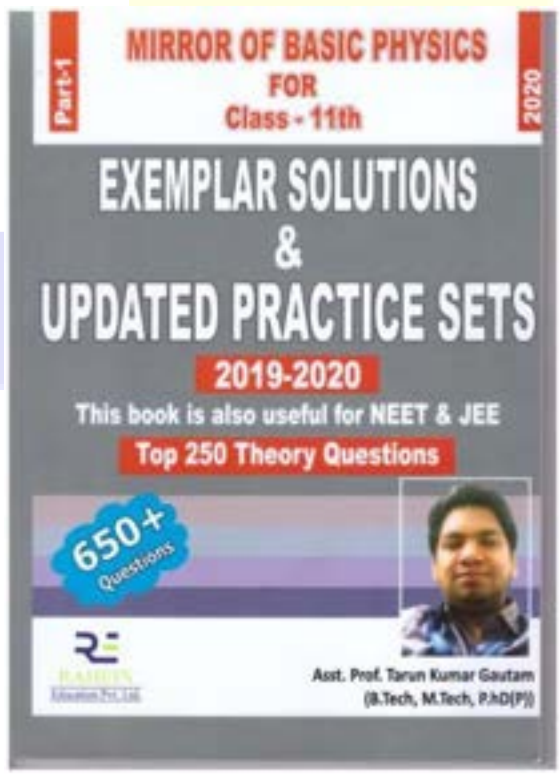


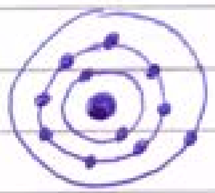




Chapter- 1

3-4 → Derivation
8 → Question
Conceptual Numerical

* $Na \rightarrow 11, \rightarrow (2, 8, 1)$



→ $Na^{\oplus}$, $Na^{\ominus}$ → Ion / charge

* charge $(q)/e$ → $\boxed{e = 1.6 \times 10^{-19} C}$

unit → coulomb (C)

+ve: Proton $= +q = +e$

-ve: electron $= -q = -e$

$$\boxed{\begin{aligned} \text{Proton} &= +e = 1.6 \times 10^{-19} C \\ \text{electron} &= -e = -1.6 \times 10^{-19} C \end{aligned}}$$

Ex: Body → 30 proton

$1e = 1.6 \times 10^{-19} C$

Total charge $= 30 \times 1.6 \times 10^{-19} C$

Q
+ + + +
+ + + +
− − − −

Total charge
$= 8$ proton $= 8 \times 1.6 \times 10^{-19} C$
$= 4$ electron $= 4 \times (-1.6 \times 10^{-19} C)$

Q
+ + + + +
− − − − −

Total charge
= (Total charge of proton) + (Total charge of electron)
$= 5(1.6 \times 10^{-19} C) + (-1.6 \times 10^{-19} C)5$
$= 0$

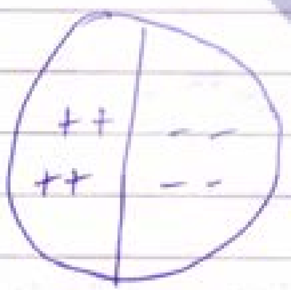
If
Net charge on body is zero
it doesn't mean, it has no charge
But net charge is zero.

Unit of charge → (C)

ex - 2C	ex - 10 μC = 10×10^{-6} C
ex - 3C	ex - 15 mC = 15×10^{-3} C
ex - −5C	

Neutral Body

Net charge = 0



Net charge = 4e + (−4e)
= 0

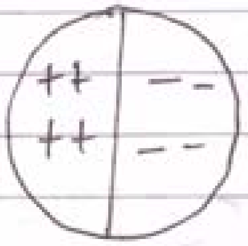
Quantization of Charge

- A body have charge in form of Integral.

$$\boxed{Q = \pm ne}$$

where, $n = 1, 2, 3, 4 \ldots\ldots$
$n \in N$

Note



Total +ve charge = 4e
Total -ve charge = -4e

Total charge = ±4e
Net charge = 0

$$\boxed{Q = \pm ne}$$

Q: A Body has 20C, how many of protons ?

Ans $Q = \pm ne$

$20 = n \times e$

$$\boxed{n = \frac{20}{1.6 \times 10^{-19}}}$$

Q Protons

$\boxed{Q = 320C}$

Q -
100 → n×5 ≤ ex
$320 = n \times 1.6 \times 10^{-19}$

$Q = \pm ne$
$320 = n \times 1.6 \times 10^{-19}$
$\frac{3200}{\cancel{1.6} \times 10^{-19}} = n$

$$\boxed{n = 200 \times 10^{19}}$$

Note -

1) $Q = \pm ne$ (Neutral Body)

2) Proton $= +e = +1.6 \times 10^{-19} C$

electron $= -e = -1.6 \times 10^{-19} C$

3) Coulomb is unit of charge.

4) $I = \frac{q}{t} = \frac{ne}{t}$

$I = \frac{q}{t} = q\nu$ ← frequency [$q = ne$]

$= ne\nu$

5) When charge move in circular path

$I = \frac{q}{t}$, $v = \frac{d}{t} \Rightarrow \boxed{t = \frac{2\pi r}{v}}$

$I = \frac{q}{2\pi r} \times v$

$$\boxed{I = \frac{ne \times v}{2\pi r}}$$

Note

I = current = $\frac{\text{charge}}{\text{time}}$

$\rightarrow$ $\boxed{I = \frac{q}{t}}$,

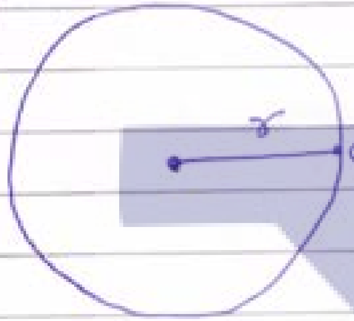
$\rightarrow$ $\boxed{I = \frac{ne}{t}}$

(2)

$\frac{1}{t} = \nu$ = frequency

$I = \frac{q}{t} = q\nu = ne \times \nu$

*** (3) A Proton particle move in circular path of radius (r) with velocity (v) = 3 m/s find the current generated.



$I = \frac{q}{t} = \frac{ne}{t}$ $\rightarrow n = 1$

$I = \frac{1 \times 1.6 \times 10^{-19} C}{t}$

$v = \frac{d}{t}$

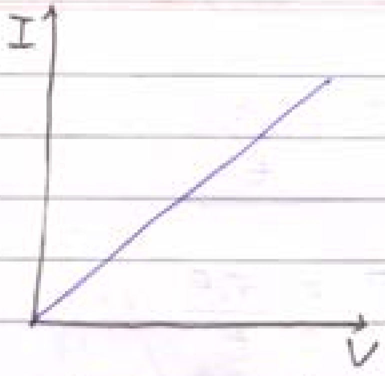
$t = \frac{2\pi r}{v}$

$I = \frac{1.6 \times 10^{-19}}{2\pi r} \times v$

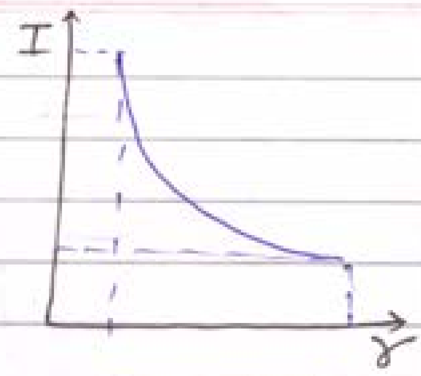
$$\boxed{I = \frac{3 \times 1.6 \times 10^{-19}}{2\pi r}}$$

Ans

4) $I = \dfrac{ne \times v}{2\pi r}$



$\boxed{I \propto v}$



$\boxed{I \propto \frac{1}{r}}$

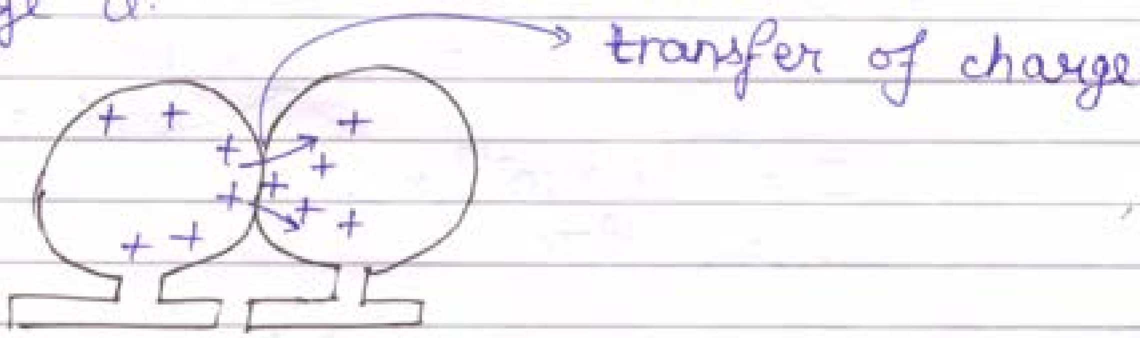
—x—x—x—x—

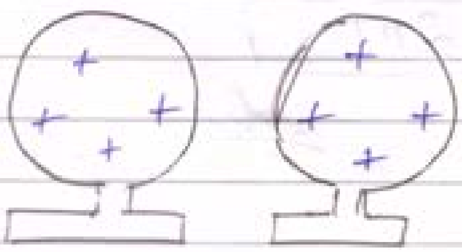
Induction

charging body without touching it with charge Q

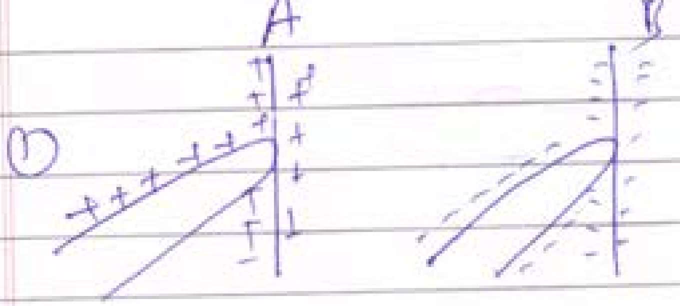
Conduction

Charging body by touching it with charge Q.

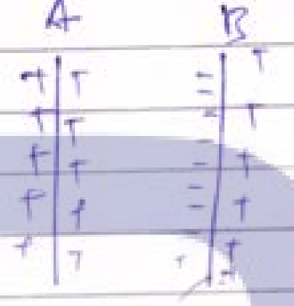




Induction

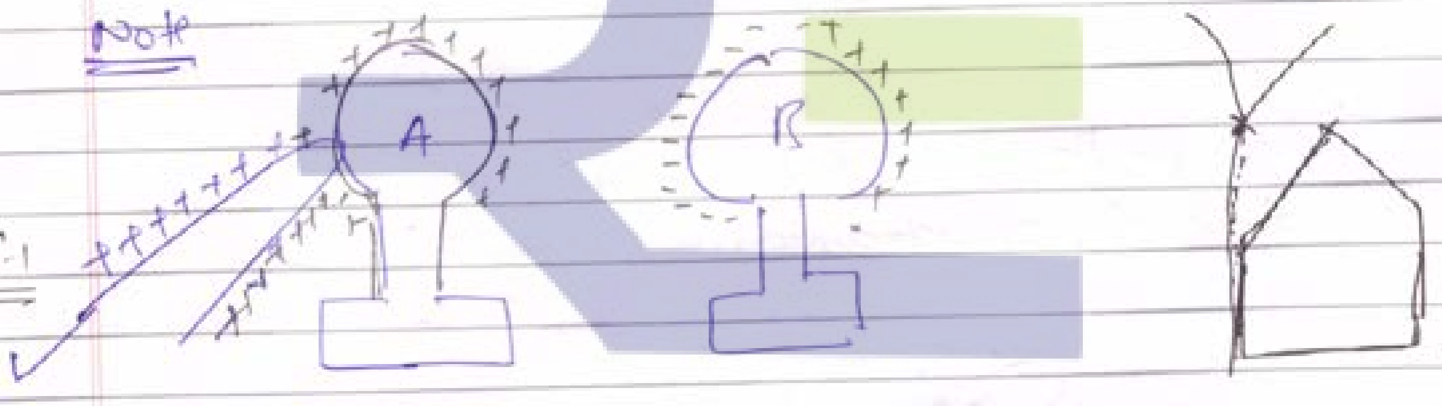
① 

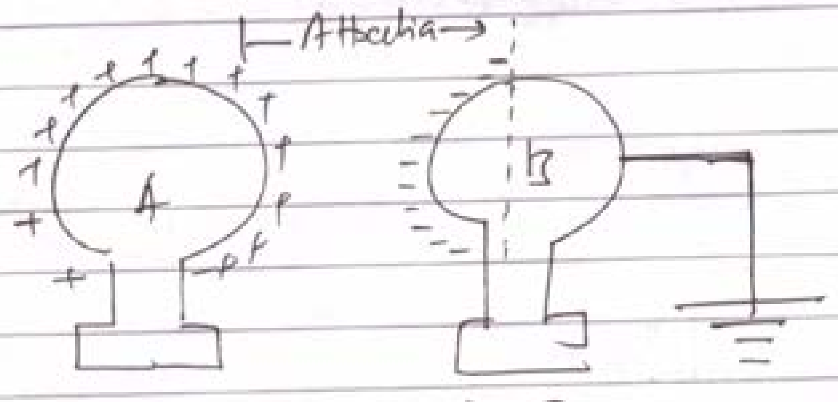
Conduction

② 

→ Induction

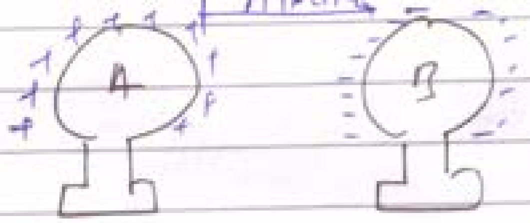
Note

C-1 

C-2 

Earthing

C-3 If we remove earthing from B



Coulb's

Columb's Law

q_1 |—— r ——→ q_2

Force < Attraction / Repulsion

q_1	q_2	f
+ve	+ve	R
+ve	−ve	A
−ve	+ve	A
−ve	−ve	R

Force B/w the Charges is product of Both Charge & divide By square of distance B/w them

$$\rightarrow f \propto q_1 q_2 \quad \text{—(i)}$$

$$\rightarrow f \propto \frac{1}{r^2} \quad \text{—(ii)}$$

$$f \propto \frac{q_1 q_2}{r^2}$$

$$\boxed{f = K\frac{q_1 q_2}{r^2}}$$

K = electrostatic Constant $= 9 \times 10^9$

[∵ ε_0 → Apsylon Nut]

$$K = \frac{1}{4\pi\varepsilon_0}$$

0 → free space

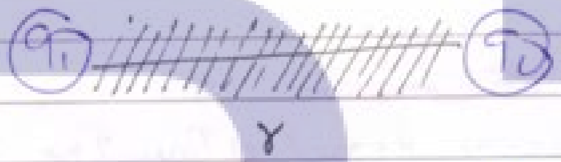
where

ε_0 = electrical permitivity of free space

$$\rightarrow \boxed{f = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}}$$

Note
(i) $|-2| = 2$
(ii) $|2| = 2$

Case.



$$\boxed{f'_{\text{new force}} = \frac{q_1\, q_2}{4\pi\varepsilon\, r^2}}$$

[∵ ε = Electrical Permitivity of Medium]
[$\varepsilon_0 = 8.85 \times 10^{-12}$]

Note:
→ ε_0 → electrical permitivity of free space
→ ε → " " " Medium
→ ε_r → Relative permitivity of Medium with free space

$$\boxed{\varepsilon = \varepsilon_0 \times \varepsilon_r}$$

C-1:

$$f_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \quad \text{—(1)}$$

C-2: Now we replace Air / free air by Medium (ε)

$$f_2 = \frac{1 \times q_1 \times q_2}{4\pi\varepsilon \times r^2} \quad \text{—(2)}$$

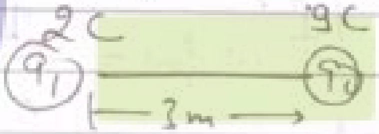
$$\varepsilon = \varepsilon_0 \times \varepsilon_r$$

$$f_2 = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$f_2 = \frac{1}{4\pi\varepsilon_0 \times \varepsilon_r}\frac{q_1 q_2}{r^2} \qquad [\because \varepsilon = \varepsilon_0 \times \varepsilon_r]$$

$$\boxed{f_2 = \frac{f_1}{\varepsilon_r}}$$

Q1: 2C & 9C charge separated by 3m. find the
(a) force?



A $f_1 = K\frac{q_1 q_2}{r^2}$

$$f_1 = \left[\frac{1}{4\pi\varepsilon_0}\right]\frac{q_1 q_2}{r^2} = \frac{9\times10^9 \times 2 \times 9}{(3)^2}$$

$$\boxed{f_1 = 18\times10^9\ N}$$

(b) If we replace free air by a another medium ($\varepsilon_r = 2$) find the new force

A $f_2 = \frac{f_1}{\varepsilon_r}$

$$f_2 = \frac{18\times10^9}{2}$$

$$\boxed{f_2 = 9\times10^9\ N}$$

$$\boxed{f_2 < f_1}$$

(c) How much % change in force?

$$\% \text{ chg} = \frac{\Delta f}{f_1} \times 100$$

$$\Rightarrow \Delta f = f_1 - f_2$$

$$\Delta f = 18 \times 10^9 - 9 \times 10^9$$

$$\boxed{\Delta f = 9 \times 10^9}$$

$$\% \text{ chg} = \frac{\Delta f}{f_1} \times 100 = \frac{9 \times 10^9}{18 \times 10^9} \times 100$$

$$\boxed{\% \text{ change} = 50\%}$$

Note. (i)  $\boxed{f_1 = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}}$

(ii)  $\boxed{f_2 = \frac{f_1}{\varepsilon_r}}$

(iii) $\Delta f = f_1 - f_2$, $[\because f_1 > f_2]$

(iv) $\% \text{ chg} = \frac{\Delta f}{f_1} \times 100 = \left(\frac{f_1 - f_2}{f_1}\right) \times 100$

$$\boxed{\% \text{ chge} = \left(1 - \frac{f_2}{f_1}\right) \times 100}$$

(iv): $f_2 = \frac{f_1}{\varepsilon_r}$ → $\varepsilon_r > 1$

Dielectric constant

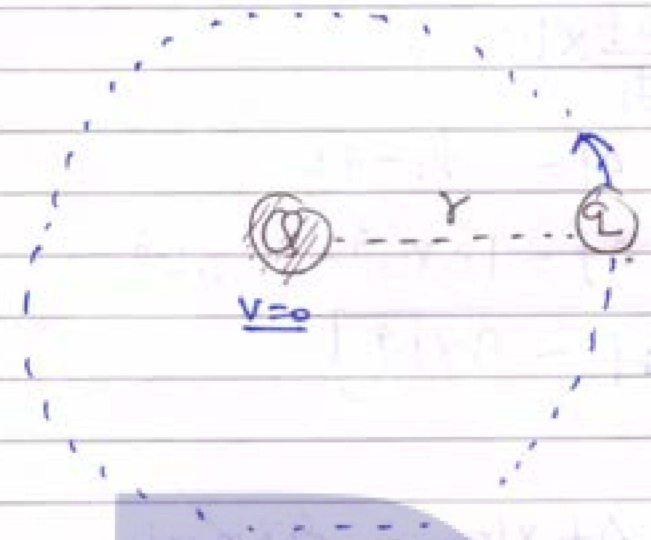
→ $\boxed{\varepsilon_r = 81}$ [water]

→ $\boxed{\varepsilon_r = \infty}$ [Metal]

CBSE
2018

Motion of charge particle

Q. A charge (q) revolving around 'Q' with velocity (v) find the velocity of (q). & draw the graph B/w V ∝ r ?



Ans

(a)

$$\rightarrow f = \frac{K \times Q \times q}{r^2} \quad \text{—(1)}$$

$$\rightarrow f = \frac{mv^2}{r} \quad \text{—(2)} \quad [\because V = \text{velocity of } q']$$

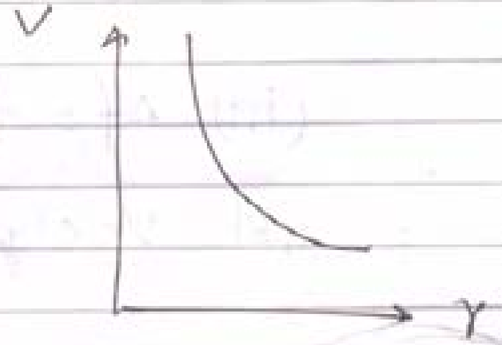
$$\rightarrow \frac{K \times Q \times q}{r^{\cancel{2}}} = \frac{mv^2}{\cancel{r}}$$

$$\frac{K \times Q \times q}{r} = mv^2$$

$$v^2 = \frac{K \times Q \times q}{r \times m}$$

$$\boxed{v = \sqrt{\frac{K \times Q \times q}{r \times m}}}$$

(b) $V \propto \frac{1}{\sqrt{r}}$



Note

(1) $I = \frac{q}{t}$

$q = I \times t$

Dimention → $q = [AT]$

Unit → $q = [A\ sec]$

$\frac{\cancel{A}\cancel{T}}{\cancel{T}} = \boxed{I = A}$

(2) $f = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, $f = [MLT^{-2}]$

$\varepsilon_0 = \frac{q_1 q_2}{4\pi \times f \times r^2}$

Dimention: $\varepsilon_0 = \frac{[AT][AT]}{[MLT^{-2}][L^2]}$

$$\boxed{\varepsilon_0 = [M^{-1}A^2L^{-3} \times T^4]}$$

Unit: $\varepsilon_0 = \frac{C \times C}{N \times m^2} = [N^{-1}C^2m^{-2}]$

$$\boxed{\varepsilon_0 = N^{-1}C^2m^{-2}}$$

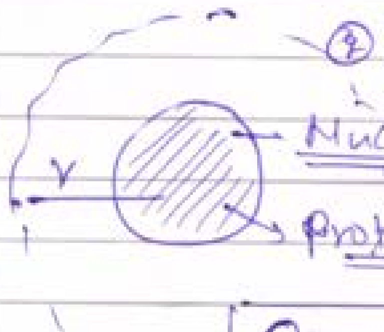
(3) Relative permitivity or Dielectric Constant

$\varepsilon_0 \times \varepsilon_r = \varepsilon$

$\boxed{\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}}$ ⟶ It is dimentionless & unitless

Q: A Charge (q) move around Nucleus, find the radius of circle Path If Charge is move with velocity (v)?

A



Nucleus: →

Proton ⇒ No of Proton = Atomic No (Z)

$$\boxed{Q = Z \times e}$$

Charge on one proton = 1e

$$\boxed{Q = Z \times e}$$

$$f = \frac{K Q_1 Q_2}{r^2} = \frac{1}{4\pi\varepsilon_0} \times \frac{Ze \times q}{r^2} \quad (1)$$

$$f = \frac{mv^2}{r} \quad (2)$$

$$\frac{mv^2}{\cancel{r}} = \frac{1}{4\pi\varepsilon_0} \times \frac{Ze \times q}{r\cancel{2}}$$

$$\boxed{\frac{mv^2 \times 4\pi\varepsilon_0}{Ze \times q} = r}$$

A

Note: [$Z = 10$, $e = 1.6 \times 10^{-19}$, $V = 5\,m/s$, $m = 0.2g$

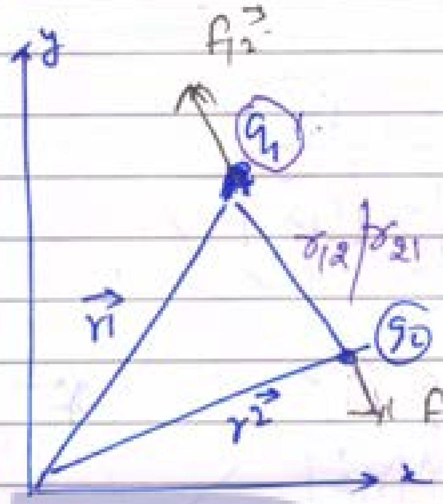
$r = ?$]

r_{12} 1 ——— 2

$-r_{21}$

1 $\leftarrow$ 2

[Vector form of Coulomb's law] →



Let q_1 & q_2 be the charge
and $\vec{r_1}$ & $\vec{r_2}$ be position vector of charge q_1 & q_2

Let $\vec{f_{12}}$ & $\vec{f_{21}}$ be the force

→ Let $\vec{f_{12}}$ is force on (q_1) by (q_2).

→ Let $\vec{f_{21}}$ is force on (q_2) by (q_1).

→ $$\vec{f_{12}} = \frac{K q_1 q_2}{|\vec{r_{12}}|^2} \hat{r_{21}} \quad \text{--- (1)}$$

$$\vec{f_{21}} = \frac{K q_1 q_2}{|\vec{r_{21}}|^2} \hat{r_{12}}$$

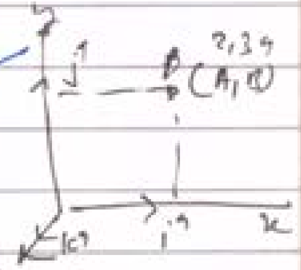
$$\therefore \hat{r_{12}} = \frac{\vec{r_{12}}}{|\vec{r_{12}}|}$$

$$\therefore |\vec{r_{12}}| = |\vec{r_{21}}|.$$

$$\therefore \hat{r_{12}} = -\hat{r_{21}}$$

Note

①



$\vec{P} = 2+3+4$

$$|\vec{P} = \underset{x}{2\hat{i}} + \underset{y}{3\hat{j}} + \underset{z}{4\hat{k}}|$$

Position vector

② Magnitude / value

$$P = |\vec{P}| = \sqrt{x^2+y^2+z^2}$$
$$= \sqrt{2^2+3^2+4^2}$$
$$= \sqrt{4+9+16}$$
$$= \sqrt{29}$$

③ Direction $(\hat{P})$

$$\hat{P} = \frac{\vec{P}}{|\vec{P}|} = \frac{\vec{P}}{P}$$

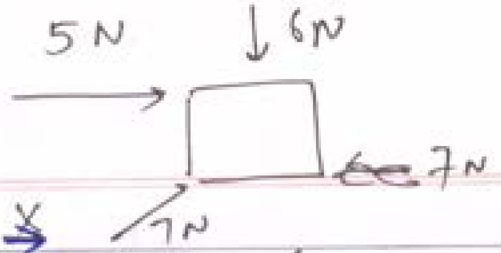
$\rightarrow \quad \vec{f_{21}} = \frac{k q_1 q_2}{|\vec{r_{21}}|^2} \hat{r_{12}}$

$$\boxed{\begin{aligned} \vec{f_{21}} &= \frac{k q_1 q_2}{|\vec{r_{21}}|^2} \cdot \frac{\vec{r_{12}}}{|\vec{r_{12}}|} \qquad \left[|\vec{r_{21}}| = |\vec{r_{12}}| \right] \\ \vec{f_{21}} &= \frac{k q_1 q_2 \, \vec{r_{12}}}{|\vec{r_{12}}|^2 \cdot |\vec{r_{12}}|} \\ \vec{f_{21}} &= \frac{k q_1 q_2 \, \vec{r_{12}}}{|\vec{r_{12}}|^3} \end{aligned}}$$

$\rightarrow \quad \vec{f_{21}} = \frac{k q_1 q_2 \, (-\hat{r_{21}})}{|\vec{r_{12}}|^2}$

$\rightarrow \quad \vec{f_{21}} = -\frac{k q_1 q_2 \, \hat{r_{21}}}{|\vec{r_{12}}|^2}$

$\rightarrow \quad \boxed{\vec{f_{21}} = -\vec{f_{12}}}$ It follow Newton III rd Law



$\vec{f} = 5\hat{i} + 6\hat{j} + 2\hat{k}$ [Vector form]

$f = |f| = \sqrt{25+36+4} = \sqrt{65}$ N

$\vec{f} = 5\hat{i}$ N

$f = 5.$ N

$\vec{f} = 5$ N

$\vec{f} = [2\hat{i} + 10\hat{j}]$ $f = \sqrt{4+100}$

$f = \sqrt{104}$ N

Note

(1) $\vec{f_{12}} = \frac{kq_1q_2}{|\vec{r_{12}}|^2} \cdot \hat{r_{21}}$

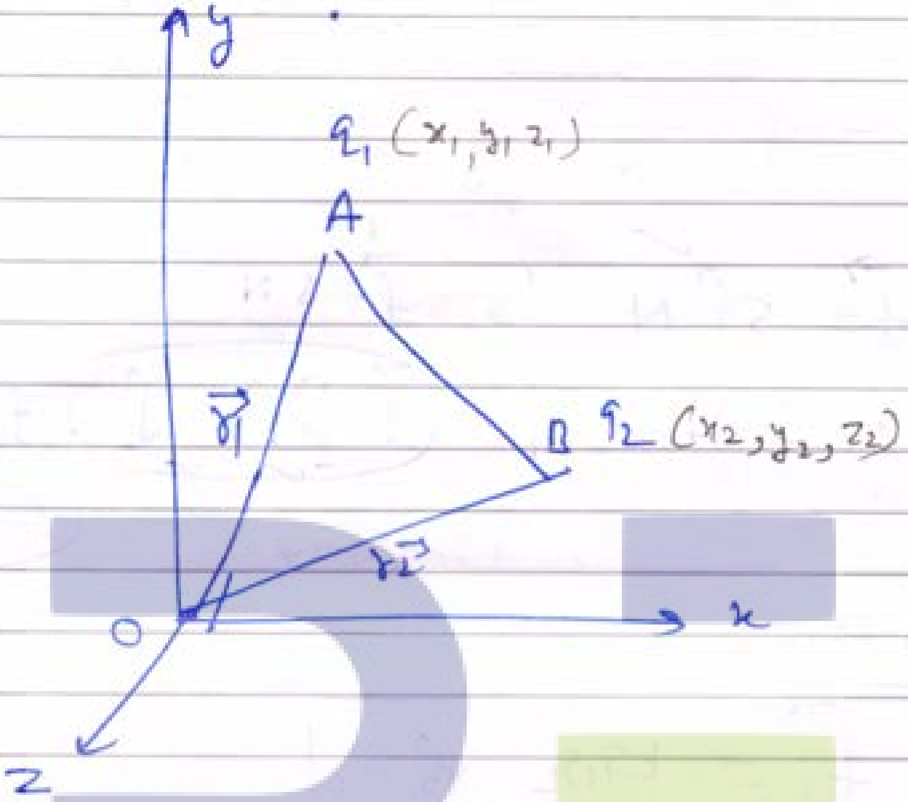
$\vec{f_{21}} = \frac{kq_1q_2}{|\vec{r_{21}}|^2} \hat{r_{12}}$

(2) $|\vec{r_{12}}| = |\vec{r_{21}}|$

(3) $\hat{r_{12}} = -\hat{r_{21}}$

(4) $\vec{f_{12}} = -\vec{f_{21}}$.

Extention:



Let $\vec{r_1}$ = position vector of (q_1)
Let $\vec{r_2}$ = " " " (q_2).

$$\vec{r_1} = x_1\hat{i} + y_1\hat{j} + z_1\hat{k}$$

$$\vec{r_2} = x_2\hat{i} + y_2\hat{j} + z_2\hat{k}$$

$$\vec{f_{12}} = \frac{k q_1 q_2}{|\vec{r_{12}}|^2} \cdot \hat{r_{21}} = \frac{k q_1 q_2}{|\vec{r_{12}}|^2} \frac{\vec{r_{21}}}{|\vec{r_{21}}|} = \frac{k q_1 q_2 \, \vec{r_{21}}}{|\vec{r_{21}}|^3}$$

$$\boxed{\vec{f_{12}} = \frac{k q_1 q_2 \cdot \vec{r_{21}}}{|\vec{r_{21}}|^3}}$$

$\rightarrow \vec{r_{21}} = \vec{r_2} - \vec{r_1}$

$\rightarrow \vec{r_{21}} = [x_2\hat{i} + y_2\hat{j} + z_2\hat{k}] - [x_1\hat{i} + y_1\hat{j} + z_1\hat{k}]$

$\rightarrow \vec{r_{21}} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$

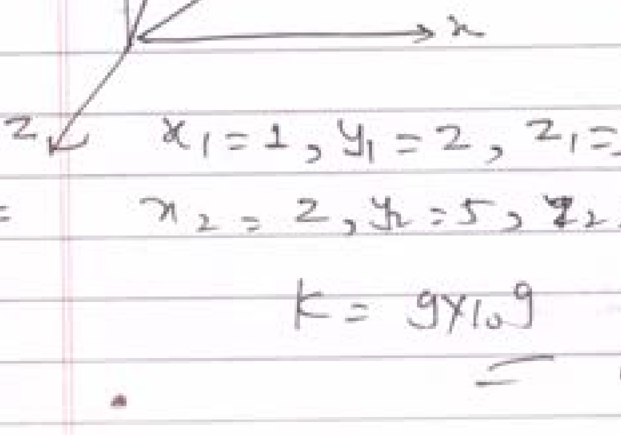
$|\vec{r_{21}}| = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$

$$\boxed{\vec{f_{12}} = \frac{kq_1q_2\left[(x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}\right]}{\left[(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2\right]^{3/2}}}$$

$\boxed{\vec{f_{21}} = -\vec{f_{12}}}$

$\boxed{(\sqrt{a})^3 \quad (a^{1/2})^3 = a^{3/2}}$

Q.



find $\vec{f_{12}}$ & $\vec{f_{21}}$

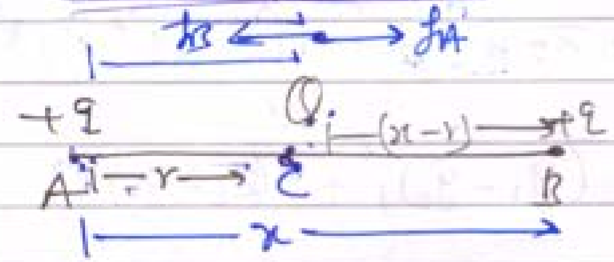
A. $x_1 = 1, y_1 = 2, z_1 = 3$ | $q_1 = 2C$
$x_2 = 2, y_2 = 5, z_2 = 6$ | $q_2 = 3C$

$k = 9 \times 10^9$

=

−ve | +ve

Q:1 → where we should place charge (Q) so system remain equilibrium?



Ans:

$$\rightarrow \underline{A} \rightarrow \underline{C} \rightarrow f_A = \frac{k\, q_A \times q_C}{AC^2} = \frac{k \times q \times Q}{r^2} \quad (1)$$

$$\rightarrow \underline{B} \rightarrow \underline{C} \rightarrow f_B = \frac{k \times q_B \times q_C}{r_{BC}^2} = \frac{k \times q \times Q}{(x-r)^2} \quad (2)$$

Direction

$$\rightarrow \boxed{f_N = f_A - f_B} = 0$$

for equilibrium $\boxed{f_N = 0}$

$$\rightarrow f_A = f_B$$

$$\rightarrow \frac{\cancel{k \times q \times Q}}{r^2} = \frac{\cancel{k \times q \times Q}}{(x-r)^2}$$

$$\rightarrow \frac{1}{r^2} = \frac{1}{(x-r)^2}$$

$$\rightarrow (x-r)^2 = r^2$$

Square root Both side

$$\rightarrow x - r = r$$

$$\rightarrow x = r + r$$

$$\rightarrow x = 2r$$

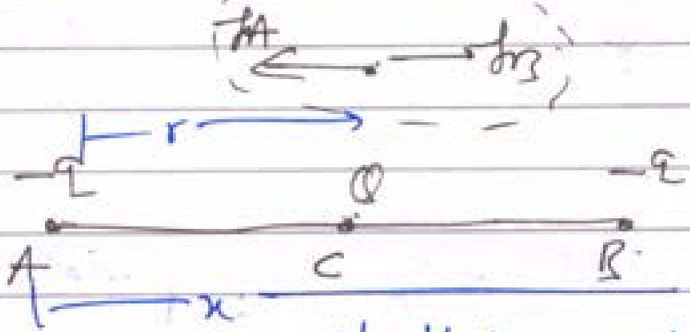
$$\boxed{r = \frac{x}{2}}$$ Ans

q_A q_C q_B

$$\left.\begin{array}{c|c|c} A \leftarrow C & B \leftarrow A & C \leftarrow A \\ A \leftarrow B & B \leftarrow C & C \leftarrow B \end{array}\right] \Rightarrow 6$$

~~Magnitude~~

Note distance



Q2

$A \to C \to f_A = \frac{k q_A \times q_C}{r_{AC}^2} = \frac{k\,|-q|\times Q}{r^2} = \frac{k \times q \times Q}{r^2}$ ①

$B \to C \to f_B = \frac{k q_B \times q_C}{r_{BC}^2} = \frac{k \times |-q| \times Q}{(x-r)^2} = \frac{k \times q \times Q}{(x-r)^2}$ ②

$\to f = f_B - f_A = 0$ [for equ.]

$\to f_B - f_A = 0$

$\to f_B = f_A$

$$\frac{k \times q \times Q}{r^2} = \frac{k \times q \times Q}{(x-r)^2}$$

$x - r = r$

$x = 2r$

$\boxed{r = x/2}$

① $\longrightarrow f_A$, $\longrightarrow f_B$

$f = f_A + f_B$

② $f_B \longleftarrow \bullet \longrightarrow f_A$

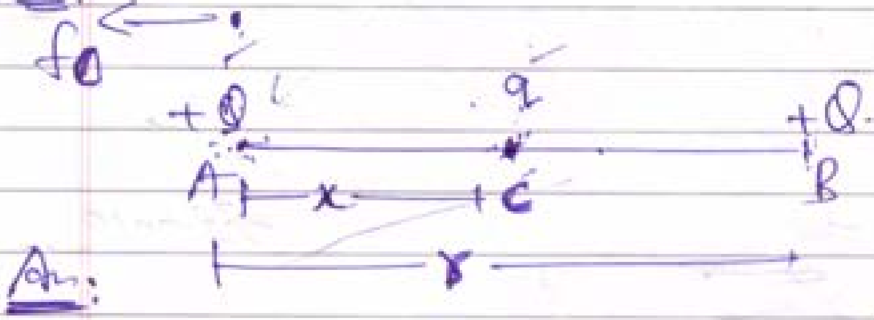
$\to f = f_B - f_A$

③ $\longleftarrow f_A$, $\longleftarrow f_B$

$\boxed{f = -f_A - f_B}$

*

2001, 2005, 2017



What is magnitude of charge (q)? and system remains equilibrium

Ans:

Force on A

$C \to A \Rightarrow f_C = \dfrac{K q_A \times q_C}{(AC)^2} = \dfrac{K \times Q \times q}{x^2}$ —(1)

$B \to A \Rightarrow f_B = \dfrac{K q_A \times q_B}{(AB)^2} = \dfrac{K \times Q \times Q}{r^2}$ —(2)

$\to f = -f_C - f_B = 0$

$\to -f_C = f_B$

$\to f_C = -f_B$

$\to \dfrac{\cancel{K} \times Q \times q}{x^2} = \dfrac{-K \times Q \times Q}{r^2}$

$\to \dfrac{q}{x^2} = \dfrac{-Q}{r^2}$

$\to \boxed{q = -\dfrac{Q}{r^2} \times x^2}$

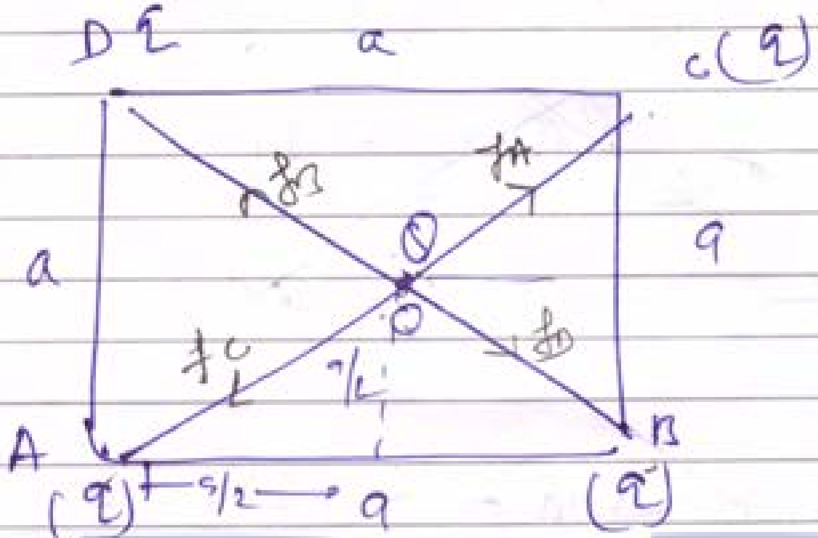
$$\boxed{f = \frac{K|q_1||q_2|}{r^2}}$$

$q_1 \xrightarrow{r} q_2$

DATE: __/__/____ PAGE 23

Note $|-2| = 2$

Q.



find the force on 'O'

A.

$A \longrightarrow O \rightarrow f_A = \frac{Kq_A \times q_0}{(AO)^2} = \frac{K \times q \times Q}{(AO)^2}$

$B \longrightarrow O \rightarrow f_B = \frac{Kq_B \times q_0}{(BO)^2} = \frac{K \times q \times Q}{(OB)^2}$

$C \longrightarrow O \rightarrow f_C = \frac{Kq_C \times q_0}{(OC)^2} = \frac{K \times q \times Q}{(OC)^2}$

$D \longrightarrow O \quad f_D = \frac{K \times q_D \times q_0}{(OD)^2} = \frac{K \times q \times Q}{(OD)^2}$

$[OA = OB = OC = OD = r]$

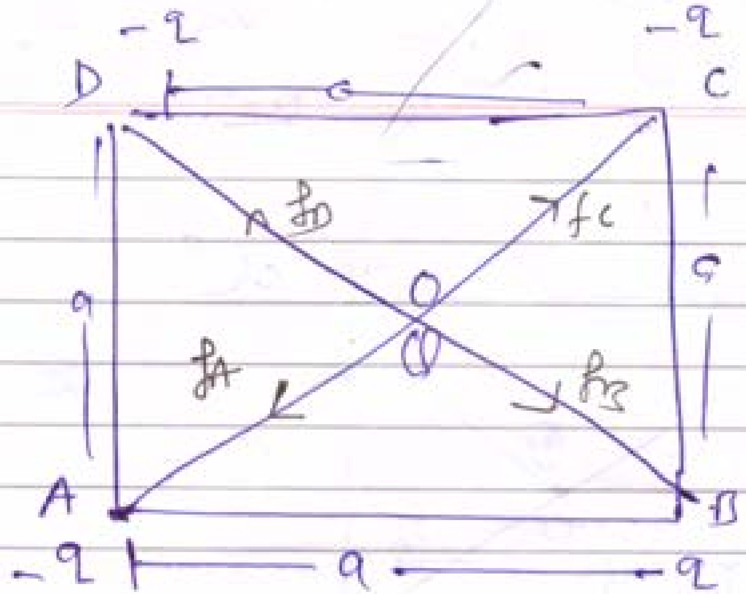
$\therefore [f_A = f_B = f_C = f_D = f]$

→ f_B & f_D cancel out each other

→ f_C & f_A " " "

So net force will be zero Ans

Q



A

$$A \rightarrow O \rightarrow f_A = \frac{K|-q| \times Q}{(OA)^2} = \frac{K \times q \times Q}{(OA)^2}$$

$$B \rightarrow O \rightarrow f_B = \frac{K \times q \times Q}{OB^2}$$

$$C \rightarrow O \rightarrow f_C = \frac{K \times q \times Q}{OC^2}$$

$$D \rightarrow O \rightarrow f_D = \frac{K \times q \times Q}{(OD)^2}$$

$[f_A = f_B = f_C = f_D = f]$ $[OA = OB = OC = OD = r]$

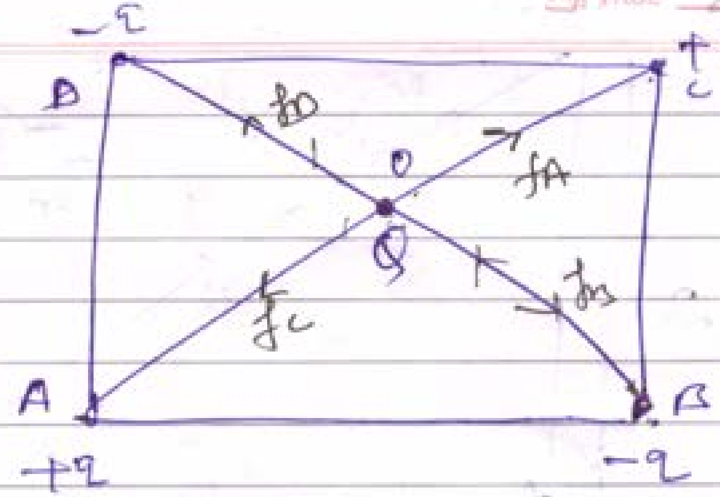
f_B & f_D are in opposite direction so they cancel out each other

Similarly f_A & f_C " " " " " " " "

A

Q

find the force at 'O'



A

$$A \longrightarrow O \rightarrow f_A = \frac{K \times q \times Q}{(OA)^2}$$

$$B \longrightarrow O \rightarrow f_B = \frac{K|-q| \times Q}{(OB)^2} = \frac{K \times q \times Q}{(OB)^2}$$

$$C \longrightarrow O \rightarrow f_C = \frac{K \times q \times Q}{(OC)^2}$$

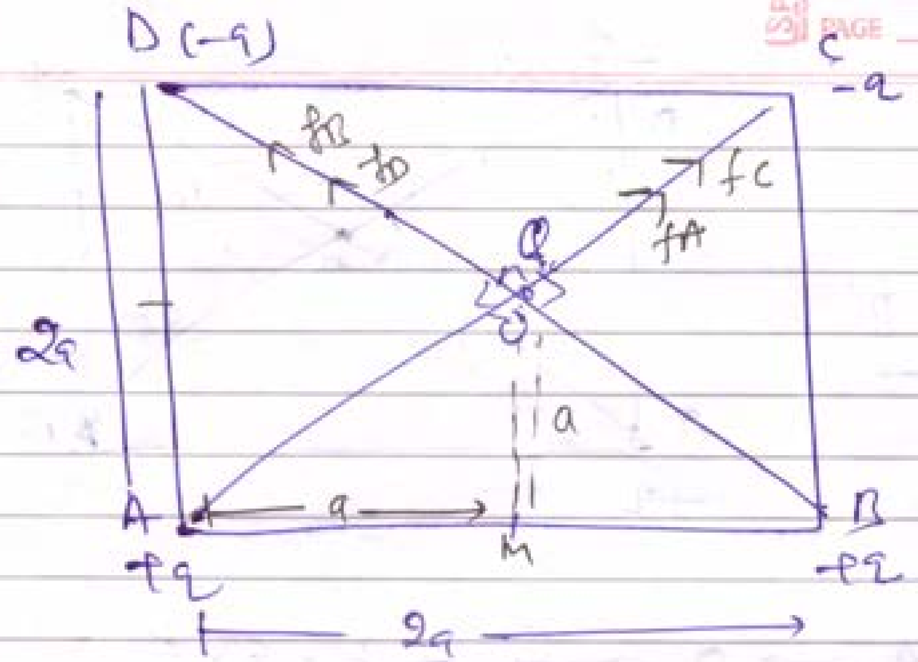
$$D \longrightarrow O \rightarrow f_D = \frac{K|-q| \times Q}{(OD)^2} = \frac{K \times q \times Q}{(OD)^2}$$

$$\boxed{f_N = 0}$$

Note

$O \leftarrow A$	$A \leftarrow O$	$B \leftarrow O$	$C \leftarrow O$	$D \leftarrow O$
$O \leftarrow B$	$A \leftarrow B$	$B \leftarrow A$	$C \leftarrow A$	$D \leftarrow A$
$O \leftarrow C$	$A \leftarrow C$	$B \leftarrow C$	$C \leftarrow D$	$D \leftarrow B$
$O \leftarrow D$	$A \leftarrow B$	$B \leftarrow D$	$C \leftarrow B$	$D \leftarrow C$

Q



A

$A \to O \to f_A = \dfrac{K \times q \times Q}{OA^2}$

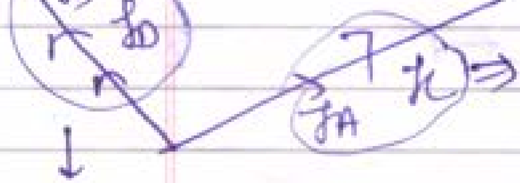
$B \to O \to f_B = \dfrac{K \times q \times Q}{(OB)^2}$

$C \to O \to f_C = \dfrac{K \times q \times Q}{(OC)^2}$

$D \to O \to f_D = \dfrac{K \times q \times Q}{(OD)^2}$.

$\therefore [f_A = f_B = f_C = f_D = f]$

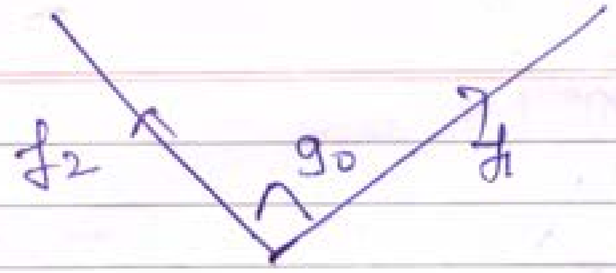
$\therefore [OA = OB = OC = OD = x]$



$\Rightarrow f_1 = f_A + f_C$

$f_1 = f + f = 2f$

$f_2 = f_B + f_D = f + f = 2f$



$\therefore f_1 = 2f$

$f_2 = 2f$

$$f_M = \sqrt{f_1^2 + f_2^2 + 2f_1 f_2 \cos 90}$$

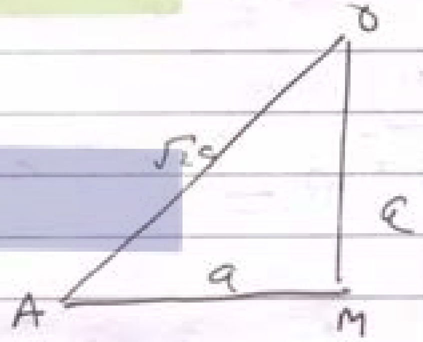
$[\because \cos 90 = 0]$

$$f_M = \sqrt{f_1^2 + f_2^2}$$

$$f_M = \sqrt{(2f)^2 + (2f)^2}$$

$$f_M = \sqrt{4f^2 + 4f^2} = \sqrt{8f^2} = 2\sqrt{2}\,f$$

$$f_M = \frac{2\sqrt{2} \times K \times q \times Q}{(OA)^2}$$



$$\boxed{f_M = \frac{2\sqrt{2} \times K \times q \times Q}{(\sqrt{2}a)^2}}$$

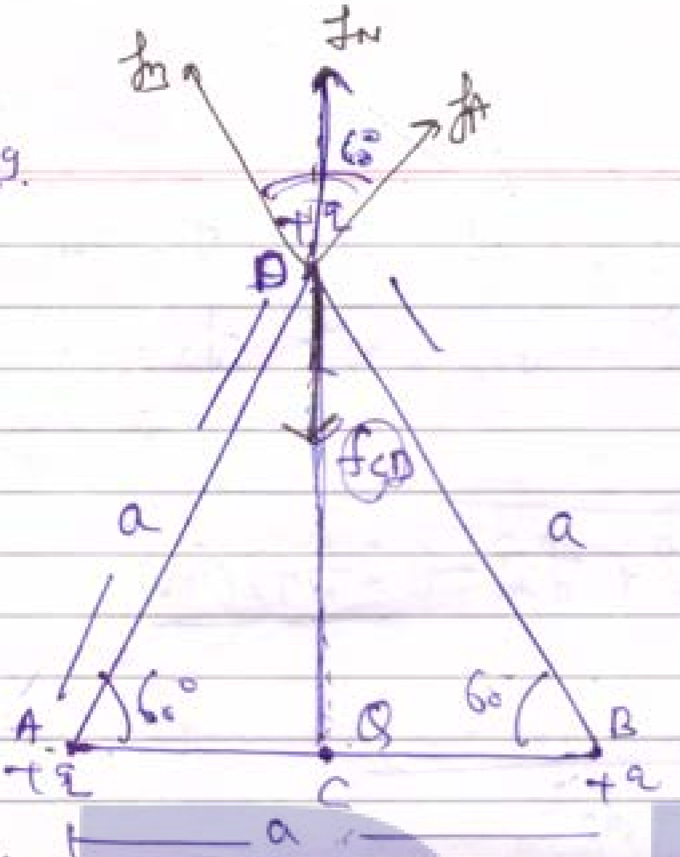
A

$AO^2 = a^2 + a^2 = 2a^2$

$AO = \sqrt{2a^2} = \sqrt{2}a$

2017, 2019.

Q:



(i) What is sign of charge at 'C' and whole system remain equilibrium

(ii) What is magnitude of charge at 'C'

A (i) Sign should be Negative.

(ii):

$$f_B = K \times \frac{q \times q}{a^2} = \frac{Kq^2}{a^2} \quad \text{— (1)}$$

$$f_A = K \frac{q \times q}{a^2} = \frac{Kq^2}{a^2} \quad \text{— (2)}$$

Let $f_B = f_A = f$

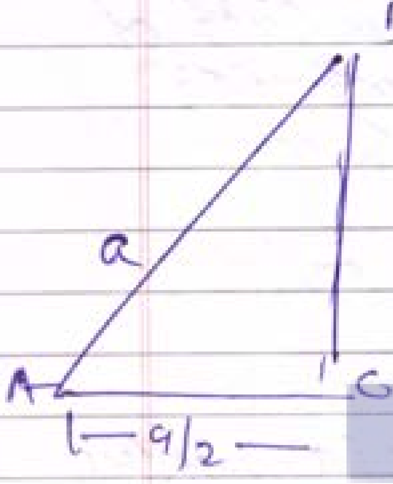
$$\rightarrow f_N = \sqrt{f_A^2 + f_B^2 + 2 f_A f_B \cos 60}$$

$$f_N = \sqrt{f^2 + f^2 + 2ff \cos 60} = \sqrt{f^2 + f^2 + f^2} = \sqrt{3f^2}$$

$$\boxed{f_N = \sqrt{3} f = \frac{\sqrt{3} \times Kq^2}{a^2}} \quad \text{— (3)}$$

F_{CD} = Force B/w (C) & (D)

$$F_{CD} = \frac{k q_C \times q_D}{(CD)^2} =$$



$$\rightarrow a^2 = CD^2 + \left(\frac{a}{2}\right)^2$$

$$\rightarrow a^2 = CD^2 + \frac{a^2}{4}$$

$$\rightarrow a^2 - \frac{a^2}{4} = CD^2$$

$$\rightarrow \boxed{\frac{3a^2}{4} = CD^2}$$

$$F_{CD} = \frac{k \times Q \times q}{\left(3a^2/4\right)} \leftarrow (4)$$

For System equilib

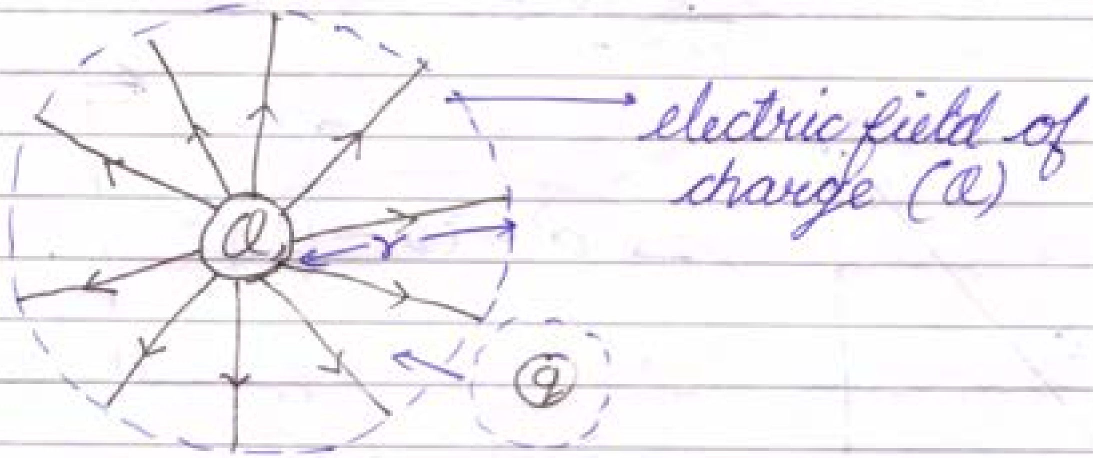
$$\rightarrow F_{net} = F_{CD}$$

$$\rightarrow \frac{\sqrt{3} \times q^{\cancel{2}} \cancel{k}}{a^{\cancel{2}}} = \frac{\cancel{k} \times Q \times \cancel{q} \times 4}{3 a^{\cancel{2}}}$$

$$\rightarrow \sqrt{3} \times q = \frac{Q \times 4}{3}$$

$$\rightarrow \boxed{\frac{3\sqrt{3}}{4} \times q = Q}$$

Electric Field



The space around the charge (Q) where other charge experienced a force. This space is called "electric field".

Test charge (q_0) - The charge used to find the electric field of other charge.

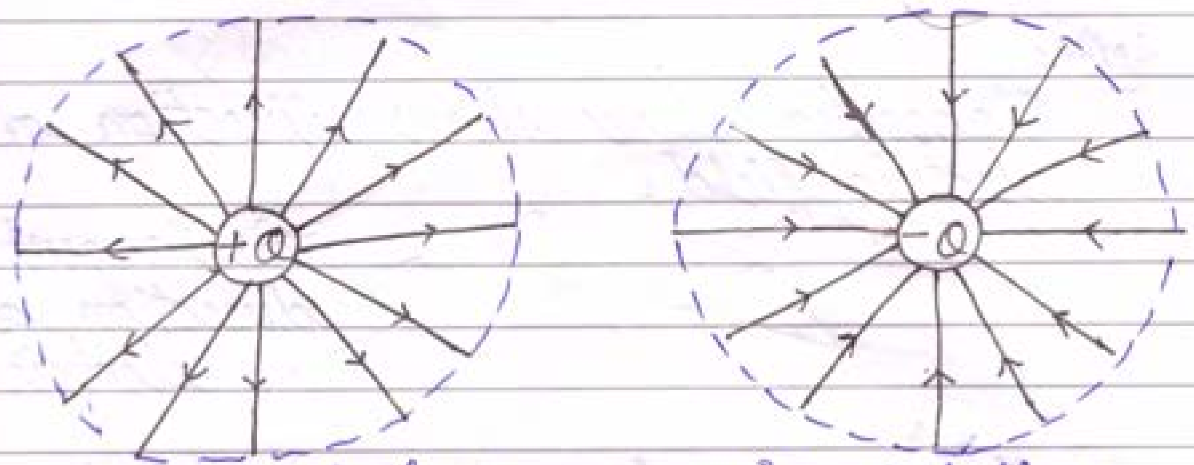
Condition
(i) $q_0 \rightarrow$ Test charge
(ii) $q_0 \Rightarrow 1$
(iii) electric field of due to Test charge is zero.

$$f = \frac{K \times Q \times q_0}{r^2}, \quad E = \lim_{q_0 \to 0} \frac{f}{q_0}$$

$$= \frac{KQ \times \cancel{q_0}}{r^2 \times \cancel{q_0}} = \frac{KQ}{r^2} \Rightarrow \boxed{E = \frac{KQ}{r^2}}$$

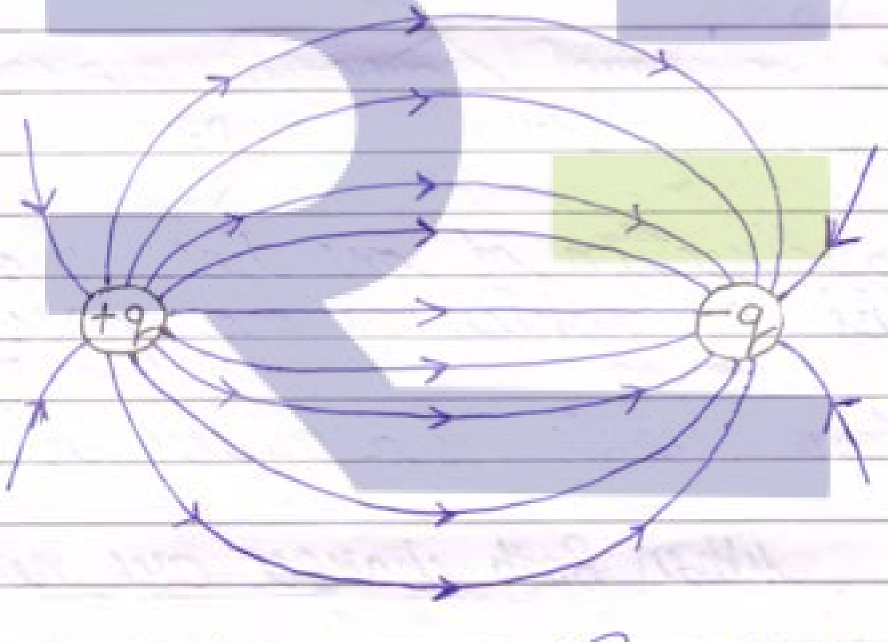
✓ Note $\lim_{q_0 \to 0}$ - meaning [(i) value of charge is 1
(ii) It has no electric field]

(1)

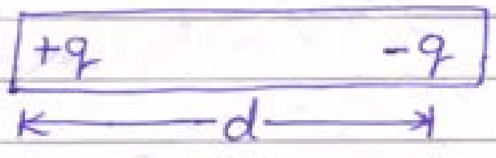


outward lines   inward lines

(2)



(+ve & -ve) charge → Pair → [Electric dipole]



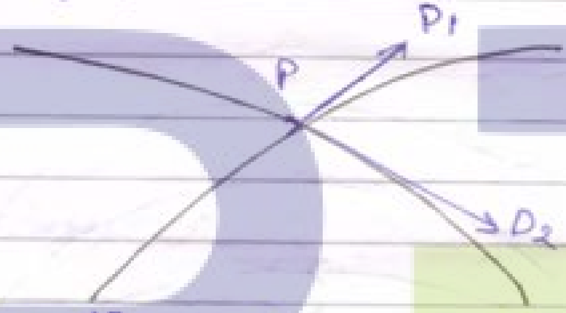
★ Line should not be intersect.

Note

(i) Tangential lines show direction of electric field.

This tangent show direction of electric field.

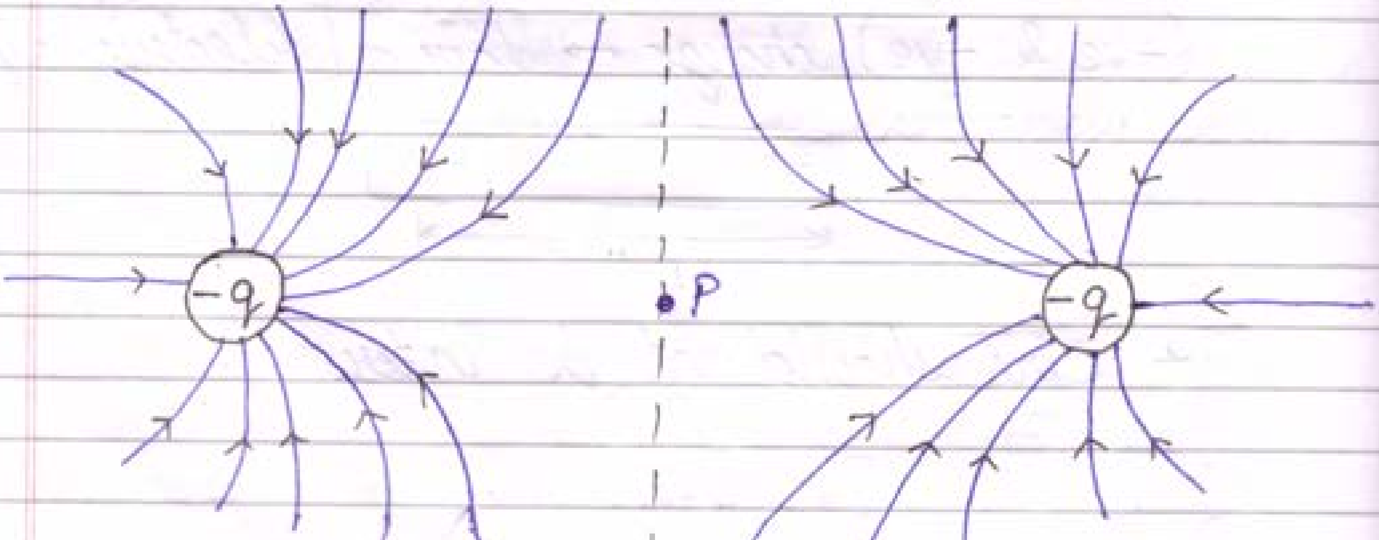
(ii) Let two cut each other / intersect each other.



Two direction of one line, show by point (P) which is not possible.

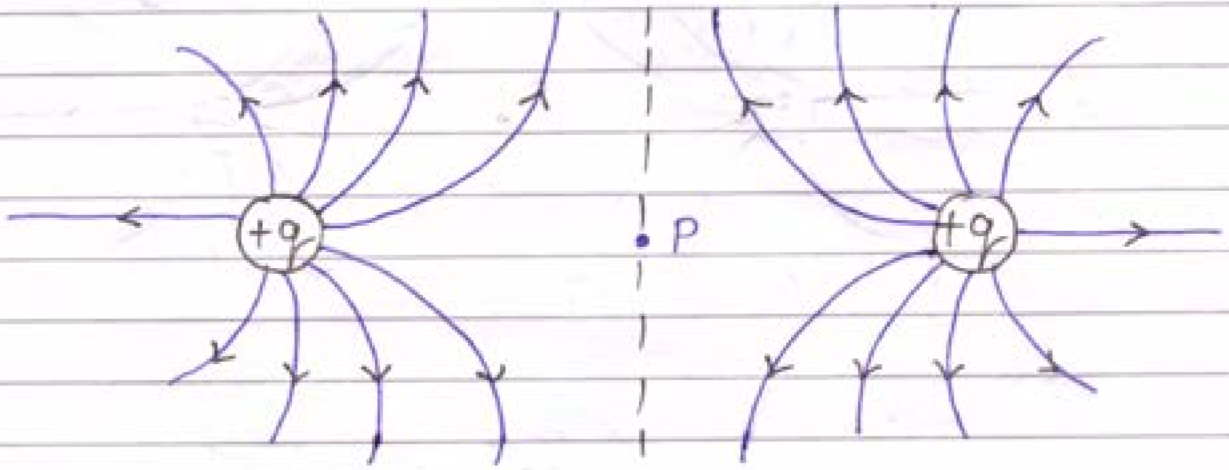
∴ Two electric field never intersect.

When Both charges are negative



where P is neutral point.

When Both charges are positive



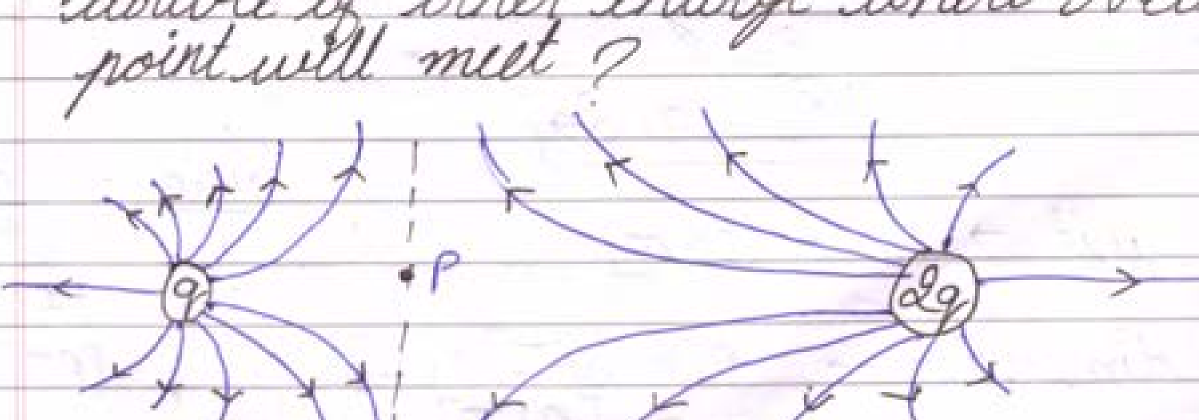
where p is neutral point.

• The point (p) where no electric field is called "Neutral point"

Condition of neutral point

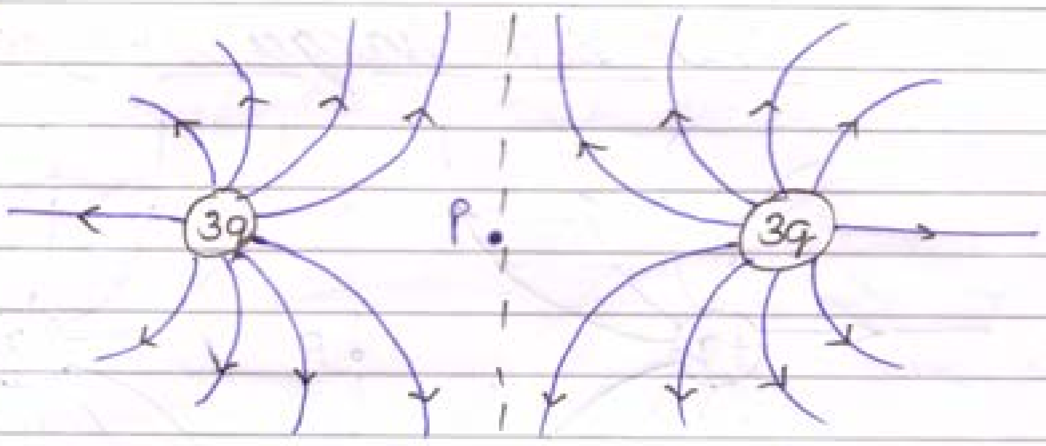
(i) Both charge should be positive.
(ii) Both charge should be negative.

Ques If magnitude of one charge become double of other charge where Neutral point will meet?



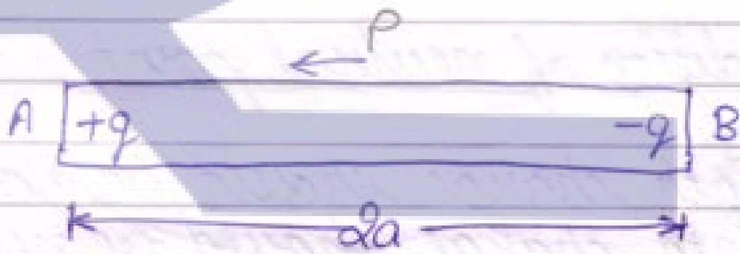
Neutral point will shift toward the less magnitude charge.

Q.



Electric Dipole

When two equal & opposite charge are separate by small distance is called "Electric Dipole"



electrical Dipole moment (P)

P = charge × (distance b/w them)

$$\boxed{\vec{P} = |q|2a}$$

unit → $\boxed{P = C \times m}$

dimension → $P = [AT] \times [L]$
$= [ALT]$

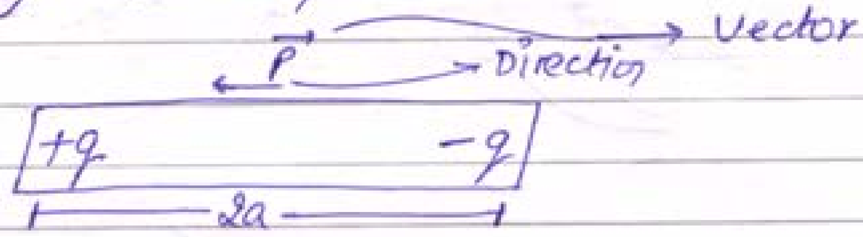
Note $I = \frac{q}{t}$

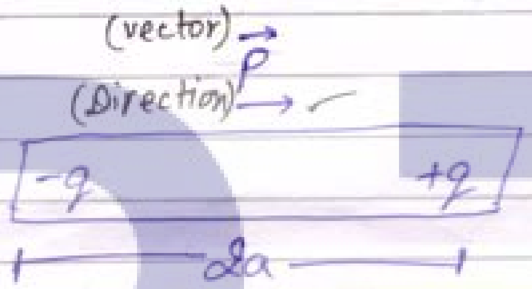
$q = It$
$q = [AT]$

- It is vector quantity.
- Direction → (-ve) to (+ve)

  Negative to positive

Note:

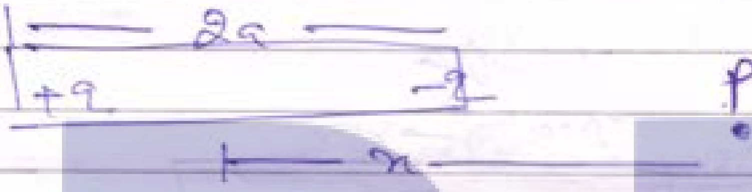
① 

② 

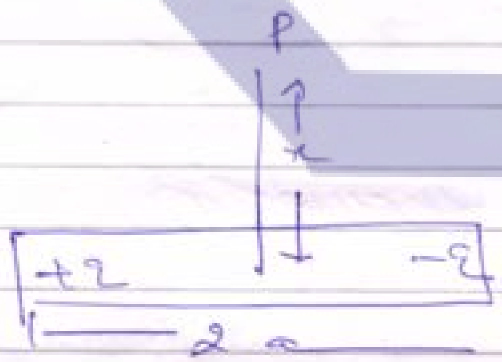
L-6

Electric field
↓

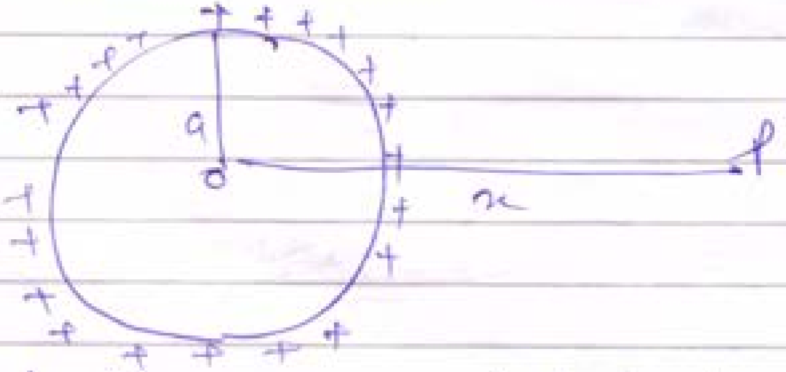
① electric field due to axial point



② electric field due to electrical dipole at equatorial point

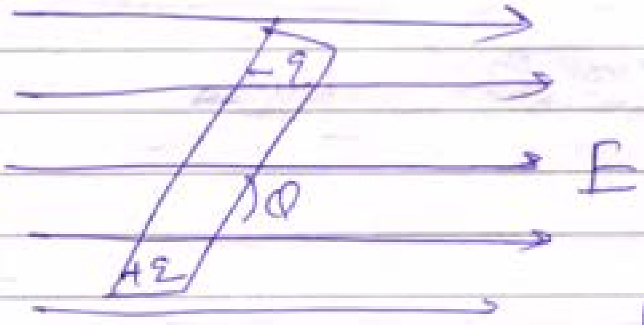


* ③



[electric field at Point (P) due to charged Ring]

(4) Torque and Workdone

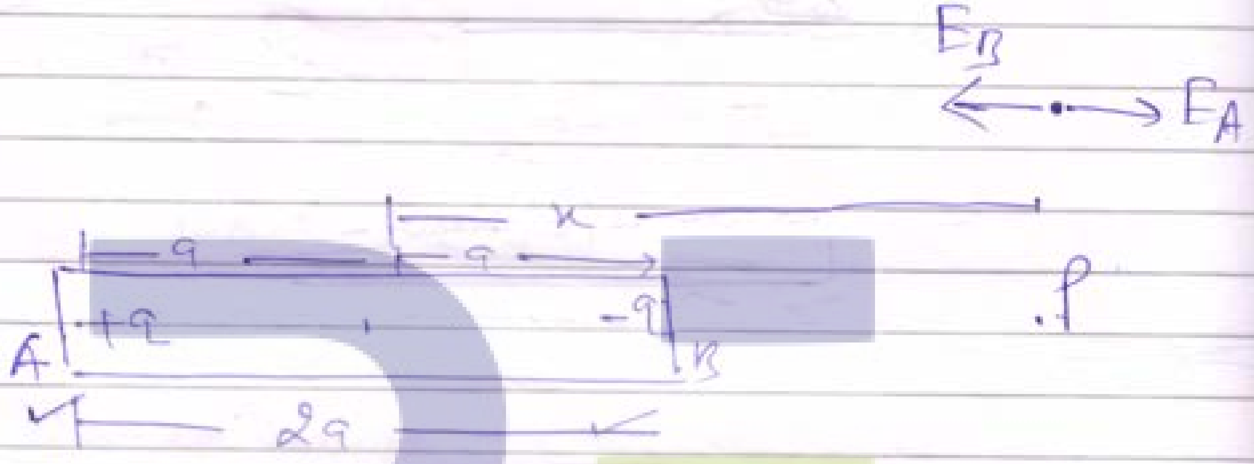


$[\theta_1 \text{ to } \theta_2]$

$\rightarrow \tau = PE\sin\theta$

$\rightarrow W = -PE[\cos\theta_2 - \cos\theta_1]$

[Electric field due to electric dipole at axial point] :→



Let 'AB' is electric dipole
and 'x' is distance B/w centre of dipole to point (P)
where we want find electric field.

Let E_A & E_B be the electric field due to (A) & (B) at point (P).

$$\rightarrow E_A = \frac{K \times q_A}{(AP)^2} = \frac{Kq}{(x+a)^2} \quad \text{— (1)}$$

$$\rightarrow E_B = \frac{K \times q_B}{(BP)^2} = \frac{K|-q|}{(x-a)^2} \quad \text{— (2)}$$

$$\boxed{E_B = \frac{K \times q}{(x-a)^2}} \quad \text{— (2)}$$

$-ve \mid +ve$

$$\rightarrow \boxed{E = E_A - E_B}$$

$$\rightarrow E = \left[\frac{k \times q}{(x+a)^2} - \frac{k \times q}{(x-a)^2}\right]$$

$$\rightarrow E = kq\left[\frac{1}{(x+a)^2} - \frac{1}{(x-a)^2}\right]$$

$$\rightarrow E = k \times q\left[\frac{(x-a)^2 - (x+a)^2}{(x+a)^2(x-a)^2}\right]$$

$$\rightarrow E = k \times q\left[\frac{(\cancel{x^2} + \cancel{a^2} - 2xa) - (\cancel{x^2} + \cancel{a^2} + 2ax)}{(x^2-a^2)^2}\right]$$

$$\rightarrow E = k \times q\left[\frac{-4xa}{[(x^2-a^2)^2]}\right]$$

$$\left[\because P = q \times 2a\right]$$

$$\rightarrow E = \frac{k \times \overbrace{(q \times 2a)}^{P} \times 2x}{(x^2-a^2)^2}$$

$$\rightarrow \boxed{E = \frac{k \times 2 \times Px}{(x^2-a^2)^2}}$$

$$\rightarrow \boxed{E = \frac{K \times 2Px}{(x^2-a^2)^2}}$$

* Spcial Case.

$a << x$ So a^2 Neglect

then $$E = \frac{K \times 2xP}{(x^2)^2} = \frac{K2xP}{x^4}$$

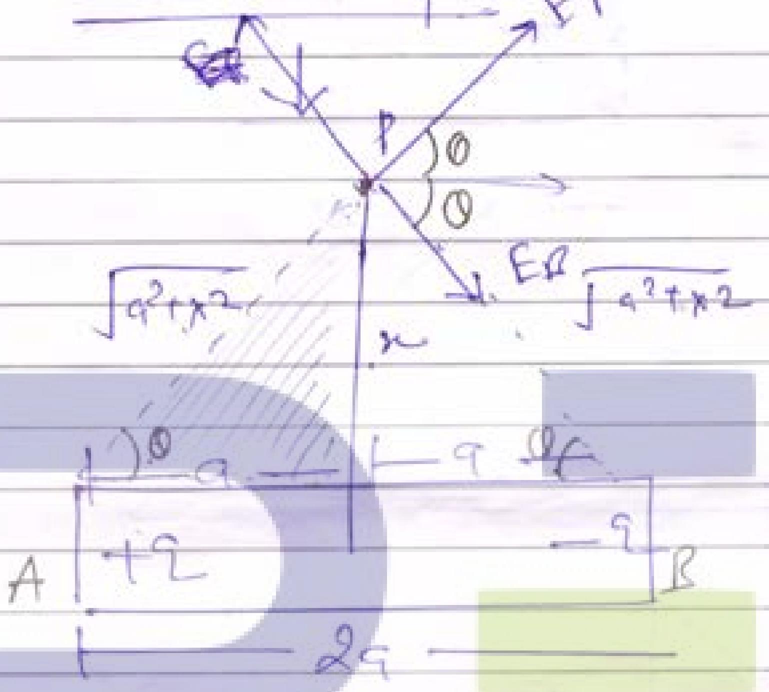
$$\boxed{E = \frac{2KP}{x^3}}$$

Electric field at axial Point

① $$\boxed{E_a = \frac{K \times 2 \times Px}{(x^2-a^2)^2}}$$

② $$\boxed{E_a = \frac{2KP}{x^3}}$$

Electric filed at Equiterial point due to electrical Dipole



PBP
HHB

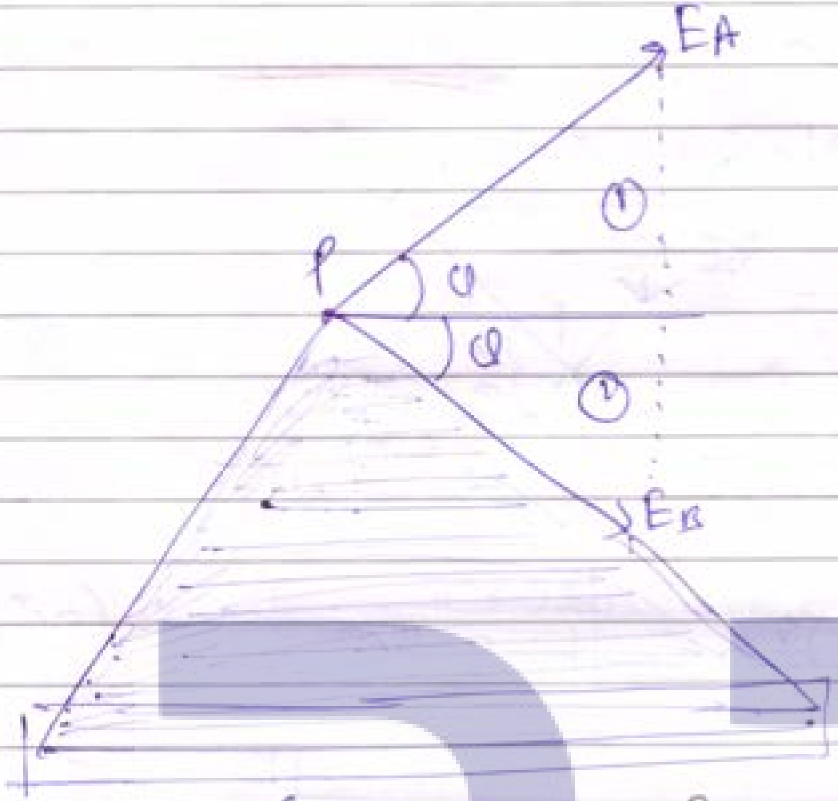
$\therefore \cos\theta = \frac{a}{\sqrt{a^2+x^2}}$

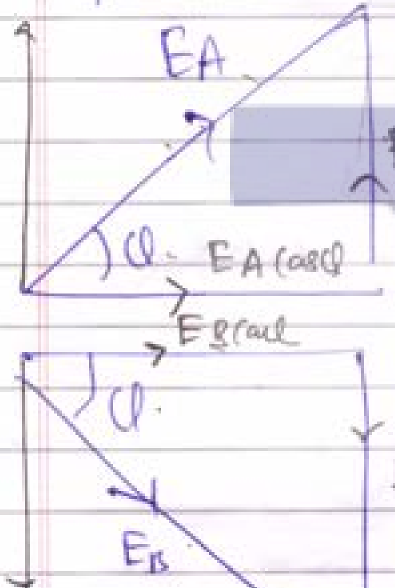
→ Let "AB" is electrical dipole & "x" is distance B/w centre of dipole to point (P) where we want find electric filed.

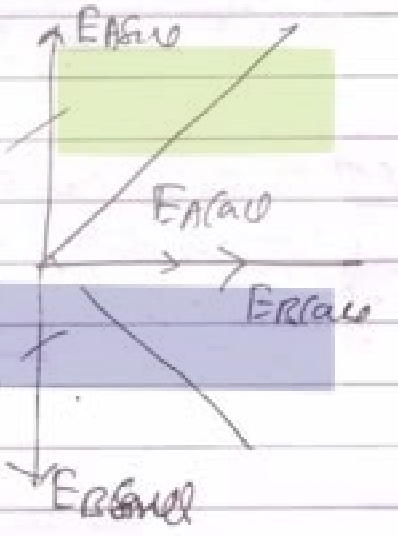
→ Let E_A & E_B be the electric filed at (A) & (B)

$$E_A = \frac{K \times q_A}{(AP)^2} = \frac{K \times q}{(\sqrt{a^2+x^2})^2} = \frac{K \times q}{(a^2+x^2)} \leftarrow (1)$$

$$E_B = \frac{K \times q_B}{(BP)^2} = \frac{K|-q|}{(\sqrt{a^2+x^2})^2} = \frac{K \times q}{(a^2+x^2)} \leftarrow (2)$$







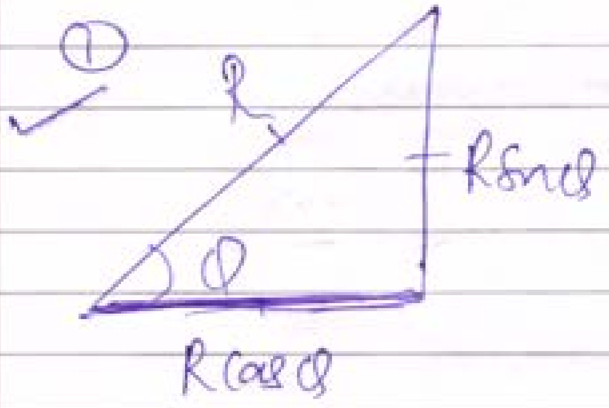
→ E_A & E_B are equal then $E_A\sin\theta$ & $E_B\sin\theta$ also equal so They cancel out eachother

→ $E = E_A\cos\theta + E_B\cos\theta$ [∵ $E_A = E_B$]

→ $\boxed{E = 2E_A\cos\theta = \dfrac{2k\times q}{(\sqrt{a^2+x^2})^2} \times \dfrac{a}{(\sqrt{a^2+x^2})} = \dfrac{2k\times q a}{(a^2+x^2)^{3/2}}}$

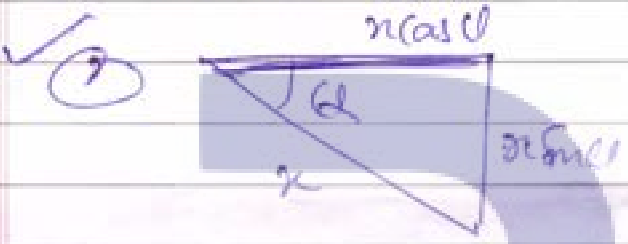
Note

1.

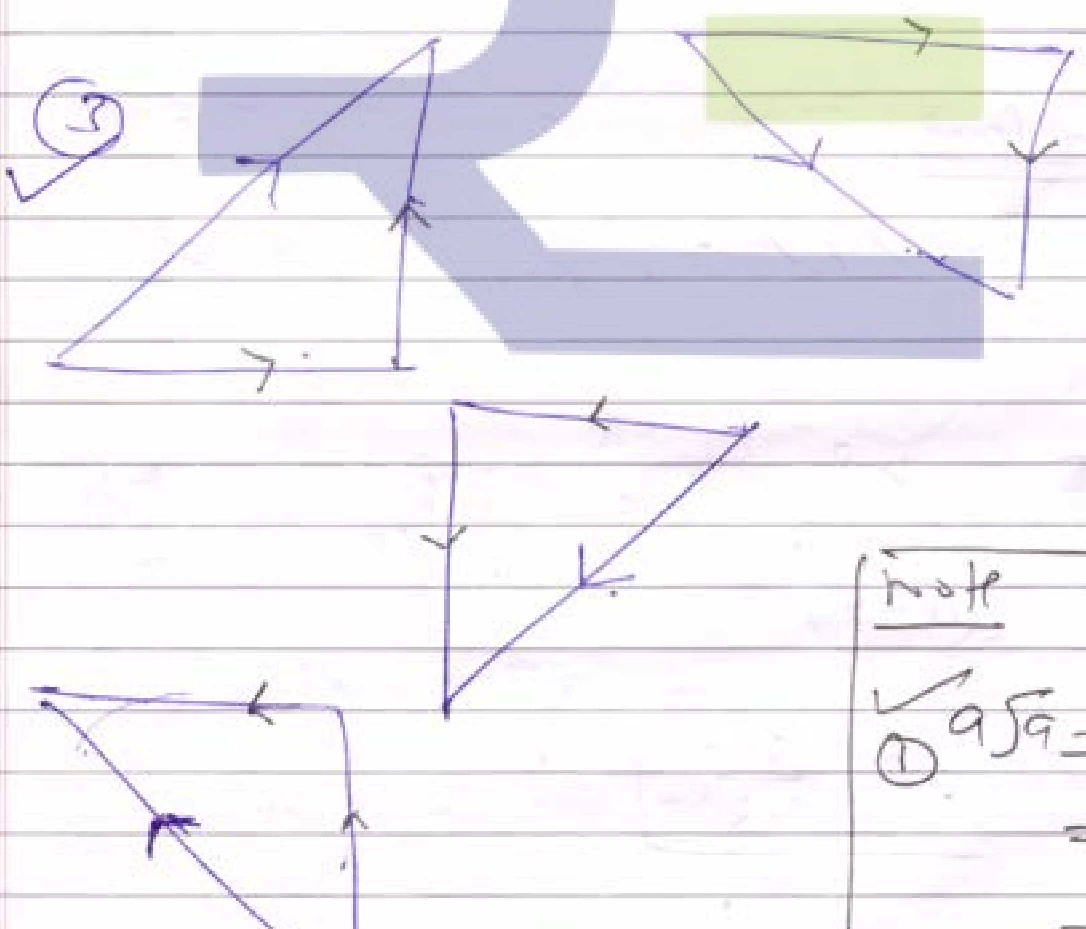


Perpendicular → sinθ
Base → cosθ

2.



3.



Note

1. $a\sqrt{a} = a a^{1/2}$
$= a^{1+1/2}$
$= a^{3/2}$

2. $x\sqrt{x} = x^{3/2}$

$$\rightarrow E = \frac{2kqxa}{(a^2+x^2)^{3/2}}$$

$$[p = q \times x]$$

$$\rightarrow E = \frac{kq(2a)}{(a^2+x^2)^{3/2}}$$

$$\rightarrow \boxed{E = \frac{k \times p}{(a^2+x^2)^{3/2}}}$$

$x < b$

Special Case.

(1) $a <<< x$, so, Neglect (a^2)

$$\rightarrow E = \frac{kp}{(a^2+x^2)^{3/2}} = \frac{kp}{(x^2)^{3/2}} = \frac{kp}{x^3}$$

$$\rightarrow \boxed{E_e = \frac{k \times p}{x^3}}$$

Note

① electric field at Equitorial Point is

$$\boxed{E_e = \frac{K \times P}{(a^2 + x^2)^{3/2}}}$$

$$\boxed{E_e = \frac{K \times P}{r^3}}$$

Relation:

Let (E_a) is axial point electric field

$$\boxed{E_a = \frac{2 \times K \times P}{r^3}} \quad ①$$

Let (E_e) is equitorial electric field

$$\boxed{E_e = \frac{K \times P}{r^3}} \quad ②$$

from ① & ②

$$\boxed{E_a = 2 \times E_e}$$

Let E_a & E_e is electric field at axial & equatorial then

Q.

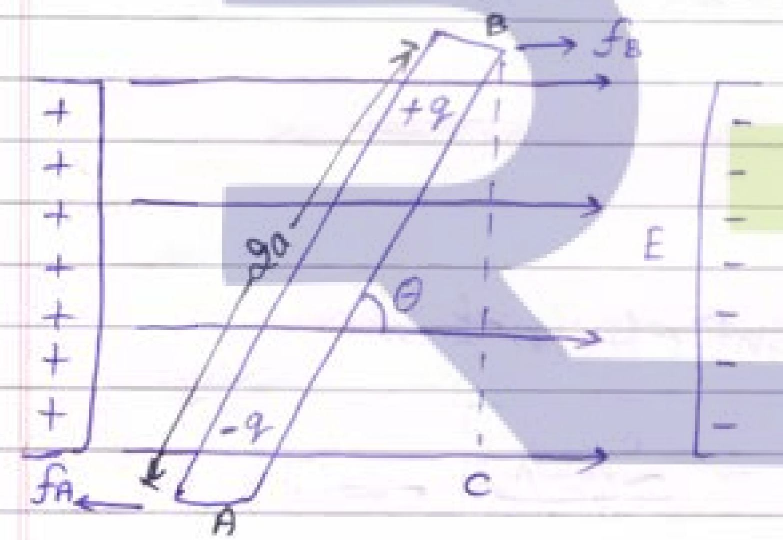
(i) $E_a = E_e$

(ii) $E_e = 2 \times E_a$

(iii) $E_a = 2E_e$

(iv) $E_a = 4E_e$

Find the Torque of electric dipole when it placed in electric field



Let 'AB' is electric dipole & be placed at 'θ' with electric field.

Let 'E' be the electric field.

Let f_A & f_B be the force on (A) and (B) of electric dipole.

$f_A = -q \times E = q \times E$ —— (1)

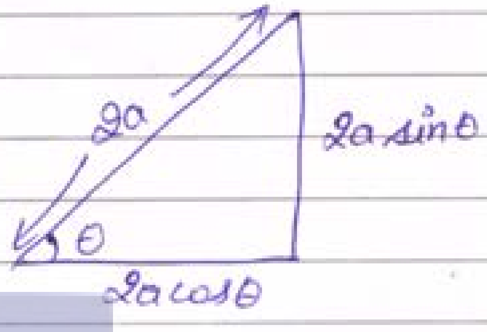
$f_B = q \times E$ opposite to f_A —— (2)

f_A & f_B be the force on equal.
So, Net force is zero.

Torque = force × perpendicular distance

$\tau = f \times d$

$\tau = f \cdot 2a\sin\theta$



$\tau = (qE)\,2a\sin\theta$

$\tau = (q \times 2a)\,E\sin\theta$

$\tau = PE\sin\theta$

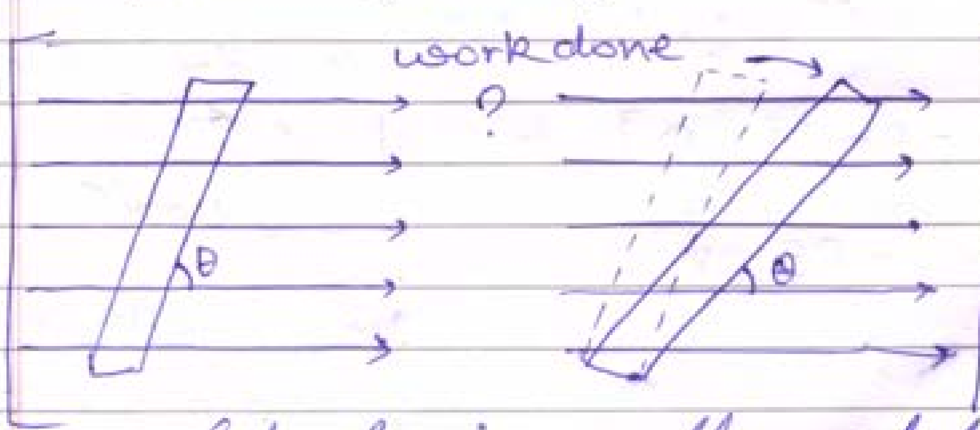
$$\boxed{\vec{\tau} = \vec{P} \times \vec{E}}$$

① $\boxed{f = q \times E}$

② $\boxed{f = \dfrac{k|q_1||q_2|}{r^2}}$

③ $\vec{A} \times \vec{B} = AB\sin\theta$

Find the work done If electrical dipole move θ_1 to θ_2.



① $W = f \cdot d$

② $W = \tau \cdot \theta$

Let dw is small workdone
$d\theta$ is small distance

$\Rightarrow \quad dw = \tau \cdot d\theta$

$dw = PE \sin\theta . d\theta$

Integration both side

$$\int dw = \int_{\theta_1}^{\theta_2} PE \sin\theta \cdot d\theta$$

$$W = PE \int_{\theta_1}^{\theta_2} \sin\theta \cdot d\theta$$

$$W = PE \left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$\boxed{W = -PE\left[\cos\theta_2 - \cos\theta_1\right]} \quad \text{Ans}$$

Note

(1) $\tau = PE\sin\theta$, (2) $\vec{\tau} = \vec{P} \times \vec{E}$

Q. Special Case

$\theta_1 = 90^\circ \Rightarrow \theta_2 = 0^\circ$

$W = -PE[\cos\theta_2 - \cos\theta_1]$

$W = -PE[\cos 0 - \cos 90]$

$W = -PE[1-0]$

$$\boxed{W = -PE}$$

Integration

(1) $\int x^n dx = \frac{x^{n+1}}{n+1}$

(2) $\int x^3 dx = \frac{x^4}{4}$

(3) $\int \frac{dx}{x} = \log x$

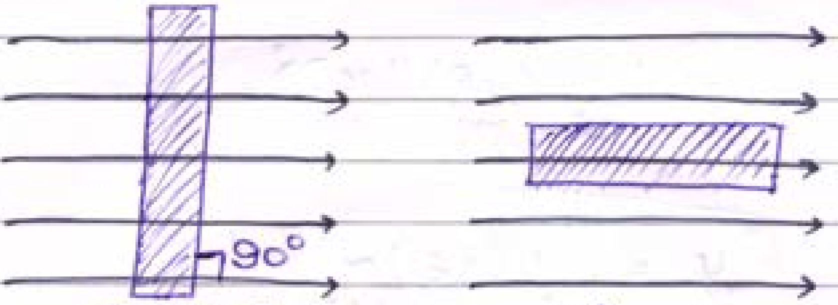
(4) $\int \sin\theta \, d\theta = -\cos\theta$

(5) $\int \cos d\theta = \sin\theta$

(6) $A \cdot B \rightarrow AB\cos\theta$

(7) $A \times B \rightarrow AB \sin\theta$

(8) $\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}$



$\theta_1 = 90°$ $\quad\quad$ $\theta_2 = 0$

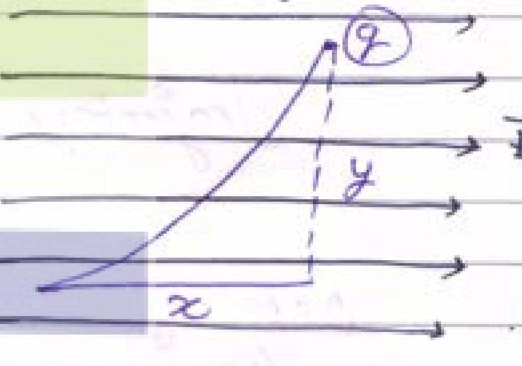
Unstable $\quad\quad$ Stable

① If $\theta = 90°$ = Unstable

② If $\theta = 0°$ = Stable

Path of charge particle in electric field

Let 'q' charge move in electric field



force experienced by charge

$$= \boxed{f = q \times E} \quad ---①$$

$$\boxed{f = m \times a} \quad ---②$$

By eqⁿ ① & ②

$$ma = q \times E$$

Accelaration of charge particle:

$$\boxed{a = \frac{q \times E}{m}}$$

$$\rightarrow \quad y = ut + \frac{1}{2}at^2$$

$$\rightarrow \quad y = 0 \times t + \frac{1}{2} \times \left(\frac{qE}{m}\right) t^2$$

$$y = \frac{1}{2}\left(\frac{qE}{m}\right) t^2$$

$\because v = \frac{x}{t}$

$t = \frac{x}{v}$

$$\rightarrow \quad y = \frac{1}{2}\left(\frac{qE}{m}\right)\left[\frac{x}{v}\right]^2$$

$$\boxed{y = \left[\frac{1}{2}\left(\frac{qE}{m}\right)\frac{x^2}{v^2}\right]}$$

$$y = \left[\frac{1}{2}\left(\frac{qE}{m}\right)\frac{1}{v^2}\right] \times x^2$$

$$y = Kx^2 \qquad \left[\because K = \frac{1}{2}\left(\frac{qE}{mv^2}\right)\right]$$

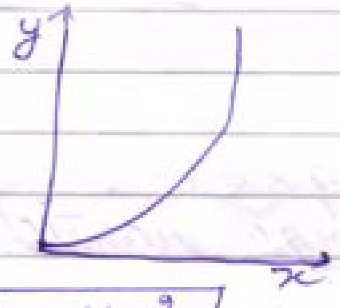
It shows path of charge particle in electric field is parabolic.

OR

Trajectory of charge in electric field is parabolic.

Note

(1)



$\boxed{y = Kx^2}$

(2) $A = KB^2$

$\boxed{A = KB^2}$

Note :-

$\longrightarrow f = ma$ ------ ①

$\longrightarrow f = q \times E$ ------ ②

$ma = qE$

$$\boxed{a = \frac{qE}{m}}$$

velocity , $v = u + at$

$v = 0 + \left(\frac{qE}{m}\right) t$

$$\boxed{v = \left(\frac{qE}{m}\right) \times t}$$

distance , $s = ut + \frac{1}{2} a t^2$

$S = 0 \times t + \frac{1}{2}\left(\frac{qE}{m}\right) t^2$

$$\boxed{S = \frac{1}{2}\left(\frac{qE}{m}\right) t^2}$$

Ques 2C charge of mass 0.2gm is moving in field 0.5 N/C for 3 sec. How much distance it covered?

Ans $q = 2C$, $m = 0.2g$, $E = 0.5$ N/C , $t = 3$ sec

$S = \frac{1}{2}\left(\frac{2 \times 0.5}{0.2}\right) \times (3)^2 \Rightarrow \frac{5 \times 9}{2}$

$S = \frac{45}{2}$ m $\Rightarrow$ 22.5 m

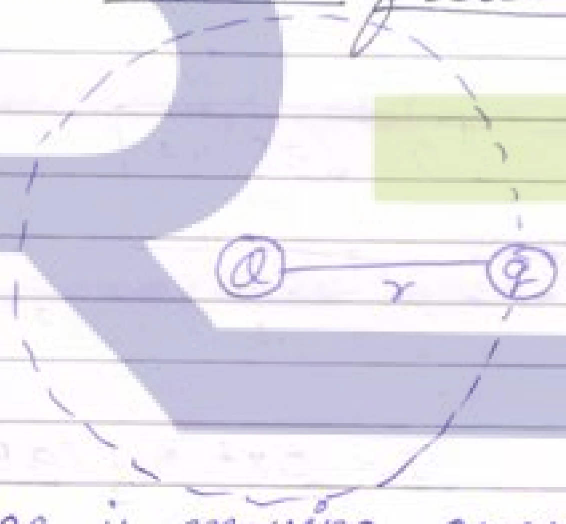
velocity $v^2 = u^2 + 2as$

$u = 0$

$$v^2 = 2\left(\frac{qE}{m}\right)S$$

$$\boxed{v = \sqrt{\frac{2qES}{m}}}$$

Circular Motion of charge particle in Electric field.



→ 'q' charge is moving around source charge (Q) which is charge (q). It will express centripetal force.

$$\rightarrow \quad f = \frac{KQ \times q}{r^2} \text{ ------ } (1)$$

$$f = \frac{mv^2}{r} \text{ ------ } (2)$$

$$\longrightarrow \quad \frac{mv^2}{\cancel{r}} = \frac{KQ \times q}{r^2}$$

$$mv^2 = \frac{KQq}{r}$$

1) <u>velocity</u>

$$\boxed{v = \sqrt{\frac{KQq}{mr}}}$$

2) <u>Radius</u>

$$mv^2 = \frac{KQq}{r}$$

$$\boxed{r = \frac{KQq}{mv^2}}$$

3) <u>Angular velocity</u> (ω)

we know that

$$v = \omega r$$

$$\omega = \frac{v}{r} = \frac{1}{r}\sqrt{\frac{KQq}{mr}}$$

$$= \sqrt{\frac{KQq}{r^2 \times rm}}$$

$$\boxed{\omega = \sqrt{\frac{KQq}{mr^3}}}$$

4) <u>Frequency</u> (ν)

$$\omega = 2\pi\nu$$

$$\sqrt{\frac{KQq}{mr^3}} = 2\pi\nu$$

$$\boxed{\frac{1}{2\pi}\sqrt{\frac{KQq}{mr^3}} = \nu}$$

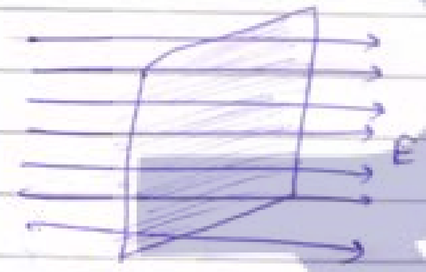
5) Time Period (T)

$$T = \frac{1}{\nu} = \quad T = \frac{1}{\frac{1}{2\pi}\sqrt{\frac{KQq}{mr^3}}}$$

$$\boxed{T = 2\pi\sqrt{\frac{mr^3}{KQq}}}$$

Electric Flux (ϕ)

Total no. of electric lines passing through per unit area called "electric flux"



$$\boxed{\phi = E \times A}$$

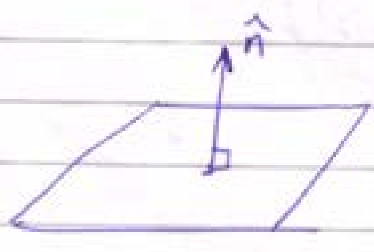
$$\boxed{\vec{\phi} = \vec{E} \cdot \vec{S}}$$

A or S $\longrightarrow$ area

$\longrightarrow$ $\phi = \vec{E} \cdot \vec{S} = ES\cos\theta$

'θ' Between Electric field (E) & Area (Area vector) (S)

Area vector ($\hat{n}$) $\longrightarrow$ is always perpendicular to the surface



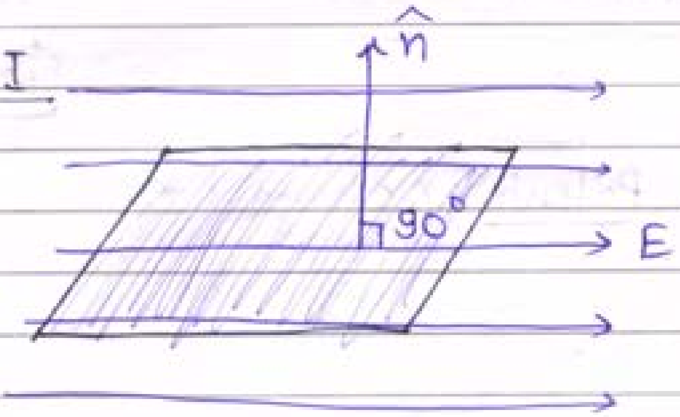
* It shows orientation of surface
* 'θ' is angle b/w (E) & ($\hat{n}$)

S $\rightarrow$ Surface area

$$\boxed{\vec{S} = S \cdot \hat{n}}$$

vector — scaler — direction ($\hat{n}$)

Case - I



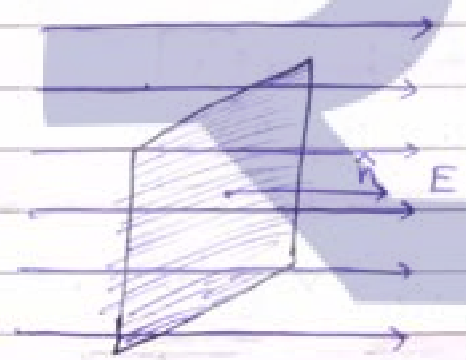
$\longrightarrow$ $\phi = ES\cos\theta$

$\theta = 90^\circ$

$\phi = ES\cos 90 = ES \times 0 \Rightarrow \underline{\underline{0}}$

$\boxed{\phi = 0}$ Minimum.

Case - II



$\phi = ES\cos\theta$

$\theta = 0^\circ$

$\phi = ES\cos 0$

$\phi = ES \times 1$

$\boxed{\phi = ES}$ maximum

unit ϕ = Flux

$\phi = E \cdot S$

$\phi = \frac{N}{C} \times m^2$

$\boxed{\phi = Nm^2C^{-1}}$

$[\because f = q \times E]$

$E = \frac{f}{q}$

$E = \frac{N}{C} = NC^{-1}$

Dimension $\phi = E \cdot S$

$\phi = \frac{f}{q} \times S$

$q = \frac{It}{AT}$

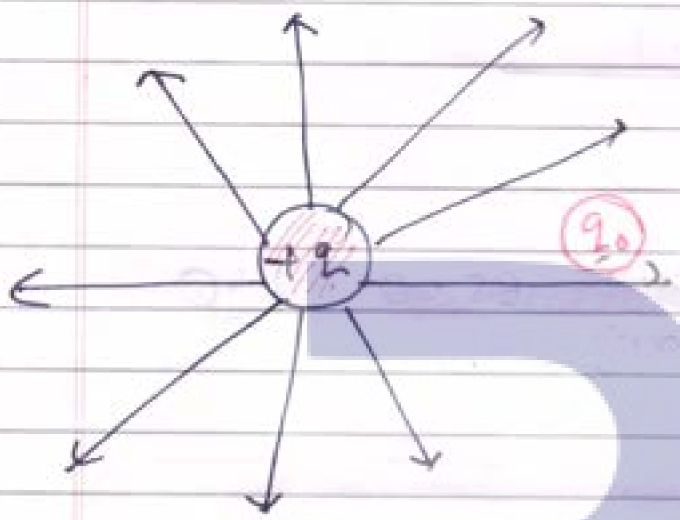
$\phi = \frac{[MLT^{-2}]}{[AT]} \times [L^2] = \boxed{\phi = [ML^3A^{-1}T^{-3}]}$

$\boxed{W = \tau \cdot \theta}$

$\boxed{W = f \cdot dx}$

electric Potential

→ $\boxed{\text{Work} = \text{Potential} \times \text{charge}}$ ←



→ (q₀) move in the field of charge (q)
then (q₀) will experience force By (q)

→ $\boxed{W = \underbrace{\text{Potential}}_{\text{given By } (+q)} \times \underbrace{\text{charge}}_{(q_0)}}$

$\boxed{\text{Potential energy} = \text{Potential} \times \text{charge} = \text{workdone}}$

$\boxed{W = V \times q_0}$

$\boxed{V = \frac{K \times q}{r}}$

$\boxed{W = \frac{K q q_0}{r}}$

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$$f = \frac{K \times Q \times q_0}{x^2}$$

Let small work done → dw

$$\boxed{dw = f \cdot dx}$$

$$\rightarrow dw = \left(\frac{K \times Q \times q_0}{x^2}\right) dx$$

Integrate Both side

$$\rightarrow \int dw = \int_{\infty}^{r} \left(\frac{K \times Q \times q_0}{x^2}\right) dx$$

$$\int x^{-2} = \frac{x^{-1}}{-1}$$

$$\rightarrow w = K \times Q \times q_0 \int_{\infty}^{r} \frac{dx}{x^2}$$

$$\left[\because \int \frac{dx}{x^2} = -\frac{1}{x}\right]$$

$$\rightarrow w = K \times Q \times q_0 \left[\frac{-1}{x}\right]_{\infty}^{r} = -KQq_0 \left[\frac{1}{r} - \frac{1}{\infty}\right]$$

GOOD WRITE

$$\boxed{W = \left[-\frac{K \times Q}{r}\right] \times q_0}$$

Work = Potential x charge

$W = V \times q_0$

→ $$\boxed{V = \left[\frac{K \times Q}{r}\right]}$$

* Potential → $\boxed{V = \frac{K \times Q}{r}}$

* $W = V \times q_0$

$$\boxed{W = \left[\frac{K \times Q}{r}\right] \times q_0}$$

Note:

1. $|W| = V \times \text{charge}$
2. $V = \frac{K \times Q}{r}$

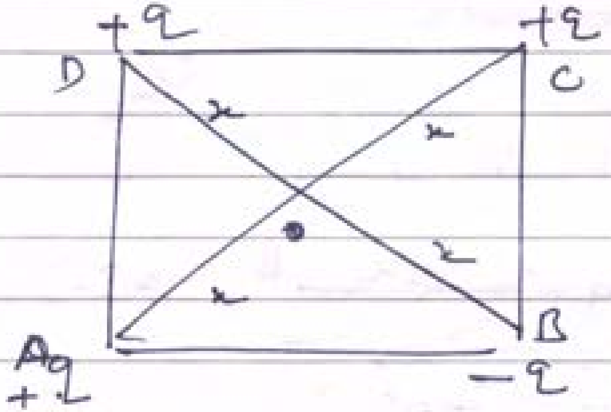
Both Scaler Quantity

3. q_0 जो आ रहा है

4. $$\boxed{W = \left[\frac{K \times Q}{r}\right] \times q_0}$$

Q: Find the potential of the system at 'O'

A



$\rightarrow V = V_A + V_B + V_C + V_D$

$\rightarrow V_A = \frac{K \times q_A}{OA} = \frac{K \times q}{x}$ — (1)

$\rightarrow V_B = \frac{K \times q_B}{OB} = \frac{-Kq}{x}$ — (2)

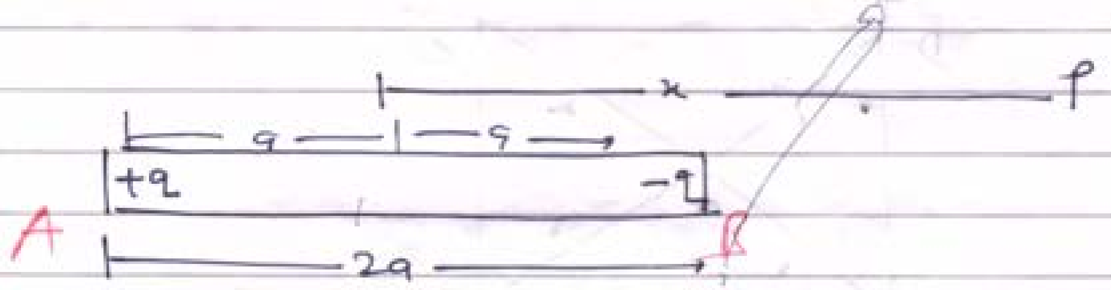
$\rightarrow V_C = \frac{Kq_C}{OC} = \frac{Kq}{x}$ — (3)

$\rightarrow V_D = \frac{Kq_D}{OD} = \frac{Kq}{x}$ — (4)

$\rightarrow \boxed{V = \frac{2K \times q}{x}}$

A

Q: find the Potential at axial point (P) of figure?



Ans. $\text{Potential} = \frac{K \times Q}{r} = \frac{-Kq}{x}$

$A \rightarrow P \rightarrow V_A$

$B \rightarrow P \rightarrow V_B$

$\rightarrow \boxed{V = V_A + V_B}$

$$V_A = \frac{K \times q_A}{(AP)} = \frac{K \times q}{(x+a)} \quad \text{--- (1)}$$

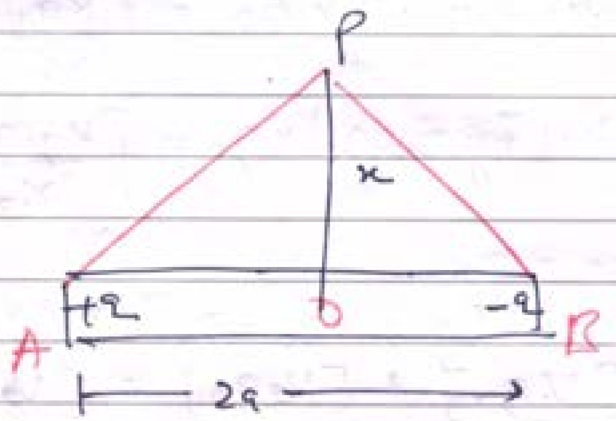
$$V_B = \frac{K \times q_B}{BP} = \frac{-Kq}{(x-a)} \quad \text{--- (2)}$$

$$\rightarrow V = K \times q \left[\frac{1}{(x+a)} - \frac{1}{(x-a)} \right]$$

$$\rightarrow V = K \times q \left[\frac{(\cancel{x}-a) - (\cancel{x}+a)}{(x+a)(x-a)} \right] = \frac{K \times q(-2a)}{(x^2-a^2)}$$

Conceptual:

Q Find the Potential at Equitorial Point of fig



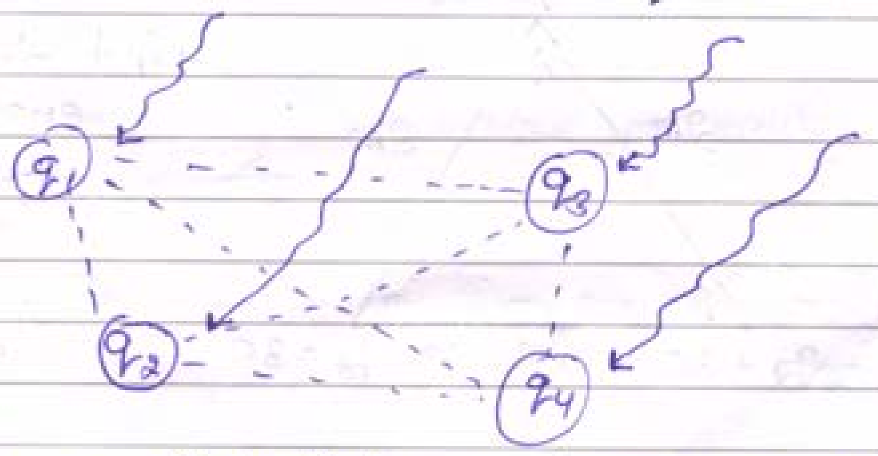
A V_A = Potential By A = $\dfrac{K \times q_A}{(AP)} = \dfrac{Kq}{\sqrt{a^2+x^2}}$ — (1)

V_B = Potential By B = $\dfrac{K \times q_B}{(PB)} = \dfrac{-K \times q}{\sqrt{a^2+x^2}}$ — (2)

$V = V_A + V_B$

$\boxed{V = 0}$

Potential energy of System



W_1 = Potential × charge = $V \times q_1$

$= 0 \times q_1$

$= 0$ — (1)

$W_2 = (\text{Potential by } q_1) \times q_2 = \left[\frac{Kq_1}{r_{12}} \times q_2\right]$ --- (2)

$W_3 = (\text{Potential by } q_1 \,\&\, q_2) \times q_3 = \left[\frac{Kq_1q_3}{r_{13}}\right] + \left[\frac{Kq_2q_3}{r_{23}}\right]$ --- (3)

$W_4 = [\text{Potential By } q_1 + q_2 + q_3] \times q_4$

$= [V_1q_4] + [V_2q_4] + [V_3q_4]$

$= \left[\frac{Kq_1q_4}{r_{14}} + \frac{Kq_2q_4}{r_{24}} + \frac{Kq_3q_4}{r_{34}}\right]$ --- (4)

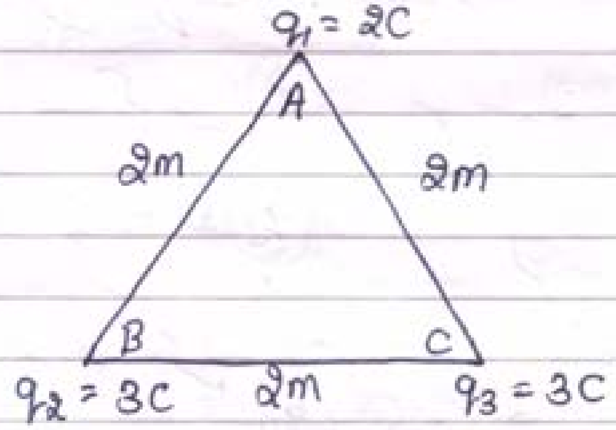
Total work done

$W = W_1 + W_2 + W_3 + W_4$

$W = 0 + \frac{Kq_2q_1}{r_{12}} + \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}} + \frac{Kq_1q_4}{r_{14}} + \frac{Kq_2q_4}{r_{24}} + \frac{Kq_3q_4}{r_{34}}$

$$\boxed{W = \sum_{\substack{i=1 \\ j=1}}^{n} \frac{Kq_iq_j}{r_{ij}}}$$

Qu



Find the Potential energy of system

$W_A = V \times q_1 \Rightarrow 0 \times q_1 = 0$ --- (1)

$W_B = V_A \times q_B \Rightarrow \frac{Kq_1q_2}{r_{12}} \Rightarrow \frac{K(6)}{2} = 3K$ --- (2)

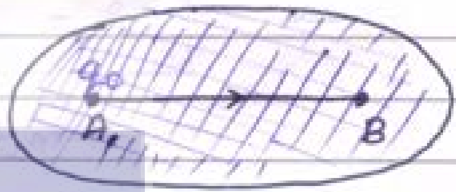
$$W_C = V_A \times q_3 + V_B \times q_3$$
$$= \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}}$$
$$= \frac{K(6)}{(2)} + \frac{K(9)}{2} = \frac{15K}{2} \quad \text{---- (3)}$$

$$W = W_A + W_B + W_C$$
$$= 0 + 3K + \frac{15K}{2}$$
$$= 11.5K \Rightarrow \underline{11.5 \times 9 \times 10^9 \ J}$$

Equipotential Surface

- The Surface where potential is same at every point.

Let (q_0) charge moves



$\rightarrow W_{AB} = V_{AB} \times q_0$

$\rightarrow \boxed{W_{AB} = [V_B - V_A] \times q_0}$

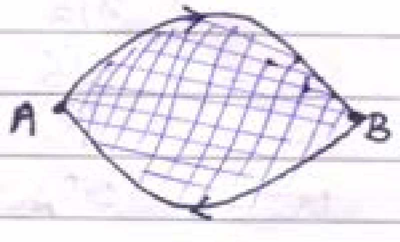
$\therefore \quad V_A = V_B = V$

$W_{AB} = [V - V] \times q_0 \Rightarrow \underline{0}$

$\boxed{W_{AB} = 0}$ workdone on equipotential surface is zero.

Note → Electrostatic force is conservative. which depends upon initial and final position but not depend upon nature of path.

$$W_{AB} = V_{AB} \times q_0$$
$$= [\underset{\text{final}}{V_B} - \underset{\text{initial}}{V_A}] \times q_0 \quad \text{------------} \quad (1)$$



$$W_{BA} = V_{BA} \times q_0$$
$$= [V_A - V_B] \quad \text{-----} \quad (2)$$

$$\rightarrow \quad W_{AB} + W_{BA} = q_0[\cancel{V_B} - \cancel{V_A} + \cancel{V_A} - \cancel{V_B}]$$
$$= q_0[0]$$
$$= \underline{0}$$

<u>Note</u>- Electric field of closed surface is zero if force is conservative.

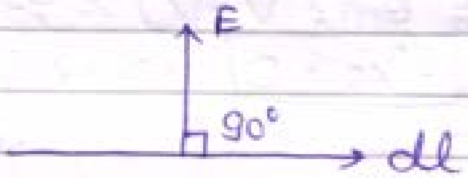
$$\rightarrow \quad \boxed{W = \oint \vec{E} \cdot \vec{ds}}$$

$\oint$ — closed surface

$$\rightarrow \quad W = \oint E\,dl \cos\theta \qquad [\vec{A} \cdot \vec{B} = AB\cos\theta]$$
$$W = \oint E\,dl \cos 90^\circ \qquad [\text{If } \theta = 90^\circ]$$
$$= 0$$

$$\boxed{W = 0}$$

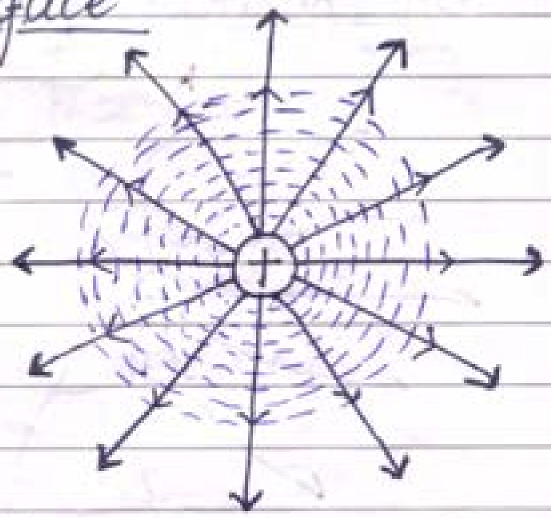
$E \perp dl$



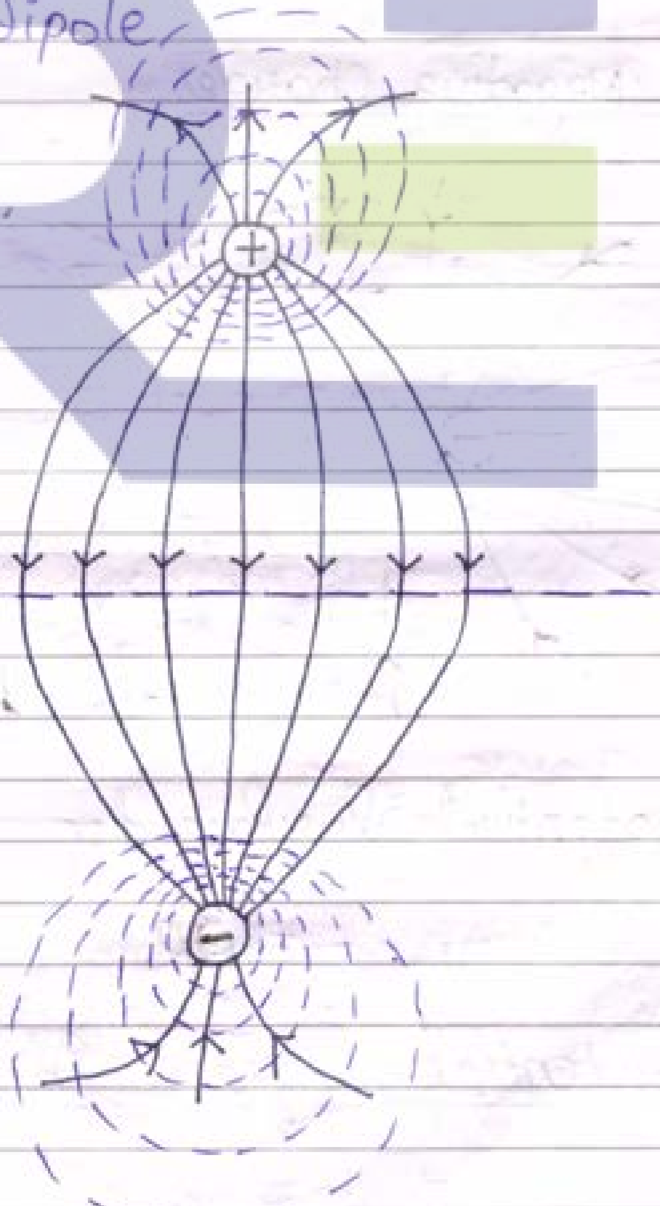
Electric field is always perpendicular to surface (equipotential)

Equipontential Surface

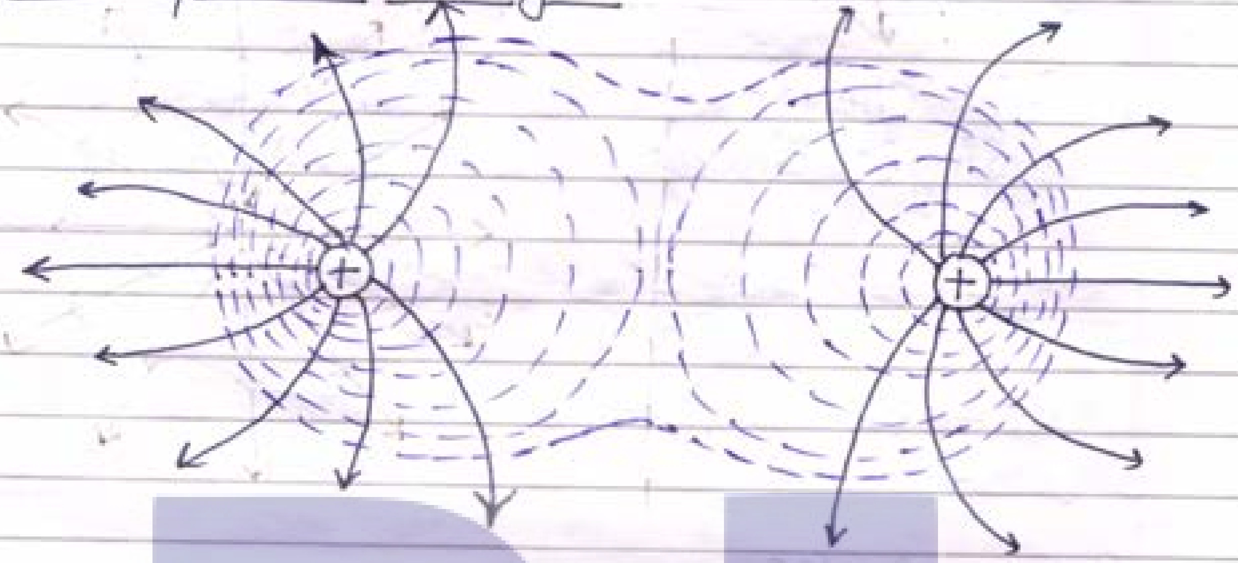
1) Point charge/
Single charge



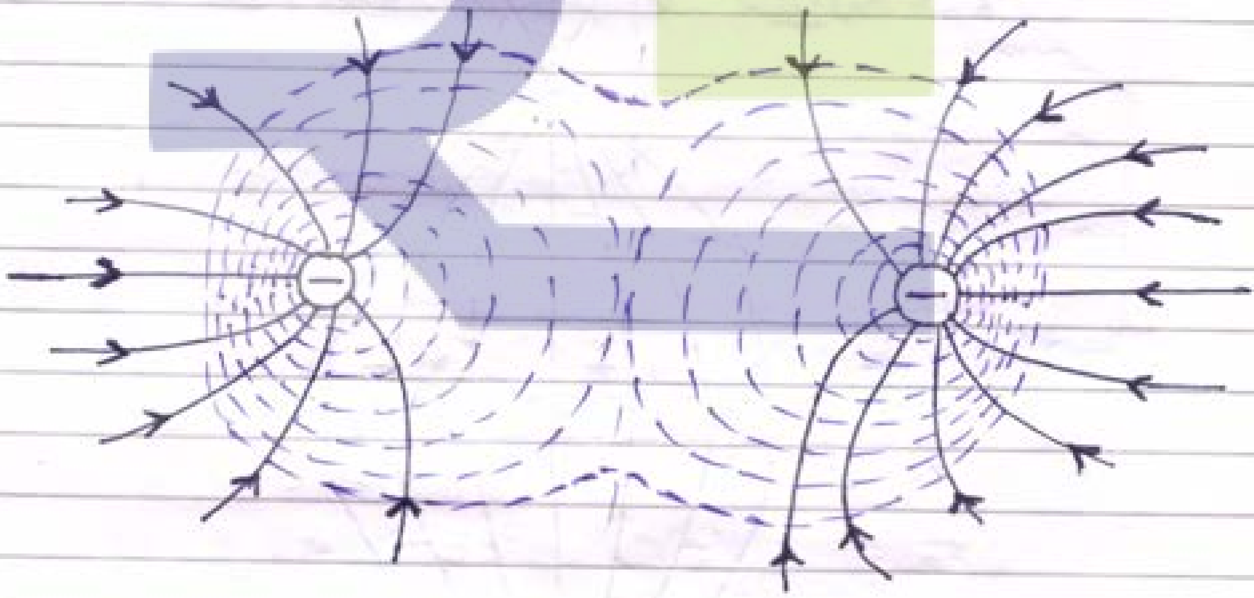
② Electric Dipole



3) Two positive charges



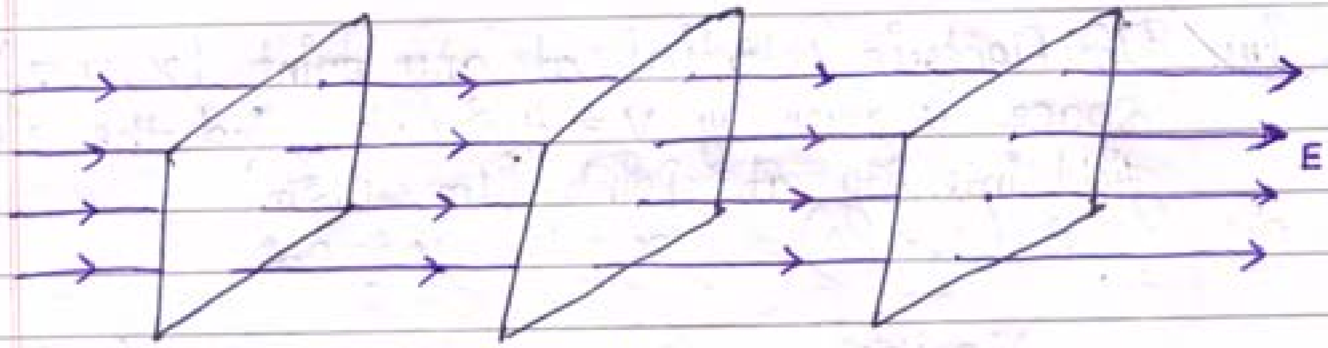
4) Two Negative Charges



Equipotential Surface for Uniform electric Field

OR

Equipotential Surface for Plane



Note: $\boxed{E = -\dfrac{dv}{dr}}$ → Potential, → distance

electric field

Electric field is negative of potential gradient

$\left[\because \dfrac{dv}{dr} = \right.$ Potential ~~charge~~ change with distance = Potential gradient$\left.\right]$

$$\boxed{E = -\text{Potential gradient}}$$

→ $E_x = -\dfrac{dv_x}{dx}$ (x – axis)

→ $E_y = -\dfrac{dv_y}{dy}$ (y – axis)

→ $E_z = -\dfrac{dv_z}{dz}$ (z – axis)

Ques A uniform electric field 10 N/C exists in the vertically downward direction. Find the increase in electric potential as goes to high 50 cm?

Ans $E = 10\ N/C$; $r = 50\text{cm} \Rightarrow 0.5\text{m}$

$\boxed{E = -\dfrac{dv}{dr}}$; $dv = -10 \times 0.5$

$\Rightarrow$ -5 Volt

Ques The Electric Potential at any point (x, y, z) in space is given by $V = 4x^2$ Volt, find the electric field intensity at Point (1m, 0.2m)

Ans $P(1, 0.2)$, $x = 1$, $y = 0.2$

$$V = 4x^2, \quad E_x = -\frac{dV_x}{dx} \Rightarrow -\frac{d(4x^2)}{dx}$$

$$= -4(2x) \Rightarrow -8x$$

$$= -8(1) \Rightarrow \underline{\underline{-8 \text{ N/C}}}$$

Note –

Ques $V = [8y^2 + y]$

Find electric field at $P(\overset{x}{1}, \overset{y}{2})$

Ans

$$E_y = -\frac{dV_y}{dy} \Rightarrow -\frac{d[8y^2+y]}{dy}$$

$$\Rightarrow -\frac{d(8y^2)}{dy} + -\frac{d(y)}{dy}$$

$$= -8(2y) - 1$$

$$= -[16y + 1]$$

$$= -[16(2) + 1] \Rightarrow -[33]$$

$$= \underline{\underline{-33 \text{ N/C}}}$$

Ques $V = (2z^3 + 4z + 8)$

Find electric field at $P(1, 2, 3)$

Ans

$$E_v = -\frac{dV_z}{dz}$$

$$= -\frac{d(2z^3 + 4z + 8)}{dz}$$

$$= -\left[\frac{d(2z^3)}{dz} + \frac{d(4z)}{dz} + \frac{d(8)}{dz}\right]$$

$$= -\left[2(3z^2) + 4 + 0\right]$$

$$= -\left[6(3)^2 + 4\right] \Rightarrow -\left[54+4\right]$$

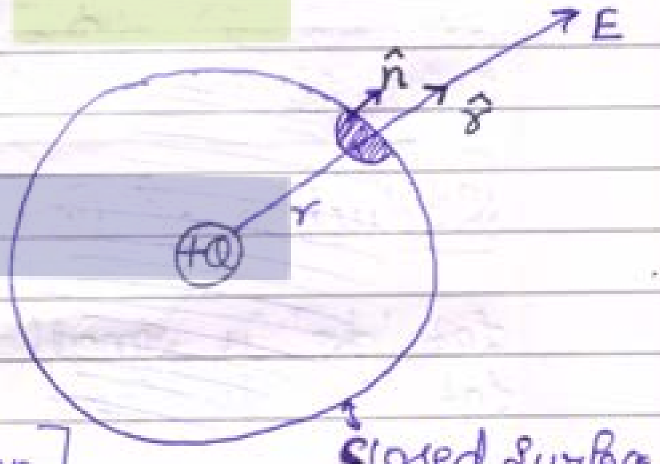
$$= \underline{-58\ N/C}$$

Gauss Theorem

The Surface Integral of electrostatic field produced by any source over any closed surface (S) enclosing a volume (V) in vaccum, i.e total electric flux over the closed surface (S) in vaccum is $1/\varepsilon_0$ times the Total charge (Q) contained inside the surface.

$$\boxed{\phi = \frac{1}{\varepsilon_0} \times Q}$$

$$\boxed{\phi = \oint \vec{E}\cdot\vec{ds} = \frac{Q}{\varepsilon_0}}$$



$\left[\begin{array}{l} \because\ \hat{n} \rightarrow \text{Area vector} \\ \quad\ \hat{r} \rightarrow \text{unit vector} \end{array}\right]$

Ans 1) Let 'E' is electric field due to closed surface

$$\boxed{\vec{E} = \frac{1 \times Q}{4\pi\varepsilon_0 r^2} \times \hat{r}}$$

Let ds is small surface area

$$\boxed{\vec{ds} = ds \cdot \hat{n}}$$

$$\phi = \oint \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2} \times \hat{r} \cdot ds \cdot \hat{n} \quad [\because \phi = \oint \vec{E} \vec{ds}]$$

$$\phi = \oint \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2} \cdot ds \, (\hat{r} \cdot \hat{n}) \quad [\because \hat{r} \cdot \hat{n} = 1]$$

$$\phi = \oint \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2} \cdot ds$$

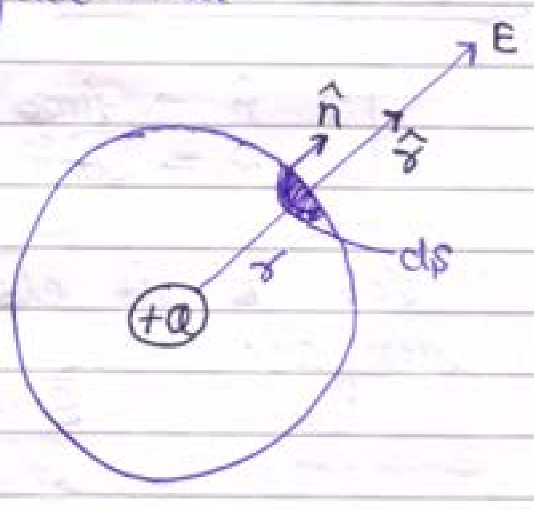
$$\phi = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2} \oint ds$$

$$\phi = \frac{1}{\cancel{4\pi}\varepsilon_0} \times \frac{Q}{\cancel{r^2}} \times \cancel{4\pi r^2} = \frac{Q}{\varepsilon_0}$$

$$\boxed{\phi = \frac{Q}{\varepsilon_0}}$$

Deduction of Coulomb's force by Gauss Theorem

Let 'ds' is small surface Area
Let 'f' is force



$$\phi = \oint \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$$

$$\oint \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$$

$$\oint E \cdot ds \cos\theta = \frac{q}{\varepsilon_0}$$

[$\hat{r}, \hat{n}$ is in same direction]

$\therefore \theta = 0°$

$$\oint E\,ds\,(1) = \frac{q}{\varepsilon_0}$$

$$E\oint ds = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0} \Rightarrow E = \frac{1}{4\pi r^2} \times \frac{q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2} \quad \text{------------ (1)}$$

As we know,

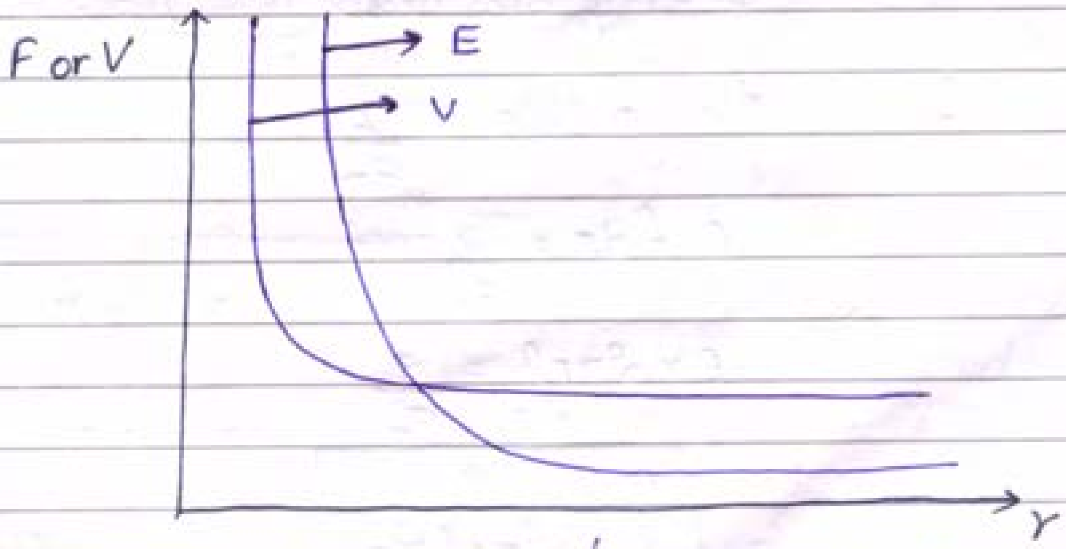
$$F = q_0 \times E \quad \text{------------ (2)}$$

Therefore, put the value of eq^n (1) into eq^n (2)

$$F = q_0 \times \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2}$$

$$\boxed{F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_0 \times q}{r^2}}$$ (which is coulomb force)

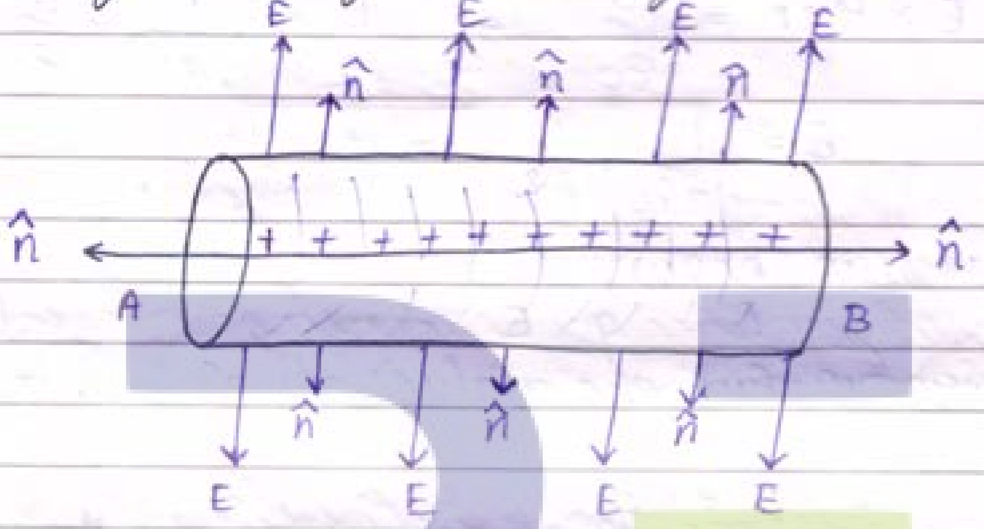
Variation of (F) and Potential (V) with distance graph:



$\boxed{E = \frac{KQ}{r^2}}$, $\boxed{E \propto \frac{1}{r^2}}$ / $\boxed{V = \frac{KQ}{r}}$, $\boxed{V \propto \frac{1}{r}}$

Applications of Gauss Theorem

★ Find the electric field Intensity of Long Straight uniform charged wire.



Let AB is Long Straight charged wire
Let 'l' is length of charged wire

$$\phi = \oint \vec{E} \cdot \vec{ds}$$

$$\phi = \oint E ds \cos\theta \qquad [\theta = 0^\circ]$$

$$\phi = \oint E ds = \frac{q}{\varepsilon_0}$$

$$E \oint ds = \frac{q}{\varepsilon_0}$$

$$E \times 2\pi r l = \frac{q}{\varepsilon_0}$$

$$\boxed{E = \frac{q}{2\pi r l \varepsilon_0}}$$

$$\lambda = \frac{q}{l}$$

$$\boxed{q = \lambda \times l}$$

put the value of q in ①

$$E = \frac{\lambda \times \cancel{l}}{2\pi r \cancel{l} \varepsilon_0}$$

$$\boxed{E = \frac{\lambda}{2\pi r \varepsilon_0}}$$

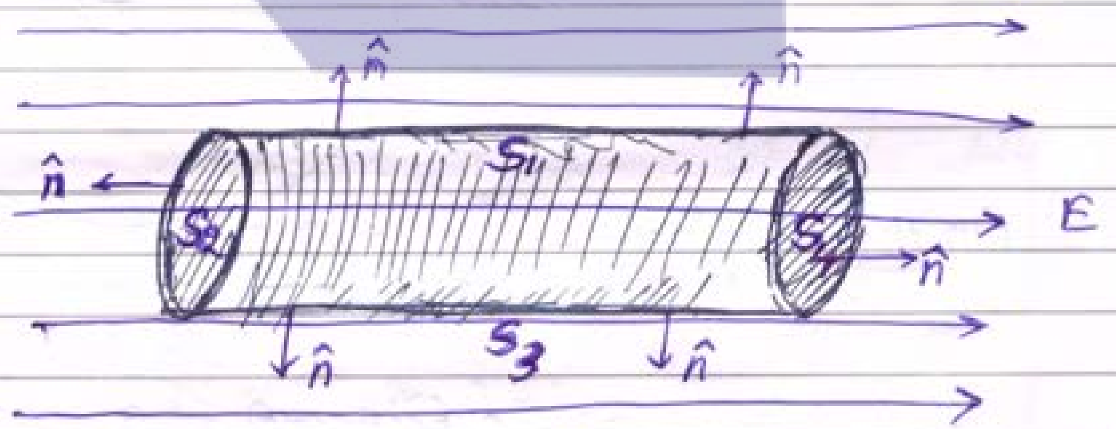
① $\lambda = \frac{q}{l}$ = Linear charge density

② $\sigma = \frac{q}{A}$ = Area/surface charge density

③ $\rho = \frac{q}{V}$ = Volume charge density

If $\lambda > 0$ → electric field outward [+ve charged]
$\lambda < 0$ → electric field inward [-ve charged]

Ques Find electric flux due to charged straight wire placed in electric field?



$$\phi = \phi_1 + \phi_2 + \phi_3 + \phi_4$$

$$\phi = \oint E dS_1 \cos\theta_1 + \oint E dS_2 \cos\theta_2 + \oint E dS_3 \cos\theta_3 + \oint E dS_4 \cos\theta_4$$

$$\phi = \oint E dS_1 \cos 90^\circ + \oint E dS_2 \cos 180^\circ + \oint E dS_3 \cos 90^\circ + \oint E dS_4 \cos 0$$

$$\phi = 0 + \oint E\,dS_2(-1) + 0 + \oint E\,dS_4(1)$$
$$= \oint E\,dS_4 - \oint E\,dS_2$$

$[\oint ds = S]$

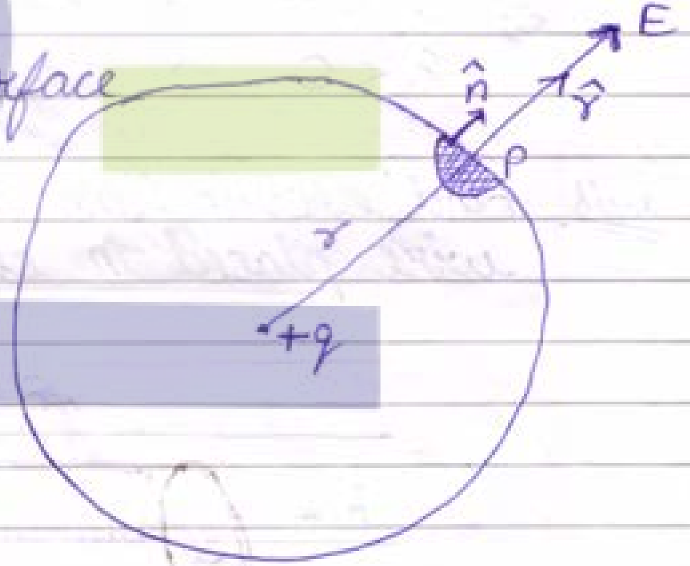
$[dS_2 = dS_4]$

$$\Rightarrow \phi = -ES_2 + ES_4 \qquad [S_2 = S_4]$$
$$= \underline{\underline{0}}$$

* Find the electric field Intensity due to spherical shell :-

Let ds is small surface area

By using Gauss Theorem



On the surface -

$$\rightarrow \oint \vec{E}\,d\vec{s} = \frac{q}{\varepsilon_0}$$

$$\rightarrow \oint E\,ds\cos\theta = \frac{q}{\varepsilon_0}$$

$[\theta = 0$ $\vec{E}$ & $\hat{n}$ are in same direc$^n]$

$$\rightarrow \oint E\,ds = \frac{q}{\varepsilon_0} \Rightarrow E\oint ds = \frac{q}{\varepsilon_0}$$

$$\rightarrow E \times 4\pi r^2 = \frac{q}{\varepsilon_0} \Rightarrow \boxed{E = \frac{q}{4\pi r^2 \varepsilon_0}}$$

Outside the surface

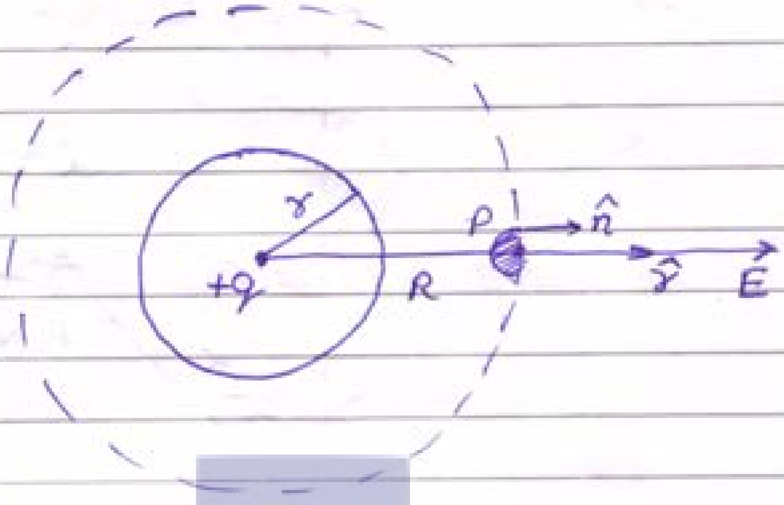
$$\oint \vec{E}\,\vec{ds} = \frac{q}{\varepsilon_0}$$

$$\oint E\,ds\cos 0^\circ = \frac{q}{\varepsilon_0}$$

$$E\oint ds = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi R^2 = \frac{q}{\varepsilon_0}$$

$$\boxed{E = \frac{q}{4\pi\varepsilon_0 \times R^2}}$$

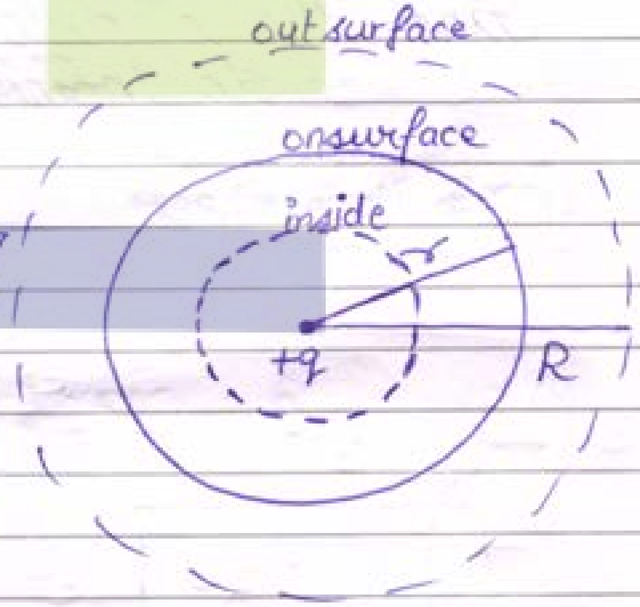


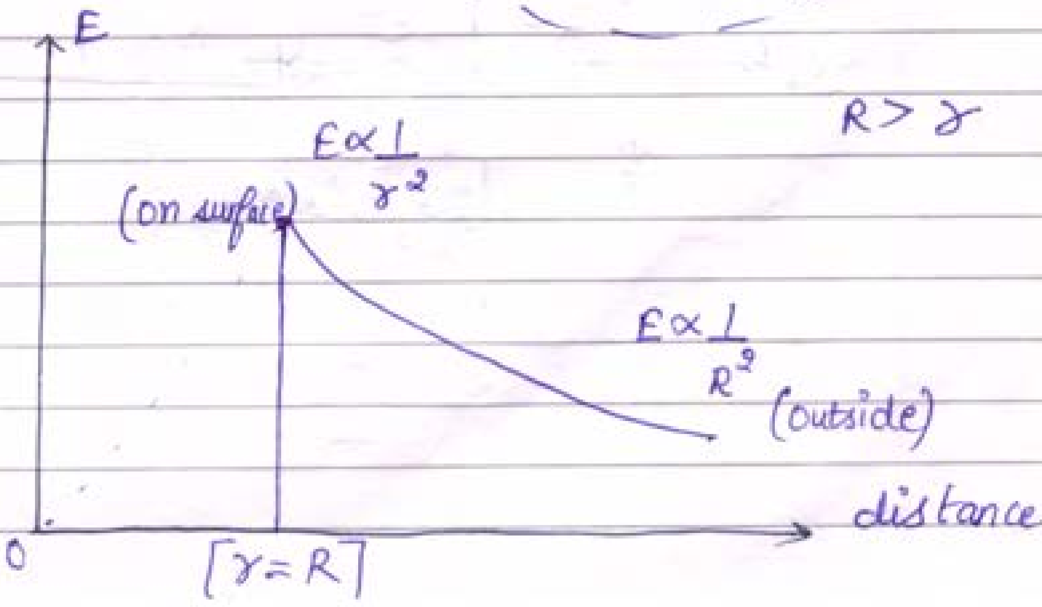
Inside the surface

$$\oint \vec{E}\,\vec{ds} = \frac{q}{\varepsilon_0}$$

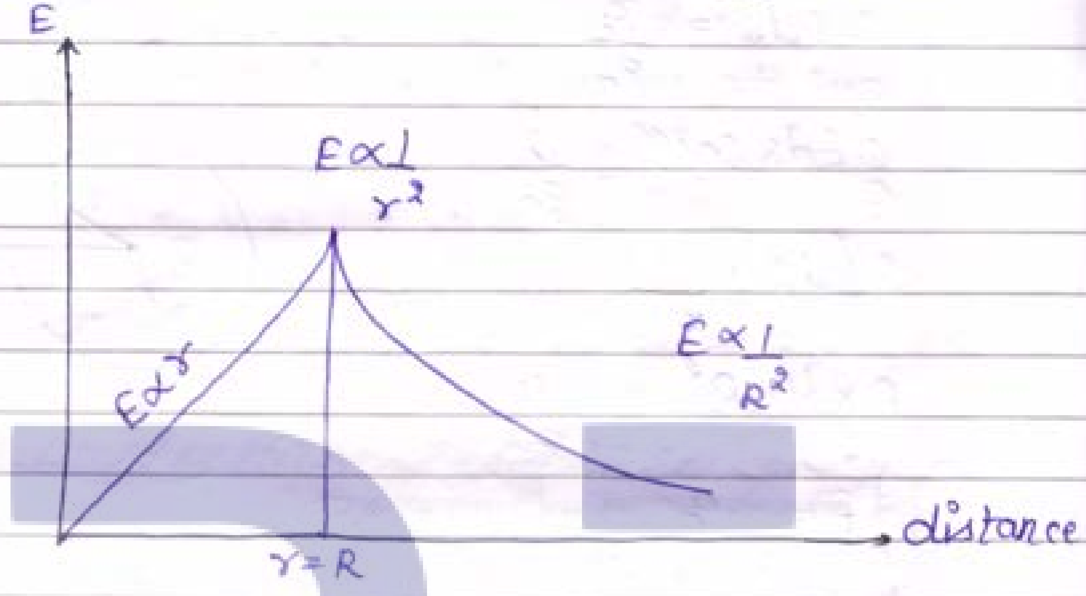
$$E\oint ds = \frac{0}{\varepsilon_0} \quad [\because q = 0]$$

$$\boxed{E = 0}$$



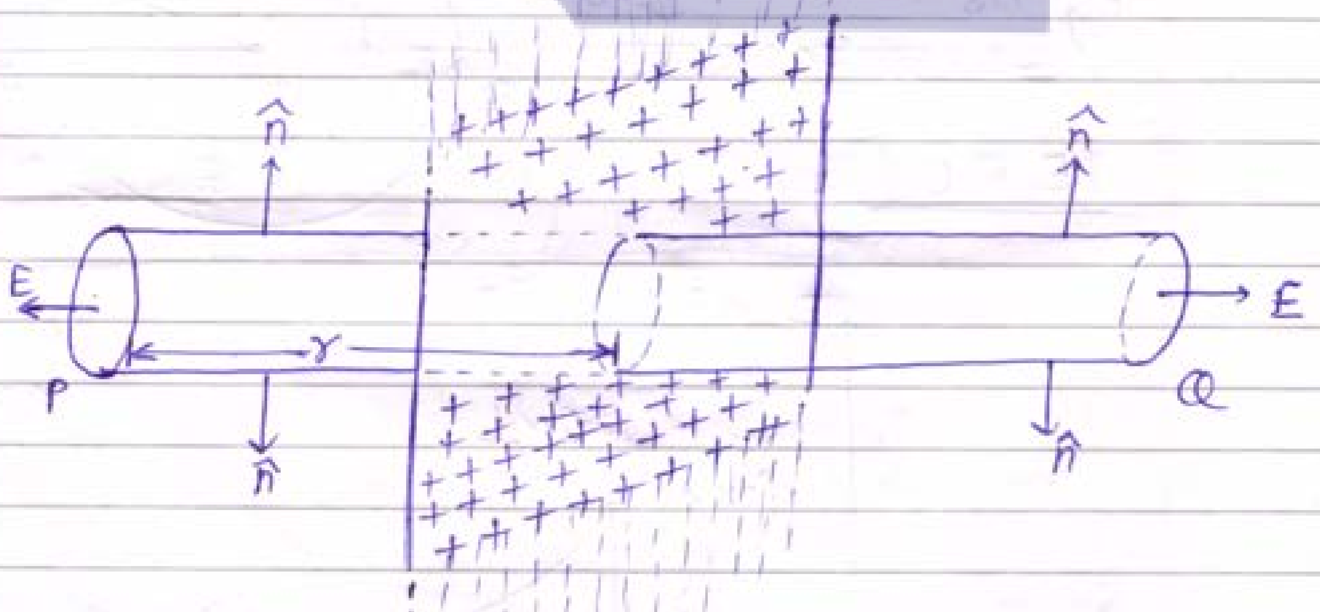


Electric field due to solid sphere/ Solid Shell.



Find the electric field intensity due to infinite plane sheet of charge

Thin Plane Sheet



Let 'σ' is Surface charge density of sheet

Let 'E' is Electric field due to sheet

Let us Imagine a cylinder edge PQ

$\hat{n}$ is area vector

Electric Flux

$$\phi = 2\vec{E}\vec{ds} \qquad [\vec{ds} = ds \cdot \hat{n}]$$

$$\phi = 2\vec{E}\,\hat{n} \cdot ds \qquad [\vec{E} = E \cdot \hat{r}]$$

$$\phi = 2E \cdot \hat{r}\,\hat{n} \cdot ds \qquad [\hat{r} \cdot \hat{n} = 1]$$

$$\phi = 2Eds \quad \text{------------} \quad (1)$$

$$\rightarrow \phi = \frac{q}{\varepsilon_0} \qquad \left[\sigma = \frac{q}{ds} \Rightarrow q = \sigma \cdot ds\right]$$

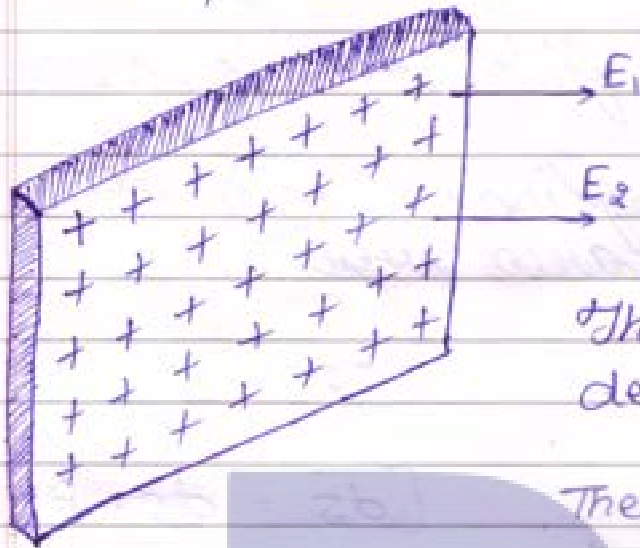
$$\phi = \frac{\sigma \cdot ds}{\varepsilon_0} \quad \text{------------} \quad (2)$$

From eq^n (1) & eq^n (2)

$$2E\cancel{ds} = \frac{\sigma \cdot \cancel{ds}}{\varepsilon_0}$$

$$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

Thick plane sheet



There are two Surface charge density σ_1 and σ_2 are the

There are two surface

$\longrightarrow \quad E = E_1 + E_2$

$\longrightarrow \quad E = \dfrac{\sigma_1}{2\varepsilon_0} + \dfrac{\sigma_2}{2\varepsilon_0}$

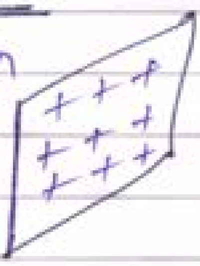
$[\because \sigma_1 = \sigma_2 = \sigma]$

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\cancel{2}\sigma}{\cancel{2}\varepsilon_0} = \frac{\sigma}{\varepsilon_0} \Rightarrow \boxed{E = \frac{\sigma}{\varepsilon_0}}$$

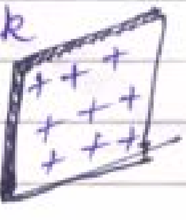
Note

Thin



$$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

Thick



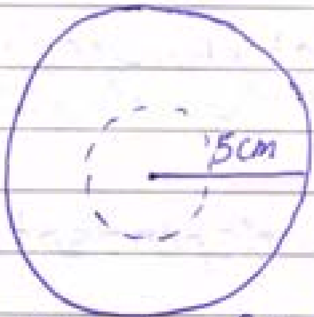
$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$

$\left[\because \sigma = \dfrac{q}{A}\right]$

$\left[\because \sigma = \dfrac{q}{S}\right]$

Ques Spherical shell has diameter 10 cm, 50 N/C is on the surface of shell, what will be electric field if radius become half?

Ans



Diameter, $D = 10\,cm$
Radius, $r = 5\,cm$
Electric field, $E = 50\,N/C$

Inside the Shell → There will be no charge so electric field inside the shell will be zero.

Ques Find the electric field of Long straight wire of radius 2 cm of length is 4m having 4C?

Ans

$$\boxed{E = \frac{\lambda}{2\pi r \times \varepsilon_0}}$$ [Using formula]

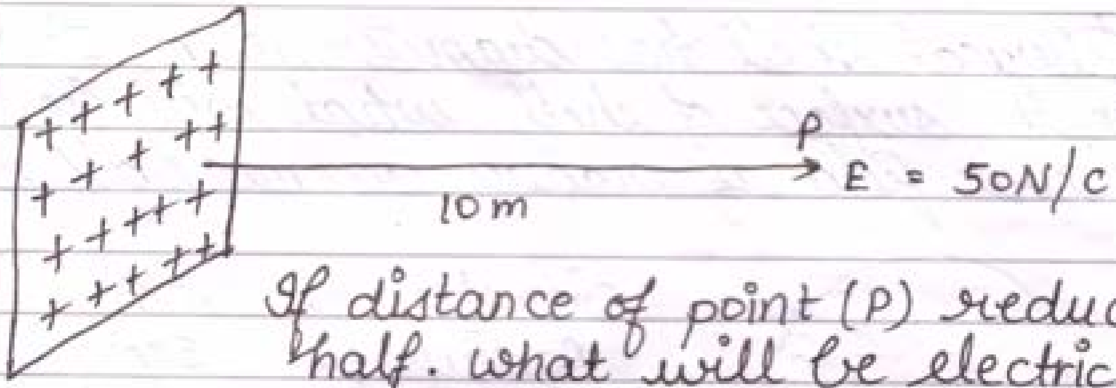
$r = 2cm = 2 \times 10^{-2} m$
$l = 4m = l$

$$\lambda = \frac{q}{l} \Rightarrow \frac{4C}{4m} = 1\ Cm^{-1}$$

$$E = \frac{1}{2 \times \frac{22}{7} \times 10 \times 10^{-2} \times 8.85 \times 10^{-12}}$$

$[\because \varepsilon_0 = 8.85 \times 10^{-12}]$

Ques



If distance of point (P) reduce by half. what will be electric field?

$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$ → It's not dependent of distance

$\boxed{\text{So, it will no change}}$

Ques If linear charge density $\lambda_1 = 5$, $E_1 = 10$
$\lambda_2 = 15$, $E_2 = ?$

Ans

$$E = \frac{\lambda}{2\pi r \varepsilon_0}$$

$$E \propto \lambda$$

$$\boxed{\frac{E_1}{E_2} = \frac{\lambda_1}{\lambda_2}}$$

$$\frac{E_2}{E_1} = \frac{\lambda_2}{\lambda_1}$$

$$E_2 = \frac{\lambda_2 \times E_1}{\lambda_1}$$

$$= \frac{\cancel{15}^{3} \times 10}{\cancel{5}}$$

$$\boxed{E_2 = 30\ N/C}$$