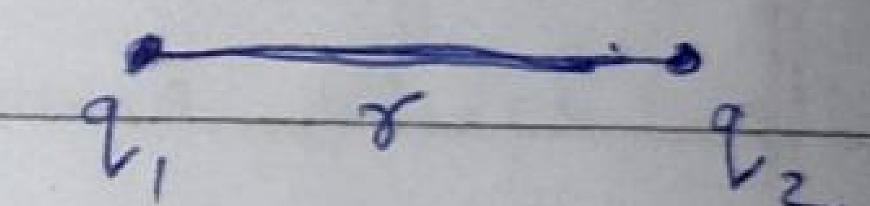
Q-1) How many e^-'s are present in 1 coulomb charge?
Q.2) Write the coulomb's law for electric charge and Derive the expression for it.

Ans. 2) Coulomb's law ⇒

The force of attraction or repulsion b/w two charges is directly proportional to product of charges and inversaly proportional to square of distance b/w them.

$$F \propto q_1 q_2 \longrightarrow ①$$
$$F \propto \frac{1}{r^2} \longrightarrow ②$$



from ① & ②,

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

$$F = K \cdot \frac{q_1 q_2}{r^2}$$

where K = constant.

In SI,

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

where, $\varepsilon_0 \rightarrow$ permitivity of the free space.
and $\boxed{\varepsilon_0 = 8.854 \times 10^{-12}\ C^2/N.m^2}$

$$\Rightarrow F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}, \quad r \rightarrow \text{distance}$$

⇒ SI unit of force is Newton (N).

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

$\because \varepsilon_0 = 8.854 \times 10^{-12}\ C^2/N.m^2$

$\pi = 3.14$

$$\Rightarrow F = \frac{1}{4(3.14)(8.854\times10^{-12})} \quad \frac{q_1 q_2}{r^2}$$

$$\Rightarrow \boxed{F = 9 \times 10^{9} \cdot \frac{q_1 q_2}{r^2}} \longrightarrow \text{This is for air medium.}$$

In any Medium -

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

where, $K \rightarrow$ dielectric constant.

$$\Rightarrow \boxed{F = \frac{1}{4\pi\varepsilon} \cdot \frac{q_1 q_2}{r^2}}$$

where, $\boxed{\varepsilon = \varepsilon_0 K}$

$\varepsilon \rightarrow$ Relative permitivity of the Medium.

Ans. 1) $Q = ne$

$n = \frac{Q}{e}$

A.T.Q., $Q = 1$,

We know, $e = 1.6 \times 10^{-19}$

$$n = \frac{1}{1.6 \times 10^{-19}} = \frac{1}{1.6} \times 10^{19} = 0.625 \times 10^{19} = 6.25 \times 10^{15}$$

Ans

Q. Relation b/w CGS unit and SI unit of charge

Ans - $1C = 3 \times 10^{9}$ stat coulomb.

where, C is SI unit of charge
stat coulomb is CGS unit of charge.

Q.1 Define charge.
Q.2 Write the type of charge.
Q.3 Write the value of e^-.
Q.4 Charge is scalar or vector?
Q.5 which charge is known as the fundamental charge & write it's value.
Q.6 write the properties of electric charge with suitable example.
Q.7. What do you mean by friction electric.
Q.8 Write the SI unit of charge. also write the CGS unit.

Ans. 1) Charge :- charge is the no. of e^- present in any atom or substance.

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

where, $n = 1, 2, 3, \ldots$
$e =$ electron
$e = 1.6 \times 10^{-19}$ C

Ans. 2) There are two types of charge -

a) positive charge
b) Negative charge

} combination of both charge is = Neutral, Ans.3 → $1e^- = 1.6 \times 10^{-19}$ C

Ans.4 → charge is scalar quantity because we can add the charge in integer form, it does not have direction.

Ans.5 → e^- is known as fundamental charge because we use e^- for ~~represent donation or acceptance~~ both, donate or ~~acceptation~~ accept. of charge.

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

Ans.6) Properties of charge :-

i) similar charges repel each other.
ii) different chares attract each other.
iii) $Q = \pm ne$
iv) charge of an isolated system remains conserved.
v) smallest unit of charge $= e^-$

Ans.7) Friction Electric :- Electric charge produced by the friction force is called Friction Electric.

Ans.8) SI unit of charge = coulomb (c)
CGS unit of charge = stat coulomb, represted by "esu"

Q.9 prove that like charge repel to each other and unlike charges attract to each other.

Q.10 Write the properties of electric charge with suitable example.

Ans. 10 Properties of electric charge :-

i) Additive property :-

$$q_T = q_1 + q_2 + q_3 + \dots + q_n$$

ii) law of conservation :- charge can neither be created or ~~neither~~ nor be destroyed. charge can only transfer from one surface to another surface.

eg.:- $Na = 11$ → $Na^+ = 10$

$Cl = 17$ → $Cl^- = 18$

28 28

iii) Quantization of charge :-

$$q = ne \quad , \text{where } n = 1, 2, 3, \dots$$

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

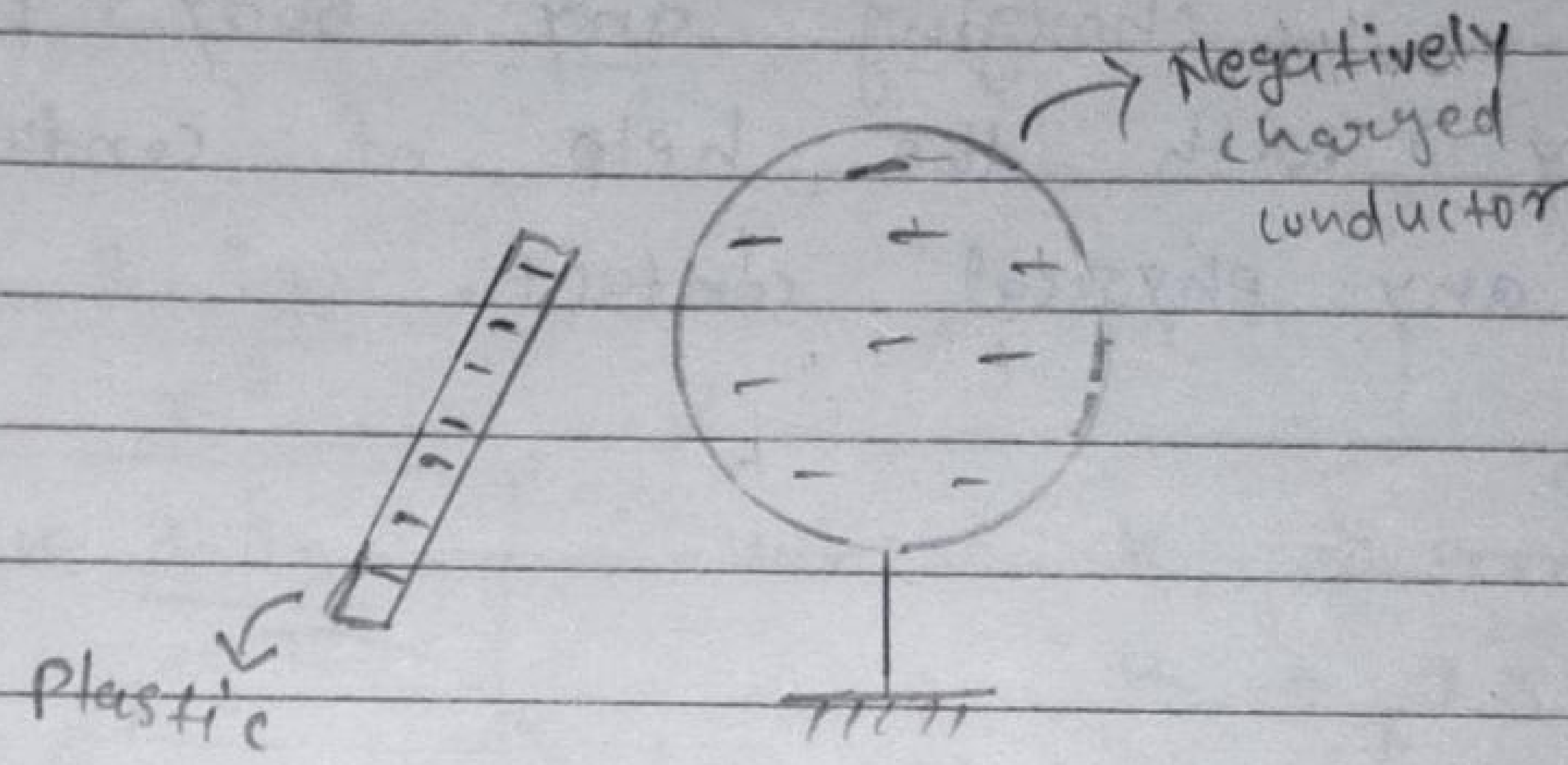
iv) a) like charges repel each other.

b) unlike charges attract each other.

Q.11 What is the meaning of Induction?

Q.12 Explain coulomb's law for electrostatic.

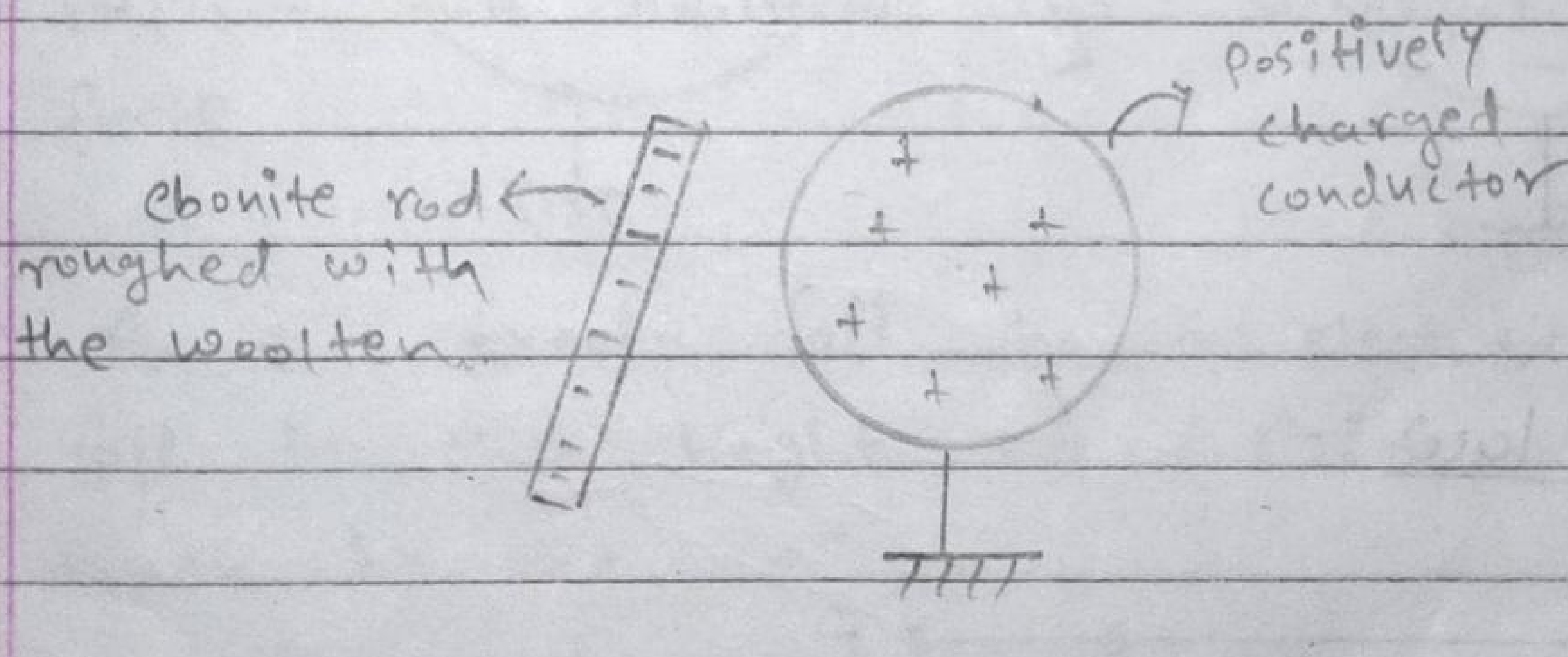
Ans. 9 i) like charges repel each other :-



Both repel each other.

We take Negatively ~~Positively~~ charged conductor and a plastic which is roughed by our dry hair then plastic also gets negative charge then we can place plastic and conductor in same place then they both repel each other.

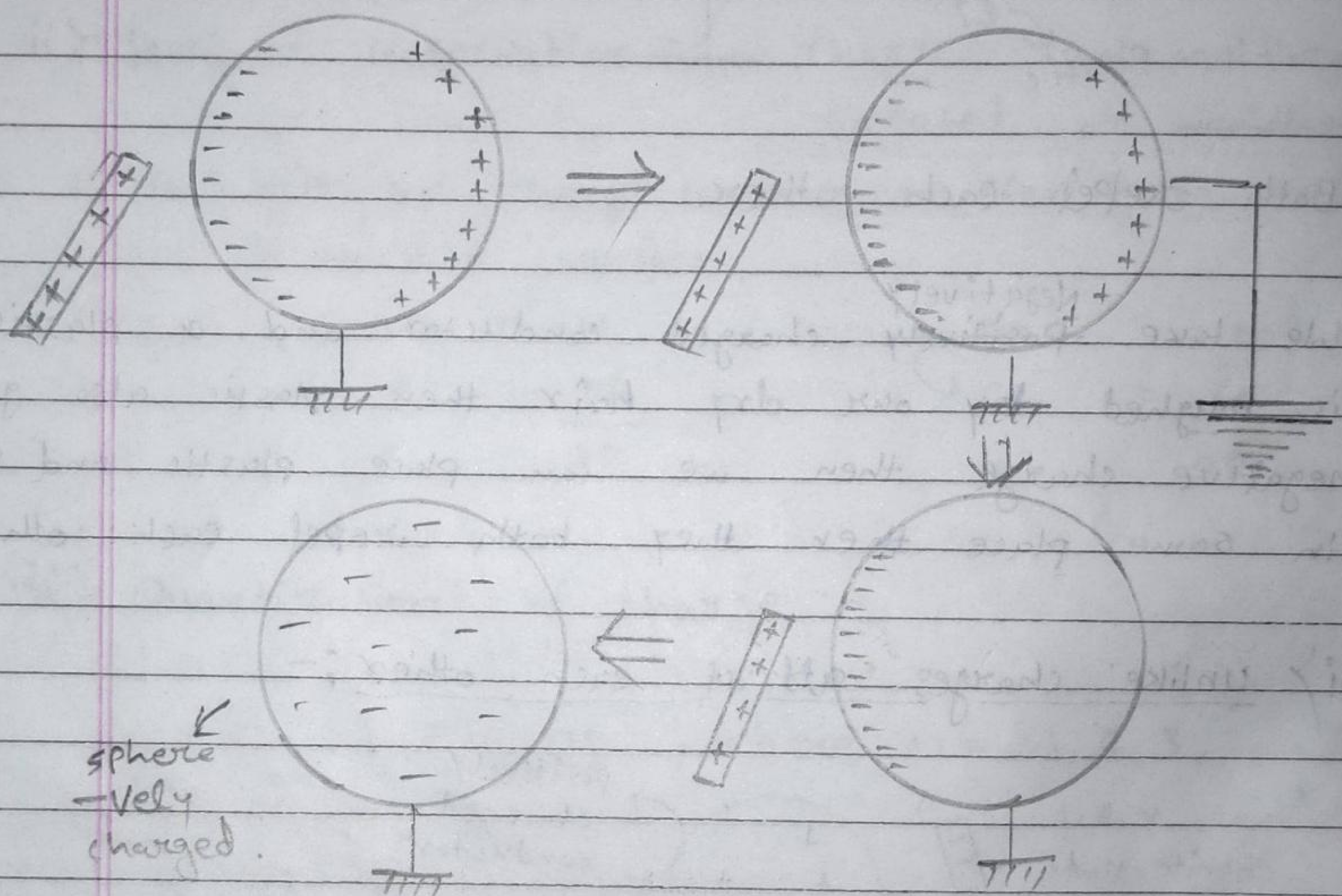
ii) Unlike charges attract each other :-



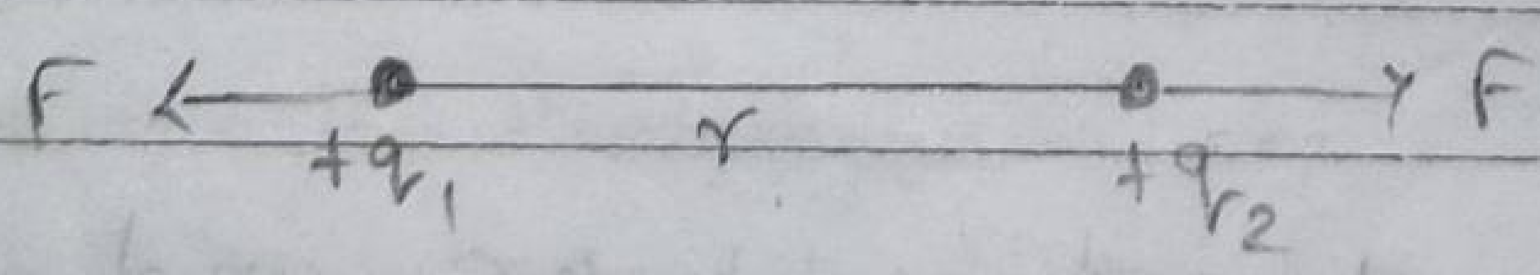
We take positively charged conductor and a ebonite rod roughed with woolten then ebonite rod gets negatively charged.

when we place ebonite rod and conductor in same place then both are attracted by each other.
Hence proved.

Ans. 11) <u>Induction</u> :- Induction is a method of charging any body positively or negatively with the help of conductor and without any physical contact.



Ans. 12 <u>coulomb's law</u> :-



According to coulomb's law, coulomb force is directly proportional to product of two charges and inversaly proportional to the square of distance between these two charges.

$$F \propto q_1 q_2$$
$$F \propto \frac{1}{r^2}$$

$\Rightarrow F \propto \frac{q_1 q_2}{r^2}$

$\Rightarrow \boxed{F = K \frac{q_1 q_2}{r^2}}$ where. $K \rightarrow$ constant ~~permitivity of free space~~

$K = 9 \times 10^9$

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

$\Rightarrow \boxed{1C = 3 \times 10^9 \text{ stat coulomb}}$

Q.13) Verify Newton's Third law of Motion by using coulomb's law.

Q.14) What is the meaning of electric field and intensity of electric field

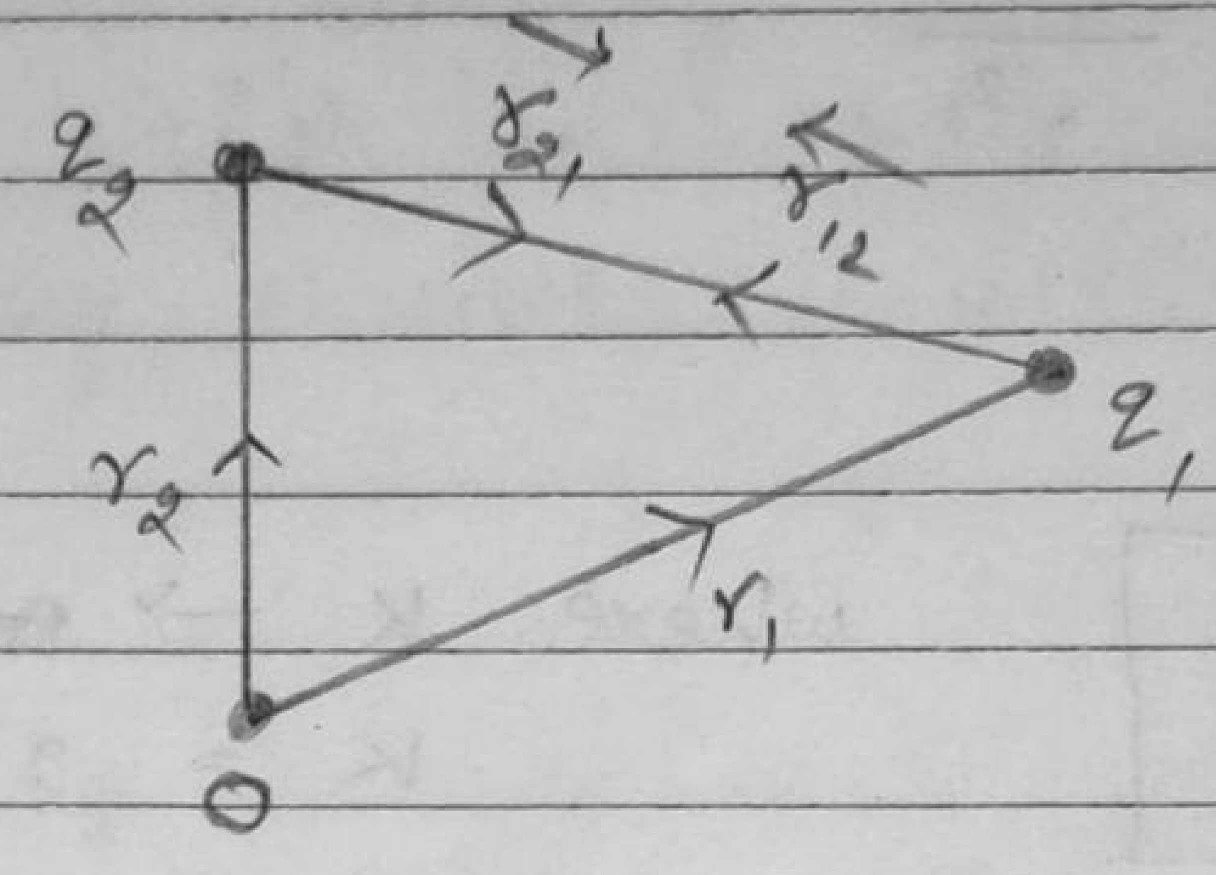
Q.15) Explain the principle of superposition for electrostatic force.

Q.16) An e^- freely fall in a electric field 2×10^4 N/C fall in the height of 1.5 cm, calculate the time taken by the e^-.

Ans.13) We know that, coulomb law is

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

let there is 2 charges seperated at distance r.



$\Rightarrow$ coulomb force, $\vec{F}_{12} = \dfrac{Kq_1q_2}{r^2}\,\hat{r}_{12}$ $\longrightarrow$ (i)

$\Rightarrow$ coulomb force, $\vec{F}_{21} = K\dfrac{q_1q_2}{r^2}\,\hat{r}_{21}$ $\longrightarrow$ (ii)

$\because \hat{r}_{12} = -\hat{r}_{21}$ $\longrightarrow$ (iii)

from eq^n (i) and (iii)

$\Rightarrow \vec{F}_{12} = \dfrac{Kq_1q_2}{r^2}(-\hat{r}_{21})$

$\Rightarrow \vec{F}_{12} = -K\dfrac{q_1q_2}{r^2}\,\hat{r}_{21}$ $\longrightarrow$ (iv)

from (ii) and (iv)

$\Rightarrow \boxed{\vec{F}_{12} = -\vec{F}_{21}}$

Hence it satisfy Newton's third law of motion.

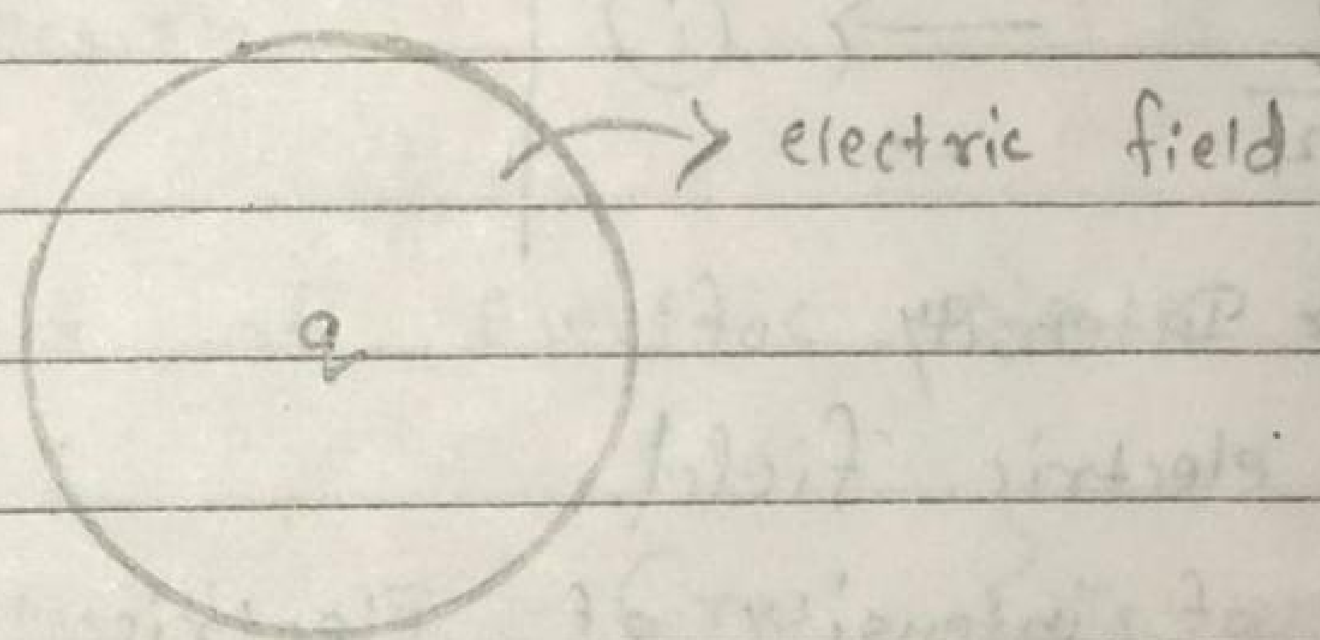
Ans.15) Principle of Superposition :-

This principle is used to find total net force on any charge.

Q.17 What do you mean by electric dipole and electric dipole moment?

Q.18 Derive an expression for force and Torque when electric dipole is placed in uniformly electric field.

Ans.14) Electric field :- The space around the charge in which we experience electrostatic force that field is called electric field.



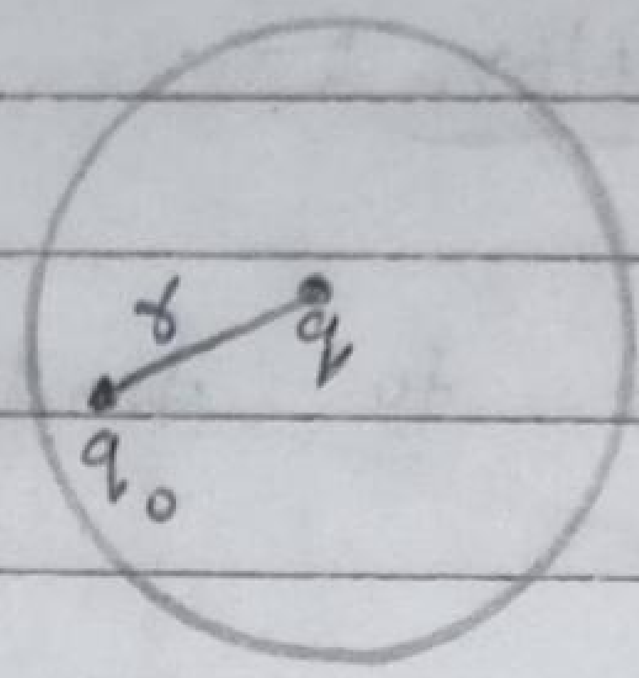
✡ unit positive charge is called Test charge, represented by "q_0"

$$\Rightarrow \boxed{|q_0| = +1}$$

Intensity of electric field :- The force experienced by test charge in electric field is known as intensity of electric field.

Coulomb force,

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



$\Rightarrow$ $F = \dfrac{K\,q\,q_0}{r^2}$

$\because$ $q_0 = 1$

Case-I $\Rightarrow$

$\Rightarrow$ $F = \dfrac{K\,q\,(1)}{r^2}$

$\Rightarrow$ $F = \dfrac{Kq}{r^2}$ ———

$\Rightarrow$ $E = \dfrac{Kq}{r^2} \longrightarrow$ (i)

where, $E \rightarrow$ Intensity of electric field

Case II $\Rightarrow$ $F = \dfrac{K\,q\,q_0}{r^2}$

$\Rightarrow$ $\dfrac{F}{q_0} = \dfrac{Kq}{r^2} \rightarrow$ (ii)

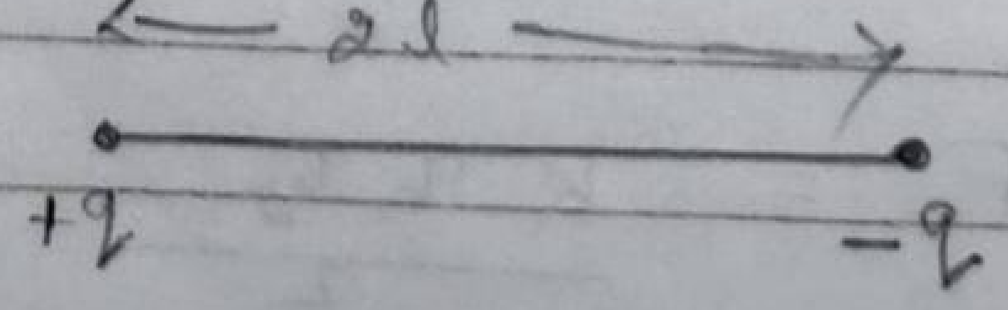
$\Rightarrow$ The direction of intensity of electric field is positive to Negative.

from (i) & (ii),

$\Rightarrow$ $\boxed{E = \dfrac{F}{q_0}}$

~~Q.19 $\Rightarrow$ Derive an expression for Torque~~

Ans. 18 **Electric Dipole :-** The pair of opposite nature charge is called electric dipole.



(or)

Same magnitude but of opposite nature is placed in minimum distance, This system is also called electric dipole.

Electric Dipole Moment (p) :- This is the product of magnitude of one charge of electric dipole and distance between both charges.

$$\boxed{p = q \times 2l}$$

→ Electric dipole moment is vector quantity.
→ The direction of electric dipole moment is negative to positive direction.

⇒ **unit :-** Unit of Electric Dipole moment is coulomb meter

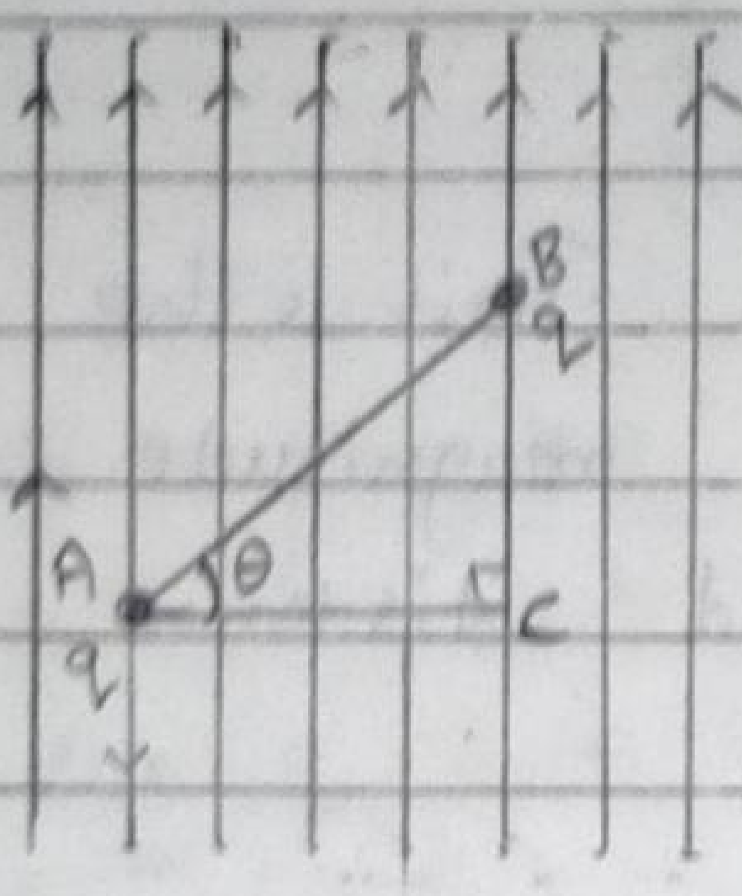
unit = Cm {coulomb meter}

Electric field :- The space around the charge in which we experience electrostatic force that field is called electric field.

Electric field is 2 types :-

i) Uniformly
ii) Non-Uniformly

⇒ **Torque on an uniformly electric field :-**



In ΔABC,

$\sin\theta = \frac{BC}{AB}$

$BC = AB \sin\theta$

$\because$ AB is distance b/w 2 charge

and we know distance $= 2l$

$BC = 2l \sin\theta.$

Now,

$$
\begin{aligned}
\text{Torque } (\tau) &= \text{force} \times (\text{perpendicular distance}) \\
&= qE \ (BC) \\
&= qE \times 2l \sin\theta \\
&= (q \times 2l) \times E \sin\theta \\
\text{Torque } (\tau) &= pE \sin\theta \qquad \{\because p = 2l \times q\}
\end{aligned}
$$

where, $p \rightarrow$ Electric dipole moment

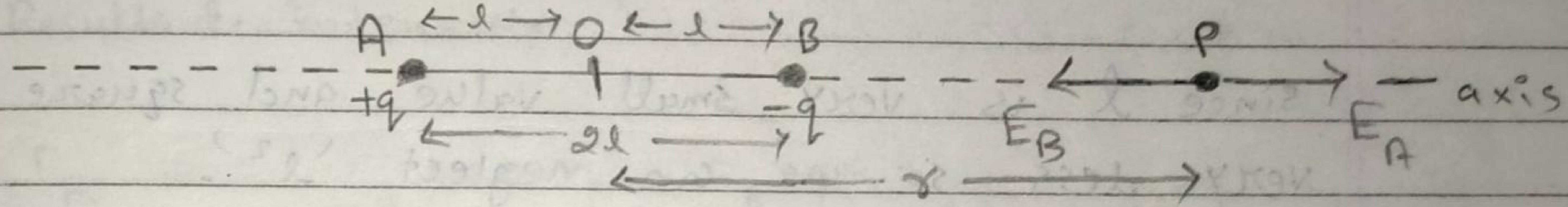
$E \rightarrow$ Intensity of electric field.

* coulomb law is invalid at less distance $= 10^{-15}$ m.

Q.13 Derive an expression for Intensity of electric field Due to electric dipole in axial position.

{axial position is also called end to end position.}

Ans. __Axial position__ :- The line joining of electric dipole, that line is called axis.
And a unit positive charge (p) is placed on axis ~~that location is called Axial position.~~ at distance 'r' from centre of electric dipole, that 'p' position is called Axial position.



$OP = r$, $OB = l$, $BP = r - l$
$OA = l$, $AP = r + l$

formula for intensity of electric field,

$$E = \frac{Kq}{r^2}$$

$$\Rightarrow E_A = \frac{Kq}{(r+l)^2} , \Rightarrow E_B = \frac{Kq}{(r-l)^2}$$

__Resultant Intensity__,

$$\Rightarrow E_R = E_B - E_A \qquad \left[\because E_B > E_A\right]$$

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

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

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

$$= Kq \left\{ \frac{(2r)\,(2l)}{(r^2-l^2)^2} \right\}$$

since l is very small value and square l is very less so we can neglect 'l^2'.

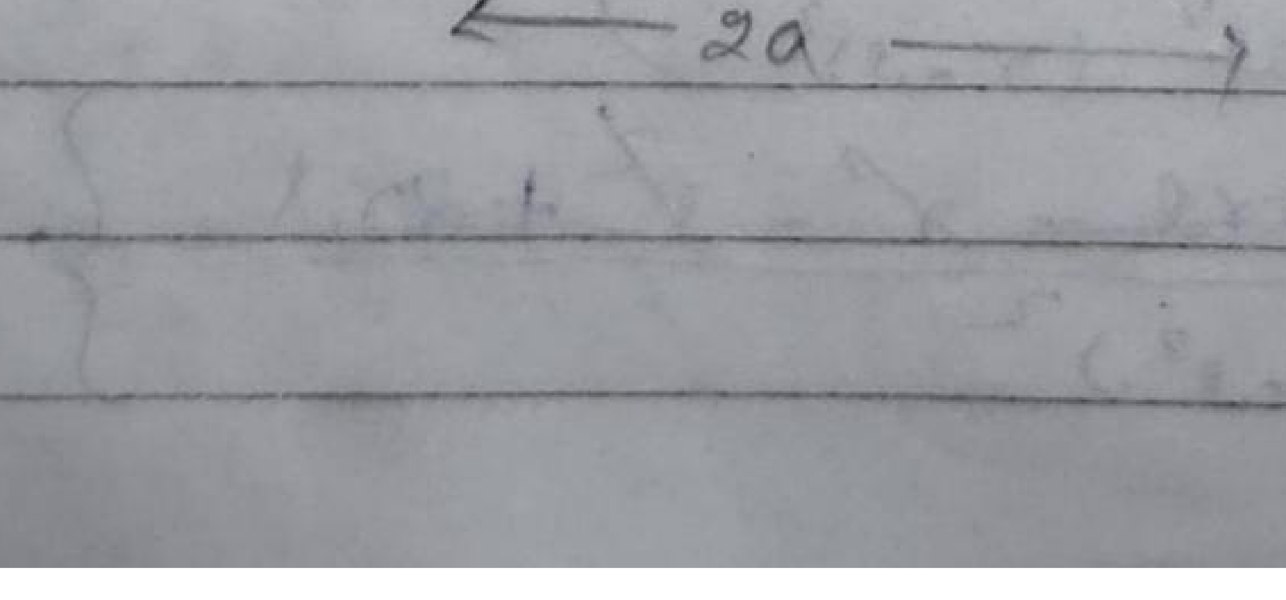
$$= Kq \times \frac{2r \times 2l}{r^4}$$

$$= \frac{K \times 2r}{r^4} \times (q \times 2l)$$

$$\boxed{E_r = \frac{2KP}{r^3}} \quad \left\{ \because P = q \times 2l \atop P \text{ is intensity of electric field} \right\}$$

Q.20. Derive an expression for Intensity of electric field due to electric dipole in equatorial Position.

Ans.



$$\Rightarrow E_A = \frac{Kq}{(AP)^2} = \frac{Kq}{(\sqrt{r^2+a^2})^2} = \frac{Kq}{r^2+a^2}$$

$$\Rightarrow E_B = \frac{Kq}{r^2+a^2}$$

from Here, $E_A = E_B$

$\Rightarrow$ Resultant intensity,

$$\Rightarrow E_R = E_A \cos\theta + E_B \cos\theta$$

$$\Rightarrow E_R = 2E_A \cos\theta \qquad \left[\because E_A = E_B\right]$$

$$\Rightarrow E_R = 2 \cdot \frac{Kq}{r^2+a^2} \cdot \frac{a}{\sqrt{r^2+a^2}} \qquad \left[\because \cos\theta = \frac{a}{\sqrt{r^2+a^2}}, \quad E_A = \frac{Kq}{r^2+a^2}\right]$$

$$\Rightarrow E_R = \frac{(2a \times q)\,K}{(r^2+a^2)^1\,(r^2+a^2)^{1/2}}$$

$$\Rightarrow E_R = \frac{PK}{(r^2+a^2)^{3/2}} \qquad \left[\because P = 2a \times q, \; P \rightarrow \text{intensity of electric field}\right]$$

$$\Rightarrow \boxed{E_R = \frac{KP}{r^3}} \qquad \left[a <<< r \text{ so}, \; a \approx 0\right]$$

Q.21 What do you mean by electrostatic lines of force ? or electric field lines ?

Ans.

Electric lines of force is an imaginary straight or curved path along which a unit positive charge tends to move in an electric field

No. of electric field lines is directly proportional to magnitude of charge.

Tangent at a point on an electric line of force gives the direction of electric field and force at that point

Two electric field lines can never intersect each other

Q.22) Define electric field lines and write the basic properties of electric field lines.

Q.23) Two electric field lines never intersect to each other. why?

Q.24) What is electric flux?

Ans. 22 Electric field lines are imaginary path in which unit positive charge are free to move that path lines are called electric field lines.

Properties :-

i) Electric field lines gives information about direction, it always start from positive and end at negative.

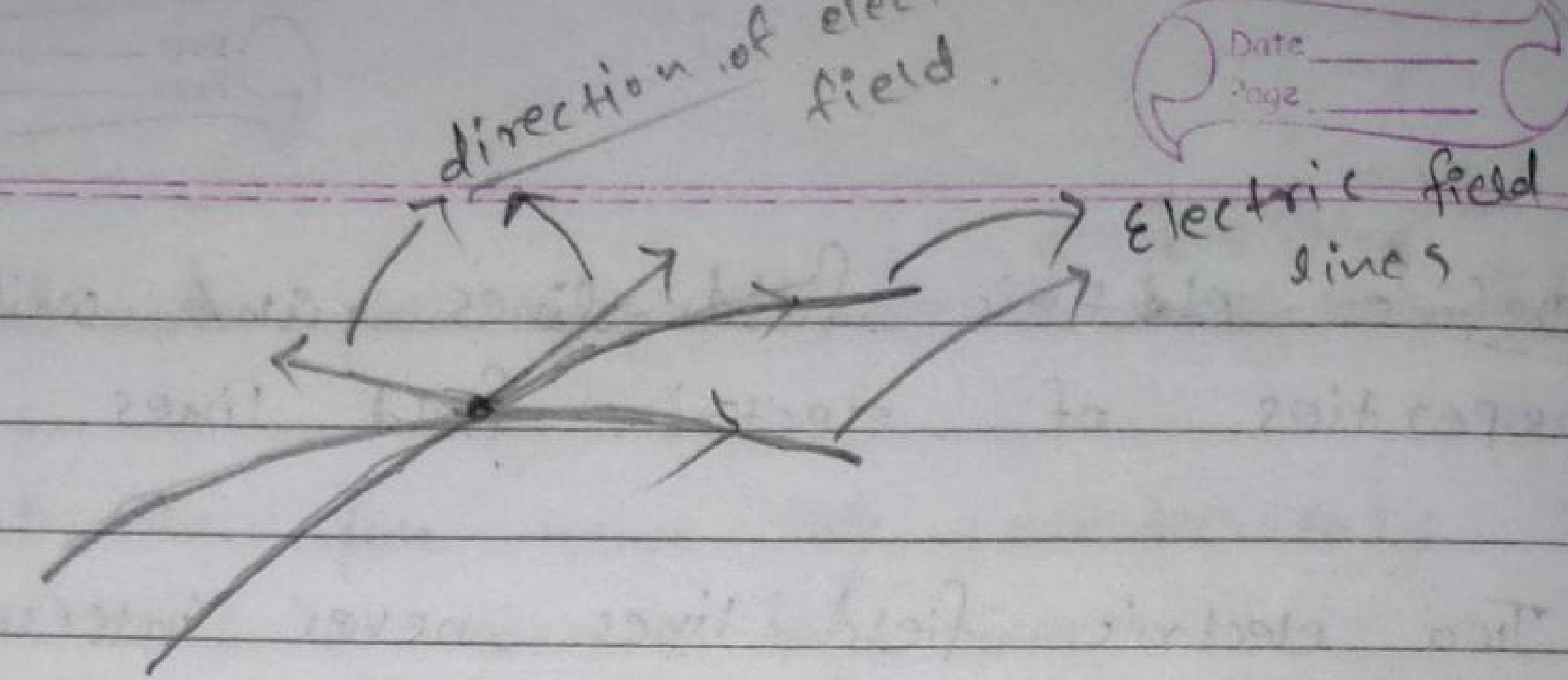
ii) Electric field lines gives information about nature of charge.

iii) Electric field lines tells about strenghth of electric field.

iv) Electric field lines never form closed loop.

v) Two electric field lines never intersect each other.

Ans. 23



When two electric field lines are intersect each other then the their is 2 direction at intersection point of electric field lines, it is not possible.

It is not possible because electric field is a vector quantity and vector quantity has only 1 direction. Therefore Two electric field lines never intersect each other.

Q.25 Write and prove Gauss's Theorem for electrostatic

Ans. 24 Electric flux :- The total no. of electric field lines of force normally passes through the unit cross section Area in electric field is called Electric flux, represented by ϕ or ϕ_E.

unit :- $\frac{Nm^2}{C}$

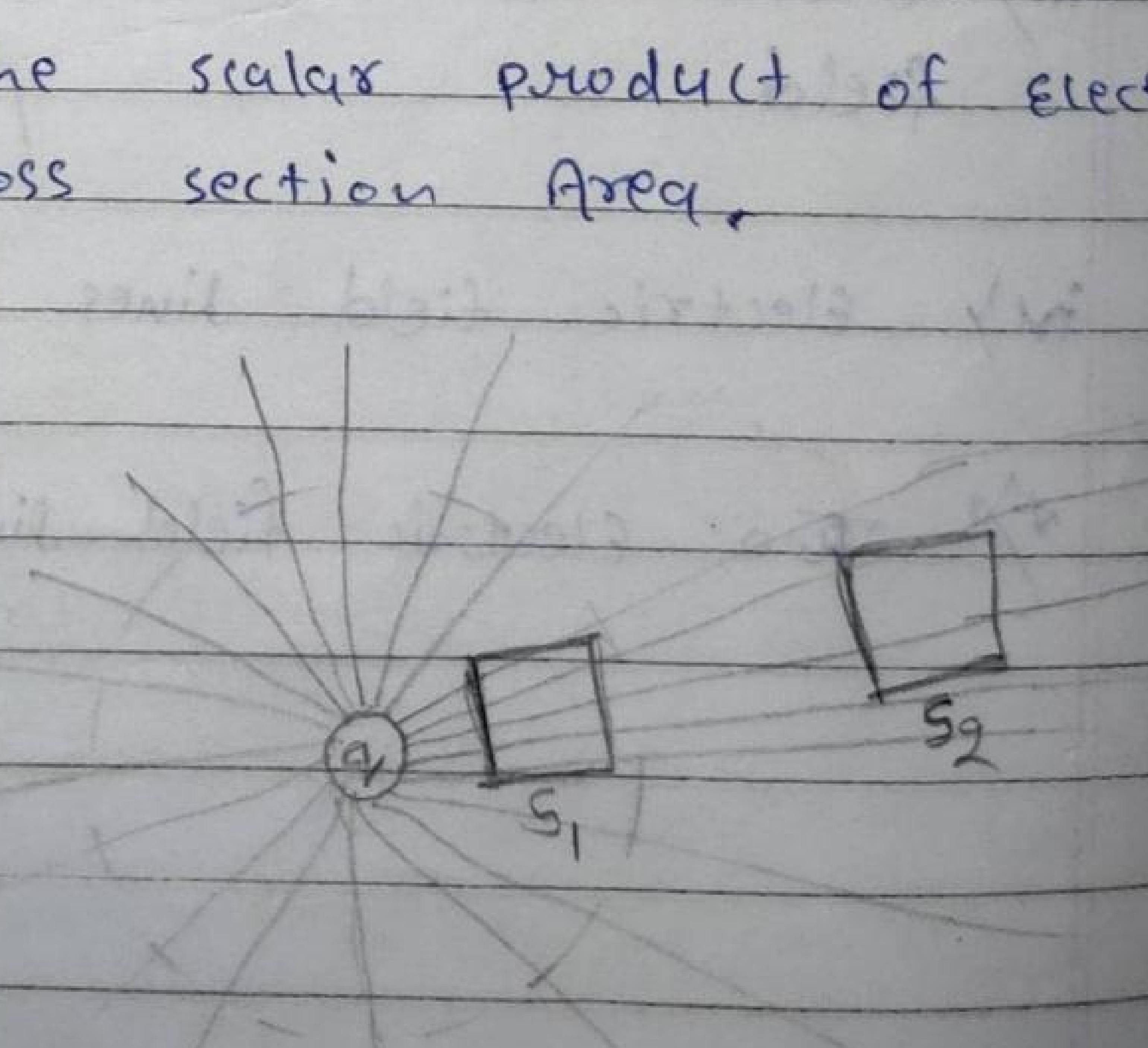
or

Electric flux is the scalar product of electric field lines and unit cross section Area.

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

or

$$\boxed{\phi_E = \vec{E} \cdot \vec{A}}$$



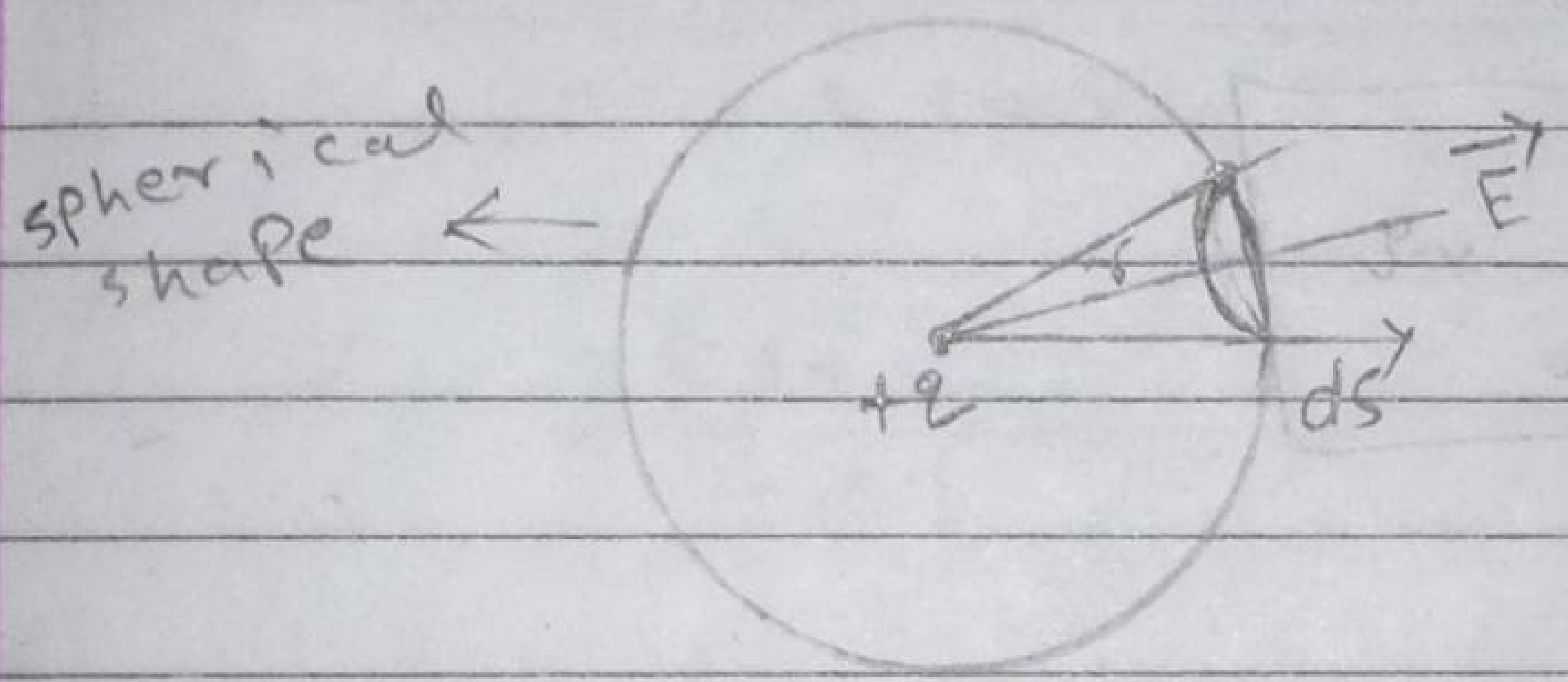
Ans. 25 → Gauss's Theorem :- Total Electric flux in closed surface ~~area~~ is equal to the area is $\frac{1}{\varepsilon_0}$ times the total charge present inside the surface, this is Gauss's Theorem.

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

where, $\phi \rightarrow$ Total Electric flux
$q \rightarrow$ Total charge

Proof :-

Electric flux $(\phi) = \vec{E} \cdot \vec{A}$.



lines are parrallel theirefore Angle b/w them is zero.

$\boxed{\theta = 0}$

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

$\Rightarrow \phi = E\,ds \cos\theta$

$\Rightarrow \phi = E\,ds \cos 0^\circ$

$\Rightarrow \phi = E\,ds$

$\Rightarrow \phi = \oint E\,ds$

$\Rightarrow \phi = \oint \frac{Kq}{r^2}\,ds$

$$\Rightarrow \phi = \oint \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}\,ds$$

$$\Rightarrow \phi = \frac{q}{4\pi\varepsilon_0 r^2} \oint ds$$

Since Total surface area of the sphere is $4\pi r^2$

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

$$\Rightarrow \phi = \frac{q \cdot \cancel{4\pi r^2}}{\cancel{4\pi}\varepsilon_0 \cancel{r^2}}$$

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

$$\Rightarrow \boxed{\phi = \frac{1}{\varepsilon_0} \times q}$$

Charge distribution :-

It is 3 Types -

i) Linear charge distribution / Linear charge density (λ) :-

~~ii) A~~

$\Rightarrow \quad \lambda = \dfrac{q}{l}$

Unit :- $\lambda = \cancel{A}$ c/m

ii) Surface charge distribution :-

$$\sigma = \frac{q}{A}$$

Unit :- $\sigma = c/m^2$

iii) Volume charge distribution :-

$$\rho = \frac{q}{V}$$

Unit :- $\rho = c/m^3$

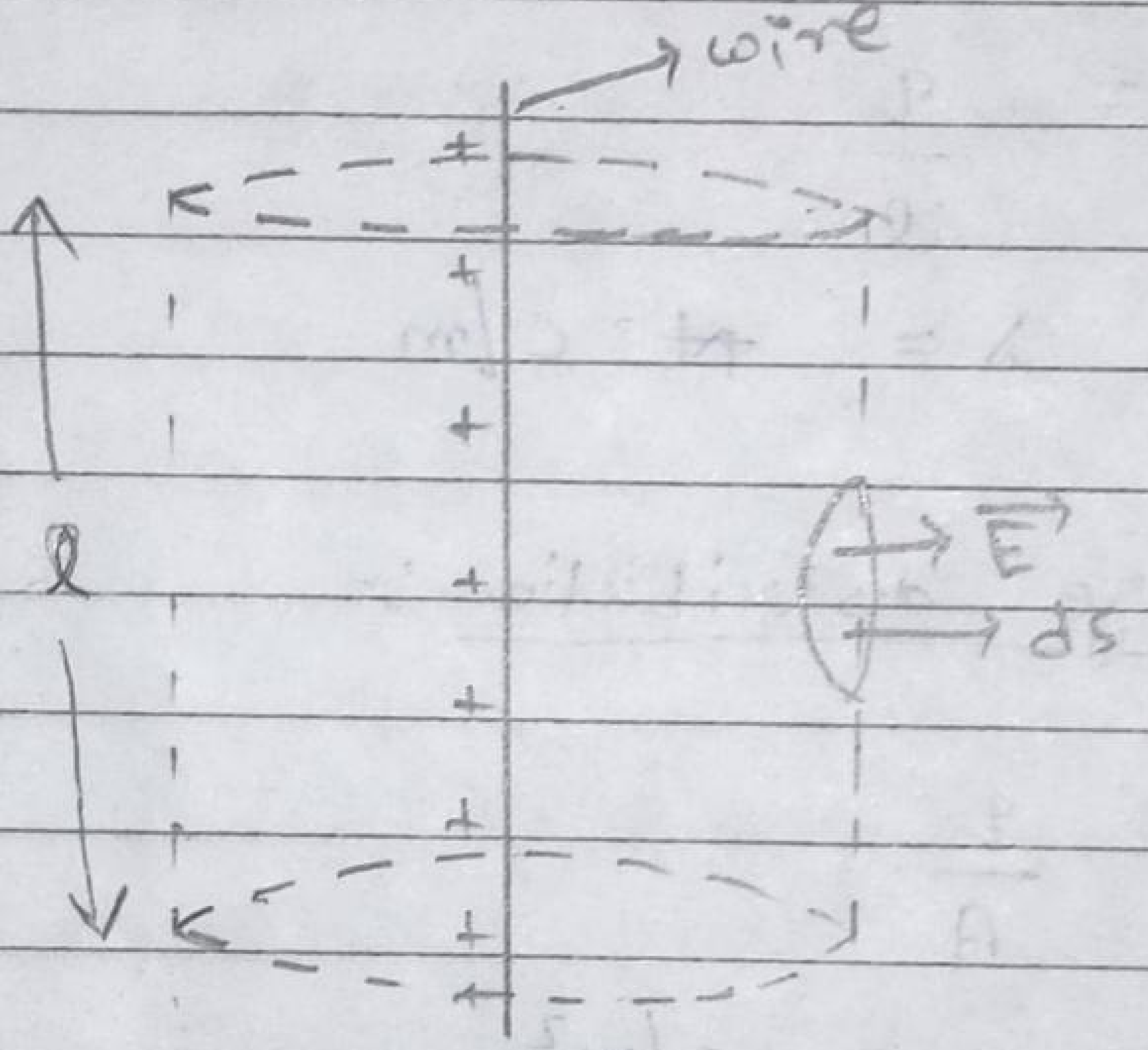
Q.26 By using Gauss's Theorem Derive ~~Derive~~ Electric field due to a infinite long straight charged wire.

Q.27 By using Gauss's Theorem Derive Electric field due to plane sheet

Q.28 By using Gauss's Theorem Derive Electric field due to Hollow spherical conductor.

Ans. 26. Electric field due to infinite long Straight Charged wire :-

Gauss's Theorem,
$$\phi = \frac{q}{\varepsilon_0}$$



According to electric flux,

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

$\Rightarrow \quad \phi = \oint E \, ds \cos 0^\circ$

$\Rightarrow \quad \phi = \oint E \, ds$

$\Rightarrow \quad \therefore \phi = \frac{q}{\varepsilon_0}$

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

$\Rightarrow \quad \frac{q}{\varepsilon_0} = E \oint (2\pi r l)$ $\quad \left\{ \because \right.$ curved surface area of cylinder $= 2\pi r h$.

$\Rightarrow \quad \frac{q}{\varepsilon_0} = E \, (2\pi r l)$

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

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{rl}$$

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

$$\Rightarrow E = K \cdot \frac{2(\lambda l)}{rl}$$

$$\Rightarrow \boxed{E = \frac{2K\lambda}{r}}$$

Ans. 27) Electric field due to plane sheet :-

Gauss's Theorem $\phi = \frac{q}{\varepsilon_0}$

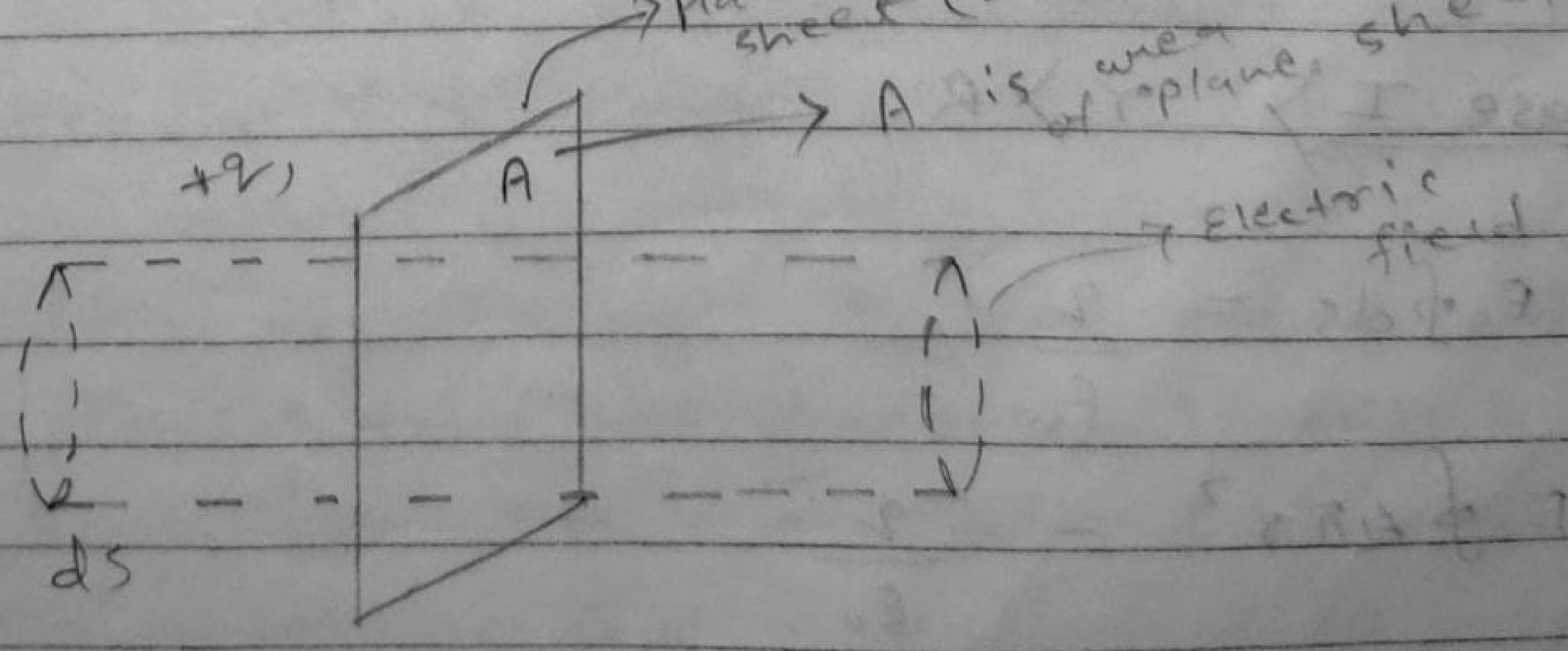
Electric flux $\phi = \vec{E} \cdot \vec{A}$

$\phi = EA\cos\theta$

$\phi = EA \quad \{\cos\theta = 1\} \; \{\theta = \frac{\pi}{2}\}$

Hence,

$$\frac{q}{\varepsilon_0} = EA \longrightarrow (1)$$



$$\Rightarrow \phi = E\,ds$$

$$\Rightarrow \phi = \oint E\,ds$$

$$\Rightarrow \phi = E \cdot 2A$$

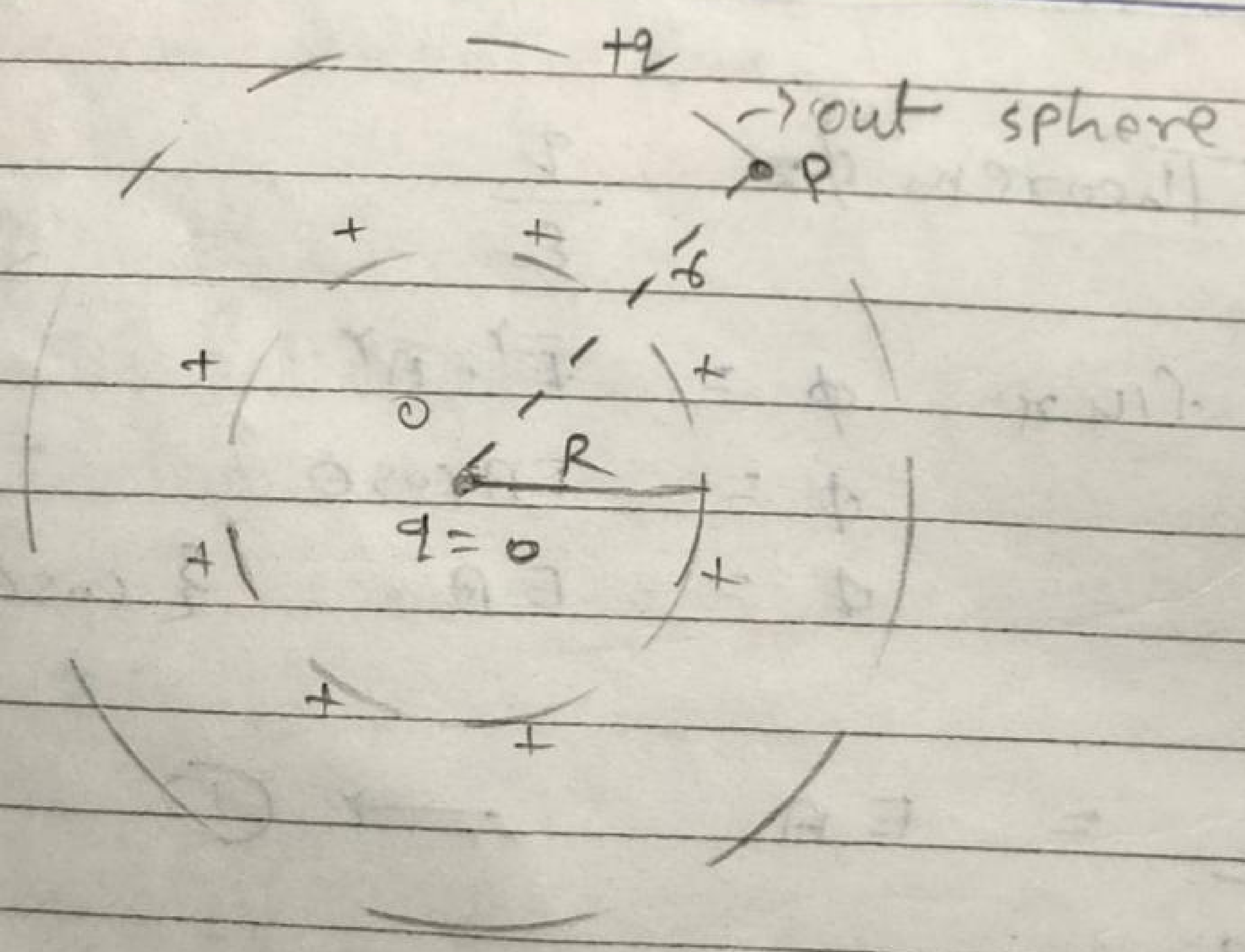
$$\Rightarrow \frac{q}{\varepsilon_0} = E \cdot 2A$$

$$\Rightarrow E = \frac{q}{2A\varepsilon_0}$$

$$\because \sigma = \frac{q}{A}$$

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

Ans. 28 Electric field due to spherical conductor :-



Case I) $r > R$.

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

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

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

$$\Rightarrow \boxed{E = \frac{Kq}{r^2}}$$

Case II) $r = R$.

$$\Rightarrow \boxed{E = \frac{Kq}{r^2}}$$

Case III) $r < R$

$\Rightarrow \boxed{E = 0}$ and $\boxed{q = 0}$