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12th Physics

Chapter :- 1st

Electric charge and Field

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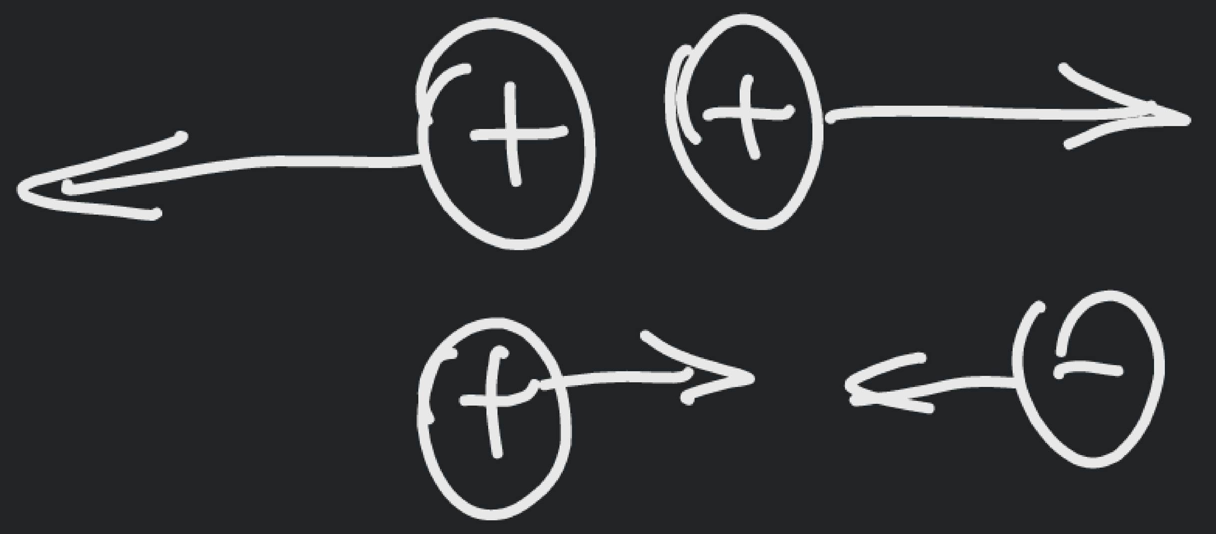
Electric charge:- It is intrinsic property of any material which shows that material is electrify or not.

- Q/q
- Unit:- Coulomb
- Dimensional formula:- [AT]
- It is a scalar quantity.

(i) +ve charge

(ii) −ve charge

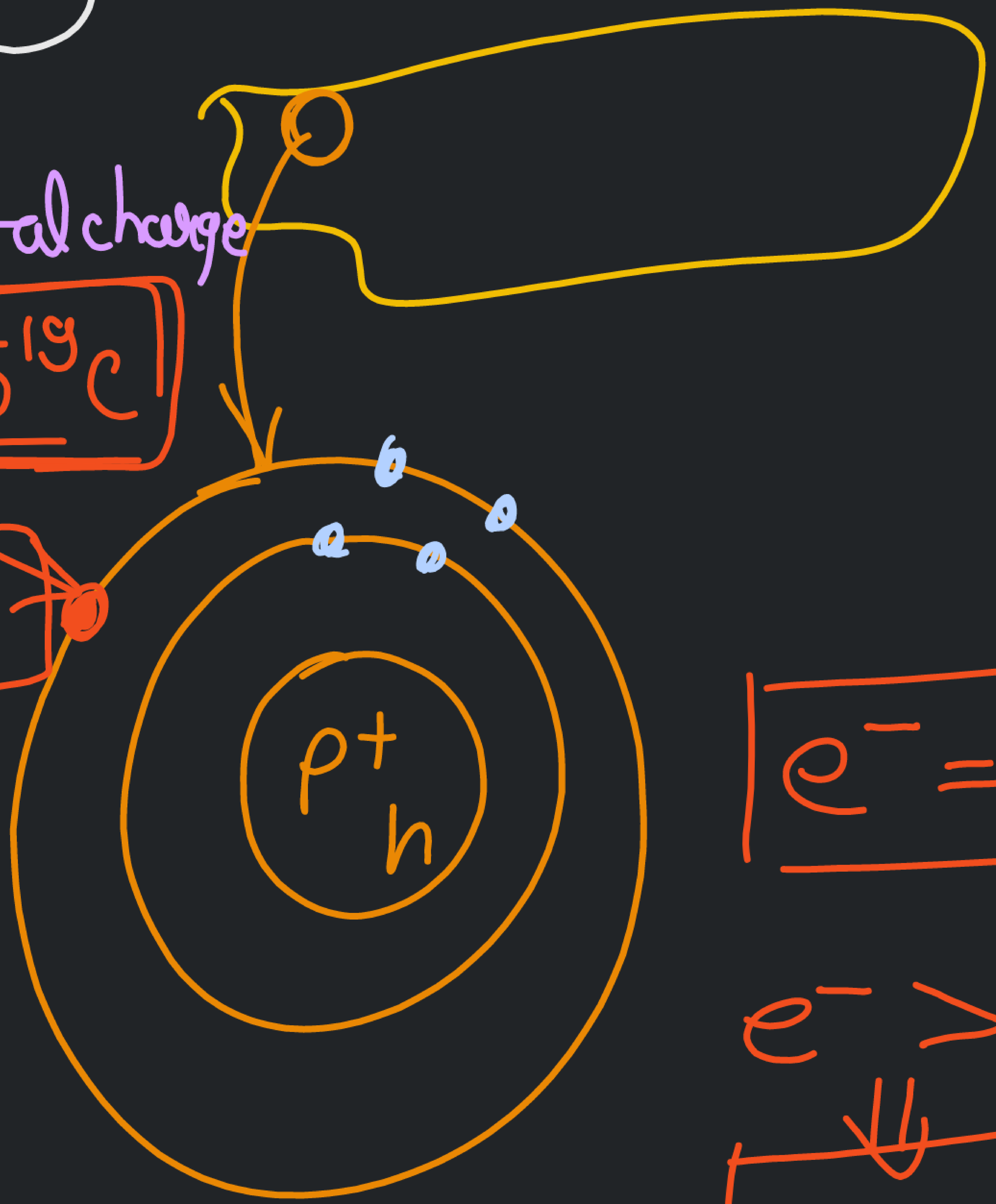


Electrical theory of charge :-

fundamental charge

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

mass $= \boxed{9.1 \times 10^{-31} kg}$



$\boxed{e^- = p^+}$

$e^- < p^+$

$\Downarrow$

+ve charge

$\boxed{e^- = p^+}$

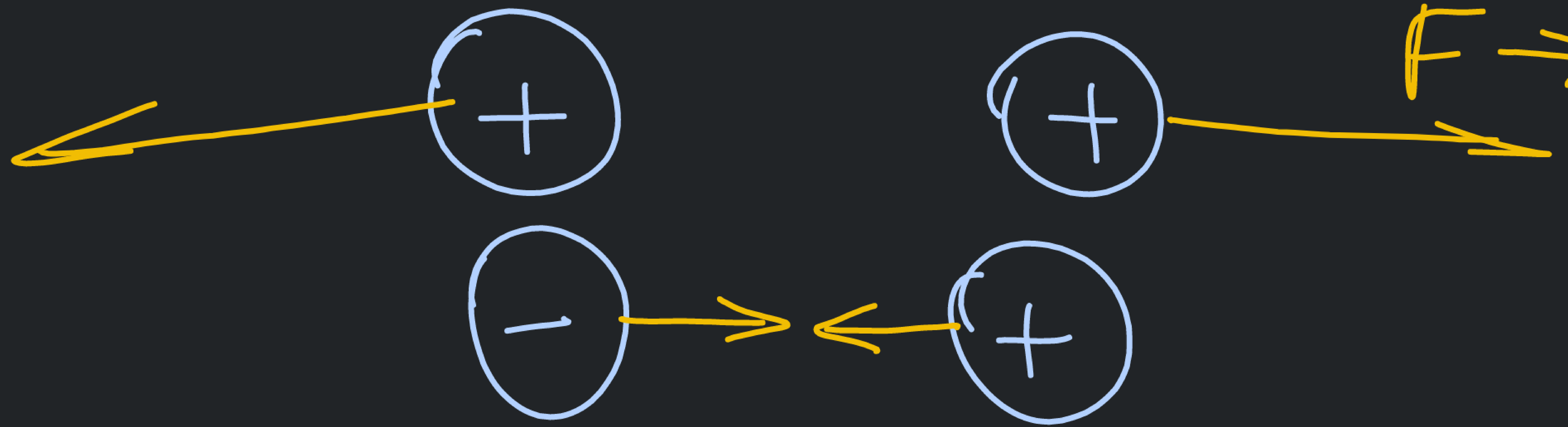
$e^- > p^+$

$\Downarrow$

$\boxed{-\text{ve charge}}$

Properties of charge :-

(i) Like charges repal each other and unlike charges attracts each other

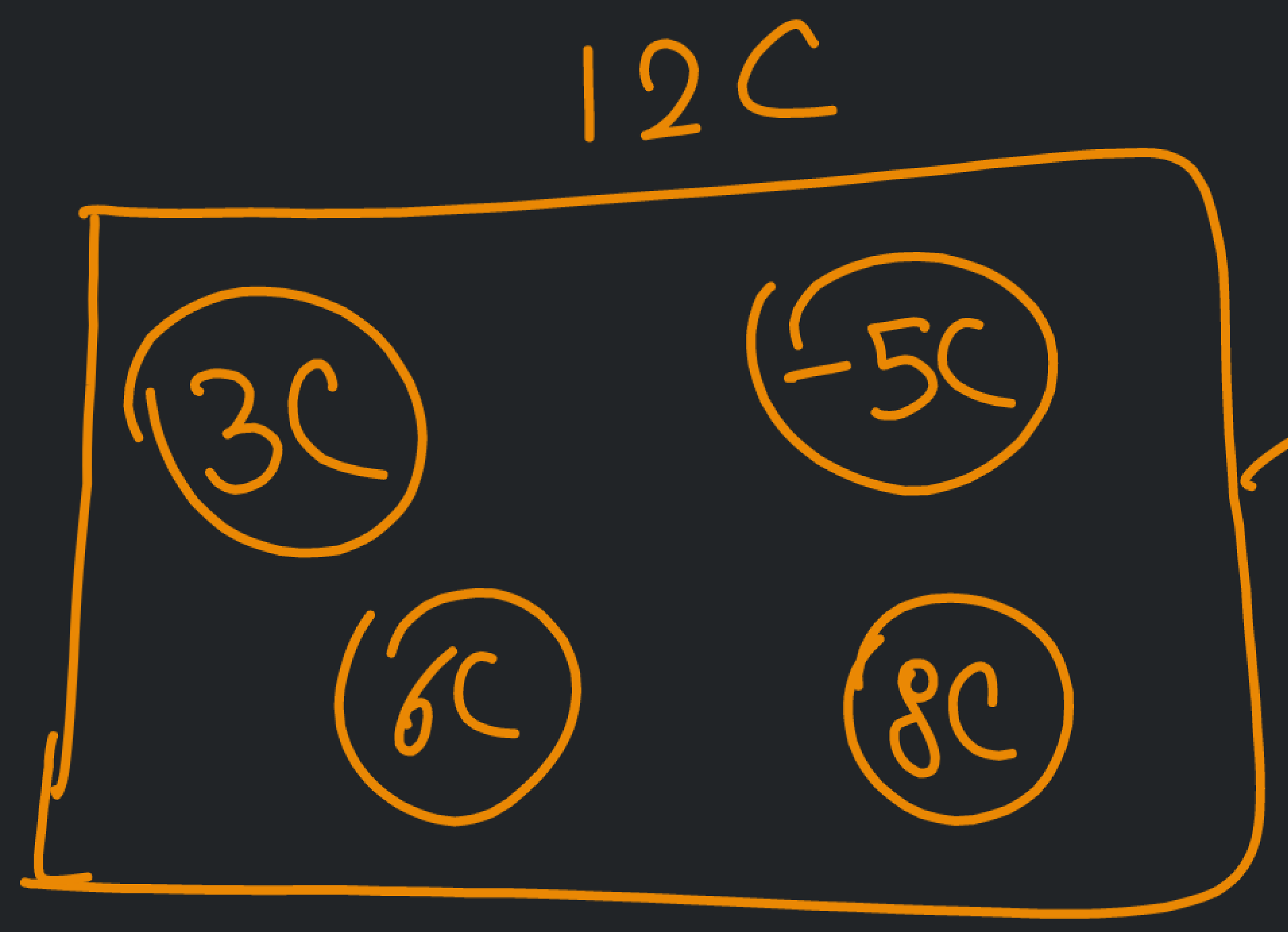


F → electrostatic force
(electric force)
(coulombian force)

② Charge can be flow from one body to another body.

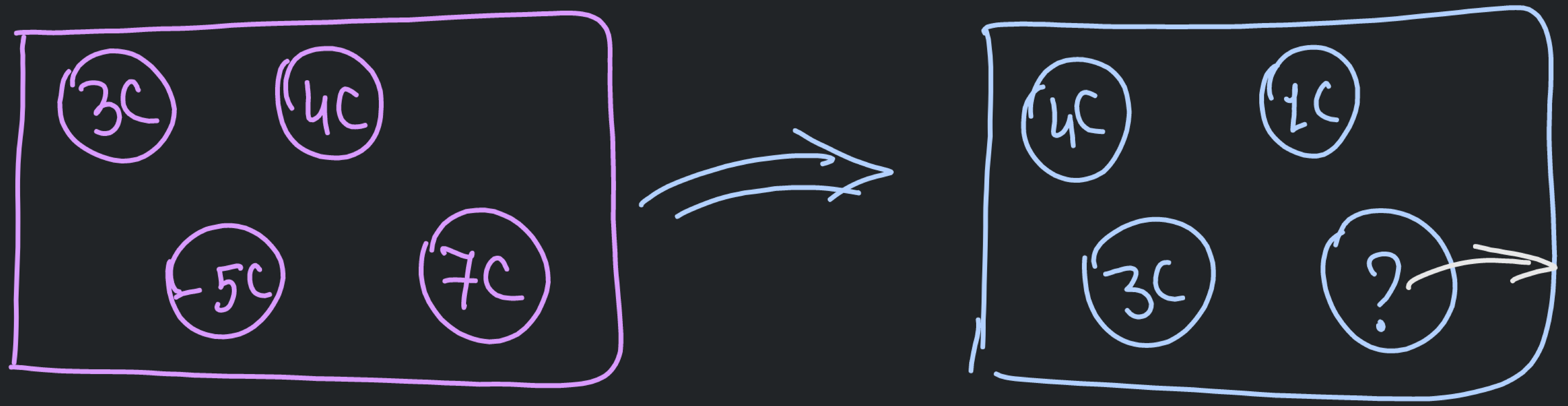
③ charges can be add by simple algebra.

Ex :-



$$Q_{net} = 3 - 5 + 6 + 8$$
$$= 12\,C$$

(4) Conservation of charge:- net charge on an isolated system is always conserved. (fix)



$\underline{\underline{x = 1\,C}}$

$3 + \cancel{4} - 5 + 7 = \cancel{4} + 1 + 3 + x$

$5 = 4 + x$

$x = 5 - 4 = \underline{1\,C}$

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(5) Quantisation of charge :- Net amount of charge on a body is integral multiple of charge on one electron.

Ex :-

$1e, 2e, 3e, \ldots\ldots ne$ ✓

$1.5e, \frac{3}{7}e, \pi e \ldots\ldots$ ✗

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

Q → amount of charge

n → no. of e^-

e → charge on one e^- $= 1.6 \times 10^{-19}\,C$

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Q. How many electrons in one coulomb charge :-

Solve :-

$Q = 1$ Coulomb

$n = ?$

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

then

$Q = ne$

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

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

$n = \frac{\cancel{10}^{5}}{\cancel{16}_{8}} \times 10^{19}$

$n = \frac{\cancel{50}}{\cancel{8}} \times 10^{18}$

$8 \overline{)50}$

$\boxed{n = 6.25 \times 10^{18}}$ → Imp obj

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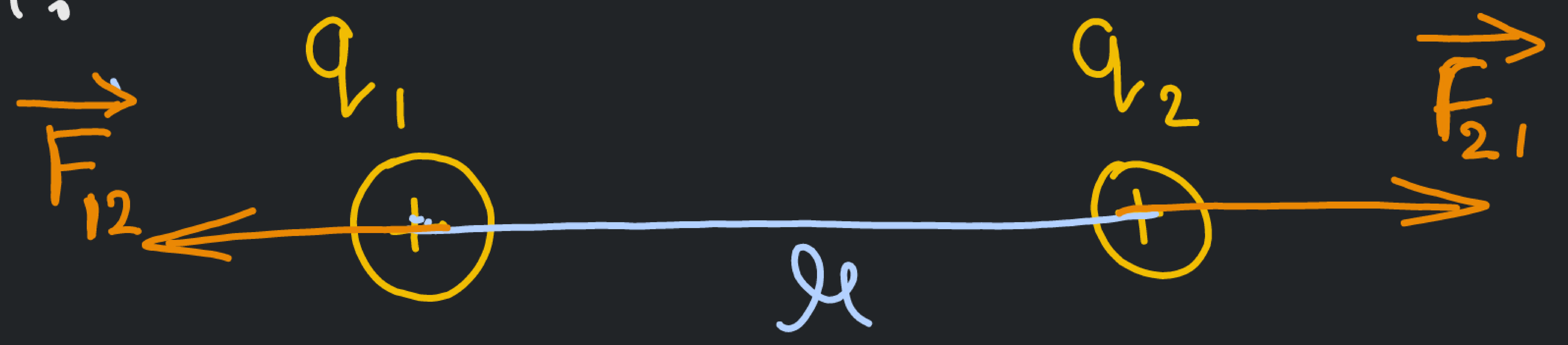
Coulomb's law:-

According to this law " attraction or repulsion force b/w two $\boxed{\text{point charges}}$ is directly proportional product of their magnitude and inversely Proportional to squre of distance b/w them.



$$|\vec{F}_{12}| = |\vec{F}_{21}| = F$$

$$F \propto q_1 . q_2$$

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

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

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

$k \rightarrow$ constant

$k = 9 \times 10^{9} \ \frac{N \times m^2}{C^2}$

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

$\varepsilon_0 \rightarrow$ permittivity of air/Vacuum

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

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

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Vector form of coulomb's law:-

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

$$\boxed{\vec{F} = K \frac{q_1 q_2}{|r^2|} \hat{r}}$$

$$\because \hat{r} = \frac{\vec{r}}{|r|}$$

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

$$\boxed{\vec{F} = K \frac{q_1 q_2}{|r^3|} \vec{r}}$$

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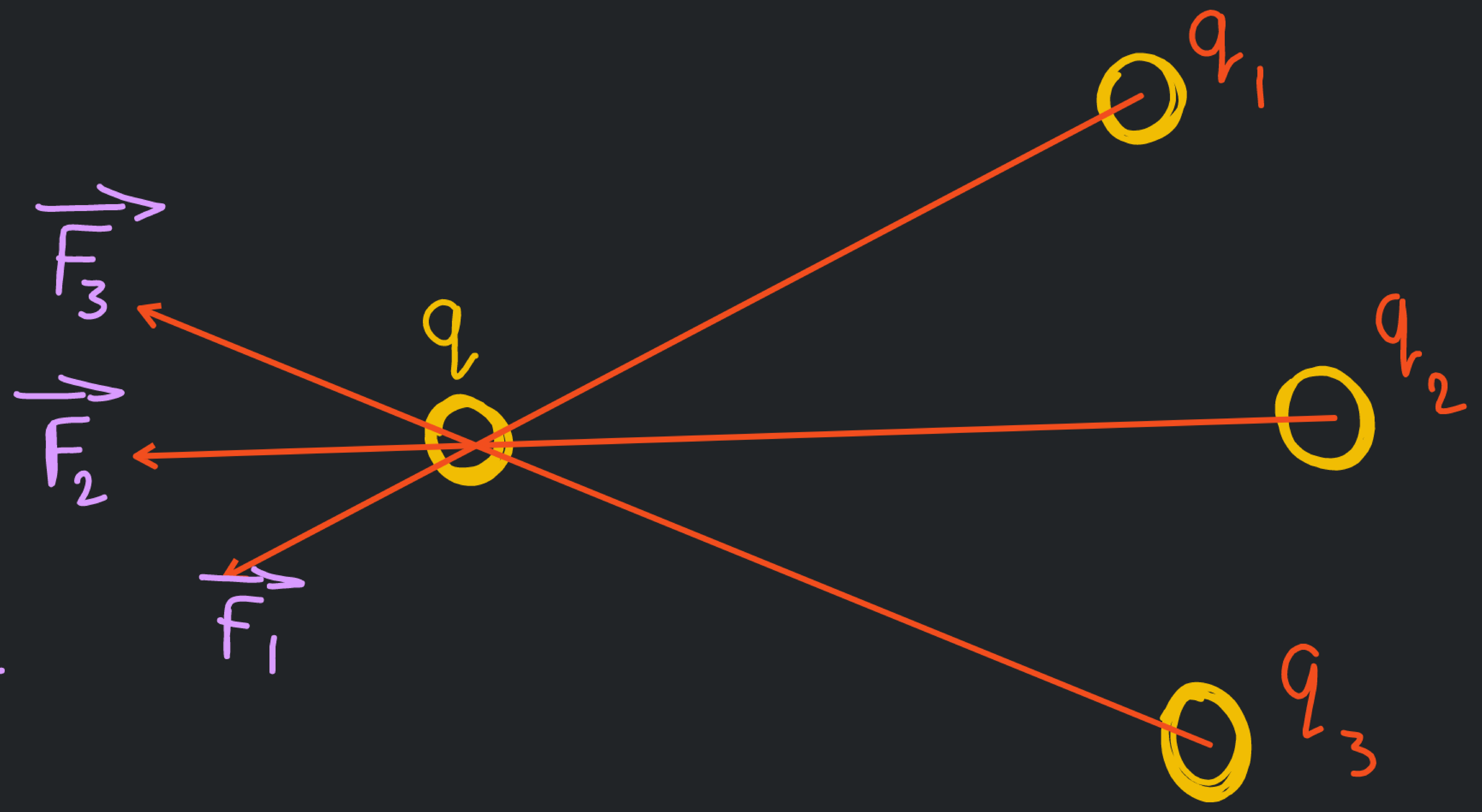
Principle of superposition :- net force on a charge by other charges is equal to vector sum of all individual forces.



$$\boxed{\vec{F}_{net} = \vec{F_1} + \vec{F_2} + \vec{F_3}}$$

Electrostatic force

(i) Attraction / Repultion

(ii) $F = K \frac{q_1 q_2}{r^2}$ | depends on medium

$K \rightarrow$ medium

(iii) It is stronger then gravitation

gravitational force

(i) attraction

(ii) $F = G \frac{m_1 m_2}{r^2}$ | hot depends medium.

$G \rightarrow \boxed{\text{Universal}}$

(iii) It is a weak force

$$\boxed{F_e \approx 10^{42} F_g}$$

Similirities :-

Electrostatic force

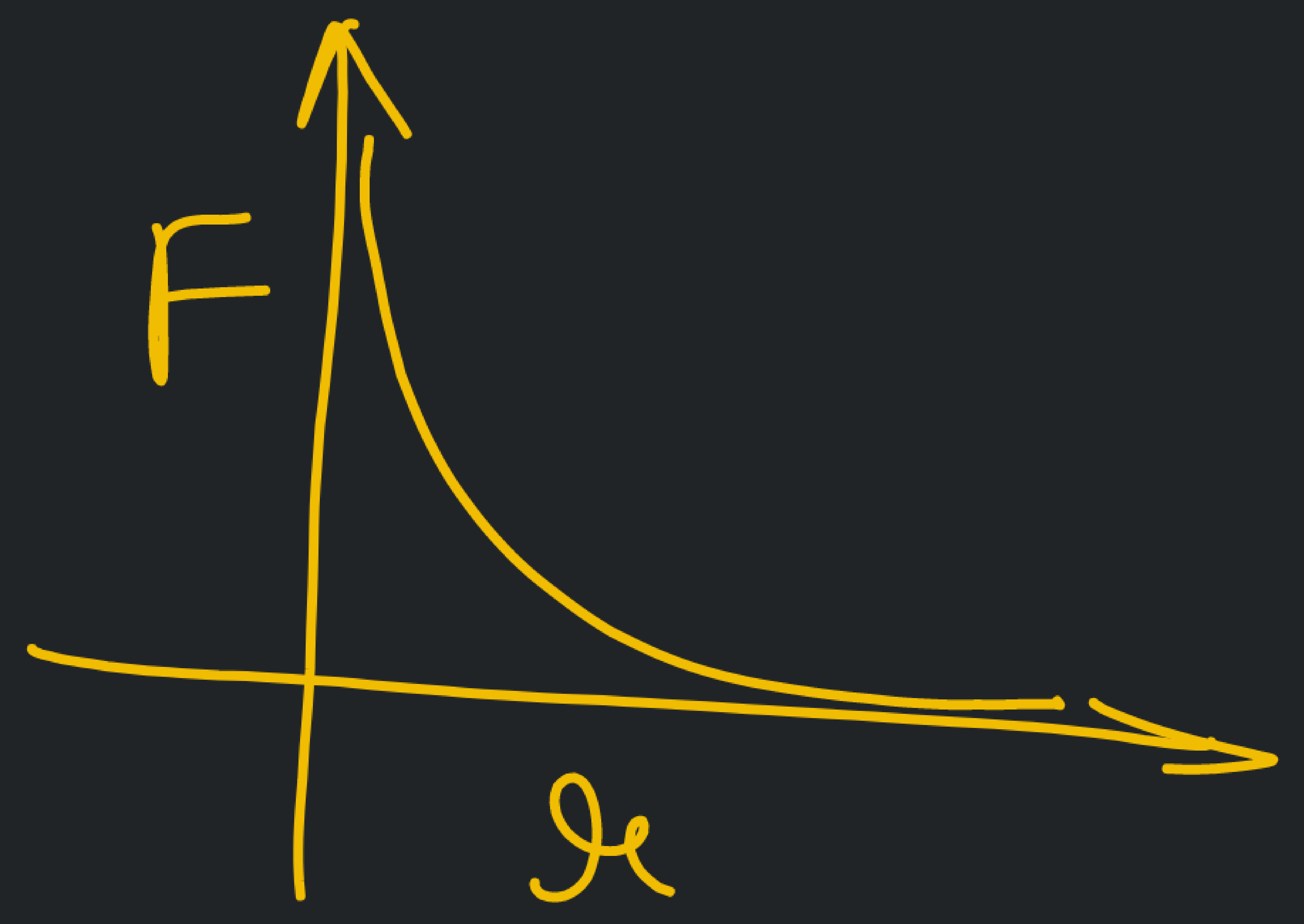
(i) Inverse square law:

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

(ii) Central force

gravitational force

(i) $F \propto \frac{1}{r^2}$



(ii) central force

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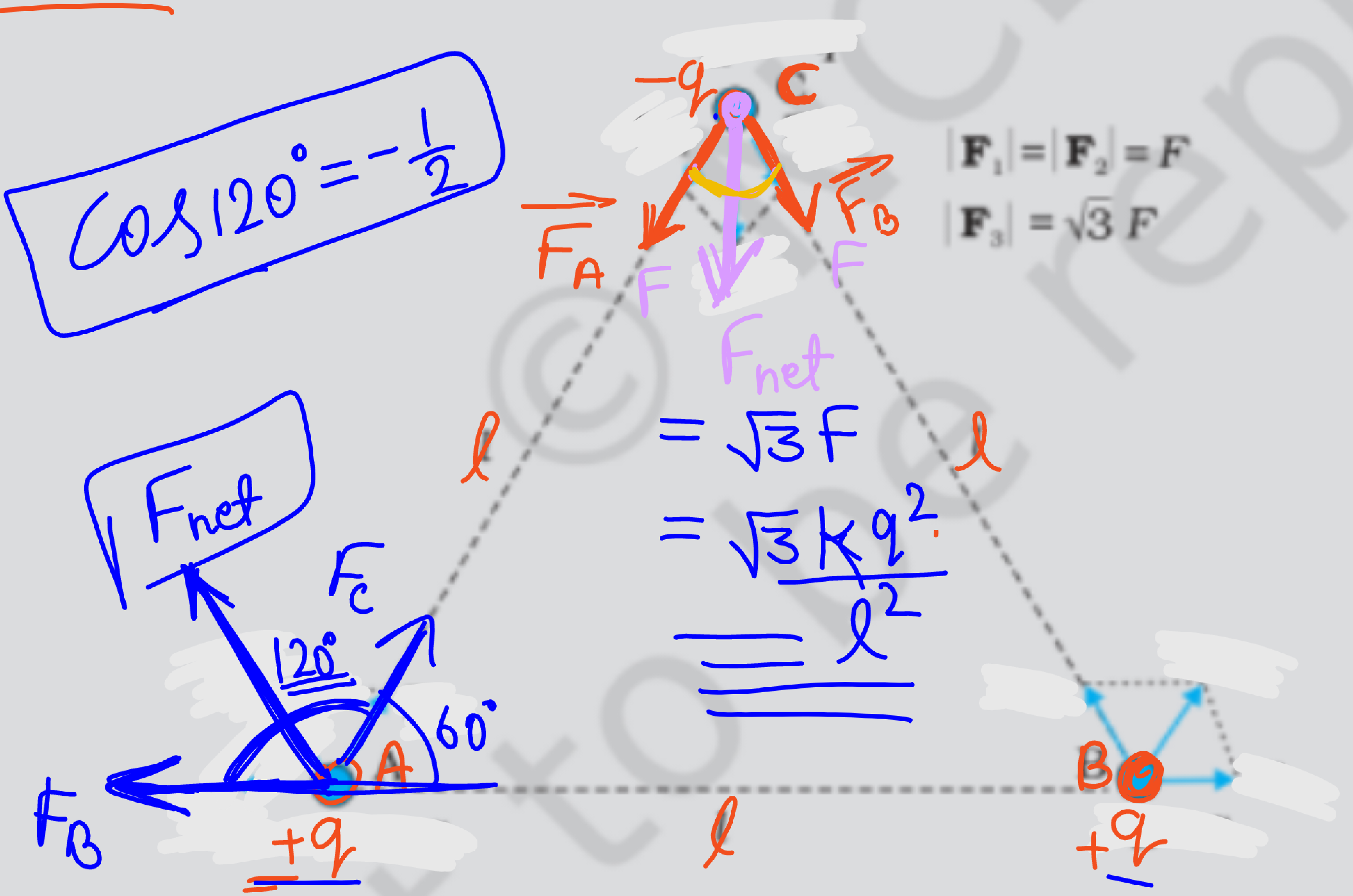
Example 1.6 Consider the charges q, q, and $-q$ placed at the vertices of an equilateral triangle, as shown in Fig. 1.7. What is the force on each charge?



Force on C

$F_A = k\dfrac{q.q}{l^2}$

$F_A = \left(\dfrac{kq^2}{l^2}\right)$

$F_B = \left(\dfrac{kq^2}{l^2}\right)$ $\rightarrow F$

$R^2 = A^2 + B^2 + 2AB\cos\theta$

$F_{net}^2 = F^2 + F^2 + 2F.F\cos 60^\circ$

$= 2F^2 + \cancel{2}F^2 \times \frac{1}{\cancel{2}}$

$F_{net} = \sqrt{3F^2}$

$\boxed{F_{net} = \sqrt{3}F}$ Ans

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1.1 What is the force between two small charged spheres having charges of 2×10^{-7}C and 3×10^{-7}C placed 30 cm apart in air?

Solve :-

$q_1 = 2 \times 10^{-7}C$

$q_2 = 3 \times 10^{-7}C$

$r = 30\,cm = 30 \times 10^{-2}\,m.$

then

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

$$F = \frac{\cancel{9} \times \cancel{10^9} \times 2 \times 10^{-7} \times 3 \times \cancel{10^{-7}}^{10^{-5}}}{\cancel{30} \times 10^{-2} \times \cancel{30} \times 10^{-2}}$$

$$\boxed{F = 6 \times 10^{-3}\ \text{Newton}}$$

1.2 The electrostatic force on a small sphere of charge 0.4 μC due to another small sphere of charge –0.8 μC in air is 0.2 N. (a) What is the distance between the two spheres? (b) What is the force on the second sphere due to the first?

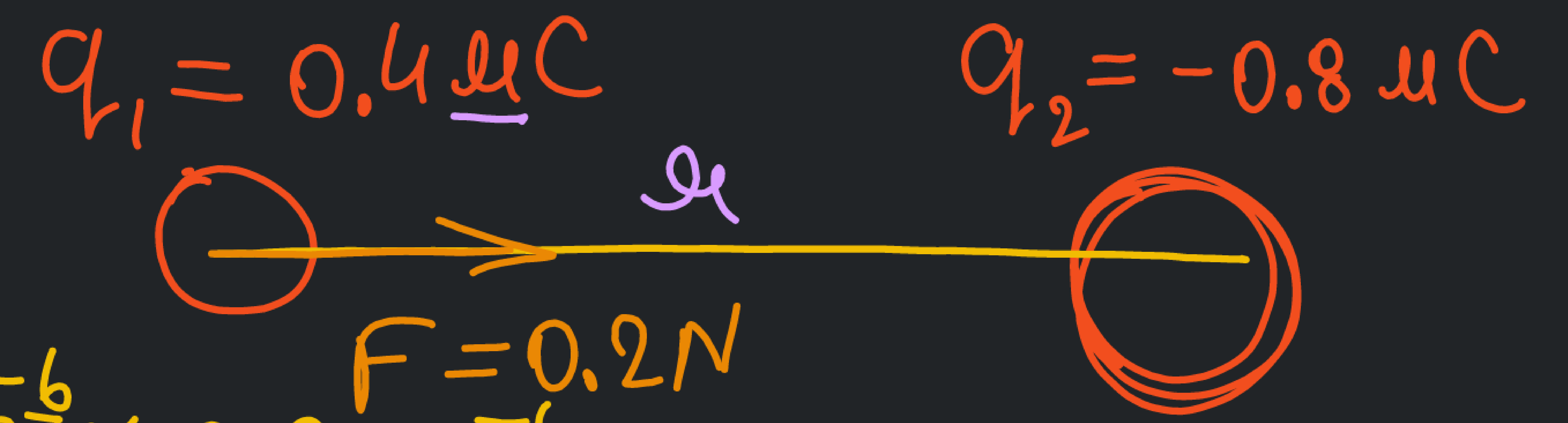
Solve: (a)

$q_1 = 0.4 \times 10^{-6}\,C$

$q_2 = 0.8 \times 10^{-6}\,C$

$F = 0.2\,N$

$r = ?$



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

$$\cancel{0.2}^{\,1} = \frac{9 \times \cancel{10^9}^{\,10^8} \times \cancel{0.4}^{\,2} \times 10^{-6} \times 0.8 \times 10^{-6}}{r^2 \times \cancel{10}}$$

$$1 = \frac{9 \times 16 \times 10^{-4}}{r^2}$$

$$r^2 = 9 \times 16 \times 10^{-4}$$

$$r = \sqrt{9 \times 16 \times 10^{-4}}$$

$$r = 3 \times 4 \times 10^{-2}$$

$$r = 12 \times 10^{-2}\,m.$$

$$\boxed{r = 12\,cm}$$

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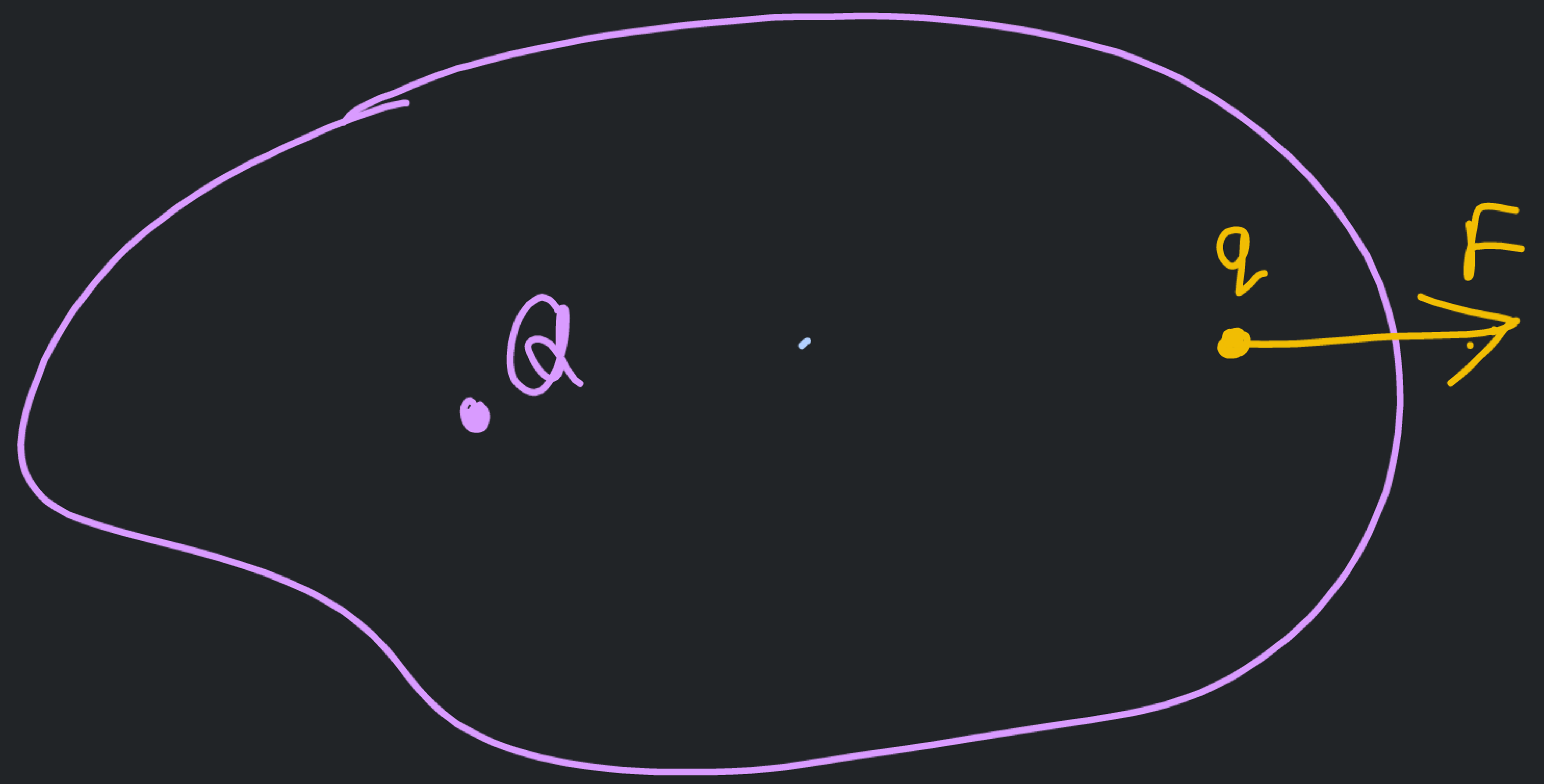
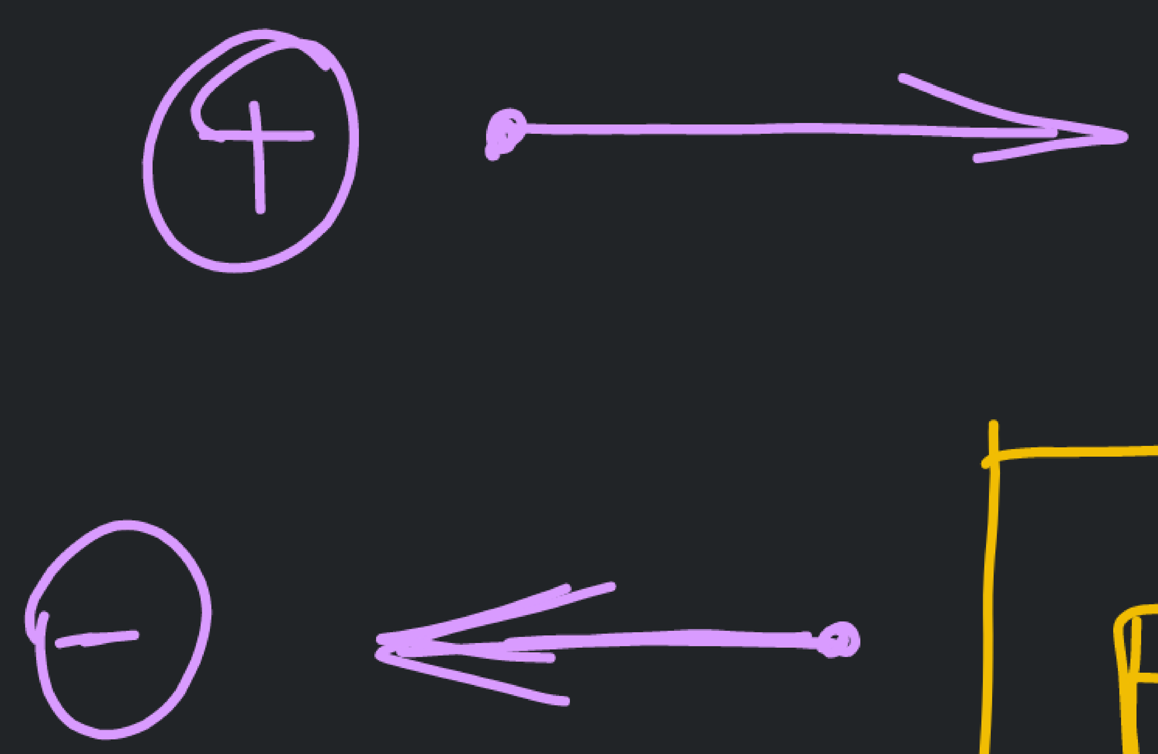
Concept of electric field :- Area around any point charge at which its infulence can be experienced by other charges.



Intensity of electric field:— Force experienced by a unit +ve charge inside a electric field is called intensity of electric field



$$\boxed{E = \frac{F}{q_0}}$$

Unit:— $\frac{\text{Newton}}{\text{Coulomb}}$ or $\frac{\text{Volt}}{\text{metre}}$

Dimensions:— $[MLT^{-3}A^{-1}] \Rightarrow |1-3|$

It is a vector quantity along the $\vec{F}$

$q_0 \rightarrow$ Test charge

$\rightarrow$ +ve

$\rightarrow$ छोटा

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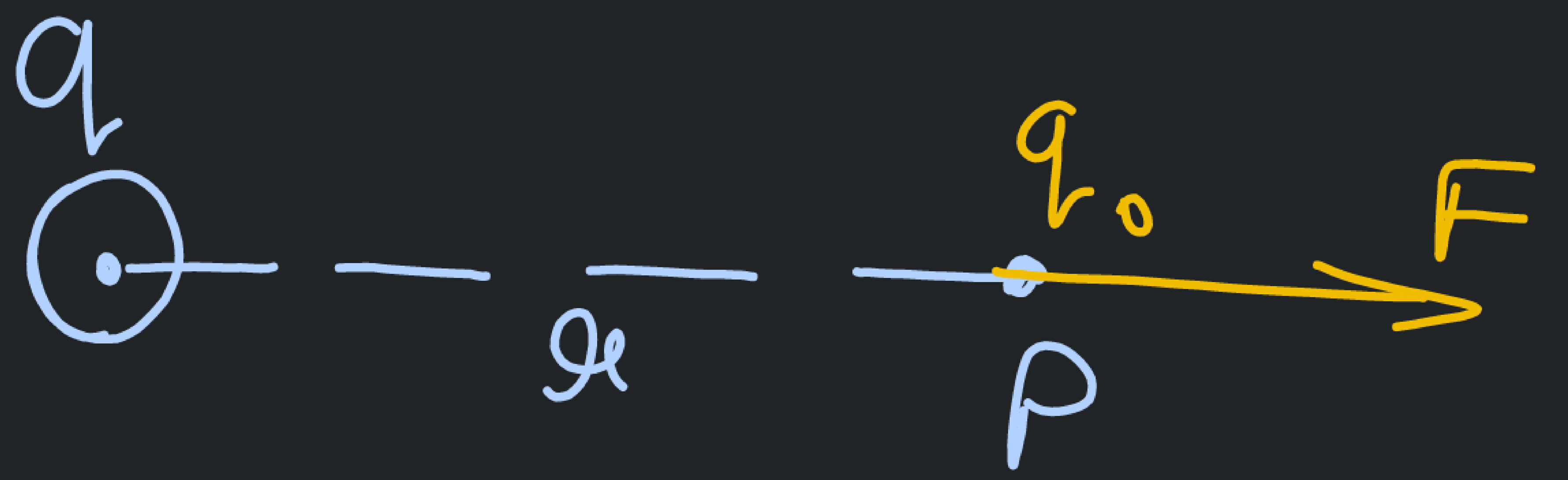
Force on a charge inside a field:—

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

$$\boxed{F = q_0 E} \longrightarrow \text{objective}$$

Intensity of electric field due to point charge :-



$$F = \frac{1}{4\pi\varepsilon_0}\frac{q\, q_0}{r^2} \quad \text{—} \ (1)$$

but

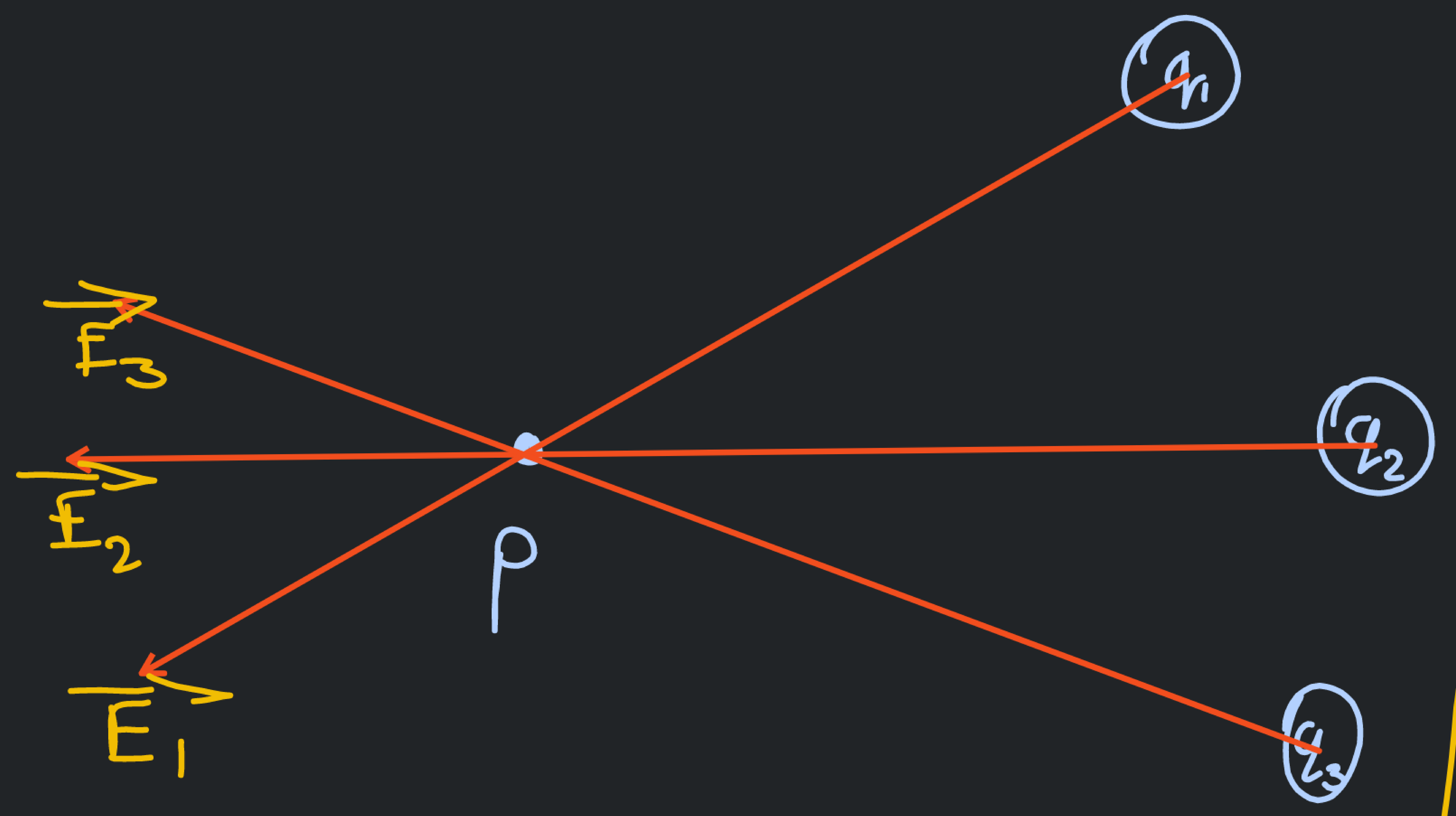
$$E = \left(\frac{F}{q_0}\right)$$

then by eq^n (1)

$$E = \frac{\dfrac{1}{4\pi\varepsilon_0}\dfrac{q\, \cancel{q_0}}{r^2}}{\cancel{q_0}}$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}} \quad N/C$$

Priciple of superposition:-



$E_{net} = ?$

$$\boxed{\vec{E}_{net} = \vec{E_1} + \vec{E_2} + \vec{E_3}}$$

Electric dipole :- It is a system of charge In which two charges of same magnitude but different nature is placed very close to each other.

Electric dipole moment :- It is the product of magnitude of one of the charge to the separation b/w the charges.

p = one of the charge × distance

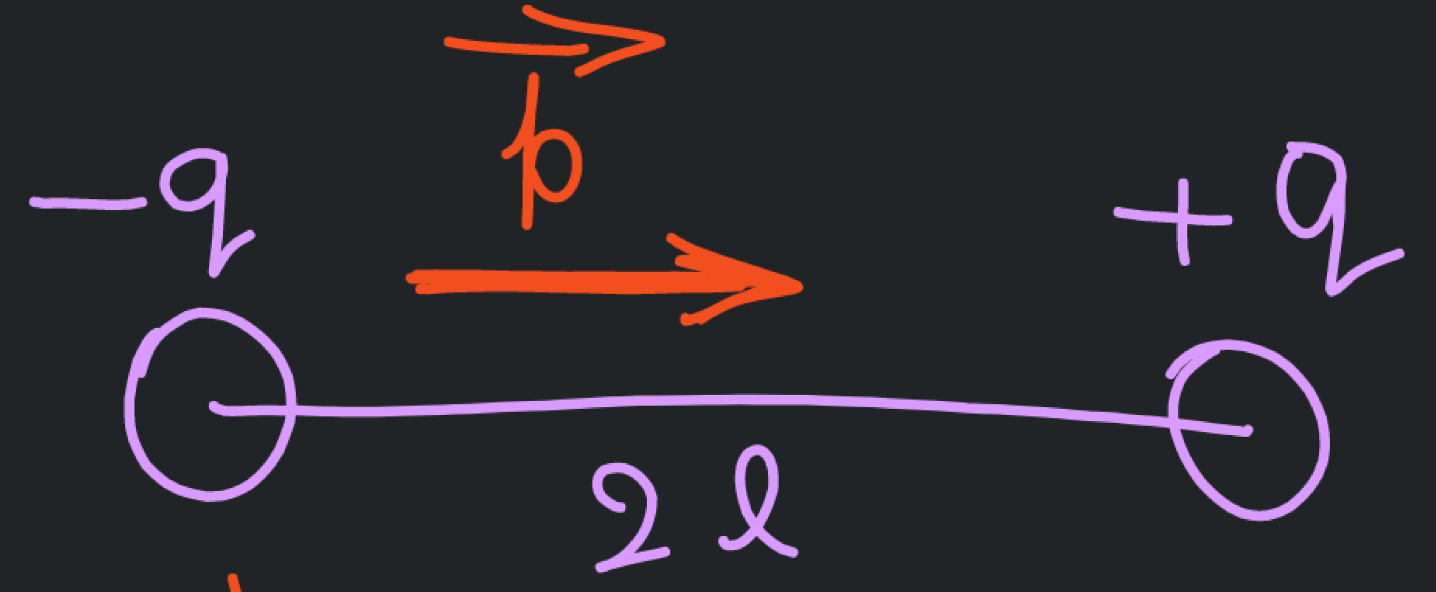
$$\boxed{p = q \times 2l}$$

Unit: Coulomb × metre

Dimensional formula:- [LTA]

It is a vector quantity.

And its direction along to the from −ve charge to +ve charge



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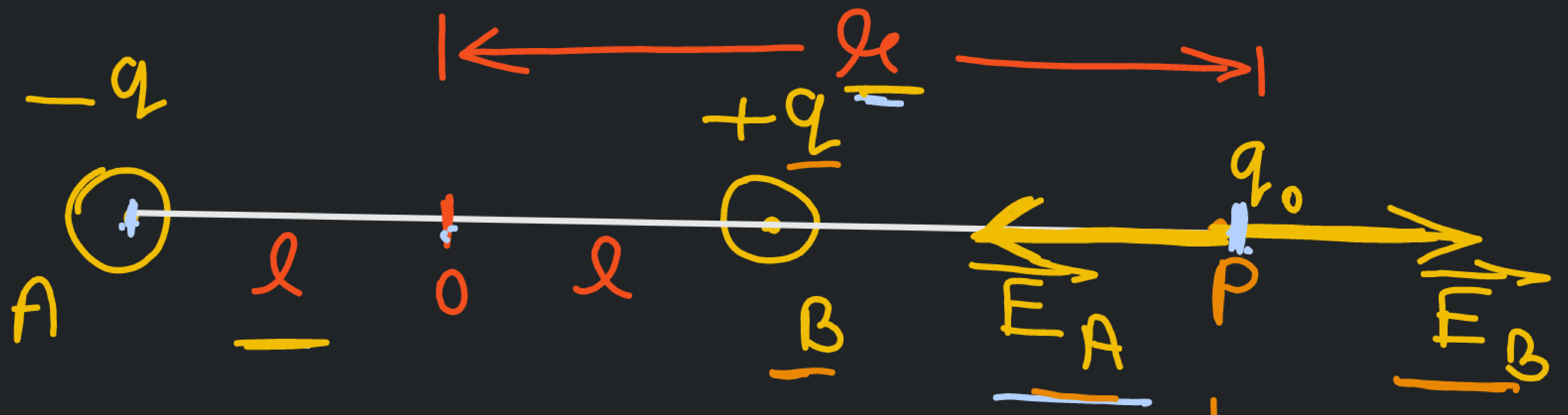
Intensity of electric field due to dipole in axial position :-



Electric field due to $-q$ charge:-

$$E_A = \frac{1}{4\pi\epsilon_0}\frac{q}{AP^2}$$

$$E_A = \frac{1}{4\pi\epsilon_0}\frac{q}{(x+l)^2} \quad \text{(1)}$$

Electric field due to $+q$ charge

$$E_B = \frac{1}{4\pi\epsilon_0}\frac{q}{BP^2}$$

$$E_B = \frac{1}{4\pi\epsilon_0}\frac{q}{(x-l)^2} \quad \text{(2)}$$

Then net field:-

$$E_{net} = E_B - E_A$$

Put the values from eq^n (1) and (2)

$$E_{net} = \frac{1}{4\pi\epsilon_0}\frac{q}{(x-l)^2} - \frac{1}{4\pi\epsilon_0}\frac{q}{(x+l)^2}$$

$$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{(x-l)^2} - \frac{1}{(x+l)^2}\right]$$

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$$E_{net} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+l)^2-(r-l)^2}{(r-l)^2(r+l)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2+l^2+2rl-(r^2+l^2-2rl)}{(r^2-l^2)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{\cancel{r^2}\cancel{+l^2}+2rl\cancel{-r^2}\cancel{-l^2}+2rl}{(r^2-l^2)^2}\right]$$

$$= \frac{q}{4\pi\varepsilon_0} \times \frac{4rl}{(r^2-l^2)^2}$$

$$= \frac{(q \times 2l) \times 2r}{4\pi\varepsilon_0 \, (r^2-l^2)^2}$$

$$[\because p = q \times 2l]$$

$$\boxed{E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{2rp}{(r^2-l^2)^2}}$$

Special case :-

If $l << r$ then neglect the value of l

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{2rp}{(r^2)^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\cancel{r}p}{r^{\cancel{4}3}}$$

$$\boxed{E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}$$

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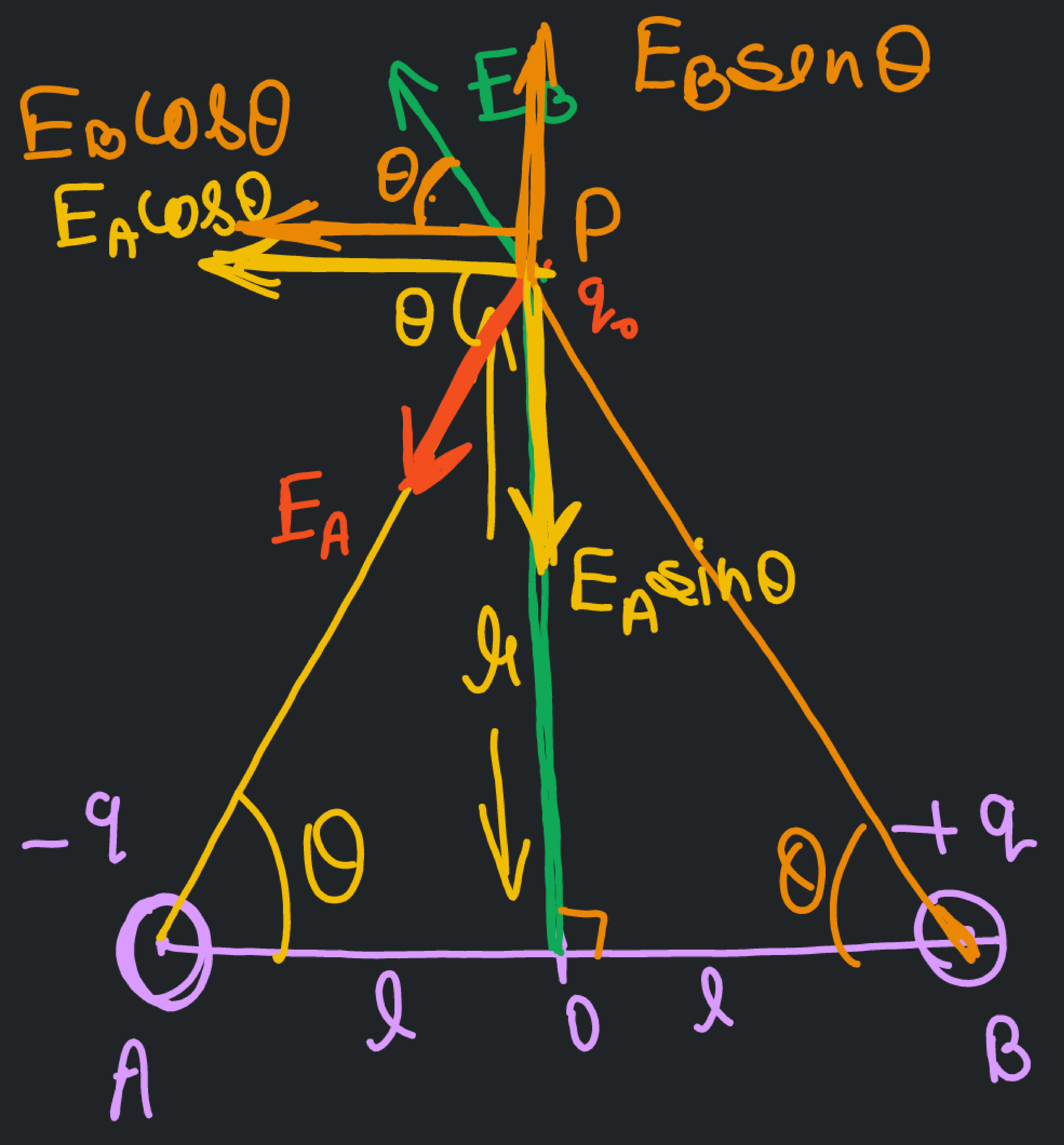
Intensity of electric field due to dipole in equitorial position (co-axial) :-



Electric field due to $-q$ charge

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{AP^2}$$

In Rt ΔAOP by PGT

$$AP^2 = r^2 + l^2$$

$$AP = \sqrt{r^2+l^2}$$

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)} \quad \text{--- (1)}$$

Electric field due to $+q$ Charge :-

$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2}$$

$$\left[\because AP^2 = BP^2 = r^2 + l^2\right]$$

$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)} \quad \text{--- (2)}$$

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

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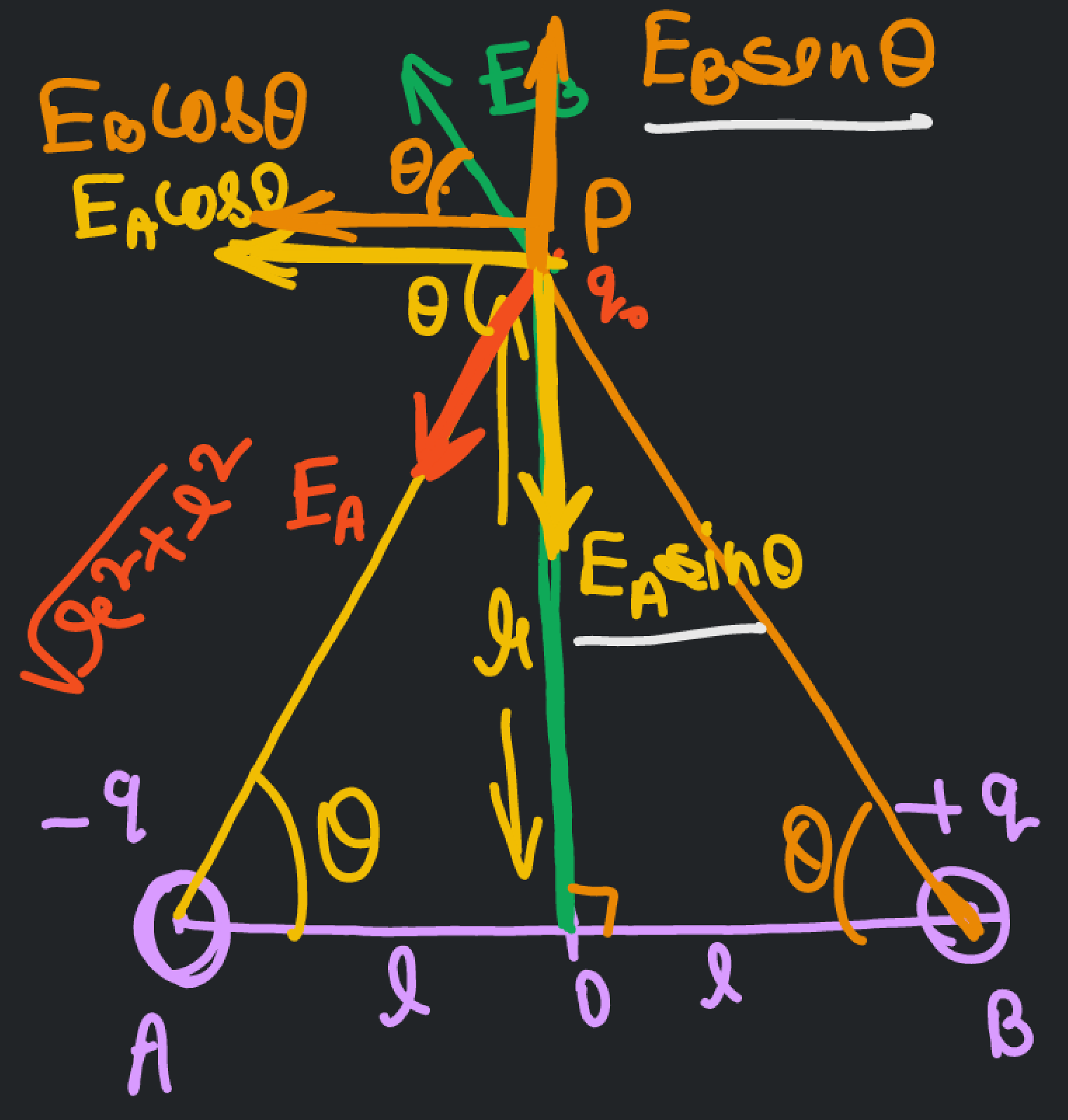

$$E_{net} = E_A\cos\theta + E_B\cos\theta + E_A\cos\theta - E_B\sin\theta$$

$$= E\cos\theta + E\cos\theta + \cancel{E\cos\theta} - \cancel{E\sin\theta}$$

$$E_{net} = 2E\cos\theta \quad \text{——— (3)}$$

[$\because$ In Rt Δ AOP

$$\cos\theta = \frac{l}{\sqrt{r^2+l^2}}$$]

by eqn (3) :-

$$E_{net} = 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+l^2)} \times \frac{l}{\sqrt{r^2+l^2}}$$

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{q \times 2l}{(r^2+l^2)^1(r^2+l^2)^{1/2}}$$

$$[\because p = q \times 2l]$$

$$\boxed{E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+l^2)^{3/2}}}$$

Special case :-

If $l << r$ then neglect the value of l

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2)^{3/2}}$$

$$\boxed{E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}}$$

N/C

Electric Field lines: (Electric Line of force)

They are the imaginary curved lines form in a electric field at which a unit positive charge can be travel.

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Properties of field lines:-

(i) They are generated from +ve charge and terminated at -ve charge.

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② They do not form closed curve.

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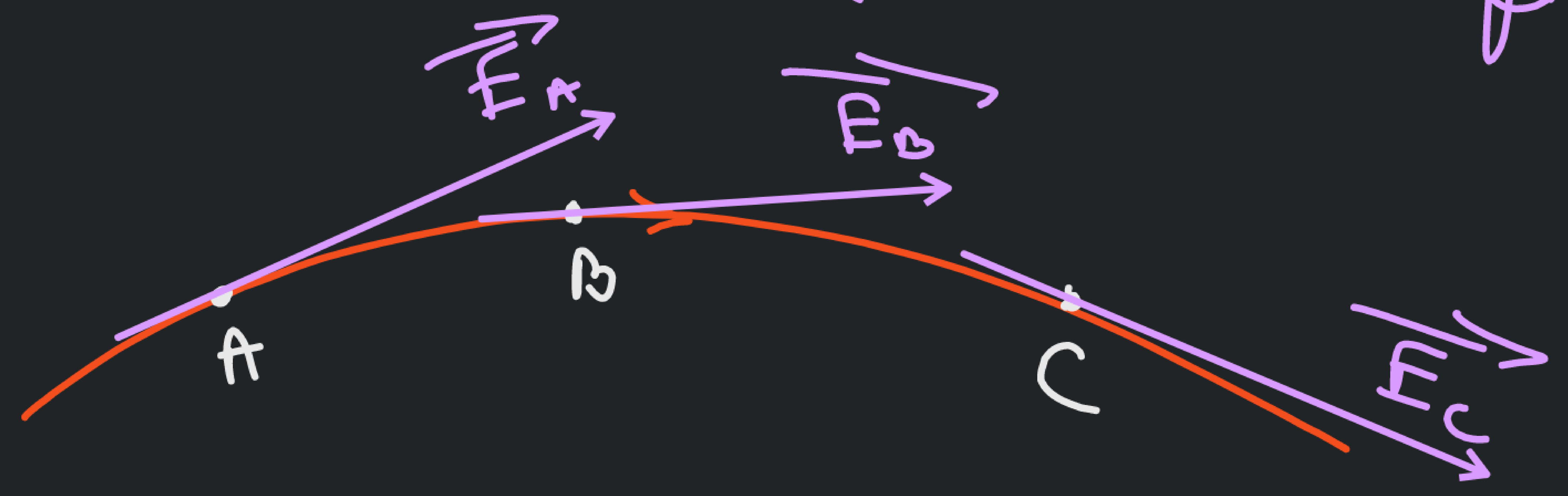
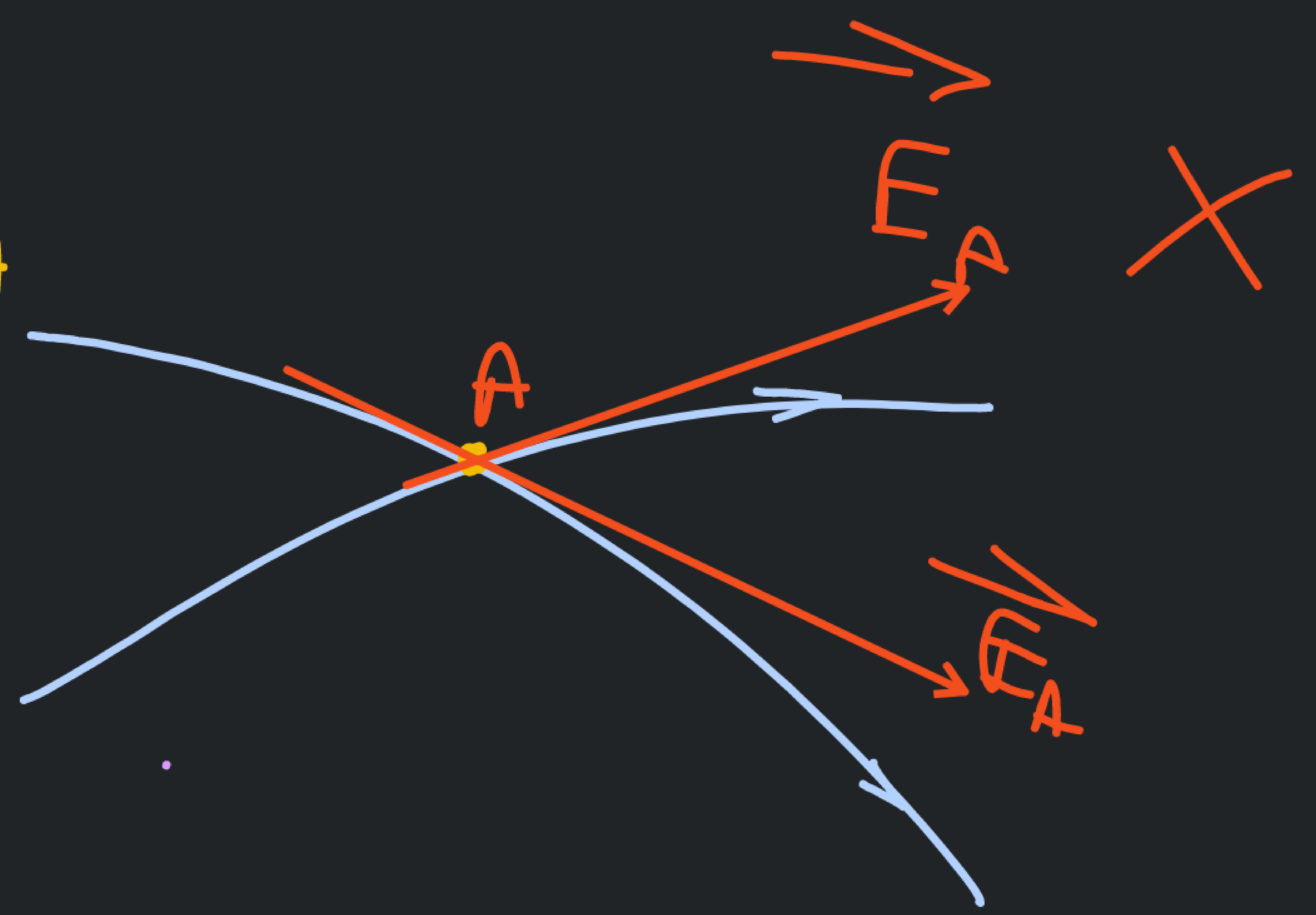
(ii) If we draw a tangent on a point at field lines gives the direction of net field at that point.



(4) Two electric field lines never intersect each other.

Reason:- If they do so then we get two direction of field at the point of intersection which is not possible.



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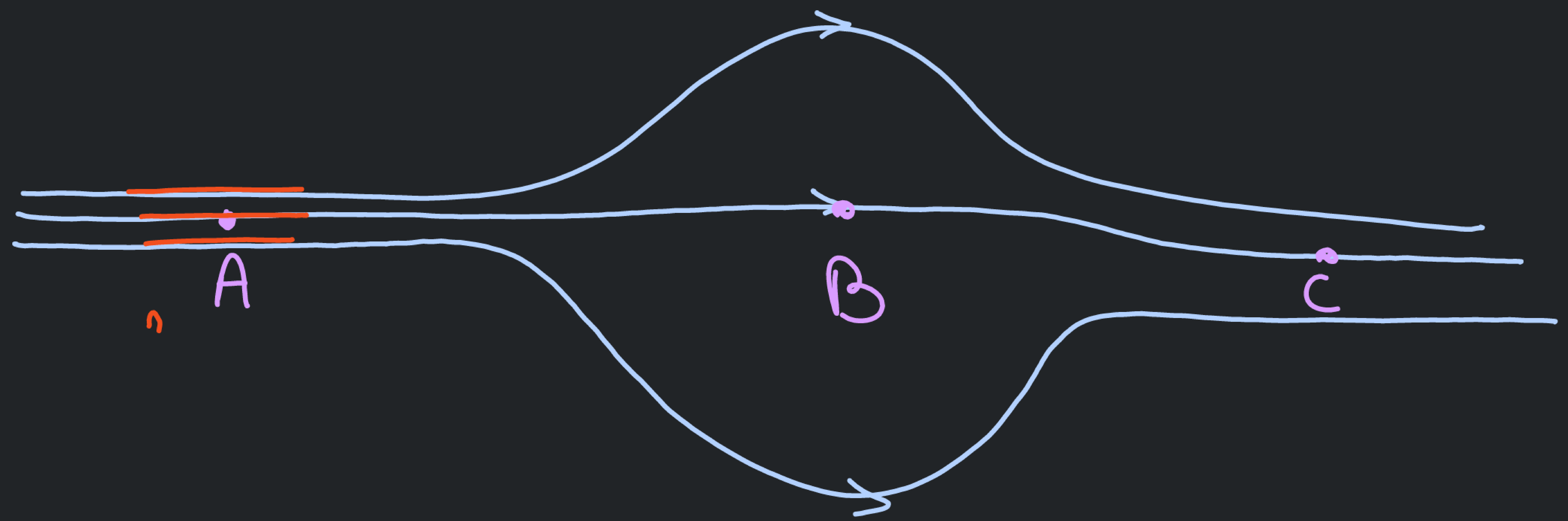
(5) Relative $\boxed{\text{clossness}}$ of field lines is proportional to magnitude of field.



$$E_A > E_C > E_B$$

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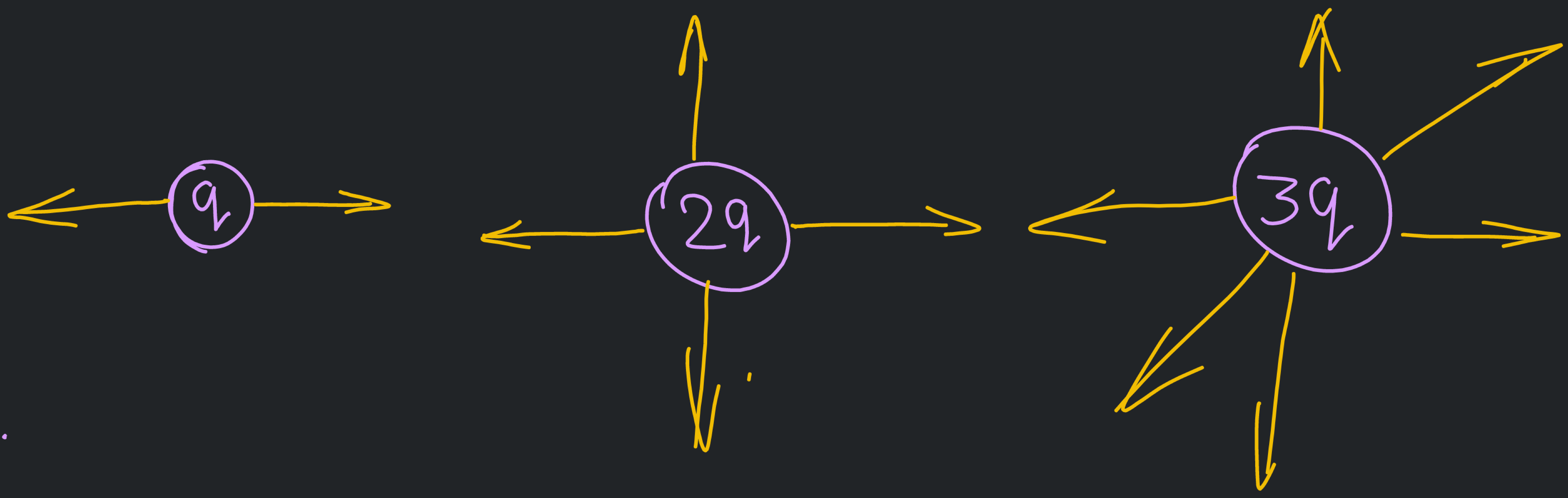
(6) magnitude of electric field is directly proportional to no. of field lines :- (subjective)



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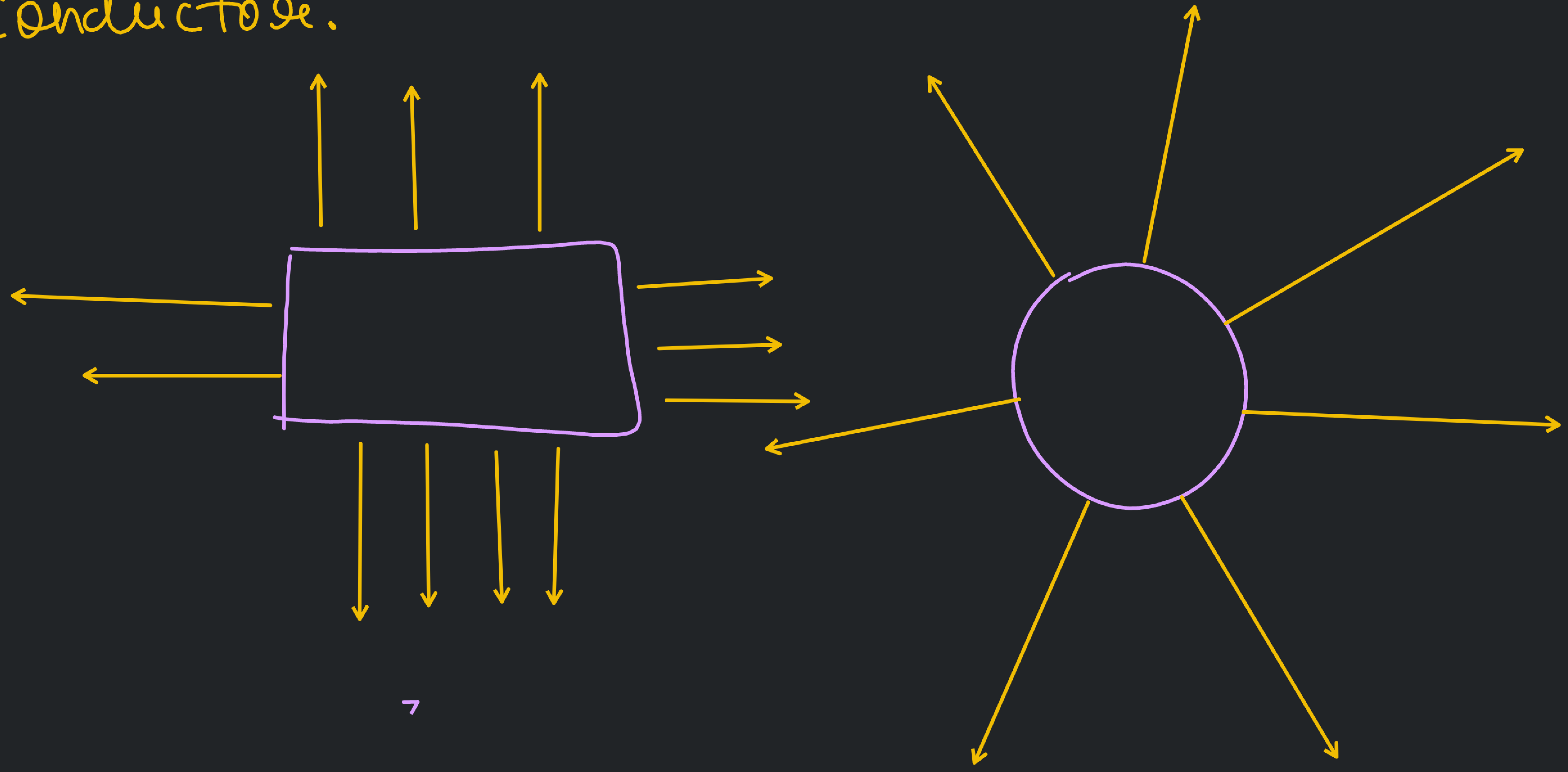
7. Field lines always perpendicular to the surface of conductor.



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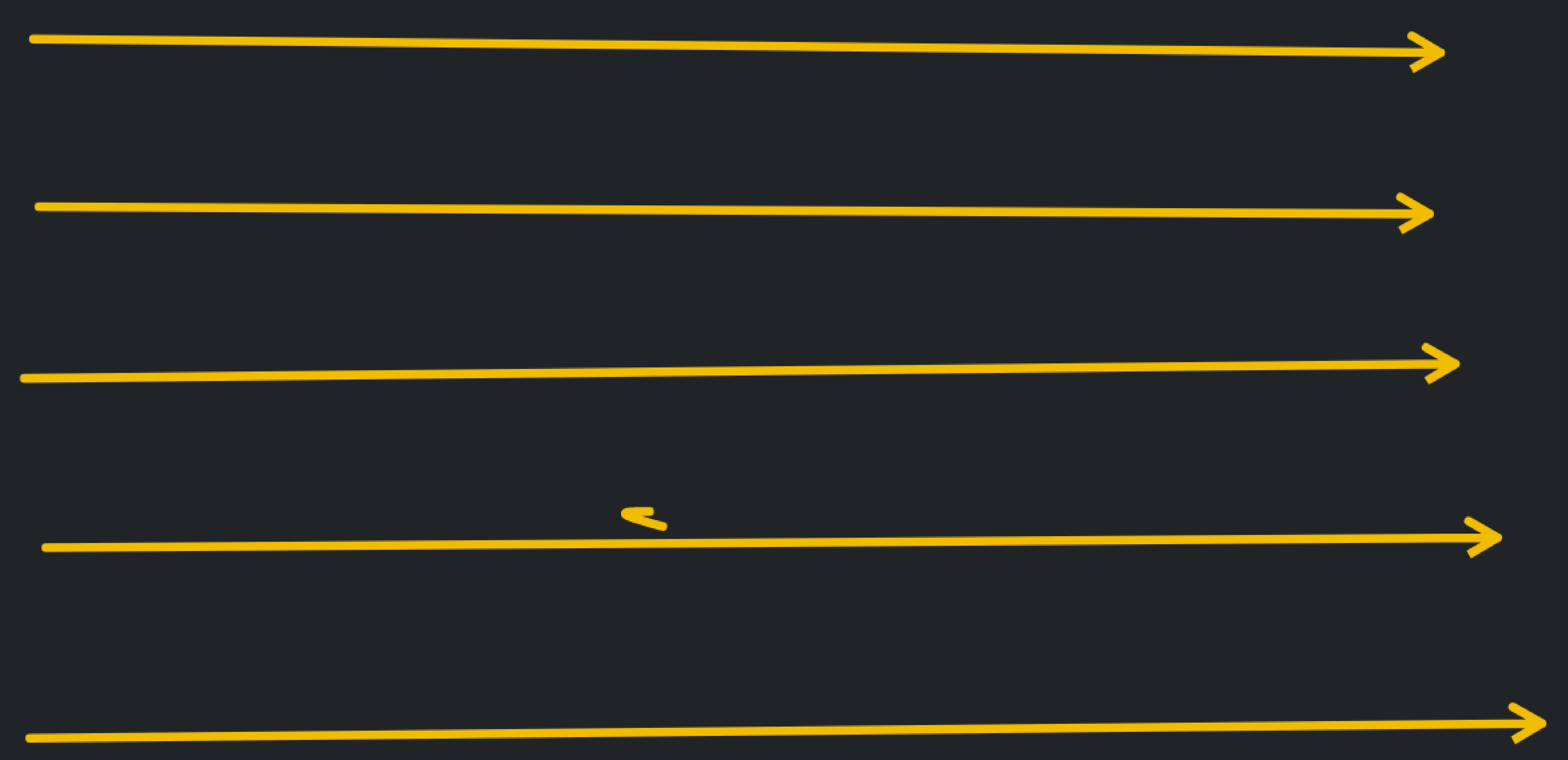
(8) Equidistance, parallel and straight field lines form <u>uniform electric field.</u>



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(9) Electric field lines are always symmetric about line joining of two charges.

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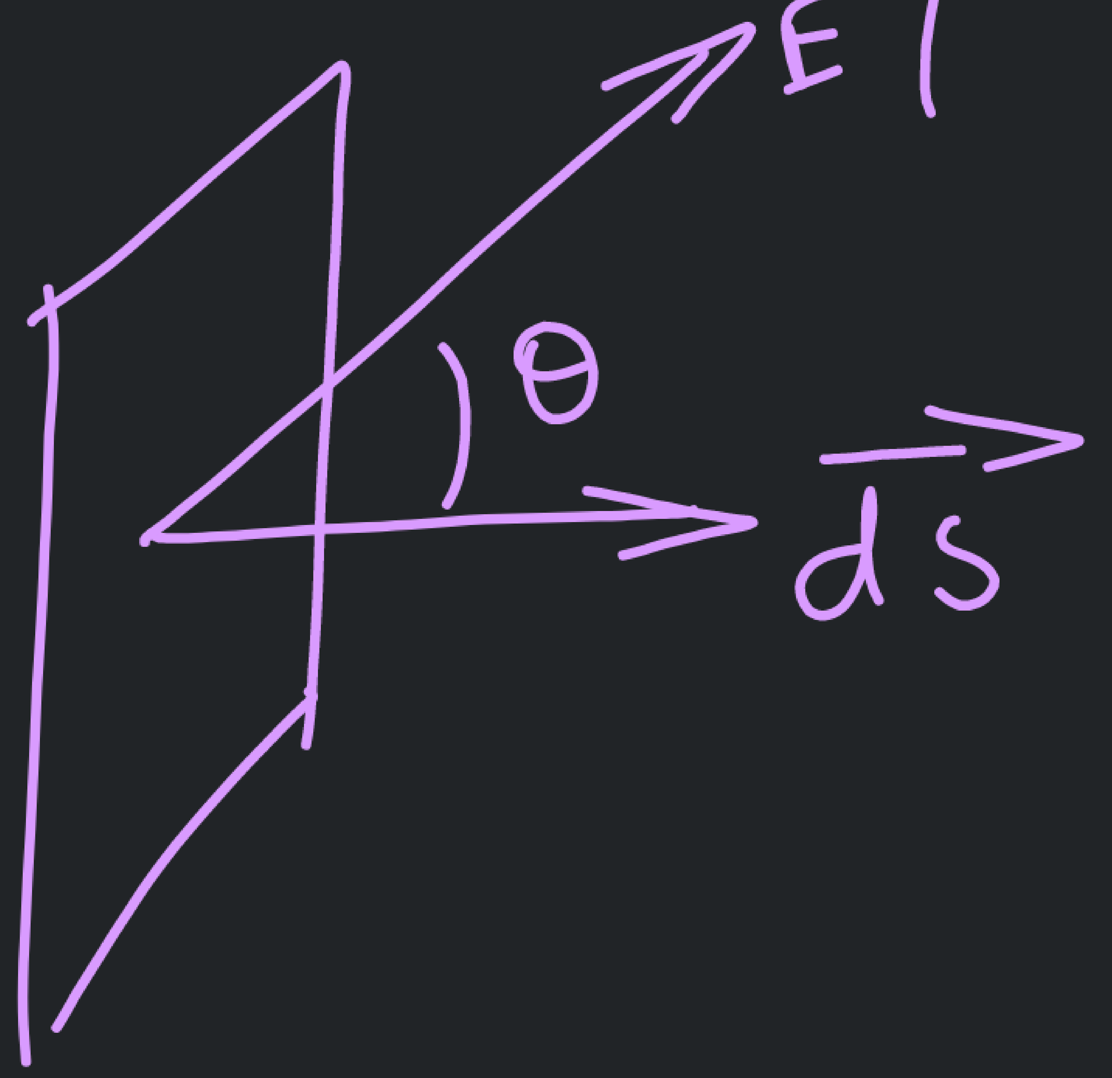
(10) Field lines are absent inside the conductor.

Electric flux:- no. of electric field lines passing through any surface normally is called electric flux associated with that surface.

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

$$\boxed{\phi_E = \underline{E}\, ds \cos\theta}$$

It is scalar quantity



Unit: $\left(\dfrac{\text{Newton} \times m^2}{\text{Coulomb}} \right)$

Dimensional formula:- 12-31

$[ML^{2}T^{-3}A^{-1}]$

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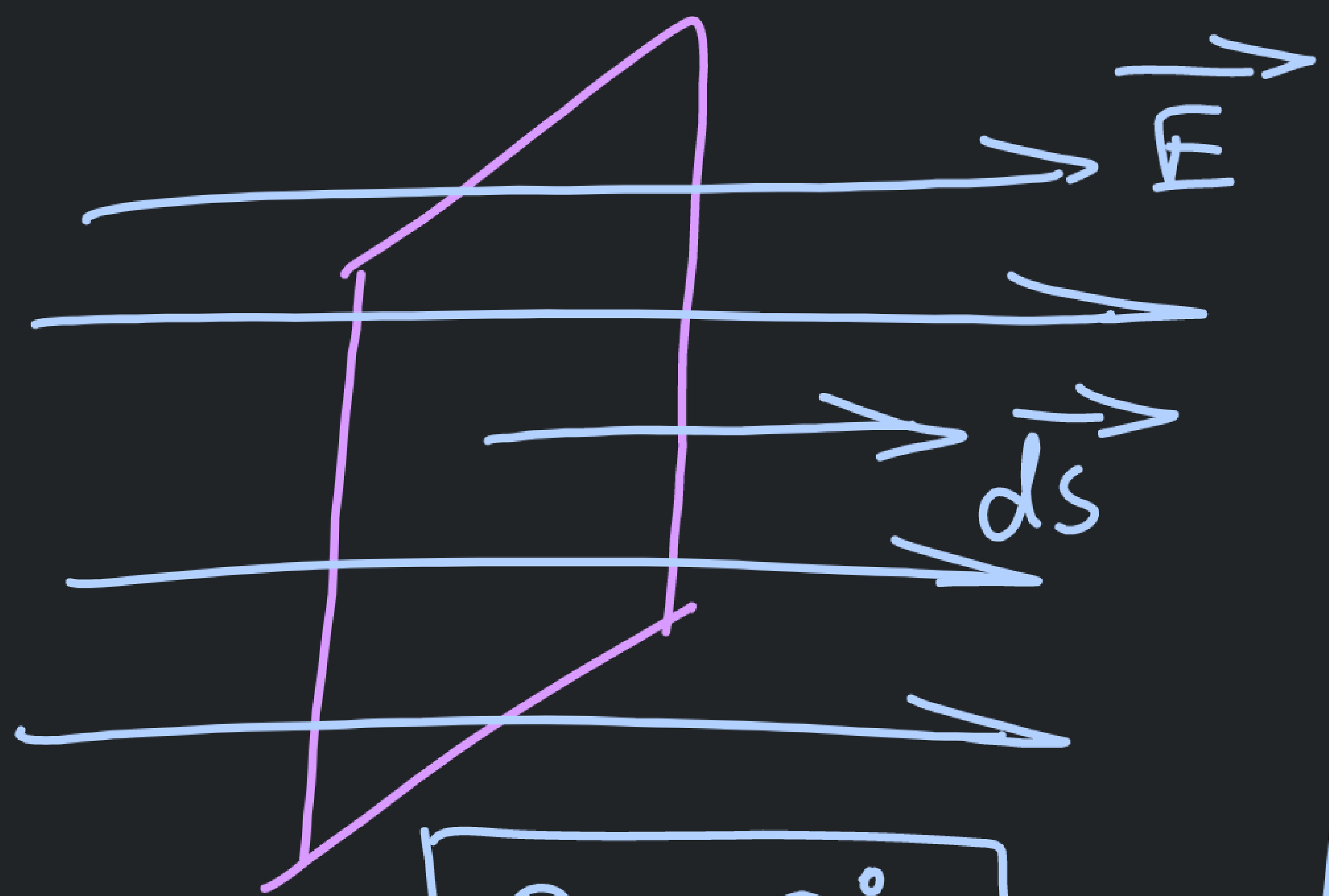
Special case:-

(i) Max. flux:-



$$\boxed{\theta = 0^\circ}$$

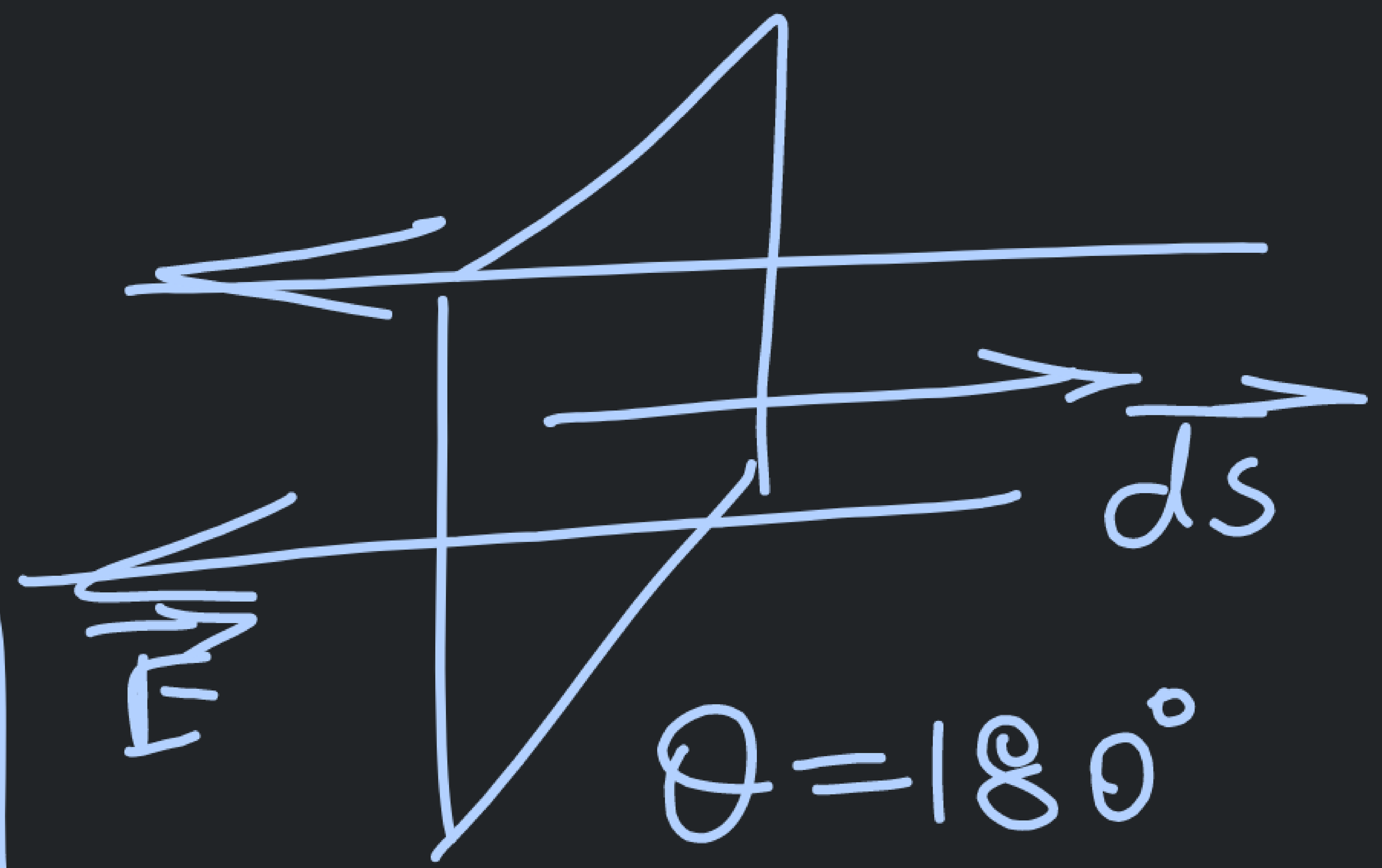
$$\phi = E\,ds\cos\theta$$

$$= E\,ds\cancel{\cos 0^\circ}^{\,1}$$

$$\phi = E\,ds \text{ (max.)}$$

(+ve flux)

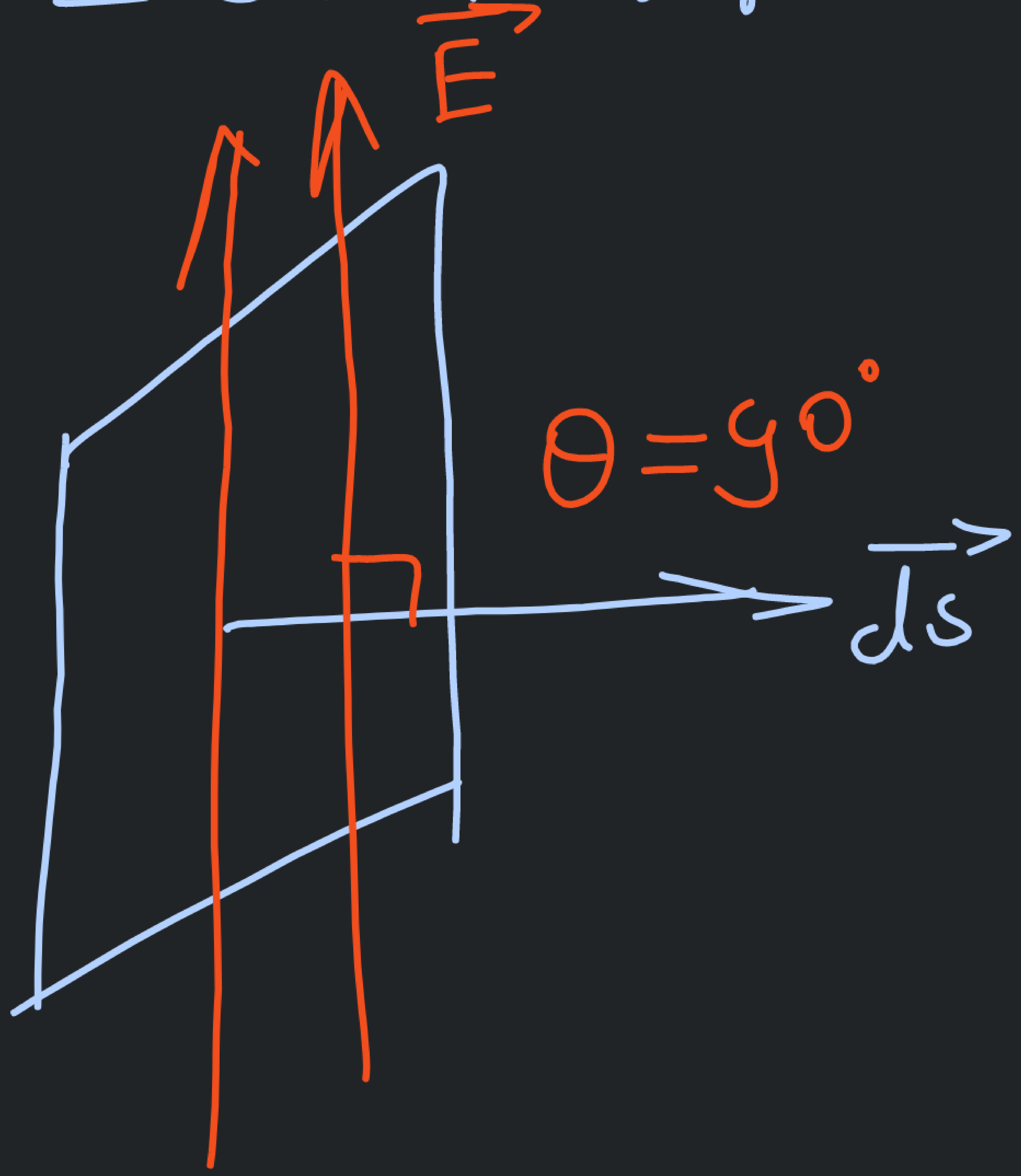
(ii) –ve flux:-



$$\phi = E\,ds\cos 180^\circ$$

$$\boxed{\phi = -E\,ds}$$

(iii) Zero flux:-



$$\phi = E\,ds\,\overset{0}{\cancel{\cos 90^\circ}}$$

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

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Gauss' law :- According to this law " net electric flux associated with closed surface is equal to $\frac{1}{\varepsilon_0}$ times of net charge present inside the closed surface."

Closed surface ⟶ 3 d
- sphere, cylinder, cube
- Gaussian surface

$$\phi_{\text{closed surface}} = \frac{1}{\varepsilon_0} \times q_{net}$$

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

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Proof :-

let a charge q present at centre of sphere with radius 'R'.

let a point P on the surface of sphere then electric field at point :-

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} \quad \text{—(1)}$$

Consider a small surface $\vec{ds}$ around point P then flux associated with $\vec{ds}$:-

$$d\phi = E\,ds\cancel{\cos\theta}\ 1$$

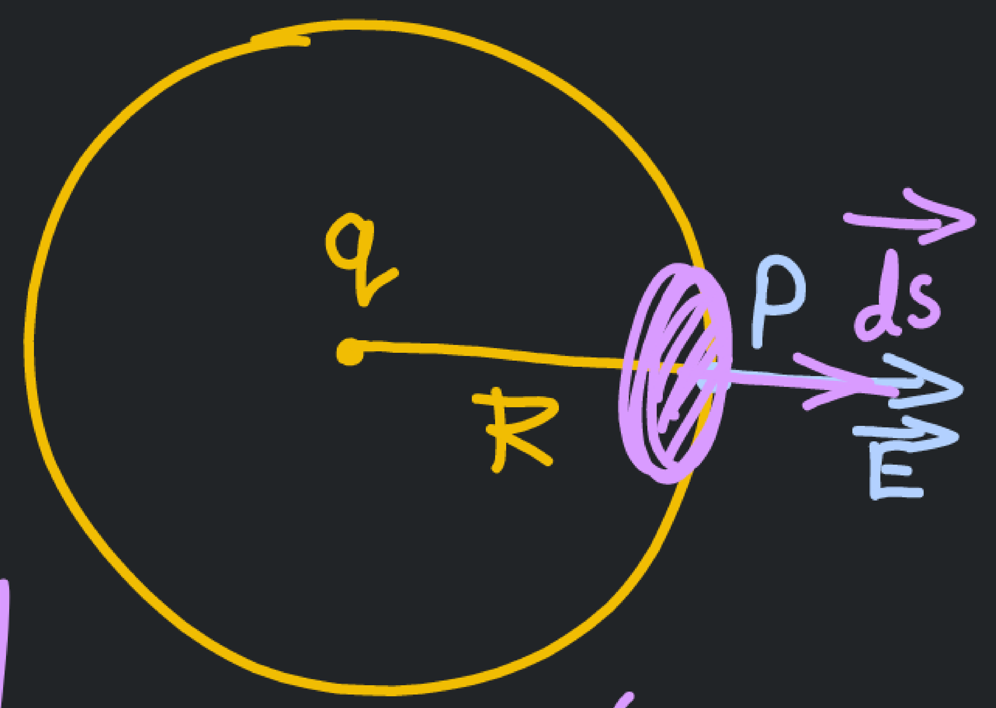
$$[\because \theta = 0° \Rightarrow \cos 0° = 1]$$

$$d\phi = E\,ds$$

Put the value of E from eqⁿ (1)

$$d\phi = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}\,ds$$

taking integral in both side of eqⁿ :-



$$\int d\phi = \int \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}\,ds$$

$$\phi = \frac{q}{4\pi\varepsilon_0 R^2}\int ds$$

$$\left[\because \int ds = 4\pi R^2\right]$$

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

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

Hence proved

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Applications of Gauss' law:—

Continous charge distribution:—

(i) Linear charge density:- charge per unit length

$$\boxed{\lambda = \frac{Q}{l}} \quad C/m.$$

(2) Surface charge density:- Charge per unit area.

$$\boxed{\sigma = \frac{Q}{A}} \quad C/m^2$$

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3 Volume charge density :- Charge per unit volume

$$\boxed{\rho = \frac{Q}{\text{Volume}}} \quad C/m^3$$

Intensity of electric field due to uniform charged infinite rod:-

flux associated with S_1 surface:-

$$d\phi_1 = E\,ds_1 \cos\theta$$

$[\because \theta = 90^\circ \Rightarrow \cos 90^\circ = 0]$

$$d\phi_1 = 0$$

$$\boxed{\phi_1 = 0}$$

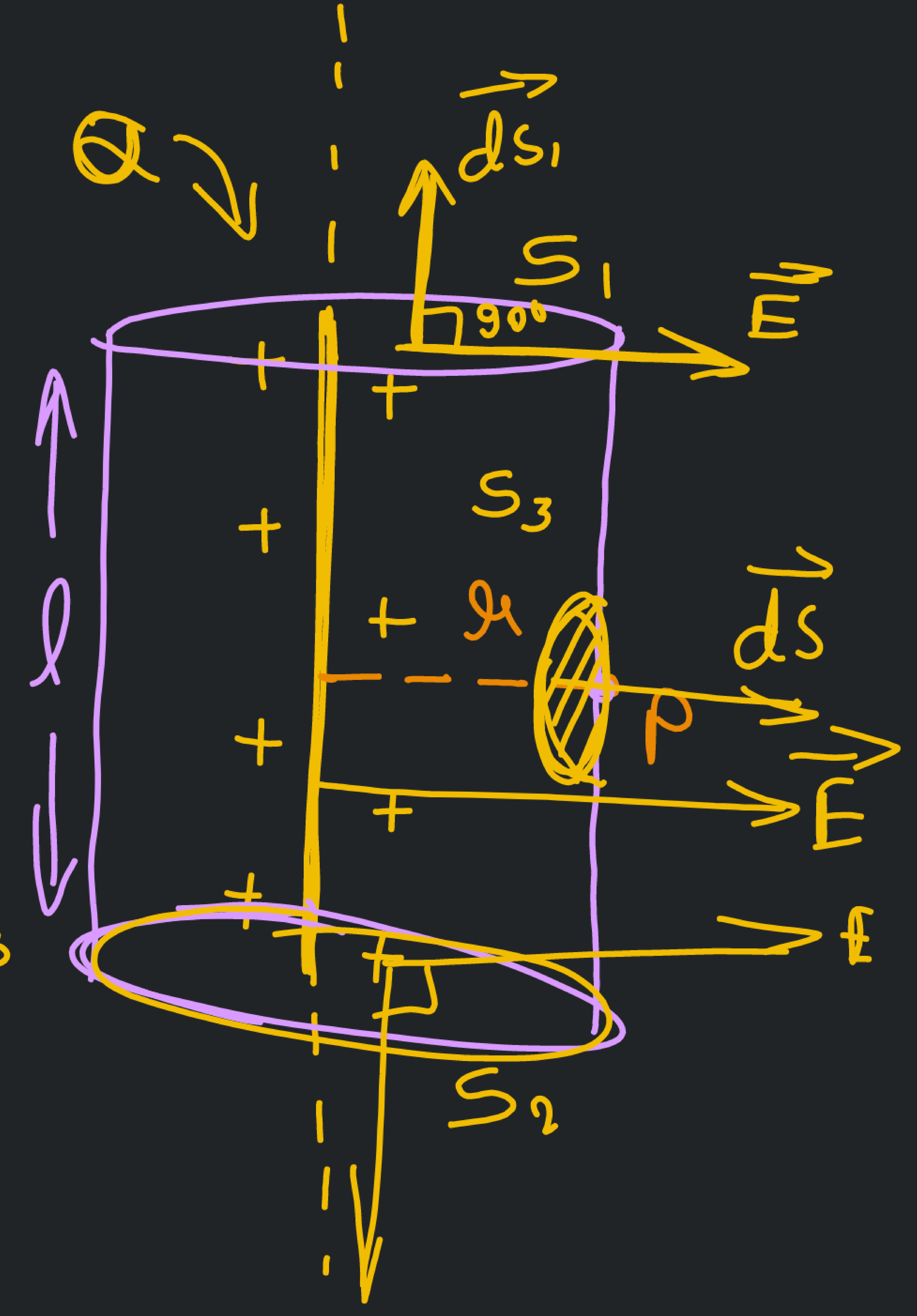
Then flux associated with S_2 - -

$$\boxed{\phi_2 = 0}$$

flux associated with S_3 surface

$$d\phi_3 = \underline{E\,ds_3}\,\cancel{\cos\theta}^{\,1}$$

$[\because \theta = 0^\circ \Rightarrow \cos 0^\circ = 1]$



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$$d\phi_3 = E\, dS_3$$

$$\int d\phi_3 = \int E\, dS_3$$

$$\phi_3 = E \int dS_3$$

$$\left[\because \int dS_3 = 2\pi r l\right]$$

$$\phi_3 = E.2\pi r l$$

net flux :-

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

$$\phi = 0 + 0 + \underline{E.2\pi r l}$$

$$\phi = \underline{E.2\pi r l} \text{ --- } (1)$$

but Gauss' law :-

$$\phi = \frac{Q}{\varepsilon_0} \text{ --- } (2)$$

by eq^n (1) and (2)

$$E.2\pi r l = \frac{Q}{\varepsilon_0}$$

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

$$E = \frac{1}{2\pi\varepsilon_0}\left(\frac{Q/l}{r}\right)$$

$$\because \lambda = \frac{Q}{l}$$

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}}\ N/C$$

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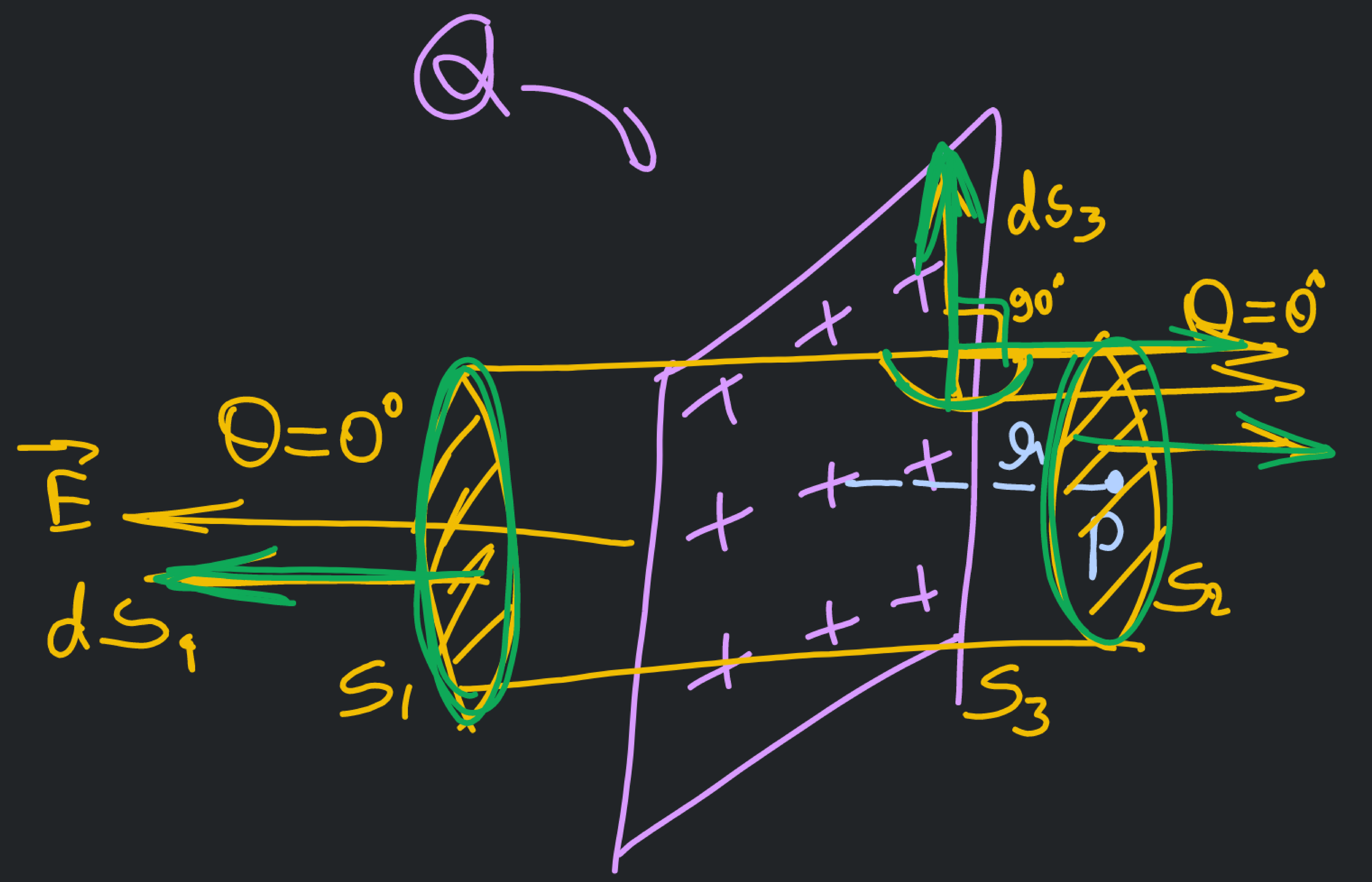
Intensity of electric field due to uniform charged sheet :-



flux associated with S_1

$$d\phi_1 = E\,dS_1 \cos\theta$$

$$[\because \theta = 0° \Rightarrow \cos 0° = 1]$$

$$d\phi_1 = E\,dS_1$$

$$\int d\phi_1 = \int E\,dS_1$$

$$\phi_1 = E \int dS_1$$

$$\underline{\phi_1 = EA}$$

similarly :-

$$\phi_2 = EA$$

and

$$\phi_3 = 0 \quad [\because \theta = 90°]$$

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then net flux :-

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

$$\phi = EA + EA + 0$$

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

but Gauss' flux :-

$$\phi = \frac{Q}{\varepsilon_0} \quad \text{---} (2)$$

by eqn (1) and (2)

$$2EA = \frac{Q}{\varepsilon_0}$$

$$E = \frac{\left(\frac{Q}{A}\right)}{2\varepsilon_0}$$

$$\left[\because \sigma = \frac{Q}{A}\right]$$

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

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Intensity of electric field due to uniform charge hollow sphere (shell)

① Outside the sphere :-

flux associated with $\vec{ds}$

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

$$[\because \theta = 0^\circ \Rightarrow \cos 0^\circ = 1]$$

$$d\phi = E\,ds$$

$$\int d\phi = \int E\,ds$$

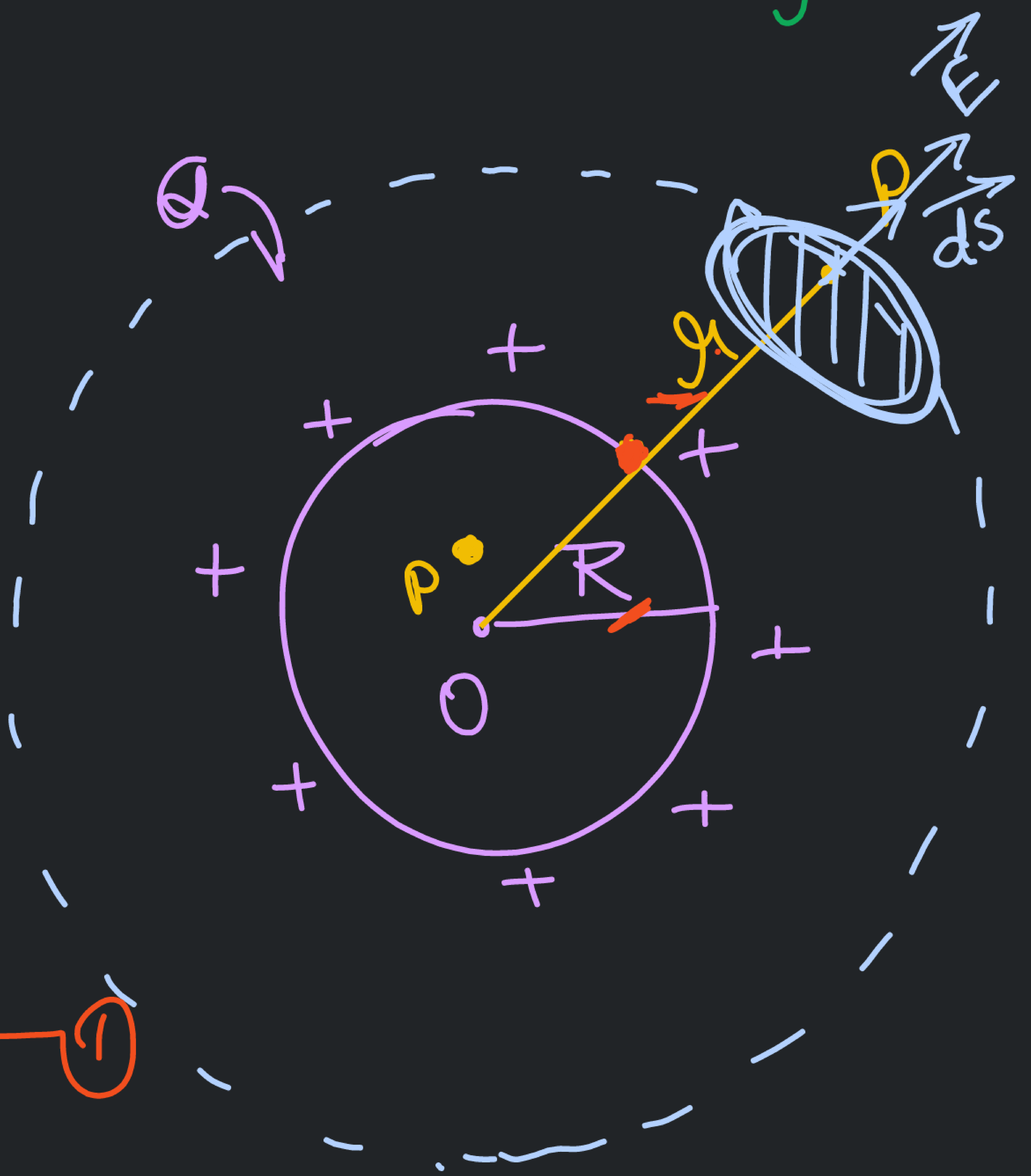
$$\phi = E\int ds$$

$$[\because \int ds = 4\pi r^2]$$

$$\phi = E.4\pi r^2 \quad \text{--- ①}$$

but Gauss' law :-

$$\phi = \frac{Q}{\varepsilon_0} \quad \text{--- ②}$$



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by eqⁿ ① and ②

$$E \cdot 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

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

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}}\ N/C$$

② On the sphere ($r = R$)

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}}\ N/C$$

constant

③ Inside the sphere :-

$$q_{inside} = 0$$

hence $\boxed{E = 0}$

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Coulomb's law with the help of Gauss' law:—

Let a charge q present at the centre of sphere of radius R then

Consider a point P and a small are ds around P on the surface of sphere. Then flux associated with $\vec{ds}$:-

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

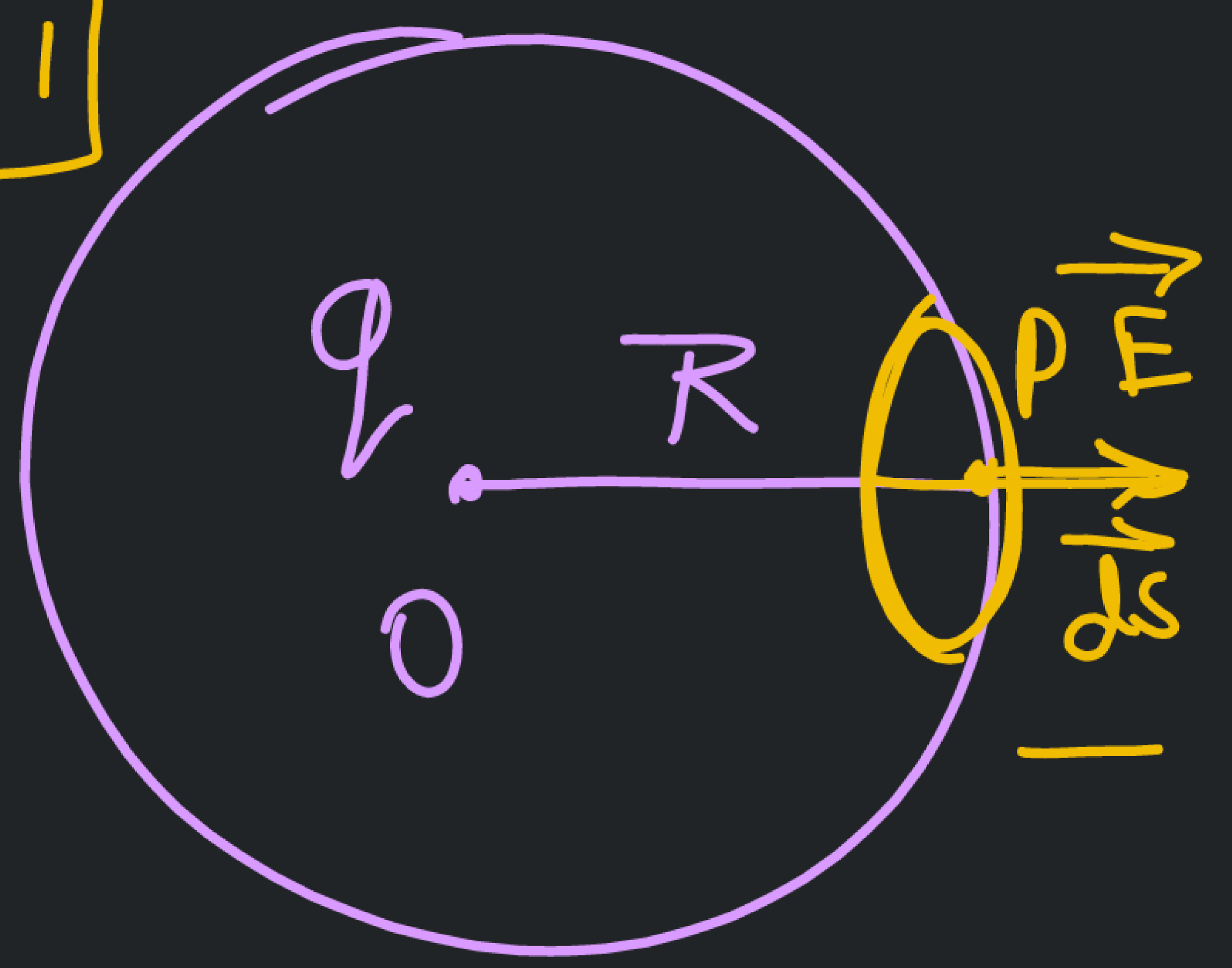
$$[\because \theta = 0^\circ \Rightarrow \cos 0^\circ = 1]$$

$$d\phi = E\,ds$$

$$\int d\phi = \int E\,ds$$

$$\phi = E\int ds$$

$$\left[\because \int ds = \underline{4\pi R^2}\right]$$



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$$\phi = E \cdot 4\pi R^2 \quad \text{---} (1)$$

but Gauss' law:-

$$\phi = \frac{q}{\varepsilon_0} \quad \text{---} (2)$$

by eqⁿ (1) and (2)

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

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

$$\boxed{E = \frac{1}{4\pi\varepsilon_0} \frac{q}{R^2}} \quad \text{---} (3)$$

but force on charge inside field:-

$$F = q_0 E$$

then

$$F = q_0 \left(\frac{1}{4\pi\varepsilon_0} \frac{q}{R^2} \right)$$

$$\boxed{F = \frac{1}{4\pi\varepsilon_0} \frac{q q_0}{R^2}} \quad \underline{\underline{N}}$$

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