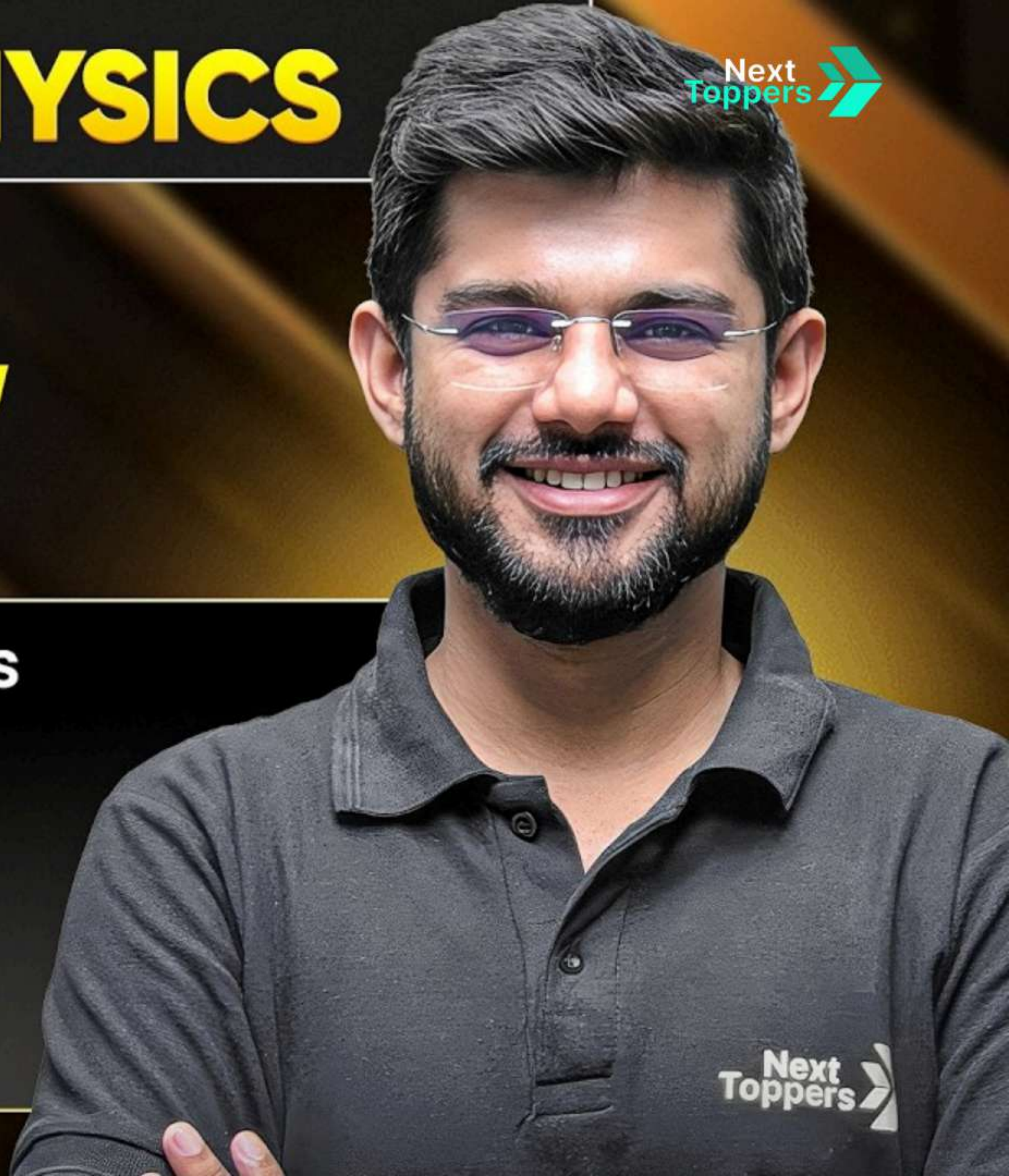


● **LIVE** **CLASS 12th PHYSICS**

Next
Toppers

BACKLOG
MARATHON
S E R I E S

1. Electric Charges and Fields
2. Electrostatic Potential and Capacitance
3. Current Electricity
4. Moving Charges and Magnetism



How's THE JOSH

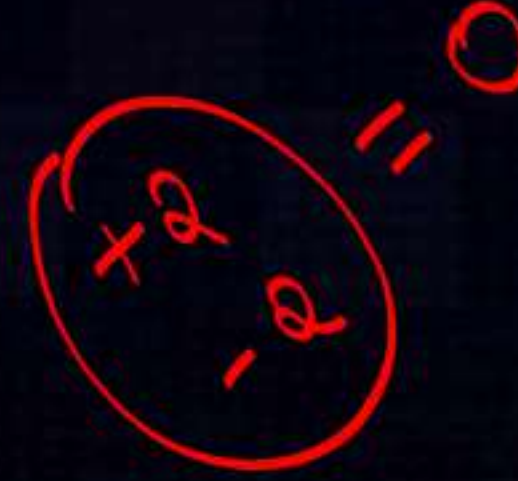


Electric **Charges and Fields**

Chapter-1

Marathon

Electric Charge



“Electric charge is a **fundamental property of matter** responsible for electrical forces ”

Key Points :

- There are two types of charges : **Positive & Negative**
- Like charges repel, unlike charges attract
- Charges are **scalars** (no direction, only magnitude)
- SI Unit : Coulomb (C)
- Charge is **always associated with matter** particles



Thales of Miletus



Charge Quantization



The total charge on any body is always an integral multiple of the elementary charge.

$$Q = 1e$$

$$Q = 2e$$

$$Q = \underline{\underline{300e}}$$



$$Q = ne$$

$$n = \pm 1, 2, 3, 4, \dots$$

Key Points :

- Elementary charge (e) is the **smallest unit** of electric charge that **exists independently**
- **Free electrons** are move from one body to another
- It is the charge of **Electron = $-e$ & Proton = $+e$**

Charge is Conserved

For an isolated system, net charge always remains **constant**



Glass rod



Silk cloth



Glass rod

$+Q$



Silk cloth

$-Q$

$\Rightarrow Q_{net} = 0$

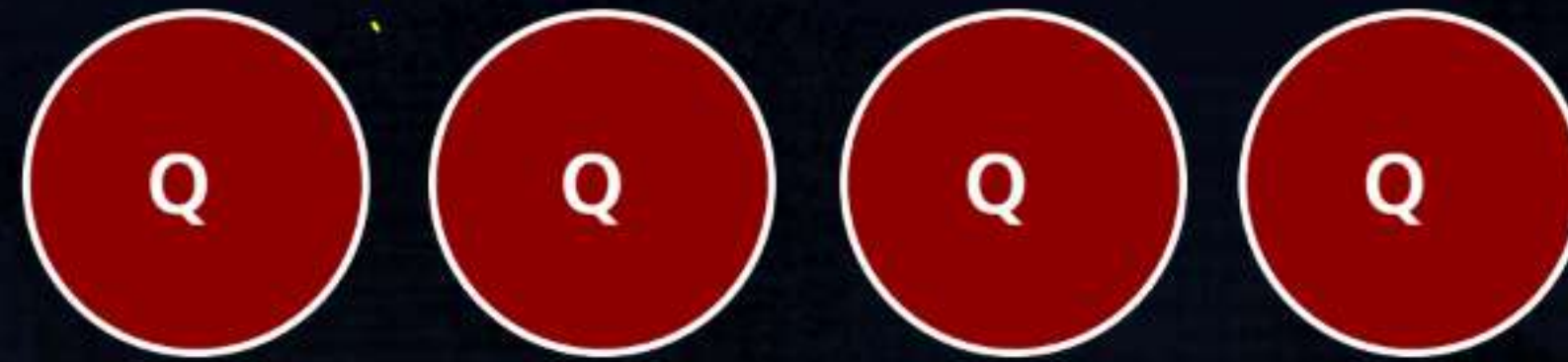
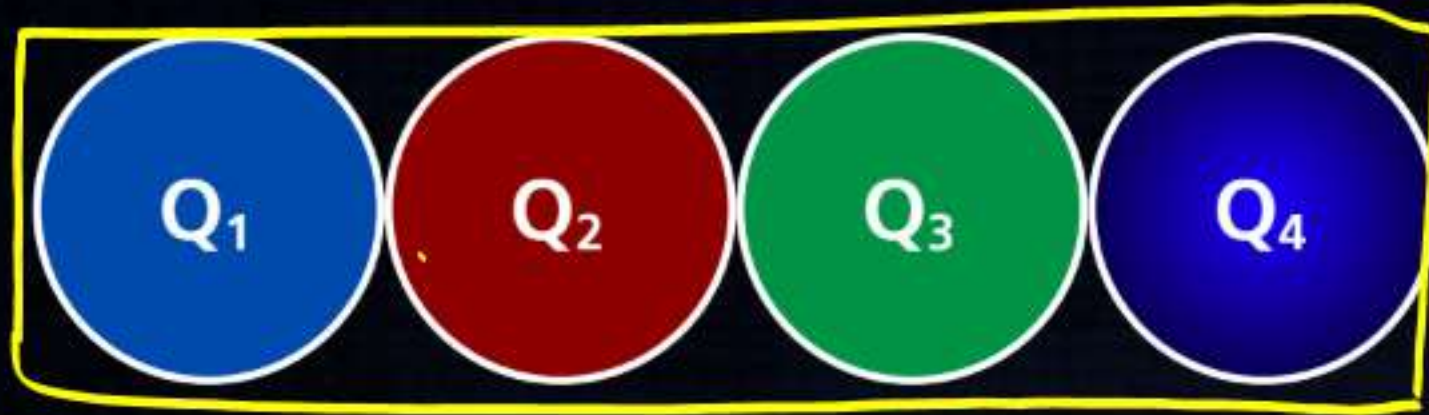
Key Points :

- One loses electrons $\rightarrow$ becomes positively charged (+)
- Other gains electrons $\rightarrow$ becomes negatively charged (-)
- Both objects get equal and opposite charges
- Total charge remains conserved



SMT

When identical conducting spheres are touched and then separated,



$$Q_{\text{initial}} = Q_1 + Q_2 + Q_3 + Q_4$$

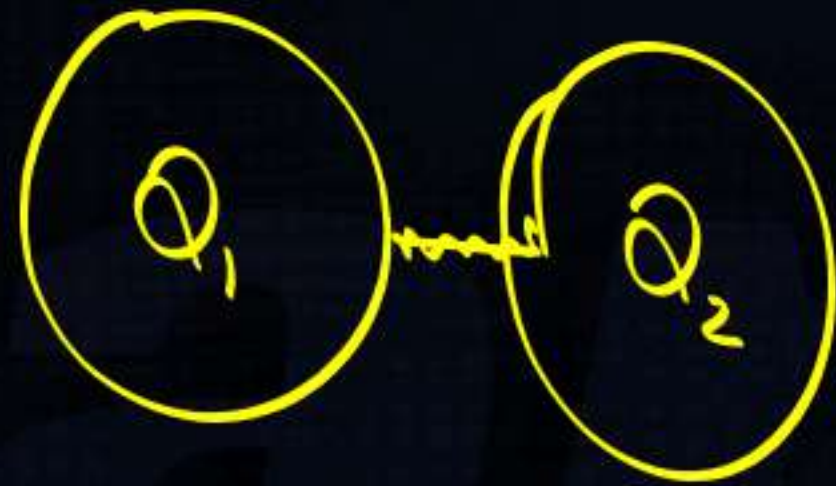
- Charge is shared **equally**.

~~≠~~

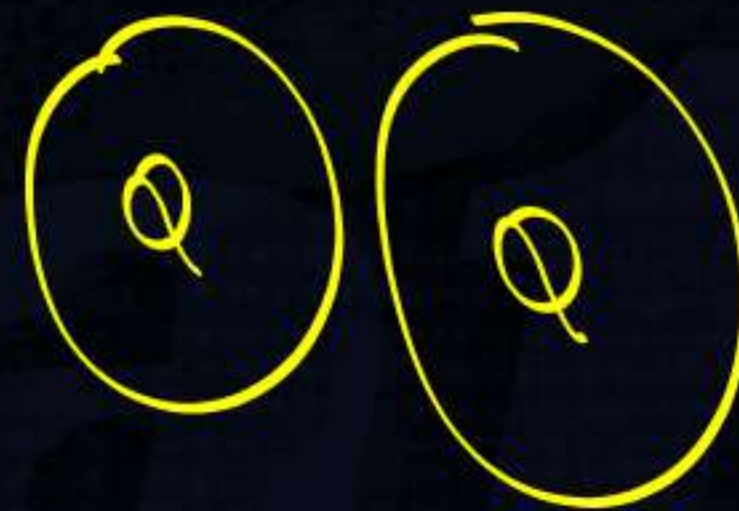
$$Q = \frac{Q_1 + Q_2 + Q_3 + Q_4}{4}$$

$$Q_{\text{Final sys.}} = Q + Q + Q + Q$$

- By **conservation of charge** the final charge on each sphere is



$\Rightarrow$



$$\del{Q = \frac{Q_1 + Q_2}{2}}$$



Find final charges on the identical spheres when brought in contact.

- a. 35 mC
- ☒ b. 15 mC
- c. -35 mC
- d. -15 mC



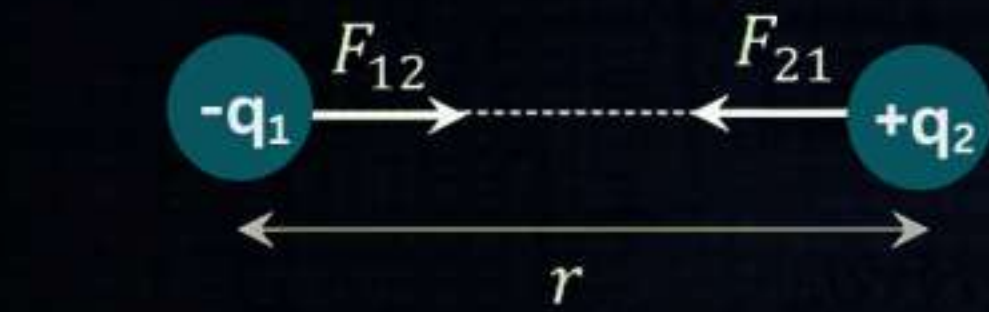


Which of the following is NOT a property of charges ? (CUET 2023)

- a. Quantisation
- b. Scalar
- c. Additive
- ☒ d. affected by frames of reference

Coulomb's Law

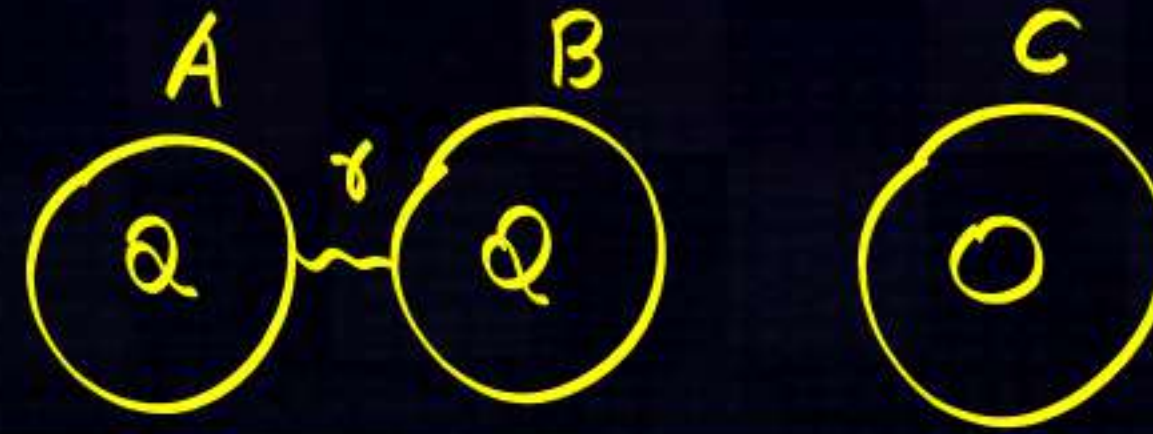
The electrostatic force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.



$$F = \frac{k Q_1 Q_2}{r^2}$$

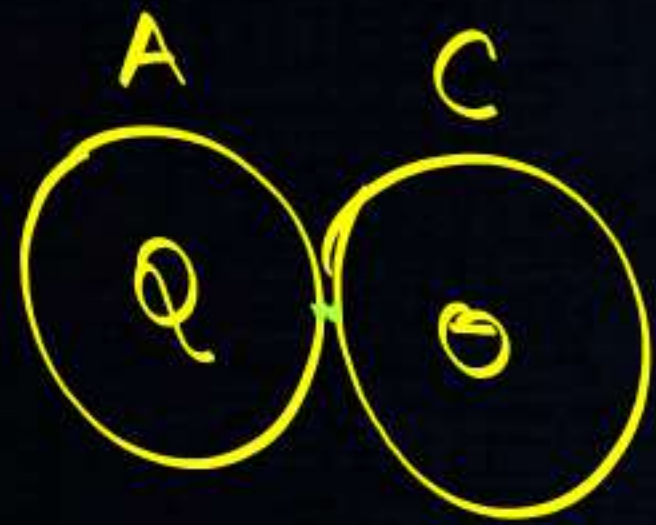
$k = \frac{1}{4\pi\epsilon_0}$
Permittivity of free space

- Acts between two point charges
- Magnitude is equal $|F_{12}| = |F_{21}|$
- Act in opposite directions
- Is an action-reaction pair
- Also called central force
- Acts along the line joining the charges
- Depends on the medium in which they are placed

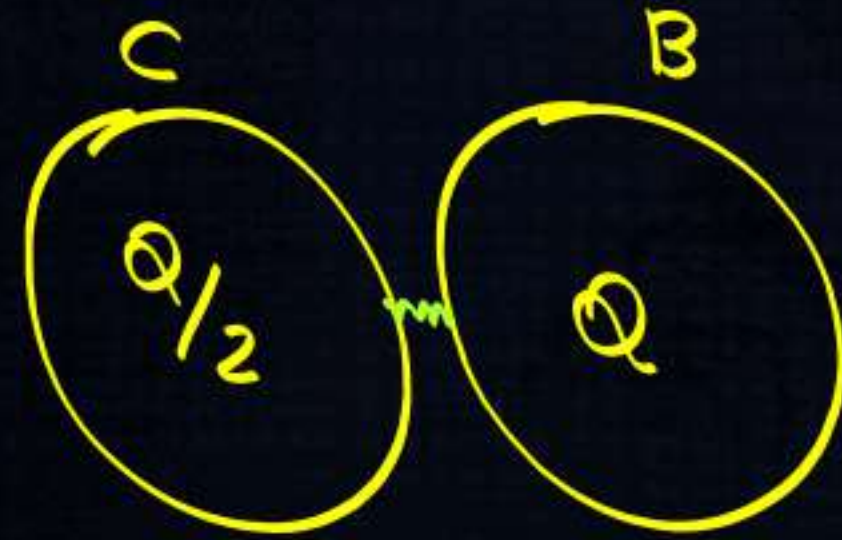


Que.

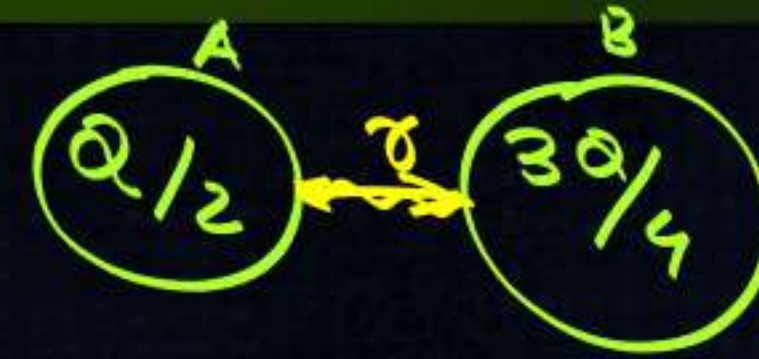
Identical spheres A and B have charge Q. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B ?



$$Q_{AC} = \frac{Q+0}{2} = \frac{Q}{2}$$



$$Q_{BC'} = \frac{Q/2 + Q}{2} = \frac{3Q}{4}$$



$$F' = \frac{k(Q/2)(3Q/4)}{r^2}$$

$$= \frac{kQ^2}{r^2} \left(\frac{3}{8} \right)$$

$$F' = \frac{3}{8} F_{\text{orig}}$$



Identical spheres A and B have charge Q. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B ?

[Boards + NEET 2025]

Ans.

$$F' = 3F/8$$

Marathon



The force between two electric charges is expressed by the equation :

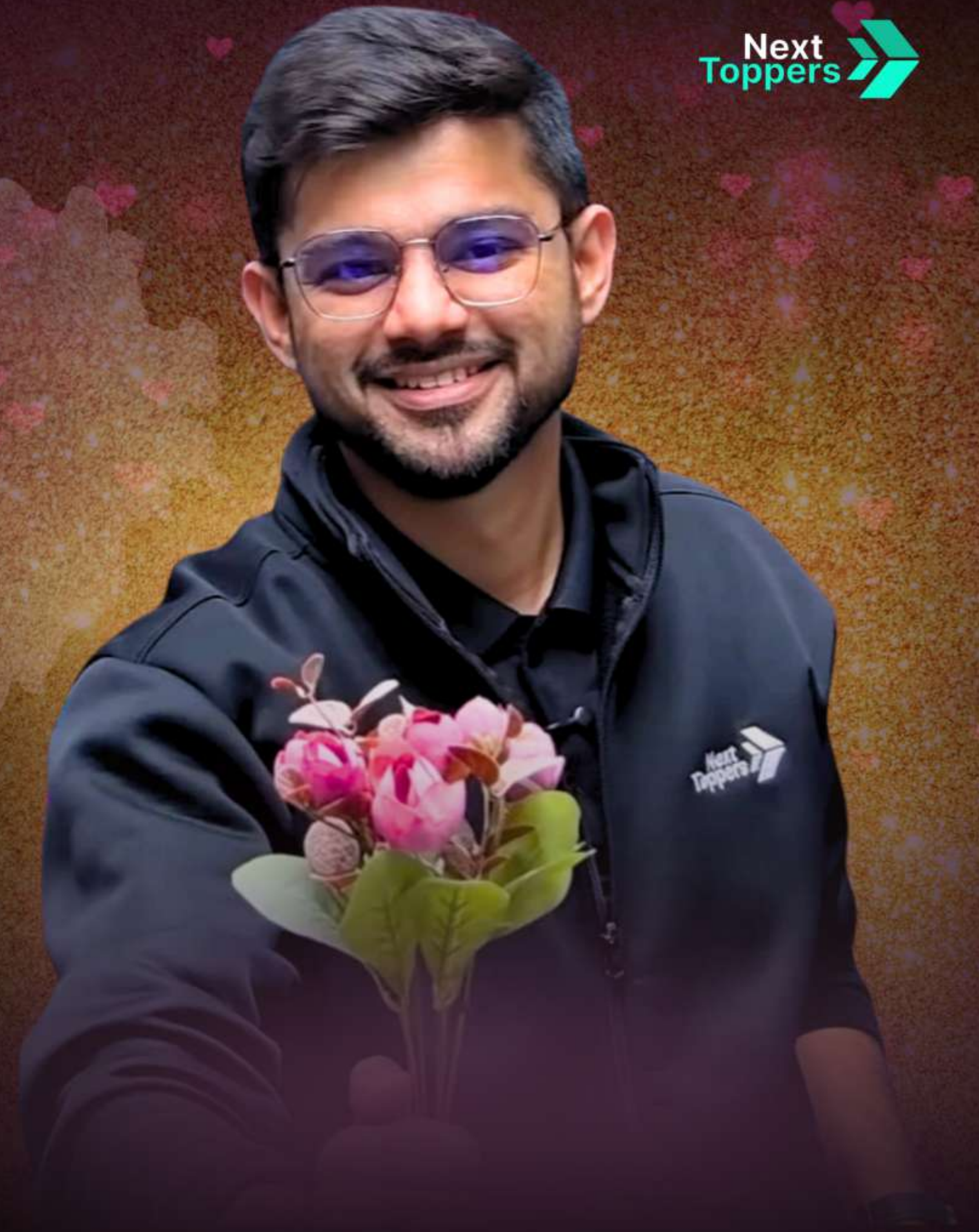
$$F = \frac{kq_1q_2}{r^2}$$

Which of the following is a correct statement?

(CUET 2023)

- a. The equation applies to point charges ✓
- b. k is Boltzmann's constant
- c. r is the radius of the spheres on which the two charges are placed
- d. The equation can only be applied to uniform electric fields

**Kambakht pyaar bhi Coulomb's
law jaisa nikla
Distance badhte hi feelings
marne lagi.**



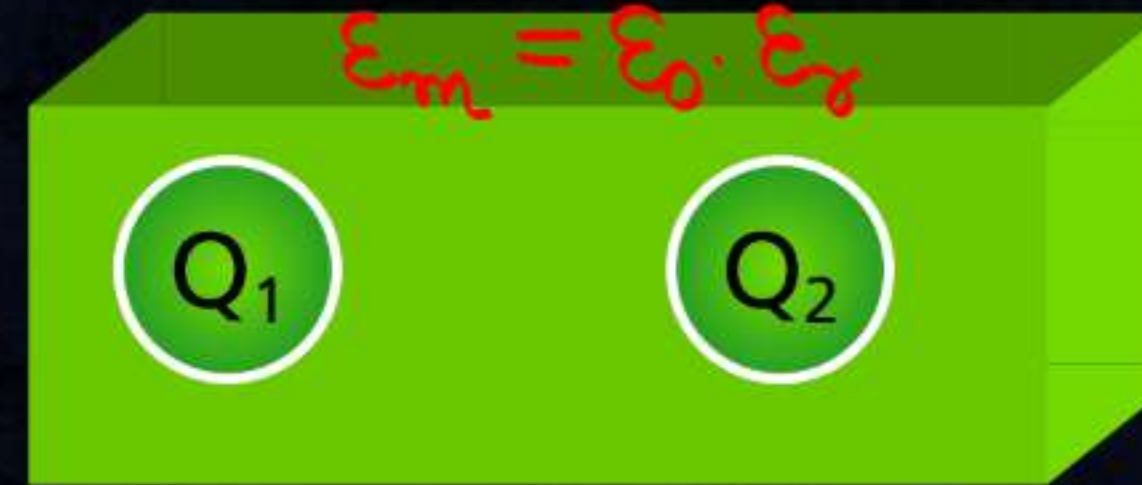
Effect of Medium

- Electrostatic force **decreases** in a medium by **a factor of its dielectric constant**.
- due to **polarization** of the medium.



$$F = \frac{k Q_1 Q_2}{r^2}$$

$$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$



$$F' = \frac{1}{4\pi\epsilon_m} \frac{Q_1 Q_2}{r^2} = \frac{1}{4\pi\epsilon_0 \epsilon_r} \frac{Q_1 Q_2}{r^2}$$

$$F' = \frac{F_{air}}{\epsilon_r} = \frac{F_{air}}{K}$$

← Dielectric constant

Medium	$K = \epsilon_r$
Z	1
Air	1.00056
Water	80
Mica	6
Teflon	2
Glass	5-10
PVC	4.5
Metal	∞

Relative permittivity

+

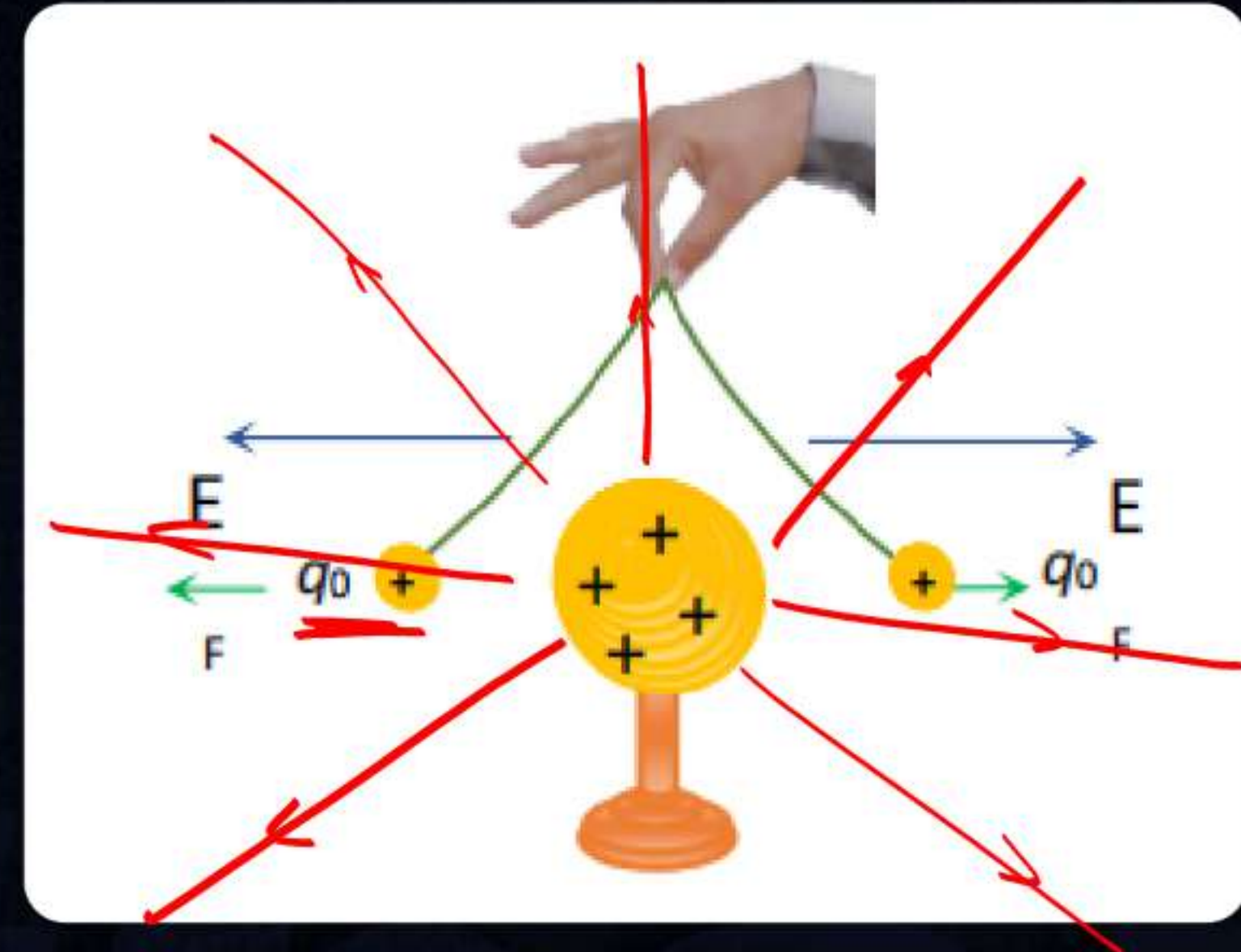
Electric Field

Electric field is the **space surrounding an electric charge** in which another charge experiences a force (electrostatic) of attraction or repulsion.

Keypoints

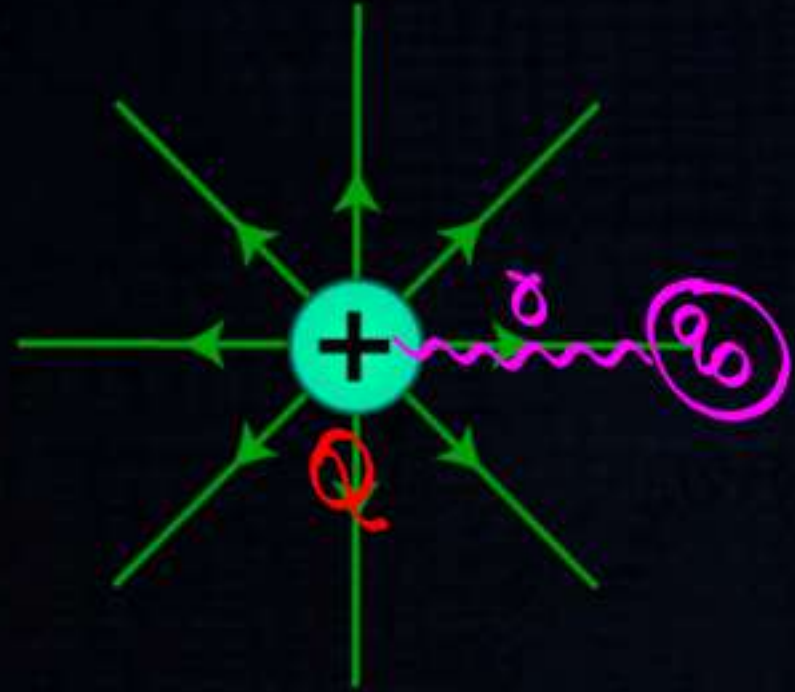
- Every charge has its own electric field.
- Vector quantity
- Unit: N/C

$$\vec{E} = \frac{\text{Electrostatic force on test charge}}{\text{Magnitude of Test charge}} = \frac{F_{\text{exp.}}}{q_0}$$



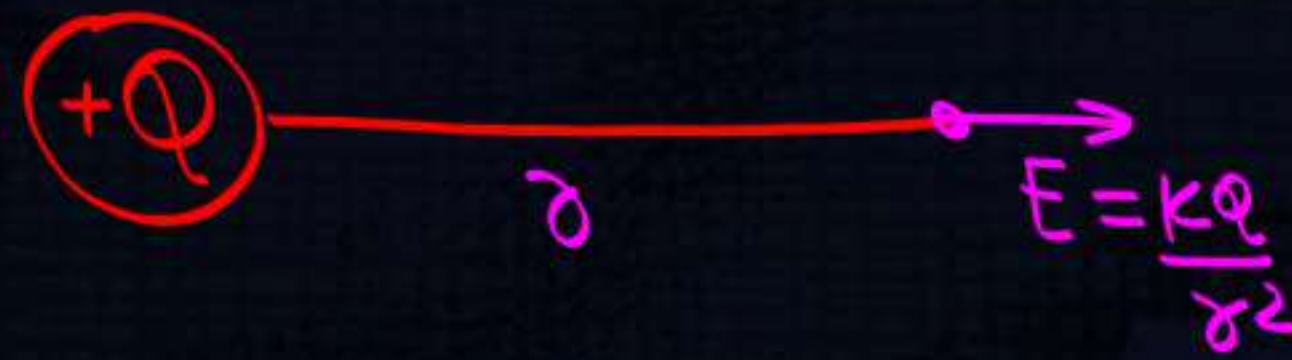
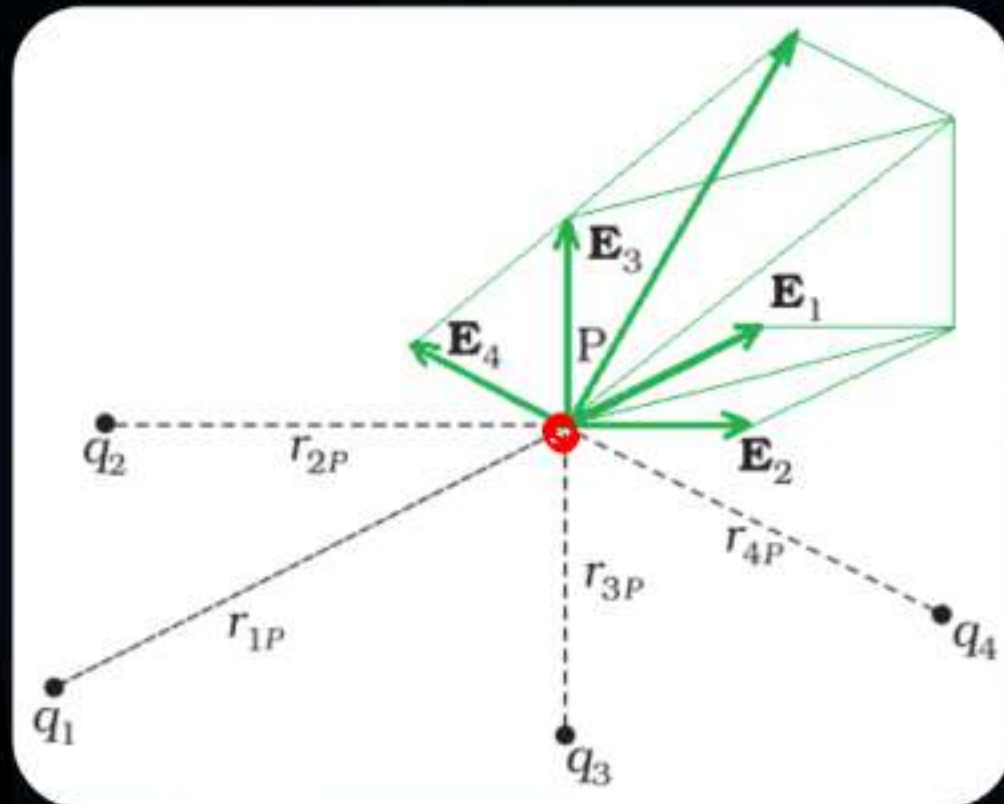
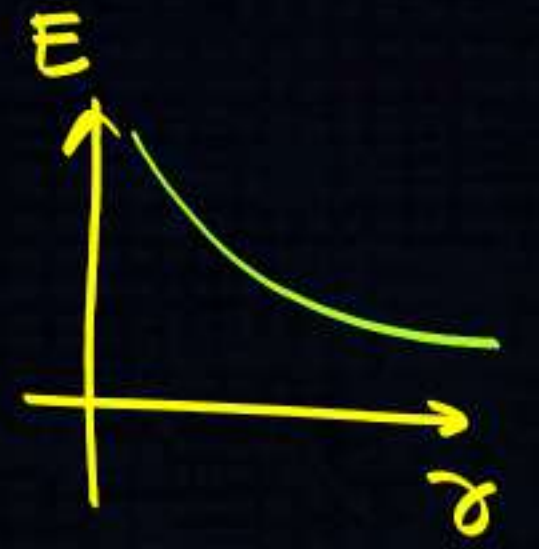
Electric field due to a point charge

The electric field intensity at a point at a distance r from a point charge Q is the force experienced per unit positive charge placed at that point.



$$\vec{E} = \frac{\text{Electrostatic force on test charge}}{\text{Magnitude of Test charge}}$$

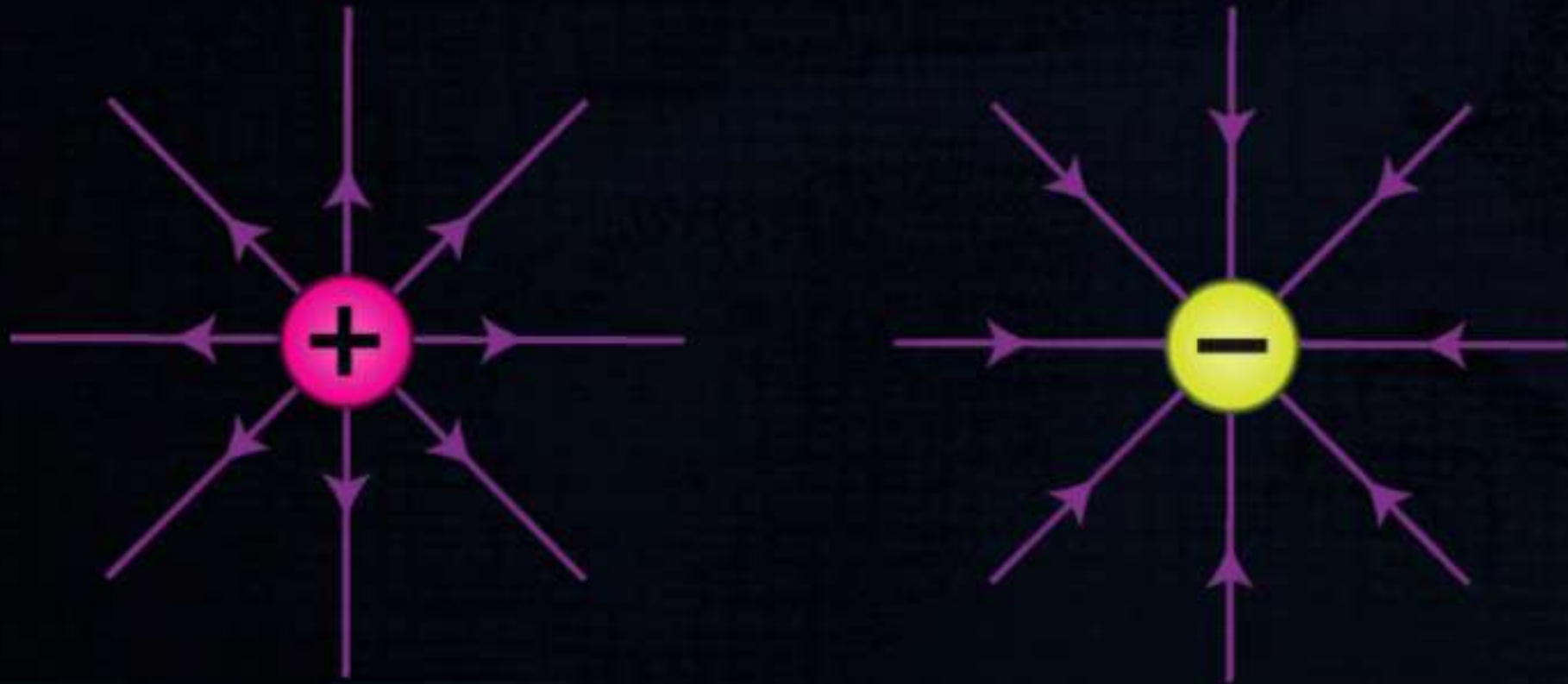
$$= \frac{k q_0 Q / r^2}{q_0} = \frac{k Q}{r^2}$$



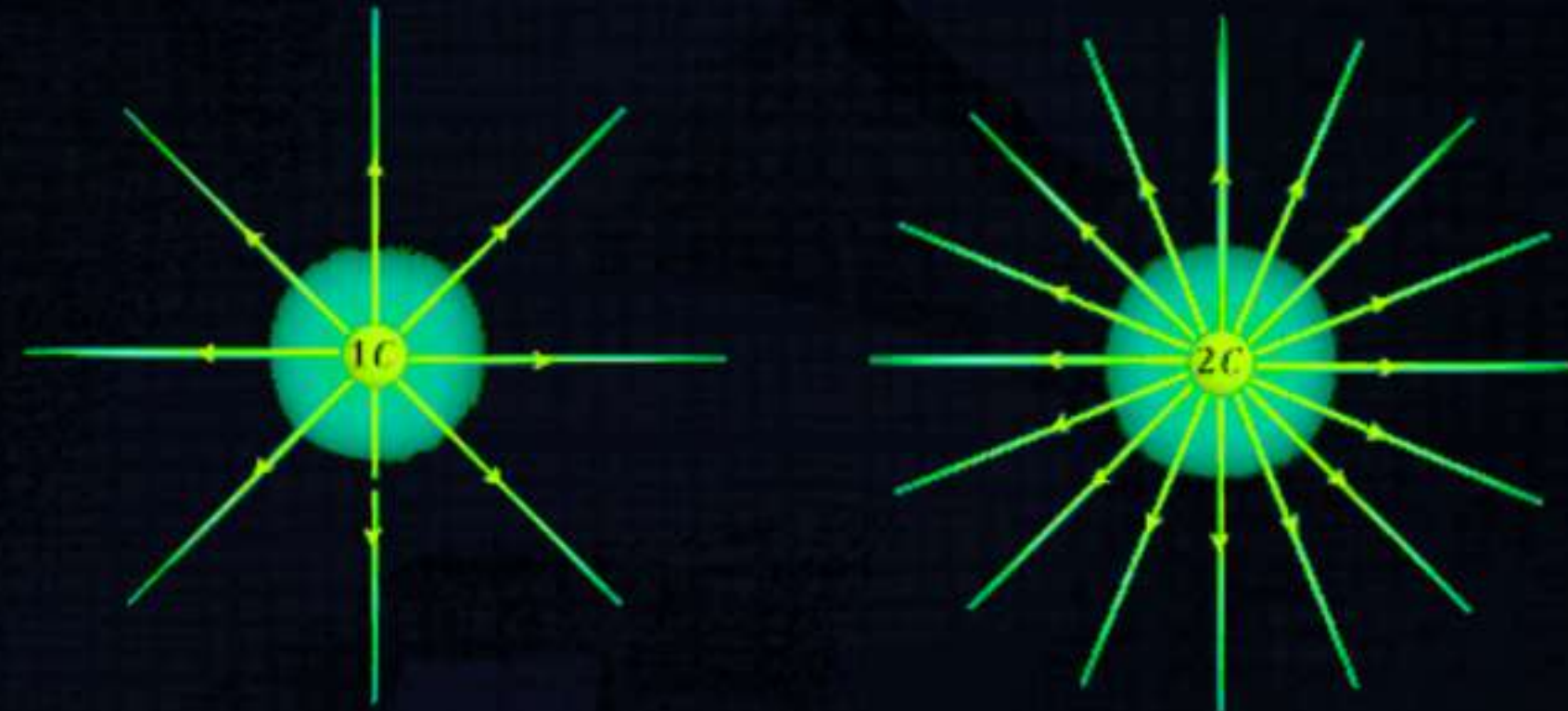
$$\vec{E}_{\text{net}} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 + \dots$$

Properties of Electric Field Lines

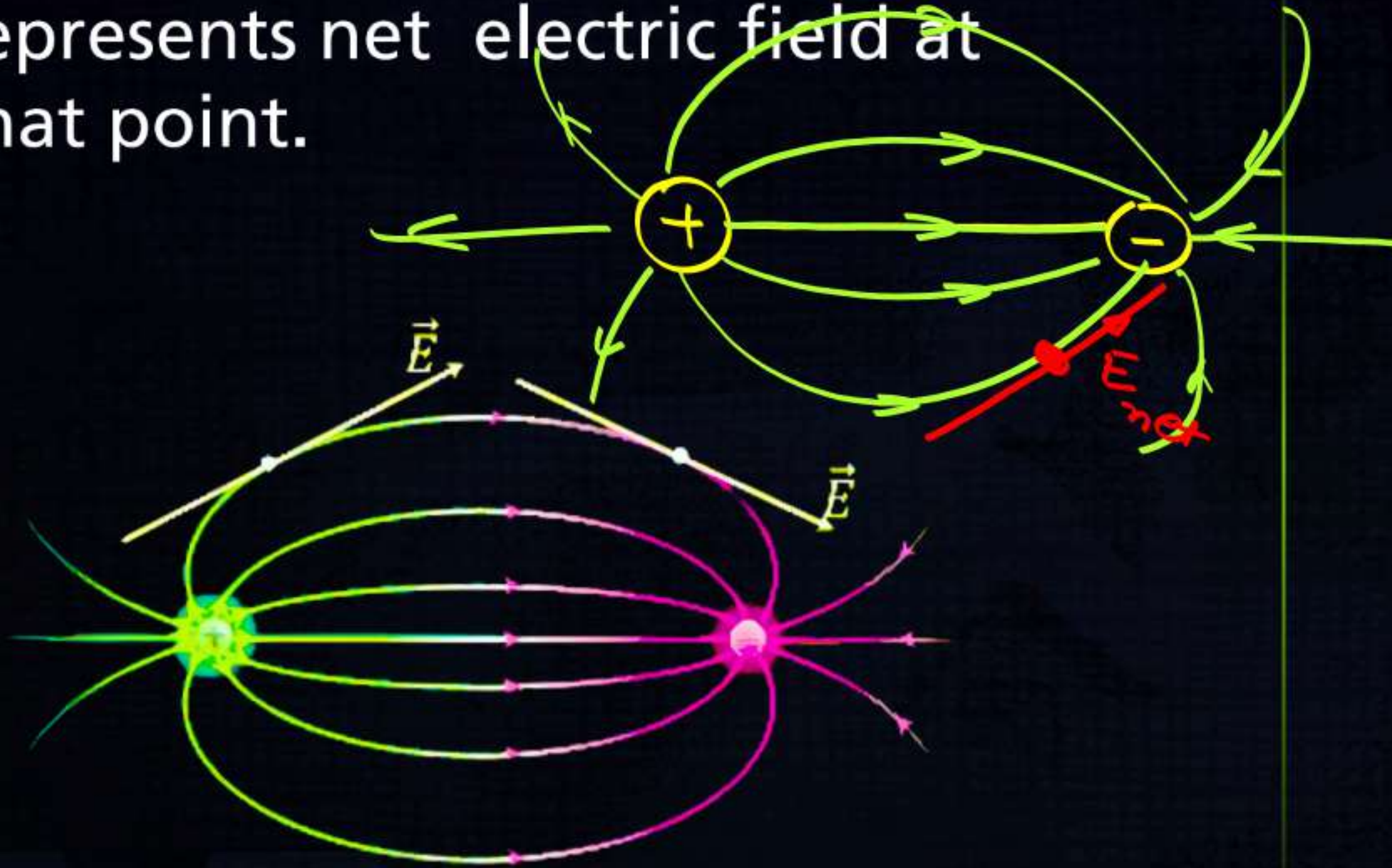
1. Electric field lines always **originate from a positive** charge and **terminate into a negative** charge



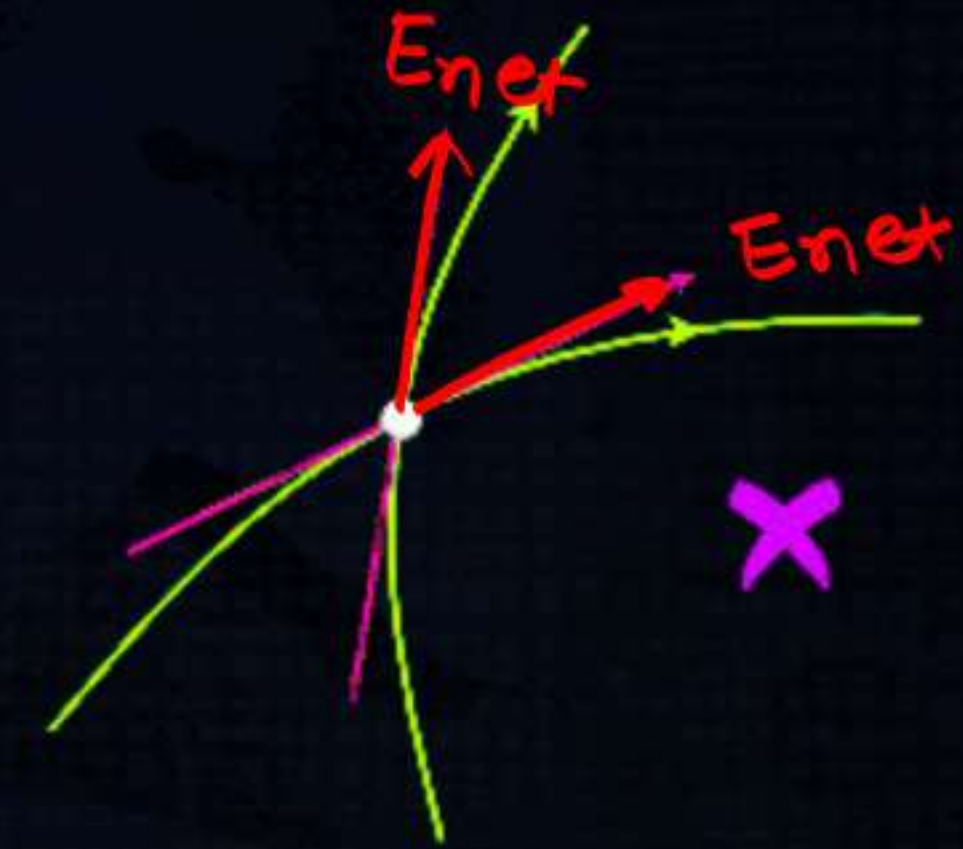
2. Number of field lines originating or terminating $\propto$ Magnitude of Charge



3. The tangent at any point on the electric field line always represents net electric field at that point.



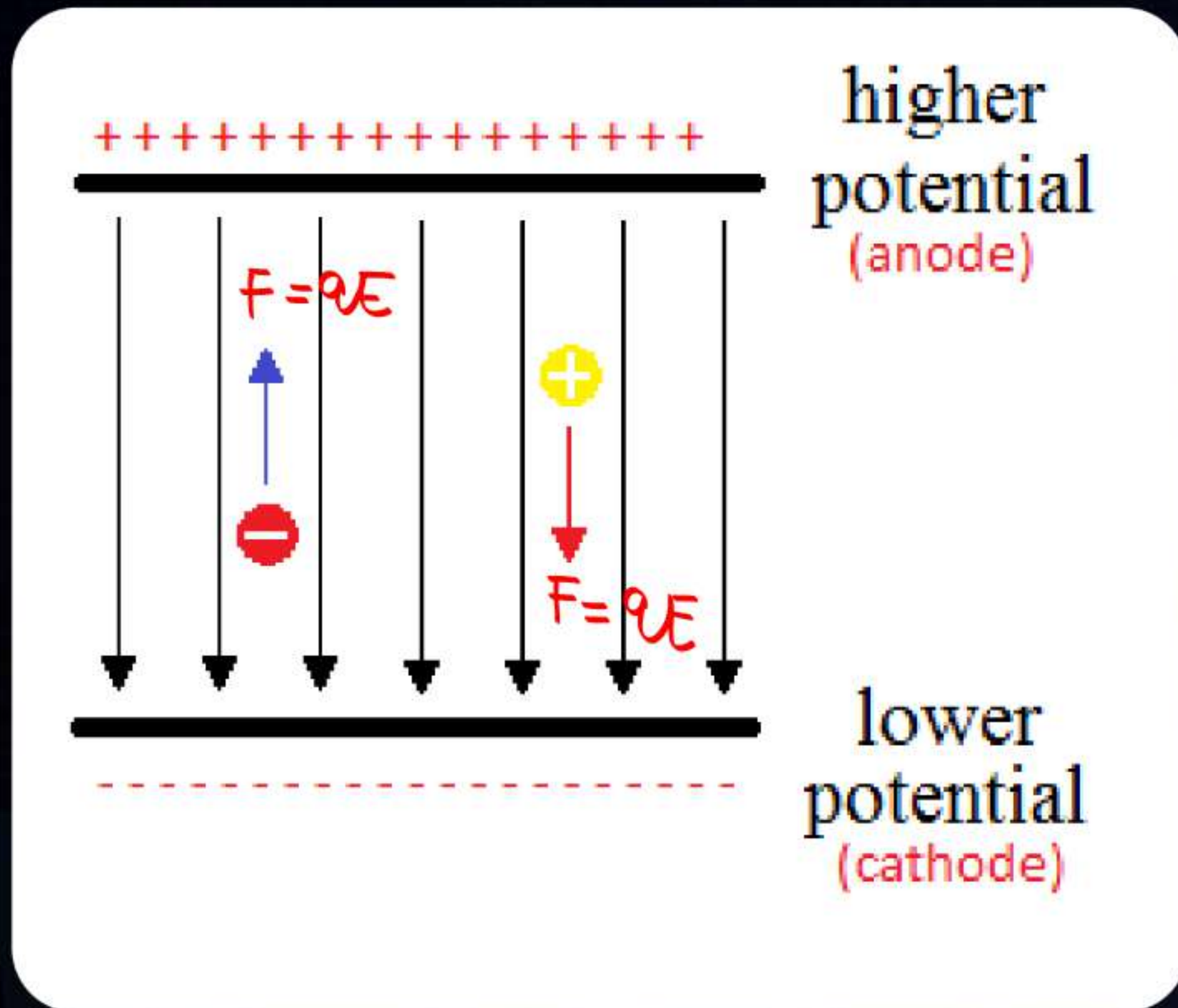
4. Two electric field lines never intersect



because if they intersect, there would be **two different directions** of electric field at that point

which is **not** possible.

5. Positive charges move along the field lines, negative charges move opposite to them.



$$F = qE$$

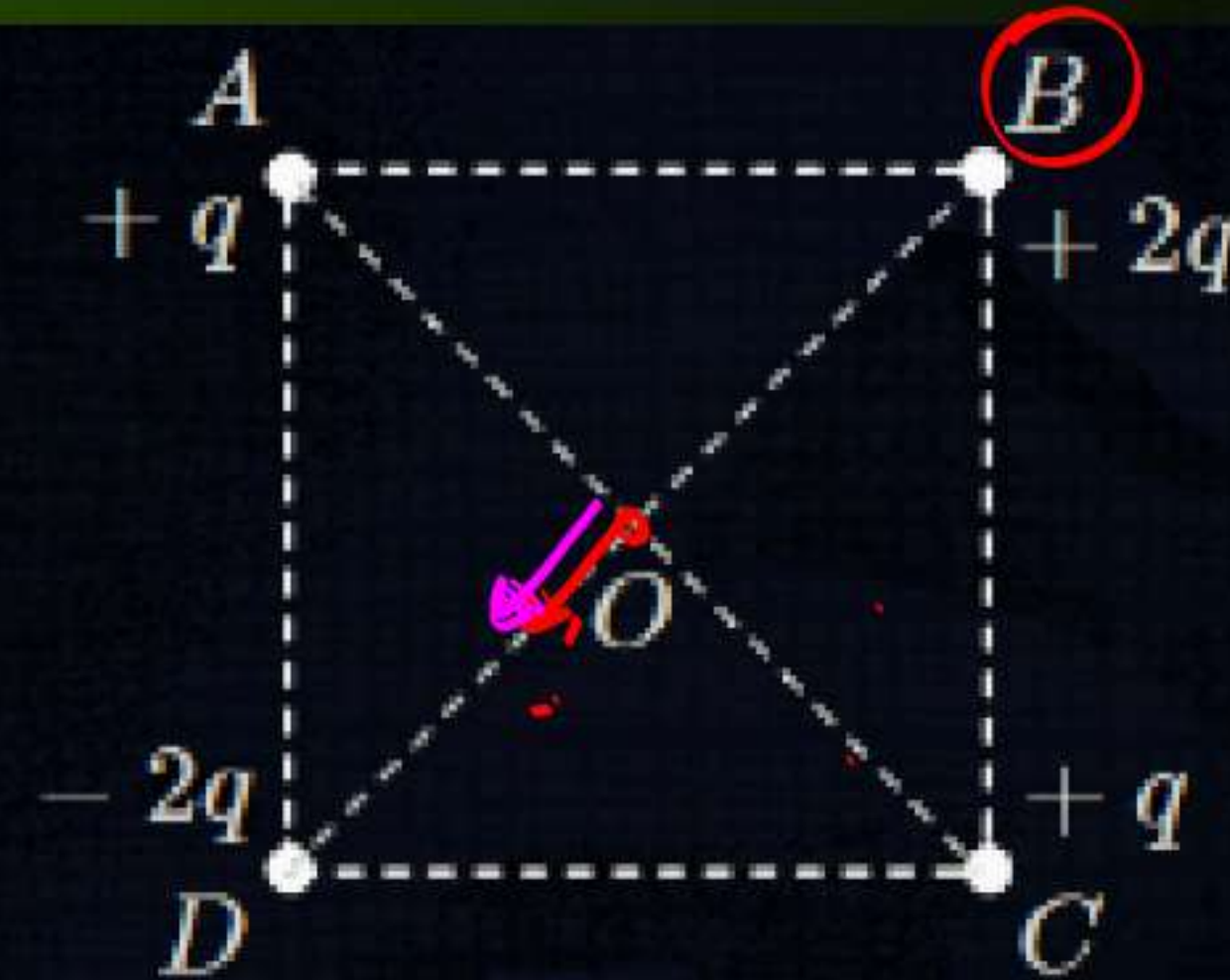
$$ma = qE$$

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

?Que.

Four charges are arranged at the corners of a square ABCD, as shown in the adjoining figure. The force on the positive charge Q kept at the centre O is

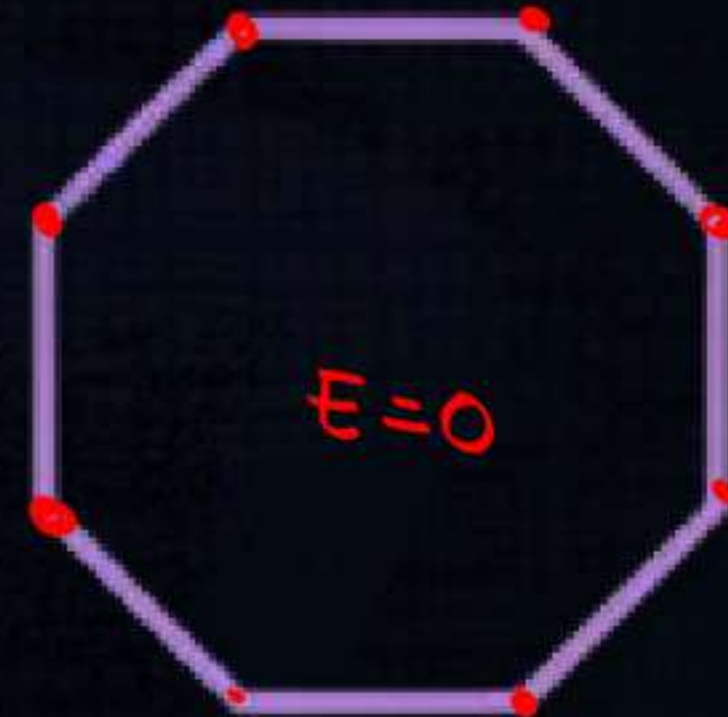
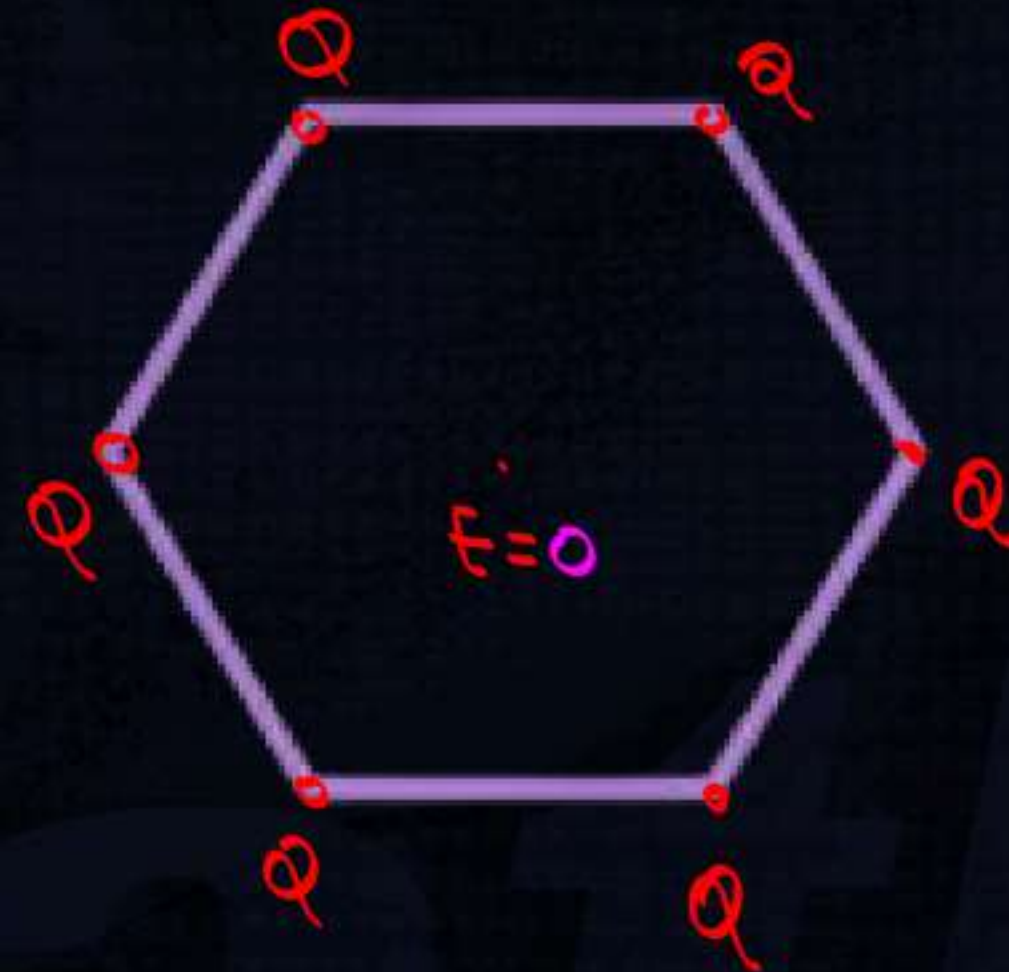
- ☒ a. Zero
- ☐ b. Along the diagonal AC
- ☒ c. Along the diagonal BD
- ☐ d. Along the diagonal AB





SMT

When identical charges are placed on the corners of a regular polygon (symmetric arrangement) then resultant field at centre of the polygon is always zero



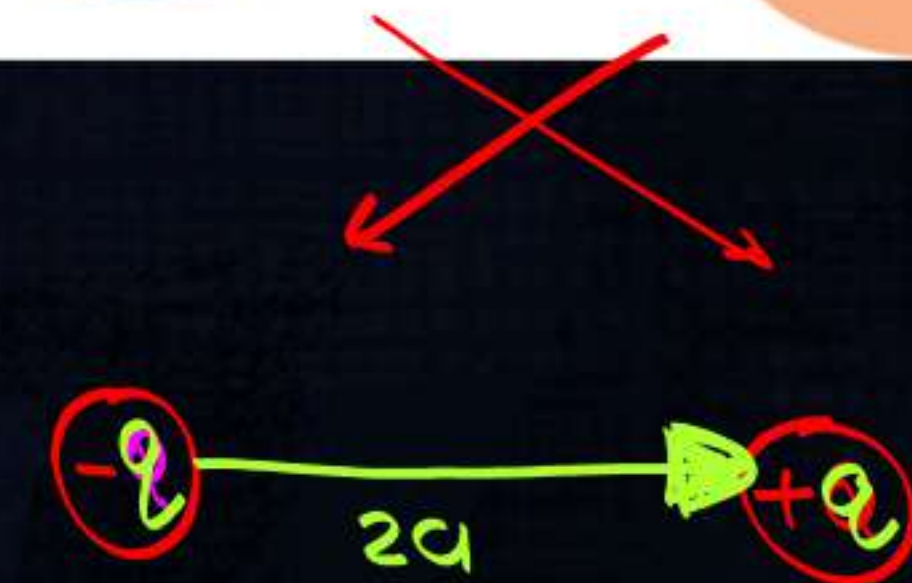
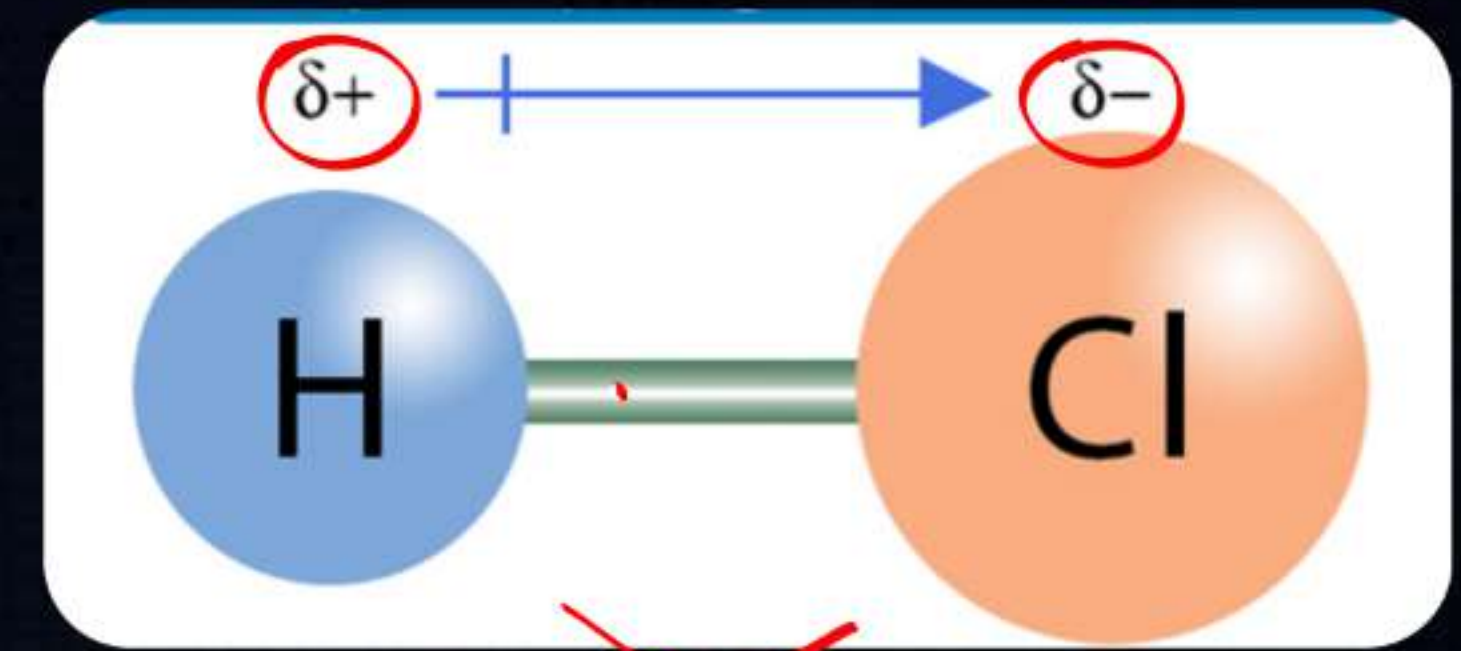
Electric Dipole

An electric dipole is a combination of two equal and opposite charges separated by a small distance.

Electric Dipole Moment

Magnitude : Product of magnitude of either of the charges and the separation distance between them.

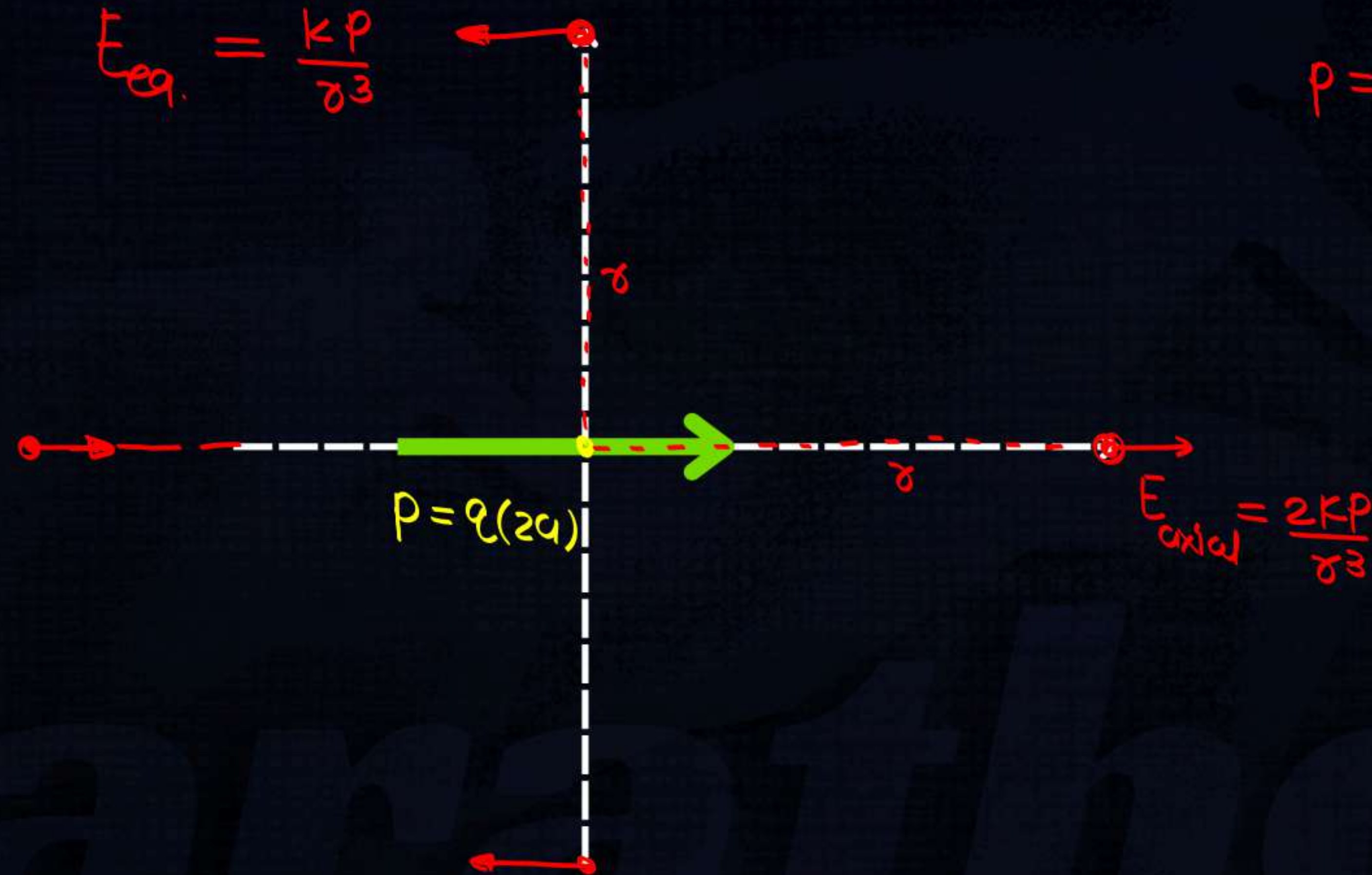
Direction : From the negative charge to positive charge



$$p = (q)(2a)$$

Electric Field due to dipole

[CBSE 2023]



Que.

A point charge is placed at any point on the axis of an electric dipole at some large distance, experiences a force F . The force acting on the point charge when it's distance from the dipole is halved will be **(CUET 2023)**

- ☒ a. $4F$
- ☒ b. $8F$
- c. $F/8$
- d. $F/4$

$$F = \frac{kq^2}{r^2}$$



$$F' \propto \frac{1}{(r/2)^3} = \frac{8}{r^3}$$

$$F = QE$$

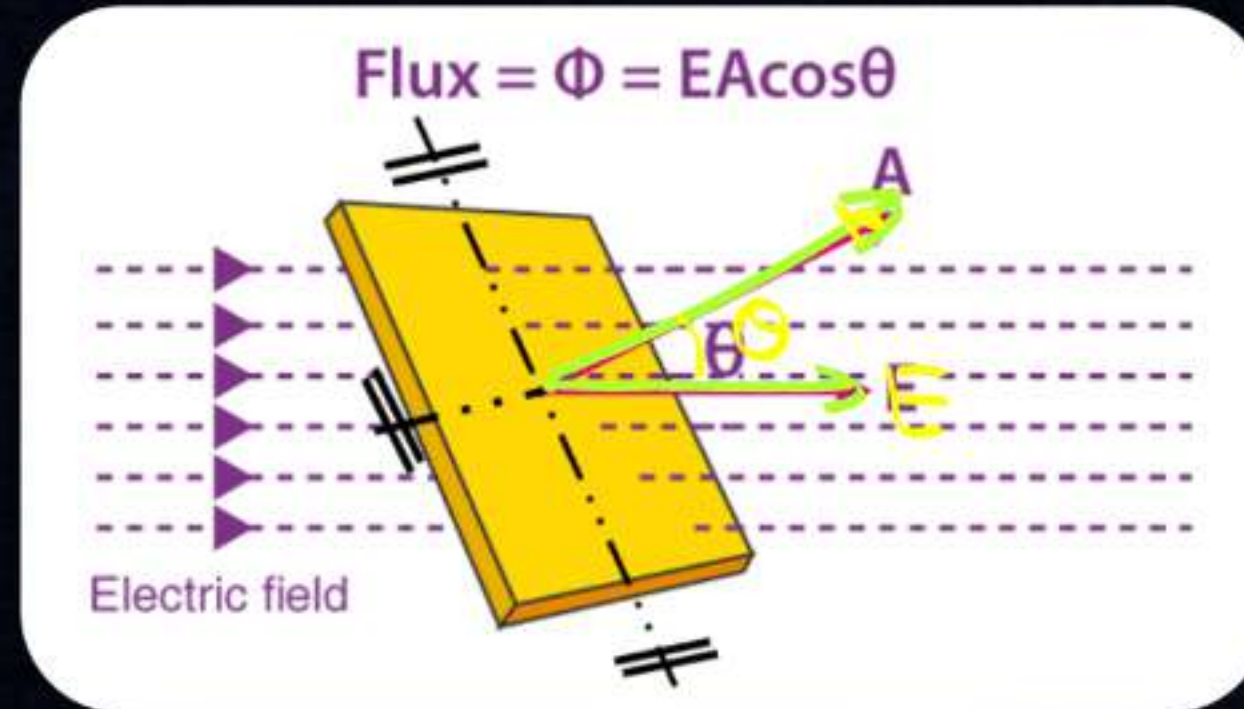
$$F = Q \frac{kp}{r^3}$$

$$F \propto \frac{1}{r^3}$$

Electric Flux (Φ_E)

[CBSE 2024]

Electric flux is the measure of the number of electric field lines passing through a surface used to measure strength of electric field



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

θ Form

$\hat{i}, \hat{j}, \hat{k}$ Form

Non-Uniform E.F.

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

$$\Phi_E = EA \cos \theta$$

$$\Phi_E = E_x A_x + E_y A_y$$

$\theta = 0^\circ$

$\theta = 90^\circ$

$\theta = 180^\circ$

$$\Phi = EA$$

$$\Phi = 0$$

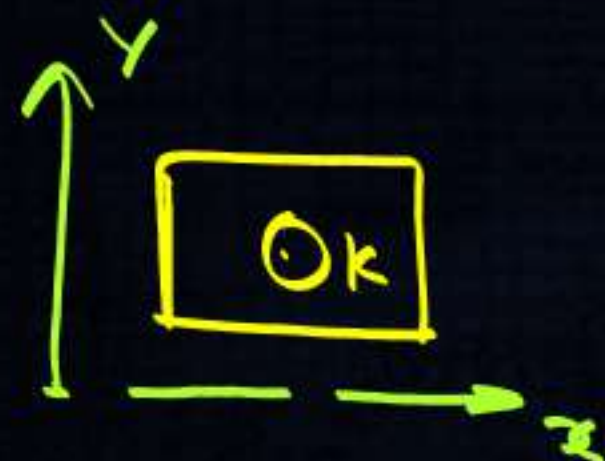
$$\Phi = -EA$$

- Scalar quantity
- Unit : $\text{N m}^2 / \text{C}$
- Dimension : $\text{M}^1 \text{L}^3 \text{T}^{-3} \text{A}^{-1}$

? Que.

If the electric field is given by $\vec{E} = 8\hat{i} + 4\hat{j} + 3\hat{k}$ N/C, Calculate the electric flux through a surface of area 100 m^2 lying in the XY plane.

$$\vec{A} = 100 \hat{k} \text{ m}^2$$



$$\begin{aligned}\Phi_E &= E_x A_x + E_y A_y + E_z A_z \\ &= (3)(100) \\ &= 300 \frac{\text{N}}{\text{C}} \cdot \text{m}^2\end{aligned}$$

 **Que.**

If the electric field is given by $E = 8 \hat{i} + 4 \hat{j} + 3\hat{k}$ N/C, Calculate the electric flux through a surface of area 100 m^2 lying in the XY plane. **[CBSE 2014]**

Ans.

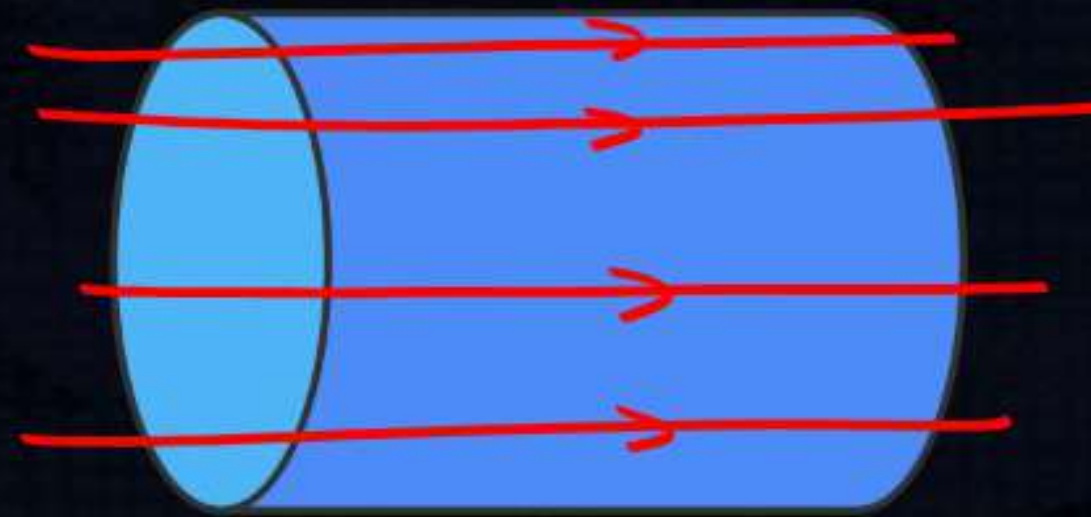
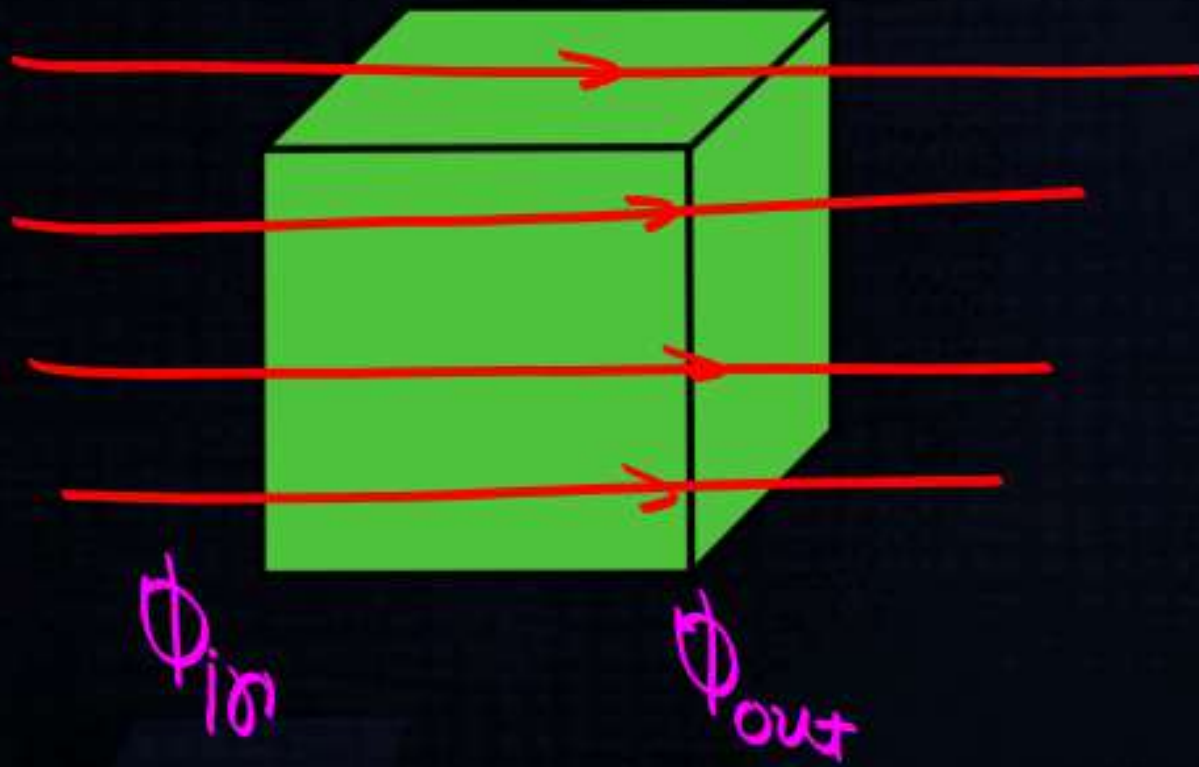
$300 \text{ Nm}^2 / \text{C}$

Marathon



SMT

The **net electric flux** through a closed ^{body} surface placed in a uniform electric field is zero



$$\phi_{\text{net}} = \phi_{\text{in}} + \phi_{\text{out}} = 0$$

(-) (+)

Gauss's Law

[CBSE 2024]

The total electric flux through a closed surface depends only on the **charge enclosed** inside the surface.

Net electric flux through a closed surface = $(1 / \epsilon_0) \times$ total charge inside



$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

↑
all q

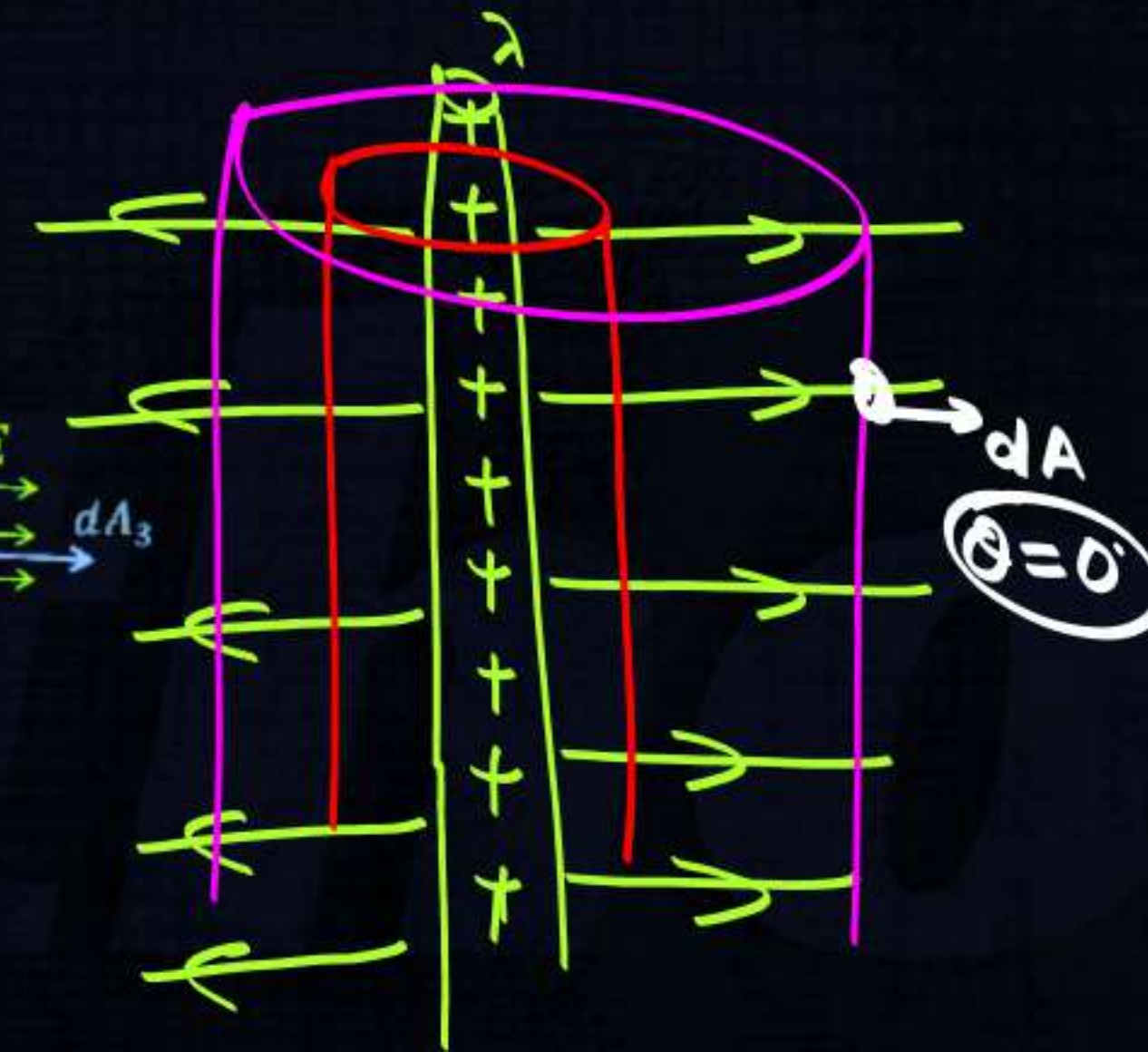
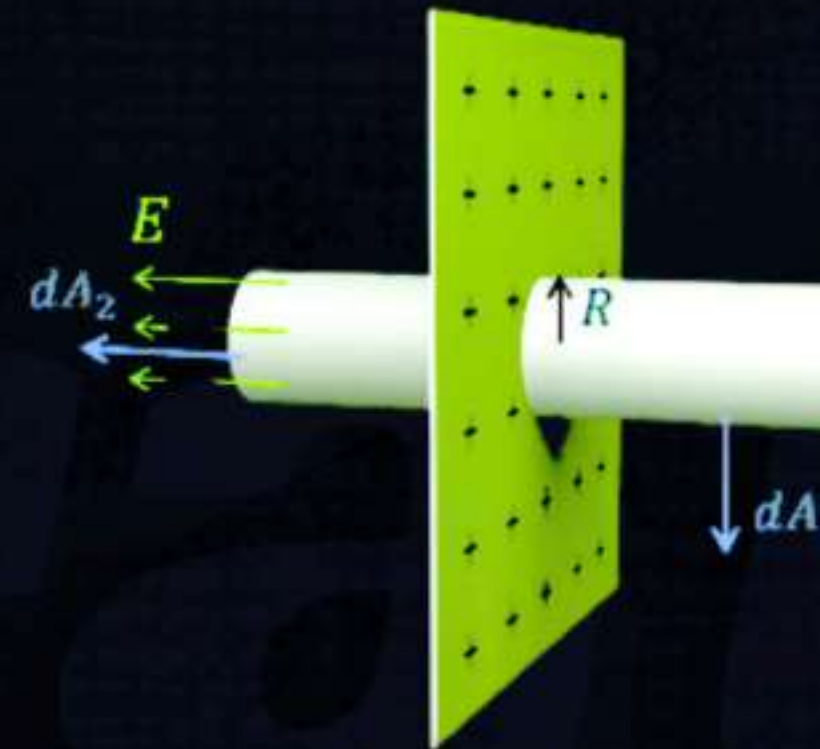
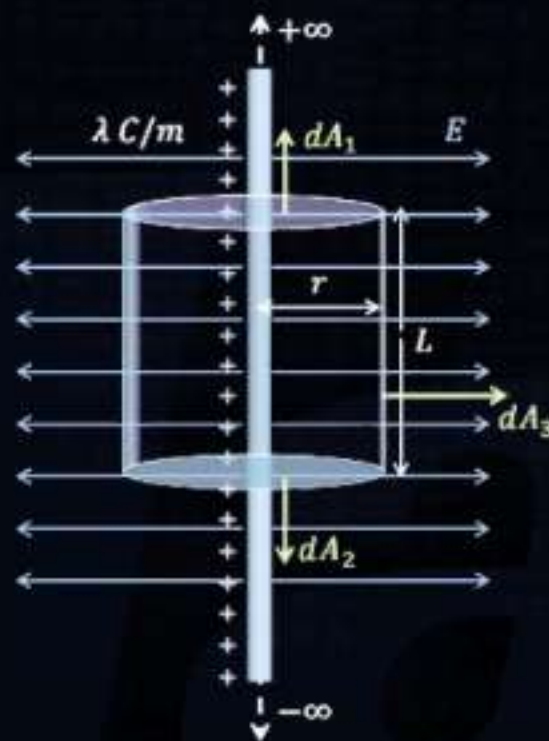
$$\Phi_E = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

Gaussian Surface

A Gaussian surface is an **imaginary closed surface** used to apply Gauss's Law

Keypoints

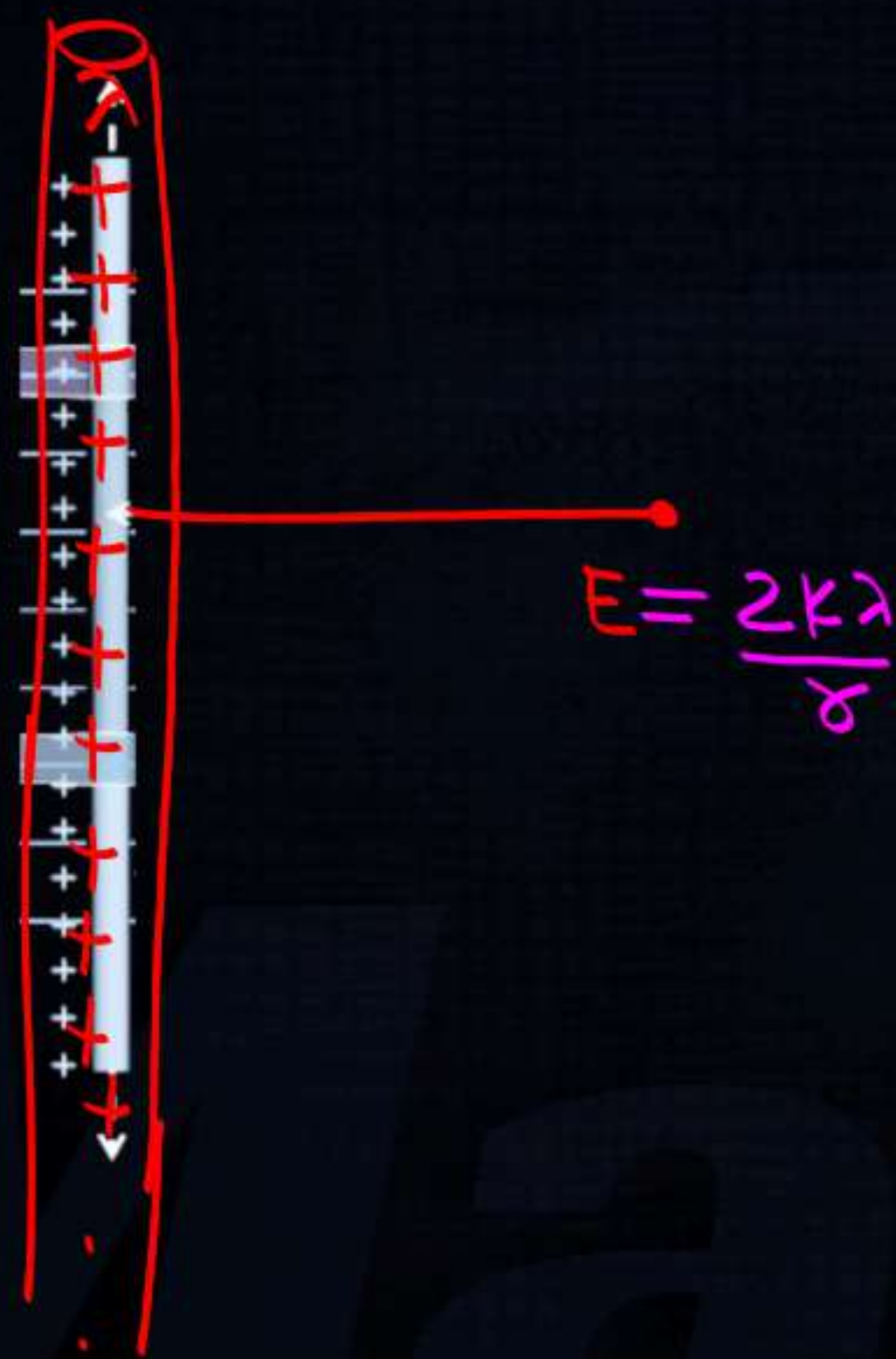
- Can be of any shape, but we choose it based on **symmetry**
- Electric field should be **same** at all points
- ✓ Angle between $\vec{E}$ and **area vector** should be same (0° or 90°) **180**
- Surface should **not pass through a charge**



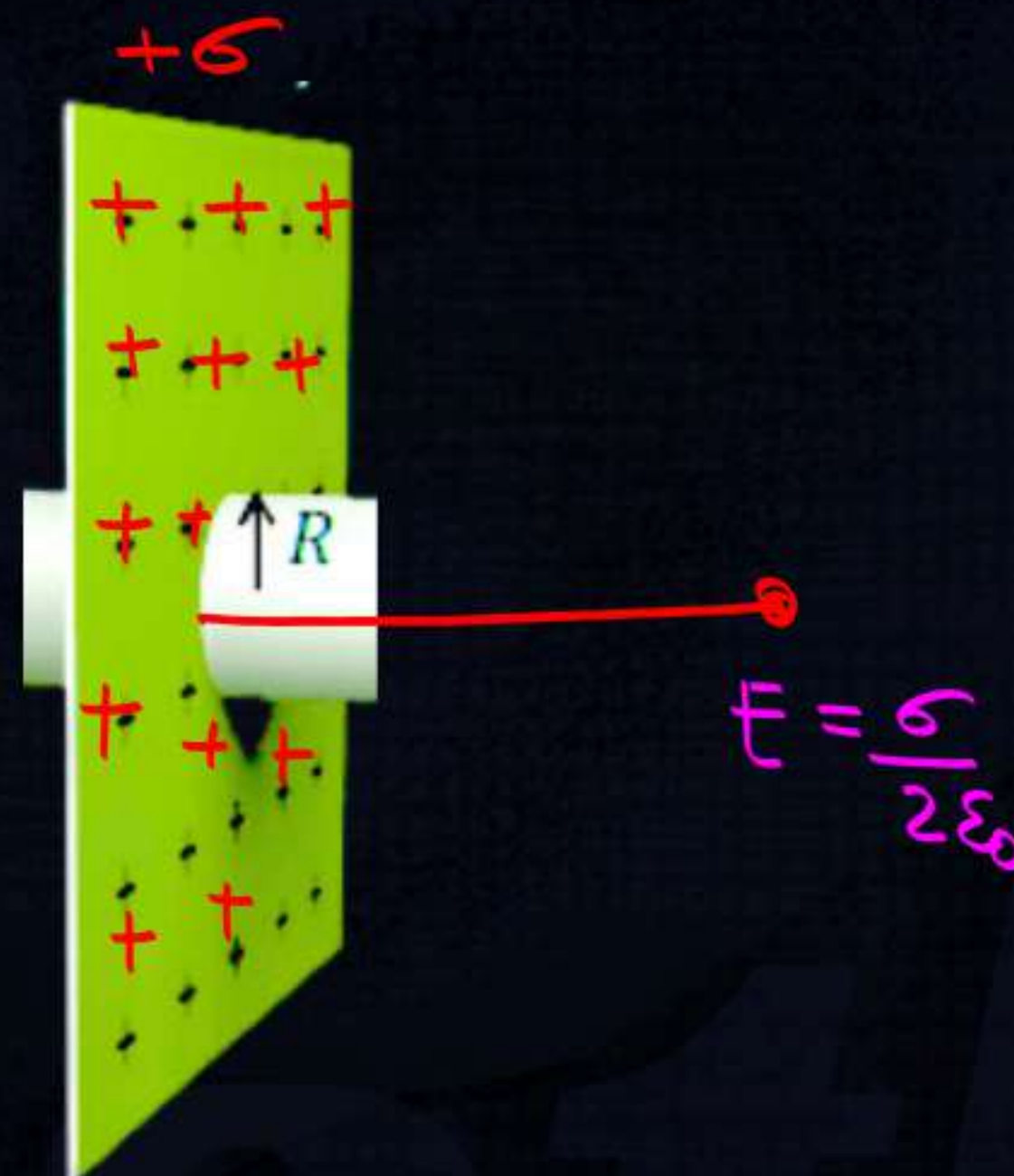
Applications of Gauss's Law

(Derivations)

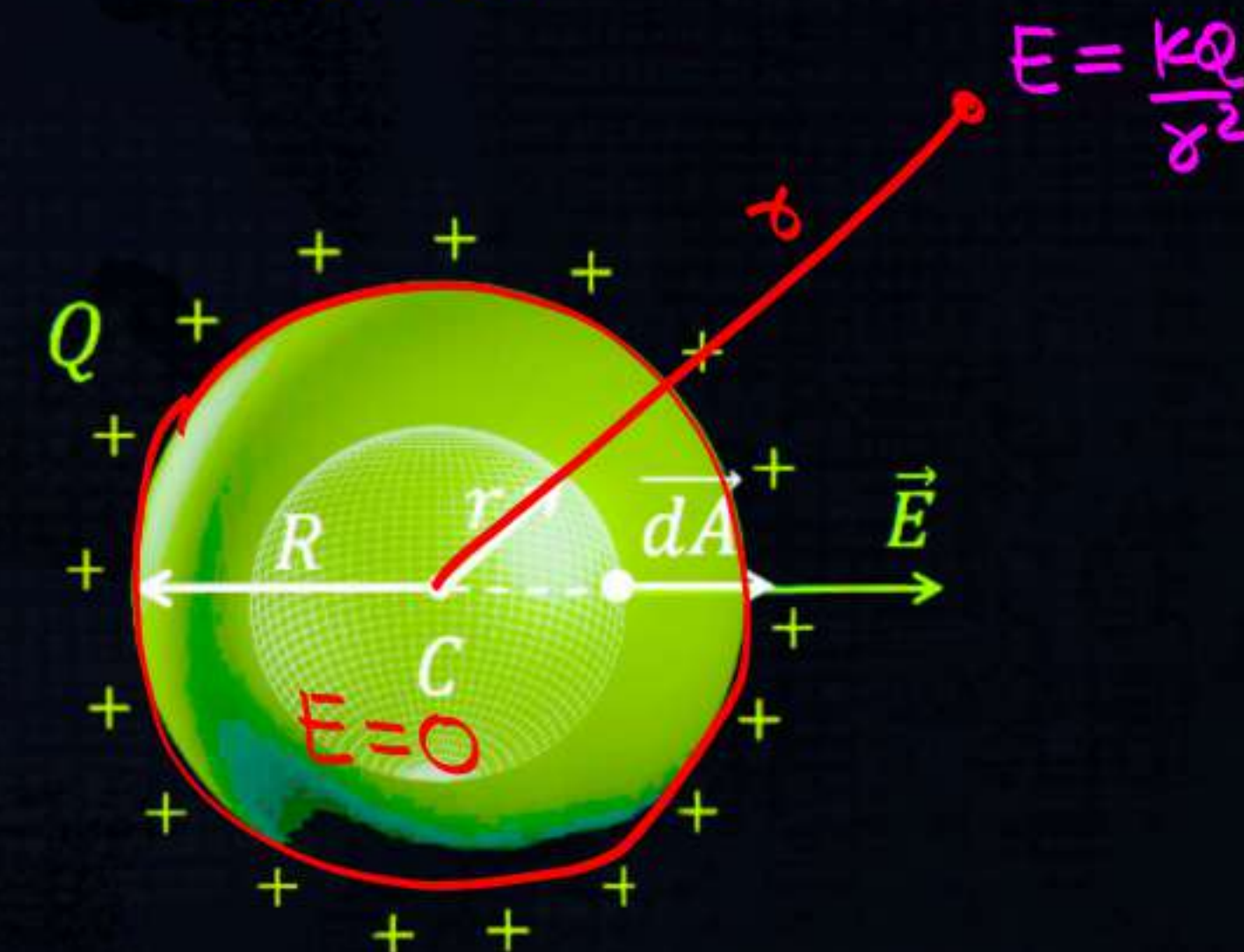
1. Infinite line of charge



2. Large thin sheet Law



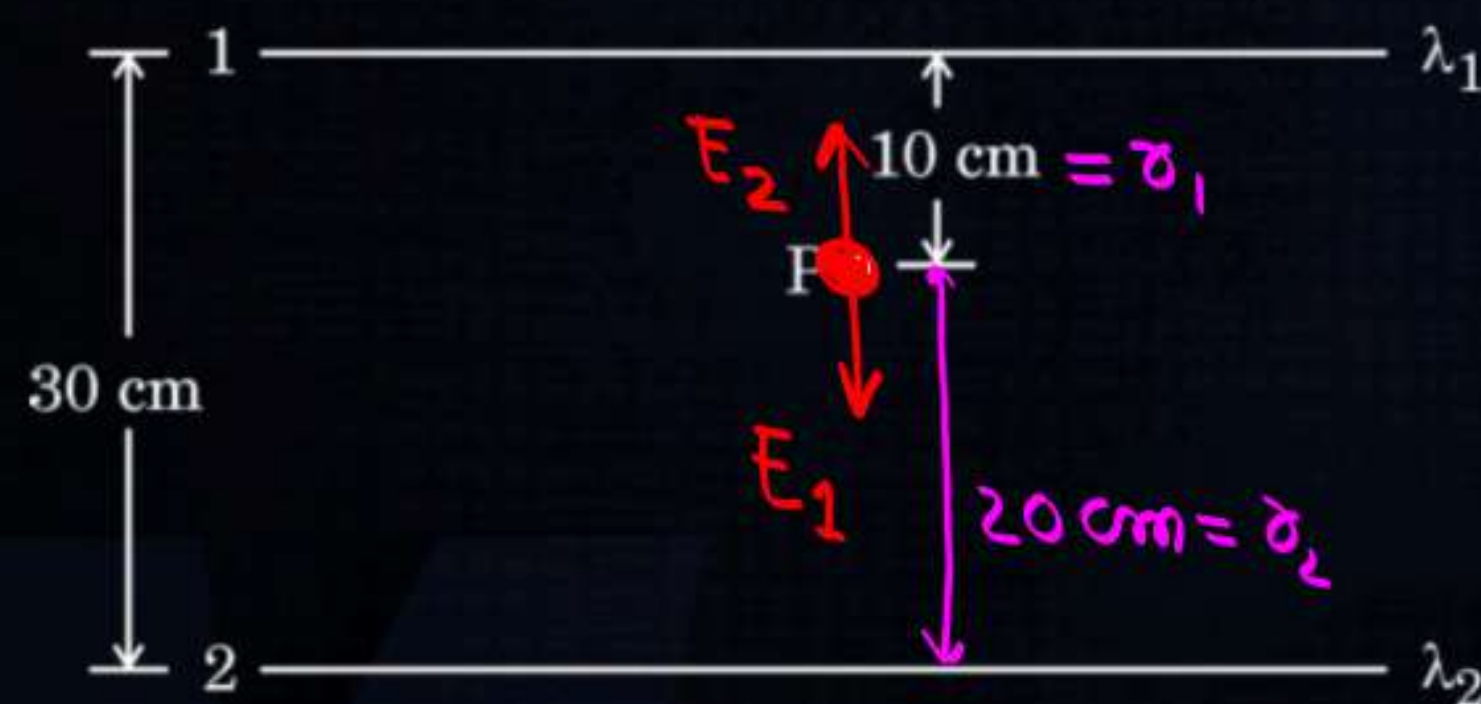
3. Shell



Que.

Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are $\lambda_1 = 10 \mu\text{C/m}$ and $\lambda_2 = 20 \mu\text{C/m}$. Find the net force $\vec{F}$ experienced by an electron held at point P. [CBSE 2014]

$$\vec{F} = qE = (-e) E_{\text{net}}$$



$$E_1 = \frac{2k\lambda_1}{r_1} = \frac{2k \left(10 \frac{\mu\text{C}}{\text{m}} \right)}{10 (\text{cm})} = E$$

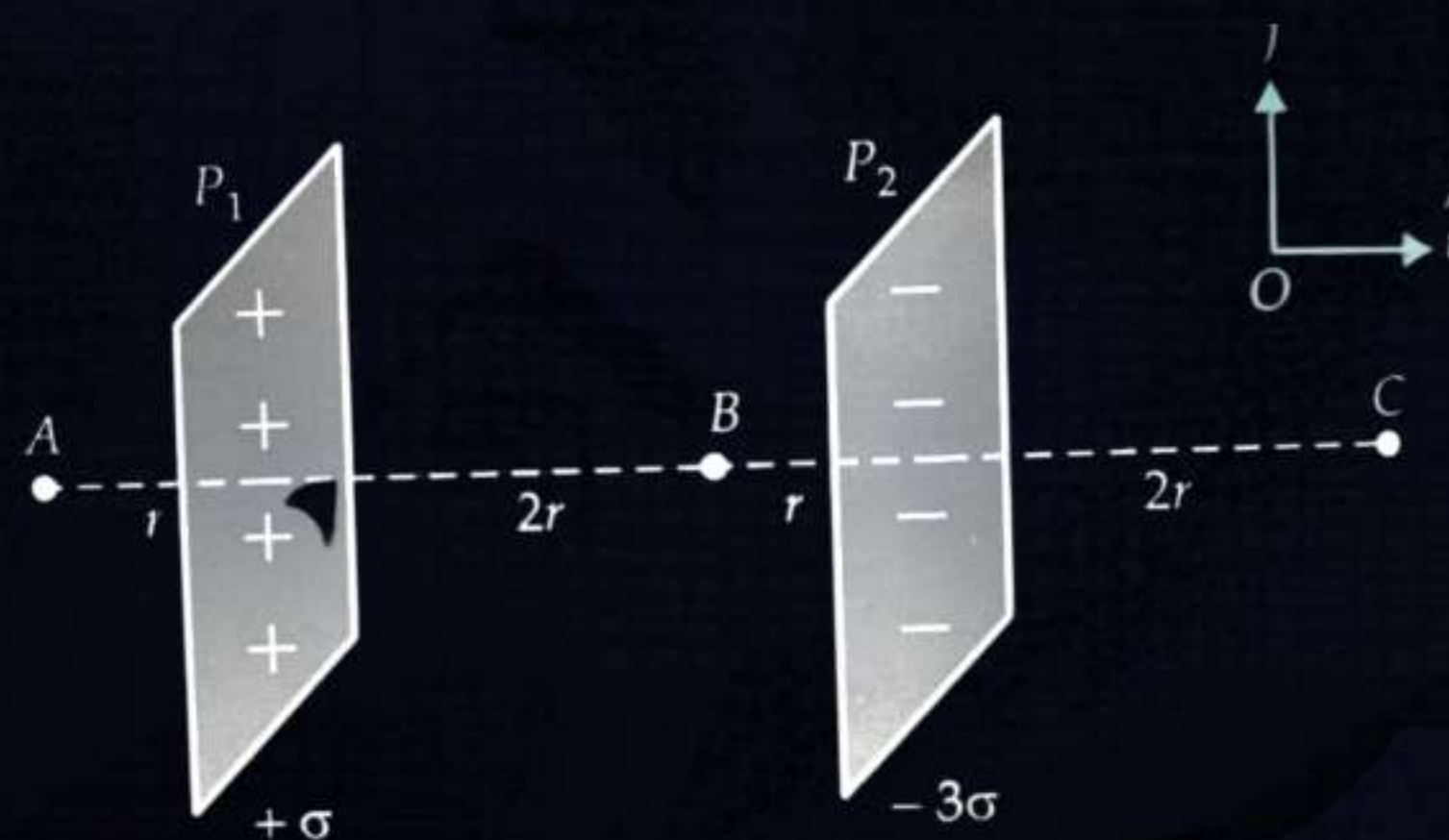
$$E_2 = \frac{2k \left(20 \frac{\mu\text{C}}{\text{m}} \right)}{(20 \text{ cm})} = E$$

$$\begin{aligned} &\Rightarrow E_{\text{net}} = 0 \\ &\therefore F_{\text{net}} = 0 \end{aligned}$$

Que.

- ① Two large plane sheets P_1 and P_2 having charge densities $+\sigma$ and -3σ respectively are arranged parallel to each other as shown in the figure. Find the net electric field (E) at points A, B and C. [CBSE 2024]

"comment"



6:38 PM

Electrostatic Potential & Capacitance

Chapter-2

Marathon

$$\Delta U = -W_{\text{conservative Force}} = W_{\text{ext.}} \quad (\Delta K = 0)$$

Electrostatic Potential Energy

EPE of a point charge, is the amount of work done in bringing the charge from infinity to the present position without changing its kinetic energy.



$$U_{12} = \frac{k q_1 q_2}{r}$$



$$U = \frac{k (-q_1) (-q_2)}{r}$$

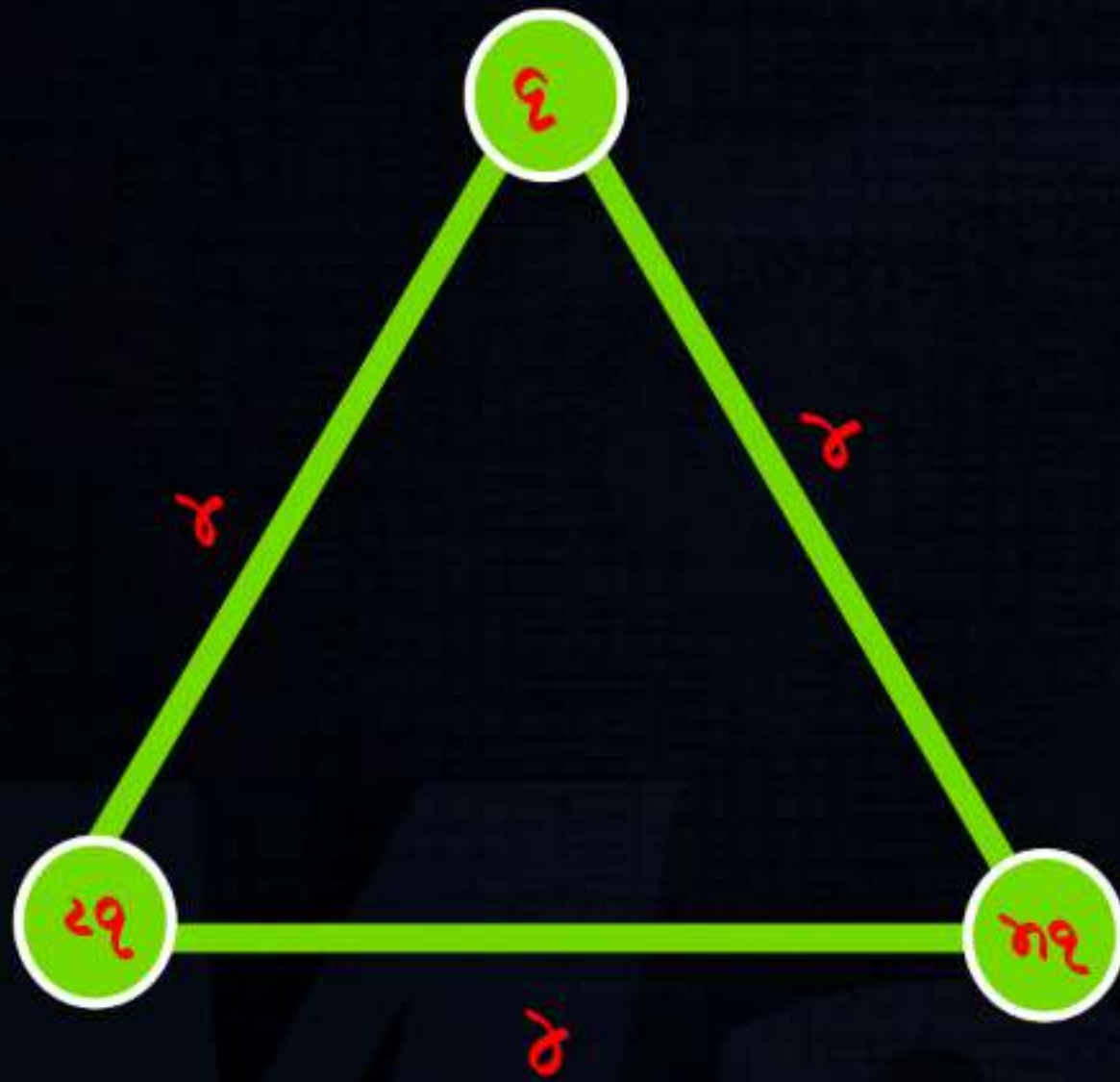


$$U = \frac{k (-q_1) (+q_2)}{r}$$

Que.

Three point charges q , $2q$ and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n .

[CBSE 2024]



$$U_{\text{total}} = \frac{k(q)(2q)}{r} + \frac{k(q)(nq)}{r} + \frac{k(2q)(nq)}{r}$$

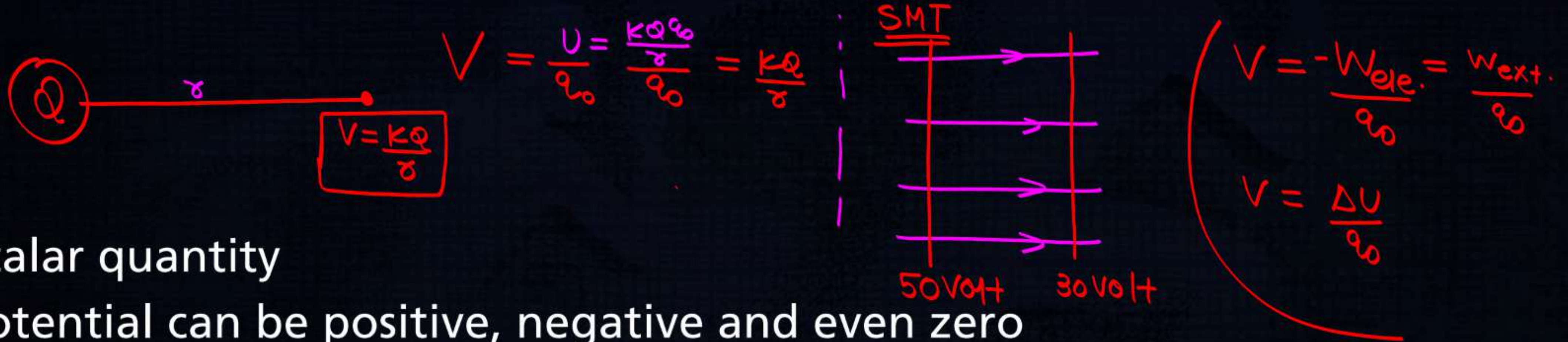
$$0 = \frac{kq^2}{r} [2 + n + 2n]$$

$$0 = 2 + 3n$$

$$n = -\frac{2}{3}$$

Electrostatic Potential

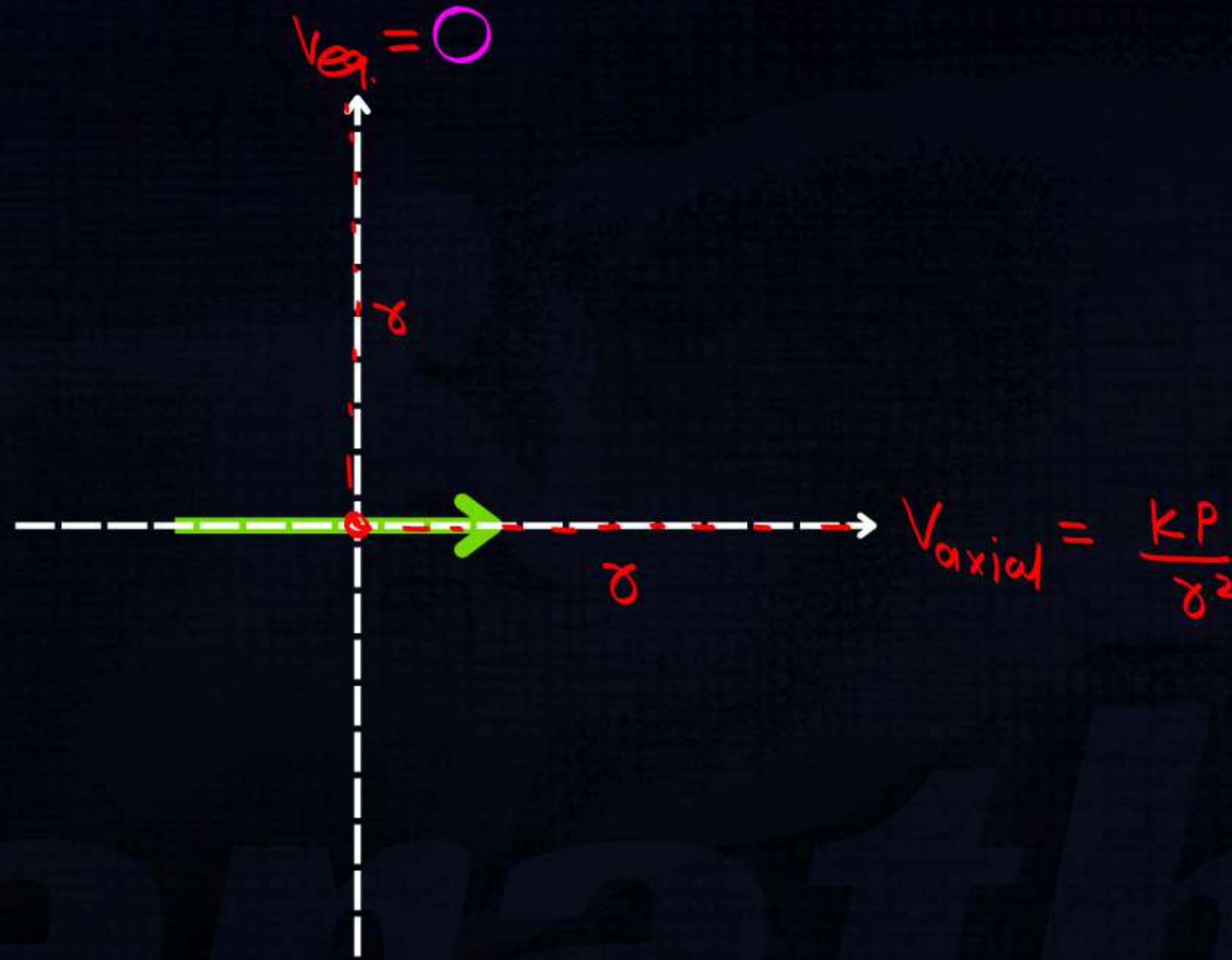
Electric potential at a point is the **amount of work done** in bringing a unit positive test charge from infinity to that point **against electrostatic forces**.



- Scalar quantity
- Potential can be positive, negative and even zero
- S.I. Unit = volt = J/C = Volt
- Dimensional formula = $[M^1 L^2 T^{-3} A^{-1}]$
- Electric potential always decreases in the direction of electric field

Potential due to a Electric Dipole

(Derivation)





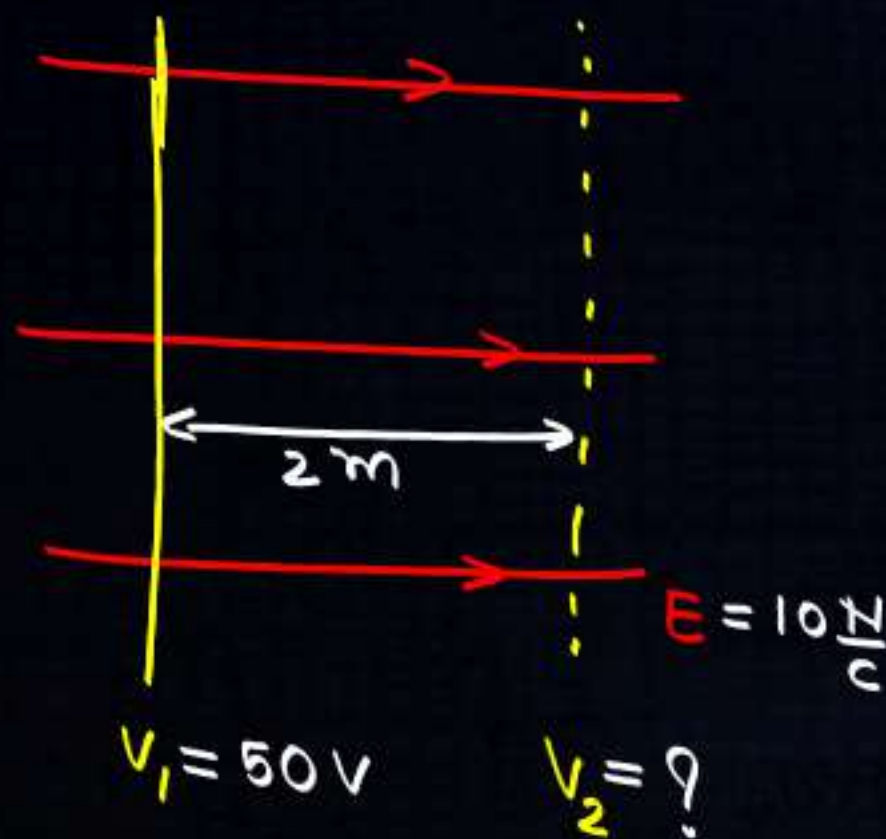
Assertion (A): Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R): It is so because the net potential at O is not zero. [CBSE 2025]

- a. Both Assertion and Reason are True and the Reason is a correct explanation of the Assertion.
- b. Both Assertion and Reason are True but Reason is not a correct explanation of the Assertion.
- ☒ c. Assertion is True but the Reason is False.
- d. Assertion is False but Reason is True.



Relation between E.F. and Potential



$$\int_1^2 dV = - \int \vec{E} \cdot d\vec{s}$$

trick

$$|\Delta V| = E \Delta x$$

$$\Delta V = (10)(2)$$

$$V_1 - V_2 = 20$$

$$50 - V_2 = 20$$

$$V_2 = 30 \text{ Volt}$$

&

$$E = - \frac{\partial V}{\partial s}$$

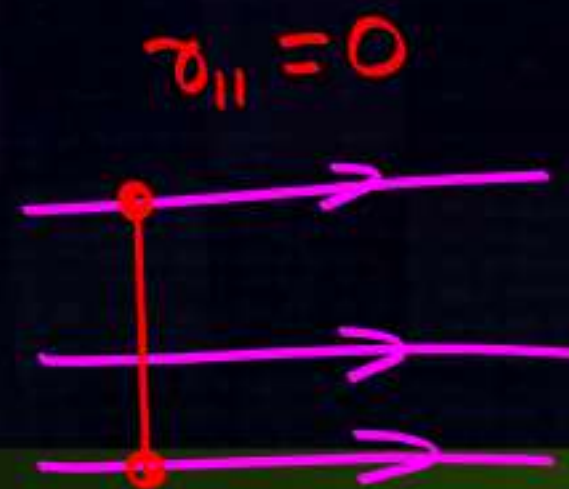
$$E_x = - \frac{\partial V}{\partial x} \quad (y \& z \text{ constant})$$

$$E_y = - \frac{\partial V}{\partial y} \quad (x \& z \text{ constant})$$



Electric field ki direction mein potential decrease hota hai

Que.



Basic
Maths

The electric field in a region is given by

$$\vec{E} = (10x + 4) \hat{i}$$

$$\Delta V = \frac{W}{q} \Rightarrow W = q \Delta V$$

where x is in m and E is in N/C. Calculate the amount of work done in taking a unit charge from

- (i) $(5 \text{ m}, 0)$ to $(10 \text{ m}, 0)$
- (ii) $(5 \text{ m}, 0)$ to $(5 \text{ m}, 10 \text{ m})$

comment

$$\Delta V = 0$$

$$W = 0$$

$$\begin{aligned} \Delta V &= -\int \vec{E} \cdot d\vec{r} = -\int E_x dx \\ &= -\int (10x + 4) \cdot dx \\ &= -\int 10x \cdot dx + -\int 4 \cdot dx \\ &= -10 \left[\frac{x^2}{2} \right] + 4[x] \\ \Delta V &= -5 [x^2]_5^{10} + 4[x]_5^{10} \end{aligned}$$

[CBSE 2024]

$$\begin{aligned} \Delta V &= -5 [100 - 25] + (4)(5) \\ &= -(5(75) + (20)) \\ &= -(375 + 20) \\ \Delta V &= -395 \text{ Volt} \\ W &= q \Delta V \\ &= -395 \text{ J} \end{aligned}$$

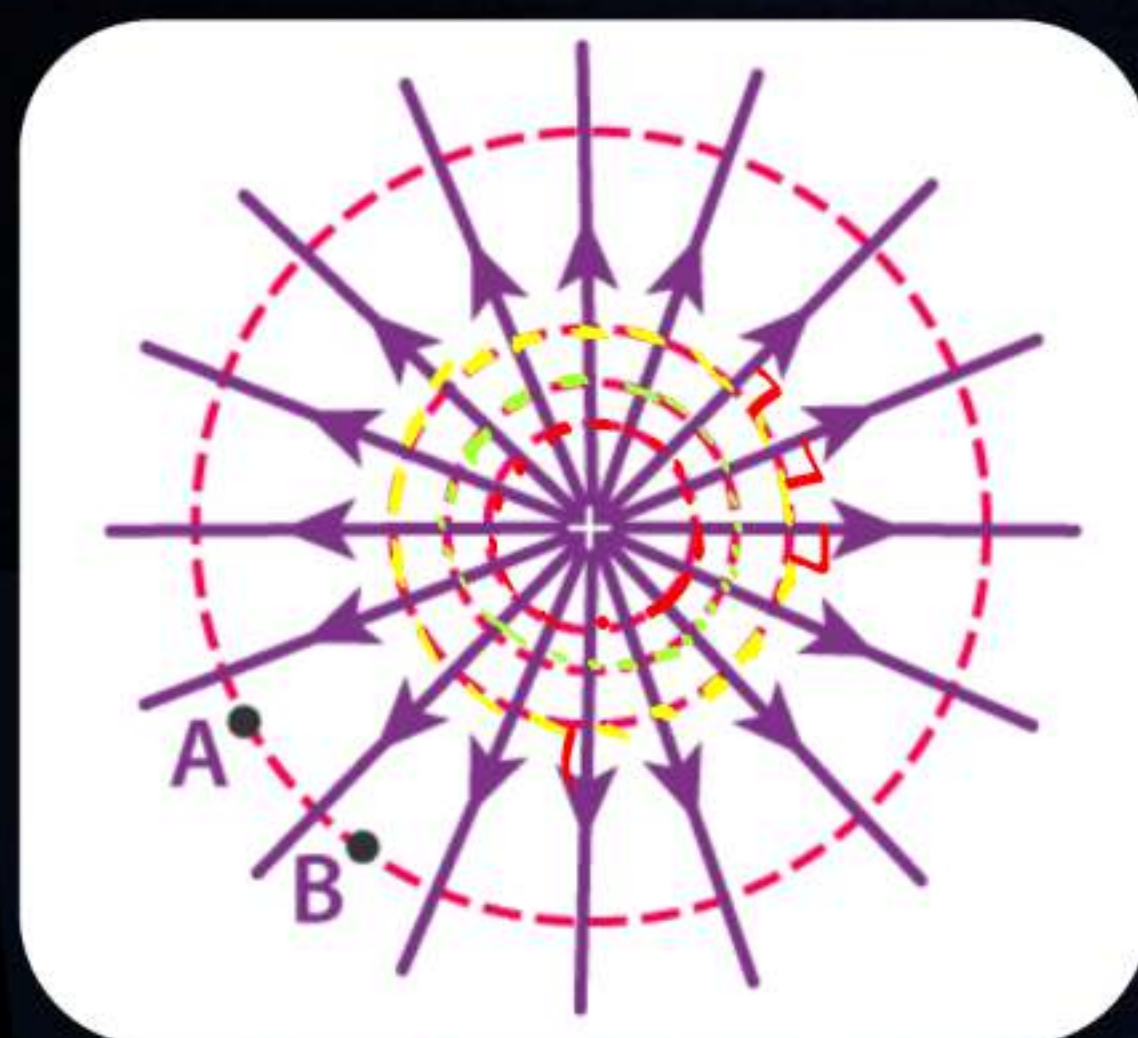
Equipotential Surfaces

(3 Marks)

[CBSE 2024]

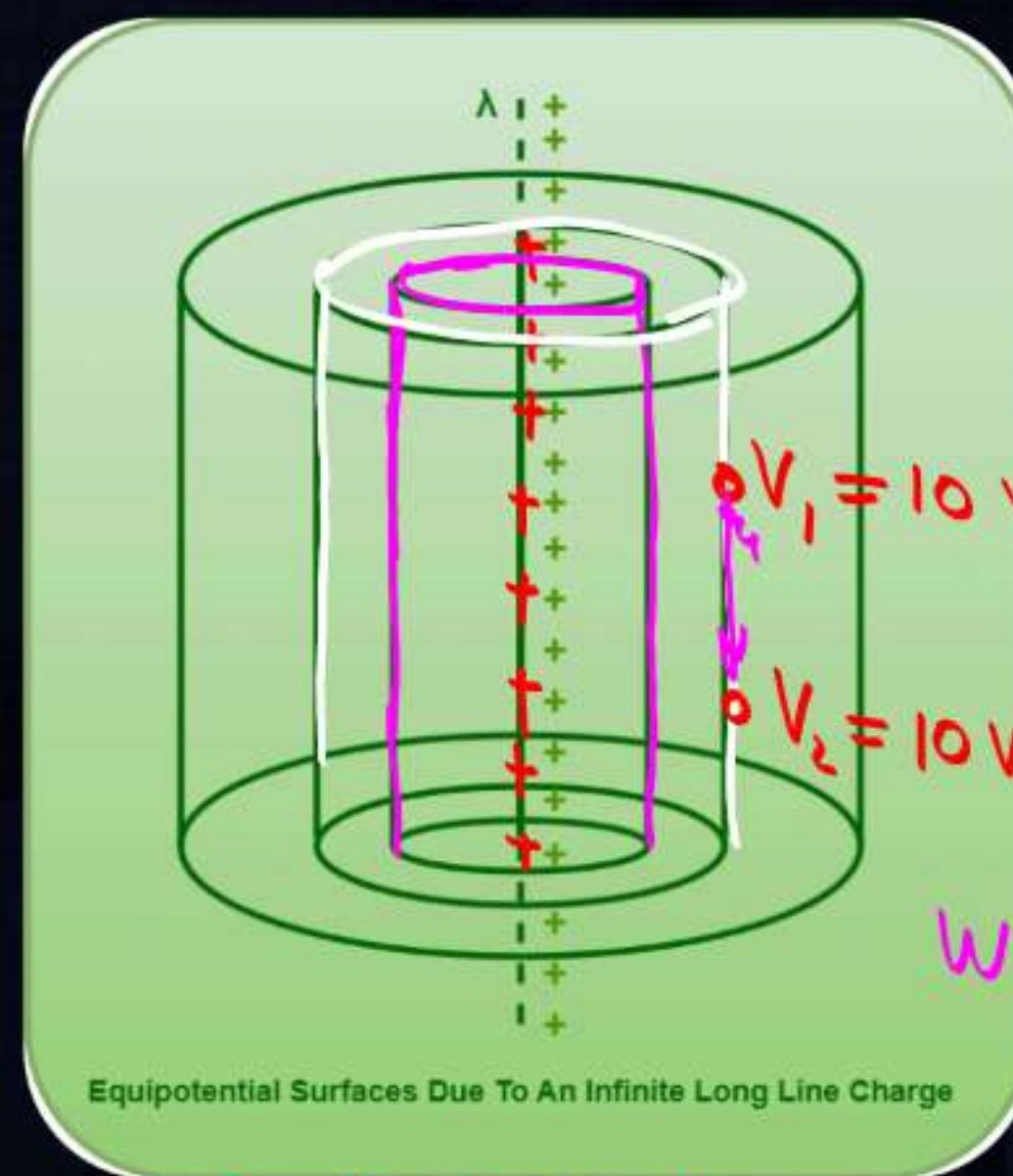
Locus of all such points which are at same potential or the surface at which potential of all the points are equal is known as equipotential surface.

Point Charge



Shell

Line Charge

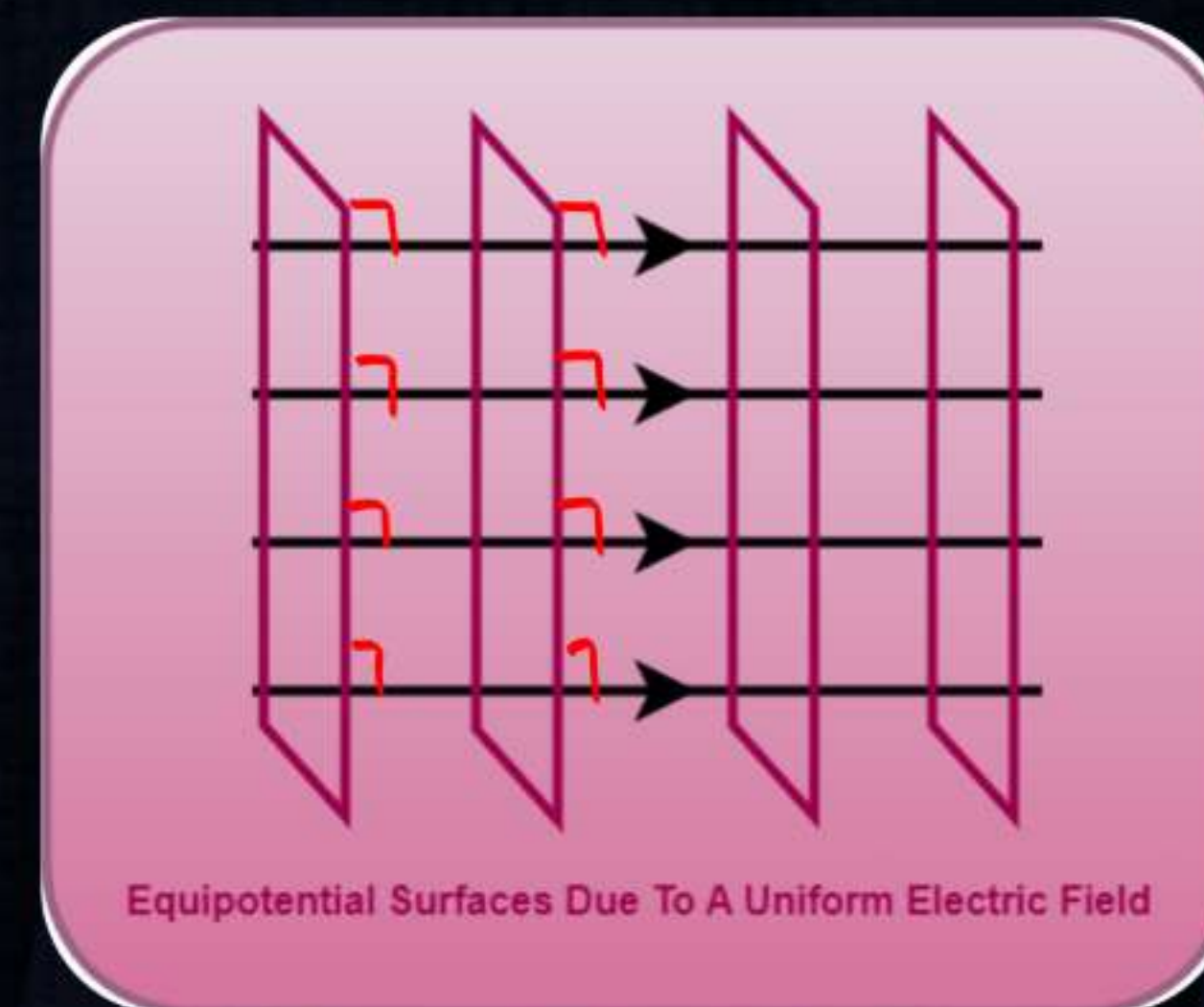


Equipotential Surfaces Due To An Infinite Long Line Charge

cylindrical

$$W = q(\Delta V) \\ = q(0) \\ = 0$$

Uniform Electric Field

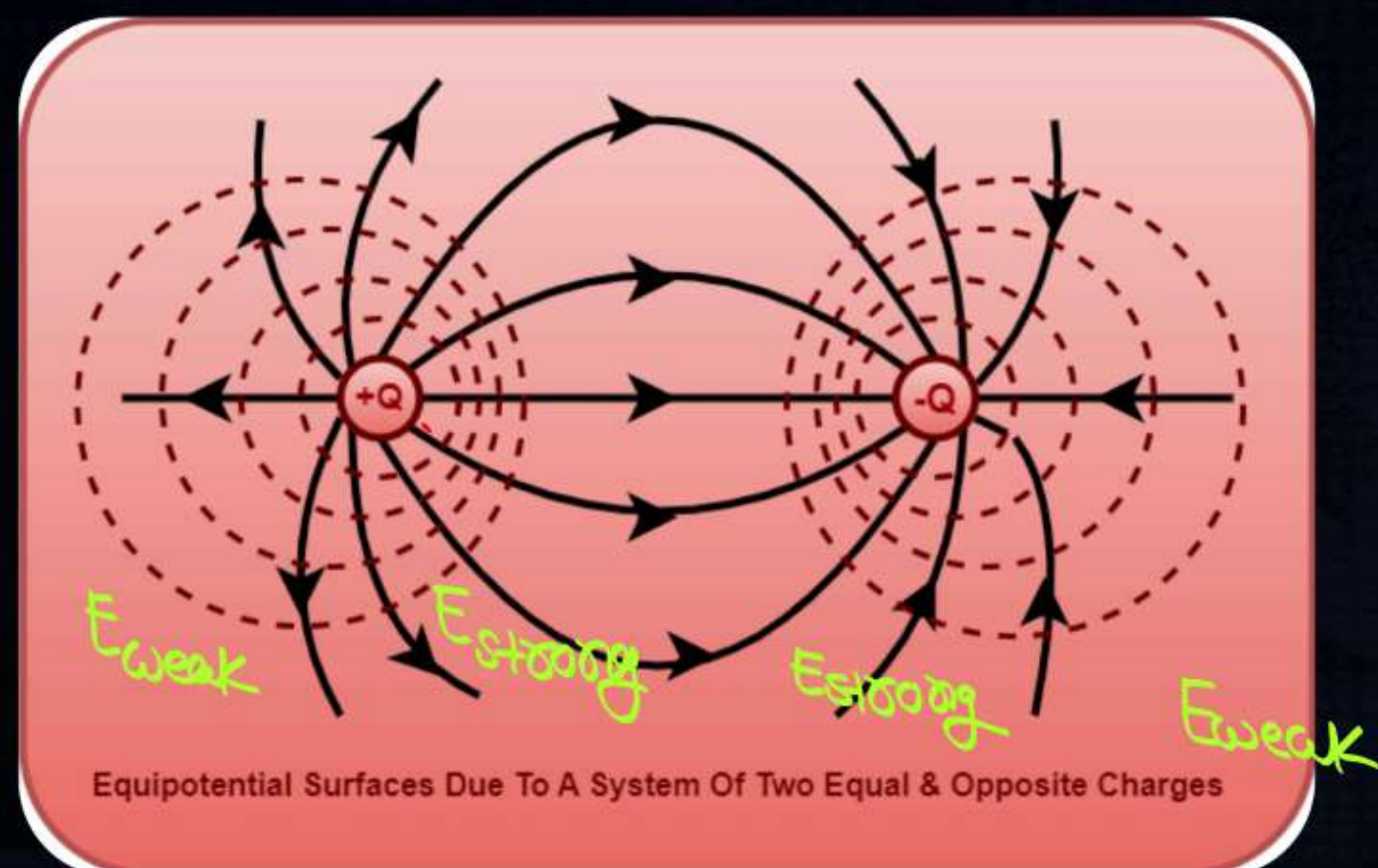


Equipotential Surfaces Due To A Uniform Electric Field

Equipotential Surfaces Of Various Charge Systems

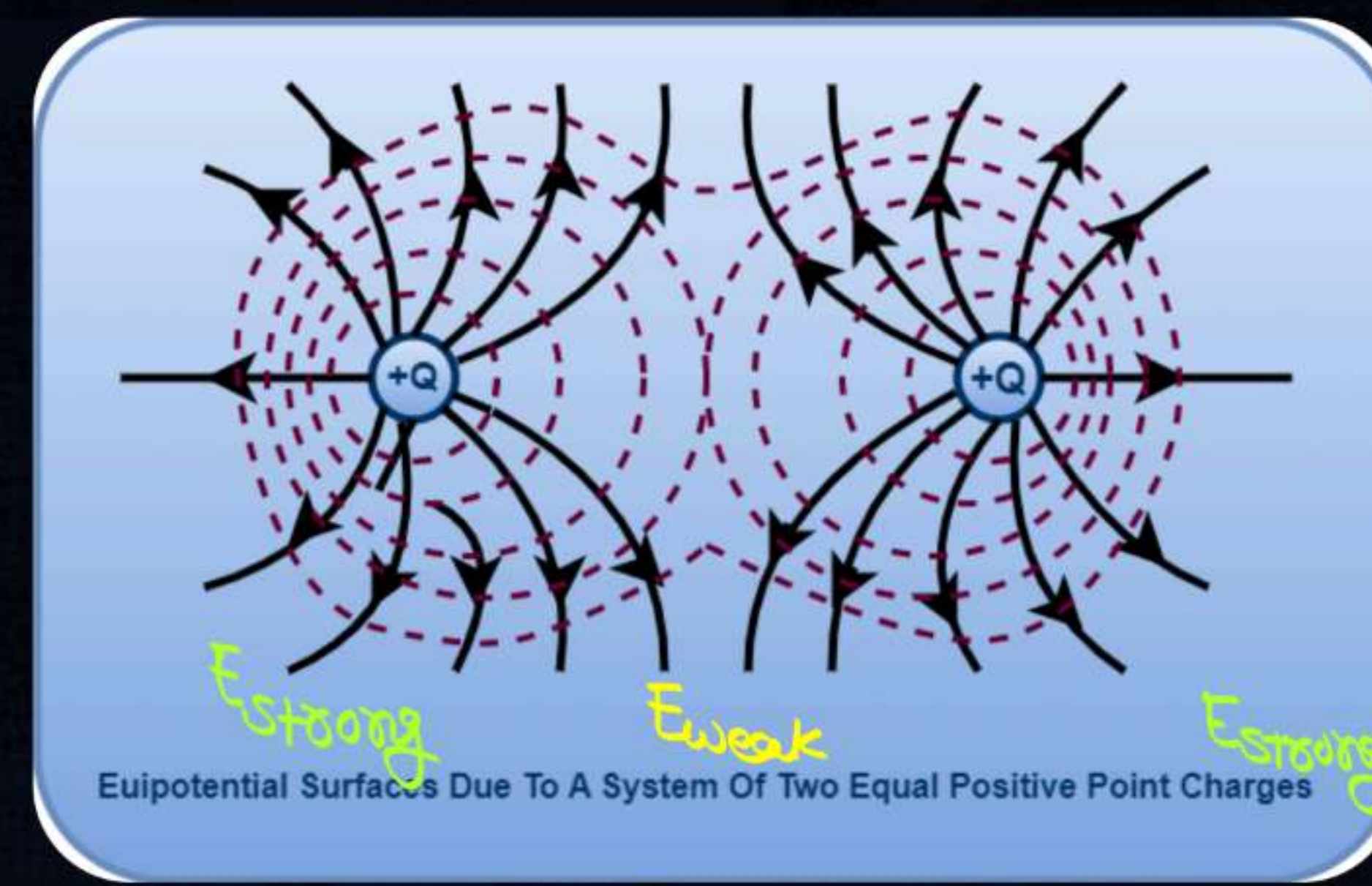
- ✓ 1. The potential difference between any two points on it is zero.
- ✓ 2. No work is done in moving a charge on an equipotential surface
- ✓ 3. Electric field is always perpendicular to an equipotential surface at every point.
- ✓ 4. Equipotential surfaces never intersect, otherwise a point would have two different potentials.
5. Closer the equipotential surfaces, stronger is the electric field in that region

Electric Dipole



Two like charges

[CBSE 2024]

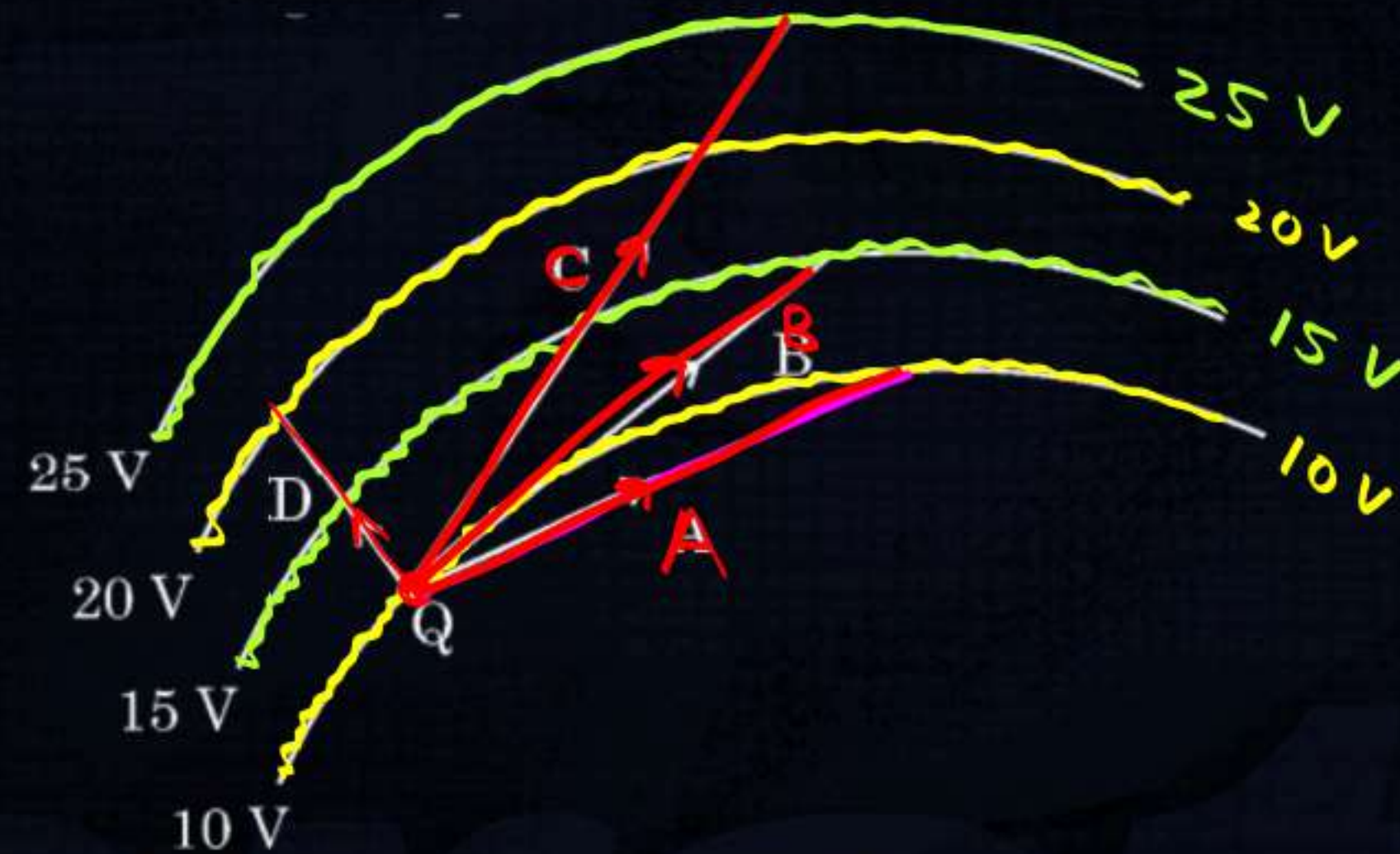


Que.

In the figure curved lines represent equipotential surfaces. A charge Q is moved along different paths A, B, C and D. The work done on the charge will be maximum along the path

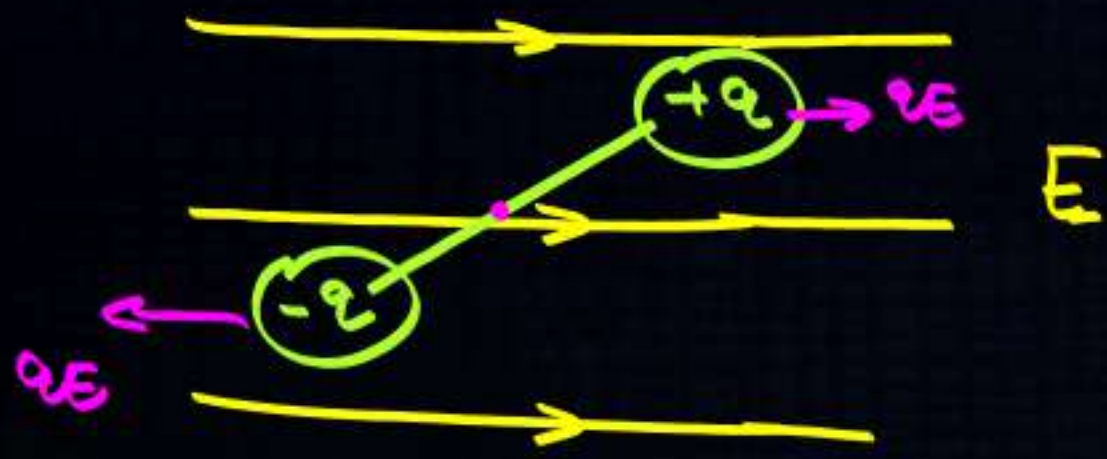
[CBSE 2025]

- a. A
- b. B
- ~~c. C~~
- d. D



Dipole in External Uniform E.Field

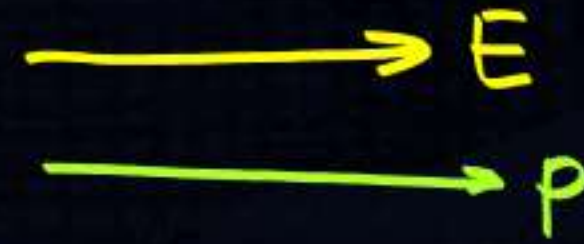
(Derivation)



$$F_{net} = 0$$

$$\tau_E = pE \sin \theta \quad || \quad \vec{\tau} = \vec{p} \times \vec{E}$$

$$U = -pE \cos \theta \quad || \quad U = -\vec{p} \cdot \vec{E}$$

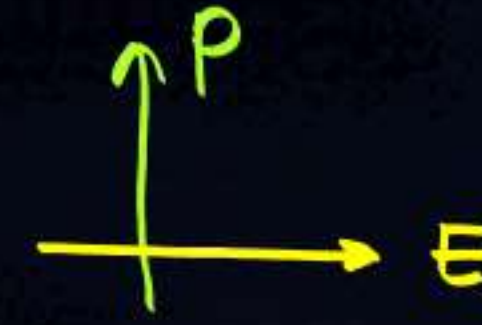


$$\underline{\underline{\theta = 0^\circ}}$$

$$* \tau = 0$$

$$* U_{min} = -pE$$

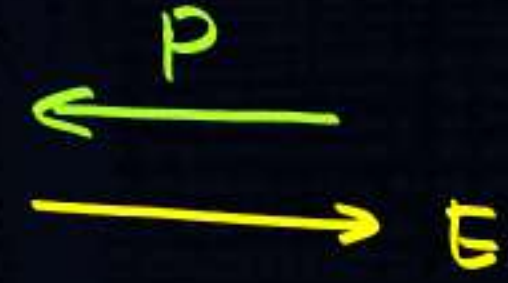
"Stable Eq"



$$\underline{\underline{\theta = 90^\circ}}$$

$$* \tau_{max} = pE$$

$$* U = 0$$



$$\underline{\underline{\theta = 180^\circ}}$$

$$* \tau = 0$$

$$* U_{max} = pE$$

"Unstable Equilibrium"



An electric dipole of dipole moment p is kept in a uniform electric field E . The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be [CBSE 2024]

- ☒ a. $2 pE$
- ☐ b. $-2pE$
- ☐ c. pE
- ☐ d. zero

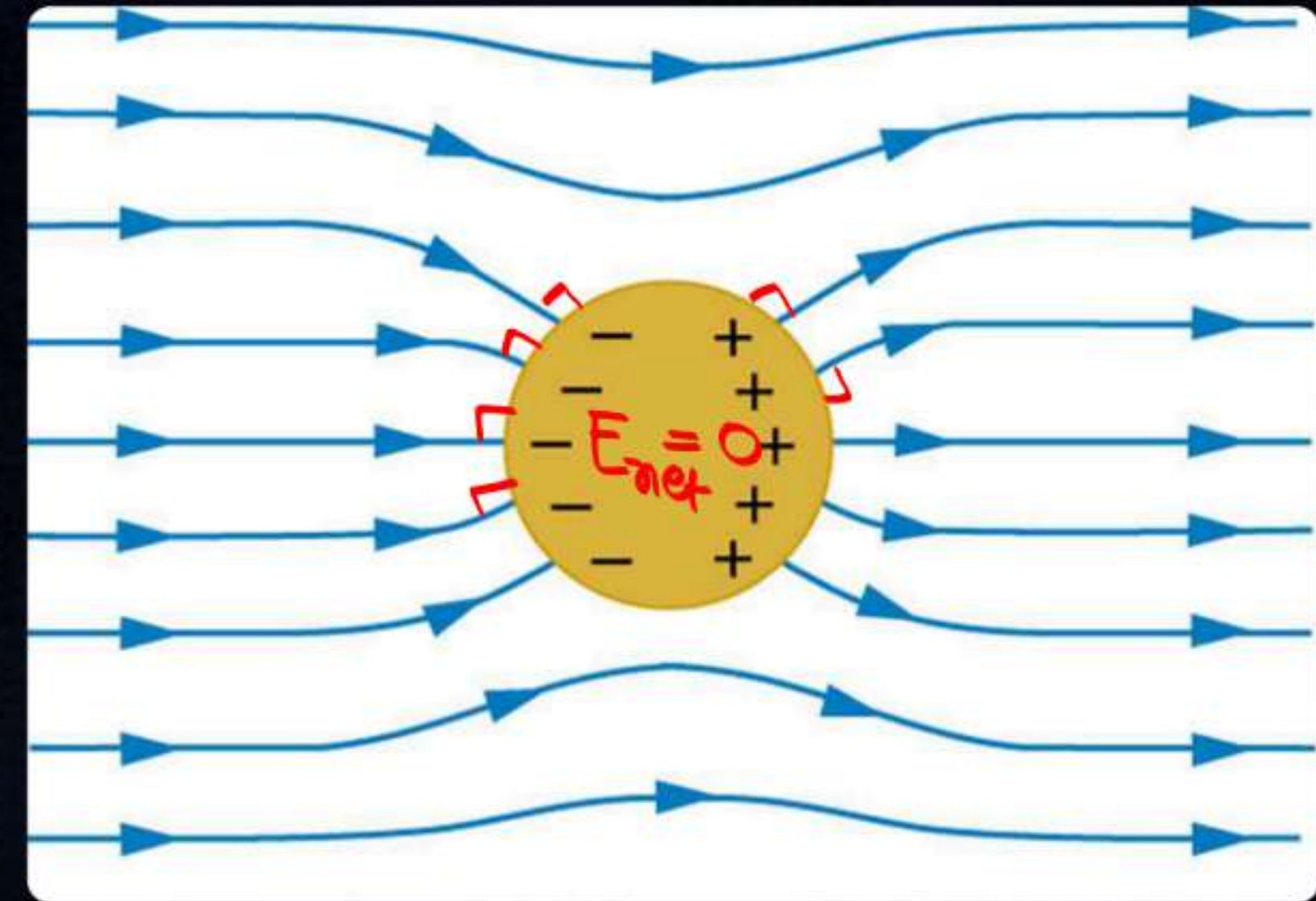
$$W_{\text{ext.}} = \Delta U = U_{\theta_f} - U_{\theta_i} = pE - (-pE) = 2pE$$

(180°) (0°)

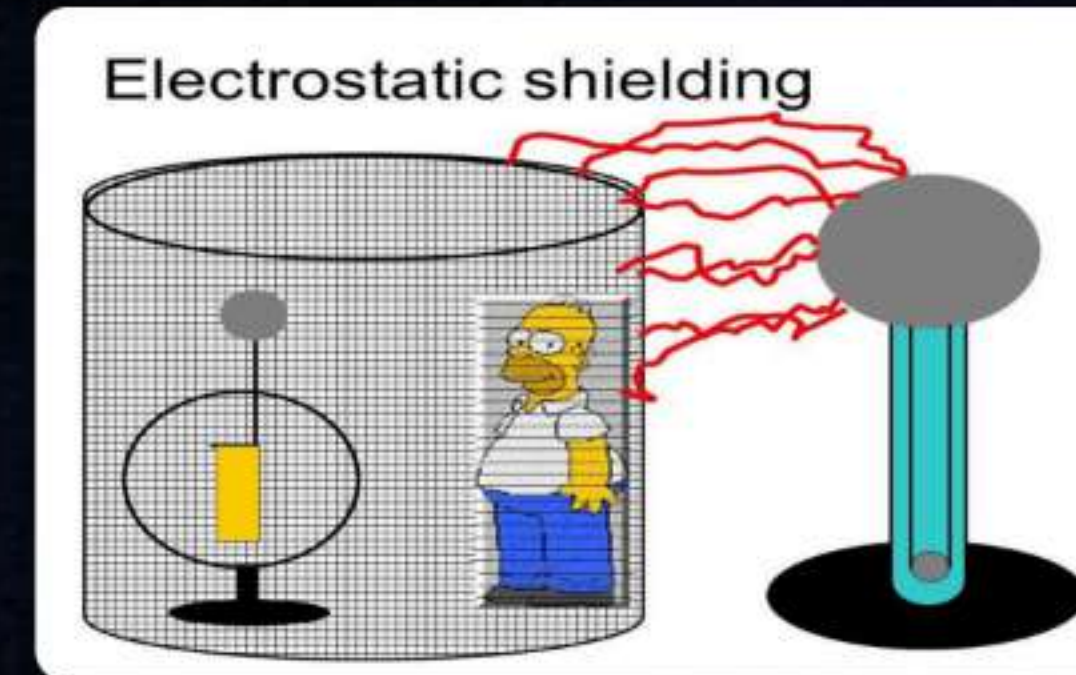
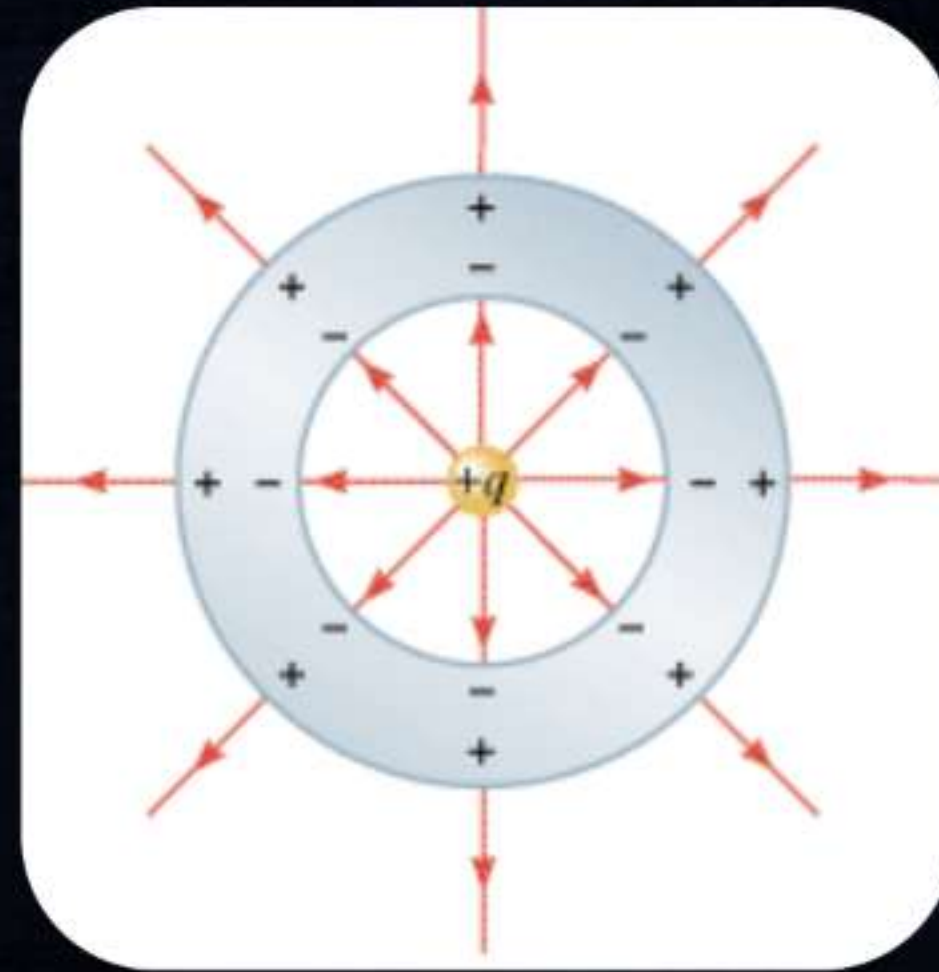
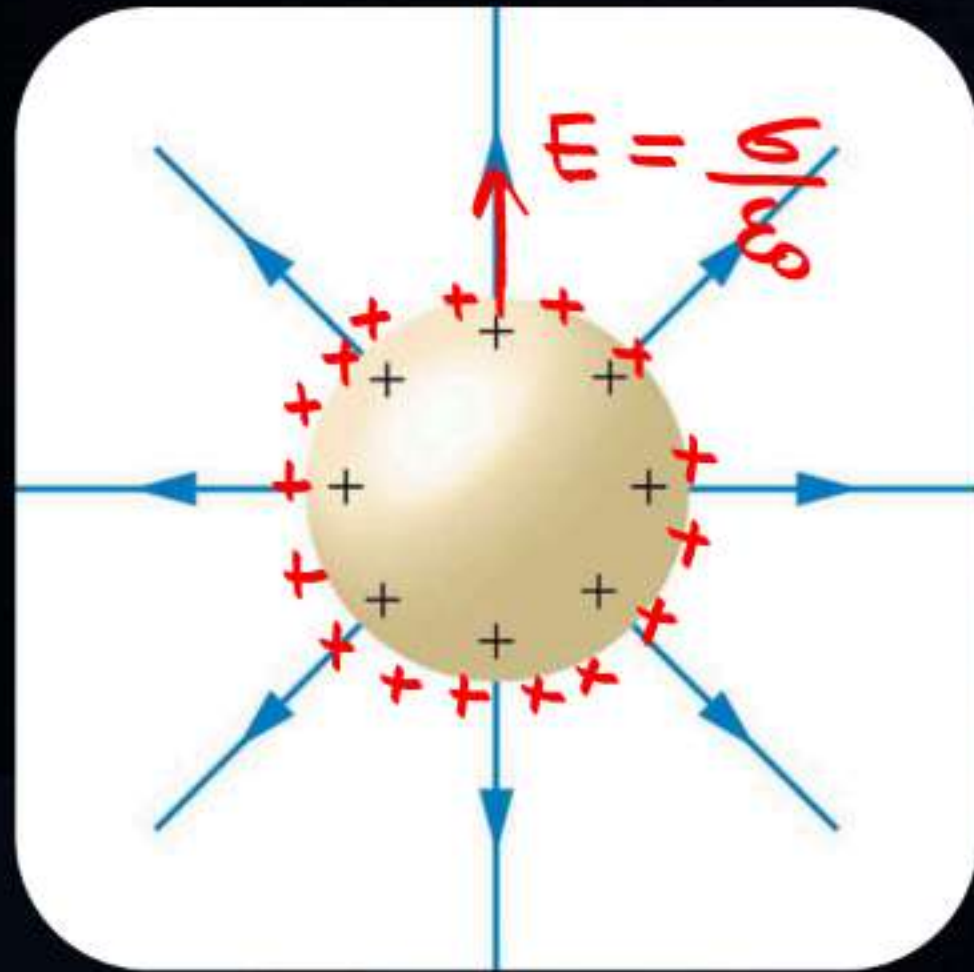
Conductors

Conductors are materials that allow electricity to flow through them easily

1. A conductor contains a large number of free electrons which can move easily within the material.
2. Net electrostatic field is zero in the interior of a conductor.
3. Just outside the surface of a charged conductor, electric field is normal to the surface.



4. **Electric field** at the surface of a charged conductor is **proportional** to the **surface charge density**.
5. **Potential is constant** within and on the surface of a conductor.



Handwritten notes for a charged sphere of radius R :

- Inside the sphere ($r < R$): $E = 0$
- On the surface ($r = R$): V_{surface}
- Inside the sphere ($r < R$): V_{inside}
- Equation: $V_{\text{inside}} = V_{\text{surface}} = \frac{kQ}{R^2}$

- This happens because the **induced charges** on the outer surface arrange themselves to exactly cancel the external field within the conductor and its cavity.
- Therefore, the cavity inside a conductor remains completely shielded from all external electric influences.
- This phenomenon is called **Electrostatic Shielding** and is the reason sensitive electronic components are kept inside metal containers (Faraday cages).

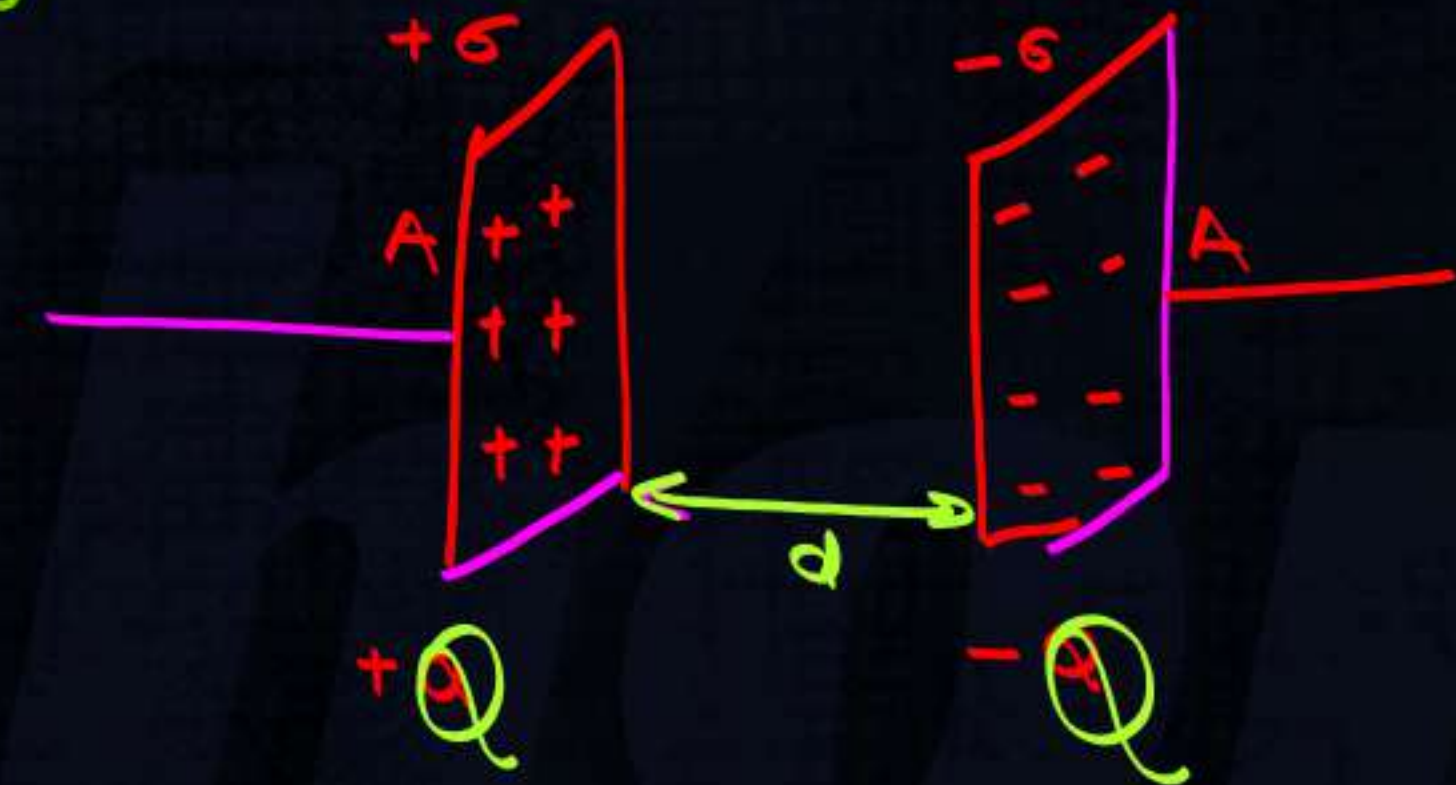
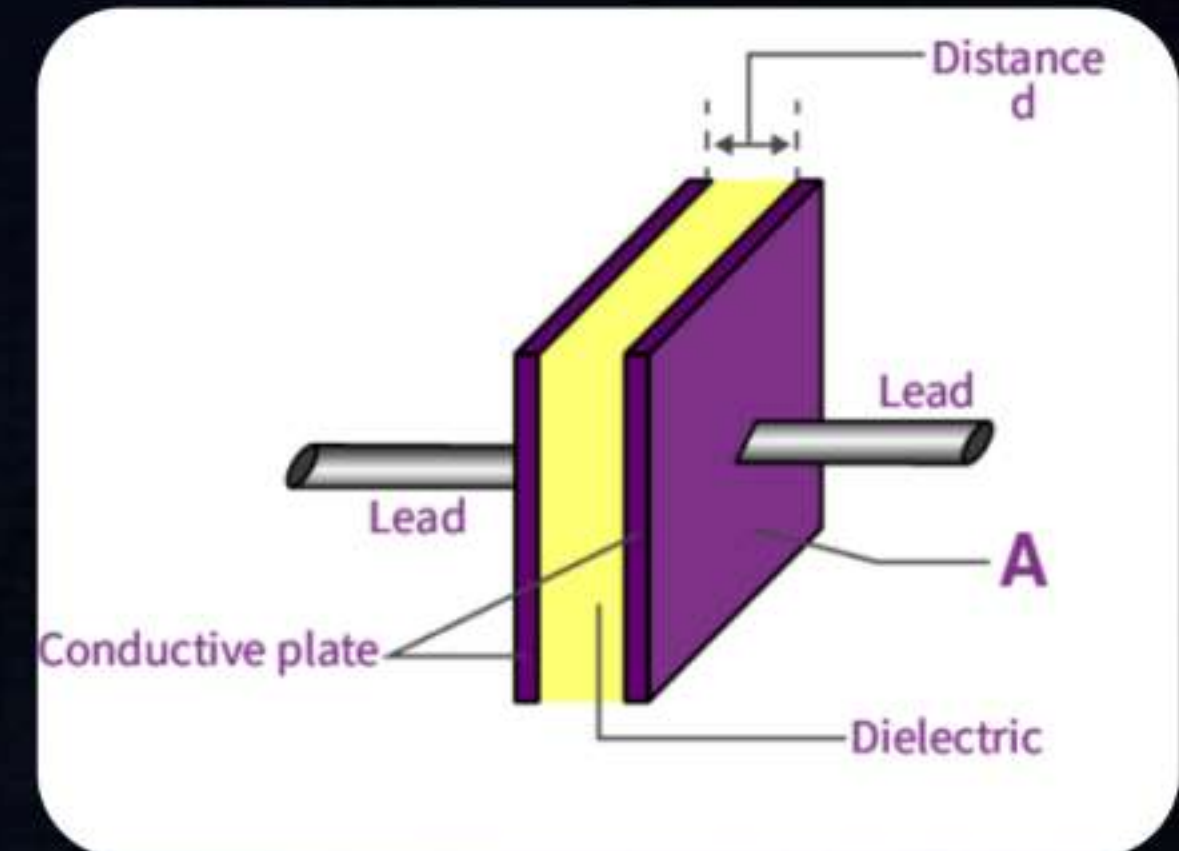
Capacitors

It is a device which is used to **store energy in form of Electric field** by storing charge.

- An instantaneous source of energy.
- two conductors which carry equal and opposite charges are separated by some distance
- Capacitor is electrically neutral.

"The capacitance of a conductor is defined as its **ability to hold charge** at a given **potential difference**"

$$C = \frac{Q}{\Delta V} = [F]$$

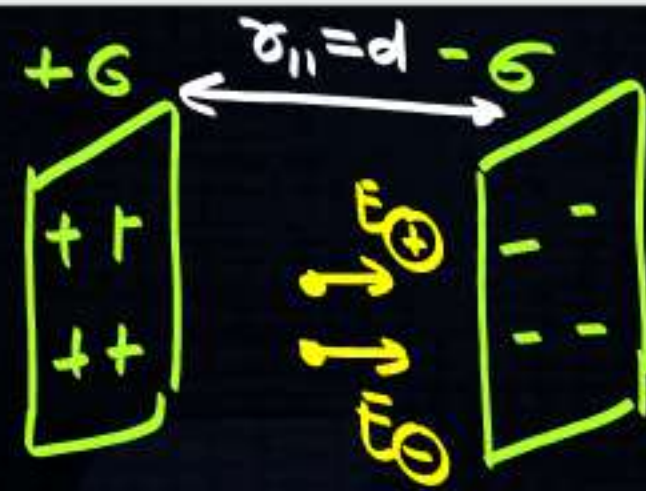
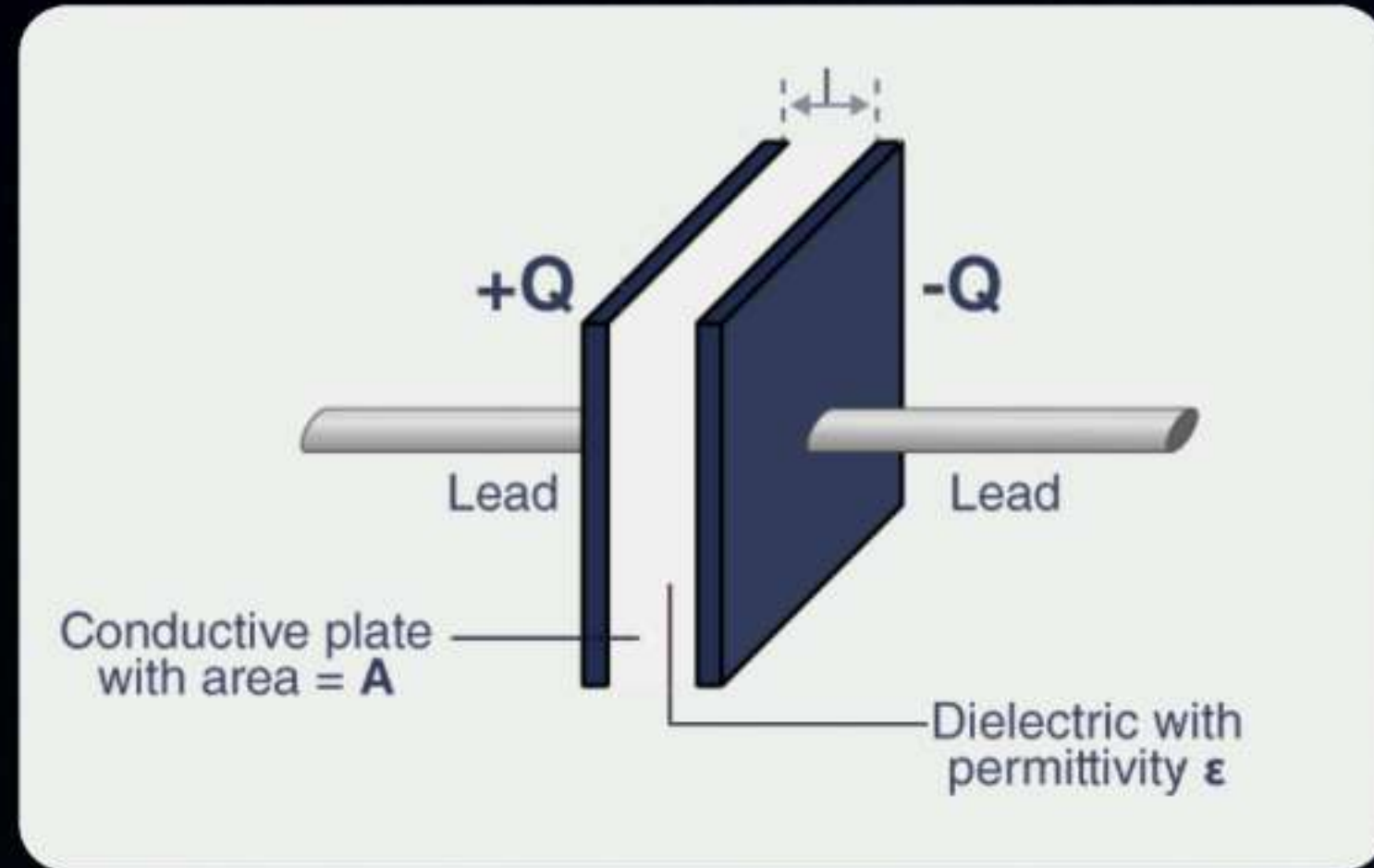


 **Que.**

A system of two conductors is placed in air and they have net charge of $+80\mu\text{C}$ and $-80\mu\text{C}$ which causes a potential difference of 16 V between them. Find the capacitance of the system. **[CBSE 2025]**

$$C = \frac{Q}{V} = \frac{80 \times 10^{-6}}{16} = 5 \times 10^{-6} \text{ F} = 5 \mu\text{F}$$

★ Capacitance of Parallel Plate Capacitors



$$E_{\text{net}} = E_{+} + E_{-}$$

$$= \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$$

$$\Delta V = E \cdot d$$

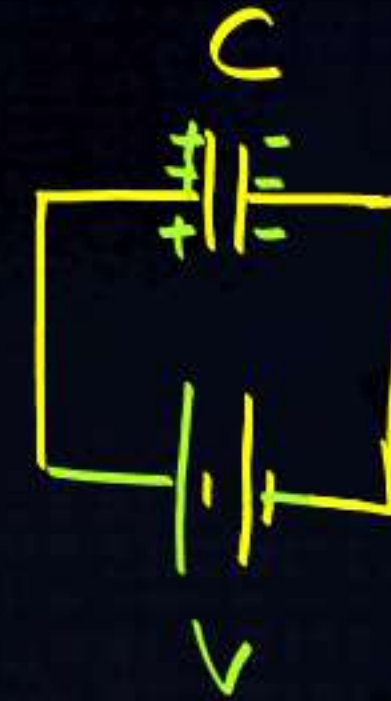
$$= E \cdot d$$

$$= \frac{Q}{A\epsilon_0} \cdot d$$

$$C = \frac{Q}{\Delta V}$$

$$= \frac{Q}{\frac{Q}{A\epsilon_0} \cdot d}$$

$$C = \frac{\epsilon_0 A}{d}$$



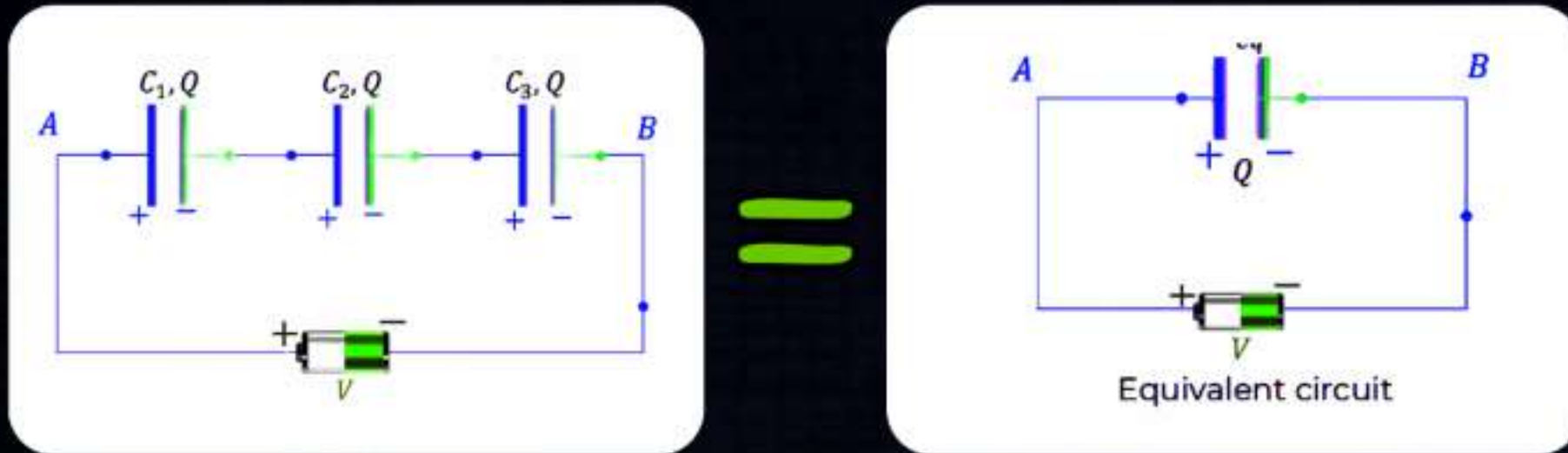
$$Q = CV$$

$$U = \frac{1}{2} CV^2$$

$$= \frac{Q^2}{2C}$$

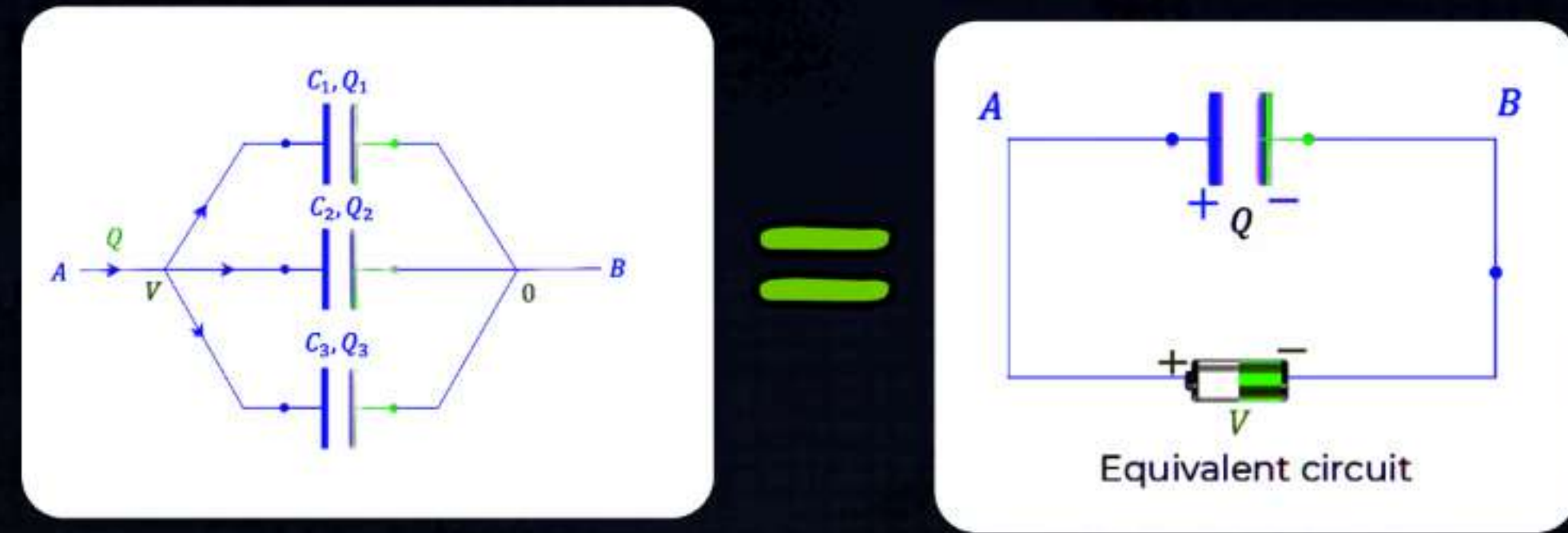
Energy stored
in capacitor

(i) Series Combination



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

(ii) Parallel Combination



$$C_{eq} = C_1 + C_2 + C_3 + \dots$$

Que.

Ten capacitors, each of capacitance $1 \mu\text{F}$, are connected in parallel to a source of 100 V . The total energy stored in the system is equal to : **[CBSE 2025]**

- a. 10^{-2} J
- b. 10^{-3} J
- c. $0.5 \times 10^{-3} \text{ J}$
- ☒ d. $5.0 \times 10^{-2} \text{ J}$

$$\begin{aligned} U &= \frac{1}{2} C_{eq} V^2 = \frac{1}{2} (10\text{C}) V^2 = \frac{1}{2} (10)(10^{-6})(10^2)^2 \\ &= 5 \times 10^{-2} \text{ J} \end{aligned}$$

$$C_{eq} = C_1 + C_2 + \dots + C_{10} = 10\text{C}$$

Marathon

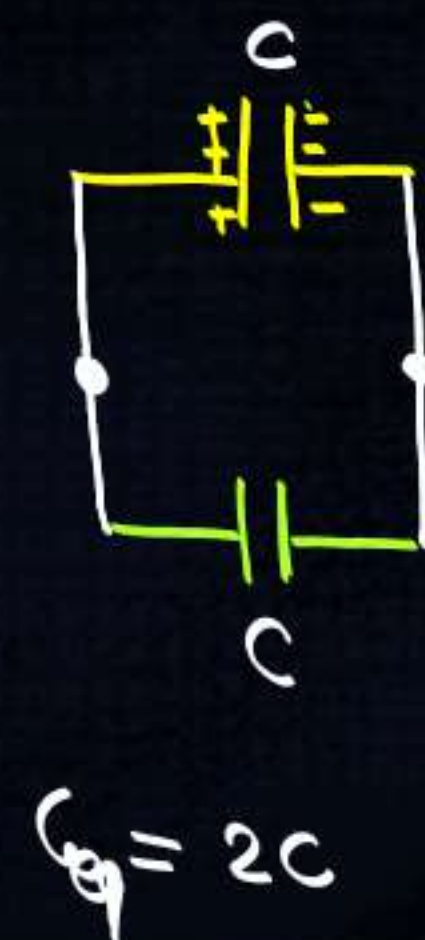
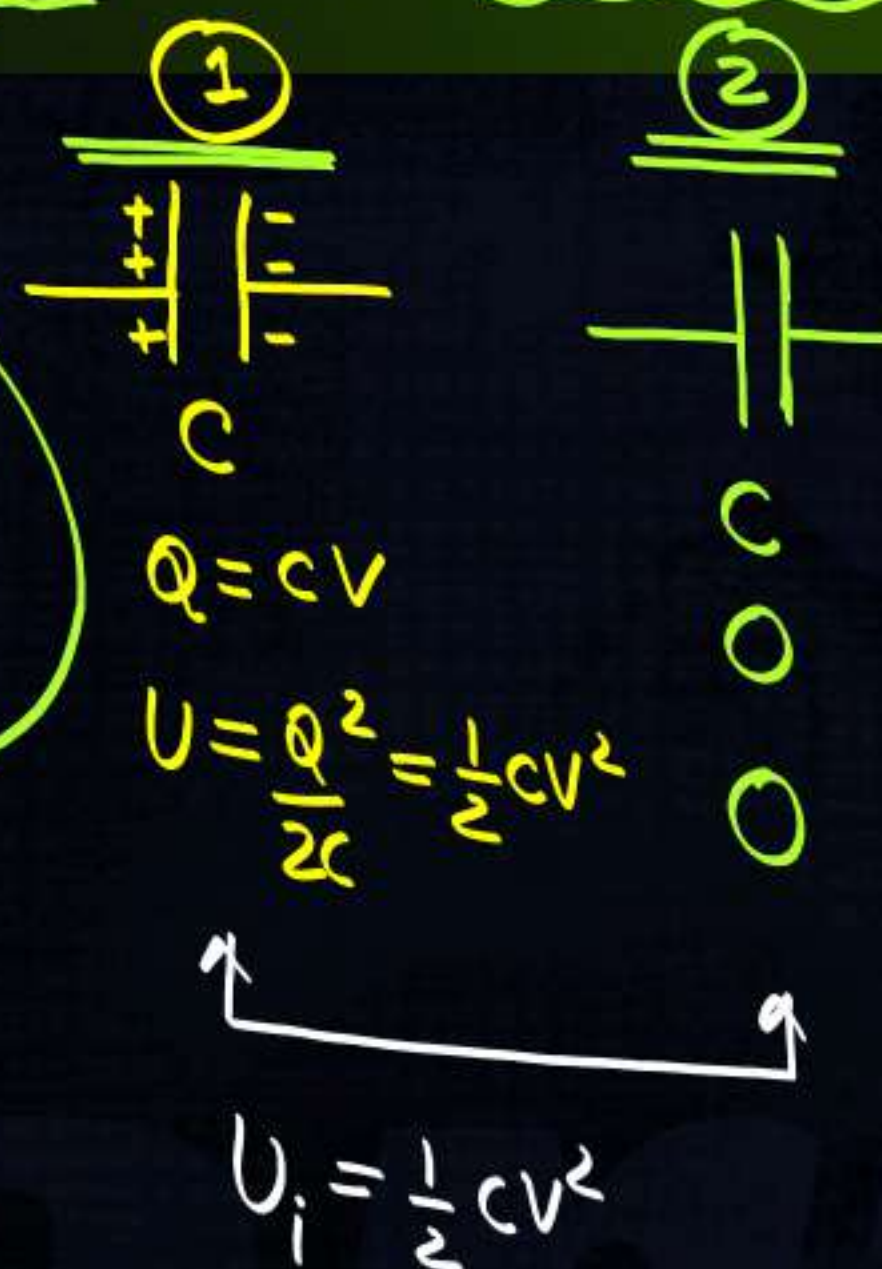
?
Que.



NEET
2026

Consider two uncharged capacitors of equal capacitance 200 pF. One of them is charged by a 100 V supply and disconnected. Now this capacitor is connected to the uncharged capacitor. The amount of electrostatic energy lost in the process is

- a. 10^{-2} J
- b. 10^{-3} J
- c. 0.5×10^{-3} J
- d. 5.0×10^{-2} J



$$V_{com.} = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2} = \frac{CV + C(0)}{C + C} = \frac{CV}{2C} = \frac{V}{2}$$

$$U_{Final} = \frac{1}{2} C_{eq} V_{com.}^2$$

$$= \frac{1}{2} (2C) \left(\frac{V}{2}\right)^2$$

$$U_{Final} = \frac{1}{2} \left(\frac{1}{2} CV^2\right) = \frac{U_{ini}}{2}$$

$$U_{loss} = U_{ini} - U_{Final}$$

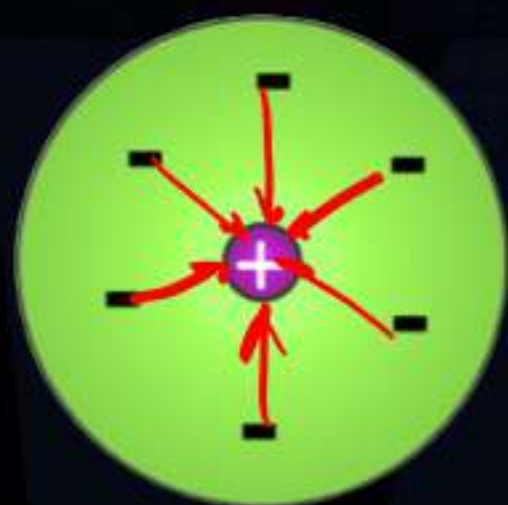
$$= \frac{U_{ini}}{2}$$

Dielectric

Non-Polar

A nonpolar molecule is a molecule in which the centres of positive and negative charges coincide

- no permanent dipole moment
- CO_2 , O_2 , N_2



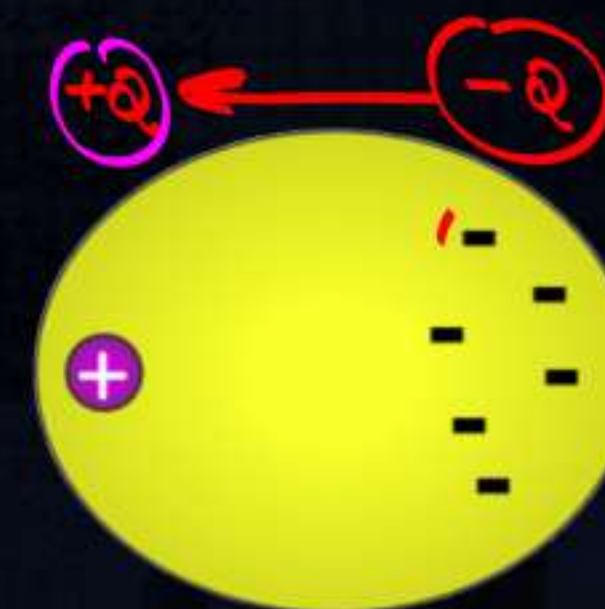
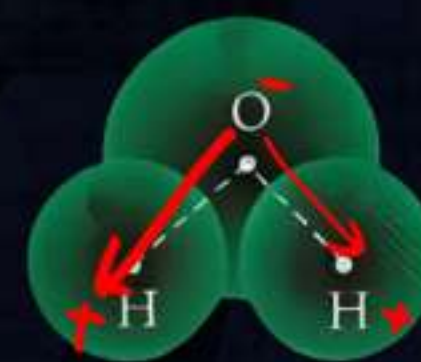
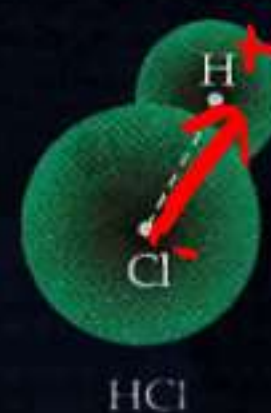
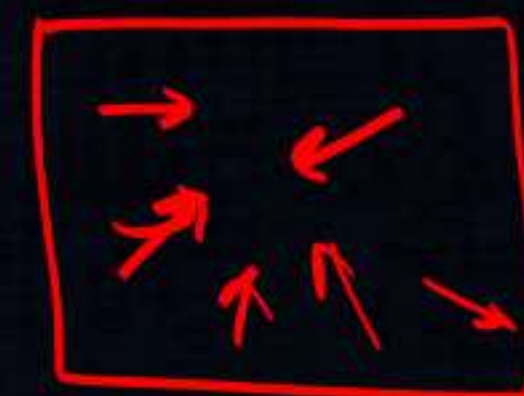
$P_{\text{atomic}} = 0$

Polar

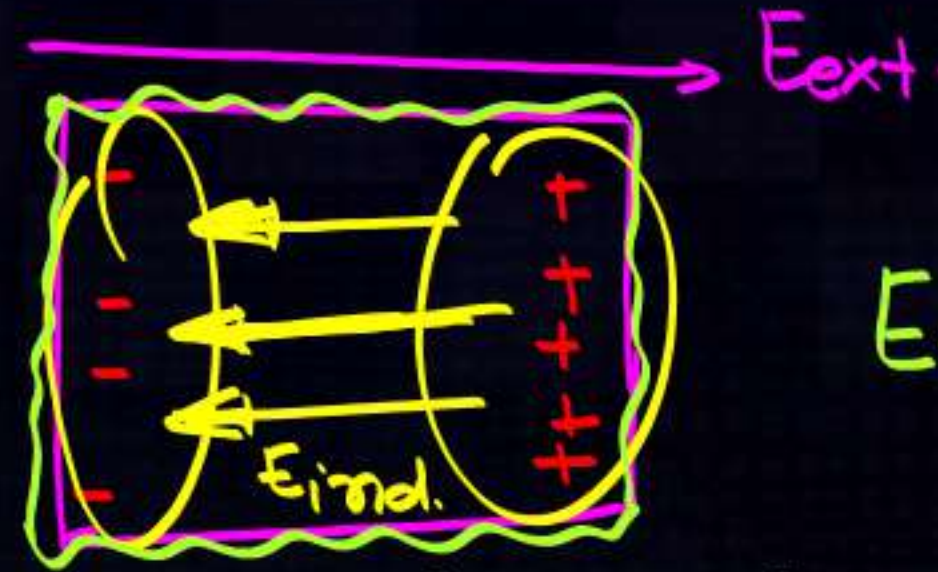
Permanent dipole moment = 10^{-30} C m

$P_{\text{atomic}} \neq 0$

- due to thermal motion & randomness
- Net dipole moment = 0
- HCl , H_2O

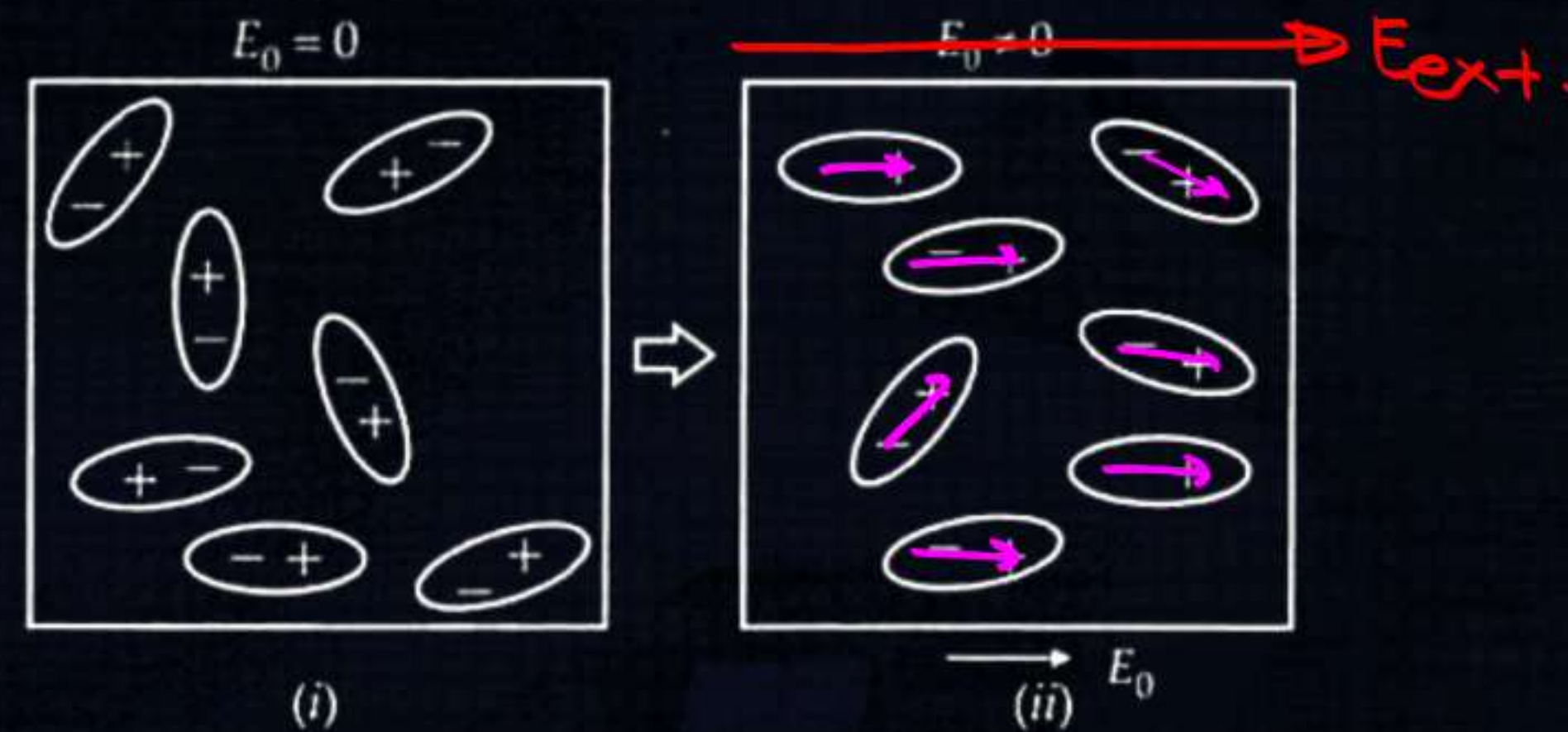
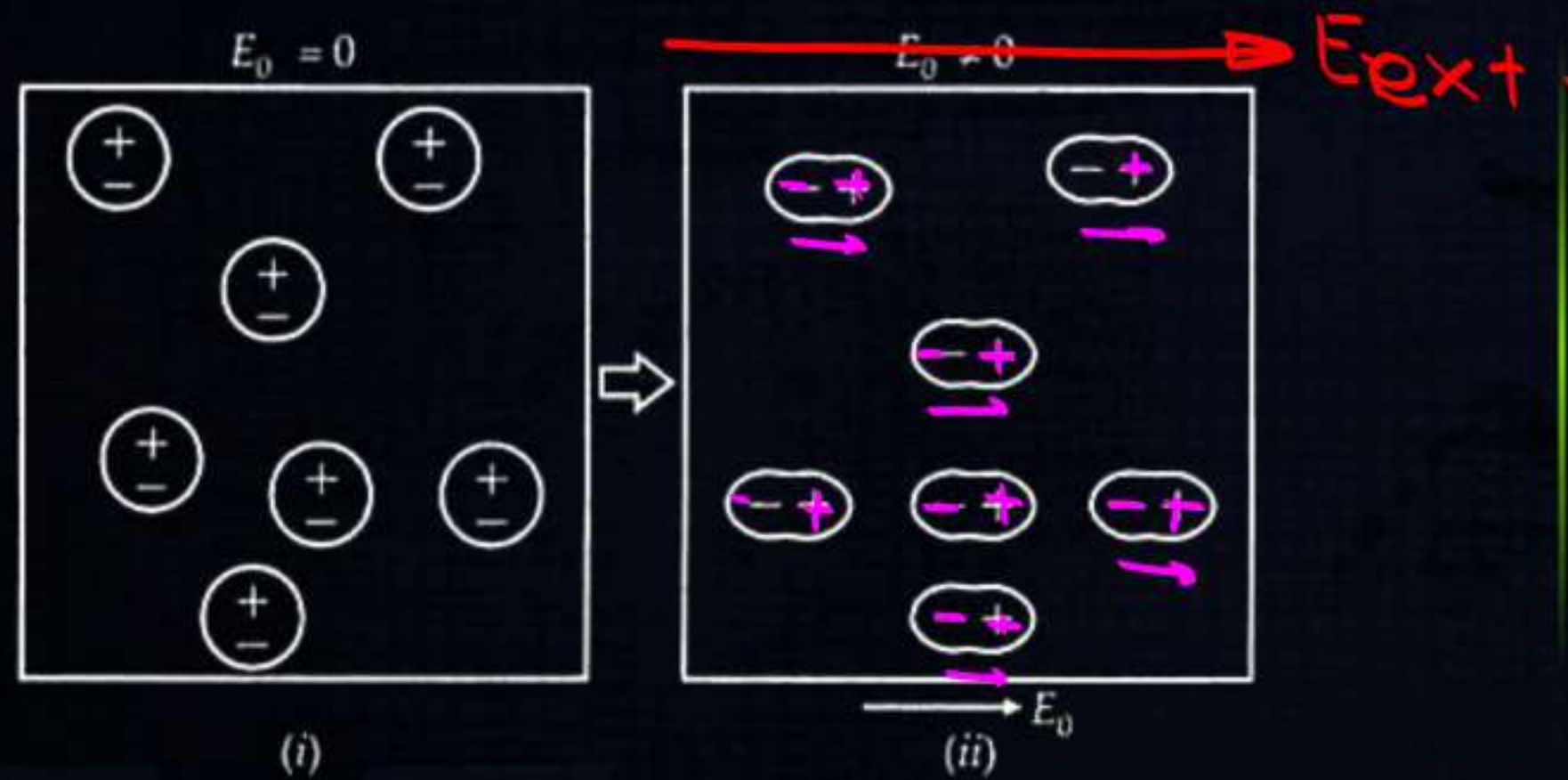


Polarization



$$E_{net} = E_{ext} - E_p = \frac{E_{ext}}{K}$$

Irrespective of whether a material is polar or nonpolar, the **application of electric field** results in the creation of a **net dipole moment** across the material.



- For an ideal dielectric material, $P =$
- Polarization depends on applied external field 🤝 & Thermal energy 😈

Que.

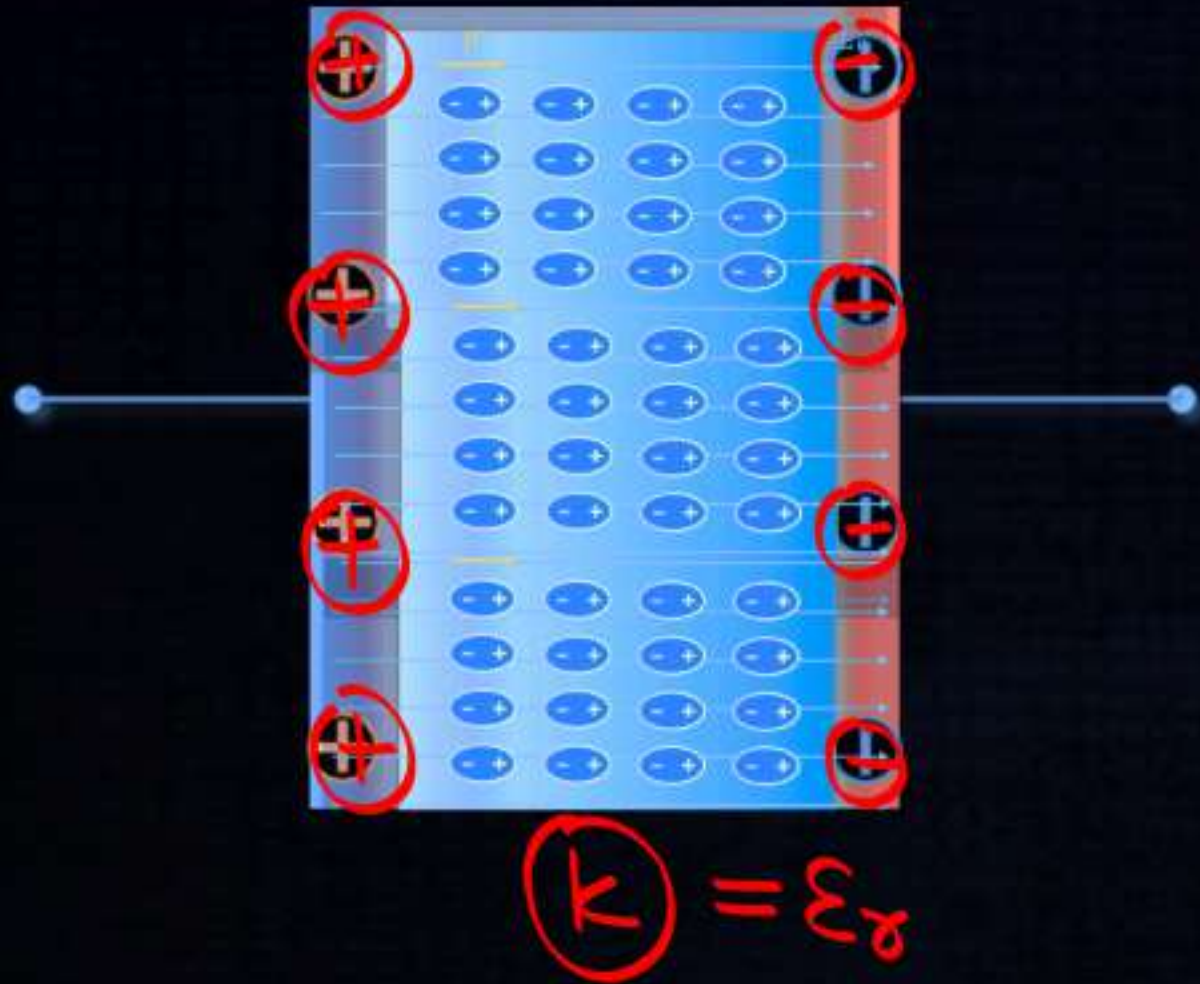
"comment"

Which of the following statements about dielectrics is correct? [CBSE 2024]

- a. A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipoles.
- b. The net dipole moments of induced dipoles is along the direction of the applied electric field.
- c. Dielectrics contain free charges.
- d. The electric field produced due to induced surface charges inside a dielectric is along the external electric field.

Marathon

Parallel Plate Capacitor Filled with Dielectric [CBSE 2024]



$$C' = \frac{\epsilon_m A}{d}$$

$$C_{\text{air}} = \frac{\epsilon_0 A}{d}$$

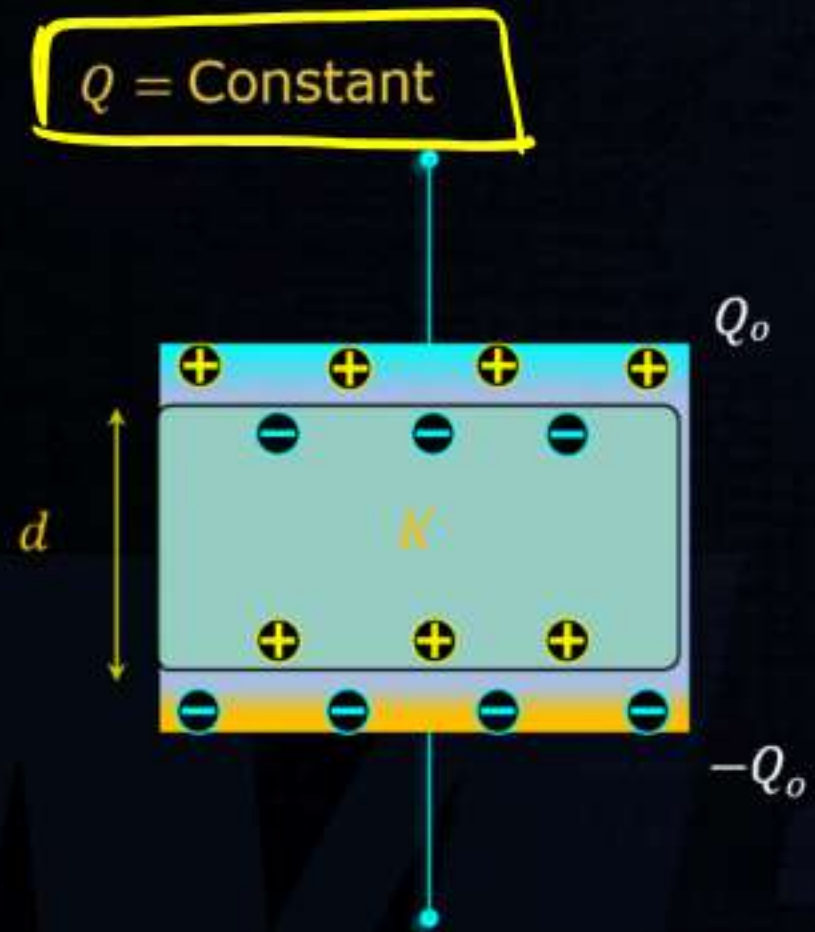
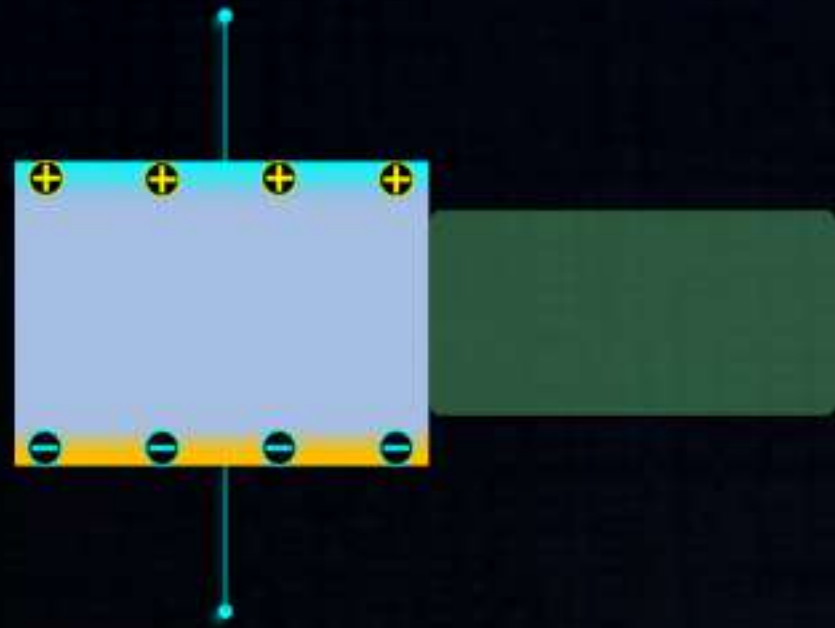
$$C' = \epsilon_r \cdot \frac{\epsilon_0 A}{d}$$

$$C' = \epsilon_r (C_0)$$

$C' = k C_0$

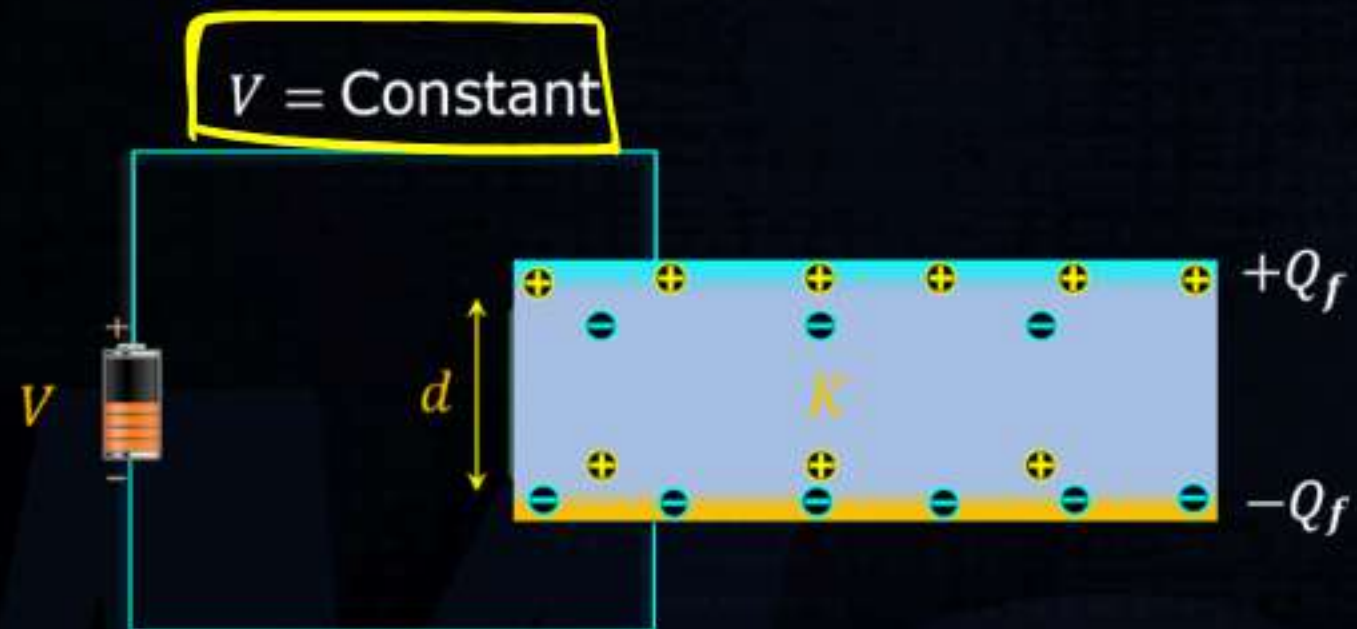
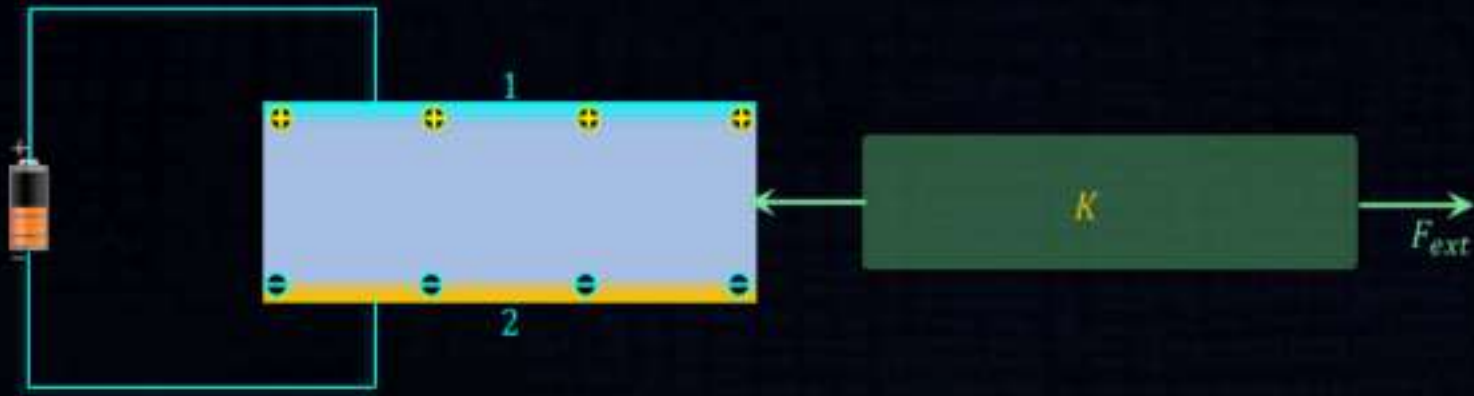
(i) Insertion of Dielectric at When Battery is Disconnected

"Q = constant"



	$C = \frac{\epsilon_0 A}{D}$	$V = \frac{Q}{C}$	$E = \frac{V}{d}$	$Q = CU$	$U = \frac{Q^2}{2C}$
Before insertion	C	V	E	Q	U
After insertion	KC	$\frac{V}{K}$	$\frac{E}{K}$	Q	$\frac{U}{K}$ (with a downward arrow indicating decrease)

(ii) Insertion of Dielectric When Battery is Connected



$$Q = CV$$

	$C = \frac{\epsilon_0 A}{D}$	$V = \frac{Q}{C}$	$E = \frac{V}{d}$	$Q = CU$	$U = \frac{CV^2}{2}$
Before insertion	C	V	E	Q	U
After insertion	KC	V	E	KQ	$KU \uparrow$



When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in it: **[CBSE 2024]**

- a. increases and the electric field inside it also increases.
- ☒ b. decreases and the electric field also decreases.
- c. decreases and the electric field increases.
- d. increases and the electric field decreases.



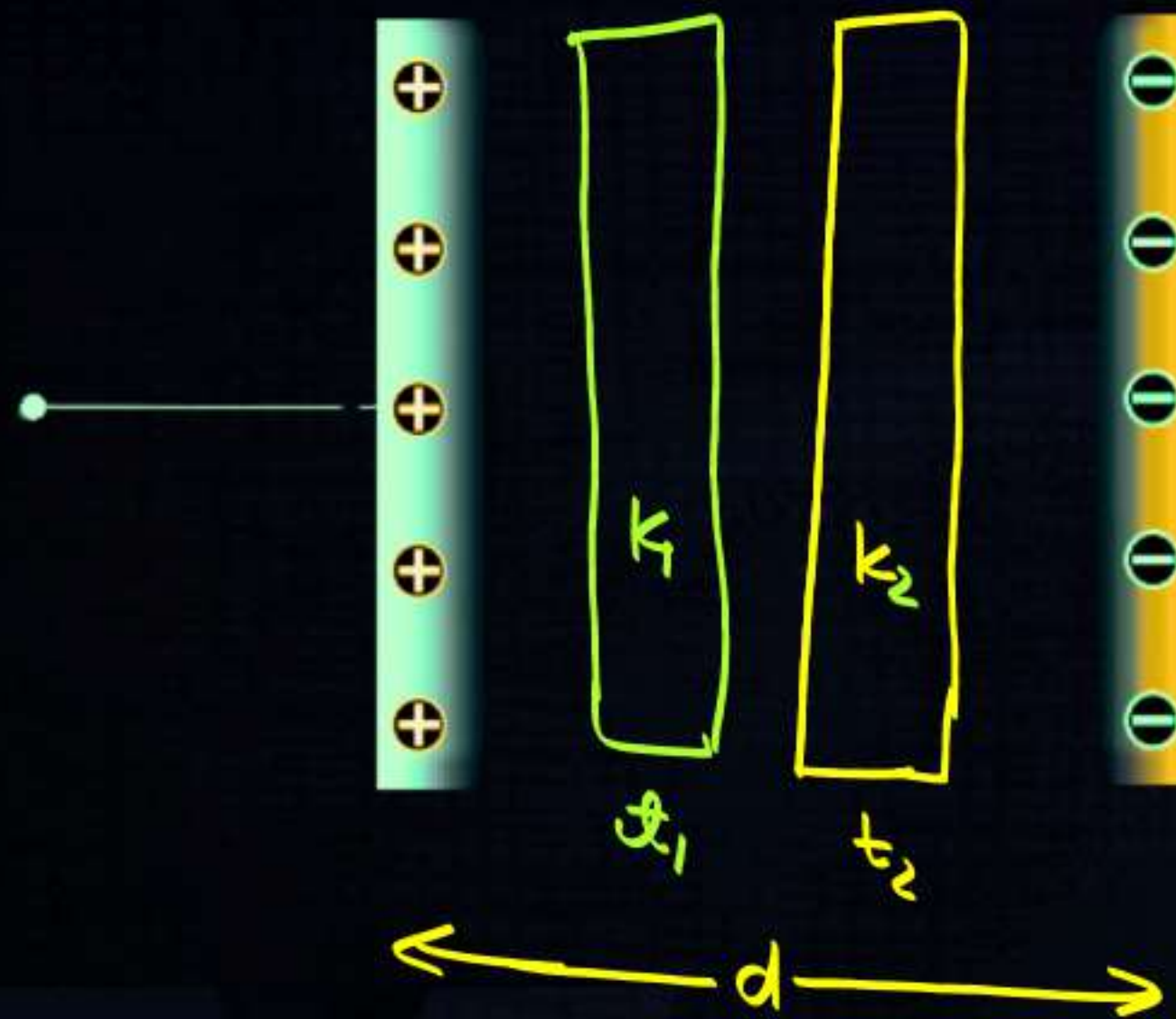
Consider two uncharged capacitors of equal capacitance 200 pF. One of them is charged by a 100 V supply and disconnected. Now this capacitor is connected to the uncharged capacitor. The amount of electrostatic energy lost in the process is

- a. 0.5 J
- b. 1.0×10^{-6} J
- c. 0.5×10^{-6} J
- d. 1.0 J

HOMEWORK

Capacitor Partially Filled with a Dielectric Slab

[CBSE 2024]



$$\# C = \frac{\epsilon_0 A}{d_{air} + \frac{t_1}{K_1} + \frac{t_2}{K_2}}$$

$$d_{air} = d - (t_1 + t_2)$$

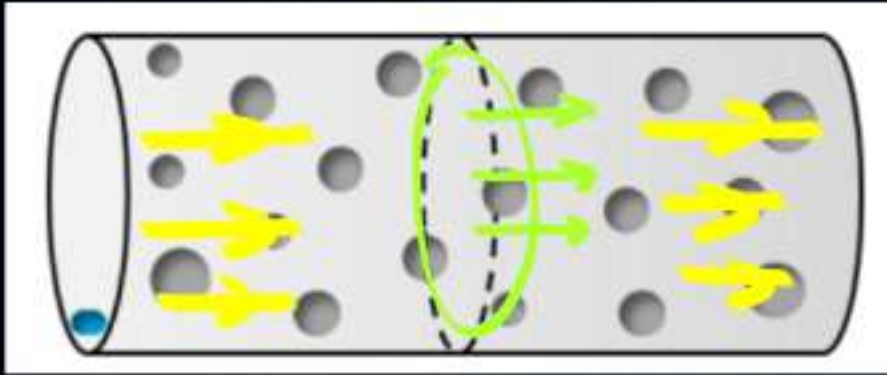
Current Electricity

Chapter-3

Marathon

Electric Current

Current through a given area is **net charge passing** per unit time through the **area**



$$i_{avg} = \frac{\Delta Q}{\Delta t}$$

$$\Delta Q = i \cdot \Delta t$$

$$\& \quad i = \frac{dQ}{dt}$$

$$\int dQ = \int i dt$$

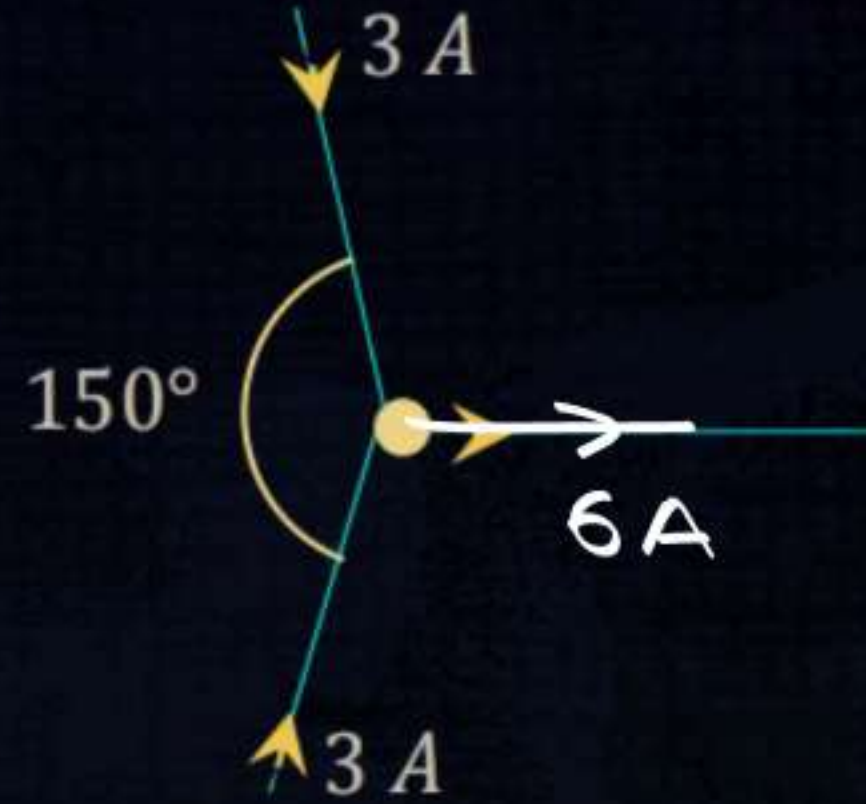
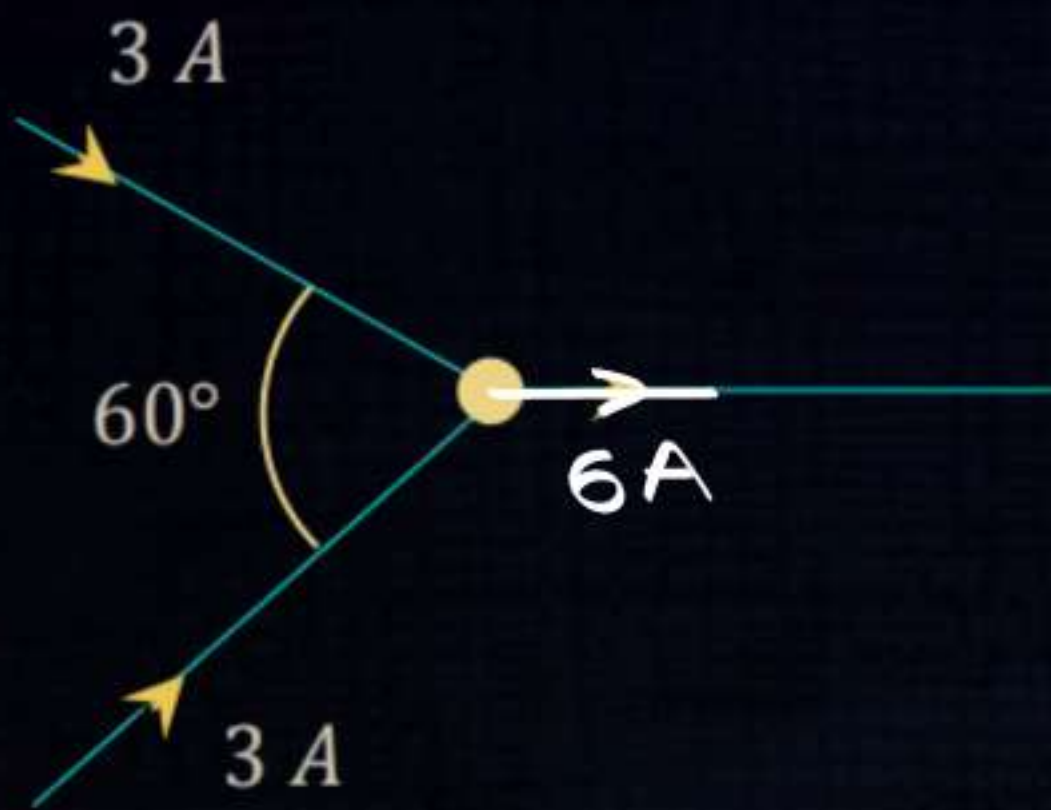


Current flows because of a potential difference between two points

- **Direction** : Higher Potential $\rightarrow$ Lower Potential
- **SI unit** : Ampere (A)

Electric current is a **scalar quantity**

[CBSE 2026]

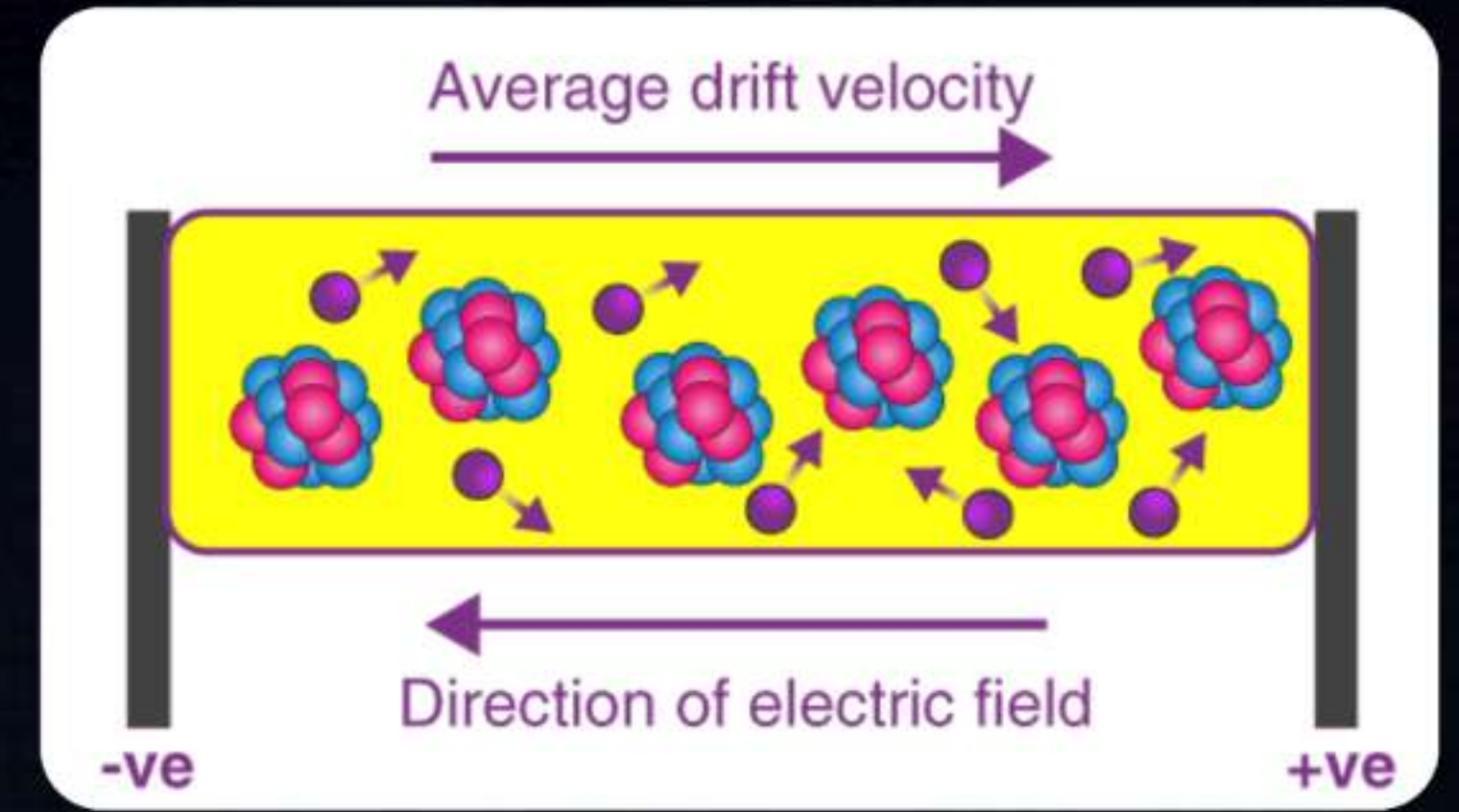


Even though current has a direction of flow, it is not treated as a vector because:

- It does not follow vector addition laws,
- Currents at a junction are added algebraically, not vectorially.

Drift Velocity

- free electron **experience force** opposite to the direction of electric field
- Due to this force these electrons start **drifting in the opposite direction of E.F.**
- During motion they face many **collision** with heavy positive ions.
- the velocity with which e^- effectively displaced is called **drift velocity**



$$F_e = eE$$

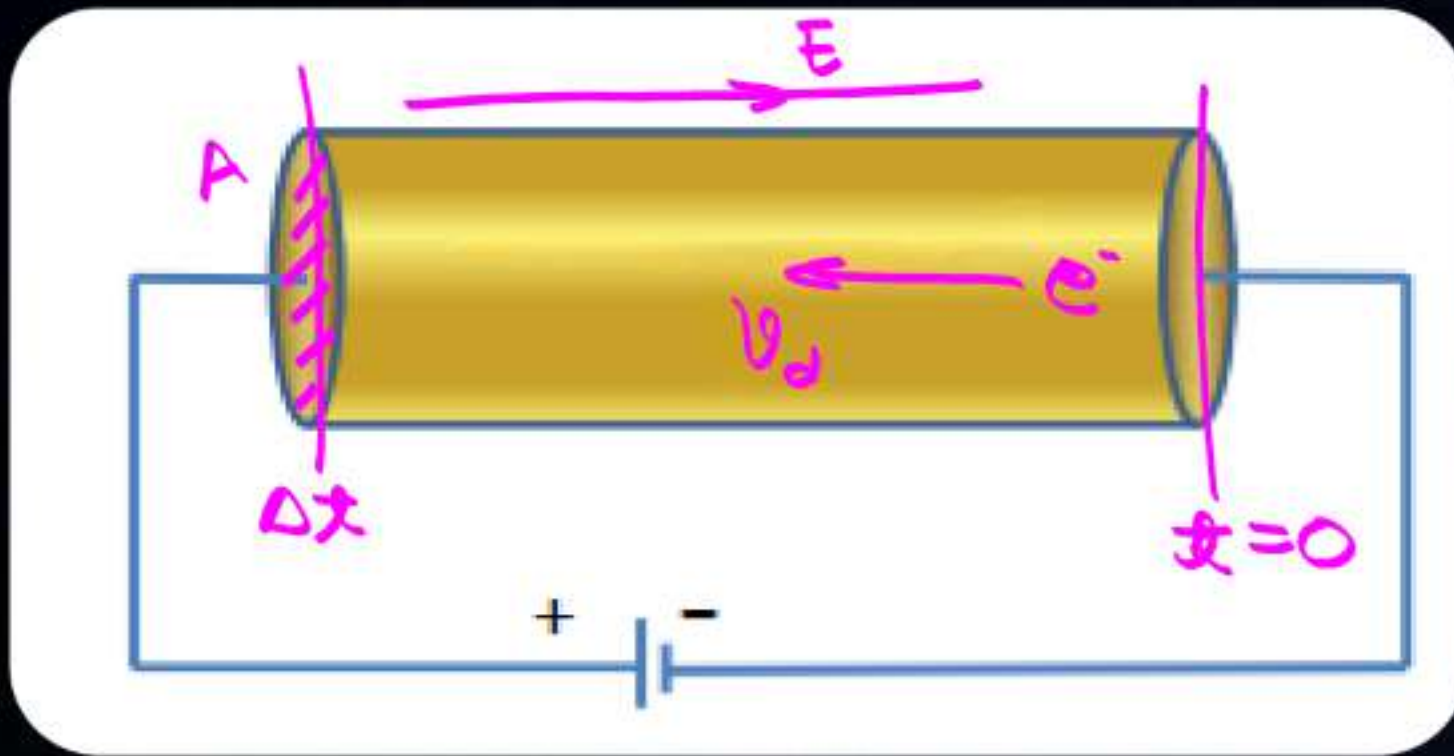
$$m_e a = eE \Rightarrow a_e = \frac{eE}{m_e}$$

$$\Rightarrow v = u + at$$

$$v_d = \left(\frac{eE}{m_e} \right) \tau$$

Relation btw Drift Velocity & Electric Current

[CBSE 2026]



$$i = \frac{\Delta Q}{\Delta t}$$

$$= \frac{Ne}{\Delta t}$$

$$n = \frac{\text{no. of Free } e^-}{\text{Volume}} = \frac{N}{\text{Volume}}$$

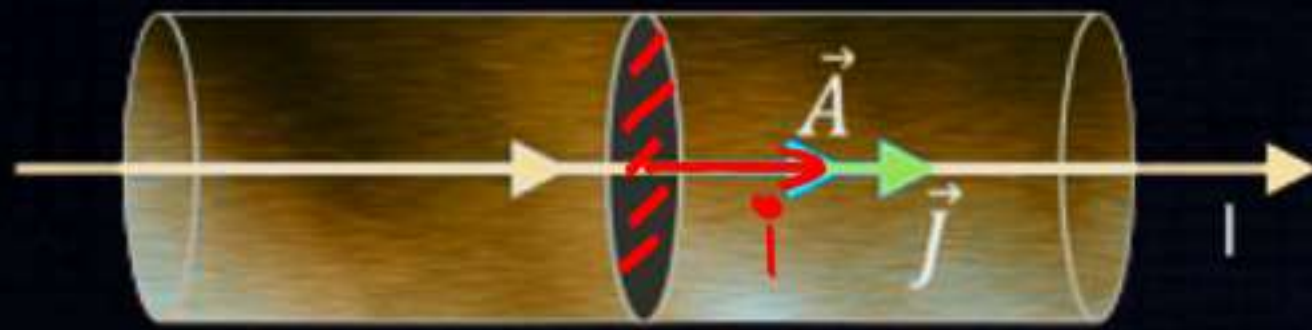
$$\Rightarrow N = n \cdot \text{Volume}$$

$$N = n (A) (v_d \Delta t)$$

$$i = \frac{nA(v_d \Delta t)e}{\Delta t}$$

$$i = neAv_d$$

Electric Current Density



- Vector quantity
- direction of current flow

$$\vec{J} = \frac{i}{A}$$

Mobility

- the drift speed per unit of electric field strength.
- Higher the speed of charge carrier in an electric field, greater is its mobility.

$$\bar{\mu} = \frac{v_{\text{drift}}}{E} = \frac{\frac{eE}{m} \tau}{E}$$

$$\mu = \frac{e}{m} \tau$$

Que.

$$i = neAv_d$$

Two copper wires having their radii in the ratio of 3: 2 are connected in series across a battery. Find the ratio of the drift velocities of the electrons in the wires.

[CBSE 2026]

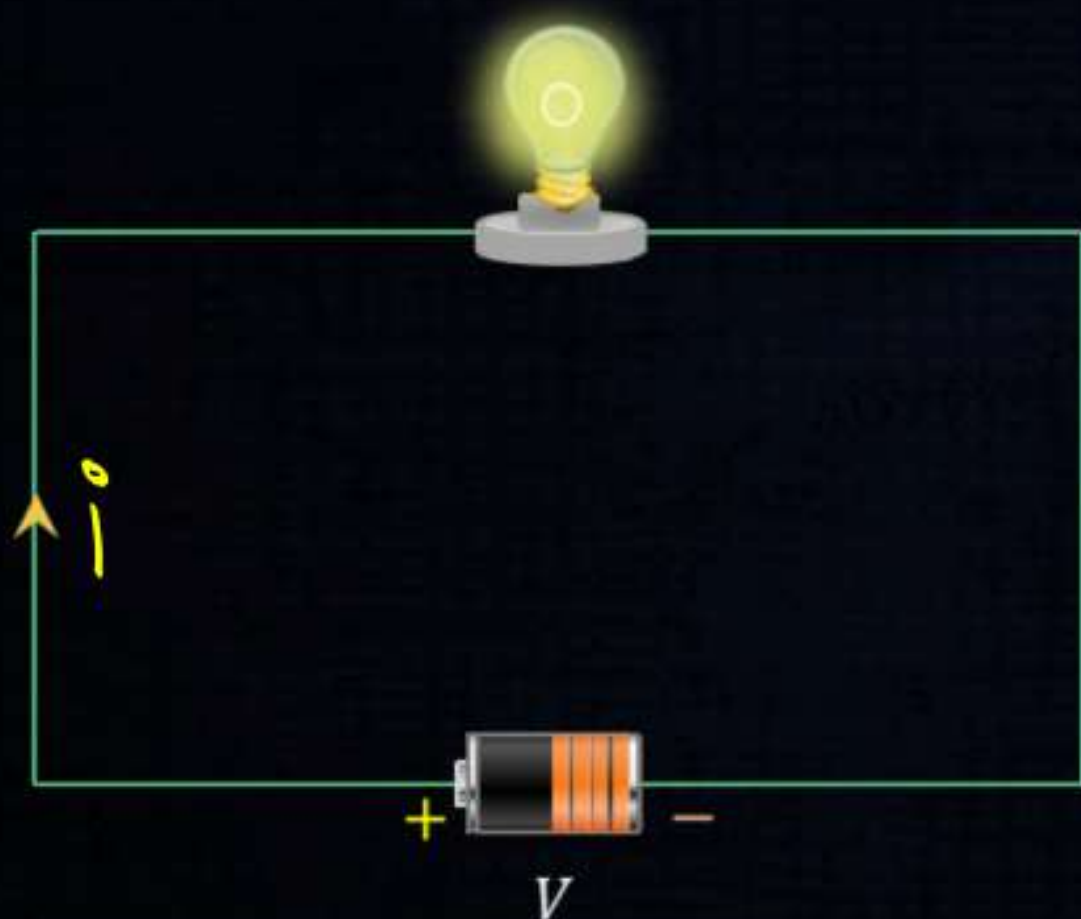
$$v_{drift} = \frac{i}{neA} \propto \frac{1}{A} \propto \frac{1}{r^2}$$

$$\text{Ans.} = 4 : 9$$

Marathon

Ohm's law

At constant temperature, the current (I) flowing through a conductor is directly proportional to the potential difference (V) across its ends.



$$I \propto V$$

$$V \propto I$$

$$V = IR$$

$$R = \frac{V}{I}$$

= constant

Vector Form

$$\vec{J} = \sigma \vec{E}$$

Task

Vector Form

Scalar Form

$$R = \frac{ml}{ne^2\tau A}$$

SI Unit : ohm

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

$$R = \frac{\rho l}{A}$$

$$\rho = \frac{m}{ne^2\tau}$$

$$\sigma = \frac{1}{\rho}$$

Que.

Two wires P and Q are made of the same material. The wire Q has twice the diameter and half the length as that of wire P. If the resistance of wire P is R, the resistance of the wire Q will be [CBSE 2025]

- a. R
b. R/2
☒ c. R/8
d. 2R

$$R_P = \frac{\rho l}{A}$$

$$R_Q = \frac{\rho (l/2)}{\pi (2)^2 \sigma_p^2}$$

Marathon

Effect of Temperature on Resistance



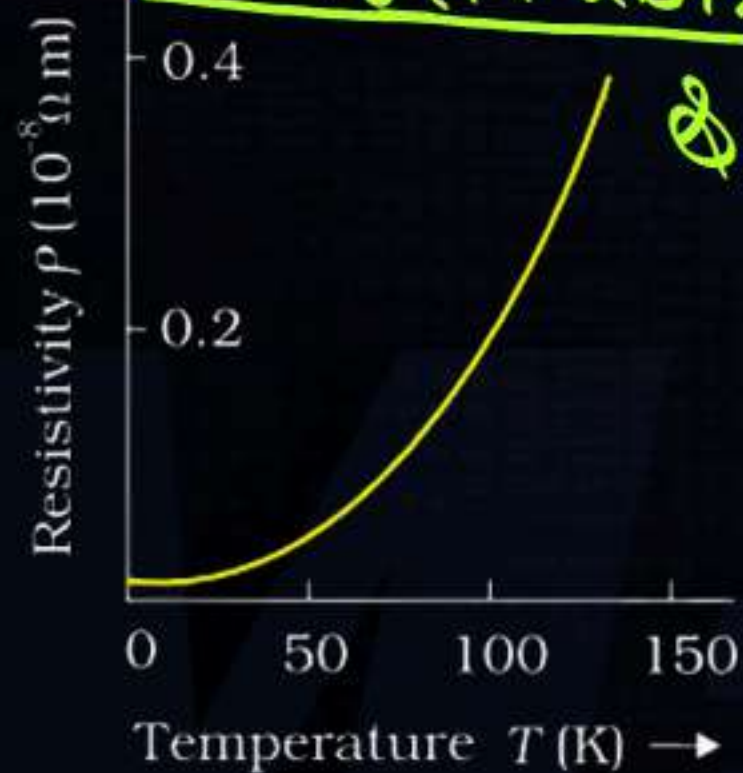
Conductor

$$\left. \begin{aligned} \Delta R &\propto \Delta T \\ \Delta R &\propto R_0 \end{aligned} \right\}$$

$$\Delta R = \alpha R_0 \Delta T$$

$$R - R_0 = \alpha R_0 \Delta T$$

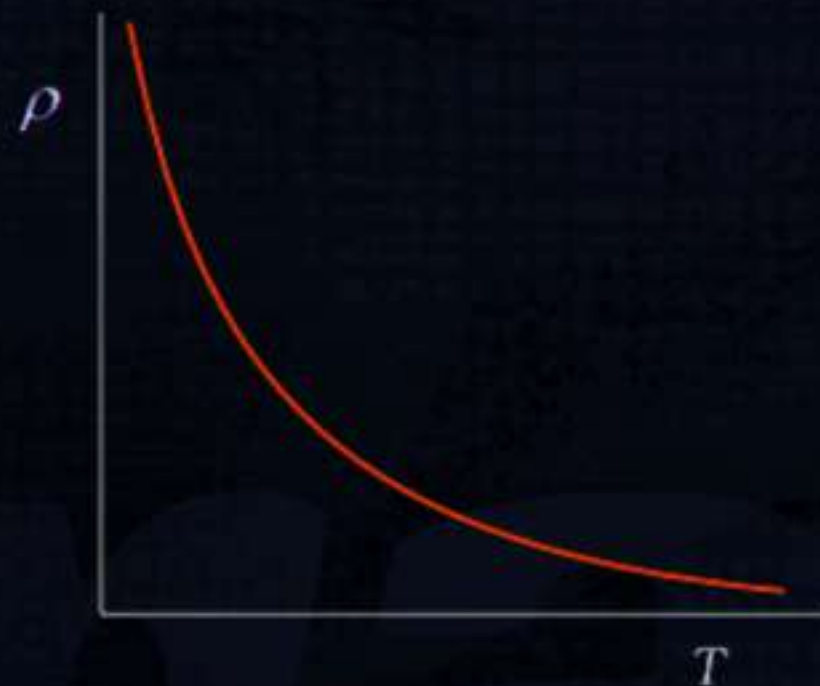
$$R = R_0 (1 + \alpha \Delta T)$$



$$\alpha \rightarrow +ve$$

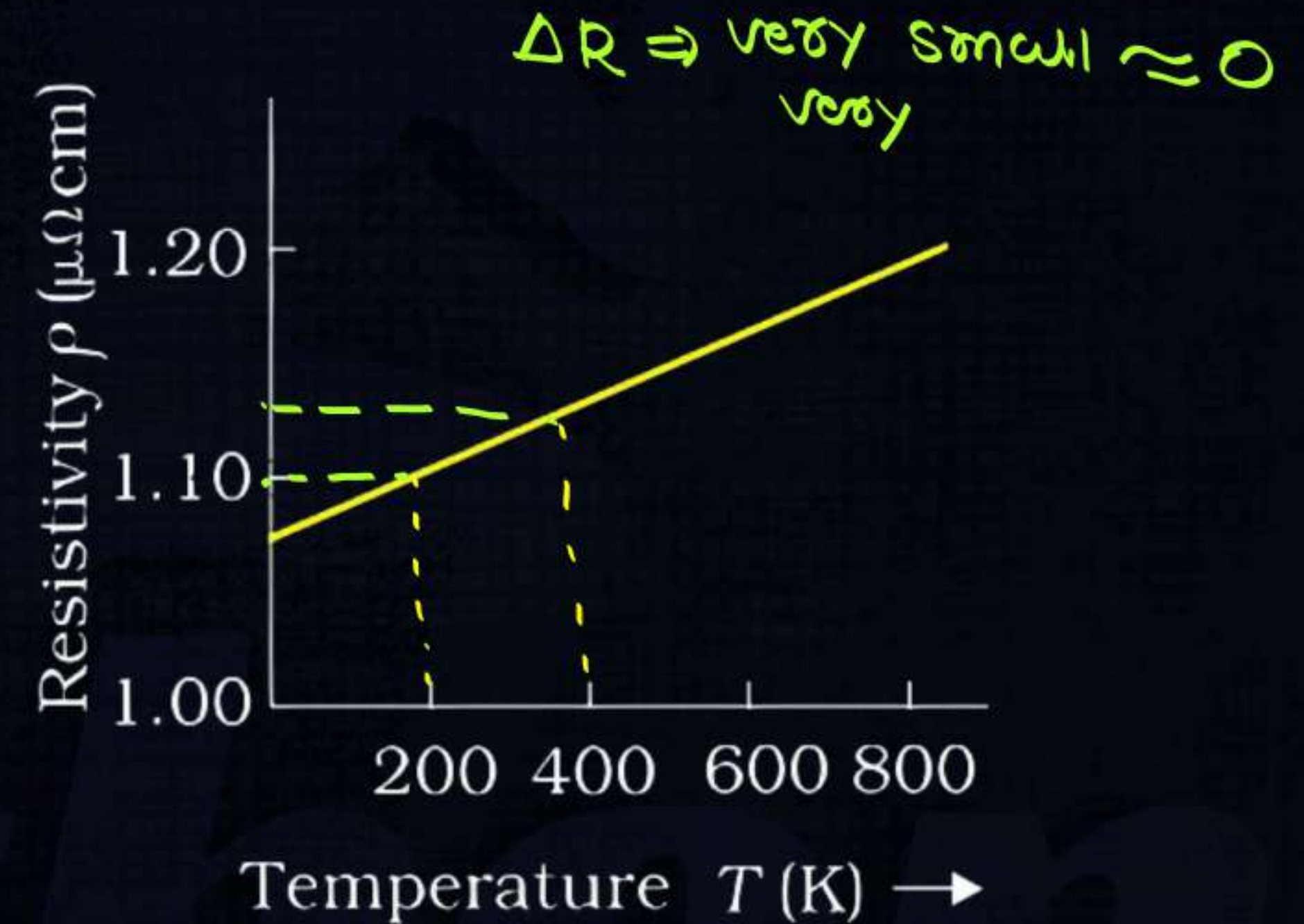
Semiconductors

$$\begin{aligned} \text{Temp. } \uparrow &\Rightarrow \rho \downarrow \\ &\Rightarrow R \downarrow \end{aligned}$$

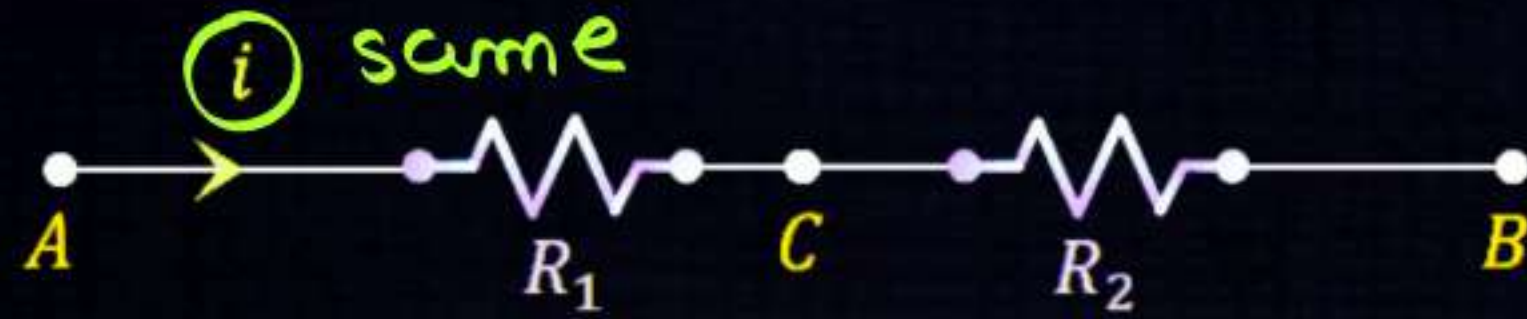


$$\alpha \rightarrow -ve$$

Nichrome , Manganin , Constantan



Series Connection

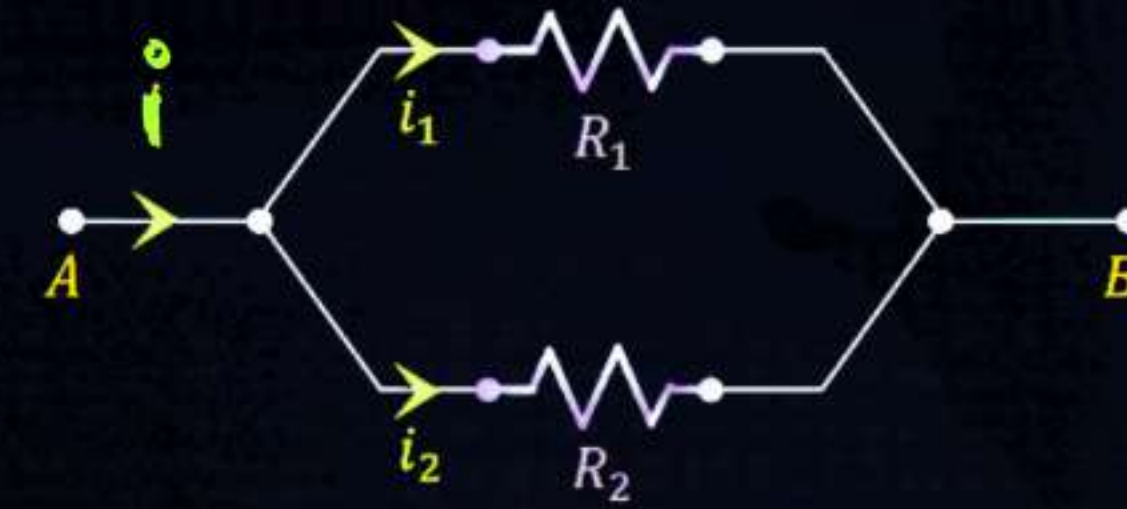


|||



$$R_{eq} = R_1 + R_2 + R_3 + \dots$$

Parallel Connection



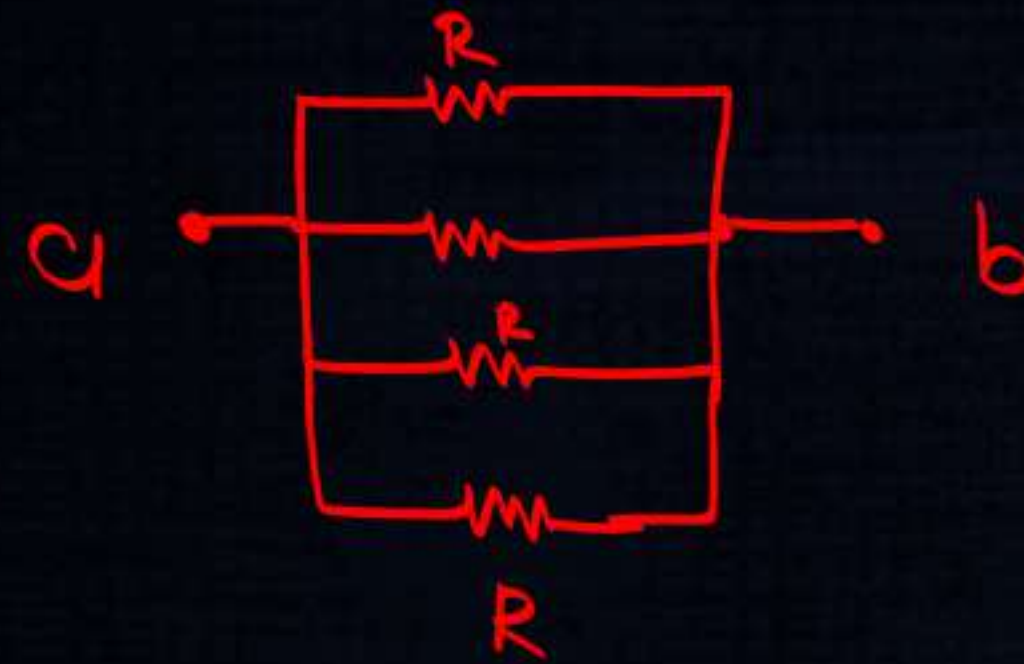
|||



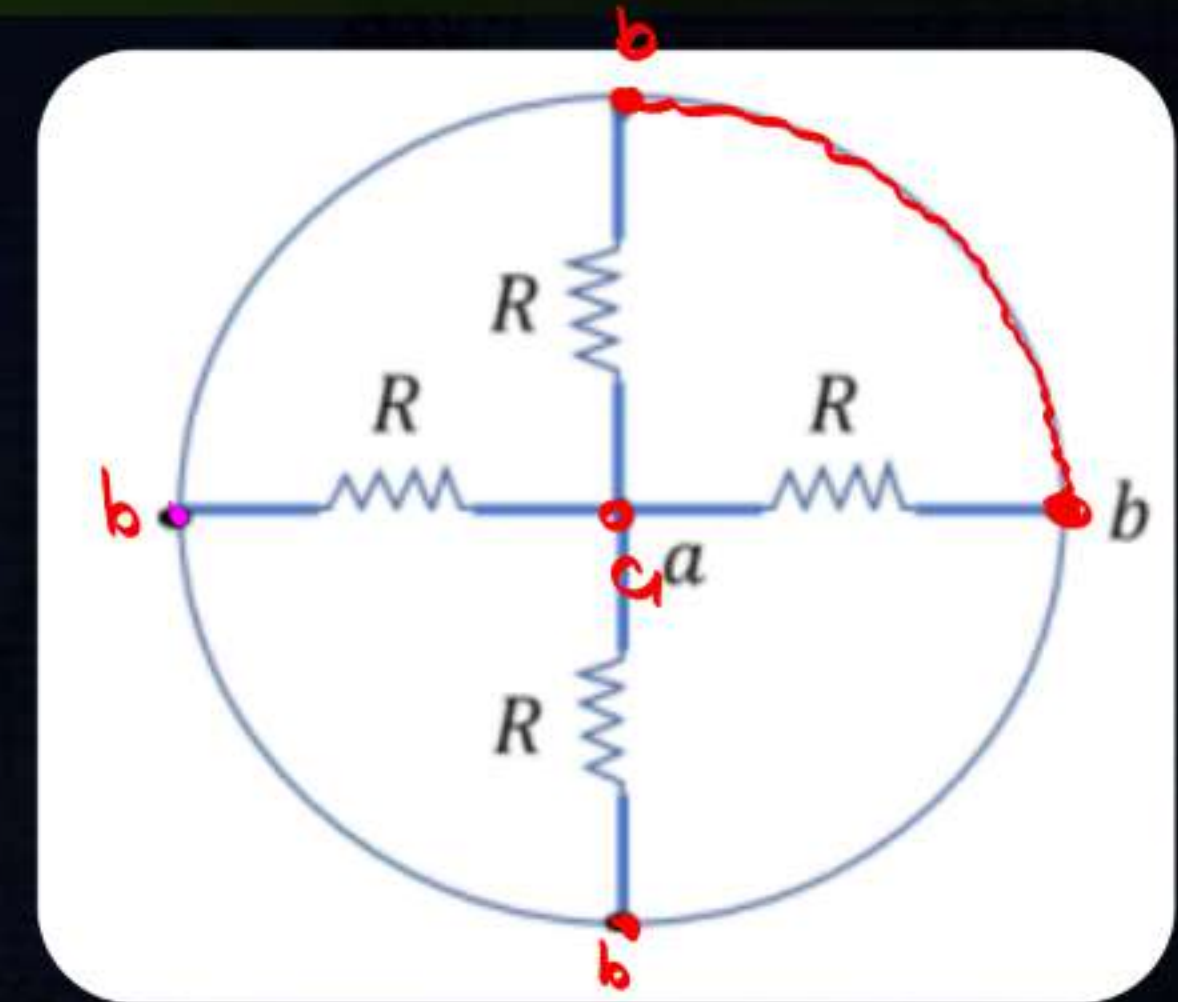
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

Que.

Calculate effective resistance across the points a & b



$$R_{eq.} = R/4$$

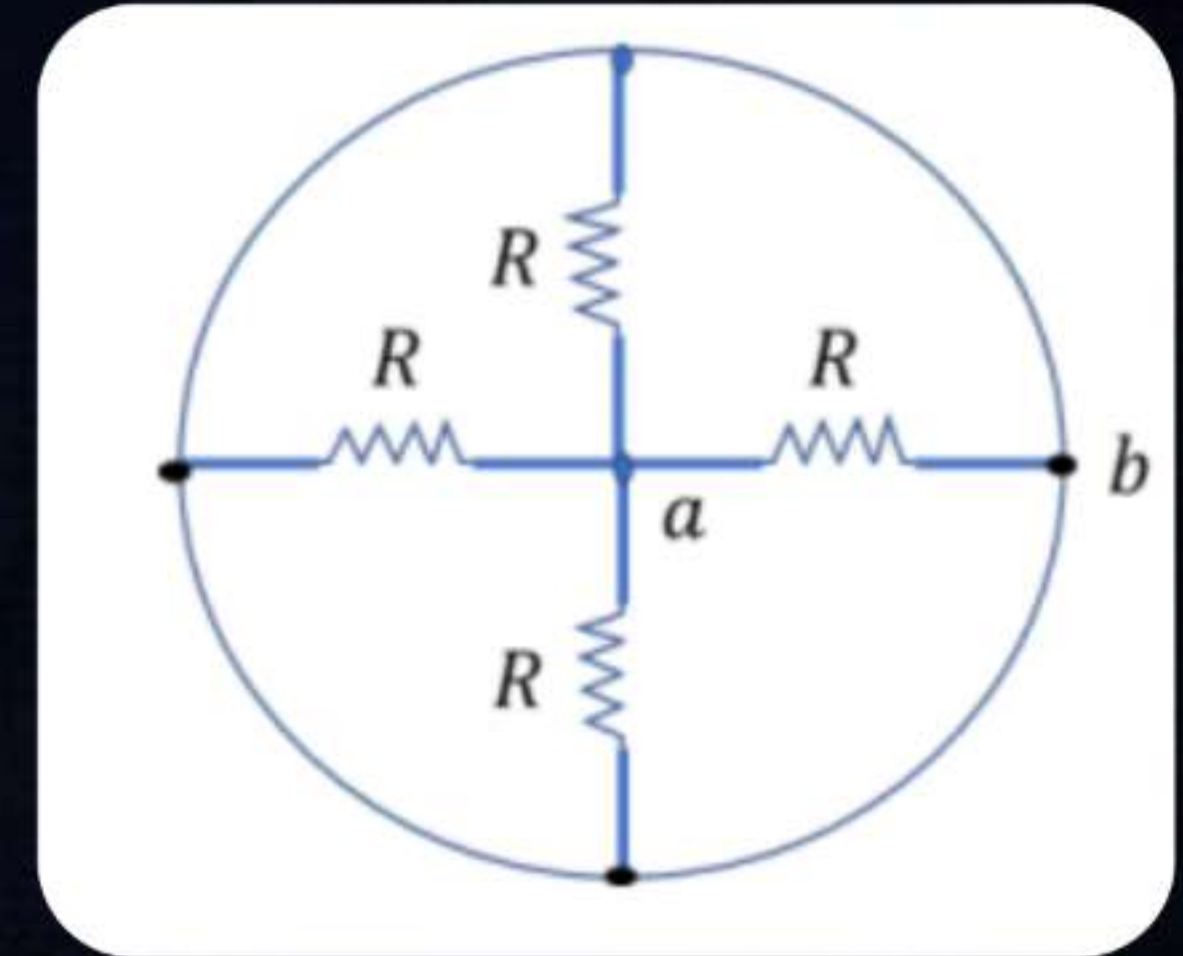


Que.

Calculate effective resistance across the points a & b

Ans.

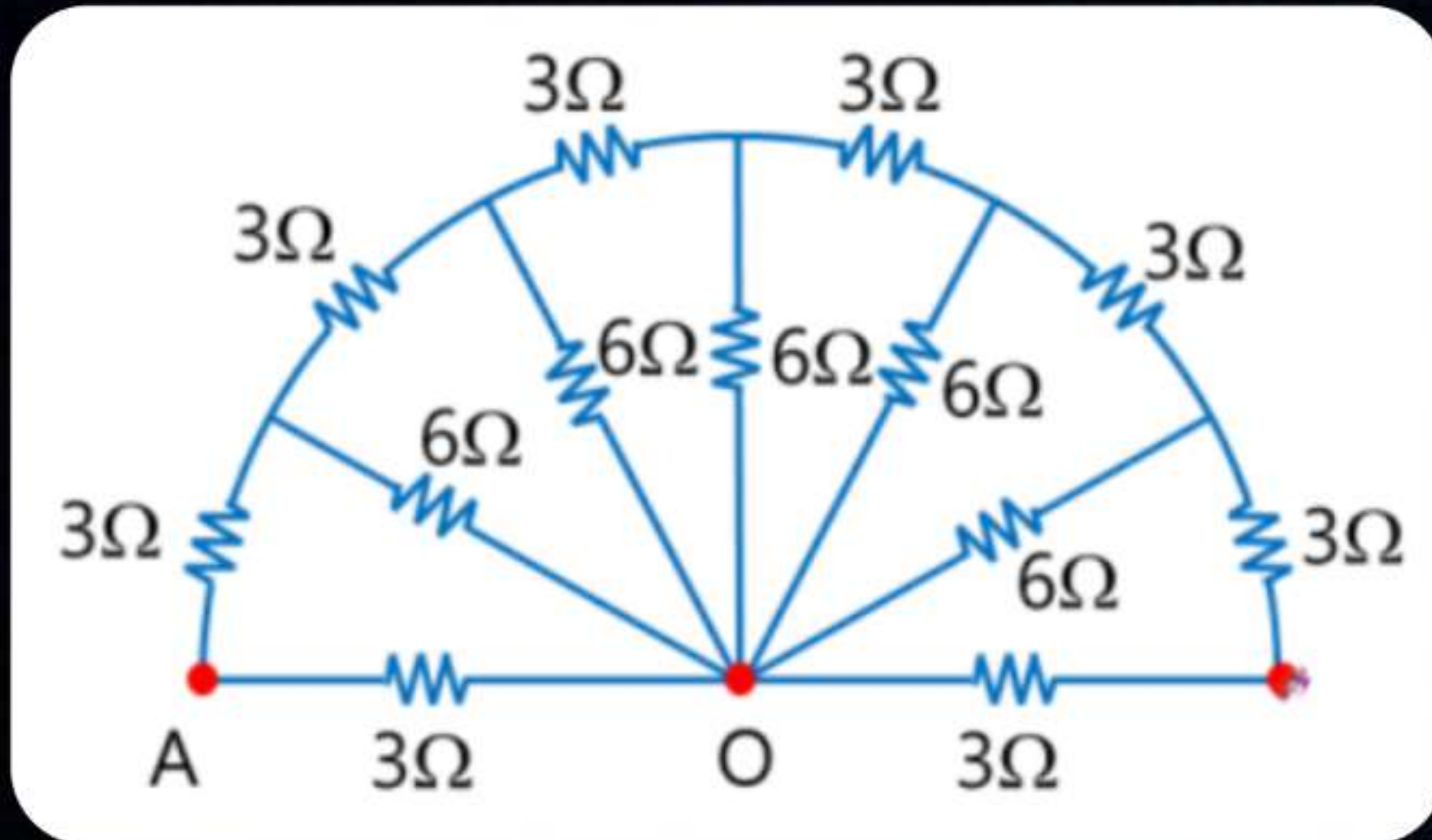
$R/4$



?
Que.



Find equivalent resistance across O and A (R_{OA}) ?



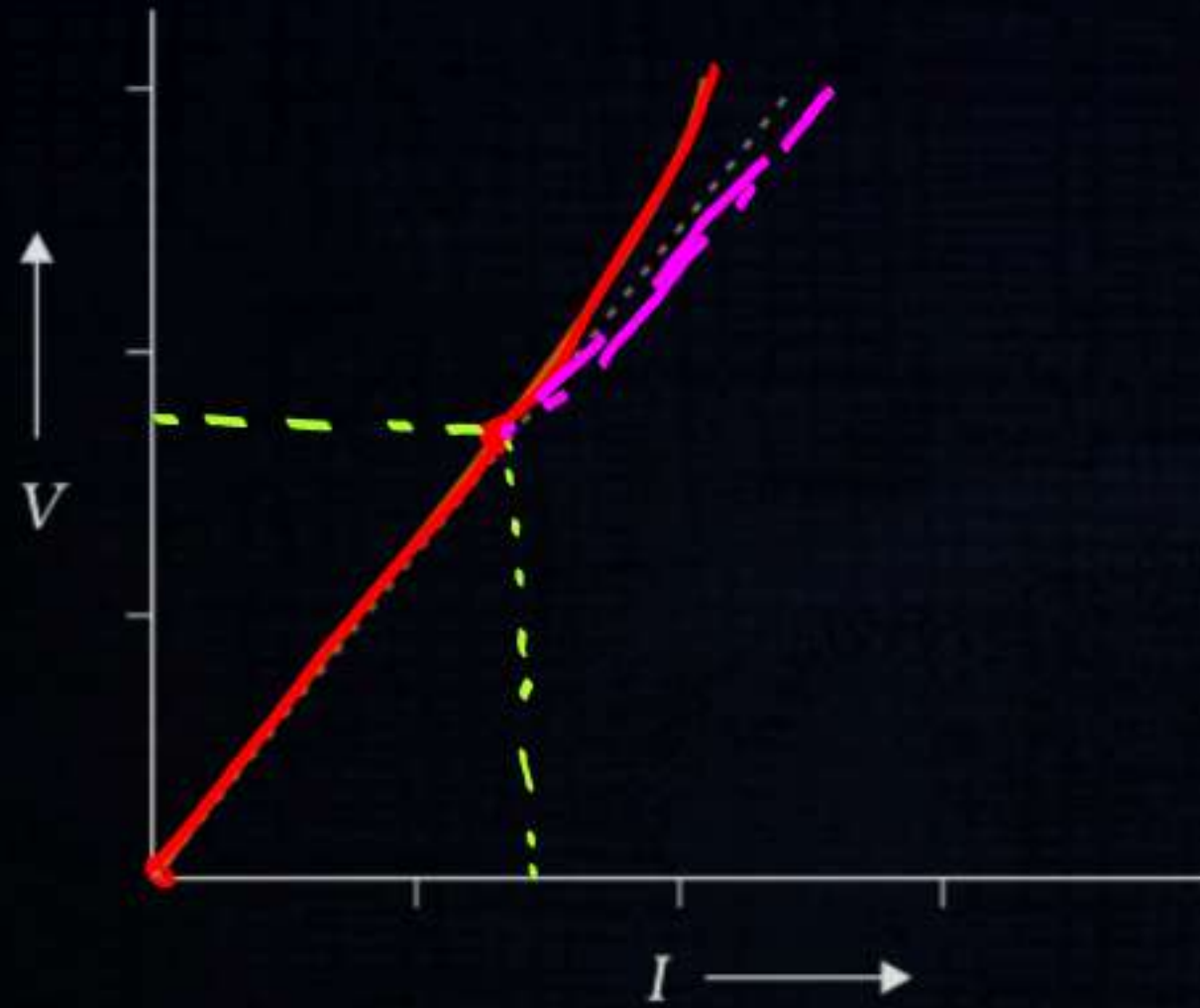
"comment"

Marathon

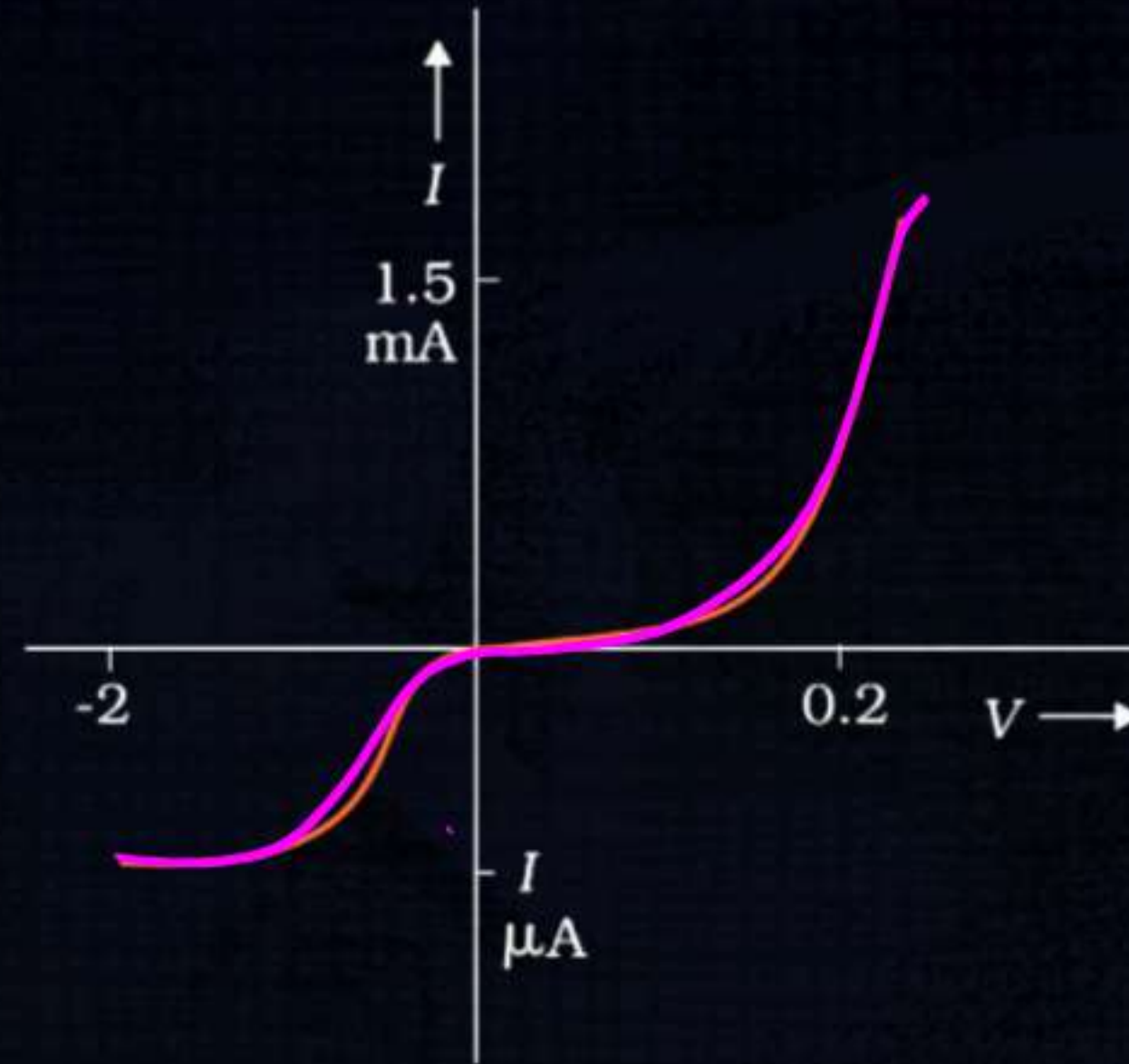
Limitations of Ohm's Law

(3 Marks)

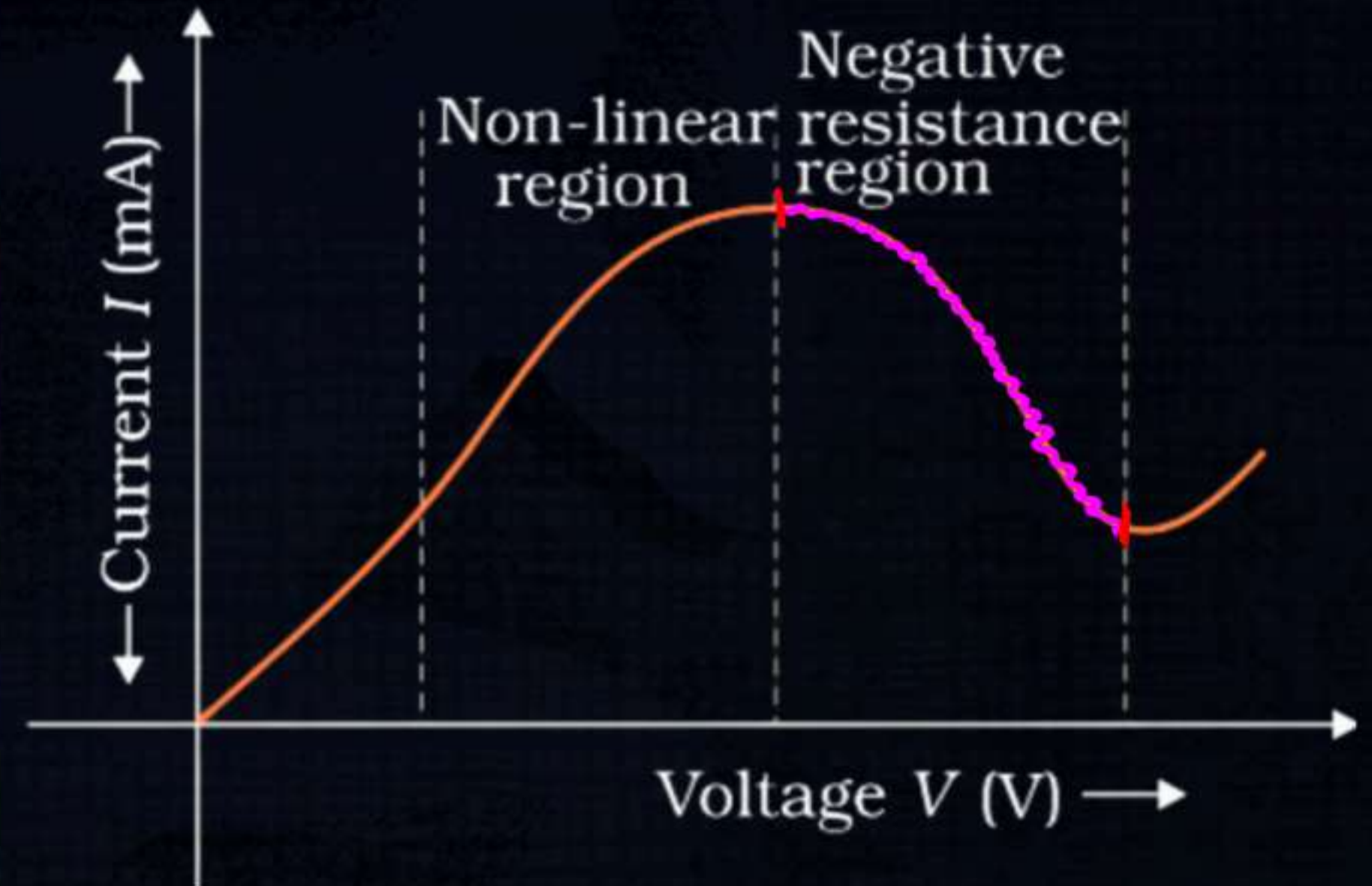
[CBSE 2024]



The dashed line represents the linear Ohm's law. The solid line is the voltage V versus current I for a good conductor.



Characteristic curve of a diode. Note the different scales for negative and positive values of the voltage and current.



Variation of Current versus voltage for GaAs.

Electric Cell

Electric cell is a device which maintains potential difference between its terminals
Converts chemical energy into electrical energy.

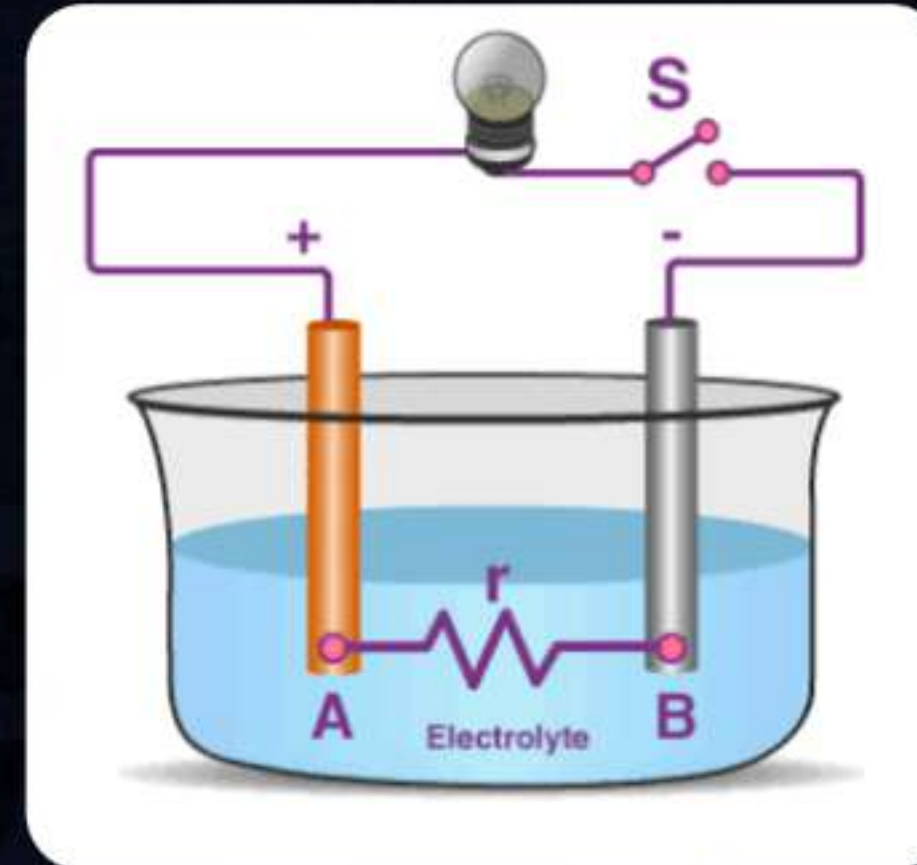
- The potential difference across the terminals of a cell when it is **not delivering any current** is called emf of the cell.

emf depends on (i) nature of electrolyte & (ii) metal of electrodes

emf does **not** depend on :

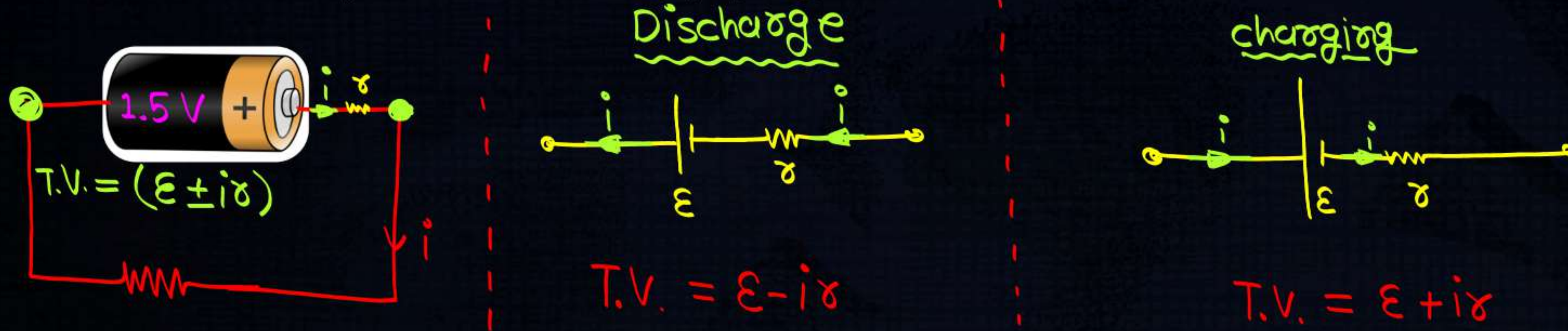
- ✗ (i) area of plates
- ✗ (ii) distance between the electrodes
- ✗ (iii) quantity of electrolyte
- ✗ (iv) size of cell

CBSE
2026

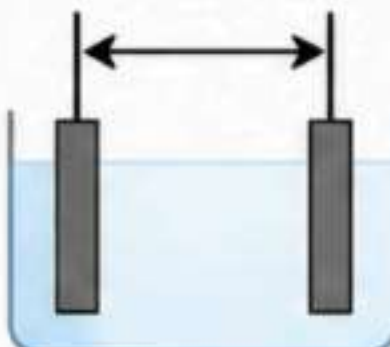
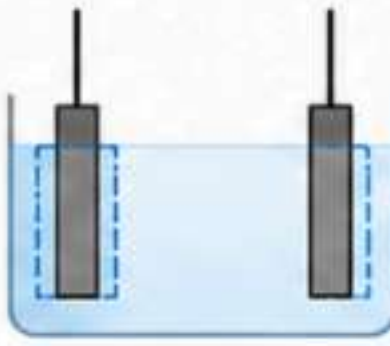


Terminal voltage & internal resistance.

Terminal voltage is the potential difference across the terminals of a cell/battery when it is supplying current to an external circuit.



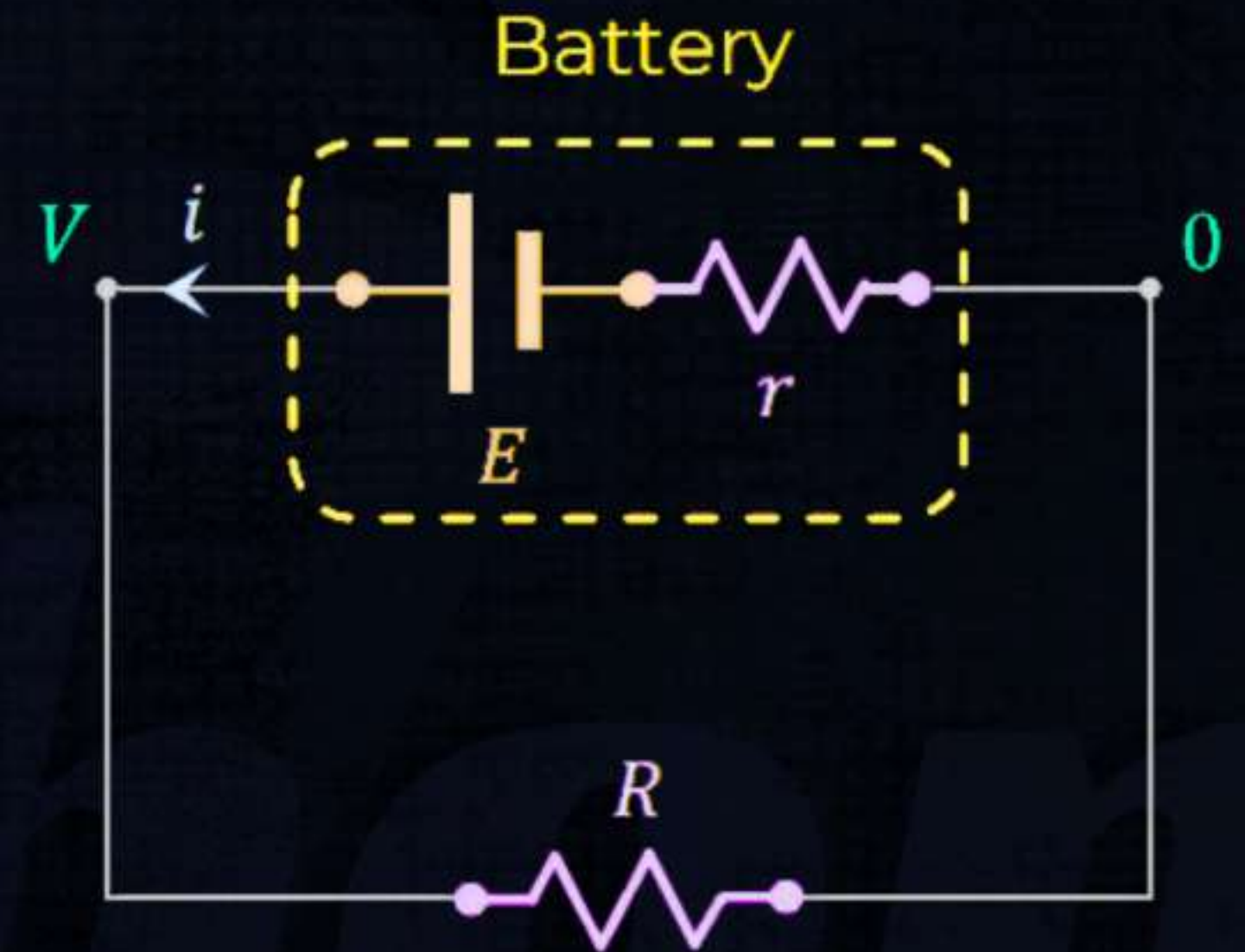
"Resistance offered by the electrolyte" of the cell when an electric current flows through it is known as **internal resistance**.

Sr. No.	FACTOR	CHANGE IN FACTOR	EFFECT ON r	ILLUSTRATION
1	Distance between two electrodes increases	Distance increases	$\Rightarrow$ r increases	 Distance increased
2	Area dipped in electrolyte increases	Area dipped increases	$\Rightarrow$ <u>r decreases</u>	 Area dipped increased
3	Concentration of electrolyte increases	Concentration increases	$\Rightarrow$ <u>r increases</u>	 Concentration increased
4	Temperature increases	Temperature increases	$\Rightarrow$ <u>r decreases</u>	 Temperature increased

Que.

A battery of emf E and internal resistance r is connected to a rheostat. When a current of 2A is drawn from the battery, the potential difference across the rheostat is 5V . The potential difference becomes 4V when a current of 4A is drawn from the battery. Calculate the value of E and r .

"HOMEWORK"

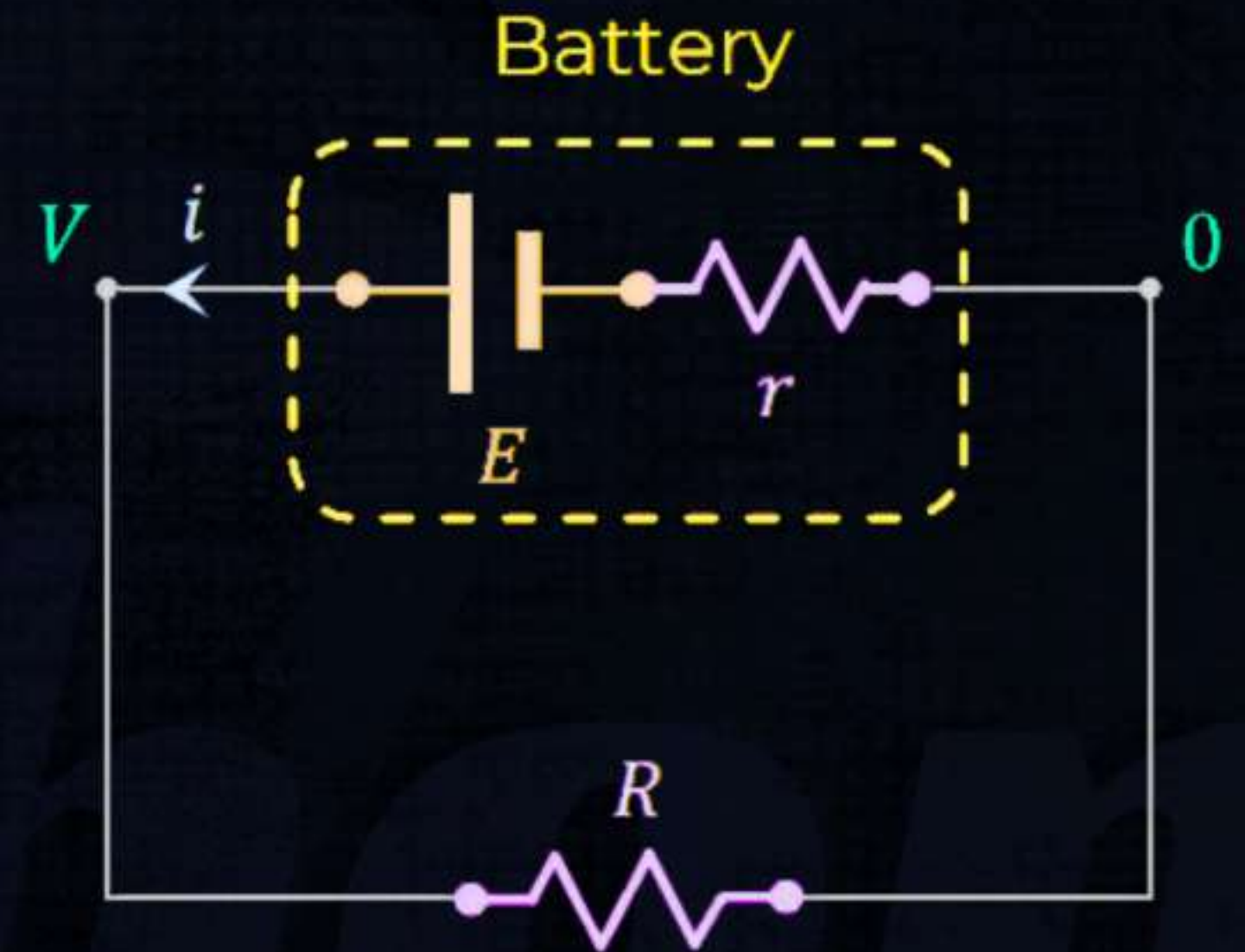


Que.

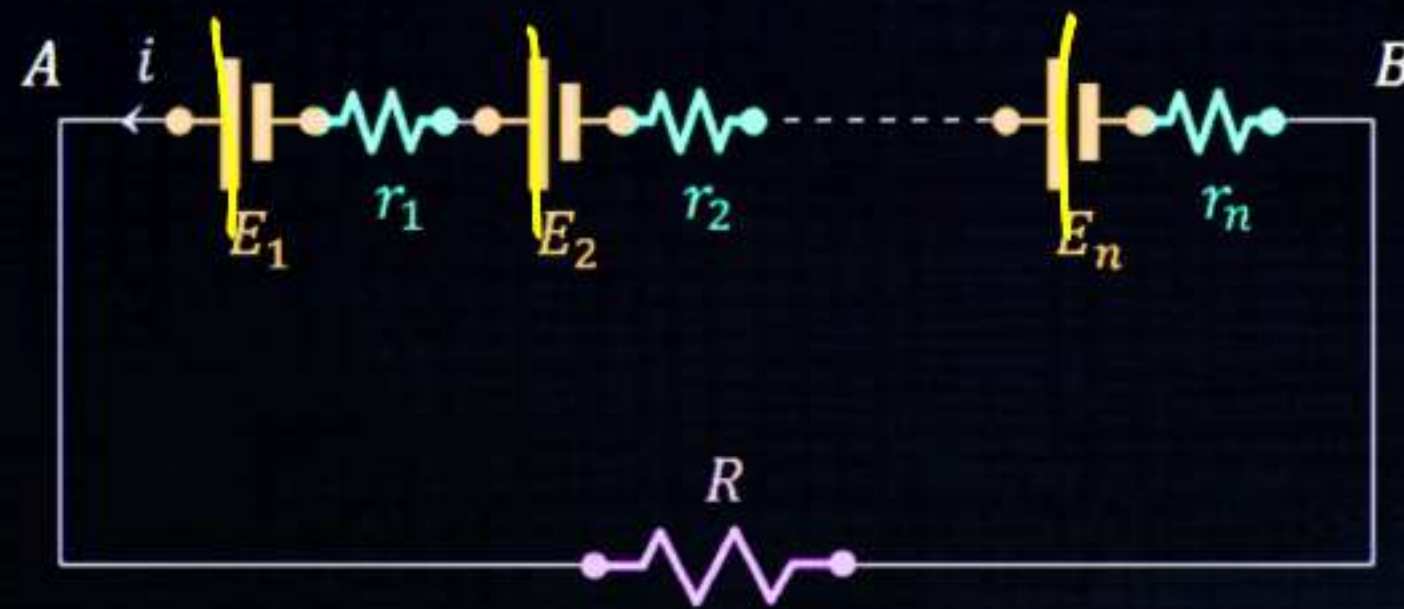
A battery of emf E and internal resistance r is connected to a rheostat. When a current of 2A is drawn from the battery, the potential difference across the rheostat is 5V . The potential difference becomes 4V when a current of 4A is drawn from the battery. Calculate the value of E and r .
[CBSE 2025]

Ans.

$r = 0.5 \text{ ohm}$ & $\text{EMF} = 6 \text{ volt}$



Series Combinations

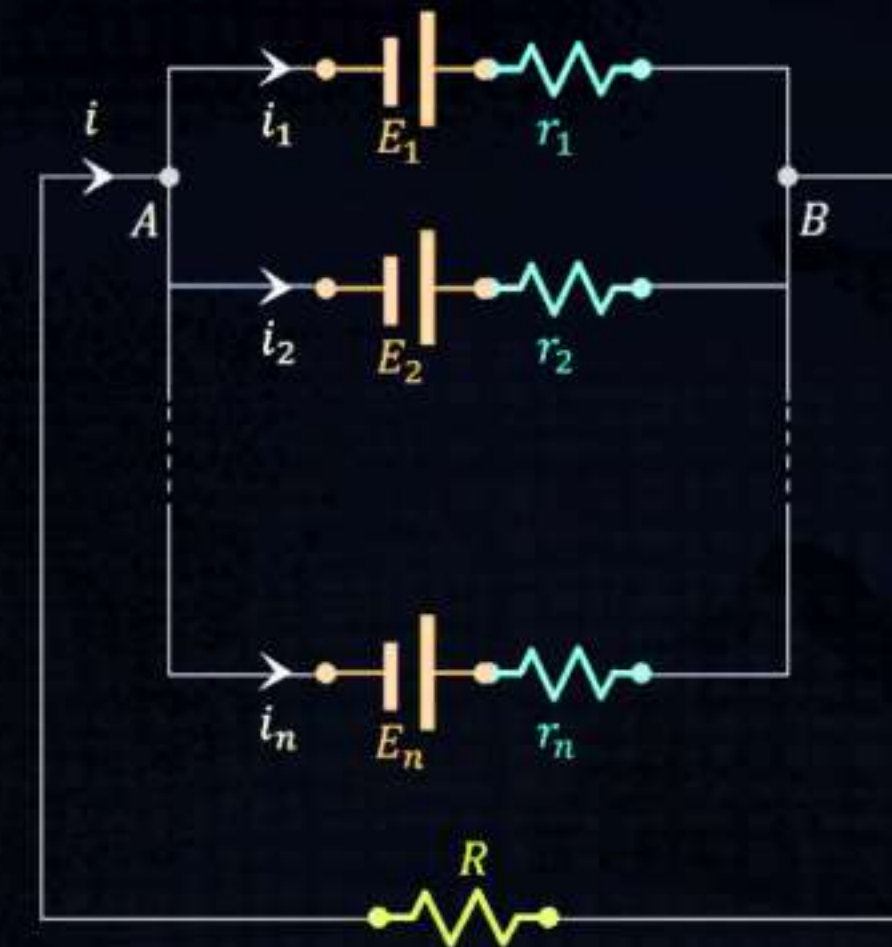


$$* \mathcal{E}_{eq} = \mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3 + \dots$$

polarity
oppo. $\Rightarrow \ominus$

$$* r_{eq} = r_1 + r_2 + r_3 + \dots$$

Parallel combination



$$* \mathcal{E}_{eq} = \frac{\frac{\mathcal{E}_1}{r_1} + \frac{\mathcal{E}_2}{r_2} + \frac{\mathcal{E}_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}} \quad \text{///}$$

$$* \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \dots$$

Que.

$\mathcal{E}_1$

$\mathcal{E}_2$

r_1

r_2

Two cells of emfs 2.0 V and 6.0 V and internal resistances 0.1Ω and 0.4Ω respectively, are connected in parallel. The equivalent emf of the combination will be :

- a. 6 V
- b. 8 V
- c. 9V
- d. 12 V

Marathon



Two cells of emfs 2.0 V and 6.0 V and internal resistances $0.1\ \Omega$ and $0.4\ \Omega$ respectively, are connected in parallel. The equivalent emf of the combination will be : [CBSE 2024]

- a. 6 V
- b. 8 V
- c. 9V
- d. 12 V



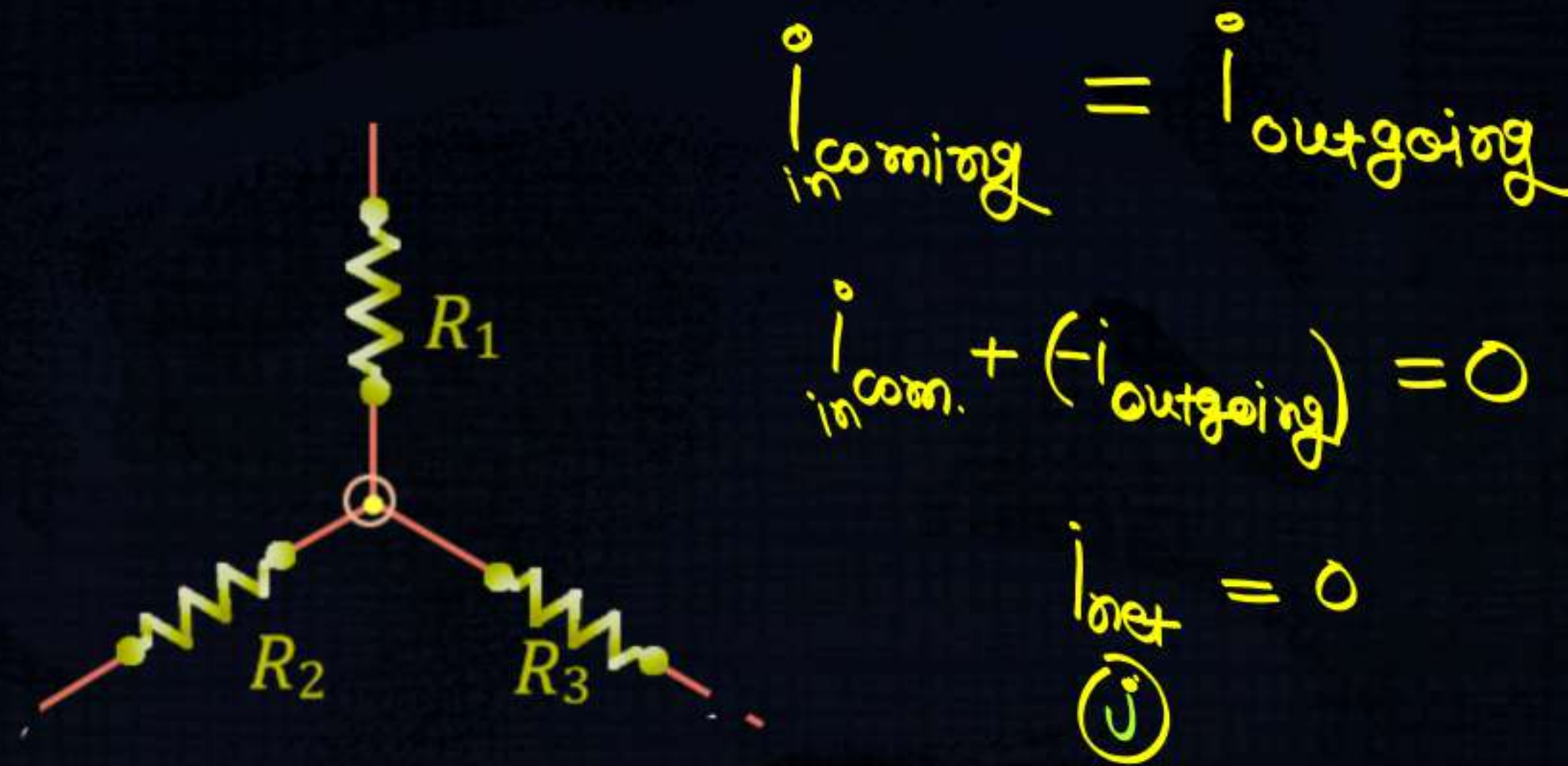
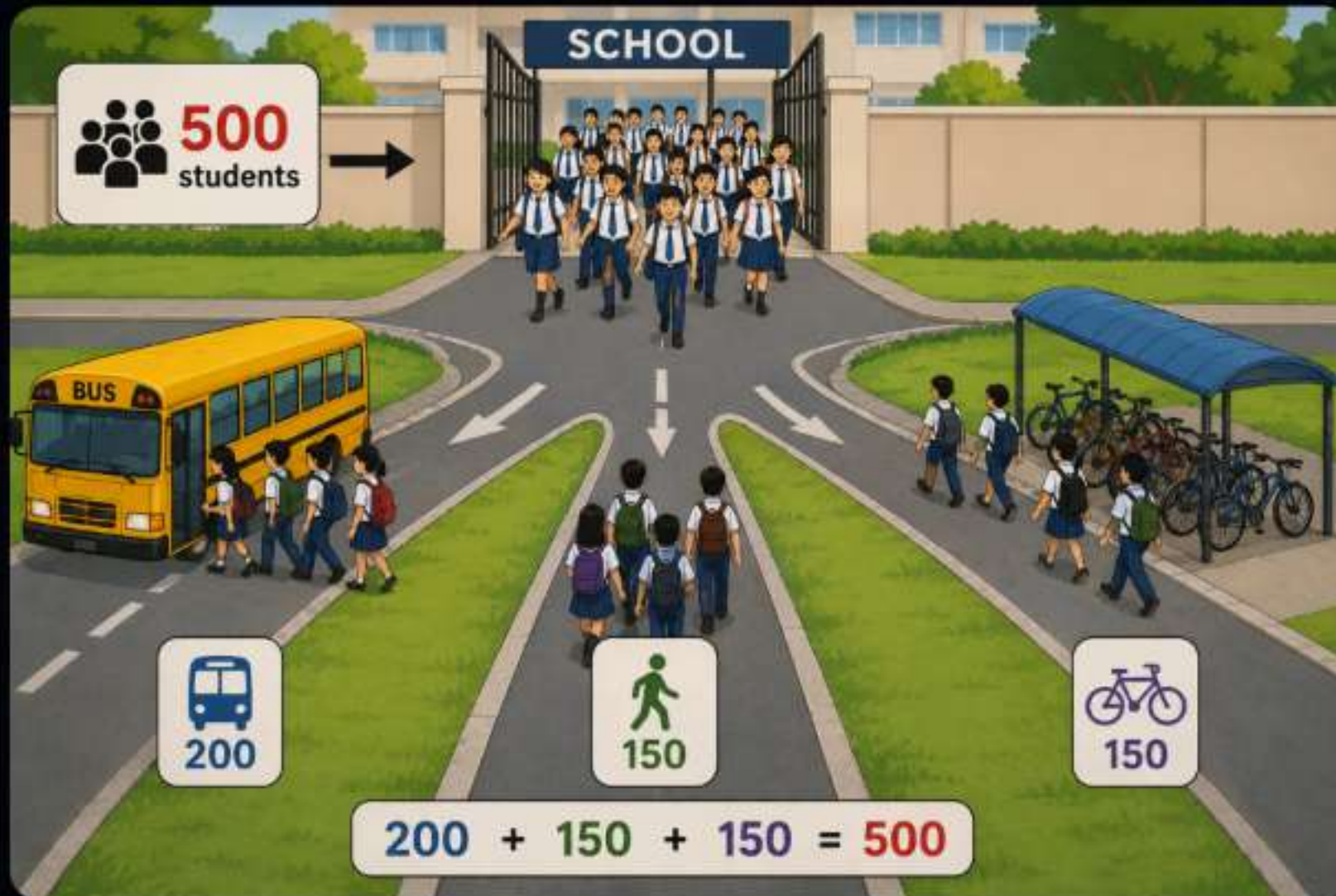
Choose the incorrect statement:

[CBSE 2024]

- a. The potential difference (V) between the two terminals of a cell in a closed circuit is always less than its emf (ϵ), during discharge of the cell.
- ✓ b. The internal resistance of a cell decreases with the decrease in temperature of the electrolyte. (F)
- c. When current is drawn from the cell then $V = \epsilon - Ir$.
- d. The graph between potential difference between the two terminals of the cell (V) and the current (I) through it is a straight line with a negative slope.

Kirchhoff's Law

(A) Kirchhoff's Current Law (Junction Rule)

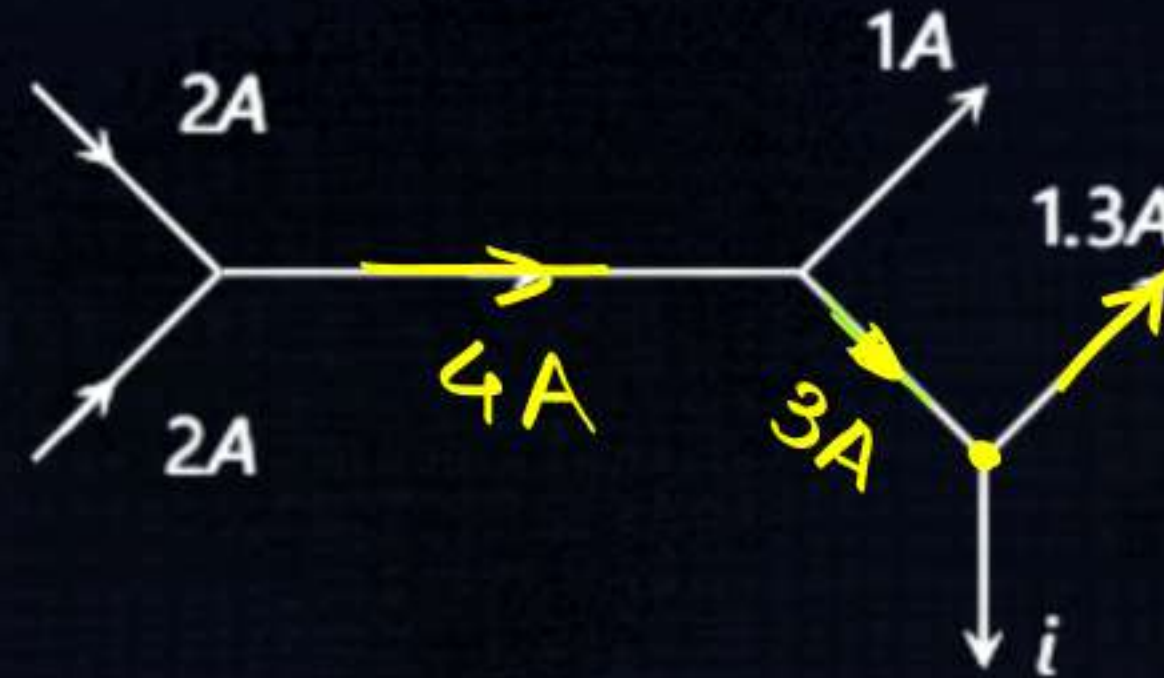


- At a node/junction, Incoming current = Outgoing current
- In an electric circuit, the algebraic sum of currents at any junction is zero.
- Based on the conservation of charge

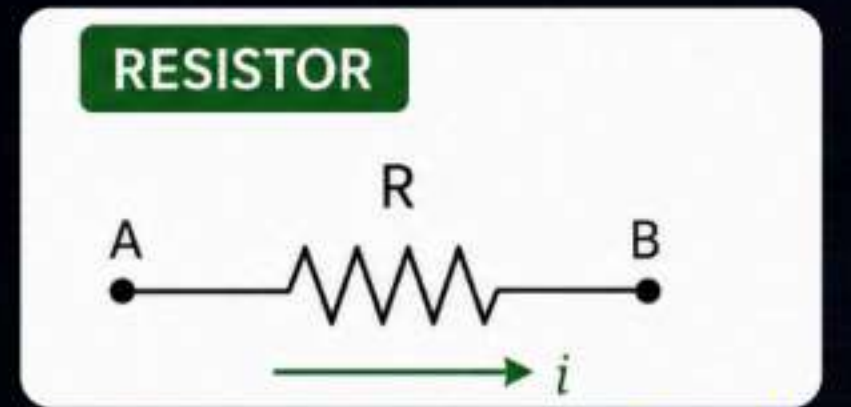
Que.

The figure below shows currents in a part of electric circuit. The current i is

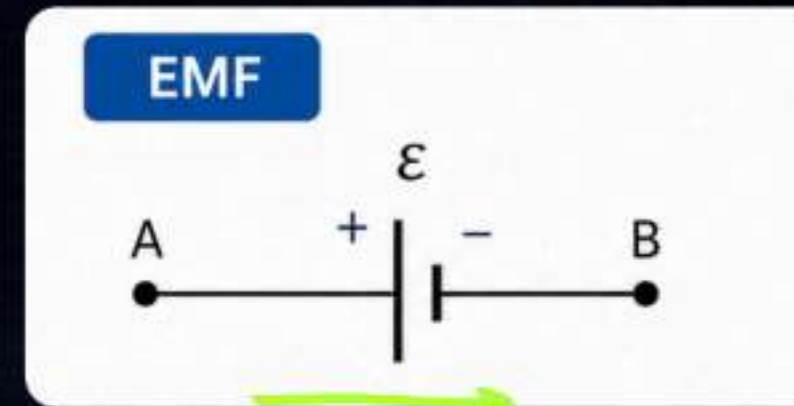
- ☒ a. 1.7 A
- ☐ b. 3.7 A
- ☐ c. 1.3 A
- ☐ d. 1 A



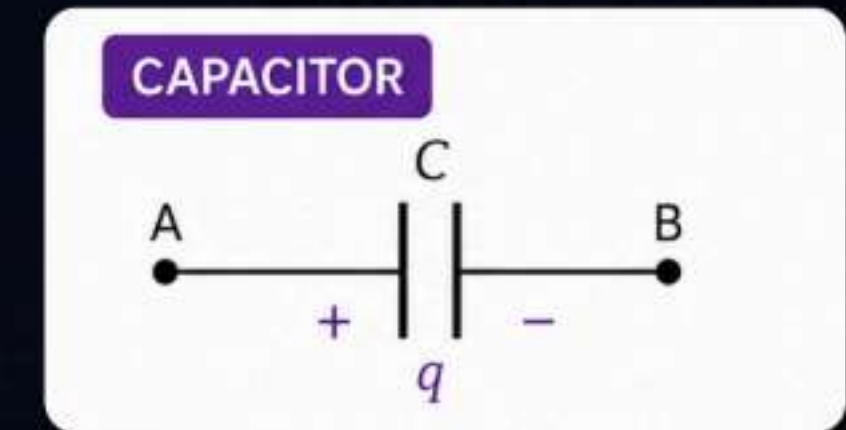
Sign convention :



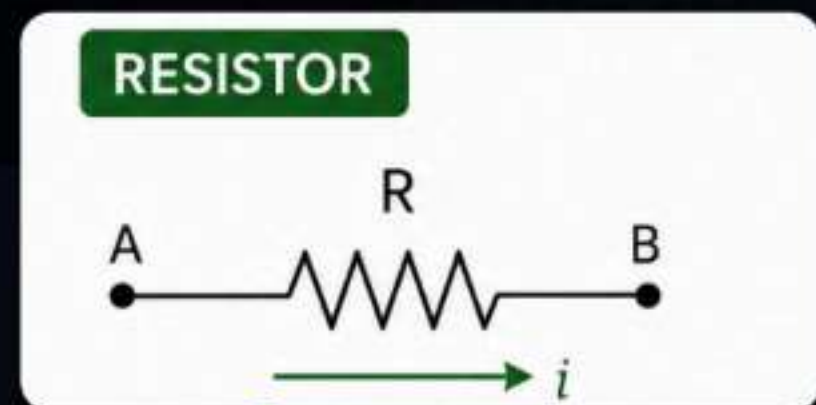
path
 $-iR$



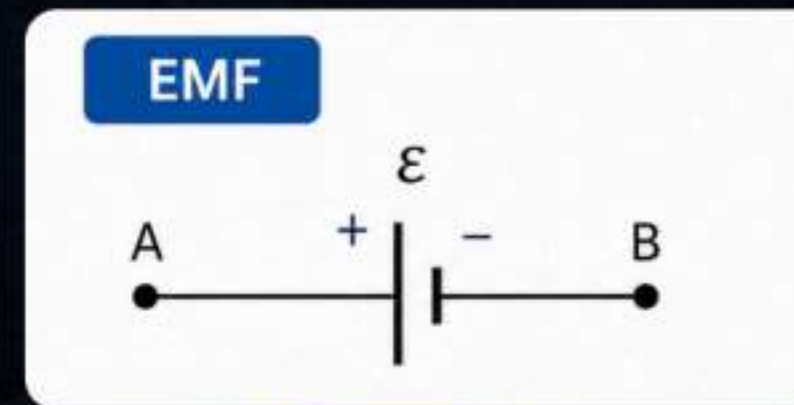
path
 $-\epsilon$



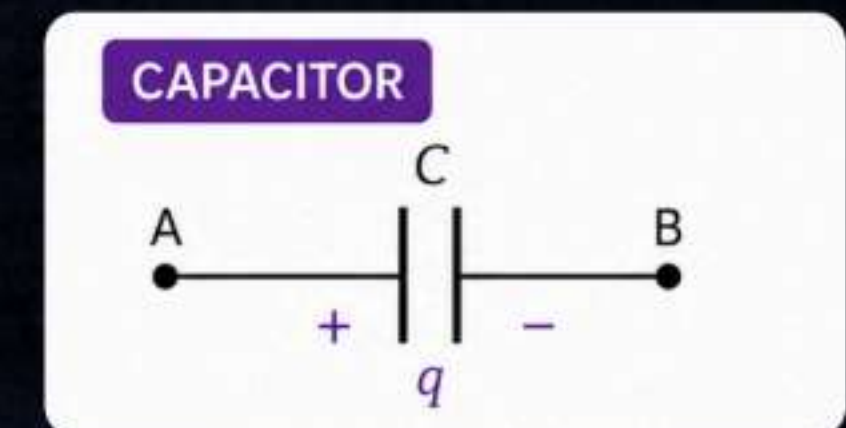
x



path
 $+iR$



path
 $+\epsilon$



x

Que.

Using Kirchhoff's rules calculate the current through the $40\ \Omega$ and $20\ \Omega$ resistors in the following circuit. [CBSE]

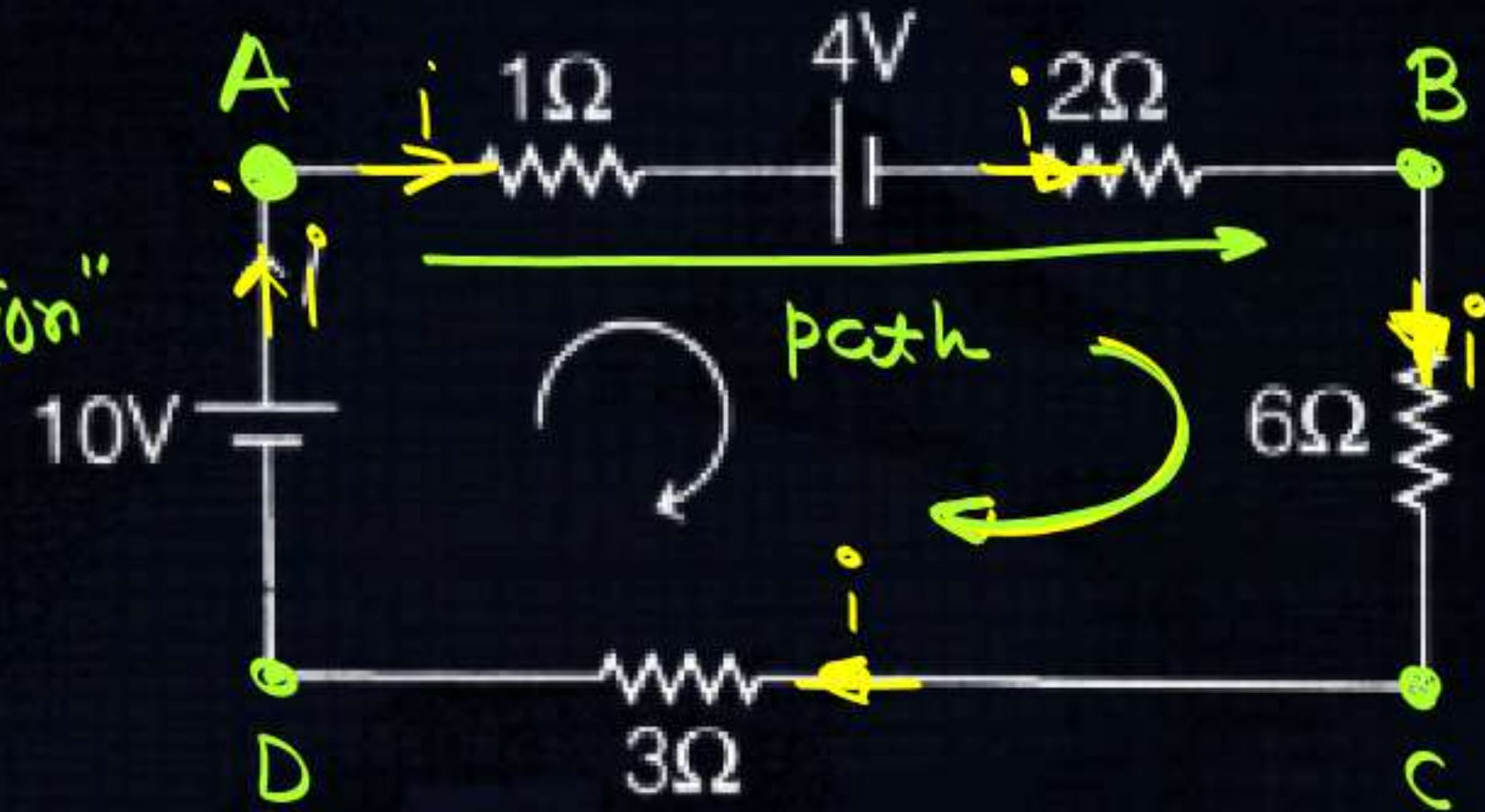
Loop Rule

KVL For loop. $\sum (p.d.) = 0$

$$\underline{-i(1)} - 4 - \underline{i(2)} - \underline{i(6)} - \underline{i(3)} + 10 = 0$$

$i = 0.5\text{ A}$

"Energy
conservation"
Based

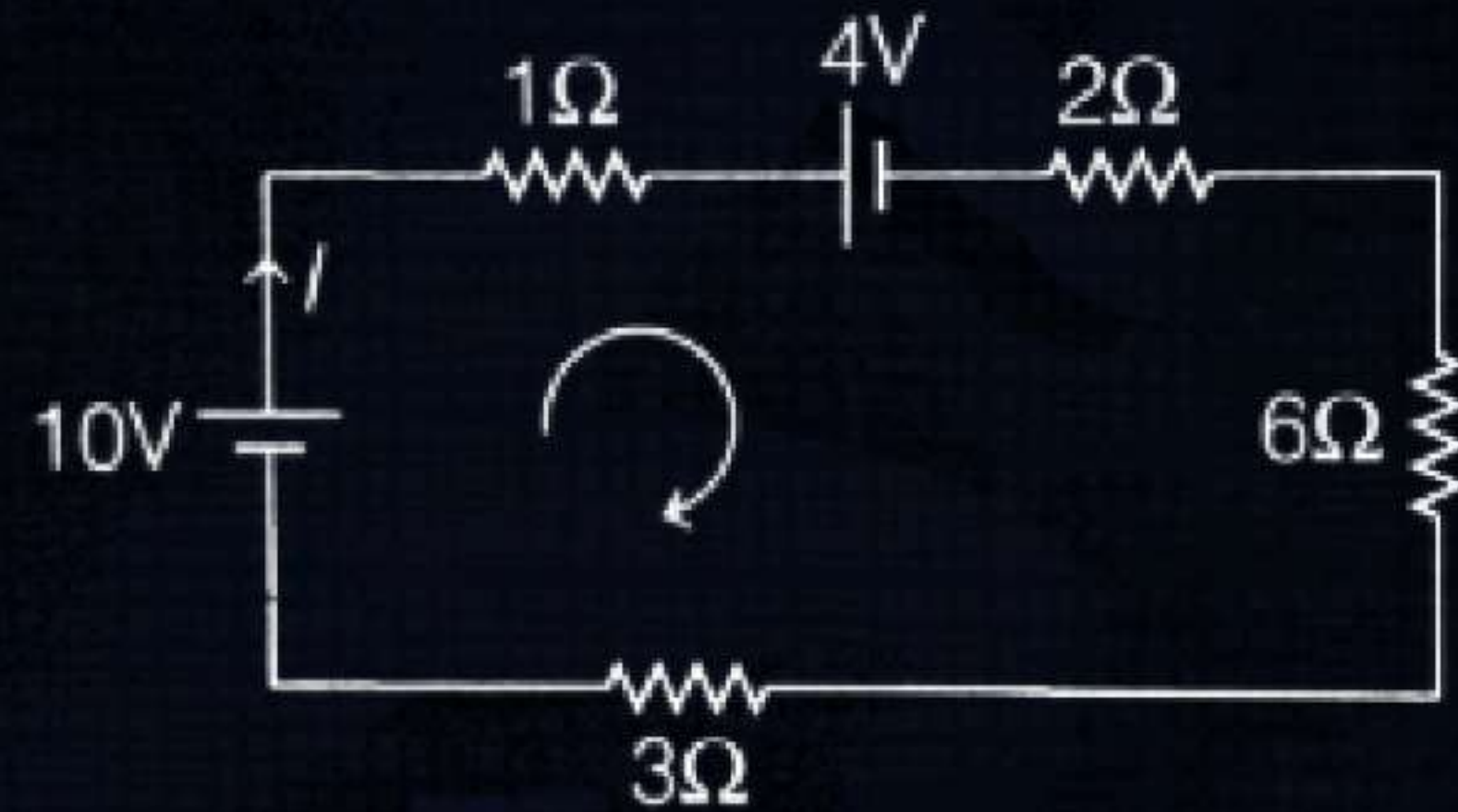


Que.

Using Kirchhoff's rules calculate the current through the $40\ \Omega$ and $20\ \Omega$ resistors in the following circuit. [CBSE]

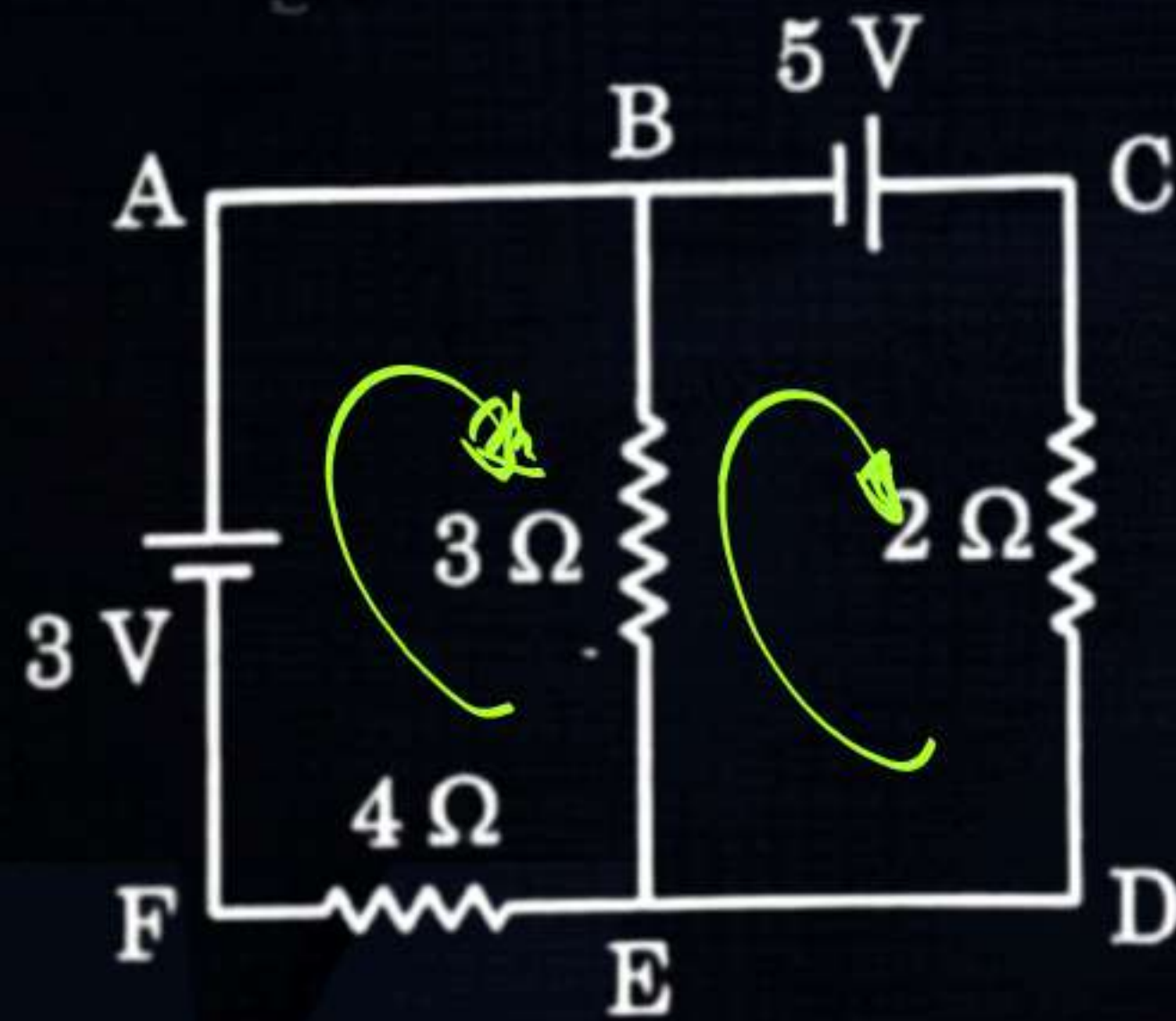
Ans.

0.5 A



Que.

Use Kirchhoff's rules to find the current through 3 & 2 resistor in the circuit shown



"HOMEWORK"

Marathon

Que.

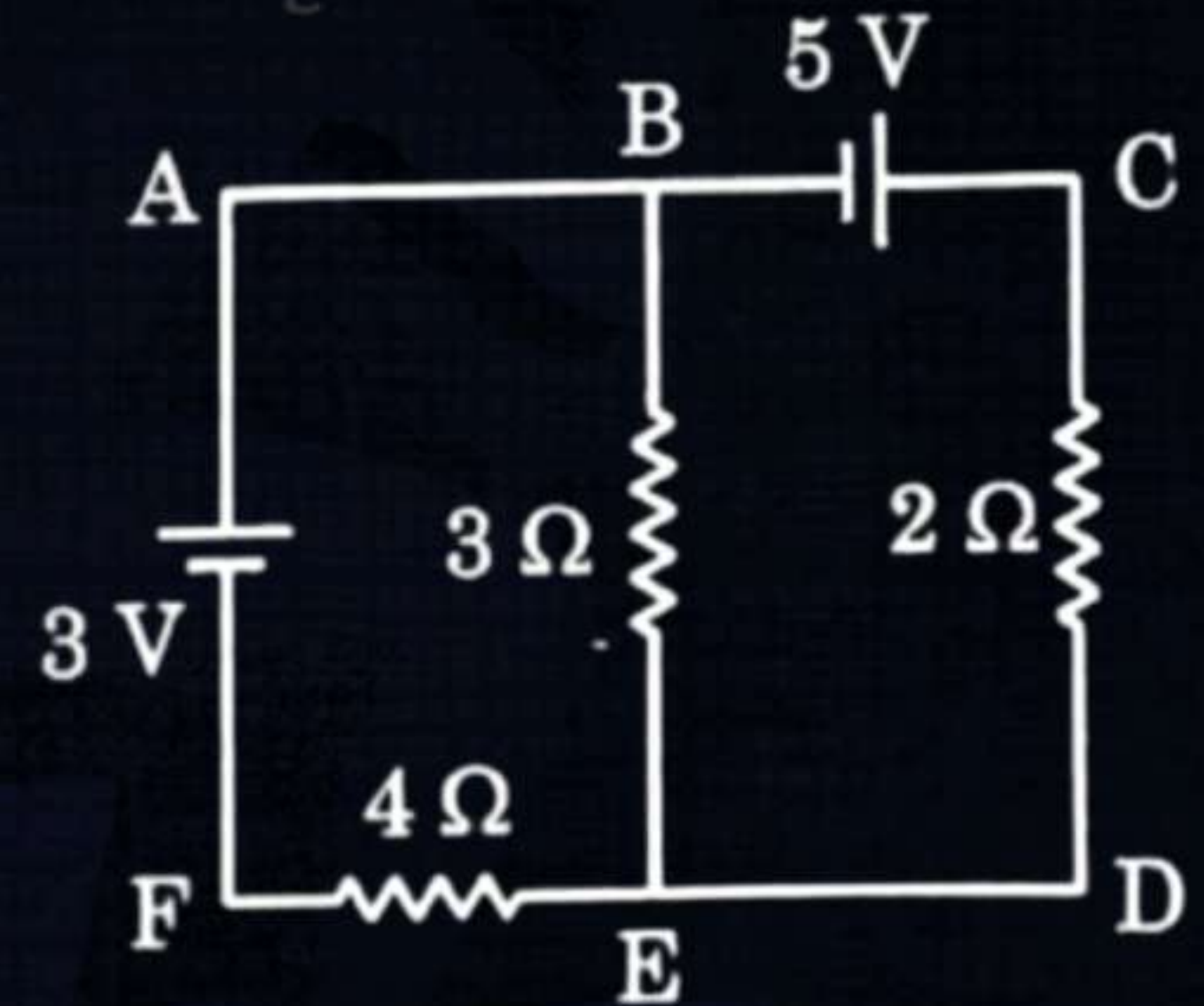
Use Kirchhoff's rules to find the current through 3 & 2 resistor in the circuit shown

[CBSE 2026]

Ans.

$$I_{3\Omega} = \frac{7}{13} \text{ A upward}$$

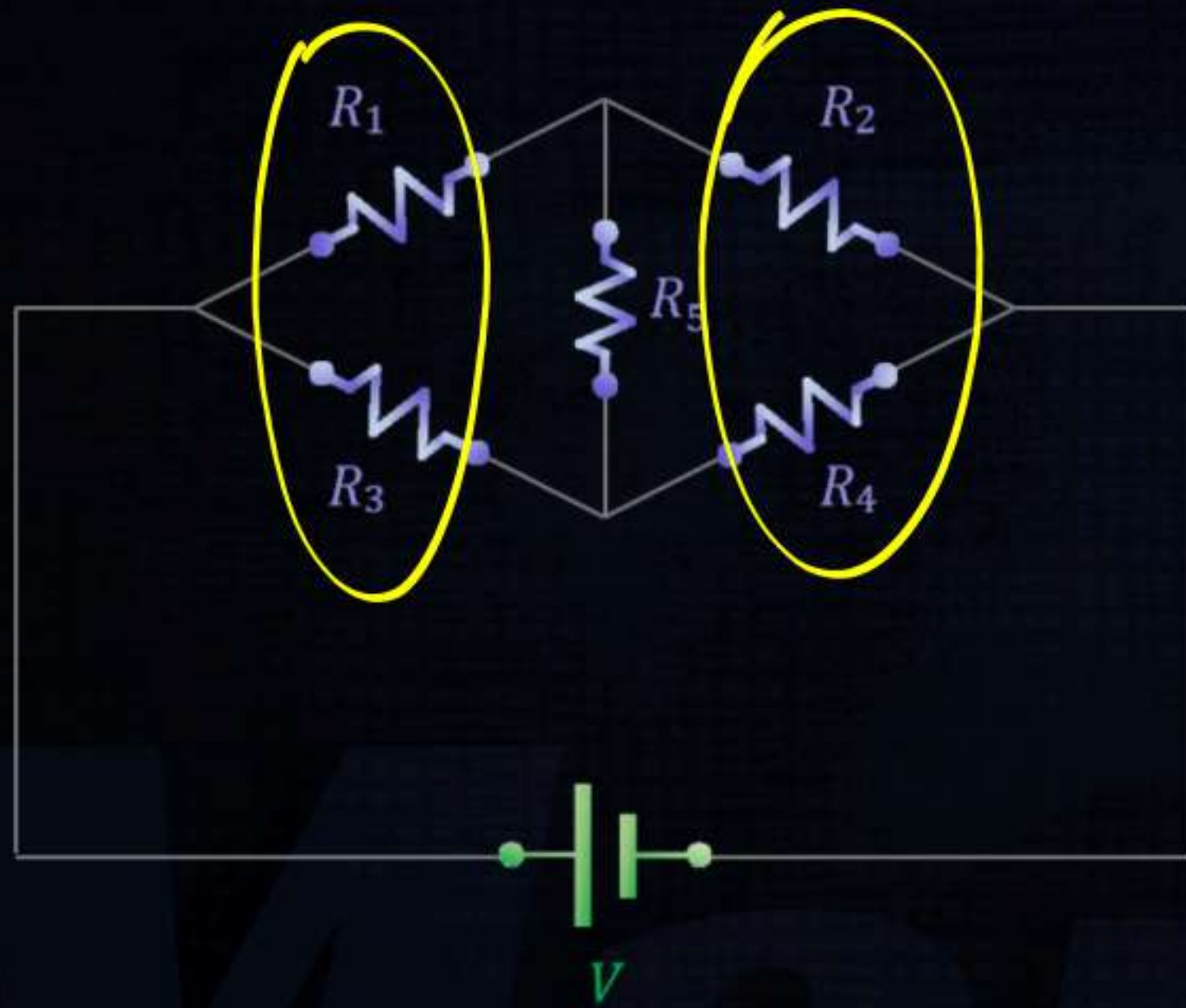
$$I_{2\Omega} = \frac{22}{13} \text{ A downward}$$



Wheatstone Bridge

[CBSE 2024]

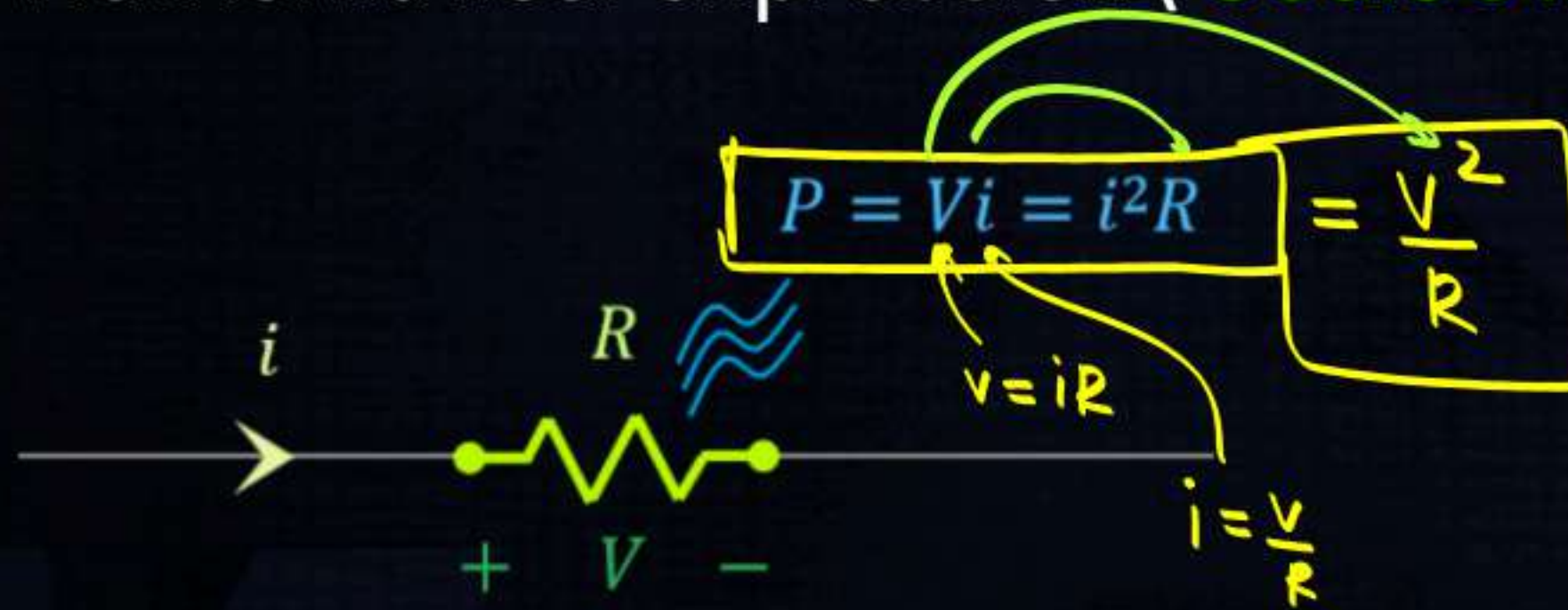
A Wheatstone bridge is an electrical circuit used to measure an unknown resistance accurately by comparing it with known resistances.



$$I_F \quad \frac{R_1}{R_3} = \frac{R_2}{R_4} \Rightarrow i_5 = 0$$

Electrical Energy and Power

- When **current flows** through a **conductor**, drifting electrons **collide** with atoms/ions.
- Electrical energy supplied by the battery is converted into **heat energy** in the conductor.
- Heat energy released from the conductor is equal to work done by the battery
- Mathematical expression (**Joule's law of heating**):



$$\text{Heat loss} = \int P \cdot dt = i^2 R t$$



V, P

$$R_{\text{bulb}} = \frac{V^2}{P}$$

9:40 PM

Moving Charges & Magnetism

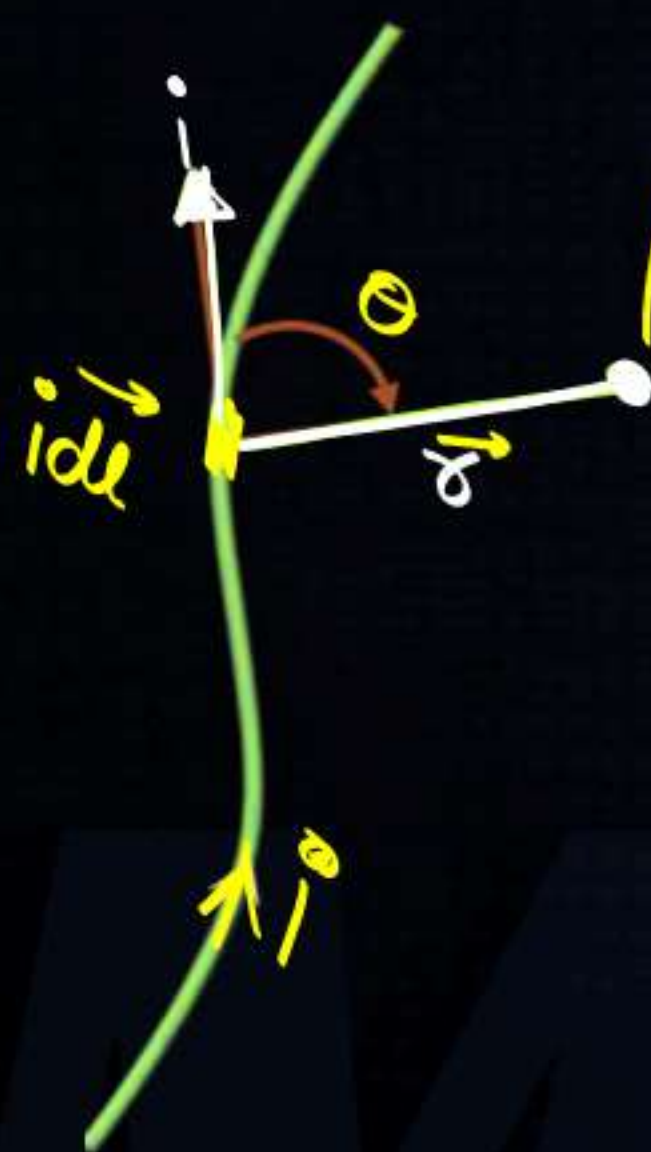
Chapter-4

Marathon

Biot - Savart's Law

(BSL)

With the help of experimental results, Biot and Savart arrived at a mathematical expression that gives the magnetic field at some point in space [CBSE 2023]



$dB \propto i dl$
 $dB \propto 1/r^2$
 $dB \propto \sin\theta$

$dB = \frac{\mu_0}{4\pi} \frac{i dl \sin\theta}{r^2}$

$\mu_0 = \text{permeability}$

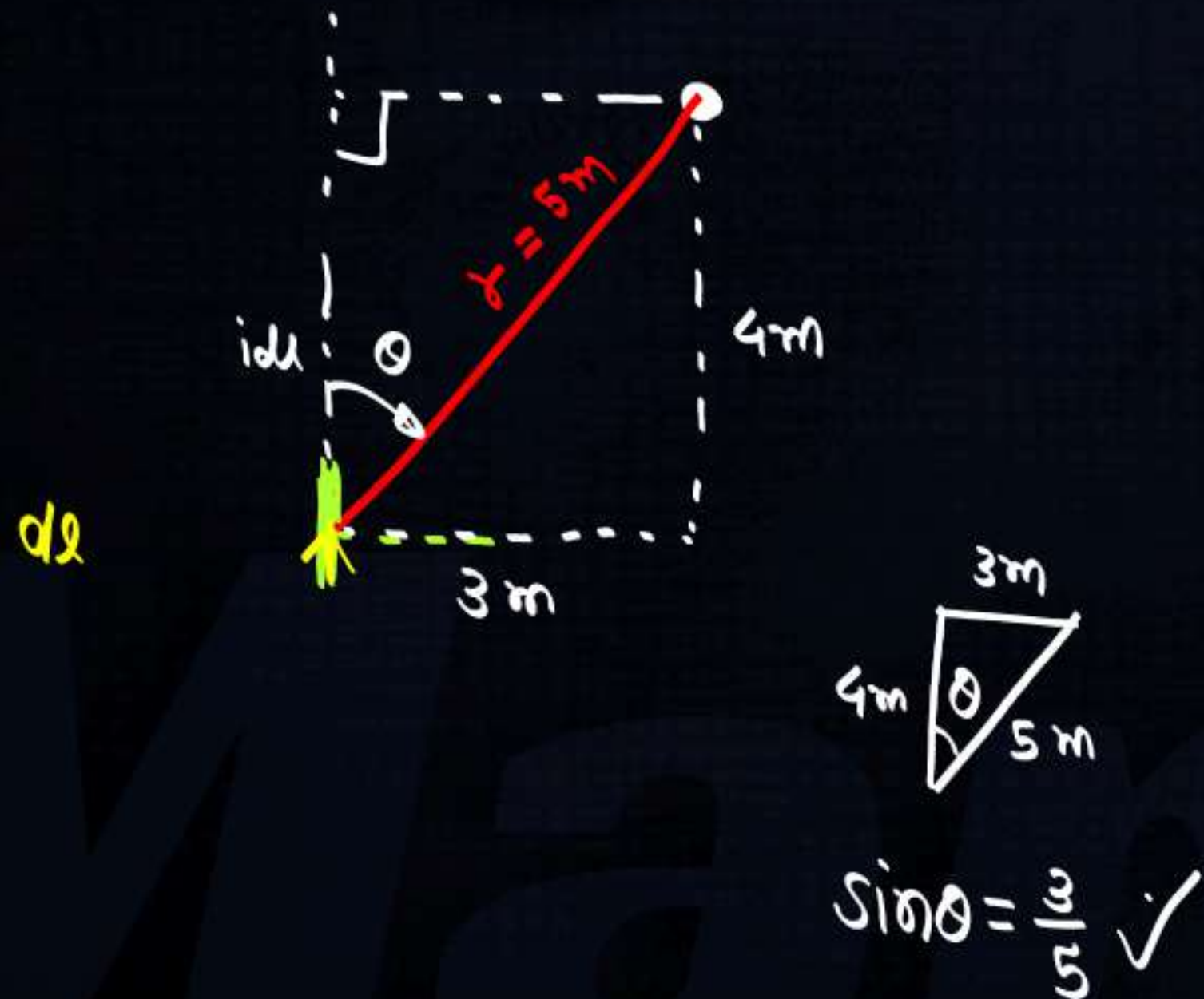
Vector Form

$$\vec{dB} = \left(\frac{\mu_0}{4\pi} \right) \frac{i \vec{dl} \times \vec{r}}{r^3}$$

direction:- $i \vec{dl} \times \vec{r}$ | Right Hand thumb Rule

Que.

A 2.0 cm segment of wire, carrying 5.0 A current in positive y -direction lies along y -axis. Find the magnetic field at a point $(3\text{ m}, 4\text{ m}, 0)$ due to this segment (part of a circuit). [CBSE 2024]



$$dB = \frac{\mu_0}{4\pi} \frac{idl \sin \theta}{r^2}$$

 Que.

A 2.0 cm segment of wire, carrying 5.0 A current in positive y-direction lies along y-axis . Find the magnetic field at a point (3 m, 4 m, 0) due to this segment (part of a circuit). [CBSE 2024]

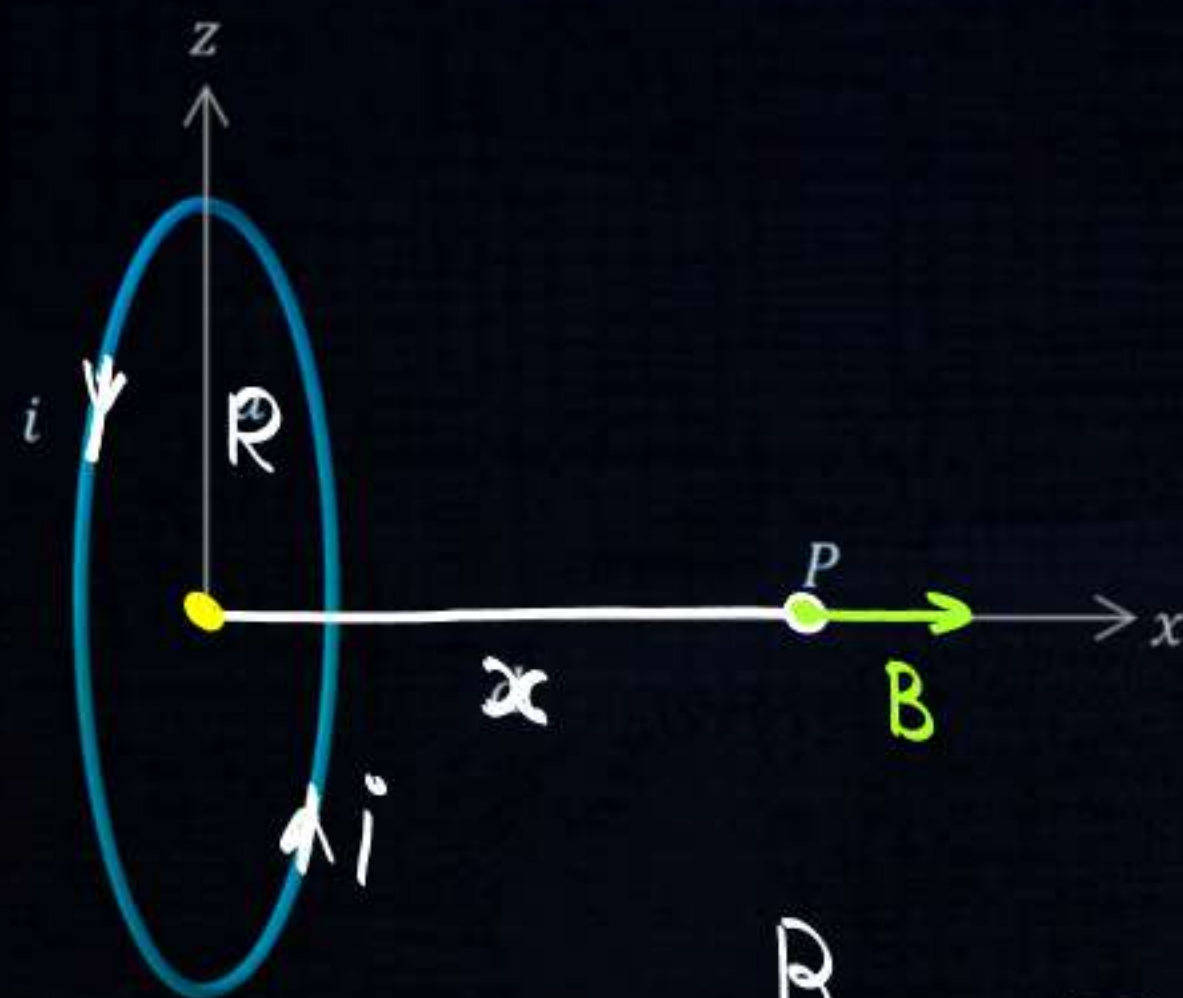
Ans.

2.4×10^{-10} T (inwards)

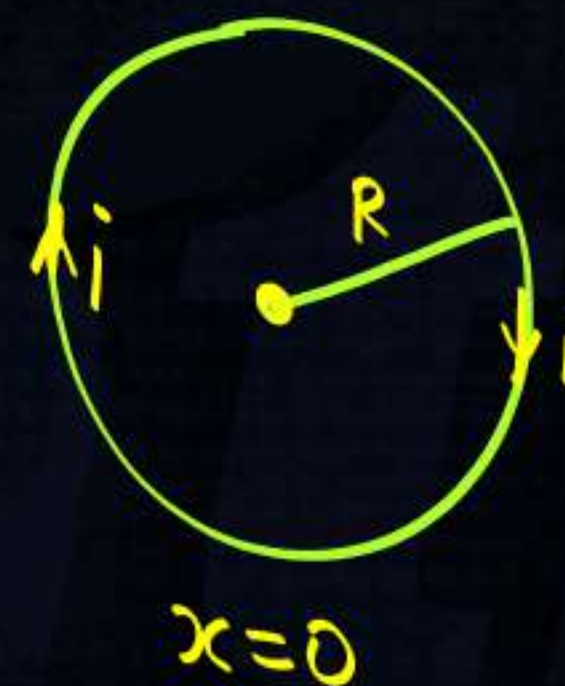
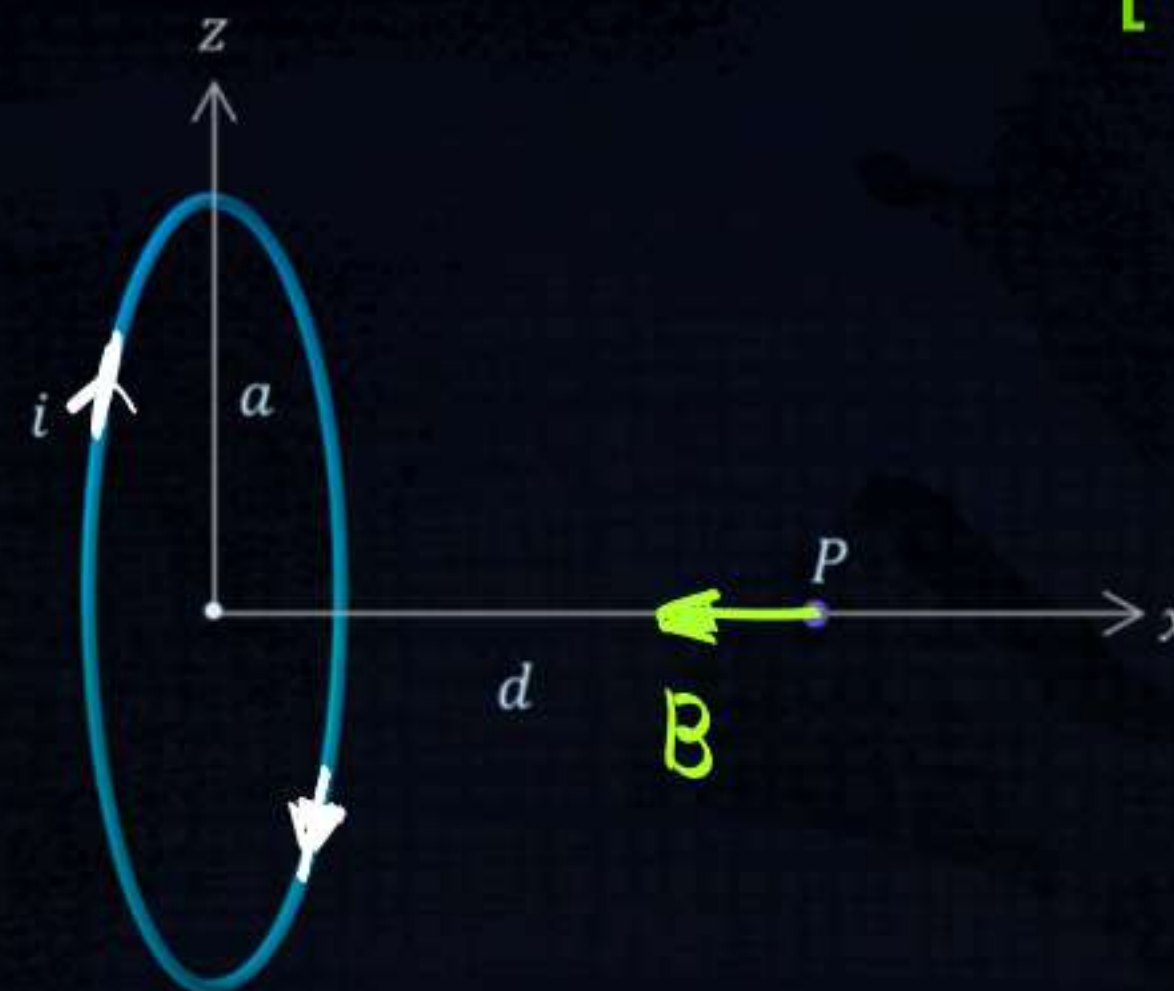
Magnetic Field on the Axis of a Coil

Ring $\Rightarrow$ Fingers curl $\Rightarrow$ (i)
thumb $\Rightarrow$ M.F.

[CBSE 2023]

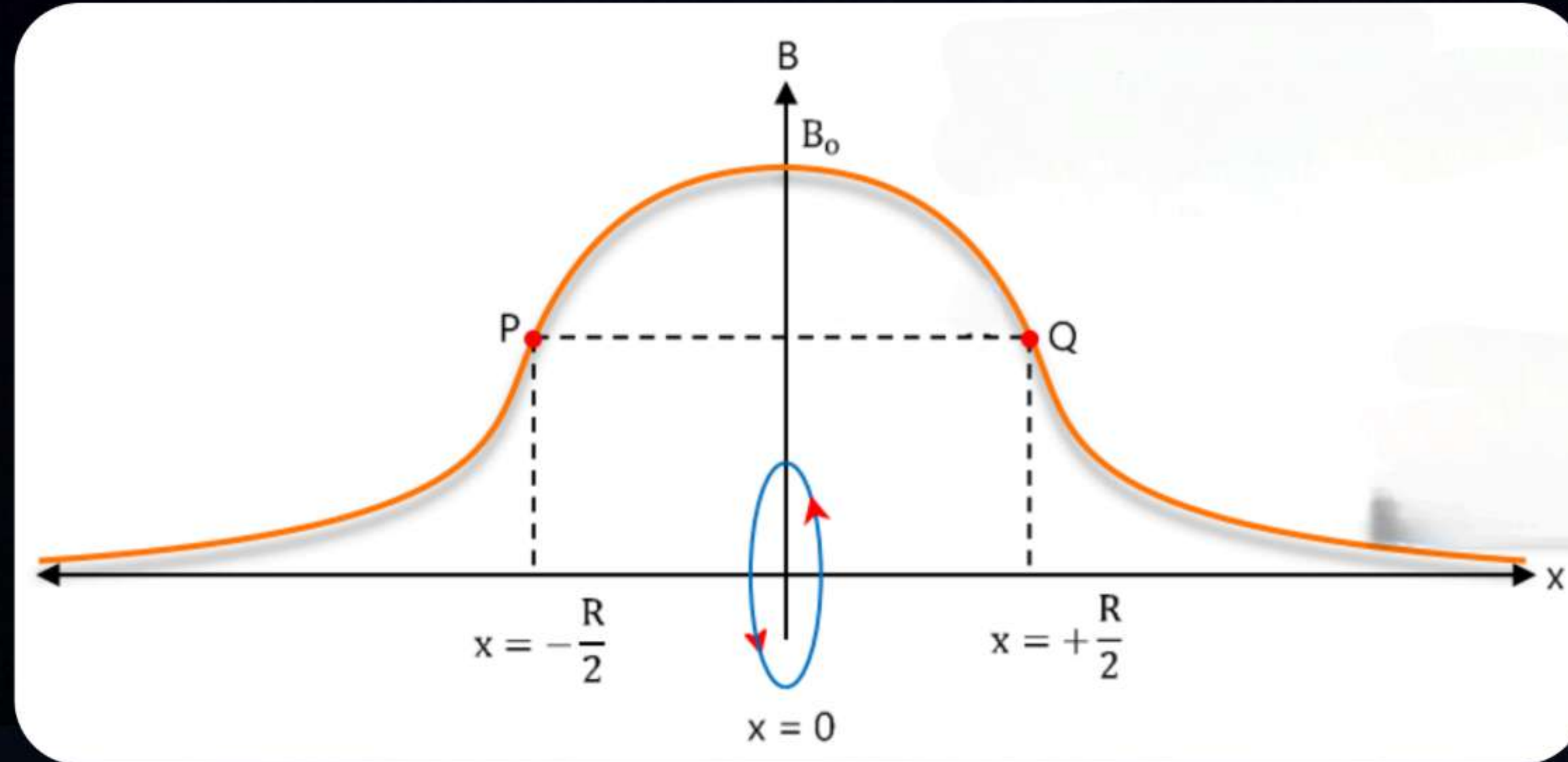


$$B_{\text{axial (Ring)}} = \frac{\mu_0 i \cdot R^2}{2(R^2 + x^2)^{3/2}}$$



$$B_{\text{centre}} = \frac{\mu_0 i}{2R} \quad \left| \quad \begin{array}{l} \text{If } N \text{ turns} \\ \Rightarrow B_{\text{centre}} = \frac{\mu_0 N i}{2R} \end{array} \right.$$

Graph



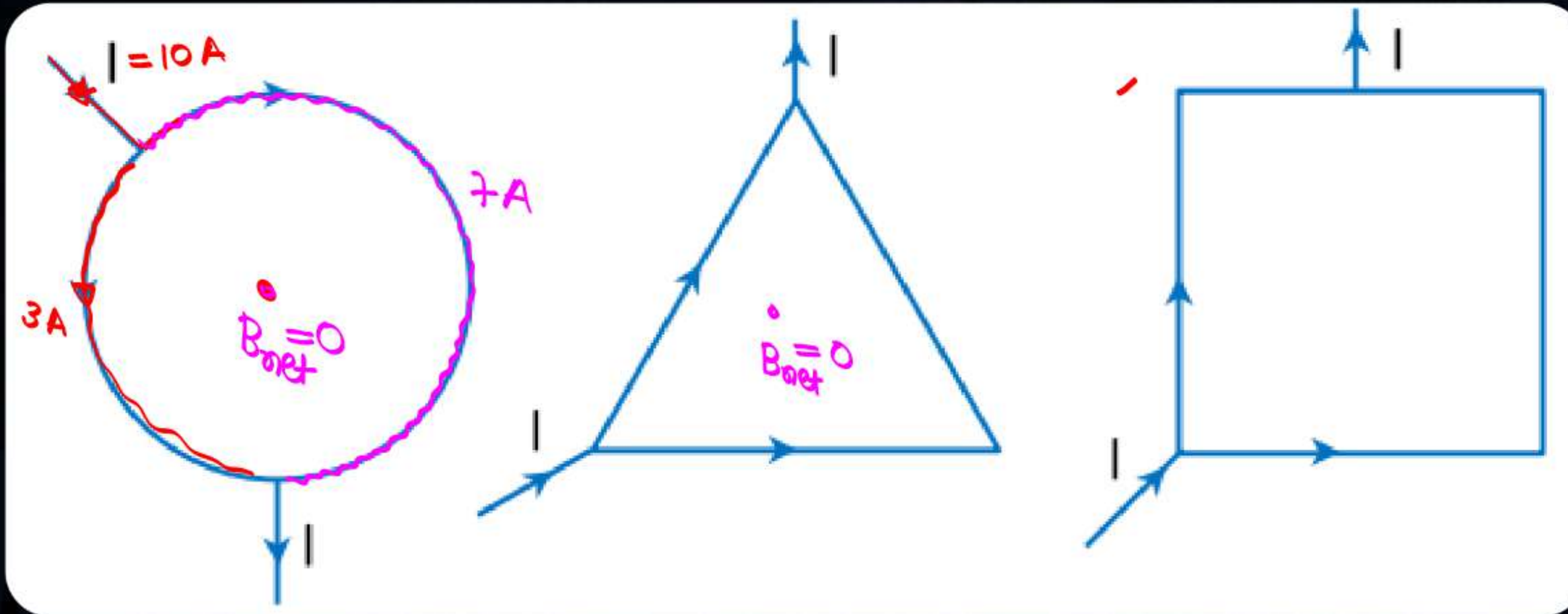


A circular coil, having 100 turns of wire, of radius (nearly) 20 cm each, lies in the XY plane with its centre at the origin of co-ordinates. Find the magnetic field, at the point $(0,0,20\sqrt{3} \text{ cm})$ when this coil carries a current of $(2/\pi) \text{ A}$. [CBSE 2016]



SMT

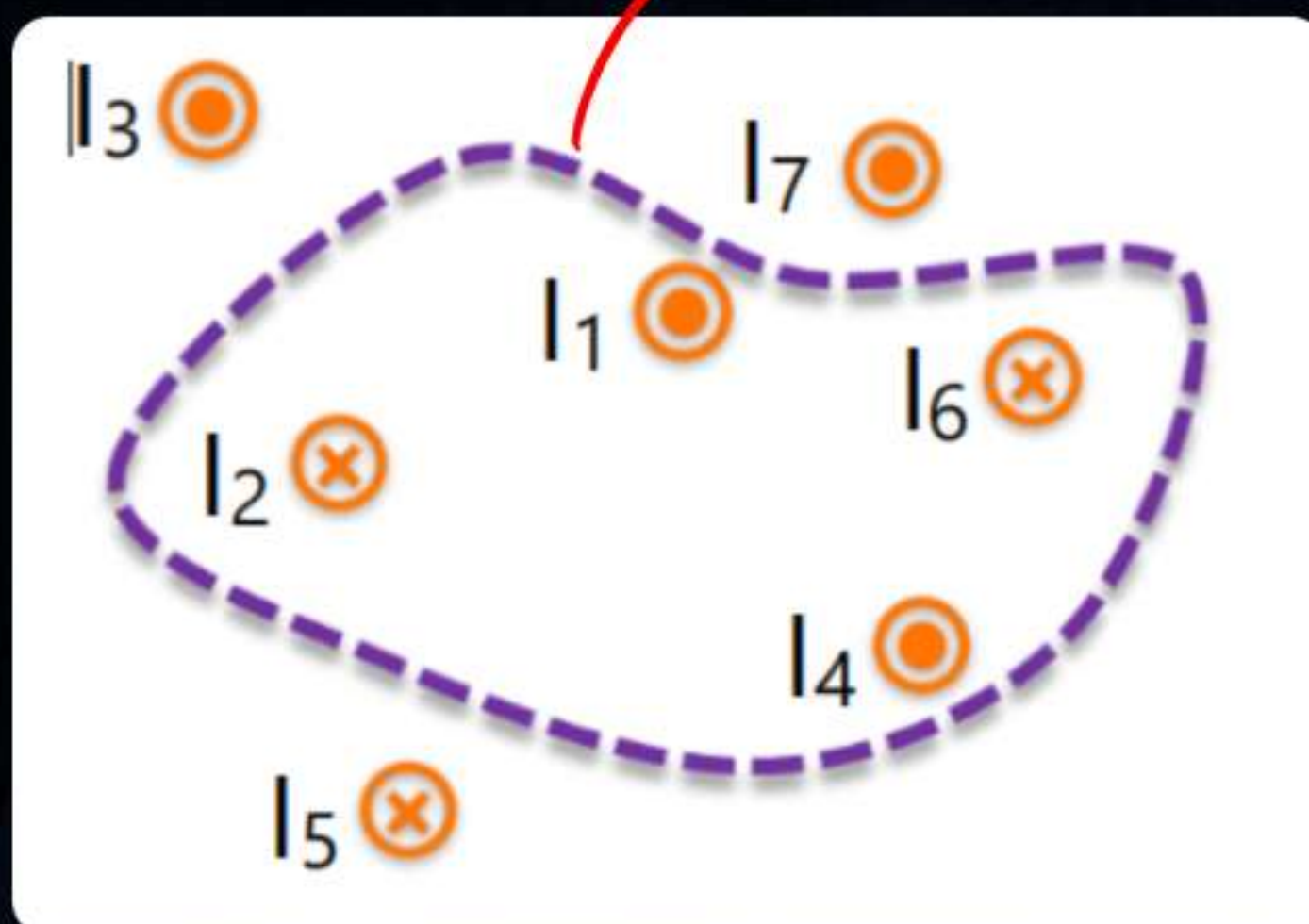
When current divides in any symmetrical planar loop made with uniform wire, then magnetic field at the centre due to this loop is ZERO.



Ampere's Circuital Law

Line integral of magnetic field along any closed path is equal to μ_0 times of enclosed current.

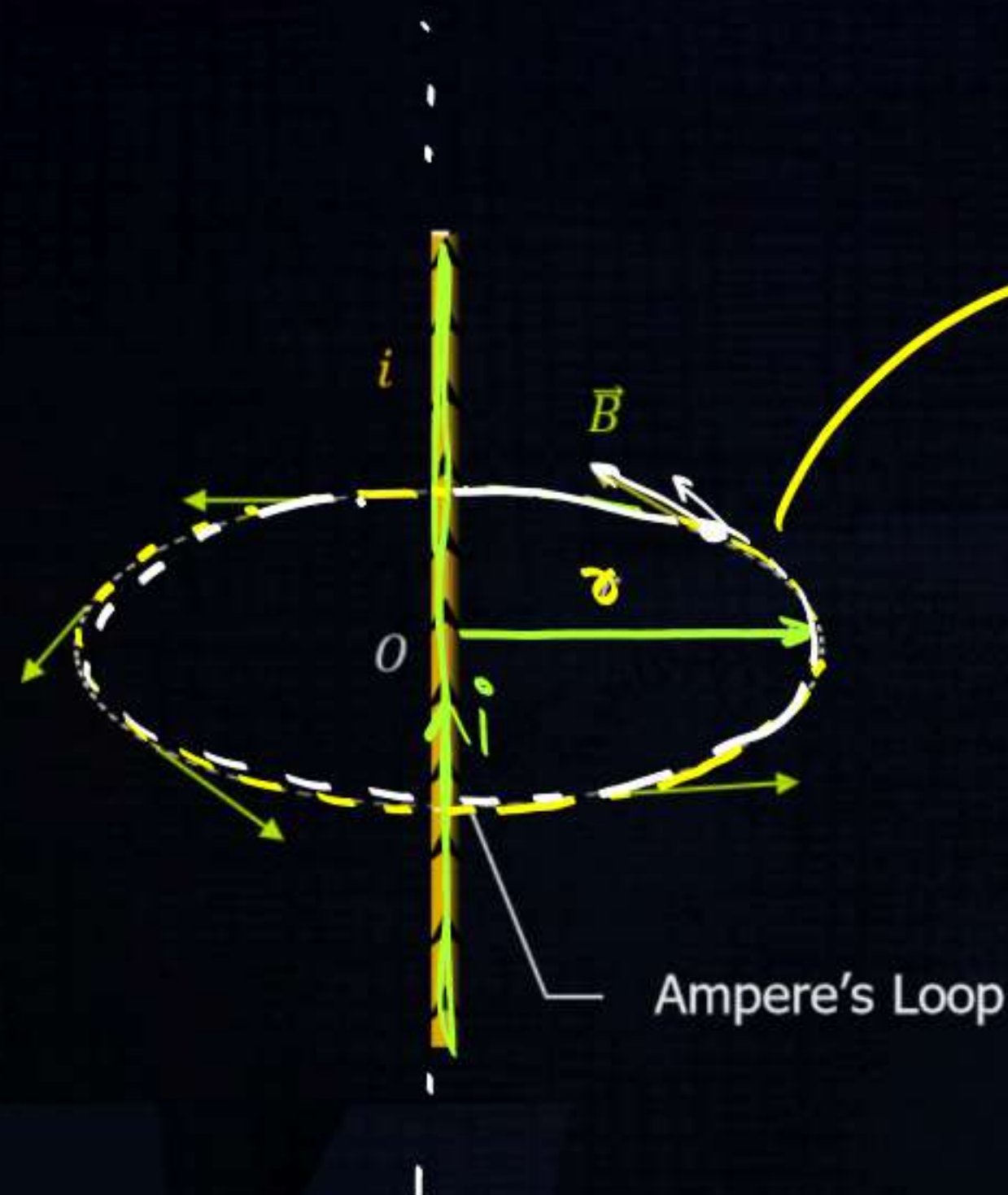
$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}}$$



Key Points :

1. It is applicable only for steady/constant current
2. It can be applied for any distribution of current but,
3. applied for symmetric distribution only for calculation purpose
4. Any shape of loop is acceptable but,
5. B & dl should be parallel or perpendicular to each other.

Magnetic Field due to Long wire



$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$$

$$B \cos 0 = \mu_0 I$$

$$B(l) = \mu_0 I$$

$$B(2\pi r) = \mu_0 I$$

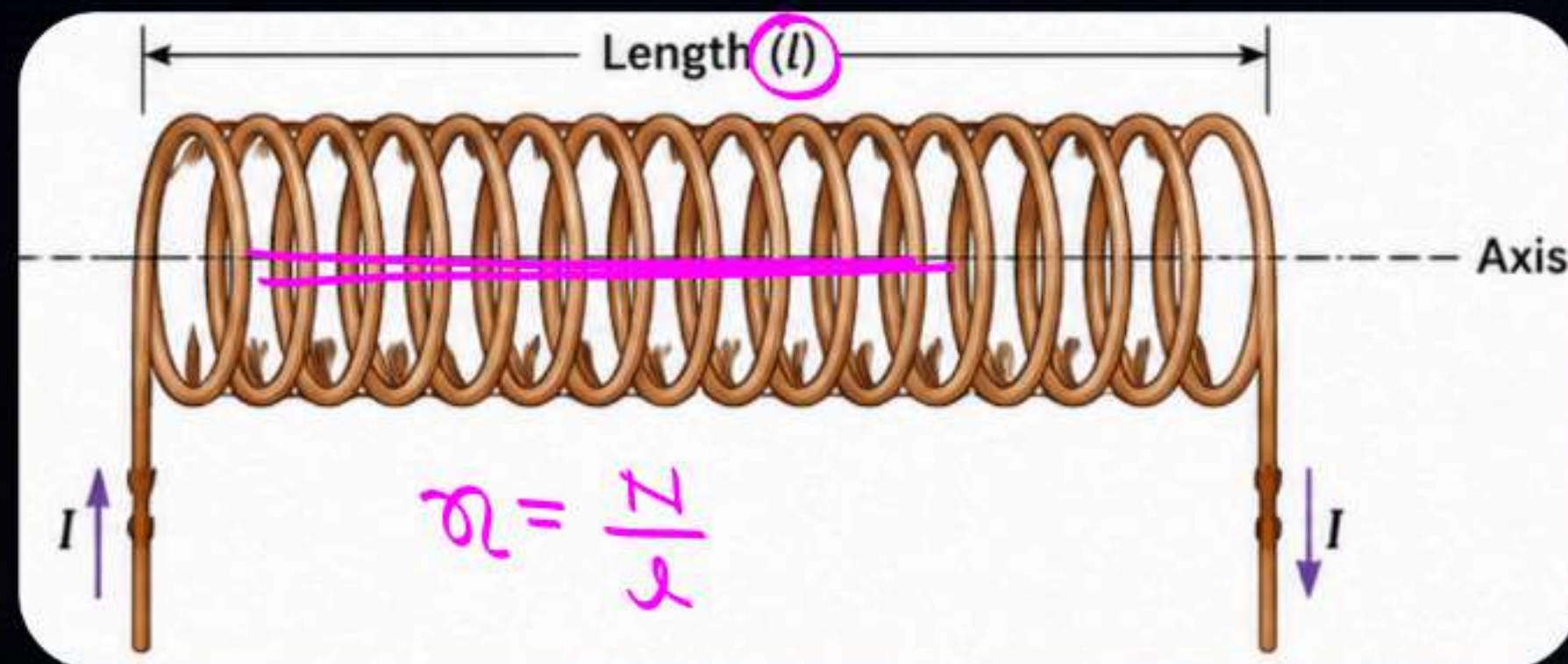
#

$$B = \frac{\mu_0 I}{2\pi r}$$

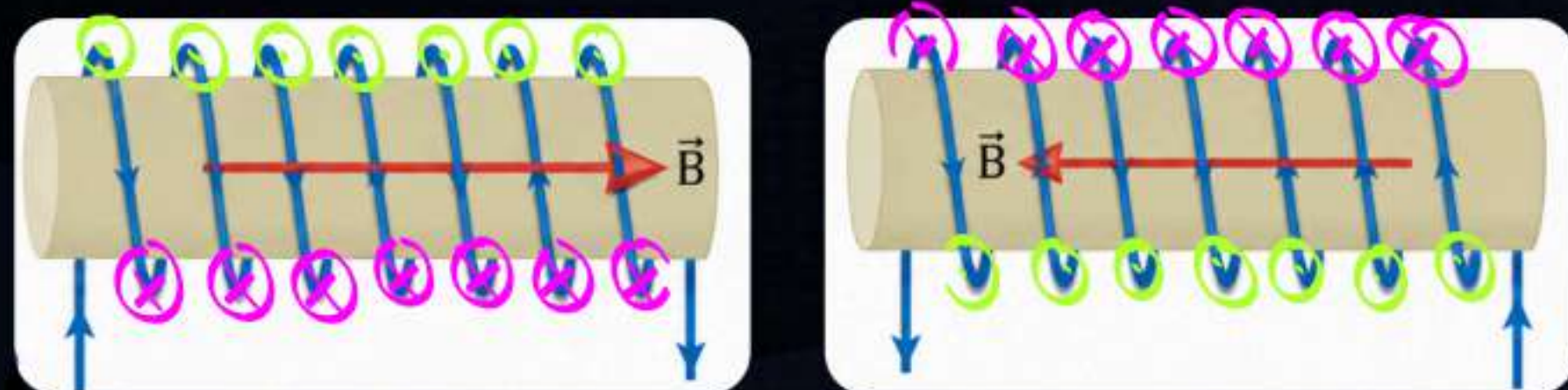
∞-wire

Magnetic Field due to Solenoid

A tightly wound, helix-shaped coil of copper wire

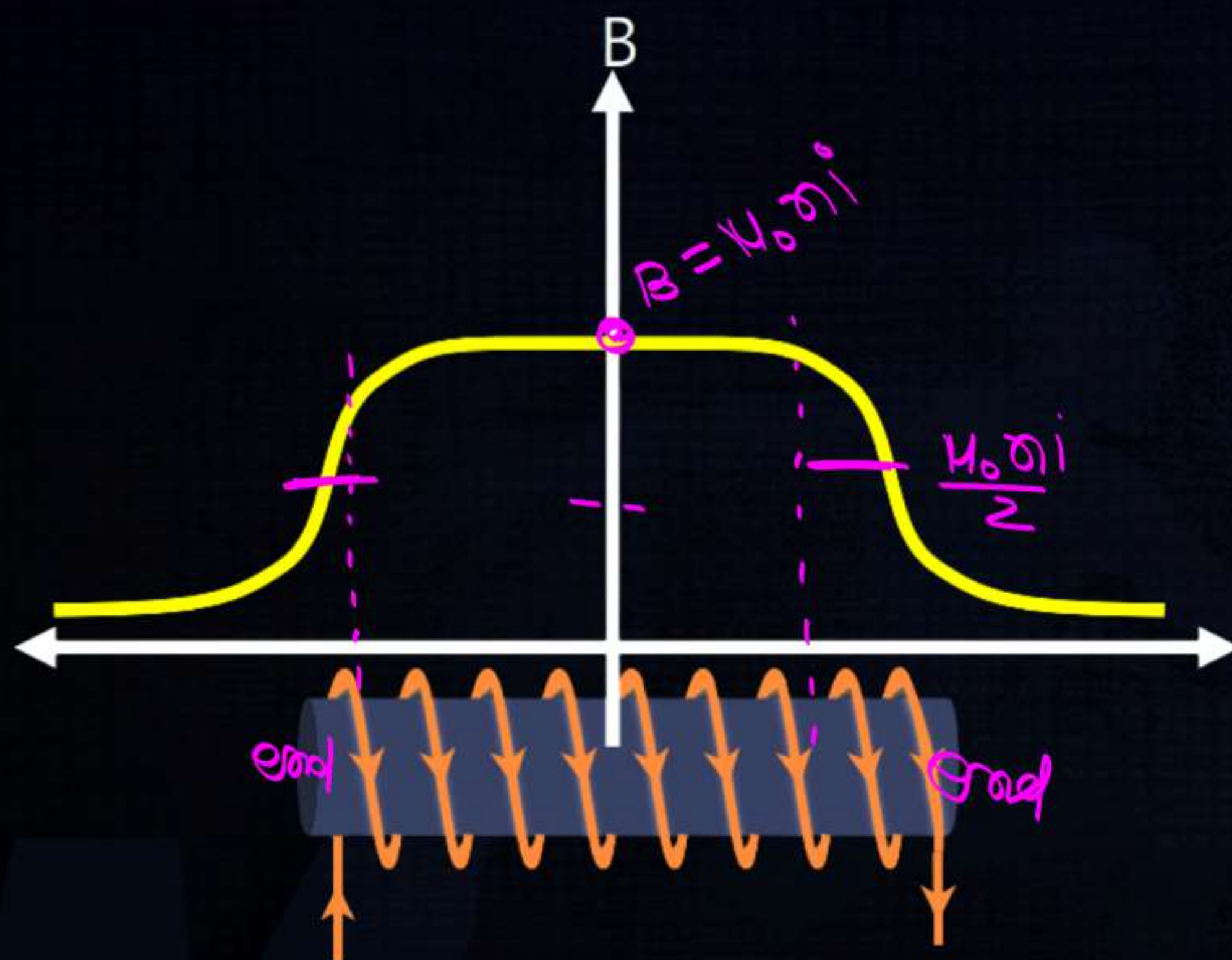


- It is used to produce uniform magnetic field.
- M.F. is produced along Axis of solenoid.
- **Outside** a long solenoid **M.F. is almost Zero.**
- Direction of the **magnetic field** is given by **Right Hand Thumb Rule.**



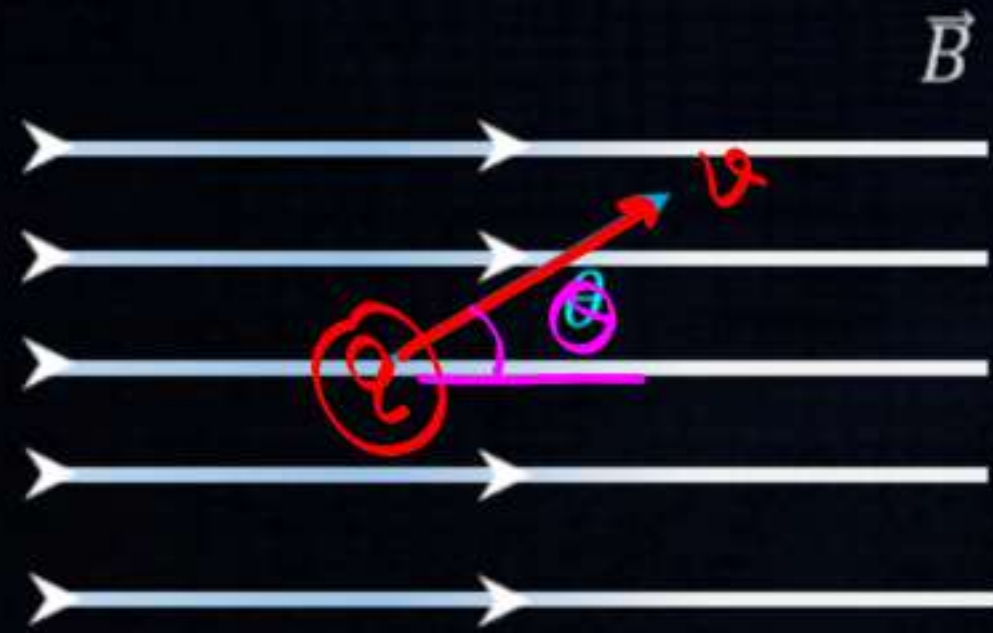
$$B_{\text{solenoid}} = \mu_0 n I$$

Graph :



Magnetic Force on a Charge

For a charge q moving with velocity v in a magnetic field B

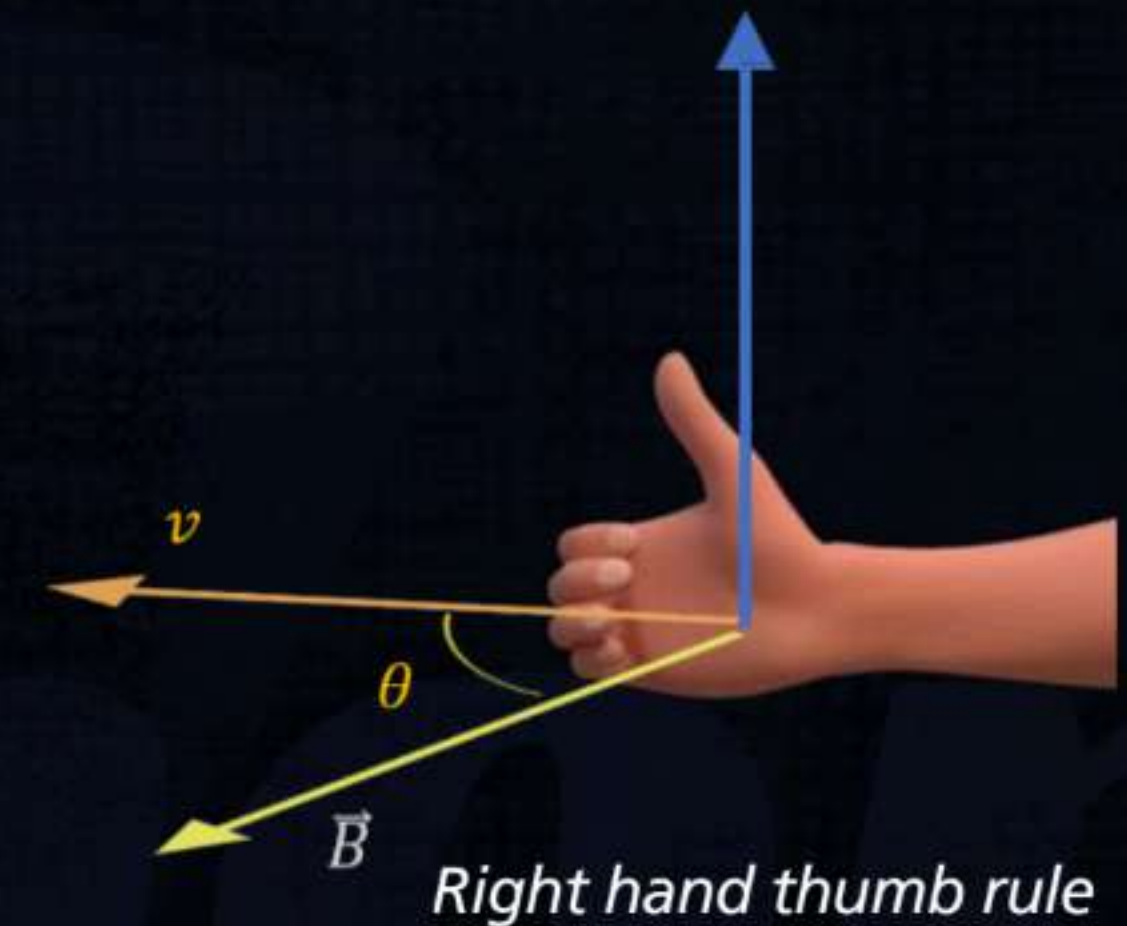


$$F_{\text{on}} = qvB \sin \theta$$

$$\vec{F}_{\text{on}} = q(\vec{v} \times \vec{B})$$

Key Points :

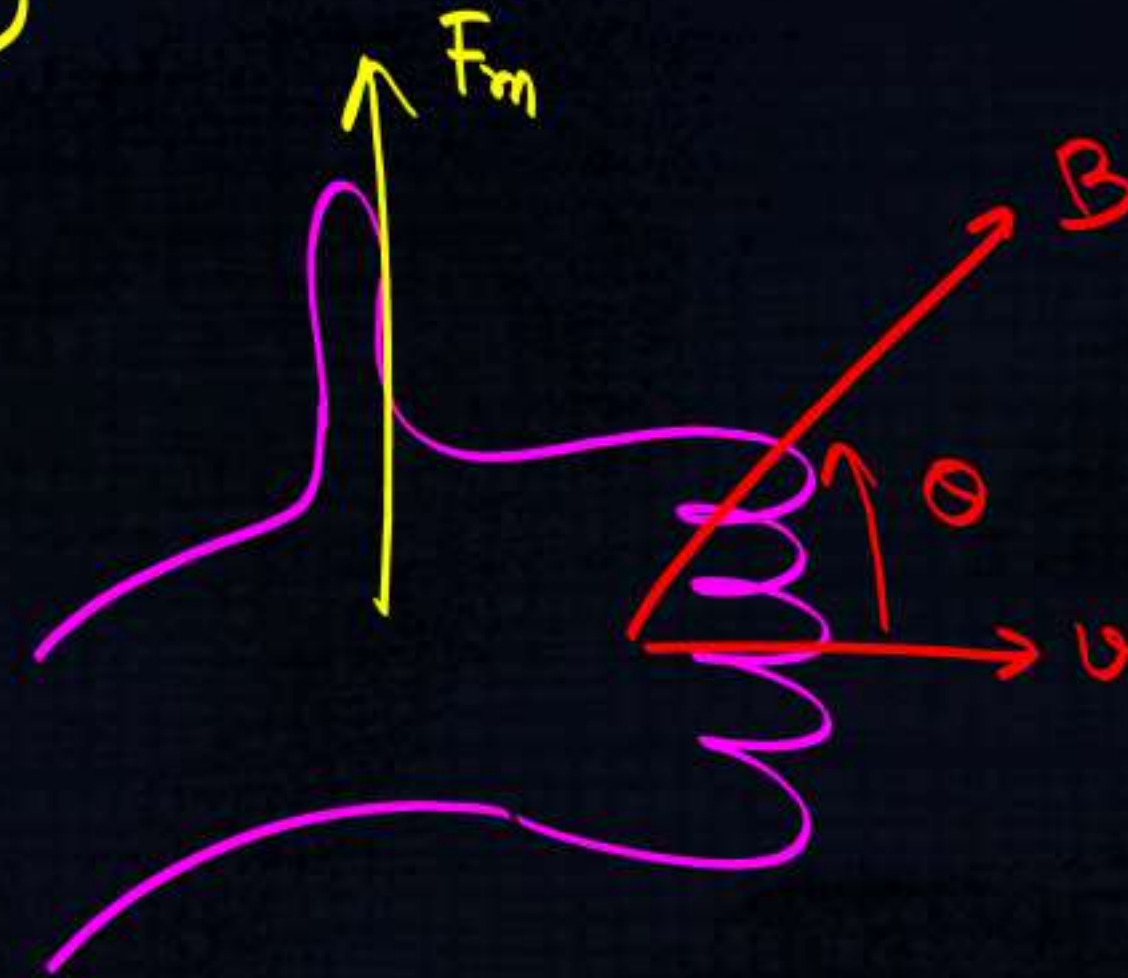
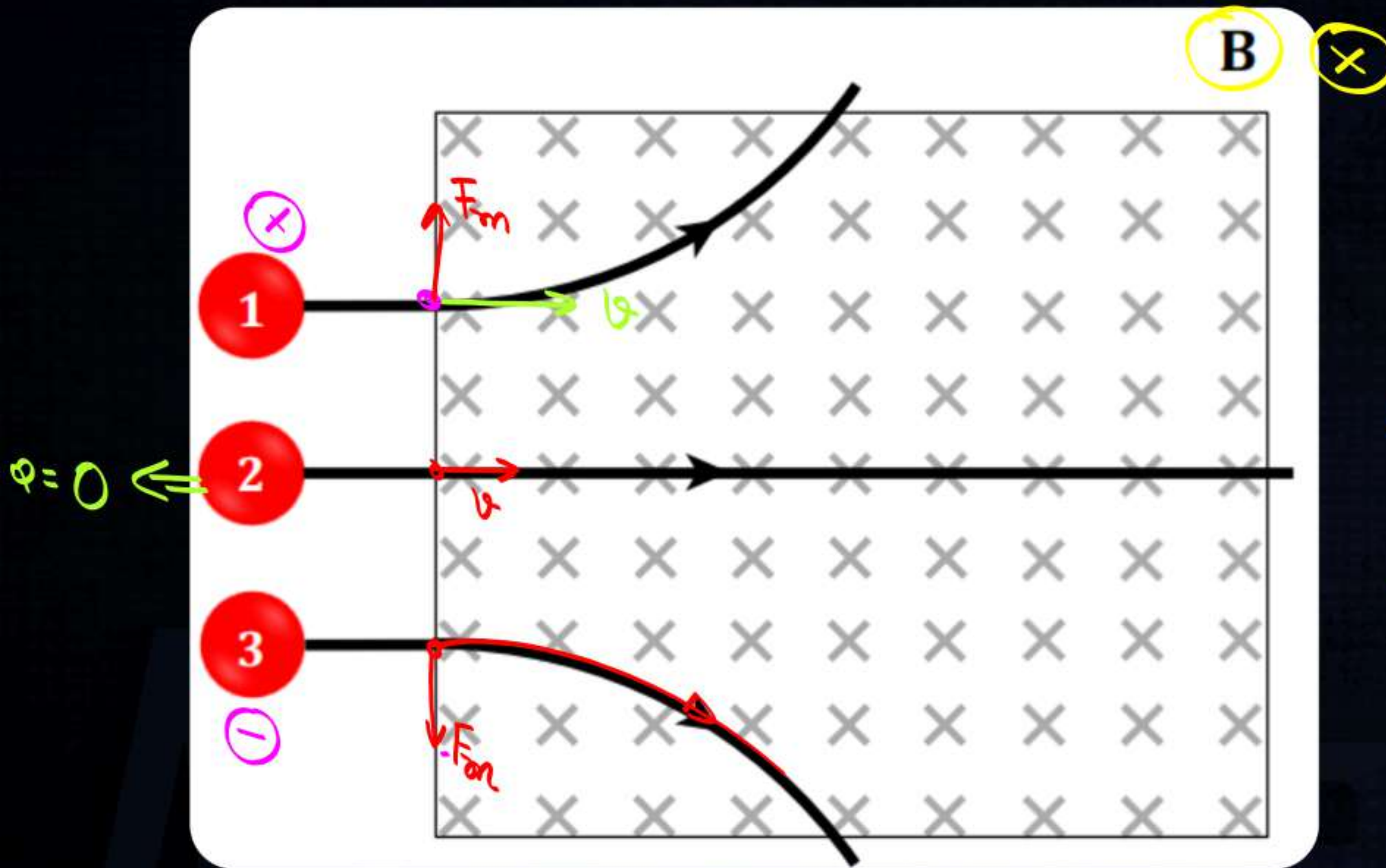
1. Only moving charges experience magnetic force
2. Force is perpendicular to both v and B
3. Direction of Magnetic Force :



Right hand thumb rule

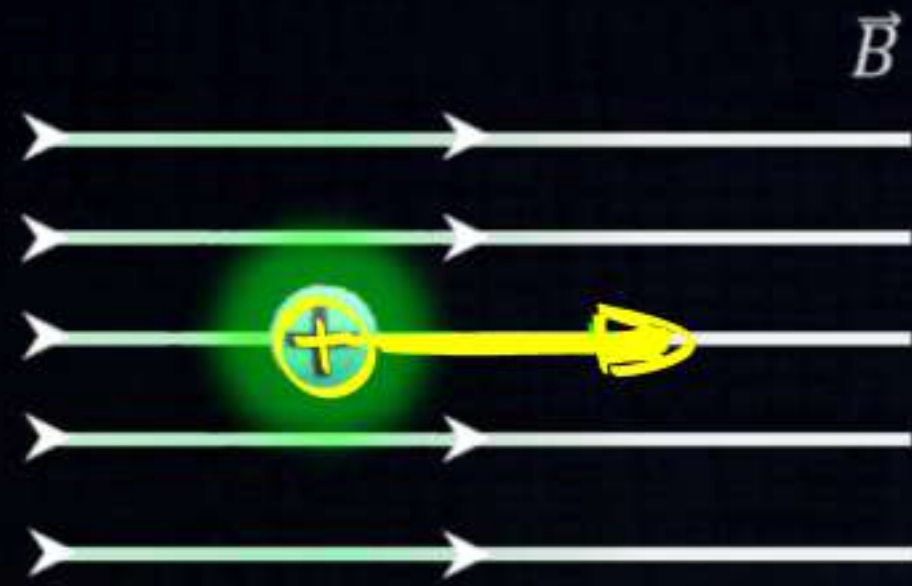
Que.

From the path followed, identify nature of charge on the particle.



Different cases

$$F_m = qvB \sin \theta$$

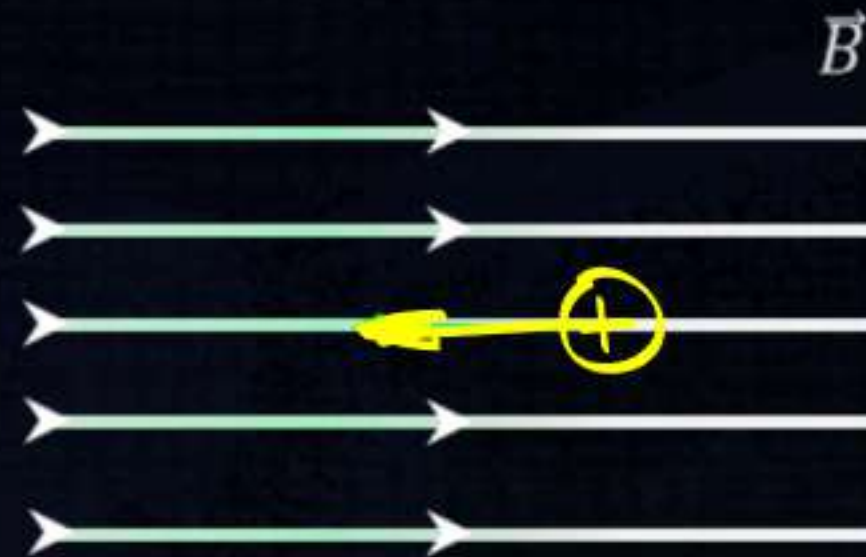


$$\theta = 0^\circ$$

$$\sin 0 = 0$$

$$F_m = 0$$

"No change"

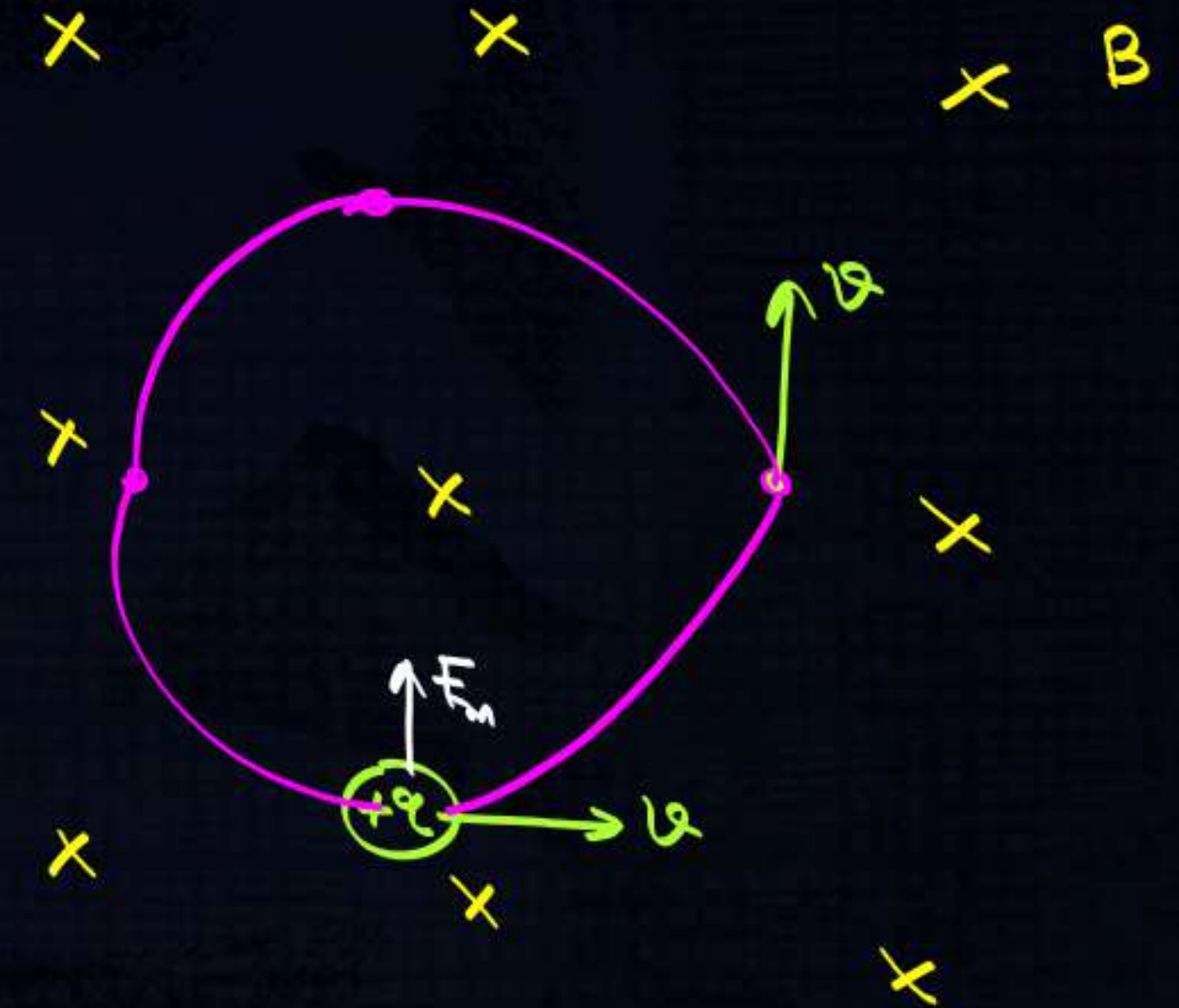


$$\theta = 180^\circ$$

$$\sin 180 = 0$$

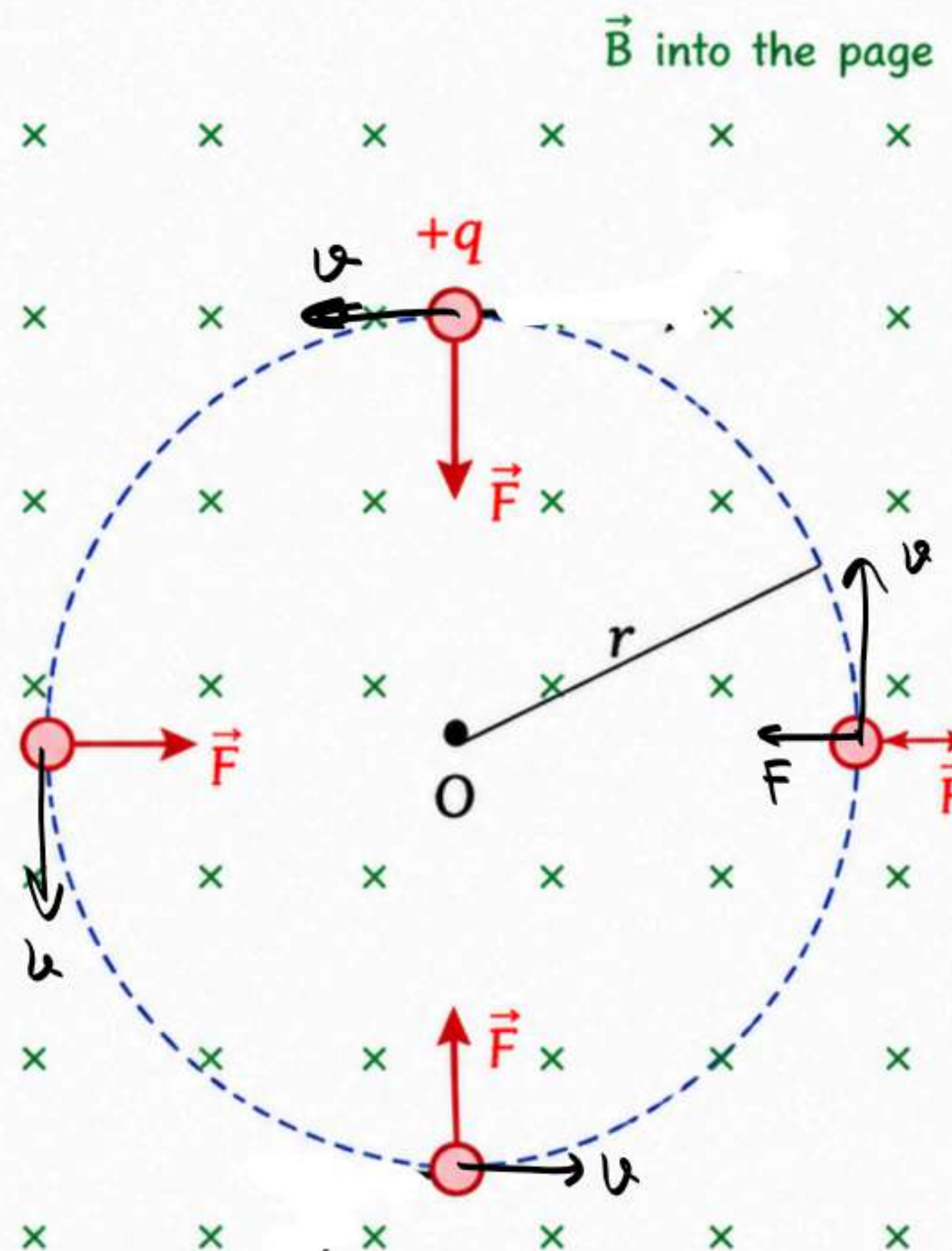
$$F_m = 0$$

No change



A charge q is shot into a uniform magnetic field $\vec{B}$ with speed v normal to the field ($\vec{v} \perp \vec{B}$).

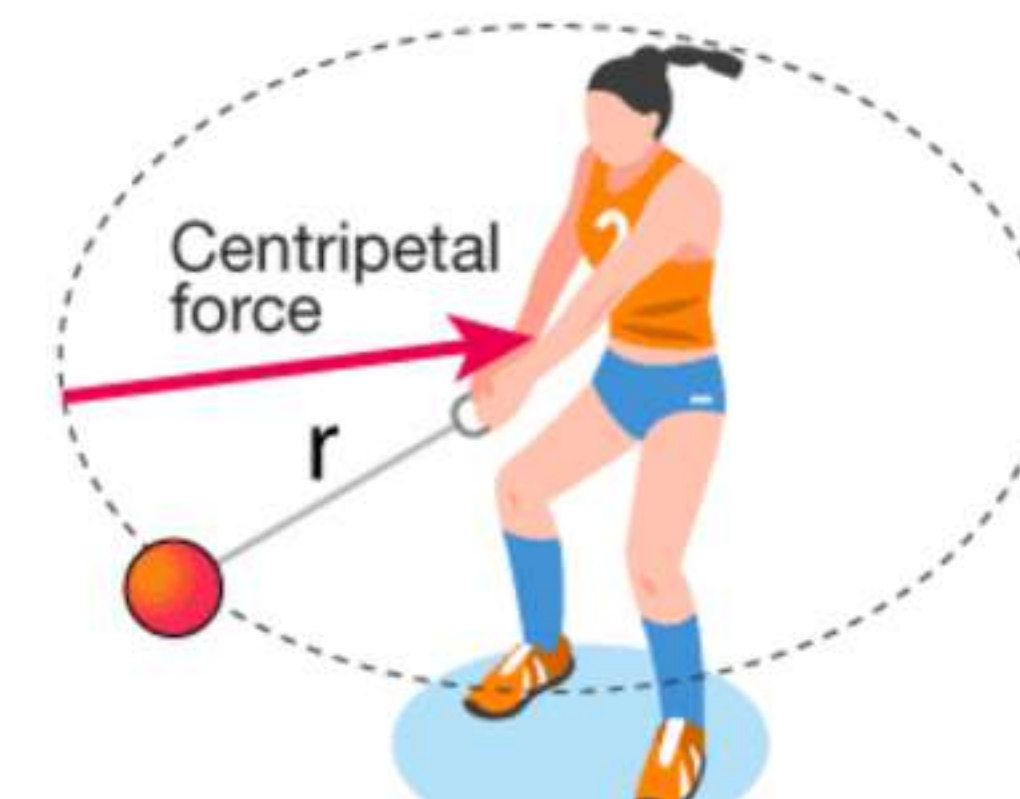
- The magnetic force on the charge is $\vec{F} = q(\vec{v} \times \vec{B})$.
Since $\vec{v} \perp \vec{B}$, the force has magnitude $F = qvB$ and is always perpendicular to $\vec{v}$.
- Being perpendicular to velocity, the force does no work. Hence, the speed of the charge remains constant. Only the direction changes.
- The force is always directed towards the center of the path. Thus, it acts as a centripetal force.
- Therefore, the charge describes a circular path.



$$F_{\text{cent.}} = F_{\text{m.f.}}$$

$$\therefore \frac{mv^2}{R} = qvB$$

$$R = \frac{mv}{qB} = \frac{p}{qB}$$



? Que.

A particle of mass m and charge q describes a circular path of radius R in a magnetic field. If its mass and charge were $2m$ and $q/2$ respectively, the radius of its path would be [CBSE 2024]

- a. $R/4$
- b. $R/2$
- c. $2R$
- ✓ d. $4R$

$$R = \frac{mv}{qB}$$

$$R' = \frac{(2m)}{\frac{q}{2}} = 4R$$



Work done by magnetic field on any charge is always ZERO!

TRUE

FALSE



Marathon



In presence of external Magnetic field (only)-

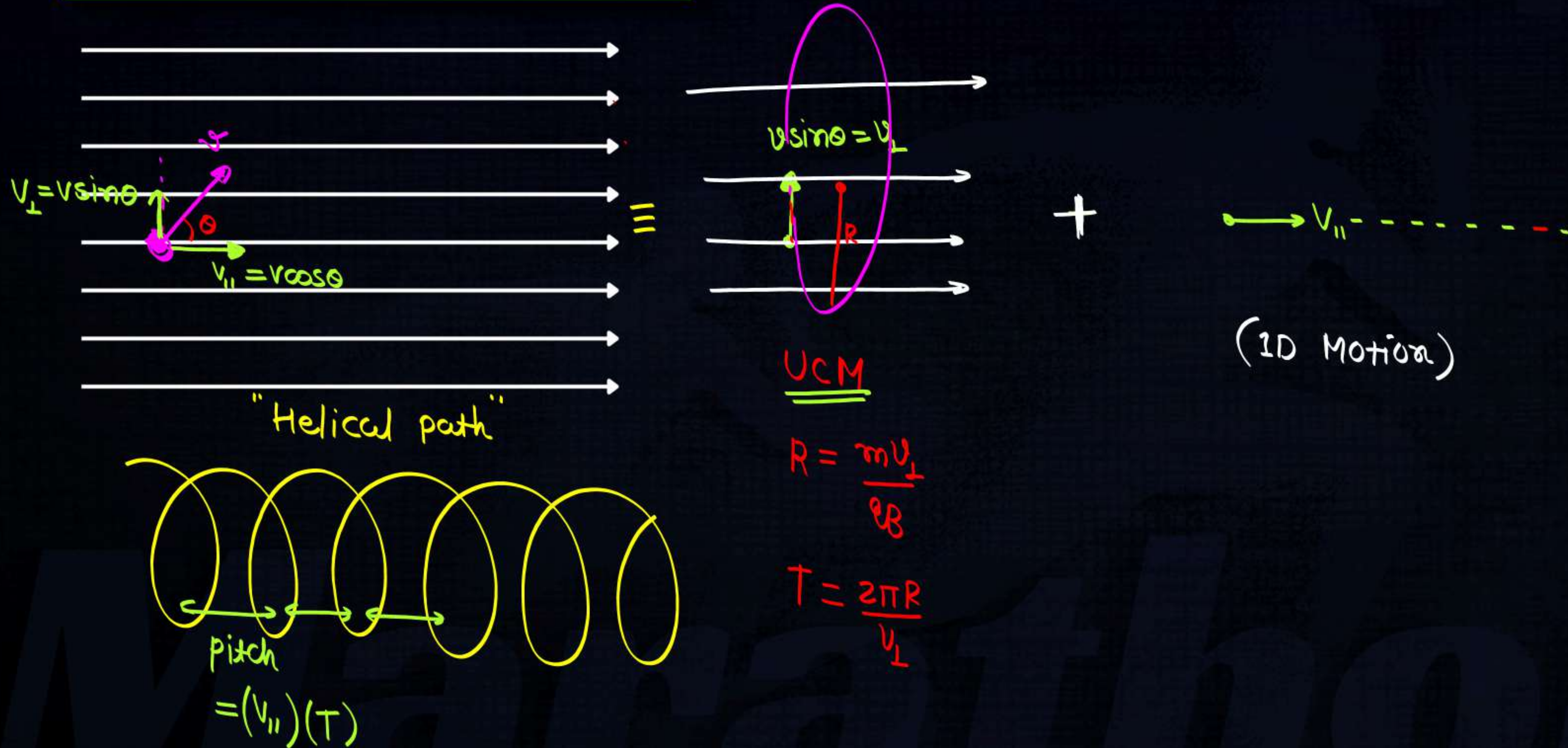
1. Can speed of a moving charge change $\Rightarrow$ No
2. Can direction of a moving charge change $\Rightarrow$ Y
3. Can velocity of a moving charge change $\Rightarrow$ Y
4. Can a stationary charge start moving $\Rightarrow$ N



In presence of external Magnetic field (only)-

1. Can speed of a moving charge change = No
2. Can direction of a moving charge change = Yes
3. Can velocity of a moving charge change = Yes
4. Can a stationary charge start moving = No

Case 4 : When $\theta \neq 0^\circ, 180^\circ$ and 90°



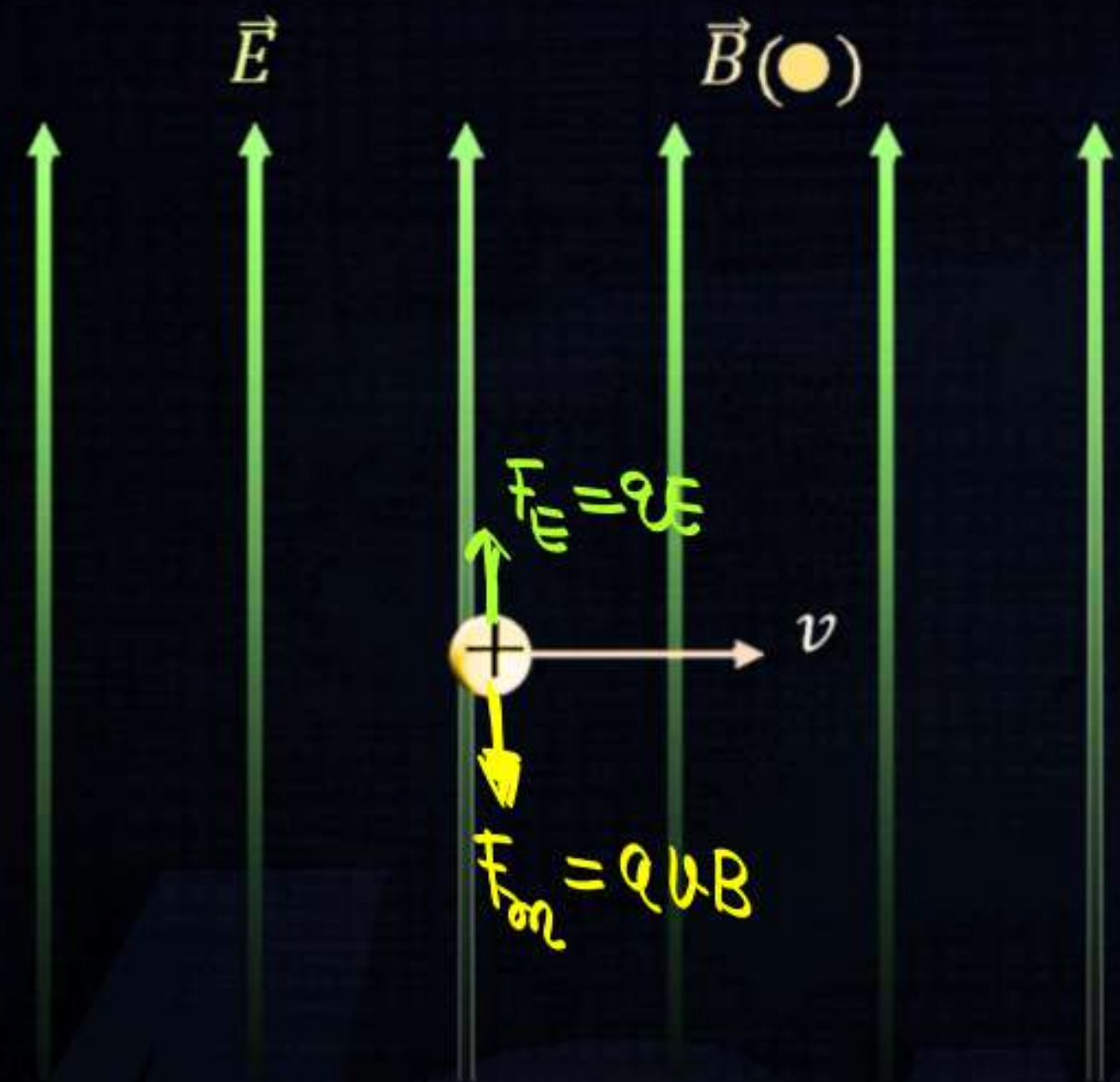
Lorentz Force

- When a charge is moving in a region, where both electric field and magnetic field exist, then electric and magnetic forces are acting on it.
- The resultant of these forces called electromagnetic or Lorentz force on charge.

$$\begin{aligned}\vec{F}_L &= \vec{F}_{E.F.} + \vec{F}_{M.F.} \\ &= q\vec{E} + q(\vec{v} \times \vec{B})\end{aligned}$$

$$\vec{F}_L = q \left[\vec{E} + (\vec{v} \times \vec{B}) \right]$$

Special Case : E , v , and B are Mutually Perpendicular



(i) $F_E > F_B$

(ii) $F_E < F_B$

~~(iii)~~ $F_E = F_B$
 $qE = qvB$
 $v = E/B$

$v = E/B$

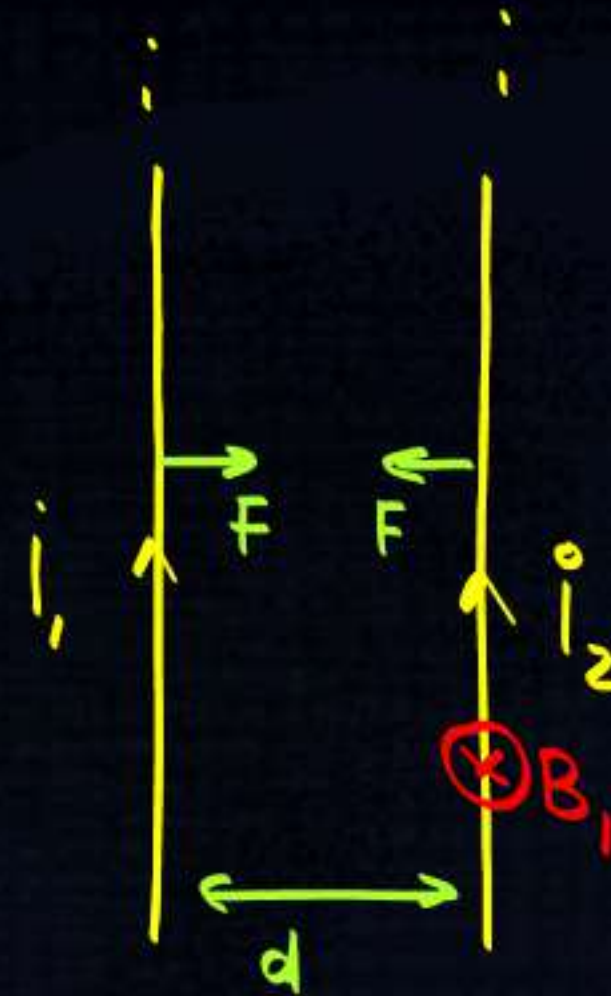
Magnetic Force on Current Carrying Element



$$F_{\text{wire}} = i l B \sin \theta$$

$$\vec{F}_{\text{wire}} = i (\vec{l} \times \vec{B})$$

[CBSE 2023]



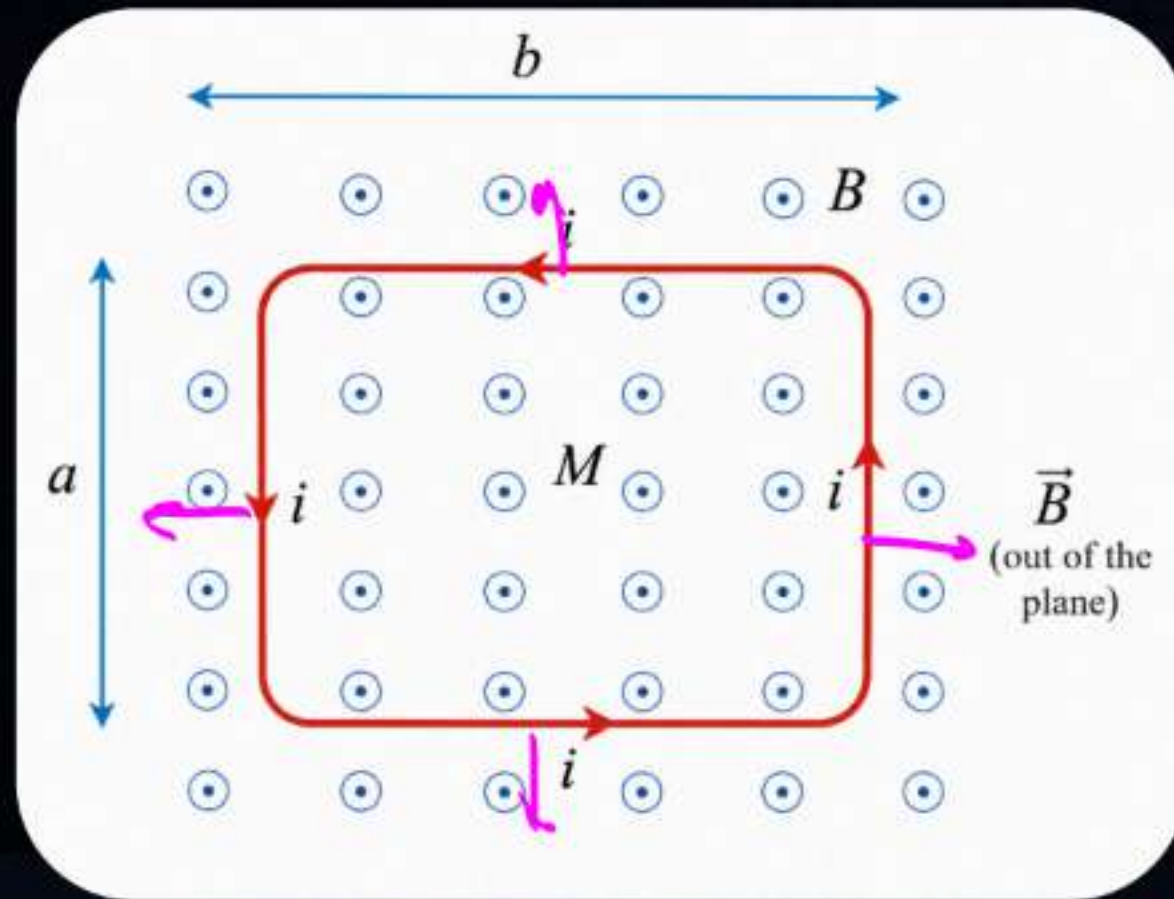
$$\frac{F}{l} = \frac{\mu_0 i_1 i_2}{2\pi d}$$

Torque on current carrying loop in Uniform M.F.

[CBSE 2026]

Electric Dipole $\rightarrow$ Magnetic Dipole

Magnetic Moment $= M = (Ni)(A)$



* $F_{net} = 0$ (Always)

* $\tau = MB \sin \theta$

$\vec{\tau} = \vec{M} \times \vec{B}$



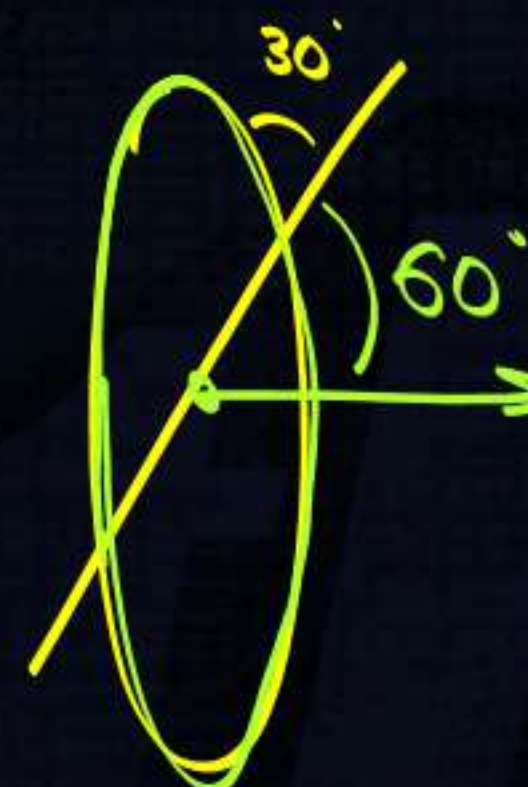
Que.

$$A = \pi r^2 = \pi \times 64 \times 10^{-4} \text{ m}^2$$

A circular coil of 30 turns and radius 8.0 cm carrying a current of 6 A is suspended vertically in a uniform horizontal magnetic field of 1.0 T. The field lines make an angle of 30° with the plane of the coil. Calculate the magnitude of the external torque that must be applied to prevent the coil from turning. What would happen if the circular coil is replaced by a planar coil of irregular shape that encloses the same area, keeping other parameters unchanged?

[CBSE 2026]

$$\tau_{M.F.} = MB \sin \theta = (Ni)(A)(B) \sin \underline{60^\circ}$$



Given: $N = 30$ turns

$$r = 8.0 \text{ cm} = 0.08 \text{ m}$$

$$I = 6 \text{ A}$$

$$B = 1.0 \text{ T}$$

Angle between field and plane = 30°

Solution:

Torque on a current carrying coil in a uniform magnetic field is given by

$$\tau = NIAB \sin \theta \quad \text{where } \theta = \text{angle between magnetic field and normal to the plane}$$

Here, angle between field and plane = 30°

$\therefore$ angle between field and normal (θ) = $90^\circ - 30^\circ = 60^\circ$

$$\begin{aligned} \text{Area of the coil, } A &= \pi r^2 = \pi (0.08)^2 \text{ m}^2 \\ &= 0.0201 \text{ m}^2 \end{aligned}$$

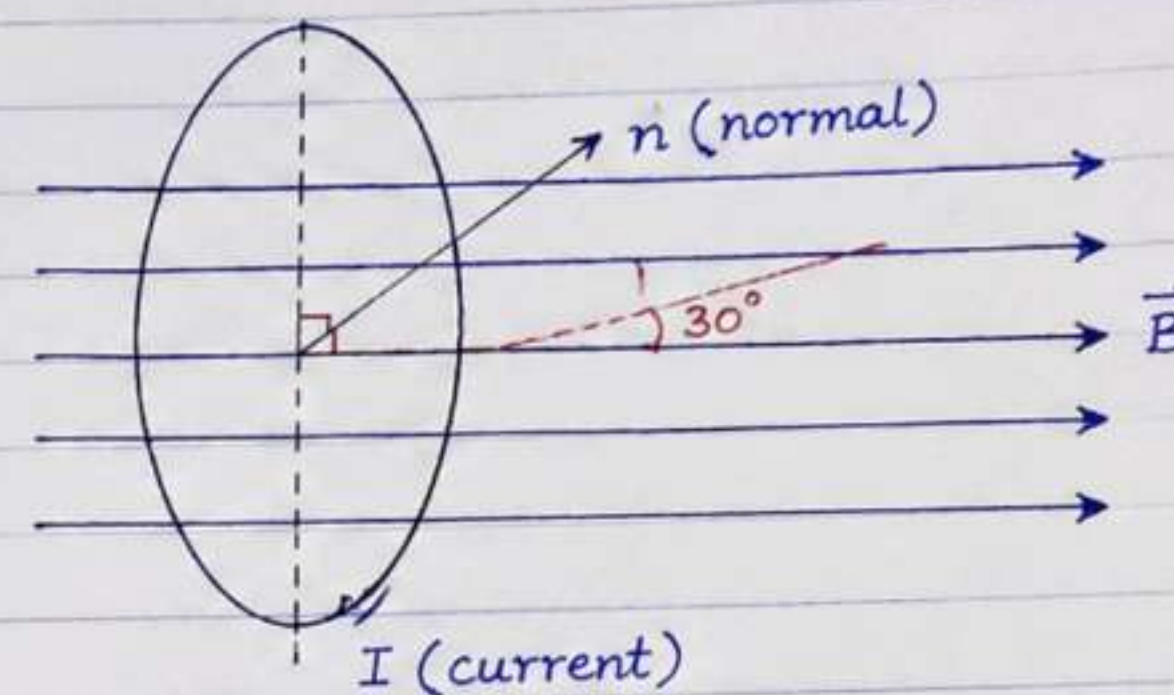
Now,

$$\begin{aligned} \tau &= NIAB \sin \theta \\ &= 30 \times 6 \times 0.0201 \times 1.0 \times \sin 60^\circ \\ &= 3.618 \times 0.866 \end{aligned}$$

$$\tau = 3.13 \text{ N}\cdot\text{m}$$

Hence, the magnitude of external torque that must be applied to prevent the coil from turning is $3.13 \text{ N}\cdot\text{m}$.

Coil suspended vertically



What happens if the circular coil is replaced by a planar coil of irregular shape that encloses the same area?

Torque on a planar coil in a uniform magnetic field depends on

- number of turns (N)
- current (I)
- area (A) enclosed by the coil
- angle (θ) between field and normal

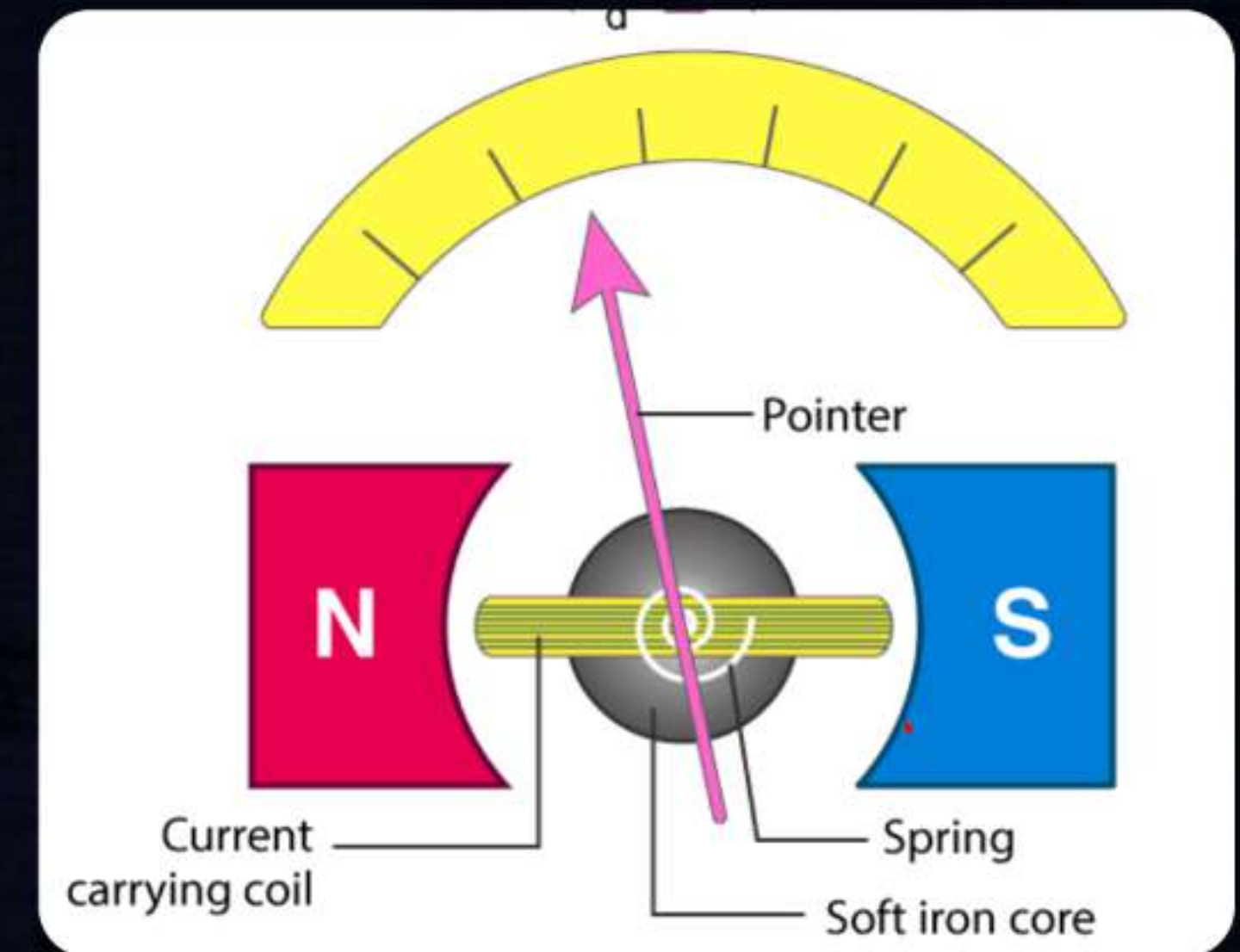
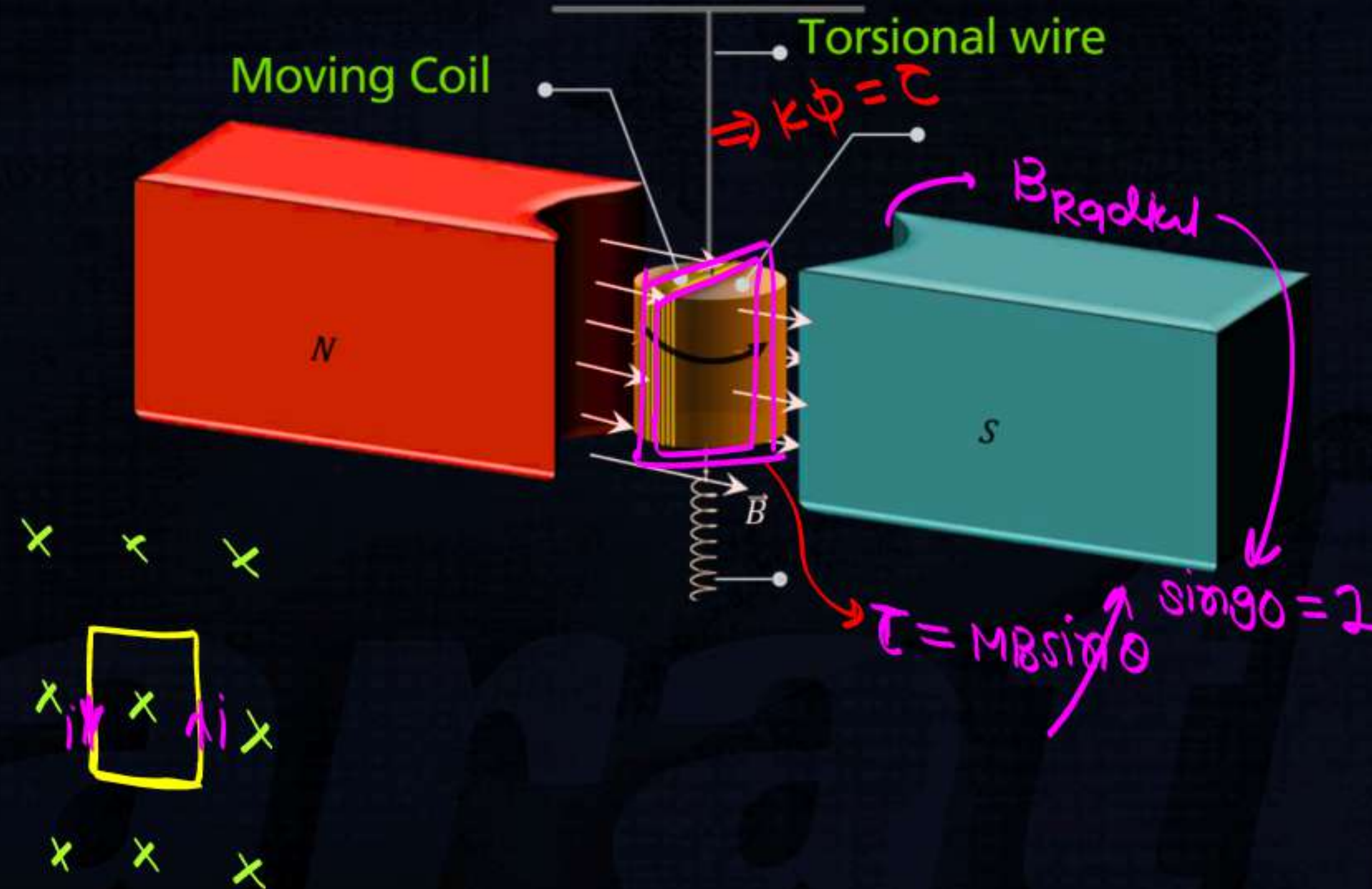
and NOT on the shape of the coil.

Since the irregular coil encloses the same area and other parameters are unchanged, the torque will remain the same.

$$\therefore \text{Torque will still be } 3.13 \text{ N}\cdot\text{m}$$

Moving coil galvanometer

A moving coil galvanometer is a **sensitive instrument** used to detect and measure **small electric currents** in a circuit.



$$\phi \propto i$$

Working Principle

A current-carrying coil placed in a magnetic field experiences a torque.

- When current flows through the coil, magnetic torque acts on it.
- This torque causes the coil to rotate.
- The rotation is opposed by a restoring torque due to a spring.
- At equilibrium:

$$\tau_{\text{Restoring}} = \tau_{\text{M.F.}}$$

$$k\phi = (Ni)(AB)\sin\theta$$

$$k\phi = NiAB$$

$$\phi \propto i$$

$$\frac{\phi}{i} = \frac{NAB}{k} \Rightarrow \text{current sensitivity}$$

Current sensitivity

$$\frac{\phi}{i} = \frac{NAB}{k}$$

can be increased by

- By increasing number of turns.
 - By increasing field strength.
 - By increasing area of cross section.
- } Best Options

Voltage sensitivity

$$\frac{\phi}{V} = \frac{NAB}{k \cdot R}$$

$$V = iR \\ i = V/R$$

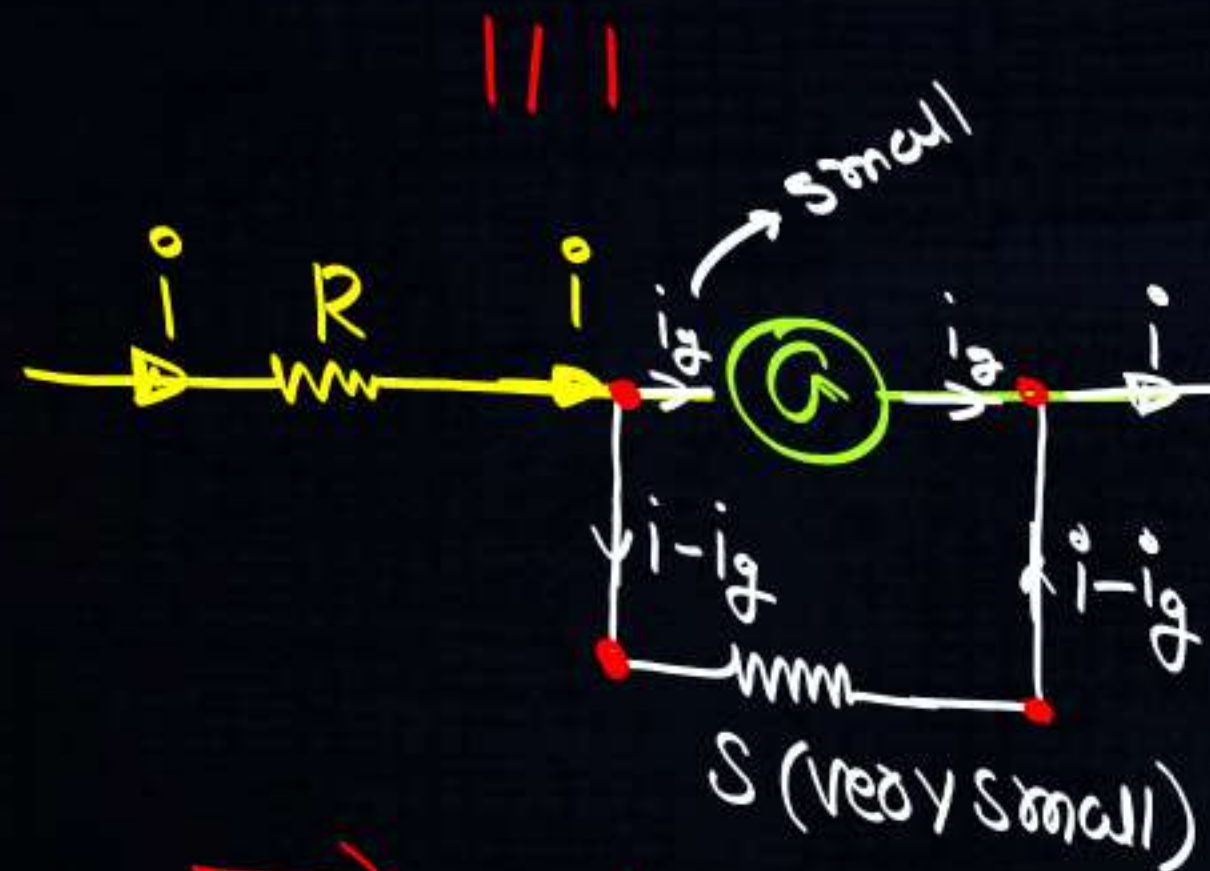
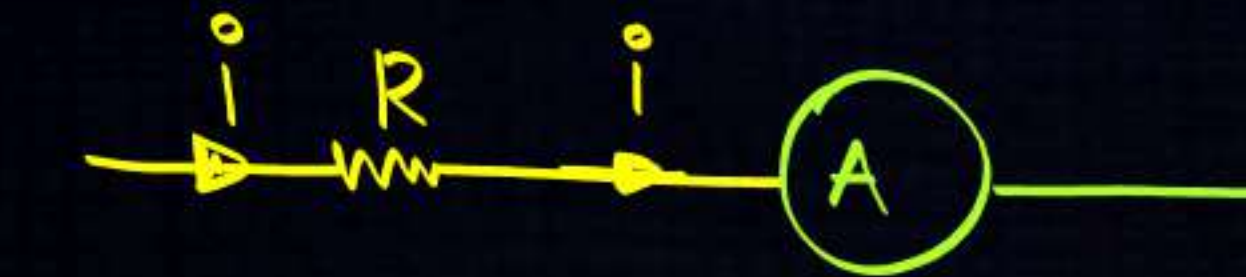
can be increased by

- By increasing field strength.
- By increasing area of cross section.

Marathon

Galvanometer into an Ammeter

$R_A = 0$ (ideal)



$\Rightarrow$

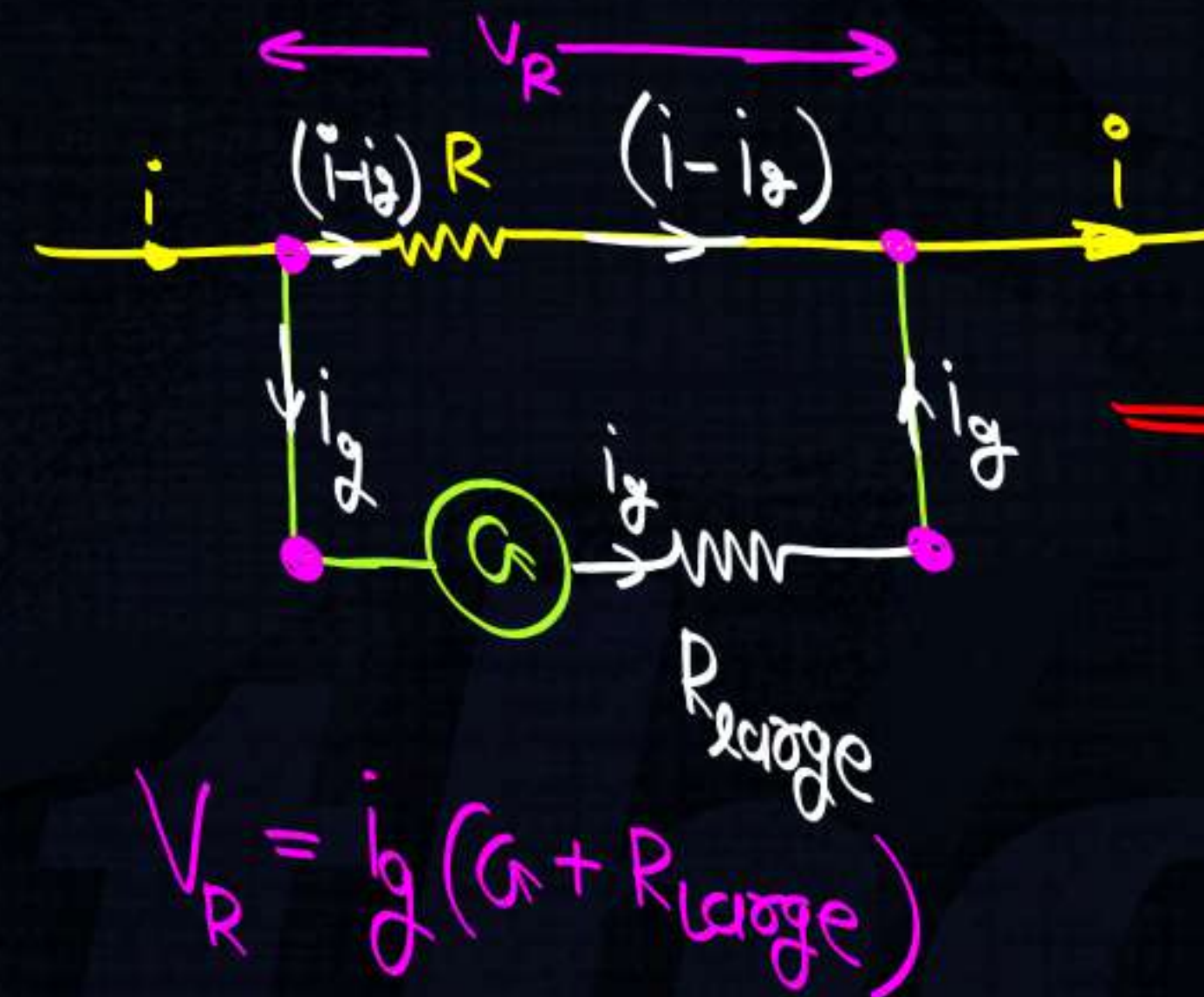
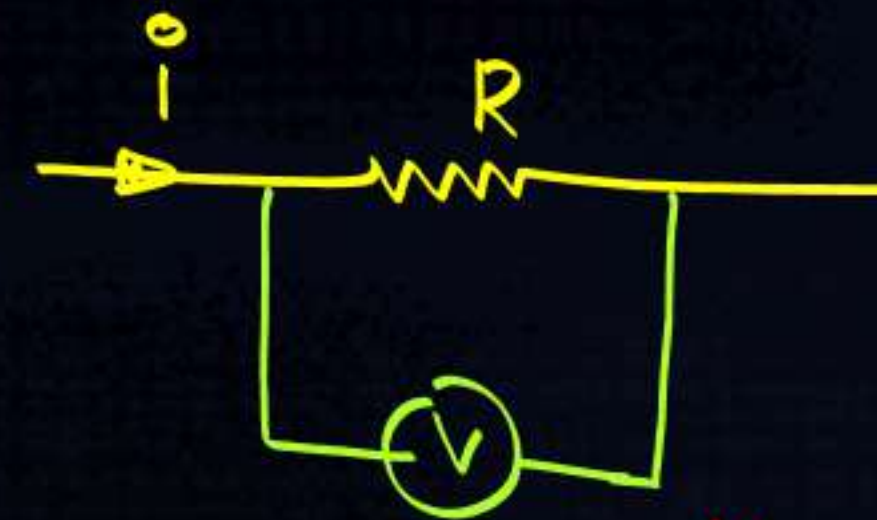
$$V_G = V_S$$

$$i_g(G) = (i - i_g)S$$

$$R_{\text{Ammeter}} = \frac{G \cdot S}{G + S}$$

Galvanometer into a Voltmeter

$R_V = \infty$ (ideal)



$$\Rightarrow R_{\text{voltmeter}} = G + R_{\text{large}}$$

$$V_R = i_g(G + R_{\text{large}})$$



A galvanometer can be converted into an ammeter of desired range by connecting a

- a. small resistance in series
- b. large resistance in series
- ~~c.~~ small resistance in parallel
- d. large resistance in parallel.

[CBSE 2025]

Backlog के
Swahaa

THANK
YOU

