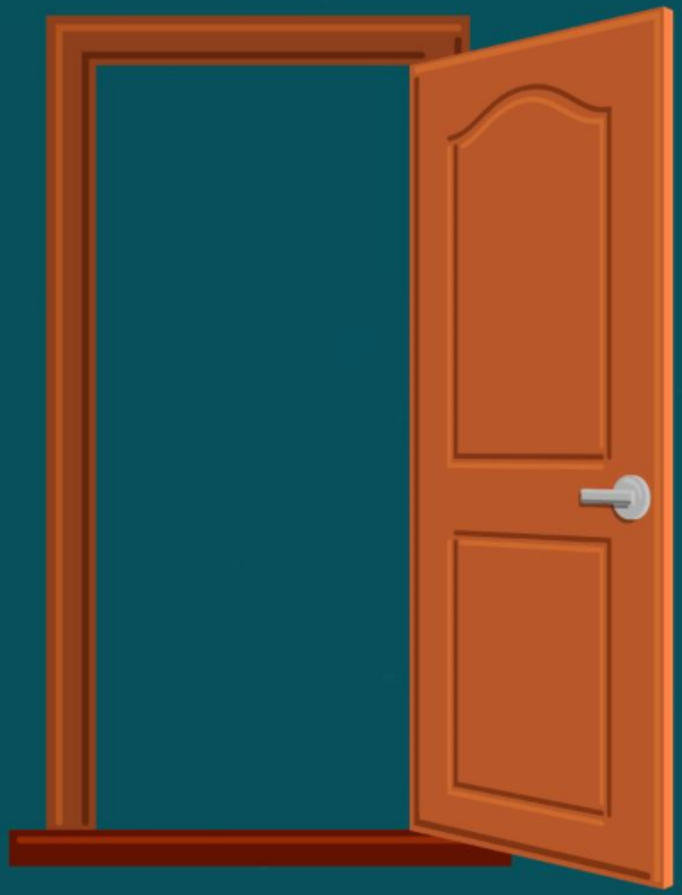
Next Toppers

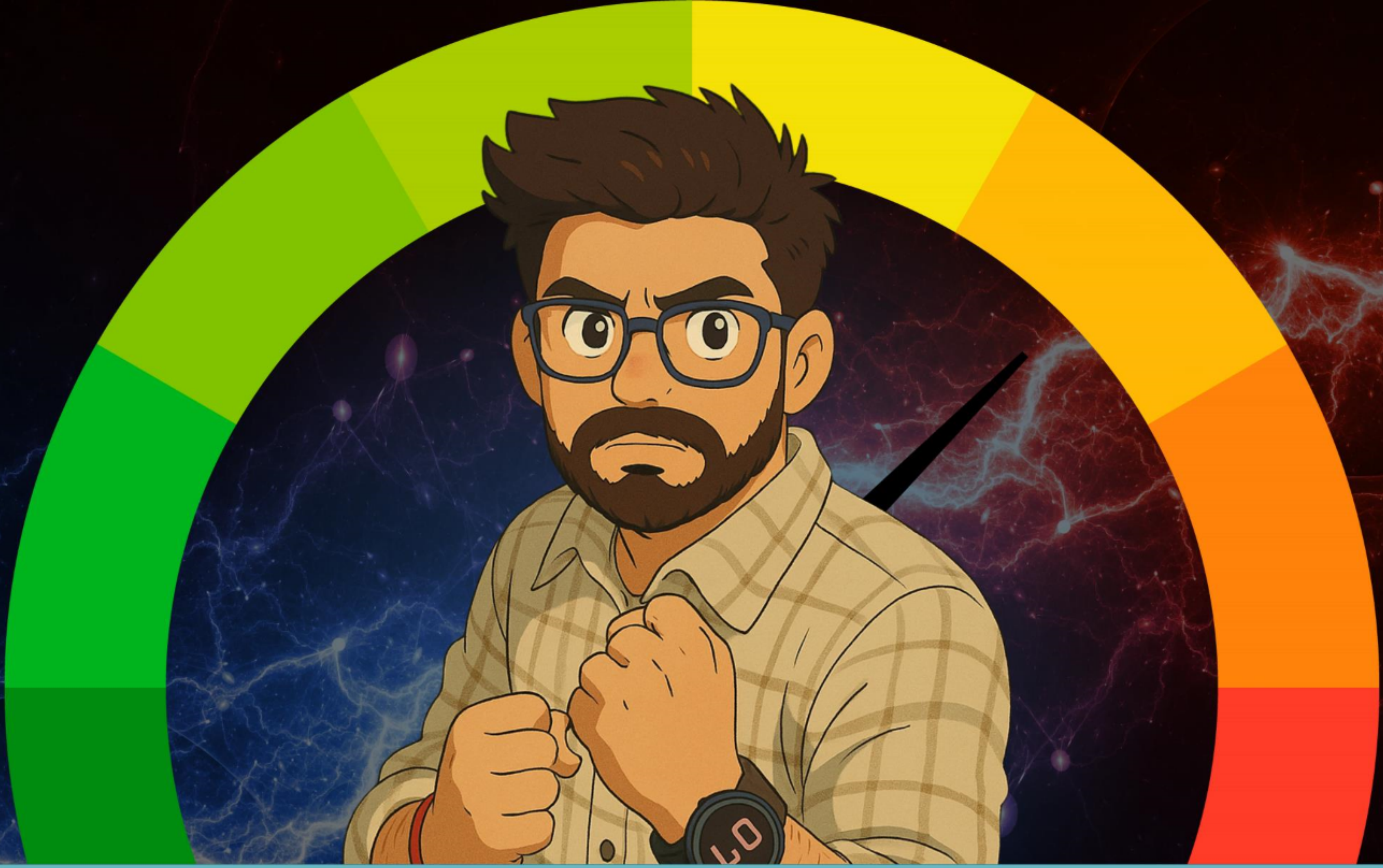
CLASS XII - PHYSICS

Electric Charges & Fields

one shot







How's the JOSH?

Flow of Chapter

a. Electric Charges.

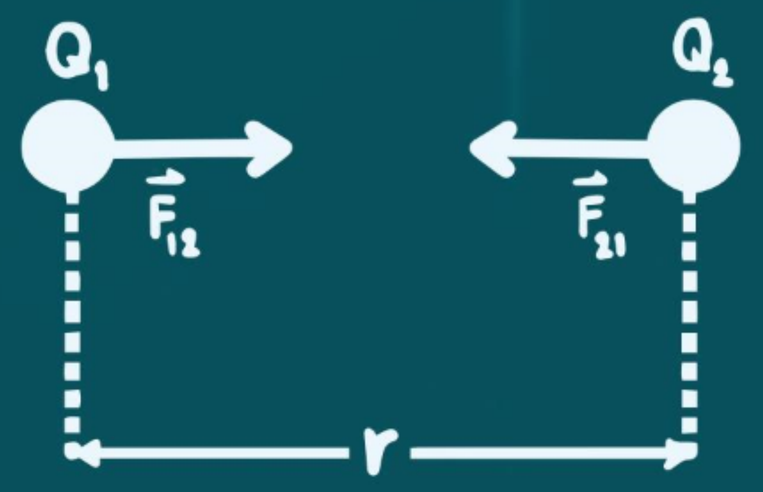
b. Coulomb's Law

c. Electric Field

d. Electric Flux

e. Gauss's Law

f. Electric Dipole



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

Electric Charges

Electromagnetism

Electrostatics

- Charges at Rest

1 & 2

Electrodynamics

- Charges in Motion

- "**Electrostatics** is the branch of physics that studies electric charges at rest."

Properties of Charges

Mass

- Intrinsic property of matter.
- Scalar quantity.
- Mass is always considered positive.

m

+ve Mass

Charge

- Intrinsic property of matter.
- Scalar quantity.
- Charge can be positive and negative.

+   − = electron

+ve Charge   -ve Charge

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

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

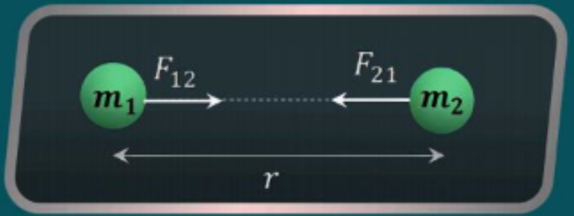
$$[Q] = It$$
$$= [A'T']$$

$$[Q] = C$$

Properties of Charges

Mass

- Mass exerts gravitational force on another mass at a distance.

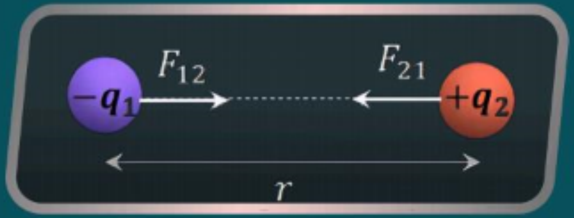


Force of Attraction

$$F = \frac{G m_1 m_2}{r^2}$$

Charge

- Charge exerts electrostatic force on another chrge at a distance.



Force of Attraction

Force of Repulsion

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

Properties of Charges

$Q=0$

mv

Mass

- Mass can exist with **zero** net charge.
- Magnitude of mass is not **independent** of its speed.

$$m = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

- where mo is the rest mass of the object.
- **Speed dependent.**

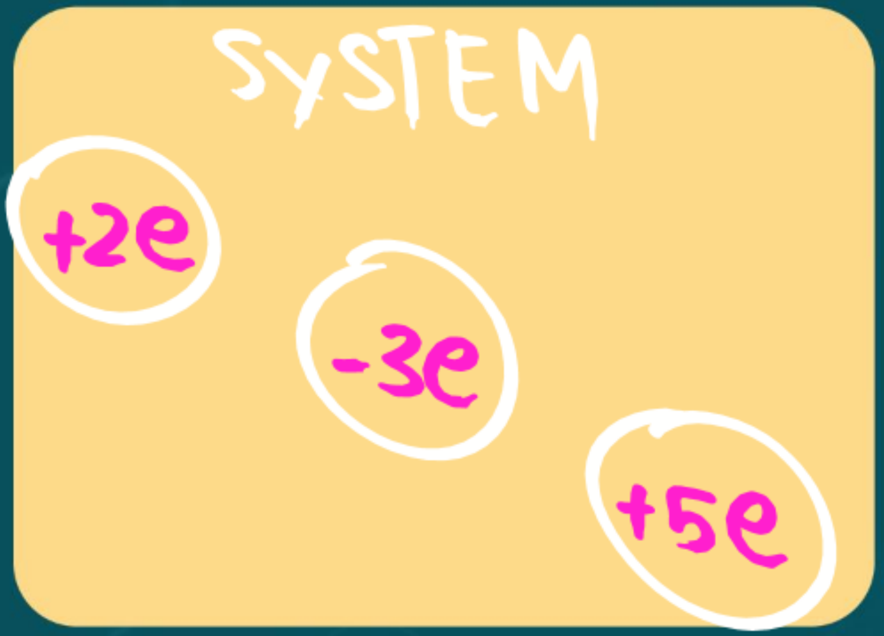
Charge

- Charge **can not** exist without mass.
- Magnitude of charge is **independent** of its speed.

Properties of Charges

Additive nature of electric charge.

Net charge of a system is the algebraic sum of all the individual charges located at different points inside the system.



$$Q_{system} = (+2e) + (-3e) + (+5e)$$

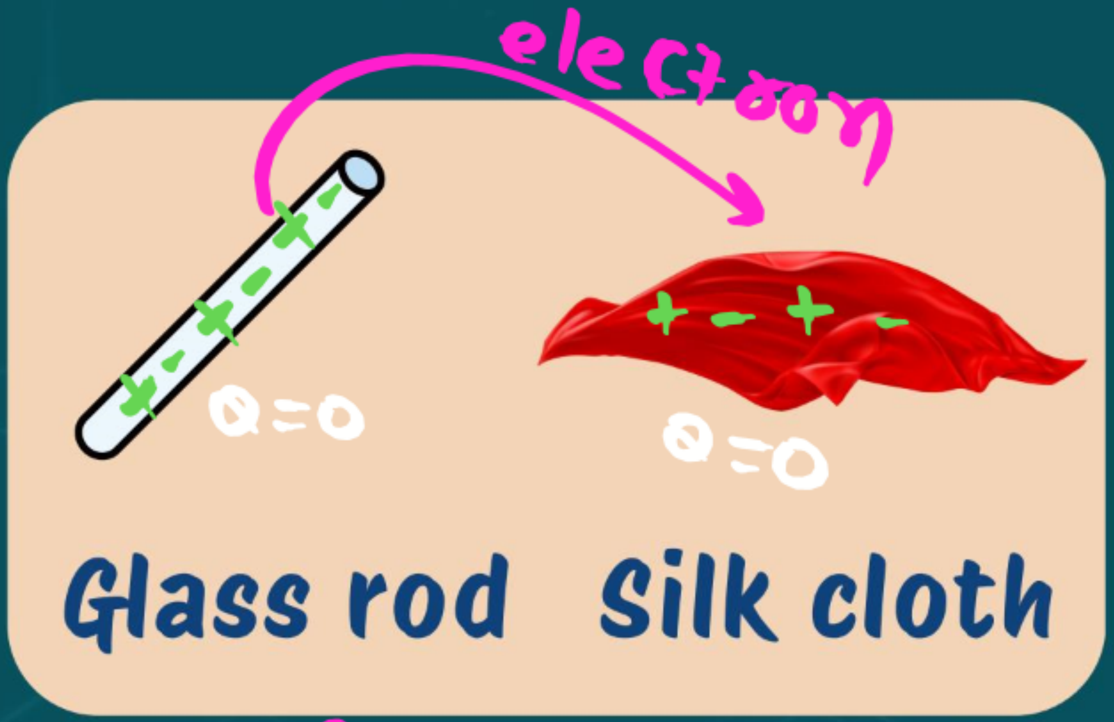
$$= 4e$$

$$= 4 \times 1.6 \times 10^{-19}\ C$$

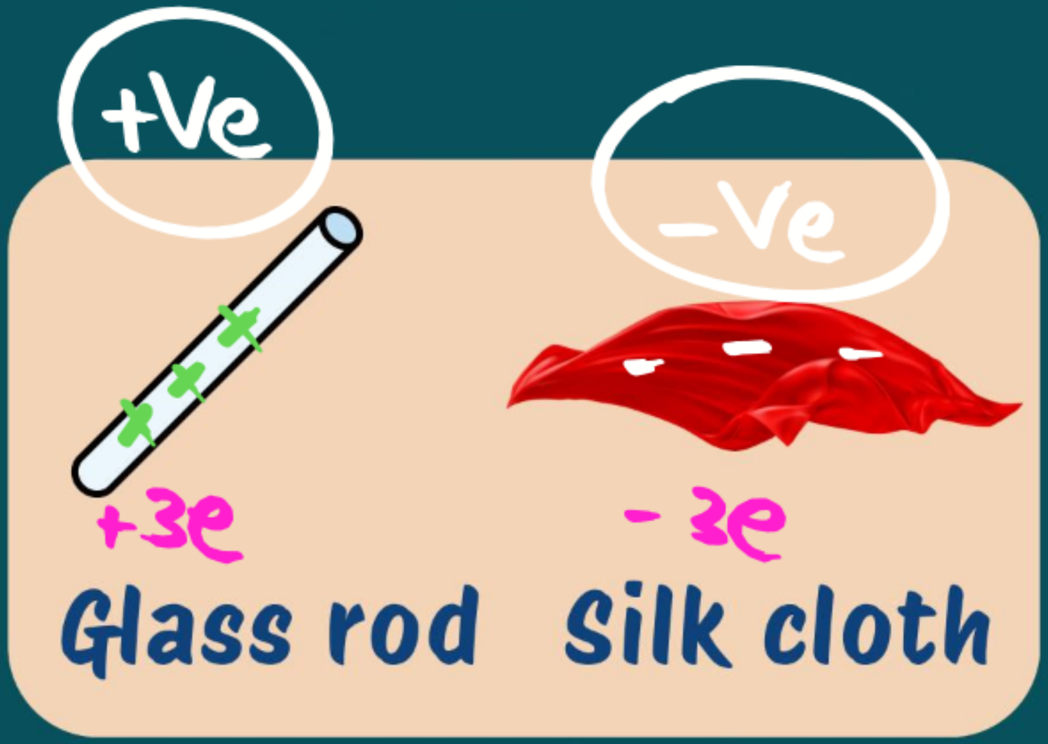
Properties of Charges

Charge is Conserved

- For an isolated system, net charge remains constant.
- Electric charge is conserved.



$Q_{syst.} = 0$



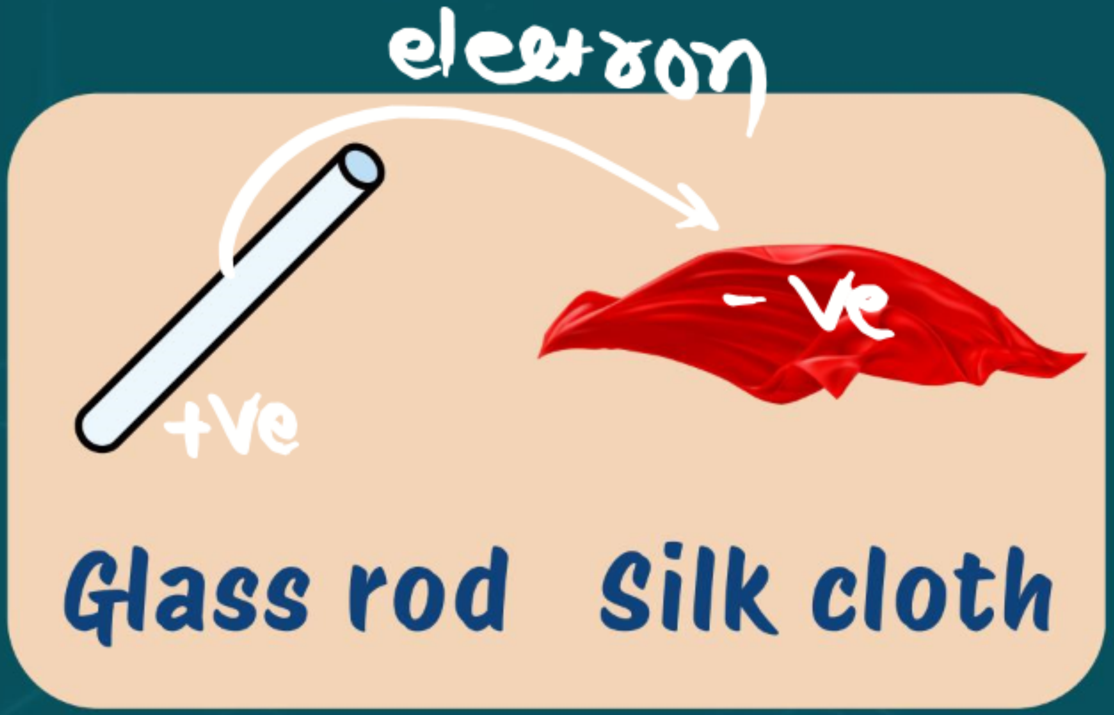
$Q_{syst} = +3e + (-3e) = 0$

Properties of Charges

Charge Quantization

[2 Marks]

The least possible value of charge that can be transferred is the charge of electron



$$\boxed{Q = +Ne}$$

$$N = 1, 2, 3, 4, 5 \ldots$$

$$N \neq \frac{1}{2}, \frac{3}{2}, \frac{5}{3}$$

Question

A neutral body ejects 10^{20} electrons in a specific process, find charge acquired by the body?

10^{20}

N

$Q=0$

$$+ve \Rightarrow Q = ne$$

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

$$Q = 16\ C$$

Next Toppers

Question

An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes

n

A) - 0.80 C
B) + 0.80 C
C) + 1.80 C
D) + 0.20 C

electrons
-ve

1C

$Q = ne$

$= 5 \times 10^{18} \times 1.6 \times 10^{-19}$

$= 8 \times 10^{-1}$

$Q = 0.8\ C$

Ans. $Q = (1C) + (-0.8)$

$= +0.2C$

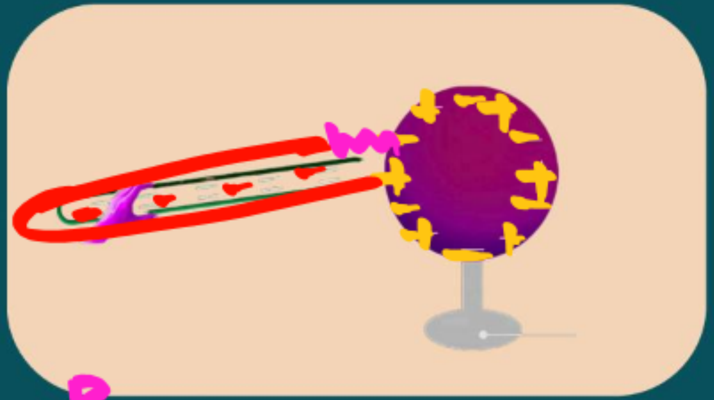
Methods of Charging

1. by Friction

Insulator

2. by Conduction

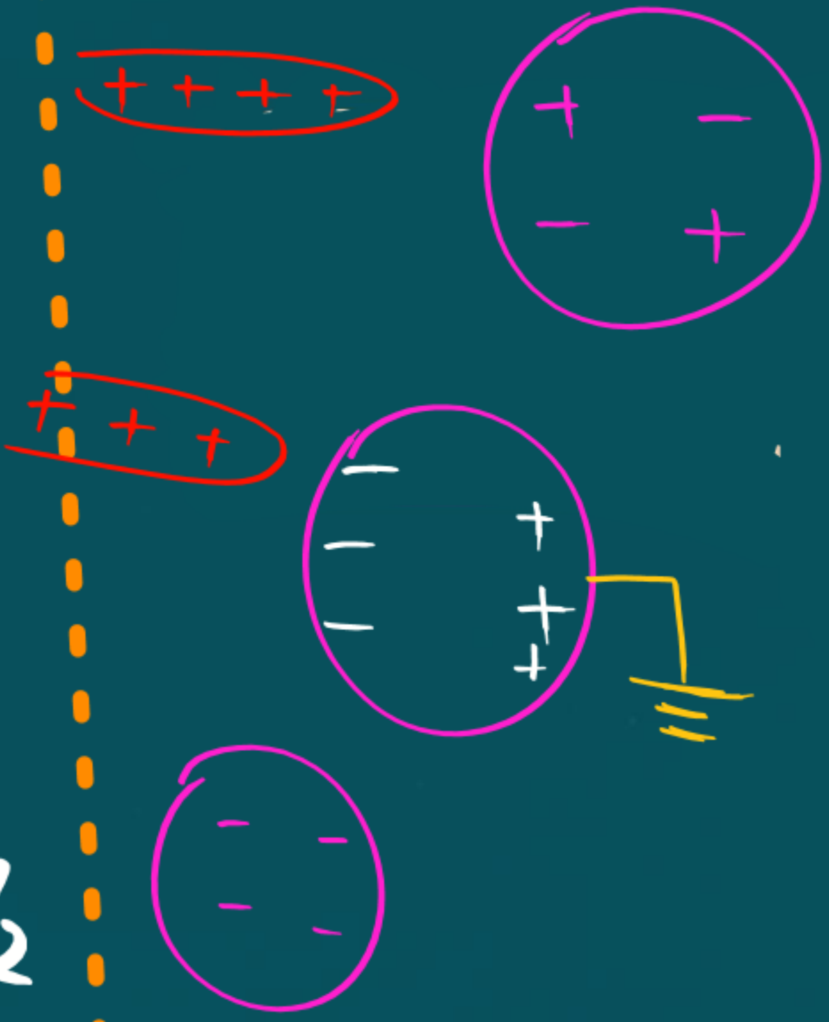
✓ conductor



$$Q'_A = Q'_B = \frac{Q+0}{2} = Q/2$$

3. by Induction

✓ conductor

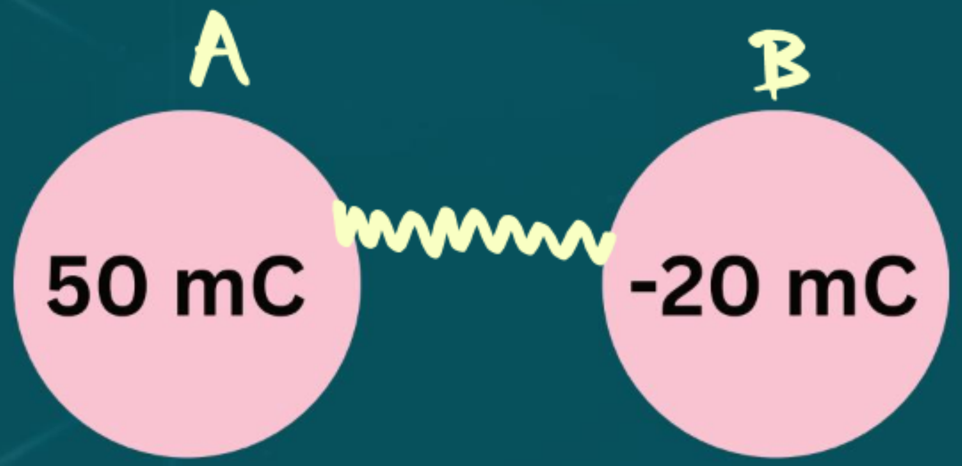


Next Toppers

Question

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

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

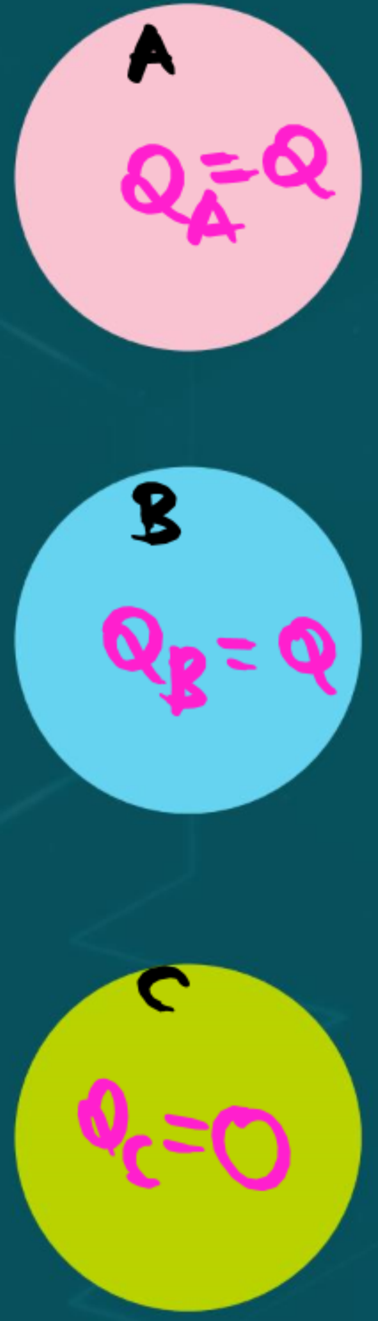


$$Q_A' = Q_B' = \frac{Q_A + Q_B}{2}$$

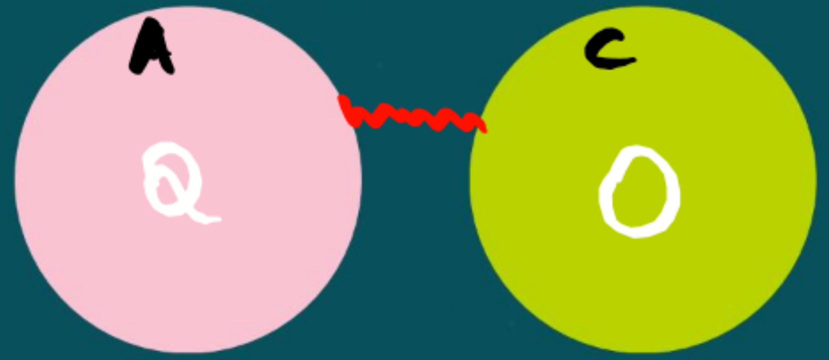
$$= \frac{(50) + (-20)}{2}$$

$$Q_A' = Q_B' = 15\ mC$$

Question



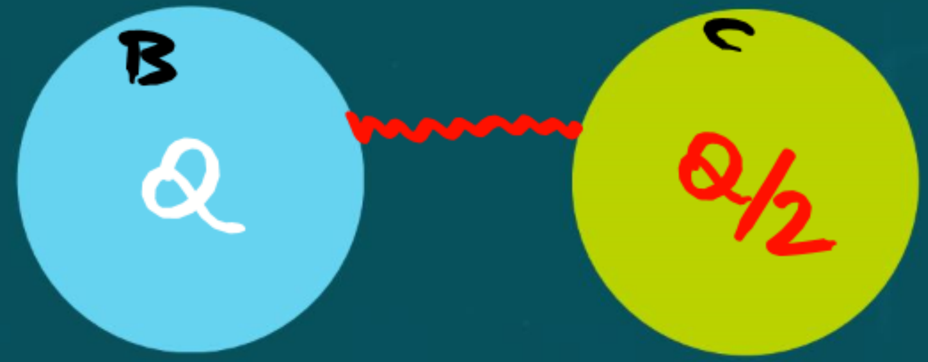
(i)



$$Q_A' = Q_C' = \frac{Q + 0}{2}$$

$$= \frac{Q}{2} \checkmark$$

(ii)

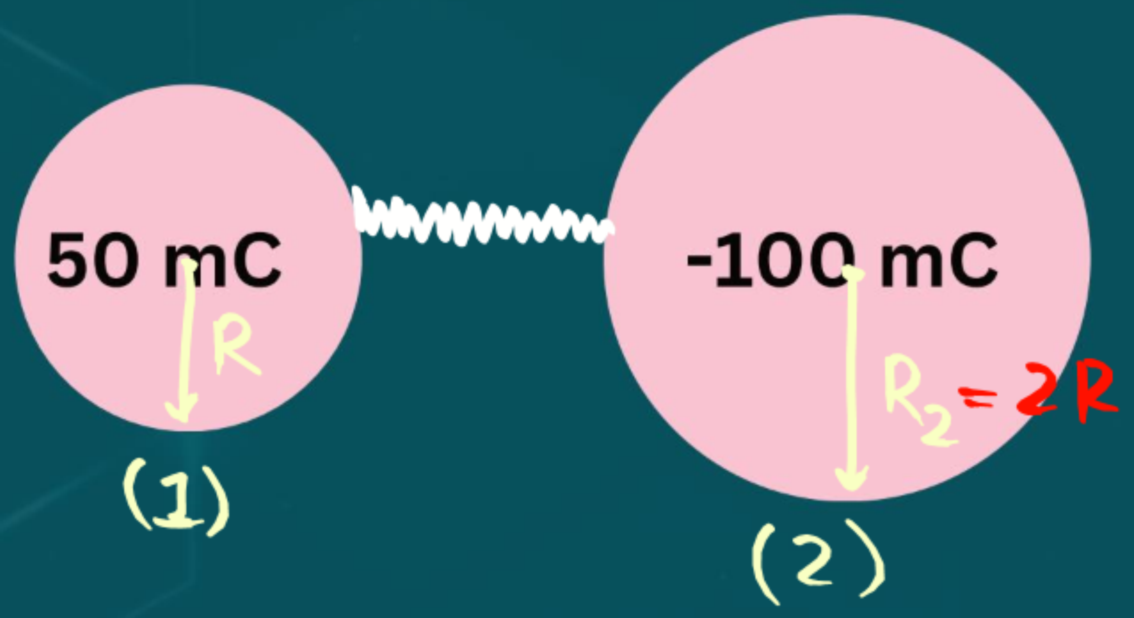


$$Q_B' = Q_C' = \frac{Q + Q/2}{2}$$

$$Q_B' = \frac{3Q}{4}$$

Question

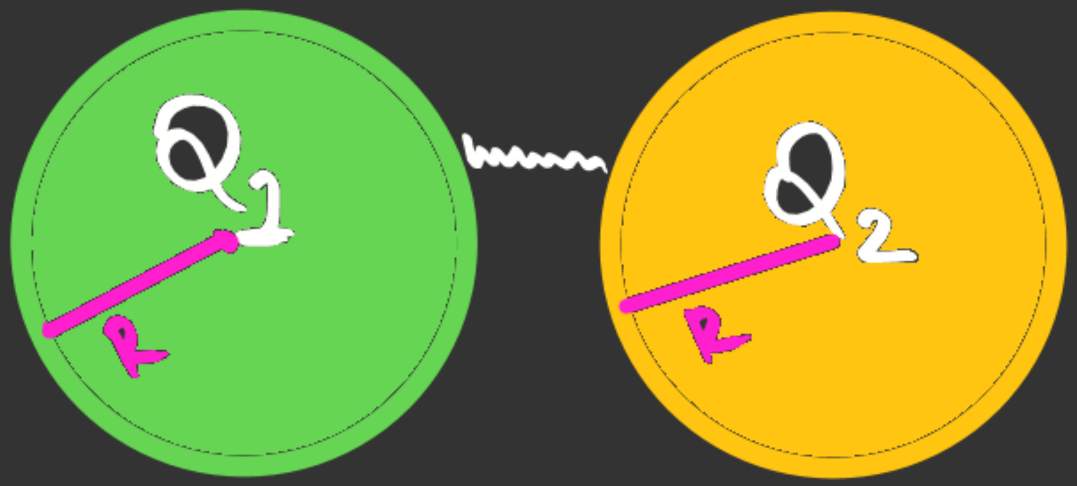
Find final charges on the spheres when switch S is closed.



$$Q_{total} = -50 \text{ mC}$$

$$Q_1' = \left(\frac{R}{R+2R}\right)(-50) = -\frac{50}{3} \text{ mC}$$

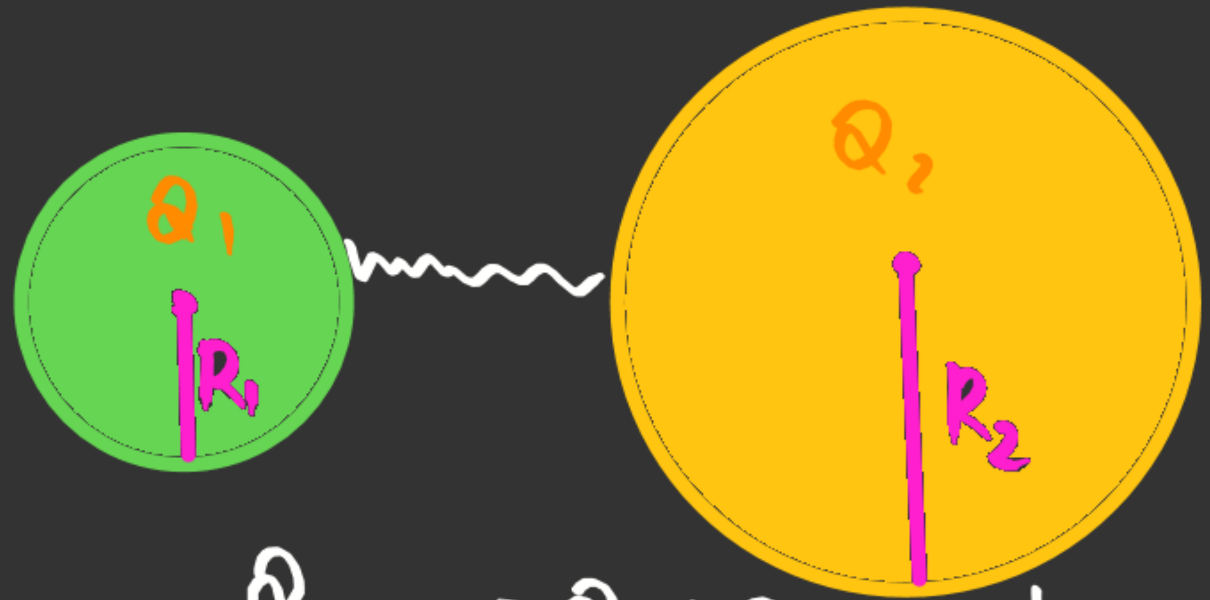
$$Q_2' = \left(\frac{2R}{2R+R}\right)(-50) = -\frac{100}{3} \text{ mC}$$



Identical

✓ $Q_1' = Q_2' = \dfrac{Q_1 + Q_2}{2}$

chp. 1 ✓



$\underline{Q_{total} = Q_1 + Q_2} = Q_1' + Q_2'$

$$\boxed{Q_1' = \left(\frac{R_1}{R_1 + R_2}\right) Q_{total}}$$

$$\boxed{Q_2' = \left(\frac{R_2}{R_1 + R_2}\right) Q_{total}}$$

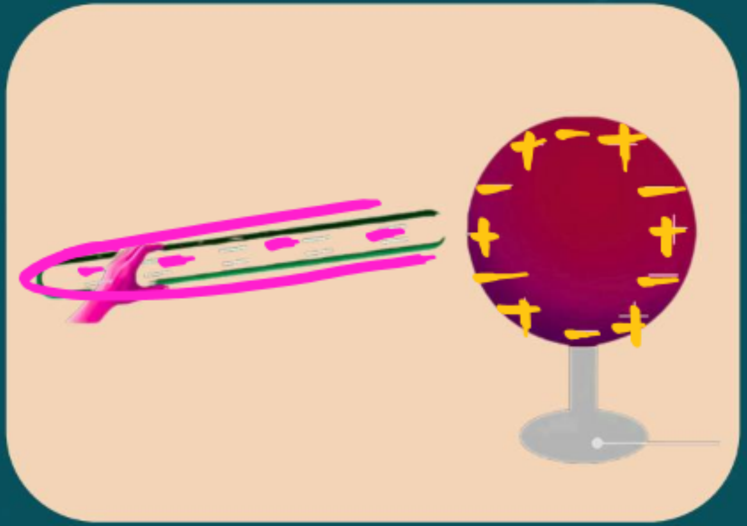
Why? ⇒ ch 2 ⇒ charge कब तक Flow?

⇒ $V_1 = V_2$

Methods of Charging

3. Charging by Induction

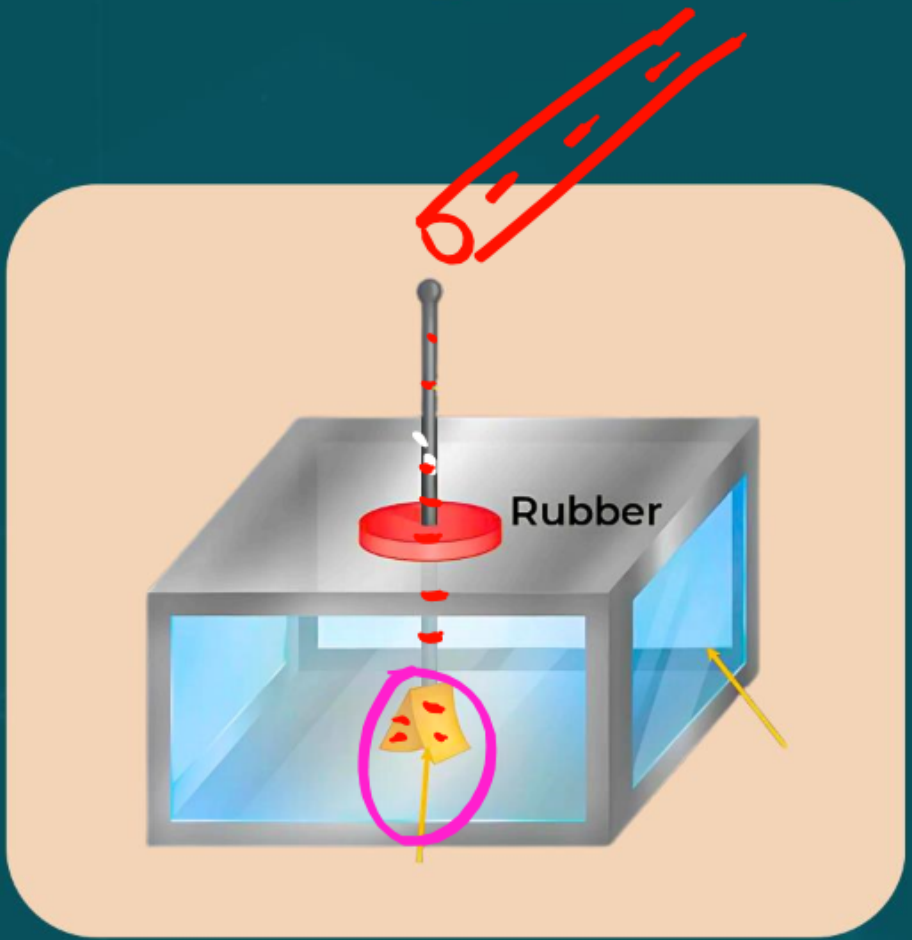
- Using this method, a neutral object can be charged without actually touching another charged object.

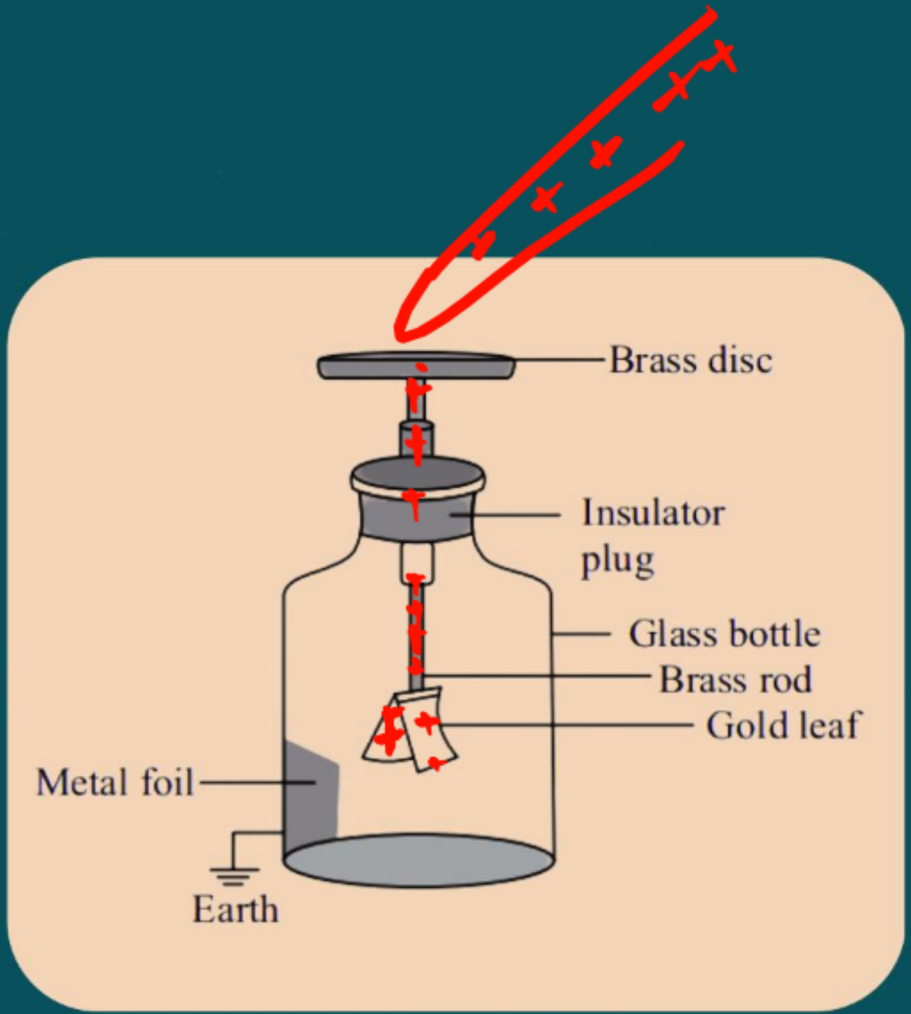


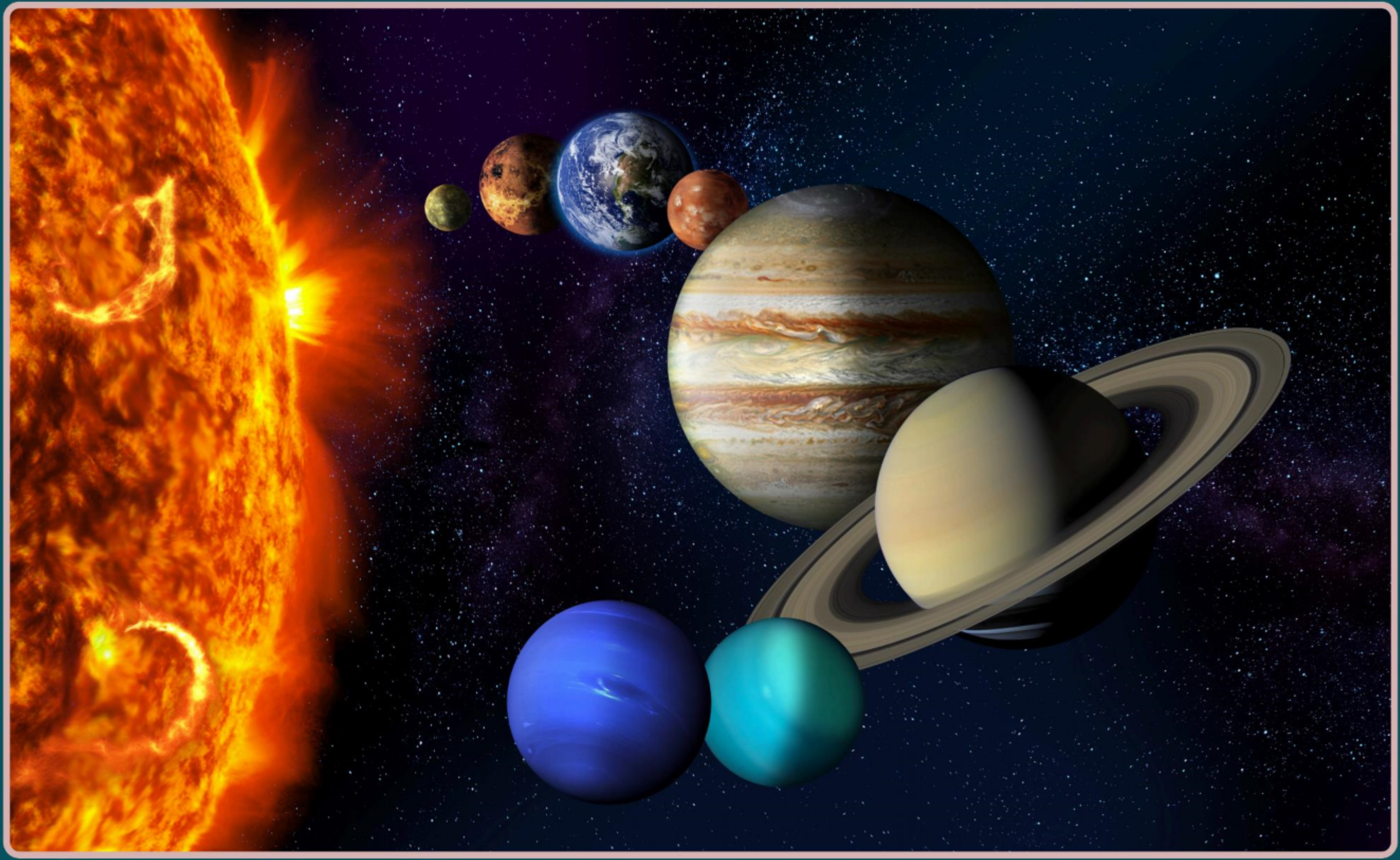
- As the rod approaches the neutral sphere, redistribution of charges takes place.

Gold leaf Electroscope

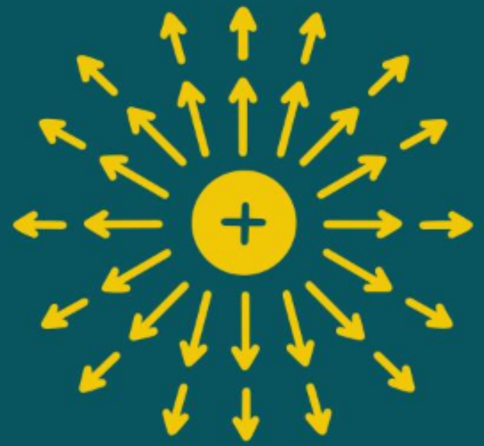
- Gold leaf Electroscope is sensitive electroscope type that is used for detecting the charges.







$$F = \frac{G m_1 m_2}{r^2}$$

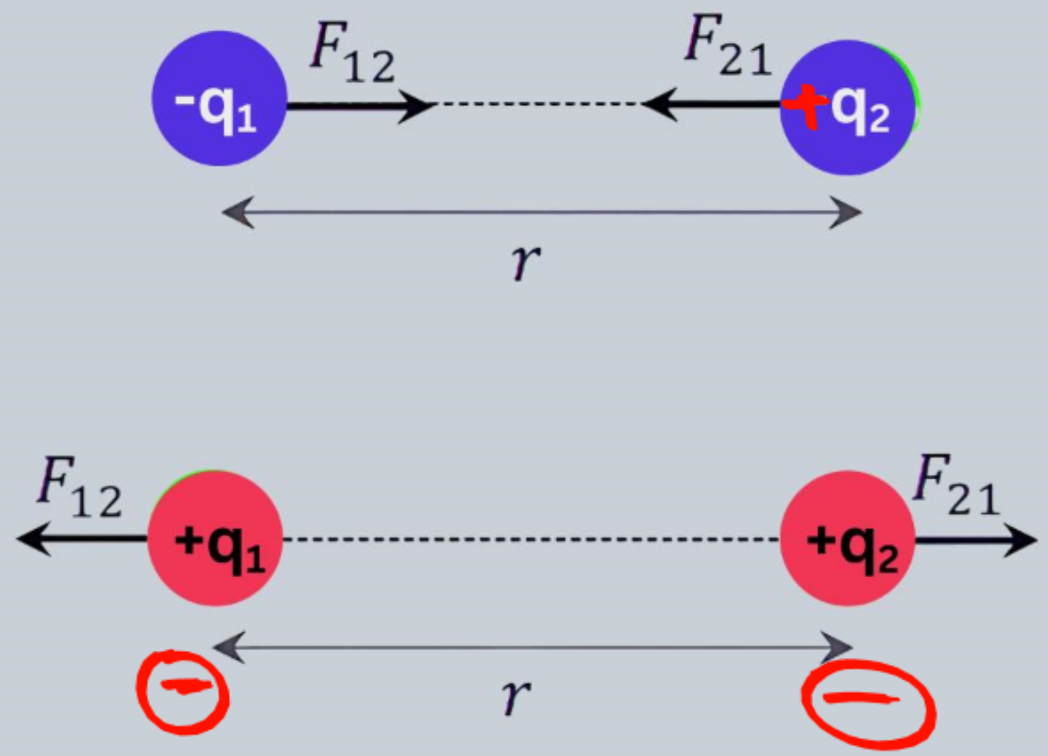


Coulomb's Law

Next Toppers

Coulomb's Law

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



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

$F \Rightarrow - \Rightarrow$ attraction

$F \Rightarrow + \Rightarrow$ Repulsion

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

k = Electrostatic constant

= Coulomb's constant

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

$$[k] = \frac{[M^1 L^1 T^{-2}][L^2]}{A^2 T^2}$$

$$[k] = M^1 L^3 T^{-4} A^{-2}$$

(CBSE)

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

ε_0 = permitivity of Free space

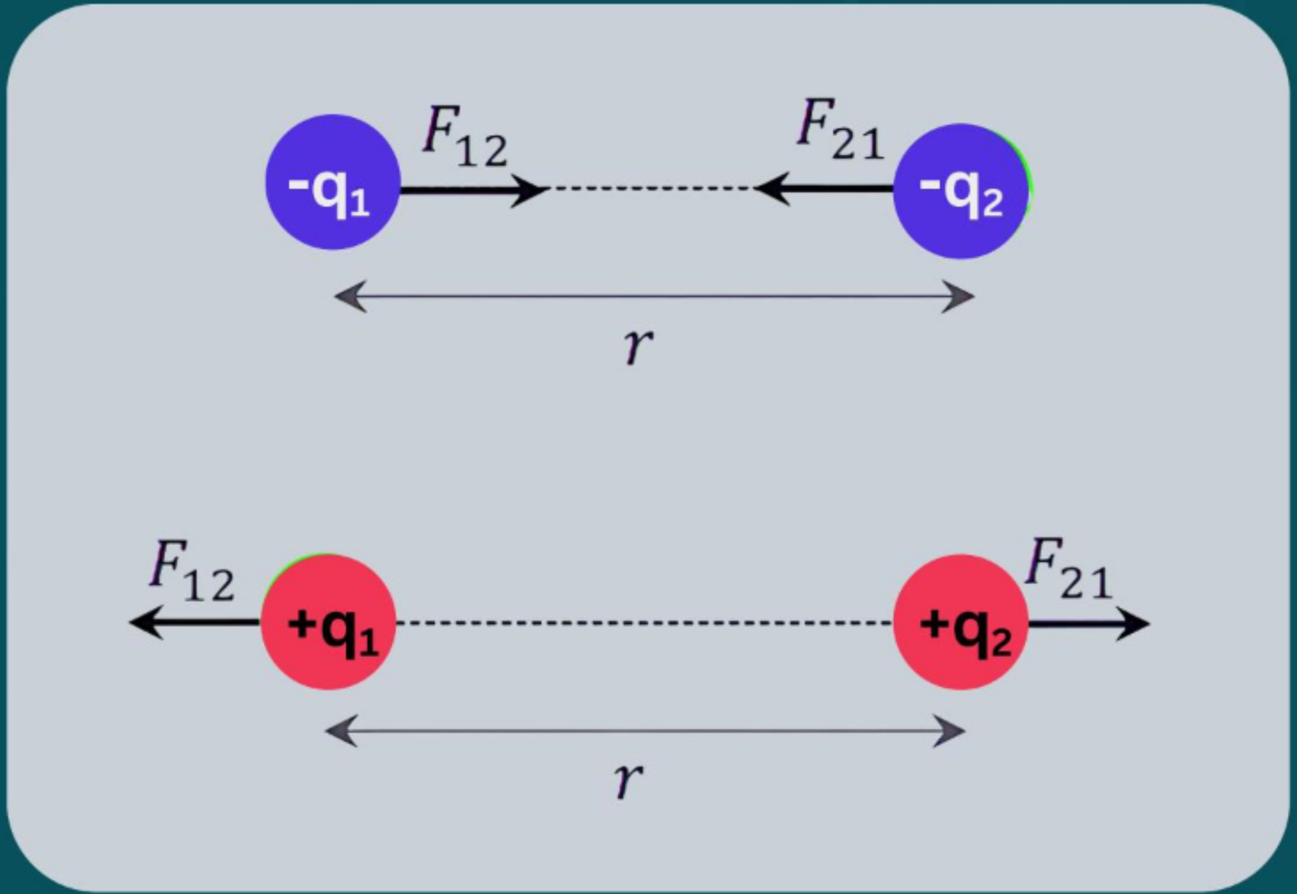
$$= 8.85 \times 10^{-12} \ \frac{C^2}{N \cdot m^2}$$

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

[CBSE]

Characteristics of electrostatics force

- Acts between two *point charges*
- Magnitude is *equal* $|\vec{F_{12}}| = |\vec{F_{21}}|$
- 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



Next Toppers

Question

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?

$= 30 \times 10^{-2}$ m
$= 3 \times 10^{-1}$ m

[NCERT Exercises 1.1]

$$F = \frac{kQ_1Q_2}{r^2} = \frac{\cancel{9} \times 10^{9} \times (2 \times 10^{-7})(3 \times 10^{-7})}{\cancel{9} \times 10^{-2}}$$

$$= 6 \times 10^{-5+2}$$

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

Question

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?

[NCERT Exercises 1.1]

Answer

$F = 6 \times 10^{-3}$ C

Limitations of Coulomb's law

- The electric charges must be at rest.
- The electric charges must be point charges

  i.e., the extension of charges must be much smaller than the separation between the charges.

- The separation between the charges must be greater than the nuclear size (10^{-15} m), because for distances (10^{-15} m), the strong nuclear force dominates over the electrostatic force.

Coulomb's Law

Type 1 : Coulomb's Law + Properties of Charges

Type 2 : Coulomb's Law + Vectors Bridge course

Type 3 : Coulomb's Law + Effect of Medium

Type 4 : Coulomb's Law + Basic Maths

Type 4 : Coulomb's Law + Mechanics 11th

Coulomb’s Law

Type 1 : Coulomb’s Law + Properties of Charges

Question

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 ?

[NEET 2025]

A B

$$F = \frac{k Q_A Q_B}{r^2} = \frac{kQ^2}{r^2}$$

कहानी

A C

C B

ii

A B

$Q'_A = \frac{Q}{2}$ $Q'_B = \frac{3Q}{4}$

$$F' = \frac{k Q'_A Q'_B}{r^2} = \frac{k\left(\frac{Q}{2}\right)\left(\frac{3Q}{4}\right)}{r^2}$$

$$\boxed{F = \frac{3F}{8}}$$

Question

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 ?

Answer

[NEET 2025]

$F' = 3F/8$

Next Toppers

Question

Two spheres having equal charges exert F force on each other. Now 20% charge of one sphere is transferred to another sphere. Then find new force between them in terms of F.

HOMEWORK

Next Toppers

Question

Two spheres having equal charges exert F force on each other. Now 20% charge of one sphere is transferred to another sphere. Then find new force between them in terms of F.

Answer

F = 0.96 F

Coulomb's Law

Type 2 : Coulomb's Law + Vectors

Derivation

C.Law = Vector Form

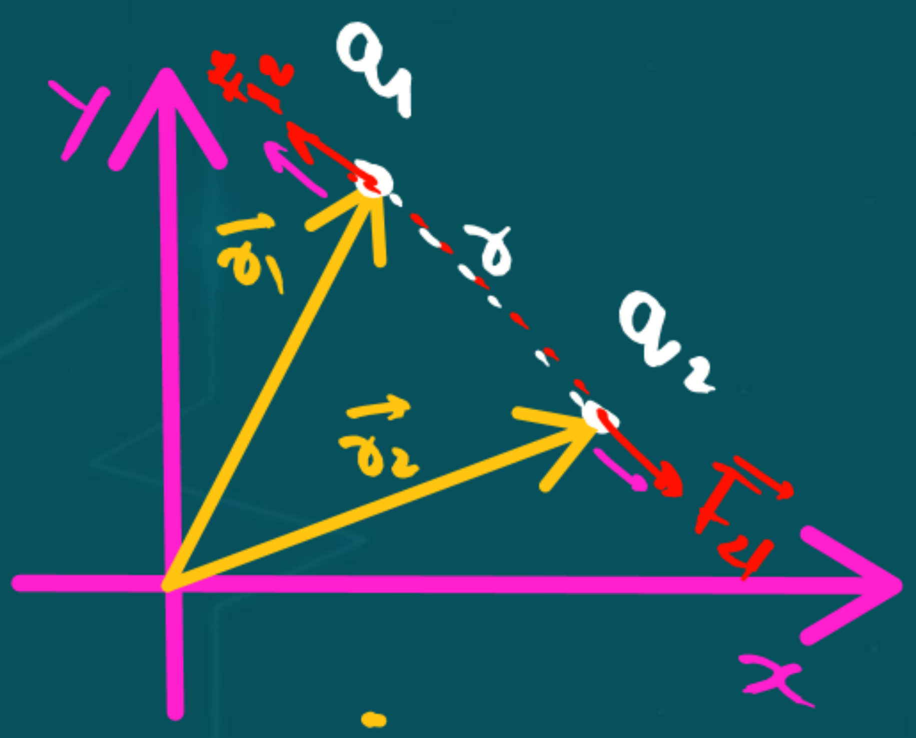
Vector Form

(CBSE)

- r_1 Position vector of q_1
- r_2 Position vector of q_2

$$\boxed{\hat{r}_{12} = -\hat{r}_{21}}$$

- $|\vec{F}_{21}| = |\vec{F}_{12}| = \dfrac{kq_1q_2}{r^2}$



- $\vec{F}_{12} = F_{12}\,\hat{F}_{12}$

$$\vec{F}_{12} = \frac{kq_1q_2}{r^2}\,\hat{r}_{12}$$

- $\vec{F}_{21} = F_{21}\,\hat{F}_{21}$

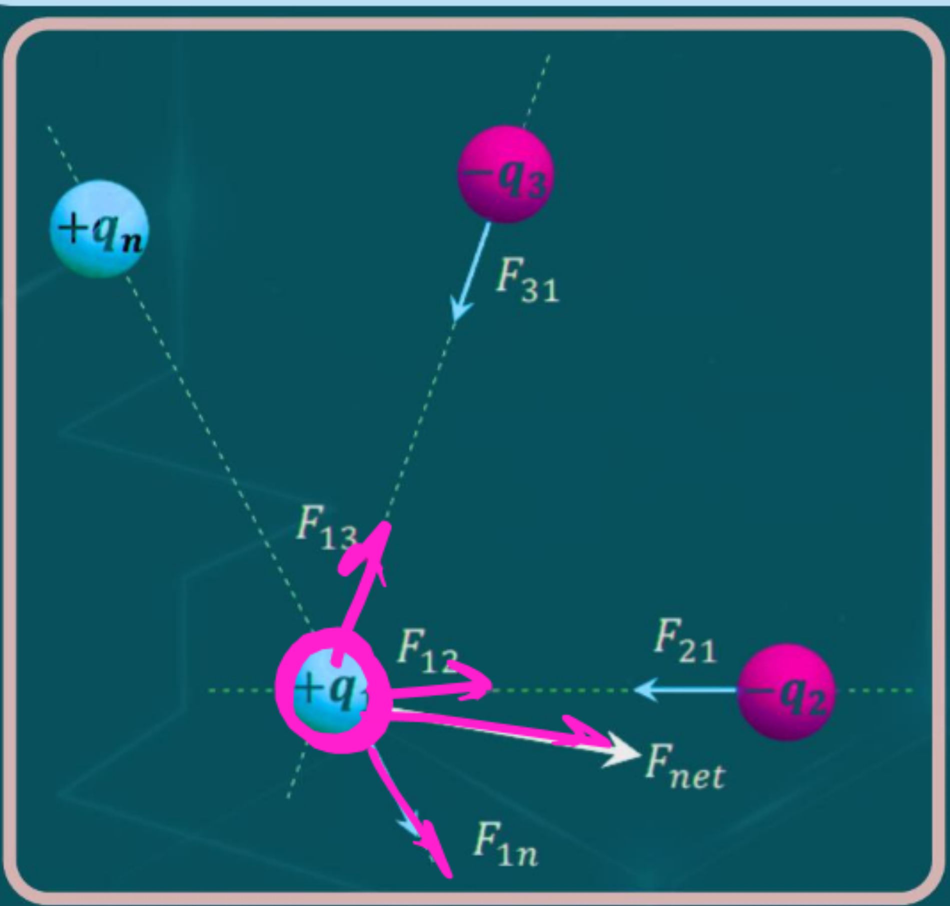
$$= \frac{kq_1q_2}{r^2}\,\hat{r}_{21}$$

$$\vec{F}_{21} = -\frac{kq_1q_2}{r^2}\,\hat{r}_{12}$$

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

Superposition Principle

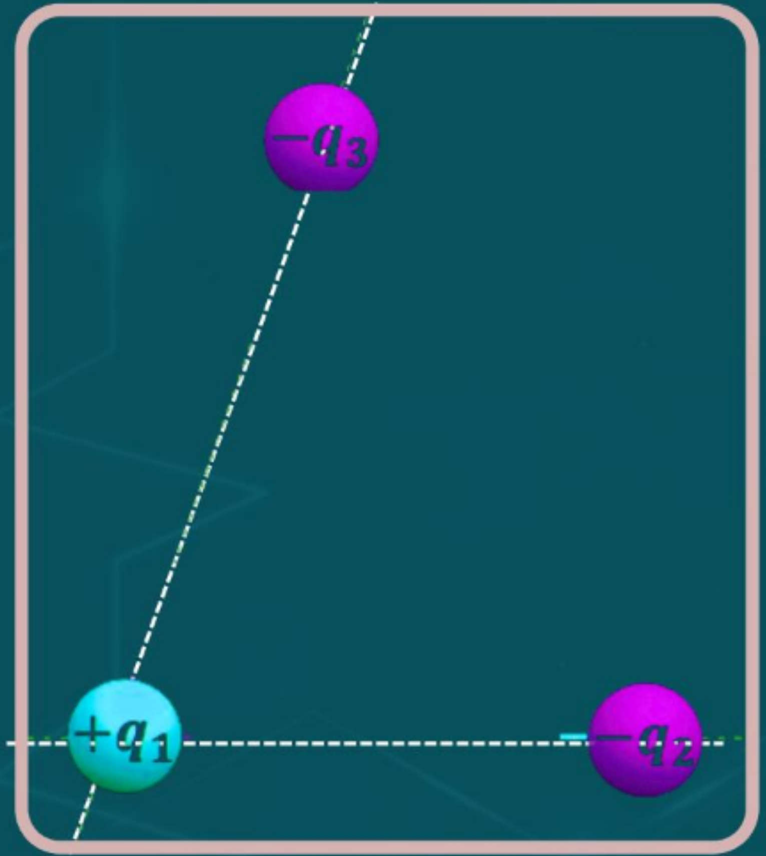
Force on any charge due to any number of other charges will be vector summation of all the electrostatic forces on that charge due to the other charges, taken one at a time.



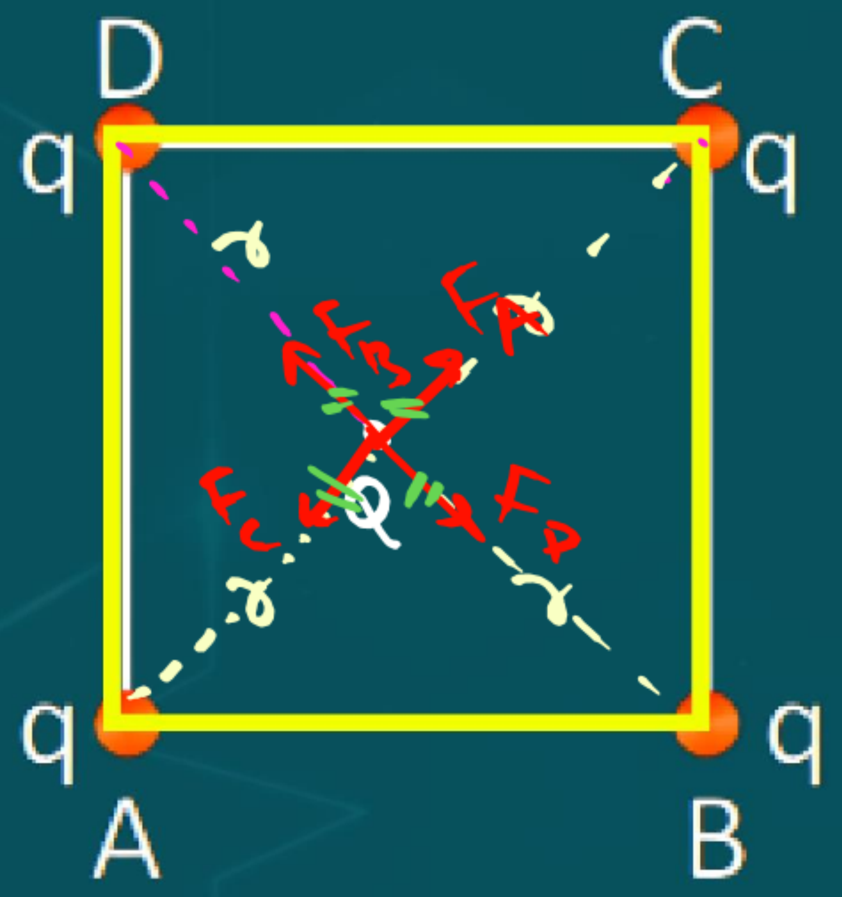
$$\vec{F}_{net} = \vec{F_1} + \vec{F_2} + \vec{F_3} + \vec{F_4} + \ldots$$

NOTE

Electrostatic force of interaction between two charges in consideration is independent of the presence of other charges.



Question



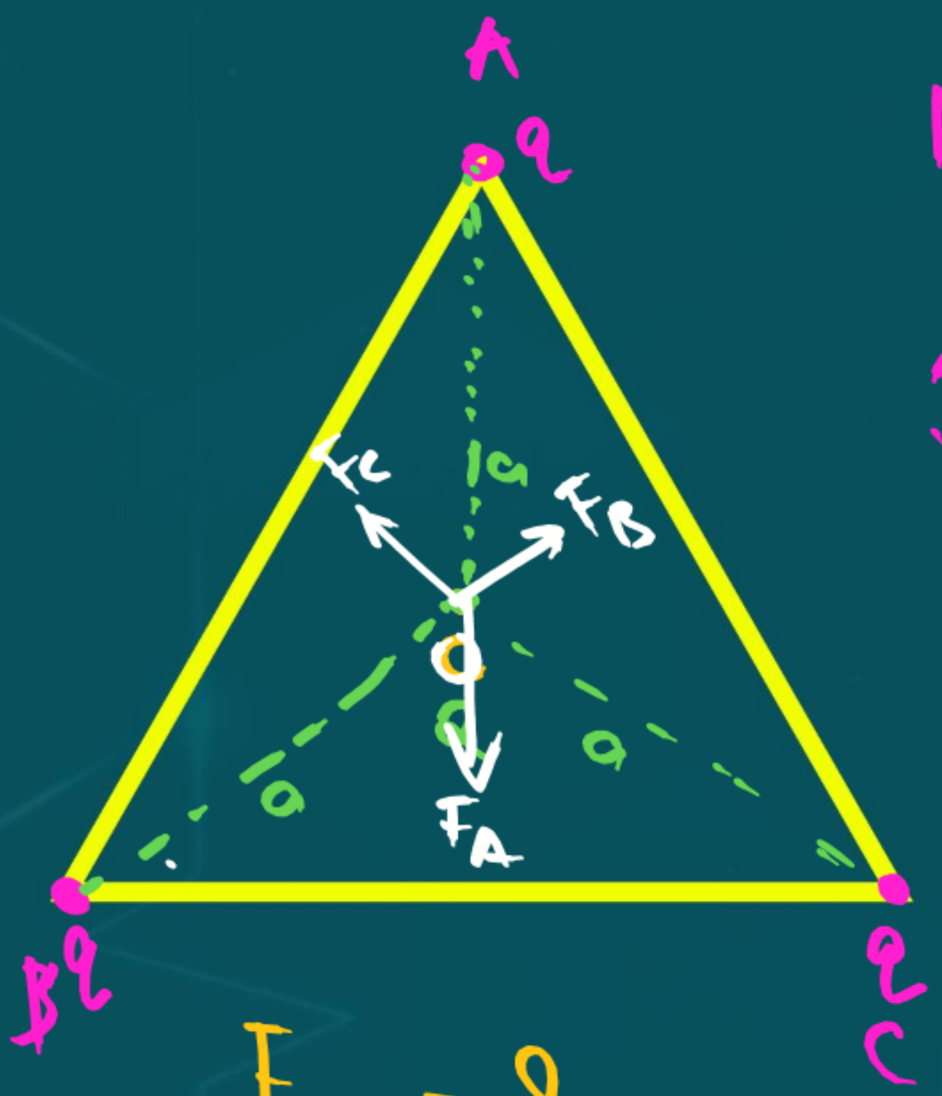
$$\vec{F}_{\substack{Q\\(net)\\(c)}} = \vec{F}_A + \vec{F}_B + \vec{F}_C + \vec{F}_D$$

$$F_A = F_B = F_C = F_D = \frac{kQq}{r^2}$$

$$F_{\substack{net\\(Q)}} = 0$$

Question

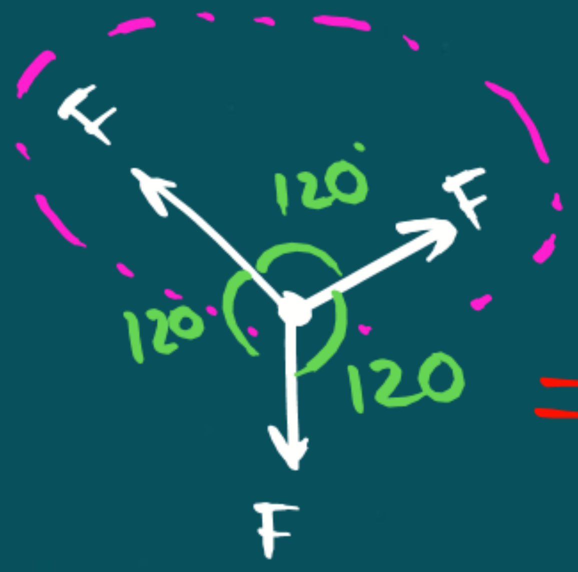
[NCERT]



$F_{net}(c) = ?$

$$\vec{F}_{net}(Q) = \vec{F_A} + \vec{F_B} + \vec{F_C}$$

$$F_A = F_B = F_C = \frac{kQq}{a^2} = F$$



$$F_{BC} = \sqrt{F^2 + F^2 + 2FF\cos 120^\circ} = F$$

$=$

$\Rightarrow F_{net} = 0$

$$\theta = \frac{360}{3} = 120$$

$$F = \sqrt{F^2 + F^2 + 2F^2(-1/2)}$$

BC

$$= \sqrt{F^2}$$

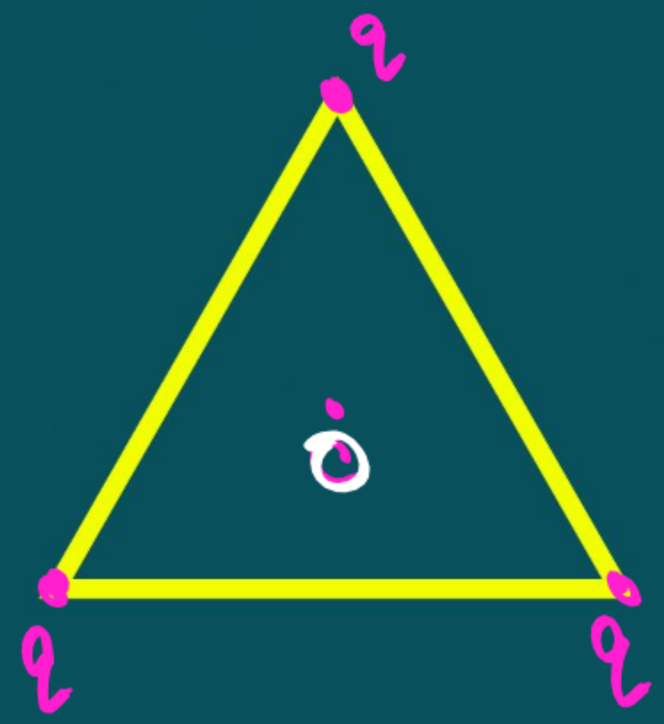
$$= F$$

Question

Consider three charges q_1 , q_2 , q_3 each equal to q at the vertices of an equilateral triangle of side l. What is the force on a charge Q (with the same sign as q) placed at the centroid of the triangle, as shown in Figure ?

[NCERT]

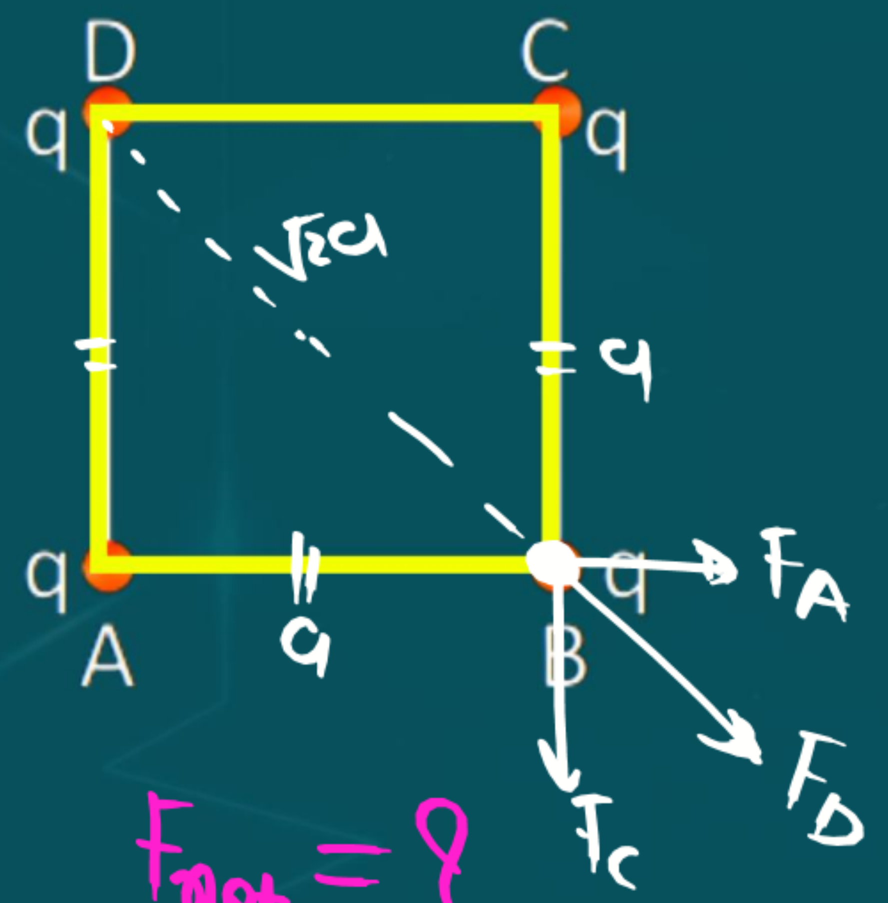
Answer



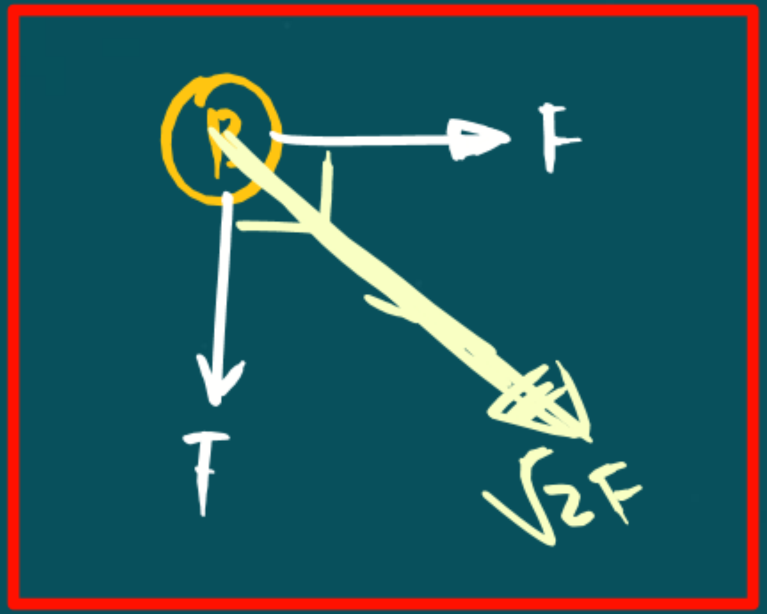
It is clear also by symmetry that the three forces will sum to zero.

Question

$$\vec{F}_{net\,(B)} = \vec{F}_A + \vec{F}_C + \vec{F}_D$$



$$F_{net\,(B)} = ?$$



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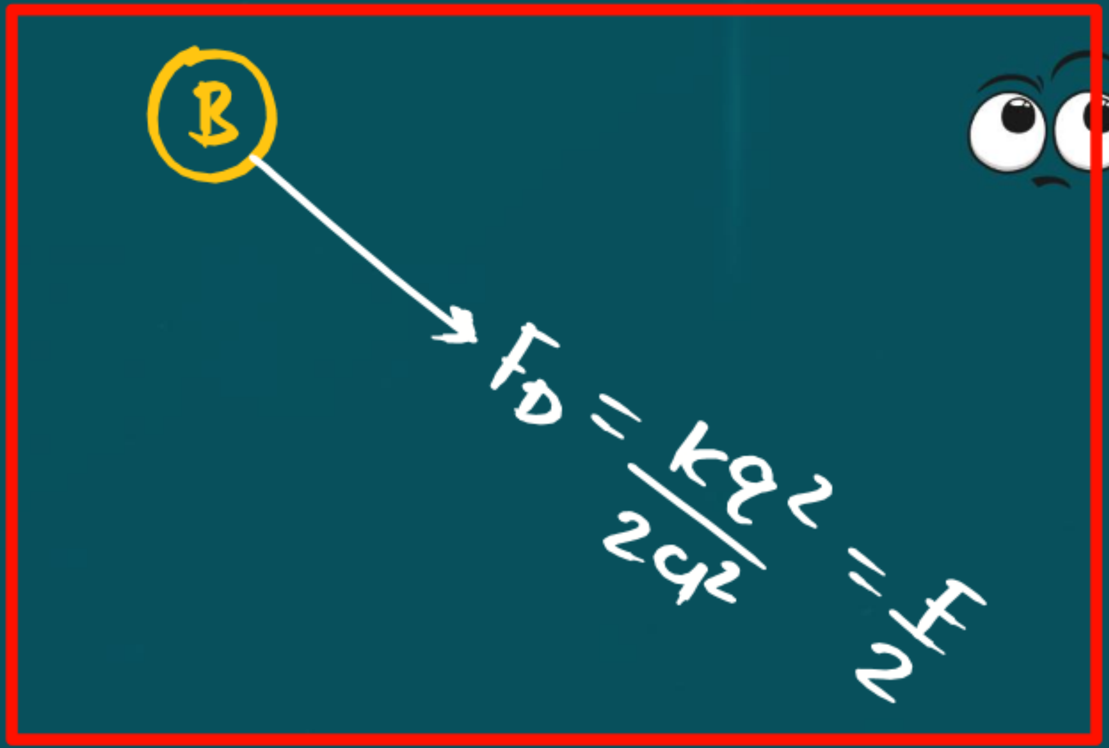


$$F_A = F_C = \frac{kq^2}{a^2} = F$$

$$F_{BC} = \sqrt{F^2 + F^2 + 2FF\cos 90^\circ}$$

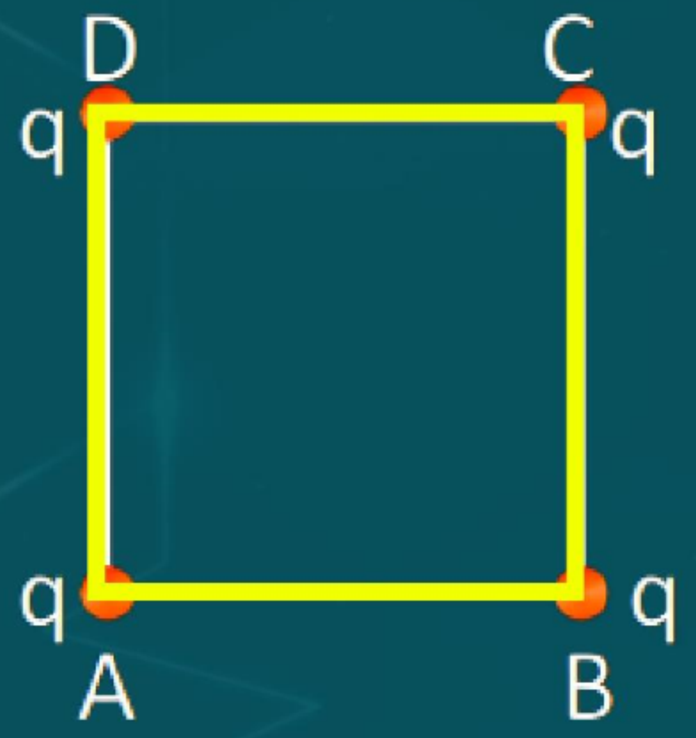
$$= \sqrt{2}F$$

$$F_{net\,(B)} = \sqrt{2}F + \frac{F}{2}$$

$$= \left(\sqrt{2} + \frac{1}{2}\right) F$$

$$= \left(\sqrt{2} + \frac{1}{2}\right) \frac{kq^2}{a^2}$$

Question



Answer

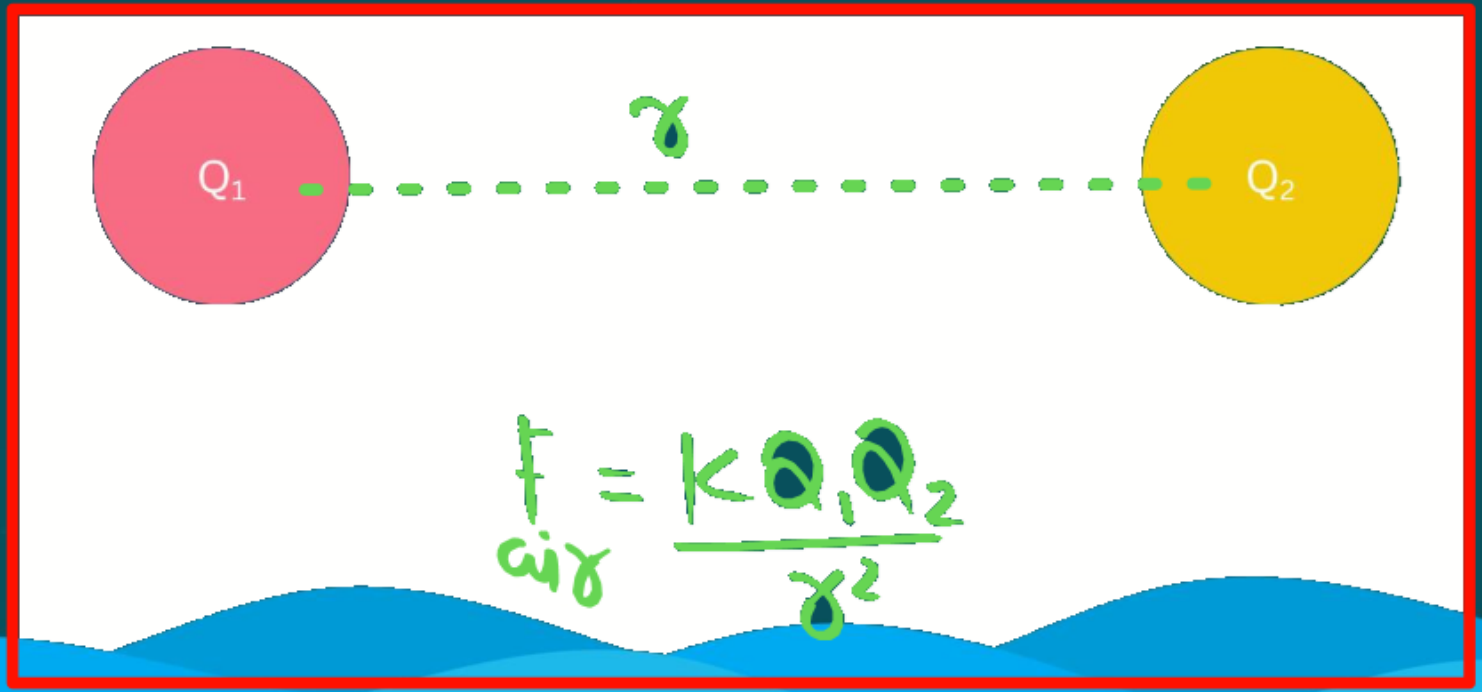
$$F_B = \frac{kq^2}{a^2}\left(\frac{1}{2} + \sqrt{2}\right)$$

Coulomb's Law

Type 3 : Coulomb's Law + Effect of Medium

Effect of Medium

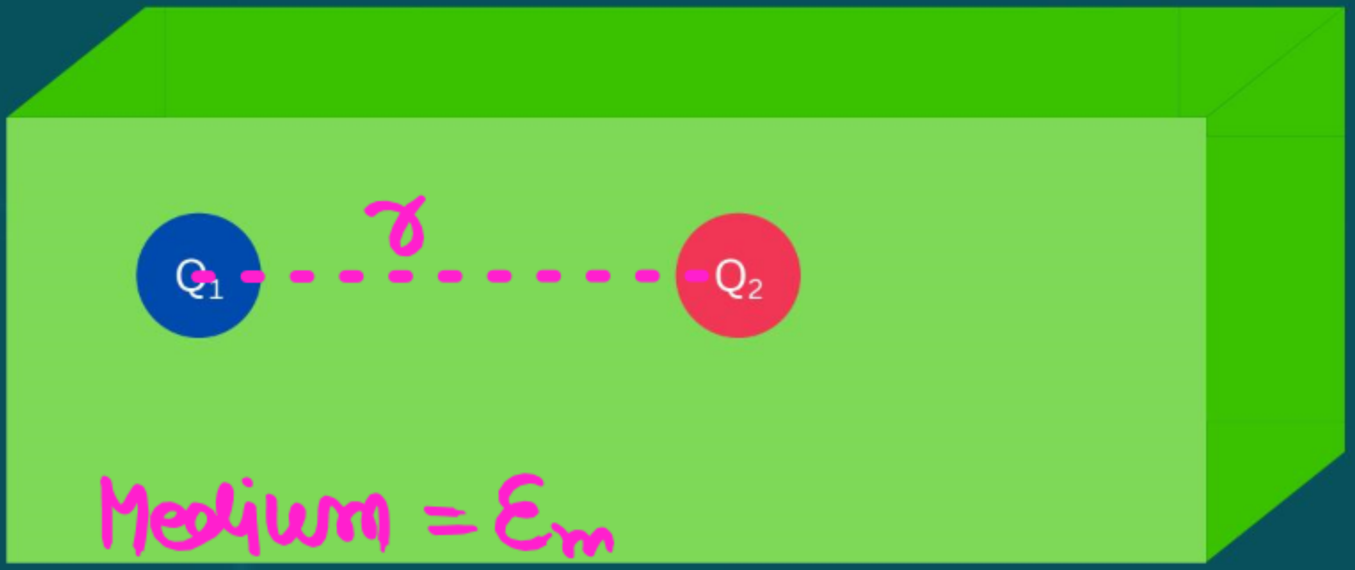
$$\Rightarrow F_{med} = \frac{F_{air}}{k} = \frac{F_{air}}{\varepsilon_r}$$



$$F_{air} = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Q_1Q_2}{r^2}$$

air

Effect of Medium



ε_m = permittivity of medium

ε_0 = permittivity of free space

$\Rightarrow \dfrac{\varepsilon_m}{\varepsilon_0} = \varepsilon_r$ = Relative permittivity $\Rightarrow \varepsilon_m = \varepsilon_0 \cdot \varepsilon_r$

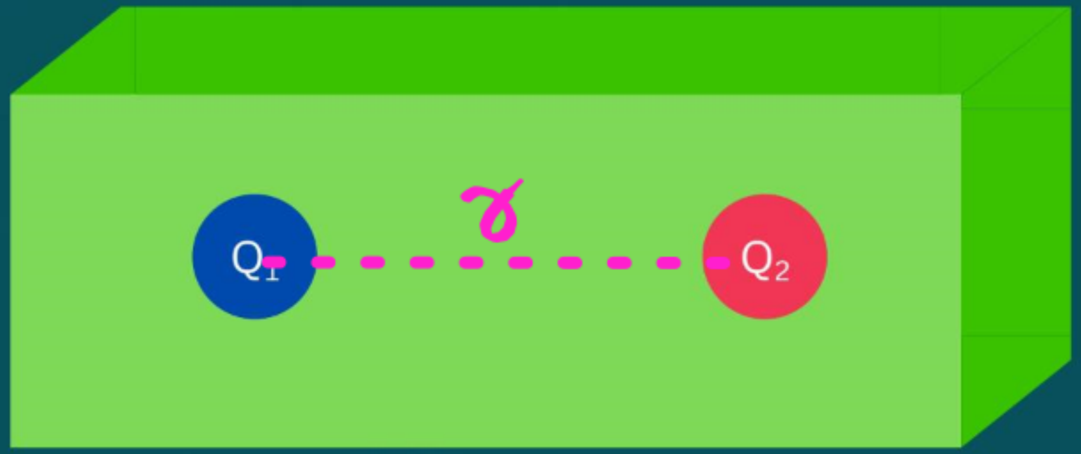
$$F_m = \left(\frac{1}{4\pi\varepsilon_m}\right)\frac{Q_1 Q_2}{r^2}$$

$$F_m = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 Q_2}{r^2}\right)\left(\frac{1}{\varepsilon_r}\right)$$

$$\boxed{F_m = \frac{F_{air}}{\varepsilon_r} = \frac{F_{air}}{K}}$$

$K \leftarrow$ dielectric constant

$$\boxed{\varepsilon_r = K}$$



Dielectric constant $(k) = \dfrac{\varepsilon_m}{\varepsilon_0}$

Medium	K
Vacuum	1
Air	1.00056
Water	80
Mica	6
Teflon	2
Glass	5-10
PVC	4.5
# Metal	∞

Q.

Q_1 —— Q_2

$F_{air} = 100\,N$

Q_1 —— Q_2

$\cancel{F_{air} = 100\,N}$

$k = 5$

$$F_m = \frac{F_{air}}{k} = \frac{100}{5} = 20\,N$$

Question

Force between two point charges q_1 and q_2 placed in vacuum at 'r' cm apart is F. Force between them when placed in a medium having dielectric K = 5 at 'r/5' cm apart will be:

[JEE MAINS]

A F/25
~~B) 5F~~
~~C) F/5~~
D) 25F

$q_1 \quad q_2$, separation r

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

$q_1 \quad q_2$, separation $r/5 = (r')$, medium (K)

$F_m = \frac{F_{air}}{K} = \frac{\frac{kq_1q_2}{(r/5)^2}}{5} = \frac{25}{5}\left(\frac{kq_1q_2}{r^2}\right)$

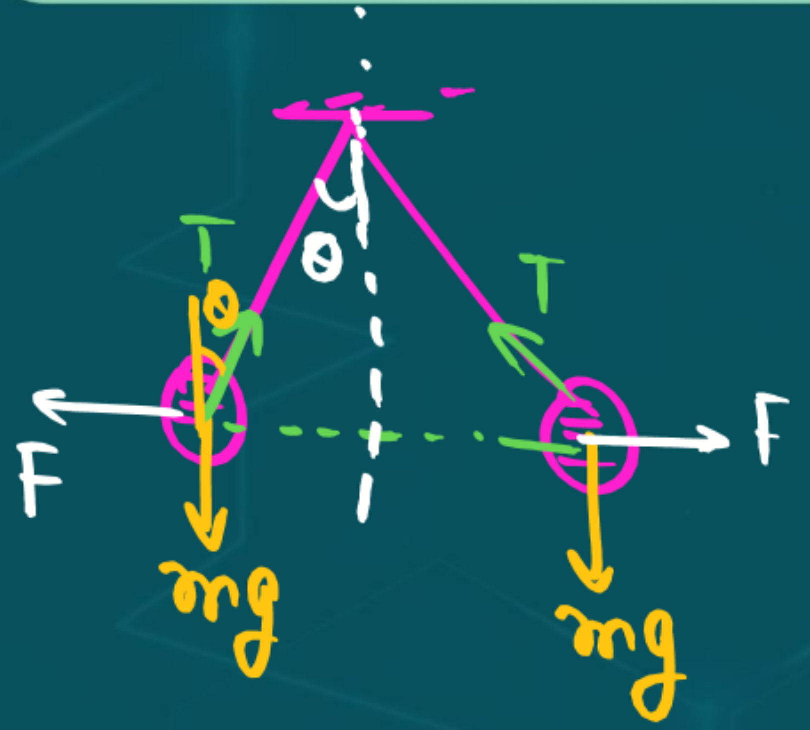
$= 5F$

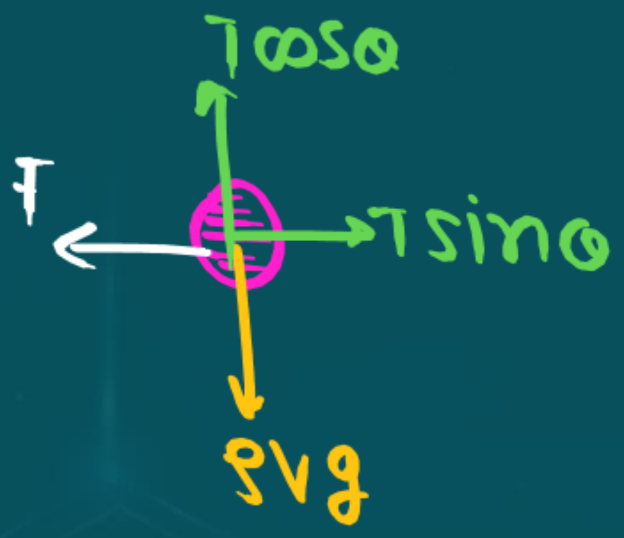
Question

$m = \rho V$

Two identical balls, each having a density ρ are suspended from a common point by two insulating strings of equal length. Both the balls have equal mass and charge. In equilibrium, each string makes an angle θ with vertical. Now, both the balls are immersed in a liquid. As a result of immersion in the liquid, the angle θ does not change. The density of the liquid is σ. The relative permittivity of the liquid is

[NEET]

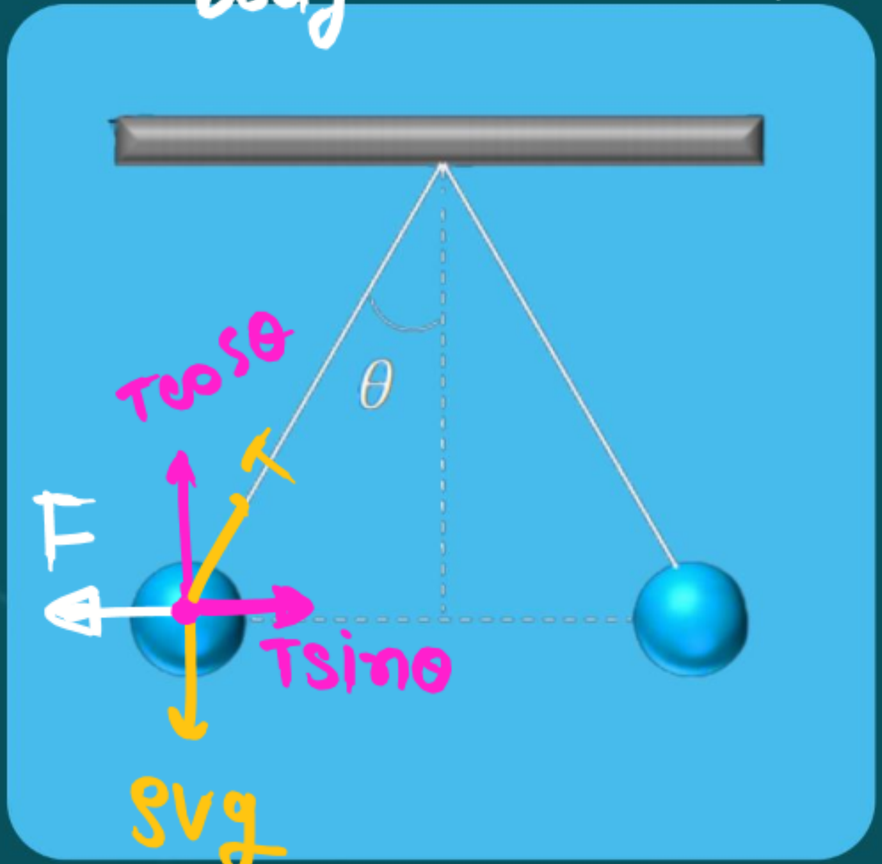


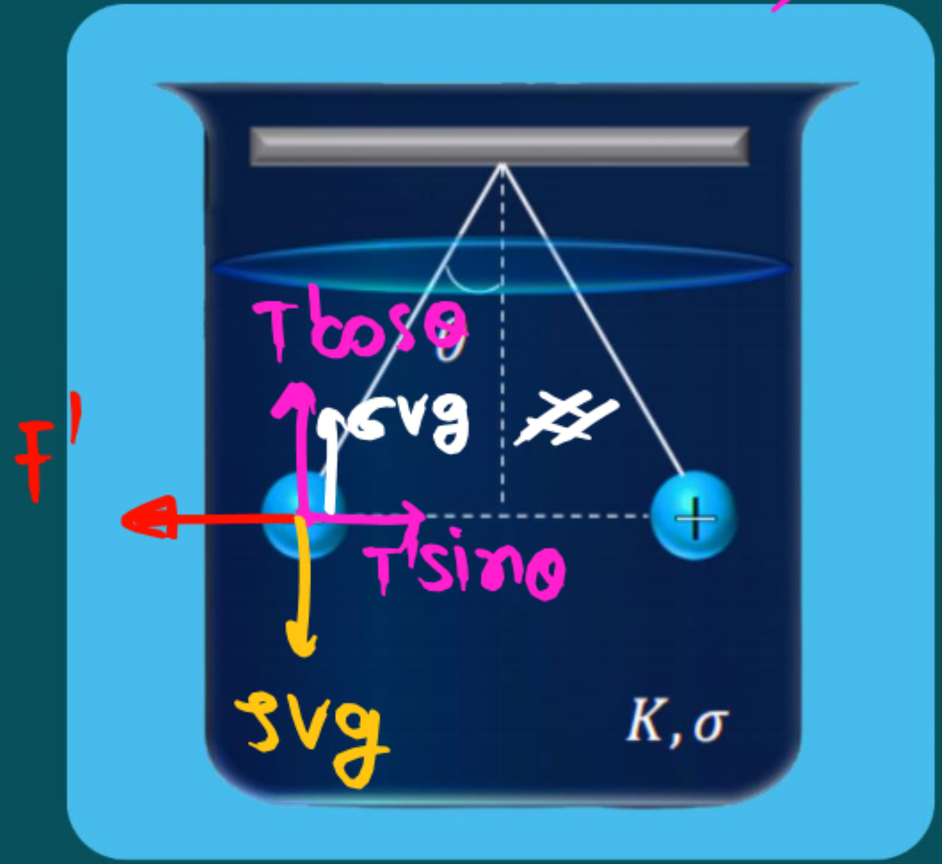


$$T\sin\theta = F$$
$$T\cos\theta = \rho V g$$

$$\tan\theta = \frac{F}{\rho V g}$$

$\rho_{body} = \rho$ & $\rho_{liq.} = \sigma =$ const. (Given)





$mg = \rho vg$

$F_B = \rho_{liq} Vg = \sigma Vg$ (Fluid)

$F' = \dfrac{F_{air}}{k} = \dfrac{F}{k}$

Dielectric const. $\longrightarrow k$

$T\sin\theta = F$
$T\cos\theta = \rho vg$

$\tan\theta = \dfrac{F}{\rho vg}$

$T'\sin\theta = F'$
$T'\cos\theta = \rho vg - \sigma vg$

$\tan\theta = \dfrac{F'}{\rho vg - \sigma vg}$

$$\frac{F}{\rho \cancel{vg}} = \frac{F'}{\rho \cancel{vg} - \sigma \cancel{vg}} \qquad F' = F/k$$

$$\frac{\cancel{F}}{\rho} = \frac{\cancel{F}/k}{\rho - \sigma}$$

$$\boxed{k = \frac{\rho}{\rho - \sigma}} = \varepsilon_r$$

Next Toppers

Question

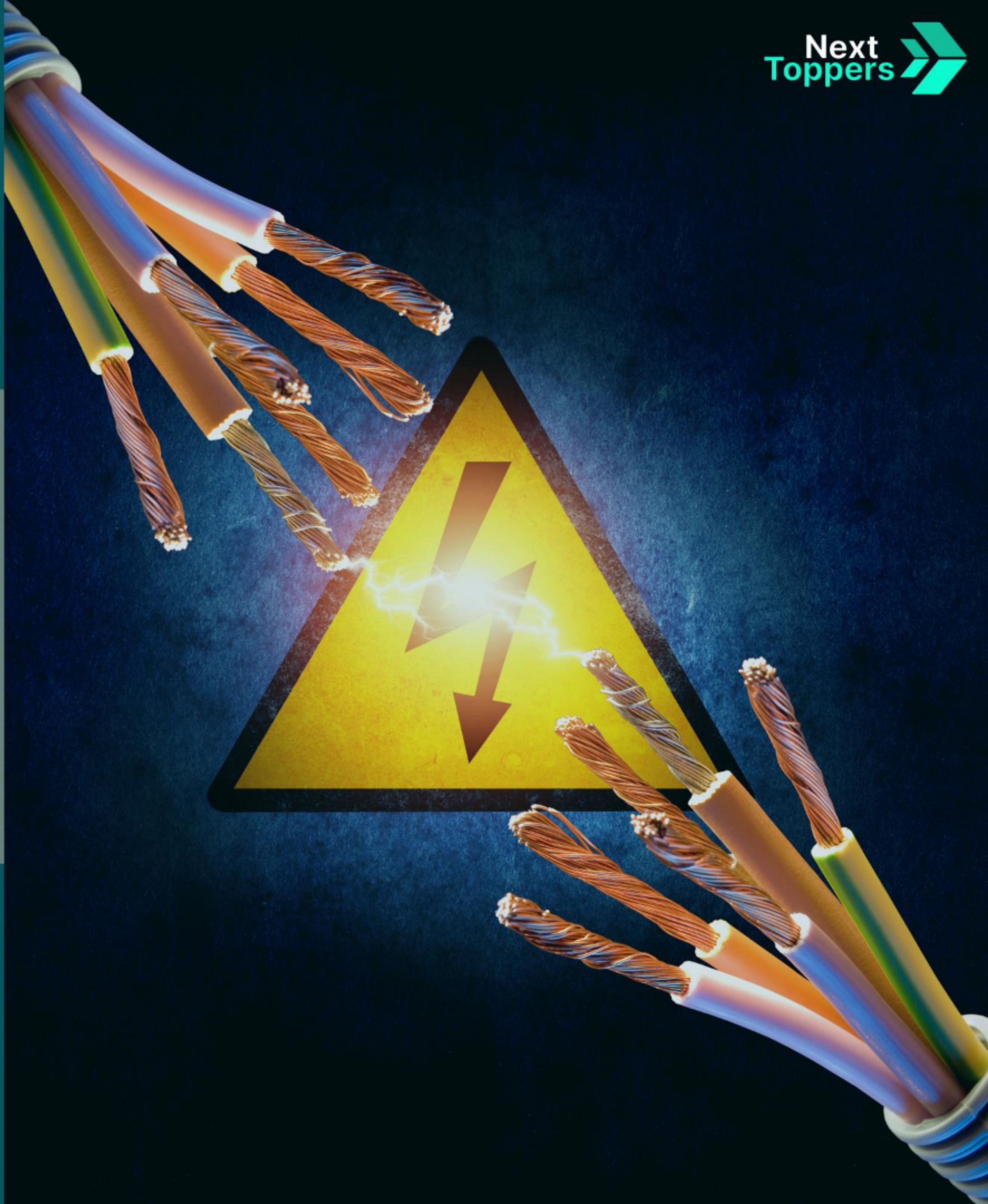
Two identical balls, each having a density ϱ are suspended from a common point by two insulating strings of equal length. Both the balls have equal mass and charge. In equilibrium, each string makes an angle θ with vertical. Now, both the balls are immersed in a liquid. As a result of immersion in the liquid, the angle θ does not change. The density of the liquid is σ. The relative permittivity of the liquid is

[NEET]

Answer

$$\epsilon_r = \frac{\rho}{\rho - \sigma}$$

Electric Field

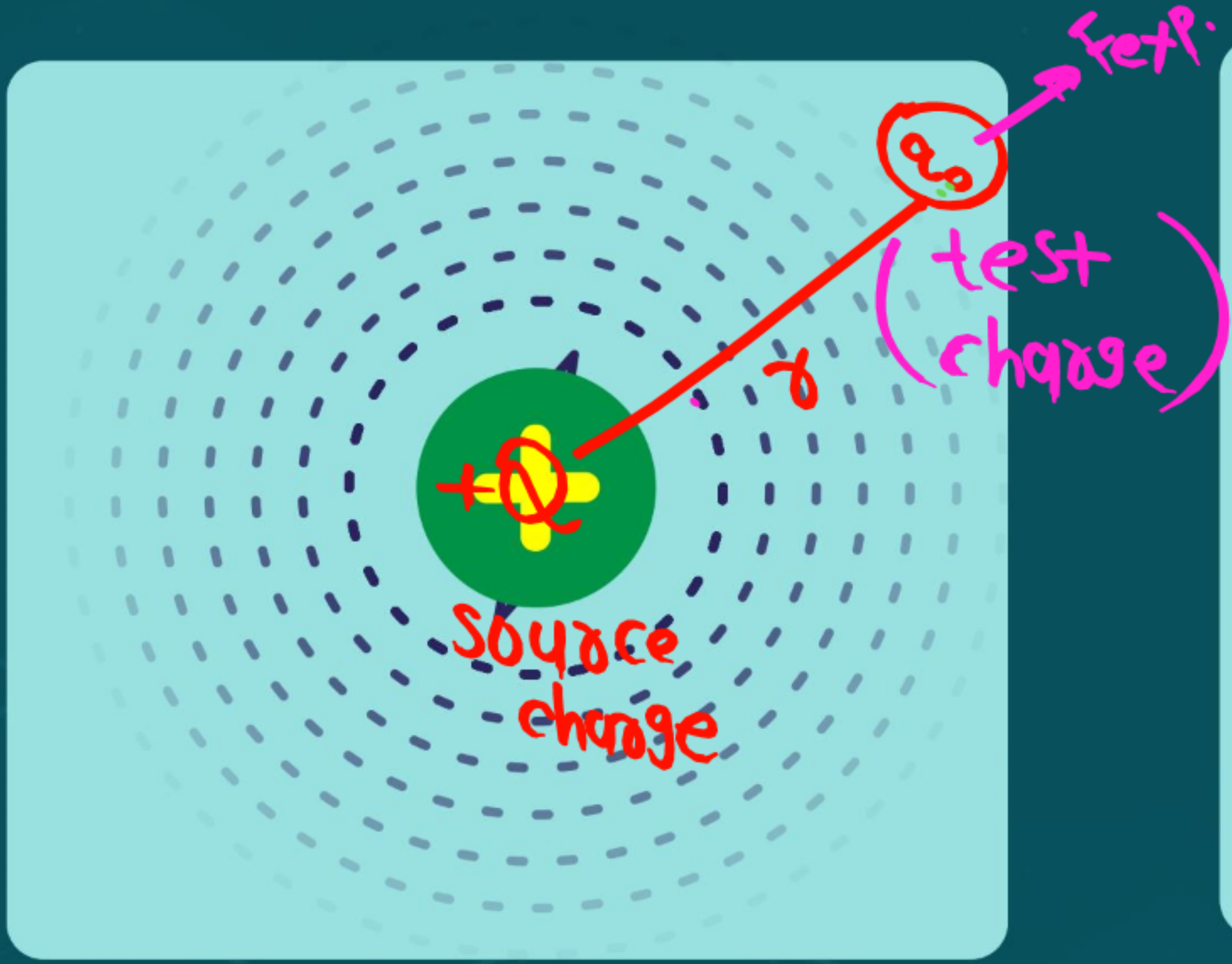


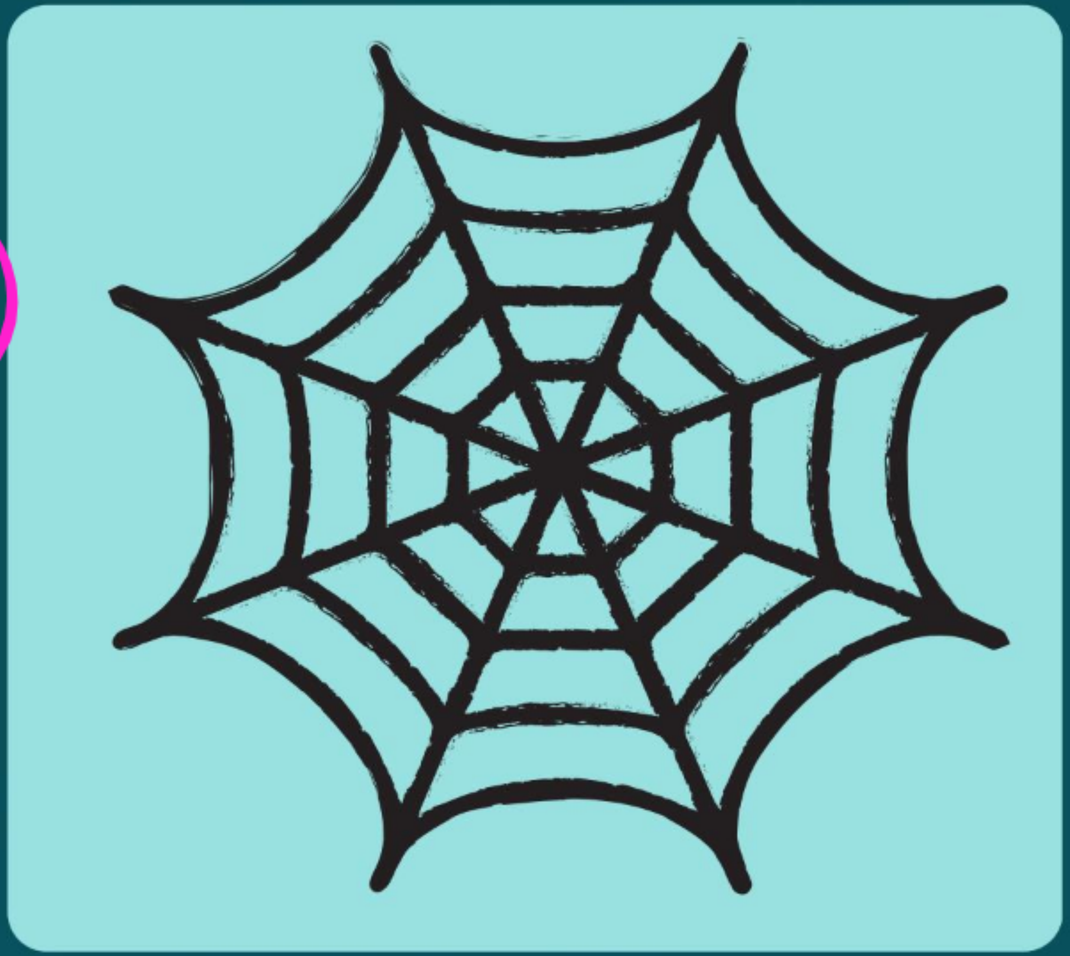
Electric Field

$Q \overset{r}{\text{———}} q$

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

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





Electric field Intensity

Electric field intensity, $\vec{E}$, is given by

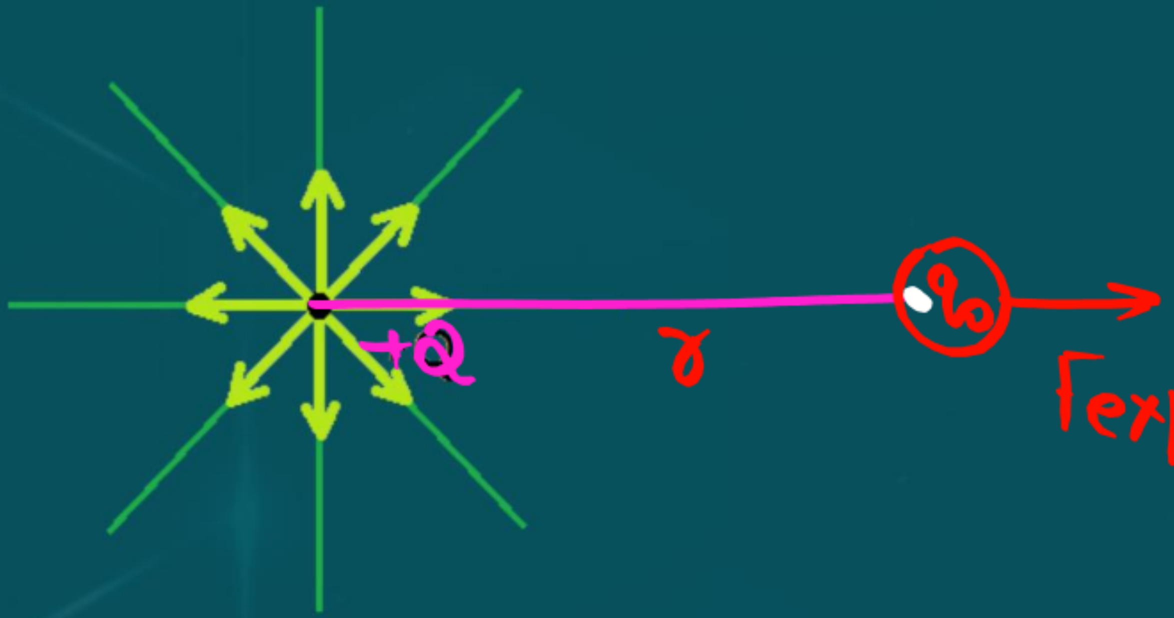
$$\boxed{\vec{E}} = \frac{\text{Electrostatic force on test charge}}{\text{Magnitude of Test charge}} = \frac{\vec{F}_{exp.}}{q_0}$$

$q_0 \Rightarrow$ small

$$[E] = \frac{N}{C} = \frac{M^1L^1T^{-2}}{A^1T^1} = M^1L^1T^{-3}A^{-1}$$

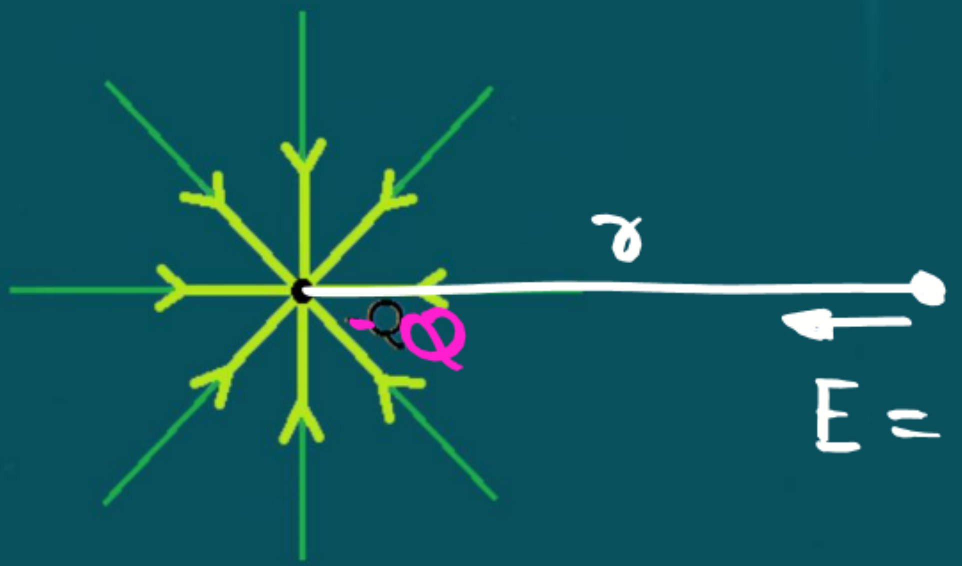
- **Electric field intensity (also called electric field) is nothing but the force exerted on a 1 C charge kept in the field.**

(i) Electric field Intensity due to a Point Charge



$$F_{exp.} = \frac{k q_0 Q}{r^2}$$

$$|\vec{E}| = \frac{F_{exp.}}{q_0} = \frac{kQ}{r^2}$$

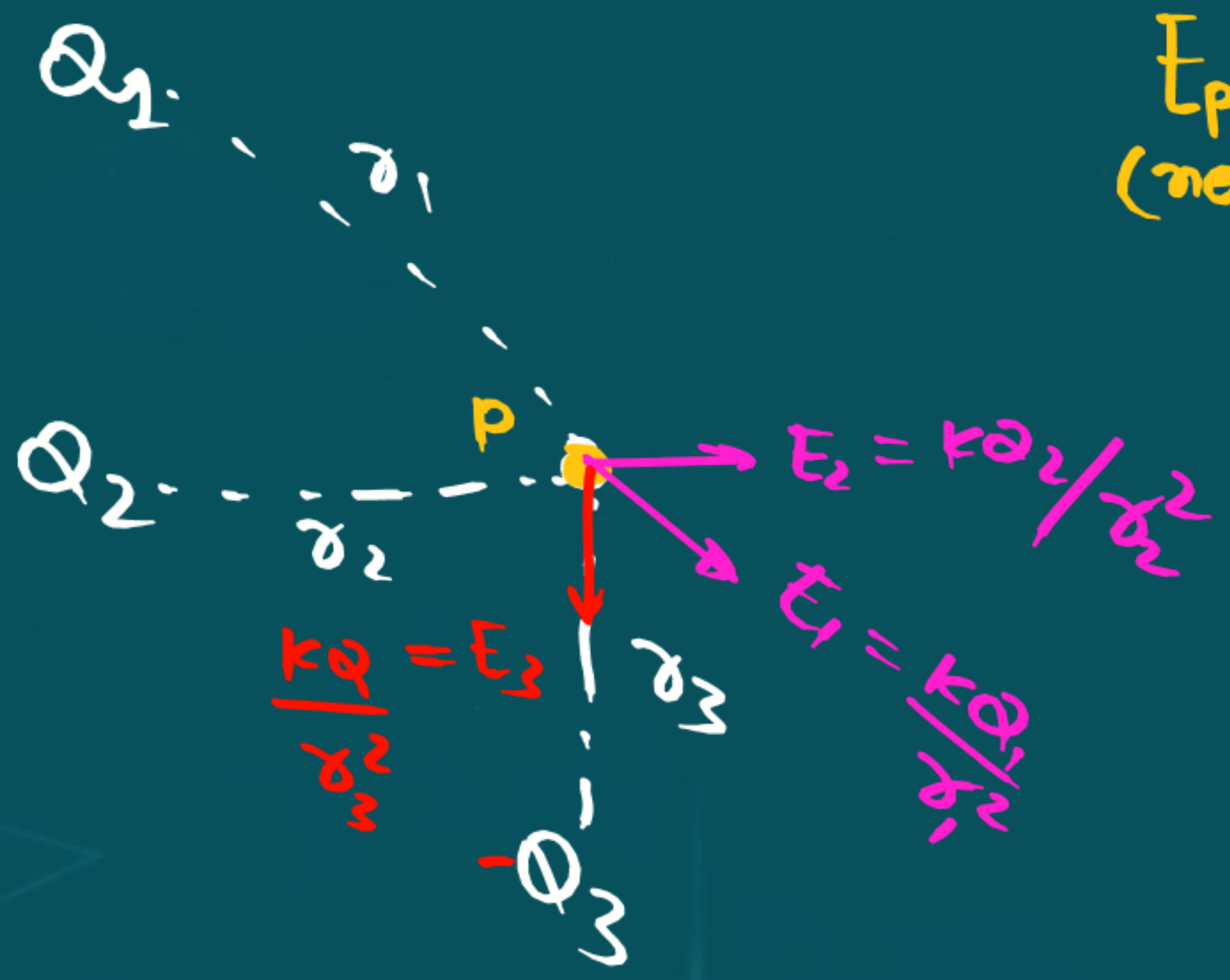


$$E = \frac{kQ}{r^2}$$

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

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

(ii) Electric field Intensity due to a system of charges



$$\vec{E}_{p\,(net)} = \vec{E_1} + \vec{E_2} + \vec{E_3} + \ldots$$

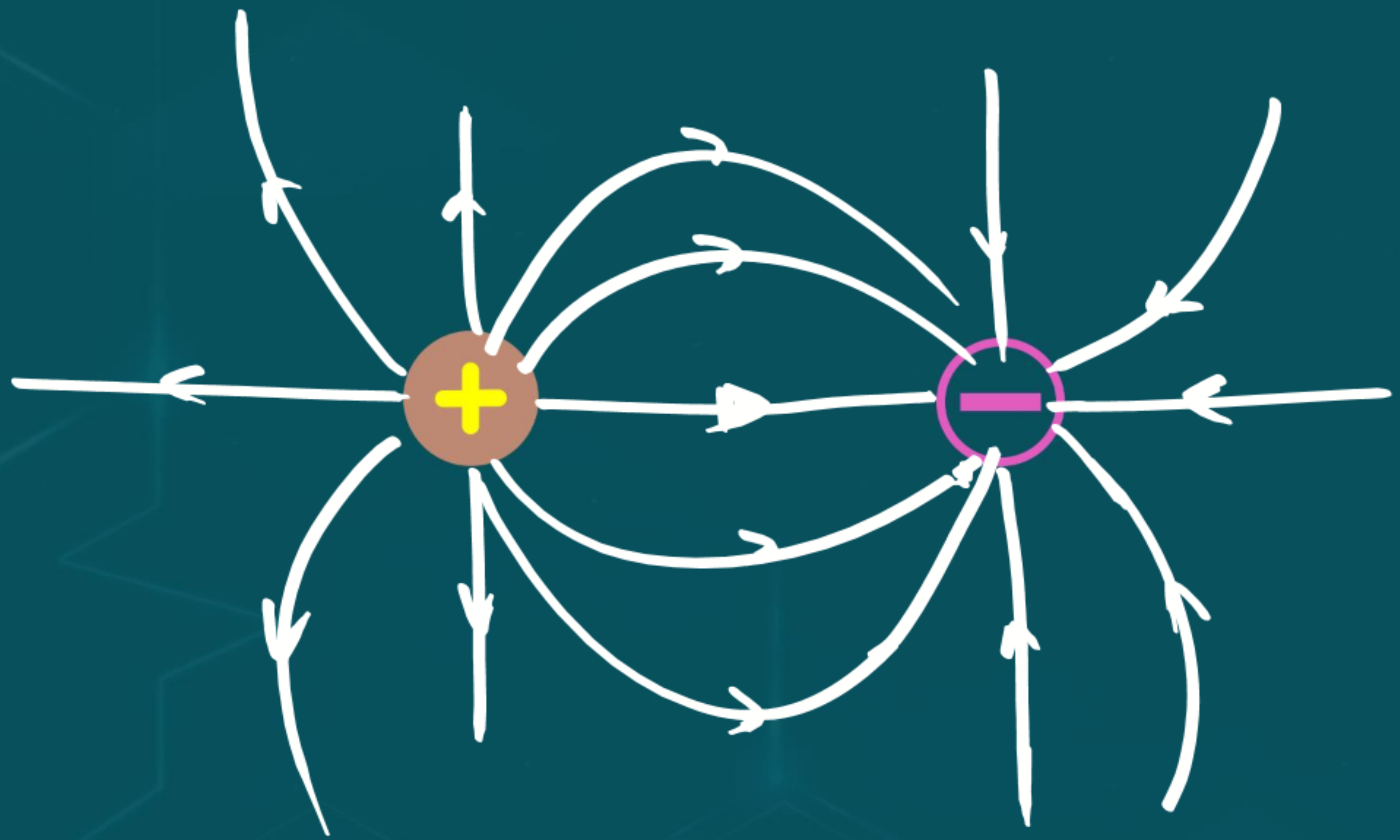
Electric Field Lines

[3 Marks]

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

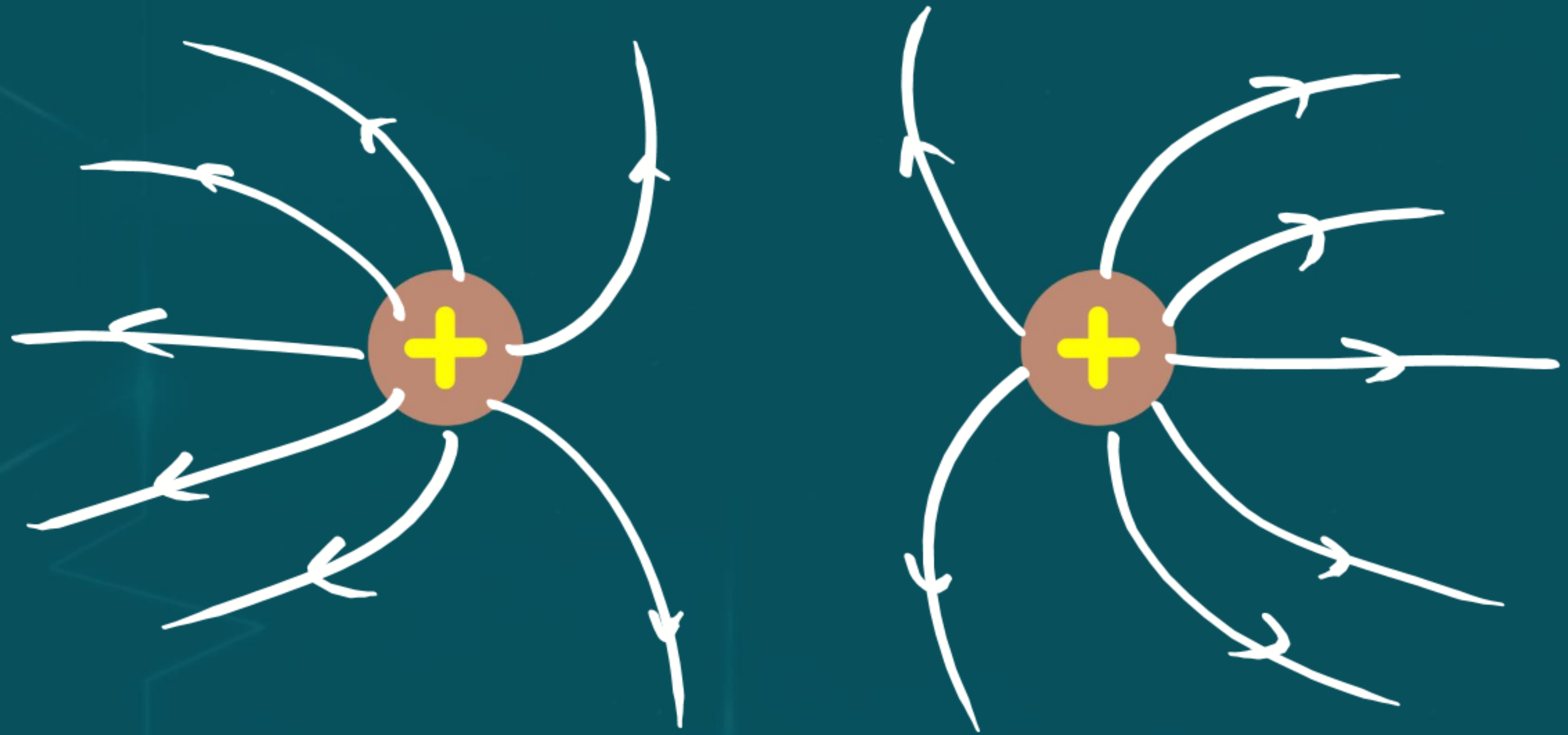
Question

Draw Electric Field Lines



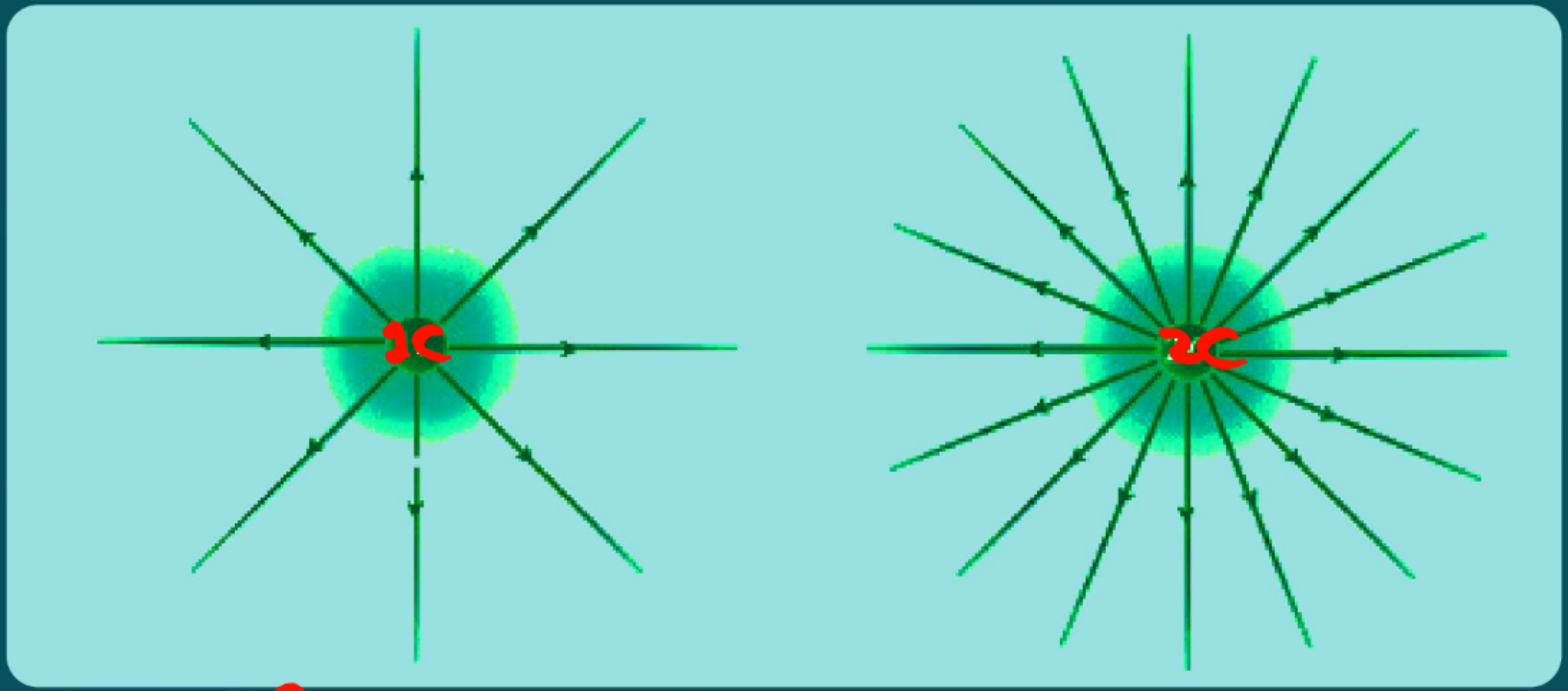
Question

Draw Electric Field Lines



Electric Field Lines

02. Number of field lines originating or terminating ∝ Magnitude of Charge

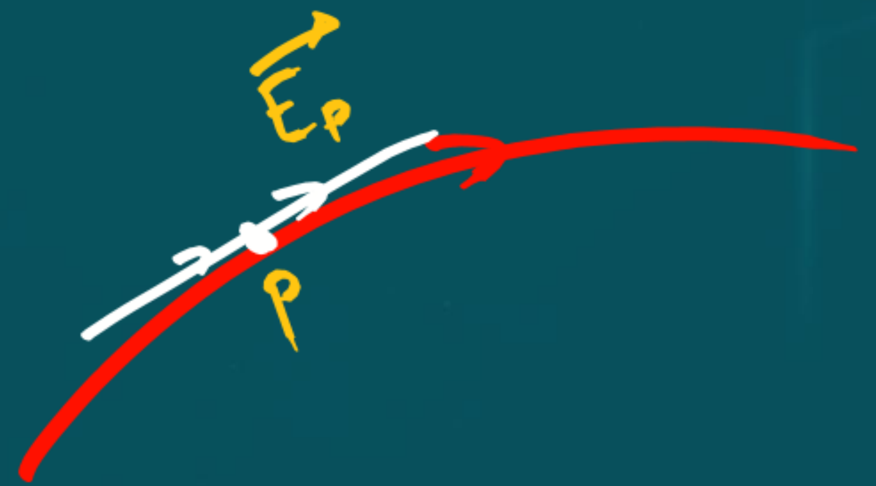


8 EFL

16 EFL

Electric Field Lines

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

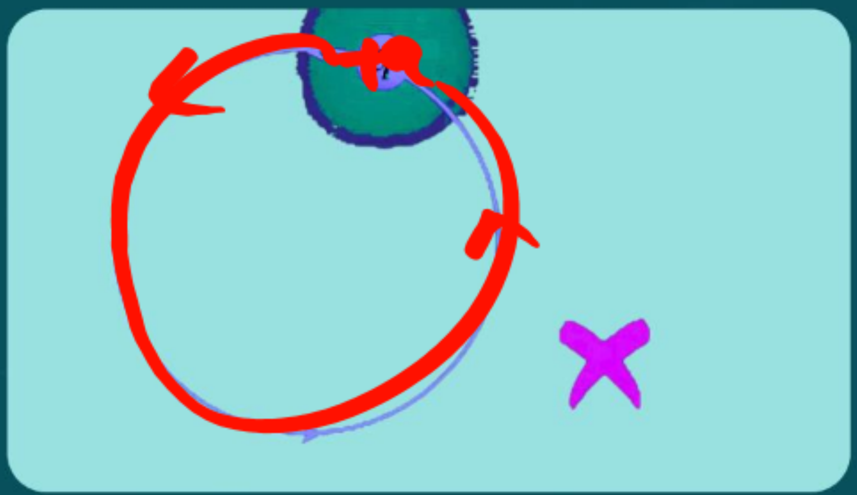


04. Two electric field lines never intersect because if they intersect, there would be two different directions of electric field at that point which is impossible

#

Electric Field Lines

05. Electric field lines due to static charges never form closed loops as any field line can never originate and terminate at the same charge.



06. Density of electric field lines is more where electric field is strong

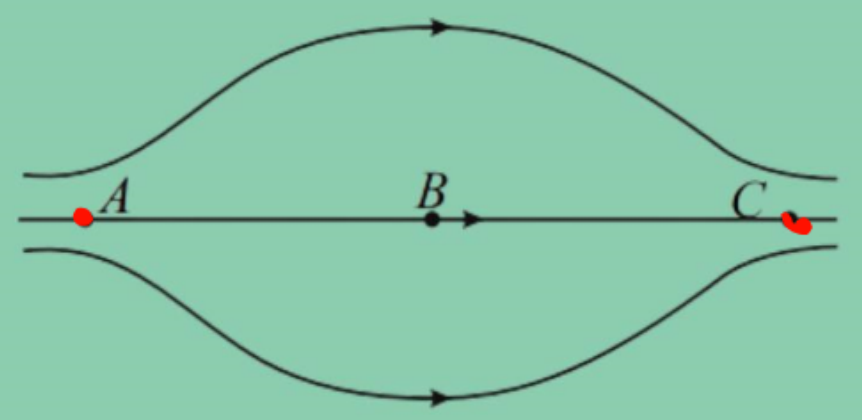
$E_A > E_B$

Next Toppers

Question

The figure shows some of the electric field lines corresponding to an electric field. The figure suggests

[NCERT]



$E_A = E_C > E_B$

(a) $E_A > E_B > E_C$

(b) $E_A = E_B = E_C$

(c) $E_A = E_C > E_B$

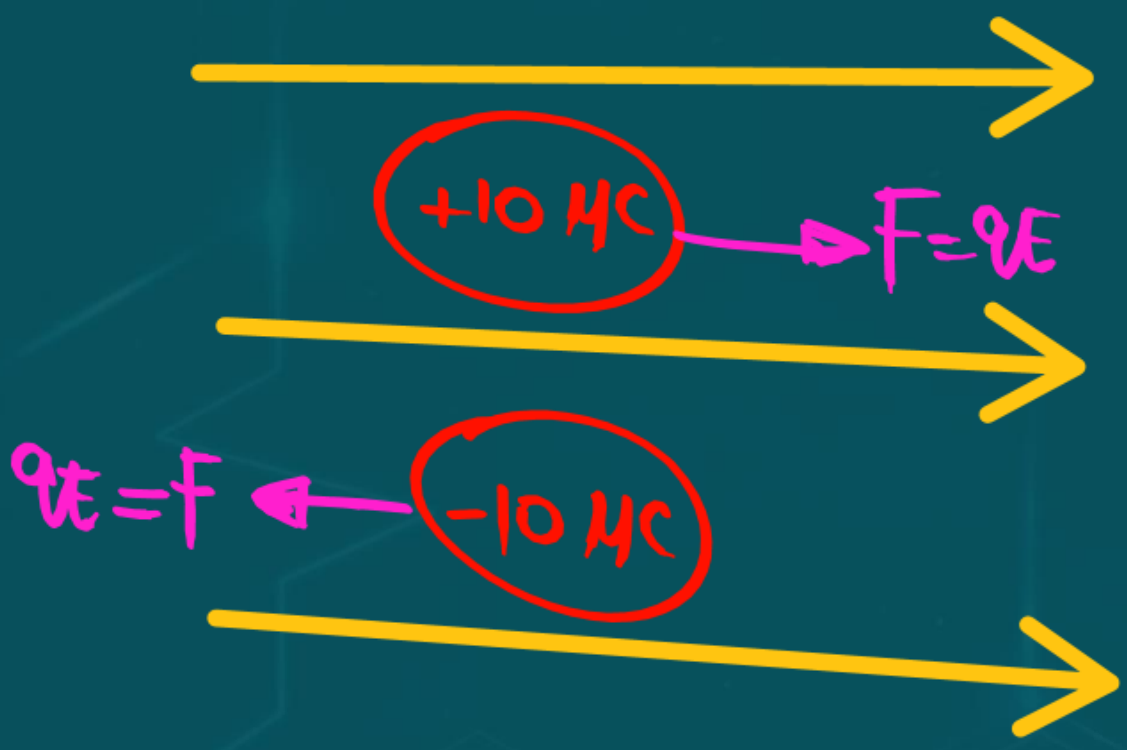
(d) $E_A = E_C < E_B$

Next Toppers

$$E = \frac{F_{exp}}{q_0} \Rightarrow \vec{F}_{exp} = q_0\vec{E}$$

Question

A charge of 10 μC (+q) and -10 μC (-q) is placed in uniform electric field of 5×10^{6} N/C directed along positive x axis, find out force acting on positive and negative charge?



$$\vec{E}_0 = 5\times10^{6}\,\hat{i}\ \text{N}$$

$$\vec{F}_{exp.} = +q\vec{E}_0 \quad (\oplus)$$

$$\vec{F}_{exp.} = -q\vec{E}_0 \quad (\ominus)$$

$$|F| = qE = 50\ \text{N}$$

Next Toppers

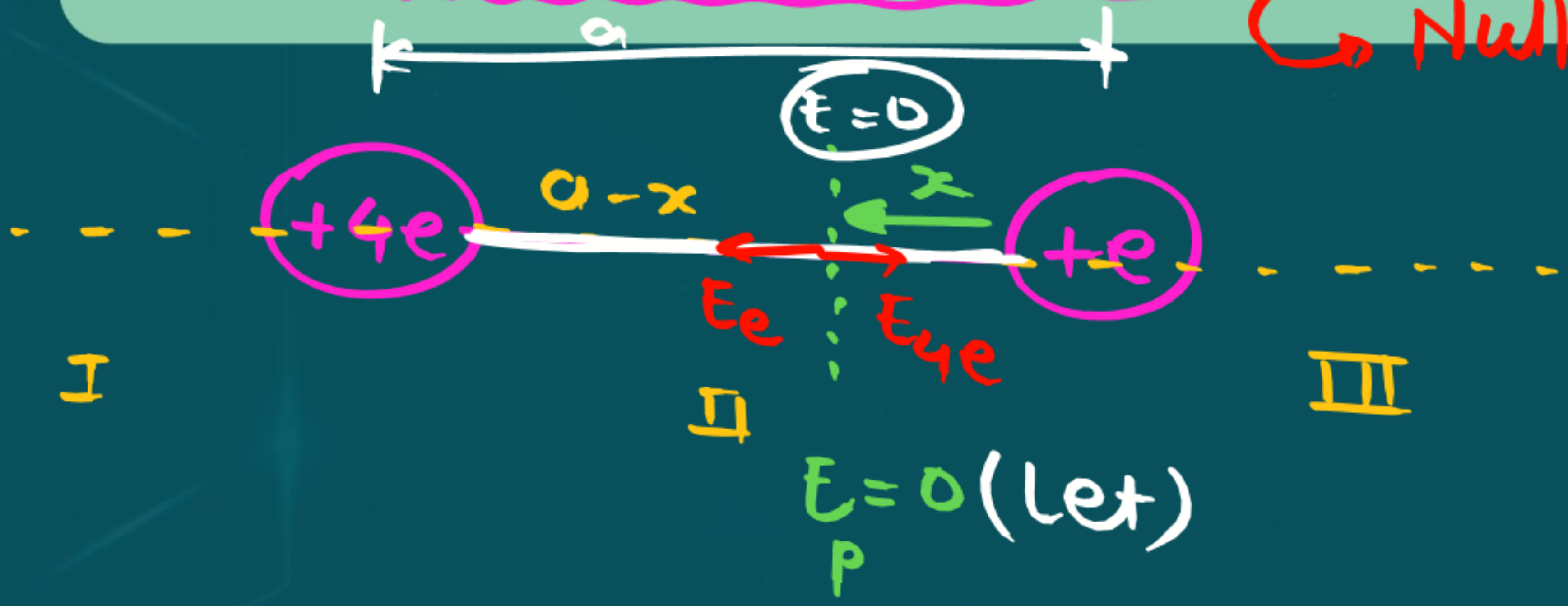
Method ✓

Question

Two 'free' point charges + 4e and +e are placed a distance 'a' apart. Find a location where electic field is zero.

Null point

[NEET]



$E_{4e} = E_e$

$E_p = 0$

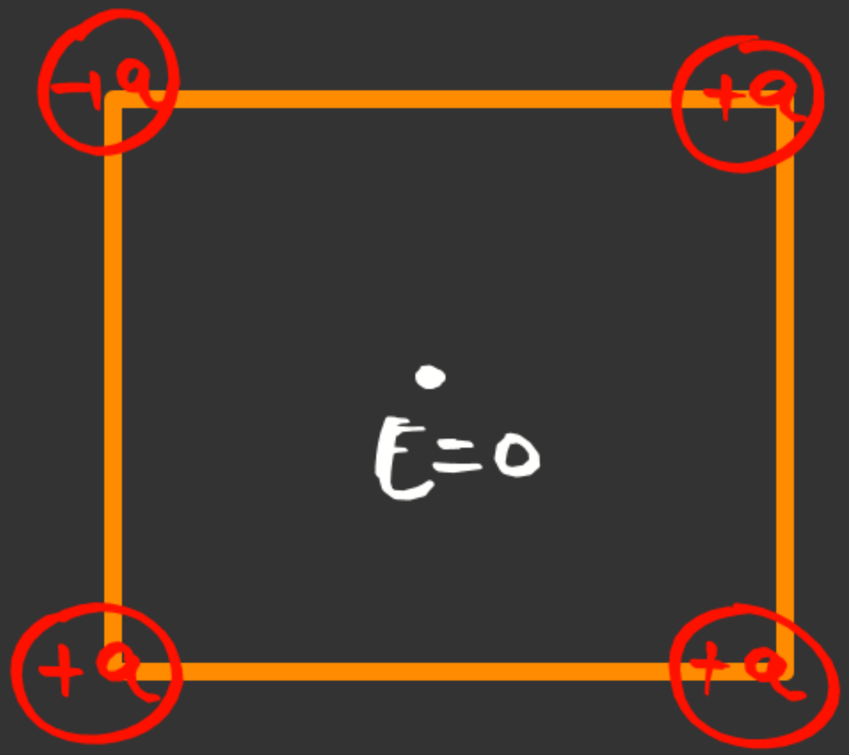
$E_{4e} = E_e$

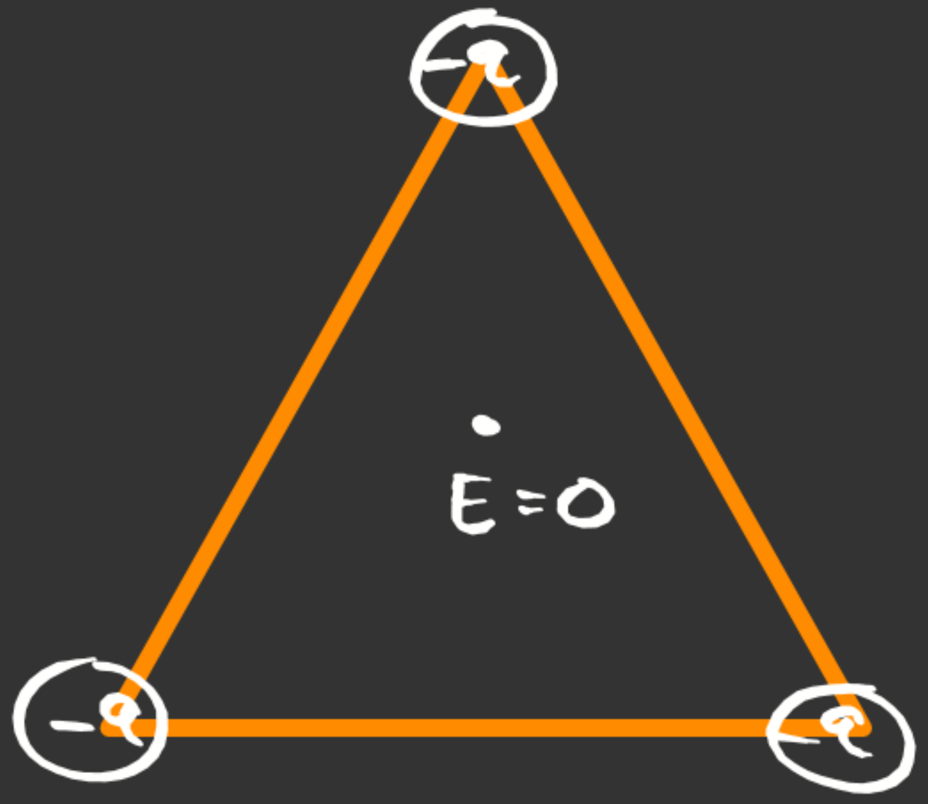
$$\frac{\cancel{k}(4\cancel{e})}{(a-x)^2} = \frac{\cancel{k}(\cancel{e})}{x^2}$$

$$\frac{2}{a-x} = \frac{1}{x}$$

$3x = a$

$$\boxed{x = a/3}$$

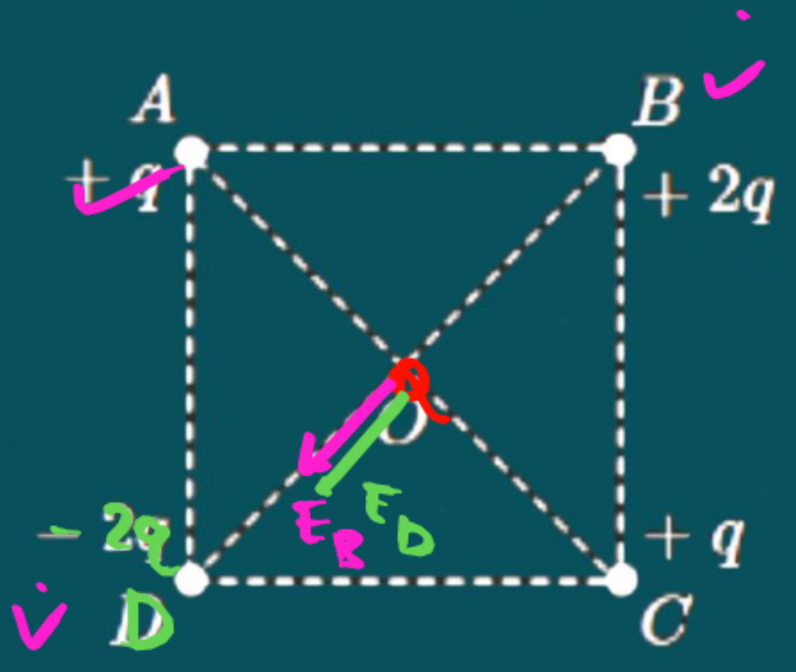

+q
+q
E=0
+q
+q


-q
E=0
-q
-q

Question

Four chages 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



$\vec{F}_{Q(net)} = Q\,\vec{E}_{net}$

$E_{net} \Rightarrow B \rightarrow D$

Next Toppers

Question

Calculate the Electric Field needed to balance an oil drop carrying 10 electrons when located between the plates of a capacitor. The mass of oil drop is 3×10^{-16} kg.

HW

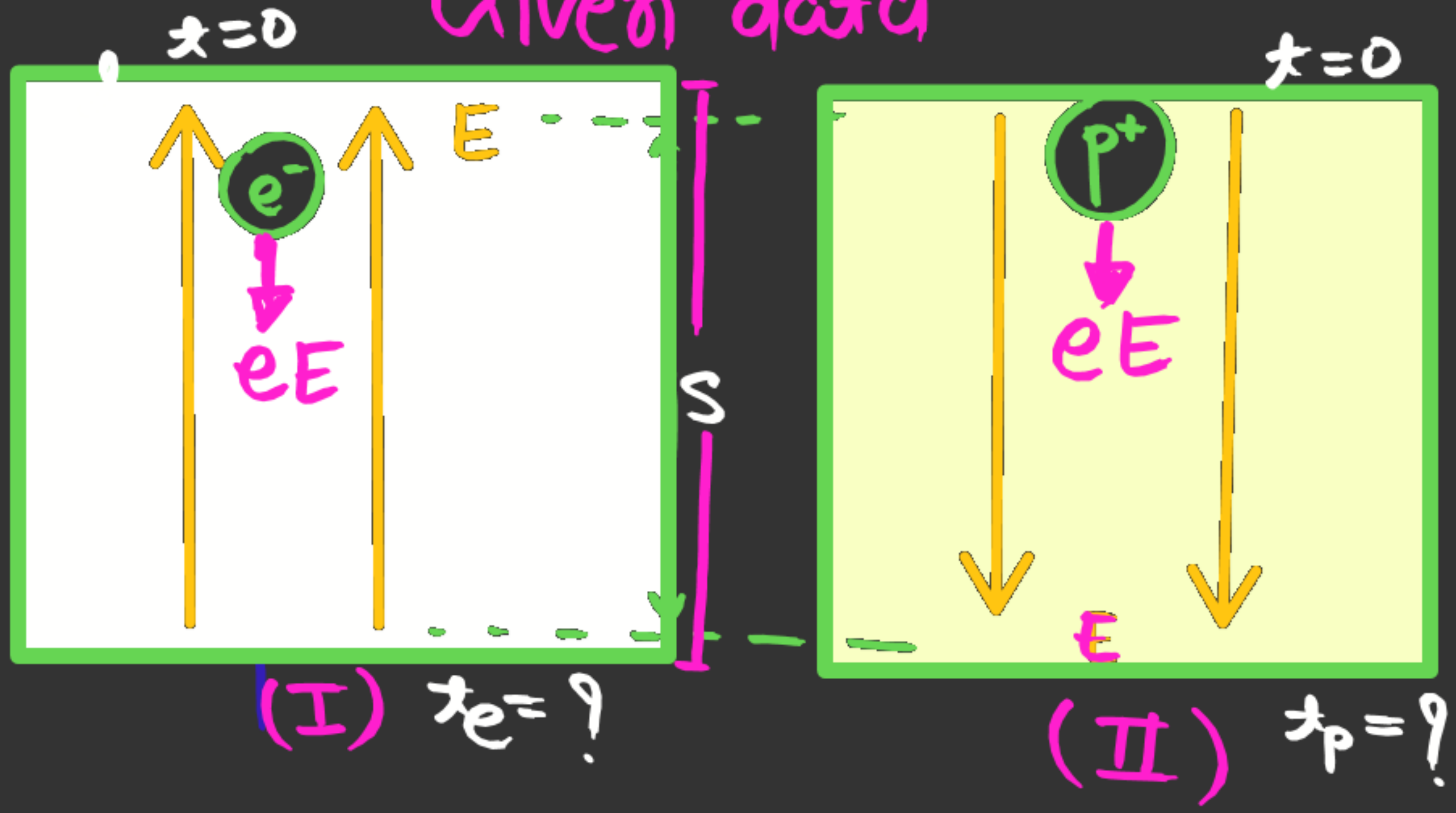
Next Toppers

Question

An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N C^{-1}. The direction of the field is reversed keeping its magnitude unchanged and a proton falls through the same distance. Compute the time of fall in each case. Contrast the situation with that of 'free fall under gravity (ignored the acceleration due to gravity in calculating the time of fall)

[NCERT]

Given data



$S = 1.5\ cm = 1.5 \times 10^{-2}\ m$ ✓

$E = 2 \times 10^{4}\ N/C$

(Given data)

$$F = eE$$

$$ma = eE$$

$$a = \frac{eE}{m} = \text{constant} \Rightarrow \text{EOM} ✓$$

$$a_e = \frac{eE}{m_e} \qquad a_p = \frac{eE}{m_p}$$

$$\Longrightarrow S = \cancel{u}^{\,0} t + \frac{1}{2} a t^2$$

$$\frac{2S}{a} = t^2$$

$$\boxed{t_e = \sqrt{\frac{2S}{a_e}}} \qquad \boxed{t_p = \sqrt{\frac{2S}{a_p}}}$$

Next Toppers

Question

An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N C^{-1} . The direction of the field is reversed keeping its magnitude unchanged and a proton falls through the same distance. Compute the time of fall in each case. Contrast the situation with that of 'free fall under gravity (ignored the acceleration due to gravity in calculating the time of fall)

Answer

[NCERT]

$t_e = 2.9 \times 10^{-9}$ S

$t_p = 1.3 \times 10^{-7}$ S

Next Toppers

Question

Two point charges q_A = 3 mC and q_B = −3 mC are located 20 cm apart in vacuum.

A) What is the electric field at the midpoint O of the line AB joining the two charges?

[NCERT Exercises 1.8]

HOMEWORK

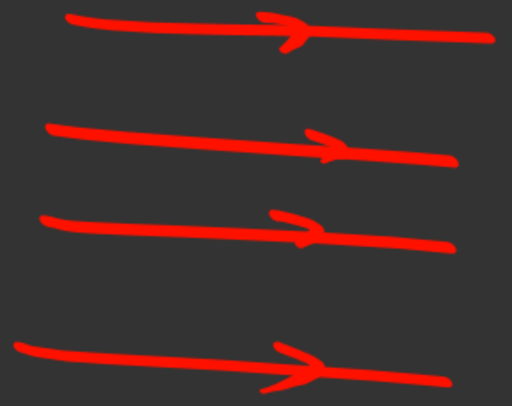
Question

Two point charges q_A = 3 mC and q_B = −3 mC are located 20 cm apart in vacuum.

(B) If a negative test charge of magnitude 1.5×10^{-9} C is placed at this point, what is the force experienced by the test charge?

[NCERT Exercises 1.8]

HOMEWORK

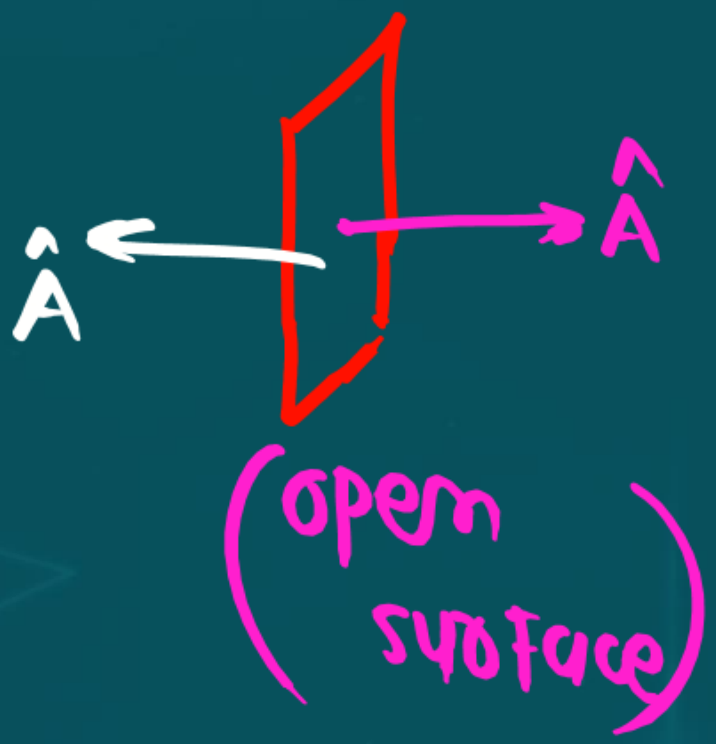


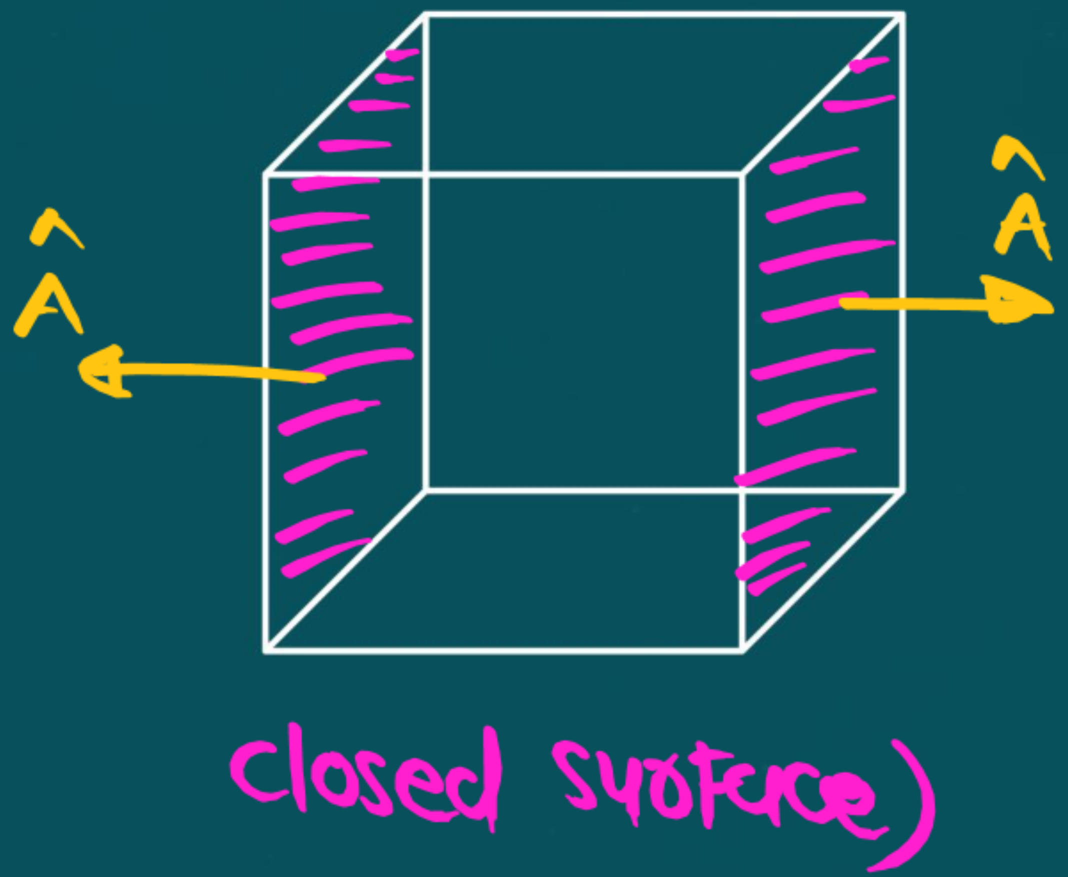
Uniform E.F.

Electric Flux

Area Vector

- Area vector for a surface is defined as a vector with magnitude same as the area of surface and direction along the outward normal to the surface.





Electric Flux

- It is the measure of the net electric lines of force crossing a surface normal to it.

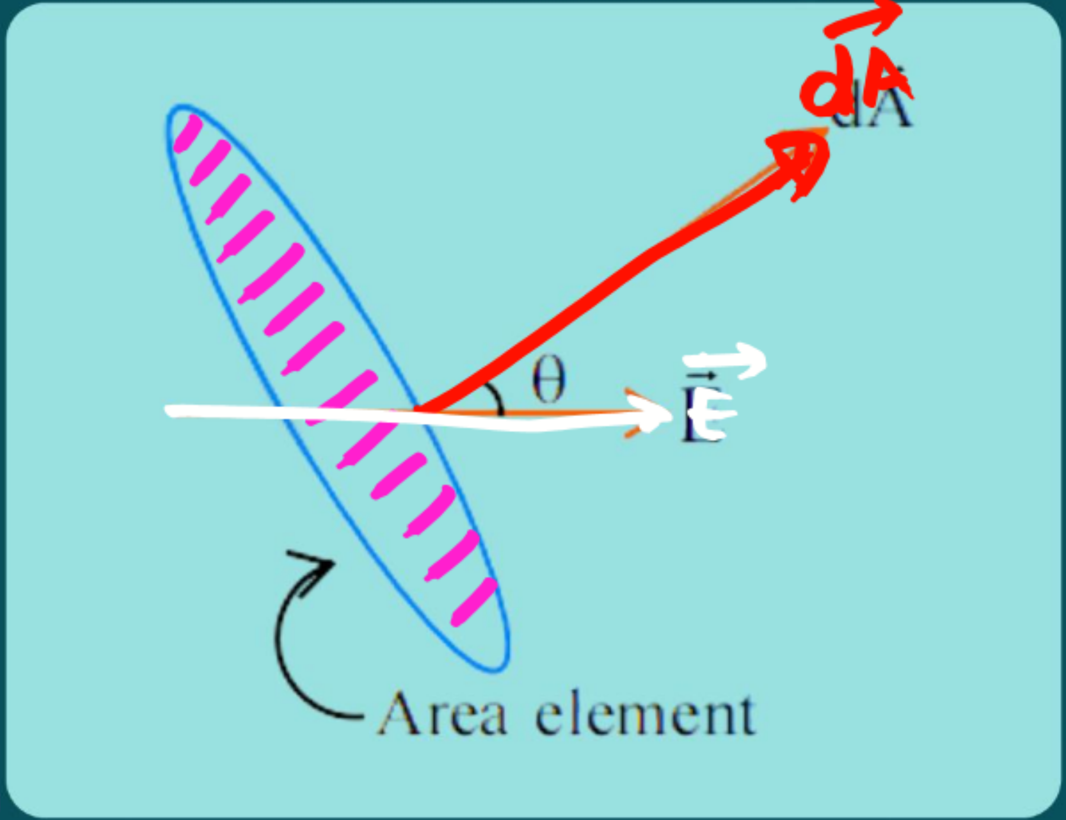
$$d\phi_E = \vec{E} \cdot \vec{dA}$$

$$\boxed{\phi_E = \int \vec{E} \cdot \vec{da}}$$

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

$$= Wb$$

$$[\phi] = M^? L^? T^? A^?$$



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

If $\vec{E} = \text{constant}$

$E = \text{uniform}$

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

scalar

PQ

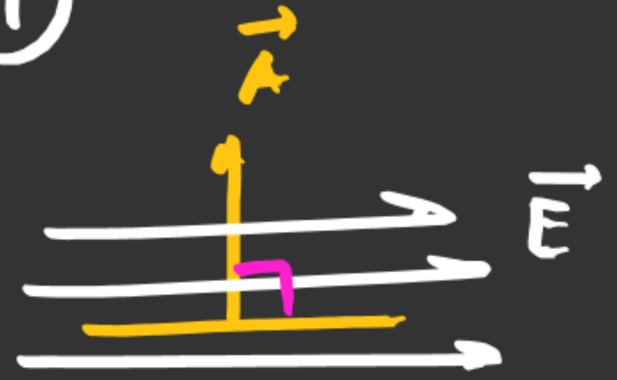
$\phi = EA\cos\theta$

$\phi \Rightarrow$ dot product

$\hat{i} \cdot \hat{i} = 1 = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k}$

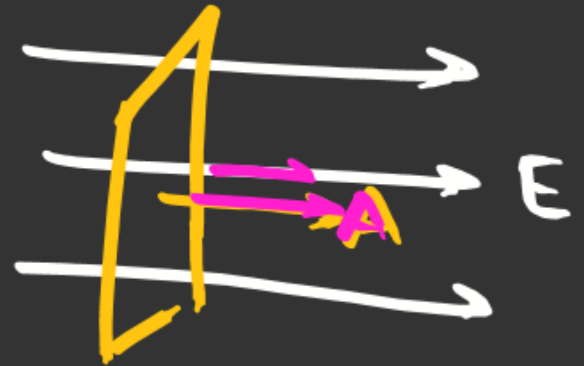
(vectors)

①



$$\left.\begin{array}{l} \theta = 90^\circ \\ \cos 90 = 0 \end{array}\right\} \phi = 0$$

②



$$\left.\begin{array}{l} \theta = 0 \\ \cos 0 = 1 \end{array}\right\} \phi = EA$$

Next Toppers

Question

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.

Given data

$$\vec{E} = 8\hat{i} + 4\hat{j} + 3\hat{k}$$

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

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

$$= 300\ \frac{N \cdot m^2}{C}$$

$\hat{i} \cdot \hat{k} = 0$ $\quad$ $\hat{k} \cdot \hat{k} = 1$

$\hat{j} \cdot \hat{k} = 0$

Question

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

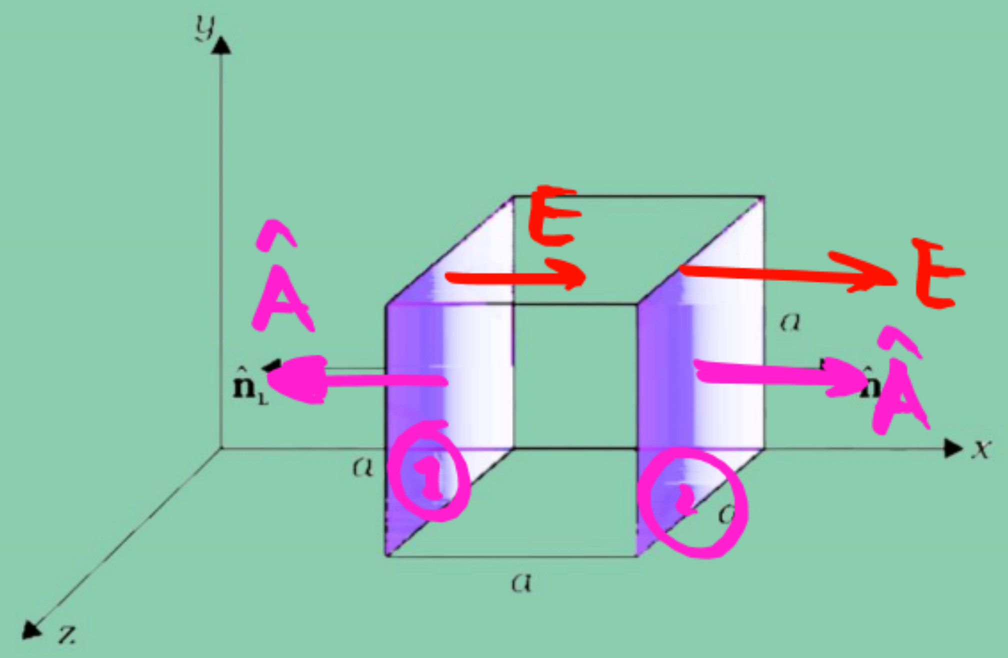
Answer

300 Nm^2 / C

Question

If the electric field is given by $\vec{E} = 8\hat{i}$ N/C, Calculate the electric flux through cube

Uniform

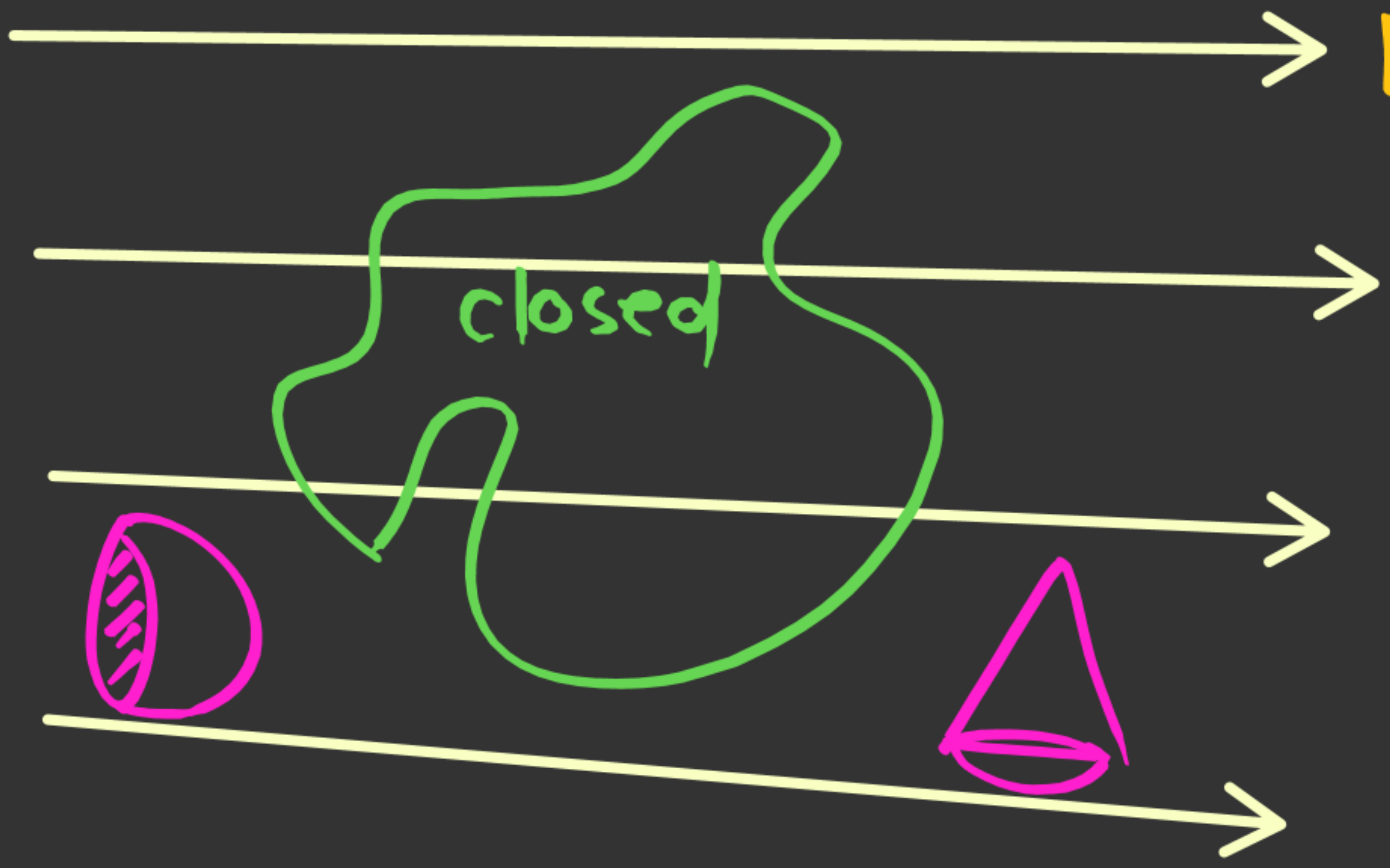


$$\phi_1 = EA\cos 180^\circ = -EA$$

$$\phi_2 = EA\cos 0 = EA$$

$$\phi_{total\,(cube)} = \phi_1 + \phi_2 + \underbrace{\ldots}_{0} = 0$$

NOTE

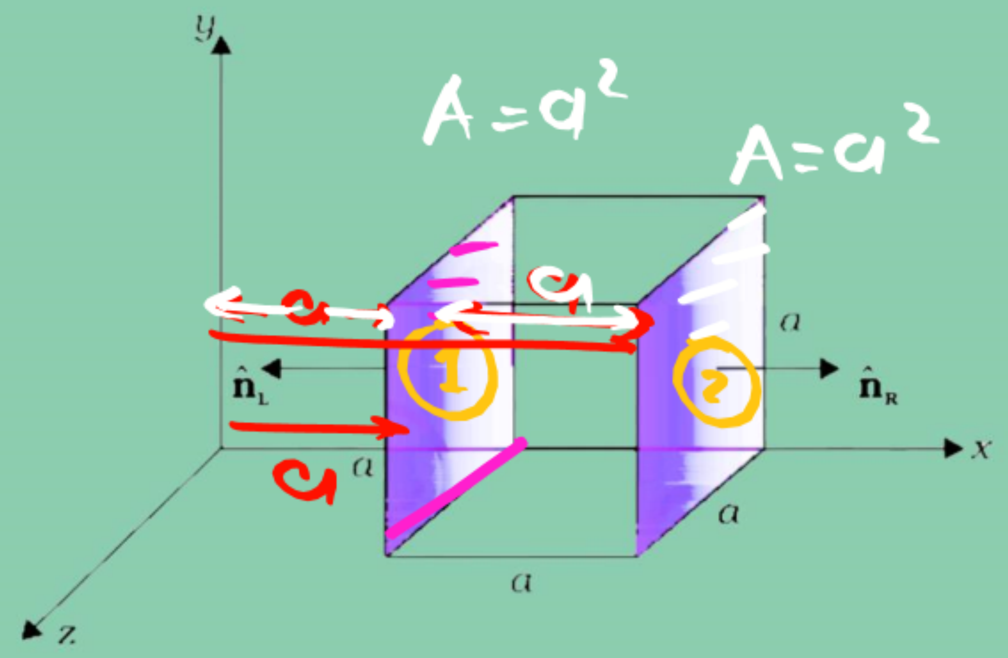


E(Uniform)

$$\phi_{net} = 0$$

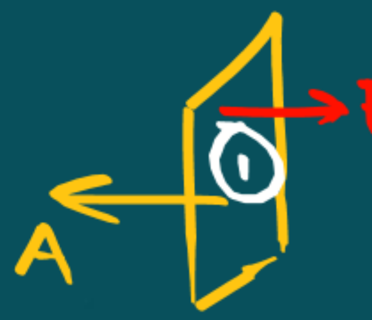
Question

The electric field components in are $E_x = \alpha x^{1/2}$ in which $\alpha = 800 N / C \ m^{1/2}$ Calculate (a) the flux through , and (b) the charge within the cube. Assume that $\alpha = 0.1$ m.



$a = 0.1$ m

$E = 800 x^{1/2}$



$E_1 = 800 a^{1/2}$

$\theta = 180°$

$\phi_1 = E_1 A$

$= 800 a^{1/2} \cdot a^2$

$E_2 = 800 (2a)^{1/2}$

$\theta = 0°$

$\phi_2 = E_2 A$

$\phi_2 = 800 (2a)^{1/2} (a^2)$

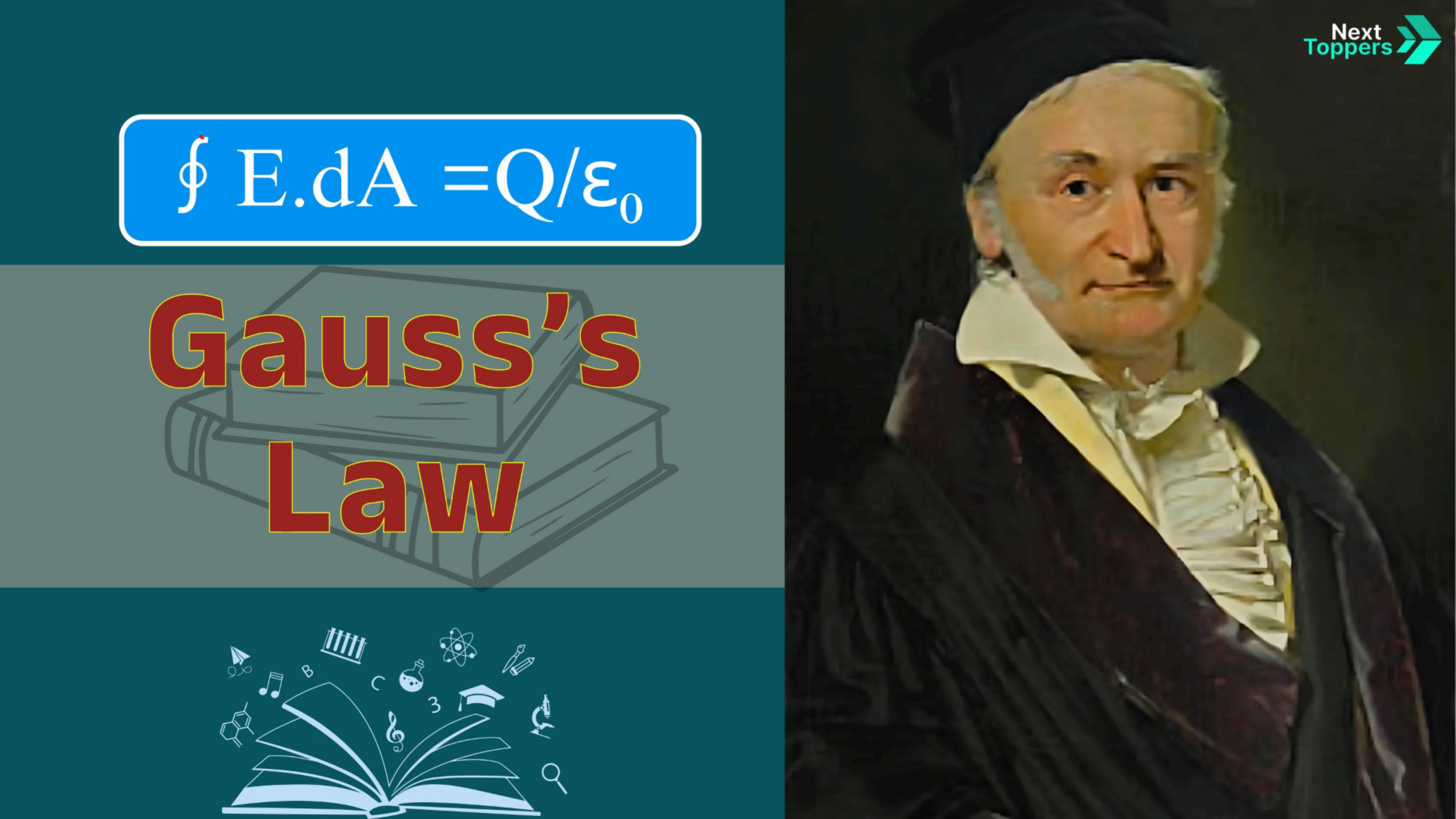
$$\Phi_{net} = \Phi_1 + \Phi_2$$
(total)

$$= -E_0 a^{1/2} a^2 + E_0 (2)^{1/2} a^{1/2} \cdot a^2$$

$$= E_0 a^{\left(\frac{1}{2}+2\right)} \left(2^{1/2} - 1\right)$$

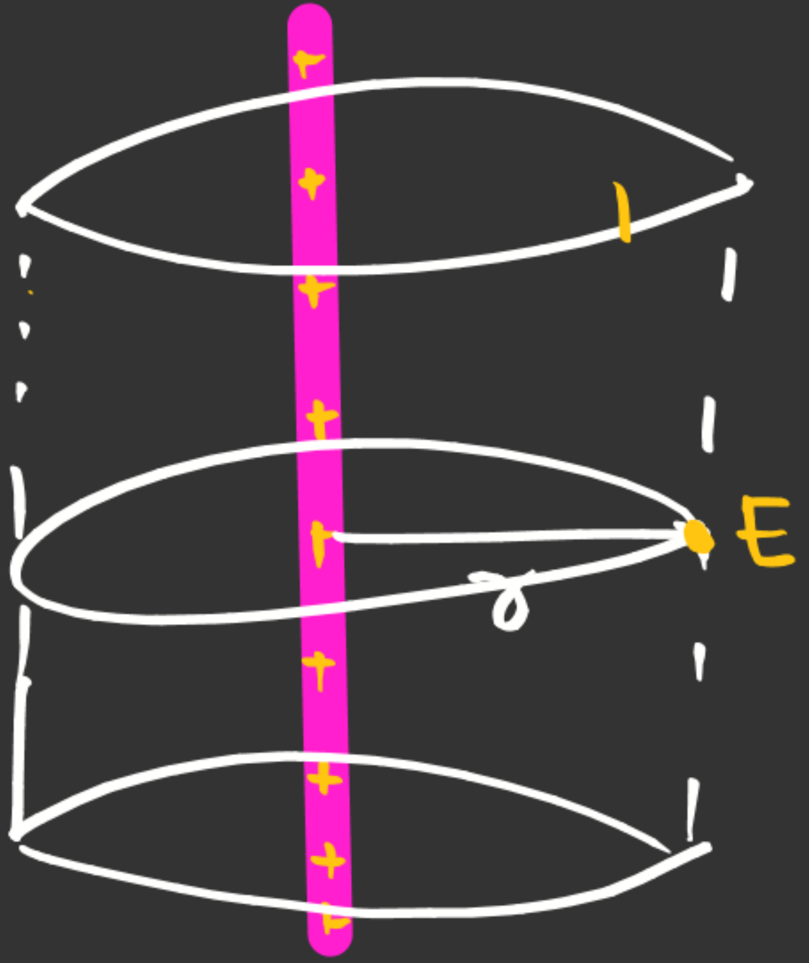
$$\Phi_{net} = E_0 a^{5/2} (\sqrt{2} - 1)$$

$$\Phi_{net} = 800\, a^{5/2} (\sqrt{2} - 1)$$



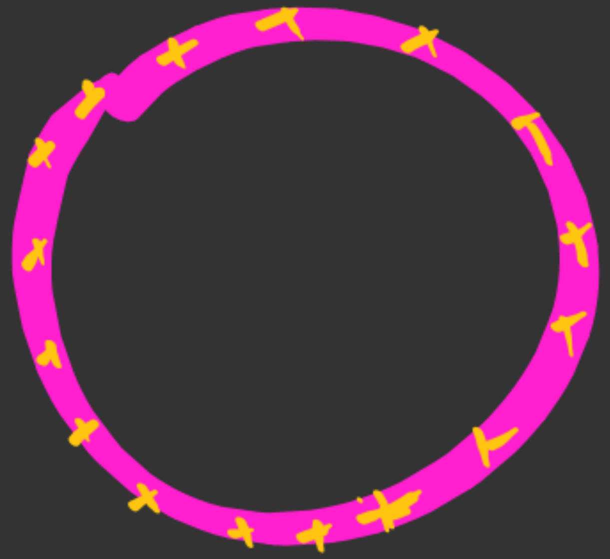
$\oint E.dA = Q/\varepsilon_0$
Gauss's Law
Next Toppers

1



2

3



$$\frac{Q_{enclosed}}{\varepsilon_0} = \oint \vec{E}\cdot\vec{dA} = \phi_E$$

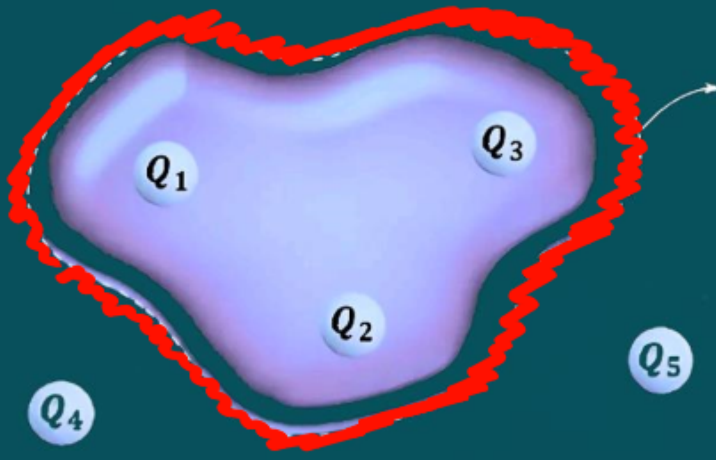
net

Gauss's Law

1 2 3

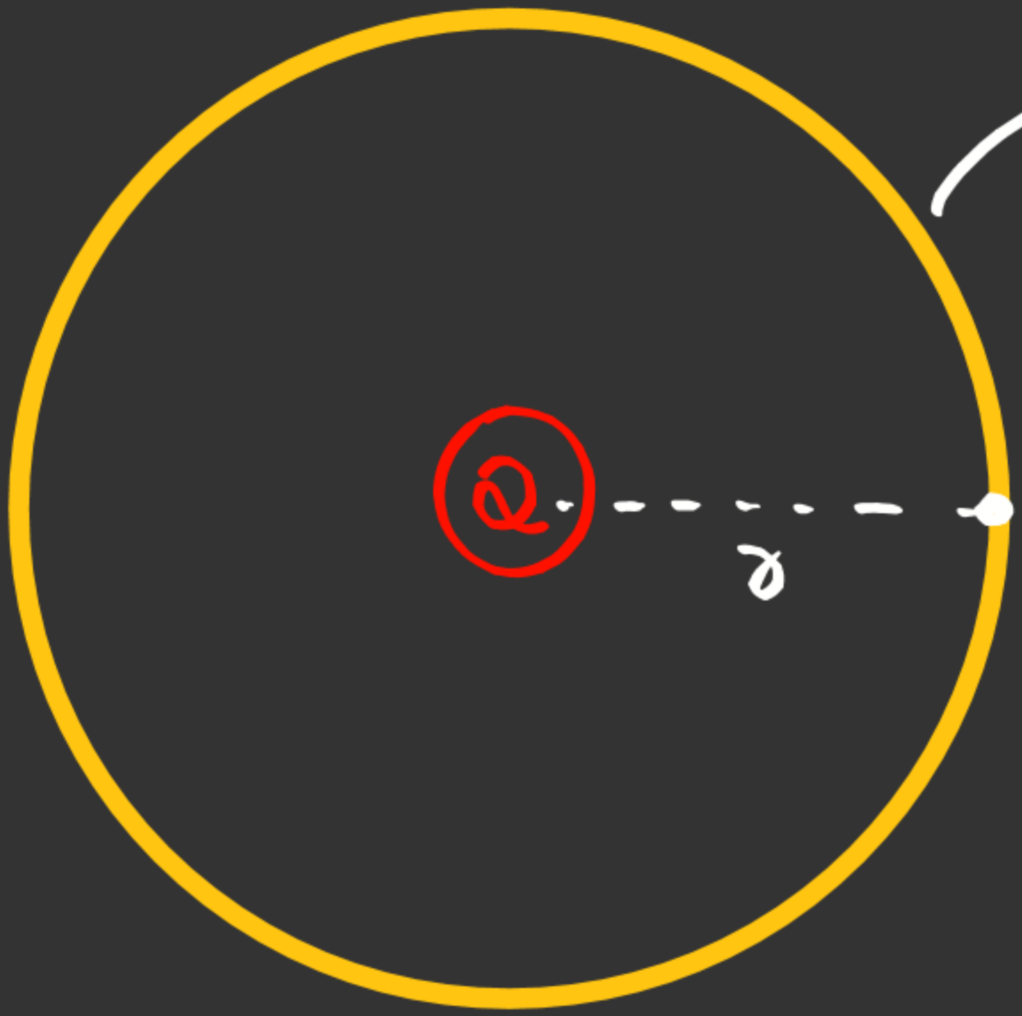
$$\oint \vec{E}.d\vec{A} = Q/\varepsilon_0 = \phi_E$$

1, 2, 3, 4, 5



Gaussin Surface

- *Enet* is due to all the charges, present outside as well as inside the Gaussian Surface.
- The effective net flux turns out to be only due to the charges present inside the Gaussian surface.



$$\oint \vec{E}\cdot d\vec{A} = Q/\varepsilon_0$$

$$E\,(4\pi r^2) = Q/\varepsilon_0$$

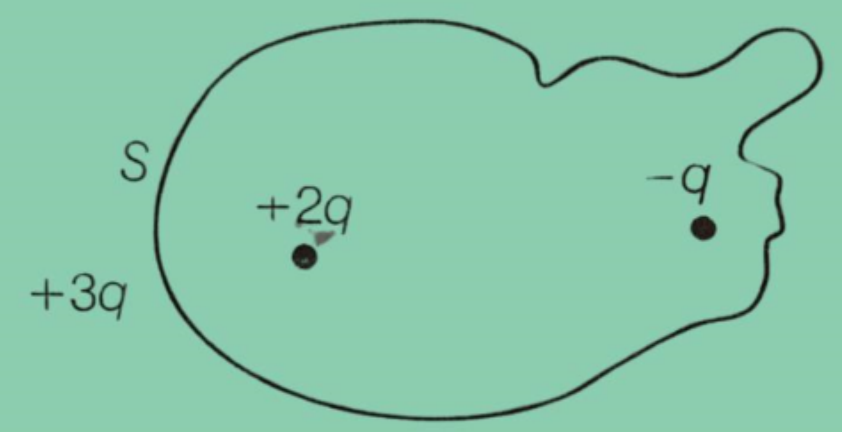
$$E = \frac{Q}{4\pi\varepsilon_0 \cdot r^2}$$

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

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

Question

Figure shows three point charges, +2q, -q and +3q. Two charges +2q and -q are enclosed within a surface S. What is the electric flux due to this configuration through the surface S?



$$\phi = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

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

Next Toppers

Question

$-2 \times 10^4 \frac{N\cdot m^2}{C}$ (Given)

A point charge causes an electric flux of to pass through a spherical Gaussian surface of 8.0 cm radius, centred on the charge. The value of the point charge is ... $\left(\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N m^2}\right)$

[JEE Mains 2025]

A) ~~15.7 x 10^{-8} C~~

B) -15.7 x 10^{-8} C

C) ~~17.7 x 10^{-8} C~~

D) -17.7 x 10^{-8} C ✓

$$\phi = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$Q_{enclosed} = \phi \cdot \varepsilon_0$$

$$= (-2\times10^4)(8.85\times10^{-12})$$

$$= -$$

Question

$-2 \times 10^{4} \frac{N\cdot m^2}{C}$

A point charge causes an electric flux of to pass through a spherical Gaussian surface of 8.0 cm radius, centred on the charge. The value of the point charge is ... $\left(\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N\, m^2}\right)$

[JEE Mains 2025]

A) 15.7×10^{-8} C

B) -15.7×10^{-8} C

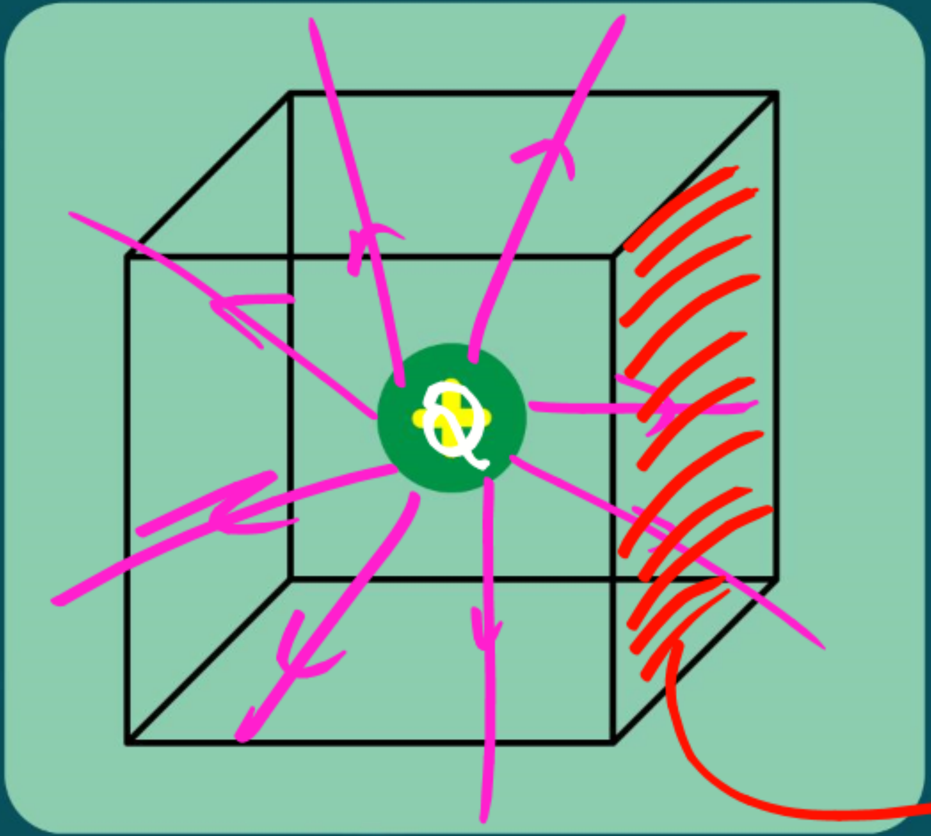
C) 17.7×10^{-8} C

D) -17.7×10^{-8} C

Question

Find the Electric flux through Cube

[CBSE]



$$\phi_{cube} = \frac{Q_{enclosed}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

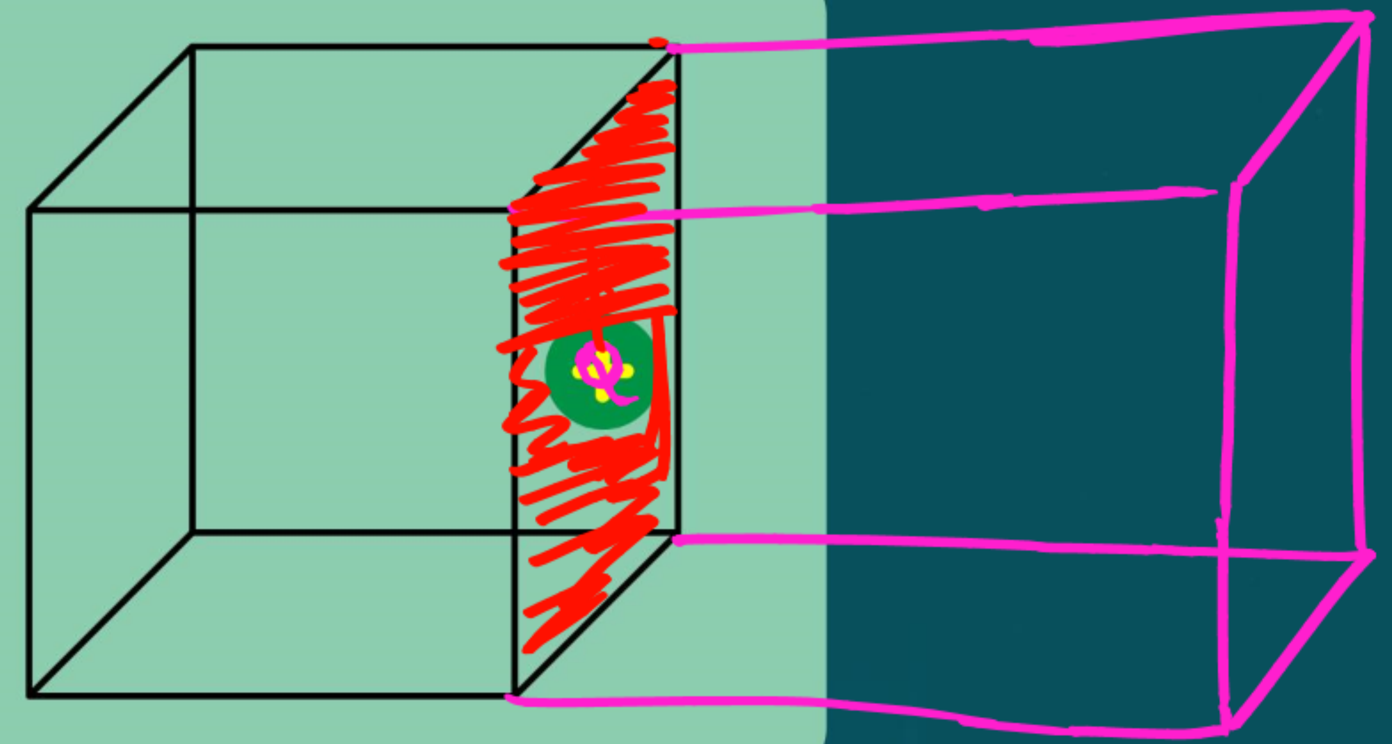
6 surface

$$\phi_{\substack{each \\ face}} = \frac{\phi_{cube}}{6} = \frac{Q}{6\varepsilon_0}$$

Question

Find the Electric flux through Cube

[CBSE]



$$\phi_{2\,cube} = \frac{Q}{\varepsilon_0}$$

$$\phi_{cube} = \frac{Q}{2\varepsilon_0}$$

1 surface $\Rightarrow \phi = 0$

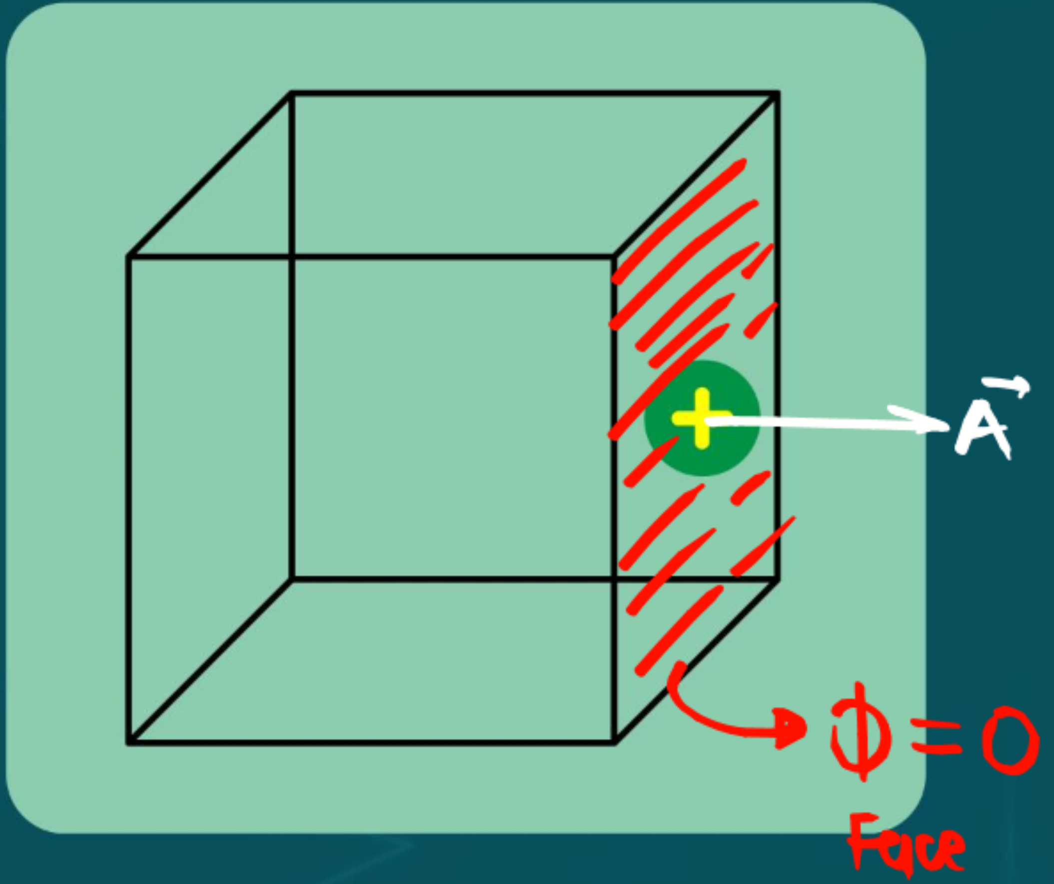
$$\phi_{\substack{each\\ 5\ face}} = \frac{\phi_{cube}}{5}$$

Next Toppers

Question

Find the Electric flux through Cube

[CBSE]



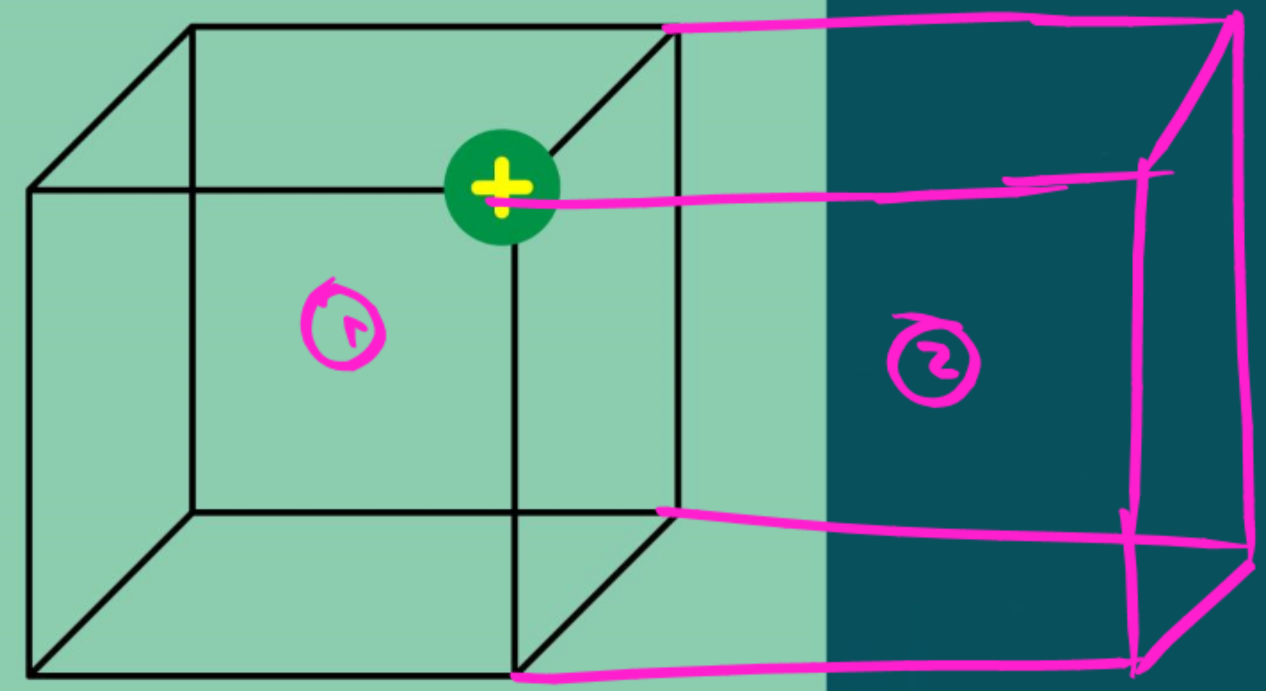
$$\phi_{cube} = \frac{Q}{2\varepsilon_0}$$

$$\left(\because \vec{E} \perp \vec{A} \Rightarrow EA\cos 90^\circ = 0 = \phi \right)$$

Question

Find the Electric flux through Cube

[CBSE]

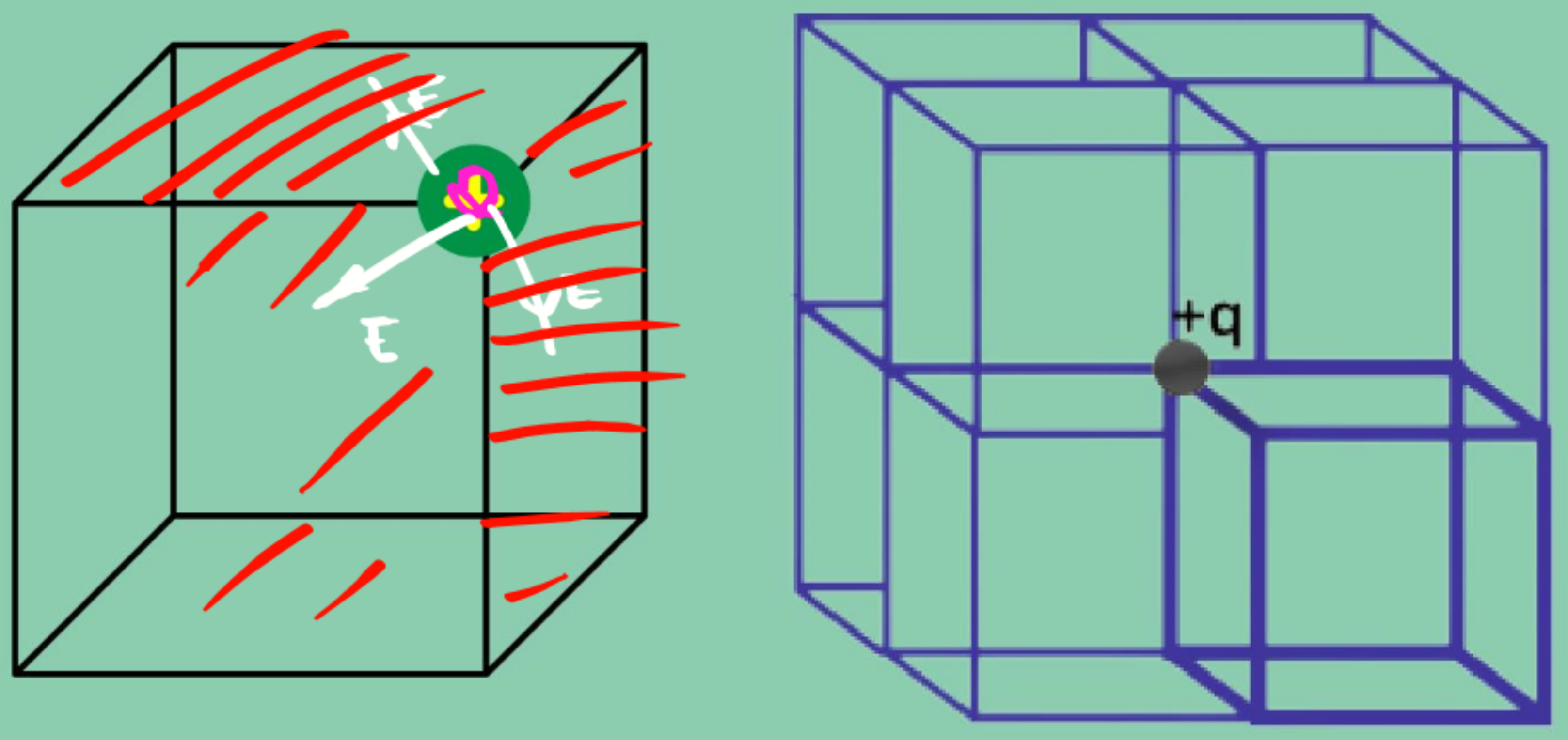


Next Toppers

Question

Find the Electric flux through Cube

[CBSE]



$\phi_{3Face} = 0$

8 cube

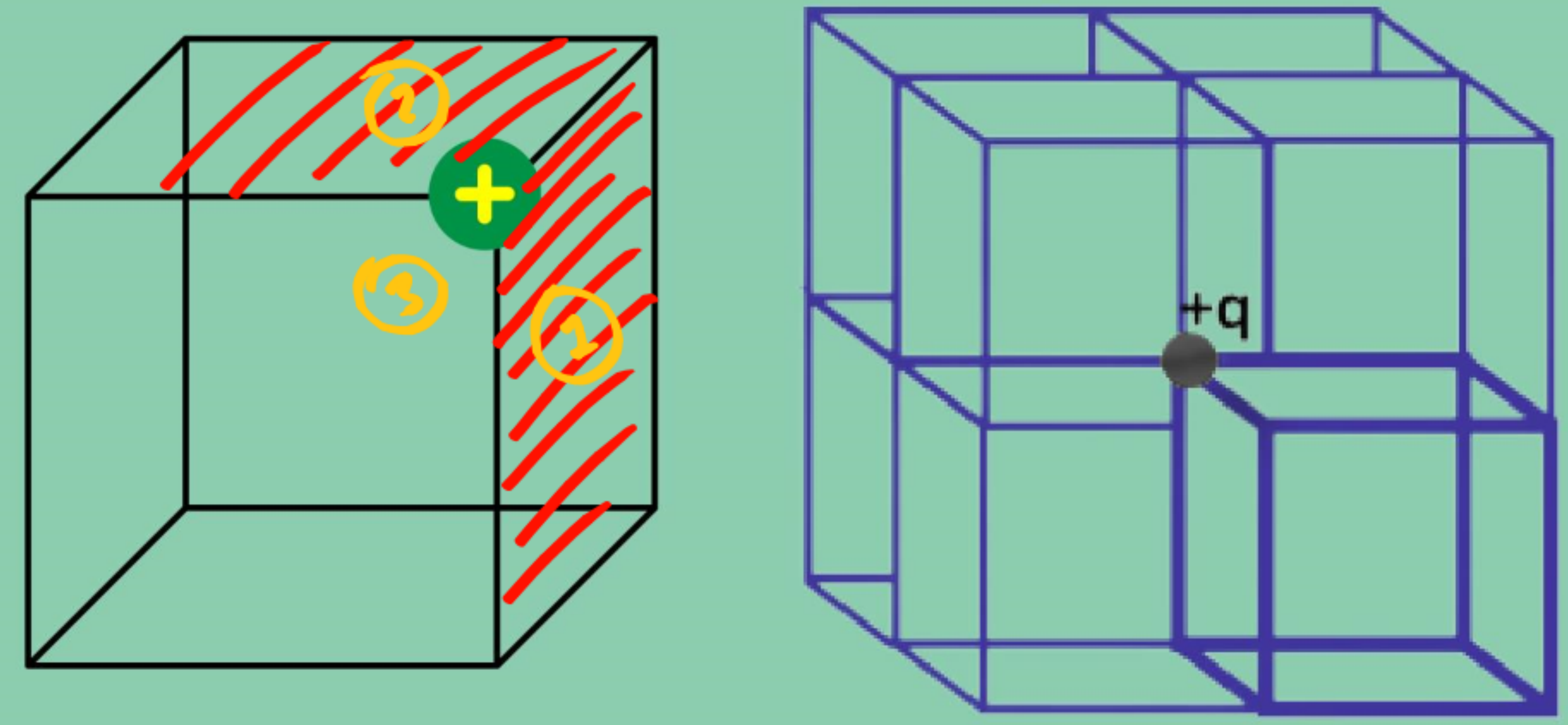
$\phi = Q/\varepsilon_0$

$\phi_{cube} = \frac{Q/\varepsilon_0}{8} = \frac{Q}{8\varepsilon_0}$

Question

Find the Electric flux through Cube

[CBSE]



$$\phi_{cube} = \frac{Q}{8\varepsilon_0}$$

$$\Downarrow$$

$$\phi_{3\,Faces} = 0$$

$$\phi_{Face} = \frac{Q/8\varepsilon_0}{3} = \frac{Q}{24\varepsilon_0}$$

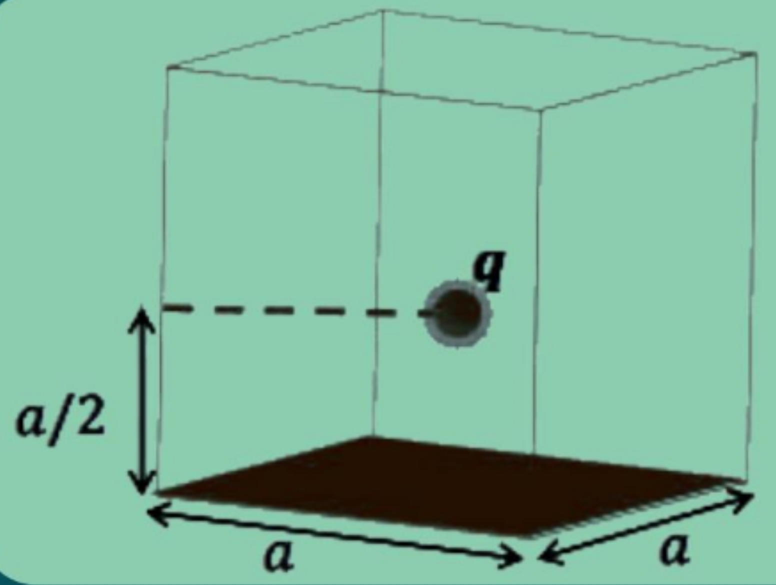
Question

A Charge q is placed at the point of intersection of body diagonals of a cube. The electric flux passing through any one of its face is

[CBSE]

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{3q}{\varepsilon_0}$

(c) $\frac{6q}{\varepsilon_0}$ (d) $\frac{q}{3\varepsilon_0}$



Question

A line charge of length a/2 is kept at the center of an edge of a cube having edge length ' a' as shown in the figure. If the density of line charge is λ C per unit length, then the total electric flux through all the faces of the cube will be **[JEE Mains 2025]**

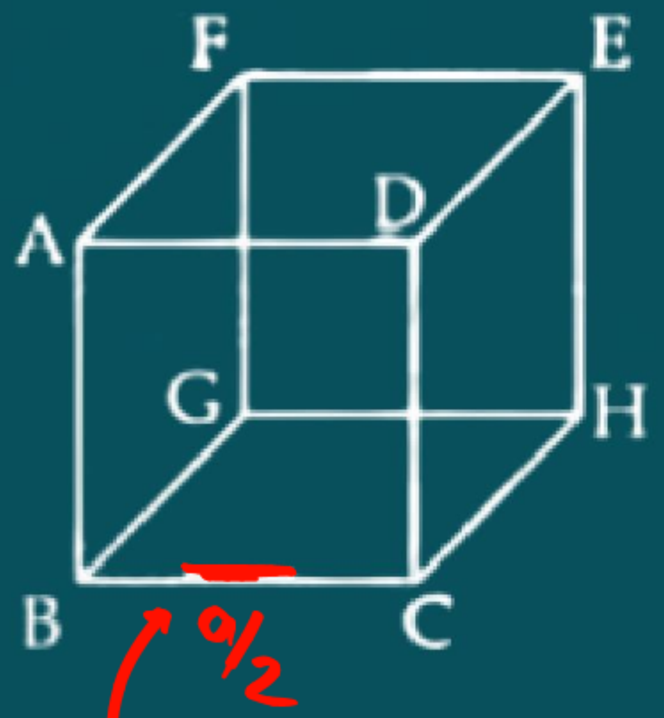
A) $\frac{\lambda a}{2\varepsilon_0}$

B) $\frac{\lambda a}{4\varepsilon_0}$

C) $\frac{\lambda a}{16\varepsilon_0}$

D) $\frac{\lambda a}{8\varepsilon_0}$

HW

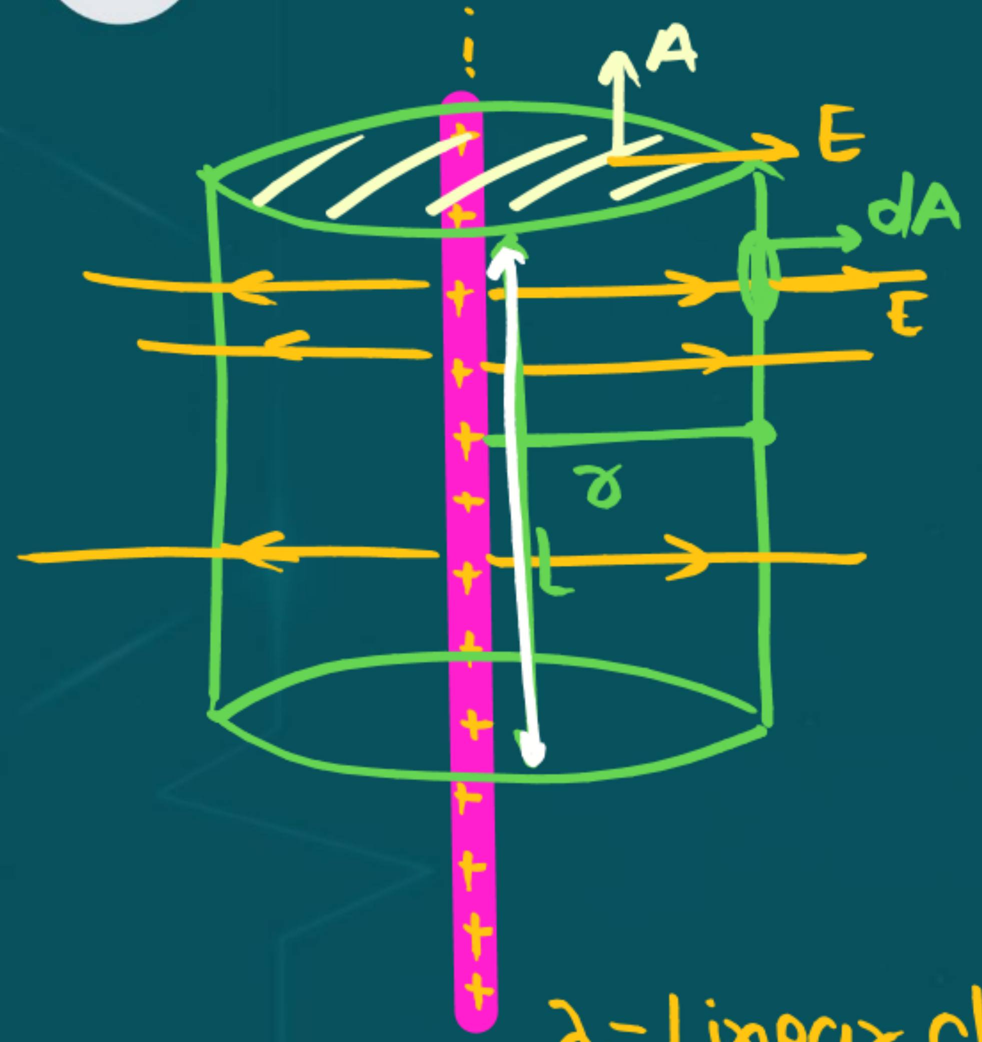


$q = (\lambda)(a/2)$

Applications of Gauss's Law

[3 Marks]

01. Electric Field due to an infinite line of charge



λ = Linear charge density

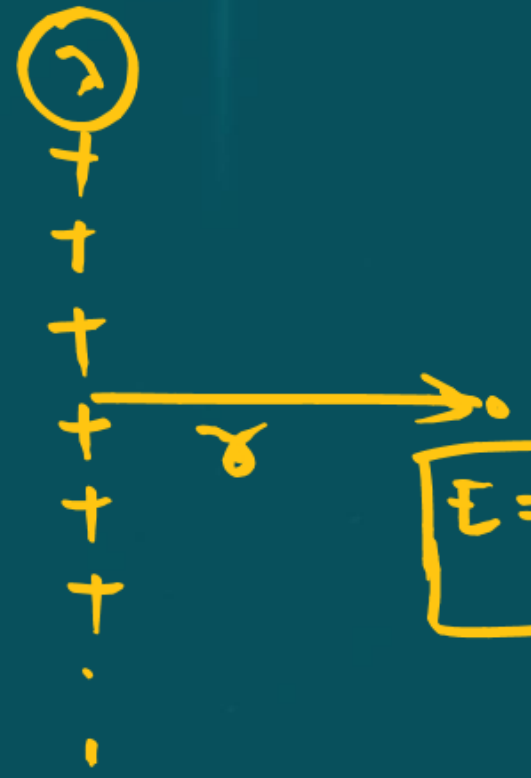
λ = constant

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$E(2\pi r L)\cos 0 = \frac{(\lambda \cdot L)}{\varepsilon_0}$$

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

$$E = \frac{2\lambda}{4\pi\varepsilon_0 \cdot r} = \frac{2k\lambda}{r}$$



$$\boxed{E = \frac{2k\lambda}{r}}$$

Next Toppers

Question

An infinite long straight wire having a charge density λ is kept along YY' - axis in XY-plane. The Coulomb force on a point charge q at a point P(x,0) will be

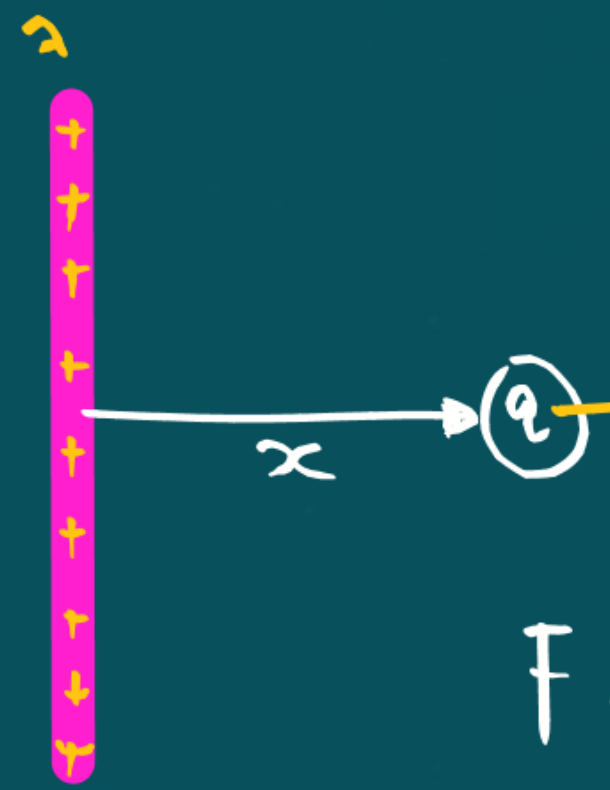
[CBSE]

~~A)~~ Attractive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$

B) Repulsive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$

~~C)~~ Attractive and $\frac{q\lambda}{\pi\varepsilon_0 x}$

D) Repulsive and $\frac{q\lambda}{\pi\varepsilon_0 x}$

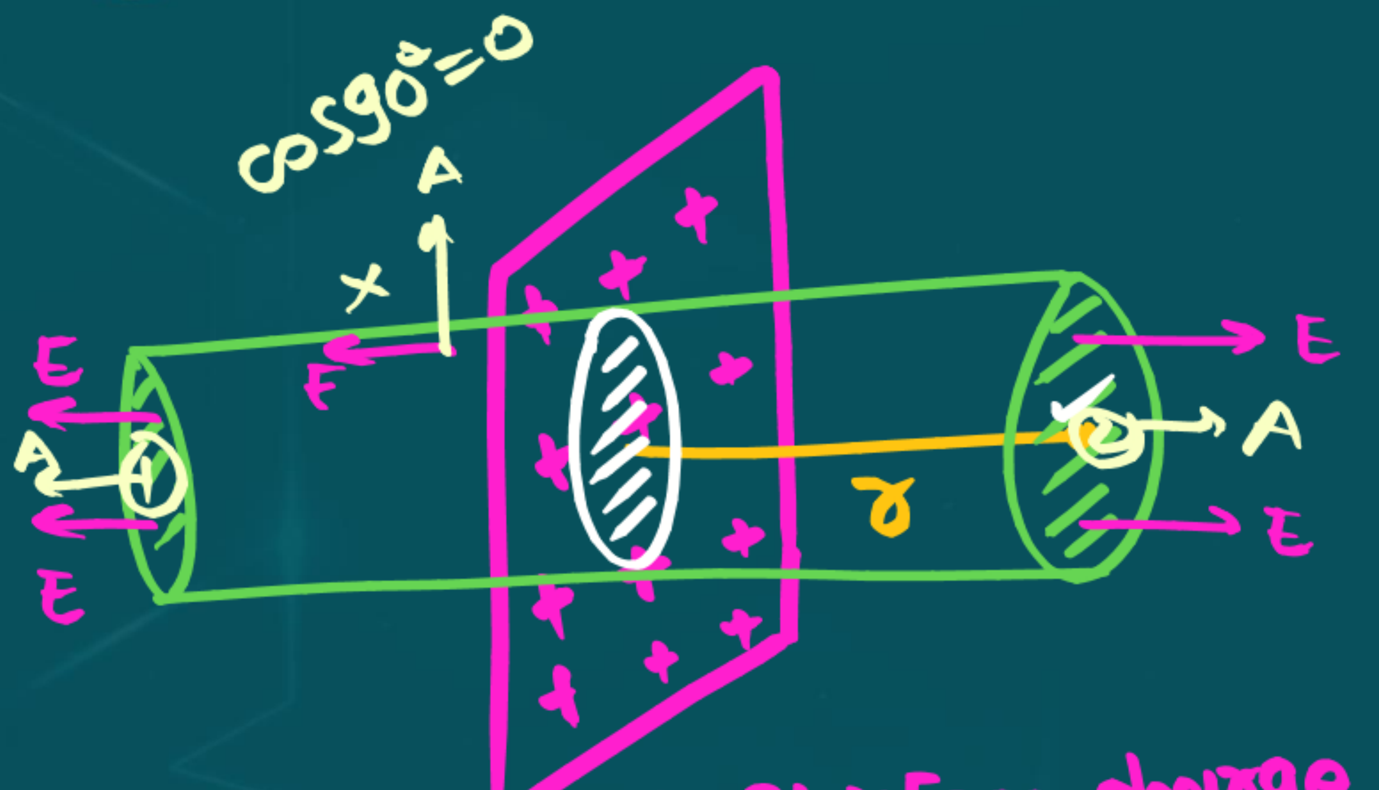


$E = \frac{2k\lambda}{x}$

$$F = qE = \frac{2k\lambda \cdot q}{x} = \frac{\lambda \cdot q}{2\pi\varepsilon_0 \cdot x}$$

Applications of Gauss's Law

02. Electric Field due to a large thin sheet



σ = surface charge density = Q/A = constant

$$\oint \vec{E} \cdot \vec{dA} = \frac{Q_{enclosed}}{\varepsilon_0}$$

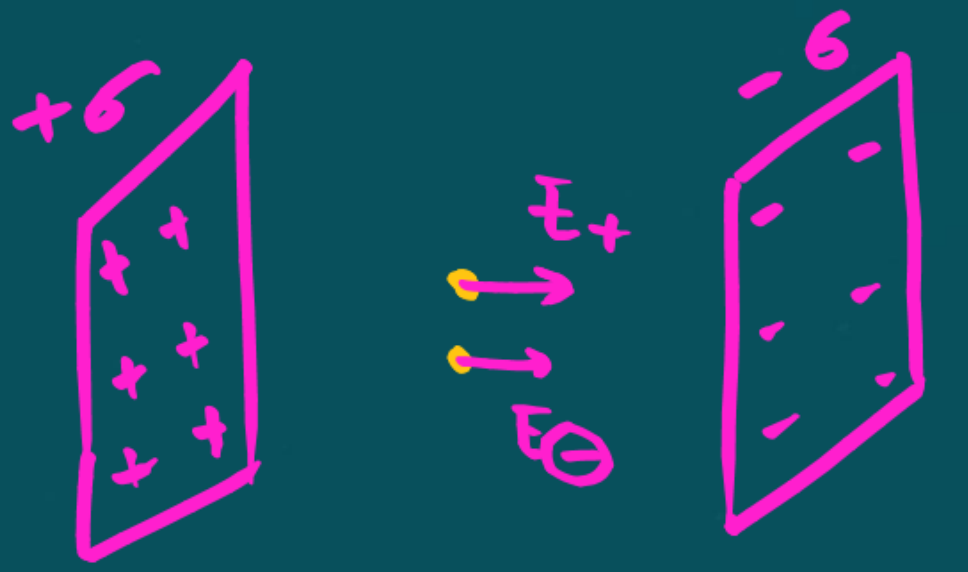
$$EA + EA + 0 = \frac{(\sigma \cdot A)}{\varepsilon_0}$$

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

Question

Two parallel large thin ~~metal~~ sheets have equal surface densities 26.4×10^{-12} C / (m^2) of opposite signs. The electric field between these sheets is

A) 1.5 N/C
B) 15×10^{-16} N / C
C) 3×10^{-10} N / C
D) 3 N/C



$$E_{net} = E_{\oplus} + E_{\ominus}$$

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

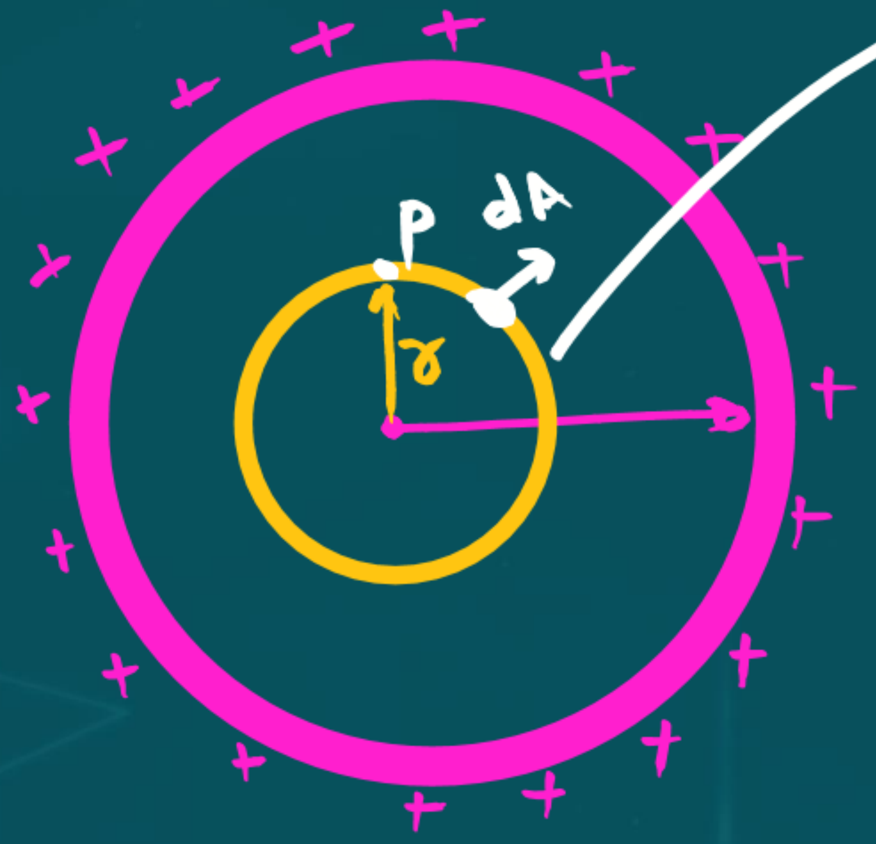
$$= \frac{\sigma}{\varepsilon_0}$$

$$= \frac{26.4 \times 10^{-12}}{8.85 \times 10^{-12}}$$

Applications of Gauss's Law

03. Electric Field due to shell/conducting sphere/shell

(i) Inside



total charge = Q

$$\oint \vec{E}\cdot\vec{da} = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$E(4\pi r^2) = \frac{0}{\varepsilon_0}$$

$$\boxed{E_{inside} = 0}$$

Applications of Gauss's Law

03. Electric Field due to shell

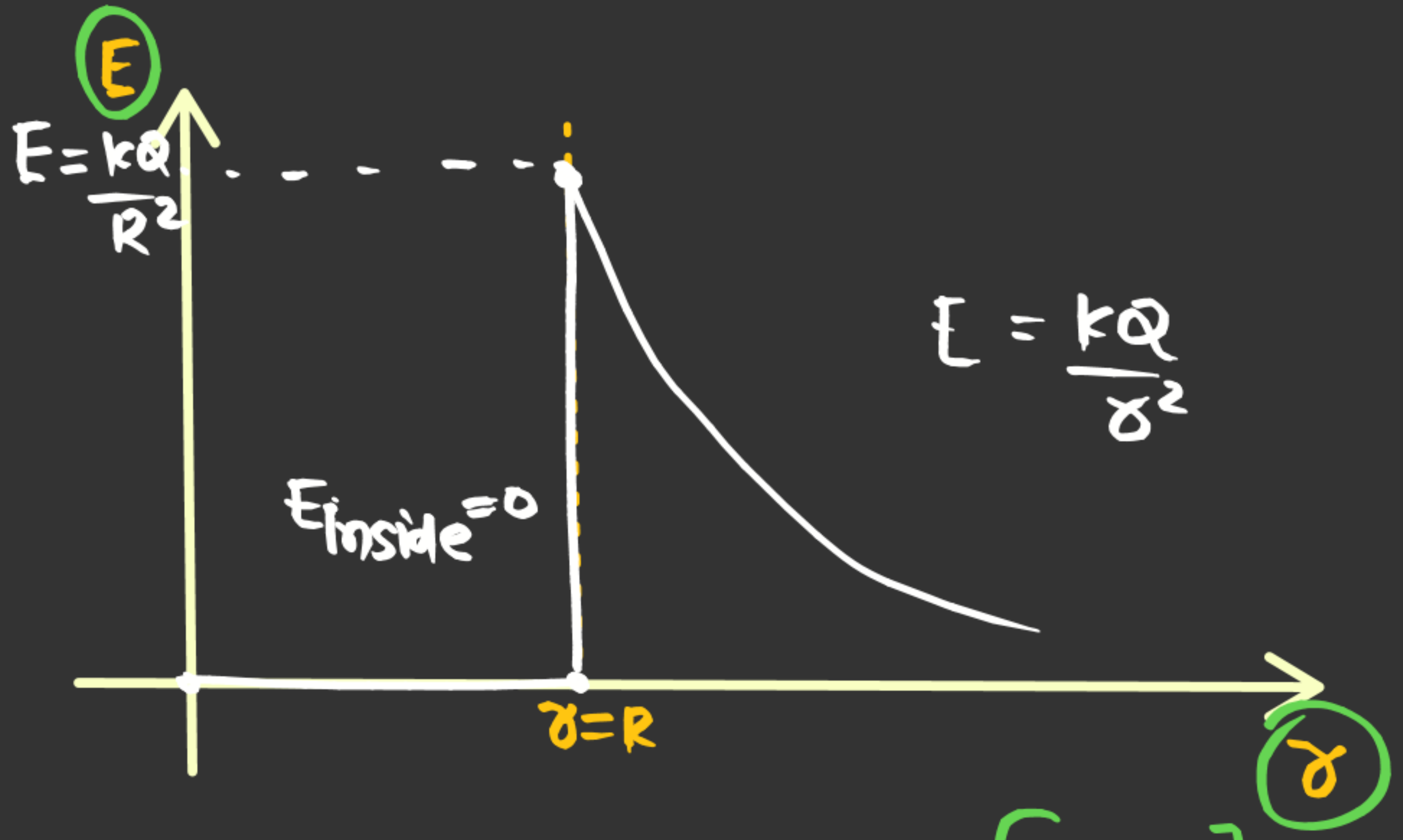
(ii) Outside ($r > R$)

$$\oint \vec{E} \cdot \vec{dA} = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$E(4\pi r^2)\cos 0^\circ = \frac{Q}{\varepsilon_0}$$

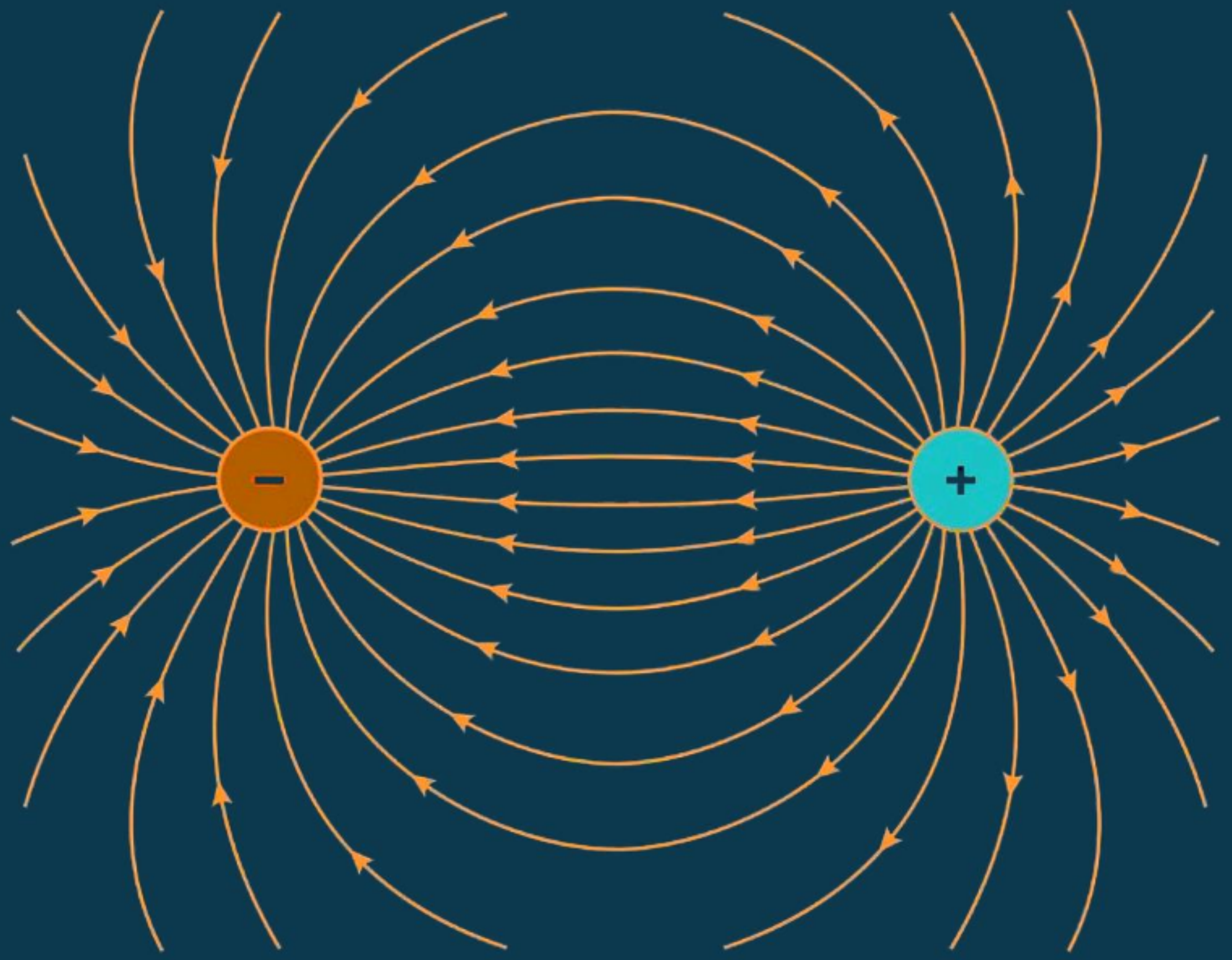
$$E = \frac{Q}{4\pi\varepsilon_0 \cdot r^2}$$

$$\boxed{E = \frac{kQ}{r^2}}$$



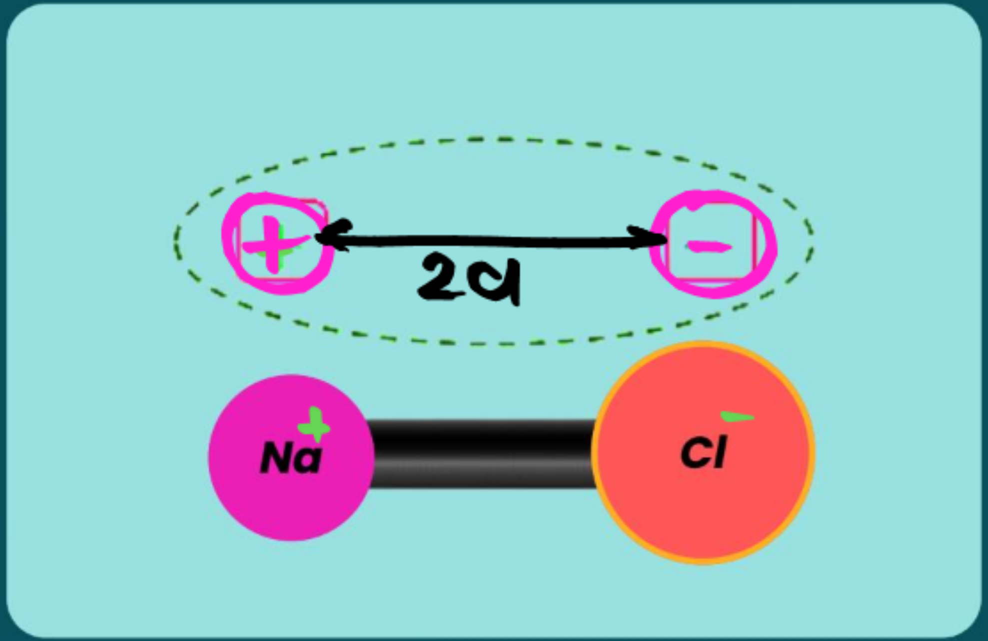
[MCQs]

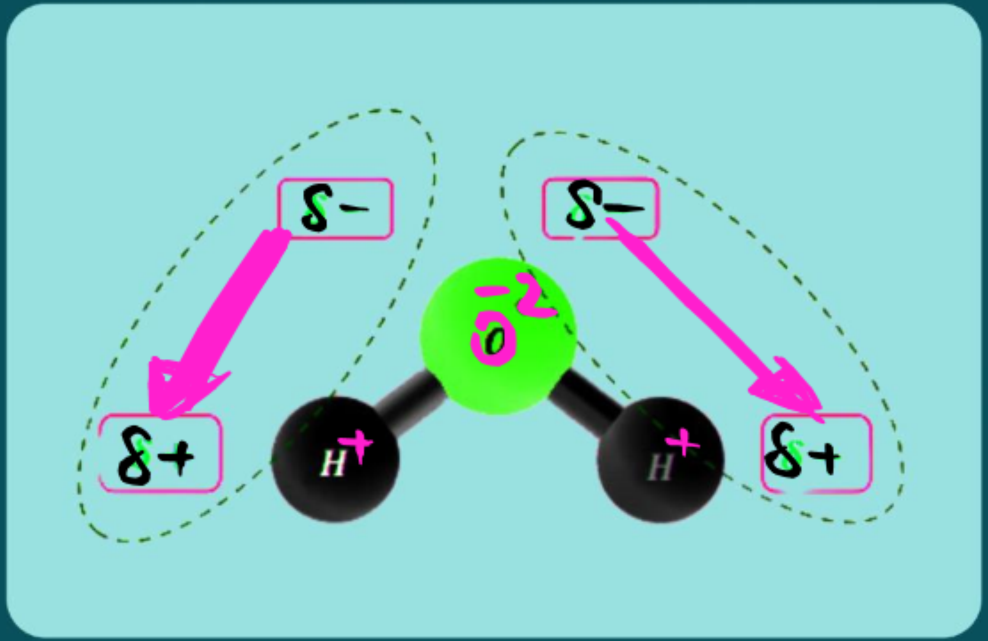
Electric Dipole



Electric Dipole

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





Na^+Cl^-

H_2O

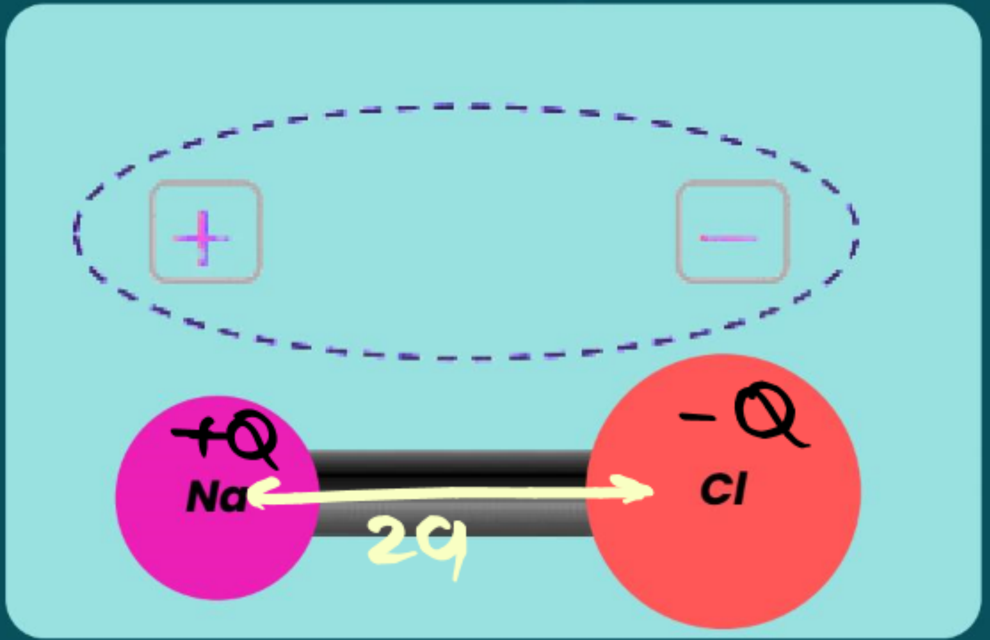
H^+ H^+ O^{-2}

Properties of Charges

Electric Dipole Moment

- **Magnitude** : Product of magnitude of either of the charges and the separation distance between them. $\Rightarrow Q(2a) = P$

- **Direction** : Along the axis of the dipole (From the negative charge to positive charge)



$\vec{P} = Q(2\vec{a})$

$\hookrightarrow$ C.m

Next Toppers

Question

Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle as shown in the figure.

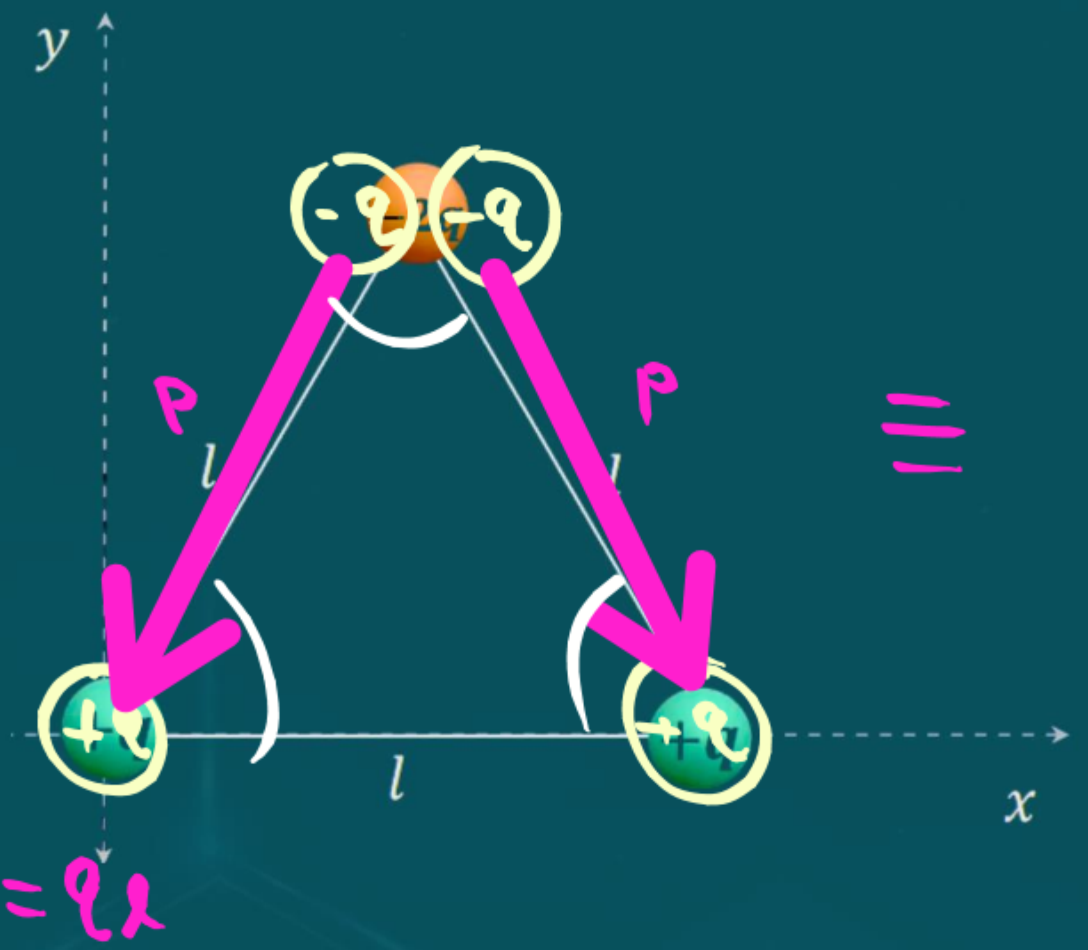
[JEE MAIN 2019]

A $\sqrt{3}ql\frac{\hat{j}-\hat{i}}{\sqrt{2}}$

B) $2ql\hat{j}$

C) $-\sqrt{3}ql\hat{j}$

D) $(ql)\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

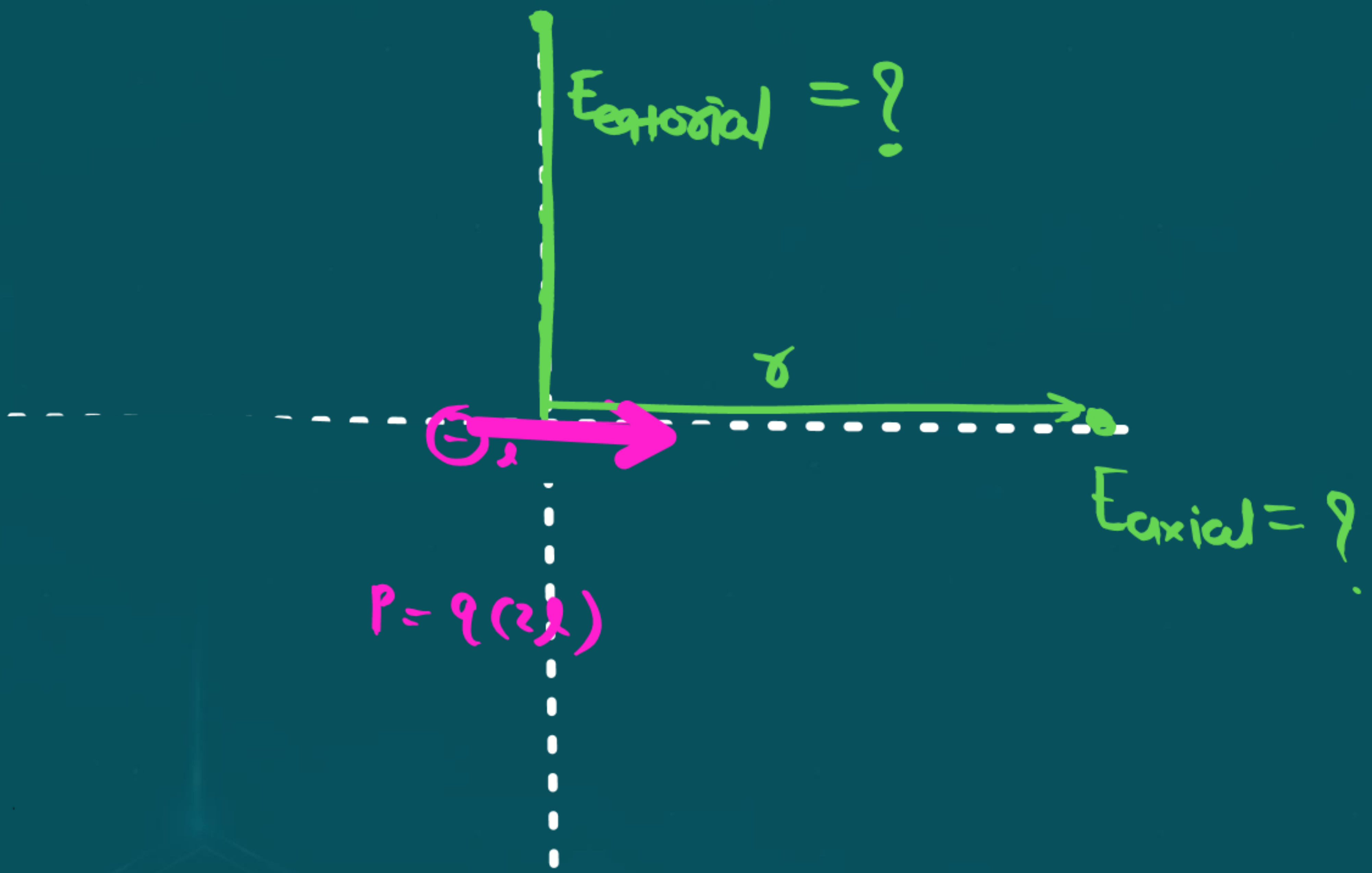


$P = ql$

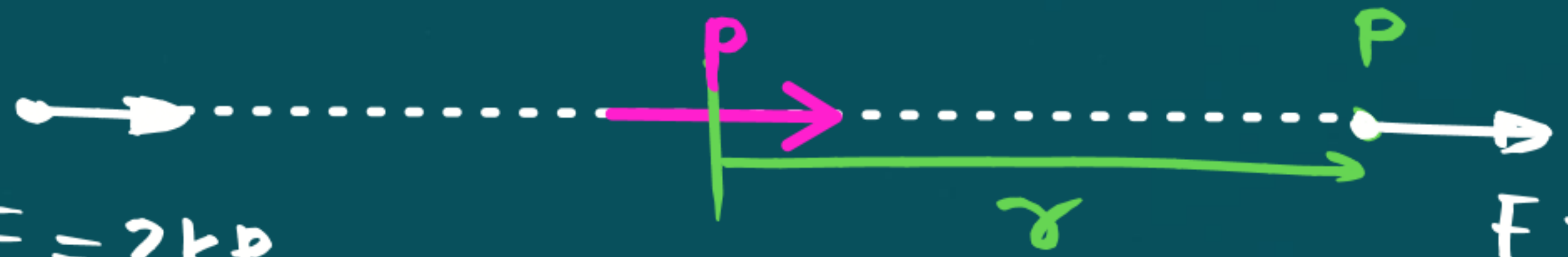
$P_{net} = \sqrt{P^2 + P^2 + 2PP\cos 60^\circ}$

Electric field due to a Dipole

(Derivation



(i) Axial Point



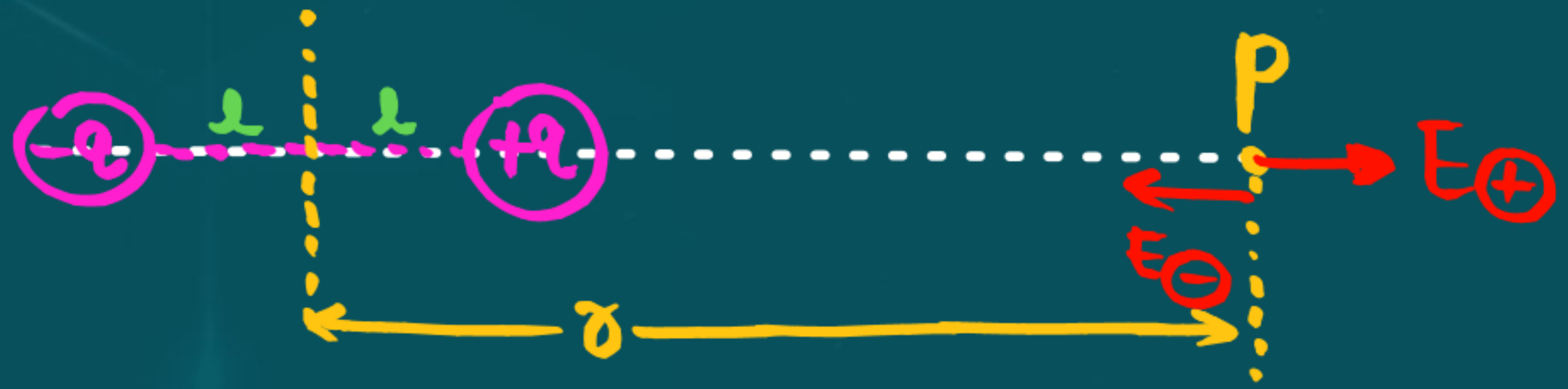
$$E = \frac{2kp}{r^3}$$

$$E = \frac{2kp}{r^3}$$

$$\vec{E} = \frac{2k\vec{p}}{r^3}$$

(i) Axial Point

$p = q(2l)$



$E_{\oplus} = \frac{kq}{(r-l)^2}$

$E_{\ominus} = \frac{kq}{(r+l)^2}$

$\rightarrow E_{\oplus} - E_{\ominus}$

Assumption

$r >> l$

$r^2 >> l^2 \Rightarrow r^2 - l^2 \approx r^2$

$E_{net} = E_{\oplus} - E_{\ominus}$

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

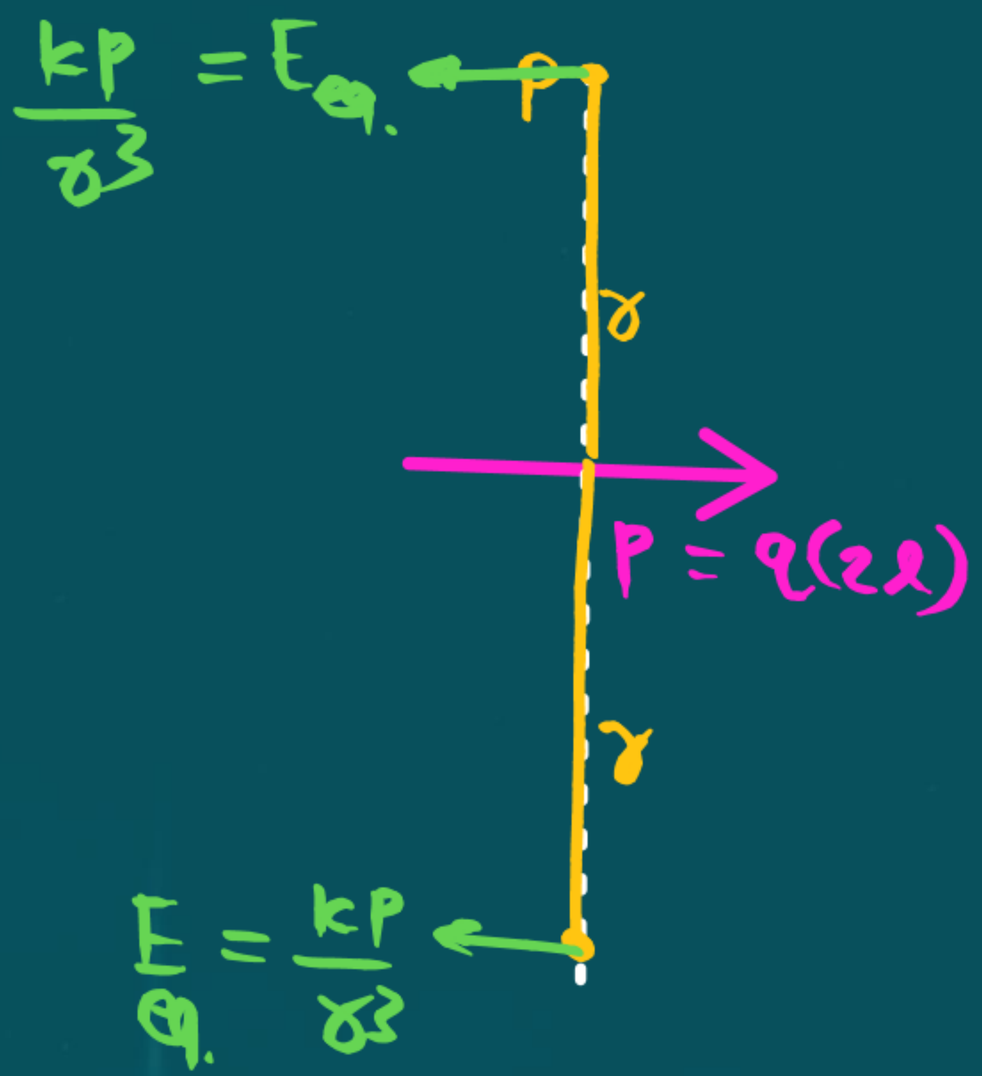
$= kq\left[\frac{(r+l)^2 - (r-l)^2}{(r+l)^2 (r-l)^2}\right]$

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

$= \frac{2k\, q(2l) \cdot \cancel{r}}{r^{\cancel{4}\,3}}$

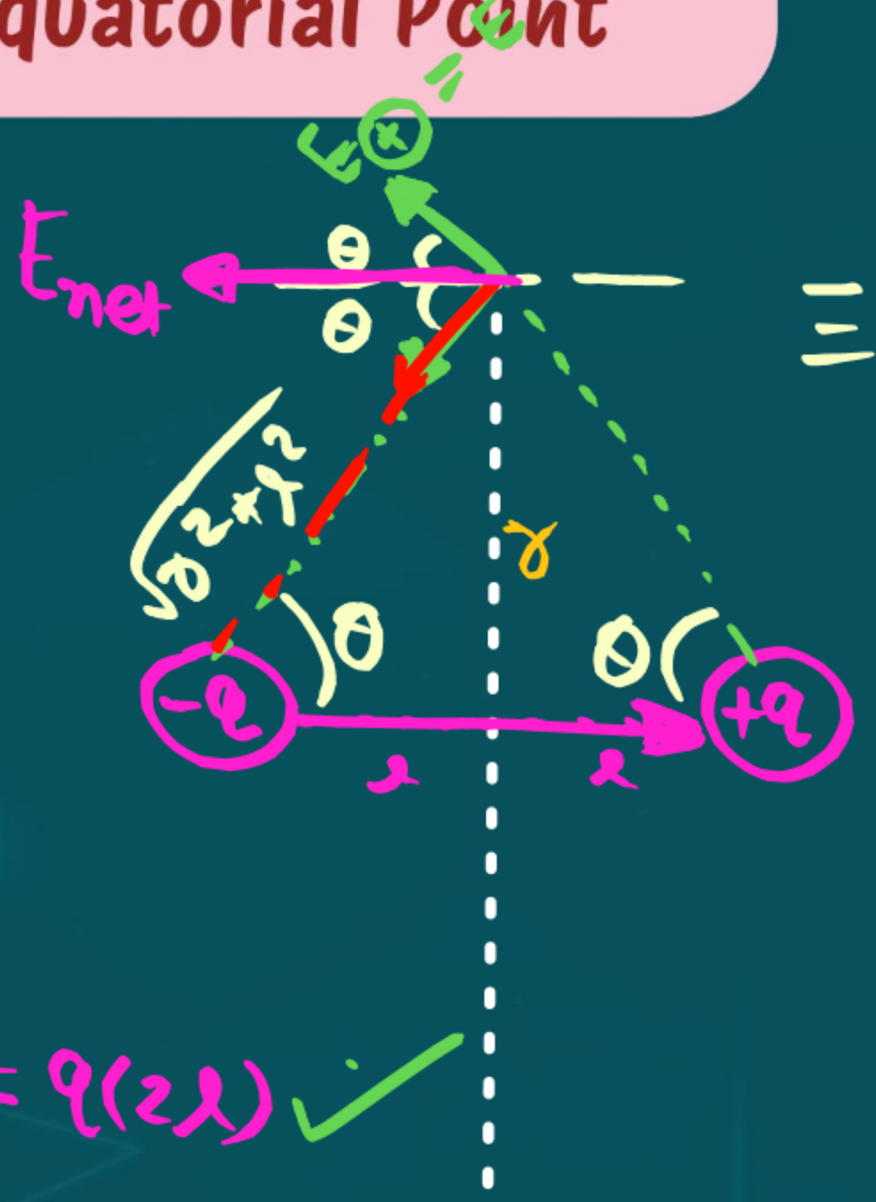
$$\boxed{E_{net} = \frac{2kP}{r^3}}$$

(ii) Equatorial Point



$$\vec{E}_{eq} = -\frac{k\vec{p}}{r^3}$$

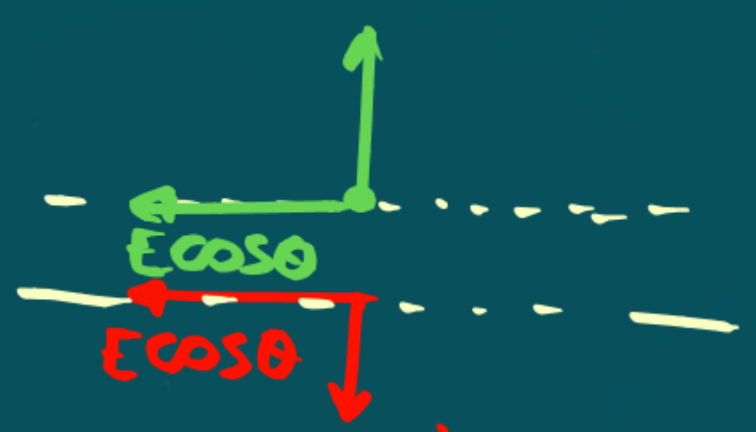
(ii) Equatorial Point



$P = q(2l)$ ✓

$$E_{+} = \frac{kq}{(r^2+l^2)} = E_{-} = E$$

$\equiv$



Assumption

$r >> l$

$r^2 >> l^2$

$r^2 + l^2 \simeq r^2$

$\equiv$

$$E_{net} = 2E\cos\theta$$

$$E_{net} = 2\frac{kq}{(r^2+l^2)} \cdot \cos\theta$$

$$= \frac{2kq}{(r^2+l^2)} \frac{(l)}{(r^2+l^2)^{1/2}}$$

$$= \frac{k\,q(2l)}{(r^2+l^2)^{3/2}}$$

$$\boxed{E_{net} = \frac{kp}{r^3}}$$

Q. $\dfrac{\vec{E}_{axial}}{E_{equitorial}} = ?$

(A) 2

(B) $-1/2$

(C) -2

(D) $1/2$

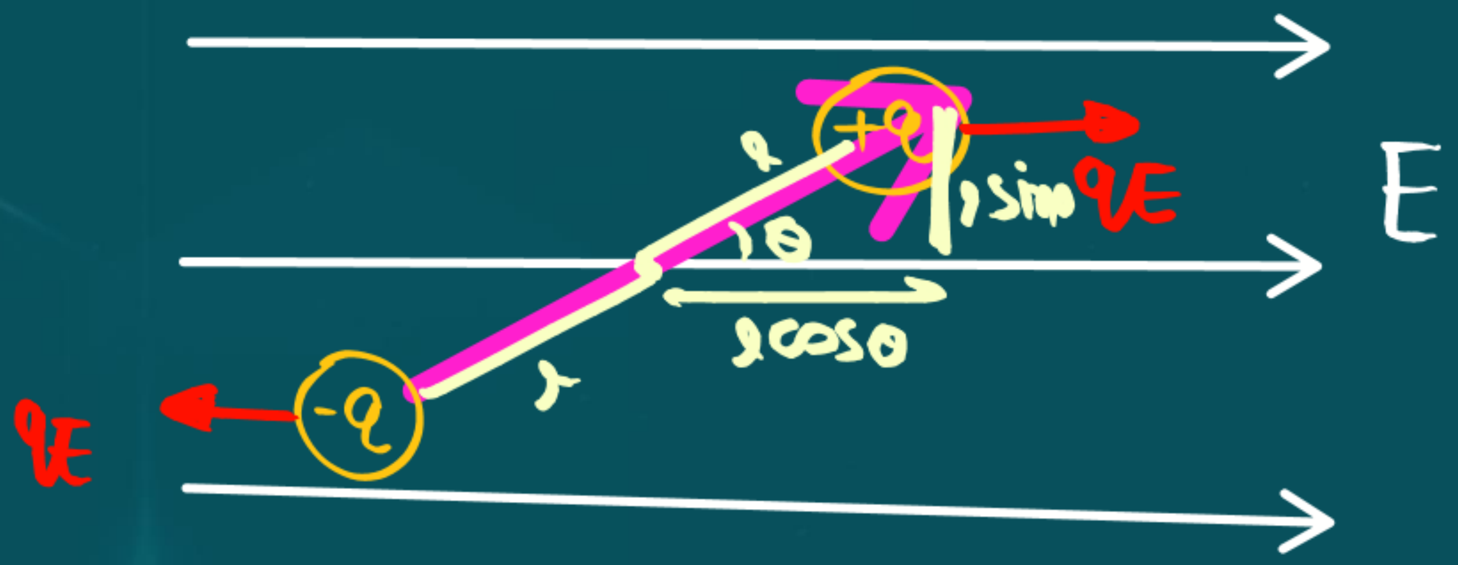
Next Toppers

Electric Dipole

kept in an External Electric field

(i) Uniform External Electric field

$p = q(2l)$

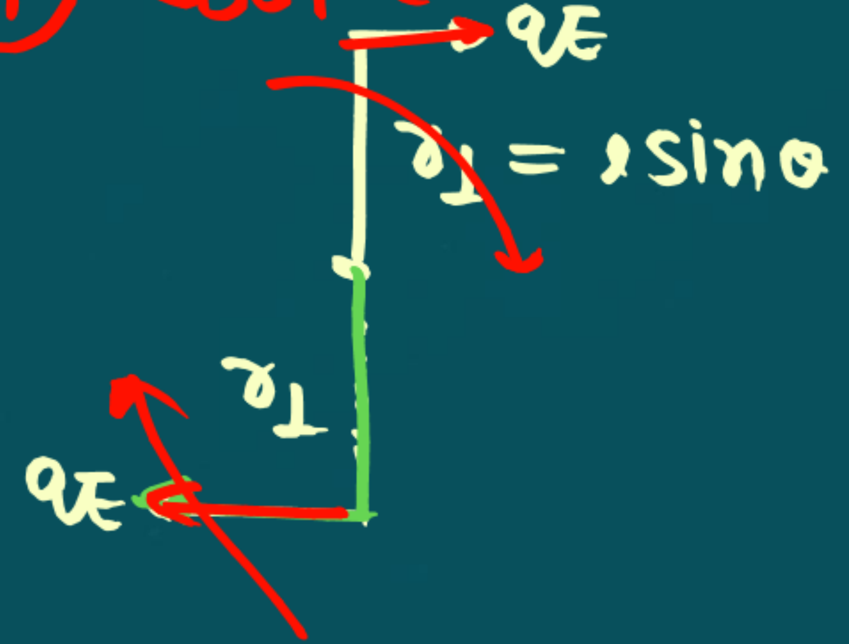


$\vec{\tau} = \vec{r} \times \vec{F}$

$|\vec{\tau}| = rF\sin\theta = r_\perp F = rF_\perp$

(i) $\vec{F}_{net} = \vec{F}_{\oplus} + \vec{F}_{\ominus} = 0$ (Always)

(ii) Torque

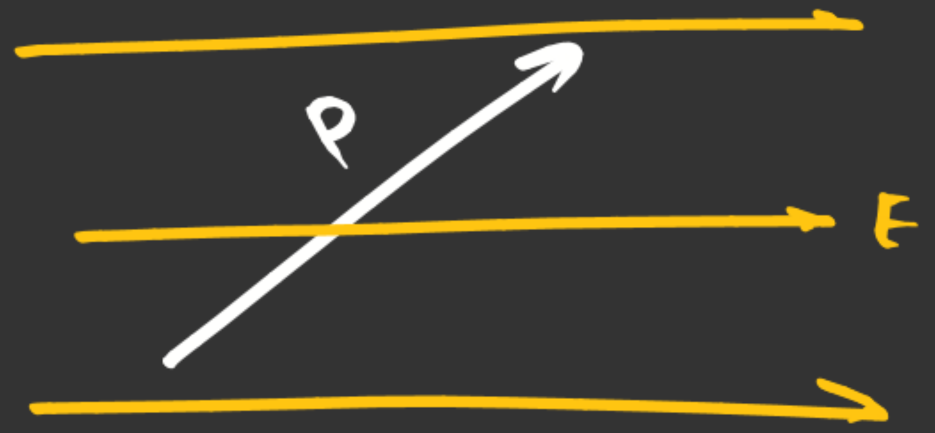


$\tau_{net} = \tau_{\oplus} + \tau_{\ominus}$

$= (qE)(l\sin\theta) + (qE)(l\sin\theta)$

$= 2qEl\sin\theta$

$\tau = \underline{q(2l)}E\sin\theta = pE\sin\theta$



type-1 $|\vec{\tau}| = PE\sin\theta$ ✓

type-2 $\vec{\tau} = \vec{P} \times \vec{E}$ ✓

cross product

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

$\vec{E} = \hat{j} - 2\hat{k}$

$\vec{\tau} = A\hat{i} + B\hat{j} + C\hat{k}$

$\Rightarrow A + B + C = ?$

$|\vec{\tau}| = PE\sin\theta$

(i) Uniform External Electric field

$F_{net} = 0$

Case-i

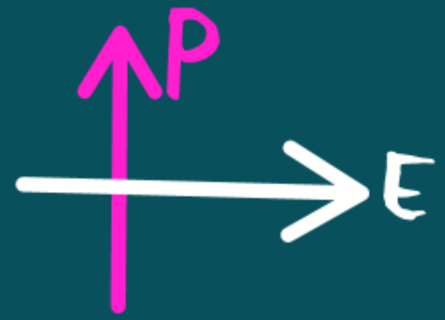
$\theta = 0^\circ$

$\sin 0 = 0$

$\tau = 0$

$\boxed{\text{M.E.}}$

Case-ii



$\theta = 90^\circ$

$\sin 90 = 1$

$\tau = PE$

Max

Case-iii

$\theta = 180^\circ$

$\sin 180 = 0$

$\tau = 0$

$\boxed{\text{M.E.}}$

Next Toppers

IMP THEORITICAL QUESTIONS

Electric Charge

1. Quantisation of charge
2. Charge is conserved

COULOMB'S LAW

1. Medium Effect
2. Vector Form (Derivation)
3. Superposition Principle

Electric Field

1. Electric Field Lines [3]
2. Continuous Charge Distribution 2, 5, 8

Electric Flux

1. Different cases of E
2. Gauss's Law
3. Application Of Gauss'a Law

E ① ② ③ IMP Derivation

Electric Dipole

Derivation

1. Electric Field at Axial Point
2. Electric Field at Equatorial Point
3. Torque in Uniform Electric Field

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