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Where Minds Pollinate

Class 11
Physics

Chapter 10

Handwritten Notes

Chapter 10 Electrostatics

Charge;

Charge is the intrinsic property of matter because of which matter can exert or feel electric and magnetic forces.

Properties;

- Charge is a scalar quantity.
- It is represented by "Q".
- Its SI unit is coloumb which is represented by "C".
- The smallest charge that can exist independently is the charge on the $\bar{e}$ or p^+ which is represented by "e" and is called fundamental charge.
- Its numerical value is $e = 1.6 \times 10^{-19} C$.
- No. of $\bar{e}$ or p^+ in one Coloumb charge are $6.25 \times 10^{18} \bar{e}$.
- An object is charged removing $\bar{e}$ from it. Charge on an object is given by relation

$$Q = ne.$$

where, Q = Charge on object, n = number of $\bar{e}$ added or removed from object and e = fundamental charge i.e $e = 1.6 \times 10^{-19} C$.

- There are two types of charge, +ve charge and -ve charge.
- like charges repel and opposite charges attract.

- Charge is always conserved.
- Charge is always quantized.
- Charges whose size is very small as compared to distance b/w them are called point charges.
- Charges that are used to detect any external electric field are called test charge.

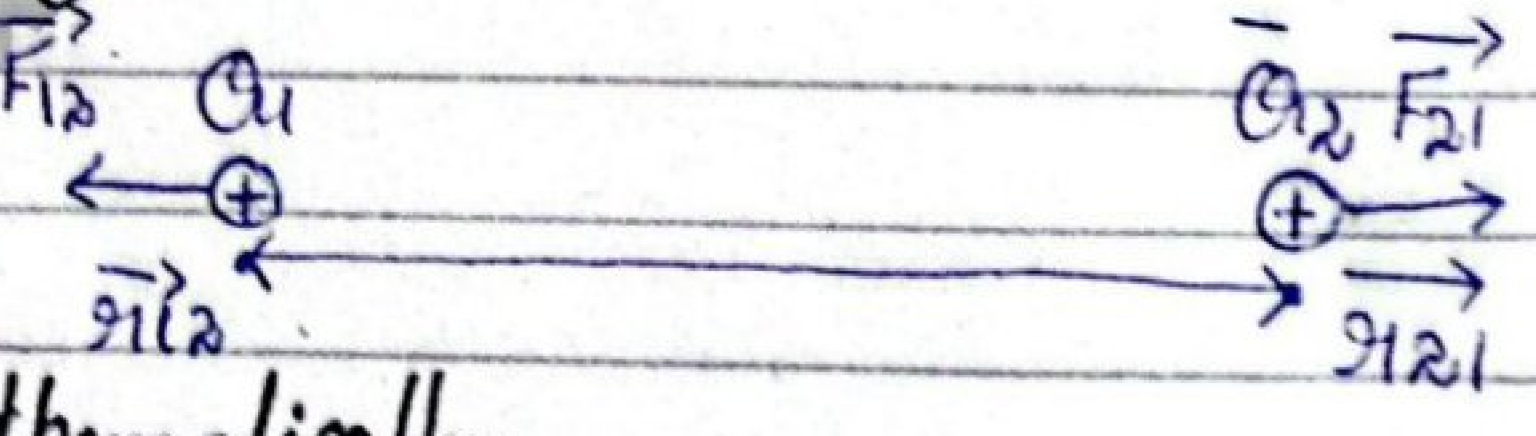
Coulomb's law

Definition:-

The magnitude of force of attraction or repulsion b/w two point charges is directly proportional to the product of charges and inversely proportional to the sq. of distance b/w the charges.

This statement is calle Coulomb's law.

Diagram:-



Mathematically:-

By definition of Coulomb's law.

$$F \propto q_1 q_2 \quad \dots ①$$

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

Combining ① and ②

$$F \propto \frac{Q_1 Q_2}{r^2}$$

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

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

where "K" is the constant of proportionality called Coloumb's Constant.
Its value depends upon the nature of medium b/w charges and systems of units used.
For free space or air, value of Coulomb's constant is max and its numerical value is

$$K = 9 \times 10^9 \frac{Nm^2}{C^2}$$

Permitivity of Medium:-

Coloumb's constant depends upon the medium b/w the charges and is written as

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

Here, "ε" is called permitivity of medium b/w charges. It is the property of the medium b/w the charges. It is the property of the medium b/w the charges to reduces the electrostatics Coulomb's force b/w the charges.

Its value is minimum for air and is given by

$$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$$

other medium have permittivity greater then air.
Therefore eq ③ is written as.

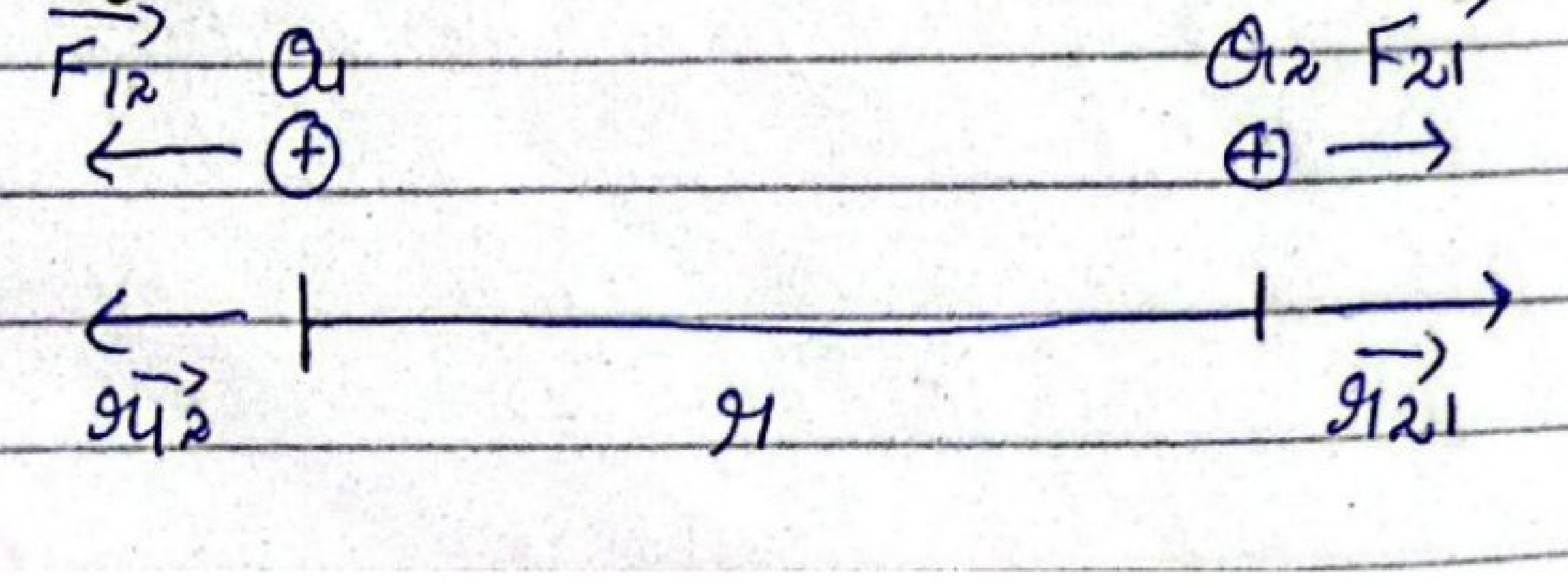
$$F = K\frac{Q_1 Q_2}{r^2}$$

$$F = \frac{1}{4\pi\varepsilon} \cdot \frac{Q_1 Q_2}{r^2}.$$

Coulomb's law in Vector form:-

Suppose "Q_1" and "Q_2" are two charges separated by "r" distance. Force on "Q_1" due to "Q_2" is "$\vec{F}_{12}$" and force on "Q_2" due to "Q_1" is "$\vec{F}_{21}$" and unit vectors in direction of $\vec{F}_{12}$ and $\vec{F}_{21}$ are respectively $\hat{r}_{12}$ and $\hat{r}_{21}$.

Diagram:-



Mathematically:

$$\vec{F_{12}} = \left(\frac{K\,q_1 q_2}{r^2}\right) \times \text{direction}$$

$$\vec{F_{12}} = \left(\frac{K\,q_1 q_2}{r^2}\right) \hat{r}_{12} \quad \ldots (A)$$

and

$$\vec{F_{21}} = \left(\frac{K\,q_1 q_2}{r^2}\right) \times \text{direction}$$

$$\vec{F_{21}} = \left(\frac{K\,q_1 q_2}{r^2}\right) \times \hat{r}_{21} \quad \ldots (B)$$

From the figure

$$\vec{r}_{21} = -\vec{r}_{12}$$

Therefore;

$$\vec{F_{21}} = -\vec{F_{12}}$$

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Diff b/w Electric and Gravitational force:

Electric Forces	Gravitational forces
• According to Coulomb's law $F_e = K\frac{q_1 q_2}{r^2}$	• According to gravitational law $F_g = G\frac{m_1 m_2}{r^2}$
• The value of electrostatic constant (K) is much larger i.e; $K = 9\times10^9 \, Nm^2/C^2$	• The value of gravitational constant (G) is much smaller as compared to electric constant. $G = 6.673\times10^{-11} \, Nm^2/Kg^2$
• It is much stronger force	• It is a weaker force.
• It may be attractive or repulsive force.	• It is attractive force only.
• It can be shielded.	• It cannot be shielded.

Electric field:-

The region or space around a source charge in which another test charge experience a force due to the source charge is called electric field.
It is just a piece of space around a source charge. It is not a physical quantity.

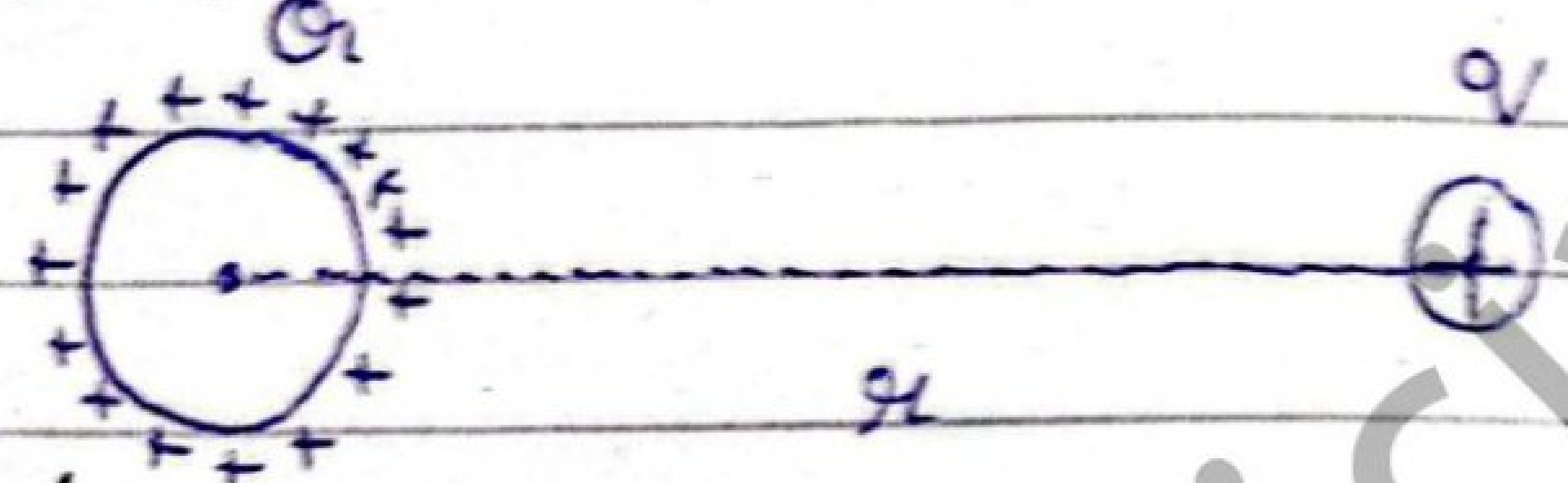
Electric field Intensity:-

Definition:-

Force Acting on one Coulomb Charge placed at any point in an electric field is called electric field intensity at that point.

- It is represented by $\vec{E}$.
- It is a vector quantity.
- Its direction is same as that of force on +ve test charge in the external field.

Diagram:-



Formula:-

$$\vec{E} = \frac{\vec{F_e}}{q}$$

which is the general formula for the electric field at any point inside the electric field.

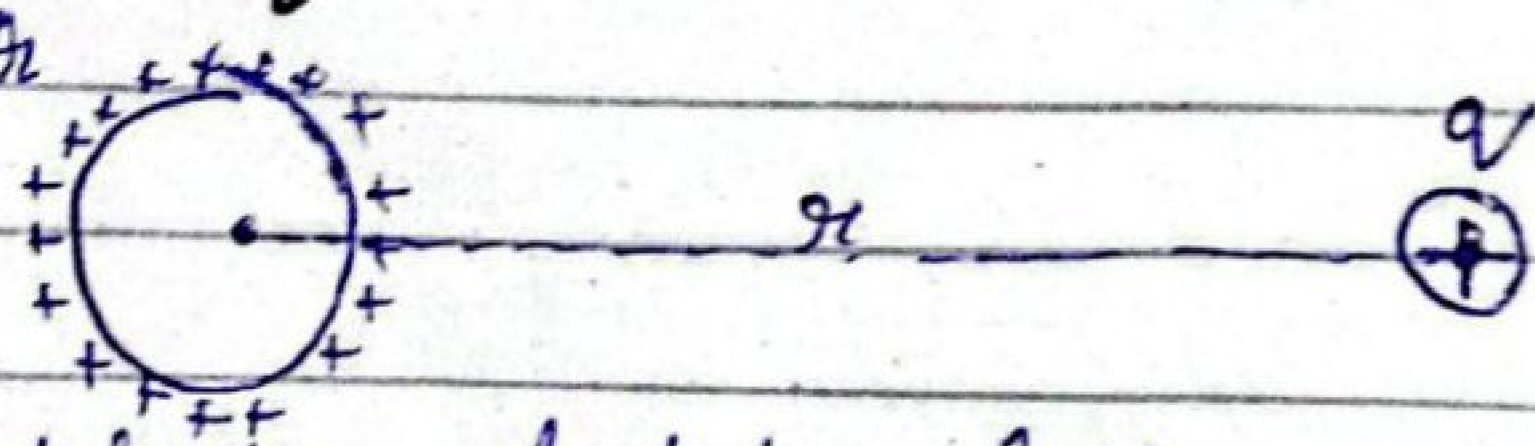
Unit:-

By definition of electric field.

$$\vec{E} = \frac{\vec{F_e}}{q}$$

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

Electric field due to a point charge:-



By definition of electric field.

$$E = \frac{F_e}{q} \qquad \therefore F_e = \frac{KQ_1Q_2}{r^2}$$

$$E = \frac{\frac{KQ_1Q_2}{r^2}}{q} \rightarrow E = \frac{KQq}{rq}$$

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

which is the electric field due to a point charge "Q" at a distance "r" from its centre.

Note:-

Example 10.2, Assignmen 10.1 and exercise numberials from Key.

Electric field lines:-

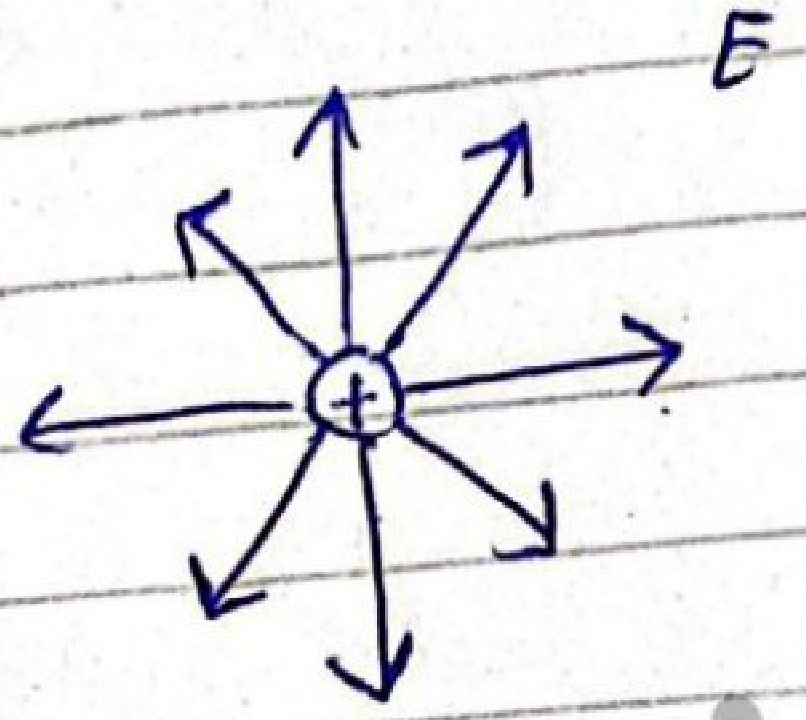
Definition:-

To visualise electric field in a region of space, we draw some imaginary lines. These imaginary lines are electric field lines.

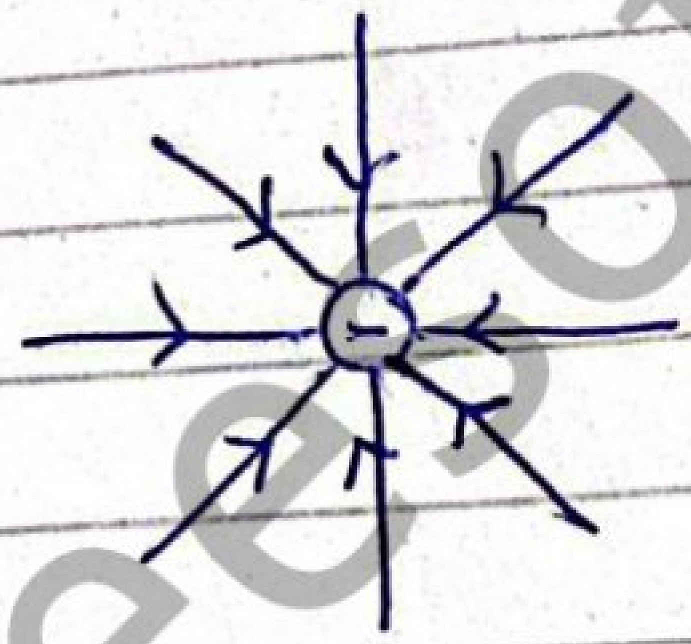
Properties:-

1. Electric field lines originate from +ve charge and terminate on the -ve charge.
2. Tangent at any point on electric field lines gives direction of electric field intensity at that point.
3. Two electric field lines never cross each other. This is because if they do so, there will be two direction of electric field intensity at a single point which is not possible.
4. A uniform electric field has straight, parallel, equally spaced lines showing constant strength.
5. Closely placed lines show a strong field, while widely placed lines show a weak field.

Electric field due to +ve pint charge:-

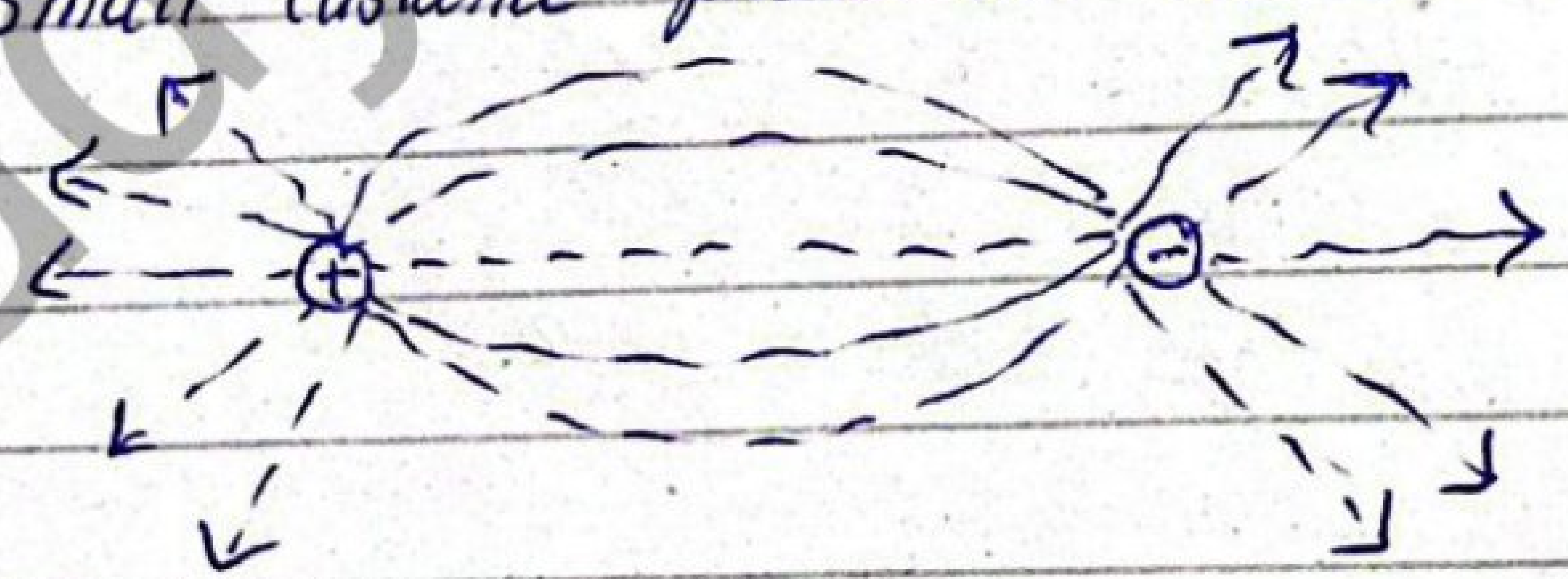


Electric field due to -ve pint charge:-

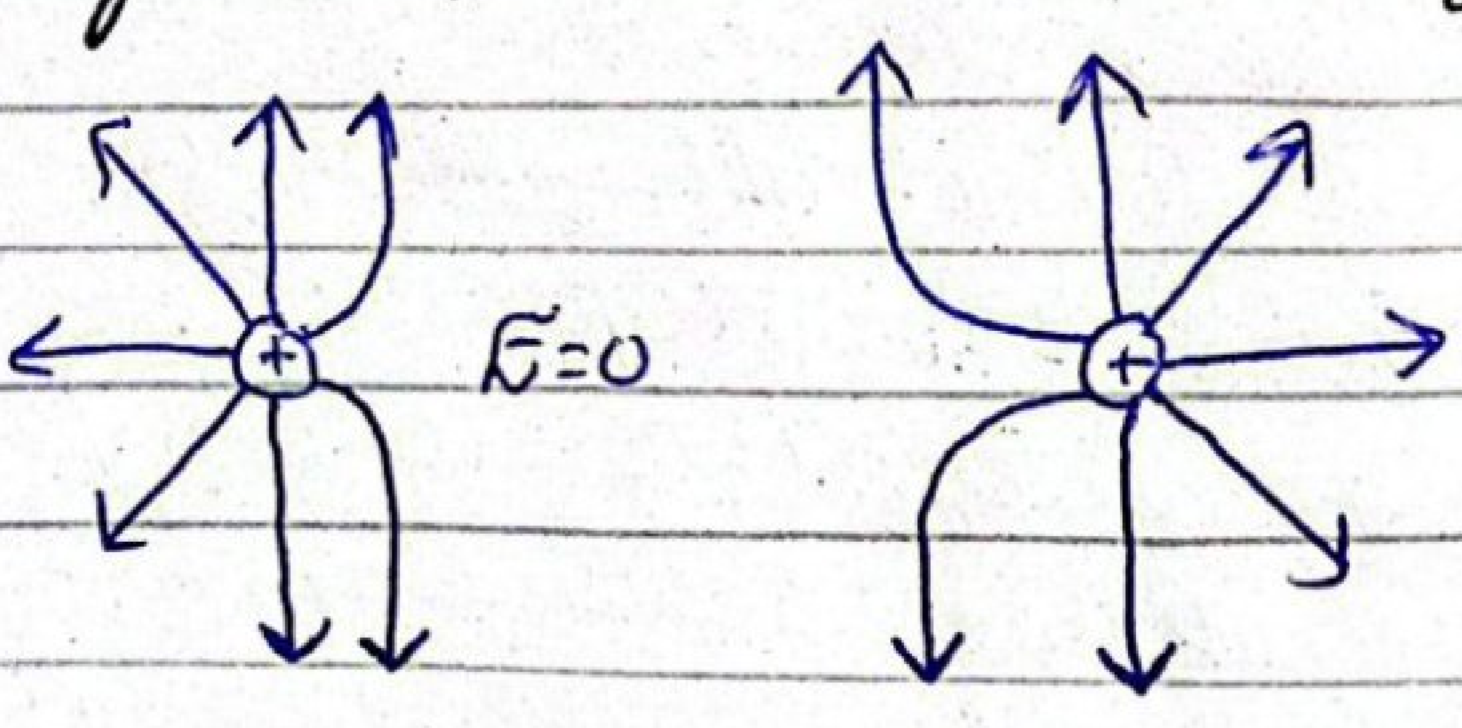


Electric field due to Electric dipole:-

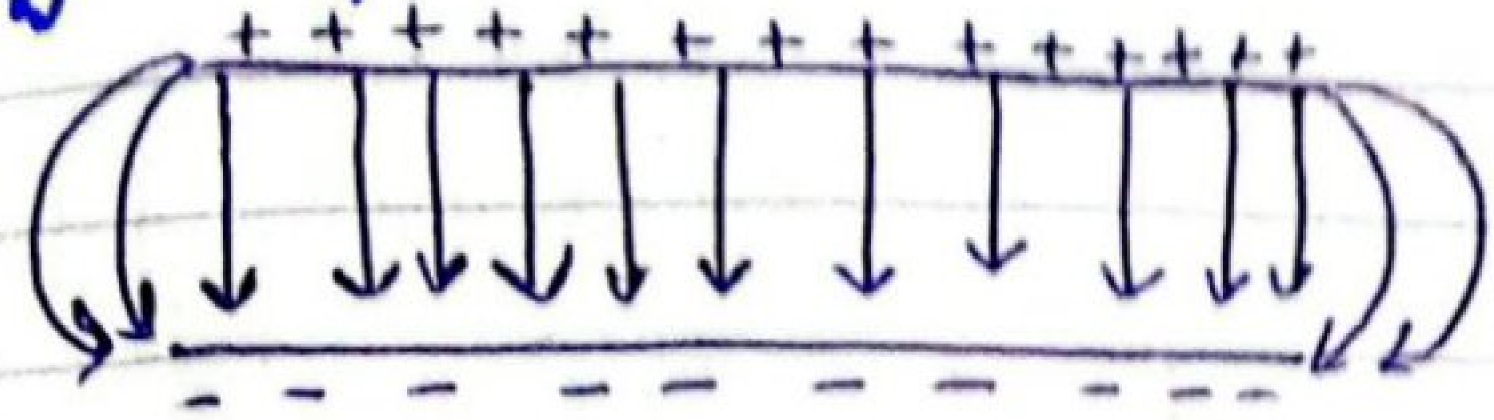
Two equal and opposite charges separated by a small distance from an electric dipole.



Electric field b/w two similar charges:-



Electric field lines b/w plates of capacitor:-



Electric field lines b/w the plates containing equal and opposite charges is uniform but electric field near the corners is not uniform because electric field lines are not straight and parallel there.
This electric field is called fringing electric field.

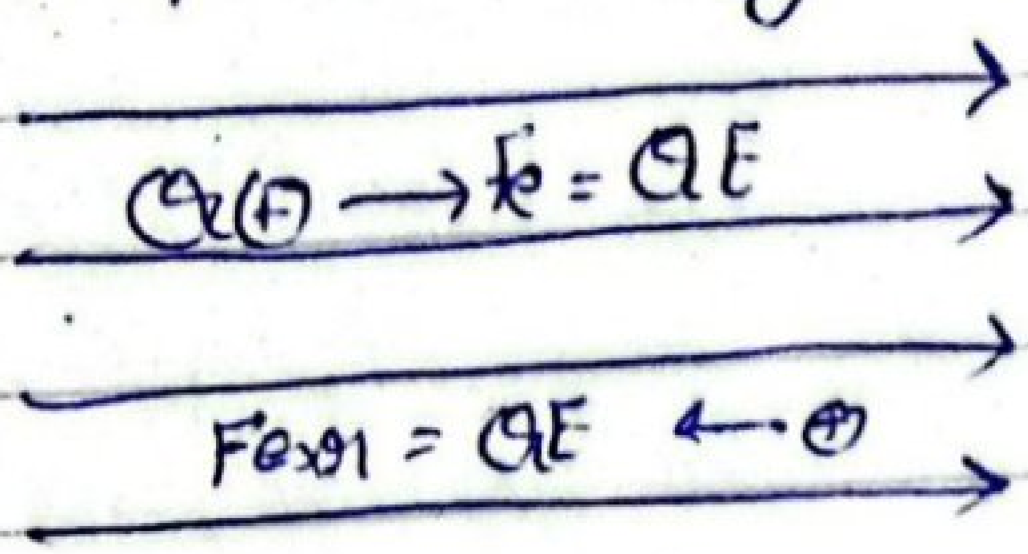
Motion of charged particle in an external electric field:-

→ A charged particle (+Q) placed in a uniform electric field (E) experiences a force.
$F = QE$.

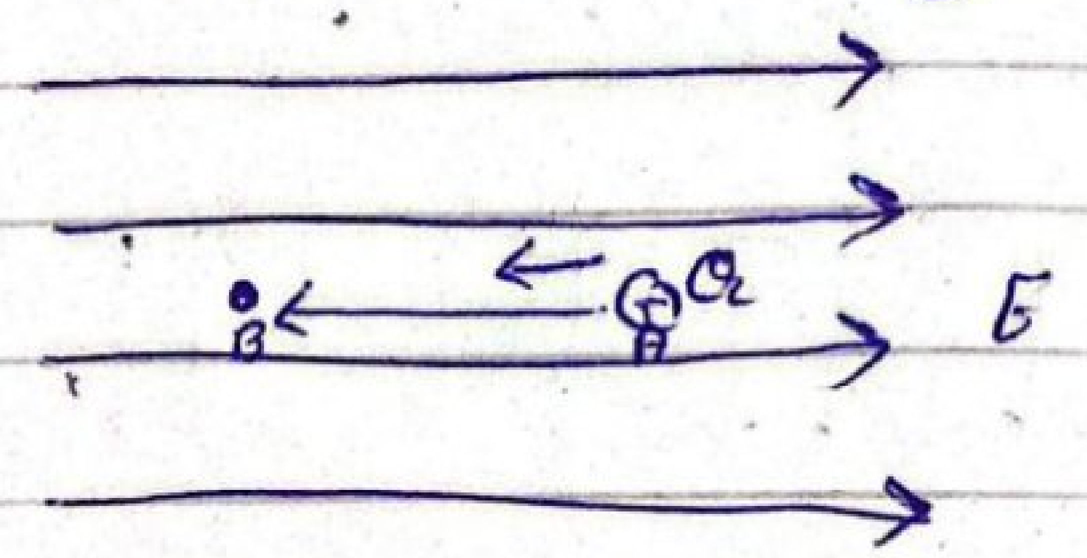
→ If the particle is free, it moves in the direction of electric field and its K.E increases.

→ To move the particle against the electric field, an external force must be applied.

→ The work done against the field is stored as electric potential energy in the particle.



Electric Potential Energy (U):-



When a charged particle is moved against the electric field from one point to another, we have to do work on the charged particle. This work is stored as electric P.E in the charged particle.

Properties:-

It is represented by "U".
Its SI unit is Joule (J).
It is a scalar quantity

Mathematically:-

By definition of Electric P.E;-
P.E = Work done against the field.

$U = \vec{F}\cdot\vec{S} = FS\cos\theta = FS\cos 0^\circ$

$U = qES$.

Electric Potential (V):-

Amount of work required to bring one Coulomb of charge from infinity (outside of field) to any point inside.
This field is called Electric Potential.
It is the energy possessed by one Coulomb of when it is placed at any point inside the field.

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Properties:-

→ It is represented by "V".
→ It is a Scalar quantity.
→ Its SI unit is JC^{-1} or Volt = V.

Formula:-

By definition of Electric Potential.

$$V = \frac{\text{Work done by external agent}}{\text{Charge}}$$

$$V = \frac{W}{Q}$$

Electric potential Energy (ΔV):-

Amount of energy gain or lost by one coulomb charge when it moves b/w two points inside the electric field.

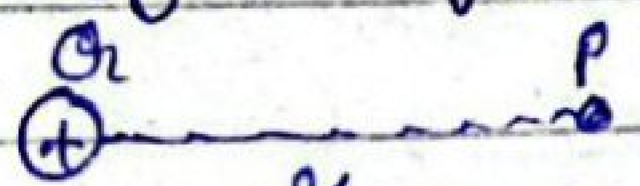
→ It is represented by "ΔV".
→ It is a Scalar quantity.
→ Its SI unit is JC^{-1} or Volt = V

Formula:-

$$\Delta V = \frac{W}{Q}.$$

Electric Potential due to a point Q:-

Electric Potential due to a point charge "Q" at a distance "r" from point charge "Q" is given by. $V = \frac{KQ}{r}$.



$$V_p = \frac{KQ}{r} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}.$$

What is Electron Volt (EV)?

Electron Volt is the unit of energy. when an electron moves b/w two points having a P. difference of "1 volt" then the amount of energy gained or lost by ē is equal to one electron volt (1ev).

Relationship b/w eV and Joule:-

We know that:

$$\Delta U = q\Delta V$$

$$\Delta U = (e)(1\ \text{volt}) \quad \because q = e$$

$$\Delta U = 1ev \qquad \Delta V = 1\ \text{volt}$$

$$\Delta U = (1 \times 1.6 \times 10^{-19} C)(J/C)$$

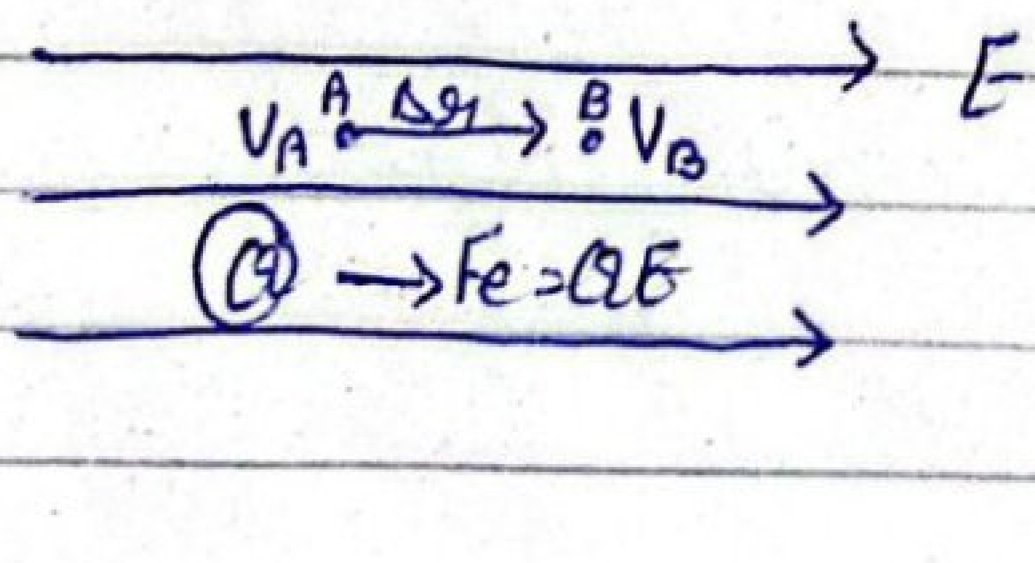
$$\Delta U = 1.6 \times 10^{-19} J$$

What do you meant by Potential Gradient? Show that $E = -\frac{\Delta V}{\Delta r}$?

Definition:-

Rate of change of Potential difference (ΔV) with respect to displacement (Δr) is called Potential gradient in an electric field. Potential Gradient is equal to the magnitude of electric field intensity.

Diagram:-



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Explanation:-

Suppose, Potential of point "A" is "V_A" and that of "B" is "V_B" such that $\Delta V = V_B - V_A$.
A charge "+Q" is allow to move from Point "A" toward point "B" through displacement $\vec{\Delta r}$.

Then, Work done on charge "Q" by field is

$$W = \vec{F} \cdot \vec{\Delta r}$$

$$W = F \Delta r \cos\theta = F\Delta r \cos 0° = F\Delta r$$

$$W = F\Delta r$$

$$W = QE\Delta r \quad \cdots \text{(A)}$$

But, work done by field on charge is equal to the decrease in Potential energy of charge.

i.e; $$W = -Q\Delta V \cdots \text{(B)}$$

Comparing (A) and (B).

$$-Q\Delta V = QE\Delta r.$$

$$-\Delta V = E\Delta r.$$

$$-\frac{\Delta V}{\Delta r} = E$$

$$E = \frac{-\Delta V}{\Delta r}.$$

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What is Faraday's Cage?

Any metallic enclosure does not allow any external electric field to enter into it. All charges remain at the external Surface of the enclosure. Any Person or object sitting inside the mettalic enclosure remains Safe from external electrical effects. This type of arrangement or metallic enclosure is Called Faraday's Cage because it was first Suggested by Faraday.

What are ferrofluids. Write Their Construction Properties and uses.

Definition:

Those fluids that become magnetized in the Presence of an external magnetic

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fields and spikes appears at the surface of fluids are called ferrofluids.

Composition:

Ferrofluids consist of water or oil with large number of small particles of ferro-magnetic materials such as iron of size less than 10 nm. These particles are so small that they can't be seen with naked eye and remain floating in the fluids homogenously.

Working:

When magnetic field is applied, these small particles become tiny magnets and arrange themselves in direction of external magnetic field and spikes are formed in ferrofluids.

Applications:

Ferrofluids are used in MRI machines, medical imaging, in loudspeakers and to carry medications in desired parts of the body.