

Electric Charge

classmate

Date _____

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Chapter - 19,

Electrostatics \rightarrow Electro (charge)
 \rightarrow Statics (rest)

* Electrostatics is the branch of physics that deals with the study of charge at rest, the force, electric field, the potential due to the charge.

* Electric charge :- Electric charge is the properties associated with matter due to which it produces an experiences electrical & magnetic effects.

- The concept of charge is due to the transfer of electron.

It is given by Benjamin Franklin

- There are two types of charge

① Positive charge :- It is deficiency of electron as compared to protons in an atoms.

② Negative charge :- It is excess of electron as compared to protons in an atoms.

\Rightarrow The S.I unit of charge is Coulomb (C) & C.G.S unit is stat. Coulomb / e.s.u / franklin.

$\Rightarrow 1 \text{ coulomb} = 3 \times 10^9 \text{ e.s.u}$

$1 \text{ faraday} = 96500 \text{ coulomb.}$

$$M_p = 1837 \text{ me}$$

* Dimension of charge

(I) Current : $\frac{\text{d}(q) \text{ charge}}{\text{d}(t) \text{ time}}$

$$\text{or } [A] = \frac{[Q]}{[t]}$$

$$\text{or } [Q] = [At],$$

Properties of charge :-

- ① Charge is the scalar quantity.
- ② Charge is transferable.
- ③ Like charges repel while unlike charges attract each other.
- ④ Charge at rest produces electric field, At uniform motion produces electric field & magnetic field, At non-uniform motion electric field & magnetic field & electromagnetic radiation.
- ⑤ Charge is always conserved.
- ⑥ Quantization of charge :-

It is stated that "The total amount of charge on any objects is integral multiple of an electronic charge."

Mathematically,

$$q = \pm ne \text{ where, } n = (\text{the integers for ex } 1, 2, 3, \dots)$$

& e = magnitude of charge electron (1.6×10^{-19} Coulomb)

- ⑦ Charge is always associated with mass
mass of 1 charge $M_e = 9 \times 10^{-31}$ kg.

Q Which of the charge isn't possible.

Ⓐ $1.6 \times 10^{-19} C$

Ⓑ $1.6 \times 10^{-18} C$

$$q = \pm ne$$

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

$n=1$ ✓ possible

$$q = \pm ne$$

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

$n=10$ ✓ possible

Ⓒ $1.6 \times 10^{-21} C$

Solve

$$q = \pm ne$$

$$1.6 \times 10^{-21} = \pm n \times 1.6 \times 10^{-19}$$

$n=0.01$ Impossible X

\Rightarrow Charging / Electrification

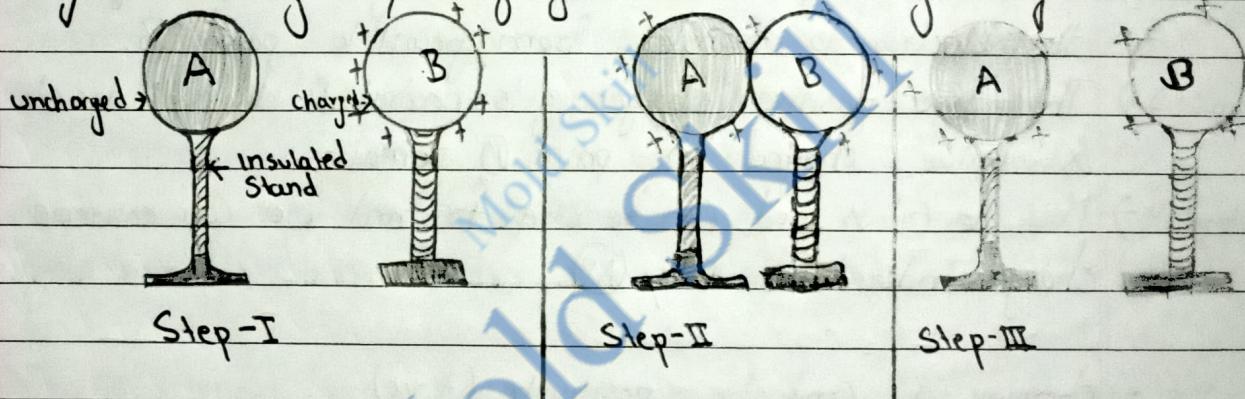
It is the process in which charge is developed in any neutral body.

- This process can be done by 3 ways:

① Charging by friction:- In friction when two bodies are rubbed then the electron transfer or electron from one body to another

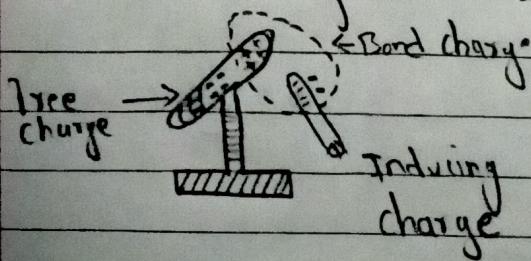
- The body having low value of work function becomes positively charged while body having high value of work function becomes negatively charged.

② Charging by Contact :- It is the process in which an uncharged body is charged by bringing contact with charged body.

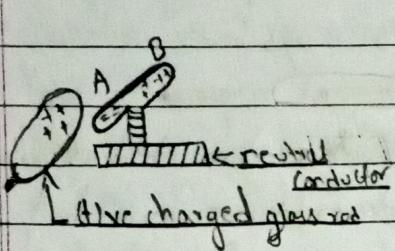


\Rightarrow Let us consider two body A & B in isolated location where A is uncharged & B is positively charged. To prove charging by contact let's make contact between A & B as shown in the figure (Step-II) after all if we separate both from physical contact we can observe that now, both are positively charged with equal value.

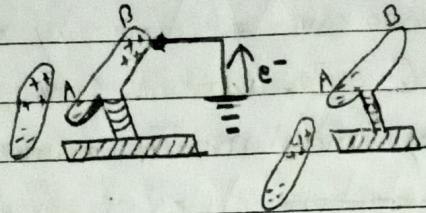
③ Charging by Induction:- It is the process in which an uncharged object is charged with opposite charge without any actual contact.



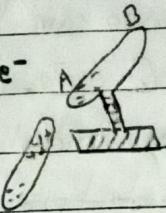
- charging a conductor ^{Negatively} ~~positively~~. (-ve)



Step:-1



Step:-2



Step:-3



Step:-4

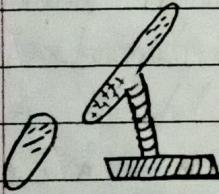
Step:-1 \Rightarrow Take a positively charged glass rod and bring it near a conducting material isolated from the earth. (AB). After that, Point A of the body acquires ^{bnd} negatively charged & end of point B acquired free positive charge.

Step:-2 \Rightarrow The end of point B needs to be grounded (earthing) which tends the electron to transfer from ground to point B.

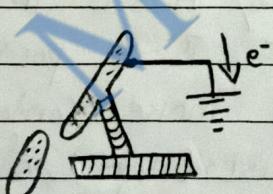
Step:-3 \Rightarrow The free positive charge gets neutral & disappear due to electron. & Induce charged in point A remains.

Step:-4 \Rightarrow Now, the Glass rod can be kept far and we can experience negative charge induced in Body (AB).

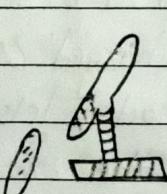
- charging a conductor positively (+ve)



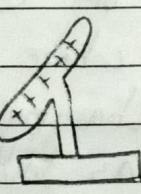
Step:-1



Step:-2

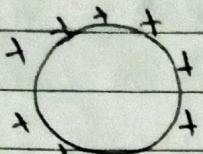


Step:-3



Step:-4

Distribution of charge:- One of the main properties of the charge is that it reside (stay) on the outer surface of a charged conductor. This is due to fact that the charges on a conductor always tries to minimize the force of repulsion. It is only possible at the farthest distance (i.e. outer surface)



uniform distribution of charge.

Charge density. It is the accumulation of charge on a particular surface of a conductor. There are three types of charge density.

i) Linear charge density :- (λ) It is the total number of charge per unit by length. It means $\lambda = \frac{q \text{ (coulomb)}}{l \text{ (length)}} = \text{C/m}$

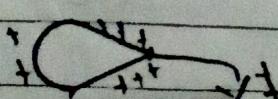
ii) Surface charge density (σ) : It is the total number of charge per unit by surface area $\sigma = \frac{q \text{ (coulomb)}}{A \text{ (Area)}} = \text{C/m}^2$

iii) Volume charge density (s) : It is the total number of charge per unit by volume $s = \frac{q \text{ (coulomb)}}{V \text{ (Volume)}} = \text{C/m}^3$

Action of points :-

$$\text{For spherical conductor: } \sigma = \frac{q}{A} = \frac{4\pi r^2 s}{4\pi r^2} = s$$

From eqn ① $\sigma \propto r^2$:- More charge is concentrated at the pointed end of a charged conductor. because of having small value of radius of curvature. the charged is leaked from the pointed ends as a result. the action of losing of charge from a pointed end of a charged conductor is known as action of point.



leaving of charge ↗

Non-uniform distribution of charge action point.

Coulomb's law :- It state that the force of attraction or repulsion between any two test charged Separated at a finite distance is

- directly proportion to the product of the charges

$$F \propto q_1 q_2 \quad (i)$$

- Inversely proportion to the square of between the distance of charges $F \propto \frac{q_1 q_2}{r^2} \quad (ii)$

Combining eqn (i) & (ii)

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

or, $F = k \frac{q_1 q_2}{r^2}$, where k is constant (Coulomb's constant) (iii)

Effect of medium

(i) For air / vacuum

from eqn (iii)

$$F = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2} \quad \text{where } \epsilon_{\text{not}} \text{ is the permittivity of air/vacuum which is } 8.85 \times 10^{-12} \text{ N}^{-1}\text{m}^{-2}\text{C}^2$$

$$\text{then, } \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2} \quad \text{therefore, } F_{\text{air}} = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2} \quad (iv)$$

(ii) For any medium

$$F_{\text{medium}} = \frac{1}{4\pi\epsilon} \times \frac{q_1 q_2}{r^2} \quad \text{where } \epsilon \text{ is the permittivity of medium}$$

The relative permittivity of a medium (ϵ_r) of a medium is defined as the ratio of permittivity of medium to the permittivity of air.

It is also known as dielectric constant (κ)

$$\epsilon_r = \frac{\epsilon}{\epsilon_0} = \kappa = \epsilon_0 \epsilon_r$$

$$\text{Then force becomes } F_{\text{medium}} = \frac{1}{4\pi\epsilon} \times \frac{q_1 q_2}{r^2} \quad (v)$$

Dividing eqn ① by iv.

$$\frac{F_{\text{medium}}}{F_{\text{air}}} \rightarrow \frac{1}{\epsilon_r}$$

$$\epsilon_r =$$

$$\frac{F_{\text{air}}}{F_{\text{medium}}}$$

The relative permittivity of a medium is also defined as the ratio of force

experienced by charge in air to the force experienced in a medium.

The value of ϵ_{medium} (ϵ_r/κ) is 1 for air & 80 for water.

Superposition Principle:- It states that "The force experienced by a given charge is the vector sum of the forces exerted on it due to all the other charges that is

$$\vec{F}_0 = \vec{F}_{01} + \vec{F}_{02} + \vec{F}_{03} + \dots + \vec{F}_{0n} \text{ where,}$$

\vec{F}_0 is the force experienced by q_0 .

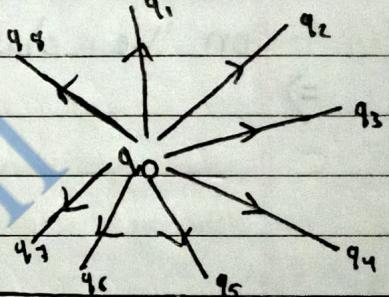
If there is 'n' of charges, $\vec{F}_0 = \vec{F}_{01} + \vec{F}_{02} + \dots + \vec{F}_{0n}$

\Rightarrow If there are two vectors \vec{A} & \vec{B}

Inclined at angle θ then resultant $\vec{R} = \sqrt{\vec{A}^2 + \vec{B}^2 + 2\vec{A}\vec{B} \cdot \cos\theta}$

Forces

experienced by q_0
due to q_i



of less than 10^{-15} m

only valid for \propto inverse square.

Concept Based problems.

9.20

b) Define quantization of charge?

\Rightarrow The total number of charge on any object is integral multiple of an electronic charge.

c) Can a body have a charge less than 1.6×10^{-19} C?

\Rightarrow Yes, A body can have a charge less than 1.6×10^{-19} because there

(c) When an object is rubbed with another object the charge developed on the object is 32 μ C. Calculate the no. of electron transferred.

\Rightarrow

Here,

$$\text{charge developed } Q = 32 \mu\text{C} = 32 \times 10^{-6} \text{ C}$$

$$\text{Magnitude of charge (e)} = 1.6 \times 10^{-19}$$

$$\text{no. of electron (n)} = ?$$

From quantization of charge $Q = \pm ne$,

$$\text{or } 32 \times 10^{-6} = \pm n \times 1.6 \times 10^{-19}$$

$$\text{or } \frac{32 \times 10^{-6}}{1.6 \times 10^{-19}} = \pm n$$

$$\text{or, } 2 \times 10^{13} = n$$

$$\therefore n = 2 \times 10^{14},$$

9.21 (a) Write down the different method of charging a body?

\Rightarrow Some method of charging a body are:-

i) By friction

ii) By physical Contact

iii) By Induction

(b) Repulsion is sure test for testing the electric charge. Explain.

⇒ Repulsion is sure test for testing the electric charge because repulsion can be observed only when two bodies have like charge & which assure that body is charged.

Q. What are the differences between the method of charging by conduction & induction.

⇒ The differences between method of charging by conduction & induction :-

<u>Conduction</u>	<u>Induction</u>
I For the electrification bodies should must be in physical contact	For the electrification bodies aren't kept in physical contact
II Like charge are taken to e can't be experienced	Like charge isn't possible in both bodies, for ex:- Positive body should be taken to charge body negative.
III Amount of charges decreases due to distribution of charge	Amount of charge remain constant.

Q. Distinguish between bounded charge & free charge.

⇒ The differences between bounded charge & free charge.

<u>Comparison</u>	<u>Bounded charge</u>	<u>Free charge</u>
Definition	The charge which are induced in a body closed to the inducing in the body far from the inducing charge are called bounded charge.	The charges which are induced in the body far from the inducing charge are called free charge.
Energy.	Energy possed by a bounded charge are both potential & kinetic energy.	Energy possed by a free charge is kinetic energy.

(b) How should you charge a body positively by the method of induction
 \Rightarrow we can charge a body positively by the method of induction
 by inducing negatively charged body to another conductor.

19.23 @ Define Linear Charge density, Surface charge density & Volume charge density.

\Rightarrow Linear charge density (λ): It is the quantity of charge per unit by length $\lambda = \frac{q}{l} = \text{Cm}^{-1}$

Surface charge density (σ): It is the quantity of charge per unit by Surface area $\sigma = \frac{q}{A} = \text{Cm}^{-2}$

Volume charge density (ρ): It is the quantity of charge per unit by Volume by Volume $S = \frac{q}{V^3} = \text{Cm}^{-3}$.

(c) why pointed end are avoided in electrical machine?

\Rightarrow Pointed end are avoided in a electrical machine because more electric charge is concentrated at the corner (point) which have small value of radius of curvature since $R \propto r^2$,

19.24 @ Define Surface density & and write down its unit

\Rightarrow Surface density α is the quantity of charge per unit by Surface area. its unit $\alpha = \frac{q}{A} = \text{Cm}^{-2}$,

(d) More charge can be stored on metal if it is highly polished
 Then when its Surface is rough?

\Rightarrow As we know chance of leakage of charges (Action of point) is highly at Sharp edge & there are number of Sharp edge on rough Surface but if metal is highly polished it doesn't have sharp edge to leak charge. Hence more charge can be stored on metal if it is highly polished.

(c) Define the term action of point.

⇒ The point from which charge can easily leak from the conductor due to high concentration of electric charge is called action of point. It basically occurs at sharp edges.

19.25 (d) State Coulomb's law in electrostatics.

⇒ Coulomb's law state that the force of attraction or repulsion between two charged separated at a fine distance is directly proportional to product of their charges & inversely proportional to the square of the distance of charges.

(e) Differentiate between electrostatic force & gravitational force.

⇒ Differences between electrostatic force & gravitational force.

Comparison	Electrostatic Force	Gravitational Force.
Statement	The force of attraction or repulsion between two charges separated at a fine distance is directly proportional to product of their charges & inversely proportional to the square of their distances.	The force of attraction of any two bodies having mass is directly proportional to the product of their masses & inversely proportional to the square of the distances between their centre.
Constant	Electrostatic force depends upon as Coulomb's constant $\frac{1}{4\pi\epsilon_0}$	Gravitational force depends on Gravitational Constant $G = 6.67 \times 10^{-11}$.
Unit	The unit of Electrostatic force is N.	The unit of Gravitational force.