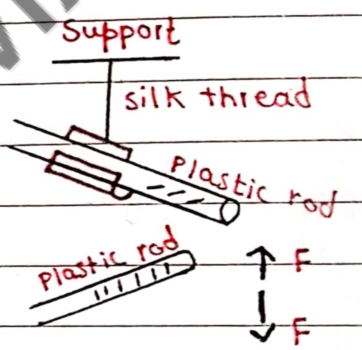
CHAPTER 13

ELECTCROSTATICS

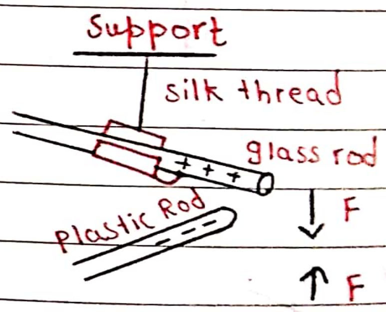
Production of Electric Charges

1. Take a plastic rod. Rub it with fur. Suspend it horizontally by a silk thread. Take another rod. Rub it with fur and bring it near to the first rod.



Conclusion:
Both rods are of same material and both are rubbed with same material so it means both have same charges and will repel each other.

2. Take a glass rod. Rub it with silk cloth and suspend it horizontally with silk thread. Take another rod made of plastic. Rub it with fur and bring it close to first rod.



Conclusion:
Both rods are made and rubbed with different material. That's why they have opposite charges and attract each other.

Electrostatic Induction

→ Whenever a charged body is brought close to an insulator conductor, the near end of conductor develops unlike charges while the far end of conductor develops like charges. This separation of charges is called electrostatic induction.

→ Separation of charges on body due to bringing charged rod near it is called electrostatic Induction

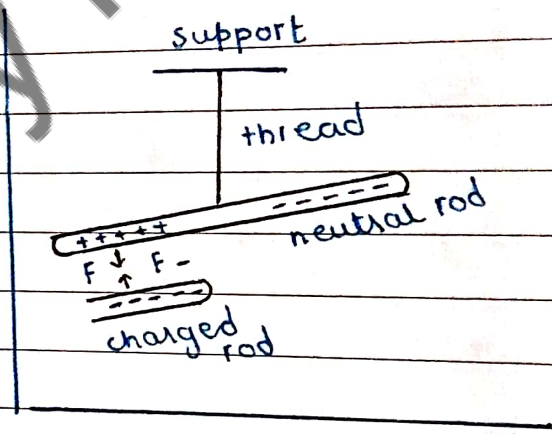
Example

* Bring a charged plastic rod near suspended neutral rod.

* The like charges will repel and develop on far end.

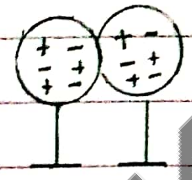
* The unlike charges will attract and develop on near end.

* Charges have been separated due to electrostatic induction



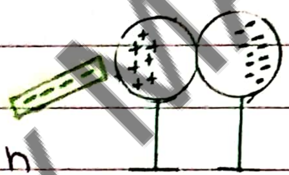
Charging By Induction

1. Bring two metal spheres and fix them on insulated stands such that they touch each other.



1

2. Bring a -ively charged rod near it. +ive charges will appear on near end due to force of attraction while -ive charges will appear on far end due force of repulsion.



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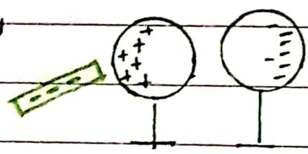
3. Without removing the rod, separate the spheres.



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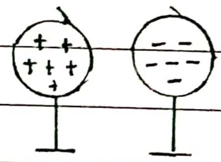
4. Charges are uniformly distributed. Equal and opposite charges appear on each sphere.



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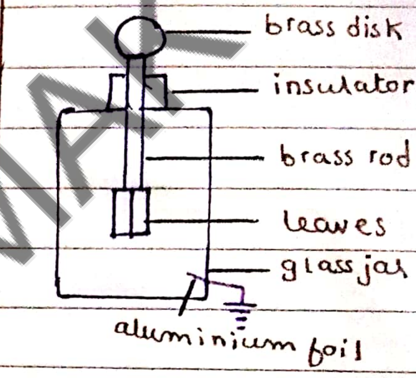
Electroscope

The gold leaf electroscope is a sensitive instrument for detecting charges.

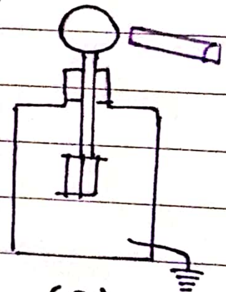
Construction

Electroscope consists of • brass rod • brass disk at the top and • 2 gold leaves suspended at its lower part. This whole assembly is fixed with the help of insulator in a glass jar.
A thin Al foil is attached on the lower portion inside the jar. It is grounded by connective Cu wire. It protects the leaves from external electrical disturbances.

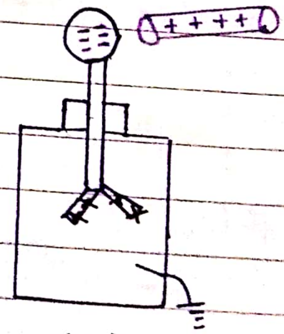


Detecting the presence of charge

(a) Take uncharged electroscope and bring a body near the disk. If there is no deflection of the leaves it means body is neutral.


(a)

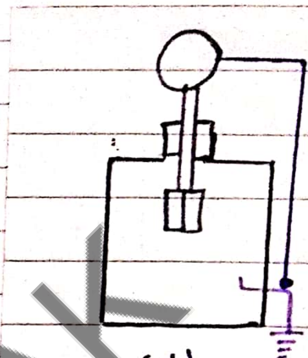
(b) Take uncharged electroscope and bring charged rod near the disk. The disk will develop unlike charges and like charges will move to the leaves. As the leaves have same charges it will repel and show divergence. This means body is charged.



(b)

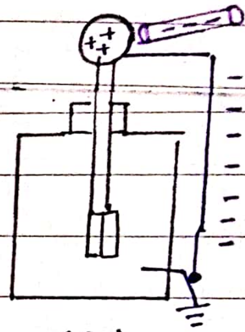
Charging Electroscop by Electrostatic Induction

(1) Take uncharged electroscope. Connect the diske to the ground with conducting wire



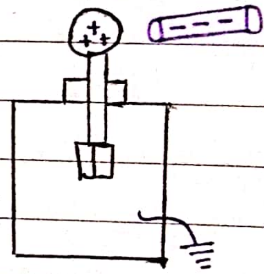
(1)

(2) Bring a -ively charged rod near the disk. The disk will develop unlike charge (+) and like charges i.e (−) will move to the ground through the conducting wire.



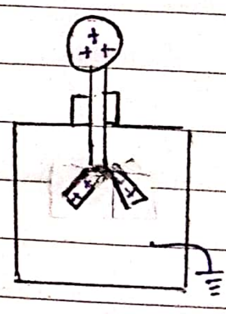
(2)

(3) Keeping the -ively charged rod near the disk. Disconnect the conducting wire.



(3)

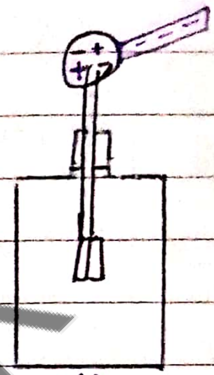
(4) Some of +ive charges will move to the leaves due to Repulsion and the leaves will diverge.



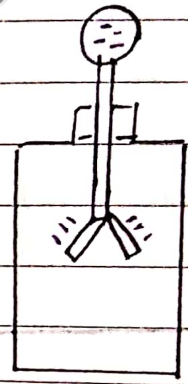
(4)

Conclusion: Electroscope has same charges on disk and leaves.

Charging By Conduction



(1)

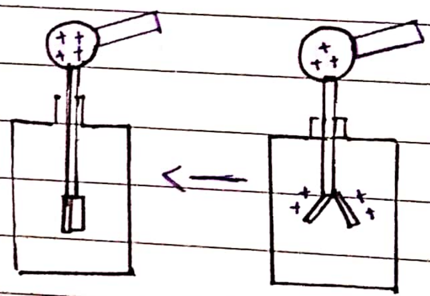


(2)

1. Take a neutral disk of electroscope and touch a -ively rod with it.

2. Negative charges will transfer to electroscope and cause its to diverge.

Identifying Conductors and Insulator

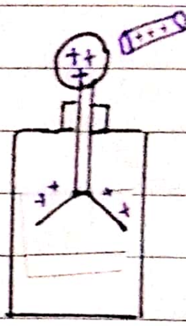


- Touch the disk of electroscope with material (charged electroscope). If the leaves collapse from their diverged position, the body would be good conductor.

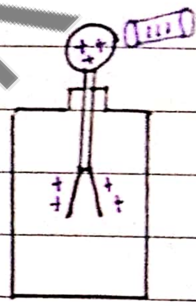
—> divergence may increase or may decrease.

- If there is no change in the divergence, it means body is insulator.

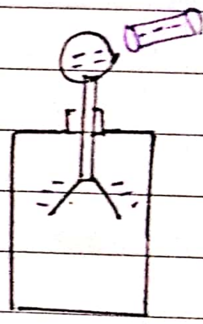
Detecting the Type of Charge



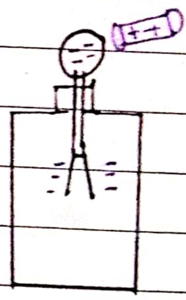
Take a positively charged electroscope. Bring a charged rod near the disk. The like charges will repel and move to the leaves. The divergence of leaves increase, it mean rod is +ive.



Take a +ively charged electroscope. Bring a charged rod near the disk. The +ive charges will move from the leaves to the disk. The divergence will decrease, it means body is -ive.



Take a negatively charged electroscope. Bring a charged body near it. The like charges will repel and move to the leaves. The divergence of leaves will increase. It means body has -ively charges.



Take a -ively charged electroscope. Bring a charged rod near it. The -ive charges will move from leaves to the disk. The divergence will decrease. It means body has +ive charge.

Coulomb's Law

Statement:

"The force of attraction or repulsion b/w 2 point charges is directly proportional to the product of 2 charges (magnitude) and inversely proportional to the square of distance b/w them.

Mathematical Explanation:

$F \propto q_1 q_2$

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

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

Unit of k :-

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

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

$k = \frac{Nm^2}{C^2} \Rightarrow Nm^2C^{-2}$

F = F b/w the 2 charges (coulomb's Force)
$q_1 q_2$ = magnitude of 2 charges
r = distance b/w the 2 charges.
k = proportionality constant.

Unit of ε_0 :-

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

$\varepsilon_0 = 1/4\pi k$

$\frac{\varepsilon_0}{k} = 1/Nm^2C^{-2} \Rightarrow C^2N^{-1}m^{-2}$

Value of k

depends upon the medium b/w 2 charges.

value of k in air $9 \times 10^9\ Nm^2C^{-2}$

Point Charges

The charges whose size is small as compared to the distance b/w them.

~ Coulomb's Force is strong Force ~

Force between the Masses	Force between the charges
Statement	
Force is directly proportional to the product of masses and inversely proportional to square of their distance	Force is directly proportional to the product of 2 charges and inversely to the square of their distance.
Mathematical Form	
$F = G \frac{m_1 m_2}{r^2}$	$F = K \frac{q_1 q_2}{r^2}$
Constant	
'G' gravitational constant	'K' coulom's constant.
Value of Constant	
$G = 6.673 \times 10^{-11} Nm^2 Kg^{-2}$	$K = 9 \times 10^9 Nm^2 C^{-2}$
→ weak force	→ strong force
$F_m < F_c$	$F_c > F_m$

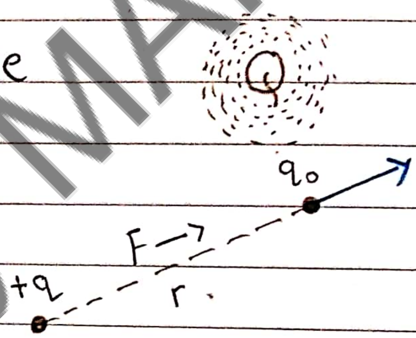
~ Electric Field ~

Statement

"Electric field is a region around a charge in which it applies electrostatic force on other charges."

Explanation

Let a charge q and its effective area is indicated by dots
q_0 = test +ive charge



When q_0 comes in the area (region) of q, it will be repelled by q

Result

The value of repulsive force depends upon the distance b/w 2 charges.

~ Electric Field Intensity ~

Electric Force can also be written as:

$$Eq = F$$ (coulomb's F in terms of 'E')

Important Features

1- SI unit of electric intensity is NC^{-1}
2- electric intensity being a force is a vector quantity
3- It's direction is the same as that of the force.
4- If the test charge is free to move it will always move in the direction of electric intensity.

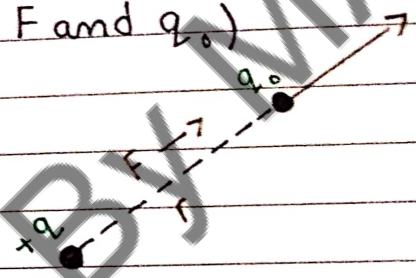
Electric Field Intensity

Statement

The electric field intensity at any point is defined as the force acting on a unit positive charge placed at that point

Mathematical Form

$$E = \frac{F}{q_o} \quad \text{(E in terms of F and } q_o\text{)}$$



$$E = F \div q_o$$

$$E = \frac{Kq_oQ}{r^2} \div \frac{q_o}{1}$$

$$E = \frac{Kq_oQ}{r^2} \times \frac{1}{q_o}$$

$$E = \frac{KQ}{r^2} \quad \text{(E in terms of Q and } r^2\text{)}$$

SI Unit

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

$$= \frac{N}{C}$$

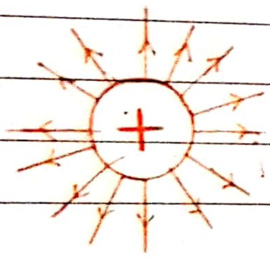
$$= NC^{-1}$$

Direction

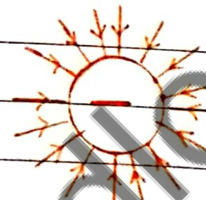
'E' is a vector quantity. Electric Field Intensity has same direction the electric force.

Electric Field Lines

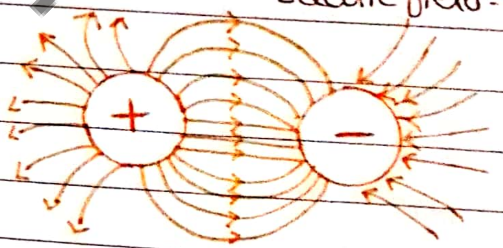
* The direction of 'Electric field Intensity' in electric field can be represented by drawing lines.
* The field lines are imaginary lines.
* These lines were introduced by Michael Faraday.
* Field lines are always directed from +ive charge towards -ive charge.



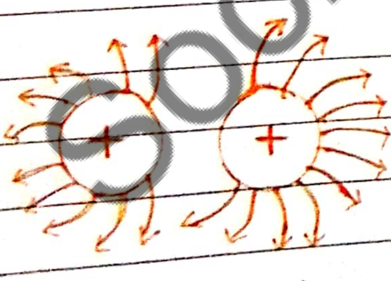
Electric Field Lines for +ive charge is outward.



Electric Field lines for -ive charge is inward

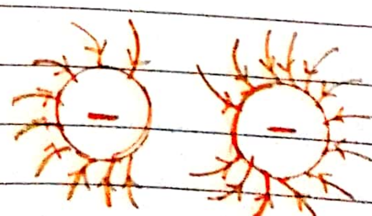


2 opposite charges attract each other.



2 +ive charges repel each other.

Electric Field = 0



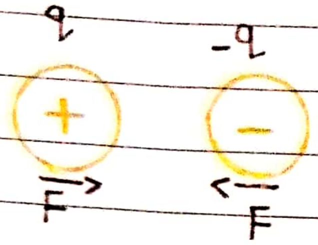
2 -ive charges repel each other

Electric Field = 0

* If space is more, electric field is weak.
* If space is less, electric field is strong.

$$\text{Spacing} \propto \frac{1}{\text{value of electric field}}$$

Variation of Magnitude of Coulomb's Force



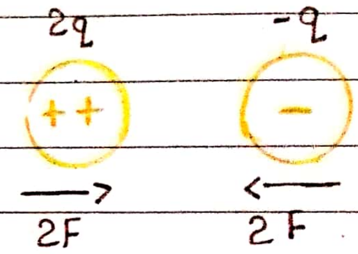
$q_1 = q$

$q_2 = -q$

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

$F' = \frac{-K q q}{r^2}$

$F' = -F$



$q_1 = 2q$

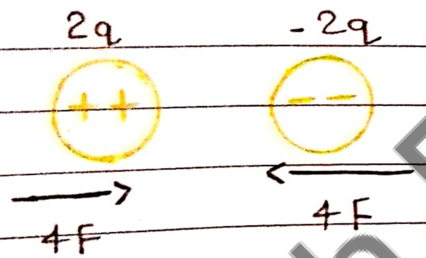
$q_2 = -q$

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

$F' = \frac{K(2q)(-q)}{r^2}$

$F' = \frac{-2Kqq}{r^2}$

$F' = -2F$



$q_1 = 2q$

$q_2 = -2q$

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

$F' = \frac{K(2q)(-2q)}{r^2}$

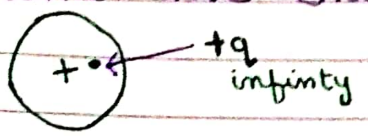
$F' = \frac{-4Kqq}{r^2}$

$F' = -4F$

Electrostatic Potential

Statement:

"Electric potential at a point in an electric field is equal to the amount of work done in bringing a unit +ive charge from infinity to that point."



Mathematical Explanation

If W is the work done in moving a +ive charge q from infinity to a certain point in the field, the 'V' at this point would be given by : $V = \frac{W}{q}$

Important Features

* Electric Potential is measure relative to some reference point.
* Electric Potential is a scalar quantity.
* Electric Potential is denoted by 'V'.

SI Unit

Its SI Unit is 'volt' which is equal to JC^{-1}

$$V = \frac{W}{q} = \frac{J}{C} = JC^{-1}$$

Other units

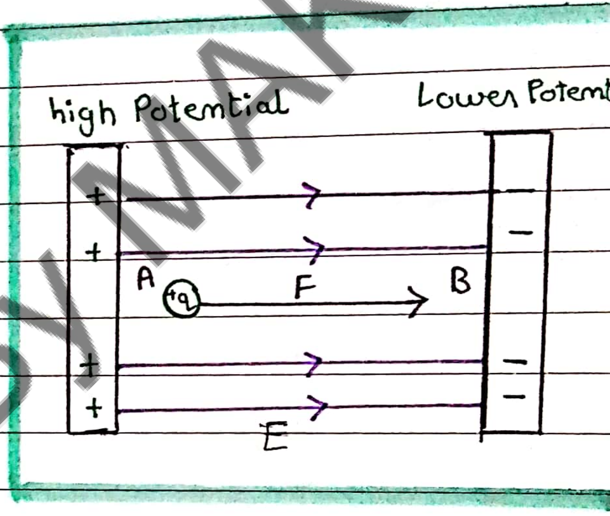
* $V = \frac{W}{q} = \frac{F \cdot d}{C} = \frac{Nm}{C} = NmC^{-1}$
* $V = \frac{W}{q} = \frac{F \cdot d}{C} = \frac{ma \cdot d}{C} = \frac{Kg\,ms^{-2} \cdot m}{C} = kg\,m^2 s^{-2} C^{-1}$

One Volt

"If one Joule of work is done against the electric field in bringing one coulomb +ive charge from infinity to a point in the electric field then the potential energy at that point will be one volt. $1V = \frac{1J}{1C}$

Explanation

When a charge is released in an electric field, it moves from a point of higher potential to a point at lower potential.



- A and B are 2 plates.
- One is +tively charged and other is -ively charged.
- Plate A is at higher potential.
- Plate B is at lower potential.

E = Electric field between plates.

Let 'a' and 'b' be the 2 points b/w the plates

V_a = Electric Potential at point a

V_b = Electric Potential at point b

According to definition

$V_a = \frac{W_a}{q}$ OR $qV_a = W_a = U_a$ = Electric Potential Energy at a

$V_b = \frac{W_b}{q}$ OR $qV_b = W_b = U_b$ = Electric Potential Energy at b

Electric Potential Difference

" The energy supplied by a unit charge as it moves from one point to other in the direction of the field is called potential difference between two points.

Electric Potential can be calculated as:

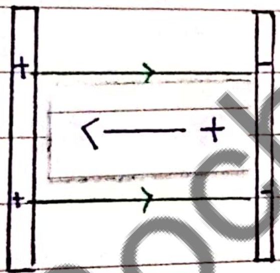
$$\Delta V = V_a - V_b$$

$$\Delta V = \frac{W_a}{q} - \frac{W_b}{q}$$

$$q\Delta V = W_a - W_b$$

$$q(V_a - V_b) = \Delta W = \Delta U$$

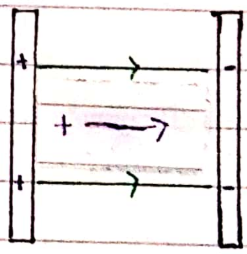
When +q move Against Electric Field



* Charge will not move by itself because we want to move against Electric field.

* We will provide energy against repulsive force that store as Electric Potential Energy.

When +q move in the direction of Electric Field



* It acquires Kinetic Energy.

* Charge will do work for us.

Capacitor

It is a device used to store electrical charge.

Explanation

1. +Q charge is transferred by the +ive terminal of the battery.
2. -Q charge is transferred by -ive terminal of the battery.
3. Charges are attached due to electrostatic force of attraction thus remain bounded.

Result

In this way, charges are stored in a capacitor for a long time.

Mathematical Explanation

The charge Q stored in plates is directly proportional to potential difference.

$$Q \propto V$$

$$Q = CV$$

Capacitance

* C is proportionality constant called 'capacitance of a capacitor'
* Capacitance is defined as ' the ability of a capacitor to store the charge.
* It is given by the ratio of charge and electric potential.

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

SI Unit

→ SI Unit of capacitance is Farad (F). It can be defined as:

(1) When 1 Volt potential is applied to the plate of a capacitor and 1 Coulomb charge is stored on the capacitor then the capacitance will be 1 Farad.

(2) When 1 Coulomb charge is stored b/w the parallel plates of a capacitor and 1 volt potential established across the plates then the capacitance of a capacitor will be 1 Farad.

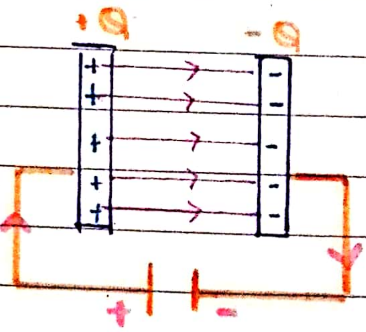
$$C = \frac{Q}{V} \qquad 1F = \frac{1C}{1V}$$

Smaller units of capacitance

* microfarad = μF = 10^{-6} F
* nano farad = nF = 10^{-9} F
* pico farad = pF = 10^{-12} F

The ratio of a charge to applied potential is called capacitance

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



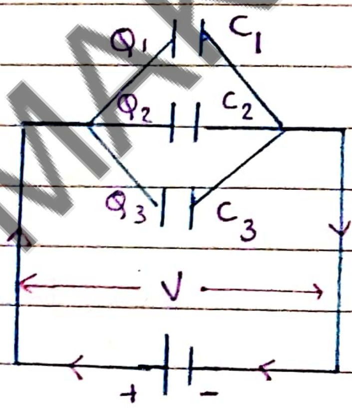
Due to accumalation of charges on the ∥ plates of capacitor, potential will develop b/w plates of capacitor known as built in potential.

Charge accumalation on plate is known as applied potential

Combination of Capacitors

Combination of capacitor are of 2 types:
1. Parallel capacitor combination
2. capacitors in series.

Capacitor in parallel



* The left plate of each capacitor is connected to +ive terminal of the battery.
* The right plate of each capacitor is connected to -ive terminal of the battery.

Characteristics of parallel capacitors

1. Each capacitor has the same potential difference.
   $V_1 = V_2 = V_3 = V$

2. The charge developed across the plates will be different.

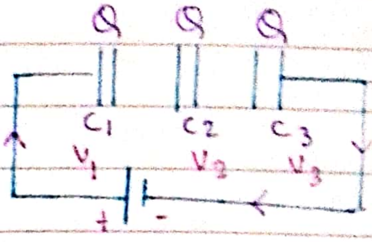
3. The total charge Q supplied by the battery:
   $Q = Q_1 + Q_2 + Q_3$
   $Q = C_1 V + C_2 V + C_3 V$
   $Q = V(C_1 + C_2 + C_3)$
   $\frac{Q}{V} = C_1 + C_2 + C_3$.

4. Equivalent capacitance can be written as:
   $C_{eq} = C_1 + C_2 + C_3$

5. If n-capacitance are connected in parallel then C_{eq} can be determined as: $C_{eq} = C_1 + C_2 + C_3 + \dots C_n$
   $C_{eq} = \sum_{r=1}^{n} C_r$

Capacitor in Series

* In this combination, the capacitors are connected side by side.



Characteristics of Series Combination

* Each capacitor has the same charge across it.

$$Q_1 = Q_2 = Q_3 = Q$$

* The potential difference across each capacitor is different.

* The voltage of the battery has been divided. Hence,

$$V = V_1 + V_2 + V_3$$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

* Equivalant capacitance can be written as:

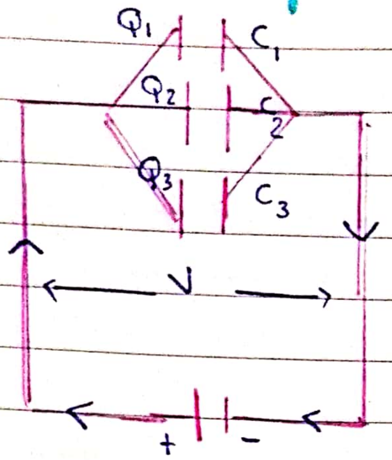
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

* If n-capacitor are connected in series then $\frac{1}{C_{eq}}$ can be determined as:

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

$$\frac{1}{C_{eq}} = \sum_{r=1}^{n} \frac{1}{C_r}$$

Parallel Capacitor



- There are many paths for the flow of charge.

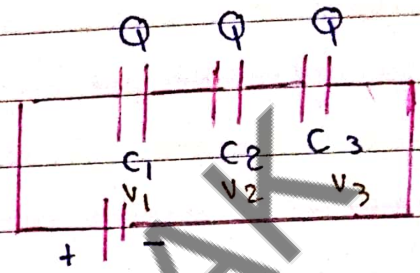
- Each capacitor has same potential difference

$V_1 = V_2 = V_3 = V$

- Each capacitor has different charge.

$Q = Q_1 + Q_2 + Q_3$

Series capacitor



- There is only one path for the flow of charge

- Potential difference across each capacitor is different

$V = V_1 + V_2 + V_3$

- Each capacitor has same charge.

$Q_1 = Q_2 = Q_3 = Q$

Electric Potential (V)

Electric potential is the amount of work done in moving a unit charge from infinity to certain point.

Mathematically :-

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

SI Unit :-

Volt = J/C

Electric Potential Energy (U)

Electric potential energy is the product of charge times potential difference.

Mathematically :-

$$W = U = q\,\Delta V$$

SI Unit :-

Joule OR electron volt.

amount of energy required when a charged particle is moved against the direction of Electric Field.

Applications of electrostatics

Electrostatic Air Cleaner

Use : It is used to remove dust particles from air.

Air : Air is a mixture of dust and pollen.

WORKING

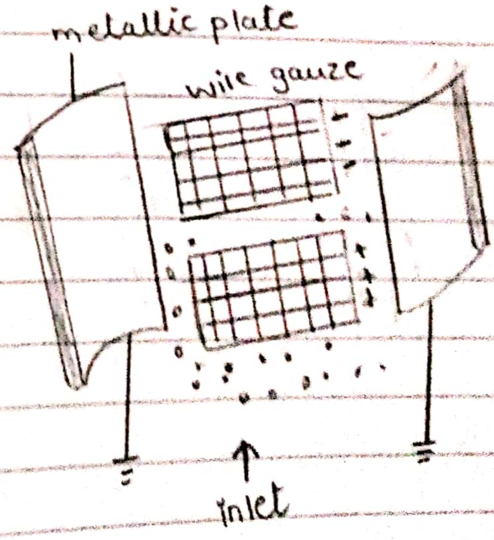
1- When the air pass through a +ively charged mesh, the airborne particles become +ively charged.

2- Then this air pass through -ively charged mesh.

3- All the +ively charged particles of dust deposited on the surface of -ively charged mesh due to force of attraction.

RESULT

Through this process we get clean air



(Spray Painting) Electrostatic Powder Painting

USE It is used to paint cars

WORKING

1- The body of the car is charged

2- The paint is oppositely charged by charging the nozzle of sprayer

3- Charged particles of paint is push out from nozzle in the form of fine mist

4- These charged particles are attracted by the oppositely charged car and uniformly distributed over the surface.

(Q.1)

What is dielectric ? Can we change its shape? why?
Dieletric is the medium (air OR sheet) between 2 plates which act as insulator.
The dielectric is made of flexible material so its shape can be changed to pack and use it in different devices and to increase the area of plate so the capacitor can fit into small space.

(Q.2)

Write the names of different types of capacitors, on which basis they are categorize ?
Capacitors are categorized on the basis of the nature of dielectric used in them and construction.

TYPES OF CAPACITORS

Fix Capacitors

* Paper capacitor
* Mica capacitor
* electrolytic capacitor

Variable Capacitors

* Tuning capacitor

~(Q.3)~

What are fixed capacitor ? write their important features.

Fixed capacitors

Fixed capacitors are those whose capacitance will not change.

Important Features

* During circuit operation, it cannot be changed
* The capacitance value will be constant.
* It's symbol is ⊣⊢

~(Q.4)~

How variable capacitor are different from fixed ?

Fixed Capacitors	Variable capacitors
It's capacitance cannot be changed	It's capacitance can be changed
Capacitance value is constant	capacitance value can b varied
It consists of 2 static plates	It consists of 2 plates; stat and rotatable.
The area and distance b/w the plates remain constant	The area and distance b/w the plates changes.

(Q.5)

How can we get variable capacitance?
In variable capacitor, arrangement is made to change the area of the plates facing each other. It consists of 2 plates. One is fixed and other is movable. The common area of plates which faces each other determines the value of capacitance. So, capacitance of the capacitor can be increased or decreased by turning the movable plates in or out of the space between the fixed plates.

(Q.6)

What is an electrolytic capacitor? What are its important features?

Electrolytic Capacitor

The capacitors which use chemical reactions to store charge are called electrolytic capacitors.

Important Features

* It stores a large amount of charge at relatively low voltages.
* It forms a thin layer of metal oxides which serve as 'dielectric'.
* It have high capacitance voltage.

It attains large capacitance

~(Q.7)~

Enlist the uses of capacitors.

USES OF CAPACITORS

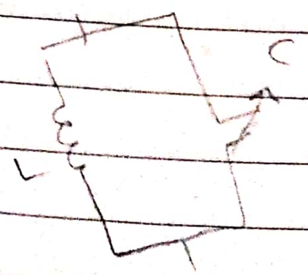
- They are used for tuning transmitters, receivers and transistor radios.
- They are used in table fans, ceiling fans, exchau fans, fan motors in air conditioners, coolers, motors washing machines, air conditioners, etc.
- They are also used in electronic circuits and computers.

~(Q.8)~

What is meant by tuning circuit?

TUNING CIRCUIT

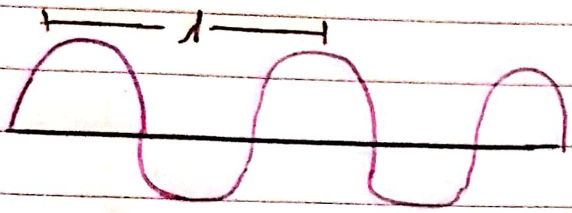
"Capacitors used in the resonant circuits that tune radios to particular frequencies. Such circuits are called tuning circuits"



(Q.9)

How low and high frequency signals are differentiated ?

Low Frequency Signal

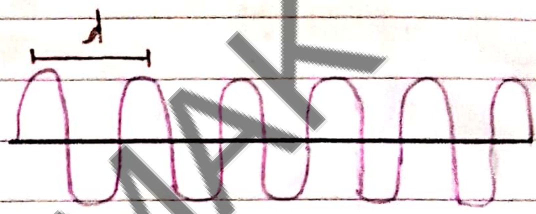


$\downarrow f = \frac{v}{\lambda \uparrow}$

→ If the λ is more, f will be less. This is called Low frequency signal.

→ Low frequency signal is not passed through the capacitor.

High Frequency Signal



$\uparrow f = \frac{v}{\lambda \downarrow}$

→ If the λ is less, f will be more. This is called high frequency signal.

→ High Frequency Signal is passed easily through capacitor.

(Q.10)

Which capacitors are superior and why?

'Electrolytic Capacitors' are superior because they can store a large amount of charge at relatively low voltages. It forms a thin layer of metal oxide which serves as dielectric due to which it attains very large capacitance.