Chapter = 13

ELECTROSTATICS

ELECTROSTATICS

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Word study:- The word electrostatics is the combination of two words i-e

Electro – means "**Charge**"

Statics – means **"Rest"**

Definition:- The branch of physics in which we study the charge at rest is known as electrostatics.

Other Name: - It is also called **"Static Electricity".**

ELECTRIC CHARGE

Definition:- A physical quantity whose presence produces an electric field is known as electric charge. OR

The source of an electric field is known as electric charge.

Symbol: - It is denoted by "**q**".

Unit:-Its S1 unit is **"coulomb"** (C).

Quantity: - It is a **scalar** quantity.

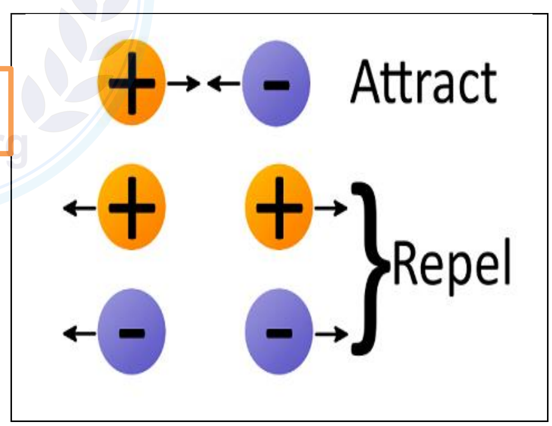
TYPES OF ELECTRIC CHARGES

There are two types of electric charges which are given below.

(1) Positive Charge.

(2) Negative Charge.

PROPERTIES OF ELECTRIC CHARGES



(i) It is an intrinsic property of fundamental particles i-e protons (+ve) and electrons (-ve).

(ii) It produces an electric field around itself.

(iii) Like charges repel and unlike charges attract each other.

(iv) It is a scalar quantity etc.

(v) It is a conservative quantity.

SOME IMPORTANT DEFINITIONS

Source Charge: - A charge which causes an electric field in the space is known as source charge.

Test Charge: - A test charge or unit charge is a positive charge which gives the strength and direction of the electric field in space without affecting it.

Electric Force: - The force between any two charged OR
The repulsive or attractive interaction between any two charged bodies is known as electric force.

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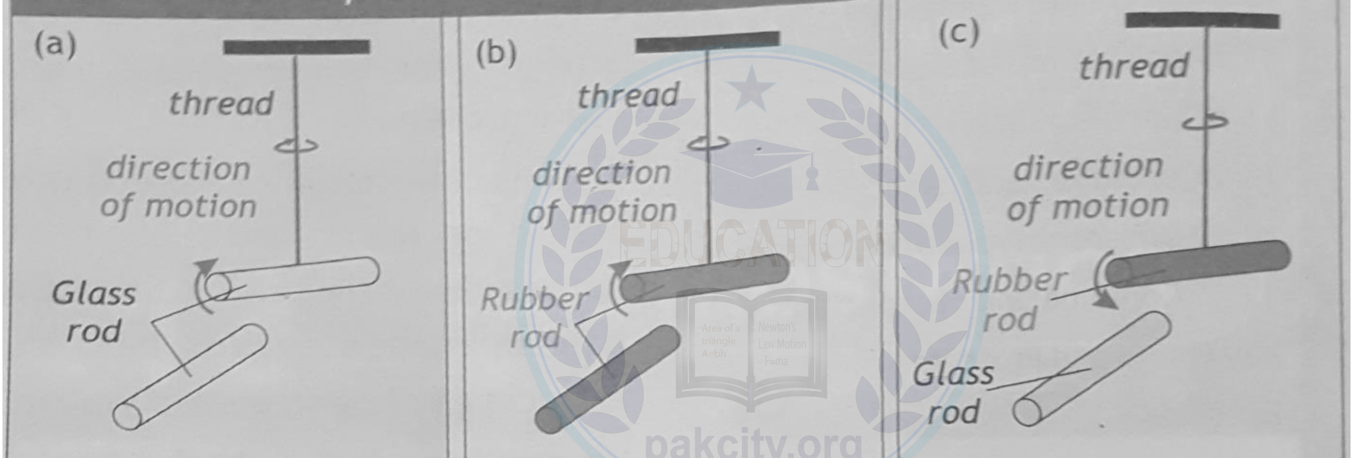
EXISTANCE AND NATURE OF ELECTRIC CHARGES

As we know that electric charge is a basic fact. We can understand the existence and the nature of charge by performing the following simple experiments.

FIGURE 13.2 - *Experiments in Electrostatics*



(a) Glass rod rubbed with silk cloth brought near another suspended glass rod rubbed with silk cloth repel each other.

(b) Rubber rod rubbed with fur brought near another suspended rubber rod rubbed with fur repel each other.

(c) Glass rod rubbed with silk cloth brought near a suspended rubber rod rubbed with fur attract each other.

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CONCLUSION

From the above experiments it is clear that

(i) The friction between two different materials produce two different kinds of charges that is positive and negative charges.

(ii) Like charges always repel each other.

(iii) Unlike charges always attract each other.

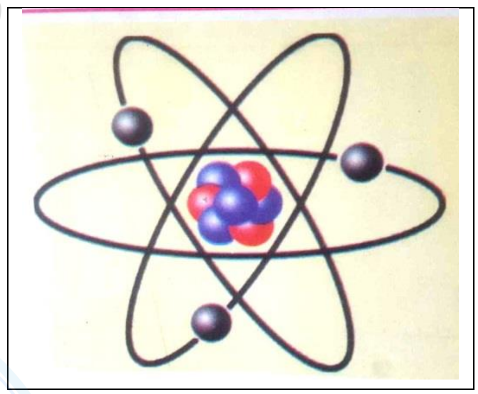
(iv) The electric force exists in charged bodies.

(v) The electric force is attractive as well as repulsive in nature.

(vi) The electric force is stronger than gravitational force.

ATOM AND ITS STRUCTURE

Definition: - The smallest and the building of matter is known as atom.



Explanation:- As we know that matter is made up of atoms. Atoms have two kinds of charges, protons contained in the nucleus of an atom have positive charge, whereas electrons orbiting around the nucleus carry negative charge, neutrons inside the nucleus have no charge as shown in figure.

Note:- The charge on an electron or proton is known as elementary or fundamental charge because all known charges are made up of electrons and protons and so all charges are integral multiples of the fundamental charges.

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ELECTRIFICATION

Definition: - The process by which we can charge a body is known as electrification.

Types of electrification:- There two methods by which we can charge a body which are given below.

(1) By rubbing

(2) By electrostatic induction.

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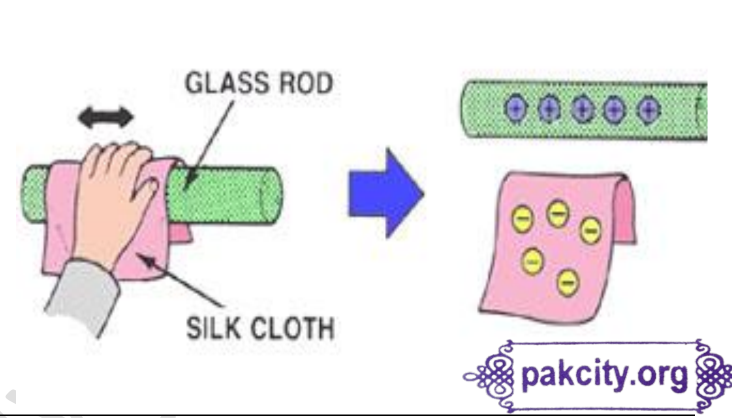
(1) CHARGING BY RUBBING

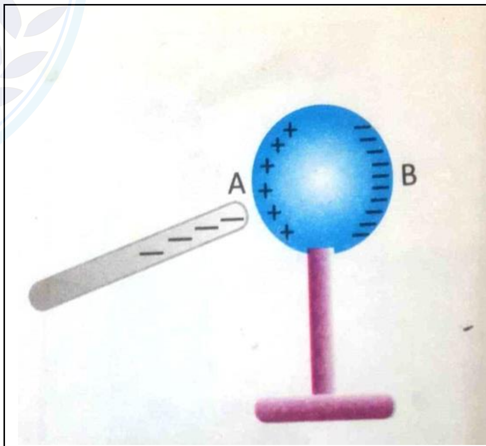
As we know that matter is made up of atoms. The atom is electrically neutral because of equal number of electrons and protons. As outermost shell electrons are loosely bounded to their nucleus, hence a small amount of energy is required to remove them. When we rub two bodies together, then during the rubbing process the electrons get (gain) energy and will transfer from one body to another body. The body which gains the electrons becomes negative charged and the body which loses becomes positive charged.



Example: - When we rub glass rod with silk cloth then the glass rod becomes positive charged and the silk cloth becomes negative charged as shown in fig.

ELECTROSTATIC INDUCTION

Definition: - The re-arrangement of electric charges inside a neutral body when a charged body is brought closer to it is known as electrostatic induction". **OR**
When a charged body is brought near a neutral body, separation of charges on neutral bodies take place such process is known as electrostatic induction. OR
A change in distribution of electrical charge in an object, caused by the influence of nearby charges is known as electrostatic induction.



Explanation:-

- It takes place in both conductors and insulators.
- The new arrangement of charges is temporary and will regain original

arrangement after the removal of charged body.

Example:-

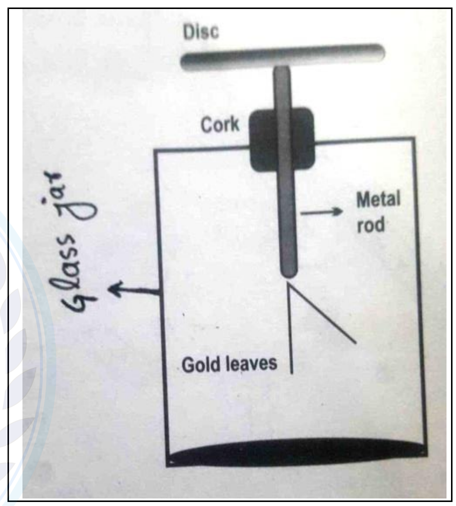
- Take a metallic sphere "AB" and place it on wooden stand as shown in figure.
- Bring a negatively charged rod near its end "A".
- The rod will attract positive charges towards itself.
- And repel negative charges away from it.
- So as a result end "A" of the sphere becomes positive and the end "B" of the sphere becomes negative as shown in figure.

ELECTROSCOPE

Word study: - The word electroscope is the combination of two Greek words.
Electro – means **"Charge".**
Scope – means **"Study".**

Definition:- It is a sensitive device which is used for detecting and testing the nature of charge on a body.

Other Name:- It is also called charge detector.



Construction: - It consists of

(i) Metal rod which has a metallic sphere (ball) at its upper end.

(ii) Thin flexible metal leaves (made of gold, silver etc.) attached to the lower end of metal rod.

(iii) Glass jar

Principle:- It works on the principle that similar charges repel each other.

Working / Use of electroscope: -

Detection: -

Condition:- Uncharged electroscope.

Steps:-

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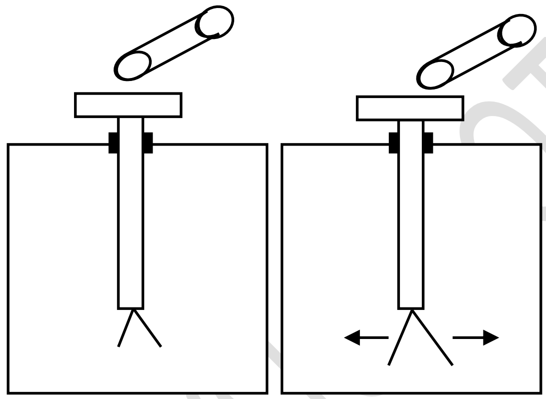
(i) To take uncharged electroscope.

(ii) In order to detect the presence of charge on a body bring it near the disc.

(iii) If the leaves of the electroscope remain in the normal position, then the body will be uncharged.

(iv) If the leaves of the electroscope diverge, then the body will be charged because of electrostatic induction. As shown in figure.



Testing The Nature Of Charge: -

Condition: - Charged Electroscope.

Steps: -

(i) Take charged electroscope either +ve or –ve.

(ii) Let the electroscope is positively charged.

(iii) Now bring the charged body under test to the disc of the electroscope.

(iv) If the divergence of leaves increase, then the body has the same kind of charge as on electroscope.

(v) If the divergence of the leaves decreases, then the charge on the body will be opposite to the charge present on the electroscope.

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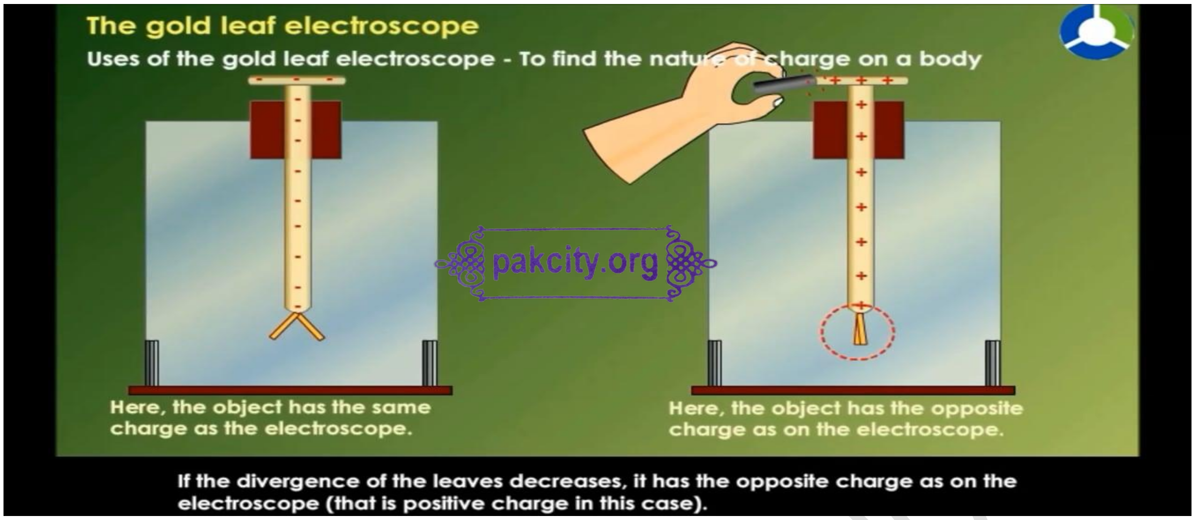

Conclusion: -

Charge on Electroscope	Charge on Brought near	Effect on Leaves
Positive	Positive body	Divergence increase
Negative	Negative body	Divergence increases
Positive	Negative body	Divergence decreases
Negative	Positive body	Divergence decreases

Point Charge:- Point charges are those charges whose sizes very small compared with distance between the charges.

COULOMB'S LAW

History:- This law was presented by French military Engineer Charles Coulomb in 1785.

Purpose:- To explain the quantitative measurement of the electric force between two charges.

Statement:- "The force of attraction or repulsion between two point charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them".

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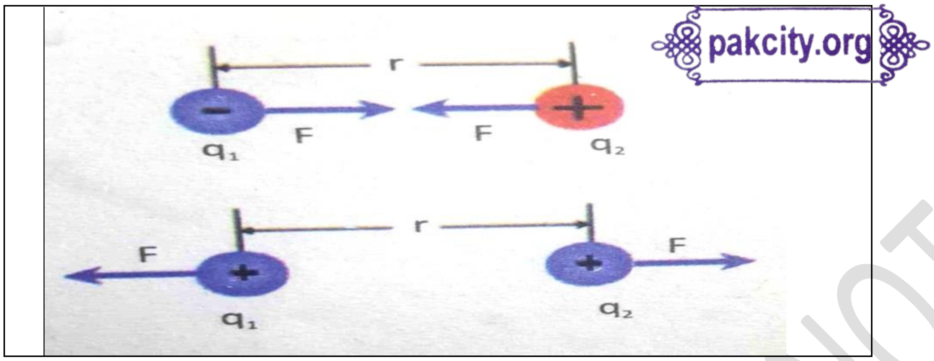
Mathematical form:- Consider two spherical charges q_1 and q_2 are placed at a distance “r” from each other. They attract or repel each other with a force “F” then



From the above statement

$$F \propto q_1 q_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$F \propto \frac{1}{r^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

By combining equation (1) and (2)

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

$$F = \text{constant} \left(\frac{q1q2}{r^2}\right)$$

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

$$F = k\left(\frac{q_1 q_2}{r^2}\right) \ldots\ldots\ldots \quad (3)$$

In equation (3) “k” is a constant of proportionality and is known as coulombs constant.

Dependence of k: - The value of “k” depends upon the following factors.

- The system of unit.
- The medium used.

If the medium between the charges is air then CGS system k=1 eq (3) become.

$$F = \frac{q_1 q_2}{r^2} \ldots\ldots\ldots\ldots\ldots \quad (4)$$

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If the medium between the charges is air then in S.I system k= $\frac{1}{4\pi\varepsilon_0}$ = 9 x10^9 Nm^2/C^2 then equation (4) becomes

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

In equation (5) "ε_0" (Epsilon) is known a permittivity of free space or air.

Limitation: - It should be noted that this law is strictly valid for point and for static charges.

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DIFFERENCE BETWEEN GRAVITATIONAL FORCE AND ELECTRIC FORCE

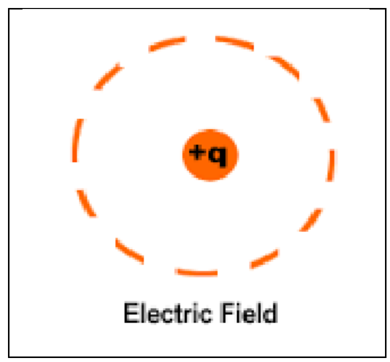
GRAVITATIONAL FORCE	ELECTRIC FORCE
This force due is to mass	This force due is to mass
It is denoted by $\vec{F_g}$.	It is denoted by $\vec{F_e}$.
Its mathematical form is $\vec{F_g} = \frac{Gm_1 m_2}{r^2}$	Its mathematical form is $\vec{F_e} = \frac{Kq_1 q_2}{r^2}$
It is a medium independent force	It is a medium dependent force
It is a weaker force	It is a stronger force
It is always attractive in nature	It is attractive as well as repulsive in nature
Its value of constant "G" is very small	Its value of constant "K" is very large

ELECTRIC FIELD

Definition:- "Any region in which a test charge would experience an electric force is known as electric field". OR

"The space around a charge in which an electric test charge would experience an electric force is known as electric field".

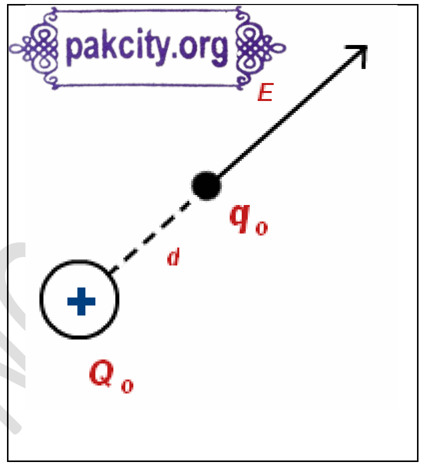
Quantity:- It is a **vector** quantity.



Note:-The test charge itself is chosen to be point and positive and so small that its presence does not distort.

ELECTRIC FIELD INTENSITY

Definition:- "The strength of the field at any point is known as electric field intensity". OR
"The influence of force acting on a unit positive test charge at any point in an electric field is known as electric field intensity". OR
"The force per unit charge is known as electric field intensity".



Symbol:- It is denoted by E.

Mathematically:-

$$\text{Electric field intensity} = \frac{Force}{charge}$$

$$E = \frac{F}{q_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Explanation:- To find the value of electric filed intensity at a point in a field we place a test charge "q_o" at that point as shown in figure.

Unit:- Its SI unit is newton per coulomb N/C (NC^{-1}).

Quantity:- It is a vector quantity.

ELECTRIC LINES OF FORCE

History:- The concept about the electric lines of force was presented by a British physicist Michal Faraday.

Purpose:- To represent the direction and magnitude of an electric field.

Definition:- "The path followed by a unit positive test charge in an electric field is known as electric lines of force".

Properties of electric lines of force:-

(i) They start from positive charge and end on negative charges.
(ii) They never cross each other.
(iii) They never forms close loops.
(iv) They always perpendicular to the charges conducting surface.
(v) Number of electric lines of force represents the strength of the electric field.
(vi)They don't exist inside the conductor etc.

GEOMETRICAL REPRESENTATION OF ELECRIC LINES OF FROCE

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(1)For positive charge:- The electric lines of force are directed outward for a positive charge as shown in figure.

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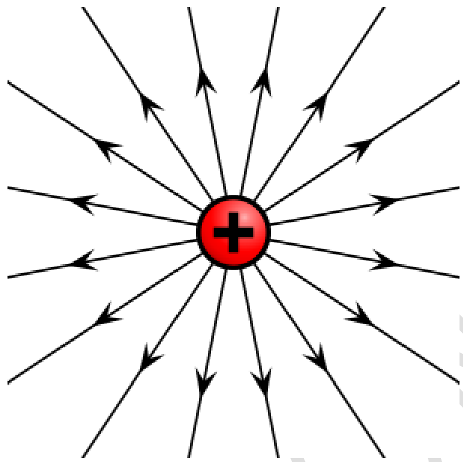

(ii)For negative charge:- The electric lines of force are inward for negative charge as shown in figure.

(iii)For two oppositely charged:-They start from positive charges and end on negative charge as shown figure.

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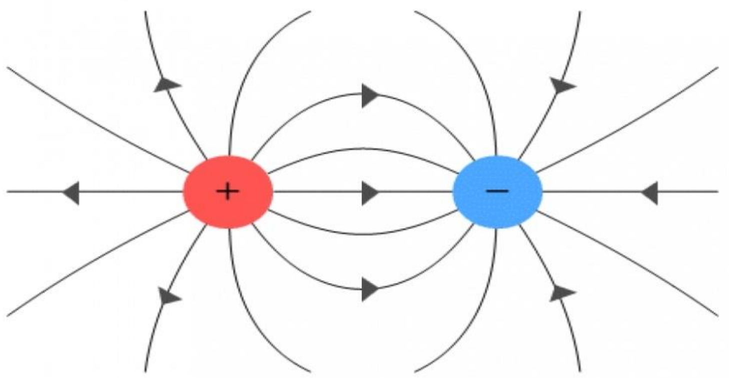

(iv)<u>For two positively charged</u>:- Fields due to two positively charges placed close together.

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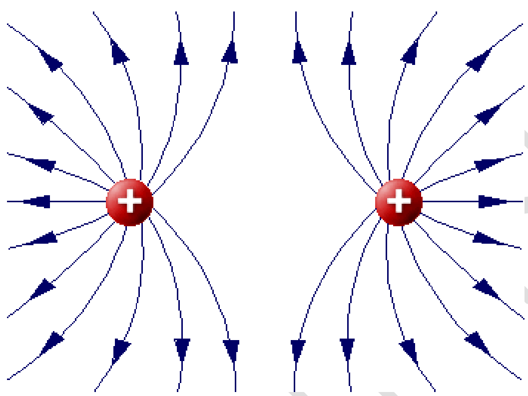

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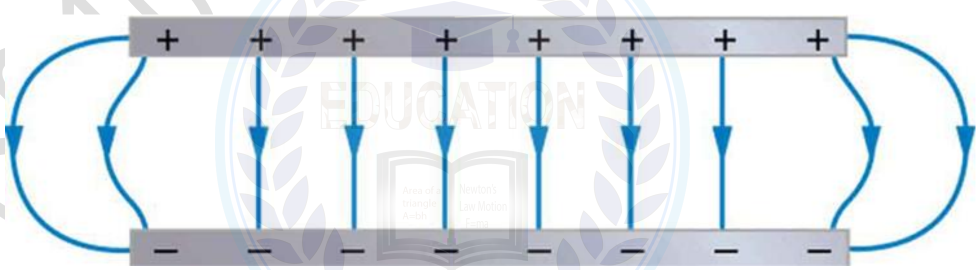
(v)<u>For two oppositely charged parallel </u>plates:-The strength of electric field is uniform between two oppositely charged parallel plates as shown in fig (E).



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ELECTRIC POTENTIAL

<u>Definition: -</u>

The amount of work done in bringing a unit positive test charge from infinity to a particular point in the electric field of a source charge is called electric potential**. OR**
The potential energy gain by a unit positive charge when brought from infinity to a particular point in the electric field is called electric potential. OR
The electric potential energy **"U"** per unit charge **"q"** in an electric field is known as electric potential.

Symbol:- It is denoted by "V".

Mathematical form:- Electrostatic Potential = $\frac{Electric\ potential\ energy}{Charge} = \frac{Work\ done}{Charge}$

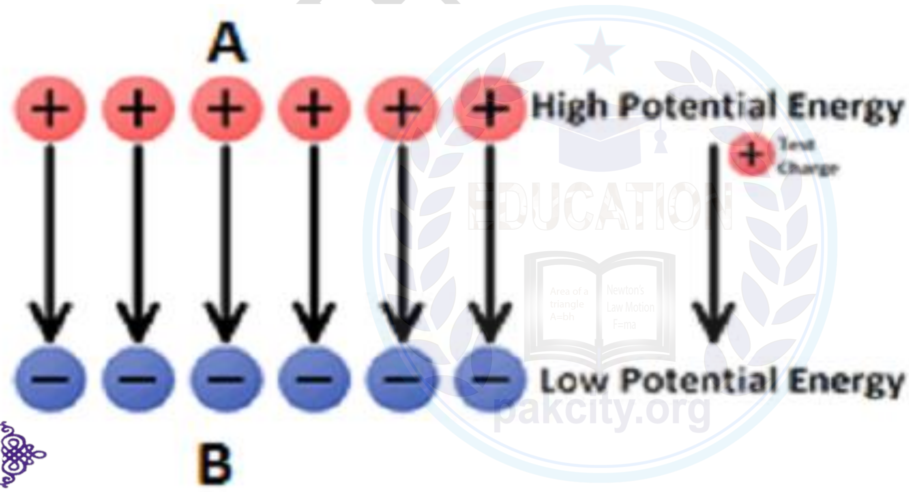
$$V = \frac{U}{q} = \frac{W}{q}$$

Quantity: - It is a **scalar** quantity.

Unit: -Its SI unit is **volt**.

Volt:- If the potential energy of one coulombs charge at a point is one joule, then potential of that point will be one volt.

Explanation:- We know that charge always moves from a region of higher potential to a region of lower potential. If we want to bring a positive charge from lower potential say "V_B" to a higher potential "V_A" as shown in figure .



Then same external work must be necessary thus

Work done = $q_o V_A - q_o V_B$

Work done = $q_o(V_A - V_B)$

Work done = $q_o\ \Delta V$ $V_A - V_B = \Delta V$

This work done will be stored in the charge as its electric potential energy. Thus Electric potential energy=ΔW

Electric potential energy = $q_o\ \Delta V$

Here "ΔV" shows the potential difference. It is defined as: the energy supplied by unite positive charge as it moves from a point of higher potential to a point of lower potential.

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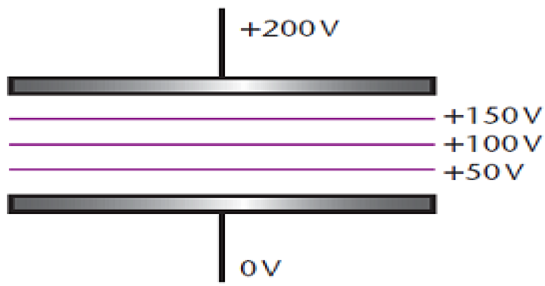
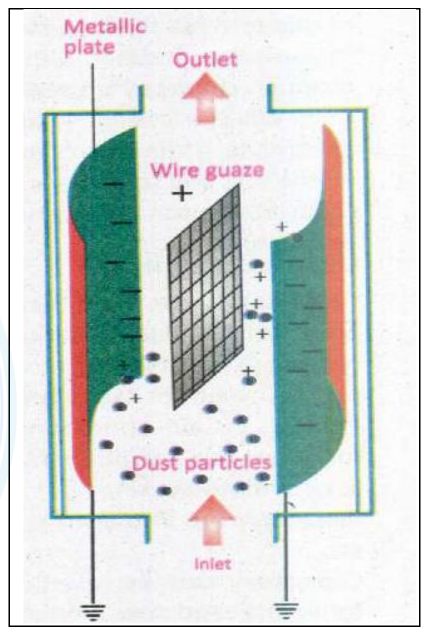


PRACTICAL APPLICATIONS OF ELECTROSTSTICS

Electrostatics Precipitator and Dust extraction: Electrostatic phenomenon can be used to separate dust from smoke particles. To reduce air pollution, modern day coal burning power stations extract dust from the smoke in chimneys before releasing it to the environment by a process called electrostatic precipitation.

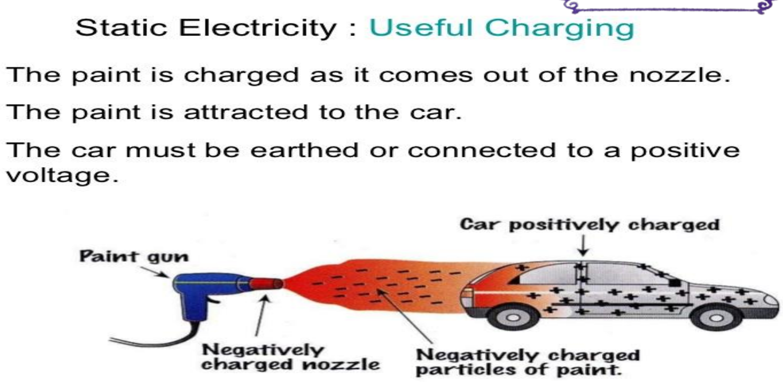


For this purpose chimneys have a highly positively charged grid (Usually a wire gauze) and negatively charged plates as shown in figure (13.12). When smoke rising from chimney containing smoke and dust particles pass through the positively charged grid they acquire a positive charge. These charged particles attracted by negatively charged plate and are deposited on them. Thus, the smoke coming out of chimney is free from dust and other particles.

Electrostatic phenomenon is also uses in photo copying machine and injects and laser printer.

(B) Electro Paintings:-

Electrostatics spray painting is a method in which electrostatically charged paint is applied as shown in figure. To paint any article by electro painting spray machine the article is made earthed first. When the paint particles emerges out through nozzle of the spray machine they acquire positive charge thus these positive charged spray induces negative charges on the body of the articles. Thus due to force of attraction a very firm coating of the paint is formed on the surface of the article. pakcity.org



DANGERS OF STATIC CHARGE OR HAZARDS OF ELECTROSTATICS

Apart from useful applications of electrostatics, it can sometime be dangerous. For example, lightning is the result of a large charges separation within a cloud. Clouds are composed of millions of ice particles and water droplets. These particles collides with other condensing moister as it rises, and when they do so, electrons are knockout. These electrons built up at the bottom of cloud and make it negatively charged as shown figure. The rising moister molecules, now have missing electrons and therefore a positively charge is gathered at the bottom of cloud. This creates a charge separation, which has an electric field that is negative at the bottom and positive at the top. As the collision continue, the electric field builds so strong that it gives the planet's surface a positive charge. When these charges becomes powerful enough, the clouds electricity is discharged toward the Earth's surface, which results in lightning.

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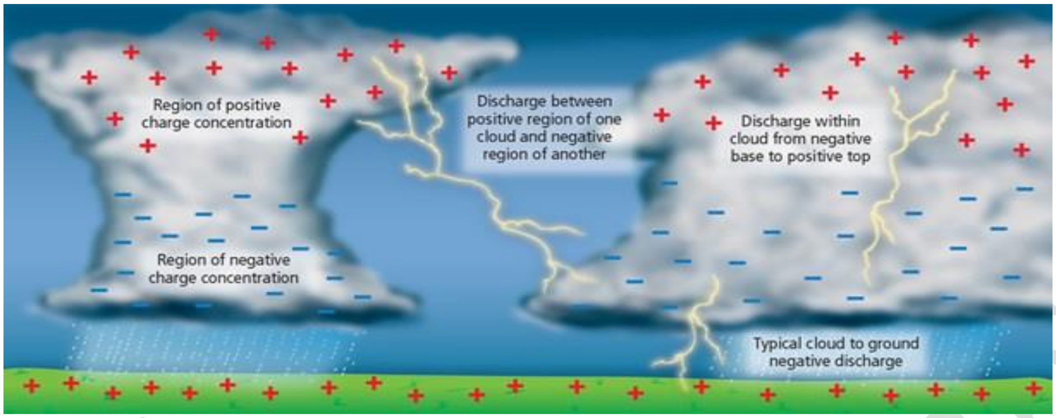
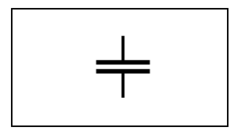


CAPACITOR

Definition:-"A device which is used for storing electric charges is known as capacitor".

Old name:- Its old name was "Condenser"

Symbol:- Its symbol circuit is

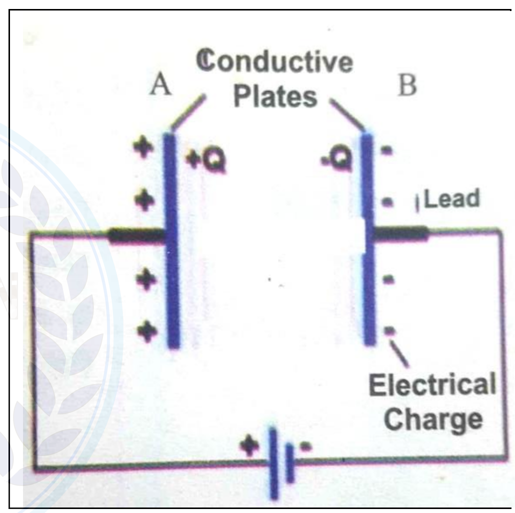


Construction:- It consists of

(i) Two parallel metal plates separated by small distance.

(ii)The medium between the two plates is air or a sheet of some insulator "dielectric".

CHARGING OF A CAPACITOR:- To charge the capacitor the plates of capacitor are connected to a battery. The positive terminal of the battery charge the plates "A" positively Q+ and due to electrostatic induction it would induce negative charge. "Q^{-}" on the inner surface of plates "B" as show in figure.



CAPACITANCE OF A CAPACITOR

Definition: -"The ability of a capacitor to store the electrical charge or electrical energy is known as capacitance of a capacitor.

Symbol:- It is denoted by "C".

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Mathematical form:- $C = \frac{Q}{V}$

Explanation:- As we know that when the capacitor start to charging. The potential difference **"V"** appears between the plates of the capacitor. When the charge **"Q"** on the plates of the capacitor increases the potential difference **"V"** between the plates of capacitor also increases. From experimental results the charge **"Q"** on the plate of a capacitor is directly proportional to the electric potential deference **"V"** between them.

Mathematically: -

Charge ∝ potential difference

$Q \propto V$

$Q = \text{constant}\,(V)$

Constant = C

$Q = C\,V$

$Q = C\,V$ ……………………….. (1)

In equation (1) **"C"** is the constant of proportionality and is known as capacitance of a capacitor. Equation (1) can be written as,

$C = \frac{Q}{V}$ ……………………….. (2)

Factors of capacitance: - The value of "C" depends upon the following factors.

(i) Area of the plates (A): - i-e $C \propto A$

(ii) Distance between the plates (d): - i-e $C \propto \frac{1}{d}$

(iii) Nature of medium between the plates ($\boldsymbol{\varepsilon}$):- $C \propto \boldsymbol{\varepsilon}$

Unit:- Its SI unit is farad (F) and is given by

$1F = \frac{1C}{1V} = 1CV^{-1}$

Farad: - The capacitance of a capacitor is one farad "if a charge of one coulomb given to one of the plates of a parallel plates capacitor produces a potential difference of one volt between them".

Convenient sub-multiples of farad: - Since farad is a very big unit so we use small units like,

- $1\,\mu F$ = micro farad = $10^{-6}F$
- 1pF = pico farad = $10^{-12}F$

Note :-

(i) Net charge on a capacitor is zero.

(ii)It charged with only D.C.

(iii)It store energy in an electric field.

Uses: - It is used in

(i)Tuner circuit in radio and T.V.

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(ii)A.C motors.

(iii)CRO.

(iv)Timer etc.

COMBINATION OF CAPACITORS

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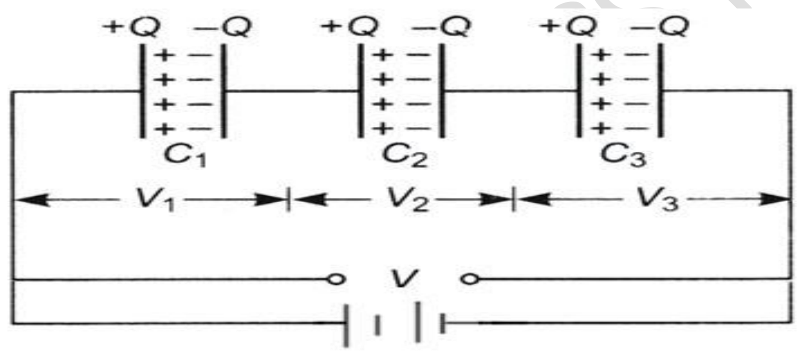
Capacitors are connected either in series or in parallel in an electrical circuit.

Series Combination of Capacitor: -

(1)Definition:- "That type of combination of two or more than two capacitors in which they are connected plate to plate is known as series combination of capacitors".

Explanation: - Consider there are three capacitors of capacitances **C_1, C_2 and C_3** are connected in series. A battery of voltage **"V"** is connected the circuit as shown in fig (S).



Characteristics features of series combination of capacitors: -

(i)It provides one path for current flow.

(ii)Same charge stored on each capacitor i-e $Q_1 = Q_2 = Q_3 = Q$

(iii)Different potential difference across each capacitor i-e

$$V_1 \neq V_2 \neq V_3$$

(iv) $V = V_1 + V_2 + V_3$ --------(1)

(v) The relation between charge, voltage and capacitance as

$$Q = CV \text{ -------- (2)}$$

For "V" equation (2) can be written as

$$V = \frac{Q}{C} \quad \text{then}$$

For V_1 :- $V_1 = \frac{Q}{C_1}$

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For V_2 :- $V_2 = \frac{Q}{C_2}$

For V_3 :- $V_3 = \frac{Q}{C_2}$

Now by putting the values of V, V_1, V_2 and V_3 in eq (1) we get.

$$\frac{Q}{C} = \frac{Q}{C1} + \frac{Q}{C2} + \frac{Q}{C3}$$

$$Q\left(\frac{I}{C}\right) = Q\left(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}\right)$$

$$Q\left(\frac{1}{C}\right) = Q\left(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}\right)$$

$$\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} \text{ .... } (3)$$

(vi) **<u>For equivalent capacitance</u>**:- Equation (3) becomes

$$\frac{1}{C_{eq}} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} \text{ .... } (4)$$

(vii) For N number of capacitors equation (4) becomes

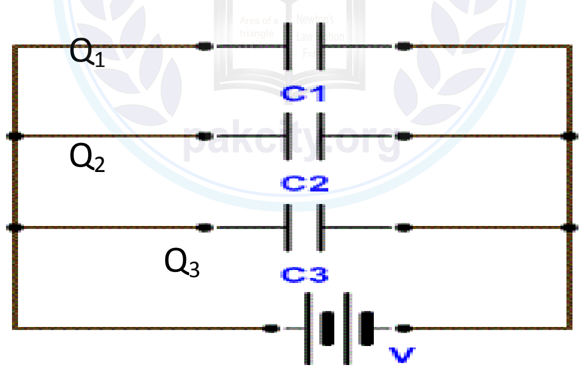
$$\frac{1}{C_{eq}} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} - - - + \frac{I}{Cn} \text{ .... } (5)$$

<u>Note:</u> - In series combination the **"C $_{eq}$"** is smaller than the smallest capacitance in the circuit and the resultant capacitance decreases.

PARALLEL COMBINATION OF CAPACITORS

<u>Definition</u>: - That type of combination of two or more than two capacitors in which the plates of the capacitors are connected parallel to each other is known as parallel combination of capacitors.

<u>Explanation</u>:- Consider there are three capacitors of capacitances C_1, C_2 and C_3 are connected in parallel circuit. A battery of voltage "V" is connected to the circuit as shown in figure.



<u>Characteristics features of parallel combination of capacitors:</u> -

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(i)It provides more than one path for current flow.

(ii)Same Potential difference across each capacitor i.e

$$V_1 = V_2 = V_3 = V$$

(iii)Different amount of charge stored on each capacitors i.e

$$Q_1 \neq Q_2 \neq Q_3$$

(iv)$Q = Q_1 + Q_2 + Q_3$ .... (1)

(v)The relation between "Q", "V" and "C" is

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$Q = CV$ .... (2)

For Q_1 :- $Q_1 = C_1V$

For Q_2 :- $Q_2 = C_2V$

For Q_3 :- $Q_3 = C_3V$

New by putting the values of Q, Q_1, Q_2 and Q_3 in eq (1) we get

$$CV = C_1V + C_2V + C_3V$$

$$V(C) = V(C_1 + C_2 + C_3)$$

$$\not{V}(C) = \not{V}(C_1 + C_2 + C_3)$$

$C = C_1 + C_2 + C_3$ .... (3)

i. For equivalent capacitance eq (3) becomes

$C_{eq} = C_1 + C_2 + C_3$ .... (4)

ii. For N number of capacitors eq (4) can be written as

$$C_{eq} = C_1 + C_2 + C_3 + \text{----------} + C_n$$

Note: **-** In parallel combination the **"C_{eq}"** is greater than the largest capacitance in the circuit and the resultant capacitance increases.

TYPE OF CAPACITORS

On the base of capacitance there are two types of capacitors which are given below.

(1) Fixed capacitor.

(2) Variable capacitor.

1.Fixed capacitor:-

Definition: -The type of capacitor whose parts are fixed by design is known as fixed capacitor. OR

Those capacitors which has fixed value of capacitance and not be change is called fixed capacitor.

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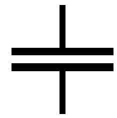
Capacitance:-They have fixed capacitance.

Symbol in circuit: - Their symbol in circuit is



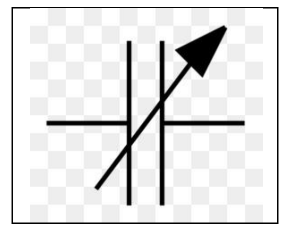
Examples: - Paper capacitors, Mica capacitors, oil capacitor, Mica capacitor, electrolyte etc.

Variable capacitor:-

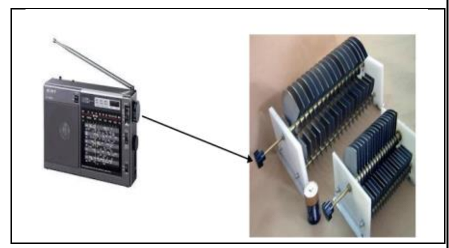
Definition:- The type capacitor whose area of the plates or the separation between the plates can be changed is known as variable capacitors.

Capacitance:- They have variable capacitance.

Symbol in circuit:- Their symbol in circuit is



Example: - The capacitor used in tuning of a radio frequency.



Different types of Capacitors:-

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CONCEPTUAL QUESTIONS

Q # 01:- Normally objects with large number of electrons are electrically neutral, why ?

Ans:-Statement:- Normally objects with large number of electrons are electrically neutral.

Reason: - It is because of equal number of electrons and protons.

Explanation: - As we know that matter is made up of atoms. The atom is electrically neutral because of equal number of electrons and protons. No net charge simply means that the amount of positive and negative charges in the object are equal. When an object is neutral, it means the positive and negative charges sum to zero (are equal and opposite)

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Conclusion:- As conclusion we find that normally objects with large number of electrons are electrically neutral.

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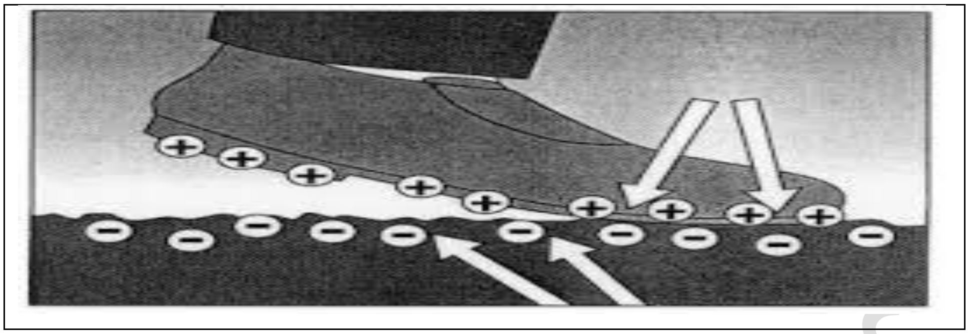
Q # 02:- How does shuffling across a carpet causes hair to stand on our body?

Ans:-Statement: - Shuffling across a carpet causes hair to stand on our body.

Reason:- It is because that like charges attract each other and un-like charges repel each other.

Explanation: - As we know that our hair is neutral. When we shuffle (rub) our feet on a carpet. We are picking electrons from the carpet and transferred to our body. So our body become charged. The hair stands up because all hair gains the same electric charge and repel each other.



Conclusion: - As conclusion we find that Shuffling across a carpet causes hair to stand on our body.

Q # 03:- Why neutral objects are always attracted by charged objects? Not repelled.

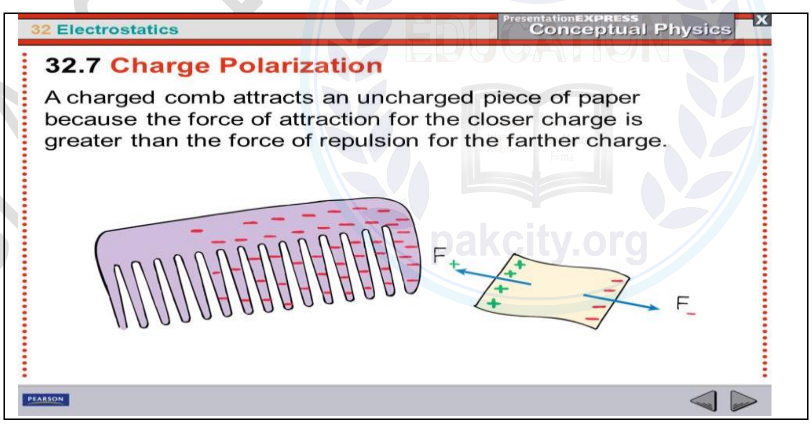
Ans:-Statement:- Neutral objects are always attracted by charged objects , not repelled.

Reason:- It is because of

(i) Like charges repel and un-like charges attract each other.
(ii) Electrostatic induction.

Explanation: - It is found that a charged object, whether positive or negative, may attract uncharged objects.

For example a charged plastic comb will pick up small pieces of paper. It is thought that when a negatively charged object gets close to an uncharged object, electrons in the uncharged object are repelled, leaving the positive charges behind. These positive charges are then attracted to the negatively charged object.



Conclusion:- As conclusion we find that neutral objects are always attracted by charged objects , not repelled.

Q# 04:- Why the pieces of paper initially attracted by charged comb fly away when they touch it?

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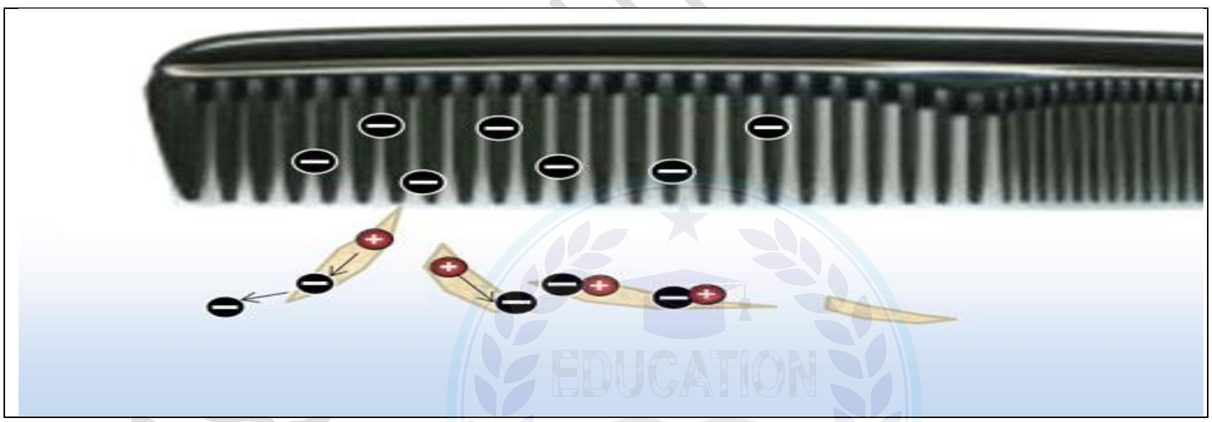
Ans:- Statement:- The pieces of paper initially attracted by charged comb fly away when they touch it.

Reason:- It is because of like charges repel each other and un-like attract each other.

Explanation:- Initially the **comb** is electrically neutral. So it has no effect on the tiny **pieces of paper**. When the **comb** is rubbed on a dry cloth, it gets electrically charged. This charged **comb** exerts an electric force on the tiny **pieces of paper** and **attracts** them because of electrostatic induction. When the comb touch the paper pieces, then some of the positive charges from the comb transfer to the paper pieces, which neutralize the negative charge on the comb and finally the pieces of paper fall due to gravity.



Conclusion:- As conclusion we find that the pieces of paper initially attracted by charged comb fly away when they touch it.

Q # 05:- Is it necessary for a charged body actually to touch the ball of the electroscope for the leaves to diverge? Defend your answer.

Ans:-Statement:- No, It is not necessary for the charged body to touch the ball of the electroscope for the leaves to diverge .

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Reason:- It is because of electrostatic induction.

Explanation:- As we know that electroscope is a device which is used for detecting and the nature of charge on a body. As the charged body, let's say its positive, is brought near the electroscope, it attracts the electrons towards itself. As the leaves and the top of the electroscope are connected, there is an absence of electrons in both of the leaves. Therefore, they repel each other and the leaves diverge.

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Conclusion:- As conclusion we find that , It is not necessary for the charged body to touch the ball of the electroscope for the leaves to diverge .

Q # 06:- How electrostatic painting is better than conventional spray painting?

Ans:-Statement: - Electrostatic painting is better than conventional spray painting.
Reason:- It is because electrostatic painting reduce the paint usage and helps to distribute the paint particle evenly and get uniform coverage.

Explanation:- As we know that electrostatic spray painting is a method in which electrostatically charged paint is applied. It has some properties which are given below.

(i) It makes a firm coating of the paint coating on the surface of vehicles.
(ii) This method is very effective, efficient and cheap.
(iii) It also requires less paint as compared to other methods.
(iv) It creates a better looking finish because the paint is distributed more evenly and uniformly.

Conclusion:- As conclusion we find that electrostatic painting is better than conventional spray painting.

Q #7: Why are lighting rods normally at a higher elevation than the buildings they protect?

Ans:-Statement:- Lightning rods are normally at a higher elevation than the buildings they protect.

Reason: - It is because the lightning rods provide a low-resistance path to ground for charge flow.

Explanation:- To prevent lightning from damaging tall buildings, lighting conductors are used. The purpose of the lightning conductor is to provide as steady discharge path for the large amount of negative charges in the air to flow from top of the building to the earth. In this way, the chances of lightning damage due to sudden discharge can be minimized. **OR** pakcity.org

As we know that lightning rods provide a low-resistance path to ground that can be used to conduct the enormous electrical currents when lightning strikes occur. If lightning strikes, the system attempts to carry the harmful electrical current away from the structure and safely to ground. The system has the ability to handle the enormous electrical current associated with the strike. If the strike contacts a material that is not a good conductor, the material will suffer massive heat damage. The lightning lightning-rod system is an excellent conductor and thus allows the current to flow to ground without causing any heat damage.

Conclusion:- As conclusion we find that Lightning rods are normally at a higher elevation than the buildings they protect.

Q #08:- What would happen if two insulating plates were used instead of conducting plates to construct a capacitor?

Ans:-Statement: - If two insulating plates were used instead of conducting plates to construct a capacitor then its capacitance decreases.

Reason:- It is because of insulators have no free electrons.

Explanation:- As we know that capacitor is a charge storing device. It consists of two conducting metal plates and an insulating material in between them.
Voltage, when applied between two plates of a capacitor, creates a potential difference between its plates. One plate becomes positive and another becomes negative because of electrostatic induction. The electric field is setup between these plates. The energy is stored in the electric field between the plates. This accumulation of charges is very less in case of insulating plates because of no free electrons.

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Conclusion:- As conclusion we find that If two insulating plates were used instead of conducting plates to construct a capacitor then its capacitance decreases.

Q#09:- The sum of the charge on both plates of a capacitor is zero. What does a capacitor store?

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Ans:-Statement:- The sum of the charge on both plates is zero it store the electrical energy.

Reason:- It is because the capacitor store energy in electric field.

Explanation:- As we know that capacitor is a charge storing device. Voltage, when applied between two plates of a capacitor, creates a potential difference between its plates. One plate becomes positive and another becomes negative. Charge on the plates of capacitor possess electrical because of work done to deposit charge on the plates. The electric field is setup between these plates. The energy is stored in the electric field between the plates. It means that there is energy available for work.

Note:- When there is a potential difference, there is an electric field.

OR

The total charge on a capacitor is always zero and in equilibrium with its surroundings. But capacitors do store electric energy. The energy is stored in an electric field. Voltage, when applied between two plates of a capacitor, creates a potential difference between its plates. One plate becomes positive and another becomes negative. As long as there is a voltage at the two ends of the capacitor, there is an electric field between them and this electric field keeps the charges in their position. The charges are imbalanced, but they move back once voltage is removed. They aren't stored there.

Conclusion:- As conclusion we find that the sum of the charge on both plates is zero it store the electrical energy.

Q#10:- If you wish to store a large amount of energy in a capacitor bank , would you connect capacitors in series or parallel ? Explain.

Ans:-Statement:- If we wish to store a large amount of energy in a capacitor bank we would connect the capacitors in parallel combination.

Reason:- It is because in parallel combination of capacitors equivalent capacitance increases.

Explanation:- As we know that

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(a)For parallel combination of capacitors:-

$$C_e = C_1 + C_2 + C_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Let C_1 = 2μF , C_1 = 3μF , C_1 = 4μF then

$$C_e = 2\mu\text{F} + 3\mu\text{F} + 4\mu\text{F} = 9\ \mu\text{F} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

(b)For series combination of capacitors:-

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$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{4} = \frac{6+4+3}{12} = \frac{13}{12} = 1.08\ \mu\text{F} \quad \ldots\ldots\ldots \quad (4)$$

Conclusion:- As conclusion from eq (2) and (4) we find that If we wish to store a large amount of energy in a capacitor bank we would connect the capacitors in parallel combination.

NUMERICAL QUESTION

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Pb#01: Determine the magnitude of the electric force on the electron of hydrogen atom exerted by the single proton that is the atom's nucleus. Assume the average distance between the electron and the proton is r = 5.3 × 10^{-11}m and charge on electrons and proton is 1.6 × 10^{-19} C.

GIVEN DATA:-

Distance between the electron and proton = r = 5.3 × 10^{-11} m

Charge on electron = q_e= 1.6 × 10^{-19} C

Charge on proton = q_p = 1.6 × 10^{-19} C

Coulomb's constant = k = 9 x 10^9 Nm^2/c^2

REQUIRED DATA:-

Electric Force = F_e = ?

SOLUTION:- As we know that

FORMULA:- $F_e = \frac{K\,q_e q_p}{r^2}$ .... (1)

CALCULATION:- By putting values in equation (1) we get

$$F_e = \frac{K\,q_e q_p}{r^2} = \frac{9\times10^9 \times1.6\times10^{-19}\times1.6\times10^{-19}}{5.3\times10^{-11}} = \frac{9\times1.6\times1.6\times10^{9-19-19}}{(5.3\times10^{-11})^2}$$

$$F_e = \frac{23.04\times10^{9-38}}{28.09\times10^{-22}} = 0.820 \text{ x } 10^{-29+22} = 0.820 \text{ x } 10^{-7}\text{N} = 8.20 \text{ X } 10^{-8} \text{ N}$$

RESULT:- F_e = 8.20 X 10^{-8} N

Pb# 02: A 5 µC point charge is placed 20 cm from a 10 µC point charge. (a) Calculate the force experienced by the 5 µC charge. (b) What is the force on the 10 µC charge? (c) What is the field strength 20 cm from the 10 µC point charge?

GIVEN DATA:-

First point charge = q_1 = 5 µC = 5 x 10^{-6} C

Second point charge = q_2 = 10 µC = 10 x 10^{-6} C

Distance between the two point charges = r = 20 cm = $\frac{20}{100}$ m = 0.2m

Coulomb's constant = k = 9 x 10^9 Nm^2/c^2

REQUIRED DATA:-

(a) Force on q_1 = F_1=?

(b) Force on q_2 = F_2 =?

(c) Electric Field strength = E =?

SOLUTION:- As we know that

(a) For force on q_1 = F_1 :-

FORMULA:- $F_1 = \frac{K q_1 q_2}{r^2}$ …………………… **(1)**

CALCULATION:- By putting values in eq (1) we get

$F_1 = \frac{K q_1 q_2}{r^2} = \frac{9 \times 10^9 \times 5 \times 10^{-6} \times 10 \times 10^{-6}}{(0.2)^2} = \frac{9 \times 5 \times 10 \times 10^{9-6-6}}{0.04} = \frac{450 \times 10^{9-12}}{0.04}$

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F_1 = 11250 x 10^{-3} = 11.250 N

F_1 = 11.250 N

(b)For force on $q_2 = F_2$:- F_2 = 11.250 N

Reason:- Because both the charges exert equal but opposite forces on each other

(C) For Electric Field strength = E :-

Formula:- $E = \frac{F}{q_1}$ ……………….. (2)

Calculation:- By putting values in eq (2) we get.

$E = \frac{F}{q_1} = \frac{11.250}{5 \times 10^{-6}} = 2.25 \times 10^6$ N/C

RESULT:-

F_1 = 11.250 N
F_2 = 11.250 N
E = 2.25 x 10^6 N/C

Pb#03:In a certain region of space, a uniform electric field has a magnitude of 4.60 × 10^4 N/C and points in the positive x-direction. Find the magnitude and direction of the force this field exerts on a charge of (a) +2.80 μC (b) 9.30 μC.

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GIVEN DATA:- Electric field intensity = E = 4.60×10^4 N/C Charge = q_1= 2.80 µC = 2.80×10^{-6}C Charge = q_2= -9.30 µC = 9.30×10^{-6}C **REQUIRED DATA:-** (a) Electric force on $q_1=F_1$=? (b) Electric force on $q_2=F_2$=? **SOLUTION:-** As we know that **(a) For Electric force on $q_1=F_1$:-** **FORMULA:-** $F_1= q_1E$ ………………… (1) **CALCULATION:-** By putting values in eq 1 we get $F_1= q_1E = 2.80 \times 10^{-6} \times 4.60 \times 10^4$ $F_1= 12.88 \times 10^{-6+4}$ N= 12.88×10^{-2} N=0.1288N	As force (F_1) is positive because both the force and field in same direction and directed towards the positive axis. **(b)For Electric force on $q_2=F_2$:-** **FORMULA:-** $F_2= q_2E$ ………………… (2) **CALCULATION:-** By putting values in eq 2 we get $F_2= q_2E = -9.30 \times 10^{-6} \times 4.60 \times 10^4$ F_2= - 42.78×10^{-2}N= -0.4278 N The negative sign shows the force is directed towards the positive axis. **RESULT:-** **(i) F_1= 0.1288N (+ x-axis)** **(ii) F_2=- 0.4278 N (- x –axis).**

Pb#04: The potential difference between two points is 110 V. When an unknown charge is moved between these two points, the work done is 550 J. What is the amount of charge?

GIVEN DATA:- Potential difference = V = 110 volt Work done = W = 550 J **REQUIRED DATA:-** Amount of charge = q = ? **SOLUTION:-** As we know that	**FORMULA:-** $V = \frac{W}{q}$ OR $q = \frac{W}{V}$ …………….. (1) **CALCULATION:-** By putting values in equation (1) we get $q = \frac{W}{V} = \frac{550}{110} = 5$ C **RESULT:-** q = 5 C

Pb#05:The capacitance of a capacitor is 3200 pF. If the potential difference between its plates is 220 V. What is the charge on each of its plates?

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CLASS 10 PHYSICS NOTES

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GIVEN DATA:- Capacitance = C = **3200 pF = 3200 x 10^{-12}**F Potential difference = V = 220 v **REQUIRED DATA:-** Charge on each plate = Q = ? **SOLUTION:-** As we know that	**FORMULA:-** Q = C V ………………… (1) **CALCULATION:- By** putting values in equation (1) we get Q = 3200 x 10^{-12} x 220 = 704000 x 10^{-12} Q = 7.04 x 10^{5}x 10^{-12} = 7.04 x 10^{5-12} Q = 7.04 x 10^{-7}C = 0.704 μC. **RESULT**:- Q = 0.704 μC.

Pb# 06:Three capacitors of capacitance 1µF, 2 µF and 3 µF are connected in series to a 110 V battery. Calculate the equivalent capacitance and voltage across each capacitor.

GIVEN DATA:-

Capacitance of 1st capacitor = C_1= $1\mu F$

Capacitance of 2nd capacitor = C_2= $2\mu F$

Capacitance of 3rd capacitor = C_3= $3\mu F$

Voltage = V = 110 volt

REQUIRED DATA:-

(a) Equivalent capacitance= C_{eq}= ?

(b) Voltage across each capacitor= $V_1, V_2\ and\ V_3$ =?

SOLUTION:- As we know that

(a) For equivalent capacitance= C_{eq}:-

FORMULA:-

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots\ldots\ldots\ldots\quad (1)$$

CALCULATION:- By putting values in eq 1 we get

$$\frac{1}{C_{eq}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{11}{6}$$

$$C_{eq} = \frac{6}{11} = 0.54\mu F = 0.5 \times 10^{-6}\ F.$$

In series combination the charge remain the same= q_1= q_2 =q_3 = Q

Charge on each capacitor :- Q= C_{eq}V= 0.54 x110= 59.4µC = 59.5 x 10^{-6} C.

(i)For V**oltage across capacitor (**C_1**) =** V_1**:-**

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<u>FORMULA</u>: - $V_1 = \frac{Q}{C_1}$ .... (A)

<u>Calculation</u>:- By putting values in eq (A) we get.

$V_1 = \frac{Q}{C_1} = \frac{59.5 \times 10^{-6}}{1 \times 10^{-6}}$ = 59.5 volt.

(ii)For V**oltage across capacitor (**C_2**) =** V_2**:-**

<u>FORMULA</u>: - $V_2 = \frac{Q}{C_2}$ .... (B)

<u>Calculation</u>:- By putting values in eq (B) we get.

$V_2 = \frac{Q}{C_2} = \frac{59.5 \times 10^{-6}}{2 \times 10^{-6}}$ = 29.75 volt.

(iii)For V**oltage across capacitor (**C_3**) =** V_3**:-**

<u>FORMULA</u>: - $V_3 = \frac{Q}{C_3}$ .... (c)

<u>Calculation</u>:- By putting values in eq (A) we get.

$V_3 = \frac{Q}{C_3} = \frac{59.5 \times 10^{-6}}{3 \times 10^{-6}}$ = 19.83 volt.

Pb# 07:Two capacitors of capacitance 2pF and 3 pF are connected in parallel to a 9 V battery. Calculate the equivalent capacitance and the charge on each capacitor.

GIVEN DATA:-

1st capacitor capacitance = C_1 = 2pF = 2x 10^{-12} F.

2st capacitor capacitance = C_2 = 3pF = 3 x 10^{-12} F

Voltage = V = 9v

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REQUIRED DATA:-

(i) Equivalent capacitance = C_{eq} = ?

(ii) Charge on each capacitor = Q_1 and Q_2 = ?

SOLUTION:- pakcity.org

(i) For Equivalent capacitance = C_{eq} :-

FORMULA:- $C_{eq} = C_1 + C_2$ .... (A)

CALCULATION:- By putting values in equation (A) we get.

$C_{eq} = C_1 + C_2 = 2 \times 10^{-12}$ F + 3×10^{-12} F = 5×10^{-12} F= 5pF.

In parallel combination the voltage remains the same = $V_1 = V_2 = V$

Charge on C_1 capacitor = $Q_1 = C_1V = 2 \times 10^{-12} \times 9 = 18 \times 10^{-12}$ = 18 pC

Charge on C_2 capacitor = $Q_2 = C_2V = 3 \times 10^{-12} \times 9 = 27 \times 10^{-12}$ = 27 pC

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