Unit: 15
Electrostatic

Static charge

Static charge (also called static electricity) is the buildup of electric charges on the surface of an object.

Cause: Static charge is developed when electrons are transferred from one object to another usually by rubbing, friction and contact. These charges do not move freely, they stay at rest on the surface.

Types of charge

1) Positive charge (+)
2) Negative charge (-)

Explanation

As we know, there are two types of charge positive charge and negative charge. Let's explain that two charges exist by examples; When we rub a glass rod with silk, the electrons will transfer

from silk to glass rod. Similarly, If we bring another rod rubbed with silk. The first rod should be hanged with a thread and then bring other. We will notice that; Both the rod will repel each other because of same charge. This means, like charges repel each other. Moreover, If we rub the ebonite rod with fur and hang the ebonite rod. Then rub another ebonite rod with fur. Now, When we brought closer both the rods rubbed with fur. They will repel because of opposite charge.

But when we brought closer a rod rubbed with fur and a rod rubbed with silk. Both the rods will attract each other. because of opposite charge.

This means;

- Like charges repel each other.
- Unlike charges attract each other.

Charge is conserved

Charge is conserved means electric charge cannot be created or destroyed. It can only be transferred from one object to another. The total charge remains constant so charge is conserved. This is also known as electrification.

Whenever we charge an object, If we remove electron. The object will have a positive charge. If we add electrons, it will have a negative charge.

Points to remember

When we rub;

- Glass rod with silk ⟶ glass positive, silk negative.
- Plastic/ebonite rod with fur ⟶ fur positive, rod negative.

Additional Questions

Q. How the object will get charged after rubbing/friction. Briefly explain with examples.

Q. How is lightning related to static electricity?

Conductors

Generally, Conductors are those materials which allow electricity to pass through it.

In Electrostatics, when conductors are in free state. The valence electron are loosely bonded to its outermost shell. This loose binding allows the electrons to be easily detached from the atom, enabling them to move freely in conductor or leave the conductor.

Example: 1) copper
2) Aluminium
3) Iron.

Insulator

Generally, Insulators are those materials which donot allow electricity to pass through it.

In Electrostatics, when insulators are in free state. Their valence electrons are tightly attached to atoms. As a result, these electrons cannot move freely, not allowing charge

to flow through it.

Example: 1) Rubber
2) Plastic
3) Glass, wood.

Charging

Charging means giving or taking away electrons from a body so that it gain an electric charge/static charge. Charge is developed due to transfer of electrons.

Methods of charging

1) Charging by friction:

Friction is a basic way for charge transfer between objects. It occurs when two different materials are rubbed together.

- Electrons are transferred from one material to other.
- One object becomes positively charged and other negatively charged.

Example: 1) Rubbing a balloon on hair.
2) Rubbing of ebonite rod with fur.

2) Charging by Contact (conduction):

When a charged object comes into contact with a neutral object. The excess of electron transfer from charged object to neutral object. Both the object will be charged.

- This happens with physical contact and touching with neutral object.
- Electron flow from charged object to neutral one.
- Both objects end with same type of charge.

Example: Touching a metal rod with a negatively charged rod → electrons transfer and both become negatively charged.

PKM2

Andar bohat boring class ha teacher betha hua ha or hum gaid ha or hamara dost ha or wo humein Dikh raha ha window se or wo Ishara karta ha ankhon se ke andar kia scene ha or hum ishara karta ha boring to wo phir bahir ana ka kehta ha.

This is bunk induction story where no physical charge are required. Now; move to topic.

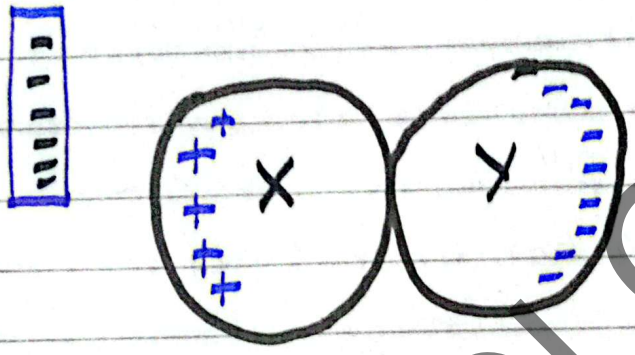
3) Charging by Induction:

Charging by induction is a way to give an object an electric charge without touching it **or** A change in distribution of electric charge in an object, caused by influence of nearby charges is called Electrostatic induction.

Example: Take two metal spheres X and Y. The charge in both metals is not. Put both the metals together. Bring a negatively charged rod near to both spheres. This negative charge repels the electrons from X while it transfers to Y. This creates a temporary separation of charge within Y with an excess of negative charge. Now; If we separate both sphere, Sphere X which lost electron becomes positively charged. Sphere Y where electrons are concentrated

on one side becomes negatively charged. This demonstrates how electrostatic induction can be used to separate charge.

(a)



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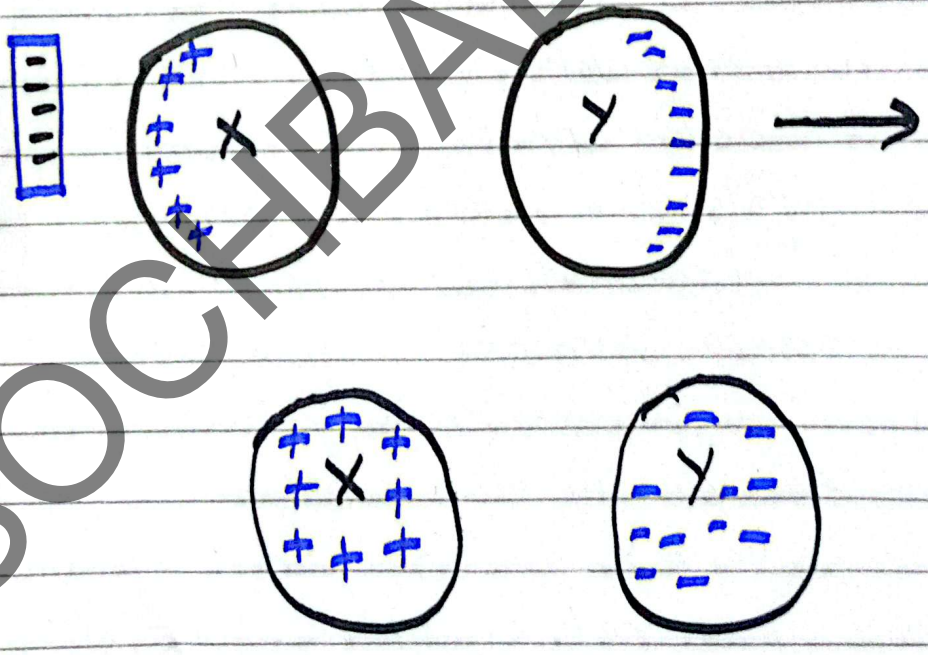


Grounding

It is the process to let the extra charge in ground. If we connect a neutral body with metal rod to ground and a charged body. Considering If it is negative, the positive charge in neutral body will remain and negative charges of neutral body while repelling will move through the metal rod towards the ground leaving only positive charges in neutral body making it a positive charge.

Additional Questions

Q. What is difference between conductor and insulator.

Q. Why do metals conduct electricity easily?

Q. Why is plastic used to cover electric wires.

Q. Can a charge move freely in insulators. Why or why not?

Q. What happens when a charged body touches a conductor

Q. Why does a charged balloon stick to a wall even though the wall is neutral?

Q. How can an uncharged metal sphere be charged by induction?

Q. What happens to charges in a conductor when a charged object is brought near it?

Q. Why do we ground an object during charging by induction?

Q. Can an insulator be charged by induction?

Q. Why is it safer to stay inside a car during lightning storm?

Q. Why does rubbing a plastic scale with hair make it attract small pieces of paper?

Q. Define electrostatic induction with the help of 2 metal spheres.

Q. How the body gets discharge by using grounding concept in electrostatic induction?

Q. Explain charging through Friction/ Conduction?

Electrical Discharging

Electrical Discharge is the process of neutralizing charges on a material surface.

1) Heating above flame

When an insulator is heated with a flame, the heat excites the electrons and can make the surrounding air conductive, aiding in charge neutralisation.

2) Exposing to humid conditions:

Placing an insulator in damp conditions promotes discharge by allowing water molecules to adhere to its surface. These polar molecules interact with charged areas, creating a thin conductive layer that facilitates charge movement.

Surface charge can be induced on insulators by Polarization.

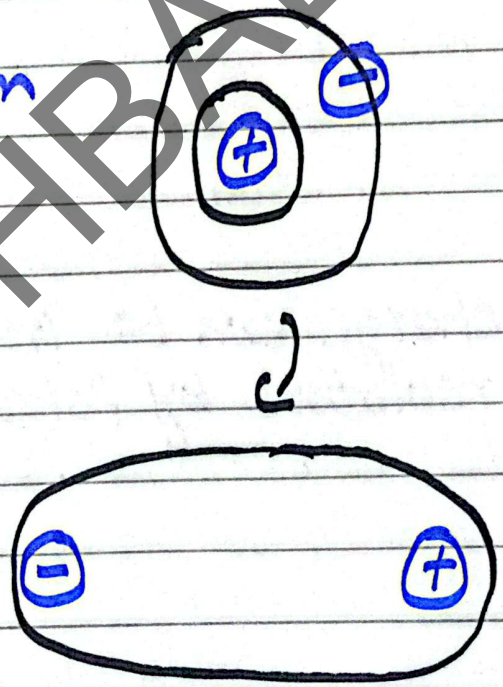
As, Insulators do not have free electrons so charge cannot move freely from one point to another.

However, when a charged body is

brought near an insulator, the electrons inside atoms/molecules shift slightly within their fixed positions.

"The process of shifting charges without leaving their atoms is called polarization."

In Polarization, the electron are pulled slightly towards or away from charged body. This creates tiny electric dipoles inside the material. As a result, the surface of the insulator develops induced charges.



Example: 1) If we comb hair by plastic comb or brush. As we rub, some electrons from hair transfer into comb giving it a negative charge. Now, take small pieces of paper nearby. The pieces of paper typically have a balanced charge. but when bought close to negatively charged comb, These pieces of paper fly towards the comb. This is because there is an electric field the negative charge repels negative charge in paper, but it also attracts some positive charge.

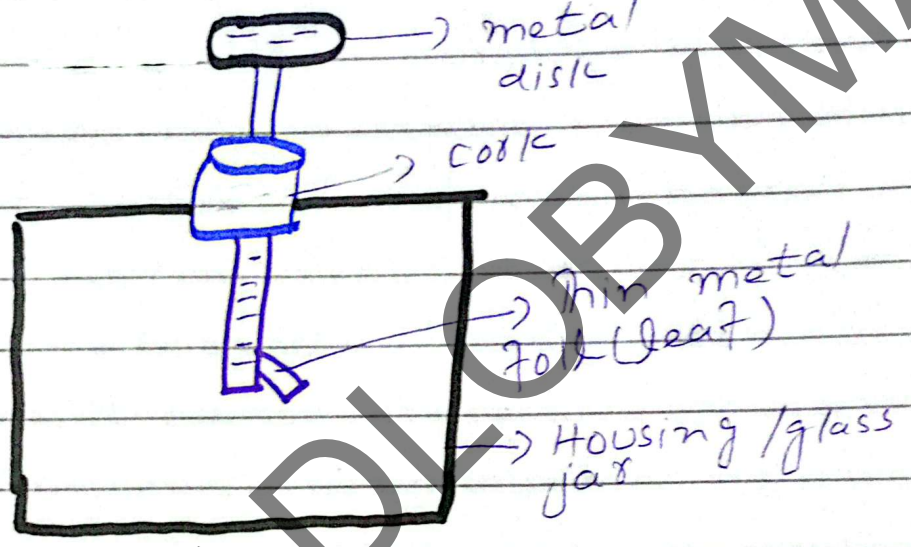
2) It can also be seen when a balloon is rubbed against hair. can attract falling stream of water.

Electroscope

An Electroscope is a simple device used to detect electric charges and to find out whether it is positive or negative. It works on the principle of electrostatic

induction and repulsion that is like charges repel and unlike charges attract.

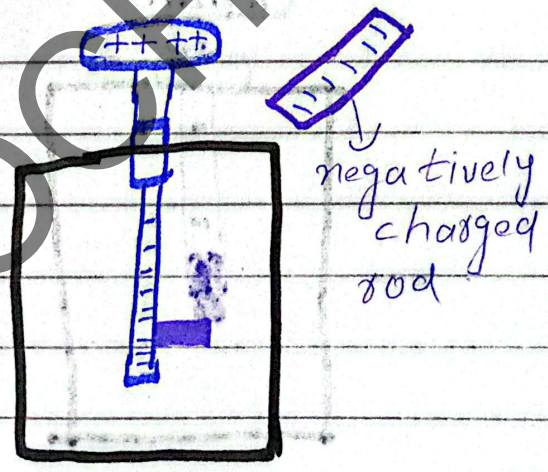
Structure

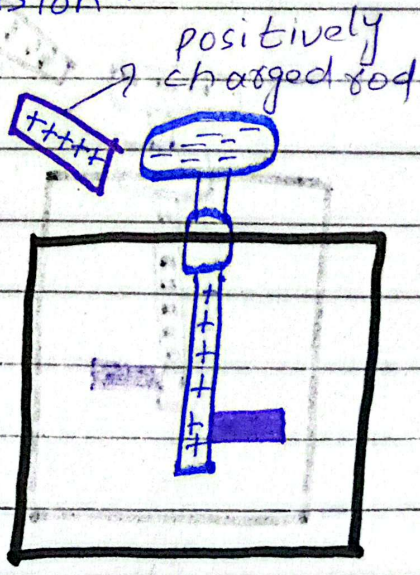


A basic electroscope consists of a metal bar with a metallic disk at its upper end. There is a cork just below disk. At lower end of electroscope, there is thin, flexible gold leaf. The lower portion of electroscope is enclosed with an insulated housing.

Function.

To detect the charge, we simply touch the metal disk with the object we want to detect. If we touch the disk with negatively charged plastic rod, some of rod's excess electron will transfer to the disk. These electron will disperse throughout the metal rod, this will cause metal leaf to repel and move away from rod rising higher Now; If we touch the disk with positively charged plastic rod. It will attract electrons from electroscope. The leaves electroscope become positively charged. Leaves diverge (spread apart) due to repulsion.



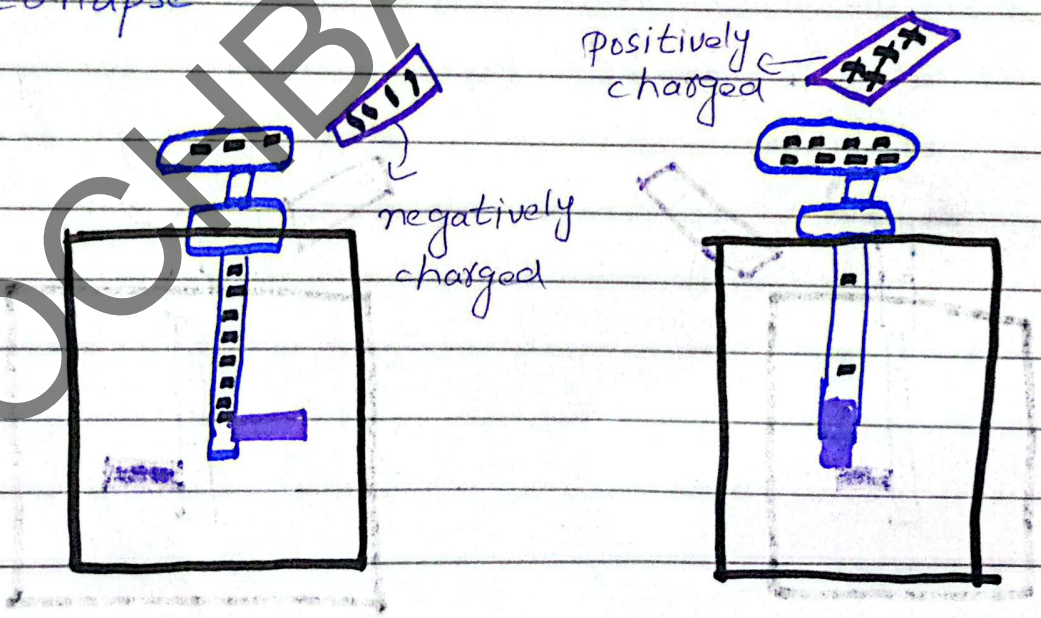


Analyze / Identification of charge.

To Identify the charge. First, we have to charge electroscope by a known charge. If we charge electroscope negative. Then;

If a negatively charged rod is brought close to already negatively charged electroscope, the leaf will diverge even further as more electrons are repelled.

If a positively charged rod is brought close to electroscope. It will attract electron up causing the leaf to collapse.



It is possible to create a positively charged electroscope using a negatively charged rod through charging by induction. By grounding the electroscope with a finger, electron can escape from bulb to ground. When a negatively charged rod is brought close to disk, electron are repelled through finger and body to earth. Removing the finger while, keeping charge nearby results in positive charge of electroscope.

Electric field

The region of space around a charge where it exerts a force on other charge is called Electric field.

Now, consider a test charge (unit positive charge) q_0 is brought into electric field of source charge Q. The source charge will exert an electrostatic force F_e on the test charge.

source charge

Test charge

"The electrostatic force exerted/experienced by test charge(unit positive charge) when it is brought to electric field of source charge is called electric field intensity."

$$E = \frac{F_E}{q_0}$$

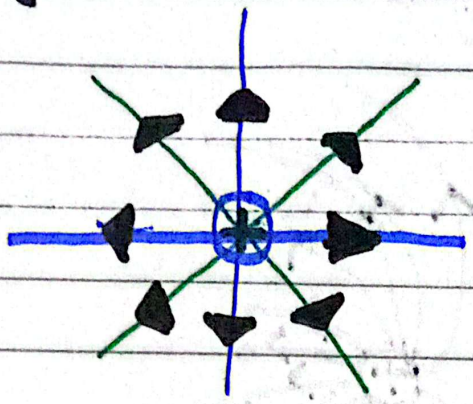
Its SI unit is N/C. It is vector quantity.

Electric field Lines

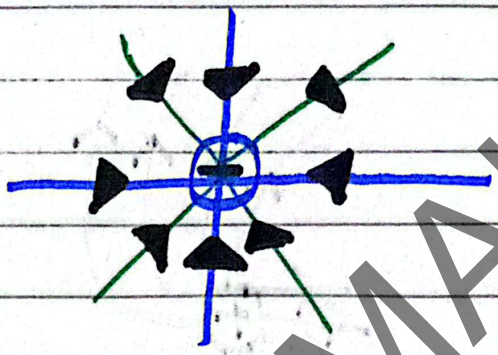
The lines which are drawn to show electric field are electric field lines. These lines were first introduced by Michael Faraday. These lines are imaginary and have no physical existence. For positive charge, the electric field lines are diverged means they are directed outward. Remember electric field lines are directed from positive to negative charge.

For negative charge, the field lines are directed towards the charge. means the field lines are directed inwards.

(a) Positive



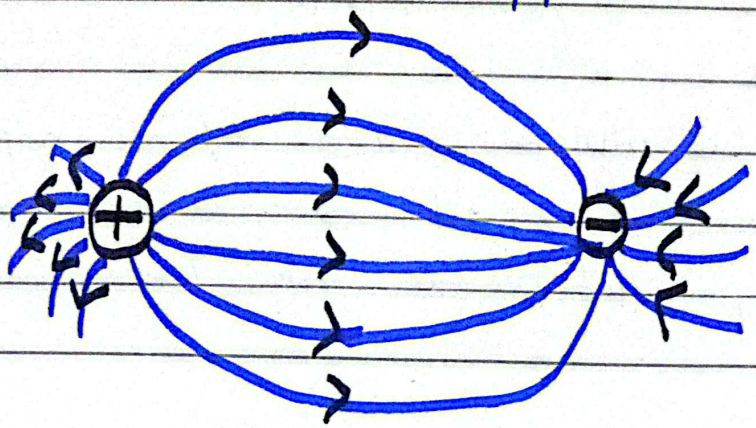
(b) negative



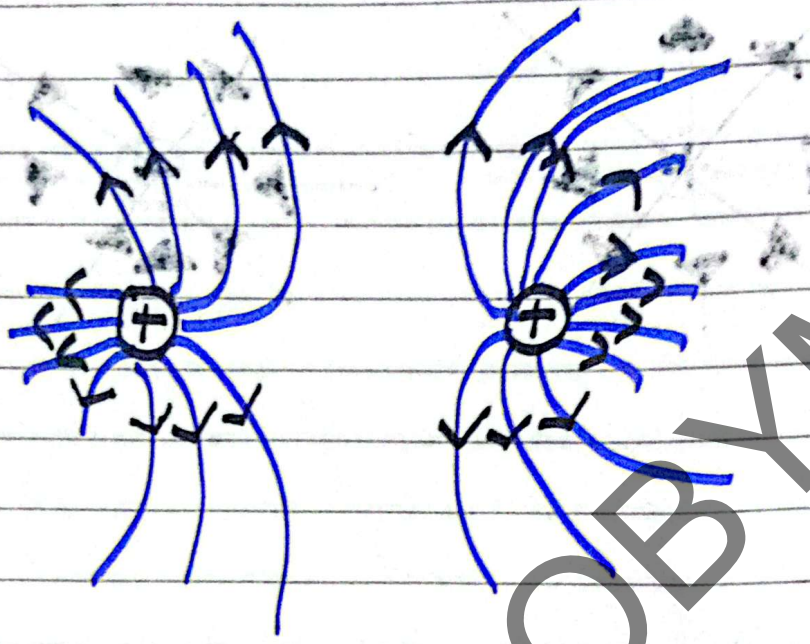
1) When opposite charges are brought closer, these lines originate from positive charge and terminate at negative charge. The concentrated lines between the charges indicate a powerful electric field in that region, particularly between the charges.

2) When similar charges are brought When similar charges are brought closer, they repel each other. This can be shown by electric field lines.

(a) opposite charges



(b) Similar charges

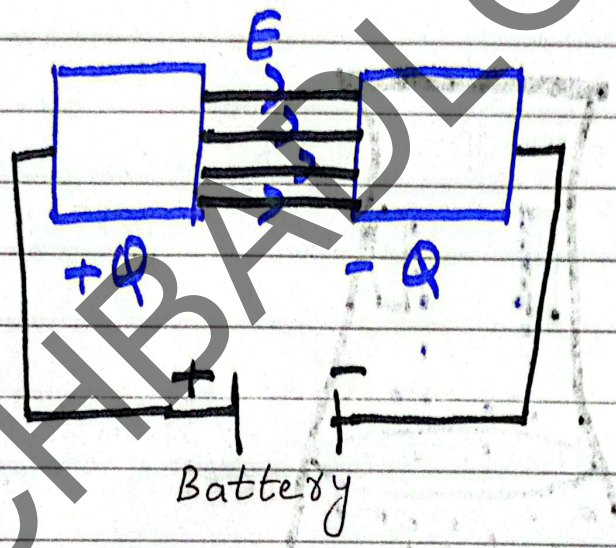


Concept of electric field in conductor & capacitor

The electric field of charged conductor have unique properties. Outside the sphere, the electric field decreases by decreasing with distance according to inverse square law. However, inside the sphere, the electric field is zero because charges distribute evenly on surface.

While studying electric fields, capacitor is an example. It consists of two parallel plates which are

oppositely charged. One plate has a positive charge and other has a negative charge. Both are connected to a battery. The electric field in this region is uniform, which means both the strength and direction of electric field remain constant throughout the space between plates.

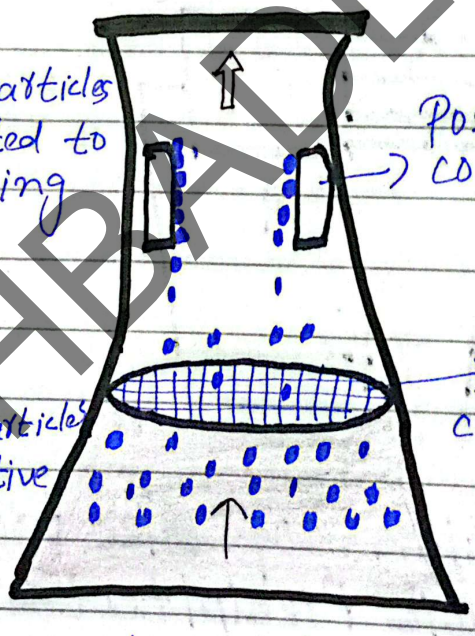


Application of Electrostatics

1) Electrostatic Precipitator and Dust Extraction

Electrostatic precipitator and dust extractor work on the principle

of electrostatics. In this process, Dust particles are given a charge by passing through Grid. Then these dirty particles attract to oppositely charged plates where they stick. The clean air then passes out and the collected dust is removed later.



2) Photocopier Machine

A photocopier machine is a device used to make copies of documents or images quickly.

The electrostatic process which is used called Xerography. The major steps include.

1) Place the paper on glass plate positively.
2) Charge the photo conducting drum.
3) A bright light shines on it and with the help of lens, reflected light forms a positive charge image on drum.
4) The toner is negatively charged. The toner is attracted to positive charge.
5) The toner is then transferred and pressed into blank paper.
6) Finally, the paper is heated to fix the toner- making a permanent copy.

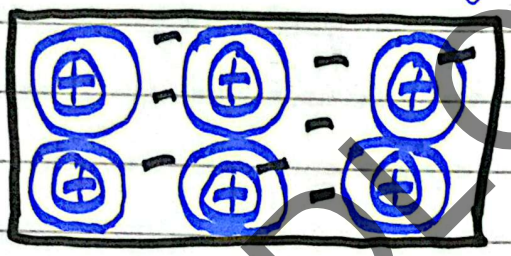
3) **Paint in car:**

Automobile manufacturers use electroplating to paint new cars. The body of car is charged and then the paint is given opposite charge by charging the nozzle of sprayer. The charge can be positive or negative on nozzle but it

must be opposite to charge of car.

Electrical Breakdown

When a very high voltage is applied, the electric field becomes strong enough to tear electrons from atoms, turning an insulator into a conductor. This causes a sudden flow of current seen as spark or lightning.



Examples

1) Corona Discharge:

Corona Discharge appears as a faint glow around sharp points or edges of conductors at high voltage. This occurs because air molecules around the conductor become ionized, causing a localized breakdown. This can be seen around power lines and during thunderstorms.

2) Lichtenberg Figures/Discharge:

In this breakdown, A branching tree-like pattern formed when high voltage passes through or over an insulator, showing the path of electric discharge.

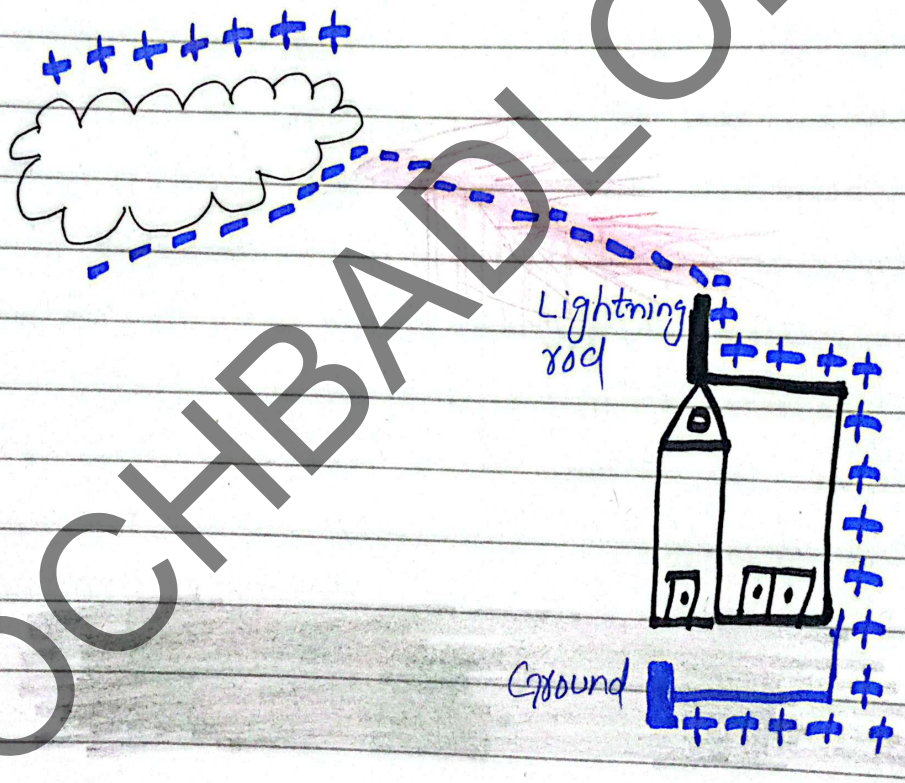
Lightning and its Generation

Lightning is a powerful release of electrical energy that occurs in clouds when air, water droplets or volcanic ash collide, causing electrical charges to separate. Positive charge rise to top of cloud while negative charges sink. This creates a conductive plasma as the cloud becomes more charged. Excess electron at the cloud's base travel to the ground in a zigzag pattern called a step leader.

The negative charge at the cloud's bottom induces a positive charge on earth's surface creating a

polarized effect: Nearby air molecules ionize and rise, forming a positive charge known as a streamer. When the streamer connects with the step leader, a complete path is established result in a lightning strike, with the negative charge moving to ground at speeds up to 100,000 km/s.

Prevention:



- In a thunderstorm, negative charge accumulates in the lowest region

of clouds. The negative electric field from the clouds repels electrons on the ground, inducing a positive charge terminal.

- The strong electric field accelerates electrons and ions, causing a chain reaction in the air, forming plasma.
- The ionized air is a conductor and it branches out from the cloud forming and are called step leaders.
- Positive charge spark out from the lightning rod, meeting the step leader. The conducting path is complete and current neutralizes.
- The current travel safely through the conductor to ground terminal.

The End