ELECTROSTATICS

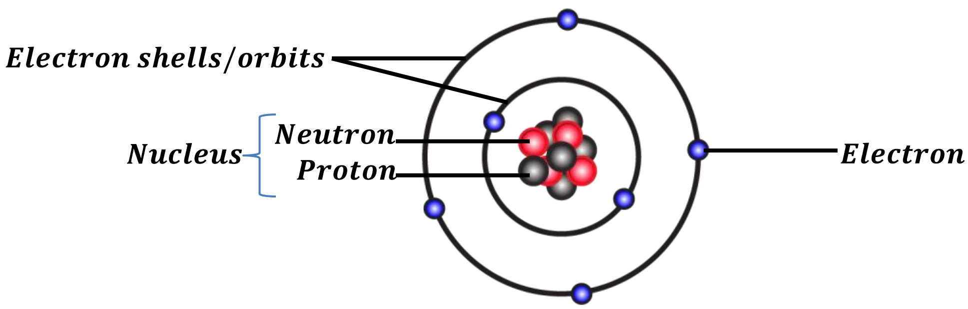
Electrostatics is the study of electric charges at rest.
These charges include;

- Positive charges (+)
- Negative charges (-)

STRUCTURE OF AN ATOM

An atom is the smallest particle of an element that can take part in a chemical reaction.
An atom consists of three particles namely;

- Electrons
- Neutrons
- Protons



Properties and location of the particles of an atom:

Particle	Location	Charge
Proton	In the nucleus of an atom	Positive charge (+)
Electron	It orbits outside the nucleus of an atom	Negative charge (-)
Neutron	In the nucleus of an atom	No charge (neutral)

Note:

In an atom, the number of protons in the nucleus is equal to the number of electrons outside the nucleus. Therefore, an atom is said to be **neutral** (has no charge).

Since the nucleus has only protons and neutrons, then it is positively charged.

NB: Any material that loses electrons becomes positively charged and any material that gains electrons becomes negatively charged.

CONDUCTORS AND INSULATORS

Conductors:

A **conductor** is a material with free electrons and can allow heat and electricity to pass through it easily.

The electrons in a conductor are free to move because they are loosely held outside the nucleus of an atom.

Examples of conductors include; all metals, carbon in form of graphite, acids, bases and salt solutions.

Insulators:

An **insulator** is a material without free electrons and cannot allow heat and electricity to pass through it easily.

The electrons in an insulator are not free to move because they are tightly or strongly held outside the nucleus of an atom.

Examples of insulators include; rubber, dry wood, glass plastic, ebonite, fur, polythene, etc.

Differences between conductors and insulators:

Conductors	Insulators
• Electrons are free to move. • Electrons are loosely held outside the nucleus of an atom. • They are good conductors of heat and electricity.	• Electrons are not free to move. • Electrons are tightly held outside the nucleus of an atom. • They are poor conductors of heat and electricity.

LAW OF ELECTROSTATICS

It states that like charges repel while unlike charges attract each other.

ELECTRIFICATION (CHARGING MATERIALS)

This is the process of producing electric charges.

There various methods of charging materials and they include:

- Charging by friction/rubbing
- Charging by contact/conduction
- Charging by induction (electrostatic induction)

Charging by friction/rubbing:

This is the best method for charging insulators

- Two insulators are rubbed together and electrons are transferred from one insulator to another.
- The insulator that gains electrons becomes negatively charged and the insulator that loses electrons becomes positively charged.
- Therefore, the two insulators acquire equal but opposite charges.

The table below shows insulators gaining ang losing electrons when rubbed:

Loses electrons	Gains electrons
Glass	Ebonite
Fur	Silk
Cellulose	Polythene

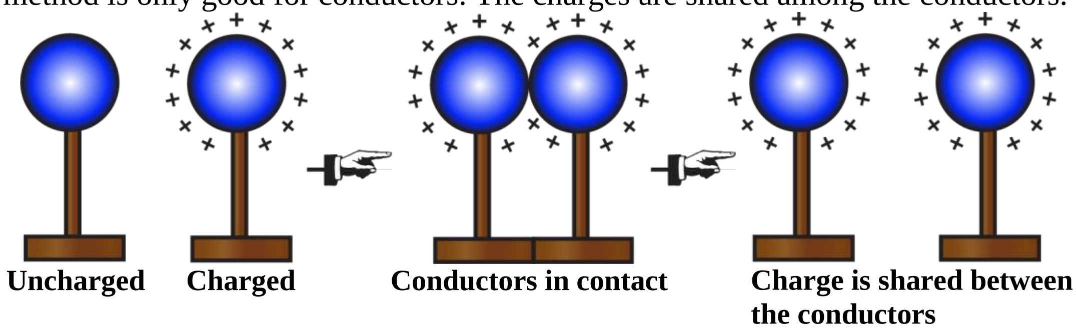
Example:

❖ When silk and glass are rubbed against each other, the glass atoms lose electrons hence acquiring a positive charge and the silk atoms gain electrons hence acquiring a negative charge.
The resulting electric force can attract small pieces of paper.

Question 1: Describe how fur and silk can be charged by friction.
- ***Fur and silk are rubbed against each other.***
- ***Fur atoms lose electrons and acquire a positive charge.***
- ***Silk atoms gain electrons and acquire a negative charge.***
- ***Therefore, fur and silk acquire equal but opposite charges.***

Question 2: Describe how ebonite and glass can be electrified.
- ***Glass and ebonite are rubbed against each other.***
- ***Glass atoms lose electrons and acquire a positive charge.***
- ***Ebonite atoms gain electrons and acquire a negative charge.***
- ***Therefore, glass and ebonite acquire equal but opposite charges.***

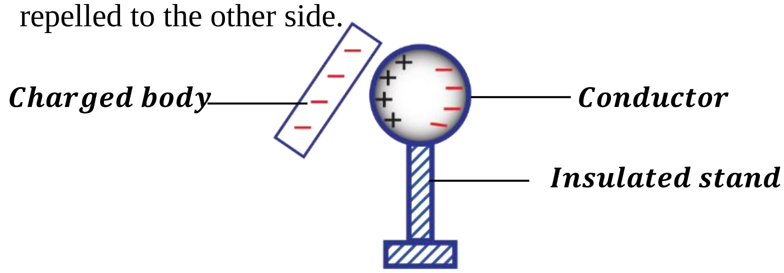
Charging by contact/conduction:
This method is only good for conductors. The charges are shared among the conductors.



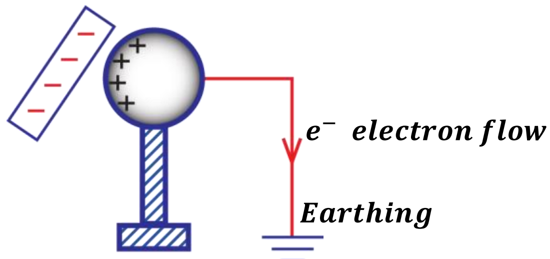
- Bring the uncharged conductor in contact with a charged conductor.
- Separate the two conductors after short period of time.
- The uncharged conductor will acquire a similar equal charge to that of a charged conductor.

Charging by electrostatic induction:
This is the method of charging a conductor without touching it with a charged body.
It involves bringing a charged body near the body to be charged.
The uncharged body acquire a charge opposite to that of a charging body.

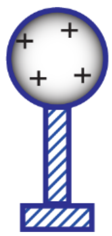
Charging a conductor positively by induction:
- Bring a negatively charged body near one side of a conductor placed on an insulated stand.
- Positive charges are induced on the side near the charged body and negative charges are repelled to the other side.



- With the charged body still in position, the other side of the conductor is earthed by connecting it with an earth wire to the ground. Electrons flow to the ground through the earth wire.

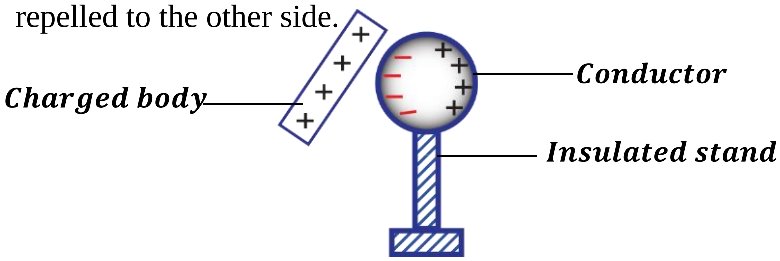


- With the charged body still in position, the earthing is removed and then the charged body is also removed.
- Positive charges distribute themselves all over the conductor and the conductor is left with a net positive charge.

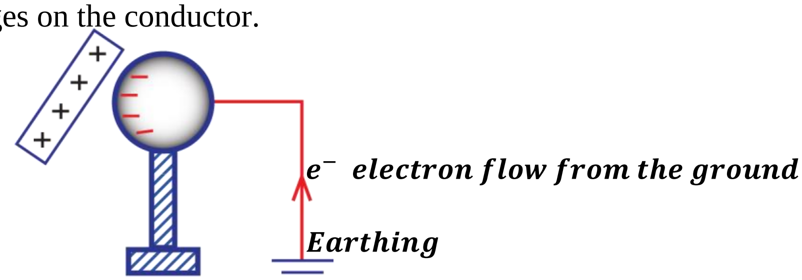


<u>Charging a conductor negatively by induction</u>:

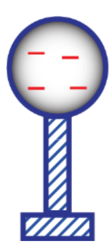
- Bring a positively charged body near one side of a conductor placed on an insulated stand.
- Negative charges are induced on the side near the charged body and positive charges are repelled to the other side.



- With the charged body still in position, the other side of the conductor is earthed by connecting it with an earth wire to the ground. Electrons flow from the ground and neutralize the positive charges on the conductor.



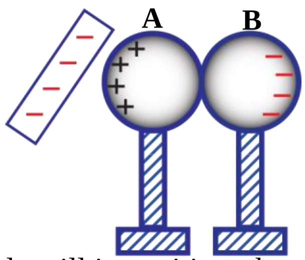
- With the charged body still in position, the earthing is removed and then the charged body is also removed.
- Negative charges distribute themselves all over the conductor and the conductor is left with a net negative charge.



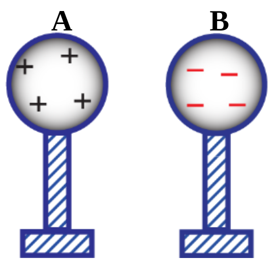
NOTE:
Earthing a conductor may also be done by touching it with the fingers since human bodies are good conductors of electricity.

Charging two conductors simultaneously with an opposite charge by induction:

- Place two conductors A and B in contact and on an insulated stand.
- Bring a negatively charged body near conductor A.
- Positive charges are induced on conductor A and negative charges repelled to conductor B.

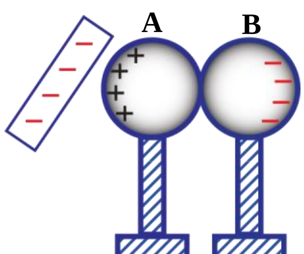


- With the charged body still in position, the conductors are separated. On removing the charged body, the charges distribute all over the conductors.
- Conductor A acquire a net positive charge and conductor B acquire a net negative charge.

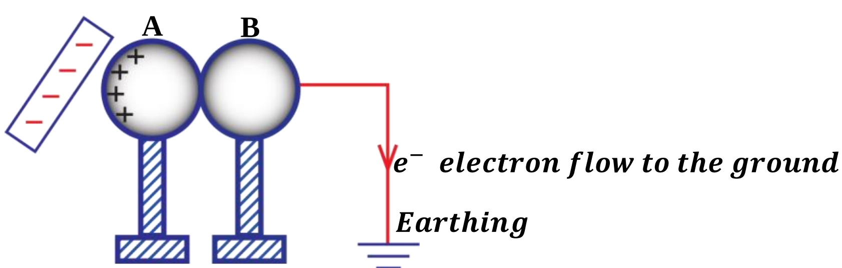


Charging two conductors simultaneously with the same charge by induction:

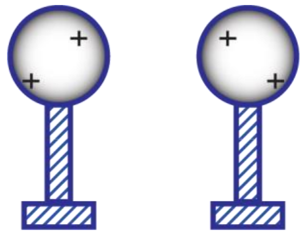
- Place two conductors A and B in contact and on an insulated stand.
- Bring a negatively charged body near conductor A.
- Positive charges are induced on conductor A and negative charges repelled to conductor B.



- With the charged body still in position, conductor B is earthed by connecting it with an earth wire to the ground. Electrons flow to the ground.



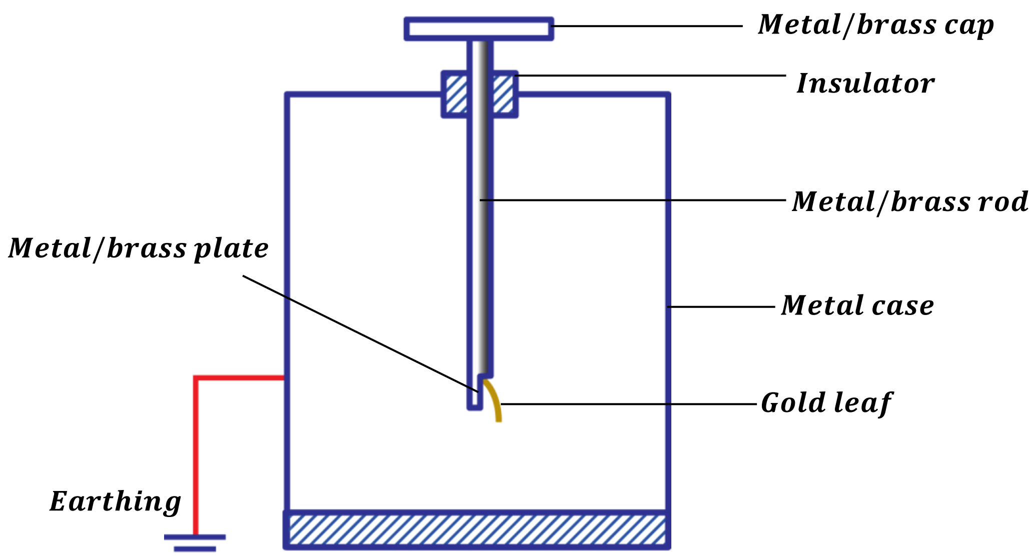
- With the charged body still in position, the earthing is removed and then the charged body is also removed.
- Positive charges distribute themselves all over the two conductors and the conductors are left with a net positive charge.



GOLD LEAF ELECTROSCOPE (GLE)

A gold leaf electroscope is an instrument used to detect the presence of charge and differentiate between the charges.

Structure of a gold leaf electroscope:



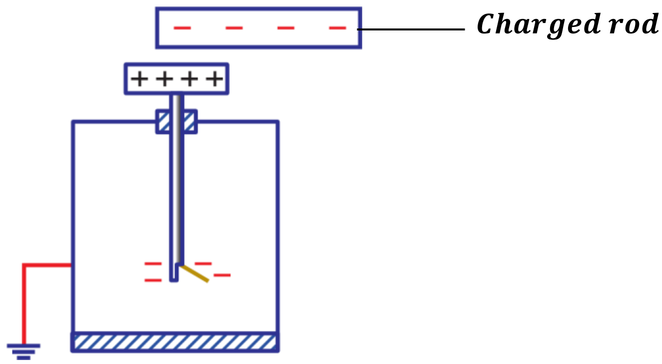
It consists of a metal cap and metal plate joined together by a metal rod.
It consists of a metal case with glass windows to protect it from draught.
The metal case is always earthed to keep it at zero potential.
The electroscope is insulated so that there is no inflow and outflow of charges

Mode of action of a gold leaf electroscope:

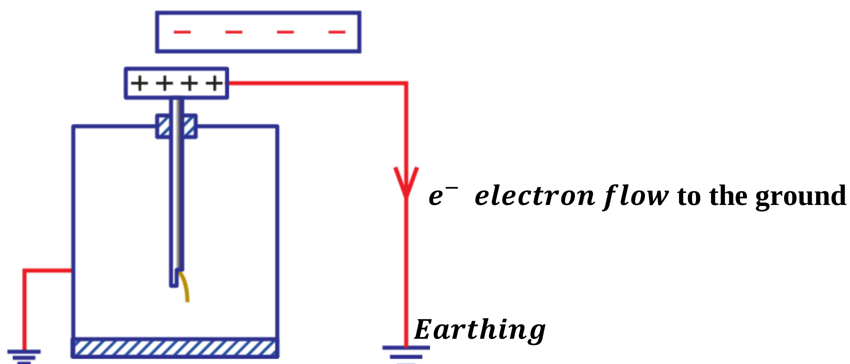
- When a charged body is brought near the cap of the electroscope, the cap will acquire an opposite charge to that on the charged body by induction.
- The charge on the body will repel all charges similar to it down to the metal rod, to the plate and the leaf.
- Due to presence of like or similar charges on the plate and gold leaf, the leaf diverges as it is repelled by the plate.
- Therefore, leaf divergence means that the body brought near with the cap carries a charge.

Charging a Gold Leaf Electroscope positively by induction:

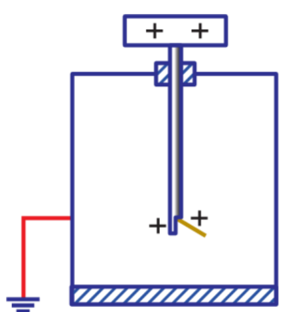
- Bring a negatively charged rod near the cap of an uncharged gold leaf electroscope.
- Positive charges are induced on the cap and negative charges are repelled down to the plate and the gold leaf. The leaf diverges due to presence of like charges at the plate and the leaf.



- With the charged rod still in position, the gold leaf electroscope is earthed by connecting it with an earth wire to the ground. Electrons flow from the plate and the leaf to the ground through the earth wire. This causes the leaf to collapse (decrease in divergence of the leaf)

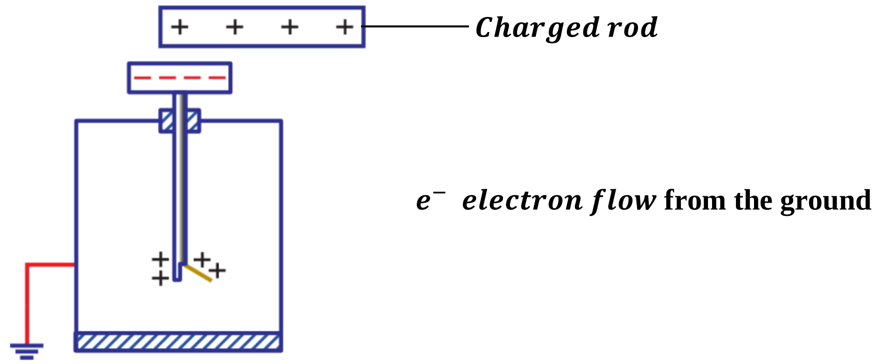


- With the charged rod still in position, the earthing is removed and then the charged rod is also removed.
- Positive charges distribute themselves all over the metal cap, plate and gold leaf. The leaf diverges again due to presence of like charges at the plate and the leaf.

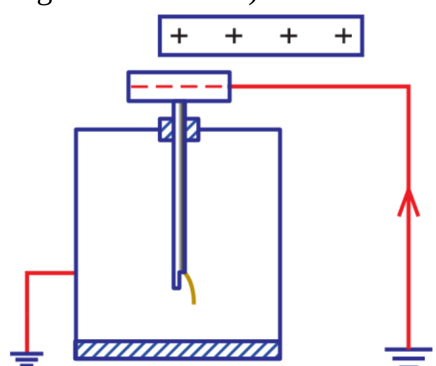


Charging a Gold Leaf Electroscope negatively by induction:

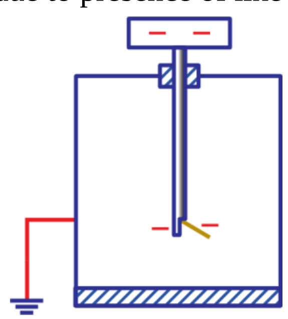
- Bring a positively charged rod near the cap of an uncharged gold leaf electroscope.
- Negative charges are induced on the cap and positive charges are repelled down to the plate and the gold leaf. The leaf diverges due to presence of like charges at the plate and the leaf.



- With the charged rod still in position, the gold leaf electroscope is earthed by connecting it with an earth wire to the ground. Electrons flow from the ground through the earth wire to neutralize the positive charges at the plate and the leaf. This causes the leaf to collapse (decrease in divergence of the leaf)



- With the charged rod still in position, the earthing is removed and then the charged rod is also removed.
- Negative charges distribute themselves all over the metal cap, plate and gold leaf. The leaf diverges again due to presence of like charges at the plate and the leaf.



USES OR APPLICATIONS OF A GOLD LEAF ELECTROSCOPE:

(i) To detect the presence of charge on a body:

- Bring the body to be tested near the cap of an uncharged gold leaf electroscope.
- If the leaf diverges, then the body has a charge.
- If the leaf remains unchanged, then the body has no charge (neutral).

(ii) To test the sign or nature of charge on a body:

- Bring the body to be tested near the cap of a charged gold leaf electroscope.
- If the leaf divergence increases, then the body has a charge similar to that on the electroscope.
- If the leaf collapses (decrease in divergence), then the body either has a charge opposite to that on the electroscope or the body is neutral. In this case, we cannot conclude. But the G.L.E is discharged by touching its cap with a finger (earthing) and then given a charge opposite to the one it had previously and the experiment is repeated. If still the leaf collapses, then the body is neutral.

NOTE:

Increase in divergence is the only sure way of testing for sign of charge on the gold leaf electroscope.

Charge on G. L. E	Charge on a body	Effect of divergence of the leaf.
$+$	$-$	*Decrease*
$+$	$+$	*Increase*
$-$	$-$	*Increase*
$-$	$+$	*Decrease*
$+$	*No charge*	*Decrease*

(iii) To identify whether a body is an insulator or conductor:

- Bring a body to be tested in contact with the cap of a positively charged gold leaf electroscope.
- If the leaf collapses suddenly/immediately, then the body is a good conductor e.g. copper
- If the leaf collapses gradually/slowly, then the bod is a semi-conductor e.g. silicon.
- If there is no change in divergence of the leaf, then the body is an insulator.

(iv) To test the magnitude of charge on the body:

- Two bodies of different sizes are similarly charged simultaneously.
- Each body is brought near the cap of the uncharged gold leaf electroscope one at a time.
- It is observed that a smaller body causes a smaller divergence of the leaf and the bigger body cause a greater divergence of the leaf.

(v) To compare and measure potentials:

- Two bodies are similarly charged simultaneously.
- Each body is brought in contact with the cap of a gold leaf electroscope one at a time.
- The divergences of the gold leaf in the two cases are noted and compared.
- The body which causes more divergence is at a higher potential than the other one.

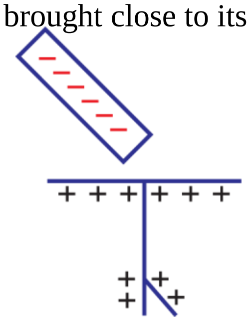
Precautions taken when carrying out electrostatic experiments:

- The experiments should be carried out on a dry. *This because moisture/water conducts electricity thus giving out inaccurate values.*
- The plate and the cap of a gold leaf electroscope should always be kept clean and dry.
- The apparatus used must be insulated.
- Accidental touches from hands and clothes should be avoided.

Sample questions:

1. A charged rod was brought close to the cap of a negatively charged electroscope. It is observed that the leaf divergence increased as the rod was moved closer to the cap. Identify the charges on the rod.
   A. Positive
   B. Positive and negative
   C. Negative
   D. No charge.

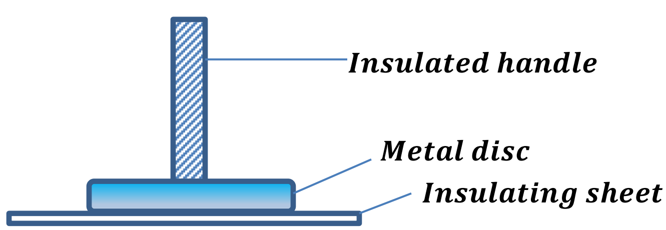
2. State and explain the observation on the leaf of a positively charged electroscope when a negatively charged rod is brought close to its cap as shown below.



Observation: The leaf collapses.
Explanation: When a negatively charged rod was brought near the cap of the electroscope, it induced positive charges at the cap and repelled negative charges down to the plate and the gold leaf leading to neutralization of the positive charges thus the gold leaf collapses.

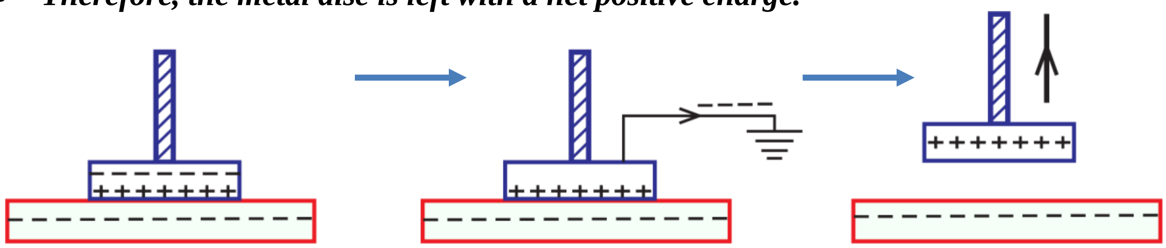
ELECTROPHORUS

This is a metal disk with an insulated handle placed on an insulating sheet previously charged by rubbing.
An electrophorus is used to produce unlimited charges by induction.



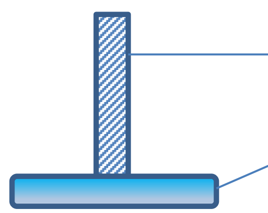
QN: Briefly describe how an electrophorus produces a positive charge.

- ***An insulating sheet is given a negative charge by rubbing.***
- ***A positive charge is induced on the lower part of the metal disc and a negative charge is repelled to the upper part.***
- ***The upper part of the metal disc is earthed by touching it with a finger to remove the negative charges.***
- ***Therefore, the metal disc is left with a net positive charge.***



PROOF PLANE:

This is a device used to transfer charge from one conductor to another.
It is the upper part of the electrophorus.



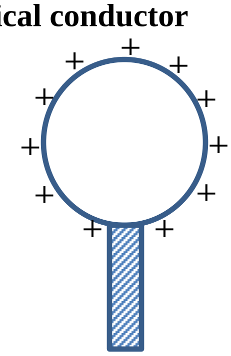
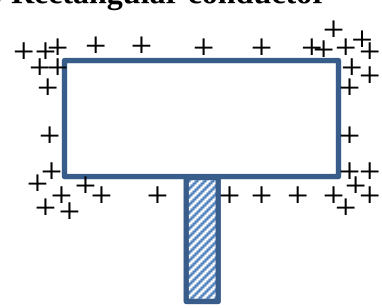
DISTRIBUTION OF CHARGE ON A CONDUCTOR

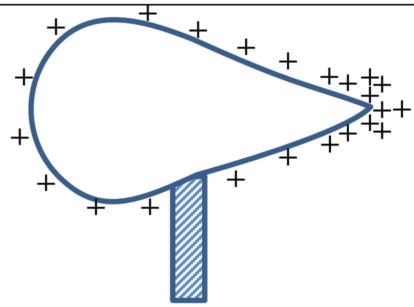
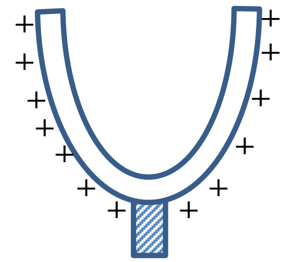
The distribution of charge on the surface of a conductor depends on the shape of that conductor. Charge is more concentrated at pointed edges of a conductor thus, there is a <u>high surface charge density</u> at sharp points.

Definition:

Surface charge density is the quantity of charge per unit area of the surface of a conductor.

Charge distribution over surfaces of conductors of different shapes:

(a) Spherical conductor	**(b) Rectangular conductor**
	
Charges are evenly distributed	Charges concentrate at sharp points

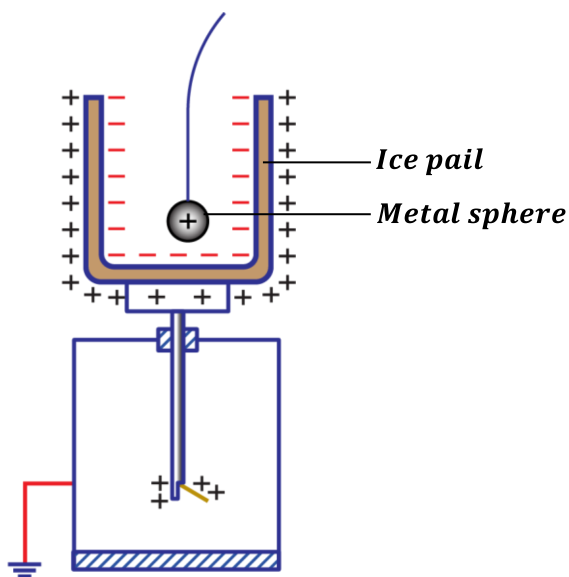
 Charges concentrate at the sharp point	 Charges reside outside on the hollow conductor.

NOTE:
In a hollow conductor charges always reside outside the conductor. This was experimented by Faraday.

<u>FARADAY'S ICE-PAIL EXPERIMENT</u>
(An experiment to shoe charge distribution in a hollow conductor)

- Place an uncharged metal ice pail on the uncharged gold leaf electroscope.
- Suspend a positively charged metal sphere on a thread and lower it into the pail without touching the pail.

<u>Observation</u>: The gold leaf diverges indicating that charge has been induced on the outside of the pail.

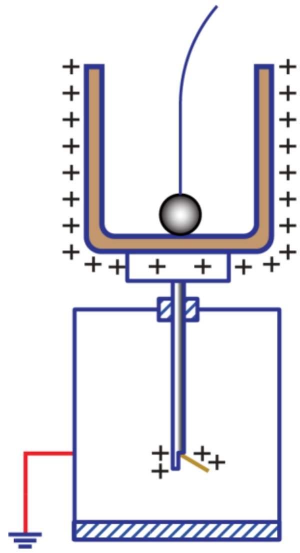


- Move the metal sphere in different positions inside the pail without touching the pail.

<u>Observation</u>: The divergence of the gold leaf does not change and when the metal sphere is completely removed from the pail and tested, it had all its charge.

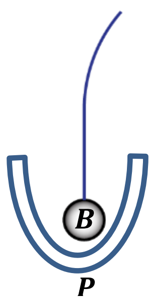
- The metal sphere is again lowered in the pail and allowed to touch the bottom of the pail.

<u>Observation</u>: There is no change in divergence of the leaf but when the metal sphere is completely removed from the pail and tested, it had no charge.



Conclusion:
- When the positively charged metal sphere touches the inside of the pail, the induced negative charges in the inside part of the pail neutralize the positive charge on the ball hence the ball remains with no charge.
- The net charge on the hollow conductor reside outside. This shows that there is no charge residing inside a charged hollow conductor.

Example:
1.



The figure above shows a negatively charged ball, B inside a metal conductor, P.
(a) Describe the distribution of charge on the metal conductor.
(i) Before B touches P
Positive charges are induced on the inside part of conductor, P and negative charges are to the outside part of conductor, P.

(ii) After B touching P
The negative charges on the ball, B neutralize the positive charges on the inside part of the conductor, P. therefore, conductor, P remains with no charge inside.

(b) After touching conductor, P, the ball is transferred to a positively charged electroscope and tested for its charge. State and explain what was observed.
There was no change in divergence of the gold leaf because the ball, B had lost its charge due to neutralization when it touched conductor, P.

ACTION AT SHARP POINTS

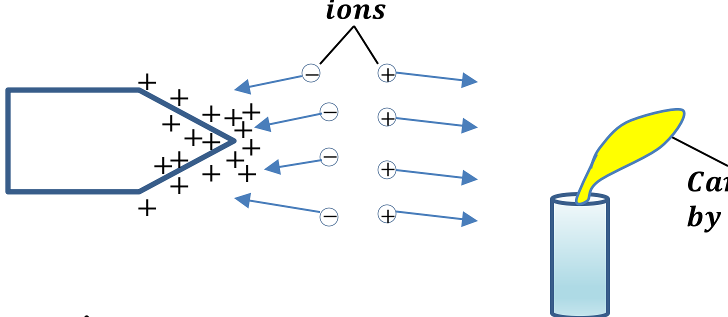
- The sharp points of a conductor have a high charge density which creates a strong electric field.
- The strong electric field ionizes the air around the sharp points forming positive and negative ions.
- Ions which have the same charge as that on the sharp points are repelled away and ions which have an opposite charge to that on the sharp points are attracted towards the sharp points resulting into neutralization of charge hence corona discharge.

Definition:

Corona discharge (charge leakage) is the process by which a pointed conductor apparently loses its charge.

NOTE:

The repelled ions from the sharp points form an electric wind which can blow a candle flame as shown below.



Sample question:

A highly charged positive sharp point is brought closer to a Bunsen burner flame.

(i) State your observation.

The flame is brown away from the sharp points.

(ii) Explain your observation.

Due to high charge density around the sharp point, the air around the sharp point is ionized forming positive and negative ions. Negative ions are attracted to the sharp point and positive ions are repelled away from the sharp point forming an electric wind which blows the candle flame.

EXERCISE:

1. What is meant by action at sharp points
2. Describe how corona discharge occurs at sharp points.

Application of action at sharp points (corona discharge):

- Used in a lightning conductor
- Used in electrostatic generators e.g Van de Graaff generator
- Used in electrostatic photocopying machines.

LIGHTNING

Lightning is a gigantic (very large) discharge between charges in clouds and the earth or between charges in the atmosphere and the earth.

- *Lightening occurs when strong negative charges in the clouds attract positive charges from the grounds and tall buildings. Due to neutralization of charges, a strong spark is developed which is seen as lightening.*

NOTE:

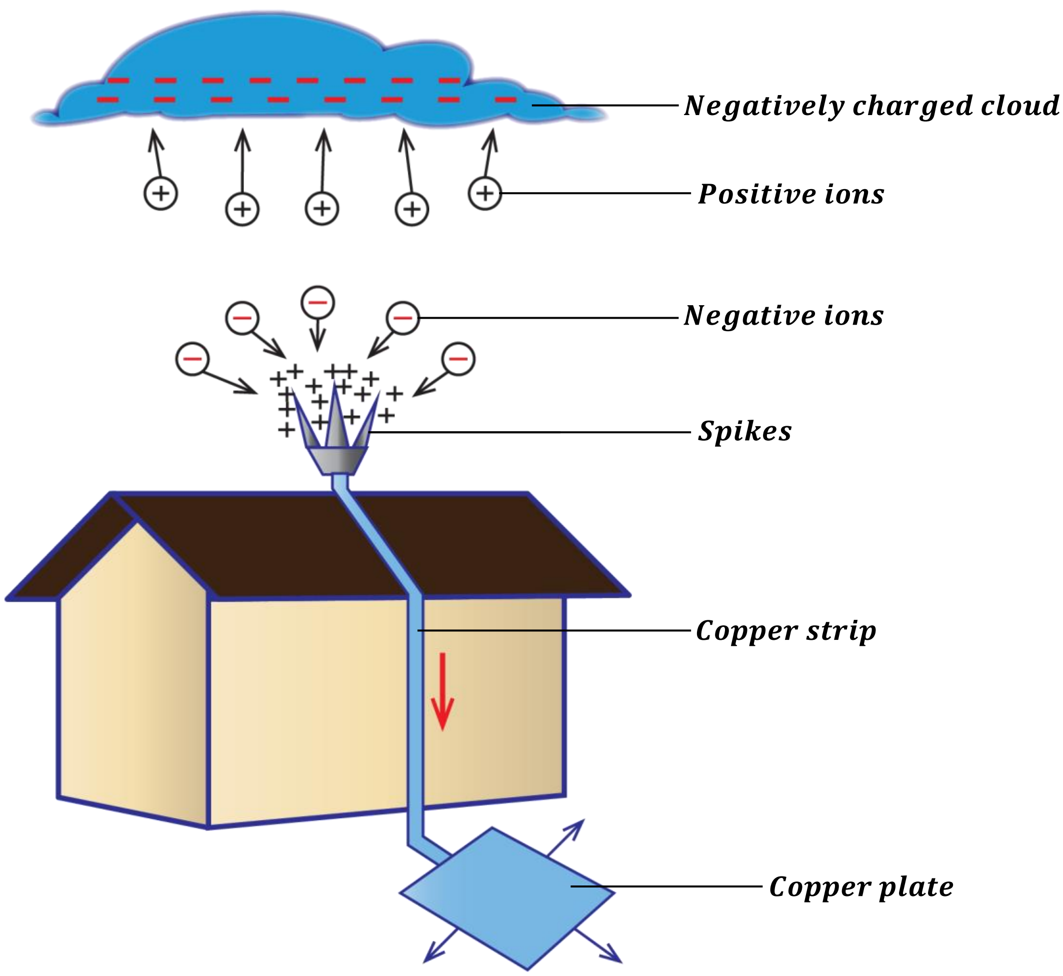
In order to minimize the effects of lightning, a lightening conductor is used to minimize the build-up of both charges at the clouds and the buildings by neutralizing them.

LIGHTNING CONDUCTOR OR ARRESTOR:

This is a device used to safe guard tall buildings from being struck/destroyed by lightning.
A lightning conductor consists of;

- **Spikes;** placed on top of a building.
- **Copper strip;** fixed to the ground and on the walls of the building from the spikes.
- **Copper plate;** buried under the ground.

How a lightning conductor works:



- When a negatively charged cloud passes over the lightning conductor, it induces positive charges on the spikes and repels negative charges to the ground through the copper strip.
- Due to the high charge density on the spikes, the air around the spikes is ionized forming positive and negative ions.
- Positive ions are repelled to the cloud and neutralize some of the negative charges on the cloud.
- Negative ions are attracted to the spikes and neutralize some of the positive charges at the spikes.
- This charge leakage on the clouds and building reduces the chances of lightning to occur.

Sample questions:

1. Explain why strips of a lightning conductor are made of thick copper wires.
   - ***This is because copper is one of the best good conductors of electricity so it can easily allow the negatives charges (electrons) to pass through it to the ground.***
   - ***When the copper wire is thick, it offers a low resistance to the flow of electrons through it.***

2. Explain why it's not advisable to touch the copper strip of a lightning conductor when it is raining.
   When a negatively charged cloud passes over a lightning conductor, negative charges (electrons) are repelled to the ground through the copper strip. These moving electrons is electricity which can cause electric shocks to a person touching the copper strip.

3. Explain why the handle of an umbrella is made from a plastic material.
   During a lightning, electric discharge (electricity) can shock a person holding an umbrella. Since a plastic material is an insulator, it does not allow electric discharge from lightning to reach the hands of the person holding the umbrella.

4. Explain why a person is not advised to take shelter under a tree when it is raining.
   When its raining, lightning always strike/destroy tall objects. Most trees are tall and have pointed tips therefore, therefore there is a high charge density at these sharp points.
   As lightning strikes the tall tree, it can also strike the person under it.

ELECTRIC FIELD

This is the region around an electric charge where an electric force is experienced.
Electric fields are represented by electric field lines.

Definition:

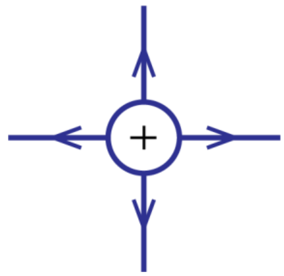
An **electric field line** is a line drawn at any point in an electric field to show the direction of an electric force at that point.

Properties of electric field lines:

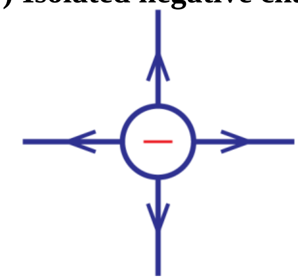
- They move from positive charge to negative charge.
- They do not cross each other.
- They repel one another side ways.
- They are in a state of tension.
- The number of electric field lines at certain point indicates the strength of the electric field.

ELECTRIC PATTERNS:

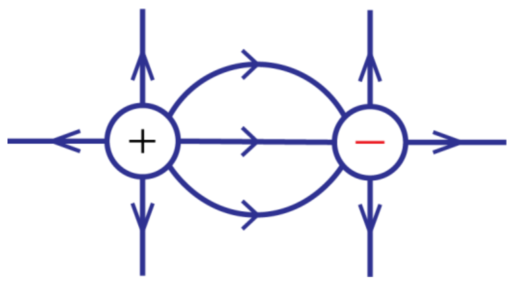
(a) Isolated positive charge;



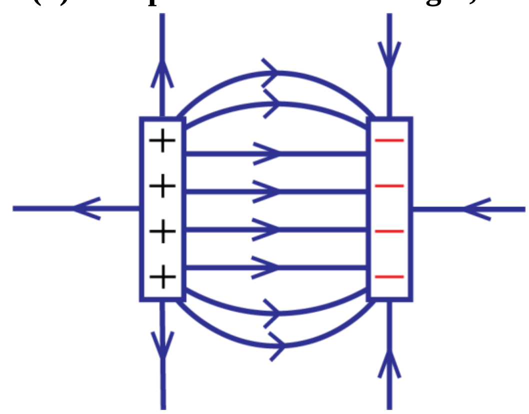
(b) Isolated negative charge;



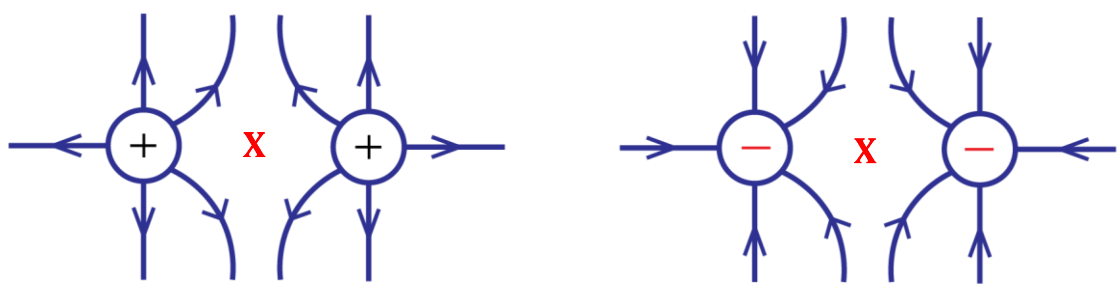
(c) Two unlike charges;



(d) Two plates of unlike charges;



(e) Two unlike charges;

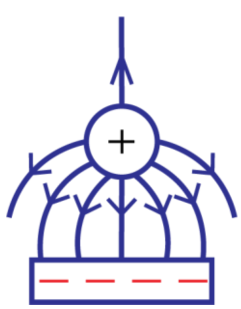


X is a neutral point

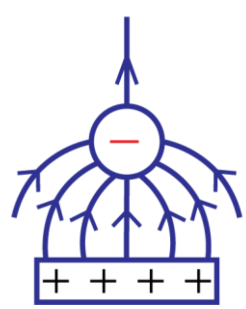
Definition:

A **neutral point** is a point in an electric field where the net electric force is zero.

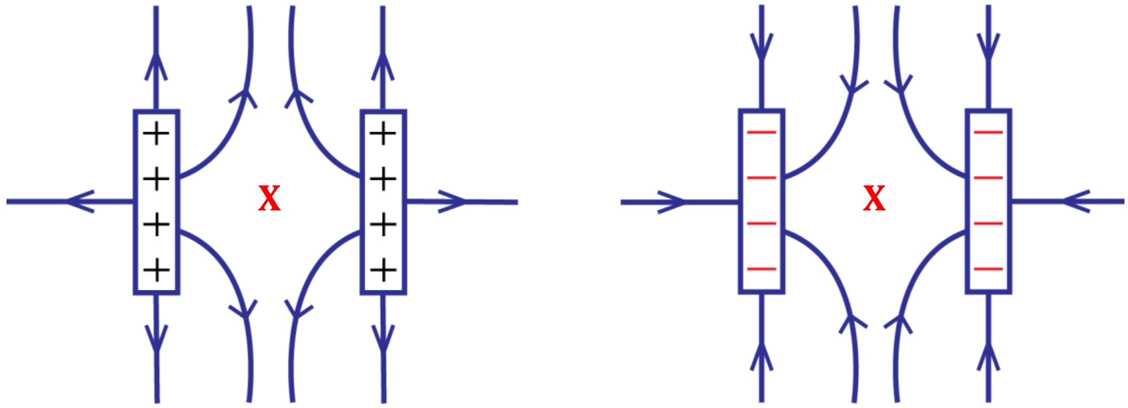
(f) A positive charge near a negative plate;



(g) A negative charge near a positive plate;



(h) Two plates of like charges;



Applications of electrostatic physics:

- Used in a lightning conductor
- Used in electrostatic generators e.g. Van de Graaff generator
- Used in electrostatic photocopying machines.
- Used in laser printers.
- Used in electrostatic precipitators for cleaning air.

EXERCISE:

1. (a) Explain why a pen rubbed with a piece of cloth attracts small pieces of places.
   (b) Why is it difficult to perform electrostatic experiments under damp conditions?
   (c) Explain why a handle of a proof plane is made of an insulator.
   (d) State three applications of electrostatic physics in the real world.

2. (a)sketch electric field patterns for the following.
   (i) Two negative charges close to each other.
   (ii) A positively charged conducting spheres.
   (iii) Two oppositely charged parallel plates
   (b) Explain how an insulator gets charged by rubbing.
   (c) Describe how lightning conductors safe guard tall buildings from being destroyed by lightning.