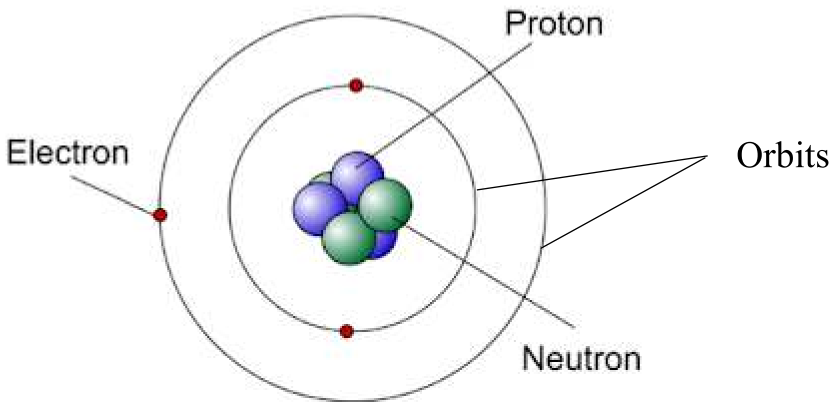
Physics for O -Level | **ELECTROSTATICS**

This is the study of charges at rest.These charges result from changes in the number of electrons in a neutral atom.

STRUCTURE OF THE ATOM

The atom consists of three particles with the following properties;

Particle	**Charge**	**Location**
(i) Neutron	No charge (neutral)	In the nucleus of the atom
(ii) Proton	Positively charged (+)	In the nucleus of the atom
(iii) Electron	Negatively charged (-)	In orbits outside the nucleus ot the atom



A neutral atom is one which has equal number of electrons (negative charges) as it has protons (positive charges).

An atom that has lost an electron(s) has more protons (Positive charges) than electrons (negative charges) and so it is said to be positively charged. Whereas an atom that has gained an electron(s) has more electrons (negative charges) than protons (positive charges) and so it is said to benegatively charged.

CONDUCTORS AND INSULATORS

A conductor is a material which allows charge to flow through it. It has loosely bound/free electrons known as Conduction electrons that are responsible for the flow of charge in them. Examples include; all metals, graphite, salt solutions, acids, bases etc.

An Insulator is a material which does not allow flow of charge through it. It has no conduction electrons because all its electrons are strongly bound by the nuclear attractive forces. Examples include; rubber, dry wood, glass, plastic, ebonite, fur, polythene, sugar solutions etc

Differences between a conductor and an Insulator.

Conductors	**insulators**
▪ Electrons easily move	▪ Electrons hardly move

▪ Electrons are loosely held to the atom ▪ Charges acquired are not fixed	▪ Electrons are tightly held to the atom ▪ Charges acquired are fixed

ELECTRIFICATION (CHARGING A MATERIAL)

This is the process of producing electric charge. The charge can be positive or negative. Such charge can be produced by a number of methods;

- By friction (or rubbing): good for both conductors and insulators
- By conduction/contact: good for only conductors
- By induction: good for conductors

Charging by Friction

Two materials of different nature are rubbed together. Electrons are transferred from one material to the other. The one that loses electrons become positively charged while the one that gains the electrons becomes negatively charged.

Characteristics

- ✓ The two bodies acquire opposite charges
- ✓ The two bodies acquire equal amounts (magnitude) of the charges.

The table below shows sample materials when rubbed together, the charges they acquire.

Acquire Positive charge	**Acquire negative charge**
Glass, Fur, Cellulose	Silk, Ebonite (hard Rubber), Polythene.

LAW OF ELECTROSTATICS

It states that "Like charges repel while unlike charges attract"

NOTE: However attraction of a charged body with any other body does not necessarily confirm that the other body is oppositely charged. The only confirmatory test for presence of charge is repulsion.

Charging by conduction

This involves sharing an already existing charge on one of the bodies.

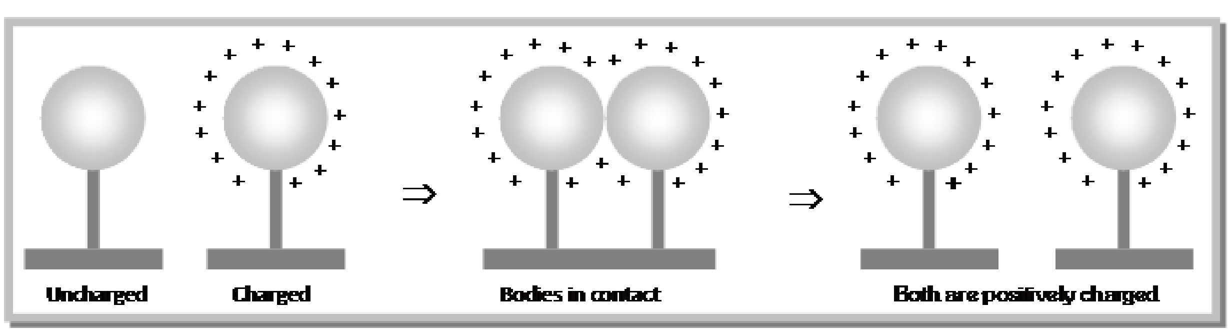


FIG (i) FIG (ii) FIG (iii)

The uncharged body is brought in contact with a charged body (Fig (ii) for a short time and then the bodies separated. The two bodies carry the same charge (Fig iii).

NOTE: Contact can also be made by connecting the two using a conducting material such as a wire.

Charging by Induction

This method involves bringing an already charged rod (material) near the body to be charged.

Characteristics of charging by induction.

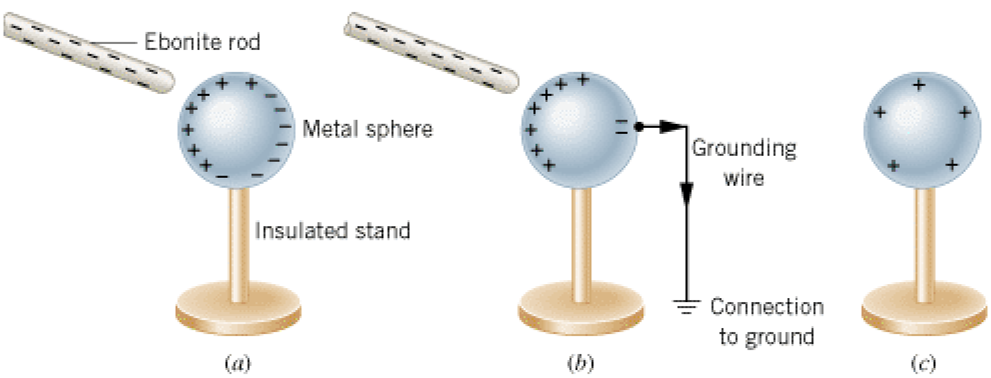
- ✓ The body acquires a charge opposite to that on the charging body.
- ✓ It is suitable for conductors

CHARGING A SPHERICAL CONDUCTOR POSITIVELY BY INDUCTION.

The spherical conductor is placed on an insulating stand. A negatively charged ebonite rod is brought close to the conductor. It induces a positive charge at the near end and a negative charge at the far end. (Fig (a)).

With the charged rod still in position, the conductor is earthed(connected to the ground).The negative charges (electrons) escape to the ground due to the repulsion by the negative charge at the ebonite rod. (Fig (b)) leaving only the positive charge on the conductor.

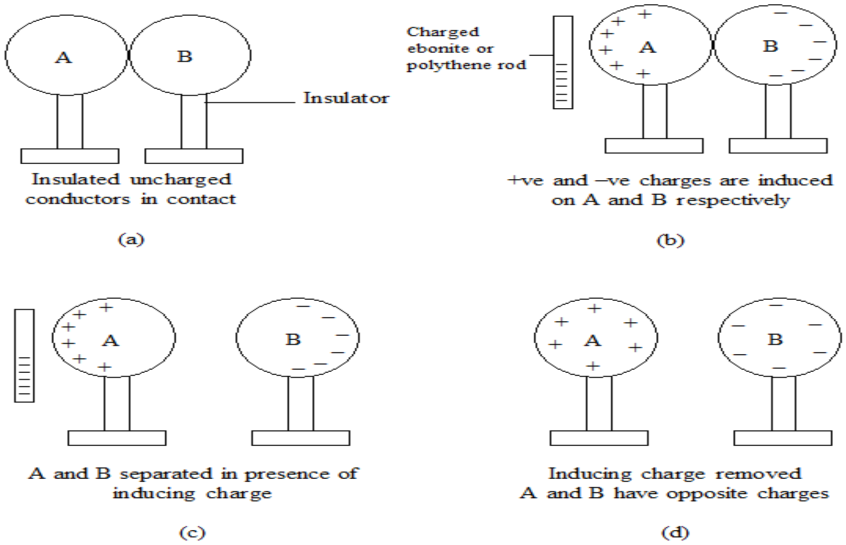
The earthing is disconnected while the ebonite rod is still in position. The rod is then removed, the charges redistribute and the spherical conductor is positively charged (Fig (c))



CHARGING TWO CONDUCTORS SIMULTANEOUSLY WITH OPPOSITE CHARGES.

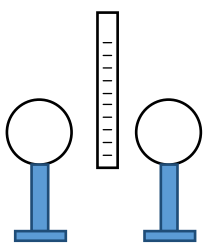
The two conductors are placed in contact on insulating stands (Fig (a)). A negatively charged ebonite rod is brought close to one of the conducting spheres (sphere A). It induces a positive charge on sphere A and a negative charge on sphere B (Fig (b)).

While the ebonite rod is still in place, the spheres are separated (Fig (c)). The rod is then removed and sphere A carries a positive charge while sphere B carries a negative charge (Fig (d)).



Exercise: Complete the figures, explaining what is happening in each case until the conclusion.

Fig (i)



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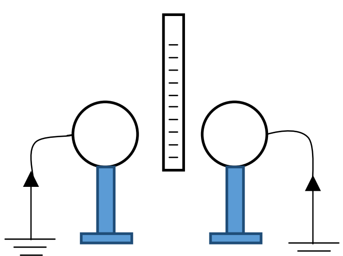

Fig (ii)

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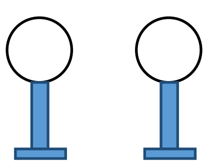


Fig (iii)

THE GOLD LEAF ELECTROSCOPE.

This is a device used for;

- ✓ Detecting presence of charge on a body
- ✓ Testing the nature or sign of charge on a body
- ✓ Comparing and measuring potentials

- ✓ Classifying conductors and insulators.

STRUCTURE OF THE ELECTROSCOPE.

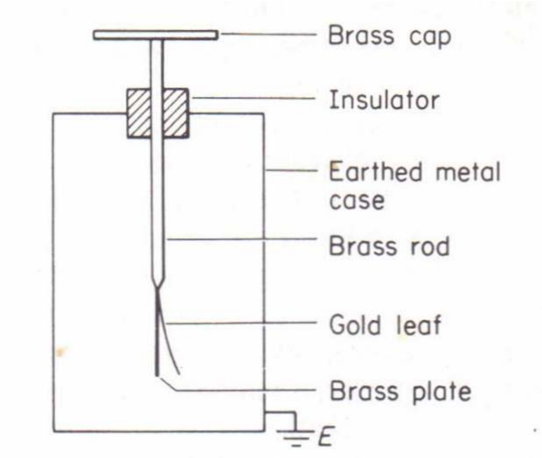


Fig. 32.1. Gold-leaf electroscope

MODE OF ACTION

When a charged body is brought near the cap of the electroscope, the cap will acquire an opposite charge to that on the 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 charges on the plate and the gold leaf, the leaf diverges as it is repelled by the plate.

Leaf divergence implies that the body brought near or in contact with the cap carries a charge.

CHARGING A GOLD LEAF ELECTROSCOPE BY INDUCTION

(I) Charging positively.

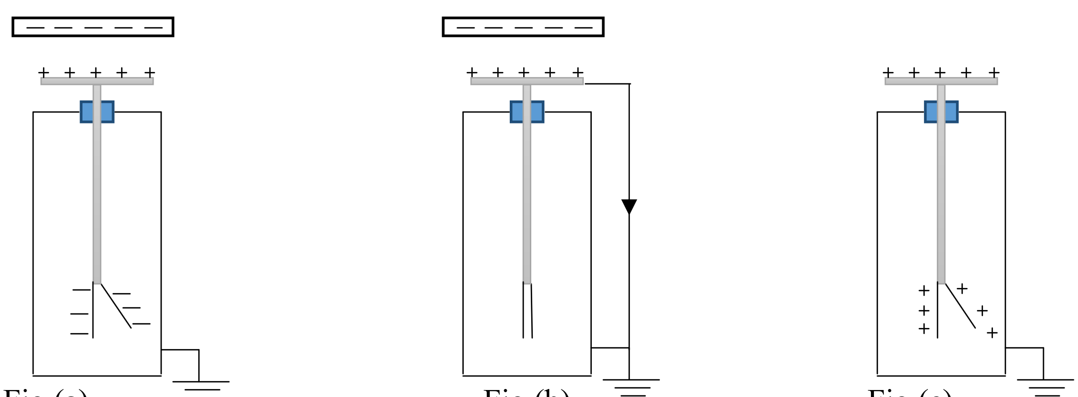


Fig (a) Fig (b) Fig (c)

A negatively charged rod is brought near the cap of the electroscope. It induces a positive charge on the cap and a negative charge on the plate and gold leaf. The leaf diverges due to repulsion of the like charges on it and the plate.

While the charging rod is still in position, the cap is earthed. The electrons(negative charges) escape to the earth and so the leaf collapses.

The earthing is disconnected while the rod is still in place. The rod is then removed and the positive charges spread out to the brass rod and leaf. The leaf diverges again hence the electroscope is positively charged.

Exercise: Describe how a gold leaf electroscope can be charged negatively by induction.

APPLICATIONS OF THE GOLD LEAF ELECTROSCOPE

(a) Detection of presence of charge.

The body to be tested is brought near the cap of a neutral gold leaf electroscope. If the leaf diverges, the body has got charge but if the leaf remains unaffected, the body is neutral (not carrying charge).

(b) Testing the nature or sign of charge on a body.

Bring the body under test near the cap of a charged G.L.E. If the leaf diverges, the body has a charge similar to that on the electroscope. However, if the leaf collapses, then the body is either neutral or it carries a charge opposite to that on the electroscope. In this case, we cannot conclude. But the electroscope is discharged by earthing and then charged with an opposite to that it had before and the experiment is repeated. If the leaf collapses again then the body is neutral.

NOTE: **An increase in leaf divergence is the only sure test for the sign of charge on a body. Increase in leaf divergence occurs when the test charge and the charge on the gold electroscope are the same.**

(c) Comparing and measuring potentials.

Two bodies which are similarly charged are brought in contact with the cap of a gold leaf electroscope each at a time. The divergence in each of the cases are noted and compared. The body which causes more divergence is at a higher potential.

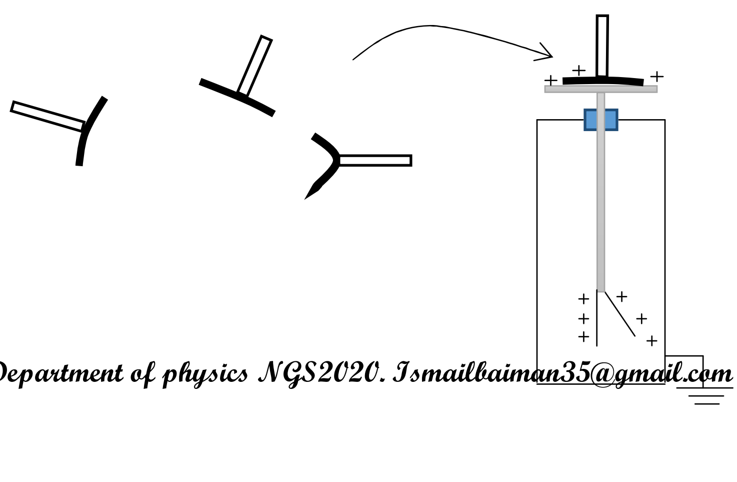
(d) Classifying insulators and conductors.

The body to be tested is brought in contact with the cap of a charged gold leaf electroscope. If the leaf collapses suddenly, then the body is a good conductor. If the leaf collapses gradually, the body is a poor conductor whereas if the leaf does not collapse at all, the body is an insulator. The leaf collapse is due to charge leakage.

DISTRIBUTION OF CHARGE ON CONDUCTORS.

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

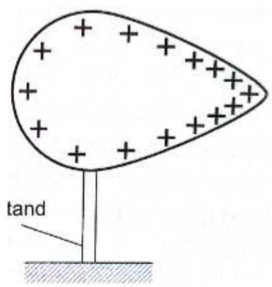
(a) Distribution over a pear shaped conductor.



The conductor is given chargeand placed on an insulating stand.

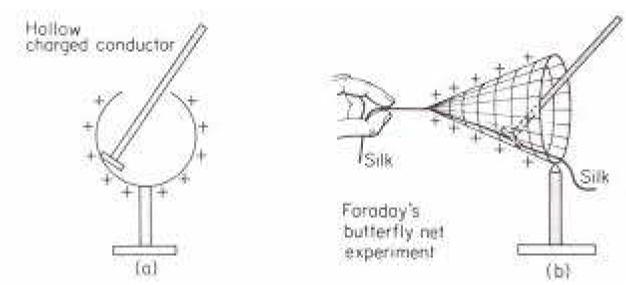
Proof planes are placed at different positions on the conductor and then transferred to the cap of an electroscope.

The angle of the leaf divergence is noted. It gives a rough magnitude of the surface density at that point. It is observed that most charges reside at the



NOTE:A proof plane is a small metal disc with an insulating handle. They are of different shapes to fit different shaped surfaces.

(b) Distribution on a hollow conductor.



The hollow conductor is given a charge and made to rest on an insulator.

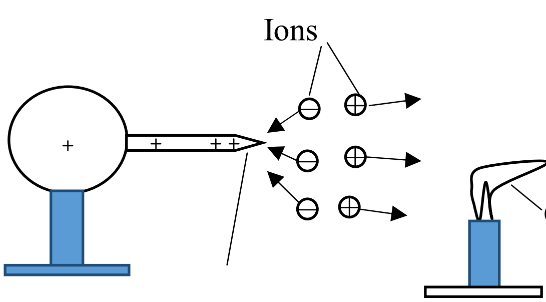
Proof planes are used to pick charges from inside and outside it, transferred to the cap of a neutral gold leaf electroscope.

It is observed that with the proof plane from inside the conductor, no deflection of the gold leaf occurred. Indicating absence of charge inside the hollow conductor. However, leaf divergence occurred with the proof plane from outside.

CONCLUSION: Charges on a hollow conductor reside on the outside.

ACTION AT POINTS

Experiments above have shown that charge concentrate at sharp points. This creates a very strong electrostatic field at charged points which ionizes the surrounding air molecules producing positive and negative ions. Ions which are of the same charge as that on the sharp points are repelled away forming an electric wind which may blow a candle flame as shown in the diagram below, and ions of opposite charge are attracted to the points. The sharp point apparently loses charge in what is called Corona discharge or Action at Points.



Candle flame blown away by an electric wind

Highly charged
sharp point.

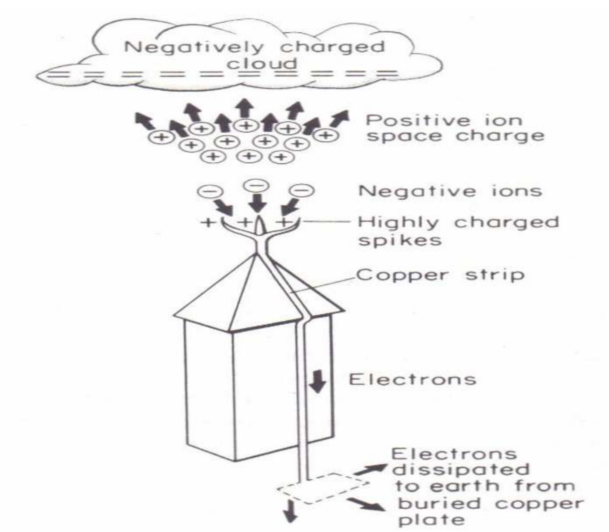
Application of action of points. (Corona discharge)

- Used in a lightning conductor
- Used in electrostatic generators. (Van de graaff generator)
- Electrostatic photocopying machines.
- Air crafts are discharged after landing before passengers are allowed because they get electrified but charge remains on the outer surface.

The lightning Conductor.

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

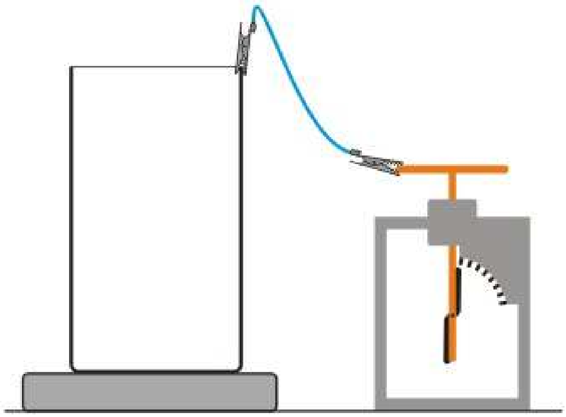
A lightning conductor is a single component in a lightning protection system used to safeguard tall buildings and tall installations from being destroyed by lightning. It provides a safe and easy passage of charge to the earth hence safe guarding the building or installation.

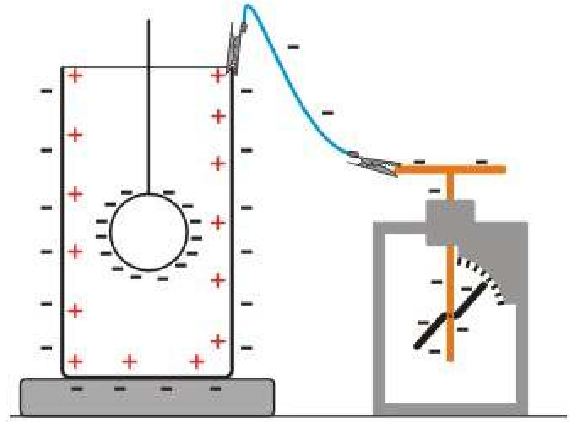


How it works

When a negatively charged cloud passes over the lightning conductor, in induces a positive charge on the spikes while electrons are dispatched to the earth through the copper strip. Because of the high charge density at the spikes(sharp points), the surrounding air is ionized. The positive ions are repelled to the cloud to neutralize it, while the negative ions are attracted to the spikes to neutralize it. Any excess charge is neutralized by electrons from the earth.

FARADAY'S ICE PAIL EXPERIMENT





A small charged sphere is lowered into the ice pail that is connected to a neutral g.l.e ***without touching it***. The gold leaf is seen to deflect, indicating that the outside of the container has got charged.When the ball is moved about inside the container without touching the walls, the leaf divergence does not change, indicating that the charge on the outside of the container is not affected by where the charged object is inside the container.

When the charged sphere is lifted out of the container, the leaf divergence decreases to zero. This shows the charges on the container were induced by the charged sphere.

The sphere is lowered into the can again, the leaf also diverges again. The ball this time is made to touch the inside of the can. The leaf divergence does not change. Even when the sphere is withdrawn from the can, the deflection stays the same. When the ball is then tested for charge, it is found to be completely uncharged, and the inside of the can is also found to be uncharged.

Conclusions:

1. The ball induced an equal but opposite charge on the inside of the ice pail.
2. The net charge on the can(after the inside has been neutralized) reside on the outside.
3. The magnitude of charge induced is independent of the position of the ball in the ice pail.

ELECTRIC FIELDS

This is a region around a charged body where electric forces are experienced. Electric fields may be represented by field lines.

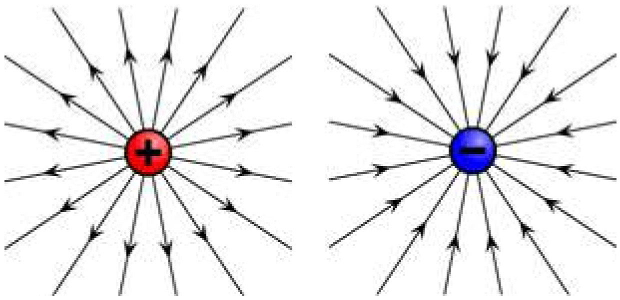
Field lines are lines drawn in an electric field such that their directions at any point give a direction of electric field at that point. The direction of any field at any given point is the direction of the forces on a small positive charge placed at that point.

Properties of electric field lines

- ✓ They begin and end on equal quantities of charge.
- ✓ They are in a state of tension which causes them to shorten.
- ✓ They repel one another side ways and so never cross each other.
- ✓ They emanate and terminate at 90^{o} to the surface.
- ✓ Their intensity is an indication of the strength of the field.
- ✓ They originate from a positive (High potential) to a negative (low potential)

ELECTRIC FIELD PATTERNS

1. Isolated point charges(or sharp electrodes)



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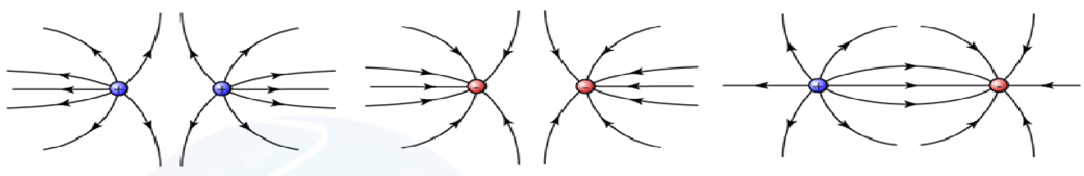


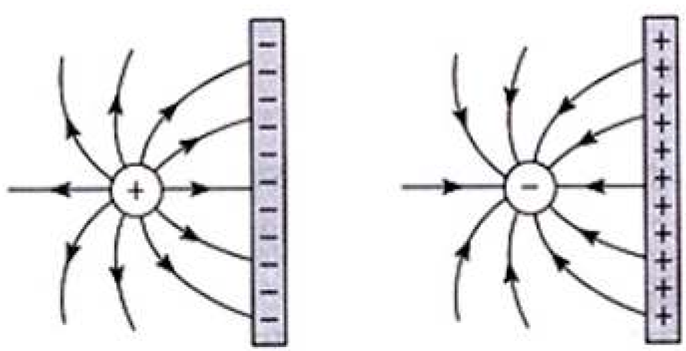
Fig 2(a) Fig 2(b) Fig 3(c)

Fig 2(a): Filed pattern for two equally positive charges near each other.

Fig 2(b): Field pattern for two equally negative charges near each other.

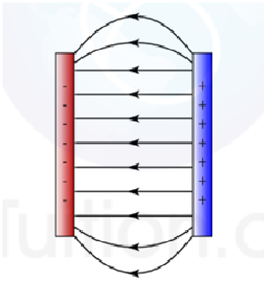
Fig 2(c): Field pattern for a positive charge near a negative charge.

3.

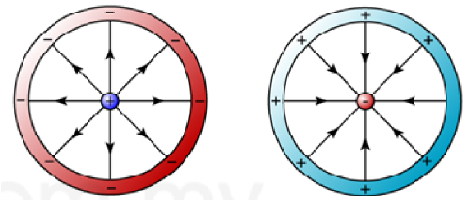


Field patterns for a point charge near a plane conductor.

4.



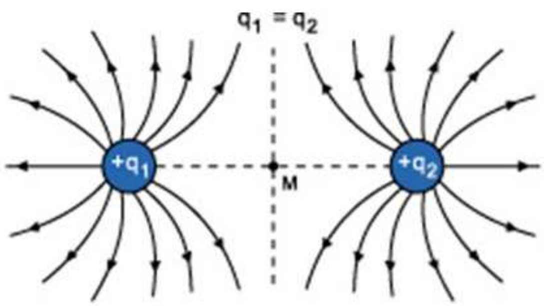
Field pattern of
two plane electrodes



Field pattern of
a pointed electrode
and a ring electrode

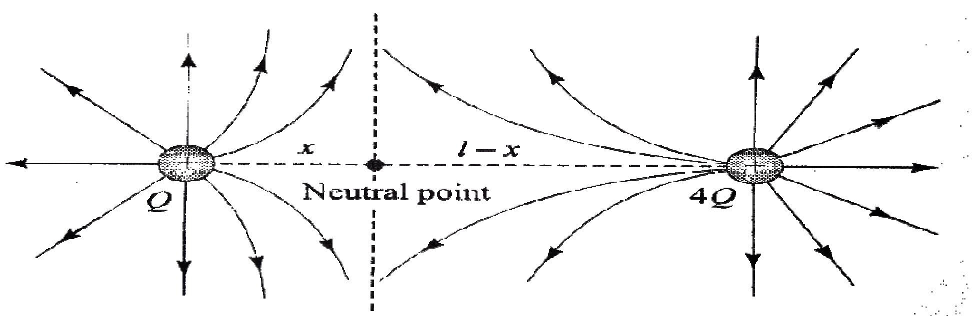
Neutral point

This is a point between two electric charges where the resultant electric field force is zero.



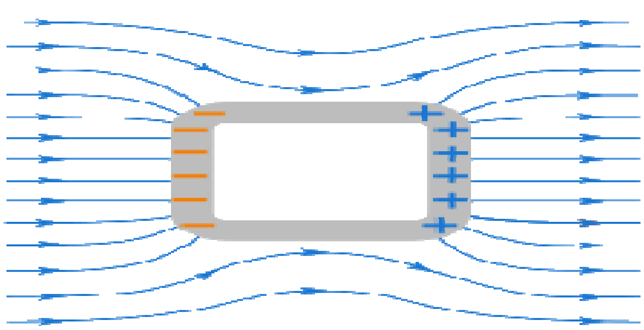
M is the neutral point

When the charges are not equal in magnitude, the point M shifts towards the smaller charge.



ELECTROSTATIC SHIELDING

This is the process of isolating a region within an electric field from the field effects.



A hollow conductor is placed in the electric field. Induction causes the field line to stop and originate at the induced charges in the conductor without passing through the conductor. An electric free region is created inside the conductor.

In lightening thunderstorm, it is safe to sit inside the car, rather than near a tree or in open ground. The metallic body of the car acts as electrostatic shielding from lightening.

Also Television cables are designed with a shield to avoid interference.