S2 New Curriculum Physics

Theme: Electricity

Chapter 7 – Electrostatics

ELECTROSTATICS

Electrostatics is the study of forces between stationary (static) charges.

For instance, when a plastic material like a pen or comb is rubbed against dry hair and then brought closer to small pieces of paper; the small pieces papers are attracted by plastic material.

Explanation: this is because the plastic material like a pen or comb acquired a charge opposite to that of the dry hair. It is this acquired charge of the plastic material that attracts the small pieces papers.

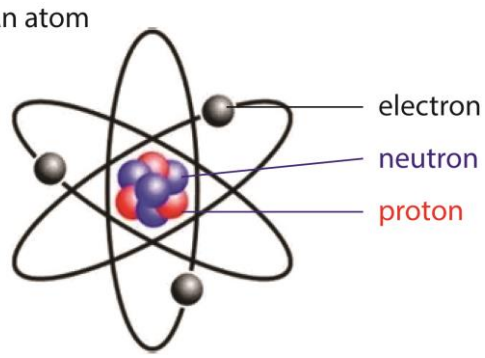
Theory of Electrostatics:

A substance is made up of atoms. The structure of an atom is made up of:

(i) Protons (ii) Neutrons (iii) electrons

The protons are positively charged. The electrons are negatively charged. The neutrons have no charge (they are neutral). The protons and neutrons are locked up in the nucleus while electrons are freely rotating in electron orbitals around the nucleus. Electrons can easily detach from an atom compared to the protons or neutrons.

An atom



When an atom loses an electron (s) it becomes positively charged. And when an atom gains electron(s) it becomes negatively charged.

Note that a neutral body has equal number of protons and electrons; appositively charged body has deficiency or shortage of electron(s); while a negatively charged body has excess or surplus electron(s).

Conductors

A **conductor** is a substance that allows the flow of electrons through it easily. This is because electrons are loosely held by the nucleus of the atoms of the conductor. The charge acquired is not fixed because electrons easily flow through the conductor.

Examples of conductor: copper, silver, aluminium, iron, human body, earth, carbon etc. In general metals are good conductor.

Conduction occurs when electrons transfer charges as they move from one part of the body to another.

Insulators

An Insulator is a substance that does not allow the flow of electrons through it easily. The charge acquired is fixed because the electrons are tightly held by the nucleus of the atom of the insulator, so electrons hardly move.

Examples are: paper, wool, silk, wood, dry air, dry wood, polythene etc.

Differences between conductors and insulator

Conductors	**Insulators**
Electrons easily move	Electrons hardly move
Electrons loosely held by nucleus.	Electrons tightly held by nucleus.
The charge acquired is not fixed	Charge acquired is fixed

Explanation why a charged body attracts an uncharged body?

When a charged body is placed near uncharged body, it repels like charges to the opposite side and induces unlike charge on the near side of uncharged body. This results in a net attractive force between charged and uncharged body.

Law of electrostatics

Like charges repel, unlike charges will attract

Charging of materials in electrostatics

(i) Electrostatic charging by rubbing (friction)

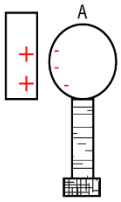
When two bodies are rubbed together, electrons are transferred from one to the other because the electrons are not equally strongly bound to both bodies. The body that loses electrons becomes positively charged while the body that gains electrons becomes negatively charged.

(ii) Charging by induction

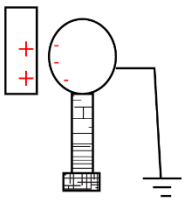
Charging by induction is a method of electrically charging an object **without direct contact** between the charged object and the one being charged.

- A charged rod is brought close (but not touching) an insulated conductor.
- The conductor is earthed while the charged body is still in place.
- Earth connection is removed.
- The conductor permanently gains a charge opposite to that of the charged body.

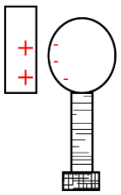
(a) **Charging a conductor negatively by induction.**



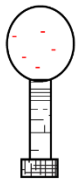
1. Bring a positively charged rod near an insulated conductor



2. Earth the conductor while the inducing rod is still in position

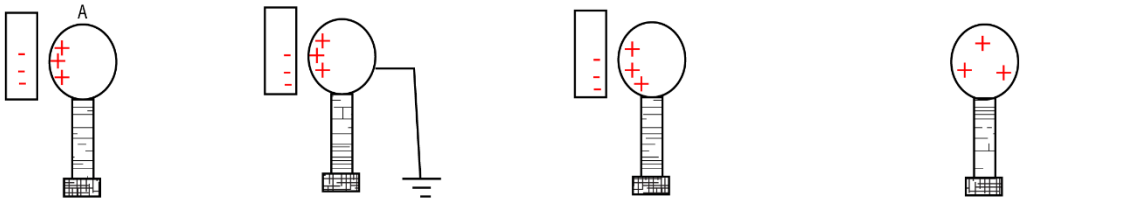


3. Remove the earthing while the inducing rod is still in position



2. Remove the inducing rod. Negative charges redistribute evenly

(b) Charging a conductor positively by induction



1. Bring a negatively charged rod near an insulated conductor

2. Earth the conductor while the inducing rod is still in position

3. Remove the earthing while the inducing rod is still in position

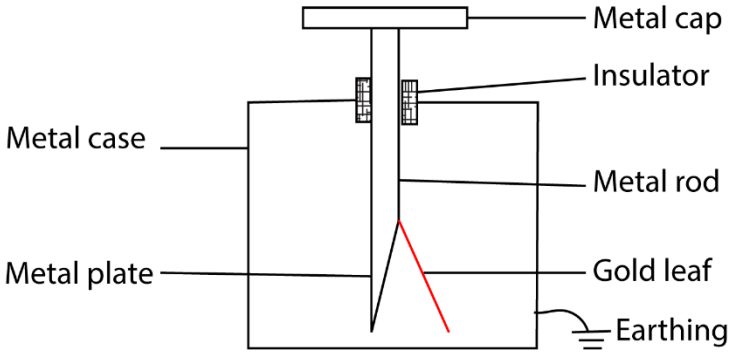
2. Remove the inducing rod. Positive charges redistribute evenly

Gold leaf electroscope

This is an instrument for testing the presence, the sign and the magnitude of the charge.

It consists of a circular metal disc (cap) attached to a metal rod with a brass plate to which is attached a thin foil of gold or aluminium.

It is fitted in a metal case with help of a plug (insulator) using Perspex window. The metal case is earthed in order to screen the electroscope from outside influences other than those brought nearer the cap and it is insulated from the ground.



Charging a gold leaf electroscope

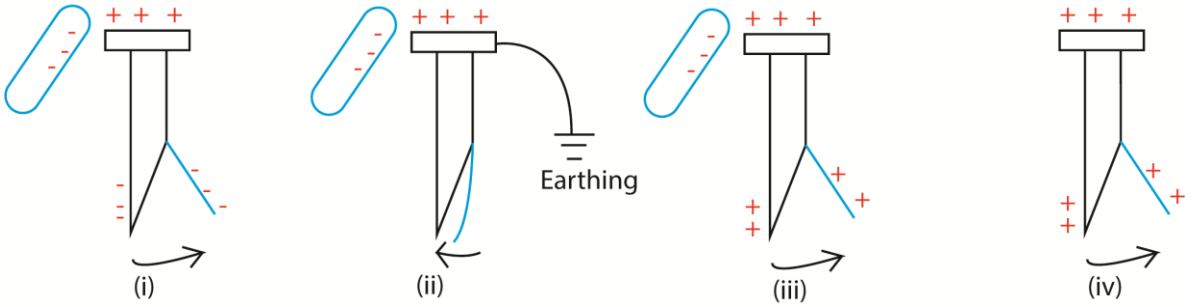
A gold leaf electroscope is charged by induction

(a) Charging gold leaf electroscope positively by induction

Procedures

- A negatively charged rod is brought a cap of GLE
- The cap is earthed while the charged body is still in place.
- Earth connection is removed.
- Lastly the charged body is removed.

Observation/explanation



(i) When a negatively charged body is brought near a cap of GLE, positive charges are induced on the cap while electrons are repelled to the metal plate and the gold leaf. The gold leaf is repelled and diverges.

(ii) When the cap is earthed say by touching it with a finger, electrons flow to the earth and the leaf collapses.

(iii) When the earth connection is removed, the remaining positive charge on the cap redistributes itself on the Gold leaf and the leaf diverges again.

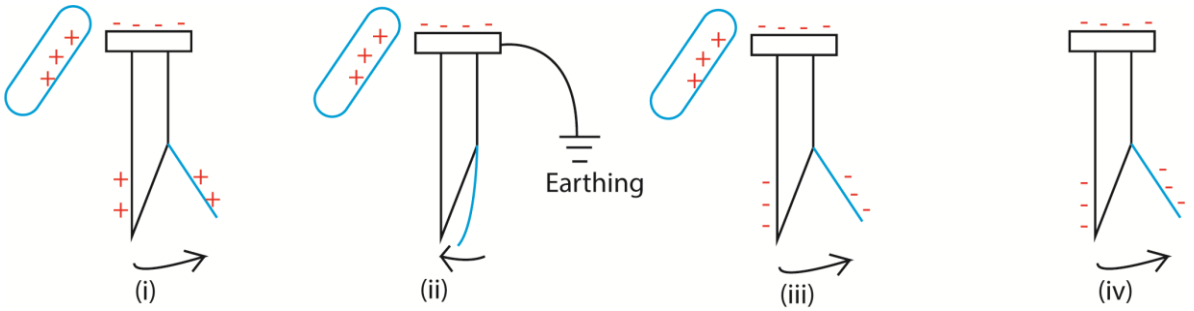
(iv) When the charged body is removed, the GLE acquires a permanent positive charge.

(b) Charging gold leaf electroscope negatively by induction

Procedures

- A Positively charged rod is brought a cap of GLE
- The cap is earthed while the charged body is still in place.
- The earth connection is removed.
- Lastly the charged body is removed.

Observation/explanation



(i) When a positively charged body is brought near a cap of GLE, positive charges are induced on the cap while electrons are repelled to the metal plate and the gold leaf. The gold leaf is repelled and diverges.

(ii) When the cap is earthed say by touching it with a finger, electrons flow from the earth and the leaf collapses.

(iii) When the earth connection is removed, the acquired negative charge on the cap redistributes itself on the Gold leaf and the leaf diverges again.

(iv) When the charged body is removed, the GLE acquires a permanent negative charge.

Uses of the gold leaf electroscope

(i) Detecting of charge on a body
(ii) Testing the nature and sign of charge on the body
(iii) Comparing the magnitude of charge on various bodies
(iv) Test the insulating and conducting properties of various substances
(v) Measure potential difference

1. To detect the presence of a charge on a body

Bring the body to be tested near the metal cap of a neutral gold leaf electroscope. When the leaf deflected, then the body has got a charge. However, it the leaf remain undeflected, then a charge is absent on the body.

2. **Testing for the nature or sign of charge**

Charge a gold electroscope (GLE) negatively. Bring the body under test near the cap of GLE: if it the leaf diverges further, then the body has a negative charge but if the gold leaf collapses, then that body is either has a positive or a neutral conductor.

The experiment is repeated is repeated where the GLE is charged is charged positively. A charged body is brought near the cap; if the gold leaf diverges more, the body is positively charged. If the gold leaf collapses, the charged body is either negatively charged or neutral conductor.

Note that an increase in divergence occurs when the charge on electroscope and the tested charge are the same. Therefore, an increase in divergence is the only sure test for a sign of charge on the body.

3. **To compare and measure potentials**

Two bodies which are similarly charged are brought into contact with the metal cap of the gold electroscope one after another. The body that cause a big divergence has a big charge.

4. **To classify conductors and insulators**

Bring the body to be tested in contact with the metal cap of a charged gold leaf electroscope. When the leaf collapses suddenly, then the body is a good conductor. If it collapses gradually, the body is a bad conductor. However, if it does not collapse then, it is an insulator.

Application of static electricity in daily life

Electrostatic Painting: Used in car manufacturing and furniture production, this technique charges paint particles so they're attracted to the object being painted. It reduces waste and ensures a smooth, even coat.

Photocopiers and Laser Printers: These machines rely on static electricity to transfer toner onto paper. A drum inside the printer is charged to attract toner particles, which are then fused onto the paper to create text and images.

Clothing Cling and Hair Static: Ever had your clothes stick together after drying or your hair stand on end after brushing? That's static electricity at play—caused by friction between different materials.

Shock from Doorknobs: That tiny zap you sometimes get when touching a metal object? It's a mini static discharge—your body builds up charge and releases it when it meets a conductor like a doorknob

Dangers of static electricity

(a) Electrostatic charges developed by a moving vehicle or aeroplanes due to rubbing with air can spark explosion during fuelling.

(b) Lightning:

Lightning is a sudden, powerful burst of electricity that occurs during storms when there's a build-up of electrical charge in the atmosphere. It happens when the difference in charge between a cloud and the ground—or between different parts of a cloud—becomes so great that it overcomes the insulating properties of air.

How It Happens:

1. **Charge Separation**: Inside storm clouds, collisions between ice particles cause electrons to be knocked off, creating areas of positive and negative charge.
2. **Electric Field Builds**: As the difference in charge grows, the electric field becomes strong enough to overcome the insulating properties of air.
3. **Discharge**: A rapid flow of electrons—what we see as a lightning bolt—jumps between the charged regions, neutralizing the imbalance.

Effects of lightning

- **Thunder**: Caused by the rapid expansion of air heated to around 30,000°C (hotter than the surface of the Sun).
- **Electromagnetic Radiation**: Lightning emits energy across a wide spectrum, including visible light and radio waves.
- **Environmental Impact**: It can ignite wildfires, influence atmospheric chemistry, and even help fertilize soil by fixing nitrogen.

Protection against lightning

1. **Install a Lightning Protection System:** This includes lightning rods, conductors, and grounding systems that safely direct lightning strikes into the ground, protecting buildings from fire and electrical surges.
2. **Use Surge Protectors**: Plug sensitive electronics into surge protectors to guard against voltage spikes caused by nearby lightning strikes.
3. **Secure the Environment:** Trim dead or overhanging trees and secure outdoor objects that could become hazardous during storms.

4. **Take Shelter During Storms**: If you're outdoors, seek shelter in a grounded building or a metal-roofed vehicle. Avoid open fields, tall trees, and water bodies.
5. **Unplug Electronics:** During a storm, unplug devices to prevent damage from power surges—even surge protectors have limits.

Revision exercise

1. (a) What is electrostatics

   (b) Explain why

   (i) a plastic rubber rubbed against hair attracts small pieces of paper

   (ii) a balloon rubbed against hair can stick on a clean wall

   (iii) charged bodies attract neutral bodies

2. (a) What is electrostatic induction?

   (b) Explain how you can charge a metal sphere negatively by induction.

   (c) Give one advantage of the process in (b) above

3. (a) Explain how a gold leaf electroscope can be used to identify a charge of a charged object.

4. (a) What is lightning?

   (b) Give any two dangers of lightning.

   (c) Give two ways how the dangers in (b) can be avoided.

Thanks

Dr. Bbosa Science