Static Electricity

Electric Charge

- Types of charges:
  - Neutrons
  - Protons
  - Electrons

- If electrons are removed , the atom becomes positively charged . - If electrons are added , the atom becomes negatively charged . - If the number of negative and positive charges are equal , the object is electrically neutral - An atom that is charged is called an ion

- The law of conservation of charge is one of the fundamental laws of Physics
  - The net charge of a closed system remains unchanged.
  - The net charge of a system is the algebraic sum of the charges while taking into consideration the positive and negative signs of the charges.

Interaction Between Charges

- Like charges repel
- Unlike charges attract

Measuring Electric Charges

- The SI unit of electric charge is the coulomb (C).
- The amount of charge carried by an electron is $1.6 \times 10^{-19} C$

Electrical Insulators and Conductors

- Objects around us can be classified into two broad categories:

1. electrical insulators
2. electrical conductors

	electrical insulators	**electrical conductors**
motion of charged particles	charged particles (electrons) are not free to move about	charged particles (electrons) are free to move about
ability to conduct electricity	low	high
method of charging	by friction (e.g. rubbing)	by induction

	electrical insulators	electrical conductors
examples	glass, perspex, silk wool	copper, steel, fluids with mobile charged particles

Electrostatic by Friction

- Some materials like silk and glass, gain static charges when they are rubbed together

Example:

- When the glass rod and silk cloth are rubbed together, electrons move from the glass rod to the silk cloth.
- The glass rod loses electrons and becomes positively charged.
- The silk cloth gains electrons and becomes negatively charged.
- The electrons transferred are not able to move freely in the silk cloth.
- They remain at the surface where the silk cloth was rubbed.
- Materials in which the electrons do not move freely are called insulators.
- Insulators are charged by friction (e.g. rubbing)
- Different materials have different affinities to electrons. Some attract electrons weakly, while others attract electrons strongly.

Electrostatic Charging by Induction

- Conductors cannot be charged by friction because mobile electrons can be easily transferred to and away from conductors.
- Metallic conductors can be charged by induction in which a conductor is charged without contact with the charging body.

Method 1: Charging two metal

1. Two metal spheres (conductors) on insulating stands are placed side by side.

- They are touching each other.

2. A negatively-charged rod is brought near, but not touching, sphere A. Like charges repel.

- Electrons in both spheres A and B are repelled to the far end of sphere B.
- sphere A has excess positive charges,
- while sphere B has excess negative charges.

3. While holding the negatively charged rod in place (near sphere A), move sphere B away from sphere A.

4. The charged rod is removed.

- Sphere A is now positively charged and sphere B negatively charged.
- Spheres A and B have an equal number of opposite charges.
- Both spheres have been charged by induction.

5. When the charged rod is removed *before* the two spheres are moved apart,

- The electrons will be redistributed in sphere A and B and both will become neutral again.

Method 2: Charging a single conductor by induction

1. A positively charged rod is brought near, but not touching, a metal conductor on insulating stand.

- The electrons in the conductor are drawn (attracted) towards the end near the positively-charged rod.

2. Without removing the positively-charged rod, the positively charged end of the conductor is earthed by touching it with a person's hand.

- Free electrons move from earth to the conductor through the person.
- This neutralises the positive charges on the end of the conductor.

> 🔰 Earthing is a process which a conducting path is connected from a conductor to earth. This allows electrons to either flow into or out of the conductor. Earth refers to a large body of charge that remains electrically neutral regardless of the amount of charge that is added or removed from it.

5. When the charged rod is removed before the earthing process is stopped,

- The excess electrons in the conductor will flow to the earth and discharging occurs. The conductor will then become electrically neutral.

Neutralising/Discharging a Charged Insulator

- A charged object is neutralised by discharging the excess charges on it.

Discharging through heating

- The heat from the flame ionises the surrounding air particles.
- For a positively-charged glass rod, the ions neutralise the excess charges on the glass rod.

Discharging due to humid conditions

- Water molecules in air are electrical conductors
- For a negatively charged insulator, excess charges are transferred to the water molecule.

Neutralising / Discharging a Charged Conductor

- A charged conductor can be discharged through earthing
- When we earth a charged conductor, we provide a path (usually lower resistance and connected to the earth) for

- excess electrons to flow away from the charged conductor, or
- electrons to flow to the charged conductor if it has excess positive charges

Hazards and Applications of Electrostatics

Hazards of Electrostatics

1. **Lightning**

- The clouds are **charged by friction** between water molecules in the clouds and air molecules in the atmosphere.
- **Negative charges** accumulate at the **bottom** of the clouds.
- These **repel** the **electrons** near the surface of the earth, causing the **surface** of the Earth to be **positively charged**.
- When the accumulation of charges is large, the **air particles** are **ionised**.
- The **ionised air particles** provide a **conducting path** for the electrons in the clouds to reach the Earth.
- When the **electrons travel down** the conducting path to the Earth, **lightning** forms.

2. **Electrostatic discharge**

- Excessive charges may build up on objects due to **friction**
- Electronic equipment, such as computer boards and hard drives, can be easily damaged by electrostatic discharge.
- Such equipment is usually packed in **antistatic packaging**.

3. **Electrostatic discharge of vehicles**

- Electric charges can accumulate on trucks due to **friction** between
  - the road and the rotating tyres of the truck
  - the moving air molecules and the body of the truck
- When a **sudden discharge** occurs, this may cause **sparks** and **ignite** any flammable items that the truck might be carrying.
- Gas tankers are equipped with a **metal chain** at the rear end hanging/touching near to the **ground** to provide an **earthing path** for excess charges.
- During refueling, the gas tankers are also connected to an earth source to prevent static charges from accumulating on the body of the gas or fuel tanker.

Applications of Electrostatics

Photocopiers

- Photocopiers make use of static electricity to produce copies of documents.

1. The metal drum inside the photocopier is coated with **selenium**.

- Selenium is a **photoconductor** (light-sensitive semiconductor). It only conducts electricity in the presence of light. When no light shines on the selenium, it is a good insulator.

- The selenium coating on the drum is initially in the dark. Behaving as an insulator, it can be electrically charged. When the selenium is illuminated, it becomes conducting wherever light falls on it.
- The drum's surface is charged **positively** by a charged wire.

2. The original image to be photocopied is placed on a sheet of clear glass above the drum.

- An intense light beam is shone onto the image.
- The **darker** areas of the image reflect less light and therefore, the corresponding regions on the drum remain **positively** charged.
- The regions on the drum corresponding to the **lighter** areas conductive. Electrons from the surroundings, which are attracted to these regions, discharge them.

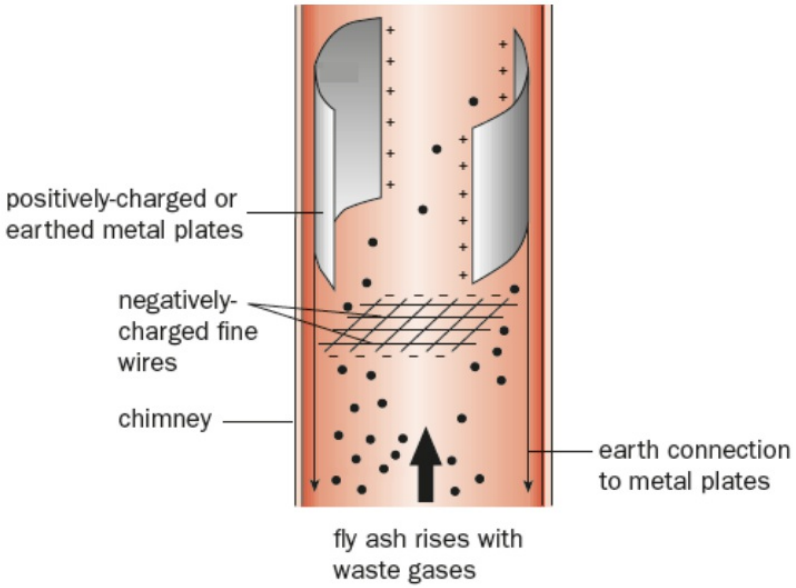
3. The drum continues turning, and the positively-charged image on the drum attracts the **negatively-charged** toner powder.

4. A **positively-charged** sheet of paper is passed over the drum's surface.

- The paper attracts the **negatively-charged** toner and the image is formed on the paper.
- The paper is heated and pressed to fuse the toner powder to the paper permanently.

Electrostatic Precipitator

- The electrostatic precipitator is used to remove fly ash from the exhaust of a chimney.



Removing fly ash from the exhaust gas

The fly ash (smoke and dust particles) is passed through a negatively charged wire grid making the particles to become negatively charged. The negatively charged particles are passed through positively charged or earthed plates which attract the negatively charged particles. Hence, air emitted into the atmosphere is cleaner. The fly ash are collected and

used in making cement.

Spray Painting

- The electrostatic spray painter is used to provide an even coat on the part to be painted.

Even Coating

As the paint leaves the nozzle, the droplets are charged by friction. These made all the paint droplets to have the same charge and repel each other. Hence, they spread out evenly. Less paint is needed because the charged droplets are all attracted to the object (neutral or positively charged).

Electromagnetic Induction

Electricity and Magnetism

Laws of Electromagnetic Induction

Faraday's law of electromagnetic induction

The magnitude of the electromotive force (e.m.f) induced in a closed circuit is directly proportional to the rate of change of the magnetic flux linkage through the area bounded by the circuit.

- Thus, the magnitude of the electromotive force (e.m.f) induced in a conductor is directly proportional to the rate at which magnetic field lines and the conductor cut each other.
- If the conductor is part of a closed circuit, the induced e.m.f produces an induced current through the conductor.

Lenz's Law

The direction of the induced electromotive force (and hence the direction of the induced current in a closed circuit) is such that its magnetic effect opposes the motion or change producing it.

- If the conductor is part of a closed circuit, the induced current produces induced magnetic poles that oppose the cause of the induced emf.

Electromagnetic induction when magnetic field strength changes

Faraday's experiments demonstrate electromagnetic induction by moving a pole of a magnet moves nearer or further away from a solenoid, such that magnetic field lines cut through the solenoid.

Case 1: S moves towards solenoid

1. The South pole of the magnet moves towards the solenoid
2. (By Faraday's law of induction,) the changing magnetic flux linkage through the solenoid (or the magnetic field lines cutting the solenoid) induces an e.m.f in the solenoid.
3. Since the circuit is closed, the induced e.m.f produces an induced current.
4. By Lenz's law, the magnet is repelled by the south pole induced on the right of the solenoid produced by the clockwise induced current when viewed from the right (using the right hand grip rule) that flows from B to A.