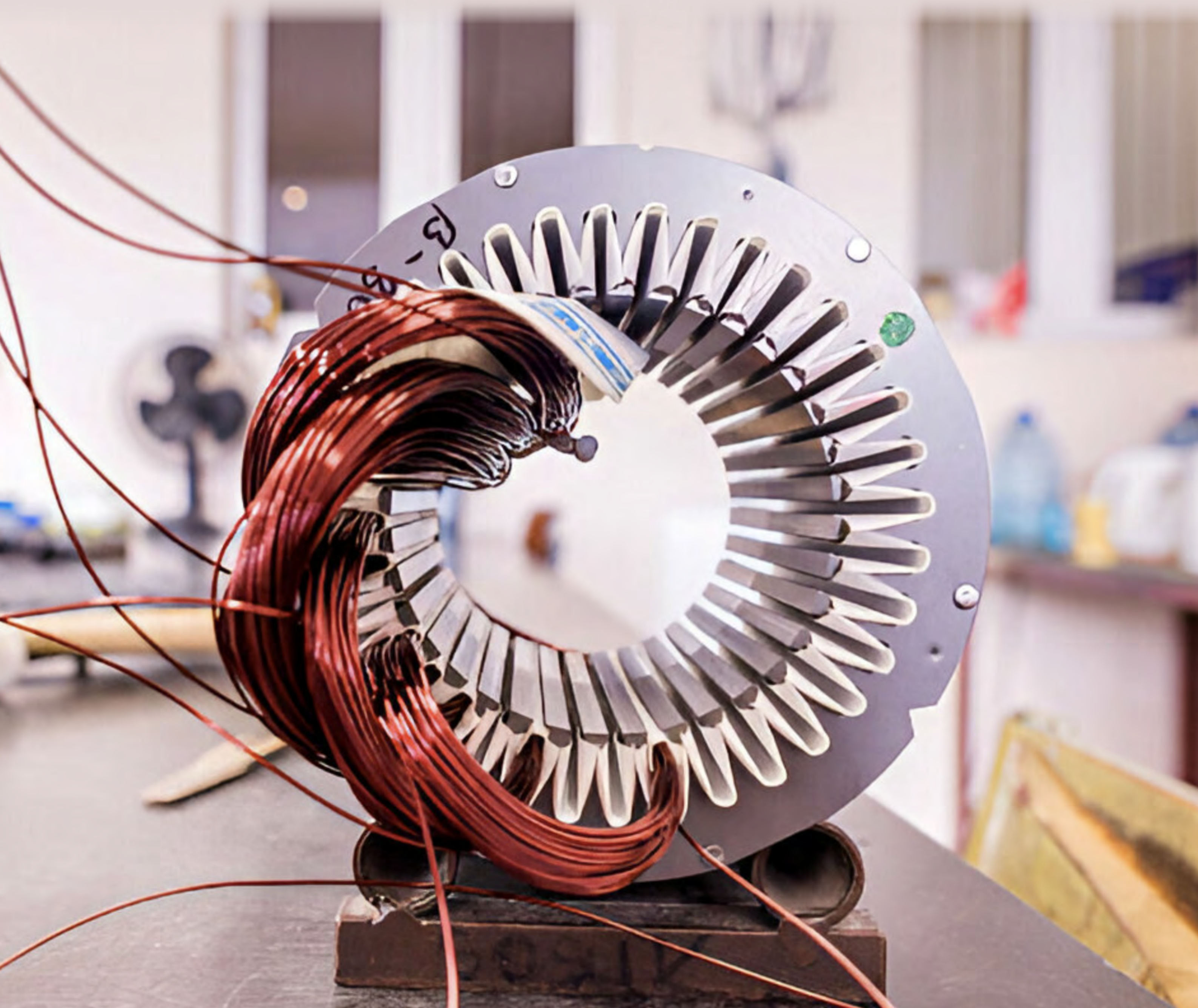
Physics Year 1

SECTION 6

ELECTRICAL CHARGE AND MAGNETISM



ELECTROMAGNETISM

1. Electrostatics

2. Magnetostatics

INTRODUCTION

Welcome to your first introduction to the field of electromagnetism! This section will provide a solid foundation in understanding how electricity and magnetism work, and how they relate to one another, both in everyday life and in various technologies.

At the end of this section, you should be able to;

- Explain how the gold leaf electroscope can detect the charge carried by a body.
- Identify electrons as mobile charge carriers.
- Explain how charge carriers in conductors, semiconductors and insulators behave.
- Explain the distribution of charges on surfaces; spherical, pear shaped and sharp points.
- Define charge as a fundamental property of matter (like mass).
- Explain the conservation of charge and its behaviour.
- Differentiate between the two charges (positive and negative).
- Distinguish between magnetic and non-magnetic materials.
- Describe the magnetic field.
- Describe the processes involved in magnetisation and demagnetisation.

Key ideas

- The Gold Leaf Electroscope is a tool used to detect electric charges.
- Mobile charge carriers, such as electrons, create electric currents by moving through conductors.
- Electric charge is a fundamental property of matter that causes it to interact with electric fields.
- Charge distribution refers to how electric charge is spread across an object, while the conservation of charge principle states that charge cannot be created or destroyed, only transferred.
- Magnetic materials are materials attracted to magnets, and non-magnetic materials, which are not.
- The magnetic field is the area around a magnet where its force can be felt. Lastly, magnetisation is the process of making a material magnetic, and demagnetisation is the process of removing its magnetism.

MOBILE CHARGE CARRIERS AND GOLD LEAF ELECTROSCOPE

Electrons

Electrons are tiny particles that orbit the nucleus of an atom. They're also mobile charge carriers, meaning they can move freely within some materials, such as metals, when they gain enough energy to escape their atoms. As they flow, they carry charge with them.

Detecting charge

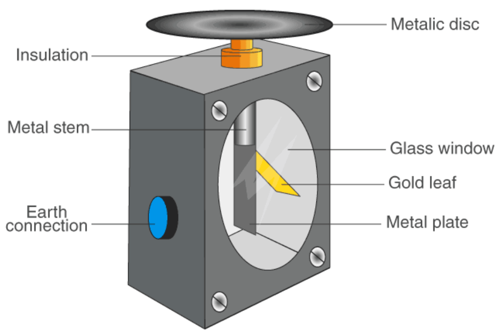


Fig 6.1: The Gold leaf electroscope

A gold leaf electroscope is an instrument for detecting and testing small electric charges. This instrument is also used for detecting and measuring static electricity or voltage.

The outside metal disc, made of brass, is connected to a narrow metal plate inside the metal case and a thin piece of gold leaf is fixed to the plate. The complete electroscope is insulated from the body of the instrument.

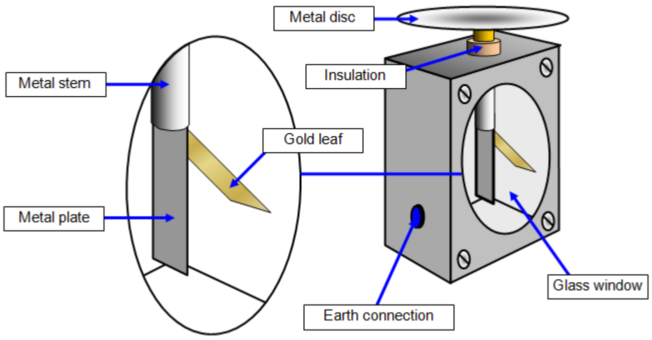


Fig 6.2: The Gold leaf electroscope

When a charged (positive or negative) body is brought near to the metal disc:

- If a negative charge is brought near, electrons in the electroscope are repelled, causing them to move downward to the leaves. This makes both leaves negatively charged, leading to divergence.
- If a positive charge is brought near, electrons from the leaves are attracted to the disc. This makes both leaves positively charged, leading to divergence.
- If the charged object actually touches the metal plate, it will transfer charge to the electroscope and the leaf will remain lifted from the metal rod.
- If a different charged object is then brought near to the electroscope its charge can be determined by observing whether the leaf is repelled further or falls closer the rod.

The leaf can be made to fall again by touching the disc and therefore allowing the built-up charge to dissipate through your body and to the earth (earthing). An earth terminal prevents the case from becoming live.

Activity 6.1: Investigating the gold leaf electroscope

Note: in the absence of practical equipment, you can use the following simulation to perform the experiment:

Materials needed:

- Gold leaf electroscope (or video/picture)
- Balloon or plastic rod for charging
- Dry cloth or fur for rubbing

Procedure:

1. Observe the electroscope and identify its key components (compare to the diagram above).

Fig 6.3: Gold-leaf electroscope with scale

2. Rub the balloon or plastic rod with the dry cloth or fur to generate static electricity.

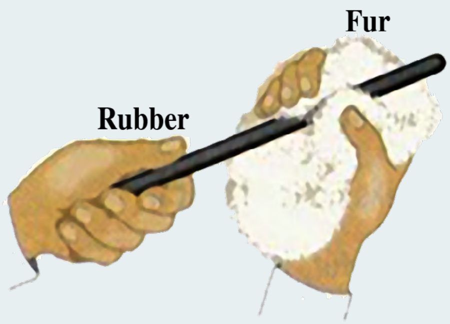


Fig 6.4: Charging a rubber rod by friction

3. Bring the charged object near the electroscope without touching it.
4. Observe how the metal leaves respond.
5. Consider ways in which you might alter the response of the electroscope and investigate these. Can you make it attract instead of repel? Can you make it repel further from the metal rod?
6. Discussion:

a. Describe the observations and explain the reasons behind the responses.

b. Discuss the concept of electric charge and its detection using the gold leaf electroscope.

Activity 6.2 Charging the Electroscope by Friction

Materials needed:

- Gold leaf electroscope
- Glass rod
- Silk cloth
- Plastic rod
- Fur cloth

Procedure:

1. Demonstration 1: Glass Rod with Silk:

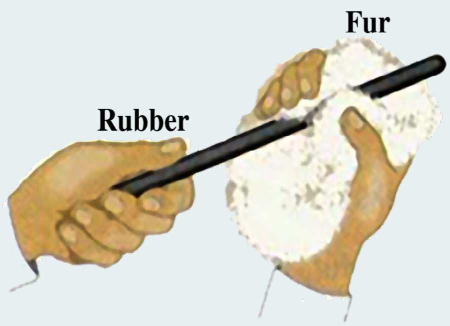


Fig 6.5: Charging a rubber rod by Friction

a. Rub the glass rod with silk to generate static electricity.
b. Predict the behaviour of the electroscope before charging.
c. Charge the electroscope by touching the glass rod to the metal rod.
d. Observe and record the behaviour of the gold leaves.

2. Demonstration 2: Plastic Rod with Fur:

   a. Rub the plastic rod with fur to generate static electricity.
   b. Predict the behaviour of the electroscope before charging.
   c. Charge the electroscope by touching the plastic rod to the metal rod.
   d. Observe and record the behaviour of the gold leaves.

3. Comparison and Discussion:

   a. Compare the behaviour of the electroscope for both demonstrations.
   b. Discuss the reasons behind the differences in behaviour.

   See Annex 6.1 for further explanation.

4. Conclusion:

   a. Summarise the key points about charging the electroscope by friction.
   b. Emphasise the importance of understanding electric charge and its detection.

Electrical Properties of Materials

Conductors have high electrical conductivity; low resistance and delocalised (free) electrons flow easily. Examples; aluminium, copper, gold.

Semiconductors have medium electrical conductivity, medium resistance and electrons flow with some restriction. However, many semiconductors can be made more or less resistive based on environmental conditions such as brightness and temperature. Examples; silicon, germanium.

Insulators have low electrical conductivity, high resistance and electrons are tightly bound and so they don't flow easily. Examples; wood, glass, plastics.

Charge carriers are particles that carry electric charge, and their behaviour differs in conductors, semiconductors, and insulators due to differences in their electronic structure and the energy levels of their electrons.

See Annex 6.2 for further information about conductors, insulators and semiconductors.

Balancing of charges and net charge

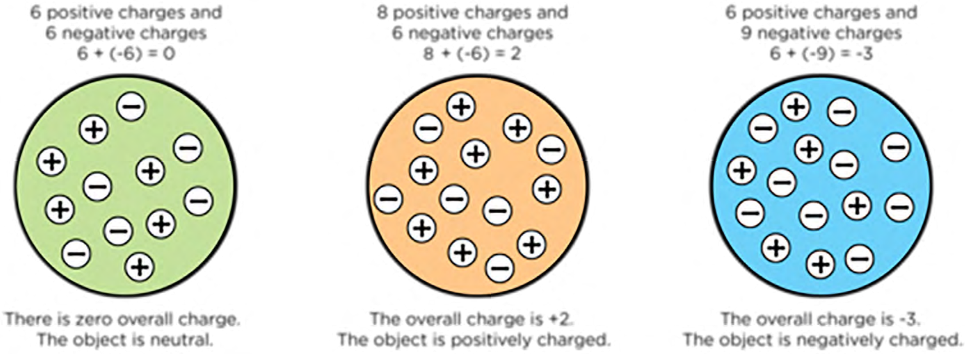


Fig 6.6: net charges of neutral, positively charged and negatively charged objects

The first diagram contains 6 negative and 6 positive charges; therefore, their overall charge is (0) zero which implies the material is neutral. The overall charge for the 2nd one is 2. That of the 3rd one is 3.

Behaviour of two bodies of different charges

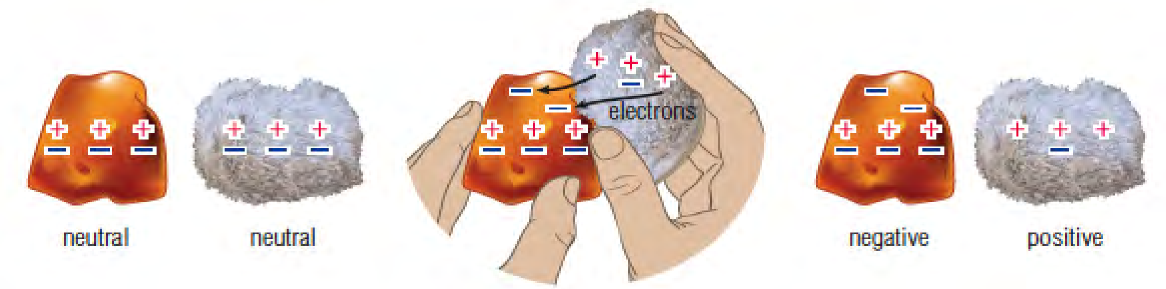


Fig 6.7: Behaviour of two bodies of different charges

If an electron is removed from an atom or material a net positive charge builds up in atom or material, and therefore the atom or material is said to be positively charged. When a neutral atom or material gains an electron, it has a net negative charge and hence the atom or material is negatively charged. Thus, when two different material such as glass and silk are put into contact by rubbing, the glass gives up some electron to the silk. Thus, the silk now has a negative charge, while the glass has a deficiency of negative charge which means that it has a positive charge (+).

Example: *Transfer of charges between human hair and a comb*

*When you comb the hair, electrons move from the **hair** to the **comb** by friction which results in negative charge on the comb and a positive charge on the hair.*

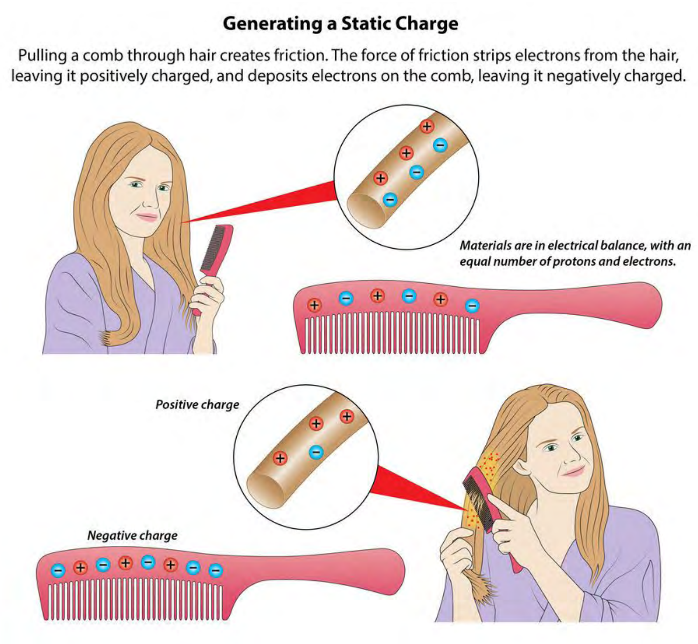


Fig 6.8: Electrostatic charging of hair by combing

Activity 6.3: Investigating the movement of charge in insulators

Fig 6.9: Balloon rubbed against hair

Explore static electricity and its effects through a fun and interactive experiment with balloons.

Materials Needed:

- A balloon (preferably latex, but be aware of those who may have allergies within the classroom)
- A smooth, dry surface (like a table or your head)
- Optional: a comb or your hair for additional effects

Procedure:

1. **Inflate the balloon:** Blow up the balloon and tie it securely.
2. **Charge the Balloon:** Rub the balloon vigorously on your hair or piece of wool fabric for about 15-30 seconds. This will create static electricity.
3. **Test the Attraction:**
   - **a.** Bring the balloon close to your hair (or the wool fabric) without touching it. Observe how your hair stands up and becomes attracted to the balloon. Slowly move the balloon away from your hair and observe how far you can go before the attraction stops.
   - **b.** You can also hold the balloon near small pieces of paper to see if they get attracted.
   - **c.** Press the charged balloon against the smooth wall. Hold it there for a few seconds and then release it. Observe how the balloon sticks to the wall.
4. **Discussion:**
   - **a.** Why did your hair stand up? Use the comb example given above to help form your answer.
   - **b.** What is static electricity?
   - **c.** Discuss why the balloon sticks to the wall. Explain how the static charge creates an attractive force between the balloon and the wall.
   - **d.** Why could a conductor, such as a metal sheet or pan, not be used in the place of the balloon for these experiments?

Safety Tips:

- Ensure that the area is dry to maximize the effects of static electricity.
- Avoid using the activity near sensitive electronic devices as static electricity can cause damage.

Activity 6.4: Investigating the movement of charge in conductors and semiconductors

Materials needed

- Light bulb
- Battery
- Wires

- Ammeter
- Plastic rod
- Switch
- NTC thermistors (optional)
- Beaker (optional)
- Kettle (optional)
- Water (optional)
- Ice (optional)
- LDRs (optional)

Procedure:

1. Connect the circuit as shown below. Begin by connecting the plastic rod in the place of component X.

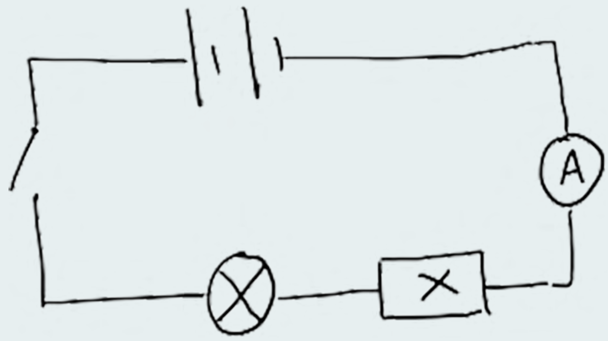


Fig 6.10: Simple electric circuit diagram with battery, lamp, and ammeter

2. Close the switch and record the reading on the ammeter.
3. Replace the plastic rod with a piece of metal wire.
4. Close the switch and record the reading on the ammeter.
5. Replace the piece of metal wire with an NTC thermistor.
6. Place the thermistor into a beaker of hot water and record the reading on the ammeter. Now, place it into a beaker of ice-cold water and record the reading on the ammeter.
7. Replace the NTC thermistor with an LDR.
8. Place the LDR under a bright light and record the reading on the ammeter. Now, cover the LDR with your hand and record the reading on the ammeter.

Discussion and conclusions:

Given that the plastic rod is an insulator, the wire is a conductor and the thermistor and LDR are both semiconductors, explain your observations of ammeter reading for each component.

See Annex 6.1 for explanations.

Activity 6.5: Classification of elements based on electrical conductivity

Observe, in the periodic table below, the group and period where conductors, semiconductors and insulators are found.

- Conductors (e.g., copper, aluminium)
- Semiconductors (e.g., silicon, germanium)
- Insulators (e.g., oxygen, nitrogen)

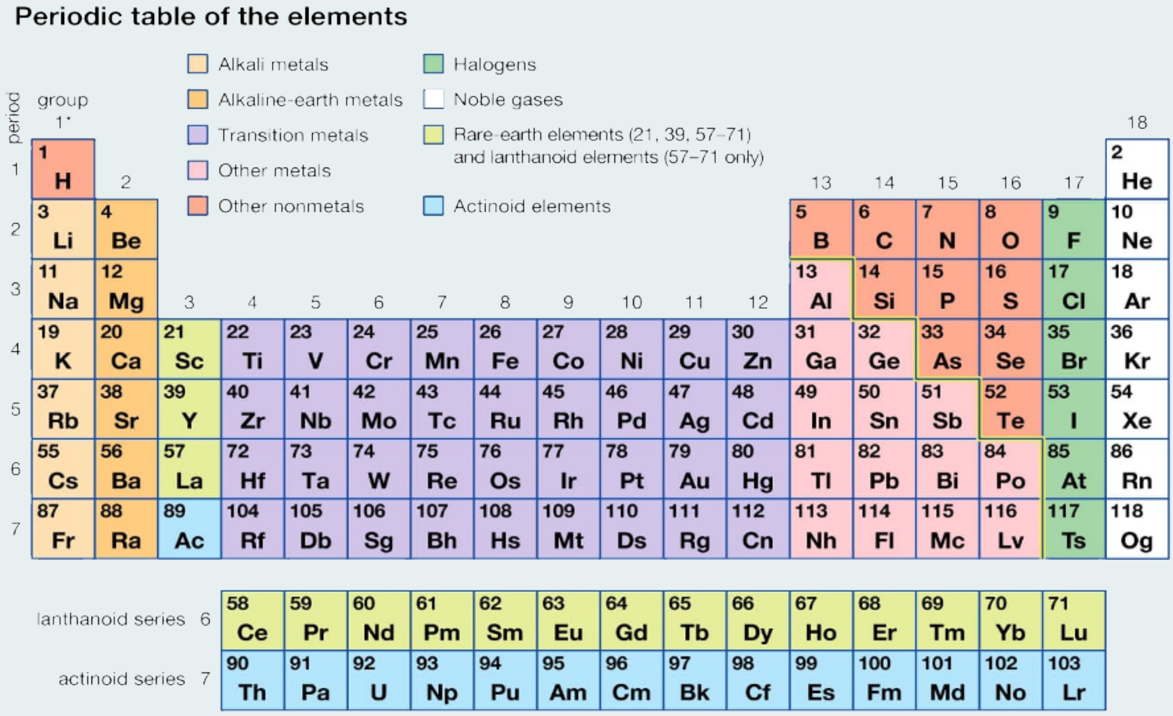


Fig 6.11: Periodic table of the elements

Activity 6.6: Classification of materials into conductors, semiconductors and insulators

Classify the materials into conductors, semiconductors and insulators

Table 6.1: Table to complete Activity 6.6

Material	Conductor	Semiconductor	Insulator
Glass			✓
Metal iron			
Silicon			
Germanium			
Plastics			
Wood			

Activity 6.7: Modelling Charge Flow in Conductors, Semiconductors, and Insulators

In small groups, model the behaviour of the charge flowing through a) a conductor, b) a semi-conductor and c) an insulator.

CHARGE

What is Electric Charge?

Electric charge is a basic property of matter (just as mass is a basic property of matter) that causes it to interact with electric and magnetic forces. Imagine it as something that can make objects attract or repel each other, like when you rub a balloon on your hair, and it makes your hair stand up!

Electric charge is measured in Coulombs (C).

Activity 6.8: Mind Mapping Matter and Charge

Objective: Create a mind map to explore and connect the fundamental properties of matter, including electric charge.

Materials Needed:

- Large sheet of paper

- Markers or coloured pencils

Procedure:

1. Write "Properties of Matter" in the centre of your paper and draw a big circle around it.
2. Think of different properties of matter and electric charge, such as:
   - **a.** Attraction to a magnet
   - **b.** Electrical conductivity (how well something conducts electricity)
   - **c.** Thermal conductivity (how well something conducts heat)
   - **d.** Physical state (solid, liquid, gas)
   - **e.** Density (how heavy something is for its size)
   - **f.** Electric charge (positive and negative charges)
   - **g.** Anything else you can think of!
3. Draw lines from the central circle to smaller circles for each property.
4. Draw lines between related properties. For example:
   - **a.** Attraction to a magnet can be connected to Electrical conductivity because some magnetic materials are also good conductors.
   - **b.** Physical state can be connected to Density because density changes with the state of matter (e.g., ice vs. water).
5. Annotate your diagram with any additional information or detail about the links that you have made between the properties.

Distribution of Charges on Surfaces

Conductors:

When you place a charge on a conductor, the charges spread out evenly throughout the body and across the surface. This is because the charges want to stay as far apart as possible.

Fig 6.12: Examples of conductors

Insulators:

When you place a charge on an insulator, it stays in the place where you put it. The charges don't move around much and stay put.

Fig 6.13: Examples of insulators

Surface Charge Density

1. Surface charge density measures how much electric charge is spread over a certain area of a surface.
2. High Surface Charge Density: When there is a lot of charge packed into a small area, we have a high surface charge density. It's like having many people squeezed into a small space.
3. Low Surface Charge Density: When the charge is spread over a larger area, the surface charge density is low. It's like having a few people in a big space where they can spread out.
4. Surface charge density helps us understand how strongly a surface can attract or repel other charges. A high density means stronger effects.

Sharp Edges and Round Surfaces

Sharp Edges:

1. Charges tend to collect at sharp edges or points. This happens because the charges get crowded together at these points, making the surface charge density higher there. It is like having more people crowding into the corners of a room.

Round Surfaces:

1. On smooth, round surfaces, charges spread out more evenly.
2. The surface charge density is lower at any single point, and the charges are more evenly distributed.

Charge distribution for an isolated spherical conductor

Charge distribution for an isolated pear-shaped conductor

Fig 6.14: Charge distribution on isolated conductors

Summary:

1. Conductors let charges spread out evenly.
2. Insulators keep charges in one place.
3. Sharp edges collect more charges, creating higher surface charge density.
4. Round surfaces have charges spread out more evenly, leading to lower surface charge density.

Activity 6.9: Exploring Static Electricity and Charge Distribution

Objective: Explore static electricity and understand how different shapes and materials (conductors and insulators) affect the distribution of electric charge.

Materials needed:

- Spherical fruits (e.g., oranges, apples)
- Tapered sticks (e.g., pencils, wooden dowels)
- Sharp metallic objects (e.g., needles, nails)
- Cloth (wool or synthetic)
- Small pieces of tissue paper
- Worksheet or table for observations

Procedure:

1. Gather the materials.
2. Rub the cloth against each object for about 30 seconds.
3. Bring each object close to small pieces of tissue paper and observe what happens.
4. Use a worksheet to record your observations.
5. Fill in details like:

Table 6.2: Table to record observation made in Activity 6.9

Name of Object	Shape of Object	Material (Conductor or Insulator)	Effect of Rubbing (Attraction or Repulsion of Tissue)

Discussion questions:

1. What happens when you rub the cloth on different objects?
2. Does the shape of the object affect static electricity?
3. Which objects are better at holding a charge, conductors or insulators? Explain why.
4. What's an example of static electricity in everyday life?

Activity 6.10: Detecting charge: Build a Simple Electroscope

Objective: Build a simple electroscope and observe how it reacts to charged objects.

Materials Needed:

- A glass jar (clear and clean)
- Aluminium foil
- Metal wire or unfolded paperclip
- Sewing needle or nail
- Scissors
- Tape/glue
- Small piece of cardboard

Procedure

1. Take the glass jar and make sure it is clean and dry.
2. Punch a small hole in the centre of the jar's lid and insert the metal wire or unfolded paperclip through it, securing it with tape or glue on the top side.
3. Cut two small strips of aluminium foil (about 2 cm wide and 4 cm long).
4. Attach these foil strips to the bottom end of the metal wire inside the jar, allowing them to hang freely as "leaves."

5. Assemble the Electroscope: Close the jar with the lid, ensuring the foil leaves are inside (if not humidity may affect it) and hanging down. The metal wire should stand vertically in the centre.
6. Test the Electroscope: Rub a plastic rod or balloon with wool to charge it, then bring it close to the top of the metal wire without touching it. Observe how the foil leaves spread apart as they gain the same type of charge and repel each other

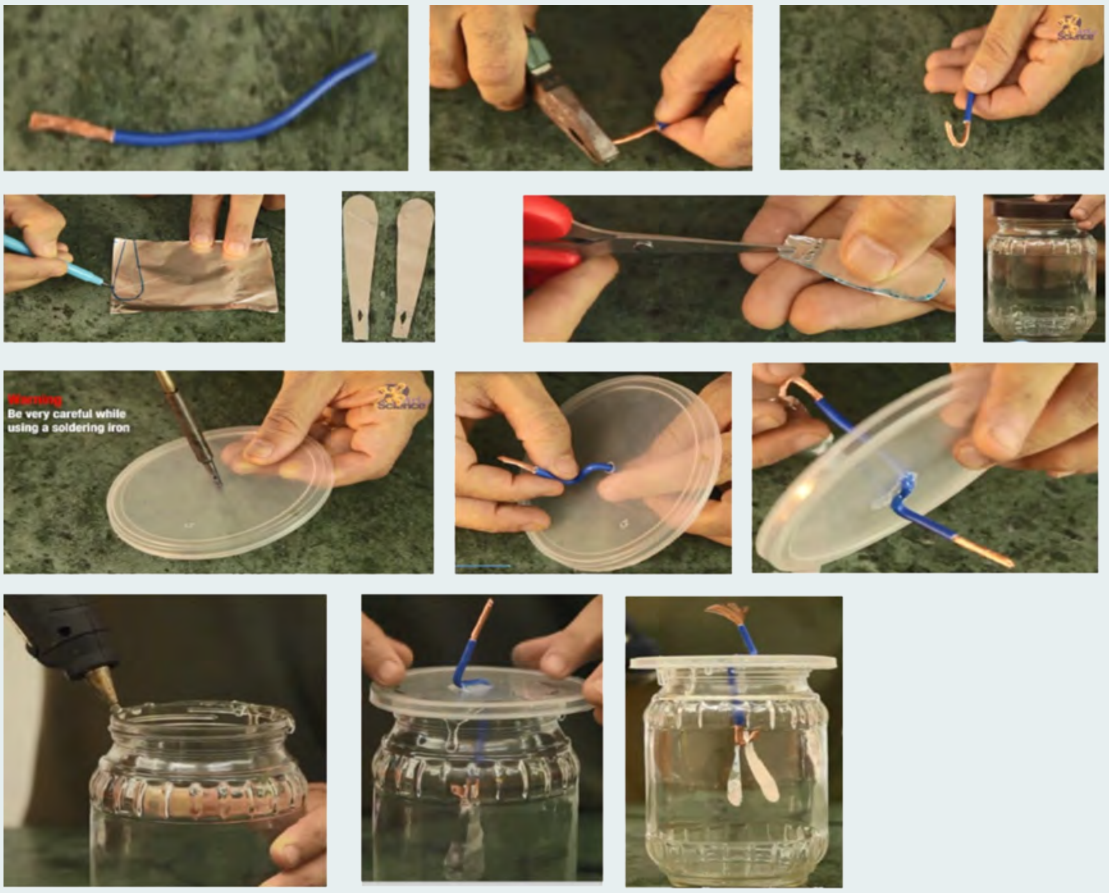


Fig 6.15: Steps to build a simple electroscope

Follow: https://youtu.be/61gr7vAkVAA to watch a video of the electroscope being built.

Questions to think about:

1. What happens to the foil when you bring a charged object near?
2. Does the foil behave differently with a pointed object like a needle?
3. How does the charge build-up affect the electroscope?

Positive and Negative Charges

Everything around us contains tiny particles, some of which are called charges. There are two types of charges: positive and negative. Positive charges are found in protons, and negative charges are found in electrons.

1. Positively Charged Object: This happens when an object loses electrons and has more protons than electrons.
2. Negatively Charged Object: This happens when an object gains electrons, making it have more electrons than protons.

When two objects have the same type of charge, they push away from each other (repel). When objects have opposite charges, they pull towards each other (attract). By exploring how different objects interact with each other, we can see these charges in action with the activities below.

So, when we rub an insulator with a dry cloth, does it gain or lose its electrons to the cloth? Does it become positively or negatively charges?

The sequence below is called the *triboelectric series.* Below can help you predict which material will be positively or negatively charged during rubbing. Materials at the top (e.g., human skin, glass) tend to lose electrons easily and become *positively charged*. Materials at the bottom (e.g., plastic, Teflon) tend to gain electrons and become *negatively charged*:

MNEMONIC

Hubert **G**ave **H**is **N**ice **W**oolen-**S**ilk **C**oat **W**ith **R**ed
Polyester, **S**o **P**lease **T**ake

Human skin

Glass

Hair

Nylon

Wool

Silk

Paper

Cotton

Wood

Rubber

Polyester

Styrofoam

Plastic (e.g., PVC)

Teflon

Activity 6.11: Creating a mnemonic for the triboelectric series

You can make up your own mnemonic of the triboelectric series to help you remember it at all times!

Positive and negative charges in nature

Example: Lightning

During a storm, clouds become charged. The top of the cloud becomes positively charged, and the bottom of the cloud becomes negatively charged.

The ground usually has a positive charge. When the difference between the charges becomes large enough, lightning occurs as electrons move from the cloud to the ground.

Activity 6.12: Simulating lightning

Objective: Understand how charge differences create lightning.

Materials needed:

- A balloon
- A metal object (like a spoon)
- A piece of wool or cloth
- A dark room

Procedure:

1. Rub the balloon with wool to create a static charge.
2. Turn off the lights so that you are in pitch black conditions.
3. Hold the charged balloon close to the metal object and observe what happens.

4. Note how the balloon's charge affects the metal object.

   Questions:

   a. What did you observe when you brought the balloon close to the metal object?

   b. How does this mimic the concept of lightning?

5. Create a storyboard of the key stages in the process which cause thunder and lightning.

Activity 6.13: Investigating the interaction of like charges

Objective: Explore how similar charges interact.

Materials needed:

- Two charged balloons (rubbed with wool), one tied to a piece of string
- A piece of wool or a dry cloth

Procedure:

1. **Charge the Balloons:** Rub both balloons with wool to create static electricity.
2. **Test Repulsion:** Hold the free balloon near to the balloon which is suspended by a string. Try to place the regions of the balloons which were rubbed with the wool close to one another.
3. **Observe and Record:** Note if the balloons attract or repel each other and explain why this has happened.

Conservation Of Charge

The principle of conservation of charge is a basic rule in electricity. It says that electric charge cannot be created or destroyed. Instead, it can only move from one place to another. This means that the total amount of charge in a closed system always stays the same. Understanding this principle helps us see how electrical devices work and how charges interact in everyday life.

Principle of Conservation of Charge

The principle of conservation of charge says that electric charge cannot be created or destroyed. It can only move from one place to another. This means the total amount of charge stays the same, even if it moves around.

This means that, in an electric circuit, the amount of charge entering a junction in a particular period of time is equal to the amount of charge leaving the junction in that same period of time. In the diagrams below, $Q_1 = Q_2 + Q_3$ and $I_1 = I_2 + I_3$, where I is the current or the 'rate of flow of charge'. This is known as Kirchhoff's First Law.

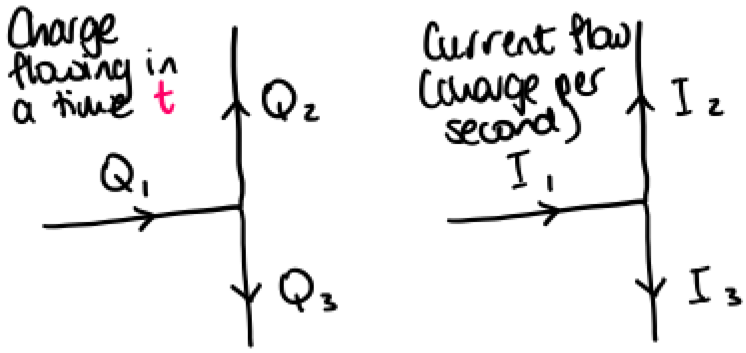


Fig 6.16: Charge and current flow at a junction

The above definition of current leads us to the relationship:

$$\text{Current, I (Amperes, A)} = \frac{\text{Charge, Q (Coulombs, C)}}{\text{time, t (seconds, s)}}$$

$$I = \frac{Q}{t}$$

Activity 6.14: Calculating charge and electron flow in electrical circuits

1. An electric car battery charges at a rate of 100 Amps. How much charge is transferred to the battery in 30 minutes?
2. A household circuit has a current of 15 Amps. How much charge flow through the circuit in one hour?
3. An LED uses a current of 20mA. How much charge flows through the LED in 5 minutes?
4. A small electronic device draws a current of 50mA. How long will it take to consume a charge of 1C?
5. For each of the examples above, find the number of electrons which make up the total charge given in the question. (Magnitude of the charge of an electron = 1.6×10^{-19}C)

Activity 6.15: Experiment to verify Kirchhoff's first law

Materials needed:

- Resistors or bulbs
- Battery
- Switch
- Connecting wires
- Ammeter

Procedure:

1. Connect the circuit as shown in the image below.

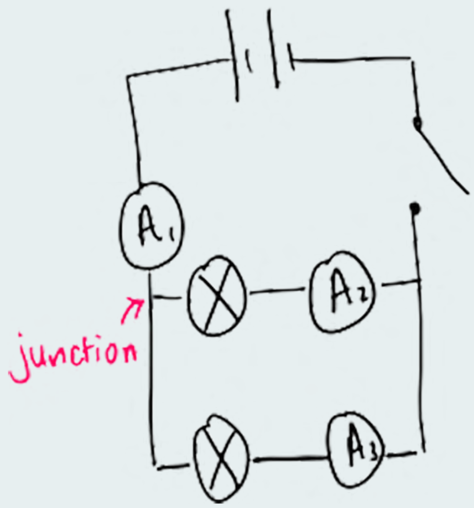


Fig 6.17: Electrical circuit showing a junction and Ammeters

2. Use the ammeter, measure the current in the positions labelled A1, A2 and A3.
3. Verify whether Kirchhoff's First Law is supported by this experiment; does the current entering the junction equal the sum of the currents leaving the junction?

Activity 6.16: Researching timeline of key discoveries in electricity and charge

Research and prepare a timeline of the key discoveries in the field of charges and electricity; ensure that you include a description of the discoveries of Franklin, Coulomb, Faraday and Maxwell.

Activity 6.17: Exploring beta decay and conservation laws (extension task)

Conduct independent research into beta-minus and beta-plus decay. Focus on:

1. Charge Conservation
2. Lepton Number Conservation
3. The Role of Neutrinos
4. Energy and Momentum Conservation

MAGNETIC AND NON-MAGNETIC MATERIALS

Welcome to this learning area, where you will explore the differences between magnetic materials and non-magnetic materials as an important part of understanding magnetic forces. Magnets are important in various technologies, and knowing which materials are attracted to magnets forms the foundation of knowledge in both science and engineering.

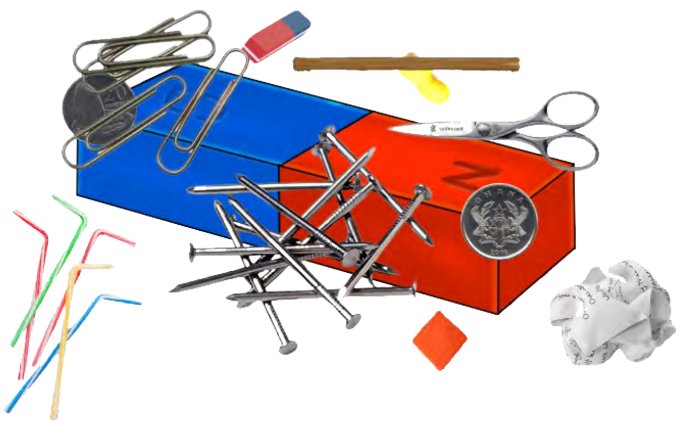


Fig 6.18: Magnetic and non-magnetic materials with a bar magnet

When you observe the picture above you will see that some materials are pulled by the magnets while other materials do not attract to the magnets. In the activities ahead, you will see how these materials behave around magnets and learn why magnetism is important in our everyday lives.

It should be noted that the red and blue bar magnet shown in the diagram and often used it school laboratories is a **permanent** magnet. This means that it has been magnetised (keep reading for more information about how this is achieved) and has remained magnetic.

The materials shown being attracted to the magnet are being **temporarily** magnetised as they enter the magnetic field of the bar magnet. This is called induced magnetism. However, when they are removed from that field they will demagnetise (hence, two paper clips do not magnetically attract one another).

The force between a permanent magnet and a temporarily magnetised material is always attractive.

Let us move into hands-on activities to see how magnets behave towards certain materials.

Activity 6.18: Test materials with a magnet to determine their magnetic properties.

Objective: Distinguish between magnetic and non-magnetic materials through hands-on experimentation.

Procedure:

1. Gather a variety of items from around your home or classroom. Ensure that you include some different types of metal as well as plastics and other insulators.
2. Use the magnet to test each item by bringing the magnet close to it.
3. Observe which items are attracted to the magnet and which are not.
4. Create a table with two columns: materials "attracted by magnet" and "not attracted by magnet." Place each item under the appropriate category based on your observations.

Table 6.3: Table to record observations made in activity 6.18

Attracted by magnet	Not attracted by magnet

Note: Materials that are attracted by the magnet are known as magnetic materials and those that are not attracted are non-magnetic materials

Discussion Questions:

1. Why are magnetic materials are used in devices like compasses, motors, refrigerator doors and generators?
2. Think of situations where non-magnetic materials are necessary, like in electronics or medical equipment. Discuss your findings with your peers.
3. Discuss items used at home or in school that are magnetic

Refer to Annex 6.5 for further information on discussions questions.

Magnetic Fields

When you hold a bar magnet in your hand, there is a real area of influence around it, even though you cannot see it. This area is called a magnetic field. When sprinkle iron filings around the bar magnet, the filings align themselves along the magnetic field lines, revealing the field's shape as shown in the figure below.

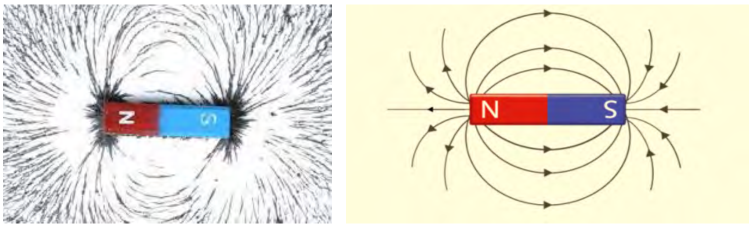


Fig 6.19: Magnetic field lines around a bar magnet (with iron filings and diagram representation)

The iron filings make the invisible magnetic field visible, giving you a clear understanding of how magnetic field surround magnets and how they affect nearby objects.

To explore this concept further, here are series of activities you can explore.

Activity 6.19: Visualising magnetic fields with iron filings, a compass and a bar magnet

Objective: To understand the properties of magnetic fields by visualising and mapping them.

Materials Needed:

- Bar magnets
- Iron filings

- Compass
- A4-sized white paper

Procedure: *Magnetic Field Mapping*

1. Place a bar magnet under a piece of white paper.
2. Gently sprinkle iron filings evenly over the paper and gently tap the paper.
3. Observe how the iron filings align themselves along the magnetic field lines around the magnet.
4. Use a compass to detect which end of the magnet is north and which is south (note: compasses point out of the North Pole and into the South Pole; this is known as the direction of the magnetic field).
5. Draw the observed pattern on a separate sheet of paper, noting the shape of the field lines and the areas in which they appear more and less densely packed. Add directional arrows to the field lines to show the North to South direction.

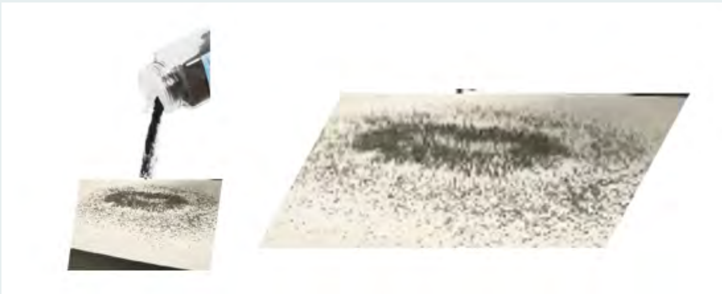


Fig 6.20: Iron fillings sprinkled on a bar magnet

Discussion questions

1. What shape did the iron filings make around the magnet?
2. How do these field lines help you understand the strength of a magnetic field?
3. Why is the compass crucial for determining the direction of the field?

Activity 6.20: Creating and experimenting with an electromagnet

Objective: Create a simple electromagnet and explore the factors that affect its strength.

Materials needed:

- Three 1.5V cells
- Copper wire
- Iron nail
- Switch
- 20 paper clips

Procedure:

1. Wrap the copper wire around the iron nail and connect the ends of the wire to the battery terminals to create an electromagnet. Ensure that there is a switch in series with the electromagnet so that it can be turned on and off; this avoids the risk of overheating.
2. Test your electromagnet by seeing how many small magnetic objects, like paper clips, it can pick up.
3. Experiment with the following variables:
   a. Increase the number of wire turns around the nail and observe the effect on the electromagnet's strength.
   b. Increase the number of dry cells to two and then to three and observe how it affects the electromagnet.

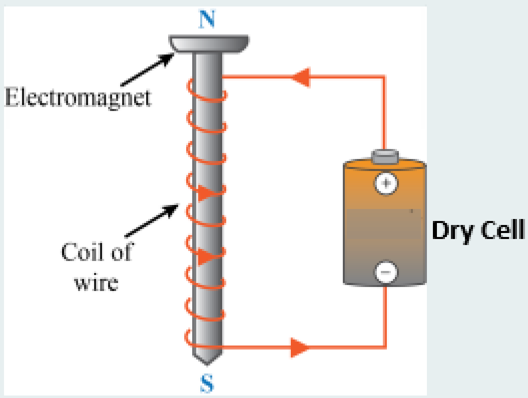


Fig 6.21: Electromagnet formed by a coil of wire around a nail connected to a cell

Discussion Questions:

1. Why do you think the iron nail makes the electromagnet stronger?
2. What happens if you use wood or plastic, instead of the iron nail?
3. How does adding more wire coils around the nail change the magnet?

Activity 6.21: Visualising Magnetic Fields with Iron Filings and a Bar Magnet

Materials needed:

- Copper wire
- Sheet of paper or card
- Two 1.5V batteries
- Switch
- Compasses

Procedure:

1. Set up a simple circuit with a straight conductor passing vertically through a piece of paper and sprinkle iron filings over the paper or place compasses around the wire as shown in the figures below

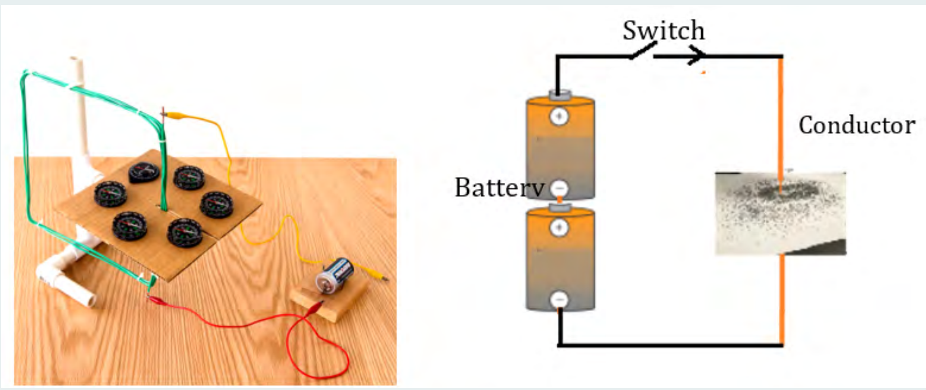


Fig 6.22: schematic of the experimental setup

2. Close the circuit to allow current to flow through the conductor.
3. Observe how the iron filings align along the magnetic field lines created by the current.
4. Draw the observed pattern and compare it with the magnetic field of the bar magnet.

Discussion Questions

1. What shape did the iron filings make around the vertical wire?
2. What does this tell you about the magnetic field around the wire?
3. What happens to the iron filings when the electricity is turned off?

Magnetisation And Demagnetisation

Welcome to this exciting learning area where you will explore how magnetisation and demagnetisation shape the world around us.

Magnetisation is the process of turning a material into a magnet. This happens when the magnetic domains (tiny regions within the material) align in the same direction, creating a magnetic field that can attract or repel other magnetic objects.

Study carefully the diagrams below and discuss your observations with you colleagues

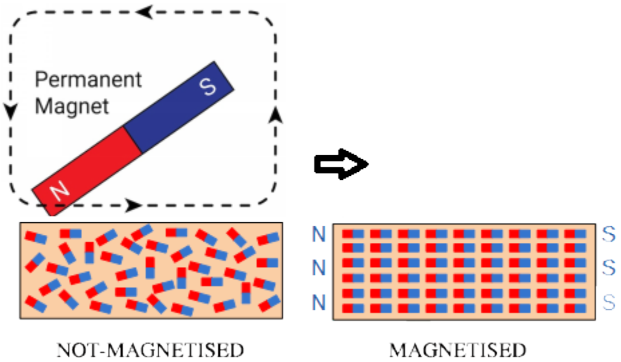


Fig 6. 23: From unmagnetised to magnetised: alignment of magnetic domains

Demagnetisation is the process of reducing or completely removing the magnetic properties of a material. This occurs when the alignment of the magnetic domains is disrupted, causing the material to lose its magnetism.

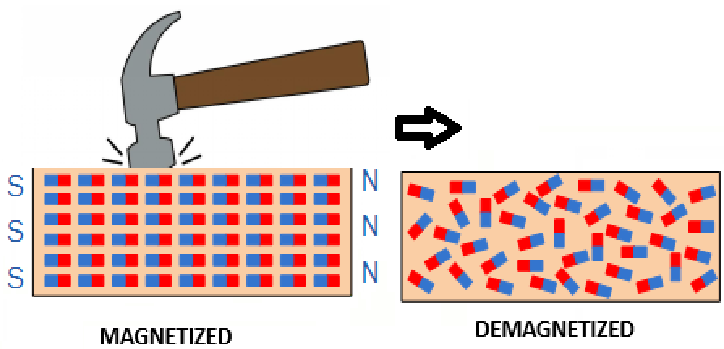


Fig 6.24: From magnetised to unmagnetised: alignment of magnetic domains

Let us explore these concepts further with the activities below

Activity 6.22: Demonstrating magnetisation methods

Objective: To show how to magnetise an iron nail using three methods: stroking, electrical, and induction.

Materials needed:

- An iron nail (about 2-3 inches long)
- A strong magnet (like a fridge magnet or bar magnet)
- A small dry cell (1.5V)
- Insulated copper wire
- A few small metal objects (e.g. paperclips or pins)

Procedure:

Task 1: Stroking Method

1. Place the iron nail flat on a surface.
2. Hold the bar magnet in one hand.
3. Rub the bar magnet along the length of the nail from one end to the other, always in the same direction.
4. Do this 20-30 times.
5. Remove the bar magnet and test the nail by trying to pick up small metal objects.
6. Note how the nail has become magnetised and can pick up metal objects.

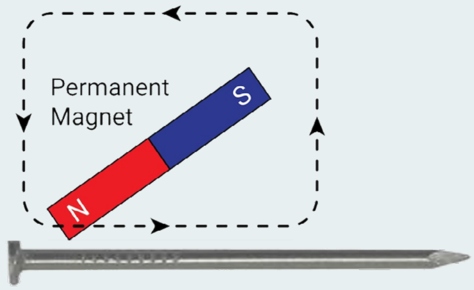


Fig 6.25: Magnetising a nail by the stroking method

Task 2: Electrical Method

1. Wrap the copper wire tightly around the iron nail, leaving the ends of the wire free. This creates a simple electromagnet.
2. Attach the ends of the wire to the terminals of the battery (one end to the positive terminal and one end to the negative terminal).

3. After a few seconds, disconnect the battery; the wire itself will no longer be magnetic when there is no current passing through it, so any retained magnetism will be due to the iron nail.
4. Test the nail by trying to pick up small metal objects.
5. Observe how the nail has become temporarily magnetised.

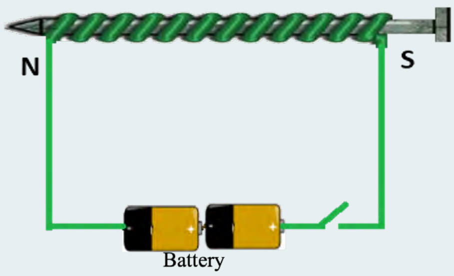


Fig 6.26: Magnetising a nail by the electrical method

Discussion Questions

1. How did each method affect the iron nail?
2. Which method was the easiest for you to perform? Why?
3. How does each method of magnetisation work to turn the nail into a magnet?

Activity 6.23: Demagnetisation Methods

Task 1: Heating Method

1. Light a candle or use a lighter.
2. Using pliers or tongs, hold the magnetised nail over the flame until it's hot, but not red-hot.
3. Allow the nail to cool naturally or dip it in water.
4. After cooling, try to pick up small metal objects.
5. Notice how the nail loses its magnetism after heating.

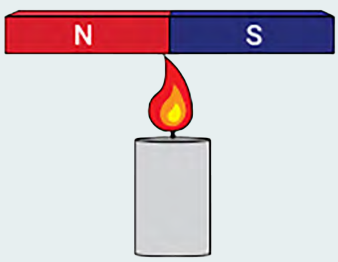


Fig 6.27: Demagnetising a magnet by heating

Task 2: Hammering Method

1. Place the magnetised nail flat on a hard surface.
2. Gently tap the nail with a hammer along its length to disrupt the magnetic domains.
3. Try to pick up small metal objects after hammering.
4. Observe how the nail's magnetism decreases or disappears.

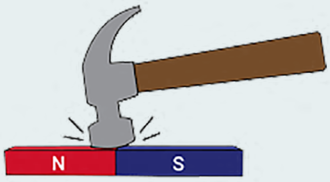


Fig 6.28: Demagnetising a magnet by hammering

Task 3: Alternating Current (AC) Method (Under teacher's guidance)

1. Under supervision, connect the magnetised nail to an AC power source through a coil.
2. Run the AC current through the coil for a few seconds, disrupting the magnetic alignment.
3. Disconnect the nail and test it by trying to pick up small metal objects.
4. Observe how the nail loses its magnetism after exposure to alternating current.

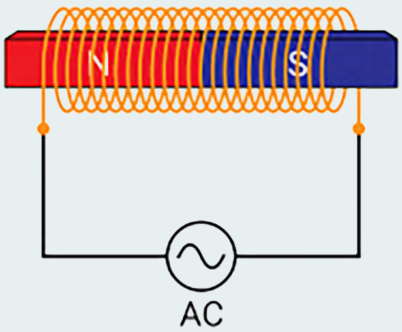


Fig 6.29: Demagnetising a magnet with alternating current (ac)

Discussion Questions

1. How did each method affect the iron nail's magnetism?
2. Which demagnetisation method worked best? Why do you think so?

Activity 6.24: Exploring the application of magnetic fields in navigation

Materials needed:

- A small needle
- A bar magnet
- A piece of cork or foam
- A bowl of water.

Procedure:

1. Rub the needle with the bar magnet about 30 times, always in the same direction.
2. Stick the needle through the piece of cork or foam and gently place it on the surface of the water as shown in the figure below

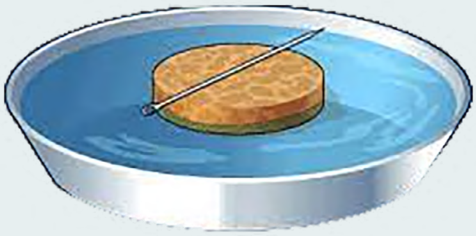


Fig 6.30: Simple compass using a magnetised nail

3. Watch as the needle slowly aligns itself to point north. You've just made a simple compass!
4. Try turning the bowl or moving it around. Does the needle always point the same way? Why do you think this happens?
5. Take your magnet outside and instruct a peer to walk a certain path by giving them instructions to follow using their magnet, e.g. "walk 200 steps to the East, now walk 30 steps to the South" etc.

Discussion Questions

1. What direction did the needle point after you floated it on the water?
2. Why do you think the needle points in a specific direction, even when you move the bowl?
3. How do you think this simple compass could be useful in finding your way?

Annex 6.1 – Solutions (Conductors, Semi-conductors and Insulators)

Activity 6.2

The glass rod charged using silk will not build up a large charge as there is little friction between the two surfaces as they are rubbed together. Friction is needed to 'do work' (transfer energy to) the electrons and hence to enable them to be liberated from one surface to build up on another. It is this separation of electrons which makes the plastic rod charged when rubbed with the fur, where there is significantly more friction.

Activity 6.3

The balloon becomes charged by the application of friction. When this happens, electrons move from your hair to the balloon or vice versa; hence, the hair and the balloon are now oppositely charged. Opposite charges attract, and so your hair sticks to the balloon.

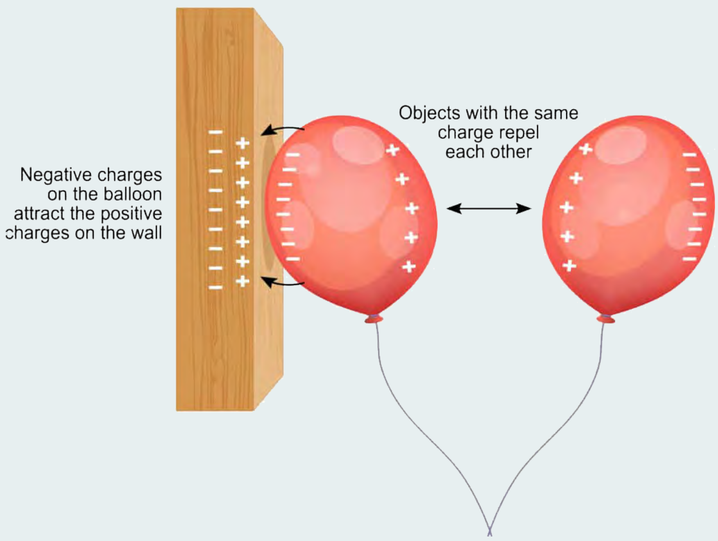


Fig 6.31: Illustration of electrostatic attraction to a wall and repulsion between like charges

When the balloon is placed next to a wall, it also sticks. This seems counter intuitive as the wall is not charged, but the atoms within the wall are able to rotate and move in such a way that the positive 'sides' of them attract to the negatively charged balloon (or vice versa if the balloon is positive) and the balloon sticks.

These demonstrations would not work using something made of metal instead of a balloon because a metal in a conductor; charge does not build up on its surface in the same way as the electrons are able to flow freely through the object and then down to the ground via your body.

Activity 6.4

Plastic rod: the ammeter reading is zero because plastic is an insulator and does not conduct electricity.

Piece of wire: the ammeter reads a current because metal is a conductor.

Thermistor: the ammeter reading is higher when the thermistor is warm; this is because the semiconducting material inside it liberates more electrons into the conduction band at higher temperatures and so a greater current is measured.

LDR: the ammeter reading is higher when the LCR is under a bright light; this is because the semiconducting material inside it liberates more electrons into the conduction band at higher brightness and so a greater current is measured.

Activity 6.6

Table 6.4:

Material	Conductor	Semiconductor	Insulator
Glass			✓
Metal iron	✓		
Silicon		✓	
Germanium		✓	
Plastics			✓
Wood			✓

Annex 6.2 – Further information (Conductors, Semi-conductors and Insulators)

Electronic Properties of materials

1. **Conductivity** is the ability of a conductor to conduct electricity due to the presence of mobile electrons in the conduction band
2. **Resistivity** is the inability of an insulator to conduct electricity due to the absence of mobile electrons in the conduction band

Conductors

Conductors are materials that allow a flow of electric charge through them. They could be described as materials which have higher electrical conductivity and lower resistivity because of completely filled mobile electrons in the conduction band at normal temperature.

Examples of conductors are earth, impure water, human beings, electrolytes, metals such as silver, copper, gold and aluminium. Non-metals such as carbon (graphite) are good conductors. Certain fluids (i.e. liquids and gases) can conduct electricity; mercury is an excellent liquid conductor.

Some liquid ionic compounds are also good conductors because they have charge carriers. These charge carriers are the ions (cations and anions) in the fluid. Electrolytes are conductors because they exist in ions. For instance, aqueous H_2SO_4 is a conductor according to the reaction:

$$H_2SO_4\,(aq) \longrightarrow \quad 2H^+ + SO_4^{2-}$$

Properties of Conductors

1. Conductors have high electrical conductivity and very low electrical resistivity at normal temperature.
2. Conductors have charge carriers. Free electrons are the charge carriers in solid conductors. For fluid conductors, the charge carriers are the ions. The number of charge carriers determines the conductivity. Larger number of charge carriers give higher electrical conductivity and vice versa.
3. Metallic bonding: Most conductors are metals, which have a unique type of bonding where electrons are delocalised and can move freely throughout the material.

4. High thermal conductivity: Conductors are also good at transferring heat. This is because the free electrons can carry both electrical and thermal energy.
5. Ductility and malleability: Many conductors are easily shaped and formed, which makes them suitable for various applications.
6. Lustrous appearance: Conductors often have a shiny or reflective surface

Semiconductors

A semiconductor is a material whose electrical conductivity lies between a conductor and an insulator. They can be described as a material which has moderate electrical conductivity and resistivity. Their conductivity can be controlled by various means, such as temperature changes, light exposure, or the addition of impurities (doping).

Temperature Sensitivity: The conductivity of semiconductors increases with temperature. As the temperature rises, more electrons gain enough energy to jump from the valence band to the conduction band, thus increasing conductivity. This is in contrast to conductors, where conductivity typically decreases with temperature.

Photoconductivity: Semiconductors exhibit photoconductivity, meaning their electrical conductivity increases when exposed to light. This property is exploited in devices like photodiodes and solar cells.

Semiconductors often exhibit nonlinear characteristics, meaning the relationship between current and voltage is not a straight line. This property is crucial for the operation of devices like transistors, which can amplify signals. Semiconductors are the building blocks of integrated circuits (ICs), which are used in virtually all electronic devices, including computers, smartphones, and communication systems.

Insulators

An insulator is a material which has a high electrical resistivity and low electrical conductivity. Examples of insulators are non-metals such as glass, plastic, rubber, wood, sand, quartz, Teflon and carbon (diamond).

An insulator is a solid whose valence band is completely filled with electrons but with a completely empty conduction band and a wider forbidden gap. The energy required to raise a valence electron into the conduction band is about 5eV – 6eV.

Properties of Insulators

1. High Electrical Resistance: Insulators have very high electrical resistance, meaning they do not easily allow the flow of electric current. This makes them ideal for protecting against electrical shocks and preventing short circuits.
2. Low Conductivity: Insulators have low electrical and thermal conductivity. They do not conduct electricity or heat efficiently, which is why they are used to isolate conductors and prevent the transfer of energy.
3. High Dielectric Strength: Dielectric strength refers to the ability of an insulating material to withstand high voltages without breaking down. Insulators have high dielectric strength, making them effective at withstanding strong electric fields.
4. Thermal Insulation: Insulators are also used to reduce the transfer of heat. They have low thermal conductivity, meaning they slow down the rate at which heat is transferred from one area to another.

These properties make insulators essential in electrical engineering, construction, and various industrial applications where the control of electricity and heat is critical.

Annex 6.3- Solutions to some activities on Charge

Activity 6.8

Compare your mind map to the one below. Note that the diagram below is just an example and that you may have considered other properties or found other links between them!

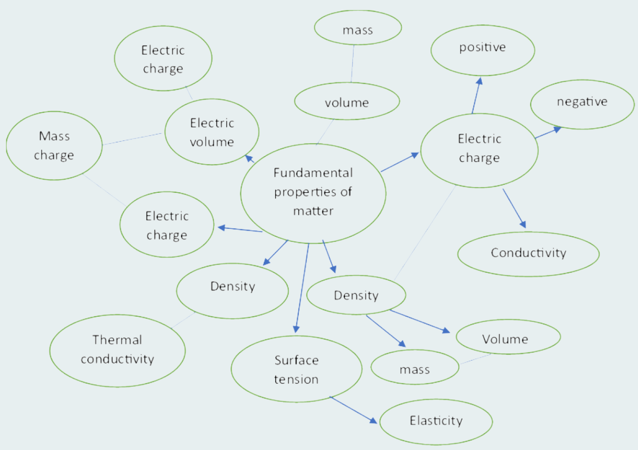


Fig 6.32: Concept map of fundamental properties of matter

Activity 6.9

Discussion questions

1. What happens when you rub the cloth on different objects?

   Answer: Some objects attract the tissue paper, showing they have built up static electricity.

2. Does the shape of the object affect static electricity?

   Answer: Yes, pointy objects can lose charge more easily, while round objects can hold the charge longer.

3. Which objects are better at holding a charge, conductors or insulators?

   Answer: Insulators, like wood or plastic, hold charge better because the electrons cannot move freely.

4. What is an example of static electricity in everyday life?

   Answer: When your hair sticks to a balloon after rubbing it, that's static electricity!

Activity 6.12

When the balloon is brought close to the spoon it creates a very small electric current, which we see as a flash of light, as the electrons which have built up on the balloon transfer to the spoon. This mimics the transfer of charge between the clouds and the ground when lightning strikes.

Activity 6.13

When the balloons are charged, they both become charged. Because they are both made of the same material, they both gain the same charge (in this case, negative). Therefore, when they are brought close to one another they repel and move away from one another.

Activity 6.14

1. $100 \times 30 \times 60 = 180{,}000$C
2. $15 \times 60 \times 60 = 54{,}000$C
3. $0.02 \times 5 \times 60 = 6$C

4. $\frac{1}{0.05} = 20$ s

5. 1.13×10^{24}, 3.38×10^{23}, 3.75×10^{19}, 6.25×10^{18}

Activity 6.17

Charge Conservation: The total electric charge stays the same during decay. In beta-minus decay, a neutron changes into a proton and gives off an electron (called a beta particle) and an antineutrino. In beta-plus decay, a proton changes into a neutron and gives off a positron and a neutrino. Even though particles change, the overall charge remains the same.

Lepton Number Conservation: Just like charge, the lepton number is also kept the same. This means that when particles like electrons or positrons are released, neutrinos or antineutrinos are released too. This keeps the lepton number balanced.

The Role of Neutrinos: Neutrinos were discovered to explain why energy and momentum seemed missing in decay processes. They help balance out the energy and momentum that can't be seen directly.

Energy and Momentum Conservation: In any decay process, energy and momentum are always conserved. Neutrinos and other particles help make sure that these important properties are balanced.

Annex 6.4 – Further information on Charge

A Bit of History

The study of electric charge has a long history, starting with ancient discoveries and leading to modern technology. Here are the key moments:

1. Ancient Greece: Thales of Miletus discovered that rubbing amber could attract small objects like feathers. This was one of the first observations of static electricity.
2. Benjamin Franklin (1706-1790): Franklin's famous kite experiment proved that lightning is a form of electricity. He also introduced terms like "positive" and "negative" charges and invented the terms "battery" and "conductor."
3. Charles-Augustin de Coulomb (1736-1806): Coulomb measured the forces between electric charges, leading to Coulomb's law, which explains how charged objects attract or repel each other.

4. Michael Faraday (1791-1867): Faraday's work on electromagnetism showed how electric charges interact with magnets, leading to inventions like electric motors and generators.
5. James Clerk Maxwell (1831-1879): Maxwell's equations connected electric and magnetic fields, laying the foundation for modern electromagnetism.

Real-World Applications of Charge

1. Electronics: Electric charge is the fundamental principle behind the operation of electronic devices, from smartphones and computers to televisions and radios.
2. Medical Devices: In medicine, electric charge plays a key role in devices like electrocardiograms (ECGs) that monitor heart activity and in procedures like electrosurgery, where electric charges are used to cut tissue.
3. Industrial Applications: Electrostatic precipitators use electric charges to remove pollutants from industrial exhaust gases. Similarly, electroplating uses electric charges to coat objects with a thin layer of metal.
4. Environmental Protection: Lightning rods use the principle of charge concentration at sharp points to protect buildings by providing a safe path for lightning discharge.
5. Printing and Photocopying: Photocopiers and laser printers rely on electric charges to attract toner particles to paper, creating images and text.

Annex 6.5 – Solutions to some activities on Magnetic Fields

Activity 6.18

Discussion questions

1. Why are magnetic materials used in devices like compasses, motors, refrigerator doors, and generators?

   Answer: Magnetic materials are used in these devices because they respond to magnetic fields. In a compass, the magnet helps point to the Earth's North. Motors and generators rely on magnets to create movement or generate electricity. Refrigerator doors use magnets to keep them closed tightly.

2. Why are non-magnetic materials important in electronics or medical equipment?

   Answer: They don't interfere with magnets, which helps equipment like MRI machines and electronic devices work correctly.

3. What are some magnetic items you use at home or school?

   Answer: Examples include fridge magnets, metal tools, and cabinet latches. These items stick to magnets because they are made of magnetic materials.

Activity 6.19

Discussion questions

1. What shape did the iron filings make around the magnet?

   Answer: The iron filings formed a pattern of lines that curve from the north pole to the south pole of the magnet, showing the shape of the magnetic field.

2. How do these field lines help you understand the strength of a magnetic field?

   Answer: The spacing of the field lines indicates the strength of the magnetic field: closer lines mean a stronger field.

3. Why is the compass crucial for determining the direction of the magnetic field?

   Answer: The pattern shown by the iron filings is symmetrical and on its own gives no indication of the north and south poles.

Activity 6.20

1. Why do you think the iron nail makes the electromagnet stronger?

   Answer: The iron nail makes the electromagnet stronger because it helps concentrate the magnetic field. Iron is a magnetic material that enhances the magnetic force created by the copper wire.

2. What happens if you use wood or plastic instead of the iron nail?

   Answer: If you use wood or plastic, the electromagnet will be weaker or might not work at all because these materials do not strengthen the magnetic field like iron does.

3. How does adding more wire coils around the nail change the magnet?

Answer: Adding more wire coils around the nail makes the electromagnet stronger because each coil has its own magnetic field and adds a further contribution to the overall field.

Activity 6.21

1. What shape did the iron filings make around the vertical wire?

Answer: The iron filings formed concentric circles around the vertical wire, showing that the magnetic field lines wrap around the wire in a circular pattern.

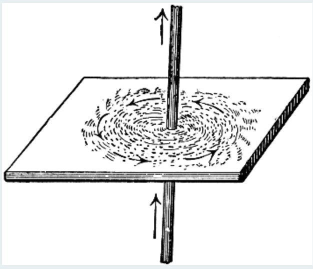


Fig 6.33: Iron filings forming concentric circles around a vertical wire

2. What does this tell you about the magnetic field around the wire?

Answer: This pattern indicates that the magnetic field around a current-carrying wire forms circular loops that encircle the wire. The direction of the field can be determined using the right-hand rule.

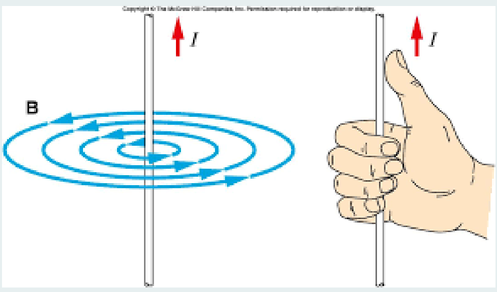


Fig 6.34: magnetic field around a current-carrying wire

3. What happens to the iron filings when the electricity is turned off?

Answer: When the electricity is turned off, the iron filings will no longer align in circular patterns around the wire because there is no magnetic field generated by the current. The filings will lose their alignment and return to a random arrangement.

Activity 6.22

1. How did each method affect the iron nail?

Answer: The stroking method gradually magnetised the nail, allowing it to pick up small metal objects. The electrical method made the nail a stronger magnet while the battery was connected, but it retained some weak magnetism when the current was removed.

2. Which method was the easiest for you to perform? Why?

Answer: The stroking method might be the easiest because it requires only a magnet and a nail, without needing additional materials like wires or batteries.

3. How does each method of magnetization work to turn the nail into a magnet?

- Stroking Method: Aligns the magnetic domains in the iron nail in one direction, turning it into a magnet.
- Electrical Method: Creates a magnetic field around the nail when electricity flows through the wire, magnetising the nail.

Activity 6.23

1. How did each method affect the iron nail's magnetism?

- Heating Method: The nail lost its magnetism after being heated.
- Hammering Method: The nail's magnetism decreased or disappeared after being tapped.
- AC Method: The nail lost its magnetism after being exposed to alternating current.

2. Which demagnetization method worked best? Why do you think so?

- Best Method: The AC method usually works best because it disrupts the magnetic domains thoroughly and effectively.
- Reason: AC current creates a fluctuating magnetic field that can completely disrupt the alignment of the magnetic domains.

Activity 6.24

1. What direction did the needle point after you floated it on the water?

Answer: The needle pointed north.

2. Why do you think the needle points in a specific direction, even when you move the bowl?

Answer: The needle points north because it aligns with Earth's magnetic field, which always points toward magnetic south (geographic north).

3. How do you think this simple compass could be useful in finding your way?

Answer: This simple compass helps you find direction by showing which way is north, helping you navigate and determine your location.

REVIEWS QUESTION

Review Question 6.1

1. Draw and explain the functions of the parts of a gold leaf electroscope.
2. Why does your hair stand up when you rub a balloon on it?
3. Why does dust sometimes cling to your TV screen?
4. Define mobile charge carriers.
5. Why do manufacturers use copper instead of rubber to produce electric wires?
6. Identify and explain the key electrical properties that differentiate conductors, semiconductors and insulators.
7. How do solar panels work during the day but not at night?

Review Questions 6.2

1. What is the principle of conservation of charge?
2. How do charges behave on the surface of a conductor?
3. Why are people advised to avoid being outdoors with metal objects during a thunderstorm?
4. How does the shape of a conductor affect charge distribution?
5. Explain why lightning rods are pointed at the top rather than flat.
6. A metal has a charge density of 8.4×10^{28} free electrons per cubic metre. If the current in the circuit is 0.3A, and the cross-sectional area of the wire is $2.5 \times 10^{-6} m^2$, what length of wire do the electrons travel, on average, during one second?

Review Questions 6.3

1. How does the magnetic field around a straight current-carrying conductor differ from that around a bar magnet? Use diagrams to support your explanation.
2. Describe the role of magnetisation in the functioning of a hard drive. How does demagnetisation ensure data security during recycling?
3. Explain the process of creating a simple electromagnet and discuss how the magnetisation process differs from that of a permanent magnet?

ANSWERS TO REVIEW QUESTIONS

Review Questions 6.1

1.

- Metal rod (stem): The metal rod extends from the top of the electroscope into the glass container. It conducts charge from the external environment to the gold leaves. When a charged object is brought near or touches the metal disc at the top, the charge is transferred down the rod to the gold leaves.
- Metal disc or cap: This is located at the top of the metal rod. It serves as the point where an external charge is introduced to the electroscope. The metal disc allows the charge to spread evenly over the rod and subsequently to the gold leaves.
- Gold leaves: The thin gold leaves are attached to the bottom of the metal rod inside the glass container. When charged, they repel each other and spread apart due to like charges repelling. The degree of separation between the leaves indicates the presence and magnitude of the charge.
- Glass container: The glass container protects the delicate gold leaves from air currents and other environmental factors that might affect their movement. It also allows for the visual observation of the leaf movement.
- Insulating stopper: Often made of rubber or another insulating material, the stopper prevents the metal rod from making contact with the glass container, ensuring that the charge remains isolated to the rod and leaves.
- Earthing terminal: Some electroscopes have an earthing terminal connected to the base, allowing the device to be grounded. This helps to discharge the electroscope, resetting it for future use.

2. When you rub the balloon against your hair, electrons (which are negatively charged particles) are transferred from your hair to the balloon. As a result of this electron transfer, the balloon becomes negatively charged and your hair becomes positively charged. Your hair strands, now all positively charged, repel each other. Since like charges repel, each strand of hair tries to move away from the others, causing them to stand up and spread out. Because the balloon is negatively charged and your hair is positively charged, there is an attraction between the balloon and your hair.

3. Dust particles in the air are usually neutral but can become slightly charged through various means (like friction with other particles). When these particles come close to the TV screen, the static charge on the screen can induce a charge on the dust particles, causing them to become attracted to the screen.

4. **Mobile charge carriers** are particles or entities within a material that can move freely and carry an electric charge. These charge carriers are responsible for conducting electricity in various substances, such as metals, semiconductors, and electrolytes.

5. Copper is a metal, and metals have a structure where some of the free electrons (conduction electrons), are not bound tightly to any particular atom. These free electrons can move easily through the metal when an electric field is applied, allowing electrical current to flow efficiently. Rubber is a non-metallic material and an insulator. In insulators like rubber, the electrons are tightly bound to the atoms and cannot move freely. The atomic structure of rubber does not have free electrons available for conduction. When an electric field is applied, the electrons in rubber do not move, which means that rubber cannot conduct electricity.

6.

Table 1.4: Comparison between conductors, semiconductors and insulators

Property	Conductors	Semiconductors	Insulators
Electrical Conductivity	High	Moderate to high (varies with type and conditions)	Low
Charge Carrier Type	Free electrons	Electrons and holes	Very few free electrons or holes
Examples	Copper, aluminium, silver	Silicon, germanium	Rubber, glass, plastic

Property	Conductors	Semiconductors	Insulators
Usage	Used in electrical wiring, connectors	Used in electronic devices (transistors, diodes)	Used as insulating materials to prevent unwanted current flow

7. When sunlight hits the solar panels, photons (particles of light) are absorbed by the semiconductor material, usually silicon, in the solar cells. Without sunlight, there are no photons to excite the electrons in the semiconductor material of the solar cells

Review Questions 6.2

1. The principle of conservation of charge states that the total electric charge in an isolated system remains constant. Charge cannot be created or destroyed, only transferred from one object to another.
2. Charges on the surface of a conductor distribute themselves in a way that minimises repulsion, spreading out evenly if the surface is smooth and symmetric, and concentrating more at points or edges where the curvature is higher.
3. Metal objects, like any conductive material, can increase the risk of lightning strikes by providing a path for the lightning to travel to the ground. However, it is the presence of a conductor near the ground and being in an exposed location that increases the risk, not the metal objects themselves attracting lightning.
4. The shape of a conductor affects how charges are distributed on its surface. In areas where the conductor is more curved or pointed, the charge density is higher because charges tend to accumulate more in regions with higher curvature. For example, a pear-shaped conductor will have higher charge density at its pointed end compared to a spherical conductor with uniform charge distribution.
5. Lightning rods are pointed at the top because charges concentrate more at sharp points. This increases the likelihood of a lightning strike being directed to the rod, safely guiding the electric charge to the ground and protecting the surrounding structure.

6. $0.3A \times 1s = 0.3C$ (total charge passing a point)

$\frac{0.3C}{1.6} \times 10^{-19}\ C = 1.88 \times 10^{18}$ electrons (total electrons passing a point)

$1.88 \times \frac{10^{18}}{8.4} \times 10^{24} = 2.33 \times 10^{-11} m^3$ (volume occupied by electrons)

$2.33 \times \frac{10^{-11} m^3}{2.5} \times 10^{-16} m^2 = 8.93 \times 10^{-6} m$ (length of wire with corresponding volume)

Review Questions 6.3

1. Magnetic field around a conductor and a bar Magnet

When current flows through a straight wire, it creates circular magnetic fields around the wire. This is different from a bar magnet, which has a magnetic field with lines going from the north pole to the south pole, forming a pattern around the magnet.

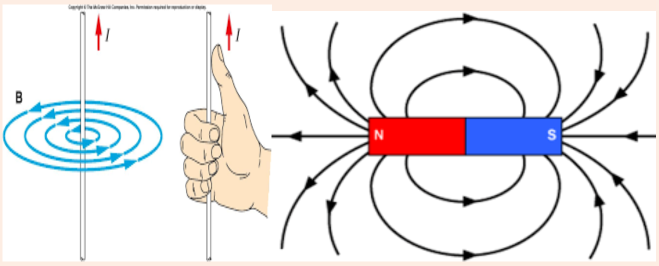


Fig 6.35: Magnetic field around a conductor and a bar Magnet

2. Role of magnetisation in hard drives

Hard drives use magnetisation to store data by changing the magnetic direction of tiny areas on a disk to represent different information. When recycling, demagnetisation erases the data, making it impossible to read.

3. Creating a simple electromagnet

To make a simple electromagnet, wrap wire around an iron nail and connect the wire ends to a battery. The nail becomes a magnet because of the electric current. Unlike a permanent magnet, which stays magnetised on its own, an electromagnet needs electricity to work.

EXTENDED READING

- Watch: Jojo science video: https://youtu.be/V7soAsGyfWQ
- Life-Online-Activity-Sheet-Static-Electricity https://www.life.org.uk/app/uploads/2023/03/Life-Online-Activity-Sheet-Static-Electricity.pdf
- Click on this link for more explanation on the door bell https://www.youtube.com/watch?v=cdW3s9-FbR0
- For more explanation on how the speaker work, click on this link: https://www.youtube.com/watch?v=RxdFP31QYAg
- For more explanation on how the magnetron work, click on this link: https://www.youtube.com/watch?v=bUsS5KUMLvw
- Khan Academy: Magnetic field lines (video) | Magnetism - I | Khan Academy - Offers a detailed explanation of different types of materials and their magnetic properties.
- https://www.khanacademy.org/science/ap-physics-2/ap-magnetic-forces-and-magnetic-fields/ap-magnets-magnetic/v/magnetic-field-lines-their-properties Magnetic Field and Field Lines - Provides a visual and descriptive explanation of magnetic fields and field lines.
- https://www.youtube.com/watch?v=TgRqNOXpq4s - Magnetization and Demagnetization - A detailed description of how materials become magnetized and the methods used to demagnetize them.
- https://www.alamy.com/static-electricity-for-example-balloons-vector-diagram-image472288286.html?imageid=E65A1DD5-338E-49B5-8437-00A60478B382&p=1369652&pn=1&searchId=ad513ccc25a1e3a8c8cd52562fd1c808&searchtype=0
- How to Make an Electroscope; https://www.wikihow.com/Make-an-Electroscope
- How to make a Simple Electroscope at Home? | DIY Electroscope | -dArtofScience; https://youtu.be/61gr7vAkVAA
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- Static electricity https://youtu.be/dq7J6k1OKpwvector-diagram-2JCAGEP.jpg
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- https://www.istockphoto.com/photo/static-electricity-experiment-with-friction-with-balloon-and-paper-pieces-gm875275124-244360647?searchscope=image%2Cfilm
- https://youtu.be/e5maAe6iVkQ
- Potato-Battery-Driven-LED/https://www.instructables.com/Potato-Battery-Driven-LED/

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    This book provides a comprehensive overview of magnetic materials, their properties, and their applications in everyday objects and advanced technologies.
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    This textbook covers the fundamental concepts of magnetism, including the identification and differentiation of magnetic and non-magnetic materials, with practical examples of their use in daily life.
17. Cullity, B. D., & Graham, C. D. (2011). Introduction to Magnetic Materials (2nd ed.). Wiley.

    This resource dives into the properties of magnetic materials, their role in electromagnetic applications, and how they differ from non-magnetic materials, offering both theoretical and practical insights.

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