Unit 5
Magnetism

Introduction to Magnetism

Magnetism is a natural force that allows certain materials, known as magnetic objects, to attract or repel each other without physical contact. This fascinating phenomenon has been known to humans for thousands of years. One of the earliest discoveries of magnetism was the lodestone, a naturally magnetized form of the iron oxide mineral magnetite, which has the ability to attract iron. Today, magnetism plays a crucial role in various aspects of our daily lives, from simple household items to advanced technology.

Magnets

A **magnet** is a material or object that produces a magnetic field, capable of attracting materials like iron and steel. Magnets come in various shapes and are used in many devices such as motors, speakers, and even in your mobile phones.

Types of Magnets

1. **Permanent Magnets:**
    - Made from materials like steel, which retain their magnetic properties over time.
    - Used in devices like speakers, mobile phones, and generators.
    - Can lose their magnetism when exposed to extreme temperatures, hammered, or improperly stroked.
2. **Temporary Magnets:**
    - These become magnetized in the presence of a magnetic field but lose their magnetism when the field is removed.
    - Examples include iron nails and paper clips.
3. **Electromagnets:**
    - Consist of a coil of wire wrapped around a metal core, usually iron.
    - They become magnets when an electric current passes through the wire.
    - The strength of an electromagnet can be controlled by adjusting the electric current.
    - Used in generators, motors, and MRI machines.

Properties of Magnets

- **Poles:** Every magnet has two poles: a North Pole and a South Pole.

- **Attraction and Repulsion:** Like poles repel each other, while unlike poles attract.
- **Indivisible Poles:** If you cut a magnet in half, each piece will still have both a North and South Pole.
- **Directionality:** A freely suspended magnet always aligns itself with the Earth's North-South direction.

Magnetic Field

A **magnetic field** is an invisible area around a magnet where magnetic forces can be detected. Magnetic fields are represented by lines called **magnetic field lines**. These lines show the direction and strength of the magnetic field, emerging from the North Pole and merging at the South Pole.

Properties of Magnetic Field Lines

- **Non-Intersection:** Magnetic field lines never intersect.
- **Closed Loops:** Magnetic field lines always form closed loops, from the North Pole to the South Pole.
- **Density:** The closer the lines, the stronger the magnetic field.
- **Direction:** Inside a magnet, the magnetic field lines run from the South Pole to the North Pole.

Earth's Magnetic Field and the Compass

Earth's Magnetic Field

Earth is surrounded by a magnetic field, similar to the field around a bar magnet. This magnetic field originates deep within Earth, specifically in the outer core, where the movement of molten iron generates this field. The shape of Earth's magnetic field is similar to that of a bar magnet, with magnetic poles that are not perfectly aligned with the geographic poles. Instead, the magnetic poles are tilted about 11° from the Earth's rotational axis.

Key Concept:

- Earth has a magnetic field that resembles the field around a bar magnet.

Understanding the Earth's Magnetic Poles

The Earth's magnetic field has two sets of poles: geographic poles (true north and south) and magnetic poles. The magnetic field lines around the Earth extend from the magnetic south pole near the geographic north pole to the magnetic north pole near the geographic south pole. This means that what we call the magnetic north pole is actually the south pole of the Earth's magnetic field, as magnetic field lines always flow from the north to the south pole of a magnet.

The Compass and Navigation

A compass is an instrument used to detect the direction of a magnetic field. It works because the compass needle, which is a small magnet itself, aligns with the Earth's magnetic field. The needle of the compass points towards the Earth's magnetic north, which, as explained earlier, is the magnetic south pole of the Earth's field.

Key Concept:

- A compass aligns with Earth's magnetic field, helping in navigation by pointing toward the magnetic north.

Earth's Magnetic Field and Animal Navigation

Interestingly, some animals can detect the Earth's magnetic field, which helps them in orientation and navigation. Examples include pigeons, bees, Monarch butterflies, sea turtles, and certain fish species.

- Earth is surrounded by a magnetic field similar to that of a bar magnet.
- The magnetic field is generated by the movement of molten iron in Earth's outer core.
- A compass works by aligning with Earth's magnetic field, pointing towards the magnetic north (which is the magnetic south pole).

Magnetic Force Between Two Parallel Current-Carrying Conductors

When two parallel conductors carry electric currents, they generate magnetic fields around them. These magnetic fields interact, causing forces to act between the conductors. The nature of the force (attractive or repulsive) depends on the direction of the currents in the two wires.

Case 1: Currents in the Same Direction

- **Explanation**: If the currents in both conductors flow in the same direction, the magnetic fields generated by each conductor will interact in such a way that the forces acting between the wires are attractive. This happens because the magnetic field lines between the conductors tend to compress, pulling the wires toward each other.

- **Key Concept**: **Attraction** occurs when the currents in both conductors are in the same direction.

Case 2: Currents in Opposite Directions

- **Explanation**: If the currents in the two conductors flow in opposite directions, the magnetic fields generated will cause the conductors to repel each other. This repulsion occurs because the magnetic field lines between the wires spread out, pushing the wires away from each other.
- **Key Concept**: **Repulsion** occurs when the currents in the two conductors flow in opposite directions.

Determining the Direction of Magnetic Forces

To determine the direction of the magnetic forces between two parallel current-carrying conductors, you can use the **right-hand rule**:

1. Point your thumb in the direction of the current in one conductor.
2. Curl your fingers in the direction of the magnetic field lines generated by this current.
3. The force on the second conductor, due to the first, will be in the direction your palm pushes.

This rule helps visualize the interaction between the magnetic fields and the resulting force on the conductors.

Key concept

- **Attraction** occurs when the currents in the two conductors are in the same direction.
- **Repulsion** occurs when the currents are in opposite directions.

Exercises

1. **Question**: Two parallel wires carry currents in the same direction. What kind of force acts between them, and why?
    - **Answer**: The wires will attract each other because their magnetic fields interact in a way that pulls them together.
2. **Question**: What kind of force acts between the hot and neutral lines hung from power poles?
    - **Answer**: The force is repulsive because the currents in the hot and neutral lines typically flow in opposite directions.