Magnetic Effects of Electric Current

Effects of Electric Current

- **Heating Effect:** As discussed in the previous chapter, electric current can produce heat.
- **Magnetic Effect:** An electric current-carrying wire creates a magnetic field around it, similar to a magnet. This means electricity and magnetism are interconnected.

Magnetic Fields

- **Compass and Magnets:** A compass needle is a small bar magnet with north and south poles. Like poles repel, and unlike poles attract.
- **Magnetic Field Lines:**
  - Iron filings near a magnet align themselves along magnetic field lines, forming a pattern.
  - These lines represent the invisible magnetic field where the magnet's force can be detected.
  - You can visualize these lines yourself using a compass or iron filings.
  - Magnetic field lines have both direction and magnitude.
  - By convention, they emerge from the north pole and merge at the south pole of a magnet.
  - Inside the magnet, the field lines go from south to north, forming closed curves.
  - The closer the lines, the stronger the magnetic field.
  - Field lines never cross each other.

Key Concepts

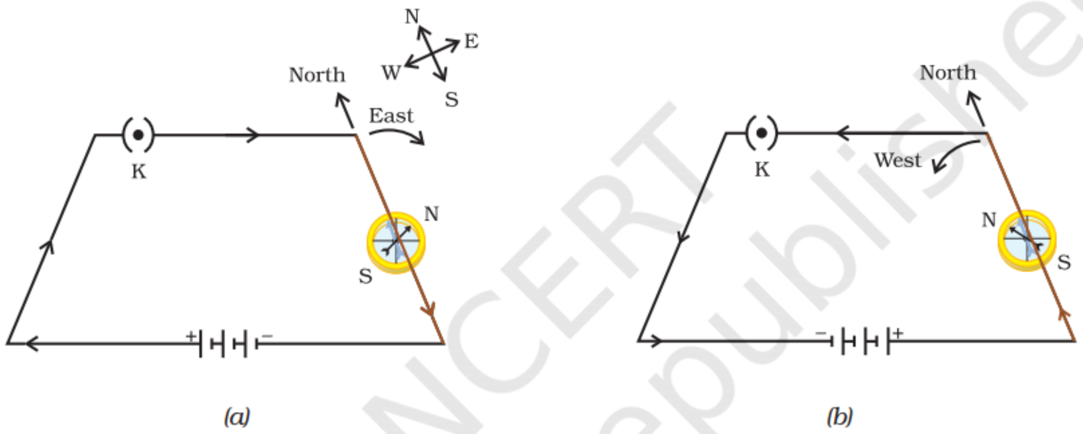
- **Electricity and Magnetism:** These two forces are fundamentally linked.
- **Magnetic Field:** An invisible region around a magnet where its force can be detected.
- **Magnetic Field Lines:** Lines that map out the direction and strength of a magnetic field.

Iron filings near the bar magnet align themselves along the field lines.

Magnetic Field Around a Current-Carrying Conductor

- **Electricity Creates Magnetism:** When electric current flows through a conductor (like a wire), it generates a magnetic field around it.
- **Shape of the Field:** The magnetic field forms concentric circles around the conductor. Imagine rings surrounding the wire.
- **Direction of the Field:** You can determine the direction of the magnetic field using the "right-hand rule":
    - Imagine gripping the wire with your right hand, with your thumb pointing in the direction of the current flow.
    - The direction your fingers curl around the wire indicates the direction of the magnetic field.
- **Strength of the Field:**
    - The strength of the magnetic field is directly proportional to the amount of current flowing through the wire. More current means a stronger field.
    - The strength of the field decreases as you move further away from the wire.

Key Concept: A current-carrying conductor creates a circular magnetic field around it. The direction and strength of this field depend on the direction and magnitude of the current.



A simple electric circuit in which a straight copper wire is placed parallel to and over a compass needle. The deflection in the needle becomes opposite when the direction of the current is reversed.

Magnetic Field Around a Straight, Current-Carrying Wire

- **Shape of the Field:** The magnetic field forms concentric circles around the wire. Imagine rings centered on the wire.
- **Factors Affecting the Field:**
    - **Current Strength:** The strength of the magnetic field increases as the current flowing through the wire increases. More current means a stronger field.

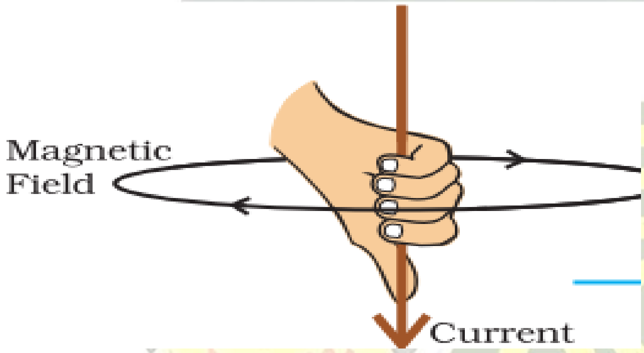
- **Distance from the Wire:** The strength of the magnetic field decreases as you move further away from the wire. The field lines become larger and larger, indicating a weaker field.

Key Concept: The magnetic field around a straight, current-carrying wire is circular. The strength of this field depends on the amount of current flowing through the wire and the distance from the wire.

Right-Hand Thumb Rule

- **Purpose:** This rule helps you easily determine the direction of the magnetic field around a current-carrying wire.
- **How to Use It:**
  1. **Imagine:** Hold the wire in your right hand.
  2. **Thumb Direction:** Point your thumb in the direction of the current flow.
  3. **Finger Direction:** The direction your fingers curl around the wire shows the direction of the magnetic field lines.

Key Concept: The right-hand thumb rule provides a simple way to visualize the relationship between the direction of current and the direction of the magnetic field it creates.



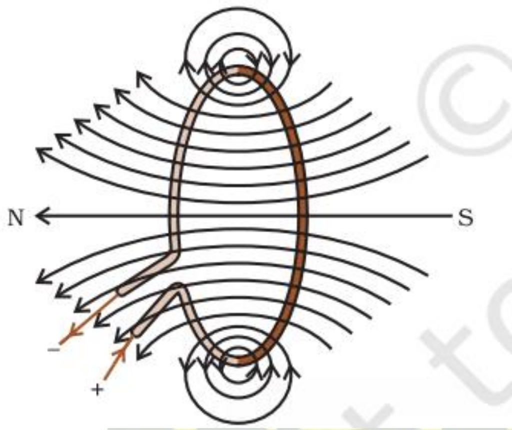
Right-hand thumb rule

Magnetic Field Around a Current-Carrying Circular Loop

- **Shape of the Field:**
  - The magnetic field lines around each point of the loop form concentric circles, just like around a straight wire.
  - However, these circles combine in a special way at the center of the loop.
  - At the center, the field lines become straight lines.
- **Direction of the Field:**
  - You can use the right-hand rule to determine the direction of the field inside the loop.
  - Every section of the wire contributes to the magnetic field in the same direction within the loop.
- **Strength of the Field:**
  - The strength of the magnetic field at the center of the loop is directly proportional to the amount of current flowing through it.

    - If the loop has multiple turns of wire (like a coil), the field strength increases with the number of turns. More turns mean a stronger field.

Key Concept: A current-carrying circular loop creates a magnetic field that is concentrated at its center. The field lines are straight at the center and form concentric circles around the loop itself.

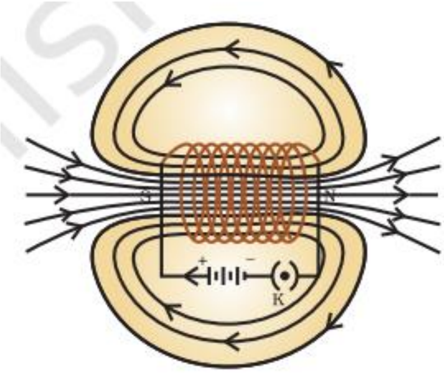


Magnetic field lines of the field produced by a current-carrying circular loop

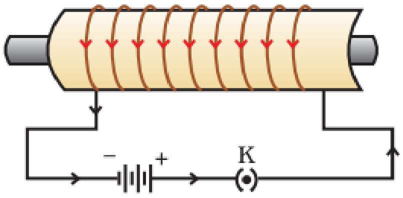
Magnetic Field of a Solenoid

- **What is a Solenoid?** A solenoid is a coil of many loops of insulated wire tightly wound in the shape of a cylinder.
- **Shape of the Field:**
    - The magnetic field lines around a solenoid resemble that of a bar magnet.
    - One end of the solenoid acts like a north pole, and the other acts like a south pole.
    - Inside the solenoid, the field lines are parallel straight lines, indicating a uniform magnetic field.
- **Strength of the Field:** The magnetic field inside a solenoid is strong and uniform.
- **Electromagnets:**
    - You can use a solenoid to create an electromagnet.
    - Place a magnetic material (like soft iron) inside the solenoid.
    - When current flows through the solenoid, it magnetizes the material, creating an electromagnet.

Key Concept: A solenoid generates a magnetic field similar to a bar magnet. The field inside the solenoid is strong and uniform, which makes solenoids useful for creating electromagnets.



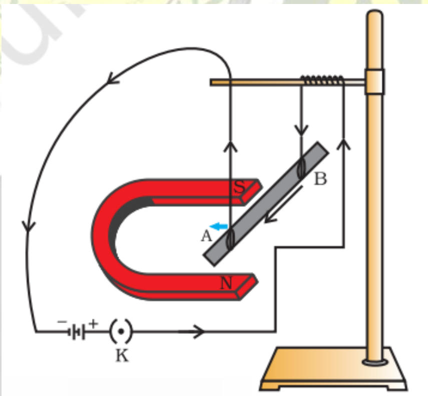
Field lines of the magnetic field through and around a current carrying solenoid.



A current-carrying solenoid coil is used to magnetise steel rod inside it – an electromagnet.

Force on a Current-Carrying Conductor in a Magnetic Field

- **Interaction:** When a current-carrying conductor is placed in a magnetic field, the magnetic field exerts a force on the conductor.
- **Force Direction:**
  - The direction of the force depends on both the direction of the current and the direction of the magnetic field.
  - The force is strongest when the current direction is at right angles to the magnetic field direction.

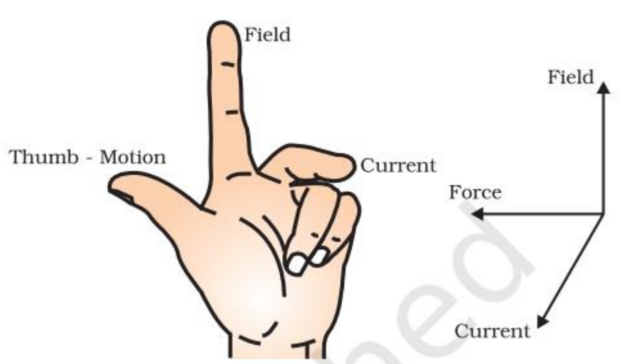
  A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field. Support for the magnet is not shown here, for simplicity.

- **Fleming's Left-Hand Rule:** This rule helps you determine the direction of the force:
  1. **Stretch:** Extend the thumb, forefinger, and middle finger of your left hand so they are perpendicular to each other.
  2. **Forefinger:** Point your forefinger in the direction of the magnetic field.
  3. **Middle Finger:** Point your middle finger in the direction of the current.

4. **Thumb:** Your thumb will then point in the direction of the force acting on the conductor.

- **Applications:** This principle is used in many devices, including:
  - Electric motors
  - Electric generators
  - Loudspeakers
  - Microphones
  - Measuring instruments

Key Concept: A current-carrying conductor experiences a force when placed in a magnetic field. The direction of this force can be determined using Fleming's Left-Hand Rule. This interaction between electricity and magnetism is fundamental to many important technologies.



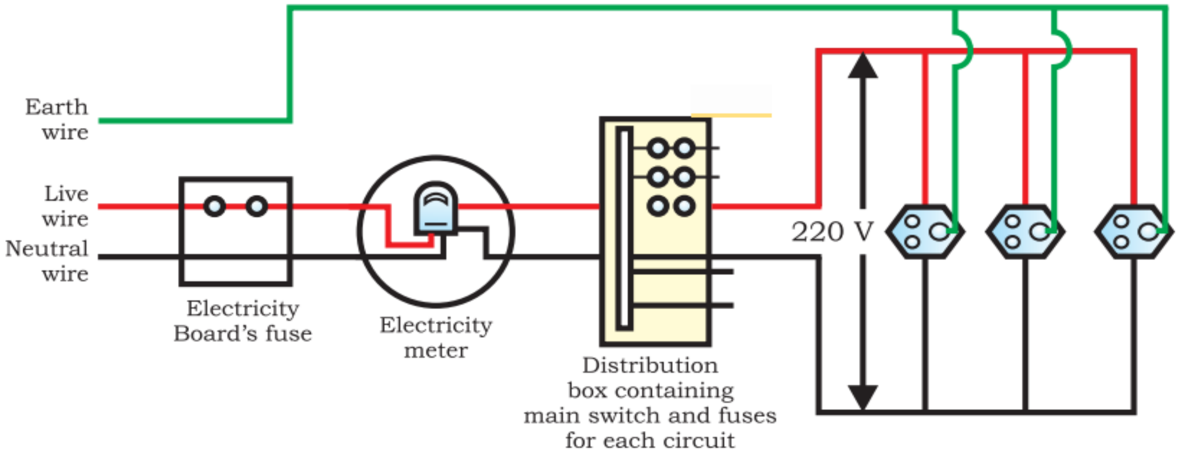
Fleming's left-hand rule

Domestic Electric Circuits

- **Power Supply:** Electricity enters our homes through overhead or underground cables.
  - **Live Wire (Red):** Carries the electric current at a high potential.
  - **Neutral Wire (Black):** Completes the circuit and has a potential close to zero.
  - **Potential Difference:** In India, the potential difference between live and neutral is 220V.
- **Home Wiring:**
  - **Meter and Fuse:** Electricity first passes through a meter and a main fuse for safety.
  - **Separate Circuits:** Homes often have multiple circuits with different current ratings for different appliances.
    - High power appliances (like geysers) use a 15A circuit.
    - Low power appliances (like bulbs) use a 5A circuit.
  - **Earth Wire (Green):** Provides a safety path for current to flow directly to the ground in case of a fault. This protects users from electric shocks. Appliances with metallic bodies are connected to the earth wire.
- **Circuit Connections:**
  - Appliances are connected in parallel to ensure each receives the same potential difference (voltage).
  - Each appliance has its own switch to control the current flow.

- **Electric Fuse:**
    - A safety device that protects circuits and appliances from damage due to overloading or short circuits.
    - Overloading happens when the current exceeds the safe limit, causing the fuse to melt and break the circuit.
    - ***Causes of Overloading:***
        - Damaged insulation causing a short circuit.
        - Faulty appliances.
        - High supply voltage.
        - Too many appliances connected to a single socket.

Key Concept: Domestic electric circuits are designed to safely distribute electricity to various appliances. Safety features like fuses and earth wires are crucial to prevent damage and protect users from electric shock.



A schematic diagram of one of the common domestic circuits