Electricity

- **Importance:** Electricity is crucial in modern society as a controllable and convenient energy source for various applications (homes, schools, hospitals, industries, etc.).

Electric Current and Circuit

- **What is electric current?**
  - Similar to water current in rivers, electric current is the flow of electric charge through a conductor (like a wire).
  - In a torch, the battery provides the electric current that flows through the bulb, making it glow.
  - Electrons make up the flow of charges in circuits with metal wires.
- **Direction of electric current:**
  - Historically, electric current was thought of as the flow of positive charges.
  - Conventionally, the direction of electric current is opposite to the flow of electrons (which are negative charges).
- **Electric circuit:**
  - A continuous, closed loop through which electric current flows.
  - A switch creates a conducting link in the circuit. If the circuit is broken (e.g., switch turned off), the current stops.
- **Measuring electric current:**
  - Electric current (I) is the amount of charge (Q) flowing through a specific area per unit of time (t): $I = Q/t$
  - SI unit of charge: coulomb (C) - 1 coulomb is the charge of about 6×10^{18} electrons
  - SI unit of current: ampere (A) - 1 ampere = 1 coulomb per second
  - Ammeter: A device used to measure electric current in a circuit (connected in series).

Electric Potential and Potential Difference

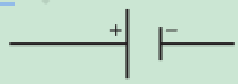
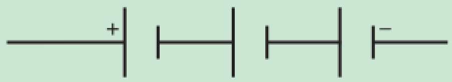
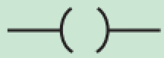
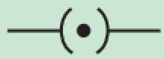
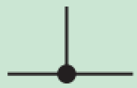
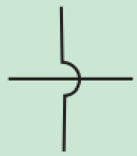
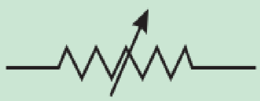
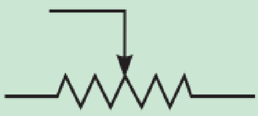
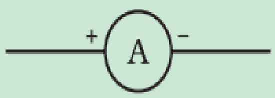
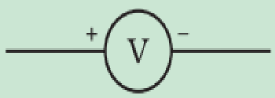
- **What makes electric charge flow?**
  - Analogy: Water flows in a tube due to a pressure difference between the ends.
  - Similarly, electric charge flows in a conductor due to a difference in electric pressure, called **potential difference**.
  - A battery creates this potential difference. The chemical action inside the battery generates the potential difference across its terminals.
- **Electric potential difference:**
  - Defined as the work done to move a unit charge from one point to another.
  - Formula: $V = W/Q$ (V = potential difference, W = work done, Q = charge)

- SI unit: volt (V) - 1 volt is the potential difference when 1 joule of work is done to move 1 coulomb of charge.

- **Measuring potential difference:**
    - Voltmeter: A device used to measure potential difference across two points in a circuit (connected in parallel).

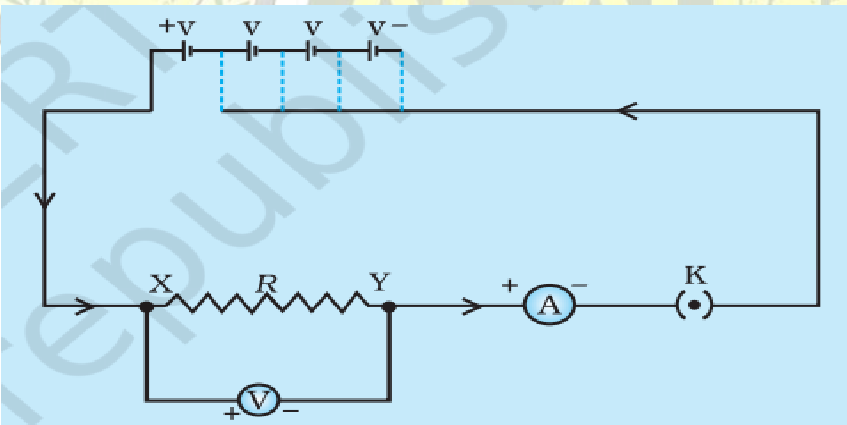
Circuit Diagram

Symbols of some commonly used components in circuit diagrams

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	 or 
8	A resistor of resistance R	
9	Variable resistance or rheostat	 or 
10	Ammeter	
11	Voltmeter	

Ohm's Law

- **Relationship:** Ohm's Law describes the relationship between voltage (V), current (I), and resistance (R) in an electrical circuit.
- **Statement:** The current through a conductor between two points is directly proportional to the voltage across the two points. This relationship holds true as long as the temperature (and other physical conditions) remain constant.
- **Formula:**
  - $V = I \times R$
  - Where:
    - V = Voltage (measured in volts)
    - I = Current (measured in amperes)
    - R = Resistance (measured in ohms)
- **Key takeaways:**
  - **Direct Proportionality:** If you increase the voltage, the current will increase proportionally (if resistance stays the same).
  - **Resistance:** Resistance is the opposition to the flow of electric current. Higher resistance means less current will flow for a given voltage.
- **Applications:** Ohm's Law is used to:
  - Calculate voltage, current, or resistance in a circuit.
  - Design and analyze electrical circuits.
  - Troubleshoot electrical problems.



Electric circuit for studying Ohm’s law

Factors Affecting the Resistance of a Conductor

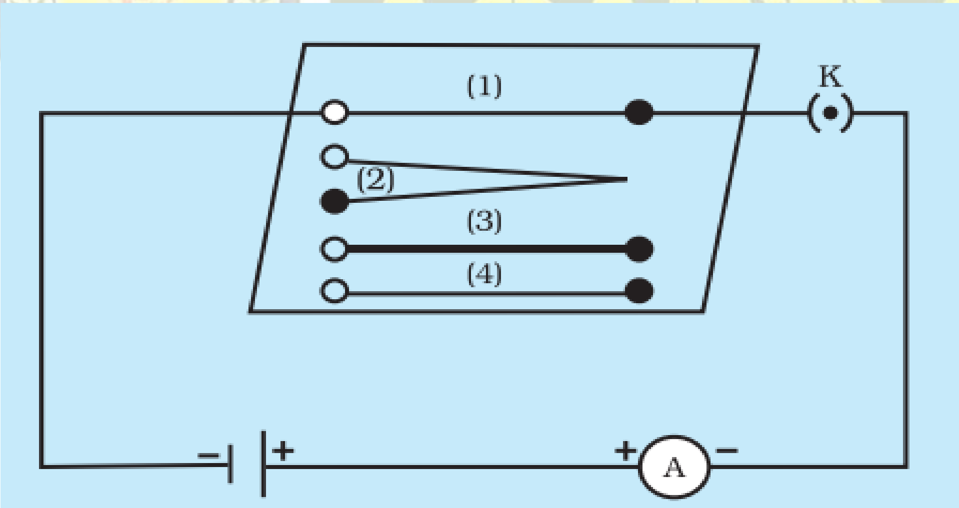
- **Material:**
  - Different materials have different resistances.

- Good conductors (like copper) have low resistance, while insulators (like rubber) have high resistance.
- This is due to the availability of free electrons in the material that can carry the electric current.

- **Length:**
  - Resistance is directly proportional to the length of the conductor.
  - Longer conductors offer more opposition to the flow of charge.
  - Think of it like a longer pipe carrying water – there's more resistance to the flow.
- **Cross-sectional area:**
  - Resistance is inversely proportional to the cross-sectional area of the conductor.
  - Thicker conductors have lower resistance.
  - Imagine a wider pipe – it allows more water to flow through with less resistance.
- **Temperature:**
  - For most materials, resistance increases with temperature.
  - Higher temperature causes atoms to vibrate more, which increases collisions with moving electrons and hinders their flow.

In summary:

- *A long, thin, hot wire made of a less conductive material will have higher resistance.*
- *A short, thick, cold wire made of a highly conductive material will have lower resistance.*



Electric circuit to study the factors on which the resistance of conducting wires depends

Electrical resistivity* of some substances at 20°C

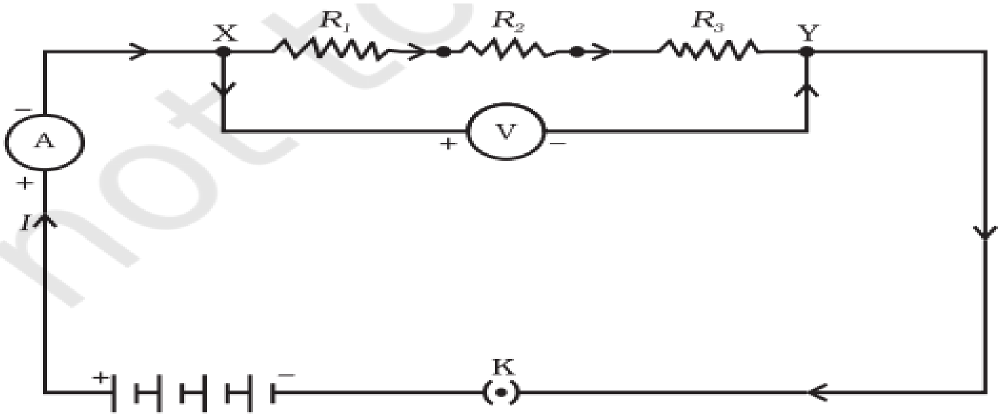
	Material	Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Resistance of a System of Resistors

When multiple resistors are connected in a circuit, they can be arranged in series or parallel. Each configuration affects the total resistance of the system differently.

Resistors in Series

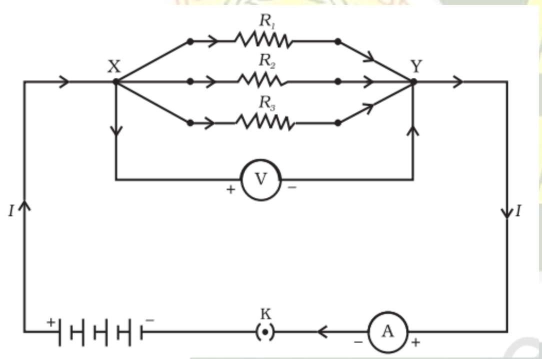
- **Connection:** Resistors are connected end-to-end, so the current flows through each resistor one after the other.
- **Total Resistance:** The total resistance (R_{total}) is the sum of the individual resistances: R_{total} = R₁ + R₂ + R₃ + ...
- **Current:** The same current flows through each resistor in the series circuit.
- **Voltage:** The total voltage across the series circuit is divided among the individual resistors.



Resistors in series

Resistors in Parallel

- **Connection:** Both ends of the resistors are connected to common points, providing multiple paths for the current to flow.
- **Total Resistance:** The reciprocal of the total resistance is the sum of the reciprocals of the individual resistances: 1/R_{total} = 1/R₁ + 1/R₂ + 1/R₃ + ...
- **Voltage:** The voltage across each resistor in the parallel circuit is the same.
- **Current:** The total current in the parallel circuit is divided among the individual resistors.



Resistors in parallel

Key Takeaways

- **Series:** Increases total resistance; same current through each resistor.
- **Parallel:** Decreases total resistance; same voltage across each resistor.

Heating Effect of Electric Current

- **Energy Transformation:** When electric current flows through a resistor, some of the electrical energy is transformed into heat energy. This is why electrical appliances get warm or hot when used.

- **Joule's Law of Heating:** This law describes the amount of heat (H) produced in a resistor:
    - $H = I^2Rt$
    - Where:
        - I = Current (in amperes)
        - R = Resistance (in ohms)
        - t = Time (in seconds)
- **Factors affecting heat production:**
    - **Current (I):** Heat is directly proportional to the square of the current. Doubling the current quadruples the heat produced.
    - **Resistance (R):** Heat is directly proportional to the resistance. Higher resistance leads to more heat.
    - **Time (t):** Heat is directly proportional to the time the current flows. Longer flow time results in more heat.
- **Applications:** The heating effect of electric current is used in many devices, including:
    - Electric heaters
    - Electric irons
    - Electric kettles
    - Hair dryers
    - Toasters
    - Fuses (heat melts the fuse wire, breaking the circuit if the current exceeds a safe level)
- **Important Note:** In a purely resistive circuit (only resistors connected to a battery), all the electrical energy from the source is converted into heat.

Practical Applications of the Heating Effect of Electric Current

While sometimes unwanted, the heating effect of electric current has many practical uses:

- **Household Appliances:** Many everyday appliances rely on Joule's heating:
    - Electric irons
    - Electric toasters
    - Electric ovens
    - Electric kettles
    - Electric heaters
- **Electric Bulbs:**
    - The filament in a light bulb is heated to a high temperature by the electric current, causing it to emit light.
    - Tungsten is used for filaments due to its high melting point.
    - Bulbs are filled with inert gases (like nitrogen and argon) to prevent the filament from oxidizing and burning out.
- **Fuses:**

- Fuses protect circuits and appliances from excessive current.
- Made of a metal or alloy with a specific melting point.
- When the current exceeds the fuse's rating, the fuse wire melts and breaks the circuit, preventing damage.

- **Other Applications:**
  - Electric stoves
  - Hair dryers
  - Soldering irons
  - Thermal printers
  - Some types of medical equipment

Key Considerations in Design:

- **Heat Dissipation:** In many applications, it's important to manage heat build-up to prevent damage to components. This can be done through:
  - Using materials with appropriate thermal conductivity.
  - Incorporating heat sinks or cooling systems.
- **Material Selection:** The choice of material depends on the application:
  - High melting point for light bulb filaments.
  - Specific melting point for fuse wires.
  - Good conductivity for heating elements.

Electric Power

- **Definition:** Electric power is the rate at which electrical energy is consumed or dissipated in an electric circuit. It's essentially how much electrical energy is used per unit of time.
- **Formula:**
  - $P = VI$
  - $P = I^2R$
  - $P = V^2/R$
  - Where:
    - P = Power (in watts)
    - V = Voltage (in volts)
    - I = Current (in amperes)
    - R = Resistance (in ohms)
- **Unit of Power:**
  - Watt (W): 1 watt is the power consumed when 1 ampere of current flows through a potential difference of 1 volt.
- **Larger Unit:**
  - Kilowatt (kW): 1 kilowatt = 1000 watts
- **Unit of Electrical Energy:**
  - Watt-hour (Wh): Energy consumed when 1 watt of power is used for 1 hour.

- Kilowatt-hour (kWh): The commercial unit of electrical energy, commonly known as a "unit."
  - 1 kWh = 1000 watts x 3600 seconds = 3.6×10^6 joules (J)