

Electricity

Electricity is a form of energy that results from the movement of electric charges. It is one of the most important sources of energy in modern life and forms the basis of many technological applications.

Introduction to Electricity

Historical Background

- The word "electricity" comes from the Greek word "elektron" meaning amber
- Thales, a Greek philosopher, first observed that certain materials attract other objects when rubbed together
- Materials were classified into two types: **vitreous** (positive charges) and **resinous** (negative charges)

Basic Concepts of Electric Charge

- **Electric charge** is a fundamental property of matter
- **Two types of charges:** Positive and negative
- **Like charges repel** each other, **unlike charges attract** each other
- Charge is a **scalar quantity**
- **SI unit:** Coulomb (C)
- **Charge on one electron:** 1.6×10^{-19} C (negative)
- **1 Coulomb = 6×10^{18} electrons approximately**

Electric Current

Definition

Electric current is the rate of flow of electric charge through a conductor.

Formula for Electric Current

$$I = Q/t$$

Where:

- I = Electric current (Ampere)
- Q = Electric charge (Coulomb)
- t = Time (seconds)

Properties of Electric Current

- **SI Unit:** Ampere (A)
- Current is a **scalar quantity**
- **1 Ampere:** Flow of 1 coulomb of charge per second
- **Direction:** By convention, current flows from positive to negative terminal (opposite to electron flow)

Types of Electricity

1. **Static Electricity:** Stationary charges
2. **Current Electricity:** Moving charges

Electric Circuit

Definition

An **electric circuit** is a closed path through which electric current can flow.

Components of Electric Circuit

- **Battery/Cell:** Source of electrical energy
- **Conductors:** Allow current to flow (copper wires)
- **Load:** Device that consumes electrical energy (bulb, resistor)
- **Switch:** Controls the flow of current

Circuit Symbols

- **Cell:** Single line (short) and long line
- **Battery:** Multiple cells
- **Wire:** Straight line
- **Bulb:** Circle with cross inside
- **Switch:** Gap with connecting line
- **Resistor:** Zigzag line

Electric Potential and Potential Difference

Electric Potential

Electric potential at a point is the work done in bringing a unit positive charge from infinity to that point.

$$V = W/Q$$

Electric Potential Difference

Potential difference between two points is the work done in moving a unit positive charge from one point to another.

$$V = W/Q$$

Where:

- V = Potential difference (Volts)
- W = Work done (Joules)
- Q = Charge (Coulomb)

Key Points

- **SI Unit:** Volt (V)
- **1 Volt:** Work done of 1 joule per coulomb of charge
- **Voltmeter:** Instrument to measure potential difference
- Always connected in **parallel** across the component

Ohm's Law

Statement

Ohm's Law states that the current flowing through a conductor is directly proportional to the potential difference applied across its ends, provided the temperature remains constant.

Mathematical Expression

$$V = I \times R$$

Where:

- V = Potential difference (Volts)
- I = Current (Amperes)
- R = Resistance (Ohms)

Other Forms

- $I = V/R$
- $R = V/I$

V-I Graph for Ohm's Law

- **Linear relationship** between voltage and current
- **Slope of the line = Resistance**
- Graph passes through origin

Applications

- Calculate unknown electrical quantities
- Design electrical circuits
- Understand behavior of electrical components

Resistance

Definition

Resistance is the property of a conductor that opposes the flow of electric current through it.

Formula

$$R = V/I$$

Properties

- **SI Unit:** Ohm (Ω)
- **Symbol:** Greek letter omega (Ω)
- Resistance depends on nature of material, temperature

Factors Affecting Resistance

$$R = \rho L/A$$

Where:

- ρ (rho) = Resistivity of material
- L = Length of conductor
- A = Cross-sectional area

Factor Analysis

1. **Length (L):** $R \propto L$ (Resistance increases with length)
2. **Area (A):** $R \propto 1/A$ (Resistance decreases with area)
3. **Material:** Different materials have different resistivities
4. **Temperature:** Resistance increases with temperature in metals

Resistivity

- **Definition:** Resistance of a conductor of unit length and unit cross-sectional area
- **SI Unit:** Ohm-meter ($\Omega \cdot m$)

- **Property of material**, independent of dimensions

Rheostat

- **Variable resistor** used to control current in a circuit
- Used to change resistance in a circuit
- Has sliding contact to vary resistance

Combination of Resistors

Series Combination

Characteristics

- **Same current** flows through all resistors
- **Different potential differences** across resistors
- **Total voltage = Sum of individual voltages**

Formula for Total Resistance

$$R_s = R_1 + R_2 + R_3 + \dots$$

Voltage Distribution

- $V_1 = IR_1$
- $V_2 = IR_2$
- $V_3 = IR_3$
- $V = V_1 + V_2 + V_3$

Parallel Combination

Characteristics

- **Same voltage** across all resistors
- **Different currents** through resistors
- **Total current = Sum of individual currents**

Formula for Total Resistance

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

Current Distribution

- $I_1 = V/R_1$
- $I_2 = V/R_2$

- $I_3 = V/R_3$
- $I = I_1 + I_2 + I_3$

Advantages of Parallel Connection

- Each appliance can be controlled independently
- If one appliance fails, others continue to work
- Each appliance gets full voltage
- Different appliances can have different current requirements

Heating Effect of Electric Current

Joule's Law of Heating

When current flows through a resistor, electrical energy is converted to heat energy.

Mathematical Expression

$$H = I^2Rt$$

Where:

- H = Heat produced (Joules)
- I = Current (Amperes)
- R = Resistance (Ohms)
- t = Time (seconds)

Alternative Forms

- $H = VIt$ (using $V = IR$)
- $H = V^2t/R$ (using $I = V/R$)

Applications

1. **Electric Heater:** Converts electrical energy to heat
2. **Electric Iron:** Uses heating effect for ironing
3. **Electric Bulb:** Filament heats up and glows
4. **Electric Fuse:** Safety device using heating effect

Electric Fuse

- **Safety device** that protects circuits from overloading
- Made of material with **low melting point** (tin-lead alloy)

- **Rated current:** Maximum current it can safely carry
- Melts when current exceeds safe limit, breaking the circuit

Electric Power and Energy

Electric Power

Electric power is the rate of consumption of electrical energy.

Formula for Power

$$P = W/t = VI$$

Where:

- P = Power (Watts)
- W = Work done (Joules)
- t = Time (seconds)
- V = Voltage (Volts)
- I = Current (Amperes)

Alternative Forms of Power

- $P = I^2R$ (using $V = IR$)
- $P = V^2/R$ (using $I = V/R$)

Units

- **SI Unit:** Watt (W)
- **1 Watt:** 1 Joule per second
- **Practical Unit:** Kilowatt (kW) = 1000 W

Electric Energy

Electric energy is the total electrical work done.

Formula

$$E = P \times t = VIt$$

Commercial Unit

- **Kilowatt-hour (kWh) or Unit**
- $1 \text{ kWh} = 1000 \text{ Wh} = 3.6 \times 10^6 \text{ J}$
- Used for electricity billing

Electricity Bill Calculation

Total Cost = Number of units × Cost per unit

Important Formulas Summary

Basic Formulas

- **Current:** $I = Q/t$
- **Potential Difference:** $V = W/Q$
- **Ohm's Law:** $V = IR$
- **Resistance:** $R = \rho L/A$

Series Circuit

- **Total Resistance:** $R_s = R_1 + R_2 + R_3$
- **Same current:** $I = I_1 = I_2 = I_3$
- **Voltage division:** $V = V_1 + V_2 + V_3$

Parallel Circuit

- **Total Resistance:** $1/R_p = 1/R_1 + 1/R_2 + 1/R_3$
- **Same voltage:** $V = V_1 = V_2 = V_3$
- **Current division:** $I = I_1 + I_2 + I_3$

Power and Energy

- **Power:** $P = VI = I^2R = V^2/R$
- **Energy:** $E = Pt = VIt = I^2Rt$
- **Heating:** $H = I^2Rt$

Key Points for Exams

1. **Electric current** is the rate of flow of charge
2. **Ohm's Law** applies only when temperature is constant
3. In **series circuits**, current is same, voltage divides
4. In **parallel circuits**, voltage is same, current divides
5. **Total resistance is maximum in series**, minimum in parallel
6. **Power depends on both voltage and current**
7. **Kilowatt-hour is the commercial unit of energy**

8. **Electric fuse** prevents damage due to overloading
9. **Resistivity is property of material**, resistance depends on dimensions
10. **Heating effect** is used in various electrical appliances

Summary

Electricity involves the flow of electric charges through conductors. The relationship between voltage, current, and resistance is governed by Ohm's Law. Understanding series and parallel combinations of resistors is crucial for analyzing circuits. The heating effect of current has numerous practical applications, while electric power and energy concepts are essential for understanding energy consumption and billing. These fundamental concepts form the basis for more advanced electrical and electronic systems.