Current Electricity

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Current Electricity

Introduction

Electric current is the flow of electric charge. It is measured in amperes (A). The SI unit of electric current is the ampere, which is defined as the flow of one coulomb of charge per second.

Electric current is caused by the movement of charged particles. These charged particles can be electrons, protons, or ions. The direction of electric current is defined as the direction of flow of positive charge.

Electric Current

- Electric current is the rate of flow of electric charge.
- It is measured in amperes (A).
- The SI unit of electric current is the ampere, which is defined as the flow of one coulomb of charge per second.
- Electric current is caused by the movement of charged particles.
- The direction of electric current is defined as the direction of flow of positive charge.

Examples of Electric Current

- The current in a wire is caused by the movement of electrons.
- The current in a battery is caused by the movement of ions.

- The current in a solar cell is caused by the movement of electrons. **Formulae**

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  The electric current through a conductor is given by: $I = \frac{V}{R}$

where: * I is the current in amperes (A) * V is the voltage in volts (V) * R is the resistance in ohms (Ω)

Electric Currents in Conductors

- Electric current is the flow of electric charge. In conductors, electric current is carried by mobile charge carriers, such as electrons or ions.
- The electric current in a conductor is directly proportional to the potential difference applied across it, provided the temperature of the conductor remains constant.
- The resistance of a conductor is a measure of its opposition to the flow of electric current. The resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area.

Ohm's Law

- Ohm's law states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points.

- Mathematically, Ohm's law can be expressed as:

$$I = V/R$$

- where:
- I is the current in amperes (A)
- V is the voltage in volts (V)
- R is the resistance in ohms (Ω)
- Ohm's law is valid for most conductors at constant temperature. However, some materials, such as semiconductors, do not obey Ohm's law.
- Ohm's law can be used to calculate the current, voltage, or resistance in a circuit. For example, if you know the voltage across a resistor and the resistance of the resistor, you can use Ohm's law to calculate the current flowing through the resistor.

Drift of Electrons and the Origin of Resistivity

- Electrons are negatively charged particles present in all materials.
- Drift velocity: Average velocity acquired by free electrons under the influence of an electric field is called drift velocity.
- Resistivity is the property of a material that opposes the flow of current.
- Resistivity arises due to collisions between free electrons and ions or atoms of the material.
- Due to these collisions, electrons lose energy and their motion becomes random.
- The resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area.

Limitations of Ohm's Law

- **Non-ohmic conductors:** Some materials do not obey Ohm's law over a wide range of voltages.
- Example: Diodes and transistors.
- **Temperature dependence:** Resistivity of materials varies with temperature.
- Ohm's law is only applicable at constant temperature.
- **High electric fields:** At very high electric fields, the drift velocity of electrons reaches a saturation value.
- Ohm's law breaks down at high electric fields.

Resistivity of Various Materials

- **Conductors:** Have low resistivity (typically < 10^-8 Ωm). Examples include copper, aluminum, and gold.
- **Semiconductors:** Have intermediate resistivity (typically 10^-6 to 10^6 Ωm). Examples include silicon and germanium.
- **Insulators:** Have high resistivity (typically > 10^6 Ωm). Examples include rubber, plastic, and glass.

- **Superconductors:** Have zero resistivity at very low temperatures (below their critical temperature, Tc). Examples include lead, mercury, and yttrium barium copper oxide (YBCO).

Temperature Dependence of Resistivity

- **Metals:** Resistivity increases linearly with temperature, given by the equation: $\rho = \rho_0(1 + \alpha t)$ where:
  - ρ is the resistivity at temperature t
  - ρ_0 is the resistivity at 0 °C
  - α is the temperature coefficient of resistivity
- **Semiconductors:** Resistivity decreases with increasing temperature, typically following an exponential relationship.
- **Insulators:** Resistivity is generally not significantly affected by temperature.

Electrical Energy

- The work done by the electric field in moving a charge from one point to another.
- Measured in Joules (J)
- Formula: $E = QV$ Where E is electrical energy, Q is charge, and V is voltage

Power Cells

- Devices that convert chemical energy into electrical energy
- Examples: Batteries, fuel cells
- Consist of two electrodes (anode and cathode) immersed in an electrolyte
- Chemical reactions at the electrodes generate electrons, which flow through an external circuit to produce current

emf (Electromotive Force)

- The maximum voltage a power cell can provide when there is no current flowing
- Measured in Volts (V)
- Determined by the chemical properties of the materials in the cell
- Formula: $emf = V_{open-circuit}$

Internal Resistance

- The resistance within a power cell that opposes the flow of current
- Measured in Ohms (Ω)
- Due to factors such as the thickness of electrodes, resistance of electrolyte, and contact resistance
- Causes the terminal voltage to be lower than the emf when current is flowing

- Formula: $V = emf - Ir$ Where V is terminal voltage, I is current, and r is internal resistance

Cells in Series

- When two or more cells are connected in series, the positive terminal of one cell is connected to the negative terminal of the next cell, and so on. - The total emf of the series combination is the sum of the emfs of the individual cells. - The total internal resistance of the series combination is the sum of the internal resistances of the individual cells. - The current through each cell is the same.

Cells in Parallel

- When two or more cells are connected in parallel, the positive terminals of all the cells are connected together, and the negative terminals of all the cells are connected together. - The total emf of the parallel combination is the same as the emf of each individual cell. - The total internal resistance of the parallel combination is less than the internal resistance of any individual cell. - The current through each cell is different, and the total current is the sum of the currents through the individual cells.

Kirchhoff’s Rules

- **Kirchhoff's Current Law (KCL)**: The sum of the currents entering a junction must be equal to the sum of the currents leaving the junction. - **Kirchhoff's Voltage Law (KVL)**: The sum of the voltages around a closed loop must be zero. **Examples:** - A battery of 6 V is connected to a circuit consisting of two resistors of 2 Ω and 3 Ω connected in series. The current through the circuit is 1 A. - Two batteries of 2 V and 3 V are connected in parallel to a circuit consisting of a resistor of 4 Ω. The total current through the circuit is 1.25 A. ## Wheatstone Bridge Theory The Wheatstone bridge is a circuit that measures an unknown resistance. It consists of four resistors, two of which are known and two of which are unknown. When the bridge is balanced, the potential difference between the two unknown resistors is zero. ## Basic Wheatstone Bridge * **Principle:** When the bridge is balanced, the ratio of the known resistances to the unknown resistances is equal to the ratio of the currents through the two unknown resistances. * **Circuit Diagram:** [Image of a basic Wheatstone bridge circuit diagram] * **Balancing

Condition:** $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ## Extended

Wheatstone Bridge * **Principle:** A modification of the basic Wheatstone bridge that includes an additional resistor in series with one of the unknown resistors. * **Circuit Diagram:** [Image of an extended Wheatstone bridge circuit diagram] *

Balancing Condition: $\frac{R_1}{R_2} = \frac{R_3 + R_5}{R_4}$ ##

Applications of Wheatstone Bridge * Measuring unknown resistances * Detecting faults in electrical circuits * Calibrating other electrical instruments * Measuring temperature (using a thermistor)