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Chapter 16: Current Electricity

Class 10th FBISE - SLO Based Notes

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16.1 Electric Current

Q1: What is electric current and how is it produced?

Electric current is the flow of electric charges (positive or negative) through a conductor. In metals, the current is due to the flow of negatively charged electrons, while in gases and electrolytes, both positive and negative charges may contribute.

Q2: What is the mathematical formula for electric current?

The electric current is defined as:

$$I = \frac{\Delta Q}{\Delta t}$$

Where:
I = Current (Ampere),
ΔQ = Charge (Coulombs),
Δt = Time (seconds)

Q3: What is the SI unit of current? How is it defined?

The SI unit of electric current is **Ampere (A)**. One ampere is defined as the flow of one coulomb of charge per second through a cross-sectional area:

$$1 \text{ A} = \frac{1 \text{ C}}{1 \text{ s}}$$

Q4: What are the sub-multiples of ampere?

- 1 milliampere (mA) = 10^{-3} A
- 1 microampere (µA) = 10^{-6} A

16.1.1 Conventional Flow of Current

Q5: What is conventional current?

Roll No. ____________ Name of Student: ____________________ Class: ___________ Date: __________

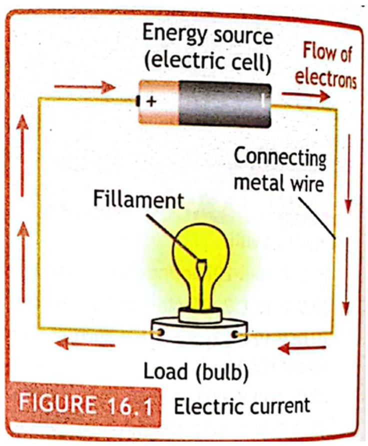

Figure 1: Flow of current through electric circuit (Figure 16.1)

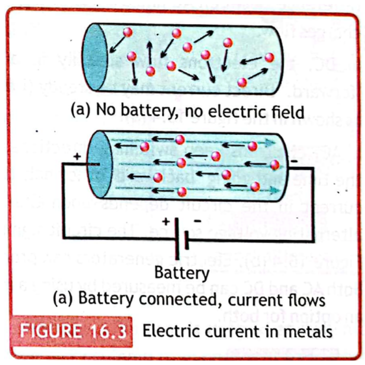

Figure 2: Electron motion in metal wire (Figure 16.3)

Before electrons were discovered, current was assumed to flow from the positive to the negative terminal. This direction is still used in circuit analysis and is known as **conventional current**.

Q6: Why is conventional current still used even though electrons flow in the opposite direction?

Conventional current simplifies circuit analysis. It produces the same results as electron flow in the opposite direction, making both interchangeable in problem-solving.

16.1.2 Electrical Conduction in Metals

Q7: What causes electric current in metals?

In metals, loosely bound valence electrons move freely. When a battery is connected, an electric field is created that pushes these electrons in one direction, producing a current.

Q8: Why do electrons drift slowly in metals?

Electrons collide with metal atoms, slowing their motion, which results in a slow net drift known as **drift velocity**, responsible for electric current.

16.2 Alternating and Direct Current

Q9: What are the two types of electric current?

The two types of electric current are:

- **Direct Current (DC)** – Charges flow in one fixed direction.
- **Alternating Current (AC)** – Charges change direction periodically.

Q10: How does DC current behave?

In DC, electrons flow steadily in a single direction. It may be uniform (steady) or slightly varying but always flows in one direction, as shown in Figure 16.4(a).

Q11: How does AC current behave?

In AC, electrons periodically reverse direction, flowing "forward" for half a cycle and "backward" for the other half. This change is due to the alternating polarity of the voltage source, as illustrated in Figure 16.4(b).

Q12: How can AC and DC be measured?

Both AC and DC can be measured using a multimeter, which typically includes settings for both types of currents.

Q13: Which type of current is more dangerous at high voltage: AC or DC?

AC is generally considered more dangerous at high voltages (above 500 V). This is because it can cause continuous muscle contraction, making it difficult to let go of the source, unlike DC which may push the victim away due to a single contraction.

16.3 Potential Difference

Q14: What is meant by potential difference?

The potential difference is the difference in electric potential between two points in a circuit. It is caused by connecting one end of a conductor to the positive terminal of a battery and the other to the negative terminal.

Q15: Why does current flow when there is a potential difference?

Current flows because the potential difference creates an electric field that pushes the charges through the conductor. This movement of charge continues as long as the potential difference exists.

Q16: What is the mathematical formula for potential difference?

$$\Delta V = \frac{\Delta U}{q} = \frac{W}{q}$$

Where:

- ΔV is the potential difference (in volts)

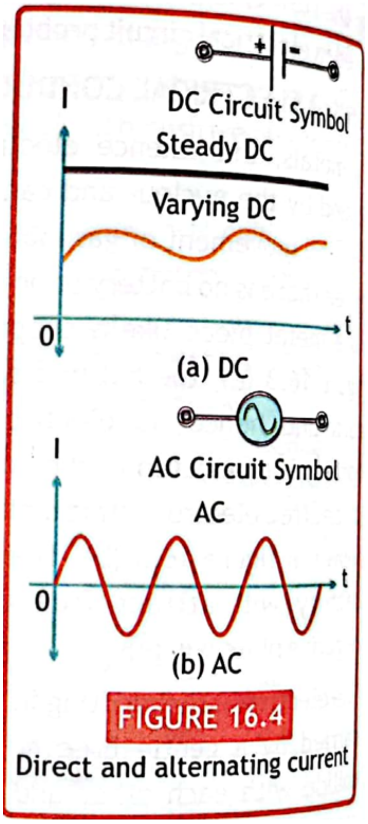

Figure 3: Direct and Alternating Current (Figure 16.4)

- ΔU is the change in potential energy
- W is the work done
- q is the charge in coulombs

Q17: What is the SI unit of potential difference?
The SI unit of potential difference is **volt (V)**. One volt is defined as:

$$1\,\text{V} = \frac{1\,\text{Joule}}{1\,\text{Coulomb}}$$

This means 1 joule of energy is needed to move 1 coulomb of charge from one point to another.

16.4 Electromotive Force (EMF)

Q18: What is meant by Electromotive Force (emf)?
Electromotive force (emf) is the energy supplied by a source, like a battery, per unit positive charge when it moves through a complete circuit. It is responsible for maintaining a steady current by converting non-electrical energy into electrical energy.

Q19: What is the role of an emf source in a circuit?

Roll No. ________ Name of Student: ________ Class: ________ Date: ________

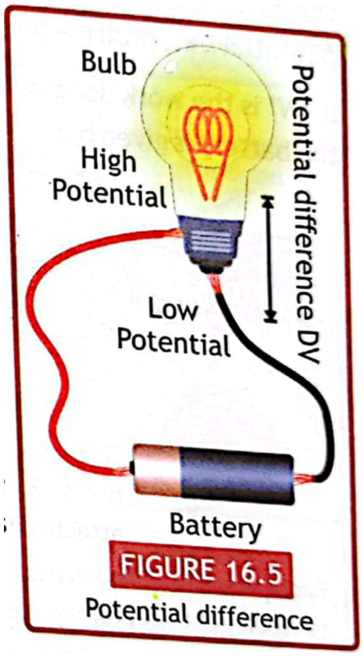

Figure 4: Potential Difference (Figure 16.5)

An emf source, such as a battery, maintains a constant potential difference across the circuit by doing work on electric charges and pushing them from low potential to high potential.

Q20: How is emf mathematically defined?

$$\varepsilon = \frac{W}{q}$$

Where:

- ε is the electromotive force (in volts)
- W is the work done by the battery (in joules)
- q is the charge (in coulombs)

Q21: What is the SI unit of emf?

The SI unit of emf is **volt (V)**, same as potential difference.

16.5 Ohm's Law

Q22: What does Ohm's law state?

Ohm's law states that the current flowing through a conductor is directly proportional to the potential difference across its ends, provided the temperature and physical conditions remain constant.

$$I \propto V \quad \text{(at constant temperature)}$$

Roll No. ______ Name of Student: ______ Class: ______ Date: ______

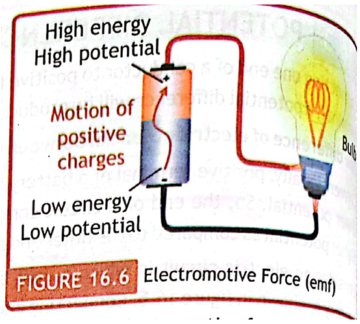

Figure 5: Electromotive Force (Figure 16.6)

Q23: How is Ohm's law expressed mathematically?

When proportionality is replaced with equality, we get:

$$I = \frac{V}{R} \quad \text{or} \quad V = IR$$

Where:

- I is the current in amperes (A)
- V is the potential difference in volts (V)
- R is the resistance in ohms (Ω)

Q24: What is resistance?

Resistance is the opposition offered by a conductor to the flow of electric current. It is a constant for a material obeying Ohm's law and is represented by R.

Q25: What are ohmic and non-ohmic devices?

Ohmic devices follow Ohm's law and have a linear $V - I$ relationship (straight line). Examples include metal wires like copper and silver. Non-ohmic devices do not obey Ohm's law; their $V - I$ graph is nonlinear. Examples include filament bulbs, thermistors, and diodes.

Q26: What are the limitations of Ohm's law?

Ohm's law is valid only for materials and devices where the temperature remains constant and the $V - I$ graph is a straight line. It cannot be applied to semiconductors, thermistors, or other nonlinear components.

Q27: How do graphs differentiate ohmic and non-ohmic behavior?

- Metal (ohmic): Straight line $V - I$ graph.
- Filament bulb: Saturates at high current.
- Thermistor: Resistance decreases with temperature; steep curve.
- Diode: Nonlinear, current flows only in one direction after threshold voltage.

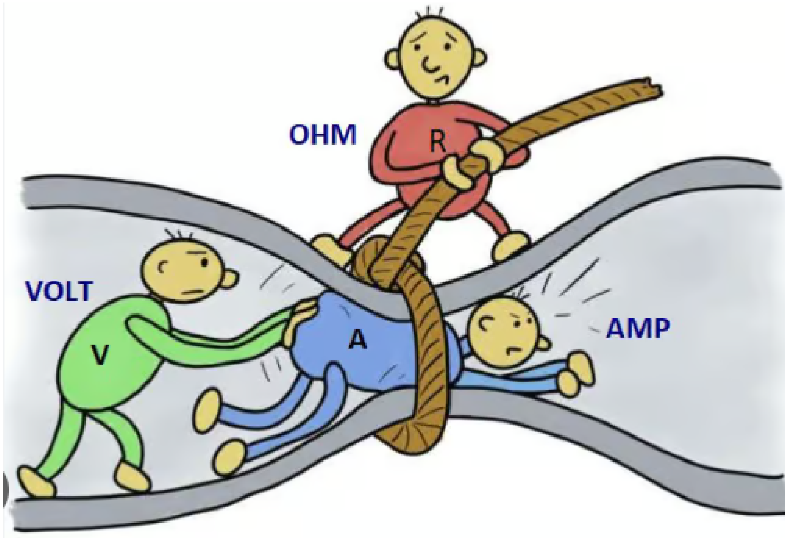

Figure 6: Ohm's Law Illustration (Figure 16.7)

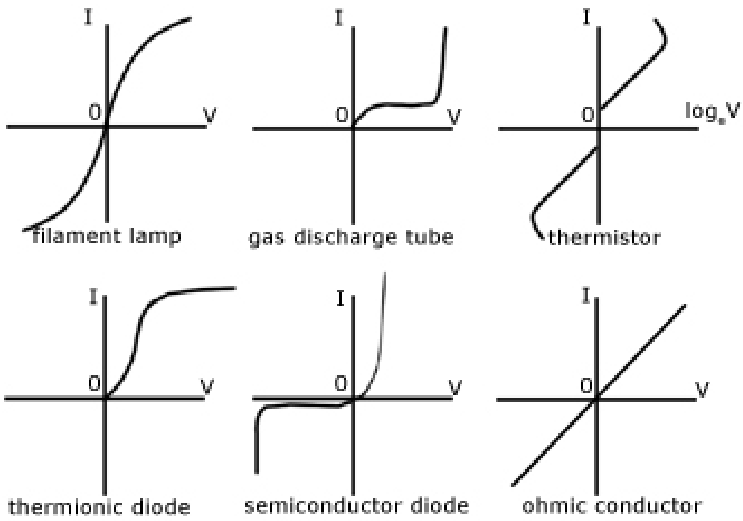

Figure 7: Ohmic and Non-Ohmic Devices (Figure 16.8)

Roll No. ____________ Name of Student: ____________________ Class: ____________ Date: __________

Figure 8: Types of resistors (Figure 16.9)

16.6 Resistance

Q22: What is resistance?

Resistance is defined as the opposition to the flow of electric charges in a conductor. It resists or limits the current flow in a circuit.

Q23: How is resistance mathematically defined?

From Ohm's law, resistance is given by:

$$R = \frac{V}{I}$$

Where:

- R is resistance (ohms, Ω)
- V is potential difference (volts)
- I is current (amperes)

Q24: What is the SI unit of resistance?

The SI unit of resistance is **ohm (Ω)**. One ohm is the resistance when one volt causes one ampere of current.

Q25: What are common submultiples of ohm?

- $1\,\text{kilo-ohm} = 1\,\text{k}\Omega = 10^3\,\Omega$
- $1\,\text{mega-ohm} = 1\,\text{M}\Omega = 10^6\,\Omega$

16.6.1 Length of Wire

Q26: How does length of wire affect resistance?

The longer the conductor, the greater the resistance.

$$R \propto L$$

16.6.2 Cross-sectional Area of Wire

Q27: How does cross-sectional area of a wire affect resistance?

Resistance is inversely proportional to the cross-sectional area of the wire.

$$R \propto \frac{1}{A}$$

16.6.3 Temperature

Q28: How does temperature affect resistance?

Resistance increases with temperature for conductors because increased temperature causes more collisions among free electrons.

$$\Delta R \propto \Delta T$$

Q29: How does resistance change in insulators and semiconductors?

In insulators and semiconductors, resistance decreases with rise in temperature because more charge carriers are generated.

16.6.4 Material Nature of Wire

Q30: How does the nature of material affect resistance?

Different materials have different resistivities. Conductors like copper and silver have low resistance, while insulators have high resistance. The resistance depends on internal structure and bonding.

16.7 Resistivity

Q22: What is resistivity?

Resistivity is the specific resistance of a material. It is defined as the resistance of a wire of unit length (1 m) and unit cross-sectional area (1 m^2) at a given temperature. It is a property of the material itself.

Q23: State the formula for resistivity and explain each term.

$$R = \rho\frac{L}{A} \quad \text{and} \quad \rho = R\frac{A}{L}$$

Where:

- R = resistance (ohms, Ω)
- ρ = resistivity (ohm-meter, $\Omega \cdot m$)
- L = length of conductor (meters)

- A = cross-sectional area (m^2)

Q24: What is the SI unit of resistivity?
The SI unit of resistivity is **ohm-meter** ($\Omega \cdot m$).

Q25: What is the relation between resistivity and conductivity?
Conductivity is the reciprocal of resistivity:

$$\sigma = \frac{1}{\rho} \quad \text{or} \quad \rho = \frac{1}{\sigma}$$

Where σ is the conductivity.

Q26: How does temperature affect resistivity?
For most conductors, resistivity increases with temperature. For semiconductors, resistivity decreases with temperature.

Q27: Write the formula for temperature dependence of resistivity.

$$\rho_T = \rho_0(1 + \alpha\Delta T)$$

Where:

- ρ_T = resistivity at temperature T
- ρ_0 = resistivity at 0°C
- α = temperature coefficient of resistivity (per °C)
- ΔT = change in temperature

Q28: What is temperature coefficient of resistivity?
It is the fractional change in resistivity per unit temperature rise. It is denoted by α.

$$\alpha = \frac{\rho_T - \rho_0}{\rho_0 \Delta T}$$

Q29: What are good conductors and good insulators in terms of resistivity?

- Good conductors (e.g., Silver, Copper) have very low resistivity.
- Good insulators (e.g., Glass, Rubber) have very high resistivity.

Q30: How do semiconductors behave in terms of resistivity?
Semiconductors have intermediate resistivity. Their resistivity decreases with increase in temperature and can be modified by adding impurities (doping).

16.8 Electrical Measuring Instruments

Devices used for measuring electrical quantities such as current, voltage, resistance, and power are called electrical measuring instruments.

Q35: What is an ammeter and how is it connected in a circuit?

An **ammeter** is a device used to measure electric current. It is connected in **series** with the component through which current is to be measured. Since an ammeter should not significantly disturb the current, it is designed to have very low resistance.

Q36: What are the different types or ranges of ammeters?

Ammeter types include:

- **Ammeter:** Measures large currents (1A to 100A)
- **Milli-ammeter:** Measures small currents in mA
- **Micro-ammeter:** Measures very small currents in A

Q37: What is a voltmeter and how is it connected in a circuit?

A **voltmeter** is used to measure the potential difference across a component. It is connected in **parallel** with the component. To avoid affecting the circuit, a voltmeter is designed to have very high resistance (about 10 MΩ).

Q38: What are the types of voltmeters based on range?

Types of voltmeters include:

- **Voltmeter:** Measures standard voltages (1V to 500V)
- **Milli-voltmeter:** Measures small voltages in mV

16.9 Experiment for Determination of Resistance

Q39: What is the purpose of the experiment shown in Figure 16.16?

The purpose of this experiment is to determine the resistance of an unknown resistor using the relation:

$$R = \frac{V}{I}$$

Where:

- R is resistance (in ohms)
- V is voltmeter reading (in volts)
- I is ammeter reading (in amperes)

Table 1: Resistivities of Some Materials at 20°C

Material	Resistivity, ρ ($\Omega \cdot m$)
Typical Metals	
Silver	1.59×10^{-8}
Copper	1.72×10^{-8}
Gold	2.24×10^{-8}
Aluminum	2.56×10^{-8}
Tin	11.0×10^{-8}
Tungsten	5.52×10^{-8}
Iron	9.71×10^{-8}
Lead	20.6×10^{-8}
Typical Semiconductors (pure)	
Carbon	3.5×10^{-5}
Germanium	$1 - 500 \times 10^{3}$
Silicon	$0.1 - 60$
Typical Insulators	
Glass	$1 - 1000 \times 10^{9}$
Fused quartz	7.5×10^{17}
Rubber	$1 - 100 \times 10^{13}$

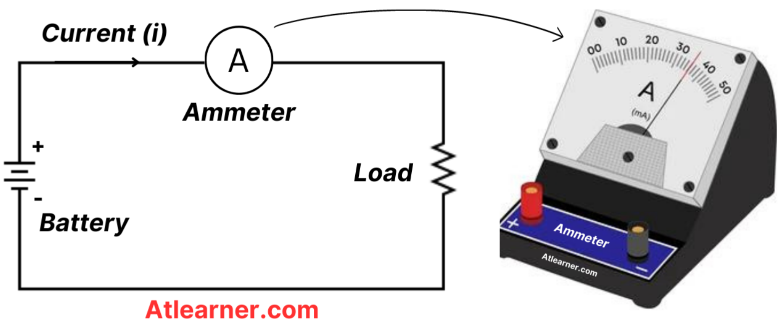

Figure 9: Analogue and digital ammeter along with circuit connection (Figure 16.12)

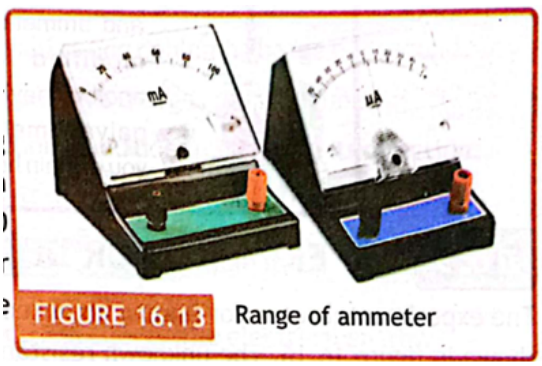

FIGURE 16.13 Range of ammeter

Figure 10: Different ranges of ammeters (Figure 16.13)

Figure 11: Analogue and digital voltmeters with circuit diagram and millivoltmeter (Figures 16.14–16.15)

Q40: How is the experimental setup arranged to find unknown resistance?

- The unknown resistance is connected in series with an ammeter.
- A voltmeter is connected in parallel with the unknown resistance.
- A rheostat (variable resistor) is also connected in series to control the current.
- The indicators of both ammeter and voltmeter must be aligned to zero before starting.

Procedure:

1. Record the least count and range of both ammeter and voltmeter.
2. Close the switch and adjust the rheostat for a small current.
3. Note the ammeter and voltmeter readings.
4. Disconnect the circuit and allow the wire to cool.
5. Repeat steps for four different values of current by adjusting the rheostat.

Observation Table:

Roll No. ____________ Name of Student: ______________________ Class: ____________ Date: __________

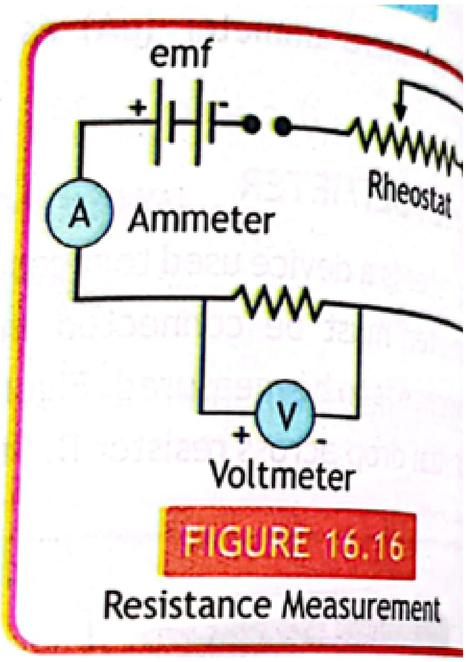

Figure 12: Resistance Measurement Setup (Figure 16.16)

Sr. No.	Ammeter Reading (A)	Voltmeter Reading (V)	Resistance $R = \frac{V}{I}$ (Ω)
1			
2			
3			
4			

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Roll No. ____________ Name of Student: ______________________ Class: ____________ Date: __________

Chapter Summary: Current Electricity

- **Electric Current** is the rate of flow of electric charges.
- **Ampere** is the SI unit of current and is defined as one coulomb charge per second.
- **Conventional Current** is the flow of positive charges per unit time from higher to lower potential.
- **Direct Current (DC)** flows in one direction only and does not change with time.
- **Alternating Current (AC)** changes direction continuously.
- **Potential Difference** is the work done in moving a unit positive charge from one point to another in an electric field.
- **EMF (Electromotive Force)** is the energy supplied by a source per unit charge. It converts non-electrical energy to electrical energy.
- **Ohm's Law** states that current is directly proportional to the potential difference across a conductor at constant temperature.
- **Resistance** is the opposition offered to the flow of electric current.
- **Resistivity** is a material-specific property defined as resistance per unit length and unit area.
- **Temperature Coefficient of Resistance** describes how resistance of a material changes with temperature.
- **Ammeter** is a device used to measure current and is always connected in series.
- **Voltmeter** is a device used to measure potential difference and is connected in parallel.

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Roll No. ____________ Name of Student: ______________________ Class: ____________ Date: ___________

Chapter 16: Current Electricity - Multiple Choice Questions

1. **Ampere-hour (Ah) is the unit of:**
   A. Electric current B. Charge C. Energy D. Resistance
   Correct Answer: C. Energy
   1 Ampere-hour is a unit of energy because it represents the energy transferred when a current of 1A flows for one hour.

2. **Which of the following is a non-ohmic device?**
   A. Copper wire B. Carbon resistor C. Diode D. All of these
   Correct Answer: C. Diode
   A diode does not follow Ohm's law; its current-voltage relationship is non-linear.

3. **Electric current is measured using:**
   A. Ammeter B. Voltmeter C. Ohmmeter D. Meter rod
   Correct Answer: A. Ammeter
   An ammeter is specifically designed to measure electric current in amperes.

4. **Voltmeter measures:**
   A. Potential difference B. Electric current C. Resistance D. Resistivity
   Correct Answer: A. Potential difference
   A voltmeter measures the voltage or potential difference between two points in a circuit.

5. **If 3 A of current flows for 2 minutes, the amount of charge will be:**
   A. 3 C B. 6 C C. 60 C D. 360 C
   Correct Answer: D. 360 C
   Using $Q = I \times t = 3 \times 120 = 360$ C, the charge transferred is 360 coulombs.

6. **A current of 1 mA is passing through a wire. Number of electrons in 10 s:**
   A. 6.25×10^{19} B. 6.25×10^{18} C. 6.25×10^{17} D. 6.25×10^{16}
   Correct Answer: B. 6.25×10^{18}
   $Q = It = 1 \times 10^{-3} \times 10 = 10^{-2}\ C$. Electrons $= \frac{10^{-2}}{1.6\times10^{-19}} \approx 6.25 \times 10^{18}$.

7. **Resistance of a material always decreases when:**
   A. Temperature increases B. Temperature decreases C. Number of free electrons increases D. Number of free electrons decreases
   Correct Answer: C. Number of free electrons increases
   More free electrons result in better conductivity and thus lower resistance.

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0309-7779091

Roll No. ____________ Name of Student: ____________________ Class: ____________ Date: __________

8. **Resistance of a metallic conductor varies inversely as:**
   A. Area of cross section B. Length C. Temperature D. All of these
   Correct Answer: A. Area of cross section
   Resistance $R \propto \frac{L}{A}$, so larger cross-sectional area reduces resistance.

9. **Directions of actual current and conventional current are:**
   A. Same B. Opposite to each other C. Perpendicular to each other D. None of these
   Correct Answer: B. Opposite to each other
   Actual current is due to electrons (negative to positive), conventional current is positive to negative.

10. **As temperature of a semiconductor increases, its resistance:**
   A. Increases B. Decreases C. Remains constant D. Becomes zero
   Correct Answer: B. Decreases
   In semiconductors, increased temperature releases more charge carriers, decreasing resistance.

11. **The SI unit of temperature coefficient of resistance (α) is:**
   A. K B. K^{-1} C. ΩK D. Ω/K
   Correct Answer: B. K^{-1}
   The unit comes from the formula $\alpha = \frac{\Delta R}{R \Delta T}$, giving K^{-1}.

12. **By increasing temperature, the resistivity of semiconductors:**
   A. Increases B. Decreases C. Remains constant D. First increases then decreases
   Correct Answer: B. Decreases
   Heating a semiconductor creates more free electrons, decreasing resistivity.

Short Response Questions

1. **Why is copper preferred over silver for household wiring, considering cost, conductivity, and durability?**
   Copper is much cheaper than silver, making it economical for large-scale wiring.
   It offers excellent electrical conductivity and mechanical strength.
   Additionally, copper is more durable and less prone to corrosion.

2. **Why free electrons in metals don't create a current without a potential difference?**
   In the absence of a potential difference, free electrons move randomly.
   This random motion results in no net flow of charge or electric current.
   A potential difference provides the directional push needed for current flow.

3. **How conventional and actual current directions affect circuit behaviour, and why conventional current is important in diagrams and calculations?**
   Actual current is due to the flow of electrons (negative to positive), while conventional is positive to negative.
   Circuit diagrams and laws like Ohm's law are based on conventional current direction.
   Using a standard direction simplifies understanding and analysis of circuits.

4. **Compare emf and potential difference, and why this distinction matters in circuit analysis.**
   EMF is the total energy supplied by a source per unit charge.
   Potential difference is the energy used between two points in a circuit.
   Differentiating them is essential for energy and power calculations.

5. **How is a current-carrying wire electrically neutral?**
   Although electrons are moving, the total number of positive and negative charges remains balanced.
   This balance ensures there is no net charge on the wire.
   Hence, the wire remains electrically neutral overall.

6. **Would the lights still work if a car battery's positive and negative terminals were interchanged?**
   Many devices, especially LED-based, are polarity-sensitive and may not work.
   Reversing polarity can stop the current or even damage components.
   So, in most cases, the lights will not function correctly.

7. **Evaluate the limits of Ohm's law for different materials, especially under extreme conditions.**
   Ohm's law applies mainly to metallic conductors at constant temperature.

Roll No. ____________ Name of Student: ______________________ Class: ____________ Date: __________

Under high temperatures or for semiconductors, current doesn't vary linearly with voltage.
Therefore, Ohm's law is not valid for all materials and conditions.

8. **How does a wire's shape affect its resistance, whether bending changes it?**
Resistance depends on length and cross-sectional area, not bending.
Bending a wire doesn't change its dimensions significantly.
So, the resistance remains the same unless the wire is deformed.

9. **The temperature coefficient of copper is 0.004 $°C^{-1}$. How does this affect copper's performance in electrical systems under varying temperatures?**
As temperature increases, copper's resistance increases linearly.
This rise in resistance can reduce current and efficiency.
Electrical systems using copper need to account for this variation.

10. **How would you define fluid resistance for a water-carrying pipe?**
Fluid resistance is the opposition faced by water as it flows through a pipe.
It arises due to friction between the fluid and the inner pipe walls.
It is similar to electrical resistance in a wire carrying current.

Roll No. ____________ Name of Student: ______________________ Class: ____________ Date: __________

Long Response Questions

1. **Explain electric current and its unit (ampere) by exploring charge flow. Discuss the difference between conventional and actual current and when this distinction matters.**
   Electric current is defined as the flow of electric charges, typically electrons, in a conductor. It is measured in amperes (A), where one ampere equals one coulomb of charge passing a point per second. Conventional current assumes positive charges flow from the positive terminal to the negative, while actual current involves negative electrons moving in the opposite direction. This distinction dates back to early scientific conventions before the discovery of electrons. Although actual current reflects physical reality, conventional current is widely used in circuit analysis and diagramming. It simplifies calculations and follows established norms in textbooks and industry. Understanding both is essential to avoid confusion in interpreting circuit behavior. The ampere remains the SI unit for quantifying current in all electrical systems.

2. **Analyse electrical conduction in metals and how external factors like temperature and magnetic fields affect electron movement and conduction efficiency.**
   In metals, conduction occurs as free electrons move through the lattice of positively charged ions. These electrons respond to electric fields, allowing current to flow. As temperature rises, the metal ions vibrate more vigorously, increasing collisions with electrons and hence resistance. This reduces conduction efficiency. Magnetic fields can influence the paths of moving electrons due to the Lorentz force, potentially causing deviations known as the Hall effect. Such effects are significant in designing sensors and measuring devices. Impurities and structural defects in metals also affect conduction. The efficiency of conduction depends on both the material's purity and external conditions. Hence, electrical devices must be designed considering environmental influences.

3. **Compare DC and AC in terms of their behaviour in circuit elements. Discuss the pros and cons of each in applications like power transmission and electronics.**
   Direct current (DC) flows in a constant direction and is used in batteries and electronic devices. Alternating current (AC) changes direction periodically and is the standard for household and industrial power. In circuit elements, DC causes steady current flow, making it ideal for low-voltage electronics. AC allows efficient long-distance power transmission due to easy voltage transformation via transformers. However, AC can induce heating and interference in sensitive circuits. DC is stable but difficult to convert between voltage levels without complex circuits. AC

is versatile and easier to generate in large-scale applications. Each has its merits depending on use: DC for electronics, AC for power grids.

4. **Examine electromotive force (emf) and its role in maintaining current.**
   Electromotive force (emf) refers to the energy supplied by a power source per unit charge to drive current in a circuit. It is not a force but a potential difference created by converting chemical, mechanical, or other energy forms into electrical energy. In a closed circuit, emf provides the energy needed to move charges against resistance. For example, in a battery, chemical reactions generate emf, pushing electrons through external circuits. Emf ensures a continuous flow of charge by maintaining a potential difference across the circuit. It is measured in volts and is essential for powering all electrical devices. Without emf, current would not persist in a circuit.

5. **Distinguish between emf and potential difference, using real-world examples like batteries.**
   EMF is the total energy provided by a source per coulomb of charge, while potential difference is the energy used between two points in a circuit. In a battery, emf is the voltage across the terminals when no current is flowing. When connected in a circuit, internal resistance causes some energy loss, and the potential difference across the terminals drops. For instance, a 12V battery might show only 11.5V under load due to internal resistance. EMF drives the entire circuit, whereas potential difference is measured across components like resistors. Understanding both helps in analyzing circuit performance and diagnosing energy losses.

6. **Critically analyse Ohmś law and its limitations for non-ohmic devices. Discuss the importance of I-V graphs and propose experiments to explore non-linear materials.**
   Ohm’s law states that current through a conductor is directly proportional to the voltage across it, provided temperature remains constant. It holds for ohmic devices like resistors, where the resistance remains fixed. Non-ohmic devices such as diodes, thermistors, and transistors do not obey Ohm’s law because their resistance changes with voltage or temperature. I-V (current-voltage) graphs help visualize this behavior: straight lines for ohmic, curves for non-ohmic. An experiment using a diode and variable power supply can show non-linear I-V characteristics. Understanding these deviations is vital in electronics where non-ohmic devices are used extensively. It reveals the dynamic behavior of electronic components.

7. **Investigate the relationship between resistance and resistivity and design an experiment to measure resistance. Discuss factors affecting accuracy, such as temperature.**
   Resistance is given by $R = \rho\frac{L}{A}$, where ρ is resistivity, L is length, and A is cross-

sectional area of the conductor. Resistivity is a material property, while resistance depends on the conductor's geometry. To measure resistance, one can connect a wire of known dimensions to a power supply and measure current and voltage using an ammeter and voltmeter. The resistance is calculated as $R = \frac{V}{I}$. Factors like wire heating can alter resistance during measurement. Minimizing temperature rise, ensuring clean connections, and using accurate instruments improve reliability of the experiment.

8. **Analyse how factors like temperature, material, length, and area affect resistance. Discuss practical applications, such as wiring or heating elements, and ways to optimize resistance.**
   Resistance increases with length and temperature, and decreases with cross-sectional area. Materials like copper and silver offer low resistance, making them ideal for wiring. Heating elements, on the other hand, use high-resistance materials like nichrome to convert electrical energy into heat. In wiring, low resistance minimizes power loss and heating. In heaters, high resistance ensures effective heat generation. Optimization involves choosing appropriate materials, controlling dimensions, and considering ambient temperature. Good insulation and ventilation further enhance performance. Engineers must balance efficiency, cost, and durability when designing electrical systems.

9. **How does temperature influence the resistance of materials, and what implications does this have for electrical components in different environments?**
   In metals, increasing temperature causes atoms to vibrate more, leading to more frequent collisions with electrons and increased resistance. In semiconductors, temperature rise can reduce resistance by generating more charge carriers. These effects must be considered when designing components for hot or cold environments. For instance, power lines sag in summer due to heat-induced resistance. Temperature-compensated resistors are used in circuits requiring stable performance. Sensitive equipment may require cooling systems. Engineers must ensure materials chosen can maintain functionality within expected temperature ranges to prevent malfunctions or damage.

10. **Examine the placement of ammeters and voltmeters in circuits and how misconnection affects measurement. Propose strategies to avoid errors.**
    Ammeters must be connected in series to measure current flowing through a component. Voltmeters must be connected in parallel to measure potential difference across a component. Incorrect placement can damage meters or provide incorrect readings. For example, connecting an ammeter in parallel may overload it. Strategies to avoid errors include proper circuit diagrams, label checking, using correct

range settings, and pre-checking with multimeters. Digital meters often have protections, but awareness is essential. Training, using simulation software, and clear instruction help students and technicians avoid costly mistakes.

Numerical Response Questions

Q1. How much time will it take to charge a 200 Ah battery when it is connected to a current of 25 A?

Given: $Q = 200 \text{ Ah} = 200 \times 3600 = 720000 \text{ C}, \quad I = 25 \text{ A}$
To Find: Time t
Solution:

$$t = \frac{Q}{I} = \frac{720000}{25} = 28800 \text{ s} = 8 \text{ hours}$$

Result: $t = 8$ hours

Q2. A 12.0 V emf source is connected to a purely resistive electrical appliance. A current of 2.0 A flows through it. Calculate the resistance.

Given: $V = 12 \text{ V}, \quad I = 2.0 \text{ A}$
To Find: R
Solution:

$$R = \frac{V}{I} = \frac{12}{2.0} = 6 \ \Omega$$

Result: $R = 6 \ \Omega$

Q3. The potential difference across the two ends of the component decreases to one fourth. What change will occur in the current?

Given: $V_2 = \frac{1}{4}V_1, \quad R = \text{constant}$
To Find: I_2
Solution:

$$I = \frac{V}{R} \Rightarrow I_2 = \frac{V_2}{R} = \frac{1}{4}I_1$$

Result: Current becomes one-fourth.

Q4. What voltage is necessary to pass a current of 50 amperes through a resistance of 100 Ω?

Given: $I = 50 \text{ A}, \quad R = 100 \ \Omega$
To Find: V
Solution:

$$V = IR = 50 \times 100 = 5000 \text{ V}$$

Result: $V = 5000$ V

Q5. The current passing through a resistor is 0.5 A at 6.0 V. What current will pass through the same resistor at 9.0 V?

Given: $I_1 = 0.5$ A, $V_1 = 6.0$ V, $V_2 = 9.0$ V
To Find: I_2
Solution:

$$R = \frac{V_1}{I_1} = \frac{6}{0.5} = 12\ \Omega \Rightarrow I_2 = \frac{V_2}{R} = \frac{9}{12} = 0.75\ \text{A}$$

Result: $I_2 = 0.75$ A

Q6. The length and area of wire are given as 2 m and 0.4 mm^2 respectively. Resistance is 0.085 Ω. Calculate resistivity.

Given: $L = 2$ m, $A = 0.4\ \text{mm}^2 = 0.4 \times 10^{-6}\ \text{m}^2$, $R = 0.085\ \Omega$
To Find: ρ
Solution:

$$\rho = R \cdot \frac{A}{L} = 0.085 \cdot \frac{0.4 \times 10^{-6}}{2} = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$$

Result: $\rho = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$

Q7. Copper wire of length 2 m has $\rho = 1.7 \times 10^{-8}\ \Omega \cdot$ m. (a) If stretched to double length, find new ρ. (b) If temp increases by 20 K, $\alpha = 3.9 \times 10^{-3}$ K^{-1}

(a) **Given:** $\rho = 1.7 \times 10^{-8}$
To Find: New ρ when length doubles
Solution: Resistivity depends on material only, not dimensions.
Result: $\rho = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$
(b) **Given:** $\Delta T = 20$ K, $\alpha = 3.9 \times 10^{-3}\ \text{K}^{-1}$
Solution:

$$\rho_T = \rho_0(1 + \alpha\Delta T) = 1.7 \times 10^{-8}(1 + 3.9 \times 10^{-3} \times 20) = 1.83 \times 10^{-8}\ \Omega \cdot \text{m}$$

Result: $\rho = 1.83 \times 10^{-8}\ \Omega \cdot \text{m}$

Q8. A metallic conductor has $\rho_0 = 1.7 \times 10^{-8}\ \Omega \cdot$ m at T_0. If temperature increases by 50 K, $\alpha = 0.004$, find new resistivity.

Given: $\rho_0 = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$, $\Delta T = 50$ K, $\alpha = 0.004$
To Find: ρ_T

Solution:

$$\rho_T = \rho_0(1 + \alpha\Delta T) = 1.7 \times 10^{-8}(1 + 0.004 \times 50) = 1.7 \times 10^{-8} \times 1.2 = 2.04 \times 10^{-8}\ \Omega \cdot \text{m}$$

Result: $\rho = 2.04 \times 10^{-8}\ \Omega \cdot \text{m}$

Chapter 16: Current Electricity — Formula Sheet

Important Formulae

- **Current (I):**

$$I = \frac{q}{t}$$

Where:

  - I: Current (Ampere, A)
  - q: Charge (Coulombs, C)
  - t: Time (seconds, s)

- **Ohm's Law:**

$$V = IR$$

Where:

  - V: Voltage (Volts, V)
  - I: Current (Amperes, A)
  - R: Resistance (Ohms, Ω)

- **Resistance of a wire:**

$$R = \rho\frac{L}{A}$$

Where:

  - ρ: Resistivity (Ohm-m, $\Omega \cdot m$)
  - L: Length of the conductor (meters, m)
  - A: Cross-sectional area (m^2)

- **Resistivity:**

$$\rho = R\frac{A}{L}$$

- **Electromotive Force (emf):**

$$\varepsilon = \frac{W}{q}$$

Where:

  - ε: emf (Volts, V)
  - W: Work done (Joules, J)
  - q: Charge (Coulombs, C)

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- **Voltage (Potential Difference):**

$$V = \frac{W}{q}$$

- **Temperature Coefficient of Resistance:**

$$\rho_T = \rho_0(1 + \alpha\Delta T)$$

or

$$\alpha = \frac{\rho_T - \rho_0}{\rho_0\Delta T}$$

Where:

  - α: Temperature coefficient (C^{-1})
  - ΔT: Change in temperature (°C or K)
  - ρ_T: Resistivity at temperature T
  - ρ_0: Resistivity at reference temperature

- **Power (Optional Advanced):**

$$P = IV = I^2R = \frac{V^2}{R}$$

- **Charge Flow from Current:**

$$q = It$$

- **Resistance using Ohm's Law:**

$$R = \frac{V}{I}$$

- **Voltage using Ohm's Law:**

$$V = IR$$

- **Current using Ohm's Law:**

$$I = \frac{V}{R}$$

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Assessment Numericals – Chapter 16: Current Electricity

Solve the following numerical problems. Show complete steps and include units in your answers.

1. A current of 5 A flows through a wire for 10 minutes. Calculate the total charge passed through the wire.
2. How much voltage is required to pass a current of 3 A through a resistance of 15 Ω?
3. A resistor of 8 Ω is connected across a 12 V battery. Find the current flowing through the resistor.
4. If a 1.5 A current flows through a bulb for 2 hours, find the total charge transferred.
5. Calculate the resistance of a copper wire that is 3 m long and has a cross-sectional area of 1.5×10^{-6} m^2. (Given $\rho = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$)
6. A 100 W bulb operates on a 250 V supply. Find the resistance of the filament.
7. The resistance of a wire is 0.2 Ω. If its temperature is increased by 40 K, and the temperature coefficient of resistance is 0.003 K^{-1}, calculate the new resistance.
8. Find the current in a circuit if a 60 V potential difference is applied across a 12 Ω resistor.
9. A heater draws 10 A from a 220 V line. Calculate the resistance of the heater and the power consumed.
10. The resistivity of a wire at $20°C$ is $2 \times 10^{-8}\ \Omega \cdot m$. What is its resistivity at $70°C$? (Take $\alpha = 0.004\ °C^{-1}$)

"Electricity is the power that drives modern life—understand it well, and you'll unlock the keys to endless innovation."

Keep questioning, keep experimenting, and remember—every great physicist started with simple circuits. Your spark begins here!

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