Chapter 16

ELECTRICITY

Physics – Class 10 (Unit 16 Notes, Unique Publications)

Electricity is the branch of physics which deals with the flow of charges.

Key Concepts

- Electric current
- Electromotive force and potential difference
- Ohm's law
- Combination of resistances
- Electrical resistivity
- Potential divider circuit
- Resistor colour codes
- Common use of electricity
- Electric power
- Household circuits and safety measures

Q.1 Define electric current and its SI unit.

Definition: *The rate of flow of charges is called an electric current. The electric current can be caused due to movement of both positive and negative charges.*

a. Mathematically

If Q charge flows in time t, then current I can be expressed as:

$$I = Q / t \quad \ldots\ldots (16.1)$$

b. Unit

- The SI unit of electric current is ampere (A).
- One ampere is defined as the flow of one Coulomb of electric charge per second: $1\ A = 1\ C\ s^{-1}$.

c. Explanation

- In an atom, the electrons and positively charged nucleus are held together by a strong force. However, some electrons can move freely as they are not tightly bonded with the nucleus.
- These electrons move randomly within a metallic conductor. However, when an external electric field is applied, these electrons move in a specific direction.

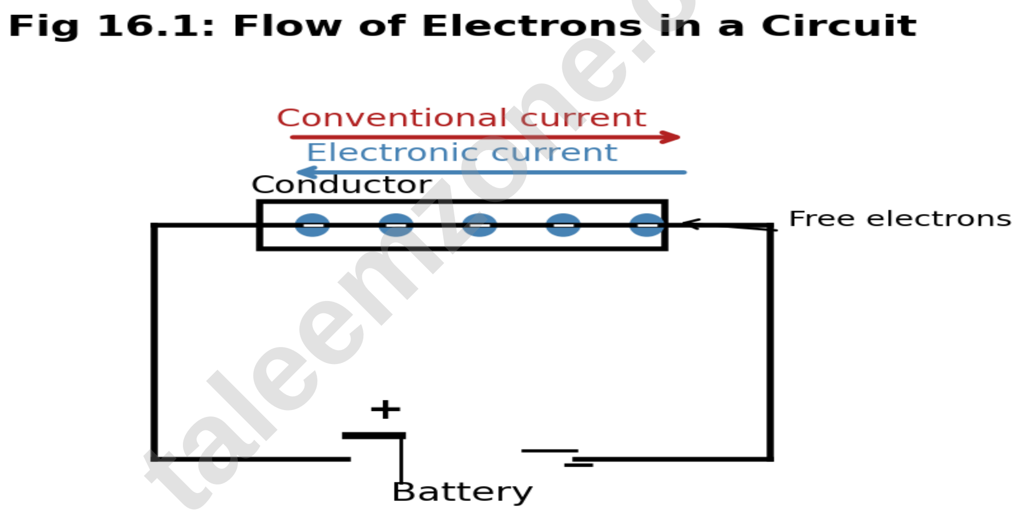


Fig 16.1: Flow of electrons in a circuit

Q.2 Differentiate between conventional current and electronic current.

Conventional Current

- The electric current was considered to be due to the flow of positive charges, known as Conventional Current. These charges move from the positive terminal to the negative terminal of the power source.

Electronic Current

- The electric current described due to the movement of electrons is known as electronic current, flowing in the opposite direction to conventional current.

- The movement of electrons in one direction corresponds to the movement of positive charges in the opposite direction.
- Despite this difference, both concepts are used in practice, with conventional current being the standard in circuit analysis.

Do You Know? — Electrolytic Cell

Q. How is electric current produced in an electrolytic cell?

Ans. In electrolysis, electric current is produced due to the flow of both positive and negative ions within the electrolyte solution. Negative ions are attracted to the anode (positive electrode), while positive ions move toward the cathode (negative electrode). This movement of ions constitutes an electric current within the internal circuit of the cell.

Q.3 Differentiate between D.C and A.C. (Types of currents)

1. Direct Current (D.C)

Definition: *Direct Current (D.C) is an electrical current where the electric charge flows in one direction only.*

- In a D.C circuit, the voltage remains constant over time, and the strength of the current does not change.
- The current provided by a battery is an example of direct current.

2. Alternating Current (A.C)

Definition: *Alternating Current (A.C) is a type of current that periodically reverses its direction.*

- Most power stations in our country produce alternating current.
- A.C changes direction every 1/50 second, and its frequency is 50 hertz (Hz).
- One advantage of A.C over D.C is that it can be transmitted over long distances with low power loss.

Fig 16.2: Types of Current

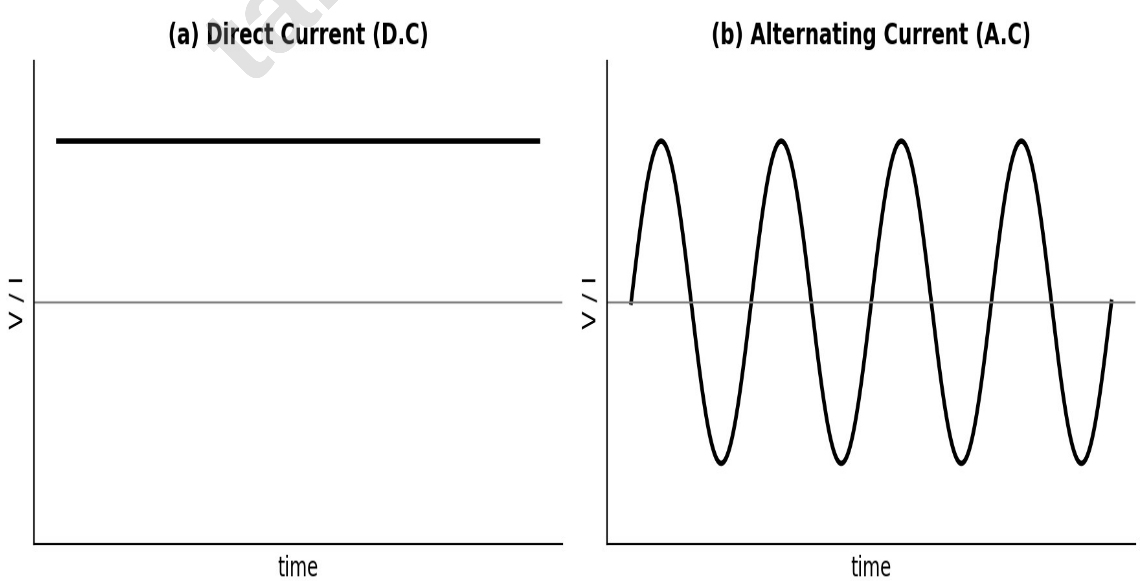


Fig 16.2: Types of current — (a) D.C (b) A.C

Do You Know? — A.C is More Dangerous than D.C

Direct Current (D.C) travels from negative to the positive terminal; it does not change its direction. D.C passing through the body cannot cause electric shock but can cause burning if the positive and negative wires come into contact.

Q.4 Differentiate between e.m.f. and potential difference.

1. Electromotive Force (e.m.f.)

Definition: *Electromotive force is the energy supplied by a battery to a unit positive charge when it flows through the closed circuit.*

$$e.m.f = Energy / Charge \quad ...... (16.2)$$

$$E = W / Q \quad ...... (16.3)$$

E is the e.m.f., W is energy converted from non-electrical forms to electrical form, and Q is the charge.

Emf of a battery can be measured directly by connecting its terminals to a voltmeter.

Fig 16.3: Circuit for Measuring e.m.f. of a Battery

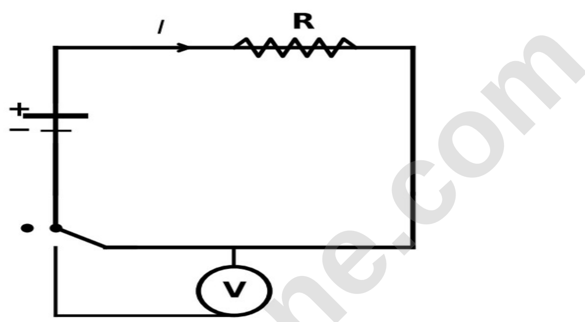


Fig 16.3: Schematic diagram for measuring e.m.f. of the battery

Explanation

- A source of e.m.f. converts non-electrical energy (chemical, thermal, or mechanical) into electrical energy. Examples: batteries (chemical), thermocouples (thermal), generators (mechanical).
- When a conductor is connected to a battery, current flows due to the potential difference between the battery's terminals.
- The battery provides energy to move positive charges from the positive terminal through the conductor to the negative terminal.
- Once the charge reaches the negative terminal (lower potential), the battery does work to push it back to the positive terminal (higher potential), keeping current flowing continuously.

2. Potential Difference

Definition: *Electric potential (V) is the amount of electric potential energy (W) per unit charge (Q) at a specific point in an electric field.*

$$V = W / Q \quad ...... (16.4)$$

Explanation

- The potential difference is the difference in the values of electric potential between two points in the electric field.
- The unit of electric potential is volt (V). One volt equals one joule of energy per coulomb ($V = J\,C^{-1}$).

- Potential difference is also called voltage — the energy used by a component in the circuit.
- Both potential difference and e.m.f. are measured in volts.
- A battery converts chemical energy into electrical energy. Inside it, a chemical reaction builds up electrons at the negative terminal and a shortage at the positive terminal, creating a potential difference that drives the current.

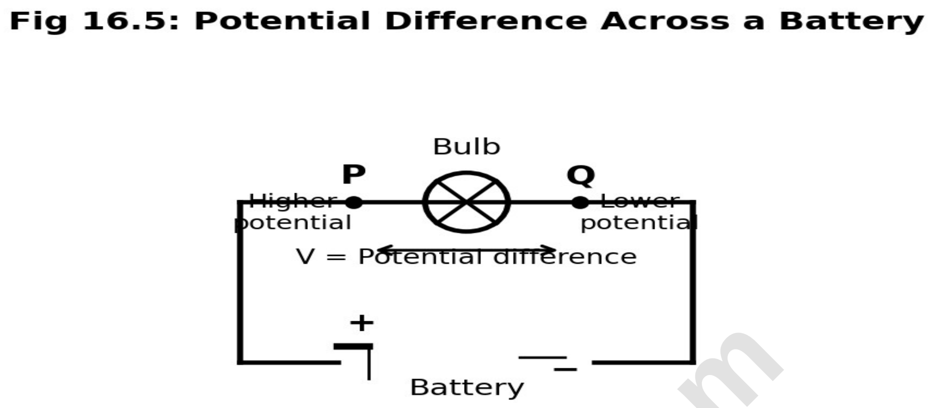


Fig 16.5: Potential difference across a battery

Q.5 Illustrate the use of ammeters and voltmeters (analogue and digital) across different ranges.

1. Ammeter

- An ammeter is a device used to measure the current flowing through a circuit.
- It must be connected in series with the component whose current is to be measured.
- There are two main types: analogue ammeters and digital ammeters, both available in different current ranges.

Do You Know? — A.C is More Dangerous than D.C

A.C. is considered more dangerous than D.C. because it periodically reverses direction. When passing through the human body, A.C. can cause continuous muscle contractions (tetany), making it difficult for a person to let go of the live source. It is also more likely to disrupt the heart's natural rhythm, leading to cardiac arrest, whereas D.C. typically causes a single muscle contraction that may throw a person away from the source.

Types of Ammeters

a. Analogue Ammeter

- Uses a needle and scale to indicate the current.
- The current flowing through the circuit generates a magnetic field that moves the needle on the scale.
- The scale usually has multiple ranges (e.g., 0–10 mA, 0–100 mA); the correct range must be selected to avoid damage and ensure accurate readings.

Use: Ideal for visual indication of current flow in basic experiments; often used in educational settings due to its simplicity.

b. Digital Ammeter

- Provides a numerical reading of the current on a digital display.
- Offers more precision than an analogue ammeter; some automatically adjust the range depending on the detected current.
- Typically more accurate and easier to read; widely used in scientific, industrial, and electrical applications.

c. Range Selection

- Low-range ammeters (e.g., 0–1 A) measure small currents, typically in laboratory experiments.
- High-range ammeters (e.g., 0–10 A) measure larger currents, such as in power systems or industrial circuits.

2. Voltmeter

- Voltage is measured using a device called a voltmeter.
- Voltmeters can be analogue or digital, and are available in different ranges to measure voltages of varying magnitudes.
- Analogue voltmeters use a needle and scale — useful for observing changes or trends over time.
- Digital voltmeters show the voltage as a numerical value, offering greater precision and ease of reading.
- Choosing the right range is important: a high-range voltmeter used for a small voltage might not give accurate readings, while a low-range voltmeter used for high voltage could be damaged.

Q.6 Calculate the total e.m.f. when multiple sources are arranged in series.

- When multiple voltage sources (e.g., batteries) are connected in series, their total electromotive force (e.m.f.) is simply the sum of their individual e.m.f.'s.
- This is because the voltage sources add energy to the charges one after the other.

E_total = E1 + E2 + ... + En

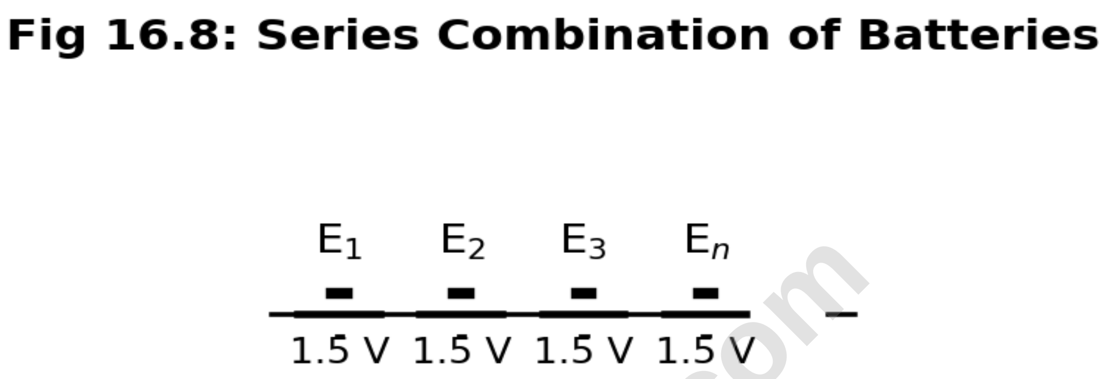


Fig 16.8: Series combination of batteries

Example: If four batteries, each with an e.m.f. of 1.5 V, are connected in series, the total e.m.f. would be 6 V.

Q.7 E.M.F. of identical sources connected in parallel.

- When multiple identical sources (such as batteries with the same voltage) are connected in parallel, the total e.m.f. across all of them remains equal to the e.m.f. of a single source.
- This is because, in parallel connections, each battery is connected directly across the same two points, meaning the voltage (e.m.f.) does not change.
- However, the total current supplied by the sources will increase due to the additional paths available for current to flow.

E_total = E1 = E2 = ... = En

Example: Four 1.5 V batteries connected in parallel give a total e.m.f. that is still 1.5 V, just as for a single battery.

Brain Teaser

Q. Three identical 5 V cells are connected in parallel. What is the total e.m.f. of the combination?

Ans. The total e.m.f. will be 5 V, because in parallel identical sources keep the same voltage — all positive and negative terminals are connected together.

Q.8 State and explain Ohm's law. Write its mathematical expression.

In 1826, George Simon Ohm investigated the relationship between electric potential difference across a conductor and the current flowing through it. The current in a conductor was increased by increasing the potential difference across its ends.

Statement

The current flowing through a conductor is directly proportional to the potential difference V across its two ends, provided the physical state (dimension, temperature etc.) of the conductor remains the same.

Fig 16.10

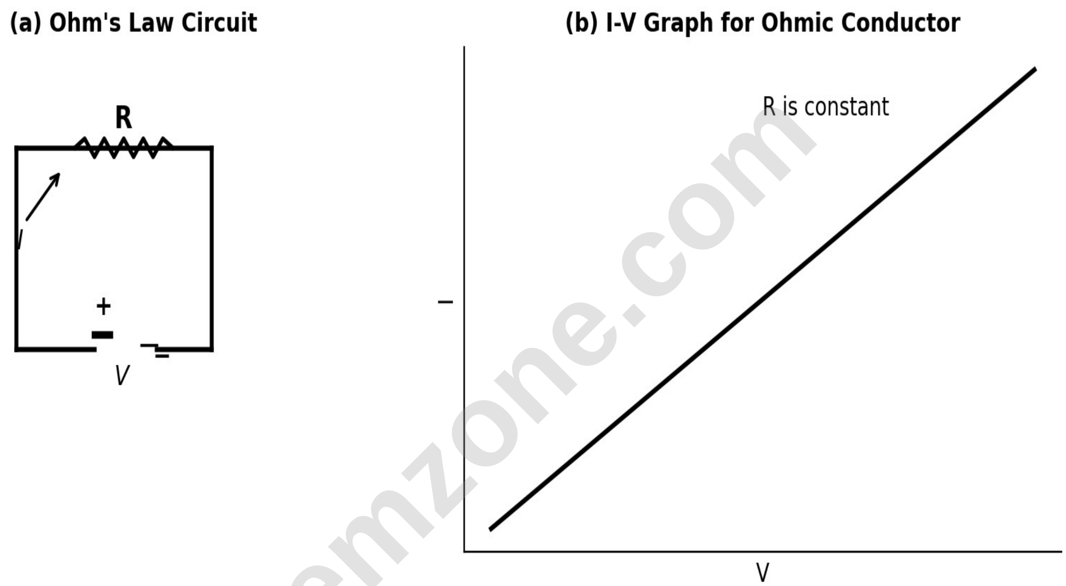


Fig 16.10: (a) Ohm's law circuit (b) I–V graph for an ohmic conductor

Mathematically

$$I \propto V \quad \Rightarrow \quad I = (1/R)\,V \quad \Rightarrow \quad V = IR \qquad \ldots\ldots (16.5)$$

where R is the constant of proportionality called the resistance of a conductor. The SI unit of resistance is ohm (Ω), and 1 Ω = 1 V A^{-1}.

Q.9 Series and Parallel Combination of Resistors

- A number of resistors can be connected in a circuit to increase or decrease the net resistance of the circuit.
- The resistors are connected either in series or in parallel, and the equivalent resistance of the circuit depends upon the type of combination.

1. Series Combination of Resistors

- When resistors are connected such that there is only one path for the current to flow, it is called a series combination of resistors.

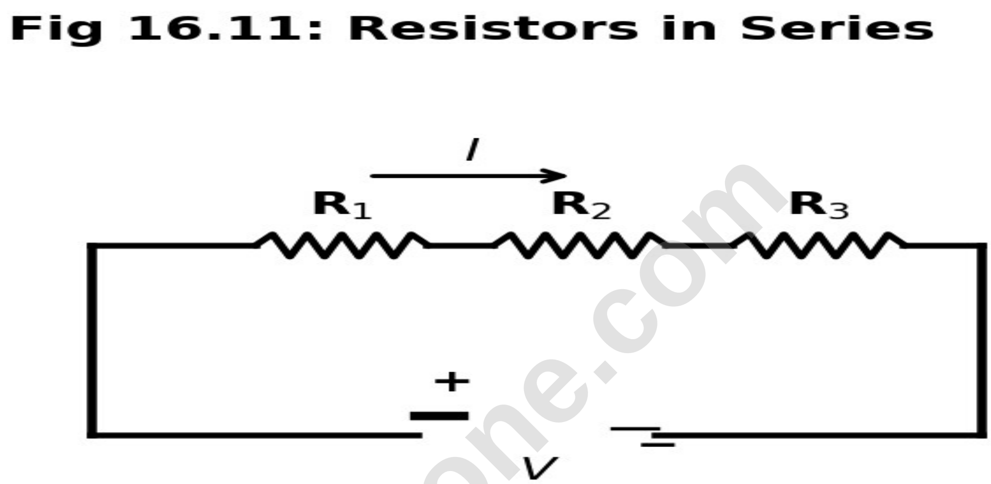


Fig 16.11: Resistors in series

Let Re be a single resistor representing the total (equivalent) resistance. The total voltage in the circuit is the sum of the voltage across the three resistors:

$$V = V1 + V2 + V3$$

Applying Ohm's Law to each resistor (current in series is same, I = I1 = I2 = I3):

$$IRe = IR1 + IR2 + IR3 \Rightarrow Re = R1 + R2 + R3 \quad \text{......} \ (16.6)$$

Thus, the equivalent resistance is equal to the sum of the individual resistances.

2. Parallel Combination of Resistors

- When there are multiple paths for current flow in a circuit, the combination of resistances is referred to as a parallel combination.
- The electric potential across each resistance is the same and equal to the applied potential.

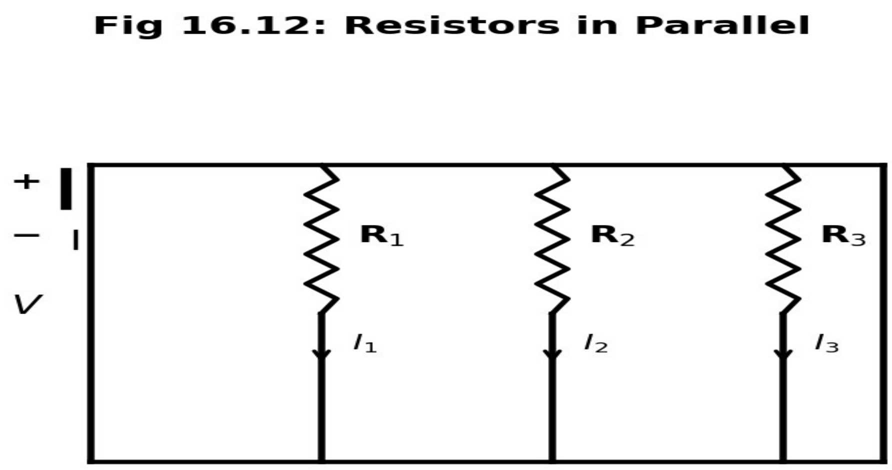


Fig 16.12: Resistors in parallel

The total current in the circuit is the sum of currents through the resistors:

$$I = I1 + I2 + I3$$

Applying Ohm's Law (voltage in parallel is the same, V = V1 = V2 = V3):

$$1/Re = 1/R1 + 1/R2 + 1/R3 \quad \ldots\ldots (16.7)$$

Thus, the reciprocal of equivalent resistance is equal to the sum of the reciprocals of the individual resistances.

Brain Teaser

Birds are safe on power wires because both their feet touch the same potential wire. There is no voltage difference, so no current flows through their bodies.

Q.10 Resistance and Resistivity of a Material

Definition: *The opposition to the flow of electric current is called resistance.*

a. Explanation

This resistance is directly proportional to the length of the conductor and inversely proportional to its area. If A is the area and L the length of a conductor:

Fig 16.13: Resistor of a Material (R = ρL/A)

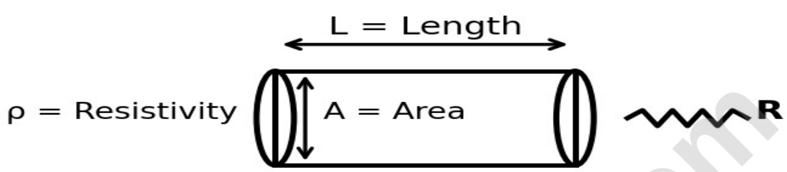


Fig 16.13: Resistance of a material — R = ρL/A

$$R \propto L \text{ and } R \propto 1/A \Rightarrow R = \rho\,(L/A) \quad \ldots\ldots (16.8)$$

Here, ρ (rho) is a constant called the electrical resistivity of a material, which quantifies how strongly a material resists electric current.

- Materials with high resistivity are poor conductors of electricity, while those with low resistivity are good conductors.
- The SI unit of resistivity is the ohm-metre (Ω m).
- Resistivity is the resistance of a material of unit length and unit cross-sectional area.

Table 16.1: Electrical Resistivity of Different Materials

Material	Electrical Resistivity (10^{-8} Ω m)
Silver	1.7
Copper	1.69
Aluminium	2.75
Tungsten	5.25
Platinum	10.6
Iron	9.8
Nichrome	100
Graphite	3500

b. Effect of Temperature on Resistance of a Resistor

(i) Resistance of a Conductor

- The resistance and resistivity of a conductor can change with temperature. In most conductors (metals), electrical resistance increases with temperature because atomic vibrations resist electron flow.
- For example, in a filament lamp, when the temperature of the filament increases, its resistance also increases.
- The increase in temperature increases the vibration of the atoms, making it harder for electrons to move — so the resistance goes up. A hot filament has more resistance than a cold one.

(ii) Resistance of a Semiconductor

- In semiconductors and insulators, resistance may decrease with temperature due to increased mobility of free charge carriers.
- For example, a thermistor (made of semiconductor material) is a resistor whose resistance decreases as its temperature increases.
- At low temperatures, the semiconductor has fewer free charge carriers, resulting in high resistance. As temperature rises, more charge carriers are released, increasing conductivity and reducing resistance.

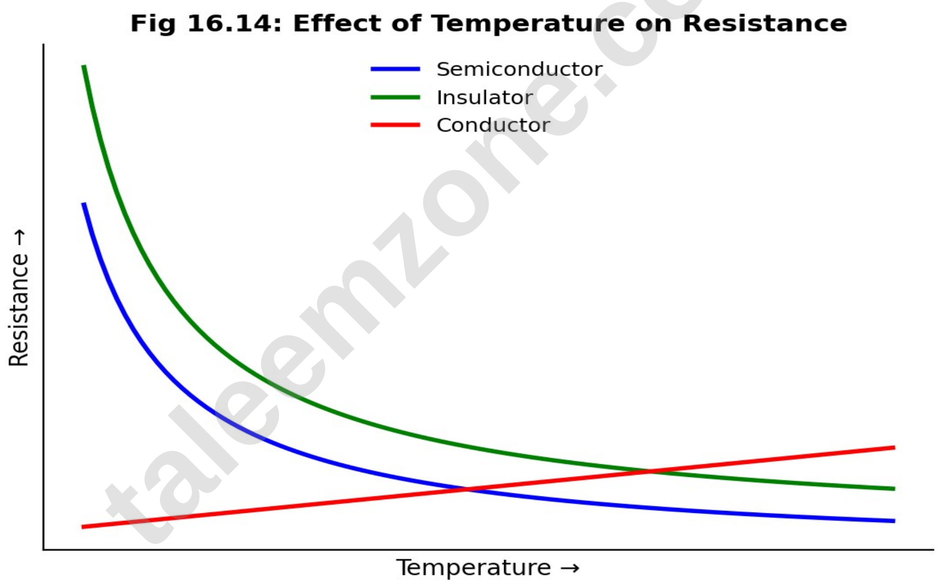


Fig 16.14: Effect of temperature on resistance of different materials

Q.11 Potential Divider Circuit

Definition: *A potential (or voltage) divider is a circuit that divides a voltage into smaller parts using resistors.*

- It consists of two or more resistors connected in series across a voltage source. The voltage across each resistor is proportional to its resistance relative to the total resistance of the circuit.

Fig 16.15: Potential Divider Circuit

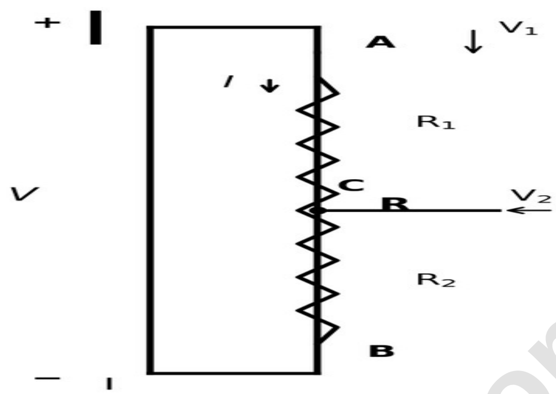


Fig 16.15: Potential divider circuit

Consider two resistors R1 and R2 connected in series. The voltage across each resistor is given by:

$$R1 / R2 = V1 / V2 \quad \text{...... (16.9)}$$

where V1 = voltage across R1, and V2 = voltage across R2.

The total voltage (V_total) is the sum of V1 and V2:

$$V\_total = V1 + V2 \quad \text{...... (16.10)}$$

The voltage across each resistor can also be calculated using:

$$V1 = V\_total \times R1 / (R1 + R2) \quad \text{...... (16.11)}$$

$$V2 = V\_total \times R2 / (R1 + R2) \quad \text{...... (16.12)}$$

Q.12 Illustrate the use of colour code for resistors.

- The resistor colour code is a system of coloured bands printed on resistors to indicate their resistance value and tolerance.
- Tolerance means how much a resistor's real value can differ from the value written on it.
- In this way, a resistor's value can be identified without using a multimeter. Each colour represents a specific digit and multiplier.

Fig 16.16: Standard Resistor Colour Code (example)

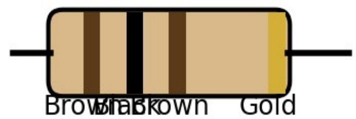


Fig 16.16: Standard resistor colour code (example)

- In a four-band resistor, the first and second bands indicate the 1st and 2nd digit, while the 3rd and 4th bands show the multiplier and tolerance.
- Example: a resistor has four bands — Red, Violet, Yellow and Gold. First two digits show 27, Yellow band is a multiplier (10^4), and gold shows tolerance (±5%). The final resistance value is 270,000 Ω, or 270 kΩ.

Table 16.2: Resistor Colour Code Chart

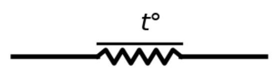
Colour	Number	Multiplier	Tolerance
Black	0	10^0	—
Brown	1	10^1	—
Red	2	10^2	—
Orange	3	10^3	—
Yellow	4	10^4	—
Green	5	10^5	—
Blue	6	10^6	—
Violet	7	10^7	—
Grey	8	10^8	—
White	9	10^9	—
Gold	—	10^{-2}	± 5 %
Silver	—	10^{-1}	± 10 %
Colourless	—	—	± 20 %

Q.13 NTC Thermistors and Light Dependent Resistors (LDR) as input sensors

1. Negative Temperature Coefficient (NTC) Thermistors

Definition: *A resistor whose resistance decreases as the temperature increases. This behaviour is due to the negative temperature coefficient, meaning the material used conducts electricity better as the temperature rises.*

Circuit symbol — NTC Thermistor
(resistance decreases as temperature increases)



Action and Use

- The increase in temperature gives more energy to the charge carriers (electrons), allowing them to move more freely through the material, which reduces the resistance.
- As temperature increases, the resistance of the NTC thermistor decreases — useful for applications where changes in temperature need to be detected.
- NTC thermistors are commonly used in temperature-sensing circuits (e.g., thermometers, temperature-monitoring circuits, temperature compensation in circuits).

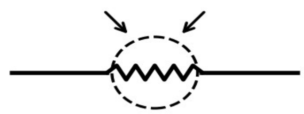
Applications

- Temperature sensors in electronic devices.
- Over-current protection in power supplies, where the thermistor can limit current based on temperature changes.

2. Light Dependent Resistors (LDRs)

Definition: *A resistor whose resistance decreases as the intensity of light increases.*

Circuit symbol — LDR
(resistance decreases as light intensity increases)



Action and Use

- The more light that falls on the LDR, the more current flows through it, as its resistance decreases.
- This occurs because the photoconductive material inside the LDR absorbs light energy, exciting electrons and reducing resistance.
- LDRs are widely used in light-sensing circuits — automatic lighting systems, brightness sensors in cameras, and other light-detection applications.

Applications

- Street lighting that automatically turns ON when it gets dark.
- Brightness sensors in cameras that adjust exposure based on ambient light levels.

Q.14 Define electric power and its SI units.

Definition: *Electric power is the rate at which electrical energy is transferred or consumed in a circuit.*

$$P = W / t$$

It measures how quickly work is done or energy is used. The SI unit of power is watt (W), where 1 W = 1 J s^{-1}.

Different Forms

Electric power P is commonly written as the product of current I and voltage V:

$$P = IV \quad \ldots\ldots (16.10)$$

Since V = IR:

$$P = I^2R \quad \text{or} \quad P = V^2/R$$

Q.15 State and explain Joule's law in electricity.

Heat produced by an electric current and the resistance of the conductor can be described by Joule's law.

Statement

The heat energy produced in a resistance is proportional to the square of the current, the resistance, and the time in which the current flows.

$$H = I^2Rt \quad (\because P = I^2R) \quad \Rightarrow \quad H = P \times t \quad \text{...... (16.10)}$$

This is the relationship between electric power P and total heat energy, showing that total heat energy H is the product of power and time.

- The power of a resistor determines how quickly heat is produced.
- For example, a 100 W resistor produces heat at a rate of 100 joules per second.
- If the 100 W resistor runs for 10 seconds, the total heat energy produced is H = P × t = 100 W × 10 s = 1,000 J.

Tidbit

Power bills measure energy, not electricity. Our electricity bills show kilowatt-hours (kWh), a measure of energy used, not electricity consumed.

Q.16 Kilowatt-hour and Cost of Electricity Bill

Electric energy is commonly consumed in very large quantities. The unit used to measure large amounts of electric energy is called the kilowatt-hour.

Definition: *The amount of energy delivered by a power of one kilowatt in one hour is called a kilowatt-hour.*

Proof of Formula

$$1\ \text{kWh} = 1{,}000\ \text{W} \times 1\ \text{hour} = 1{,}000\ \text{W} \times 3600\ \text{s} = 3.6 \times 10^6\ \text{J} = 3.6\ \text{MJ}$$

The energy in kilowatt-hours can be obtained by the formula:

$$\text{Energy (kWh)} = (\text{watt} \times \text{time of use in hours}) / 1{,}000$$

The electric meter installed in our houses measures the consumption of electric energy in kilowatt-hours, according to which we pay our electricity bills.

Cost of Electric Bill

If the cost of one kilowatt-hour (i.e., one unit) is known, the electricity bill can be calculated:

$$\text{Cost of electricity} = \text{Number of units consumed} \times \text{Cost of one unit}$$

$$= [(\text{watt} \times \text{time of use in hours}) / 1{,}000] \times \text{Cost of one unit}$$

When designing circuits, it is important to choose components with suitable power ratings to ensure safety, reliability, and efficiency.

Brain Teaser

Q. If two appliances are rated 100 W and 1,000 W, both used for 1 hour, do they consume equal energy or different? Why?

Ans. The 1000 W appliance consumes 10 times more energy, according to the formula E = P × t.

Q.17 Why are domestic supplies connected in parallel?

1. Household Circuits and Safety Measures

Household circuits safely distribute electricity through different pathways in a home. Safety measures protect against electrical hazards.

2. Household Circuits

- In a parallel circuit, every appliance — refrigerator, bulbs, or TV — gets its own direct connection to the power supply. Each appliance works independently.
- We can turn OFF the lights in the kitchen without shutting down the TV in the living room.
- Parallel circuits are safer and more reliable — if one appliance breaks or a fuse blows, the rest of the home's power stays ON.
- Connecting a home's electrical system in parallel gives every appliance its own consistent voltage, independent operation, and reliable performance.

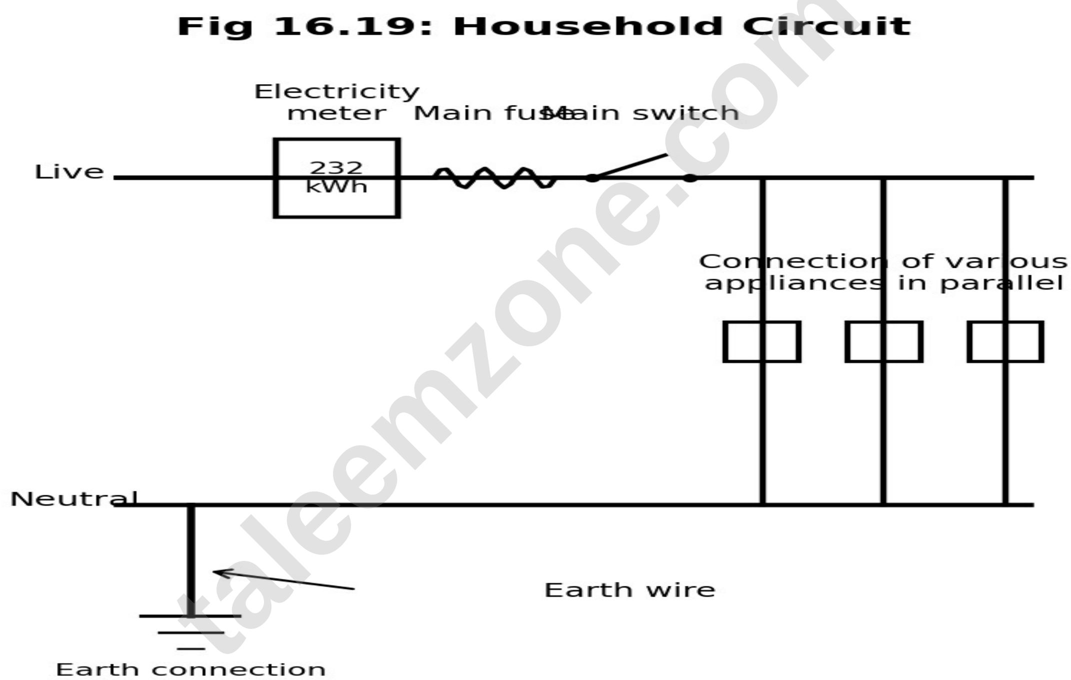


Fig 16.19: Household circuit

Q.18 Hazards of Electricity and Safety Measures

1. Hazards of Electricity

Common electric hazards occur due to:

- Malpractice (incorrect use) or lack of maintenance, which can lead to serious accidents like shocks, fires, or even fatalities.
- Damaged insulation — the protective covering on wires wears out or gets cut, exposing live wires and causing electric shocks or short circuits.
- Overheating cables — wires carrying more current than they are designed for heat up and can potentially start a fire.

- Overloading — plugging too many devices into a single socket, extension lead, or power strip can draw excess current, overheating the circuit and causing fires.

2. Safety Measures — Fuse and Circuit Breakers

- Fuses and trip switches (circuit breakers) are essential safety devices used to avoid these hazards.
- Fuses contain a thin wire that melts due to the flow of high current; the resulting break in the circuit stops the flow of electricity.
- Trip switches automatically cut OFF power when they detect a fault, such as an overload or short circuit.
- Both devices are connected to the live wire of the circuit, ensuring the entire circuit is switched OFF safely in case of a problem.
- One of the most critical safety features in a circuit is the earth wire. If a fault occurs — such as a live wire touching a metal casing — the earth wire provides a low-resistance path for the current to flow safely into the ground.
- This prevents the casing from becoming live and triggers the fuse or trip switch to cut OFF the power.
- This is why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed.
- Double-insulated appliances (like many power tools) have plastic casings, which cannot conduct electricity.
- Appliances with metal casings (like washing machines) are connected to the earth wire for safety.

Brain Teaser

Q. Why can a tiny device like a smartphone charger trip the main switch if something goes wrong?

Ans. A fault such as a short circuit or insulation failure creates a sudden, very large current flow. The circuit breaker is designed to detect this dangerous overcurrent and instantly cut off power to the entire circuit to prevent overheating, fire, or electric shock.

Q. Imagine your home has no earth wire. What could happen if the live wire touches the metal body of an appliance?

Ans. The casing becomes live at full mains voltage. Anyone touching the appliance would get a severe electric shock, as current would flow through their body to the ground — there would be no safe, low-resistance path to quickly blow the fuse, leaving the dangerous fault active.

Q.19 A typical main circuit consists of three wires.

- The live wire (line wire), which carries the current from the power supply.
- The neutral wire, which completes the circuit.
- The earth wire, which provides a safety path for fault currents.

Fig 16.22: Main Circuit Wires

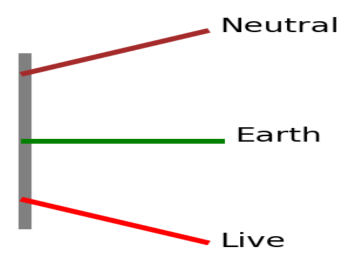


Fig 16.22: Main circuit wires — Live, Neutral, Earth

- Despite these safety measures, electric shocks can still occur and can be extremely dangerous.
- When electricity passes through the human body, it can cause burns at the entry and exit points.
- More seriously, it can disrupt the body's electrical signals, leading to cardiorespiratory failure (heart and lungs stop working) or seizures.
- This is why proper safety mechanisms — fuses, circuit breakers, and earthing — are so important to prevent accidents and protect lives.

Symbols of Various Electrical Components

Component	Component	Component
Open Switch	Thermistor	LDR
Closed Switch	Cell	Battery
Fuse	Lamp	Voltmeter
Diode	Ground	Ammeter
Resistor	Buzzer	Inductor

Q.20 Uses of Electricity

- Electricity is one of the most versatile forms of energy used in daily life.
- Heating: powers devices like electric heaters, stoves, and water heaters.
- Lighting: from bulbs in our homes to streetlights and flashlights.
- Battery charging: powers chargers for phones, laptops, electric vehicles, and other portable devices.
- Powering motors: found in washing machines, refrigerators, industrial machinery, electric cars and trains.
- Electronic systems: the backbone of computers, televisions, smartphones, and other gadgets.

Formula Sheet

Sr. #	Formula	Description
1	$I = Q / t$	Electric current
2	$E = W / Q$	Electromotive force
3	$V = W / Q$	Potential difference
4	$E = E1 + E2 + E3 + ...+ En$	Total e.m.f. of series combination
5	$E_{total} = E1 = E2 = ... = En$	Total e.m.f. of parallel combination
6	$Re = R1 + R2 + R3$	Equivalent resistance of series combination
7	$V = IR$	Ohm's law
8	$1/Re = 1/R1 + 1/R2 + 1/R3$	Equivalent resistance of parallel combination
9	$R = \rho L / A$	Resistance of a conductor
10	$V1 = V \times R1 / (R1+R2)$	Voltage across R1 (potential divider)
11	$V2 = V \times R2 / (R1+R2)$	Voltage across R2 (potential divider)
12	$P = VI$	Electric power
13	$P = I^2R$	Electric power
14	$P = V^2 / R$	Electric power
15	$H = Pt = I^2Rt$	Electric (heat) energy

Solved Examples

Example 16.1

A battery does 120 J of work to move a charge of 20 C through a circuit. What is the potential difference across the circuit?

Given: $W = 120\ J$, $Q = 20\ C$. To find: $V = ?$

$$V = W/Q = 120\ J / 20\ C = 6\ V$$

Result: The potential difference is 6 volts.

Example 16.2

Two resistors of 8 Ω and 24 Ω are connected in parallel across a 30 V power supply. Calculate the total resistance and the current drawn from the power supply.

Given: $R1 = 8\ \Omega$, $R2 = 24\ \Omega$, $V = 30\ V$. To find: $Re = ?$

$$1/Re = 1/R1 + 1/R2 = 1/8 + 1/24 = 4/24 \Rightarrow Re = 24/4 = 6\ \Omega$$

Using Ohm's Law:

$$I = V/Re = 30\ V / 6\ \Omega = 5\ A$$

Result: The total resistance and current are 6 Ω and 5 A respectively.

Example 16.3

An aluminium wire has a length of 15 m, a cross-sectional area of $3 \times 10^{-6}\ m^2$, and a resistivity of $2.82 \times 10^{-8}\ \Omega$ m. Calculate its resistance.

Given: $\rho = 2.82 \times 10^{-8}\ \Omega\ m$, $L = 15\ m$, $A = 3 \times 10^{-6}\ m^2$. To find: $R = ?$

$$R = \rho(L/A) = (2.82\times10^{-8}\ \Omega\ m) \times (15\ m / 3\times10^{-6}\ m^2)$$

$$R = (2.82 \times 10^{-8}) \times (5 \times 10^{6}) = 0.141\ \Omega$$

Result: The resistance of the wire is 0.141 Ω.

Multiple Choice Questions — Exercise

1. The direction of conventional current is:

(a) negative to positive terminal (b) positive to negative terminal (c) both directions at once (d) no fixed direction

2. What type of electric current flows in one direction only?

(a) Alternating current (b) Direct current (c) Induced current (d) Pulsating current

3. The device used to measure electric current:

(a) voltmeter (b) ammeter (c) ohmmeter (d) wattmeter

4. What is the function of an e.m.f. source in a circuit?

(a) reduce resistance (b) provide energy to drive charges (c) store electrical energy (d) convert electrical to mechanical energy

5. The relationship between voltage, current and resistance is:

(a) $V = IR$ (b) $V = I/R$ (c) $V = I^2R$ (d) $V = R/I$

6. What happens to the resistance of a metal conductor when its temperature increases?

(a) decreases (b) remains constant (c) increases (d) becomes zero

Answer Key

1-b 2-b 3-b 4-b 5-a 6-c

SLO Based Additional MCQs + Past Papers MCQs of Punjab Boards

Electric Current and its Measurement

1. What is the SI unit of electric current?

(a) Volt (b) Coulomb (c) Ampere (d) Ohm

2. The direction of conventional current is:

(a) negative to positive (b) positive to negative (c) same as electronic current (d) random

3. An ammeter must be connected in:

(a) parallel with the component (b) series with the component (c) either series or parallel (d) across the battery

Electromotive Force and Potential Difference

4. Electromotive force (e.m.f.) is defined as:

(a) work done to move a unit charge through a component (b) the energy supplied by a source to a unit charge in a complete circuit (c) potential difference across a resistor (d) the rate of flow of charge

Ohm's Law and Resistances

5. According to Ohm's law, the current flowing through a conductor is:

(a) directly proportional to the resistance (b) inversely proportional to the voltage (c) directly proportional to the voltage (d) independent of the voltage

6. Three resistors of 4 Ω, 6 Ω, and 8 Ω are connected in series. The equivalent resistance is:

(a) 18 Ω (b) 10 Ω (c) 1.8 Ω (d) 0.18 Ω

7. The resistance of a conductor is:

(a) directly proportional to length and inversely proportional to area (b) inversely proportional to length and directly proportional to area (c) directly proportional to both (d) inversely proportional to both

Electric Power and Energy

8. The formula for electric power is:

(a) $P = I/R$ (b) $P = V/I$ (c) $P = IV$ (d) $P = V/R$

Household Circuits and Safety

9. The unit of electrical energy commonly used in household electricity bills is:

(a) Joule (b) Kilowatt-hour (c) Watt (d) Volt

10. Household circuits are connected in parallel because:

(a) it allows each appliance to get the same voltage (b) it reduces the total current (c) it is easier to install (d) it is the only way to connect appliances

Answer Key

1-c 2-b 3-b 4-b 5-c 6-a 7-a 8-c 9-b 10-a

Exercise Short Questions

16.1 How does an ammeter measure electric current?

Ans. An ammeter measures electric current by allowing the current to pass through it. It is connected in series with the circuit component. The current produces a magnetic or electronic effect inside the ammeter, calibrated to show the current directly in amperes. Ammeters have very low resistance to avoid changing the circuit current.

16.2 What is the main difference between direct current and alternating current?

Direct Current (D.C)	Alternating Current (A.C)
The current flows in one direction only.	The current periodically reverses its direction.
Voltage and current strength remain constant over time.	Voltage and current change magnitude and direction with time.
Example: current from a battery.	Example: current supplied by power stations.

16.3 Define electromotive force (e.m.f.). Write its SI units.

Ans. Electromotive force is the energy supplied by a battery to a unit positive charge when it flows through the closed circuit.

Formula: $E = W / Q$. Unit: volt (V).

16.4 State Ohm's law and define resistivity.

Ans. Ohm's Law: The current flowing through a conductor is directly proportional to the potential difference across its ends, provided the physical conditions remain constant.

Formula: $V = IR$.

Definition (Resistivity): Resistivity is the resistance of a material of unit length and unit cross-sectional area. Unit: Ohm-metre (Ω m).

16.5 What is the formula for calculating the equivalent resistance of resistors connected in series?

Ans. Formula: $Re = R1 + R2 + R3$.

Explanation: In a series circuit, the current is the same through all resistors. The total resistance is the sum of individual resistances, which increases the overall opposition to current flow.

16.6 How does temperature affect the resistance of a conductor?

Ans. When temperature increases, the resistance of a metal conductor increases. This is due to increased vibration of atoms, which oppose the flow of electrons. As a result, current flow becomes more difficult, hence resistance increases with temperature.

SLO Based Additional Short Questions + Past Papers Short Questions of Punjab Boards

Electric Current

Q.1 Define electric current and explain how it is produced in a conductor?

Ans. Electric current is the rate of flow of electric charge through a conductor. It is produced when a potential difference is applied across the conductor. The applied voltage causes free electrons to move in a definite direction. This continuous flow of charges constitutes electric current.

Q.2 Explain the difference between conventional current and electron flow.

Ans. Conventional current is considered to flow from the positive terminal to the negative terminal. Electron flow actually occurs from the negative terminal to the positive terminal. Conventional current direction is assumed for simplicity in circuit analysis. Both describe the same current but in opposite directions.

Q.3 Why is electric current measured in amperes?

Ans. Electric current measures the rate of flow of charge. One ampere is defined as one coulomb of charge flowing per second. This unit helps quantify how much charge moves in a given time. Hence, ampere is the standard unit of electric current.

Potential Difference and e.m.f.

Q.4 Define potential difference and state its importance in an electric circuit.

Ans. Potential difference is the work done to move a unit charge between two points. It provides the energy needed to drive charges through a circuit. Without potential difference, no current can flow. It is measured in volts using a voltmeter.

Q.5 Distinguish between potential difference and electromotive force (e.m.f.).

Ans. Potential difference is the energy used per unit charge between two points in a circuit. Electromotive force is the energy supplied per unit charge by the source. Potential difference appears across components, while e.m.f. comes from the source.

Q.6 Why is a voltmeter connected in parallel in a circuit?

Ans. A voltmeter measures the potential difference across a component. Parallel connection allows it to compare voltages at two points. It has very high resistance to avoid drawing current. This ensures accurate voltage measurement.

Resistance and Resistivity

Q.7 Define resistance and state the factors affecting it.

Ans. Resistance is the opposition offered by a conductor to the flow of current. It depends on the length of the conductor, the cross-sectional area, and the nature of the material. Temperature also affects the resistance of a conductor.

Q.8 What is resistivity and why is it called a material property?

Ans. Resistivity is the resistance of a material of unit length and unit area. It depends only on the nature of the material and does not depend on length or thickness. Hence, it is a characteristic property of a material.

Q.9 How does temperature affect the resistance of a metallic conductor?

Ans. When temperature increases, atomic vibrations increase. These vibrations obstruct the motion of electrons. As a result, the resistance of the conductor increases. Thus, metals show increased resistance at higher temperatures.

Ohm's Law

Q.10 State Ohm's law and explain its limitations.

Ans. Ohm's law states that current is directly proportional to voltage at constant temperature. It applies only to metallic conductors. It is not valid if temperature changes. It does not apply to diodes or filament lamps.

Q.11 What is the significance of the V–I graph for an ohmic conductor?

Ans. The V–I graph for an ohmic conductor is a straight line. It shows that voltage is directly proportional to current. The slope of the graph represents resistance. A straight line confirms the validity of Ohm's law.

Combination of Resistors

Q.12 Explain why series combination of resistors is not used in household circuits.

Ans. In series combination, voltage is divided among appliances. Each appliance gets less voltage. If one appliance fails, the circuit breaks. Hence, series combination is unsuitable for household wiring.

Q.13 Why is parallel combination preferred for domestic wiring?

Ans. In parallel combination, each appliance gets full voltage. Appliances work independently of each other. Failure of one appliance does not affect others. This makes parallel combination safer and reliable.

Electric Power

Q.14 Define electric power and state its SI unit.

Ans. Electric power is the rate at which electrical energy is consumed. It indicates how fast an appliance uses electrical energy.

Unit: The SI unit of power is watt. Higher power means higher energy consumption.

Q.15 Explain the relationship between electric power, current, and voltage.

Ans. Electric power depends on both current and voltage. It is directly proportional to current flowing in the circuit. It is also directly proportional to applied voltage. Thus, higher voltage or current increases power consumption.

Constructed Response Questions

16.1 Why is it important that an ammeter has very low resistance and is connected in series, while a voltmeter has very high resistance and is connected in parallel? What would happen if they were connected incorrectly?

Ans. An ammeter has very low resistance and is connected in series.

Reason: Low resistance ensures that the current in the circuit is not reduced. Series connection allows the ammeter to measure the same current flowing through the component. If connected in parallel, a large current would flow through the ammeter, damaging it.

A voltmeter has very high resistance and is connected in parallel.

Reason: High resistance prevents drawing significant current from the circuit. Parallel connection allows measurement of potential difference across a component. If connected in series, it would reduce the circuit current.

16.2 If a copper wire is replaced with an aluminium wire of the same dimensions, how would the current and power consumption change in the same circuit? Explain using the concept of resistivity.

Ans. Current decreases and power consumption decreases when aluminium replaces copper.

Reason: Aluminium has higher resistivity than copper. Higher resistivity means higher resistance for the same length and area. According to Ohm's law, V/I = R — higher resistance reduces current. Power consumption would also decrease because power depends on current ($P = I^2R$).

16.3 In a household lighting circuit, what practical problems might arise if the bulbs were connected in series instead of parallel?

Ans. The bulbs would receive less voltage.

Reason: In series, voltage is divided among bulbs, so each bulb would glow dimly. If one bulb fails, the entire circuit would break, and all bulbs would turn OFF, making the system unreliable.

16.4 You are tasked with designing a fuse for a device that operates at 230 V and 5 A. What rating would you choose for the fuse and why? What could go wrong if the rating is too low or too high?

Ans. A fuse rated slightly above 5 A should be chosen.

Reason: The fuse must allow normal current but melt during excess current. If the rating is too low, the fuse will melt during normal operation. If the rating is too high, it will not protect the device during overload.

16.5 Explain why A.C is more suitable for power transmission across cities, even though D.C is used in batteries and portable electronic devices.

Ans. A.C is more suitable for long-distance transmission.

Reason: A.C can be transmitted at high voltage with low current, reducing energy loss in transmission lines. A.C voltage can also be easily changed using transformers. D.C is suitable for batteries and electronic devices because it provides constant voltage.

Comprehensive Questions

16.1 Explain the concept of electric current. How is it related to the movement of charges, and how is it measured in a circuit?

Ans. See Q.1 of theory.

16.2 Define electromotive force (e.m.f.) and potential difference. How does a battery create a potential difference, and what is the role of e.m.f. in maintaining the flow of current?

Ans. See Q.4 of theory.

16.3 State and explain Ohm's law. How does the resistance of a conductor affect the flow of current, and how can Ohm's law be applied in practical electrical circuits?

Ans. See Q.8 of theory.

16.4 Differentiate between series and parallel combinations of resistors. Provide mathematical expressions for calculating the total resistance in both types of circuits.

Ans. See Q.9 of theory.

16.5 What is meant by resistivity of a material? How does it depend on the material, and what role does temperature play in changing the resistivity of conductors and semiconductors?

Ans. See Q.10 of theory.

Numerical Problems

16.1

A charge of 25 coulombs passes through a circuit in 10 seconds. Calculate the current flowing through the circuit.

Given: $Q = 25\ C$, $t = 10\ s$

$$I = Q/t = 25\ C / 10\ s = 2.5\ A$$

Result: The current is 2.5 A.

16.2

Three resistors of 4 Ω, 6 Ω, and 8 Ω are connected in series to a 24 V battery. Find the total resistance and the current flowing through the circuit.

Given: $R1 = 4\ \Omega$, $R2 = 6\ \Omega$, $R3 = 8\ \Omega$, $V = 24\ V$ (series)

$$R\_total = R1 + R2 + R3 = 4 + 6 + 8 = 18\ \Omega$$

$$I = V / R\_total = 24\ V / 18\ \Omega = 1.33\ A$$

Result: Total resistance is 18 Ω and current is 1.33 A.

16.3

Two resistors of 10 Ω and 30 Ω are connected in parallel across a 20 V power supply. Calculate the total resistance and the current drawn from the power supply.

Given: $R1 = 10\ \Omega$, $R2 = 30\ \Omega$, $V = 20\ V$ (parallel)

$$1/R\_total = 1/R1 + 1/R2 = 1/10 + 1/30 = 4/30 \Rightarrow R\_total = 7.5\ \Omega$$

$$I = V / R\_total = 20\ V / 7.5\ \Omega = 2.67\ A$$

Result: Total resistance is 7.5 Ω and current is 2.67 A.

16.4

Four 1.5 V batteries are connected in series in a flashlight. Determine the total electromotive force (e.m.f.) supplied to the circuit.

Given: $n = 4$ batteries, $E = 1.5\ V$ each (series)

$$E\_total = E1 + E2 + E3 + E4 = 1.5 + 1.5 + 1.5 + 1.5 = 6\ V$$

Result: Total e.m.f. is 6 V.

16.5

A circuit has a 5 A current passing through a 7 Ω resistor. Calculate the power dissipated in the resistor and the energy consumed in 10 minutes.

Given: $I = 5\ A$, $R = 7\ \Omega$, $t = 10\ min = 600\ s$

$$P = I^2R = (5A)^2 \times 7\Omega = 25 \times 7 = 175\ W$$

$$E = P \times t = 175\ W \times 600\ s = 105{,}000\ J = 105\ kJ$$

Result: Power dissipated is 175 W and energy consumed is 105 kJ.

Important Questions of Board Examination

(i) Define and explain conventional current.

(ii) How can you differentiate between e.m.f and potential difference?

(iii) State and explain Ohm's law.

(iv) What is meant by resistance of a conductor? Define its measuring unit. Also explain the factors upon which the resistance of a conductor depends.

(v) Define specific resistance and prove that $R = \rho L/A$. (Also asked as: derive the relation between resistance R and specific resistance ρ of a wire of length L and cross-sectional area A / write a note on specific resistance / describe the factors on which resistance of a wire depends and define specific resistance / define specific resistance and prove that $\rho = RA/L$)

(vi) Define Joule's law. Derive its equation.

(vii) What is difference between D.C and A.C?

(viii) Determine equivalent resistance of series combination of resistors. (OR write down characteristics of series combination of resistors.)

(ix) Determine equivalent resistance of parallel combination of resistors. (OR write down characteristics of parallel combination of resistors.)

(x) Define electric power and its units. Derive its equation and prove that $P = I^2R$.

(xi) How is cost of electricity consumed calculated?

(xii) Describe briefly the hazards of household electricity.

(xiii) Describe safe use of electricity in homes. (OR describe four safety measures that should be taken in connection with the household circuit.)

Important Short Questions of Board Examination

(i) Define electric current and its SI units.

(ii) Differentiate between electronic and conventional current.

(iii) Differentiate between D.C. and A.C.

(iv) Differentiate between e.m.f and P.D.

(v) State Ohm's law. Write mathematical equation.

(vi) Define resistance of a conductor.

(vii) Define resistivity and its SI units.

(viii) What is the effect of temperature upon resistance of a conductor and insulator.

(ix) State two applications of NTC thermistors.

(x) State two applications of LDR.

(xi) Define electric power and its SI units.

(xii) State Joule's law.

(xiii) Define kilowatt hour and show that 1 kWh = 3.6 MJ.

(xiv) Why domestic supplies are connected in parallel?

(xv) Explain the purpose and function of an ammeter in an electrical circuit.

(xvi) How a voltmeter is used to measure the voltage in a circuit.