CHAPTER 16

Electricity

Student's Learning Outcomes (SLOs)

After studying this chapter, students will be able to:

- define and calculate electric current, using the equation; $I = Q/t$
- explain electrical conduction in metals in terms of the movement of free electrons.
- state that current is measured in amperes and that one ampere is equal to one coulomb per second (Cs^{-1}).
- differentiate between direct current D.C and alternating current A.C.
- differentiate between conventional and electronic current.
- justify and illustrate the use of ammeters (analogue and digital) with different ranges.
- define e.m.f. as the electrical work done by a source in moving a unit charge around a complete circuit, using the equation; E = W/Q.
- define potential difference (p.d.) as the work done by a unit charge passing through a component, using the equation; V = W/Q.
- state that e.m.f. and p.d. are measured in volts and that one volt is equal to one joule per coulomb (JC^{-1}).
- illustrate the use of voltmeters (analogue and digital) with different ranges.
- calculate the total e.m.f when multiple sources are arranged in series.
- state that the e.m.f of identical sources connected in parallel is equal to the e.m.f. of one of the sources.
- define and calculate resistivity, explaining its direct proportionality to resistance and length, and inverse proportionality to cross-sectional area.
- define and apply Ohm's law using the equation; R = V/I.
- describe the effect of temperature increase on the resistance of a resistor, such as in a filament lamp.
- draw circuit diagrams using components such as cells, batteries, power supplies, generators, switches, resistors, thermistors (NTC, light-dependent resistors (LDRs), lamps, motors, ammeters, voltmeters, transformers, fuses, relays, diodes, and LEDs.
- calculate the combined resistance of resistors in series.
- calculate the combined resistance of resistors In parallel.
- calculate current, voltage, and resistance in parts of a circuit or the whole circuit.
- describe the action of negative temperature coefficient (NTC) thermistors and light-dependent resistors (LDRs) and their use as Input sensors.
- analyze the function of variable potential dividers in circuits, using the equation; $R_1/R_2 = V_1/V_2$.
- justify and illustrate the use of colour codes for resistors.
- use the equation; power = current × voltage (P = IV) to solve simple problems.
- use the equation energy = current × voltage × (multiply) time (E = IVt) to solve simple problems.

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- define the kilowatt-hour (kWh).
- explain the need to choose components with suitable power ratings.
- calculate the cost of using electrical appliances where the energy unit is the kWh.
- explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings.
- explain what happens when a live wire touches a metal case that is earthed.
- explain why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed.
- state that a mains circuit consists of a live wire (line wire), a neutral wire, and an earth wire.
- explain why fuses and circuit breakers are connected into the live wire for the circuit to be switched OFF safely.
- explain why domestic supplies are connected in parallel.

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q.1: What do you know about electricity?

Ans. Electricity is a branch of physics which deals with the flow of charges. The movement of charges results in the flow of electric current which plays an important role in our daily lives. The electricity illuminates our homes, fuels our industries, and connects us across vast distances.

16.1 Electric Current

Q.2: What is electric current? How electric current is different from conventional current?

Ans. Electric current: Amount of charge passing through any cross section of a conductor per unit time is called electric current.

Explanation: In an atom, the electrons and positively charged nucleus are held together by strong force. However, some of electrons can move freely as these 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). This flow of charges is called an electric current. The electric current can be caused due to movement of both positive and negative charges.

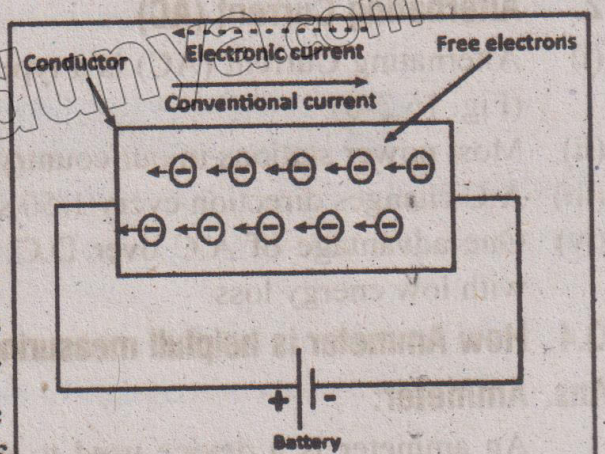


Fig 16.1: Flow of electrons in a circuit

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

$$I = \frac{Q}{t} \quad \text{.....(16.1)}$$

Unit: The SI unit of electric current is ampere (A).

Ampere: One ampere is defined as the flow of one coulomb of electric charge per second, which can be written as; $1\ A = 1\ C\ s^{-1}$.

Conventional Current:

Before the discovery of electrons, the electric current was considered to be due to flow of positive charges, named as Conventional Current. These charges move from positive terminal to the negative terminal of the power source. Later, after the discovery of electrons, the electric current was described due to the movement of electrons which was named as electronic current. The movement of electrons in one direction corresponds to the movement of positive charges in opposite direction. Despite this difference, both concepts are used in practice, with conventional current being the standard in circuit analysis.

Q3. Write the types of electric current.

Ans. Types of Electric Current:

1. Direct Current (DC)
2. Alternating Current (AC)

1. Direct Current (DC)

(i) Direct Current (DC) is an electrical current where the electric charge flows in one direction only (Fig. 16.2-a).

(ii) In a D.C circuit, the voltage remains constant over time, and the strength of the current does not change.

(iii) The current provided by a battery is an example of direct current.

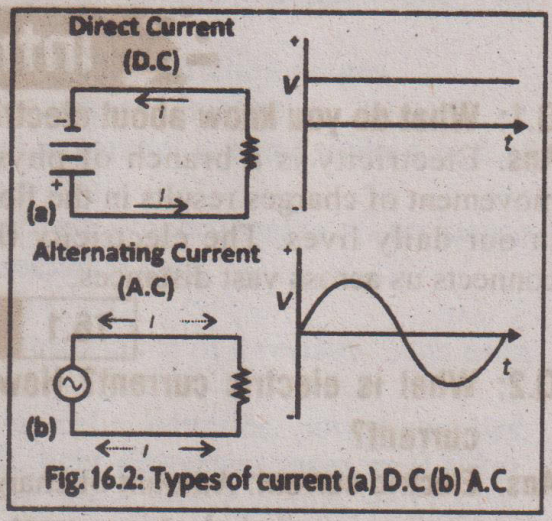


Fig. 16.2: Types of current (a) D.C (b) A.C

2. Alternating Current (AC)

(i) Alternating Current (AC) is a type of current that periodically reverses its direction (Fig. 16.2-b).

(ii) Most power stations in our country produce alternating current.

(iii) A.C changes direction every 1/50 second, and its frequency is 50 hertz (Hz).

(iv) One advantage of A.C over D.C is that it can be transmitted over long distances with low energy loss.

Q.4: How Ammeter is helpfull measuring the electric current? Also write its types.

Ans. 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.

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Types of Ammeters:

There are two main types of ammeters:

i. analogue ammeters ii. digital ammeters

Both types are available in different current ranges to measure both small and large currents. In Fig. 16.3, we can see the digital ammeter (left) and analog ammeter (right) side by side, illustrating the difference in display type and range options. Both types are connected in series with the load to measure current, but the display method and ease of reading differ significantly.



Fig. 16.3: Comparison of digital and analogue ammeters

i. Analogue Ammeter:

An 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, and the correct range must be selected depending on the expected current. Analogue ammeters typically have multiple selectable ranges, such as 0-100mA, 0-10A, etc. The correct range must be selected to avoid damage to the device and to ensure accurate readings.

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

ii. Digital Ammeter:

A digital ammeter provides a numerical reading of the current on a digital display. It offers more precision compared to an analog ammeter. Digital ammeters also come with various ranges, and some automatically adjust the range depending on the detected current. They are typically more accurate and easier to read than analog meters. Digital ammeters are widely used in scientific, industrial, and electrical applications where precise measurements are critical.

Range Selection: Ammeters are equipped with multiple ranges to accommodate different magnitudes of current. Selecting the correct range is important to ensure that ammeter is not damaged and to provide an accurate measurement. Low-range ammeters (e.g. 0-1 A) are used to measure small currents, typically in laboratory experiments.

High-range ammeters (e.g. 0-10 A) are used to measure larger currents, such as those in power systems or industrial circuits.

16.2 Electromotive Force and Potential Difference

Q.5: How (EMF) electromotive force and potential difference (P.D) are interrelated?

Ans. Electromotive force (e.m.f.) and potential difference (p.d.) are two important concepts, both measured in volts (V).

Volt: One volt is defined as one joule of energy per coulomb of charge ($1\ V = 1J\ C^{-1}$).

Joule: 1 joule of energy is used to move 1 coulomb of charge, the voltage is 1 volt.

Electromotive Force (e.m.f):

Electromotive force is energy supplied by a battery to a unit positive charge when it

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flows through the closed circuit.

Formula:

Mathematically;

$$e.m.f = \frac{Energy}{Charge} \quad \text{..... (16.2)}$$

$$\text{or} \quad E = \frac{W}{Q} \quad \text{..... (16.3)}$$

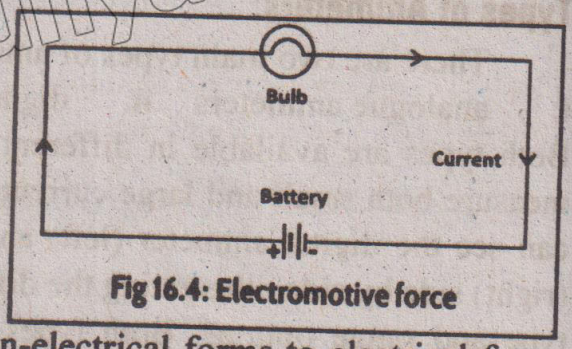


Fig 16.4: Electromotive force

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

Measurement:

Emf of battery can be measured directly by connecting its terminal to a voltmeter as shown in Fig.

Explanation: A source of electromotive force (e.m.f.) converts non-electrical energy, like chemical, thermal, or mechanical energy, into electrical energy. Examples of such sources include batteries (which convert chemical energy), thermocouples (which convert thermal energy), and generators (which convert mechanical energy). 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 the positive terminal through the conductor to the negative terminal (Fig. 16.4). Once the charge reaches the negative terminal (lower potential), the battery does work to push it back to the positive terminal (higher potential). This cycle keeps the current flowing continuously. In short, the e.m.f. supplies the energy needed to keep the charges in motion.

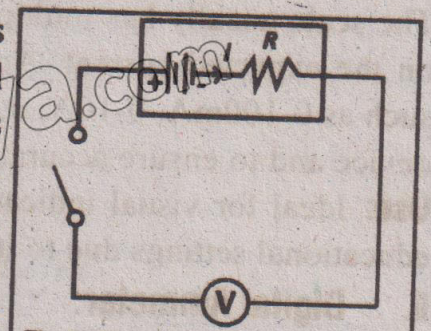


Fig 16.5: Schematic diagram for measuring e.m.f of the battery

Potential Difference:

The potential difference is the difference in the values of electric potential between two points in the electric field.

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

Formula: i.e; $$V = \frac{W}{Q} \quad \text{.....(16.4)}$$

Unit: The unit of electric potential is volt (V). One volt is equals to one joule per coulomb ($V = J\,C^{-1}$).

Voltage: Potential difference is also called voltage which is the energy used by a component in the circuit. Voltage can also be referred to e.m.f. which is the energy supplied by a source like a battery. Both potential difference and e.m.f. are measured in volts.

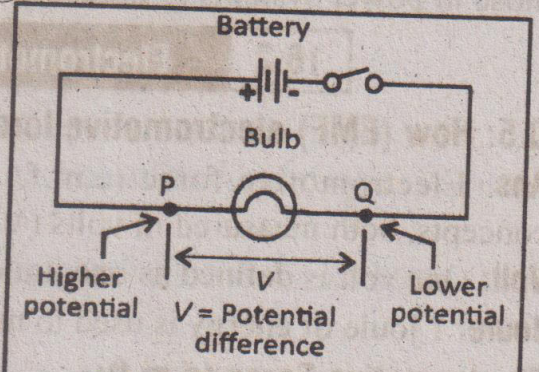


Fig. 16.7: Types of voltmeters

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Potential Difference:

A battery converts chemical energy into electrical energy. Inside the battery, a chemical reaction causes a buildup of electrons at the negative terminal and a shortage of electrons at the positive terminal. This imbalance creates a potential difference between the terminals, which allows electrons to flow through a connected circuit, generating an electric current. The battery continues to drive this flow as long as the chemical reaction is active, providing a steady supply of energy. In short, the chemical action inside the battery creates a potential difference that allows the current in the circuit.

Q.6: How potential difference is measured?

Ans. Voltmeter:

Voltage can be measured using a device called voltmeter.

Types:

Voltmeter can also be of two types.

1. Analogue 2. Digital

Both types are available with different ranges, allowing them to measure voltages of varying magnitudes.

Analogue Voltmeters:

Analogue voltmeters use a needle and a scale to display the voltage, making them useful for observing changes or trends over time.

Digital voltmeters:

Digital voltmeters, on the other hand, show the voltage as a numerical value on a screen, offering greater precision and ease of reading.

Low range and high range voltmeters:

A low-range voltmeter might measure millivolts (mV), while a high-range voltmeter could measure hundreds or even thousands of volts. Choosing the right range is important, using a low-range voltmeter for a high voltage could damage the device, while using a high-range voltmeter for a small voltage, might not provide accurate readings. Analogue and digital voltmeters are shown in Fig. 16.7.

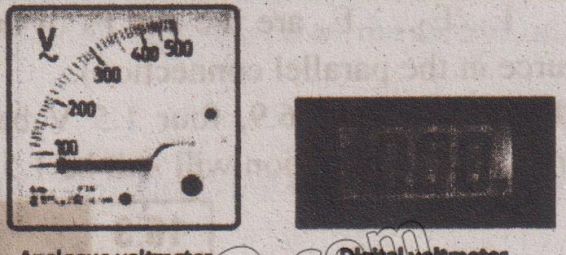


Fig. 16.7: Types of voltmeters

Q.7: How e.m.f is calculated in series connected sources?

Ans. Total e.m.f. of Series Connected Sources:

When multiple voltage sources (e.g., batteries) are connected in series (Fig. 16.8), their total electromotive force (e.m.f.) is simply the sum of their individual e.m.f. This is because the voltage sources add energy to the charges one after the other.

Formula:

$$E_{total} = E_1 + E_2 + ... + E_n$$

where

E_{total} = total e.m.f

E_1, E_2, ..., E_n = e.m.f of the individual sources

Example: If four batteries, each with an e.m.f of 1.5 V (Fig. 16.8), are connected in series, the total e.m.f would be 6 V.

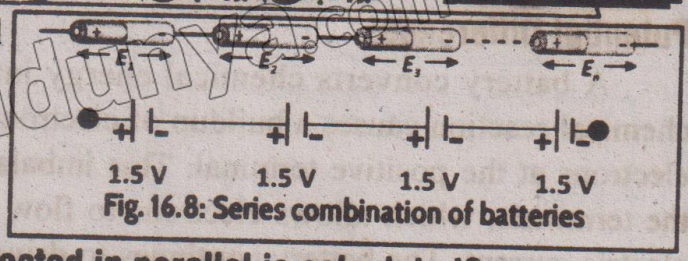


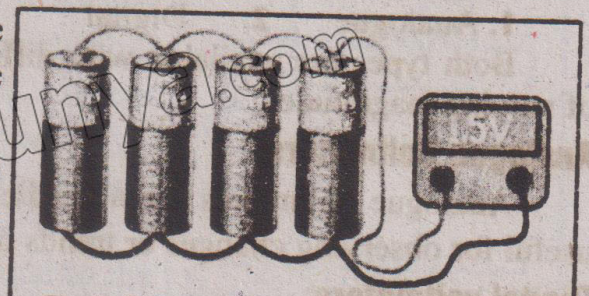
Fig. 16.8: Series combination of batteries

Q.8: How e.m.f. of identical sources connected in parallel is calculated?

Ans. e.m.f of Identical Sources Connected In Parallel:

When multiple identical sources (such as batteries with the same voltage) are connected in parallel (Fig. 16.9), 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.

Explanation: In a parallel connection, each source contributes current independently while maintaining the same voltage across each of them. This results in the total e.m.f. remaining equal to the e.m.f. of one of the individual sources, but the total current becomes the sum of the individual currents provided by each source.


Fig. 16.9: Four 1.5 V batteries connected in parallel

Formula: For identical sources in parallel:

$$E_{total} = E_1 = E_2 = ... = E_n$$

where

E_{total} is the total e.m.f. across the parallel sources.

E_1, E_2,..., E_n are the e.m.f's of the individual sources (which are identical for each source in the parallel connection).

Example: In Fig. 16.9, four 1.5 V batteries are connected in parallel. The total e.m.f. across the combination will still be 1.5 V, just as it is for a single battery.

16.3 Ohm's Law

Q.9: State and explain Ohm's Law.

Ans. Ohm's Law:

Statements:

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

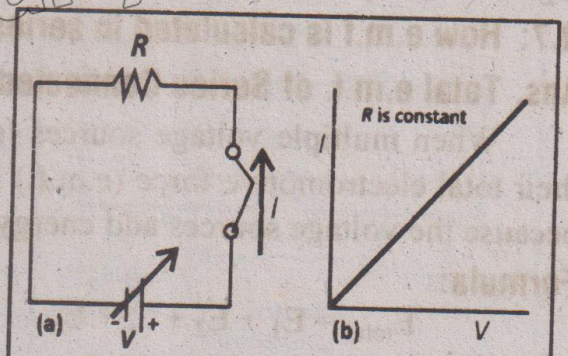


Figure 16.10 (a) Ohm's law circuit (b) I-V graph ohmic conductor

Explanation: In 1826, George Simon Ohm made an investigation of the relationship between electric

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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.

Formula: Mathematically;

$$I \propto V$$

$$I = \frac{1}{R} V$$

$$V = IR \quad \text{.....(16.5)}$$

where R is constant of proportionality called resistance of a conductor.

Unit: The SI unit of resistance is ohm (Ω) and $1\ \Omega = 1 V\ A^{-1}$.

16.4 Combination of Resistances

Q.10: Determine the equivalent resistance of series combination.

Ans. Combination of resistances:

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.

Series Combination of Resistors:

When resistors are connected in such a way that there is only one path for the current to flow, then it is called series combination of resistors. Consider three resistors R_1, R_2 and R_3 connected in series as shown in Fig. 16.11.

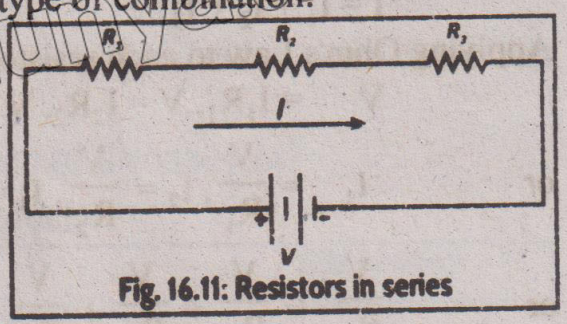


Fig. 16.11: Resistors in series

Current in series combination:

When this combination is connected to a battery of V volts, it draws current I from the battery. Let R_e be a single resistor representing the total resistance of the circuit, also called equivalent resistance.

Voltage in series combination:

The total voltage in the circuit will be the sum of voltage across the three resistors.

i.e; $V = V_1 + V_2 + V_3$

Applying Ohm's Law to each resistor, we have

$V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$

or $IR_e = IR_1 + IR_2 + IR_3$

$IR_e = I(R_1 + R_2 + R_3)$

$R_e = R_1 + R_2 + R_3$ .....(16.6)

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

Q.11: Determine the equivalent resistance of parallel combination.

Ans. Parallel Combination of Resistors:

When there are multiple paths for current flow in a circuit (as indicated in the diagram), the combination of resistances is referred to as parallel combination.

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Potential difference: The electric potential across each resistance is the same and equal to the applied potential. Each resistor has a steady current flowing through it.

Consider three resistors R_1, R_2 and R_3 connected in parallel (Fig. 16.12).

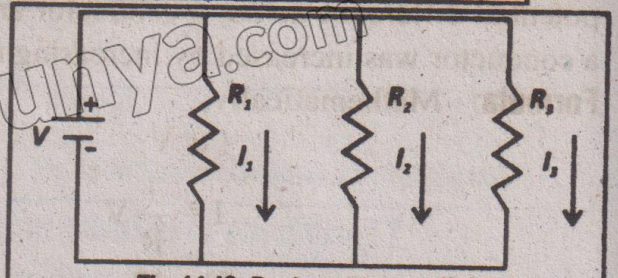


Fig. 16.12: Resistors in parallel

Equivalent resistance: When these are connected to a battery of V volts, it draws a current I from the battery. R_e is a single resistor. This resistor is such that when it is connected to the same battery of V volts, it also draws current I from the battery. This resistor is therefore called equivalent resistor and its resistance is called equivalent resistance.

Total current in parallel combination:

The total current in the circuit will be the sum of currents flowing through the resistors;

$$I = I_1 + I_2 + I_3$$

Applying Ohm's Law to each resistor, we have

$$V = I_1R_1,\ V = I_2R_2,\ V = I_3R_3$$

or $$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$$

or $$\frac{V}{R_e} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

or $$\frac{V}{R_e} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \text{.....(16.7)}$$

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

16.5 Electrical Resistivity

Q.12: Define resistance. Also explain electrical resistivity.

Ans. Resistance:

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

Mathematical expression: The resistance is directly proportional to the length of the conductor and inversely proportional to its area. If A is the area and R is the resistance of a conductor (Fig. 16.13), then mathematically we can write it as:

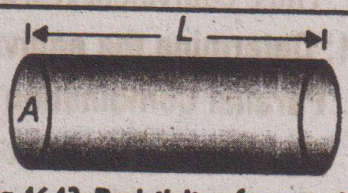


Fig. 16.13: Resistivity of a material

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$$R \propto L \text{ or } R \propto \frac{1}{A}$$

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

$$R = \rho \frac{L}{A} \quad \text{.....(16.8)}$$

Table 16.1

Material	Electrical resistivity ($10^{-8}\ \Omega$ m)
Silver	1.7
Copper	1.69
Aluminium	2.75
Tungsten	5.25
Platinum	10.6
Iron	9.8
Nuchrome	100
Graphite	3500

Electrical Resistivity: "Resistance of a cubic metre of a material is called resistivity."
Here, ρ is a constant called electrical resistivity of a material which quantifies how strongly a material resist to electric current.

Formula:

$$\rho = \frac{RA}{L}$$

Unit: SI unit of resistivity is the ohm-metre (Ω m).

Note: Materials with heigh resistivity are poor conductors of electricity, while those with low resistivity are good conductors.

Q.13: Explain the effect of temperature on resistance of a conductor?

Ans. Effect of Temperature on Resistance of a Conductor:

The resistance and the resistivity of a conductor can change with temperature. In most conductors such as metals, the electrical resistance increases with temperature because atomic vibrations resist electron flow.

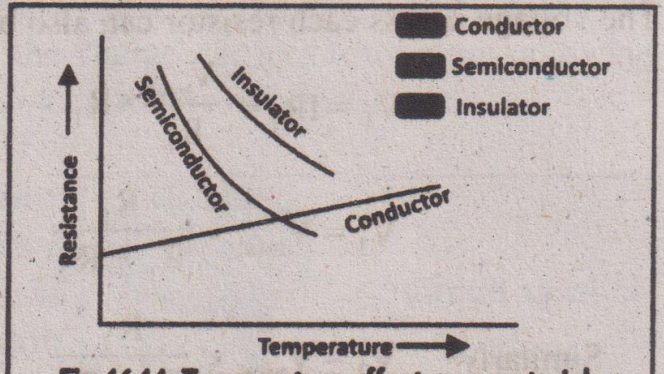


Fig. 16.14: Temperature effect on a materials

Example: For example, in a filament lamp, when the temperature of the filament (resistor) increases, its resistance also increases. This occurs because the filament is made of metal, and metals have free electrons that causes the flow of electric current. The increase in the temperature of a resistor increases the vibration of its atoms. These vibrations make it harder for the electrons to move. As a result, the flow of current becomes more difficult, and the resistance goes up. So, a hot filament has more resistance than a cold one.

Semiconductors and Insulators:

In the case of semiconductors and insulators, resistance may decrease with temperature due to increase in the mobility of free charge carriers.

Example: For example, thermistor, which is made up of a semiconductor material, is a type of resistor whose resistance decreases as its temperature increases. At low temperatures, the semiconductor material has fewer free charge carriers (electrons or holes), resulting in high resistance. As the temperature rises, more charge carriers are

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released, increasing conductivity and reducing resistance. Due to change in resistance, the resistivity also changes accordingly. The effect of temperature on resistance of different materials is graphically shown in Fig.16.14.

16.6 Potential Divider Circuit

Q.14: How potential divider circuit work? Explain.

Ans. Potential divider circuit: 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 (Fig. 16.15). The voltage across each resistor is proportional to its resistance relative to the total resistance of the circuit.

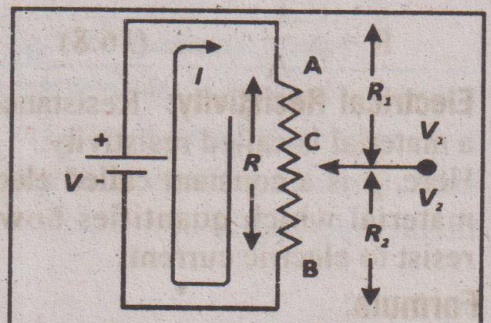


Fig. 16.15: Potential divider circuit

Mathematical expression:

Consider two resistors R_1 and R_2 connected in series. The voltage across each resistor is given by

$$\frac{R_1}{R_2} = \frac{V_1}{V_2} \quad \text{.....(16.9)}$$

where V_1 = voltage across R_1

and V_2 = voltage across R_2

The total voltage (V_{total}) is the sum of V_1 and V_2:

$$V_{total} = V_1 + V_2 \quad \text{.....(16.10)}$$

The voltage across each resistor can also be calculated using the formulae:

$$V_1 = IR_1 = \frac{V_{total}}{R_e} \times R_1$$

$$V_1 = V_{total} \times \frac{R_1}{R_1 + R_2} \quad \text{.....(16.11)}$$

Similarly $$V_2 = V_{total} \times \frac{R_2}{R_1 + R_2} \quad \text{.....(16.12)}$$

16.7 Resistor Colour Codes

Q.15: What is resistor colour codes. How it is work?

Ans. Resistor colour codes:

The resistor colour codes is a system of coloured bands printed on resistors to indicate their resistance value and tolerance (Fig.16.16). Tolerance means how much a resistor's real value can be different from the value written on it. In this way, resistor's values can be identified without using multimeter. Each colour

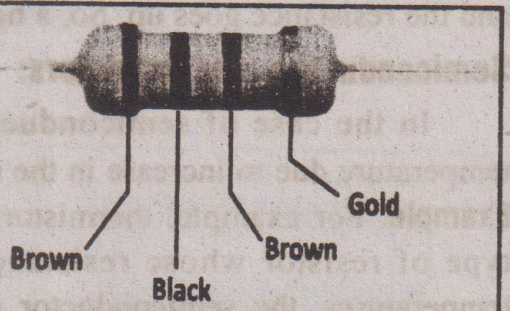


Fig. 16.16: 100-ohm resistor colour codes

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represents a specific digit and multiplier. In a four band resistor, the first and second bands indicate 1st and 2nd digit, the 3rd and 4th bands show 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), gold shows tolerance (±5 %). The final value of resistance is 270,000 Ω or 270 kΩ. The standard resistor colour codes are given in Table 16.2.

Table 16.2: Standard resistor colour codes

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}	± 05 %
Sliver	-	10^{-1}	± 10 %
Colourless	-	-	± 20 %

Q.16: What is negative temperature coefficient (NTC) thermistors? Write its actions and applications.

Ans. Negative Temperature Coefficient (NTC) Thermistors:

A Negative Temperature Coefficient thermistor (NTC) and its circuit diagram is shown in Fig. 16.17. It is a type of resistor whose resistance decreases as the temperature increases. This behaviour is due to the negative temperature coefficient, meaning that the material used in the thermistor conducts electricity better as the temperature rises. 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.

Action and Use:

As the temperature increases, the resistance of the NTC thermistor decreases. This makes it useful for applications where changes in temperature need to be detected. NTC thermistors are commonly used in temperature-sensing circuits, such as those found in electronic devices (e.g., thermometers, temperature monitoring circuits, and temperature compensation in circuits).

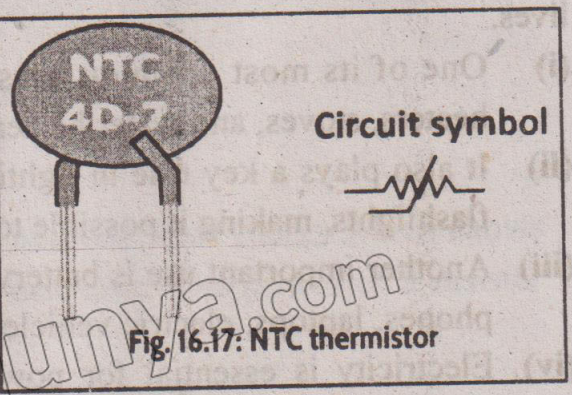


Fig. 16.17: NTC thermistor

Applications:

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

Q.17: How light dependent resistors (LDRs) works? Write its action and applications.

Ans. Light-Dependent Resistors (LDRs)

A circuit diagram of a light dependent resistor (LDR) is shown in Fig. 16.18. It is a

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type of resistor whose resistance decreases as the intensity of light increases. 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, which excites electrons, allowing them to move more freely and thus reduces the resistance.

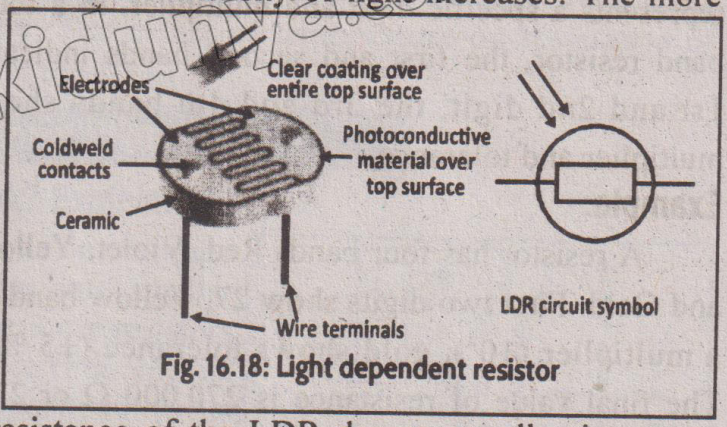


Fig. 16.18: Light dependent resistor

Action and Use:

As light intensity increases, the resistance of the LDR decreases, allowing more current to pass through. LDRs are widely used in light-sensing circuits, where changes in light intensity are monitored. They are commonly used in automatic lighting systems, brightness sensors in cameras, and other applications where light level detection is needed.

Applications:

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

16.8 Common Use of Electricity

Q.18: Write some common uses of electricity.

Ans. Common Use of Electricity:

Electricity is one of the most versatile forms of energy that is used in our daily lives.

(i) One of its most common uses is heating, where it powers devices like electric heaters, stoves, and water heaters to keep us warm and cook our food.

(ii) It also plays a key role in lighting, from the bulbs in our homes to streetlights and flashlights, making it possible to see and work even after dark.

(iii) Another important use is battery charging, as electricity powers the chargers for our phones, laptops, electric vehicles, and other portable devices.

(iv) Electricity is essential for powering motors, which are found in appliances like washing machines, refrigerators, and industrial machinery, as well as in electric cars and trains.

(v) Electricity is the backbone of electronic systems, running computers, televisions, smartphones, and other gadgets that keep us connected and entertained.

Conclusion:

In short, electricity is everywhere, making our lives easier, safer, and more efficient.

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Q.19: What is electric power?

Ans. Electric power:

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

Formula:

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

As $P = IV$ .....(16.13)

$V = IR$

So $P = I^2R$

or $P = V^2/R$ .....(16.14)

Unit:

It measures how quickly work is done or energy is used. The SI unit of power is watt (W).

$$P = w/t$$

$$1\ W = J\ s^{-1}$$

Q.20: State Joule's Law and derive its formula.

Ans. Joule's Law

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

"The heat energy produced in a resistance is equal to the product of square of the current, resistance and time."

Formula:

Mathematically; $H = I^2Rt$

or $H = P \times t$ ..... (16.15)

Total heat energy(H):

This is the relationship between electric power P and total heat energy which shows that the total heat energy H is the product of power and time. The power of a resistor determines how quickly heat is produced.

Example:

For example, a 100 W electric bulb produces heat at a rate of 100 joules per second. The total heat energy depends on how long the electric bulb operates.

For instance, if the 100 W electric bulb runs for 10 seconds, the total heat energy produced is:

$$H = P \times t = 100\ W \times 10\ s = 1{,}000\ J$$

Kilowatt-hour:

Electrical energy is commonly consumed in very large quantity. The unit which is used to measure large amount of electrical energy is called kilowatt-hour. It is defined as:

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

One kilowatt-hour (1kWh) = 1,000 W × 1 hour ..... (16.16)

= 1,000 W × (3600 s)

= 3.6×10^6 J = 3.6 MJ

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

$$\text{The amount of electrical energy in kilowatt-hour} = \frac{\text{Power in watts} \times \text{time of use in hours}}{1{,}000}$$

Electric meter:

The electric meter installed in our houses measures the consumption of electrical energy in the units of kilowatt-hour according to which we pay our electricity bills. If the cost of one kilowatt-hour i.e., one unit is known, we can calculate the amount of electricity bill by the formula:

Cost of electricity = Number of units consumed × Cost of one unit

$$= \frac{\text{Power in watts} \times \text{time of use in hours}}{1{,}000} \times \text{Cost of one unit}$$

Importance:

When designing circuits, it is important to choose components with suitable power ratings. Selecting components with the right power ratings ensures safety, reliability, and efficiency.

16.10 Household Circuits and Safety Measures

Q.21: What do you know about Household Circuits and hazards of electricity?

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

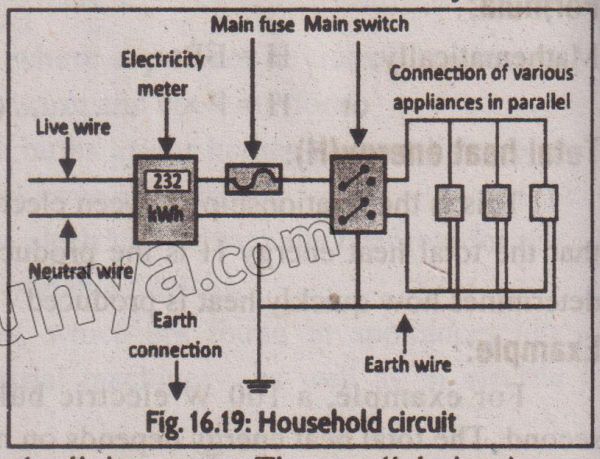


Fig. 16.19: Household circuit

Household Circuits:

In a parallel circuit, every appliance like our refrigerator, bulbs, or TV gets its own direct connection to the power supply. In the parallel circuits, each appliance works independently. We can turn OFF the lights in the kitchen without shutting down the TV in the living room. The parallel circuits are safer and more reliable. If one appliance breaks or a fuse blows, the rest of our home's power stays ON. In short, connecting our home's electrical system in parallel is like giving every appliance its own superpower consistent voltage, independent operation, and reliable performance. It is the smartest way to keep our home running smoothly and efficiently. Figure. 16.19 demonstrates a household circuit.

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Hazards of Electricity:

Common electric hazards occur due to:

1. **Malpractice:**

Malpractice (incorrect use) or lack of maintenance, and they can lead to serious accidents like shocks, fires, or even fatalities.

2. **Damaged Insulation:**

One major hazard is damaged insulation, where the protective covering on wires wears out or gets cut, and exposing live wires. This can cause electric shocks or short circuits.

3. **Overheating:**

Another danger is overheating cables, which happens when wires carry more current than they are designed for, causing them to heat up and potentially start a fire.

4. **Overloading:**

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

Q.22: What safety measures can be taken to prevent Hazards of electricity?

Ans. Fuses and trip switches (circuit breakers) are essential safety devices to avoid these hazards. Fuses contain a thin wire that melts due to flow of high current. As a result, breaking of the circuit stops the flow of electricity. Different types of fuses are shown in Fig. 16.20. Trip switches, on the other hand, automatically cut OFF power when they detect a fault, like an overload or short circuit (Fig. 16.21). Both devices are connected to the live wire of the circuit, ensuring that 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.

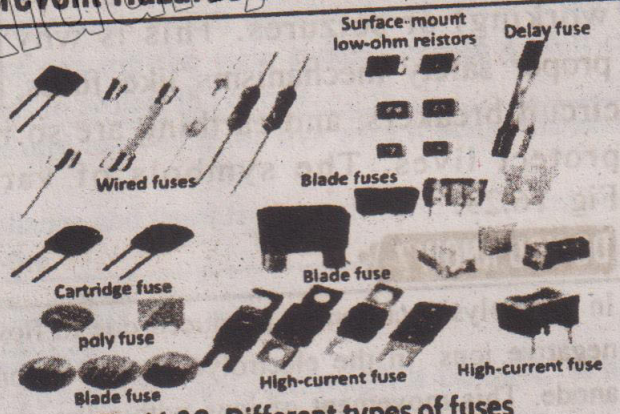


Fig. 16.20: Different types of fuses


Fig. 16.21: A trip switch

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 casings made of plastic, which cannot conduct electricity. Appliances with metal casings, like washing machines, are connected to the earth wire for safety.

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Main Circuit Wires:

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; and the earth wire, which provides a safety path for fault currents (Fig. 16.22).

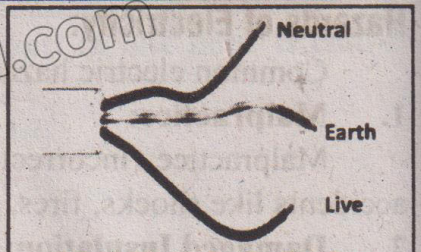


Fig. 16.22: Main circuit wires

Hazards of Electricity:

Despite these safety measures, electric shocks can still occur, and they 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 (where the heart and lungs stop working) or seizures. This is why proper safety mechanisms like fuses, circuit breakers, and earthing are so important which help to prevent accidents and protect lives. The symbols of various electrical components are shown in Fig. 16.23.

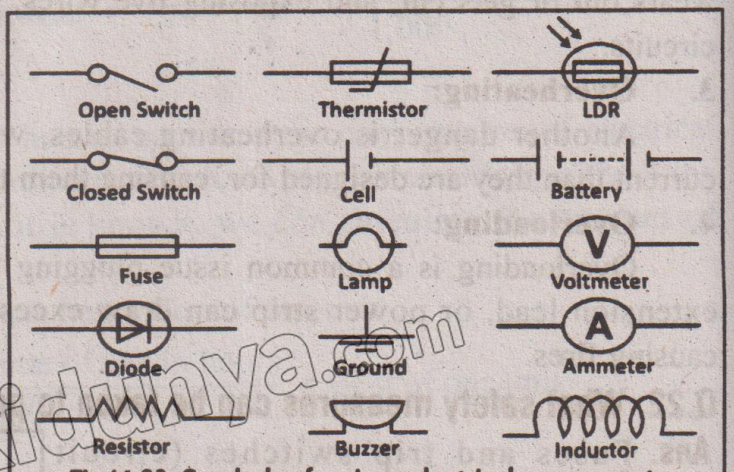
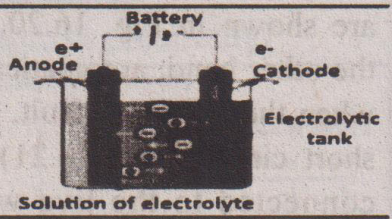
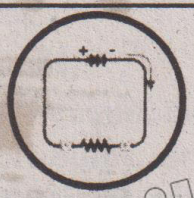


Fig.16.23: Symbols of various electrical components

DO YOU KNOW?

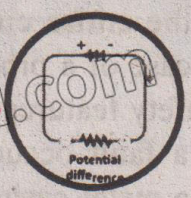
In electrolysis, current is produced due to flow of both positive and negative ions. In the electrolyte, negative ions are attracted to the anode. This movement of ions within the electrolyte constitutes an electric current within the internal circuit.





EMF

The electromotive force is the types of energy which forces a unit positive charge to move from the positive to the negative terminal of the source. It separates the two charges from each other.



VOLTAGE

Voltage is the difference in electric potential between two points. The voltage between two points is equal to the work done per unit of charge against a static electric field to move a test charge between two points.

Tidbits

In any circuit, electic current prefers the path of least resistance, just like water flowing downhill.

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

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

Brain Teaser

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

Ans. When identical cells are connected in parallel, the total e.m.f of the combination remains same as the e.m.f of single cell.
Since each cell has an emf of 5 volts, then total emf of combination. Will also be 5 volt.

2. If two appliances are rated 100W and 1000W, both used for 1 hour. Do they consume equal energy or different? Why?

Ans. They consume different energy, the 1000W appliance consumes 10 time more energy than 100W appliance. The reason for this behavior is because electric energy consumption depends on Power × time.
For 100 W ; E = 100W × 1 hour = 100 Wh
For 100 W ; E = 1000W × 1 hour = 1000 Wh

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

Ans. A tiny device like a smartphone charger can trip the main switch because the problem is not its size, but the fault it creates. Even a small device can trip the main switch because a fault can cause heavy current and the safety system responds to protect the circuit.

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

Ans. If the live wire touches the metal body of an appliance and there is no earth wire, the metal body becomes live, posing a risk of electric shock and fire.

Examples

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?

Solution:

Given that; W= 120J, Q = 20C
To find; V = ?
Using the formula; V = W/ Q
Substituting the values; V = 120 J / 20 C = 6 V

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.

Solution:

Given that; $R_1 = 8\ \Omega$, $R_2 = 24\ \Omega$ and V = 30 V
To find; R_e = ? and I = ?
Using the formula for parallel resistance: $1/R_e = 1/R_1 + 1/R_2$
Substituting the values; $1/R_e = (1/8) + (1/24)$
$1/R_e = (3/24) + (1/24)$

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$1/R_e = 4/24$ or $R_e = 24/4 = 6\ \Omega$

Now, we calculate total current by using Ohm's Law:

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

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.**

Solution:

Given that; Resistivity $\rho = 2.82 \times 10^{-8}\ \Omega$ m

Length $L = 15$ m, $A = 3 \times 10^{-6}\ m^2$

To find;

Resistance R = ?

Using the formula: $R = \rho (L/A)$

Substituting the values

$R = (2.82 \times 10^{-8}\ \Omega\ m) \times (15\ m / 3 \times 10^{-6}\ m^2)$

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

$R = 0.141\ \Omega$

The resistance of the wire is 0.141 Ω.

16.4 **Calculate the one-month cost of using a 100 W ceiling fan for 10 hours daily in your room. Assume that the price of one unit is Rs.25.**

Solution:

Given that; Power $P = 100\ W = 0.1\ kW$

Time $t = 10$ hour per day

Number of days = 30

Number of units consumed = Power × Time × Days

= 0.1 x 10 x 30 = 30 units

Total cost = Units consumed × Price per unit

= 30 × 25 = Rs. 750

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

16.1 Electric Current

1. **The electric current can be caused due to the movement of:**

   (a) Positive charges (b) Negative charges (c) Both a & b (d) None of these

2. **Amount of charge passing through any cross section of a conductor per unit time is called:**

   (a) power (b) electric current (c) voltage (d) work

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3. **Electric current is represented by:**
(a) i (b) V (c) I (d) A

4. **One amphere (1A) is also written as:**
(a) $1Cs^{-1}$ (b) $\frac{1}{2}Cs^{-1}$ (c) $-1A$ (d) $= ms^{-1}$

5. **The current was considered to be due to flow of only positive charges, named as:**
(a) Conventional current (b) Direct current
(c) Indirect current (d) Alternating current

6. **The movement of both positive and negative charges are called which current?**
(a) conventional current (b) electric current
(c) electronic current (d) both b and c

7. **Which current changes its direction?**
(a) direct current (b) alternating current
(c) conventional current (d) non-electronic current

8. **Which types of current is produced by Pakistan's Power Stations?**
(a) alternating current (b) direct current
(c) conventional current (d) electronic current

9. **In circuit, electric current refer which path to flow?**
(a) High resitance (b) median resitance (c) least resistance (d) none of these

16.2 Electromotive Force and Potential Difference

10. **SI unit for emf and potential difference is:**
(a) Watt (b) Joule (c) Ampere (d) Volt

11. **If 1 Joule of energy is used to move 1 coulomb of charges, the voltage is called:**
(a) 5 volt (b) 10 volt (c) 1 volt (d) 0.5 volt

12. **Thermocouples convert thermal energy into:**
(a) mehanical energy (b) electrical energy
(c) chemical energy (d) light energy

13. **e.m.f of a battery can be measured directly by the use of which meter?**
(a) Ammeter (b) Voltmeter (c) Galvanometer (d) none of these

14. **The energy used by a component in the circuit is called:**
(a) Voltage (b) Pontential difference
(c) Electrical potential (d) All of these

15. **In a series combination, what will be the effect on total e.m.f?**
(a) increased (b) decreased (c) not changed (d) moderate

16.3 Ohm's Law

16. **Ohm's Law presented by:**
(a) Newton (b) Alexander fleming
(c) George Simon (d) Ruther ford

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17. **The unit of R (restance of a conductor) is:**
(a) Ohm (b) Newton (c) Ampere (d) Volt

16.4 Combination of Resistances

18. **When there are multiple paths for current flow in a circuit, the combination of resistance is called:**
(a) parallel (b) series (c) both a & b (d) none of these

16.5 Electrical Resistivity

19. **The factor which effect the resistance is:**
(a) pressure (b) temperature (c) catalyist (d) all of these

16.6 Potential Divider Circuit

20. **A potential divider is a circuit that divides voltage into parts:**
(a) Bigger (b) Smaller (c) Moderate (d) Nano

16.7 Resistor Colour Codes

21. **The resistor colour codes is a system of coloured bands which indicates:**
(a) resistance (b) tolerance (c) both a & b (d) current
22. **As the temperatue increases, the resistance of NTC thermistor:**
(a) increase (b) unchaged (c) decrease (d) moderate
23. **LDR stands for:**
(a) Light dependent resistor (b) Light divider resistor
(c) Light drawn resistance (d) Light driver resultant

16.9 Electric Power

24. **The amount of energy delivered by a power of one Kilowatt in one hour is called:**
(a) One Kilowatt hour (b) Two Kilowatt hour
(c) One hundred Kilowatt hour (d) None of these
25. **The unit which is used to measure large amount of electric energy is:**
(a) Miliwatt-hour (b) Kilowatt-hour (c) Mili watt-sec (d) Kilowatt-min

16.10 Household Circuits and Safety Measures

26. **Which circuit is more rafer and reliable?**
(a) parallel (b) series (c) both a & b (d) none of these
27. **Which are the hazards of electricity?**
(a) Malpractice (b) Damage insulation
(c) Over heating (d) All of these
28. **Fuses and trip switches connected to which wire in a circuit?**
(a) Neutral (b) Earth (c) Live (d) All of these
29. **A typical main circuit consist of wires:**
(a) Two (b) Three (c) Four (d) Five

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30. **Which wire carry the curent from the power supply?**
(a) Neutral wire (b) Earth wire (c) Live wire (d) None of these

Answers

1.	(c)	2.	(b)	3.	(c)	4.	(a)	5.	(a)	6.	(b)	7.	(b)
8.	(a)	9.	(c)	10.	(d)	11.	(c)	12.	(b)	13.	(b)	14.	(d)
15.	(a)	16.	(c)	17.	(a)	18.	(a)	19.	(b)	20.	(b)	21.	(c)
22.	(c)	23.	(a)	24.	(a)	25.	(b)	26.	(a)	27.	(d)	28.	(c)
29.	(b)	30.	(c)										

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

16.1 Electric Current

1. What is electricity?

Ans. Electricity is a branch of physics which deals with the flow of charges. The movement of charges results in flow of electric current which illuminates our homes, fuels our industries and connects us across the world.

2. Define electric current.

Ans. Amount of charge passing through any cross section of a conductor per unit time is called electric current.

It is represented by I.

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

The SI unit of electric current is Ampere (A).

3. Differentiate between direct current and alternating current.

Ans.

Direct current	Alternating current
(i) Direct current is an electric current where the electric charge flows in one direction.	(i) Alternating current is a type of current that periodically reverse its direction.
(ii) In DC circuit, the voltage remains constant over time.	(ii) In AC circuit, the voltage changes polarity.
(iii) The frequency of DC is zero.	(iii) The frequency of AC is 50 hertz (Hz)

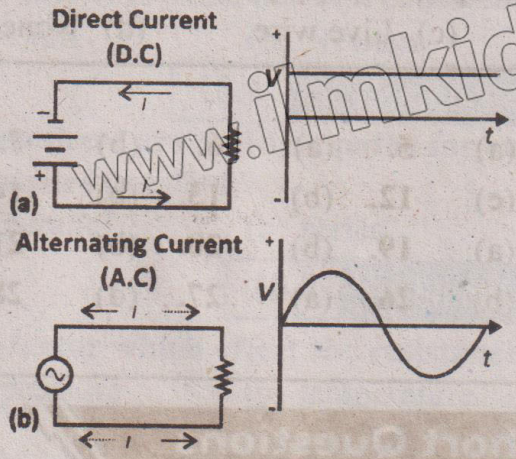
4. Write an advantages of AC over DC.

Ans. One advantage of A.C over D.C is that it can be transmitted over long distances with low energy loss.

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5. Draw figures which represent AC and DC. Direct current.

Ans.



6. What is the use of Ammeter?

Ans. Ammeter is a device used to measure the current flowing a circuit. It must be connected in series with the component whose current is to be measured.

7. Write the difference between analogue and digital Ammeter.

Ans.

Analogue Ammeter	Digital Ammeter
(i) An analogue ammeter uses a needle and scale to indicate the current.	(i) A digital Ammeter provides a numerical reading of the current an a display.
(ii) It is typically have multiple selectable ranges which are selected manually.	(ii) They also come with various ranges which are automatically adjust the range depending on elected current.

8. Why AC is more dangerous than DC?

Ans. Direct current (D.C) is a current that travels from negative to the positive terminal. It does not changes its direction. It is the current, we can get from a battery. DC passing our body cannot cause electric shock but can cause during if the positive and negative wires can come in contact.

16.2 Electromotive Force and Potential Difference

9. Define e.m.f.

Ans. Electromotive force is the energy supplied by a battery to a unit positive charge when it flows through the closed circuit. It is represented by E. It's unit is volt.

$$E = \frac{W}{Q}$$

10. Define potential difference (Electric potential).

Ans. Electric potential (V) is the amount of electric energy (W) per unit change (Q) at a specific point in a electric field.

It is represented by V. It's unit is Volt (V)

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

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11. What is the role of volt meter?

Ans. Voltage can be measured using a device called voltmeter. Voltmeter has two types:

(i) Analogue voltmeter (ii) Digital voltmeter

12. How analogue voltmeter is different from digital voltmeter?

Ans.

Analogue Voltmeter	*Digital Voltmeter*
Analogue voltmeter use a needle and a scale to display the voltage, making them useful for observing changes or tends over time.	*Digital voltmeter, show the voltage as a* numerical value on a screen, offering greater precision and ease of reading.

13. Why choosing right range voltmeter is important?

Ans. Choosing the right range is important using a low-range voltmeter, for a high voltage could damage the device, while using a high range voltmeter for a small voltage, might not provide accurate readings.

16.3 Ohm's Law

14. What is Ohm's Law?

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

$$I \propto V$$

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

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

$$\boxed{V = IR}$$

15. Why birds remaine safe while sitting on the electric wire?

Ans. Birds are safe because both their feet touch the same potential wire. there is no voltage difference, so no current flows through their bodies.

16.5 Electrical Resistivity

16. Define resistance.

Ans. The opposition to the flow of electric current is called resistance. Resitance is represented by R.

$$R \propto L, \quad R \propto \frac{1}{A}$$

Formula: $\boxed{R = \rho \frac{L}{A}}$

17. Why resistance increases in filament lamp while increases the temperature.

Ans. In filament lamp, when the temperature of the filament increases, its resistance also increases. This occurs because the filament is made of metal, and metals have free

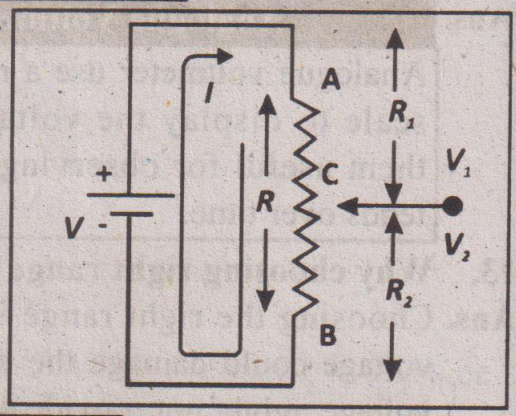
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electrons that causes the flow of electric current. While increase in temperature the vibration of atom also increases. These vibrations make hardel for the movement of electrons. As a result resistance increase.

16.6 Potential Divider Circuit

18. What do you know about potential divider circuit?

Ans. A potential 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.



16.7 Resistor Colour Codes

19. Write uses of negative temperature co-efficient (NTC) thermistors.

Ans. As the temperature increases, the resistance of the NTC thermistor decreases. This makes its useful for applications where changes in temperature need to be detected. NTC thermistor our commonly used in temperature sensing circuit.

i. Temperature sensors in electronic devices.

ii. Over current protections in power supplies, where the thermistor can limit current based on temperature changes.

20. Write few applications of LDRs.

Ans. i. Street lighting that automatically turns ON when it gets dark.

ii. Brightness sensors in cameras that adjust exposure based on ambient light levels.

16.8 Common Use of Electricity

21. Write few uses of electricity.

Ans. i. One of the most common use of electricity is heating, which keep, us warm.

ii. Another important use is battery charging, which charge our phones, Laptops and electric vehicles.

iii. Electricity is the backbone of electronic systems, running computers, televisions etc.

16.9 Electric Power

22. Define electric power.

Ans. Electric power is the rate at which electrical energy is transferred or consumed in a circuit. It is denoted by P.

$P = IV$ .....(i)

$V = IR$ .....(ii)

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Putting eq (ii) in (i)

$$\boxed{P = I^2R}$$

23. What is Joule's Law?

Ans. 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.

Methamatically:

$$H = I^2RT$$

$$\boxed{H = P \times T} \quad \therefore \quad \boxed{P = I^2R}$$

24. Why it is important to choose suitable power components of circuit?

Ans. When designing circuit, selecting components with right power ratings ensures safety, reliability and efficiency.

16.10 Household Circuits and Safety Measures

25. Write few hazards of electricity.

Ans. Following are the main hazards of electricity:

i. Malpractice or lack of maintenance.
ii. Damaging insulation which expose live wire.
iii. Overheating potentially start a fire.
iv. Over landing into a single socket lead to overheating and causing fires.

26. What is the role of fuses and trip switches?

Ans. Fuses and trip switches are essential safety devices to avoid electric hazards. Fuses contain a thin wire that melts due to flow of high current. As a result, breaking of the circuit stops the flow of electricity.

27. What are the roles of different wires in a circuit?

Ans. **Live Wire:** The live wire (line wire), which carries the current from the power supply.

Neutral Wire: Neutral wire, which completes the circuit.

Earth Wire: The earth wire, which provides a safety path for fault currents.

Exercise Questions (Solved)

A. Multiple Choice Questions

Tick (✓) the correct answer.

16.1 The direction of conventional current is:

(a) from negative to positive terminal (b) from positive to negative terminal
(c) in both directions at the same time (d) it does not have a fixed direction

16.2 What type of electric current flows in one direction only?

(a) Alternating current (b) Direct current
(c) Induced current (d) None of these

16.3 The device used to measure electric current:

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

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16.4 What is the function of an electromotive force (e.m.f.) source in a circuit?

(a) To reduce resistance in the circuit
(b) To provide energy to drive charges through the circuit
(c) To store electrical energy for later use
(d) To convert electrical energy into mechanical energy

16.5 The relationship between voltage, current, and resistance is:

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

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

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

Answers

16.1 (b) **16.2** (b) **16.3** (b) **16.4** (b) **16.5** (a) **16.6** (c)

B. Short Answer Questions

16.1 How does an ammeter measure electric current?

Ans. An ammeter measures electric current by being connected in series with the circuit, having low reisstance, and displaying a calibrated reading of the current.

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

Ans.

Direct current	Alternating current
(i) Direct current is an electric current where the electric charge flows in one direction.	(i) Alternating current is a type of current that periodically reverse its direction.
(ii) In DC circuit, the voltage remains constant over time.	(ii) In AC circuit, the voltage changes polarity.
(iii) The frequency of DC is zero	(iii) The frequency of AC is 50 hertz (Hz)

16.3 Define electromotive force (e.m.f.).

Ans. Electromotive force is the energy supplied by a battery to a unit positive charge when it flows through the closed circuit. It is represented by E. It's unit is volt.

$$E = \frac{W}{Q}$$

16.4 State Ohm's law and define resistivity.

Ans. Ohm's Law: Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance between them.

Mathematically, ohm's Law is expressed as: $V = IR$

Resistivity: Resistance of a cubic metre of a material is called resistivity.

i.e. $R = \rho\left(\frac{L}{A}\right)$

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

Ans. When resistors are connected in series, the total resistance is the sum of the individual resistances.

If resistors R_1, R_2, R_3, ... are connected in series, the equivalent resistance (R_{eq}) is given by

$R_{eq} = R_1 + R_2 + R_3 + ...$

16.6 How does temperature affect the resistance of a conductor?

Ans. As temperature increases, the resistance of a conductor generally increases.

C. 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 needs very low resistance to avoid impeding current flow and is connected in series to measure the total current. A voltmeter needs very high resistance to avoid drawing currect and is connected in parallel to measure the potential difference accurately. If an ammeter is connected in parallel, it creates a short circuit. If a voltmeter is connected in series, it significantly inpedes current flow.

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

Ans. When a copper wire is replaced with an aluminium wire of the same dimensions both current and power consumption will decrease.

According to Ohm's Law $\boxed{I = \frac{V}{R}}$, if the voltage (V) of the circuit the same, the current (I) is inversely proportional to the resistance. Since the aluminium wire has a higher resistance, the total current in the circuit will decrease.

It you talk about power consumption it can be expressed as: $\boxed{P = \frac{V^2}{R}}$

In Aluminium wire, the total power consumption of the circuit will decrease because the increased resistance limits.

Resistivity: Resistivity is expressed by (ρ). It is an intrinsic property of a material that measures how strongly it opposes the flow of electric current.

- Copper has a resistivity $1.68 \times 10^{-8}\ \Omega$ at 20°C.
- Aluminium has high resistivity $2.82 \times 10^{-8}\ \Omega$ at 20°C.

$$\boxed{\rho = \frac{RA}{L}}$$

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

Ans. In a house hold lighting circuit, connecting bulbs in series rather than the standard parallel configuration cause following major practical issues:

i. In a series circuit, the same current flows through all components. If one bulb fails (e.g., the filament breaks), the entire circuit is broken, and all the bulbs will go out.

ii. In a series circuit, the voltage is divided among the components. If multiple bulbs are connected in series, each bulb receives a fraction of the total voltage. This means each bulb will be dinner than if it were connected to the full voltage.

iii. Adding more bulbs in series increases the total resistance of the circuit, further reducing the current and making all the bulbs even dimmer.

iv. Troubleshooting a series circuit is difficult. If one bulb is not working, it can be hard to identify which bulb is the problem, as all the bulbs will be off.

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. i. The fuse rating should be slightly higher than the normal operating current to avoid nuisance tripping (blowing the fuse during normal operation). A fuse rating too close to the operating current might cause the fuse to blow due to minor current fluctuations.

ii. A suitable fuse rating would be 6A. This allows for a small margin above the normal operating current of 5A.

iii. If the fuse rating is too low (e.g, 5A or less), the fuse will blow frequently during normal operation, interrupting the device's function.

iv. If the fuse rating is too high (e.g., 10A), the fuse may not blow quickly enough or at all during a fault condition (like a short circuit or overload).

This could allow excessive current to flow, potentially damaging the device or causing a fire hazard.

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. 1. Easy Conversion of Voltage: A.C can be easily changed to different voltage levels using transformers. Changing D.C voltage is much more complex and expensive.

2. Low energy waste: By increasing the voltage for transmission, we can lower the current. Since energy lost as heat is calculated as $P_{loss} = I^2R$, a lower current (I) significantly reduces the amount of electricity worked that trip from the power plant to the city.

3. Less Expensive: A.C allows for low-current transmission we can use thinner wires. If we sent high current D.C across a city, we would need massive, heavy cables to prevent them over heating, which would be expensive.

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D. 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 Answer Q. # 2, 3, 4.

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 Answer Q. # 5, 6.

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 Answer Q. # 9.

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 Answer Q. # 10, 11.

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 Answer Q. # 12, 13.

E. Numerical Problems

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

Ans. Given

Charge = Q = 25 C

Time = t = 10 s

To find: current = I = ?

Formula: $I = \frac{Q}{t}$

Solution: $I = \frac{Q}{t}$

By substituting values

$$I = \frac{25C}{10s}$$

$$\boxed{I = 2.5\ A}$$

Thus, current flowing through circuit is 2.5 amperes.

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

Ans.

Given: $R_1 = 4\Omega$; $R_2 = 6\Omega$; $R_3 = 8\Omega$

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Voltage = V = 24V

To find: R_T = ?

I = ?

Formula:

Total resistance = $R_1 + R_2 + R_3$

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

Solution:

Total resistance = $R_1 + R_2 + R_3$

$= 4\Omega + 6\Omega + 8\Omega$

$R_T = 18\Omega$

using Ohm's Law

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

$$I = \frac{24V}{18\Omega} = 1.33A$$

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

Ans. Given: $R_1 = 10\Omega$, $R_2 = 30\Omega$

To find:

Total resistance = R_T = ?

Current = I = ?

Formula:

Total resistance in parallel

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\text{Current} = \frac{V}{R_{Total}}$$

Solution:

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{10} + \frac{1}{30}$$

$$\frac{1}{R_{Total}} = \frac{3+1}{30} = \frac{4}{30}$$

$$R_{Total} = \frac{30}{4} = 7.5\Omega$$

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$\boxed{R_{Total} = 7.5\Omega}$

Current drawn from power supply.

$$I = \frac{V}{R_{Total}}$$

$$I = \frac{20V}{7.5\Omega} = 2.67A$$

$\boxed{I = 2.67A}$

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.

Ans. Given: number of battries = 4

Voltage = 1.5V

To find:

Total e.m.f = ?

Solution:

Total e.m.f = V × n

= 1.5V × 4

Total e.m.f = 6.0V

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

Ans. Given:

Current = I = 5A

Resistance = R = 7Ω

Time = t = 10 minutes = 600s

To find:

Power dissipated = P = ?

Energy consumed = E = ?

Solution:

Using Formula $P = I^2 R$

and $E = P \times t$

Now $P = I^2 R$

By substituting values

$P = (5A)^2 \times (7\Omega)$

$P = (25 \times 7)\ W$

$\boxed{P = 175\,W}$

Also using

$E = P \times t$

By substituting values

$E = (175\ W) \times (600s)$

$E = 105000J$

$\boxed{E = 105kJ}$

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