CLASS 10 NOTES

SCIENCE

Electricity

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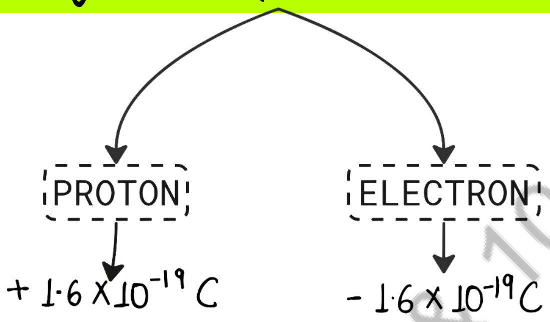
Electricity

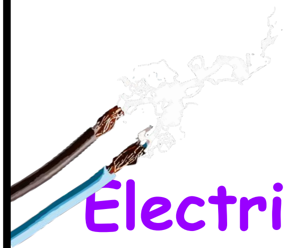
Electric charge: (Symbol=q)

A physical phenomenon characterized by an excess or deficiency of electrons in a body.

- It is a scalar quantity.
  - The SI unit of charge is the Coulomb **(C)**.

Magnitude of electric charge:





Electric Current: (symbol=i)

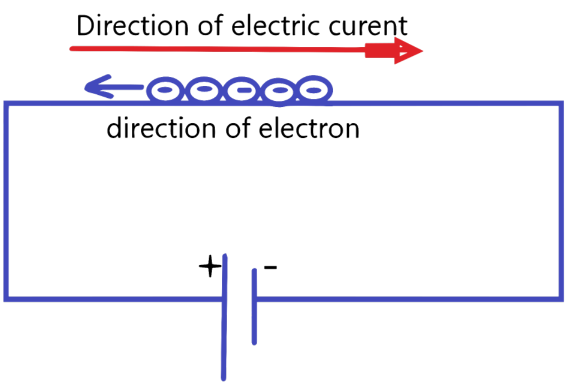
Exam me aayega

The quantity of electric charge 'Q' flowing through a specific cross-sectional area in unit time 't'.

- It is a scalar quantity.
- The SI unit of current is the Ampere (A).

$$\mathrm{I(amperes)} = \frac{\mathrm{Q(coulombs)}}{\mathrm{t(seconds)}}$$

The direction of **electric current** is considered opposite to the flow of **electrons**, and in a circuit, conventional current flows from the battery's **positive** terminal to the **negative** terminal.



Q A current of 1 A is drawn by a filament of an electric bulb. Number of electrons passing through a cross section of the filament in 16 seconds would be roughly:

Solution: Given : $I = 1A, t = 16s, e = 1.6 \times 10^{-19} C$

Step 1: Current drawn by the filament

$I = \frac{Q}{t} = \frac{Ne}{t}$ (Since $Q = Ne$, where N is the number of electrons crossing in time t)

$\Rightarrow N = \frac{It}{e} \ldots (1)$

Step 2: Substituting the values in equation (1)

$$N = \frac{It}{e} = \frac{1A \times 16s}{1.6 \times 10^{-19} C} = 10^{20}$$

Hence, number of electrons passing through a cross section of the filament in 16 seconds would be 10^{20}.

Electric Potential: (Symbol=V) ← E.M.A

The amount of work done (1 W) when moving a unit positive charge (1C) from infinity to a specific point.

- It is a scalar Quantity.
- SI unit is volt (V)

$$V\,(\text{volts}) = \frac{W\,(\text{joules})}{Q\,(\text{coulombs})}$$

Electric Potential Difference: (Symbol=ΔV)

It quantifies the energy expended per unit of electric charge. Electric potential, delineated as the variance in electric potential energy between two locations within an electric field, corresponds to the energy expended for each charging unit when transporting it from one point to another in an electrostatic field.

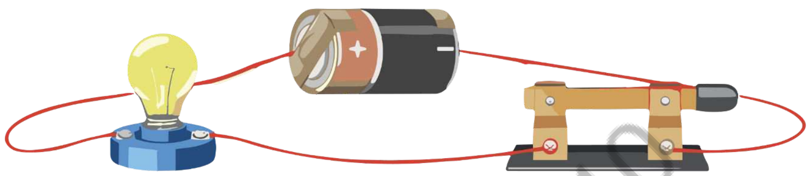
- It is a scalar Quantity.
- SI unit is joules per coulomb.

The measurement of the electric potential difference between two points in a circuit is accomplished using a device known as a **voltmeter**.

Electric circuit:

An electric circuit is a closed and unbroken loop that facilitates the flow of electric current. It comprises diverse components, such as a current source (like a cell or battery), a load (such as a bulb or any appliance), a switch (for opening or closing the circuit), a fuse, and interconnecting wires, typically constructed from copper.

- When the switch is closed, the circuit is termed a closed circuit (allowing the current to flow).
- Conversely, when the switch is open, the circuit is referred to as an open circuit (preventing the flow of current).



Circuit Diagram:

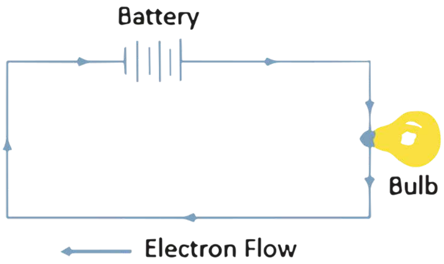
It is a visual depiction of a circuit wherein various electrical components are represented by their symbols.

S.N	Components	Symbols
1.	Electric cell	
2.	Battery	
3.	Plug key (switch open)	
4.	Plug key (switch closed)	
5.	A wire joint	
6.	Wires crossing without joining	
7.	Electric bulb	or
8.	A resistor of resistance R	
9.	Variable resistance or rheostat	or
10.	Ammeter	A
11.	Voltmeter	V
12.	Fuse	

Ohm's Law: E.M.A

According to this principle, the electric current coursing through a conductor exhibits a direct proportionality to the applied potential difference across its terminals, under the condition that physical factors like temperature remain constant.

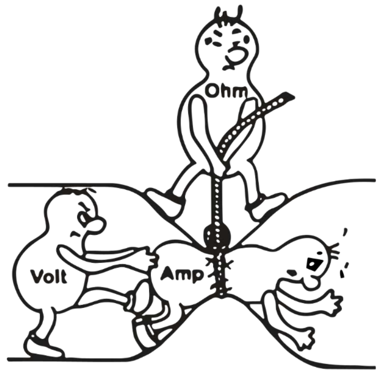
Ohm's Law

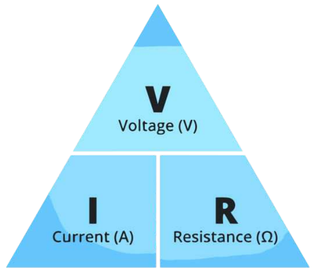


Resistance (R) = Bulb

Current (I) = Flow of Electron

Voltage (V) = Battery





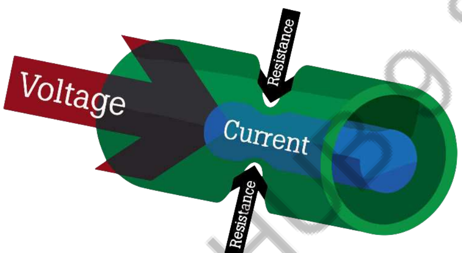
V= I · R

R = V : I

I = V : R

Resistance: (Symbol=Ω) ← E.M.A

It is the characteristic of a conductor that hinders or resists the movement of electric charge through it. This property is known as resistance. Resistance is a scalar quantity, and its unit in the International System of Units (SI) is the ohm, denoted by the symbol Ω.



The resistance of a conductor depends on several factors, including:

1. **Length (L):** The longer the conductor, the greater the resistance.
2. **Cross-sectional Area (A):** Wider pathways (larger cross-sectional area (A) in a conductor make it easier for electric current to flow by reducing resistance.
3. **Material Resistivity (ρ):** Different materials have different inherent resistances. Resistivity is a property of the material itself.
4. **Temperature (T):** Generally, resistance increases with temperature. This is a more complex relationship and depends on the material.

The relationship between these factors is described by the formula:

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

where:

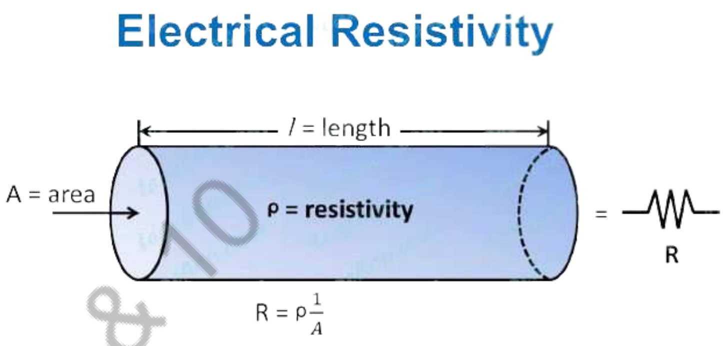
- R is the resistance,
- ρ is the resistivity of the material,
- L is the length of the conductor, and
- A is the cross-sectional area.

Resistivity: ← E.M.A

Resistivity is a property of materials that describes their ability to impede the flow of electric current. It is denoted by the symbol (ρ) (rho) and is measured in ohm-meters (Ω·m) in the International System of Units (SI). The formula for resistivity (ρ) is:

$$R = \rho(L/A)$$

Resistivity (ρ) is a material property measuring its resistance to electrical current flow. Conductors like metals have low resistivity, allowing easy current flow, while insulators have high resistivity. Ohm's Law (I=V/R) relates current (I), voltage (V), and resistance (R), where resistance depends on the material's resistivity (ρ) length (L), and cross-sectional area (A).



Secret Questions

Q1) Name the device/instrument used to measure a potential difference. How is it connected to an electric circuit? **[CBSE 2016]**

Solution: The device that is used to measure potential difference is a voltmeter. A voltmeter is connected in parallel to an electric circuit.

Q2) Many free electrons are present in metals yet no current flows in the absence of electric potential. Explain the statement with reason. **[CBSE 2014]**

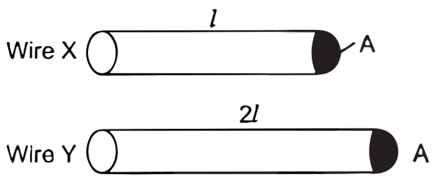
Solution: Though there are a large number of free electrons present in a conductor, their motion is random motion in the absence of potential difference. Their average velocity is zero. Hence there is no current flowing in a conductor. But when a potential difference is applied across the ends of the conductor, it sets the electrons to move in a direction. The motion of charge produces an electric current in the conductor.

Q3) List two differences between a voltmeter and an ammeter in a tabular form. **[CBSE 2014]**

Solution:

	Voltmeter	Ammeter
1.	It is used to measure P.D. across two points in an electric circuit.	It is used to measure electric current in an electric circuit.
2.	Its resistance is very high.	Its resistance is very low.
3.	An voltmeter is connected in parallel in an electric circuit.	An ammeter is connected in series in an electric circuit.

Q4) Out of the two wires X and Y shown below. Which one has greater resistance. Justify your answer.



Solution: If X and Y are of same material

then length of wire $X = l$

Area of cross-section $= A$

$$R_X = \rho \frac{l}{A}$$

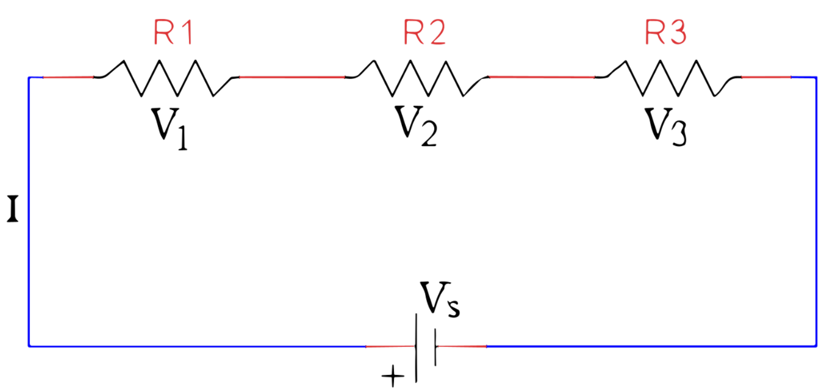
Similarly, $$R_Y = \rho \frac{2l}{A}$$

$$\frac{R_Y}{R_X} = 2$$

or $$R_Y = 2R_X$$

wire Y has two times resistance than that of wire X.

Series Combination:



I=Same

V=Divide

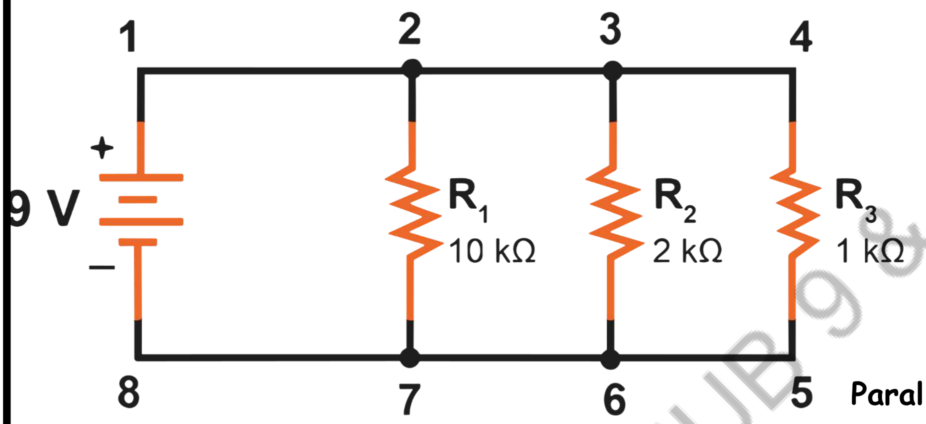
$$\boxed{R_{eq} = R_1 + R_2 + R_3}$$

Series combination formula:

Total resistance is the sum of individual resistances.

1. **Adding Resistances:** In a series circuit, you just add up all the resistances to find the total resistance.
2. **Total Resistance is Higher:** The total resistance in a series is greater than any single resistor.
3. **One Stops, All Stop:** If one component in a series circuit stops working, everything in the circuit stops.
4. **Not for Different Devices:** Series circuits are not good for devices like bulbs and heaters because they need different amounts of current.

Parallel Combination:



I=Divide

V=Same

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Parallel combination formula: Inverse of total resistance equals the sum of inverses of individual resistances

1. **Add Inverses:** In a parallel circuit, sum the inverses of individual resistances to find the reciprocal of the total resistance.
2. **Lower Total Resistance:** The overall resistance in parallel is less than that of any single resistor.
3. **Diverse Currents:** Different currents flow through components in parallel.
4. **Continued Operation:** If one component fails, others continue to operate in a parallel circuit.

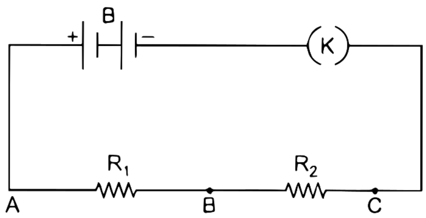
Secret Questions

Q1) (a) Draw a circuit diagram to show how two resistors are connected in series. **[CBSE 2006)**

(b) In a circuit, if the two resistors of 5 ohm and 10 ohm are connected in series, how does the current passing through the two resistors compare?

Solution:

a.

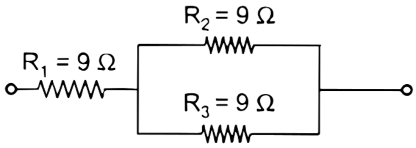


b. In series combination of resistances, the current remains same.

Q2) Show how would you join three resistors, each of resistance 9 Ω so that the equivalent resistance of the combination is (i) 13.5 Ω (ii) 6 Ω?

Solution:

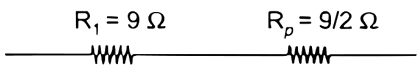
i.



Resistor R_2 and R_3 are in parallel combination

$$\therefore \quad \frac{1}{R_p} = \frac{1}{9} + \frac{1}{9} = \frac{2}{9}\,\Omega$$

or
$$R_p = \frac{9}{2}\,\Omega$$



Now R_1 and R_p are in series.

$$\therefore \quad R_{eq} = R_1 + R_p = 9 + \frac{9}{2} = \frac{27}{2}\,\Omega$$

$$R_{eq} = 13.5\,\Omega$$

ii. To get $6\,\Omega$ resistance R_1 and R_2 are in Series

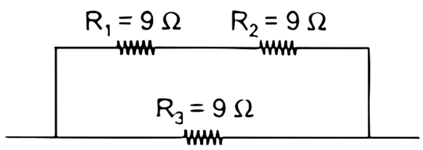
$$\therefore \quad R_s = 9 + 9 = 18\,\Omega$$

and R_s and R_3 are in parallel so,

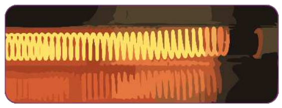
$$\frac{1}{R_{eq.}} = \frac{1}{R_s} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq.}} = \frac{1}{18} + \frac{1}{9} = \frac{1+2}{18} = \frac{3}{18}$$

$$R_{eq.} = 6\,\Omega$$



Heating effect of electric current:



In an electric circuit, the source must continuously provide energy to maintain current flow. Some energy sustains the current, while the rest dissipates as heat—known as the heating effect of electric current.

Joule's Law of Heating: E.M.A

This law indicates that the heat generated in a resistor is:

1. Directly proportional to the square of the current (I) flowing through the resistance (R).
2. Directly proportional to the resistance (R) in the circuit.
3. Directly proportional to the time (t) for which the current flows.

$$\boxed{H = I^2Rt}$$

Practical applications of the heating effects of electric current include:

Producing Light (Electric Bulb): The bulb features a tungsten filament with high resistivity and melting point. The application of voltage heats the filament, making it white-hot and emitting light.

Electric Fuse: A safety device in household circuits, it contains a lead and tin alloy with a specific melting point. If the current surpasses the safe limit, the fuse wire heats, melts, and interrupts the circuit, safeguarding other elements from potential hazards.

Power: ← E.M.A

1. Definition of Electrical Power (P): Electrical power (P) is defined as the rate at which electric charge is consumed or transferred in a circuit per unit of time.

2. Scalar Quantity: Electrical power is a scalar quantity, meaning it only has magnitude and no direction.

3. Unit of Electrical Power: The unit of electrical power is the watt (W). The relationship between power (P), current (I), and resistance (R) is given by Ohm's Law (P = I^2R).

$P = VI$ → Using Ohm's Law

→ $V = IR$ → $P = (IR)I = I^2R$

→ $I = V/R$ → $P = V(V/R) = V^2/R$

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

1. **Kilowatt (kW):**
   - 1 kilowatt (1 kW) is equivalent to 1000 watts (1000 W).
2. **Megawatt (MW):**
   - 1 megawatt (1 MW) is equivalent to (10^6) watts (1,000,000 W).
3. **Gigawatt (GW):**
   - 1 gigawatt (1 GW) is equivalent to (10^9) watts (1,000,000,000 W).
4. **Horsepower (HP):**
   - 1 horsepower (1 HP) is approximately equal to 746 watts (746 W).

Commercial unit of electrical energy:

1 {kilowatt-hour (kWh)} = 1000 watt-hours (Wh)

Since 1 watt-hour is equal to 3600 joules (J):

1000 {Wh} = 1000 * 3600 J

This simplifies to

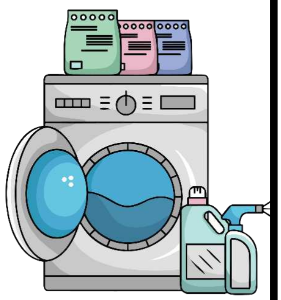
1000 {Wh} = 3.6 * 10^6{J}

So, 1 kilowatt-hour is equivalent to (3.6 times 10^6) joules.

Number of units consumed by electric appliances:

Certainly! The number of units consumed by an electric appliance is calculated by multiplying its power (in kilowatts) by the time it is in use (in hours). The formula is:

Energy (kWh) = Power (kW) * Time (hours)



For example, if you have a 1.5 kW appliance running for 3 hours:

{Energy (kWh)} = 1.5 {kW} * 3 hours = 4.5 {kWh}

So, the appliance consumes **4.5** kilowatt-hours of energy during that period.

#Top Seven Question:

Q1) What is the function of a galvanometer in a circuit? **[CBSE 2019]**

Solution: A galvanometer is used to detect and measure electric currents in a circuit. It indicates the presence and direction of current flow.

Q2) State Ohm's law. **[Delhi 2016]**

Solution: If the physical conditions of a conductor remain the same then the current through a conductor is directly proportional to the potential difference b/w the two ends of the conductor.

$$I \propto V \Rightarrow V = IR$$

Q3) The power of a lamp is 60 W. Find the energy in joules consumed by it in 1 s. **[CBSE 2014]**

Solution:

$$P = 60\,\text{W},\ t = 1\,\text{s}$$
$$\text{Energy} = (VI)t$$
$$E = P \times t = 60 \times 1\,\text{J}$$
$$E = 60\,\text{J}$$

Q4) An electric kettle of 2 kW works for 2 h daily. Calculate the **[CBSE 2014]**

(a) energy consumed in SI and commercial units

(b) cost of running it in the month of June at the rate of ` 3.00 per unit.

Solution: (a) Given: $P = 2\,\text{kW} = 2000\,\text{W}$

$$t = 2\,\text{h}$$

Electric energy, $E = P \times t = 2 \times 2 = 4\ \text{kWh}$

(b) Total energy consumed in month of June (having 30 days)

$$\text{Electric kettle} = (4 \times 30)\ \text{kWh} = 120\,\text{kWh}$$
$$= 120\ \text{units.}$$

Cost of running electric kettle:

$$= ₹120 \times 3 = ₹360$$

Q5) **(a)** Explain why a conductor offers resistance to the flow of current.

(b) Differentiate between conductor, resistor, and resistance.

Solution: **a.** When a current is passed through a conductor, the atoms or molecules of the conductor produce a hindrance in the path of flow of electrons. This hindrance in the path of the flow of charge is called the resistance of the conductor.

b. A substance that allows it to pass the charges through them easily is called a conductor. Resistor: A conductor having some value of resistance is called a resistor. Resistance: It is the property of any conductor by virtue of which it opposes the flow of charge through it.

Q6) Two conducting wires of the same material, equal length, and equal diameter are connected in series. How does the heat produced by the combination of resistance change? **[CBSE 2010]**

Solution: Let the resistances of two wires are R each.

Heat produced by individual resistor

$$H' = \frac{V^2}{R}t$$

Resistance is series, $R_S = R + R = 2R$

Heat produced by combination of resistors

$$H' = \frac{V^2}{2R}t$$
$$\frac{H'}{H} = \frac{1}{2}$$
$$H' = \frac{H}{2}$$

Q7) **(a)** Define the term 'volt'.

(b) State the relation between work, charge, and potential difference for an electric circuit. Calculate the potential difference between the two terminals of a battery, if 100 joules of work is required to transfer 20 coulombs of charge from one terminal of the battery to the other.

Solution: a. Potential difference b/w two points in an electric field is said to be 1 volt if the amount of work done in bringing a unit positive charge from one point to another point is 1 J.

b. Given: $W = 100\,\text{J},\ Q = 20\,\text{C},\ V = ?$

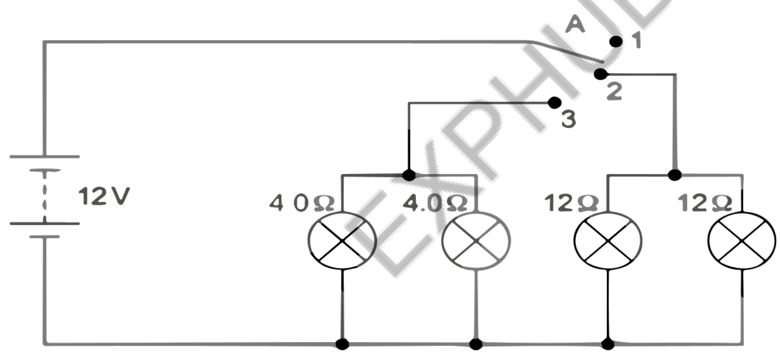
As $\quad V = \dfrac{W}{Q} \Rightarrow V = \dfrac{100}{20}\,\text{JC}^{-1}$

$V = 5\,\text{JC}^{-1}$

$V = 5\ \text{Volt.}$

Competency Based Question:

Q1)



Vinita and Ahmed demonstrated a circuit that operates the two headlights and the two sidelights of a car, in their school exhibition. Based on their demonstrated circuit, answer the following questions.

(i) State what happens when switch A is connected to

a) Position 2

b) Position 3

(ii) Find the potential difference across each lamp when lit.

(iii) Calculate the current

a) in each 12 Ω lamp when lit.

b) In each 4 Ω lamp when lit.

Solution:

(i) Switch A connected to:

a) Position 2: Both headlights and sidelights are turned on.

b) Position 3: Only the sidelights are on.

(ii) Potential Difference Across Each Lamp When Lit:

The potential difference across each lamp is determined by the voltage supplied to the circuit. If the car's electrical system operates at a standard voltage (e.g., 12V), then each lamp receives this voltage when lit.

(iii) Current Calculation:

a) In Each 12 Ω Lamp When Lit:

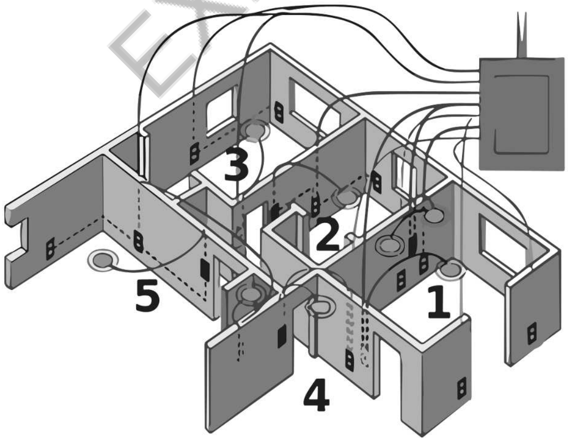
Ohm's Law (V = IR) can be used to calculate current. If the potential difference (V) is known and the resistance (R) of the lamp is given, the current (I) can be found.

b) In Each 4 Ω Lamp When Lit:

Similar to part (a), apply Ohm's Law using the potential difference across the lamp and its resistance to find the current.

It's crucial to note that without specific values for potential difference (voltage) or other electrical parameters, exact numerical calculations cannot be performed. You would need these values to substitute into Ohm's Law (V = IR) to find the current in each lamp.

Q2)



The diagram above is a schematic diagram of a household circuit. The house shown in the above diagram has 5 usable spaces where electrical connections are made. For this house, the mains have a voltage of 220 V and the net current coming from the mains is 22A.

(a) What is the mode of connection to all the spaces in the house from the mains?

(b) Spaces 5 and 4 have the same resistance and spaces 3 and 2 have respective resistances of 20Ω and 30Ω. Space 1 has a resistance double that of Space 5. What is the net resistance for space 5?

(c) What is the current in space 3?

(d) What should be placed between the main connection and the rest of the house's electrical appliances to save them from accidental high electric current?

Solution:

(a) The mode of connection to all the spaces in the house from the mains is Parallel Connections. Elements connected in parallel connections are connected along numerous paths, and each element has the exact voltage across it, proportional to the voltage across the network.

(b) From Ohm's law; we have

$R = \frac{V}{I} = \frac{220}{22} = 10\ \Omega$

For parallel connections; we have

$$\frac{1}{R_1} + \frac{1}{R_2} + \ldots = \frac{1}{R_{eq}}$$
$$\frac{1}{2x} + \frac{1}{30} + \frac{1}{20} + \frac{1}{x} + \frac{1}{x} = \frac{1}{10}$$
$$\frac{1}{2x} + \frac{1}{x} + \frac{1}{x} = \frac{1}{10} - \frac{1}{30} - \frac{1}{20}$$
$$\frac{5}{2x} = \frac{1}{60}$$
$$60 \times 5 = 2x$$
$$2x = 300$$
$$x = \frac{300}{2}$$
$$x = 150\ \text{ohm}$$

(c) Current in Space 3 is given by

$$i_3 = \frac{220}{20}$$

$$i_3 = 11\ \text{A}$$

Current in Space $3 = 11\ \text{A}$

(d) Fuse wire should be placed between the main connection and the rest of the house's electrical appliances to save them from accidental high electric current. The fuse is positioned in the live wire just after the 'electricity meter' of the customer.