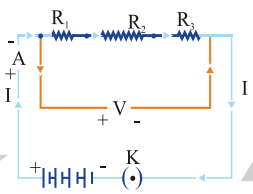


Chapter - 11

Electricity

Electric Current

SI unit

Ampere

What is it

It is the rate of flow of electric charges (electrons) in a conductor.

Experimentaly

Measured by an ammeter

How is it connected

always in series in a circuit through which we measure current

What is a circuit

Electric circuit is a continuous and closed path of an electric current.

Direction of current flow in circuit

Positive terminal of the cell to the negative terminal

Mathematically

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

Where

Q is the net charge that flows across cross-section of a conductor in time.

- **Charge** is a fundamental particle in an atom. It may be positive or negative.
- Like charges repel each other.
- Unlike charges attract each other.

coulomb (C) : S. I. unit of charge

1 coulomb charge = Charge present on approx. 6×10^{18} electrons

- Charge on 1 electron = Negative charge of 1.6×10^{-19} C

$$Q = ne$$

Where Q = Charge (total)

n = No. of electrons

e = Charge on 1 electron

Current (I) : The rate of flow of charge is called current.

$$\text{Current} = \frac{\text{Charge}}{\text{Time}}$$

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

S. I. unit of current = Ampere (A)

$$1 \text{ A} = 1 \text{ Cs}^{-1}$$

$$1 \text{ mA} = 10^{-3} \text{ A}$$

$$1 \mu\text{A} = 10^{-6} \text{ A}$$

Current is measured by Ammeter. Its symbol is —— $\overset{+}{}$ A $\overset{-}{}$ ——

Ammeter has low resistance and always connected in series.

Direction of current is taken opposite to flow of electrons as electrons were not known at the time when the phenomenon of electricity was discovered first and current was considered to be flow of positive charge.

Potential Difference (V) : Work done to move a unit charge from one point to another.

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

1 volt : *When 1 joule work is done in carrying one Coulomb charge then potential difference is called 1 volt.*

S. I. unit of Potential difference = Volt (V)

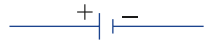
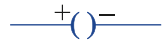
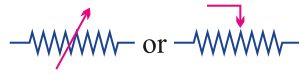
$$1\ V = 1\ JC^{-1}$$

1 Volt : When 1 joule work is done in carrying one coulomb charge then potential difference is called 1 volt.

Voltmeter : Instrument to measure potential difference.

- It has high resistance and always connected in parallel. Symbol is V.
- Cell is the simplest device to maintain potential difference.
- Current always flow from higher potential to lower potential.

Symbols of Some Commonly Used Components in Circuit :

Electric cell	:	
Battery	:	
Key (open)	:	
Key (closed)	:	
Wire joint	:	
Wire Crossing (without join)	:	
Electric bulb	:	
Resistance	:	
Rheostat	:	
Ammeter	:	

Voltmeter : 

Ohm's Law : Potential difference across the two points of a metallic conductor is directly proportional to current passing through the circuit provided that temperature remains constant.

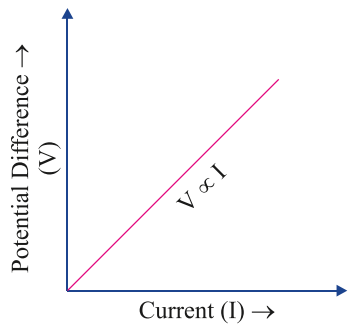
- Mathematical expression for Ohm's law :

$$V \propto I$$

$$V = IR$$

R is a constant called resistance for a given metal.

- V-I graph for Ohm's law :



Resistance (R) : It is the property of a conductor to resist the flow of charges through it.

- Ohm (Ω) : S. I. unit of resistance.
- $1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$ *When potential difference is 1 V and current through the circuit is 1 A, then resistance is 1 ohm.*

Rheostat : Variable resistance is a component used to regulate current without changing the source of voltage.

Factors on which the Resistance of a Conductor depends :

Resistance of a uniform metallic conductor is

(i) directly proportional to the length of conductor,

(ii) inversely proportional to the area of cross-section,

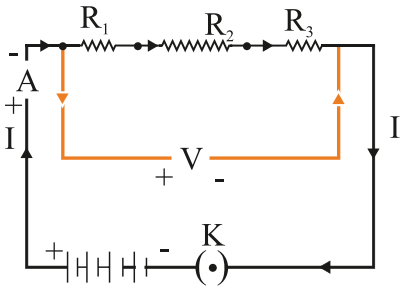
(iii)directly proportional to the temperature and

(iv)depend on nature of material.

Resistivity (ρ) : It is defined as the resistance offered by a cube of a material of side 1 m when current flows perpendicular to its opposite faces.

- Its S.I. unit is ohm-metre (Ωm).
- Resistivity does not change with change in length or area of cross-section but it changes with change in temperature.
- Range of resistivity of metals and alloys is 10^{-8} to 10^{-6} Ωm.
- Range of resistivity of insulators is 10^{12} to 10^{17} Ωm.
- Resistivity of alloy is generally higher than that of its constituent metals.
- Alloys do not oxidize (burn) readily at high temperature, so they are commonly used in electrical heating devices.
- Copper and aluminium are used for electrical transmission lines as they have low resistivity.

Resistors in Series :



When two or more resistors are connected end to end, the arrangement is called series combination.

- Total/resultant/overall/effective resistance in series

$$R_s = R_1 + R_2 + R_3$$

- Current through each resistor is same.
- Equivalent resistance is larger than the largest individual resistance.
- Total voltage = Sum of voltage drops

$$V = V_1 + V_2 + V_3$$

- Voltage across each resistor :

$$V_1 = IR_1$$

$$V_2 = IR_2 \qquad [V_1 + V_2 + V_3 = V]$$

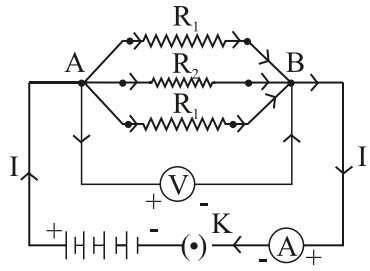
$$V_3 = IR_3 \qquad V = IR$$

$$V = IR_1 + IR_2 + IR_3$$

$$\Rightarrow \quad IR = I(R_1 + R_2 + R_3)$$

$$\Rightarrow \quad R = R_1 + R_2 + R_3$$

Resistors in Parallel :



- Voltage across each resistor is same and equal to the applied voltage.
- Total current is equal to sum of currents through the individual reistances.

$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

- Reciprocal of equivalent resistance is equal to sum of reciprocals of individual resistances.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- Equivalent resistance is less than the value of the smallest individual resistance in the combination.

Advantages of Parallel Combination over Series Combination

(i) In series circuit, when one component fails, the circuit is broken and none of the component works.

(ii) Different appliances have different requirement of current. This cannot be satisfied in series as current remains same.

(iii)The total resistance in a parallel circuit is decreased.

Heating Effect of Electric Circuit

If an electric circuit is purely resistive, the source of energy continually get dissipated entirely in form of heat. This is known as heating effect of electric current.

As $E = P \times T \Rightarrow t\ VI$ {E = H}

Heat produced, $H = VIt$ {V = IR}

Or Heat produced, $H = I^2Rt$

Joule's Law of Heating Effect of Electric Current

It states that the heat produced in a resistor is

(i) directly proportional to square of current, $H \propto I^2$

(ii) directly proportional to resistance for a given current, $H \propto R$

(iii) directly proportional to time for which current flows through the conductor, $H \propto t$.

So, $$H = I^2Rt$$

- Heating effect is desirable in devices like electric heater, electric iron, electric bulb, electric fuse, etc.
- Heating effect is undesirable in devices like computers, computer monitors (CRT), TV, refrigerators etc.
- In electric bulb, most of the power consumed by the filament appears a heat and a small part of it is radiated in form of light.
- *Filament of electric bulb is made up of tungsten* as

  (i) it does not oxidise readily at high temperature.

  (ii) it has high melting point (3380° C).
- The bulbs are filled with chemically inactive gases like nitrogen and argon to prolong the life of filament.

Electric Fuse : It is a safety device that protects our electrical appliances in case of short circuit or overloading.

- Fuse is made up of pure tin or alloy of copper and tin.
- Fuse is always connected in series with live wire.
- Fuse has low melting point.
- Current capacity of fuse is slightly higher than that of the appliance.

Electric Power : The rate at which electric energy is consumed or dissipated in an electric circuit.

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

S.I. unit of power = watt (W)

$$1 \text{ watt} = 1 \text{ volt} \times 1 \text{ ampere}$$

- Commercial unit of electric energy = kilo watt hour (kWh)

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

$$1 \text{ kWh} = 1 \text{ unit of electric energy}$$

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Define S.I. unit of :
   (a) Electric current
   (b) Potential difference
   (c) Resistance
   (d) Electric power
   (e) Electrical energy consumed
2. Define the term resistivity.
3. Device used for measuring the current is…… .
4. Name the element of filament of a bulb.
5. Write two types of resistors combination.
6. How the voltmeter is connected in a circuit ?
7. How the ammeter is connected in a circuit?
8. Why the filament of bulb has high melting point ?
9. How does fuse wire protect electrical appliances ?
10. Define IKWh in terms of units
11. On what factors does resistance of a conductor depend ?

I. MULTIPLE CHOICE QUESTIONS

12. What is the rate of flow of electric charges called?
    a) Electric potential b) Electric conductance
    c) Electric current d) None of these
13. Which of the following is the SI Unit of Electric Current?
    a) ohm b) ampere
    c) volt d) faraday
14. Which instrument is used for measuring electric potential?
    a) Ammeter b) Galvanometer
    c) Voltmeter d) Potentiometer

15. When one unit electric charge moves from one point in an electric circuit, then the amount of work done in joules is known as?
    a) Electric current
    b) Electric resistance
    c) Electric conductance
    d) Potential difference
16. The hindrance presented by material of conductor to the smooth passing of electric current is known as:
    a) Resistance
    b) Conductance
    c) Inductance
    d) None of these
17. The resistance of a conductor is directly proportional to:
    a) Its area of cross-section
    b) Density
    c) Melting
    d) Length
18. The purpose of a rheostat is:
    a) Increase the magnitude of current only
    b) Decrease the magnitude of current only
    c) Increase or decrease the magnitude of current
    d) None of these
19. Point to be kept in mind for verification of Ohm's Law is:
    a) Ammeter and voltmeter should be connected in series
    b) Ammeter should be connected in series and voltmeter in parallel
    c) Ammeter should be connected in parallel and voltmeter in series
    d) Ammeter and voltmeter should be connected in parallel
20. A fuse wire is inserted in a?
    a) Live wire
    b) In the neutral wire
    c) In the earth wire
    d) May be connected in any line

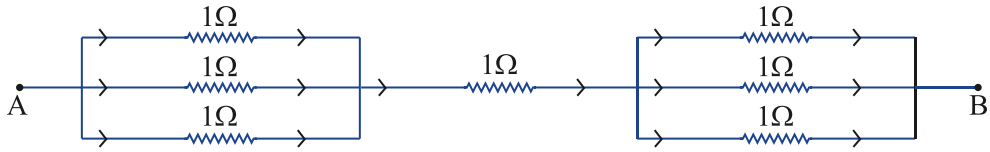
21. When electric current is passed, electrons move from:
    (a) high potential to low potential.
    (b) low potential to high potential.
    (c) in the direction of the current.
    (d) against the direction of the current.

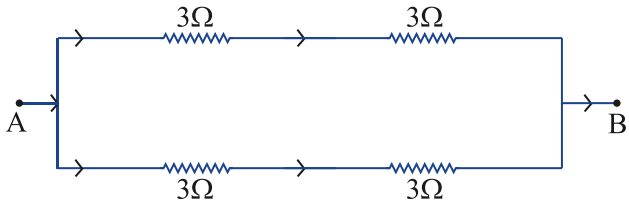
Very Short Answer Type Questions:

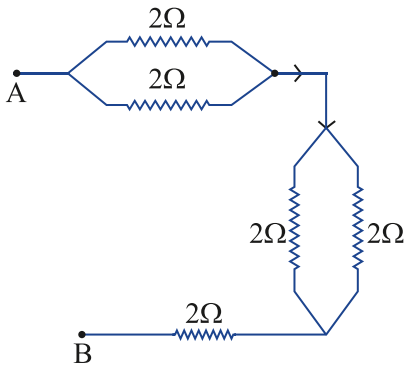
1. What is electricity?
2. What is the SI unit of electric charge?
3. What is the SI unit of electric current?
4. Which device is used for measuring electric current?
5. An ammeter is attached to the circuit in which combination?

SHORT ANSWER TYPE QUESTIONS

1. State Ohm's law. Derive relation between I, V and R. Draw the graph between V and I.
2. What is Joule's heating effect of current P ? Derive its expression.
3. What would be new resistance if length of conductor is doubled and thickness is halved ?
4. Find the effective resistance between A and B.



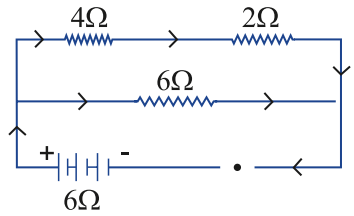




5. Which is the better way to connect lights and other appliances in domestic wiring and why ?

6. Explain the Joule's law of heating. How and on what factors does the heat produced in a conductor depends ?

7. In the circuit given below, calculate :



(a) Total effective resistance.

(b) Potential difference across 4Ω, 2Ω.

8. Three resistances of 2Ω, 3Ω and 5Ω are connected in electric circuit. Find :

(a) maximum effective resistance.

(b) minimum effective resistance.

9. On what factors, the resistance of a conductor depends ? Give the mathematical expression. Give the SI unit of resistivity.

Competency Based Question:

The Government of India ordered a nationwide lockdown for 3 weeks on 25th March. 2020 to control the spread of COVID-19. The lockdown has been extended with gradual relaxation. It had a significant impact on the electricity demand due to reduction in commercial and industrial activities. The all India electricity consumption dropped by 22% in the first week of lockdown as compared to the peak of the previous week. In the initial lockdown period, the daily electricity consumption was 25-30% lower than its corresponding value in 2019 (see Figure 1). The residential electricity consumption, on the other hand, is expected to have increased during the lockdown as people spent more time at home.

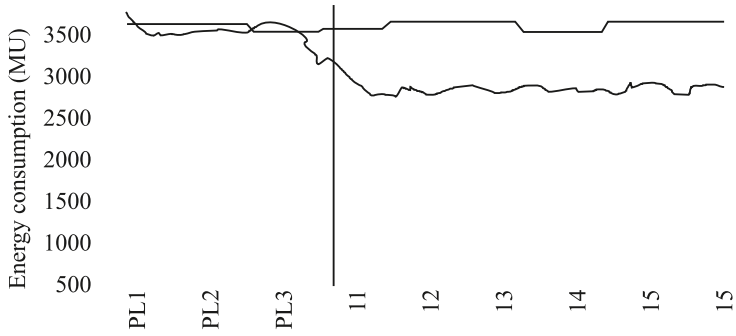


Figure 1: Daily all India electricity consumption (MUs)

1. What is the probable reason of fluctuation in electricity consumption in 2020 as compared to 2019.
   a) reduction in commercial and industrial activities
   b) people spent more time at home.
   c) both of these
   d) There is no change in electricity consumption.

Appliance	watts	hours/Month	kWh/Month
Ceiling Fan	65	15-730	1-47
Electric Heater	1200	30-90	36-108
Iron	1000	1-10	1-10
Washing Machine	1800	7-40	13-72
Computer (Monitor & Printer)	200	25-160	5-32

2. 'watt is the S.I. unit of-

   a) electric current b) power

   c) potential difference d) Energy

3. Electricity bills come in terms of units of etectricity which have been consumed.

   Here, 1 Unit = ...

   a) 3.6×10^5 joules

   b) 3.6×10^5 watts

   c) 3.6×10^6 watts

   d) 3.6×10^6 joules

4. Total energy consumed is given by-

   a) $E = QXt$ b) $E = Q/t$

   c) $E = P X t$ d) $E = P/t$

5. A 4kW electric heater is connected to a 220V source of power. What will be the amount of energy, it will consume in 2hrs ?