ELECTRICITY

CONTENTS

ELECTRIC CURRENT (CHARGE IN MOTION)

Definition : The quantity of electric charge flowing through cross section of a given conductor in one second is called current.

Thus, if Q is the charge which flows through a conductor in time t, then the current (I) is given by

$$\text{Current (I)} = \frac{\text{Charge (Q)}}{\text{Time (t)}}$$

The electric current (or current) is a scalar quantity.

◈ **Unit of current**

The SI unit of charge (Q) is coulomb (C), and that of time (t) is second (s). So,

SI unit of current

$$= \frac{1\,\text{coulomb}}{1\,\text{second}} = 1\ \text{C s}^{-1} = 1\ \text{ampere}$$

The unit coulomb per second (Cs^{-1}) is called ampere (A)

◈ **Direction of Electric Current :**

The direction of flow of the positive charge taken as conventional direction of the electric current.

When we consider the flow of electric current in an ordinary conductor, such as a copper wire, the direction of current is taken as opposite to the direction of the flow of electrons.

FLOW OF CURRENT IN A METAL

Metals show a very different kind of bonding called metallic bonding. According to this bonding, the outermost electrons are not bound to any particular atom, and move freely inside the metal randomly as shown in fig. So, these electrons are free electrons. These free electrons move freely in all the directions. Different electrons move in different directions and with different speeds. So there is no net movement of the electrons in any particular direction. As a result, there is no net flow of current in any particular direction.

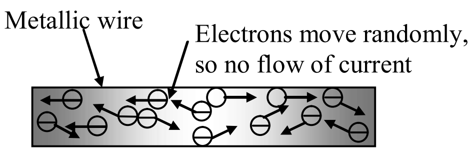


Fig. Flow of electrons inside a metal wire when no potential is applied across its ends

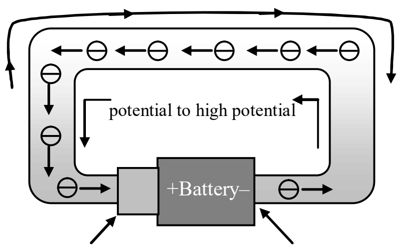
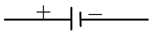
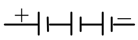
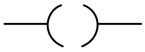
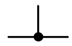
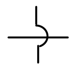
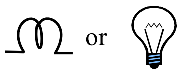
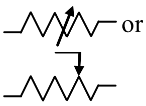
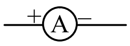
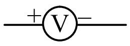


Fig. Flow of electrons inside a metal wire when the two ends of a wire are connected to the two terminals of a battery

➢ ELECTRIC SYMBOLS

Many different kinds of equipments or components are used in setting up electrical circuits. To draw the diagrams of electrical circuits on paper these equipments/components are shown by their symbols. Here are some symbols used in the electric circuit diagrams.

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	
8.	A resistor of resistance R	
9.	Variable resistance or rheostat	
10.	Ammeter	
11.	Voltmeter	
12.	Fuse	

➢ OHM'S LAW

◈ **Definition** : According to the Ohm's law at constant temperature, the current flowing through a conductor is directly proportional to the potential difference across the conductor.

Thus, if I is the current flowing through a conductor and V is the potential difference (or voltage) across the conductor, then according to Ohm's law.

$$I \propto V \quad \text{(when T is constant)}$$

or, $I = \frac{V}{R}$ ...(i)

where R is a constant called the **resistance of the conductor.**

Equation (i) may be written as,

$V = I \times R$ ...(ii)

◈ **Unit of resistance :**

The SI unit of resistance (R) is ohm. Ohm is denoted by the Greek letter omega (Ω).

From Ohm's law, $R = \frac{V}{I}$

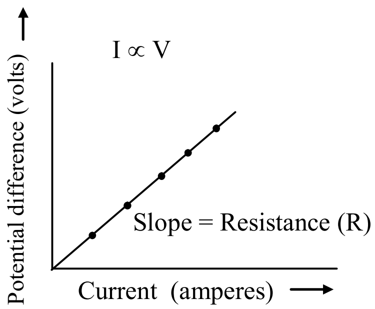
Now, if, V = 1 volt and I = 1 ampere

Then, $R = \frac{1\,\text{volt}}{1\,\text{ampere}}$

Thus, 1 ohm is defined as the resistance of a conductor which allows a current of 1 ampere to flow through it when a potential difference of 1 volt is maintained across it.

◈ **Results of Ohm's law**

- Current flowing through a conductor is directly proportional to the potential difference across the conductor.



- When the potential difference in a circuit is kept constant, the current in inversely proportional to the resistance of the conductor.

$$I \propto 1/R$$

- The ratio of potential difference to the current is constant. The value of the constant is equal to the resistance of the conductor (or resistor).

$$V/I = R$$

➢ RESISTANCE OF CONDUCTOR

The movement of electron gives rise to the flow of current through metals. The moving electrons collide with each other as well as with the positive ions present in the metallic conductor. These collisions tend to slow down the speed of the electrons and hence oppose the flow of electric current.

The property of a conductor by virtue of which it opposes the flow of electric current through it is called its resistance.

- Resistance is denoted by the letter R.
- The SI unit of resistance is **ohm**. The ohm is denoted by the Greek letter (Ω) called **omega.**
- Resistance is a scalar quantity.

Factors on which resistance of conductor depends

- **Effect of the length on the resistance of a conductor**
  The resistance of a conductor is directly proportional to the length. That is
  Resistance of a conductor. ∝ Length of the cond.
- **Effect of the area of cross-section on the resistance of a conductor**
  The resistance of a conductor is inversely proportional to its area of cross-section. That is,
  Resistance of a conductor ;
  $$R \propto \frac{1}{\text{Area of cross-section (a) of the conductor}}$$
  * If the area of cross-section of the conductor is **doubled**, its resistance gets **halved**.
- **Effect of temperature on the resistance of a conductor**
  The resistance of all pure metals increases with a rise in temperature. The resistance of alloys increases very slightly with a rise in temperature. For metal when temperature increases resistance increases and for semiconductors when temperature increases resistance decreases.
- **Effect of the nature of material on the resistance of a conductor**
  Some materials have low resistance, whereas some others have much higher resistance. In general, an alloy has higher resistance than pure metals which from the alloy.
  * Copper, silver, aluminium etc., have very low resistance.
  * Nichrome, constantan etc., have higher resistance. Nichrome is used for making heating elements of heaters, toasters, electric irons etc.

RESISTIVITY

$$R \propto \ell$$

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

So, $$R \propto \frac{\ell}{a}$$

or $$R = \rho \times \frac{\ell}{a} \qquad ...(i)$$

where ρ (rho) is called resistivity of the material of conductor.

If, $l = 1$ m and $a = 1\ m^2$

Then $$R = \rho \qquad ...(ii)$$

Thus, if we take 1 metre long piece of a substance having a cross-sectional area of 1 meter^2, then the resistance of that piece of the substance is called its resistivity.

Resistivity of a substance can also be defined as follows :

The resistance offered by a cube of a substance having side of 1 metre, when current flows perpendicular to the opposite faces, is called its resistivity.

Units of resistivity

From equation (i), we can write

$$\rho = \frac{R \times a}{\ell}$$

So, SI unit of resistivity (ρ) $= \frac{\text{ohm} \times m^2}{m} = $ ohm.m

Thus, the SI unit of resistivity is ohm. m (or Ω . m)

Classification of Material on Basis of Resistivity

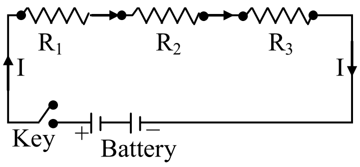
- **Substances showing very low resistivities :** The substances which show very low resistivities allow the flow of electric current through them. these type of substances are called conductors.
  For example, copper, gold, silver, aluminium and electrolytic solutions are conductors.

- **Substances having moderate resistivity:** The substances which have moderate resistivity offer appreciable resistance to the flow of electric current through them. Therefore, such substances are called *resistors*. For example, alloys such as nichrome, manganin, constantan and carbon are typical resistors.
- **Substances having very high resistivity:** The substances which have very high resistivities do not allow electricity to flow through them. The substances which do not allow electricity to pass through them are called insulators. For example, rubber, plastics, dry wood, etc. are insulators.

➤ COMBINATION OF RESISTANCES

◈ Series Combination

When two or more resistances are joined end-to-end so that the same current flows through each of them, they are said to be connected in series.



When a series combination of resistances is connected to a battery, the same current (I) flows through each of them.

- **Law of combination of resistances in series :** The law of combination of resistances in series states that when a number of resistances are connected in series, their equivalent resistance is equal to the sum of the individual resistances. Thus, if R_1, R_2, R_3 ..., etc. are combined in series, then the equivalent resistance (R) is given by,

$$R = R_1 + R_2 + R_3 + ... \quad ....(i)$$

- **Derivation of mathematical expression of resistances in series combination :** Let, R_1, R_2 and R_3 be the resistances connected in series, I be the current flowing through the circuit, i.e., passing through each resistance, and V_1, V_2 and V_3 be the potential difference across R_1, R_2 and R_3, respectively. Then, from Ohm's law,

$$V_1 = IR_1, V_2 = IR_2 \text{ and } V_3 = IR_3 \quad ...(ii)$$

If, V is the potential difference across the combination of resistances then,

$$V = V_1 + V_2 + V_3 \quad ...(iii)$$

If, R is the equivalent resistance of the circuit, then $V = IR$ ...(iv)

Using Eqs. (i) to (iv) we can write,

$$IR = V = V_1 + V_2 + V_3$$

$$= IR_1 + IR_2 + IR_3$$

or, $IR = I(R_1 + R_2 + R_3)$

or, $R = R_1 + R_2 + R_3$

Therefore, when resistances are combined in series, the equivalent resistance is higher than each individual resistance.

- **Some results about series combination :**

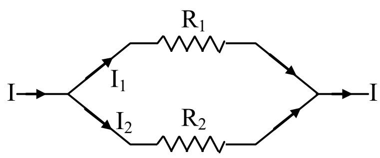
(i) When two or more resistors are connected in series, the total resistance of the combination is equal to the sum of all the individual resistances.

(ii) When two or more resistors are connected in series, the same current flows through each resistor.

(iii) When a number of resistors are connected in series, the voltage across the combination (i.e. voltage of the battery in the circuit), is equal to the sum of the voltage drop (or potential difference) across each individual resistor.

◈ Parallel Combination

When two or more resistances are connected between two common points so that the same potential difference is applied across each of them, they are said to be connected is parallel.



When such a combination of resistance is connected to a battery, all the resistances have the same potential difference across their ends.

- **Derivation of mathematical expression of parallel combination :**

  Let, V be the potential difference across the two common points A and B. Then, from Ohm's law

  Current passing through $R_1, I_1 = V/R_1$ ...(i)

  Current passing through $R_2, I_2 = V/R_2$ ...(ii)

  Current passing through $R_3, I_3 = V/R_3$ ...(iii)

  If R is the equivalent resistance, then from Ohm's law, the total current flowing through the circuit is given by,

  $$I = V/R \quad ...(iv)$$

  and $$I = I_1 + I_2 + I_3 \quad ...(v)$$

  Substituting the values of I, I_1, I_2 and I_3 in Eq. (v),

  $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad ...(vi)$$

  Cancelling common V term, one gets

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

  The equivalent resistance of a parallel combination of resistance is less than each of all the individual resistances.

- **Important results about parallel combination :**

(i) Total current through the circuit is equal to the sum of the currents flowing through it.

(ii) In a parallel combination of resistors the voltage (or potential difference) across each resistor is the same and is equal to the applied voltage i.e. $v_1 = v_2 = v_3 = v$:

(iii) Current flowing through each resistor is inversely proportional to its resistances, thus higher the resistance of a resistors, lower will be the current flowing through it.

❖ SOLVED EXAMPLES ❖

Ex.1 A TV set shoots out a beam of electrons. The beam current is 10μA.

(a) How many electrons strike the TV screen in each second ?

(b) How much charge strikes the screen in a minute?

Sol. Beam current, $I = 10\ \mu A = 10 \times 10^{-6} A$

Time, t = 1 s

So,

(a) Charge flowing per second,

$Q = I \times t = 10 \times 10^{-6} A \times 1s = 10 \times 10^{-6} C$

We known,

Charge on an electron $= 1.6 \times 10^{-19} C$

So, No. of electrons striking the TV screen per second $= \frac{10 \times 10^{-6} C}{1.6 \times 10^{-19} C}$

$= 6.25 \times 10^{14}$

(b) Charge striking the screen per min

$= (6.25 \times 10^{14} \times 60) \times 1.6 \times 10^{-19} C$

$= 6.0 \times 10^{-3} C$

Ex.2 A current of 10A exists in a conductor. Assuming that this current is entirely due to the flow of electrons (a) find the number of electrons crossing the area of cross section per second, (b) if such a current is maintained for one hour, find the net flow of charge.

Sol. Current, I = 10 A

Charge flowing through the circuit in one second, Q = 10 C ($\because \frac{\text{Charge}}{\text{Time}} = \text{Current}$)

(a) We know, Charge on an electron

$= 1.6 \times 10^{-19} C$

So, No. of electrons crossing per second

$= \frac{10 C}{1.6 \times 10^{-19}} = 6.25 \times 10^{19}$

(b) Net flow of charge in one hour

= Current × Time

= 10 A × 1 h

10 A × (1 × 60 × 60 s) = 36000 C

Ex.3 A current of 5.0 A flows through a circuit for 15 min. Calculate the amount of electric charge that flows through the circuit during this time.

Sol. Given : Current, I = 5.0 A

Time, t = 15 min. = 15 × 60 s = 900 s

Then, Charge that flows through the circuit,

Q = Current × Time

= 5.0A × 900 s

= 4500 A.s = 4500 C

Ex.4 A piece of wire is redrawn by pulling it until its length is doubled. Compare the new resistance with the original value.

Sol. Volume of the material of wire remains same. So, when length is doubled, its area of cross-section will get halved. So, if *l* and a are the original length and area of cross-section of wire,

Original value of the resistance, $R = \rho \times \frac{\ell}{a}$

and,

New value of the resistance,

$$R' = \rho \times \frac{2\ell}{a/2} = \rho\frac{\ell}{a} \times 4 = 4R$$

Ex.5 Calculate the resistance of 100 m long copper wire. The diameter of the wire is 1 mm.

Sol. Using the relationship,

$$R = \rho \times \frac{\ell}{a} = \rho \times \frac{\ell}{\pi r^2}$$

We have, $r = \frac{1}{2}$ mm $= 0.5 \times 10^{-3}$ m

$$R = \frac{1.6 \times 10^{-6}\,\text{ohm.cm} \times 100\text{m}}{3.141 \times (0.5 \times 10^{-3}\,\text{m})^2}$$

R = 2.04 ohm

Ex.6 If four resistances each of values 1 ohm are connected in series. Calculate equivalent resistance.

Sol. **In series,**

$R_1 = R_2 = R_3 = R_4 = 1$ohm

putting values, we get,

$R_s = 1 + 1 + 1 + 1 = 4$

Ex.7 Suppose a 6-volt battery is connected across a lamp whose resistance is 20 ohm the current in the circuit is 0.25 A, calculate the value of the resistance from the resistor which must be used.

Sol. Lamp resistance, R = 20 ohm

Extra resistance from resistor, R = ? (to be calculated)

For R and R' in series,

Total circuit resistance, $R_s = R + R'$

From relation, (Ohm's law) $R_s = \frac{V}{I}$

Putting values, we get, $R_s = \frac{6}{0.25}$

= 24 ohm

But $R_s = R + R'$

Hence $R' = R_s - R$

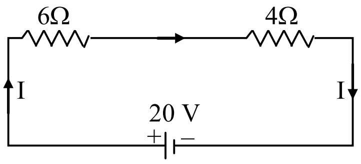
= 24 – 20 = 4 ohm

Extra resistance from resistor,

R' = 4 ohm.

Ex.8 A resistance of 6 ohms is connected in series with another resistance of 4 ohms. A potential difference of 20 volts is applied across the combination. Calculate the current through the circuit and potential difference across the 6 ohm resistance.

Sol. For better understanding we must drawn a proper circuit diagram. It is shown in fig.



We use proper symbols for electrical components.Resistances are shown connected in series, with 20 V battery across its positive and negative terminals. Direction of current flow is also shows from positive terminal of the battery towards its negative terminal.

Potential difference, V = 20 V

Potential difference across 6 Ω,

V_1 = ? (to be calculated)

Total circuit resistance = 10 Ω

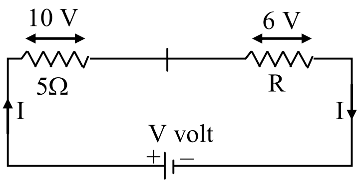
From Ohm's law, $R_s = \frac{V}{R_S}$

Circuit current, **I = 2 ampere or (2A)**

Putting values, we get, $V_1 = 2 \times 6 = 12$ volts

Potential difference across 6 Ω resistance = 12 V

Ex.9 Two resistances are connected in series as shown in the diagram.



(i) What is the current through the 5 ohm resistance ?

(ii) What is the current through R ?

(iii) What is the value of R ?

(iv) What is the value of V ?

Sol. First resistance, $R_1 = 5\ \Omega$

(i) Current through 5 ohm resistance, $I = ?$

(ii) Current through R, $I = ?$

(iii) Value of second resistance, $R = ?$

(iv) Potential difference applied by the battery, $V = ?$

(i) From Ohm's law, $R = \frac{V}{I}$

We have, $I = \frac{V}{R} = \frac{V_1}{R_1}$

$I = \frac{10}{5} = 2$ ampere

Current through 5 Ω resistance = 2 ampere (2A).

(ii) Since R is in series with 5 Ω, same current will flow through it,
Current through R = 2 A.

(iii) From Ohm's law, $R = \frac{V}{I}$

$R_2 = \frac{V_2}{I}$

$R_2 = \frac{6}{2} = 3$ ohms

Resistance R has value = 3 ohms.

(iv) From relation, $V = V_1 + V_2$

$V = 10 + 6 = 16$ volts

$V = 16$ volts

Ex.10 Resistors R_1, R_2 and R_3 having values 5Ω, 10Ω, and 30Ω respectively are connected in parallel across a battery of 12 volt. Calculate (a) the current through each resistor (b) the total current in the circuit and (c) the total circuit resistance.

Sol. Here,

$R_1 = 5\Omega$, $R_2 = 10\Omega$, $R_3 = 30\ \Omega$, $V = 12$ V

(a) $I_1 = ?$ $I_2 = ?$ $I_3 = ?$

(b) $I = I_1 + I_2 + I_3 = ?$

(c) $R_p = ?$

(a) From relation, (Ohm's law), $R = \frac{V}{I}$

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

Putting values, we get, $I_1 = \frac{V}{R_1} = \frac{12}{5} = 2.4$ A

$I_2 = \frac{V}{R_2} = \frac{12}{10} = 1.2$ A

$I_3 = \frac{V}{R_3} = \frac{12}{30} = 0.4$ A

(b) Total current, $I = I_1 + I_2 + I_3$

$I = 2.4 + 1.2 + 0.4 = 4$ A

(c) From relation $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

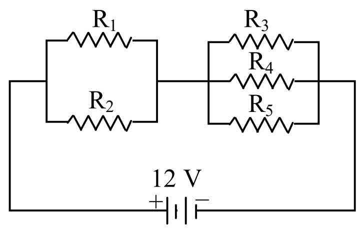
$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = \frac{6+3+1}{30} = \frac{10}{30}$$

$R_p = 3$ ohm.

Ex.11 Resistors R_1 = 10 ohms, R_2 = 40 ohms, R_3 = 30 ohms, R_4 = 20 ohms, R_5 = 60 ohms and a 12 volt battery is connected as shown. Calculate :

(a) the total resistance and (b) the total current flowing in the circuit.

Sol. The situation is shown in (figure).



For R_1 and R_2 in parallel

$$\frac{1}{R_{P_1}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10} + \frac{1}{40} = \frac{4+1}{40} = \frac{5}{40} = \frac{1}{8}$$

or $R_{P_1} = 8$ ohm

For R_3, R_4 and R_5 is parallel

$$\frac{1}{R_{P_2}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60}$$

$$= \frac{2+3+1}{60} = \frac{6}{60} = \frac{1}{10}$$

or $R_{P_2} = 10$ ohm.

(a) For R_{P_1} and R_{P_2} in series.

Total resistance, $R = R_{P_1} + R_{P_2}$

Putting values, we get, $R = 8 + 10 = 18$

Total resistance, R = 18 ohms. Ans.

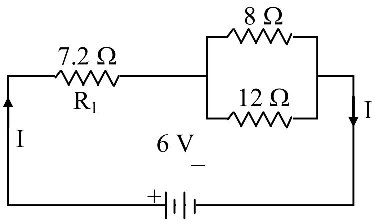
(b) From relation, (Ohm's law) $R = \frac{V}{I}$

We have, $I = \frac{V}{R}$

Putting values, we get, $I = \frac{12}{18} = \frac{2}{3} = 0.67$

Total current, **I = 0.67 A. Ans**

Ex.12 In the circuit diagram given below. find



(i) total resistance of the circuit

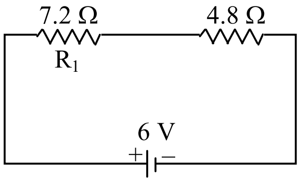
(ii) total current flowing in the circuit

(iii) potential difference across R_1

Sol. **(i) For total resistance**

8 Ω and 12 Ω are connected in parallel.

Their equivalent resistance comes in series with 7.2 Ω resistance as shown in fig.



With 7.2 Ω and 4.8 Ω in series

$R_s = 7.2 + 4.8 = 12\ \Omega$

Total circuit resistance = 12 ohms.

(ii) For total current

Total circuit resistance, R = 12 ohm

Potential difference applied, V = 6 V

I = ?

From Ohm's law $R = \frac{V}{I}$

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

$I = \frac{6}{12} = 0.5$

Total circuit current = **0.5 A** **Ans.**

(iii) For potential difference across R_1

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

$V = IR$

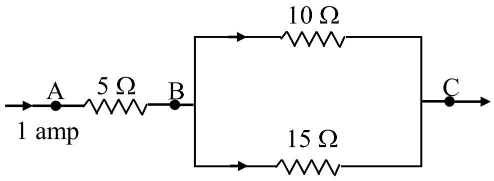
$V_1 = IR_1$

$V_1 = 0.5 \times 7.2$

$= 3.6$ V

Potential difference across, V_1 = **3.6 V. Ans**

Ex.13 Three resistances are connected as shown in diagram through the resistance 5 ohms, a current of 1 ampere is flowing :



(i) What is the current through the other two resistors?

(ii) What is the potential difference (p.d.) across AB and across AC ?

(iii) What is the total resistance.

Sol. **(i) For current in parallel resistors**

For same potential difference across two parallel resistors,

$V = I_1R_1 = I_2R_2$ i.e. $= \frac{I_1}{I_2} = \frac{R_2}{R_1}$

Current divides itself in inverse ration of the resistances.

Also total current, $I = I_1 + I_2$

$\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{15}{10} = \frac{3}{2}$

Also, $I_1 + I_2 = 1$ amp.

$I_1 = 0.6$A, $I_2 = 0.4$ A. Ans.

Current is **0.6 A** through 10 Ω

(ii) For p.d. across AB

From Ohm's law, $R = \frac{V}{I}$, $V = IR$

$V = 1 \times 5 = 5V$

P.D. across AB = **5 V. Ans**

For parallel combination of 10 Ω and 15 Ω P.D. across BC, $V = I_1R_1 = 0.6 \times 10 = 6$ V

P.D. across AC = P.D. across AB + P.D. across BC.

$= 5 + 6 = 11$ V

(iii) For total circuit resistance

For 10 Ω and 15 Ω in parallel

$$R_p = \frac{10\times15}{10+15} = \frac{150}{25} = 6\ \Omega$$

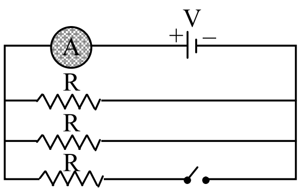
Total resistance = 5 + 6 = 11 Ω

Total circuit resistance **= 11 Ω. Ans**

$$\left[\text{Also } R = \frac{V}{I} = \frac{11}{1} = 11\Omega\right]$$

Ex.14 In the diagram shown below (Fig.), the cells and the ammeter both have negligible resistance. The resistors are identical. With the switch K open, the ammeter reads 0.6 A. What will be the ammeter reading when the switch is closed ?

Sol.



Let the cell have potential difference V and each resistor have resistance R

With key open

Potential difference, = V

Circuit resistance of two parallel resistors,

$$R_{P_1} = \frac{R}{n_1} = \frac{R}{2}\Omega$$

Circuit current, $I_1 = 0.6$ A

With key closed

Potential difference = V

Circuit resistance of three parallel resistors,

$$R_{P_2} = \frac{R}{n_2} = \frac{R}{3}\Omega$$

Circuit current, $I_2 = ?$

For same potential difference V

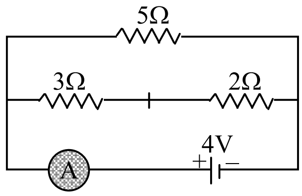
$$V = I_1 R_{P_1} = I_2 R_{P_2}$$

$$I_2 = \frac{I_1 R_{P_1}}{R_{P_2}}$$

$$I_2 = 0.6 \times \frac{R}{2} \times \frac{3}{R} = 0.9$$

Circuit current with closed key = **0.9 A**.

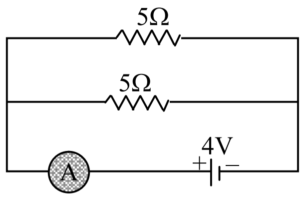
Ex.15 In the circuit diagram.



Find (i) total resistance

(ii) current shown by the ammeter A.

Sol. 3 Ω and 2 Ω in series become 5 Ω. Equivalent circuit is shown in fig.



(i) For total resistance

$R_1 = R_2 = 5\ \Omega$ are in parallel.

$$R_p = \frac{5\times5}{5+5} = \frac{25}{10} = 2.5\ \Omega$$

Circuit resistance **= 2.5 ohm**

(ii) For circuit current

Potential difference, V = 4 V

Circuit resistance $R_p = 2.5\ \Omega$

Circuit current, I = ? (to be calculated)

From Ohm's law, $R = \frac{V}{I}$

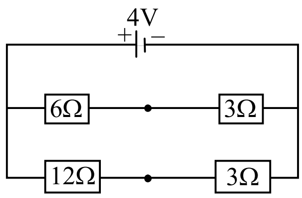
$$I = \frac{V}{R_P}$$

$$I = \frac{4}{2.5} = 1.6\text{ A}$$

Circuit current = **1.6 A**

Ammeter reads circuit current **1.6 A**

Ex.16 For the circuit shown in the following diagram what is the value of



(i) current through 6 Ω resistor

(ii) potential difference (p.d.) across 12 Ω.

Sol. **(i) For current through 6 Ω**

Current from 4 V battery flows through first parallel branch having 6 Ω and 3 Ω in series. Current in this branch

$$I = \frac{4}{6+3} = \frac{4}{9} = \mathbf{0.44\ A}$$

(ii) For p.d. across 12 Ω

Current through second parallel branch

$$I = \frac{4}{12+3} = \frac{4}{15}\ A$$

P.D. across 12 Ω, $V = \frac{4}{15} \times 12 = 3.2$ V.

ELECTRIC ENERGY

When a potential difference is applied across a wire, current starts flowing in it. The free electrons collide with the positive ions of the metal and lose energy. Thus energy taken from the battery is dissipated. The battery constantly provide energy to continue the motion of electron and hence electric current in the circuit. This energy is given to ions of the metal during collision and thus temperature of wire rises. Thus, energy taken from the battery gets transferred in to heat. This energy is called electrical energy. This effect is also called 'Heating Effect of Current'.

If

R = Resistance of wire

I = Current in wire

V = Potential difference across wire.

Flow of charge in 't' time = It.

Energy dissipated W = Vq = VIt,

$\because$ V = IR,

$$\therefore\ W = VIt = I^2Rt = \frac{V^2}{R}\ t = Vq$$

This energy is equal to work done by battery or heat produced in the wire.

ELECTRICAL POWER

The rate of loss of energy in an electrical circuit is called electrical power. It is denoted by'P'

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

units of power = joule/sec, watt, horse power

1 watt = 1 joule/sec, 1 HP = 746 watt

unit of electrical energy = watt second, kilowatt hour

1 kilowatt hour (kwh) = 3.6×10^6 Joule

Points to Be Remember

- **Current :** The rate of flow of charge (Q) through a conductor is called current .
  Current (I) is given by,
  $$\text{Current} = \frac{\text{Charge}}{\text{Time}} \text{ or } \quad I = \frac{Q}{t}$$
  The SI unit of current is ampere (A) : 1A = 1 C/s
  The current flowing through a circuit is measured by a device called ammeter. **Ammeter** is connected in series with the conductor. The direction of the current is taken as the direction of the flow of positive charge.
- **Ohm's law :** At any constant temperature, the current (I) flowing through a conductor is directly proportional to the potential (V) applied across it.
  Mathematically,
  $$I = V/R \text{ or } \quad V = IR$$
- **Resistance :** Resistance is the property of a conductor by virtue of which it opposes the flow of electricity through it. Resistance is measured in ohms. Resistance is a scalar quantity.
- **Resistivity :** The resistance offered by a cube of a substance having side of 1 meter, when current flows perpendicular to the opposite

faces, is called its resistivity (ρ). The SI unit of resistivity is ohm.m.

- **Equivalent resistance :** A single resistance which can replace a combination of resistances so that current through the circuit remains the same is called *equivalent resistance.*

- **Law of combination of resistances in series :** When a number of resistance are connected in series, their equivalent resistance is equal to the sum of the individual resistances.

  If R_1, R_2, R_3, etc. are combined in series, then the equivalent resistance (R) is given by,

  $$R = R_1 + R_2 + R_3 + ...$$

  The equivalent resistance of a number of resistances connected in series is higher than each individual resistance.

- **Law of combination of resistances in parallel :** When a number of resistances are connected in parallel, the reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances.

If R_1, R_2, R_3, etc. are combined in parallel, then the equivalent resistance (R) is given by.

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

The equivalent resistance of a number of resistances connected in parallel is less than each of all the individual resistances.