CURRENT ELECTRICITY

Electric Current (Charge in Motion)

- **Defination :** The quantity of electric charge flowing through a 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

We have

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

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

$$\text{SI unit of current} = \frac{1 \text{ coulomb}}{1 \text{ second}} = 1 \text{ C s}^{-1}$$

The unit coulomb per second (C s^{-1}) is called ampere (A). So, the SI unit of current (I) is ampere. The unit ampere is denoted by the letter A.

Sometimes a smaller unit of current called milliampere (mA) is also used.

$$1 \text{ milliampere} = \frac{1}{1000} \text{ ampere}$$

or $$1 \text{ mA} = \frac{1}{1000} \text{ A} = 10^{-3} \text{ A}$$

Definition of Ampere :

From above,

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

If, Q = 1 coulomb and

t = 1 second, then

$$I = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

$$= 1 \text{ coulomb per second}$$

$$= 1 \text{ C s}^{-1} = 1 \text{ A}$$

Direction of Electric Current :

The direction of flow of the positive charge taken as the 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.

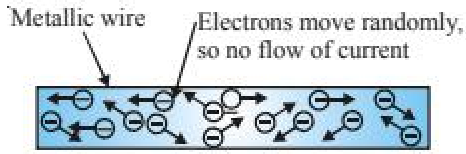


Fig. Flow of electrons inside a metal wire when no potential is applied across its ends

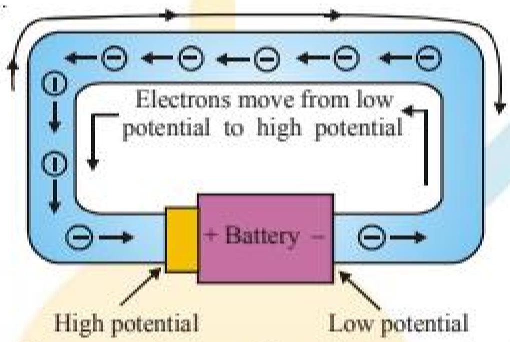
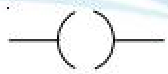
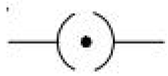
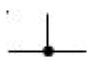
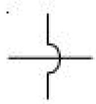
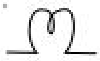


Fig. Flow of electrons inside a metal wire when the two ends of a wire are connectedto the two terminals of a battery

Electric Symbols

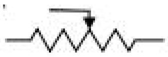
Many different kinds of equipments or components are used in setting up electrical circuits. To draw the diagrams of electrical circuits on paper these equipments/components are shown by their symbols. Here are some symbols used in the electric circuit diagrams.

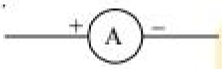
S.N.	Components	Symbols
1.	Electric cell	
2.	Battery	
3.	Plug key (switch open)	
4.	Plug key (switch closed)	
5.	A wire joint	
6.	Wires crossing without joining	

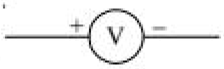
7. Elecctric bulb  or 

8. A resistor of resistance R 

9. Variable or resistance  or

or rheostat 

10. Ammeter 

11. Volmeter 

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

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

Equation (i) may be written as,

$$V = I \times R \qquad \text{...(ii)}$$

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

Then ratio, 1 volt / 1 ampere is taken as one unit of resistance, i.e. equals 1 ohm.

So,

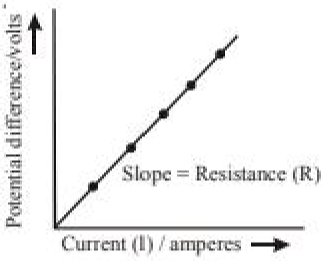
$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

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.

$$I \propto V$$



- 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 colloide 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 is length. That is

  R → Resistance of a conductor

  l → Length of the conductor

  $$R \propto l.$$

- **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 matal when temperature increases resistance increases and for semiconductors when themperature 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 iron etc.

Resistivity

$R \propto \ell$

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

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

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

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

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

Then $R = \rho$ ...(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

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

SI unit of resistance (R) is ohm (Ω)

SI unit of length (l) is metre (m)

SI unit of area of cross-section (a) is $metre^2$ (m^2)

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

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

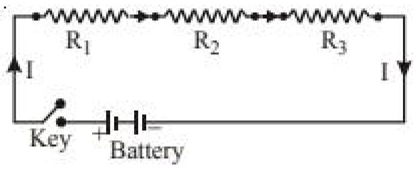
◈ **Classification of Material on Basis of Resitivity**

- **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,

$$R = R_1 + R_2 + R_3 + \ldots \qquad \text{....(i)}$$

◆ **Derivation of mathamatical 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,

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

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

$$V = V_1 + V_2 + V_3 \qquad \text{...(iii)}$$

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.**

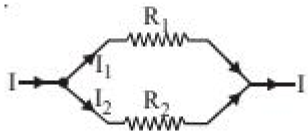
(i) When two or more resistors are connected in series, the total resistance of the combination is equal to the sum of all the individual resistances.

(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 parrallel 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 10 A. How many electrons strike the TV screen in each second? 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

(a) So,

Charge flowing per second,

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

We known,

Charge on an electron = 1.6×10^{-19}C

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

= 6.25×10^{14}

(b) Charge striking the screen per min

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

= 6.0×10^{-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

= 1.6×10^{-19}C

So, No. of electrons crossing per second

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

(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 untill 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-sction 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,

$$R' = \rho \times \frac{2\ell}{a/2} = \rho\frac{1}{a} \times 4 = 4R.$$

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

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

$R = 2.04$ ohm

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

Sol. **In series,**

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

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 calculate 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 $R' = R_s - R$

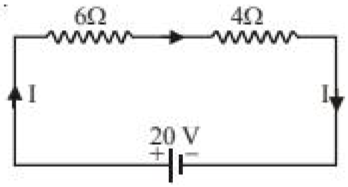
= 24 – 20 = 4 ohm

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 differecnce 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 $6\ \Omega$,

$$V_1 = ? \text{ (to be calculated)}$$

Total circuit resistance = $10\ \Omega$

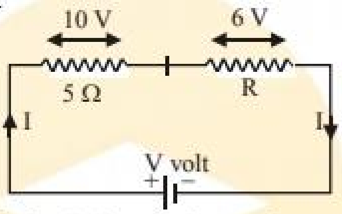
From Ohm's law, $R_s = \frac{V}{R_s}$

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

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

Potential difference across $6\ \Omega$ 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, $I = \frac{V}{R} = \frac{V_1}{R_1}$

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

Current through $5\ \Omega$ resistance = 2 ampere (2A).

(ii) Since R is in series with $5\ \Omega$, same current will flow through it,

Current through R = 2 A.

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

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

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

Resistance R has value = 3 ohms.

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

$$V = 10 + 6 = 16 \text{ volts}$$
$$V = 16 \text{ volts.}$$

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**

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

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

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

$$I = 2.4 + 1.2 + 0.4 = 4\ \text{A}$$

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

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

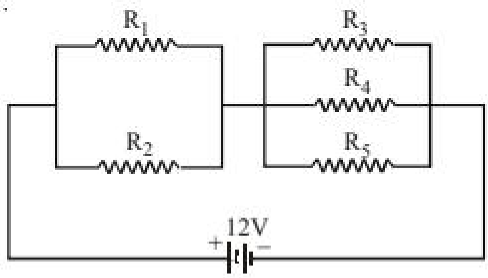
$$R_p = 3 \text{ ohm.}$$

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 conected 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

$$\frac{1}{R_{p1}}=\frac{1}{R_1}+\frac{1}{R_2}=\frac{1}{10}+\frac{1}{40}=\frac{4+1}{40}=\frac{5}{40}=\frac{1}{8}$$

or R_{P1} = 8 ohm.

For R_3, R_4 and R_5 is parallel

$$\frac{1}{R_{p2}}=\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}=\frac{1}{30}+\frac{1}{20}+\frac{1}{60}$$

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

or R_{p2} = 10 ohm.

(a) For R_{p1} and R_{p2} in series.

Total resistance, $R = R_{P1} + R_{p2}$

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 Calculate the equivalent resistance when two resistances of 3 ohms and 6 ohms are connected in parallel.

Sol. Circuit diagram is shown in fig.

$R_1 = 3\ \Omega$

$R_2 = 6\ \Omega$

Resistances in parallel combination, R_p = ?

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

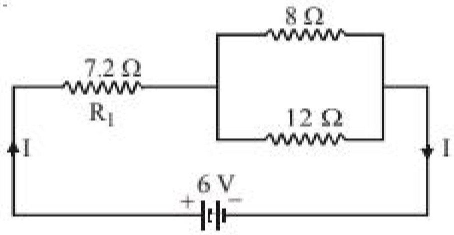
$$\frac{1}{R_p}=\frac{R_2+R_1}{R_1R_2}$$

$$R_p=\frac{R_1R_2}{R_1+R_2}$$

Putting values, we get $R_p=\frac{3\times 6}{3+6}=\frac{18}{9}=2$

Equivalent resistance is **2 ohms.** **Ans.**

Ex.13 In the circuit diagram given below. find



(i) total resistance of the circuit

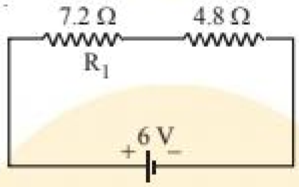
(ii) total current flowing in the circuit

(iii) potential difference across R_1.

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

8 Ω and 12 Ω are connected in parrelel.

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.**

(ii) **For potential difference across R_1**

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

$$V = IR$$

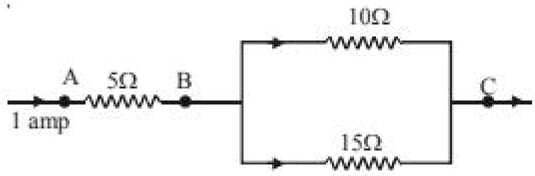
$$V_1 = IR_1$$

$$V_1 = 0.5 \times 7.2$$

$$= 3.6\ V$$

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

Ex.14 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 leaverse 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.

$\mathbf{I_1 = 0.6A,\ I_2 = 0.4\ A.}$ **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. acroos 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

$$R_P = \frac{10 \times 15}{10 + 15} = \frac{150}{25} = 6\ \Omega$$

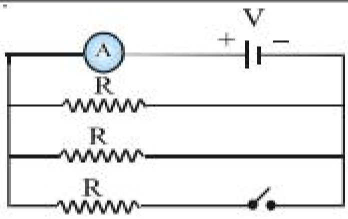
Total resistance = 5 + 6 = 11 Ω

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

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

Ex.15 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,

$$R_{p1} = \frac{R}{n1} = \frac{R}{2}\Omega$$

Circuit current, $I_1 = 0.6$ A

With key closed

Potential difference = V

Circuit resistance of three parallel resistors,

$$R_{p2} = \frac{R}{n_2} = \frac{R}{3}\Omega$$

Circuit current, $I_2 = ?$

For same potential difference V

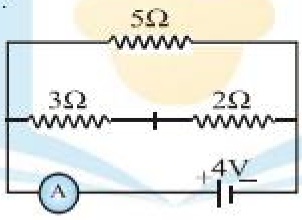
$$V = I_1R_{p1} = I_2R_{p2}$$

$$I_2 = \frac{I_1R_{p1}}{R_{p2}}$$

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

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

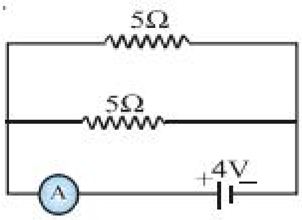
Ex.16 In the circuit diagram.



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

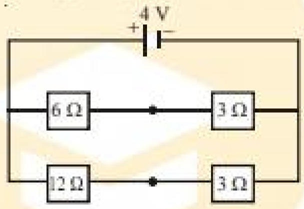
$$I = \frac{V}{R_p}$$

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

Circuit current **= 1.6 A**

Ammeter reads circuit current **1.6 A**

Ex.17 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, $V = \frac{4}{15} \times 12 = 3.2\ V.$

Points to Be Remember

◆ **Current (or electrical current) :** The rate of flow of charge through a conductor is called current. Current is measured in ampere unit, denoted by A.

◆ **Current :** The rate of flow of charge (Q) through a conductor is called current .

Current (I) is given by,

$$\text{Current} = \frac{\text{Charge}}{\text{Time}} \quad \text{or} \quad I = \frac{Q}{t}$$

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,

  $$I = V/R \quad \text{or} \quad V = IR$$

- **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.

EXERCISE - 1

VERY SHORT ANSWER TYPE QUESTIONS.

Q.1 Define current.

Q.2 What is the SI unit of current?

Q.3 Define one ampere.

Q.4 What is the conventional direction of electric current? How does it differ from the direction of flow of electrons?

Q.5 What is the charge of an electron?

Q.6 What do you mean by elementary charge?

Q.7 State Ohm's law.

Q.8 What is the unit of resistance?

Q.9 Define one ohm.

Q.10 Write the formula for resistance of a wire of length l and cross-section A.

Q.11 Define specific resistance.

Q.12 Write the unit of specific resistance.

Q.13 Distinguish between resistance and resistivity.

Q.14 Two resistors R_1 and R_2 are joined in series. Find the equivalent resistance.

Q.15 Two resistors R_1 and R_2 are joined in parallel. Find the equivalent resistance.

SHORT ANSWER TYPE QUESTIONS

Q.1 Define current. Is it a scalar quantity or a vector quantity? What is meant by the conventional direction of current?

Q.2 Define resistance.

Q.3 On what factors does the resistance of a conductor depend?

Q.4 Define resistivity. Write the formula for resistivity.

Q.5 What is the formula for the combination of resistances when they are combined in :
(i) series and
(ii) parallel ?

Q.6 Why is the series arrangement not used for domestic circuits?

Q.7 How does the resistance of a wire vary with its cross-sectional areal?

Q.8 A Piece of wire is redrawn by pulling it until its length id doubled. Compare the new resistance with the original value .

LONG ANSWER TYPE QUESTIONS

Q.1 Define charge. What do you understand by positive and negative charge ? Write down the expression for force between two charges.

Q.2 State Ohm's law. How it can be verified experimentally?

Q.3 Describe the conditions for constituting an electric current. Explain the mechanism of flow of electrons in a conductor.

Q.4 Derive the expression for the equivalent resistance when two resistors are joined in series.

Q.5 Derive the expression for the equivalent resistance when two resistors are joined in parallel.

MULTIPLE CHOICE QUESTIONS

Q.1 The unit of resistivity is-
(A) Ω (B) $\Omega\ m^{-1}$
(C) Ω-m (D) Ω^{-1}

Q.2 Which of the following statements does not represent Ohm's law?
(A) Current /potential difference = constant
(B) Potential difference = current × resistance
(C) Potential difference/current = constant
(D) Current = potential difference × resistance

Q.3 For which of the following substances does resistance decrease with increase in temperature?
(A) Copper (B) Mercury
(C) Carbon (D) Platinum

Q.4 If a wire is stretched to double its length, its resistance will become.
(A) two times (B) half
(C) four times (D) one-fourth

Q.5 In a metal.

(A) all the electrons are free
(B) all the electrons are bound to their parent atoms
(C) there are no free electrons
(D) some electrons are free

Q.6 The free electrons in a metal are free to-

(A) move on the surface only
(B) escape throughout the surface
(C) move throughout the interior of the metal
(D) fall into the nuclei

Q.7 When two resistances are connected in parallel,

I. the total resistances is less than each of the resistance
II. the potential difference across each resistance is the same.
III. a larger current flows through the smaller resistance.

Which of the above statement (s) is/are correct?

(A) I (B) II
(C) III (D) I, II and III

Q.8 Which of the following statement (s) is/are correct?

(A) Electrons flow from a body at a negative potential to a body at a positive potential.
(B) Electrons flow from a body at higher negative potential to a body at a lower negative potential.

(C) Electrons flow from a body at a lower positive potential to a body at a higher positive potential.
(D) All of the above.

Q.9 If a charge of 12.5 nC flows in 50 ms, the current flowing is-

(A) 2.5×10^{-7} A (B) 6.25×10^{-7} A
(C) 2.5×10^{-5}A (D) 625 A

Q.10 Electricity constituted by moving electric charges, is called.

(A) positive electricity
(B) negative electricity
(C) current electricity
(D) static electricity

Q.11 Time rate of flow of electric charge measures electric

(A) circuit (B) current
(C) potential differece (D) cell.

Q.12 The law which gives a relation between electric potential difference and electric current, is called.

(A) Faraday's law (B) Oersted's law
(C) Ohm's law (D) Newton's law

Q.13 In series combination, total resistance

(A) decreases
(B) increases
(C) may decrease or increase according to the situation
(D) no particular observation.

Q.14 In parallel combination, total resistance

(A) decreases
(B) increases
(C) may decrease or increase according to the situation
(D) no particular observation

FILL IN THE BLANKS

Q.1 The unit of electric current is ....

Q.2 In .... combination of resistors, the total resistance is more than the highest resistance.

Q.3 Conductors have .... free electrons.

Q.4 Insulator have .... free electrons.

Q.5 The substances whose resistivity lies between those of conductors and insulators are called ....

Q.6 The substance which lose their resistance completely at very low temperature are called ....

Q.7 Electrical charge is measured in units called the ....

Q.8 The current flowing through a conductor is directly proportional to .... between the ends of the conductor, provided the temperature and the state of matter of the conductor remain unchanged.

Q.9 The same current flows through through all the resistances if they are connected in ....

Q.10 When resistances are connected in series, the effective resistance is .... than each of the individual resistances.

Q.11 .... is an example of a non-metal which conducts electricity.

NUMERICAL PROBLEMS

Q.1 If the charge on an electron be 1.6×10^{-19} C, how many electrons should pass through a conductor in 1 second to constitute 1ampere current?

Q.2 How many electrons pass through a lamp in one minute if the current be 200 mA? (Charge on an electron, e = 1.6×10^{-10} C).

Q.3 A conductor carries a current of 0.2A. Find the amount of charge that will pass through the cross-section of the conduction is 30 s. How many electrons will flow in this time-interval? (Charge on an electron, e = 1.6×10^{-19} C.)

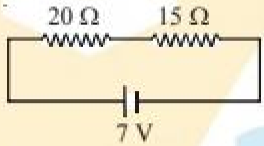
Q.4 The potential difference between the two points of a wire carrying 2 amperes current is 0.1 volt. Calculate the resistance between these points.

Q.5 A resistance of 12 ohm is connected in parallel with another resistor X. The resultant resistance of the combination is 4.8 ohms. What is the resistance X?

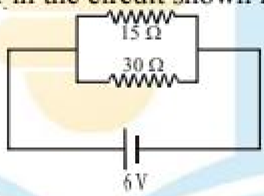
Q.6 Three resistances 12 ohms each are connected in parallel. Three such combinations are connected in series. What is the total resistance?

Q.7 How will you connect three resistors of 3 Ω, 4 Ω and 7 Ω respectively so as to obtain a resultant resistance, of 3.5 Ω ?

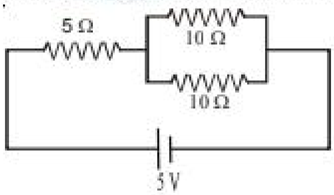
Q.8 Find the current through the circuit shown in figure 5.E1. Also find the potential difference across the 20-Ω resistor.



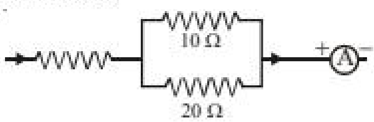
Q.9 Find (a) the equivalent resistance, (b) the current passing through the cell, and (c) the current passing through the 30-Ω resistor in the circuit shown in figure.



Q.10 Find the current supplied by the cell in the circuit shown in figure.



Q.11 Figure shows a part of an electric circuit. The reading of the ammeter is 3.0 A. Find the currents through the 10-Ω and 20-Ω resistors.



TRUE OR FALSE

Q.1 A metal has a large number of electrons but a non-metal has only a small number of electrons.

Q.2 All the electrons of a metal are free to move anywhere inside the metal.

Q.3 A voltaic cell converts chemical energy into electrical energy.

Q.4 Resistance of a metallic conductor does not depend upon its length.

Q.5 A thick wire has smaller resistance while a thin wire has larger resistance.

Q.6 Resistance of metals increases with increase in temperature.

Q.7 Resistance of metals increases with increase in temperature.

Q.8 Resistance of alloys decreases with the increase in temperature.

Q.9 Electric current is due to flow of electrons.

Q.10 An ammeter measures an electric current flowing through a circuit.

Q.11 In a series combination of resistors, the total resistance is more than the highest resistance.

Q.12 The quantity of charges flowing past a point multiplied by the time gives the current.

Q.13 The resistivity of all pure metals increases with rise in temperature.

Q.14 Ohm's law is the relation between the power used, the current and potential difference.

Q.15 A series circuit has only one conducting path fro the electrons that move through it ; a parallel circuit has multiple conducting paths.

Q.16 A conducting wire offers resistance to flow of electrons repel each other.`

EXERCISE - 2

SINGLE CORRECT TYPES QUESTIONS

Q.1 A current of 5 A exists in a 10 Ω resistance for 4 minutes. How many coulombs pass through any cross-section of the resistor in this time?

(A) 12 C (B) 120 C
(C) 1200 C (D) 12000 C

Q.2 A current of 0.5 A flows in a 60 W lamp, then the total charge passing through it in two hours will be.

(A) 1800 C (B) 24 00 C
(C) 3000 C (D) 3600 C

Q.3 A charge of 2×10^{-2} C moves at 30 revolutions per second in a circle of diameter 80 cm. The current linked with the circuit is.

(A) 0.02 A (B) 20 A
(C) 0.60 A (D) 60 A

Q.4 Current of 4.8 ampere is flowing through a conductor. The number of electrons crossing per second the cross-section of conductor will be.

(A) 3×10^{19} (B) 3×10^{20}
(C) 7.68×10^{20} (D) 7.68×10^{21}

Q.5 The resistance of a wire is R Ω. The wire is stretched to double its length keeping volume constant. Now the resistance of the wire will become.

(A) 4 R Ω (B) 2 R Ω
(C) R / 2Ω (D) R / 4Ω

Q.6 If an increase in length of copper wire is 0.5% due to stretching, the percentage increase in its resistance will be.

(A) 0.1% (B) 0.2%
(C) 1% (D) 2%

Q.7 A wire 1 m long has a resistances of 1 Ω. If it is uniformly stretched, so that its length increases by 25%, then its resistance will increase by.

(A) 25% (B) 50%
(C) 56.25% (D) 77.33%

Q.8 A given piece of wire of length l radius r and resistance R is stretched uniformly to a wire of radius r / 2. The new resistance is

(A) 16 R (B) 4 R (C) R/4 (D) R/16

Q.9 What length of a copper wire of cross-sectional are 0.01 mm^2, resistivity 1.7×10^{-8} Ωm, will be needed to repare a resistance of 1.7 kΩ?

(A) 0.1 km (B) 0.7 km
(C) 1 km (D) 10 km

Q.10 1 kg piece of copper is drawn into a wire 1 mm thick, and another piece into a wire 2 mm thick. Compare the resistance of these wires.

(A) 2 : 1 (B) 4 : 1
(C) 8 : 1 (D) 16 : 1

Q.11 A resistor of 20 cm length and resistance 5 ohm is stretched to a uniform wire of 40 cm length. The resistance now is-

(A) 10 ohm (B) 5 ohm
(C) 20 ohm (D) 200 ohm

Q.12 Certain wire has resistance of 10 Ω. If it is stretched by 1/10th of its length, then its resistance is nearly.

(A) 9 Ω (B) 10 Ω (C) 11 Ω (D) 12 Ω

Q.13 Masses of the three wires of same material are in the ratio of 1 : 2 : 3 and their lengths in the ratio of 3 : 2 : 1. Electrical resistance of these wires will be in the ratio of.

(A) 1 : 1 : 1 (B) 1 : 2 : 3
(C) 9 : 4 : 1 (D) 27 : 6 : 1

Q.14 A wire of resistance 6 Ω is cut into three equal pieces, which are joined to form a triangle. The equivalent resistance between any two corners of the triangle is.

(A) (3 / 4) Ω (B) (4 / 3) Ω
(C) 2 Ω (D) 4 Ω

Q.15 The equivalent resistance of network of three 2 Ω resistors can not be.

(A) 0.67 Ω (B) 2 Ω
(C) 3 Ω (D) 6 Ω

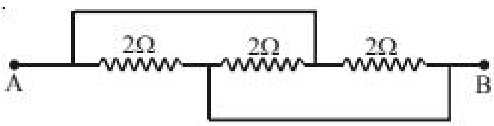
Q.16 Four wires each of same length diameter and material are connected to each other to form a square. If the resistance of each wire is R, then equivalent resistance across the opposite corners is.

(A) R (B) R/2
(C) R/4 (D) none of the above

Q.17 Three resistances each of 4 Ω are connected in the form of an equilateral triangle. The effective resistance between any two corners is.

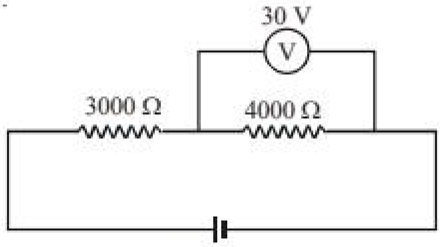
(A) (3/8) Ω (B) (8/3) Ω
(C) 8 Ω (D) 12 Ω

Q.18 The electrical resistance between points A and B of the fig. 13.43 shown is.



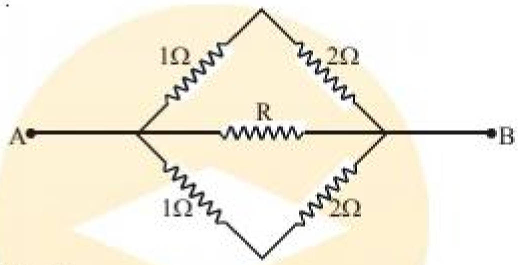
(A) (2/3) Ω (B) 2 Ω
(C) (3/2) Ω (D) 6 Ω

Q.19 In the circuit fig, the voltmeter reads 30 V. What is the resistance of the voltmeter?



(A) 1200 Ω (B) 700 Ω
(C) 400 Ω (D) 300 Ω

Q.20 The equivalent resistance between points A and B in the fig, is 1 Ω. What is the value of unknown resistance R?

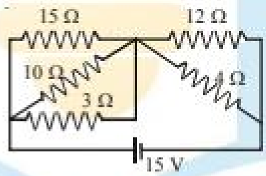


(A) 1 Ω (B) 3 Ω
(C) 6 Ω (D) 9 Ω

PASSAGE BASED QUESTIONS

Passage - 1 (Qus. 21 to Qus. 27)

The fig. shows a network of *five* resistances and a battery.



Answer the following questions.

Q.21 The total resistance of the network across the battery is-
(A) 5 Ω (B) 6 Ω
(C) 3.5 (D) None of these

Q.22 The current coming out of the battery is-
(A) 2.5 A (B) 3 A
(C) 4 A (D) None of these

Q.23 The voltage drop across the 10 Ω resistor is.
(A) 6 V (B) 9 V
(C) 10 V (D) None of these

Q.24 The current in the 15 Ω resistor is-

(A) 1 A (B) 0.6 A

(C) 1.5 A (D) 0.4 A

Q.25 The current through the 12 Ω resistor is

(A) 0.4 A (B) 0.6 A

(C) 0.75 A (D) 1 A

Q.26 The power dissipated in the 3 Ω resistor is

(A) 25 Ω (B) 37.5 Ω

(C) 12 Ω (D) 3.6 Ω

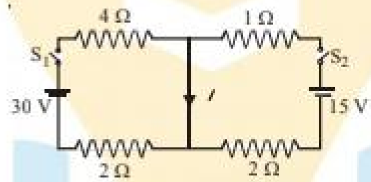
.27 The maximum power is dissipated in the resistor of

(A) 15 Ω (B) 12 Ω

(C) 4 Ω (D) 6 Ω

Passage - 2 (Qus. 28 to Qus. 32)

The fig. shows a network of four resistance and two batteries along with two switches S_1 and S_2.



Answer the following questions.

Q.28 With the S_1 closed and S_2 opened.

(A) The current in the 4 Ω resistor in 5 A

(B) The current in the 1 Ω resistor is zero

(C) The current in the middle branch is I = 5 A

(D) All the above

Q.29 With the switch S_2 closed and S_1 opened.

(A) The current in the 4Ω resistor is zero

(B) The current in the 1Ω resistor is 5 A.

(C) The current in the middle branch is I = 5 A

(D) All the above

Q.30 With both the switches S_1 and S_2 closed.

(A) The current in the 4 Ω resistor is zero.

(B) The current in the 1Ω resistor is zero.

(C) The current in the middle branch is zero.

(D) None of these

Q.31 With both the switches closed, the maximum power is dissipated in.

(A) 1 Ω (B) 2 Ω

(C) 4 Ω (D) Middle branch

Q.32 With both the switches closed

(A) the 4 Ω and 2 Ω resistances in the left loop are in parallel.

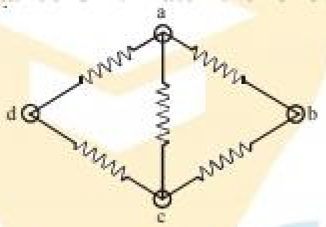
(B) the 4 Ω and 2 Ω resistances in the left loop are in series.

(C) the left loop and the right loop are in series.

(D) the left loop and the right loop are in parallel.

COLUMN MATCHING

Q.33 In the figure shown, each resistance is R. Match the following :



Column-I		**Column-II**
(A) Resistance between a and b	(P)	$\frac{R}{2}$
(B) Resistance between a and c	(Q)	$\frac{5}{8}R$
(C) Resistance between b and d	(R)	R
	(S)	none

Q.34 Three wires of same material are connected in parallel to a source of emf. The length ratio of the wires is 1 : 2 : 3 and the ratio of their area of cross section is 2 : 4 : 1. Then match match the following :

Column-I	**Column-II**
(A) Resistance ratio	(P) 6 : 6 : 1
(B) Current ratio	(Q) 1 : 6 : 6
(C) Power ratio	(R) 1 : 1 : 6
	(S) None

ANSWER KEY

EXERCISE-1

D. MULTIPLE CHOICE QUESTIONS :

1. C **2.** D **3.B** **4.** A **5.** D **6.** C **7.** D **8.** D
9. C **10.** C **11.** B **12.** C **13.** B **14.**A

E. FILL IN THE BLANKS :

1. Ampere **2.** Series **3.** Large number of **4.** no
5. Semiconductors **6.** Superconductors **7.** Coulomb
8. Potential difference **9.** Series **10.** More **11.** Graphite

F. NUMERICAL PROBLEMS :

1. 6.25×10^{18} **2.** 7.5×10^{19}
3. 6C, 3.75×10^{19} **4.** 0.05Ω
5. 8Ω **6.** $12\ \Omega$
7. 3Ω & 4Ω in series corrected, in parallel with 7Ω. **8.** 0.2A, 4V
9. (A) 10Ω (B) 0.6A (C) 0.2A **10.** 0.5A
11. 2A, 1A

G TRUE OR FALSE :

1. F **2.** F **3.** T **4.** F **5.** T **6.** F
7. T **8.** F **9.** T **10.** T **11.** T **12.** F
13. T **14.** F **15.** T **16.** F

HINTS & SOLUTIONS

A. SINGLE CORRECT QUESTION.

1. $q = I\,t = 5 \times (4 \times 60) = \mathbf{1200\ C}$.

2. $q = I\,t = 0.5 \times (2 \times 60 \times 60) = \mathbf{3600\ C}$

3. $I = q/T = q\nu$

$= 2 \times 10^{-2} \times 30 = 0.6\ A$

4. $n = I\,t/e = 4.8 \times 1/1.6 \times 10^{-19}$

$= 3 \times 10^{19}$

5. When wire is stretched to double its length, its resistance becomes four times.

6. Approximate change in resistance = 2 × % change in length by stretching.

7. New length, $l' = l + \frac{25}{100} l = \frac{125}{100} l$;

Let new area of cross-section = A'. Then

$A\,l\,d = A'\,l'\,d$ or $A' = A\,l / l'$

or $A' = A \times l / \left(\frac{125}{100} \times \ell\right) = \frac{100}{125} A$

$R = \frac{\rho \ell}{A}$ and $R' = \frac{\rho \ell'}{A'}$

$$= \frac{\rho\left(\frac{125}{100}\right)\ell'}{\left(\frac{100}{125}\right)A} = \frac{\rho \ell}{A}\left(\frac{125}{100}\right)^2$$

$= 1.5625\ R$

% increase in resistance

$$= \left(\frac{R' - R}{R}\right) \times 100$$

$$= \left(\frac{1.5625 - 1}{1}\right) \times 100 = 56.25\%$$

8. $R \propto 1 / r^4$.

9. $R = \frac{\rho \ell}{A}$ or $l = \frac{RA}{\rho}$

$$= \frac{1.7 \times 10^3 \times (1 \times 10^{-8})}{1.7 \times 10^{-8}}$$

10. Let d be the density of the material of cooper wire. Let l_1, l_2 be the lengths of cooper wires of diameter 1 mm and 2 mm respectively. As

mass = volume × density = $(\pi D^2/4)\, l d$, so

$$1 = \frac{\pi(10^{-3})^2}{4} l_1 \times d = \pi \times \frac{(2\times10^{-3})^2}{4} l_2 \times d$$

or $l_1 = 4 l_2$

Now $R = \frac{\rho\ell}{\pi D^2/4}$ i.e. $R \propto \frac{1}{D^2}$

$$\therefore \frac{R_1}{R_2} = \frac{\ell_1}{\ell_2} \times \frac{D_2^2}{D_1^2} = 4 \times 10^2 = 16.$$

11. $A_1 l_1 = A_2 l_2$ or $A_2 = A_1 l_1 / l_2$

$= A_2 \times 20/40 = A_1/2.$

Since $R_1 = \rho\, l_1/A_1$ and $R_2 = \rho\, l_2/A_2$

$$= \frac{\rho \times 2\ell_1}{(A_1/2)}$$

$$= 4\frac{\rho\ell_1}{A_1} = 4 \times 5 = 20\ \Omega$$

12. $R = \rho\ l\ /\ A = 10$

Now length $l_1 = l + l\ /\ 10 = 11l\ /\ 10$

$\therefore$ New area $A_1 = Al\ /$

$= Al\ (11\ l\ /\ 10) = (10\ /\ 11)A$

$\therefore$ New resistance,

$R_1 = \rho l_1/A_1 = \rho\ (11l/10)\ /\ (10\ /\ 11)A$

$$= \frac{121}{100}\frac{\rho\ell}{A} = \frac{121}{100} \times 10 = \mathbf{12.1\ \Omega}$$

13. Mass, M = volume × density = $A\ l \times d$,

or $A = M/ld$

Resistance $R = \rho\ l\ /\ A = \rho\ l\ /\ (M\ /\ ld)$

$$= \frac{\rho\ell^2 d}{M}$$

So $R \propto l^2\ /\ M$

Thus $R_1 : R_2 : R_3 = \frac{\ell_1^2}{M_1} : \frac{\ell_2^2}{M_2} : \frac{\ell_3^2}{M_3}$

$$= \frac{3^2}{1} : \frac{2^2}{2} : \frac{1^2}{3}$$

$= \mathbf{27 : 6 : 1}$

14. If three identical resistances each of resistances R are connected in the form of a triangle, the equivalent resistance between the ends of the sides is 2 R/2 Ω

($\because$ R + R) are in parallel with R.)

Here R = 2Ω

$\therefore$ Equivaletn resistance

$$= 2 \times 2 / 3 = 4 / 3\ \Omega$$

15. Three resistances each of resistance 2 Ω can not produce a resistance equivalent to the individual resistance, when in parallel, their effective resistance will be 2/3 = 0.67 Ω. In series, the effective resistance = 3 × 2 = 6 Ω. Here two in parallel are in series with one resistance will give us

$$= \frac{2 \times 2}{2+2} + 2 = 3\Omega$$

16. The resistance of two arms on the opposite corners of a square = R + R = 2 R. Therefore for equivlalent resistance between two opposite corners of a square, we have two resistances each of value 2 R in parallel.

17. The equivalent resistance between two corners of equilateral triangle having resistance R in each arm = 2 R / 3 = 2 × 4 / 3 = 8 / 3 Ω

18. Here each of 2 Ω resistance will be in parallel combination between points A and B. The effective resistance = R/3 = 2/3 Ω.

19. The pot. diff. across 300 Ω = 60 – 30 = 30 V.

Therefore the effective resistance of voltmeter reisistnac R and 400 Ω in parallel will be equal to 300 Ω, as 60 V is equally divided between two parts. So

$$300 = \frac{R \times 400}{R + 400}$$

or 300 R + 120000 = 400 R

or **R = 1200 Ω**

20. Effective resistance in parallel combination is $R_p = 1\ \Omega$.

Thus $\frac{1}{1} = \frac{1}{3} + \frac{1}{R} + \frac{1}{3}$ or $\frac{1}{R} = 1 - \frac{2}{3} = \frac{1}{3}$

or R = 3 Ω.