CHAPTER

8

Electricity

Chapter Objectives

- Electric Charge and Electric Current
- Electric Potential and Potential Difference
- Ohm's Law
- Resistance
- Specific Resistance (Resistivity)
- Electromotive Force (emf) of a Cell (e)
- Combination of Resistors
- Electrical Energy
- Heating Effect of Electric Current
- Electric Power
- House Wiring (Ring System)
- Power Distribution

Electricity is an essential part of life in today's world. It is a controllable and convenient form of energy. It is being used in almost every sector of modern society like households, commercial, transport and industry, etc., to make life faster and easier.

Electric Charge and Electric Current

Electric Charge

It is a physical entity which is defined by excess or deficiency of electrons on a body. A body is said to be **negatively charged**, if it **gains** electrons. e.g., An ebonite rod rubbed with fur acquires negative charge.A body is said to be **positively charged**, if it **loses** electrons.e.g., A glass rod rubbed with a silk cloth acquires positive charge.

The SI unit of electric charge is **coulomb** (C).

The total charge acquired by a body is an integral multiple of magnitude of charge on a single electron. This principle is called **quantisation of charge.**

The possible value of charge on a body can be $\pm ne$.

where, n = number of electrons lost or gained by the body

and e = charge on one electron (1.6×10^{-19} coulomb).

Electric Current

It is defined as the rate of flow of electric charge through any cross-section of a conductor in unit time.
If q amount of charges flows through a conductor in t time, then

$$\boxed{\text{Electric current, } I = \frac{\text{Charge } (q)}{\text{Time } (t)} = \frac{ne}{t}} \qquad (\because q = ne)$$

where, n = number of electrons flowing through the conductor.
The SI unit of electric current is **ampere** (A). It is a scalar quantity. When 1 coulomb of charge flows through any cross-section of a conductor in 1 second, then the electric current flowing through it is said to be 1 ampere.

i.e., $1 \text{ ampere} = \dfrac{1 \text{ coulomb}}{1 \text{ second}} \Rightarrow 1\text{ A} = \dfrac{1\text{C}}{1\text{s}}$

Smaller units of current are **milliampere** ($1 \text{ mA} = 10^{-3}$ A) and **microampere** ($1\ \mu\text{A} = 10^{-6}$ A).

Note Charge is 1 coulomb if 6.25×10^{18} electrons move or 1 ampere current flows in 1 second.

Direction of Electric Current

The direction of electric current is taken as opposite to the direction of the flow of electrons (negative charges). In an electric circuit, the current flows from positive terminal of the cell to the negative terminal.

Example 1. **A current of 150 mA flows through a circuit for 2 min. Find the amount of charge that flows through the circuit.**

Sol. Given, current, $I = 150 \text{ mA} = 150 \times 10^{-3}$ A

Time, $t = 2$ min $= 2 \times 60 = 120$ s

Amount of charge, $q = ?$

We know that, $q = I \times t$

$\Rightarrow q = 150 \times 10^{-3} \times 120$

$\Rightarrow q = 18$ C

So, 18 C of charge flows around the circuit.

Example 2. **A total of 6×10^{46} electrons flow through a current carrying conductor when connected through an external power supply for 20 s. Find the value of current in the conductor.**

Sol. Given, total number of electrons, $n = 6 \times 10^{46}$ electrons, time, $t = 20$ s, current, $I = ?$

We know that, $q = ne$ ...(i)

(from the principle of quantisation of electric charge)

and $I = \dfrac{q}{t}$ ...(ii)

From Eqs. (i) and (ii), we get

$$I = \frac{ne}{t} = \frac{6 \times 10^{46} \times 1.6 \times 10^{-19}}{20} \quad (\because e = 1.6 \times 10^{-19} \text{ C})$$

$= 0.48 \times 10^{27}$ A

$= 4.8 \times 10^{26}$ A

Thus, the current through the conductor is 4.8×10^{26} A.

Electric Potential and Potential Difference

Electric Potential

Electric potential at a point in region of some charge or charges is defined as the amount of work done when a unit positive charge is moved from infinity to that a point.

If work done in moving a positive charge q from infinity to the point is W, then electric potential V of that point is

$$\boxed{V = \frac{W}{q}}$$

The SI unit of electric potential is volt (V).
It is a scalar quantity.

Electric Potential Difference (ΔV)

It is defined as work done in moving a unit positive charge from one point to another in region of charges.

Let W be the work done in moving a charge q from point B to point A, then the potential difference $(V_B - V_A)$ between these two points is given by

$$\Delta V = V_B - V_A = \frac{W}{q}$$

The electric potential difference between two points is said to be 1 volt, if 1 joule of work is done in moving 1 coulomb of electric charge from one point to other point.

Thus, $1 \text{ volt} = \dfrac{1 \text{ joule}}{1 \text{ coulomb}}$

$\Rightarrow 1\text{ V} = \dfrac{1\text{ J}}{1\text{ C}} \Rightarrow 1\text{ V} = 1\text{ J/C} = 1\text{ JC}^{-1}$

Smaller units of electric potential,

$1 \text{ mV} = 10^{-3}\text{V}, \quad 1\ \mu\text{V} = 10^{-6}$ V

Larger units of electric potential,

$1 \text{ kV} = 10^{3}$ V, $\quad 1 \text{ MV} = 10^{6}$ V

Example 3. **Calculate the potential difference between two terminals of a battery, if 100 J of work is required to transfer the charge of 20 C from one terminal of the battery to the other.**

Sol. Given, work done, $W = 100$ J, charge, $q = 20$ C

Potential difference, $\Delta V = ?$

We know that, $\Delta V = \dfrac{W}{q} = \dfrac{100}{20} = 5$ V

The potential difference between two points is 5 V.

Example 4. **How much work is done in moving a charge of 2 C from a point of 118 V to a point at 128 V?**

Sol. Given, charge, $q = 2$ C

Potential at point A, $V_A = 118$V

Potential at point B, $V_B = 128$ V

Work done, $W = ?$

We know that, potential difference, $\Delta V = V_B - V_A$
$= 128 - 118 = 10$ V

$\therefore$ Work done, $W = \Delta V \times q = 10 \times 2 = 20$ J

So, the work done in moving the charge is 20 J.

CHECK POINT 01

1. If a body has positive charge, then what does it mean?
2. What is the nature of charged acquired by an ebonite rod when rubbed with a fur?
3. In which direction does current flow in an electric circuit?
4. Is current scalar or vector?
5. The charge on an electron is 1.6×10^{-19}C. Find the number of electrons that will flow per second to constitute a current of 2A.
   Ans. 1.25×10^{19} electrons
6. If work done in moving a charge of 20 mC from infinity to a point in an electric field is 15 J, then what is the electric potential at this point? ***Ans.*** 7.5×10^{2} V

Ohm's Law

According to this law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remain unchanged.

If V is the potential difference applied across the ends of a conductor through which current I flows, then according to Ohm's law,

$$V \propto I \quad \text{(at constant temperature)}$$

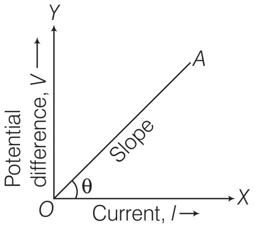
or $$V = IR$$

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

where, R is the constant of proportionality called resistance of the conductor at a given temperature. From the above formula, it is clear that current is inversely proportional to resistance.

V-I Graph

The graph between the potential difference V and the corresponding current I is found to be a straight line passing through the origin for metallic conductors.



V-I graph for metal conductor

Slope of *V-I* graph, gives resistance,

i.e., $$\text{slope} = \tan\theta = \frac{\Delta V}{\Delta I} = \frac{V}{I} = \text{resistance}$$

Resistance

It is that property of a conductor by virtue of which it opposes/resists the flow of charges through it. Its SI unit is **ohm**, it is represented by the Greek letter Ω.

Resistance of a conductor is given by $R = \frac{V}{I}$.

It is said to be 1 ohm, if a potential difference of 1 volt across the ends of the conductor makes a current of 1 ampere to flow through it.

i.e., $$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}} \Rightarrow 1\ \Omega = \frac{1\text{ V}}{1\text{ A}} = 1 \text{ VA}^{-1}$$

Example 5. **The potential difference between the terminals of an electric heater is 75 V when it draws a current of 5A from the source. What current will the heater draw, if the potential difference is increased to 150 V?**

Sol. Given, potential difference, $V = 75$ V

Current, $I = 5$ A

We know that, $R = \frac{V}{I}$

$$\Rightarrow \quad R = \frac{75}{5} = 15\ \Omega$$

When potential difference is increased to 150V, then current is

$$I' = \frac{V'}{R} = \frac{150}{15} = 10\text{ A}$$

So, the current through the heater becomes 10 A.

Some Important Terms Related to Resistance

Some important terms related to resistance are as follow

(i) **Resistor** A component in an electric circuit which offers resistance to the flow of electrons constituting electric current is known as resistor. These are used to make those electrical devices, where high resistance is required. It reduces current in a circuit, e.g., Alloys like nichrome, manganin and constantan.

(ii) **Rheostat/Variable Resistance** It is a variable resistor, which is used to control the flow of electric current by manually increasing or decreasing the resistance.

(iii) **Good Conductor** A material which offers low resistance to the flow of electrons or electric current in an electric circuit is known as a good conductor, e.g., Silver, copper, aluminium are good conductors, among these, silver is the best conductor of electricity.

(iv) **Poor Conductor** A material which offers higher resistance to the flow of electrons or electric current in an electric circuit is known as poor conductor, e.g., Mercury, lead, stainless steel, alloys of iron and chromium.

(v) **Insulator** A material which offers very high resistance to the flow of electrons or electric current in an electric circuit is known as insulator, e.g., Rubber, dry wood and plastic. Electric current does not flow through it.

(vi) **Semiconductor** A material which offers intermediate resistance (more than conductor and less than insulator) to the flow of electrons or electric current in an electric circuit is known as semiconductor, e.g., Germanium, silicon, etc.

Factors on which the Resistance of a Conductor Depends

The electrical resistance of a conductor depends on the following factors

(i) **Length of the Conductor** The resistance of a conductor R is directly proportional to its length l.

i.e., $$R \propto l \qquad \text{...(i)}$$

Due to this, when the length of a wire is doubled/halved, then its resistance also gets doubled/halved.

(ii) **Area of Cross-section of the Conductor** The resistance of a conductor R is inversely proportional to its area of cross-section A.

i.e., $$R \propto \frac{1}{A} \qquad \text{...(ii)}$$

Due to this, when the area of cross-section of wire is doubled, then its resistance gets halved and if area of cross-section of wire is halved, then its resistance will get doubled.

Note When a conductor is stretched (increased its length), then its area of cross-section decreases accordingly but the volume (i.e., area $\times$ length) of the conductor remains the same.

(iii) **Nature of the Material of the Conductor** The resistance of a conductor depends on the nature of the material of which it is made.

Some materials have low resistance, whereas others have high resistance.

Hence, from Eqs. (i) and (ii), we can write

$$R \propto \frac{l}{A} \text{ or } R = \rho \frac{l}{A}$$

where, ρ is the constant of proportionality called **resistivity** or **specific resistance** (discussed in later section) of the conductor.

(iv) **Effects of Temperature** With the increases in the temperature of a conductor, the random motion of the electrons also increases. Due to this, the collisions between the electrons and the positive ions also increases. Therefore, the resistance of a conductor also increases with the increases in its temperature.

Note With rise in temperature resistance of semiconductors and electrolytes decreases and for alloys it increases.

Example 6. **A wire of given material having length l and area of cross-section A has a resistance of $10\,\Omega$. What would be the resistance of another wire of the same material having length $l/4$ and area of cross-section $2.5A$?**

Sol. For first wire, length = l, area of cross-section = A

and resistance, $R_1 = 10\,\Omega$

i.e., $$R_1 = \frac{\rho l}{A} = 10\,\Omega \Rightarrow \rho = \frac{10A}{l} \qquad \text{...(i)}$$

For second wire, length = $l/4$, area of cross-section = $2.5A$ and resistance,

$$R_2 = \rho \frac{l/4}{2.5A} = \frac{10A}{l} \cdot \frac{l}{4 \times 2.5A} = 1\Omega \qquad \text{(from Eq. (i))}$$

So, the resistance of that wire is $1\,\Omega$.

Ohmic and Non-Ohmic Resistors

The conductor which obeys Ohm's law is called ohmic resistor (or linear resistance). e.g., Silver, nichrome, copper, iron, etc. The V-I graph for these resistor is a straight line passing through the origin (refer to the graph on page 03). Whereas those conductor which does not obey Ohm's law is known as non-ohmic resistor (or non-linear resistance). e.g., Triode valve, junction diode, transistor, etc. The V-I graph for these resistors is a curve line.

Also, it is not necessary for the graph of non-ohmic resistors to pass through the origin.

Specific Resistance (Resistivity)

It is defined as the resistance of a conductor of unit length and unit area of cross-section. Its SI unit is ohm-metre (Ω-m).

The resistivity of a material does not depend on its length or thickness but depends on the nature of the substance and temperature. It is a characteristic property of the material of the conductor and varies only, if its temperature changes. Insulators such as glass, rubber, ebonite, etc., have very high resistivity (10^{12} to 10^{17} Ω-m), while conductors have very low resistivity (10^{-8} to 10^{-6} Ω-m).

Alloys have higher resistivity than that of their constituent metals. They are used to make heating elements of devices such as electric iron, heaters, etc. This is because they do not oxidise easily at high temperatures. The high resistivity of alloys also allow dissipation of electrical energy in the form of heat. Tungsten is used almost exclusively for filaments of electric bulbs, whereas copper and aluminium are generally used for electrical transmission lines.

Conductivity

It is defined as the reciprocal of resistivity of a conductor. It's SI unit is mho per metre ($\Omega^{-1}m^{-1}$) or siemen per metre (S/m). It is expressed as

$$\sigma = \frac{1}{\rho}$$

Example 7. Resistance of a metal wire of length 2 m is 30 Ω at temperature 25°C. If the diameter of the wire is 0.6 mm, then what will be the resistivity of the metal at that temperature?

Sol. Given, length of wire, $l = 2$ m

Resistance, $R = 30\,\Omega$

Temperature, $T = 25°$ C

Diameter of wire, $d = 0.6$ mm $= 6 \times 10^{-4}$ m

Resistivity of the wire, $\rho = ?$

We know that, $\rho = \frac{RA}{l} = \frac{R\pi d^2}{4l}$ $\quad \left(\because A = \frac{\pi d^2}{4}\right)$

$$= \frac{30 \times \pi \times (6 \times 10^{-4})^2}{4 \times 2} = 4.24 \times 10^{-6}\ \Omega\text{-m}$$

The resistivity of the metal at 25°C is $4.24 \times 10^{-6}\ \Omega$-m.

Superconductors

The resistance of certain metal or alloy e.g., mercury, lead, niobium, etc., drop to zero, when they are cooled below a certain temperature. These conductors are known as superconductors. In these types of conductors, once a current starts flowing through them, they persist it even when there is no potential difference across them.

CHECK POINT 02

1. Keeping the potential difference constant, the resistance of a circuit is halved. By how much does the current change?
2. The potential difference across a wire is 75 V and its electric resistance is 30 Ω. Find out the electric current through the wire. ***Ans.*** 2.5 A
3. Define the electric resistance of a wire and also write its SI unit.
4. What is the difference between a good conductor and a poor conductor? Give two examples of each.
5. If the length of a wire is halved and its cross-sectional area is doubled, then what would be the resistance of the wire? (Given, initially the resistance of the wire is *R*) ***Ans.*** $R/4$
6. What is the difference between Ohmic and non-Ohmic resistors?
7. Define the resistivity of a material and also write its SI unit.

Electromotive Force (emf) of a Cell (ε)

Electric cell has to do some work in maintaining the current through a circuit. The work done by the cell in moving unit positive charge through the whole circuit (including the cell) is called the electromotive force (emf) of the cell. If during the flow of q coulomb of charge in an electric circuit, the work done by the cell is W, then

$$\text{emf of the cell, } \varepsilon = \frac{W}{q}$$

Its unit is joule/coulomb or volt.
If $W = 1$ joule and $q = 1$ coulomb, then $\varepsilon = 1$ volt, i.e., if in the flow of 1 coulomb of charge, the work done by the cell is 1 joule, then the emf of the cell is 1 volt.

Internal Resistance (r)

It is defined as the resistance offered by the electrolyte of the cell to the flow of current through it. It is denoted by r. Its unit is also ohm.

Internal resistance of a cell depends on the following factors

(i) It is directly proportional to the separation between the two plates of the cell.
(ii) It is inversely proportional to the plate area dipped into the electrolyte.
(iii) It depends on the nature, concentration and temperature of the electrolyte and increases with increase in concentration.

Terminal Potential Difference (V)

Terminal potential difference of a cell is defined as the potential difference between the two terminals of the cell in a closed circuit (i.e., when current is drawn from the cell). It is represented by V and its unit is volt. It is always less than the emf of the cell.

Combination of Resistors

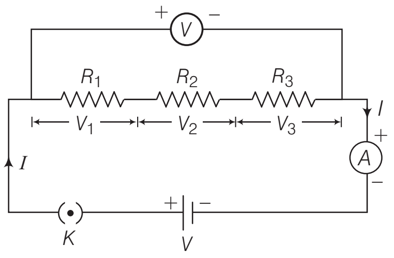
Two or more resistors can be connected with each other by different combination methods in order to achieve the desired equivalent resistance in a particular circuit.

There are two methods of joining the resistors together which are as given below

Series Combination of Resistors

When two or more resistors are connected end to end, then they are said to be connected in series.

The following figure shows the connection of resistors in series



Series combination of resistors

This figure has been drawn because it matches with the matter mentioned below. But the figure already needs an explaination where in we had to write, the voltage drop is been calculate by the voltmeter V_1, V_2 and V_3.

Because the symbol —(V)— is of the voltmeter, rather than first signifying the potential drop in the circuit. An applied potential V produces current I in the resistors and R_1, R_2 and R_3 causing a potential drop V_1, V_2 and V_3 respectively, through each resistor.

Total potential, $V = V_1 + V_2 + V_3$

By Ohm's law, $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$

Thus, $\quad V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$

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

If R is the equivalent resistance and $V = IR$

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

$\Rightarrow \quad \boxed{R = R_1 + R_2 + R_3}$

Some important points regarding series combination of resistors are as follow

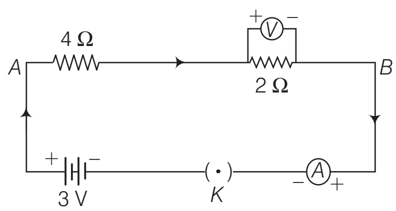
(i) The equivalent resistance is equal to the sum of the individual resistances.

(ii) The equivalent resistance is thus greater than the resistance of either resistor. This is also known as **maximum effective resistance**.

(iii) The current through each resistor is same.

(iv) The potential difference across each resistor is different.

Example 8. Study the following electric circuit. Find the readings of (i) the ammeter and (ii) the voltmeter.



Sol. In the given circuit, the resistance of 4Ω and a bulb of resistance 2Ω are connected in series, so equivalent resistance of the circuit,

$$R = R_1 + R_2 = 4\ \Omega + 2\ \Omega = 6\ \Omega$$

(i) Total current flowing in the circuit,

$$(I) = \frac{\text{Potential difference } (V)}{\text{Total resistance } (R)} = \frac{3}{6} = 0.5\text{A}$$

In series combination, current flowing through each component of the circuit is same and is equal to the total current flowing in the circuit. So, 0.5 A current will flow through the ammeter, therefore its reading will be 0.5 A.

(ii) Reading of voltmeter = Potential difference across 2Ω bulb

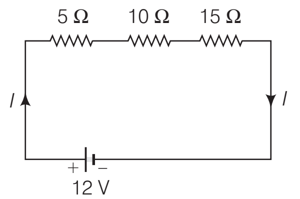
$\therefore \quad V = IR = 0.5 \times 2 = 1\text{ V}$

($\because$ current flowing through the bulb is 0.5 A)

Example 9. **Three resistors of 5 Ω, 10 Ω and 15 Ω are connected in series with a 12 V power supply. Calculate their combined resistance, the current that flows in the circuit and in each resistor and the potential difference across each resistor.**

Sol. Given, $R_1 = 5\Omega$, $R_2 = 10\Omega$, $R_3 = 15\Omega$, $V = 12\text{V}$, $R = ?$, $I = ?$ and $V_1, V_2, V_3 = ?$

According to question, the three resistors are connected in series combination, then equivalent resistance,



$$R = R_1 + R_2 + R_3 = 5 + 10 + 15 = 30\ \Omega$$

$\therefore$ The current flowing through the circuit

$$(I) = \frac{\text{Potential of power supply } (V)}{\text{Total resistance of the circuit} (R)}$$

$$= \frac{12}{30} = \frac{2}{5} = 0.4\text{ A}$$

In series combination, the current flowing through each resistor is equal to total current flowing through the circuit. Therefore, current flowing through each resistor is 0.4 A.

$\therefore$ Potential difference across first resistor,

$$V_1 = IR_1 = 0.4 \times 5 = 2\text{ V}$$

Potential difference across second resistor,

$$V_2 = IR_2 = 0.4 \times 10 = 4\text{ V}$$

and potential difference across third resistor,

$$V_3 = 0.4 \times 15 = 6\text{ V}$$

Disadvantages of Series Combination

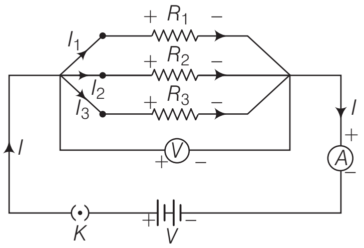
(i) In series combination, if any of the components fail to work, the circuit will break and then none of the components will be able to operate.

(ii) It is not possible to connect a bulb and a heater in series because they need different values of current to operate properly. Due to this, we do not use series circuit.

Parallel Combination of Resistors

When two or more resistors are connected simultaneously between two points, then they form a parallel combination.

The following figure shows the connection of resistors in parallel



Parallel combination of resistors

An applied potential V produces current I_1 in R_1, I_2 in R_2 and I_3 in R_3.

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

By Ohm's law, $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$

If R is the equivalent resistance, then $I = \frac{V}{R}$

Thus, $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$ [from Eq. (i)]

$$\Rightarrow \quad \frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

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

Some important points regarding parallel combination of resistors are as follow

(i) The reciprocal of equivalent resistance is equal to the sum of the reciprocal of individual resistances.

(ii) The equivalent resistance is less than the resistance of either resistor. This is also known as **minimum effective resistance**.

(iii) The current from the source is greater than the current through either resistor.

(iv) The potential difference across each resistor is same.

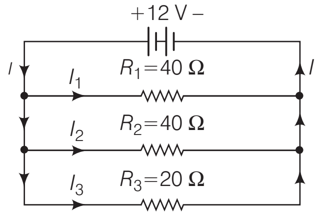
Note For n equal resistances combined in series (equivalent resistance R_s) and in parallel (equivalent resistance R_p), then

$$\frac{R_s}{R_p} = n^2$$

Example 10. **Two 40 Ω resistors and a 20 Ω resistor are all connected in parallel with a 12 V power supply. Calculate their effective resistance and the current through each resistor. What is the current flowing through the supply?**

Sol. Given, $R_1 = 40\ \Omega$, $R_2 = 40\ \Omega$, $R_3 = 20\ \Omega$, $V = 12\text{V}$, $R = ?$, $I, I_1, I_2, I_3 = ?$

According to circuit, the three resistors are connected in parallel combination, then effective resistance,



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

$$= \frac{1}{40} + \frac{1}{40} + \frac{1}{20}$$

$$= \frac{1+1+2}{40} = \frac{4}{40} = \frac{1}{10}$$

$$\Rightarrow \quad R = 10\ \Omega$$

So, the three resistors together have an effective resistance of 10 Ω.

Each resistor has a potential difference of 12 V across it.

As in parallel combination, the potential difference across each resistance is equal to the total potential difference applied on the combination.

Also, current, $I = \frac{\text{potential difference } (V)}{\text{resistance } (R)}$

Current through 40 Ω resistor, $I_1 = \frac{12}{40} = 0.3\text{ A}$

Also, $I_2 = 0.3\text{ A}$

Current through 20 Ω resistor, $I_3 = \frac{12}{20} = 0.6\text{ A}$

∴ Current throught the supply,

$$I = I_1 + I_2 + I_3 = 0.3\text{ A} + 0.3\text{ A} + 0.6\text{ A} = 1.2\text{ A}$$

Applications of Parallel Combination in Daily Life

Parallel combination of resistances is very useful in circuits used in daily life. This is because, these circuits have components of different resistances which requires different amounts of current.

Parallel circuit divides the current among the components (electrical gadgets), so that they can have necessary amount of current to operate properly. This is the reason of connecting electrical appliances in parallel combination in household circuit.

Mixed Combination of Resistors

In this type of combination, circuit has some resistances connected in series combination and some in parallel combination. This type of combination is also called complex circuit.

While solving problems of mixed combination of resistances, there are many points to be considered which are given as below

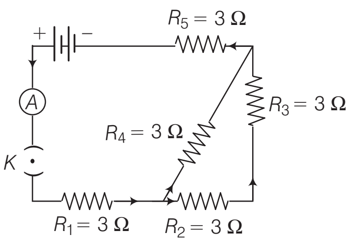
(i) Mixed combination circuit can always be reduced to a simple circuit containing only one resistor. For this examine, the given circuit and replace the resistors that are connected in parallel or in series with their equivalent resistances.

(ii) Draw the new circuit after making the changes and repeat the same procedure again as discussed above, till a simple circuit is obtained.

(iii) If the current through or potential difference across a resistor in the complex circuit is to be found, then start with the simple circuit reduced from the complex circuit and gradually work your way back through the circuits, using $V = IR$.

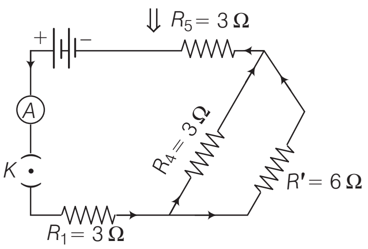
(iv) While calculating the equivalent resistance, do not consider the battery, if its resistance is not given but, if its resistance is given, then consider it and treat it as an individual resistor.

Example 11. Consider the circuit diagram as given below:



If $R_1 = R_2 = R_3 = R_4 = R_5 = 3\,\Omega$, then find the equivalent resistance of the circuit.

Sol. From the given combination, it can be observed that R_2 and R_3 are in series order. As current through R_2 and R_3 is same. So, their equivalent resistance is $R' = R_2 + R_3$ $= 3\Omega + 3\Omega = 6\Omega$. Now, the given circuit can be redrawn as shown below



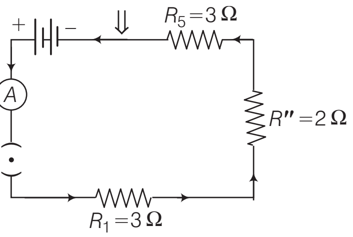
Now, it can be seen that R_4 and R' are in parallel combination. As, currents through R_4 and R' are different. So, their equivalent resistance can be calculated as below

$$\frac{1}{R''} = \frac{1}{R'} + \frac{1}{R_4}$$

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

$\therefore \quad R'' = 2\Omega$

Now, the given circuit can be redrawn as shown below



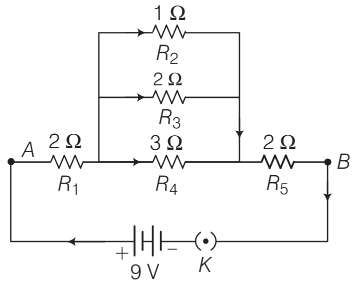
Now, it is clear from the diagram that all the resistances R_5, R'' and R_1 are in series combination.

As, current through R_1, R'' and R_5 is same.

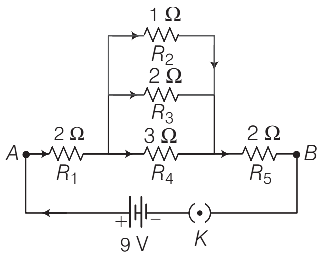
$\therefore$ Equivalent resistance of the circuit is

$$R = R_5 + R'' + R_1$$
$$= 3\Omega + 2\Omega + 3\Omega = 8\Omega$$

Example 12. **Find the equivalent resistance of the following circuit. Also, find the current and potential at each resistor.**



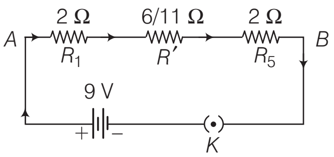
Sol. In the given circuit, R_2, R_3 and R_4 are in parallel combination. As, currents through R_2, R_3 and R_4 are different. Let equivalent resistance of R_2, R_3 and R_4 be R'.



$$\frac{1}{R'} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6} \Rightarrow R' = \frac{6}{11}\,\Omega$$

Now, the given circuit can be redrawn as shown below



Now, R_1, R' and R_5 are in series combination.

As, current through R_1, R' and R_5 is same.

So, equivalent resistance of the whole circuit is

$$R = R_1 + R' + R_5 = 2 + \frac{6}{11} + 2$$

$$= \frac{22 + 6 + 22}{11} = \frac{50}{11} \text{ W}$$

Now, total current flowing through the circuit,

$$I = \frac{V}{R} = \frac{9}{\frac{50}{11}} = \frac{99}{50} \approx 2 \text{ A}$$

Current through R_1 and R_5 will be same as these are in series combination and will be equal to the total current flowing through the circuit.

$\therefore \quad I = I_1 = I_5 = 2\text{ A}$

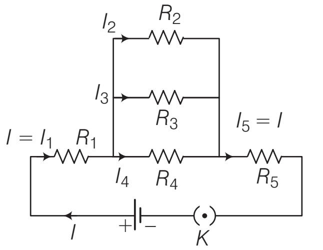
Potential drop at $R_1, V_1 = I_1 R_1 = 2 \times 2 = 4\text{ V}$

Potential drop at $R_5, V_5 = I_5 R_5 = 2 \times 2 = 4\text{ V}$

Now, potential drop at R', V' can be calculated as

$$V = V_1 + V_5 + V' \Rightarrow \quad 9 = 4 + 4 + V'$$

$\Rightarrow \quad V' = 1\text{ V}$



As R_2, R_3 and R_4 are in parallel combination, so potential drop at all resistances will be same as 1 V.

$$V_2 = V_3 = V_4 = V' = 1\text{ V}$$

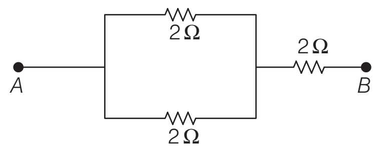
Current through R_2, $I_2 = \frac{V_2}{R_2} = \frac{V'}{R_2} = \frac{1}{1} = 1\text{ A}$

Similarly, $I_3 = \frac{V_3}{R_3} = \frac{V'}{R_3} = \frac{1}{2} = 0.5\text{ A}$

and $\quad I_4 = \frac{V_4}{R_4} = \frac{V'}{R_4} = \frac{1}{3} = 0.33\text{ A}$

CHECK POINT 03

1. In which type of combination of different resistors it will have an equal value of electric current through each resistor?
2. Which type of combination of resistors will have equivalent resistance less than the least resistance?
3. If different resistors have same value of electric potential across them, then in which way they are connected to each other?
4. Four resistors of equal resistance R are connected in parellel, find the equivalent resistance. ***Ans.*** $R/4$
5. What do you understand by mixed combination of resistance?
6. Five resistances are connected as shown in the figure. Determine the total resistance between A and B.



Ans. 3 Ω

Electrical Energy

Now-a-days electricity is used in doing many works through different instruments. Thus, electric energy can be defined as the ability of electric current to do some work through different instrument.

Some examples of electric energy are given below

(i) When an electric current is passed through a heating element of a heater, oven, etc, it gets heated up due to its resistance. Thus, electrical energy is converted into heat energy.

(ii) When an electric current is passed through an electrical motor its coil begin to rotate and simultaneously the coil gets heated up slightly. The electrical energy is converted into mechanical energy and sometimes into heat energy.

(iii) When an electric current is passed through an electric lamp, the filament of the bulb gets heated and it glows. Thus, electrical energy is converted into heat and light energy.

(iv) When the output of a microphone which is in the form of electric pulses is passed to a loud speaker, the electrical energy is converted into sound energy.

Measurement of Electrical Energy

Assuming a conductor as a resistance wire which resists the flow of current through it.

So, work must be done by the current source for continuous flow of the current. Now, we calculate the work done by the source when the current I flows through a wire of resistance R. This work done will be equal to the electric energy.

When an electric charge q moves against a potential difference V. Then,

amount of work, $W = q \times V \quad$ ...(i)

From definition of current, we know that

$$I = \frac{q}{t} \quad \text{or} \quad q = I \times t \qquad \text{...(ii)}$$

From Ohm's law,

$$\frac{V}{I} = R \quad \text{or} \quad V = IR \qquad \text{...(iii)}$$

Substituting the values of q and V in Eq. (i), we get

$$W = (I \times t) \times IR = I^2 Rt = VIt = \frac{V^2 t}{R}$$

$$\therefore \quad \boxed{\text{Electric energy, } E = I^2 Rt = VIt = \frac{V^2 t}{R}}$$

SI unit of electrical energy is joule (J),

where, 1 Joule = 1 volt × 1 ampere × 1 sec

Commercial Unit of Electrical Energy

To measure the electrical energy consumed commercially, joule is not sufficient. So, to express electrical energy consumed commercially a special unit **kilo-watt-hour** is used in place of joule. It is also called 1 unit of electrical energy.

1 kilowatt hour or 1 unit of electrical energy is the amount of energy dissipated in 1 hour in a circuit, when the electric power in the circuit is 1 kilowatt.

1 kilowatt hour (kWh)

$$= 3.6 \times 10^6 \text{ joule (J)} = 3.6 \times 10^{13} \text{ erg}$$

Heating Effect of Electric Current

When an electric current is passed through a high resistance wire like nichrome wire, then the wire becomes very hot and produces heat. This is called the heating effect of current.

This effect is obtained by the transformation of electrical energy into heat energy.

e.g., An electric fan becomes warm, if it is used continuously for longer time, etc.

Assuming that all electrical work done or electrical energy consumed is converted into heat energy, i.e., heat produced. So, heat produced is given by

$$H = I^2 \times R \times t$$

Thus, it is known as **Joule's law of heating.**

This law implies that heat produced in a resistor is

(i) directly proportional to the square of current for a given resistance.

(ii) directly proportional to the resistance for a given current.

(iii) directly proportional to the time for which the current flows through the resistor.

Electric Power

It is defined as the amount of electric energy consumed in a circuit per unit time.

If W be the amount of electric energy consumed in a circuit in t seconds, then the electric power is given by

$$P = \frac{W}{t}$$

But W = electric energy $= Vq = VIt$ $\quad (\because q = It)$

$$\therefore \quad P = \frac{VIt}{t}$$

$$\Rightarrow \quad P = VI$$

According to Ohm's law, $V = IR$

$$\therefore \quad P = IR \times I = I^2R$$

$$\Rightarrow \quad = \frac{V^2}{R} \qquad \left(\because I = \frac{V}{R}\right)$$

The SI unit of electric power is watt (W).

Electric power is said to be 1 watt, if 1 ampere current flows through a circuit having 1 volt potential difference.

i.e., 1 watt = 1 volt × 1 ampere = 1 VA

Note

- Bigger units of power are as given below:
  1 kilowatt (kW) = 10^3 W
  1 megawatt (MW) = 10^6 W
  1 gigawatt (GW) = 10^9 W
- Practical unit of power is horse power.
  1 HP = 746 W
- Number of units consumed by electric appliances is
  $$= \frac{\text{watt} \times \text{hours}}{1000}$$

Power Rating of Common Appliances

The electrical appliances such as electric bulb, geyser bulb, heater, etc., are rated with power and voltage. e.g., An electric bulb is rated as 100W – 220V, etc.

With the help of the rating of the appliances, we calculate the following two quantities such as

(i) The resistance of the filament of the bulb (coil).

$$R = \frac{V^2}{P} = \frac{(\text{Voltage rating of appliance})^2}{\text{Power rating of appliance}}$$

This is the resistance of the element (filament) of an appliance (bulb) while in use.

(ii) Safe limit of current through the filament of the bulb (coil).

$$I = \frac{P}{V} = \frac{\text{Power rating of appliance}}{\text{Voltage rating of appliance}}$$

If the current exceeds this value, the power supplied at the rated voltage V exceeds the rated power and the appliance gets damaged.

House Hold Consumption of Electrical Energy

An electric meter measures the electrical energy consumed by the different appliances at home. It always calculate the energy in kWh.

∴ The electrical energy consumed by a household appliance in a certain time (t) is given as, Energy (in kWh) = power (in kW) × time (in hour)

$$= \frac{\text{power (in watt)} \times \text{time (in hour)}}{1000}$$

$$= \frac{V(\text{volt}) \times I(\text{ampere}) \times t(\text{hour})}{1000}$$

Now, cost of the electricity will be given as,
cost of electricity = energy consumed (in kWh) × rate in rupees per unit.

Example 13. An electric fan runs from the 220 V mains. The current flowing through it is 0.5 A. At what rate is the electrical energy transformed by the fan? How much energy is transformed in 2 min?

Sol. Given, potential difference, $V = 220$ V,

current, $I = 0.5$ A, time, $t = 2\,\text{min} = 120\,\text{s}$, power, $P = ?$

We know that,

power, $P = VI = 220 \times 0.5 = 110$ W

and $E = Pt = 110 \times 120 = 13200$ J

So, the power of fan is 110 W and it transforms 13200 J of energy.

Example 14. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 0.5 min.

Sol. Given, resistance, $R = 20\,\Omega$, Current, $I = 5$ A

Time, $t = 0.5\,\text{min} = 0.5 \times 60 = 30\,\text{s}$

Heat, $H = ?$

We know that, heat, $H = I^2Rt$

$H = (5)^2 \times 20 \times 30 = 25 \times 20 \times 30 = 15000\,\text{J} = 1.5 \times 10^4$ J

So, the heat developed is 1.5×10^4 J.

Example 15. 200 J of heat is produced 10 s in a 5 Ω resistance. Find the potential difference across the resistor.

Sol. Given, heat, $H = 200$ J, resistance, $R = 5\,\Omega$,

time, $t = 10$ s, potential difference, $V = ?$

We know that,

heat, $H = I^2Rt \Rightarrow I = \sqrt{\frac{H}{Rt}} = \sqrt{\frac{200}{5 \times 10}} = 2\text{A}$

So, the potential difference across the resistor is

$V = IR$ (by Ohm's law)

$= 2 \times 5 = 10$ V

Example 16. An electric refrigerator rated 500 W operates 6 hours/day. What is the cost of the energy to operate it for 30 days at ₹4.5 per kWh?

Sol. Energy consumed by refrigerator in 30 days

$= 500\text{W} \times 6\frac{\text{hour}}{\text{day}} \times 30\,\text{days}$

$= 90000\,\text{Wh} = 90\,\text{kWh}$

∴ Cost of energy to operate the refrigerator for 30 days

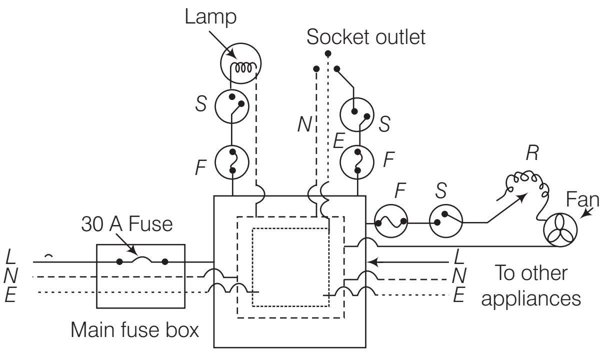
= 90 kWh × ` 4.5 per kWh = ` 405

CHECK POINT 04

1. Explain, why the current that makes the heater element very hot, only slightly warms the connecting wires leading to the heater?
2. An electric heater of resistance 500 Ω is connected to a mains supply for 30 min. If 15 A current flows through the filament of the heater, then calculate the heat energy produced in the heater. ***Ans.*** 20.25×10^7 J
3. What is the maximum power in kilowatts of the appliance that can be connected safely to a 13A, 230V mains socket? ***Ans.*** 2.99 kW
4. Power of a lamp is 60W. Find the energy in joules consumed by it in 1 s. ***Ans.*** 60 J
5. What is the heating effect of electric current?
6. What is the safe limit of current through the filament of the bulb?

House Wiring (Ring System)

In a house, the wiring is commonly done by the ring system. A ring system of wiring connecting a lamp, a socket with switch and a fan with regulator is shown in the figure given below.



A schematic diagram of main circuit

In this system, the wires starting from the main fuse box run around all the rooms of the house and then come back to the fuse box again forming the ring. The fuse box contains a fuse of rating about 30 A for each ring circuit.

Advantages of the Ring System

The advantages of the ring system are given as

(i) Each appliance can operate independently, without affecting the other appliances connected in the system.

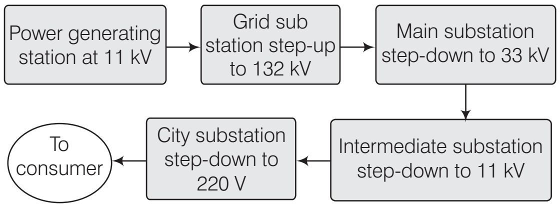
(ii) If a new appliance has been installed in a room, a new line up to the distribution box is not required but it can directly connect to the ring circuit of the room.

Power Distribution

The electric power is generated at the power generating stations. The power from these station is transmitted over long distances at a high voltage to minimise the loss of energy in form of heat in the line wires used for transmission.

This is because at high voltages the value of current is very less. Therefore, from the relation of the heating effect produced i.e., $H = I^2RT$, will also be less at low current.

Hence, the energy loss will be least.



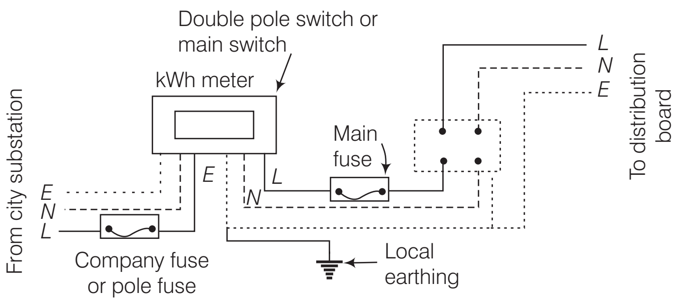
Block diagram representing the power distribution

Components of Household Electric Circuit

1. Main Circuit

Electricity generated at power stations is brought to our homes by two thick copper or aluminium wires. One of these is called **live wire** (in red insulation cover), which is at a potential of 220 V with a frequency of 50 Hz and the other is called **neutral wire** (in black insulation cover), which is at zero potential. There is also a third wire i.e., earth wire.

The neutral and the earth wires are connected together at the local substation, so that both the wire are at the same potential.



A schematic diagram of main circuit

The live wire carries current from the source to the distribution board while the neutral wire is for the return path of current. The connections are made to the distribution board through a main fuse and a main switch.

The main fuse is connected in the live wire while the main switch is connected in the live and neutral wires. The main switch is a double pole switch. It has an iron covering.

The covering is earthed. This switch is used to cut the connections of the live as well as the neutral wires. Usually, there are two separate circuits in a house, the lighting circuit with a 5 A fuse (bulbs, fans, etc) and the power circuit with a 15 A fuse (geysers, air coolers, etc.).

2. Switch

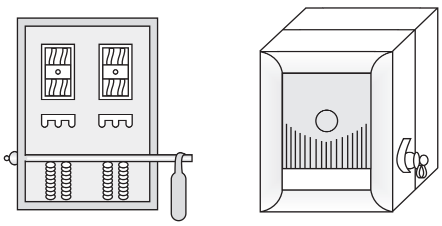
In an electrical circuit switch is used to start or stop the flow of current.

Depending upon work, construction and current rating, switches are classified as given below

(i) **Main Switch** It is a two pole or three pole single way switch. Normally, it is DPIC or TPIC type switch. They are used to switch ON/OFF the main line current.

It is basically of two types

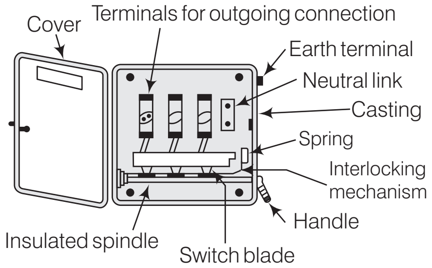
(a) **Double Pole Iron Clad or DPIC Switch** It works as a main switch for single phase AC or DC. A fuse is connected in series with each line. It is used for controlling single phase 2-wire circuits. The switch switches ON/OFF the phase line and neutral line simultaneously. These switches are constructed for 15 A to 200 A and 250 V to 660 V. The metal covering of switch should be compulsorily grounded.



Double pole iron clad switch

(b) **Three Pole Iron Clad or TPIC Switch** It works as a main switch for 3-phase AC line. It is used for controlling a 3-phase power with 4-wire system. A fuse and a neutral link is connected in series with each line. The switch switches ON/OFF all the three phase lines simultaneously. These switches are constructed for 30 A to 400 A and 400 V to 1100 V.

The metal covering of switch should be compulsorily grounded.

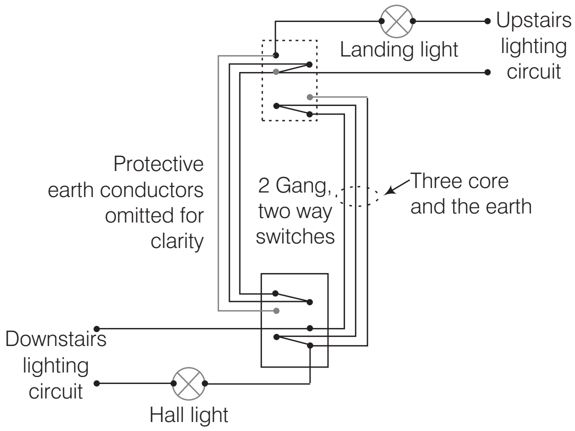


Three pole iron clad or TPIC switch

Note **DPIC and TPIC are Different from Other Switches** DPIC and TPIC switches are switched ON in upward direction and OFF in downward direction but rest other switches are ON in downward direction and OFF in upward direction. This property makes them different from others.

(c) **Two-way Switch** It means two or more switches in different locations to control one lamp. They all are wired in such a way, so that operation of either switch will control the lights.

This figure illustrates how lights is controlled from two different locations

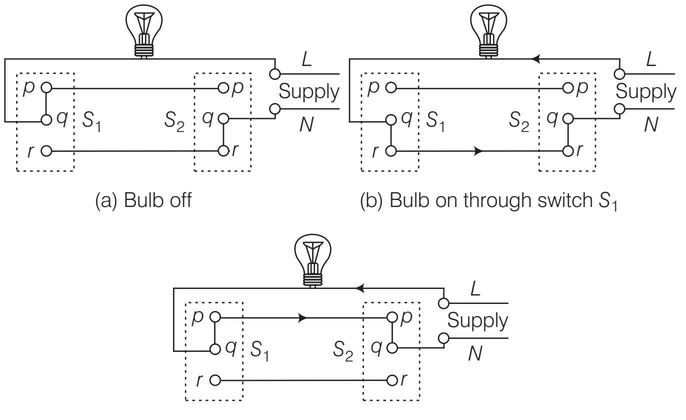


A schematic diagram of two-way switch circuit

3. Staircase Wiring

It is a dual control switch system in which the double pole type switches are used at the top and bottom of a staircase. Let a switch S_1 be fitted at the bottom and a switch S_2 at the top of the staircase.

While going up a person puts on the light by operating the switch S_1 so that the connection '*pq*' changes to '*qr*' and makes the current to flow in the circuit. On reaching at the top, he operates the switch S_2 to put off the light so that the connection '*rq*' changes to '*qp*' and the flow of current stops.



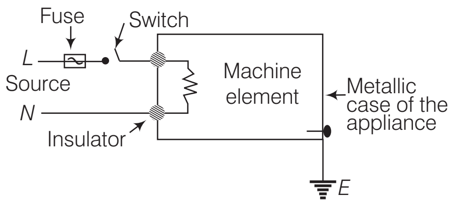
(a) Bulb off (b) Bulb on through switch S_1

(c) Bulb on through switch S_2

4. Earthing

Earthing means to connect the metal case of the appliance to the earth (i.e., zero potential) by means of a metal wire called the earth wire (in green insulation cover). One end of the metal wire is buried in the earth. The appliances are connected to the earth by using the top pin of a 3-pin plug.

Earthing saves us from electrical shocks. The symbol ⏚ used for earthing appliances.



Earthing of an appliance

5. Electric Fuse

Fuse is used as a safety device in household circuits and is based on heating effect of current. It is connected in series with the mains supply.

A fuse consists of an alloy of **lead** and **tin** which has appropriate melting point.

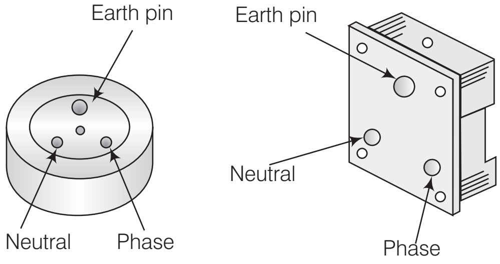
It is required to rate the fuses for different current values such as 1 A, 2 A, 5 A, 10 A, 15 A, etc.

When the current flowing through the circuit exceeds the safe limit, the temperature of the fuse wire increases and due to heating effect it gets melts and breaks the circuit. This helps to protect the other circuit elements from hazards caused by heavy current.

6. 3-Pin Plug and Socket with Conventional Location of Wires

According to electricity rules, 3-pin socket should be used where third pin is used as the earth pin, it is thick pin and is at the top between the other two pins of the other two pins, right pin is used as phase and the left pin as neutral.

There is no pin for the earth available in 2-pin socket and it is used in low voltage applications. The pins are splitted at the ends to provide a spring action so that it gets fit in the socket holes tightly. The earth pin is thicker and longer than the other two. Whereas socket is used to supply the current to the electrical equipment from the switch board. They are of 2-pin with rating 5 A, 250 V and 3-pin of rating 5 A/ 15 A, 250 V. Similar to switches, sockets are of two types i.e., one type is fixed above the surface of switch board and second type below the surface of switch board.



3-Pin socket

Safety Precautions

The safety precautions are as

(i) a switch should not be touched with wet hands.
(ii) the switch should always be connected in the live wire.
(iii) electrical appliances should be properly earthed.
(iv) always use appropriate fuse rating in the live wire of the circuit.

Conventional Colour Coding of Wires

The colour coding of wires in a cable are as

Wires	Colour	
	Old Convention	New Convention
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green or Yellow

CHECK POINT 05

1. Write on advantage of using ring system in house wiring.
2. What is a two-way switch?
3. Why electrical appliances are earthed?
4. What is a fuse?
5. Define a socket.
6. Write colour codes of live and neutral wire.

SUMMARY

- An electric charge is a physical entity which is defined by excess or deficiency of electrons on a body. The SI unit of electric charge is coulomb (C).
- The total charge acquired by a body is an integral multiple of magnitude of charge on a single electron. This principle is called quantisation of charge.
- Electric current is defined as the rate of flow of electric charge through any cross-section of a conductor in unit time.
  Electric current $(I) = \dfrac{\text{Charge } (q)}{\text{Time } (t)}$. The SI unit of electric current is ampere (A).
- Electric potential is defined as the amount of work done when a unit positive charge is moved from infinity to a point.
  Electric potential $(V) = \dfrac{\text{Work done } (W)}{\text{Charge moved } (q)}$. The SI unit of electric potential is volt (V).
- Electric potential difference is defined as the work done per unit charge in moving a unit positive charge from one point to other point.
- A closed and continuous path through which electric current flows is known as electric circuit.
- According to Ohm's law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remains unchanged.
  $$V \propto I \quad \text{or} \quad V = IR$$
  where, R is the constant of proportionality called resistance of the conductor at a given temperature.
- Resistance is the property of a conductor due to which it opposes the flow of electric current through it. Mathematically,
  $$\text{Resistance } (R) = \frac{\text{Potential difference } (V)}{\text{Electric current } (I)}$$

The SI unit of resistance is ohm (Ω).

- At a given temperature resistance of a conductor depends on its (i) length l, (ii) cross-section area A and (iii) nature of the material of the conductor.
  It is found that $R \propto l$ and $R \propto \dfrac{1}{A}$, Mathematically, $R = \rho\dfrac{l}{A}$
  where, ρ is the constant of proportionality called resistivity or specific resistance of the conductor.
- Resistivity of a conductor is defined as the resistance of a conductor of unit length and unit area of cross-section.
  The SI unit of resistivity is ohm-metre (Ω-m).
- If R_1, R_2 and R_3 be the individual resistors joined in series, then the equivalent resistor R_S is given by
  $$R_S = R_1 + R_2 + R_3$$
- If R_1, R_2 and R_3 be the individual resistors joined in parallel, then the equivalent resistor R_P is given by
  $$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
- When an electric current is passed through a high resistance wire like nichrome wire, then the wire becomes very hot and produces heat. This is called the heating effect of current.
- As per Joule's law of heating the electric energy consumed is given by
  $$W = qV = VIt = I^2Rt = \frac{V^2t}{R}$$
- Electric power (P) is defined as the amount of electric energy consumed in a circuit per unit time $(P) = \dfrac{W}{t}$.
- The SI unit of electric power is watt (W).
- In the ring system, the wires starting from the main fuse box run around all the rooms of the house and then come back to the fuse box again forming the ring.
- The electric power is generated at the power generating stations. The power from the generating station is transmitted over long distances at a still high voltage to minimise the loss of energy in form of heat in the live wires used for transmission.
- In an electrical circuit switch is used to start or stop the flow of current.
- Main Switch It is a two pole or three pole single way switch.
- Two-way switch means two or more switches in different locations to control one lamp.
- Staircase wiring is a dual control switch system in which the double pole type switches are used at the top and bottom of a staircase.
- To avoid from the risk of electrical shock, the metal body of appliances is earthed. Earthing means to connect the metal case of the appliance to the earth (i.e., zero potential) by means of a metal wire called the earth wire.
- Fuse is a safety device which protects the electrical circuit from short circuiting and overload.
- In a 3-pin plug, the top pin is for earthing, the left pin is for live and the right pin is for neutral. The pins are splitted at the ends to provide a spring action so that the fit in the socket holes tightly. The earth pin is thicker and longer than the other two.
- Conventional colour codes of wires are live-brown, neutral-light blue and earth-green or yellow.

EXAM PRACTICE

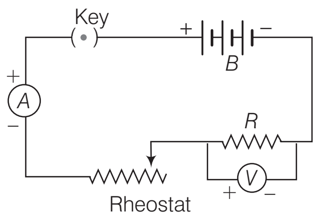
a 2 Marks Questions

1. (i) State Ohm's law.

(ii) Diagrammatically illustrate how you would connect a key, a battery, a voltmeter, an ammeter, an unknown resistance R and a rheostat so that it can be used to verify the above law.

Sol. (i) According to Ohm's law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remain unchanged. ***[1]***

(ii) *To illustrate the Ohm's law, we draw the following circuit as*

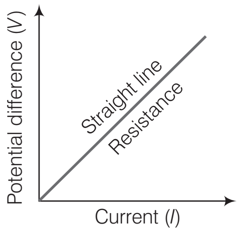


where, B is battery, V is voltmeter and A is ammeter. ***[1]***

2. (i) Sketch a graph to show the change in potential difference across the ends of an ohmic resistor and the current flowing in it. Label the axes of your graph.

(ii) What does the slope of the graph represent? ***[2008]***

Sol. (i)



[1]

(ii) The slope of the graph represents resistance of the resistor. ***[1]***

3. Define specific resistance and state its SI unit. ***[2017]***

Sol. **Specific Resistance** or **Resistivity** (ρ), of a conductor is defined as the resistance of a conductor of unit length and unit area of cross-section.

Specific resistance or resistivity is the characteristic property of the material of the conductor and depends only on the nature of the material and temperature. ***[1]***

As we known, the resistance is given by

$$R = \rho \frac{l}{A} \quad \Rightarrow \quad \rho = \frac{RA}{l} = \frac{\Omega \text{m}^2}{\text{m}} = \Omega\text{-m}$$

Its SI unit is ohm-m (Ω-m). ***[1]***

4. (i) What is an ohmic resistor?

(ii) Two copper wires are of the same length, but one is thicker than the other.

(a) Which wire will have more resistance?

(b) Which wire will have more specific resistance? ***[2014]***

Sol. (i) **Ohmic Resistor** The conductor which obeys Ohm's law is called ohmic resistor or linear resistance., e.g., Silver, aluminium, copper, nichrome, etc. ***[1]***

(ii) (a) Thin wires will have more resistance, because the resistance of the wire varies inversely to the area of the wire, i.e., $R \propto \frac{1}{A}$. ***[1/2]***

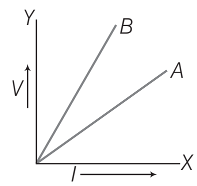
(b) Thick wire will have more specific resistance.

Because $\rho = \frac{RA}{l}$. ***[1/2]***

5. Should the resistance of an ammeter be low or high? Give reason.

Sol. The resistance of an ammeter should be low. An ammeter has to be connected in series with the circuit to measure current. In case, its resistance is not very low, its inclusion in the circuit will reduce the current to be measured. In fact, an ideal ammeter is one which has zero resistance. ***[2]***

6. The V-I graph for a series combination and for a parallel combination of two resistors is shown in the figure below. Which of the two A or B, represents the parallel combination? Give a reason for your answer. ***[2016]***



Sol. In parallel combination, resultant resistance becomes less than the resultant resistance in series combination. From the given graph, the scope represents the resistance. According to graph, slope of line A is less than the slope of line B. So, line A represents the parallel combination. ***[2]***

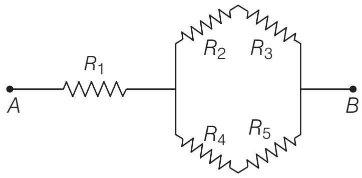
7. n resistors, each of resistance R are first connected in series and then in parallel. What is the ratio of the total effective resistance of the circuit in series to parallel combination?

Sol. In series combination, $R_S = nR$ **[1/2]**

In parallel combination, $R_P = \frac{R}{n}$ **[1/2]**

$$\because \quad \frac{R_S}{R_P} = \frac{nR}{R/n} = n^2$$ **[1]**

8. Derive an expression for equivalent resistance in the following case



Decide which resistances are in series and parallel. Solve for series and then for parallel. Combine both the results to get the equivalent resistance.

Sol. R_2 and R_3 are in series.

Thus, for this combination, $R' = R_2 + R_3$

Similarly, R_4 and R_5 are in series,

So, $R'' = R_4 + R_5$ **[1]**

R' and R'' are in parallel.

$$\therefore \quad R''' = \frac{R' R''}{R' + R''} = \frac{(R_2 + R_3)(R_4 + R_5)}{R_2 + R_3 + R_4 + R_5}$$

R_1 and R''' are in series.

$$\therefore \quad R_{eq} = R_1 + \frac{(R_2 + R_3)(R_4 + R_5)}{R_2 + R_3 + R_4 + R_5}$$ **[1]**

9. In an electrical circuit, three incandescent bulbs A, B and C of ratings 40 W, 60 W and 100 W respectively, are connected in parallel to an electric source. Write the order of brightness.

Sol. Bulbs are rated presuming that they all are to be connected with the same voltage supply (say 220 V in India). In parallel combination, voltage remains same, so greater the power (watt), greater the brightness. Therefore, brightness B of three bulbs are as

$$B_{100} > B_{60} > B_{40}$$ **[1 + 1]**

10. (i) What is the colour code for the insulation on the earth wire?

(ii) Write an expression for calculating electrical power in terms of current and resistance.

Sol. (i) The colour code for the insulation on the earth wire is green or yellow. **[1]**

(ii) The expression for calculating electrical power (P) in terms of current (I) and resistance (R) is given by $P = I^2 R$. **[1]**

11. (i) Which part of an electrical appliance is earthed?

(ii) State a relation between electrical power, resistance and potential difference in an electrical circuit.

Sol. (i) Metallic body of an electrical appliance is earthed. **[1]**

(ii) The relation between electrical power, resistance and potential difference in a circuit is given by

$$P = \frac{V^2}{R}$$ **[1]**

12. Of the three connecting wires in a household circuit

(i) Which two of the three wires are at the same potential?

(ii) In which of the three wires should the switch be connected?

Sol. (i) Neutral and the earth wire are at the same potential, because the earth wire and neutral wire are connected together. **[1]**

(ii) Switch should be connected in live wire. **[1]**

13. Identify the following wires used in a household circuit.

(i) The wire is also called as the phase wire.

(ii) The wire is connected to the top terminal of a three pin socket. **[2018]**

Sol. (i) Live wire is also called as the phase wire. **[1]**

(ii) Earth wire is connected to the top terminal of three pin socket. **[1]**

14. (i) Name the device used to protect the electric circuits from overloading and short circuit.

(ii) On what effect of electricity does the above device work? **[2013]**

Sol. (i) Electric fuse is used to protect the electric circuit from overloading and short circuits. **[1]**

(ii) Heating effect of electric current. **[1]**

15. (i) Give two characteristic properties of copper wire which make it suitable for use as fuse wire.

(ii) Name the material which is used as a fuse wire.

Sol. (i) *The two characteristic properties of copper wire are as*

(a) it should be of low melting point and high resistivity. **[1]**

(b) it should be a good conductor of electricity.

(ii) The alloy of tin and lead is used as fuse wire. **[1]**

16. State the characteristics required in a material to be used as an effective fuse wire. ***[2016]***

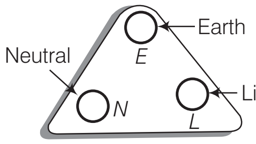
Sol. *Characteristics required in a material to be used as an effective fuse wire are given below*

(i) High resistance and ***[1]***

(ii) Low melting point. ***[1]***

17. Draw a labelled diagram of a 3-pin socket.

Sol. *The 3-pin socket diagram is shown below*



[2]

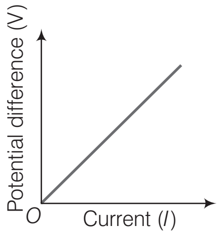
C 3 Marks Questions

18. (i) Draw a graph of potential difference (V) *versus* current (I) for an ohmic resistor.

(ii) How can you find the resistance of the resistor from this graph?

(iii) What is a non-ohmic resistor?

Sol. (i) *The graph of potential difference* (V) *and current* (I) *for ohmic resistance is shown below* ***[1]***



(ii) The resistance of the resistor is given by the slope of the straight line in the V-I graph. ***[1]***

(iii) **Non-ohmic Resistor** The conductor which does not obey Ohm's law is known as non-ohmic resistor. ***[1]***

19. (i) A substance has nearly zero resistance at a temperature of 1K. What is such a substance called?

(ii) State any two factors which affect the resistance of a metallic wire. ***[2010]***

Sol. (i) The substance which has nearly zero resistance at a temperature of 1K is called as superconductor. ***[1]***

(ii) *The two factors which affect the resistance of a metallic wire are*

(a) length of the wire (l), i.e., $R \propto l$

(b) area of cross-section (A), i.e., $R \propto \dfrac{l}{A}$ ***[2]***

20. Read the following informations :

(i) Resistivity of copper is lower than that of aluminium which in turn is lower than that of constantan.

(ii) Six wires labelled as A, B, C, D, E and F have been designed as per the following parameters :

Wire	Length	Diameter	Material	Resistance
A	l	$2d$	Aluminium	R_1
B	$2l$	$d/2$	Constantan	R_2
C	$3l$	$d/2$	Constantan	R_3
D	$l/2$	$3d$	Copper	R_4
E	$2l$	$2d$	Aluminium	R_5
F	$l/2$	$4d$	Copper	R_6

Answer the following questions using the above data:

(a) Which of the wires has maximum resistance and why?

(b) Which of the wires has minimum resistance and why?

(c) Arrange R_1, R_3 and R_5 in ascending order of their values. Justify your answer.

Sol. (a) Wire C has maximum resistance because it has maximum length, least thickness and highest resistivity. ***[1]***

(b) Wire F has the minimum resistance, since it has least length, maximum thickness and least resistivity. ***[1]***

(using, $R = \rho \dfrac{l}{A}$)

(c) $R_3 > R_5 > R_1$

(using relation, $R = \rho \dfrac{l}{A}$ and comparison) ***[1]***

21. What is meant by "electrical resistance" of a conductor? State how resistance of a conductor is affected when (i) a low current passes through it for a short duration and (ii) a heavy current passes through it for about 30 s.

Sol. Electrical resistance of a conductor may be defined as the basis property of any substance due to which it opposes the flow of current through it. Current is inversely proportional to resistance. ***[1]***

(i) The resistance of the conductor will increase when a low current pass through it for a short duration. ***[1]***

(ii) The resistance of the conductor will decrease when a heavy current pass through it. ***[1]***

22. (i) Write an expression for the electrical energy spent in the flow of current through an electrical appliance in terms of I, R and t.

(ii) At what voltage is the alternating current supplied to our houses?

(iii) How should the electric lamps in a building be connected? ***[2012]***

Sol. (i) The expression for the electrical energy, $E = I^2 Rt$. **[1]**

(ii) Alternating current supplied to our houses is at voltage 220 V. **[1]**

(iii) The electric lamp in a building should be connected in parallel. **[1]**

23. (i) An electric bulb is marked 100 W, 250 V. What information does this convey?

(ii) How much current will the bulb draw, if connected to a 250 V supply? **[2011]**

Sol. (i) It conveys that when the bulb is lighted on 250 V supply, it consumes 100 W electrical power i.e., 100 J of electrical energy is consumed in 1s. **[2]**

(ii) Current draw, $I = \frac{P}{V} = \frac{100}{250} = 0.4\text{ A}$ **[1]**

24. (i) A fuse is rated 8 A. Can it be used with an electrical appliance rated 5 kW, 200 V? Give a reason.

(ii) Name the safety devices which are connected to the live wire of a household electric circuit. **[2018]**

Sol. (i) Given, power $(P) = 5\text{ kW} = 5 \times 10^3\text{ W}$

$V = 200\text{ V}$

We know that, $I = \frac{P}{V}$

$$I = \frac{5 \times 10^3}{200} \Rightarrow I = 2.5 \times 10$$

$\therefore \quad I = 25\text{A} > 8\text{A}$

Thus, it cannot be used as the appliance will get fused. **[1½]**

(ii) Fuse, MCB **[1½]**

25. (i) Two sets A and B of three bulbs each, are glowing in two separate rooms. When one of the bulbs in set A is fused, the other two bulbs also cease to glow. But in set B, when one bulb fuses, the other two bulbs continue to glow. Explain why this phenomenon occurs?

(ii) Why do we prefer arrangements of set B for house circuiting? **[2014]**

Sol. (i) The bulbs of set A are connected in series. Therefore, when one bulb fuse the current stop flowing. Whereas, the bulbs of set B are connected in parallel. When one bulb fuse, then current flows through the other bulbs. **[2]**

(ii) We prefer arrangement of set B for house circuiting, because the potential difference in it is same. **[1]**

26. (i) Which particles are responsible for current in conductors?

(ii) Two which wire of a cable in a power circuit, should the metal case of a geyser be connected?

(iii) To which wire, should the fuse be connected? **[2017]**

Sol. (i) Electrons are responsible for the conduction of current in conductors. **[1]**

(ii) Earth wire of a cable in a power circuit should be connected to the metal case of geyser. **[1]**

(iii) Fuse should be connected to live wire. **[1]**

27. (i) A cell is sending current in an external circuit. How does the terminal voltage compare with the emf of the cell?

(ii) What is the purpose of using a fuse in an electrical circuit?

(iii) What are the characteristic properties of fuse wire? **[2012]**

Sol. (i) Terminal voltage is less than that of emf of the cell.

(ii) The purpose of using a fuse in an electrical circuit is to limit the electric current in an electric circuit when there is overheating or overloading in the circuit. A fuse is used as safety device. **[2]**

(iii) The characteristic properties of fuse wire are low melting point and high resistance. **[1]**

28. (i) Which particles are responsible for current in conductors?

(ii) To which wire of a cable in a power circuit should the metal case of a geyser be connected?

(iii) To which wire should the fuse be connected? **[2016]**

Sol. (i) Electrons are responsible for the conduction of current in conductors. **[1]**

(ii) Earth wire of a cable in a power circuit should be connected to the metal case of geyser. **[1]**

(iii) Fuse should be connected to live wire. **[1]**

29. (i) An electrical gadget can give an electric shock to its user under certain circumstance. Mention any two of these circumstances.

(ii) What preventive measure provided in a gadget can protect a person from an electric shock? **[2013]**

Sol. (i) *The two circumstances, which give electric shock are as*

(a) an electric shock may be caused due to poor insulation of wires.

(b) when wires of electric appliances are touched with wet hands. **[2]**

(ii) To prevent from electric shocks, the insulation of wires must be of good quality and it should be checked from time to time particularly when they become old. **[1]**

30. (i) Name the colour code of the wire which is connected to the metallic body of an appliance.

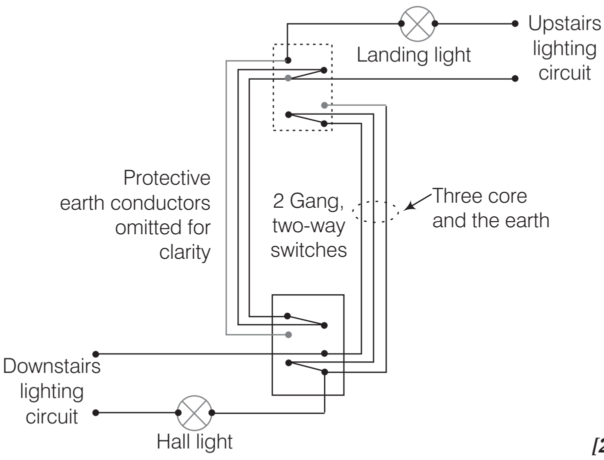
(ii) Draw the diagram of a dual control switch when the appliance is switched 'ON' ***[2017]***

Sol. (i) *The colour coding of wires in a cable are as follow*

Wires	Colour	
	Old Convention	**New Convention**
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green or Yellow

[1]

(ii) **Two-Way or Dual Way Switch** It means two or more switches in different locations to control one lamp. This figure illustrates that lights to be controlled from both locations.

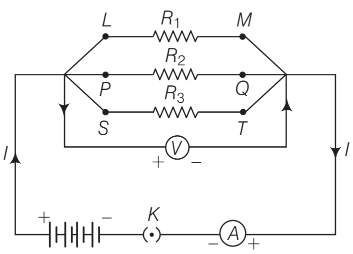


[2]

d 4 Marks Questions

31. How will you conclude that the same potential difference (voltage) exists across three resistors connected in a parallel arrangement to a battery?

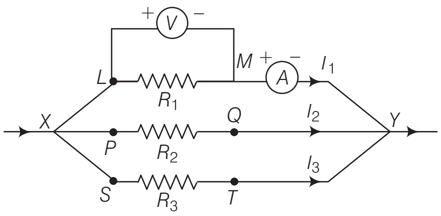
Sol. The experimental set up comprises of three resistors R_1, R_2 and R_3 which are joined in parallel combination and connecting them with a battery, an ammeter (A), a voltmeter (V) and a plug key K, as shown in Fig. (a). The key K is closed and the voltmeter and ammeter readings are recorded.



(a)

[1½]

The key K is open and removing the ammeter and voltmeter from the circuit and insert the voltmeter V in parallel with R_1 and ammeter in series with the resistor R_1, as shown in Fig. (b). Again, the voltmeter and ammeter readings are recorded.



(b)

[1½]

Similarly, measuring the potential differences across resistances, R_2 and R_3. It is found that voltmeter gives identical reading which leads to conclude that the voltage or potential difference across each resistors is same and equal to the potential difference across the combination. ***[1]***

32. (i) The potential difference between two points in an electric circuit is 1 V. What does it mean? Name a device that helps to measure the potential difference across a conductor.

(ii) Why does the connecting cord of an electric heater not glow while the heating element does?

(iii) *Electrical resistivities of some substances at 20 °C are given as below*

Silver	: 1.60×10^{-8} Ω-m
Copper	: 1.62×10^{-8} Ω-m
Tungsten	: 5.2×10^{-8} Ω-m
Iron	: 10.0×10^{-8} Ω-m
Mercury	: 94.0×10^{-8} Ω-m
Nichrome	: 100×10^{-8} Ω-m

Answer the following questions using above data:

(a) Among silver and copper, which one is a better conductor and why?

(b) Which material would you advise to be used in electrical heating devices and why?

Sol. (i) The potential difference between two points is 1 V, means that, if a charge of 1 C is moved from one point to the other, then 1 J of work is required. The potential difference across a conductor is measured by means of an instrument called the voltmeter. ***[1]***

(ii) The electric power P is given by

$$P = I^2 R$$

The resistance of the heating element is very high. Large amount of heat generates in the heating element and it glows hot.

The resistance of connecting cord is very low. Thus, negligible heat generates in the connecting cord and it does not glow. ***[1]***

(iii) (a) Silver is a better conductor due to its lower resistivity.

(b) Nichrome should be used in electrical heating devices due to very high resistivity. ***[2]***

33. Obtain an expression for the heat produced in a conductor when a voltage V is applied across it. Heating effect of electric current is desirable as well as undesirable. Explain this statement.

Sol. When an electric charge Q moves against a potential difference V, then the amount of work done is given by

$$W = Q \times V \quad \dots\text{(i)}$$

We also know that, $I = Q / t$

So, $\quad Q = I \times t \quad$ ...(ii)

and from Ohm's law, $\quad V = IR \quad$ ...(iii)

Putting the values of Eqs. (ii) and (iii) in Eq. (i), we get

$$W = I \times t \times I \times R$$

$\therefore$ Work done, $W = I^2 Rt$ ***[1½]***

Assuming that all the electrical work done or all the electrical energy consumed is converted into heat energy.

$\therefore \quad W = H = I^2 Rt$ ***[1]***

Heating effect of electric current is desirable because it as useful for the functioning of electrical bulbs, etc, and undesirable because it bads to unnecessary loss of energy in the form of heat. ***[1½]***

34. (i) Which is the better way to connect lights and other appliances in domestic circuit, series connection or parallel connection? Justify your answer.

(ii) An electrician has made electric circuit of a house in such a way that, if a lamp gets fused in a room of the house, then all the lamps in other rooms of the house stop working.

What is the defect in this type of circuit wiring? Give reason.

Sol. (i) Parallel connection is a better way to connect lights and other appliances in domestic circuit. ***[1]***

It is because

(a) when we connect a number of devices in parallel combination, each device gets the same potential as provided by the battery and it keeps on working even, if other devices stop working.

(b) parallel connection is helpful when each device has different resistances and requires different current for its operation as in this case the current divides itself through different devices unlike series connection. ***[1]***

(ii) Electrician has made series connection of all the lamps in electric circuit of house because of which, if one lamp gets fused, all the other lamps stop working. ***[1]***

This is due to the fact that when devices are connected in series, then if one device fails, the circuit gets broken and all the devices in that circuit stop working. ***[1]***

35. (i) Explain the meaning of the statement 'current rating of a fuse is 5A.

(ii) In the transmission of power, the voltage of power generated at the generating stations is stepped up from 11 kV to 132 kV before it is transmitted. Why? ***[2017]***

Sol. (i) Current rating of fuse is 5A means, it is a safety device having short length of thin wire having low melting point of a particular amount of current 5A. Whenever current through this fuse exceeds the 5A limit, it will melt and break the circuit and save main circuit components from damage. ***[2]***

(ii) Step-up transformer increases the amplitude of alternating voltage from 11 kV to 132 kV before it is transmitted to get better efficiency with less loss of energy. ***[2]***

Numerical Based Questions

36. Calculate the amount of charge that flows through a conductor when a current of 5A flows through it for 2 min.

Sol. Given, $I = 5\text{A}, t = 2 \text{ min} = 2 \times 60 \text{ s} = 120 \text{ s}, q = ?$

We know that, charge, $q = I \times t$

$\Rightarrow \quad q = 5 \times 120 = 600 \text{ C}$

Thus, the amount of charge flowing through conductor is 600 C. ***[2]***

37. A current of 1 A is drawn by a filament of an electric bulb. What would be the number of electrons passing through a cross-section of the filament in 16 s?

Sol. Given, $\quad I = 1 \text{ A}, t = 16 \text{ s}$

We know that, current, $I = \frac{q}{t} = \frac{ne}{t}$

$(\because q = ne)$

$\Rightarrow \quad n = \frac{I \times t}{e} = \frac{1 \times 16}{1.6 \times 10^{-19}}$

$(\because e = 1.6 \times 10^{-19} \text{ C})$

$= 10^{20}$ electrons ***[2]***

38. Calculate the work done in moving a charge of 4 C from a point at 220 V to a point at 230 V.

Sol. Given, charge, $q = 4$ C

Potential at point A, $V_A = 220$ V

Potential at point B, $V_B = 230$ V

Work done, $W = ?$

$\therefore$ Potential difference, $\Delta V = V_B - V_A$

$$= 230 - 220 = 10 \text{ V}$$

We know that, work done,

$$W = \Delta V \times q = 10 \times 4 = 40 \text{ J}$$ ***[2]***

39. A metal wire of resistance 6 Ω is stretched so that its length is increased to twice its original length. Calculate its new resistance. ***[2013]***

Sol. Given, $R_1 = 6\,\Omega$, $l_1 = l$

$$l_2 = 2l_1 = 2l,\ R_2 = ?$$

$$R_1 = \rho\frac{l_1}{A_1} \text{ and } R_2 = \rho\frac{l_2}{A_2}$$ ***[1]***

The volume of metal wire remains same.

$$\therefore \quad A_1 l_1 = A_2 l_2 \quad \Rightarrow \quad \frac{l_2}{l_1} = \frac{A_1}{A_2}$$

Now, $$\frac{R_2}{R_1} = \frac{l_2}{A_2}\times\frac{A_1}{l_1} = \frac{l_2}{l_1}\times\frac{l_2}{l_1}$$

$$\Rightarrow \quad R_2 = R_1\left(\frac{l_2}{l_1}\right)^2 = 6\left(\frac{2l}{l}\right)^2 = 24\,\Omega$$ ***[1]***

40. A copper wire of resistivity 1.63×10^{-8} Ω-m has cross-section area of $10.3\times10^{-4}\ \text{cm}^2$. Calculate the length of the wire required to make a 20 Ω coil.

Sol. Given, $\rho = 1.63\times10^{-8}$ Ω-m

$$A = 10.3\times10^{-4}\ \text{cm}^2 = 10.3\times10^{-4}\times10^{-4}\ \text{m}^2$$

$$R = 20\,\Omega,\ l = ?$$

We know that, $R = \dfrac{\rho l}{A}$

$$\Rightarrow \quad l = \frac{RA}{\rho} = \frac{20\times10.3\times10^{-4}\times10^{-4}\ \text{m}^2}{1.63\times10^{-8}\ \Omega\text{-m}}$$

$$= \frac{20\times10.3\times10^{-8}}{1.63\times10^{-8}}$$

$$= 126.38 \text{ m}$$ ***[3]***

41. How is the resistance of a wire affected, if (i) its length is doubled and (ii) its radius is doubled?

Sol. (i) $\therefore \quad R = \dfrac{\rho l}{A}$ $\left(\begin{array}{l}\text{where, } l = \text{length of wire and}\\ A = \text{area of cross-section of wire.}\end{array}\right)$

$$R' = \frac{\rho l\times2}{A}$$

$$\because \quad R' = 2R$$ ***[1½]***

i.e., resistance will be doubled, if length of the wire is doubled.

(ii) $\therefore \quad R = \dfrac{\rho l}{A} \Rightarrow R = \dfrac{\rho l}{\pi r^2}$ $\quad (\because A = \pi r^2)$

$$R' = \frac{\rho l}{\pi(2r)^2} = \frac{\rho l}{\pi r^2}\times\frac{1}{4} = \frac{R}{4}$$

Thus, resistance will decrease by four times, if radius of wire is doubled. ***[1½]***

42. A metal wire has diameter of 0.25 mm and electrical resistivity of 0.8×10^{-8} Ω-m.

(i) What will be the length of this wire to make a resistance 5 Ω?

(ii) How much will the resistance change, if the diameter of the wire is doubled?

Sol. Given, diameter = 0.25 mm

Resistivity, $\rho = 0.8\times10^{-8}$ Ω-m

Resistance, $R = 5\Omega$

(i) We know that, $R = \dfrac{\rho l}{A}$

$$\Rightarrow \quad l = \frac{RA}{\rho} = \frac{5\Omega\times\pi\times\left(\frac{0.25}{2}\times10^{-3}\right)^2}{0.8\times10^{-8}}$$

$$\left(\because A = \pi r^2 \text{ and } r = \frac{D}{2}\right)$$

$$= \frac{5\times\pi\times1.56\times10^{-8}}{0.8\times10^{-8}}$$ ***[1]***

(ii) Resistance,

$$R = \frac{\rho l}{A} = \frac{\rho l}{\pi\left(\frac{D}{2}\right)^2} \qquad \left(\because A = \pi r^2 \text{ and } r = \frac{D}{2}\right)$$

$$= \frac{\rho l}{\pi}\times\frac{4}{D^2}$$

New resistance,

$$R' = \frac{\rho l}{A} = \frac{\rho l}{\pi \left(\frac{2D}{2}\right)^2} \quad (\because D \text{ has become } 2D)$$

$$= \frac{\rho\, l}{\pi\, D^2}$$ **[1]**

Now, $\frac{R'}{R} = \frac{\rho l}{\pi D^2} \div \frac{\rho l \times 4}{\pi D^2} = \frac{\rho l}{\pi D^2} \times \frac{\pi D^2}{\rho l \times 4} = \frac{1}{4}$

$\therefore \quad R' = \frac{R}{4}$

Thus, resistance will decrease by 4 times. **[1]**

43. You have three resistors of values 2 Ω, 3 Ω and 5 Ω. How will you join them so that the total resistance is more than 7 Ω?

(i) Draw a diagram for the arrangement.

(ii) Calculate the equivalent resistance. ***[2018]***

Sol. To get total resistance more than 7Ω. We can connect 2Ω, 3Ω and 5Ω in series.

(i) 

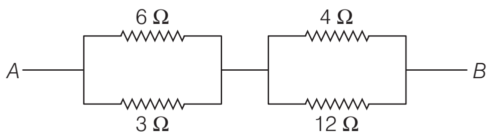
[1]

(ii) $R_{eq} = R_1 + R_2 + R_3$ (for series combination)

$R_{eq} = 2 + 3 + 5$

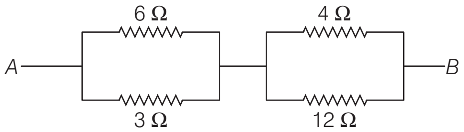
$R_{eq} = 10\Omega$ **[1]**

44. (i) Find the equivalent resistance between *A* and *B*.



(ii) State whether the resistivity of a wire changes with the change in the thickness of the wire. ***[2018]***

Sol. (i)



In the circuit 6Ω and 3Ω are in parallel combination.

$$\therefore \quad \frac{1}{R_{P_1}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{P_1} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6 \times 3}{6 + 3} = \frac{18}{9} = 2\Omega$$

4Ω and 12Ω resistance are in parallel combination.

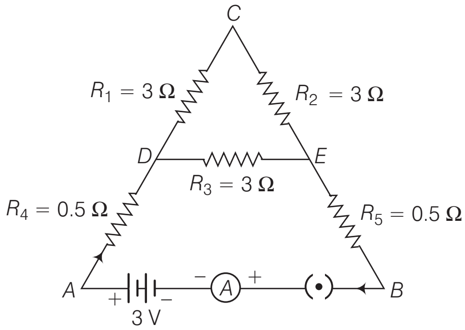
$$R_{P_2} = \frac{R_3 \times R_4}{R_3 + R_4} = \frac{4 \times 12}{4 + 12} = \frac{48}{16} = 3\Omega$$

Total resistance of circuit,

$R_T = R_{P_1} + R_{P_2} = 2 + 3 = 5\Omega$ ***[1½]***

(ii) Resistivity is a material property it does not changes with change in thickness of wire. ***[1½]***

45. Five resistors are connected in a circuit as shown in figure. Find the ammeter reading when the circuit is closed.



Sol. R_1 and R_2 are in series.

$$R_{S1} = R_1 + R_2 = 3 + 3 = 6\ \Omega$$

R_{S1} and R_3 are in parallel.

$$\therefore \quad \frac{1}{R_P} = \frac{1}{R_{S1}} + \frac{1}{R_3} = \frac{1}{6} + \frac{1}{3} = \frac{1}{2}$$

$\Rightarrow \quad R_P = 2\ \Omega$ **[1]**

R_4, R_P and R_5 are in series.

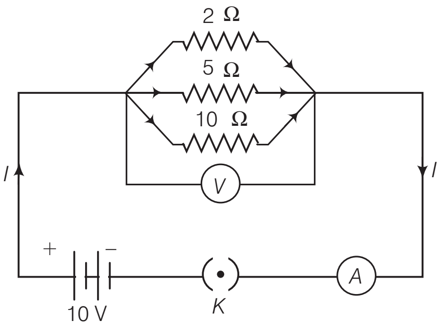
$\therefore \quad R_S = R_4 + R_P + R_5$ **[1]**

$= 0.5 + 2 + 0.5 = 3\ \Omega$

Then, current, $I = \frac{V}{R_S}$

$= \frac{3}{3} = 1\text{ A}$ **[1]**

46. A circuit diagram is given as shown below:



Calculate

(i) the total effective resistance of the circuit.

(ii) the total current in the circuit.

(iii) the current through each resistor.

Sol. Given, $R_1 = 2\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 10\ \Omega$, $V = 10\ \text{V}$

(i) Total effective resistance as the combination is in parallel,

$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{5} + \frac{1}{10} = \frac{5+2+1}{10} = \frac{8}{10}$$

$$\Rightarrow \qquad R_{\text{eff}} = \frac{10}{8} = 1.25\ \Omega$$ **[1]**

(ii) Total current, $I = I_1 + I_2 + I_3 = 5 + 2 + 1 = 8\ \text{A}$ **[1]**

(iii) Current through each resistor,

$$I_1 = \frac{V}{R_1} = \frac{10}{2} = 5\ \text{A},$$

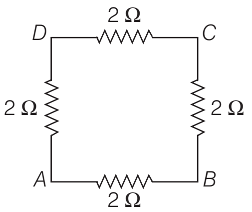
$$I_2 = \frac{V}{R_2} = \frac{10}{5} = 2\ \text{A} \text{ and } I_3 = \frac{V}{R_3} = \frac{10}{10} = 1\ \text{A}$$ **[1]**

47. Four resistances of $2.0\ \Omega$ each are joined end to end, to form a square *ABCD*. Calculate the equivalent resistance of the combination between any two adjacent corners. ***[2015]***

Sol. Resistance between two adjacent corners *A* and *B* is

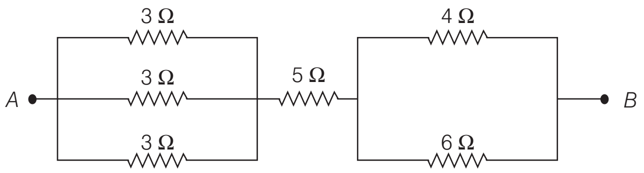
$$\frac{1}{R} = \frac{1}{R_{AB}} + \frac{1}{R_{BC} + R_{CD} + R_{AD}}$$

$$= \frac{1}{2} + \frac{1}{2+2+2} = \frac{1}{2} + \frac{1}{6} = \frac{3+1}{6} = \frac{4}{6} = \frac{2}{3} \Rightarrow R = \frac{3}{2} = 1.5\ \Omega$$



[2]

48. Find the equivalent resistance between points *A* and *B*.



[2014]

Sol. The three resistance $3\ \Omega$ are in parallel.

$$\frac{1}{R_1} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{3}{3} = 1\ \Omega \ \Rightarrow R_1 = 1\ \Omega$$

and the resistance $4\ \Omega$ and $6\ \Omega$ are in parallel. **[1]**

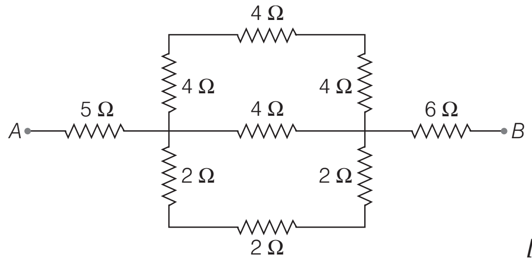
$$\frac{1}{R_3} = \frac{1}{4} + \frac{1}{6} = \frac{3+2}{12} = \frac{5}{12}\ \Omega$$

$$\Rightarrow \qquad R_3 = \frac{12}{5} = 2.4\ \Omega$$ **[1]**

The resistances R_1, $5\ \Omega$ and R_3 are in series. So, total resistance

$$R = R_1 + 5 + R_3 = 1 + 5 + 2.4 = 8.4\ \Omega$$ **[1]**

49. Calculate the equivalent resistance between the points *A* and *B* for the following combination of resistors.



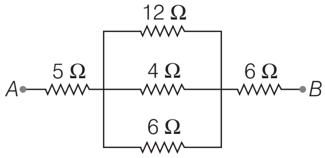
[2013]

Sol. The three resistance each of $4\ \Omega$ are in series.

$$\therefore \qquad R_1 = 4 + 4 + 4 = 12\ \Omega$$

The three resistance $2\ \Omega$ are in series.

$$\therefore \qquad R_2 = 2 + 2 + 2 = 6\ \Omega$$



[1]

The resistance $4\ \Omega$, $12\ \Omega$ and $6\ \Omega$ are in parallel.

$$\therefore \qquad \frac{1}{R_2} = \frac{1}{4} + \frac{1}{12} + \frac{1}{6} = \frac{3+1+2}{12} = \frac{6}{12} = \frac{1}{2}\ \Omega$$

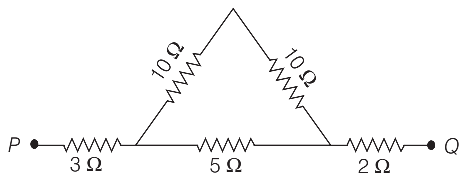
$$\Rightarrow \qquad R_3 = 2\ \Omega$$ **[1]**

The resistors R_1, R_2 and R_3 are in series.

$$\therefore \qquad R_{\text{eq}} = R_1 + R_2 + R_3$$

$$\Rightarrow \qquad R_{\text{eq}} = 5 + 2 + 6 = 13\ \Omega$$ **[1]**

50. Calculate the equivalent resistance between *P* and *Q* from the following diagram.



[2012]

Sol. The two resistance $10\ \Omega$ are in series.

$$R = 10 + 10 = 20\ \Omega$$

The resistance $5\ \Omega$ and R are in parallel. **[1]**

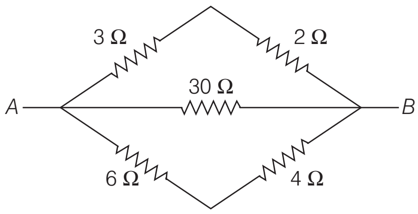
$$\therefore \qquad \frac{1}{R_1} = \frac{1}{5} + \frac{1}{20} = \frac{4+1}{20} = \frac{5}{20} = \frac{1}{4}$$

The resistors R_1, $3\ \Omega$ and $2\ \Omega$ are in series. **[1]**

$\therefore$ Equivalent resistance,

$$R_{\text{eq}} = 3 + 4 + 2 = 9\ \Omega$$ **[1]**

51. Calculate the equivalent resistance between A and B from the following diagram.



[2011]

Sol. Resistance 3 Ω and 2 Ω are in series.

$\therefore \qquad R_1 = 3 + 2 = 5\ \Omega$

Also resistance 6 Ω and 4 Ω are in series.

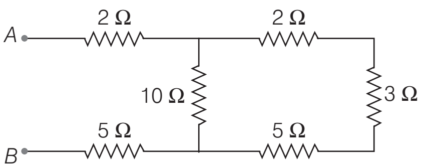
$\therefore \qquad R_2 = 6 + 4 = 10\ \Omega$

Equivalent resistance between A and B is

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

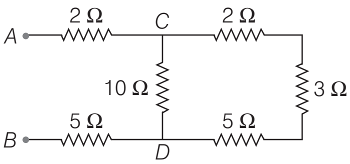
$R_{eq} = 3\ \Omega$ **[2]**

52. Six resistances are connected together as shown in the figure. Calculate the equivalent resistance between the points A and B.



[2010]

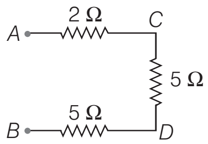
Sol. Resistance between the point C and D,



[1]

$$\frac{1}{R_{CD}} = \frac{1}{10} + \frac{1}{2+3+5} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5}$$ **[1]**

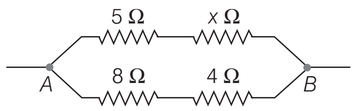
$\therefore \qquad R_{CD} = 5\ \Omega$



Now, equivalent resistance between the points A and B.

$$R_{AB} = R_{AC} + R_{CD} + R_{BD}$$
$$= 2 + 5 + 5 = 12\ \Omega$$ **[1]**

53. The equivalent resistance of the following circuit diagram is 4 Ω. Calculate the value of x. **[2009]**



Sol. $\dfrac{1}{R_{AB}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} \Rightarrow \dfrac{1}{4} = \dfrac{1}{5+x} + \dfrac{1}{8+4}$

$\Rightarrow \qquad \dfrac{1}{4} = \dfrac{1}{5+x} + \dfrac{1}{12}$

$\Rightarrow \qquad \dfrac{1}{5+x} = \dfrac{1}{4} - \dfrac{1}{12} = \dfrac{3-1}{12} = \dfrac{2}{12} = \dfrac{1}{6}$

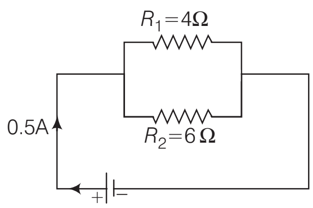
$\Rightarrow \qquad 5 + x = 6 \Rightarrow x = 6 - 5 \Rightarrow x = 1\ \Omega$ **[2]**

54. Two resistor of 4 Ω and 6 Ω are connected in parallel to a cell to draw 0.5 A current from the cell.

(i) Draw a labelled circuit diagram showing the above arrangement.

(ii) Calculate the current in each resistor.

Sol. (i) *The circuit is shown below*



[2]

(ii) Let the current flowing through resistance R_1 is I and current flowing through R_2 resistance is $0.5 - I$.

$\therefore \qquad I \times 4 = (0.5 - I) \times 6$

$\Rightarrow \qquad 4I = 3 - 6I$

$\Rightarrow \qquad 10I = 3$

$\Rightarrow \qquad I = 0.3$ A

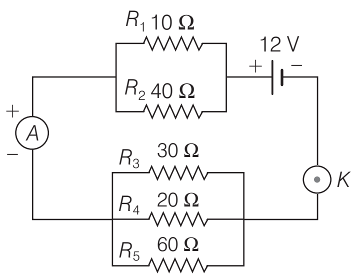
$\therefore$ Current flowing through $R_1 = 4\ \Omega$ is 0.3 A and current flowing through $R_2 = 6\ \Omega$ is

$0.5 - 0.3 = 0.2$ A **[2]**

55. Five resistors of different resistance are connected together as shown in the figure. A 12 V battery is connected to the arrangement. Calculate **[2010]**

(i) the total resistance in the circuit.

(ii) the total current flowing in the circuit.



Sol. (i) $\dfrac{1}{R_{12}} = \dfrac{1}{10} + \dfrac{1}{40} = \dfrac{4+1}{40} = \dfrac{5}{40} = \dfrac{1}{8}$

$\Rightarrow \qquad R_{12} = 8\,\Omega$ **[2]**

$$\frac{1}{R_{345}} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60} = \frac{2+3+1}{60}$$

$$\frac{1}{R_{345}} = \frac{6}{60} = \frac{1}{10} \Rightarrow R_{345} = 10\,\Omega$$

Total resistance, $R = R_{12} + R_{345}$

$= 8 + 10 = 18\,\Omega$

(ii) Total current, $I = \dfrac{V}{R} = \dfrac{12}{18} = \dfrac{2}{3} = 0.67$ A **[2]**

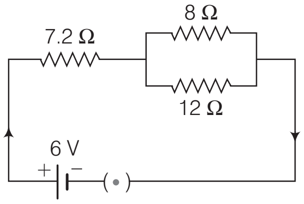
56. Three resistors are connected to a 6 V battery as shown in the figure.

Calculate

(i) the equivalent resistance of the circuit.

(ii) total current in the circuit.

(iii) potential difference across the 7.2 Ω resistor. ***[2012]***



Sol. (i) Resistances 8 Ω and 12 Ω are in parallel.

$\therefore \quad \dfrac{1}{R_1} = \dfrac{1}{8} + \dfrac{1}{12} = \dfrac{3+2}{24} = \dfrac{5}{24} \Rightarrow R_1 = \dfrac{24}{5} = 4.8\,\Omega$ **[1]**

Now, resistances R_1 and 7.2 are in series.

$\therefore \quad R_{eq} = 4.8 + 7.2 = 12\,\Omega$

(ii) $I = ?$

$$I = \frac{V}{V_{eq}} = \frac{6}{12} = \frac{1}{2} = 0.5\text{ A}$$ **[1]**

(iii) Potential difference across 7.2 Ω resistor

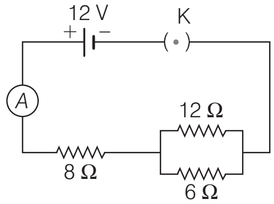
$= 0.5 \times 7.2 = 3.6$ V **[1]**

57. Three resistors are connected to a 12 V battery as shown in the figure given below.

(i) What is the current through the 8 Ω resistors?

(ii) What is the potential difference across the parallel combination of 6 Ω and 12 Ω resistors?

(iii) What is the current through the 6 Ω resistor? ***[2011]***



Sol. (i) Resistances 12 Ω and 6 Ω are parallel.

So, $\dfrac{1}{R_1} = \dfrac{1}{12} + \dfrac{1}{6} = \dfrac{3}{12} = \dfrac{1}{4} \Rightarrow R_1 = 4\,\Omega$

Equivalent resistance,

$$R_{eq} = 4 + 8 = 12\,\Omega \Rightarrow I = \frac{V}{R_{eq}} = \frac{12}{12} = 1\text{A}$$ **[1]**

(ii) Potential Difference (PD) across parallel combination of resistances 6 Ω and 12 Ω is **[1]**

$$V = I \times R_1 = 1 \times 4 = 4\text{ V} \left(\because R_{eq} = \frac{6 \times 12}{6+12} = 4\,\Omega\right)$$

(iii) Current through 6 Ω resistor is $= \dfrac{4\text{V}}{6\Omega} = 0.67$ A **[1]**

58. A music system draws a current of 400 mA, when connected to a 12 V battery.

(i) What is the resistance of the music system?

(ii) The music system is left playing for several hours and finally the battery voltage drops and the music system stops playing when the current drops to 320 mA. At what battery voltage does the music system stop playing? ***[2016]***

Sol. Given, current, $I = 400\text{ mA} = 400 \times 10^{-3}\text{ A} = 0.4\text{ A}$

voltage, $V = 12$ V

(i) Resistance of music system,

$$R = \frac{V}{I} = \frac{12}{0.4} = \frac{120}{4} = 30\,\Omega$$ **[1]**

(ii) Resistance of music system, $R = 30\,\Omega$

Current, $I = 320\text{ mA} = 0.32$ A

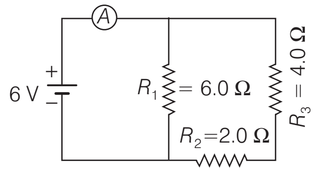
$\because$ By Ohm's law, $R = \dfrac{V}{I} \Rightarrow V = IR$

$\Rightarrow \qquad V = 0.32 \times 30$

$\Rightarrow \qquad V = \dfrac{32}{100} \times 30 = \dfrac{960}{100}$

$\Rightarrow \qquad V = 9.60$ V **[2]**

59. Three resistors of 6.0 Ω, 2.0 Ω and 4.0 Ω respectively are joined together as shown in the figure. The resistors are connected to an ammeter and to a cell of emf 6.0 V. ***[2008]***



Calculate

(i) the effective resistance of the circuit.

(ii) the current drawn from the cell.

Sol. (i) $R_S = R_2 + R_3 = 2 + 4 = 6\,\Omega$

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3} \Rightarrow R_{\text{eq}} = 3\,\Omega$$ ***[1]***

(ii) $I = \frac{E}{R} = \frac{6}{3} = 2\text{ A}$ ***[1]***

60. Two resistors with resistances 5 Ω and 10 Ω respectively, are to be connected to a battery of emf 6 V, so as to obtain

(i) (a) minimum current.

(b) maximum current.

(ii) How will you connect the resistances in each case?

(iii) Calculate the strength of the total current in the circuit in the two cases.

Sol. (i) (a) For obtaining minimum current, the two resistors should be connected in parallel.

(b) For obtaining maximum current, the two resistors should be connected in series. ***[1]***

(ii) Given, $R_1 = 5\,\Omega$, $R_2 = 10\,\Omega$, $V = 6$ V

For parallel combination, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

$$= \frac{1}{5} + \frac{1}{10} = \frac{2+1}{10} = \frac{3}{10} \Rightarrow R = \frac{10}{3}\,\Omega$$

∴ Total current in the circuit,

$$I = \frac{V}{R} = \frac{6 \times 3}{10} = 1.8\text{ A}$$ ***[1]***

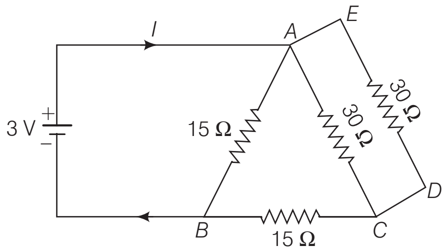
(iii) For series combination,

$$R = 5 + 10 = 15\,\Omega$$

∴ Total current in the circuit,

$$I = \frac{V}{R} = \frac{6}{15} = 0.4\text{ A}$$ ***[1]***

61. (i) Find the value of current I in the circuit given as below



(ii) You have four resistors of 8 Ω each. Show how would you connect these resistors to have effective resistance of 8 Ω?

Sol. (i) R_{AC} and R_{ED} are in parallel, so

$$\frac{1}{R'_P} = \frac{1}{R_{AC}} + \frac{1}{R_{ED}} = \frac{1}{30} + \frac{1}{30} = \frac{1}{15}$$

$$\Rightarrow \quad R'_P = 15\ \Omega$$

Now, R'_P and R_{BC} are in series, so

$$R'_S = R'_P + R_{BC}$$
$$= 15 + 15 = 30\ \Omega$$

Again, R_{AB} and R'_S are in parallel, so

$$\frac{1}{R''_P} = \frac{1}{R_{AB}} + \frac{1}{R'_S} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

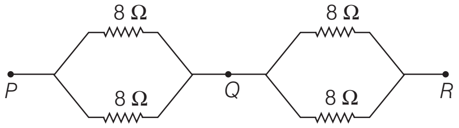
$$\therefore \quad R''_P = 10\,\Omega$$

So, current flowing through the circuit is

$$I = \frac{V}{R''_P} = \frac{3}{10} = 0.3\text{ A}$$ ***[2]***

(ii) Two 8 Ω resistors are connected in parallel. Two such parallel combination must be connected in series to get effective resistance of 8 Ω.

Such combination is shown as below



[2]

62. Two resistances when connected in parallel give resultant value of 2 Ω, when connected in series the value becomes 9 Ω. Calculate the value of each resistance.

Sol. We know that two resistances are in parallel and hence

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

Given, $R_P = 2\,\Omega$

$$\Rightarrow \quad 2 = \frac{R_1 R_2}{R_1 + R_2}$$ **[1]**

$\therefore \quad 2(R_1 + R_2) = R_1 R_2$ ...(i)

Now, same resistances are in series, $R_S = R_1 + R_2$

Given, $R_S = 9\,\Omega$ and $9 = R_1 + R_2$ ...(ii)

From Eqs. (i) and (ii), we get

$$R_1 R_2 = 18$$

Again, using Eq. (ii), we get

$$R_2 = 9 - R_1$$

$\therefore \quad R_1 (9 - R_1) = 18$

$\Rightarrow \quad R_1^2 - 9R_1 + 18 = 0$

$\Rightarrow R_1^2 - 6R_1 - 3R_1 + 18 = 0$ **[1]**

(by splitting the middle term)

$\Rightarrow \quad (R_1 - 6)(R_1 - 3) = 0$

Either, $R_1 = 6$ or $R_1 = 3$ and $R_2 = 3\,\Omega$ or $R_2 = 6\,\Omega$

Thus, two resistances are $3\,\Omega$ and $6\,\Omega$. **[1]**

63. An electric bulb of resistance $500\,\Omega$, draws a current of 0.4 A. Calculate the power of the bulb and the potential difference at its end. ***[2017]***

Sol. Given, resistance of bulb, $R = 500\,\Omega$, current, $I = 0.4$ A, power, $P = ?$, potential difference, $V = ?$

As we known power, $P = I^2 R$

$$= (0.4)^2 \times 500$$

$\therefore$ Power, $P = 80$ W

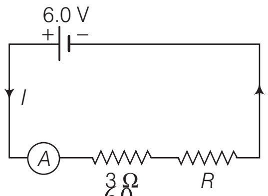
Potential difference, $V = IR = 0.4 \times 500 = 200$ V **[2]**

64. The figure shows a circuit, when the circuit is switched on, the ammeter reads 0.5 A.

(i) Calculate the value of the unknown resistor R.

(ii) Calculate the charge passing through the $3\,\Omega$ resistor in 120 s.

(iii) Calculate the power dissipated in the $3\,\Omega$ resistor. ***[2013]***



Sol. (i) $I = \dfrac{V}{R} \Rightarrow 0.5 = \dfrac{6.0}{3 + R}$ **[1]**

$$\Rightarrow 3 + R = \frac{6}{0.5} \Rightarrow R = \frac{60}{5} - 3 = 9\,\Omega$$

(ii) $Q = I \times t = 0.5 \times 120 = 60$ C **[1]**

(iii) $P = VI = I^2 R = (0.5)^2 \times 3$

$$= 0.25 \times 3 = 0.75 \text{ W}$$ **[1]**

65. Calculate the quantity of heat produced in a $20\,\Omega$ resistor carrying 2.5 A current in 5 min. ***[2016]***

Sol. Given, resistance, $R = 20\,\Omega$

Current, $I = 2.5$ A

Time, $t = 5$ min $= 5 \times 60 = 300$ s **[1]**

According to Joule's law of heating,

$$H = I^2 Rt = (2.5)^2 \times 20 \times 300$$

$$= \frac{625}{100} \times 20 \times 300 = 625 \times 20 \times 3$$

$$H = 37500 \text{ J}$$ **[1]**

66. An electrical heater is rated 4 kW, 220 V. Find the cost of using this heater for 12 h, if one kWh of electrical energy costs 3.25.

Sol. Given, $P = 4$ kW, $V = 220$ V, $t = 12$ h

$$E = P \times t = 4 \times 12 = 48 \text{ kWh}$$

Cost of energy consumed $= 48 \times 3.25 =$ ₹156 **[2]**

67. An electric iron is rated 220 V, 2 kW.

(i) If the iron is used for 2 h daily, find the cost of running it for one week if it costs ₹4.25 per kWh.

(ii) Why is the fuse absolutely necessary in a power circuit? ***[2018]***

Sol. (i) Given, power $(P) = 2 \times 10^3$ W $= 2$ kW

Voltage $(V) = 220$ V

Time $(t) = 2$h daily for 1 week $= 2 \times 7 = 14$h

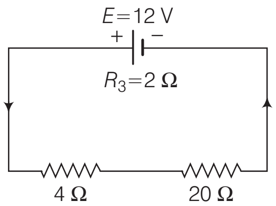
Electrical energy (in kWh)

$$= P \times t = 2 \times 14 = 28 \text{ kWh}$$

Running cost $= 28 \times 4.25 =$ ₹119. **[2]**

(ii) The purpose of using a fuse in an electrical circuit is to limit the electric current in a electric circuit. It prevents overheating or overloading in the circuit when a short circuit occurs. **[2]**

68. A battery of emf 12 V and internal resistance $2\,\Omega$ is connected with two resistors A and B of resistance $4\,\Omega$ and $6\,\Omega$ respectively joined in series. ***[2016]***



Find

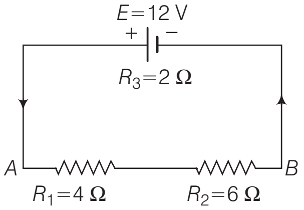
(i) current in the circuit.

(ii) the terminal voltage of the cell.

(iii) the potential difference across 6 Ω resistor.

(iv) electrical energy spent per minute in 4 Ω resistor.

Sol. According to question,



(i) Current in the circuit is given by

$$V = IR_{eq}$$

$$I = \frac{V}{R_{eq}} = \frac{12}{4+6+2} = 1\text{A}$$ **[1]**

($R_{eq} = R_1 + R_2 + R_3$, for series combination)

(ii) Terminal voltage of cell is given by

$$TPD = E - Ir = 12 - 1 \times 2 = 10 \text{ V}$$ **[1]**

(iii) Potential difference across 6 Ω resistance is given by

$$V = IR_2 = 1 \times 6 = 6 \text{ V}$$ **[1]**

(iv) Electric energy spent per minute is given by

$$I^2Rt = 1^2 \times 4 \times 60 \quad (\because 1 \text{ min} = 60 \text{ s})$$

$$= 240 \text{ J}$$ **[1]**

69. An electrical appliance is rated at 1000 kVA, 220 V. If the appliance is operated for 2h, calculate the energy consumed by the appliance in

(i) kWh (ii) joule

Sol. Given, $P = 1000$ kVA $= 1000$ kW, $t = 2h$

(i) Energy consumed in kWh is

$$E = P \times t = 1000 \times 2 = 2000 \text{ kWh}$$ **[1]**

(ii) Energy consumed in joule is

$$E = 2000 \times 3.6 \times 10^6 \text{ J} = 7.2 \times 10^9 \text{ J}$$ **[1]**

70. Two bulbs are marked 100 W, 220 V and 60 W, 110 V. Calculate the ratio of their resistance. **[2011]**

Sol. $P_1 = 100$ W, $P_2 = 60$ W, $V_1 = 220$ V,

$$V_2 = 110 \text{ V}, \frac{R_1}{R_2} = ?$$

We know that power is given by **[1]**

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

$$\therefore \quad R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V_2^2}{P_2}$$

$$\Rightarrow \quad R_1 = \frac{(220)^2}{100} \text{ and } R_2 = \frac{(110)^2}{60}$$

$$\frac{R_1}{R_2} = \frac{\frac{(220)^2}{100}}{\frac{(110)^2}{60}} = \frac{(220)^2 \times 60}{(110)^2 \times 100} = \frac{12}{5}$$ **[2]**

71. An electric heater is rated 1000 W – 200 V. Calculate

(i) the resistance of the heating element.

(ii) the current flowing through it. **[2009]**

Sol. Given, $P = 1000$ W, $V = 200$ V **[1]**

(i) $R = \frac{V^2}{P} = \frac{200 \times 200}{1000} = 40\ \Omega$

(ii) $I = \frac{P}{V} = \frac{1000}{200} = 5\text{A}$ **[1]**

72. If the current I through a resistor is increased by 100% (assume that temperature remains unchanged), then find the increase in power dissipated.

Sol. Since, $P = I^2R$

Current after increased by

$$100\% = I + \frac{100I}{100} = 2I$$

$$P' = (2I)^2R = 4I^2R$$ **[1]**

$\therefore$ Percentage increase in power dissipation

$$= \frac{P' - P}{P} \times 100$$

$$= \frac{4I^2R - I^2R}{I^2R} \times 100$$

$$= \frac{I^2R(4-1)}{I^2R} \times 100$$

$$= 3 \times 100 = 300\%$$ **[1]**

73. An electrician puts a fuse of rating 5 A in that part of domestic electrical circuit in which an electric heater of rating 1.5 kW, 220 V is operating. What is likely to happen in this case and why?

Sol. Given, $P = 1.5 \text{ kW} = 1.5 \times 10^3 \text{ W}, \ V = 220\text{V}$

$\therefore$ The current drawn by heater, $I = \frac{P}{V}$ **[1/2]**

$$= \frac{1.5 \times 10^3 \text{ W}}{220 \text{ V}} = 6.8 \text{ A}$$ **[1/2]**

The above amount of current is greater than the rated value of fuse current. Hence, the fuse will melt and break the circuit. **[1]**

74. The potential difference between two terminals of an electric iron is 220V and the current flowing through its element is 5A. Calculate the resistance and wattage of the electric iron.

Sol. The potential difference between two terminals of an electric iron $(V) = 220\text{V}$, current flowing through its element $(I) = 5$ A.

Therefore, resistance, $R = \dfrac{V}{I} = \dfrac{220}{5}\,\Omega$

$$R = 44\,\Omega$$ **[1]**

We know that, power, $P = V \times I$

$$= 220 \times 5 = 1100\text{ W}$$ **[1]**

75. An electric geyser rated at 1500 W, 250 V is connected to a 250 V line mains. Solve

(i) the electric current drawn by it.

(ii) energy consumed by it in 50 h.

(iii) cost of energy consumed, if each unit costs ₹ 6.

Sol. Given, power, $P = 1500\text{W}$, voltage, $V = 250$ V

(i) $\therefore$ Electric current drawn,

$$I = \frac{P}{V} = \frac{1500}{250} = 6\text{ A}$$ **[1]**

(ii) $\therefore$ Energy consumed, E = Power $\times$ Time

$= 1500 \times 50$ $\qquad (\because\ t = 50\text{ h})$

$= 75000$ Wh $\qquad (\because 1\text{ kW} = 1000\text{ W})$

$= 75$ unit $\qquad (\because 1\text{ unit} = 1\text{ kWh})$

(iii) $\because$ Cost of energy consumed

$= 75 \times 6 =$ ₹ 450 **[1]**

76. An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum rate. The applied voltage is 220 V. What is the value of current and the resistance in each case?

Sol. We know that the power input is $P = VI$

Thus, the current, $I = \dfrac{P}{V}$ **[1]**

When heating is at the maximum rate,

$$I = \frac{840\text{ W}}{220\text{ V}} = 3.82\text{ A}$$

and the resistance of the electric iron is

$$R = \frac{V}{I} = \frac{220\text{ V}}{3.82\text{ A}} = 57.59\,\Omega$$ **[1]**

When heating is at the minimum rate,

$$I = \frac{360\text{ W}}{220\text{ V}} = 1.64\text{ A}$$

and the resistance of the electric iron is

$$R = \frac{V}{I} = \frac{220\text{ V}}{1.64\text{ A}} = 134.15\,\Omega$$ **[1]**

77. An electrical bulb is rated 40 W, 220 V. How many bulbs can be connected in parallel with each other across the two wires of 220 V line, if the maximum allowable current is 6 A?

Sol. Given, $P = 40$ W, $V = 220$ V, $I = 6$ A

We know that, $R = V^2/P = (220)^2/40$

$$= 48400/40 = 1210\Omega$$ **[1]**

Now, $V = IR_{eq} \Rightarrow R_{eq} = V/I = 220/6 = 36.66\,\Omega$

Suppose, there are x number of bulb in parallel

$$1/36.66 = x/1210$$

$\therefore \quad x = 1210/36.66 = 33.006 \approx 33$ **[1]**

78. A heater coil connected to 200 V has a resistance of 80 Ω. If the heater is plugged in for the time t such that 1 kg of water at 20°C attains a temperature of 60°C. Find

(i) the power of heater.

(ii) the heat absorbed by water.

(iii) the value of t in seconds.

Sol. (i) $\therefore$ Power of heater,

$$P = \frac{V^2}{R} = \frac{200 \times 200}{80} = 500\text{ W}$$ **[1]**

(ii) $\therefore$ Heat absorbed by water, $H = mC\theta_R$

$= 1 \times 4200 \times 40$

$(\because \theta_R = 60° - 20° = 40°\text{C}, C = 4200\text{ J/kg °C})$

$= 168000$ J

$= 168$ kJ **[1]**

(iii) $\therefore$ Energy consumed by heater, $H = P \times t$

$$168000 = 500 \times t \Rightarrow t = \frac{168000}{500} = 336\text{ s}$$ **[1]**

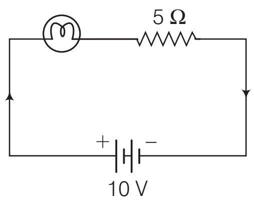
79. (i) A current of 1 A flows in a series circuit having an electric lamp and a conductor of 5 Ω when connected to a 10 V battery. Calculate the resistance of the electric lamp.

(ii) Now, if a resistance of 10 Ω is connected in parallel with this series combination, then what change (if any) in current flowing through 5 Ω conductor and potential difference across the lamp will take place? Give reason.

Sol. (i) Let the resistance of the lamp be R_1 and resistance of conductor be $R_2 = 5\,\Omega$

$\therefore$ Total resistance in series, $R_S = R_1 + R_2 = R_1 + S$

Current, $I = 1\text{ A}$, voltage, $V = 10\text{ V}$



Using Ohm's law, $V = IR_S$

$$10 = 1(R_1 + 5) \Rightarrow R_1 = 5\,\Omega$$

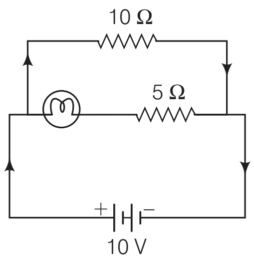
Thus, the resistance of electric lamp is $5\,\Omega$. **[2]**

(ii) Now, a resistance of $10\,\Omega$ is connected in parallel with the series combination. Therefore, the total resistance of the circuit is given by

$$\frac{1}{R_P} = \frac{1}{R_1 + 5} + \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{R_P} = \frac{1}{5+5} + \frac{1}{10} \Rightarrow \frac{1}{R_P} = \frac{1}{10} + \frac{1}{10}$$

$$\therefore \quad R_P = 5\,\Omega$$



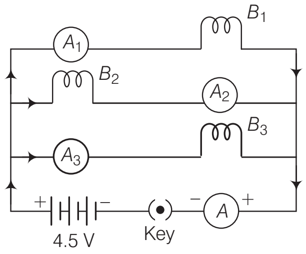
Hence, current flowing in the circuit,

$$I = \frac{V}{R} = \frac{10}{5} = 2\text{ A}$$

Thus, 1 A current will flow through $10\,\Omega$ resistor and 1 A will flow through the lamp and conductor of $5\,\Omega$ resistance.

Hence, there will be no change in current flowing through 5Ω conductor. Also, there will be no change in potential difference across the lamp. **[2]**

80. B_1, B_2 and B_2 are three identical bulbs connected as shown in figure. Ammeters A_1, A_2 and A_3 are connected as shown in figure. When all the bulbs glow, then the current of 3 A is recorded by ammeter A.



(i) What happens to the glow of the other two bulbs when bulb B_1 gets fused?

(ii) What happens to the reading of A_1, A_2, A_3 and A when the bulb B_2 gets fused?

(iii) How much power is dissipated in the circuit when all the three bulbs glow together?

Sol. Resistance of combination of three bulbs in parallel,

$$R_{eq} = \frac{V}{I} = \frac{4.5}{3} = 1.5\,\Omega$$

If R is the resistance of each wire, then

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$$

or $$\frac{1}{R_{eq}} = \frac{3}{R}$$

or $$R = 3R_{eq} = 3 \times 1.5 = 4.5\,\Omega$$

Current in each bulb,

$$I = \frac{V}{R} = \frac{4.5\text{ V}}{4.5\,\Omega} = 1\text{ A}$$

[1]

(i) When bulb B_1 gets fused, then the currents in B_2 and B_3 remain same $I_2 = I_3 = 1$ A, so their glow remains unaffected.

(ii) When bulb B_2 gets fused, then the current in B_2 becomes zero and currents in B_1 and B_3 remain 1 A.

$\therefore$ Total current, $I = I_1 + I_2 + I_3$

$$= 1 + 0 + 1 = 2\text{ A}$$

Current in ammeter A_1, $I_1 = 1$ A

Current in ammeter A_2, $I_2 = 0$

Current in ammeter A_3, $I_3 = 1$ A

Current in ammeter A, $I = 2$ A **[1]**

(iii) When all the three bulbs are connected, then power dissipated, $P = \dfrac{V^2}{R_{eq}} = \dfrac{(4.5)^2}{1.5} = 13.5\text{ W}$

[1]

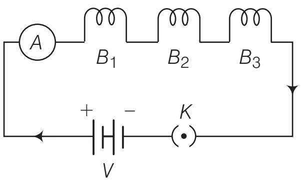
81. Three incandescent bulbs of 100 W each are connected in series in an electric circuit. In another set of three bulbs of the same wattage are connected in parallel to the source.

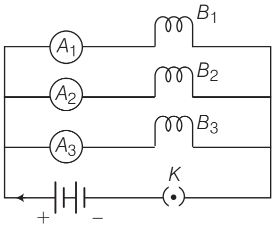
(i) Will the bulb in the two circuits glow with the same brightness? Justify your answer.

(ii) Now, let one bulb in both the circuits get fused. Will the rest of the bulbs continue to glow in each circuit? Give reason.

Sol. (i) Let us assume that the resistance of each bulb be R.

The circuit diagram in two cases may be drawn as given below





Equivalent resistance in series combination,

$$R_S = R + R + R = 3R$$

voltage $= V$

Let current through each bulb in series combination be I_1. **[1]**

By Ohm's law, $V = I_1 \times 3R$

$$\Rightarrow \qquad I_1 = \frac{V}{3R}$$

$\therefore$ Power consumption of each bulb in series combination,

$$P_1 = I_1^2(3R) = \left(\frac{V}{3R}\right)^2 \times 3R = \frac{V^2}{9R^2} \times 3R = \frac{V^2}{3R} \qquad \text{...(i)}$$

For parallel circuit, **[1]**

the resistance of each bulb $= R$

Voltage across each bulb $= V$

($\because$ same voltage in parallel combination)

$\therefore$ Power consumption of each bulb in parallel combination is given by

$$P_2 = \frac{V^2}{R} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{P_2}{P_1} = \frac{(V^2/R)}{(V^2/3R)} = \frac{V^2}{R} \times \frac{3R}{V^2} = 3$$

$$\Rightarrow \qquad P_2 = 3P_1$$ **[1]**

Therefore, each bulb in parallel combination glows 3 times brighter to that of each bulb in series combination.

(ii) When one bulb gets fused in both the circuits, then in series combination, circuit gets broken and current stops flowing, whereas in parallel combination, same voltage continues to act on the remaining bulbs and hence other bulbs continues to glow with same brightness. **[1]**

CHAPTER EXERCISE

2 Marks Questions

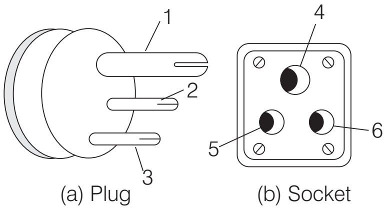
1. Mention two special features of the material used as arms element of an electric iron.
2. It is possible to replace resistors joined in series by an equivalent single resistor of resistance. How?
3. Derive the relation between kilowatt hour and joule.
4. What kind of graph is obtained by plotting values of V and I? Why?
5. You are given three bulbs of 40W, 60W and 100W. Which of them has lower resistance? Also, relate 1kWh and SI unit of energy.
6. Electric fuse is an important component of all domestic circuits. Why? Also, name two common materials used as heating elements.

3 Marks Questions

7. (i) Name two devices based on Joule's heating effect.
   (ii) Name two safety devices used in domestic circuiting.
   (iii) A bulb is rated at 110V, 80W. What does this mean?
8. Make a table with the names of three electrical appliances used in your home in one column, their power, voltage rating and approximate time for which each one is used in one day in the other columns.
9. (i) How does earthing prevent electrical shock?
   (ii) In a 3-pin plug, why is the earth pin made longer and thicker than the other two pons?
10. Draw a labelled diagram of a 3-pin socket. Also, state the purpose of a fuse in an electric or circuit.

4 Marks Questions

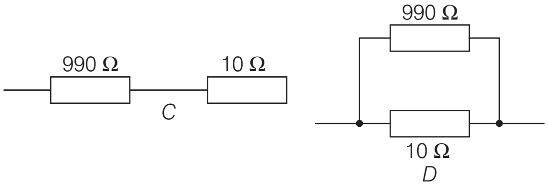
11. A wire is cut into three equal parts and then connected in parallel with the same source.
    How will its
    (i) resistance and resistivity gets affected?
    (ii) How would the total current and the current through the parts change?
12. How will you conclude that the same potential difference (voltage) exists across three resistors connected in a parallel arrangement to a battery?
13. How does the heat produced in a wire or a conductor depend upon the
    (i) current passing through the conductor?
    (ii) resistance of the conductor?
14. (i) Under what circumstances does one get an electric shock from an electric gadget?
    (ii) What is meant by earthing of an electrical appliance? How does earthing offer protection?
15. (i) What is a fuse wire?
    (ii) The diagram (a) and (b) given below are of a plug and a socket with arrow marked as 1, 2, 3 and 4, 5, 6 respectively on them. Identify and wite live (L), neutral (N) and the earth (E) against the correct number.



(a) Plug (b) Socket

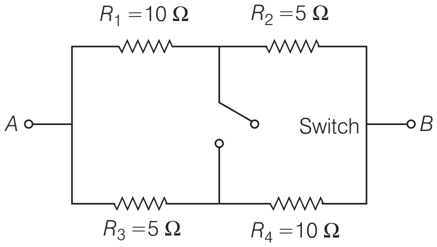
Numerical Based Questions

16. A copper wire of resistivity $1.63 \times 10^{-8}\ \Omega$-m has cross-section area of $16.3 \times 10^{-4} \text{cm}^2$. Calculate the length of the wire required to make a 20 Ω coil.
    Ans. 200 m
17. Which resistor arrangement, C or D has the lower resistance?



18. You have two metallic wires of resistances 3 Ω. How will you connect these wires to get the effective resistance of 2 Ω?

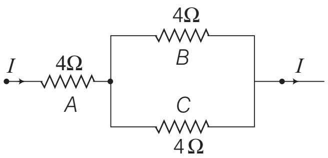
19. Find the equivalent resistance for the following circuit, when



(i) switch is closed (ii) switch is open

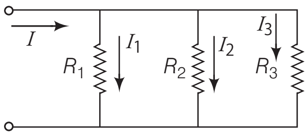
Ans. (i) $\frac{20}{3}\Omega$, (ii) 7.5Ω

20. Three 4 Ω resistors, *A*, *B* and *C* are connected as shown in figure. Each of them dissipates energy and can with stand a maximum power of 36 W without melting. Find the maximum current that can flow through the three resistors.



Ans. 3A, 1.5A, 1.5A

21. What is current resistance in each resistor for a parallel combination of 3.0 Ω, 3.5 Ω and 4.0 Ω resistors. The battery connected is of 8 V. Also, find the effective resistance and effective current.



Ans. $I_1 = 2.7\,\text{A}$, $I_2 = 2.3\,\text{A}$, $I_3 = 2.0\,\text{A}$

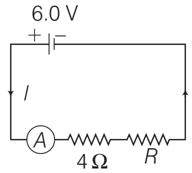
22. A geyser has a label 2kW, 240V. What is the cost of using it for 30 min, if the cost of electricity is 3 per commercial unit? ***Ans.*** 3

23. A family uses a light bulb of 100W, a fan of 100W, and heater of 1000W, each for 8h a day. If the cost of electricity is `2 per unit, what is the expenditure for the family per day on electricity? ***Ans.*** 19.20

24. In a house, an electric bulb of 100W is used for 10 h and an electric heater of 1000W is used for 2 h. Calculate the cost of using bulb and the heater for 30 days. Take the cost of one unit of electrical energy as 2. ***Ans.*** 180

25. In an electrical circuit, two resistors of 4 Ω and 8 Ω are connected in series to a 12V battery. Find the heat dissipated by the 4 Ω resistor in 5s. ***Ans.*** 5J

26. The figure shows a circuit, when the circuit is switched on the ammeter reads 0.5A.



(i) Calculate the value of the unknown resistor *R*.

(ii) Calculate the charge passing through the 4 Ω resistor in 60s.

(iii) Calculate the power dissipated in the 4 Ω resistor.

Ans. (i) 8 Ω, (ii) 30 C, (iii) 1W