ELECTRICITY

TOPIC 1

ELECTRIC CURRENT AND CIRCUIT

Electricity is a form of energy and can be readily transmitted over large distances with relatively small loss in energy. In this chapter we will discuss about electric circuits, potential difference and flow of current in an electric circuit. We will also discuss Ohm's law and the heating effect of electric current and its applications.

A continuous and closed path of an electric current is called an electric circuit.

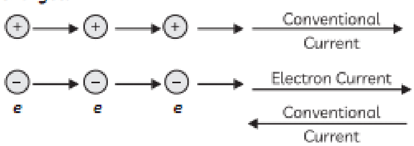
Electric Current

Electric current is expressed by the amount of charge flowing through a particular of area in unit time. It is defined as the rate of flow electric charges i.e., the charge flowing per unit time.

Let Q denote the amount of charge flowing across a given point in the conductor in time t, then the current flowing is given by, $I = Q/t$.

Conventional Direction of Current flow

It is the direction in which the positive charges flow which is opposite to the direction of flow of negative charges.



Ampere: One Ampere is defined as the current flowing when 1 Coulomb of charge flows across a point in 1 second.

$$1 \text{ Ampere} = \frac{1 \text{ Coulomb}}{1 \text{ second}}$$

Small quantities of current are expressed in milliampere (1 mA = 10^{-3} A) or in microampere (1 μA = 10^{-6} A).

Coulomb: It is the SI unit of charge and is the charge carried by 6×10^{18} electrons, since the charge of 1 electron = 1.6×10^{-19} C.

Ammeter: It is an instrument to measure electric current in a circuit and is always connected in series in a circuit through which the current is to be measured. The electric current flows in the circuit shown from the positive terminal to the negative terminal of the cell through the bulb and the ammeter.

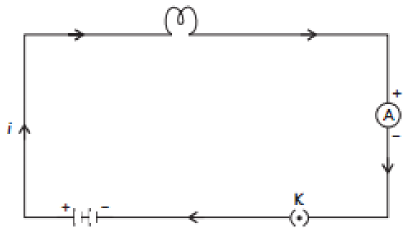


Figure above shows the schematic diagram of a typical electric circuit comprising a cell, an electric bulb, an ammeter and a plug key. The electric current flows in the circuit from the positive terminal of the cell to the negative terminal of the cell through the bulb and ammeter.

Flow of charge inside a conductor: When a wire is connected to a battery, the electrons which were drifting randomly in all directions, now become aligned in a particular direction and current begins to flow across the wire. When a steady current flows through a conductor, the electrons in it move with a certain average drift velocity.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

1. How is static electricity different from current electricity?

Ans. Electricity is basically categorised into static and current electricity. The difference between the two is as follows:

S. No.	Static electricity	Current electricity
(1)	Static electricity is caused by the building up of electrical charges on surfaces of objects.	Current electricity is caused by the flow of the electrons along a conductor.
(2)	Static current happens sporadically and is usually uncontrolled.	Current electricity is normally controlled and is used in a wide range of applications.
(3)	Static electricity is generated by friction or sudden contact-for instance, rubbing two materials against each other.	Current electricity is generated by batteries and power plants.

TOPIC 2

ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

Electric Potential

Electric potential at a point is defined as the work done in moving a unit positive charge from infinity to that point.

Potential Difference

Potential Difference between two points on a conductor carrying current is defined as the work defined in moving a unit positive charge from one point to the other.

$$\text{Potential Difference} = \frac{\text{Work Done (W)}}{\text{Charge (Q)}}$$

Volt: One volt is the potential difference between two points in a current carrying conductor when 1 Joule of work is done in moving a charge of 1 Coulomb from one point to another.

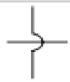
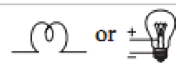
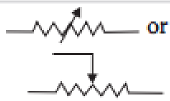
$$1 \text{ Volt} = \frac{1 \text{ Joule}}{1 \text{ Coulomb}}$$

Voltmeter: It is an instrument to measure the potential difference. The voltmeter is always connected in parallel across the points between which the potential difference is to be measured.

TOPIC 3

CIRCUIT DIAGRAM

A circuit diagram is a schematics diagram of an electric circuit in which different components of the circuit are represented by conventionally used symbols.

S. No.	Components	Symbols
(1)	An electric cell	
(2)	A battery or a combination of cells	
(3)	Plug key or switch (open)	
(4)	Plug key or switch (closed)	
(5)	A wire joint	
(6)	Wires crossing withot joining	
(7)	Electric bulb	
(8)	A resistor of resistance R	
(9)	Variable resistance or rheostat	
(10)	Ammeter	
(11)	Voltmeter	

TOPIC 4

OHM'S LAW

Let us find out if there is any relationship between the potential difference across a conductor And the current through it.

Resistance

It is a property of a wire which retards the flow of the current through the wire. It is due to the opposition encountered by the electrons as the electrons are restrained by the attractive force of the atoms and also due to the collisions with other electrons and with the atoms.

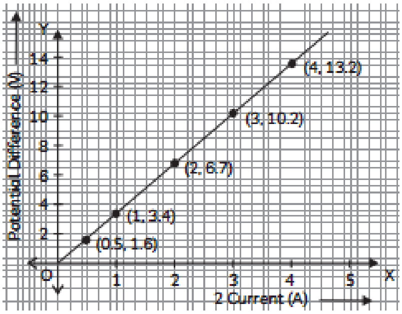
1 Ohm

It is the unit of resistance. The resistance of a conductor is said to be 1 Ohm when a potential difference of 1 Volt across the ends of the conductor produces a current of 1 ampere.

Rheostat

It is a device which is used in an electric circuit to change the resistance in the circuit.

Ans. The graph between V and I is drawn below:



The resistance of the resistor can be found from the graph by finding the slope of the VI graph.

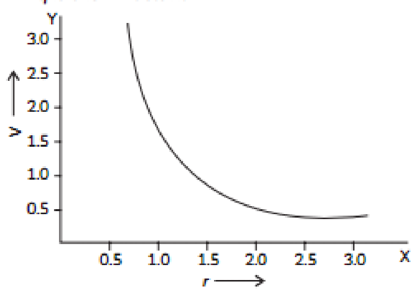
R = slope of VI graph

$$= \frac{V_2 - V_1}{I_2 - I_1} = \frac{13.2 - 1.6}{4 - 0.5} = \frac{11.6}{3.5} = 3.31 \text{ Ohm}$$

Case Based Questions

[4 marks]

6. *Electric force is the force that pushes apart two like charges, or that pulls together two unlike charges. The electric potential (also called the electric field potential, potential drop, the electrostatic potential) is the amount of work energy needed to move a unit of electric charge (a Coulomb) from a reference point to the specific point in an electric field. The graph of variation of electric potential arising from a point charge Q with distance r from the charge q is shown below:*



Note: Both the charges Q and q are positive charges.

(A) What conclusion can be made from the above graph between electric potential (V) and distance (r) from the given charge?

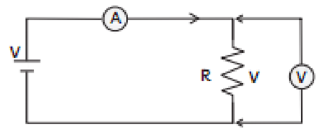
(B) Calculate the work done in moving a charge of 5 C across two points having a potential difference 12 V.

(C) Name instrument which is used to measure potential difference between two points. What type of connection is used to connect it? Draw circuit diragram.

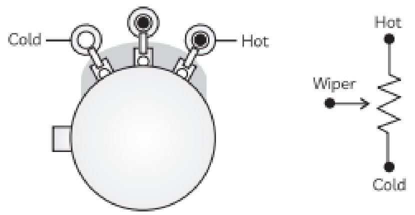
Ans. (A) As can be seen from the graph, the electric potential is very less when r > 2.0 m. However, as the point charge Q is brought closer to the given charge q, the electric potential increases. Moreover, as both charges are positive charges, more and more energy is required to bring the two charges close to each other due to the strong force of repulsion between the two charges.

(B) The relation between potential difference between two points, work done and charge is $V = \frac{W}{Q}$. Therefore, Work Done = VQ = 12 X 5 J = 60 J

(C) The instrument used to measure potential difference between two points is voltmeter and is always connected in parallel across the points between which the potential difference is to be measured.



7. *Potentiometers, or "pots" for short, are used for volume and tone control in electric guitars. They allow us to alter the electrical resistance in a circuit at the turn of a knob. The guitar pickups provide the voltage and current source, while the potentiometers provide the resistance. From Ohm's Law we can see how increasing resistance decreases the flow of current through a circuit, while decreasing the resistance increases the current flow. If two circuit paths are provided from a common voltage source, more current will flow through the path of least resistance.*



We can visualize the operation of a potentiometer from the drawing shown in next column.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

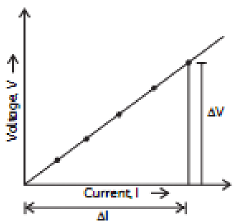
[2 marks]

2. While studying the dependence of potential difference (V) across a resistor on the current (I) passing through it, in order to determine the resistance of the resistor, a student took 5 readings for different values of current and plotted a graph between V and I. He got a straight line graph passing through the origin. What does the straight line signify? Write the method of determining resistance of the resister using this graph.

Ans. The graph obtained after plotting the values of V and I is a straight line passing through the origin which shows that the potential difference (V) and the current flowing (I) vary linearly with each other thereby verifying Ohm's Law.

Further, I = 0 when V = 0, as the graph passes through the origin.

Resistance of the resistor can be determined by finding the slope of the VI graph as we know from Ohm's Law that $V = IR$, where R is the resistance of the resistor. $\therefore R = \frac{V}{I}$



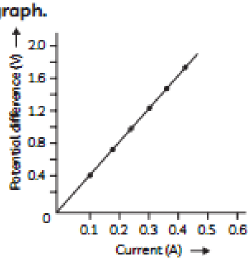
R = Slope of VI graph

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

Short Answer Type-II Questions (SA-II)

[3 marks]

3. A V-I graph for a nichrome wire is given below. What do you infer from this graph? Draw a labelled circuit diagram to obtain such a graph.



Ans. We infer from the graph that $\frac{V}{I}$ is a constant ratio. *i.e.*, V α I which is ohm's law. This constant ratio $\left(\frac{V}{I}\right)$ is called the resistance (R) of the conductor.

In 1827, a German physicist G. Siman Ohm found out the relationship between the current (I) flowing in a metallic wire and the potential difference across its terminals.

The potential difference (V) across the ends of a given metallic wire is in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same.

$$V \propto I$$

$$\frac{V}{I} = \text{Constant}$$

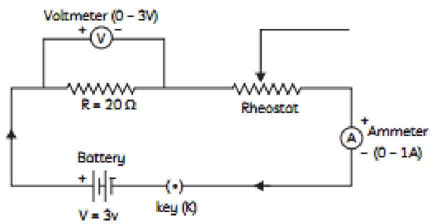
$$V = IR$$

4. You have following material:

An ammeter (0-1*A*), a voltmeter (0-3*V*), a resistor of 20 Ω, a key, a rheostat, a battery of 3 *V* and seven connecting wires.

Using this material draw a labelled circuit diagram to study the dependence of potential difference (*V*) across a resistor on the current (*I*) passing through it.

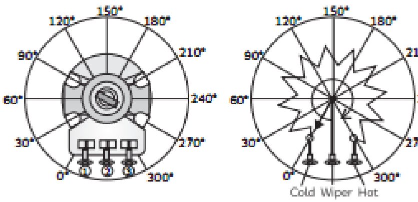
Ans. Labelled circuit diagram to study the dependence of potential difference (*V*) across a resistor on the current (*I*) is drawn below:



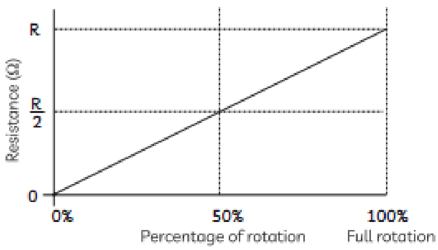
5. The values of current I flowing in a given resistor for the corresponding values of potential difference V across the resistor are given below:

I (amperes)	0.5	1.0	2.0	3.0	4.0
V (volts)	1.6	3.4	6.7	10.2	13.2

Plot a graph between V and I and calculate the resistance of that resistor.



Imagine a resistive track connected from terminal 1 to 3 of the pot. Terminal 2 is connected to a wiper that sweeps along the resistive track when the potentiometer shaft is rotated from 0° to 300°. This changes the resistance from terminals 1 to 2 and 2 to 3 simultaneously, while the resistance from terminal 1 to 3 remains the same. As the resistance from terminal 1 to 2 increases, the resistance from terminal 2 to 3 decreases, and vice-versa.



(A) Which property of the circuit is altered when we turn the knob in the potentiometer or pots used in electric guitars?

(B) At what angles is potentiometer shaft turned to obtain minimum and maximum resistances respectively?

(C) (i) When the shaft undergoes 50% rotation, the effective resistance between its terminal?

(ii) Which device is used to change resistance in a circuit?

Ans. (A) When the knob in the potentiometer used in electric guitar is turned, it changes the resistance in the circuit, thereby changing the current flowing in the circuit.

(B) When the potentiometer shaft is turned at 0°, it refers to the "cold" terminal and at this position the resistance is minimum. When the potentiometer shaft is turned at 300°, it refers to the "hot" terminal and at this position the resistance is maximum.

(C) (i) As can be seen from the graph, the value of resistance becomes R/2 when the shaft undergoes 50% rotation, that is, when it is rotated through 150°.

(ii) In an electric circuit, a device called rheostat is used tochange the resistance in the circuit.

TOPIC 5

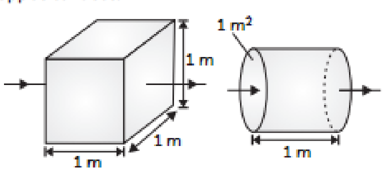
FACTORS ON WHICH RESISTANCE OF A CONDUCTOR DEPENDS

Consider a wire of length L, area of cross section A and having a resistance R. Then the resistance of the wire directly proportional to the length of the wire and inversely proportional to the area of cross section of the wire. *i.e.*,

$$R \propto L \text{ and } R \propto 1/A, \text{ or}$$
$$R = \rho L/A$$

Resistivity

It is an important property of materials and is defined as the resistance offered by a cube of a material of side 1 m when current flows perpendicular to the opposite faces.



(a) (b)

It is measured in ohm-m. It is a characteristic property of the material and varies with temperature. Metals and alloys have very low resistivity but insulators have very high resistivity.

Applications of Alloys

Alloys are used in electric heating devices such as electric irons, geysers & toasters for the following reasons:

(1) The resistivity of alloys is generally higher than that of pure metals which form the alloy.

(2) They do not oxidize readily at high temperature since resistivity changes less rapidly with changes in temperature.

TOPIC 6

RESISTANCE OF A SYSTEM OF RESISTORS

There are two methods of joining the resistors together. Figure below shows an electric circuit in which three resistors having resistances R_1, R_2 and R_3, respectively, are joined end to end. Here the resistors are said to be connected in series.

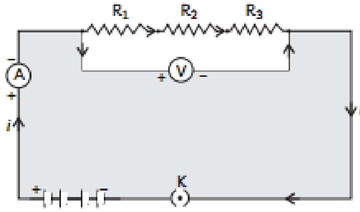
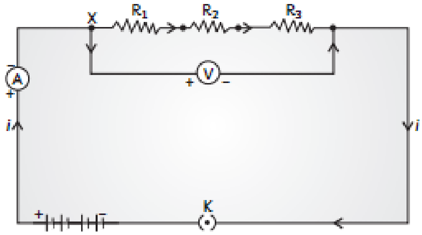


Figure below shows a combination of resistors in which three resistors are connected together between points X and Y. Here, the resistors are said to be connected in parallel.



Resistors in Series

If the resistors are connected in such a way that there is only one path through current flows, they are said to be connected in series. The potential difference V is equal to the sum of the potential differences V_1, V_2 and V_3. That is the total potential difference across a combination of resistors in series is equal to the sum of the potential difference across the individual resistors.

That is,

$V = V_1 + V_2 + V_3$

The effective resistance in series combination is given by $R = R_1 + R_2 + R_3$

Resistors in Parallel

If the resistors are connected in such a way that the potential difference across each resistor is same, they are said to be connected in parallel.

Comparison of Resistors in Series and Parallel

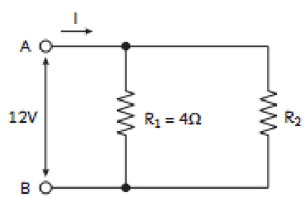
Resistors in Series	Resistors in Parallel
The resistance of the combination of resistors is equal to the sum of the individual resistors.	The sum of the reciprocals of the individual resistances is equal to the reciprocal of equivalent resistance, R.
The total voltage across the combination is equal to the sum of the voltage drop across the individual resistors.	The voltage across each resistor is the same and is also equal to the voltage across the whole group.
The current is same in every part of the circuit	The currents in various resistors are inversely proportional to the resistances. The total current is the sum of the currents flowing in different branches.
$R = R_1 + R_2 + R_3$, where R_1, R_2 and R_3 are the resistances in series and R is the equivalent resistance.	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, where R_1, R_2 & R_3 are the resistances in series and R is the equivalent resistance.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

8. A student has two resistors-2 Ω and 3 Ω. She has to put one of them in place of R_2 as shown in the circuit. The current that she needs in the entire circuit is exactly 9A. Show by calculation which of the two resistors she should choose.



Ans. The overall current needed = 9A. The voltage is 12V

Hence by Ohm's Law V = IR,

The resistance for the entire circuit = $\frac{12}{9}$

$= \frac{4}{3}\,\Omega = R$

R_1 and R_2 are in parallel.

Hence, $R = \frac{(R_1R_2)}{(R_1+R_2)} = \frac{4R_2}{(4+R_2)} = \frac{4}{3}$

$R_2 = 2\Omega$

Explanation: Given $R_1 = 4\Omega$, R_2 = ?

$I = 9A$

$V = 12\ V$

According Ohm's law

$R = VI$

$R = \frac{12}{9} = \frac{4}{3}$

R_1 and R_2 are connected in parallel

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

$$\frac{3}{4} = \frac{1}{4}+\frac{1}{R_2}$$

or $$\frac{1}{R_2} = \frac{3}{4}-\frac{1}{4} = \frac{2}{4}$$

or $R_2 = 2\Omega$

Out of two resistors 2Ω and 3Ω, the student should choose 2Ω resistor.

Short Answer Type-II Questions (SA-II)

[**3** marks]

9. Two resistors with resistance 5 Ohm and 10 Ohm respectively are to be connected to a battery of 6V so as to obtain:

(A) Minimum current flowing

(B) Maximum current flowing

(i) How will you connect the resistors in each case?

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

Ans. (A) If we want minimum current, we will connect the resistors in series.

If we want maximum current we will connect them in parallel.

(B) R_1 = 5 ohms; R_2 = 10 ohms

(i) When connected in series

$R = 10 + 5 = 15$ ohms

$V = 6V$

Therefore, $I = \frac{V}{R} = \frac{6}{15} = 0.4\ A$

When the resistors are connected in parallel

$$R = \frac{R_1 \times R_2}{R_1+R_2} = \frac{50}{15}$$

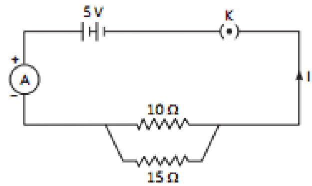
= 3.33 ohms

Therefore, $I = \frac{V}{R} = \frac{6}{3.33}$

$= 1.801\ A$

10. Study the following circuit and answer the questions that follows:

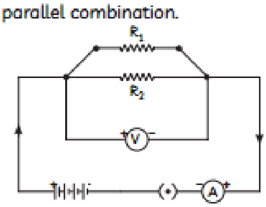
(A) State the type of combination of two resistors in the circuit.



(B) How much current is flowing through (i) 10 ohms and (ii) 15 ohms resistor?

(C) What is the ammeter reading?

Ans. (A) Resistors in the circuit are connected in parallel combination.



(B) (i) Let I_1 be the current flowing through R_1 = 10 ohm

Now $I_1R_1 = V$

$$I_1 = \frac{V}{R_1} = \frac{5}{10} = 0.5\ A$$

(ii) Let I_2 be the current flowing through R_2 = 15 ohm

Now $I_2R_2 = V$

$$I_2 = \frac{V}{R_2} = \frac{5}{15} = 0.33\ A$$

(C) This can also be done like this source resistors are connected in parallel

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

$$= \frac{1}{10}+\frac{1}{15} = \frac{3+2}{30} = \frac{5}{30} \text{ or } \frac{1}{6}\,\Omega$$

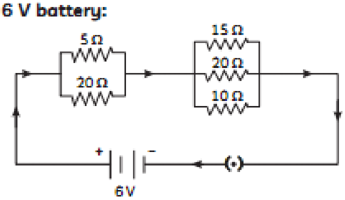
$R = 6\ \Omega$

As per ohm's law $V = IR$

$$I = \frac{V}{R} = \frac{5}{6} = 0.83 \text{ A}$$

11. (A) What is meant by the series combination and parallel combination of resistances?

(B) In the circuit diagram given below five resistances of 5 Ω, 20 Ω, 15 Ω, 20 Ω and 10 Ω, are connected as given in figure to a 6 V battery:



Calculate total resistance in the circuit.

Ans. (A) **Resistors connected in series:** In a series combination of resistors the current is the same in every part of the circuit or the same current flows through each resistor, *i.e.*, there is only one path for the flow of current. When several resistors are joined in series, the resultant resistance of the combination R_S equals the sum of their individual resistances, R_1, R_2, R_3.

$$R_S = R_1 + R_2 + R_3$$

Parallel Combination of resistors: In a parallel circuit each resistor is placed in its own separate branch. A parallel circuit provides multiple paths for the current to flow.

The reciprocal of the equivalent resistance of a group of resistors joined in parallel is equal to the sum of the reciprocals of the individual resistors.

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

(B) To find total resistance in the circuit.

Let R_A be the value of total resistance in first combination *i.e.* 5Ω and 20Ω.

Then $$\frac{1}{R_A} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_A} = \frac{1}{5} + \frac{1}{20} = \frac{4+1}{20} = \frac{5}{20}$$

or $R_A = 4\ \Omega$

Let R_B be the value of resistance in this combination. Then,

$$\frac{1}{R_B} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

$$\frac{1}{R_B} = \frac{1}{15} + \frac{1}{20} + \frac{1}{10}$$

$$= \frac{4+3+6}{60}$$

$$= \frac{13}{60}$$

or $R_B = \frac{60}{13}\ \Omega$

Total resistance across the circuit will be:

$$R_A + R_B = 4\ \Omega + \frac{60}{13}\ \Omega$$

$$= 8.6\ \Omega$$

TOPIC 7

HEATING EFFECT OF ELECTRIC CURRENT

Electric Energy

Work must be done continuously to maintain current in a conductor as the conductors offer resistance to the flow of current. The amount of work done W in carrying a charge Q through a wire of resistance R in time t is given by $W = QV$. Since $Q = I \times t$, therefore, $W = V \times I \times t$, where V is the potential difference across the wire. Since by Ohm's law, $V = IR$, therefore, $W = I^2Rt$.

The electric energy dissipated or consumed is directly proportional to the square of the current I, directly proportional to the resistance R and to the time t during which current flows. $H = I^2Rt$.

Joule's Law of Heating

The relation $H = I^2Rt$ implies that heat produced in a resistor is directly proportional to the square of current for a given resistance and directly proportional to the resistance for a given current and directly proportional to the time for which the current flows through the resistor.

Applications of Heating Effects of Current

The electric iron, toaster, oven, kettle, etc. are some of the electrical devices which are based on Joule's heating. The electric heating is also used to produce light. The fuse is another application of Joule's heating.

The Electric Bulb

The filament of the bulb must retain as much of the heat generated as is possible so that it gets hot and emits light. A metal having high melting point such as Tungsten should be used so that it does not melt at very high temperatures. The filament should be thermally isolated. The bulbs are filled with inert gases such as nitrogen and argon so as to prolong the life of filament.

Fuse

It protects circuits and appliances by stopping the flow of any unusually high electric current. The fuse is placed in series with the device. It consists of a piece of wire made of a metal or an alloy of appropriate melting point. If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases which melts the fuse wire and breaks the circuit.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

12. Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then in parallel in a circuit across the same potential difference. Find the ratio of heat produced in series and parallel combination.

Ans. The two conducting wires are of same material, same lengths and diameters. Therefore, their resistances will also be equal.

Let the resistance in each wire be R.

So in series, $R_s = R + R = 2R$

In parallel, $\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$

Or, $R_p = \frac{R}{2}$

We know that heat produced is given by

$$H = \frac{V^2}{R} \times t$$

$$H_s = \frac{V^2}{R_s} \times t$$

$$H_p = \frac{V^2}{R_p} \times t$$

$$\frac{H_s}{H_p} = \left(\frac{V^2}{R_s} \times t\right) \div \left(\frac{V^2}{R_p} \times t\right)$$

$$\frac{H_s}{H_p} = \frac{R_p}{R_s} = \frac{R/2}{2R} = \frac{1}{4}$$

$H_s : H_p = 1 : 4$

Short Answer Type-II Questions (SA-II)

[3 marks]

13. Justify the following statements:

(A) Tungsten is used exclusively for filaments of electric lamps.

(B) Series arrangement is not used for domestic circuits.

(C) Copper and aluminium wires are usually employed for electricity transmission.

Ans. (A) Due to high melting point/high resistance.

(B) In series arrangement, same current will flow through all the appliances which is not required as every appliance needs current of different values. / If one component fails, the circuit is broken and none of the components works.

(C) Good conductors of electricity/ Have low value of resistivity/ Less loss during transmission. (any one)

Case Based Questions

[4 marks]

14. *The electric heaters, toasters, geysers, iron and kettles are common appliances used throughout the world. The heaters have a metal coil which has high resistance that permits a certain amount of current to flow through them to provide the required heat as per the Joule's law of heating. The electric kettle and irons have a lot of resistors in them. The resistors limit the amount of current to flow through them to provide the required amount of heat. The size of resistors used in them is determined by using Ohm's law.*

(A) The resistance of a resistor is reduced to half of its initial value, potential difference remaining unchanged. What change occurs in the heating effects of the resistor?

(B) Another common application of Joule's heating is the fuse used in electric circuits. Write one property of fuse.

(C) (i) Consider an electric iron which consumes 1 kW electric power when operated at 220 V. Find the rating of ideal fuse that should be used in this case and the heat generated in the electric iron in 30 seconds.

(ii) A resistance of 30 ohm is connected to a 6 V battery. The heat energy in joules generated per minute will be:

Ans. (A) When the resistance of a resistor becomes half of its initial value, the current becomes double as per Ohm's law. Therefore, by Joule's law of heating,

$$H=(2I)^2\left(\frac{R}{2}\right)t=4I^2\frac{R}{2}t=2I^2Rt.$$

This shows that the heating effect in the resistor will become two times.

(B) The fuse is placed in series with the device so as to protect the device by stopping any unusually high current.

(C) (i) The rating of ideal fuse can be calculated by first finding the current flowing through the electric iron. We know that the electric power P is given by P = VI, which means that $I=\frac{P}{V}=\frac{1000}{220}=4.54A$. In this case, a 5A fuse must be used.

To calculate the heat generated, we will use the formula H = Pt = 1000 × 30J = 3.0 × 10^4J or 30*kj*.

(ii) The heat generated in a resistor is given by Joule's law of heating, $H=I^2Rt$.

Here, $I=\frac{V}{R}=\frac{6}{30}=0.2A$, R = 30 Ohm and t = 60 s.

Therefore, $H=(0.2)^2\times30\times60=72$ J

TOPIC 8

ELECTRIC POWER

Electric power is defined as the rate at which electrical work is done or the rate at which electrical energy is consumed or dissipated. The power *P* is given by

$$P = W/t = I^2R$$

Watt

Watt is the unit of power and is defined as the power consumed when 1 A of current flows at a potential difference of 1 V. Thus, Electric Power in Watts = Volt ampere.

When electrical energy is consumed at the rate of 1 J per second, power consumed is said to be 1 Watt.

Kilowatt hour

Kilowatt hour is the commercial unit of electric energy and is defined as the energy consumed when 1 KW is used for 1 hour.

1 kWh = 1 kW × 1 hour = 1000 watt × 3600 second = 3.6 × 10^6 joule

Electrical appliances are not connected in series

Different appliances need different values of current for their proper operation. Whereas, in a series circuit, the current is constant throughout the circuit. Also, when one component fails in a series circuit, the entire circuit is broken and none of the components work. On the other hand, a parallel circuit divides the current through the electrical gadgets.

MOST LIKELY Questions

Short Answer Type-I Questions (SA-I)

[2 marks]

15. The electric power consumed by a device may be calculated by either of the two expressions P = I^2R or P = V^2/R. The first expression indicates that it is directly proportional to R whereas the second expression indicates inverse proportionality. How can the seemingly different dependence of P on R in these expressions be explained?

Ans. The expression P = I^2R is used for calculating electric power when only current I and resistance R are known, whereas P = V^2/R is used for calculating power when voltage V and resistance R are known.

16. **The following table given below shows the information about two heaters A and B. Analyse the table and answers the following questions:**

	Power	Voltage
Heater A	100W	220V
Heater B	150W	220V

(A) Which Heater has higher resistance?

(B) If 1KWh is priced at 30 paise, which heater will be costlier if they run for 1 hours each?

Ans. (A) Heater A has higher resistance

Heater A

$$\rho = VI$$

$$\therefore \quad I = \frac{\rho}{V} = \frac{100}{220} = 0.45A$$

$$\therefore \quad R = \frac{V}{I} = \frac{220}{0.45} = 489\Omega$$

Heater B

$$I = \frac{150}{220} = 0.68A$$

$$\therefore \quad R = \frac{220}{0.68} = 323\rho$$

(B) *(b)* Cost by heater A

$$= \frac{10 \times 1 \times 0.3}{1000 \times 10 \times 10} = 0.038 ₹$$

Cost by heater B

$$= \frac{150 \times 1 \times 0.3}{1000 \times 10 \times 10} = 0.045 ₹$$

So heater B will be costly as it consumes more energy.

Short Answer Type-II Questions (SA-II)

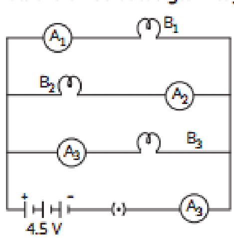
[**3** marks]

17. **B_1, B_2 and B_3 are three identical bulbs connected as shown in the figure. When all the three bulbs glow, a current of 3A is recorded by the ammeter A.**

(A) What happens to the glow of the other two bulbs when bulb B_1 gets fused?

(B) What happens to the reading of A_1, A_2, A_3 and A, when bulb B_2 gets fused?

(C) How much power is dissipated in the circuit when all the three bulbs glow together?



Ans. Let R_{eq} be the net resistance of the combination of three bulbs in parallel, then,

$$R_{eq} = \frac{V}{I} = \frac{4.5}{3} = 1.5\ \Omega$$

All bulbs are identical, so they must have the same resistance.

Let R be the resistance of each bulb and all bulbs are connected in parallel, hence,

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$$

$$\frac{1}{R_{eq}} = \frac{3}{R}$$

$$R = 3 \times R_{eq}$$

$$= 3 \times 1.5 = 4.5\ \Omega$$

Current flowing across each bulb,

$$I = \frac{V}{R} = \frac{4.5}{4.5} = 1\ A$$

Current through each bulb:

(A) If B_1 gets fused, the current in B_2 and B_3 will remain unaffected, as voltage across bulbs B_2 and B_3 remains the same. Hence, glow of the other two bulbs will not be affected.

(B) When bulb B_2 gets fused, the current through B_2 will be zero and the current in B_1 and B_3 will remain 1A.

Now, net current,

$A = A_1 + A_2 + A_3$

$= 1 + 0 + 1 = 2A$

Thus, current in ammeter, A_1 = 1 ampere

Current in ammeter, A_2 = 0

Current in ammeter, A_3 = 1 ampere

Current in ammeter, A = 2 ampere.

(C) Power dissipated when all three bulbs glow together,

$$P = V \times I$$

$$P = 4.5 \times 3 = 13.5\ W$$

Alternate method: Power dissipated,

$$P = \frac{V^2}{R_{eq}} = \frac{(4.5)^2}{1.5} = 13.5\ W$$

$$P = 13.5\ W$$

18. (A) **An electric bulb is rated at 200 V; 100 W. What is its resistance?**

(B) **Calculate the energy consumed by 3 such bulbs if they glow continuously for 10 hours for complete month of November.**

Ans. (A)

V = 220 V

P = 100 W

R = ?

P = VI

V = IR

$$P = \frac{V \times V}{R} \text{ Or } P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{200 \times 200}{100}$$

$$R = 400\ \Omega$$

(B) P = 100 W (given 3 such bulbs) or $\frac{100}{1000}$ =

0.1 kW

No. of bulbs = 3

time t = 10 hours

Number of days in the month of November = 30

$$E = P \times t$$

Total energy consumed by 3 bulbs in 30 days

$$= 3 \times 0.1 \times 10 \times 30 = 90 \text{ kWh}$$

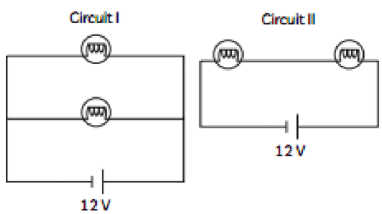
Hence, the energy consumed by 3 such bulbs for the month of November will be 90 kWh.

Case Based Questions

[4 marks]

19. *Components of an electrical circuit or electronic circuit can be connected in series or parallel. Components connected in series are connected along a single conductive path, so the same current flows through all of the components but voltage is dropped across each of the resistances. Components connected in parallel are connected along multiple paths so that the current can split up; the same voltage is applied to each component.*

In the circuit I shown below, the two bulbs have been connected in parallel whereas in circuit II, they are connected in series.



(A) Two bulbs of 60 W and 40 W are connected in parallel. The current through the 60 W bulb is 0.6 A. What will be the current through the 40W bulb?

(B) What will be the total resistance between the points A and B ?

(C) A certain circuit is composed of two parallel resistors. The total resistance is 4 Ohm. One of the resistors is 6 Ohm. What will be the value of the other resistor?

Ans. (A) When devices are connected in parallel, the potential difference across them is equal but the currents are in inverse ratios of their resistances.

Let V be the potential difference, I current across 60 W bulb and I2 across 40 W bulb.

$$P = VI \Rightarrow V = \frac{P}{I}$$

Therefore, $V = \frac{60}{0.6} = 100$ V.

The current I_2 through 40 W bulb is:

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

$$I = \frac{40}{100} \text{ A} = 0.4\text{A}$$

(B) The resistances 1 Ohm and 2 Ohm are in parallel. Their equivalent resistance is

$$\frac{1}{R_p} = \frac{1}{1} + \frac{1}{2} = \frac{3}{2} \Rightarrow R_p = \frac{2}{3}\ \Omega = 0.67\Omega$$

This combination is connected in series with the 4 Ohm and 3 Ohm resistances.

Therefore, equivalent resistance between A and B is (4 + 0.67 + 3) Ohm or 7.67 Ohm.

(C) The equivalent resistance for resistances connected in parallel is given by:

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

$$\Rightarrow \quad \frac{1}{4} = \frac{1}{6} + \frac{1}{R_2}$$

$$\Rightarrow \quad \frac{1}{R_2} = \frac{1}{4} - \frac{1}{6} = \frac{3-2}{12} = \frac{1}{12}$$

$$\Rightarrow \quad R_2 = 12\Omega$$

20. *Electrical energy is the energy derived from electric potential energy or kinetic energy of the charged particles. In general, it is referred to as the energy that has been converted from electric potential energy. In many cases it is necessary to calculate the energy usage by an electric device or a collection of devices, such as in a home. The electrical energy (E) used can be reduced either by reducing the time of use or by reducing the power consumption of that appliance or fixture. This will not only reduce the cost, but it will also result in a reduced impact on the environment. Improvements to lighting are some of the fastest ways to reduce the electrical energy used in a home* *or business. About 20% of a home's use of energy goes to lighting, while the number for commercial establishments is closer to 40%. A few common electrical appliances and their power ratings are given below:*

	Load Types	Power Ratings
(1)	Light bulbs (incande-scent	60W, 80W, 100W
(2)	Electric (steam) iron	2400W
(3)	Standing fan	70W
(4)	Water heater/Kettle	2000W
(5)	Electric blender	350W
(6)	Refrigerator	200W
(7)	Microwave oven	1200W
(8)	Hand dryer	1800W

(A) What can be concluded from the table shown above?

(B) What does it mean when an electrical water heater/kettle which is marked 2000 W, 220 V?

(C) (i) Calculate the resistance of the refrigerator (Power rating 200 W, 220 V).

(ii) If the microwave oven and the electric blender of power ratings 1200 W and 350 W respectively are both used for 5 hours daily, calculate the electrical energy consumed in a day.

Ans. (A) The larger the power rating in the electrical appliance, the more is the energy used every second as the energy consumption of an electrical appliance depends on the power rating and the usage time. The longer the usage time, the more electrical energy is consumed.

(B) The electrical energy consumed by an appliance is given by E = Pt. As mentioned, P = 2000 W. Therefore, electrical energy consumed in 1 second would be 2000 J. It will be 2000 X 3600 J or 7.2 X 10^6 J, if it is used for one hour.

(C) (i) The relation between Power and resistance is given by

$$R = \frac{V^2}{P} = \frac{220 \times 220}{200} = 242 \text{ Ohm}$$

(ii) The electrical energy consumed in a day is given by E=Pt = 1200 X 5 + 350 X 5 Wh = 7750 Wh = 7.75 kWh or 7.75 u