Chapter 12
Electricity

Intext Questions

On Page 200

Question 1: What does an electric circuit mean?

Solution: An electric circuit consists of electric devices, switching devices, etc. These things are connected by conducting wires.

Question 2: Define the unit of current.

Solution: The unit of electric current is ampere (*A*). 1 *A* is defined as the flow of 1 *C* of charge through a wire in 1 *s*.

Question 3: Calculate the number of electrons constituting one coulomb of charge.

Solution:

$1e = 1.6 \times 10^{-19}\ C$

$\therefore$ 1 C of charge is contained in $\dfrac{1}{1.6\times10^{-19}} = 6.25\times10^{18}$ electrons

On Page 202

Question 1: Name a device that helps to maintain a potential difference across a conductor.

Solution: It can be any source of electricity like cell, battery, etc that helps to maintain a potential difference across a conductor.

Question 2: What is meant by saying that the potential difference between two points is 1 V?

Solution: If 1J of work is required to move a charge of amount 1C from one point to another, then it is said that the potential difference between the two points is 1V.

Question 3: How much energy is g ven to each coulomb of charge passing through a 6 V battery?

Solution: The energy given to each coulomb of charge is equal to the amount of work required to move it.

The amount of work is:

$$V = \frac{w}{q}$$
$$w = V \times q$$

Where, q = 1 C

Potential difference = 6 V, w = 6J

On Page 209

Question 1: On what factors does the resistance of a conductor depend?

Solution: The resistance of a conductor depends upon the following factors:

(a) Length of the conductor

(b) Cross-sectional area of the conductor

(c) Material of the conductor

(d) Temperature of the conductor

Question 2: Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?

Solution:

Resistance of a wire, $R = \rho \frac{l}{A}$

where,

ρ = Resistivity of the material of the wire

l = Length of the wire

A = Area of cross-section of the wire

Resistance is inversely proportional to the area of cross-section of the wire.

Thicker the wire, lower is the resistance of the wire and vice-versa. Therefore, current can flow more easily through a thick wire than a thin wire.

Question 3: Let the resistance of an electrical component remains constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?

Solution:

Ohm's law

$V = IR$

where,

Resistance of the electrical component = R

Potential difference = V

Current = I

Now,

$$I' = \frac{V'}{R'} \Rightarrow I' = \frac{V}{2R} \Rightarrow I' = \frac{1}{2}\left(\frac{V}{R}\right)$$

$$\Rightarrow I' = \frac{I}{2}$$

Therefore, the amount of current flowing through the electrical component is reduced by half.

Question 4: Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?

Solution: Alloys are used for making coils of electric toasters and electric irons as melting point of alloys are higher and they do not melt easily.

Question 5: Use the data in Table 12.2 to answer the following:

Table 12.2 Electrical resistivity of some substances at 20°C.

	Material	Resistivity
Conductors	Silver	1.6×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.2×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-6}
	Constantan	49×10^{-6}
Alloys	Manganin	44×10^{-6}
	Nichrome	100×10^{-6}
	Glass	$10^{10}-10^{14}$
Insulators	Hard rubber	$10^{13}-10^{16}$
	Ebonite	$10^{15}-10^{17}$
	Diamond	$10^{12}-10^{13}$
	Paper	10^{12}

(a) Which among iron and mercury is a better conductor?

(b) Which material is the best conductor?

Solution:

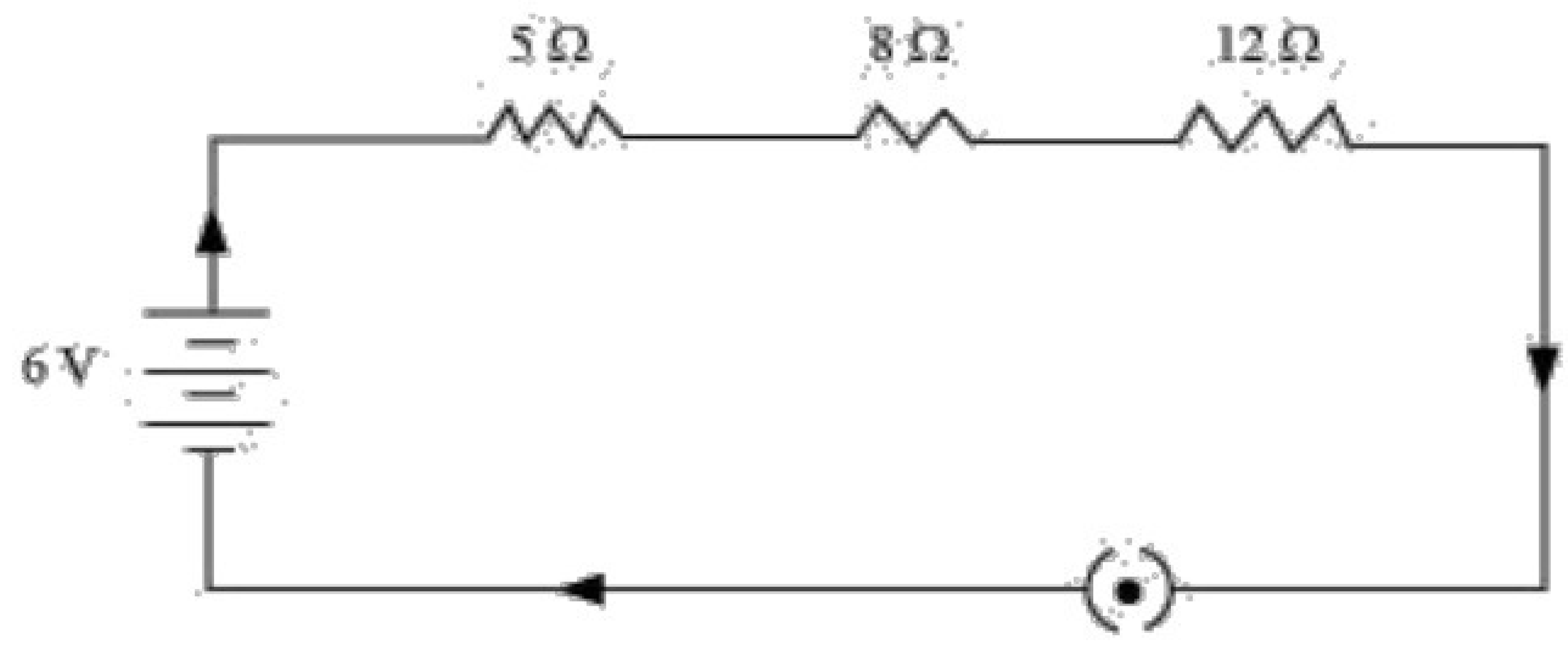
(a) Iron is a better conductor than mercury.

(b) Resistivity of silver is the lowest among the listed materials. Hence, it is the best conductor.

On Page 213

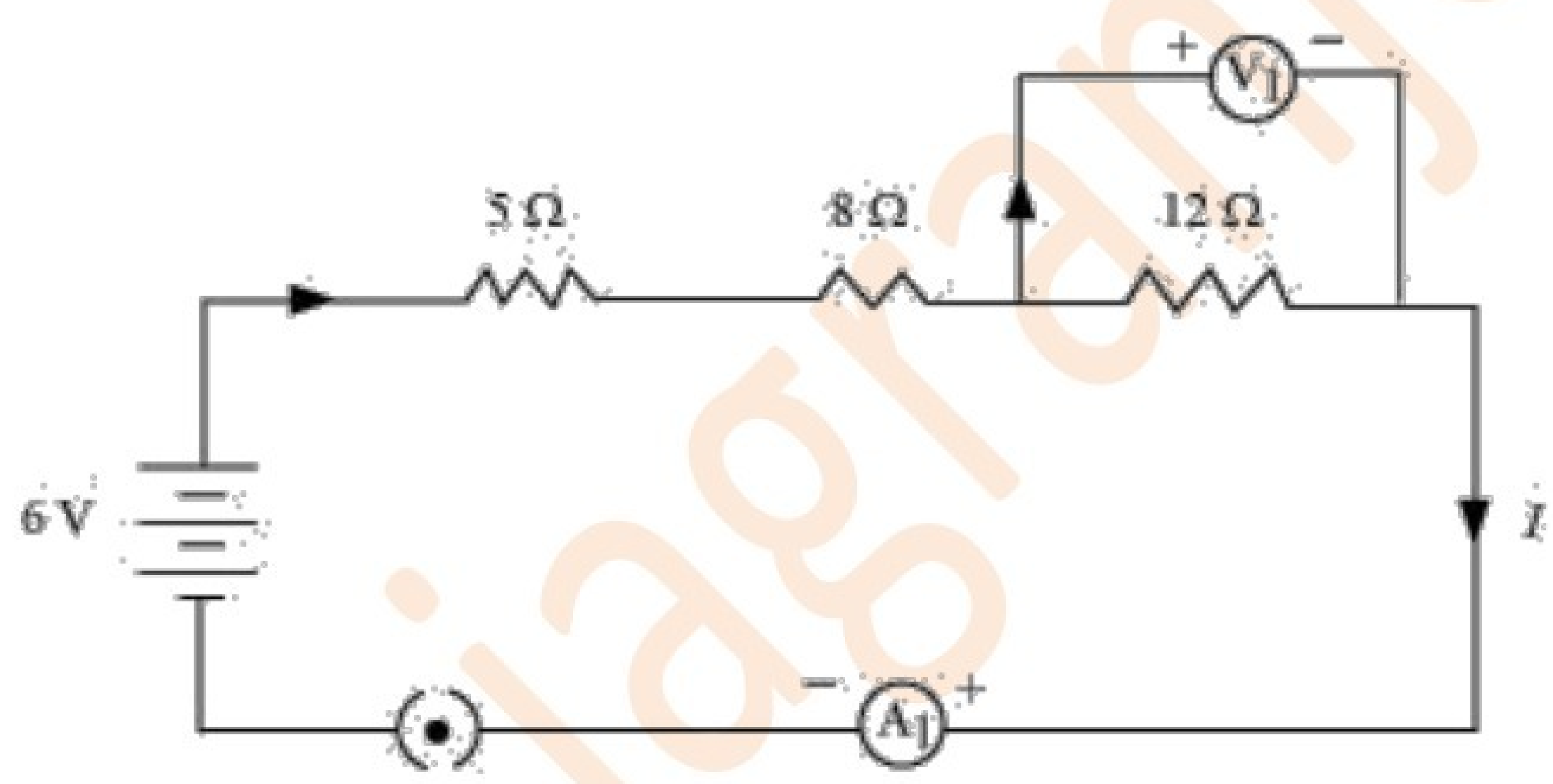
Question 1: Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.

Solution:



Question 2: Redraw the circuit of question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter?

Solution:



The resistances are connected in series.

Ohm's law can be used to obtain the readings of ammeter and voltmeter.

According to Ohm's law,

$V = IR$,

Potential difference, $V = 6$ V

Resistance of the circuit, R *is:*

$$R = 5 + 8 + 12 = 25\Omega$$
$$I = \frac{V}{R}$$
$$I = \frac{6}{25}$$
$$I = 0.24A$$

Potential difference across 12 Ω resistor = V_1

Current flowing through the 12 Ω resistor, I = 0.24 A

Therefore, using Ohm's law, we obtain

$$V_1 = IR = 0.24 \times 12 = 2.88V$$

Hence, the reading of the ammeter will be 0.24 A. The reading of the voltmeter is 2.88 V.

On Page 216

Question 1: Judge the equivalent resistance when the following are connected in parallel − (a) 1 Ω and 10^6Ω, (b) 1 Ω and 10^3Ω and 10^6Ω.

Solution:

(a) When 1 Ω and 10^6 Ω are connected in parallel:

Let R be the equivalent resistance.

$$\frac{1}{R} = 1 + \frac{1}{10^6}$$
$$R = \frac{10^6}{10^6 + 1} \approx \frac{10^6}{10^6} = 1\Omega$$

Therefore, equivalent resistance = 1 Ω

(b) When resistances are connected in parallel:

Let R be the equivalent resistance.

$$\frac{1}{R}=1+\frac{1}{10^3}+\frac{1}{10^6}$$
$$\frac{1}{R}=\frac{1+10^6+10^3}{10^6}$$
$$R=0.999\Omega$$

Therefore, equivalent resistance = 0.999 Ω

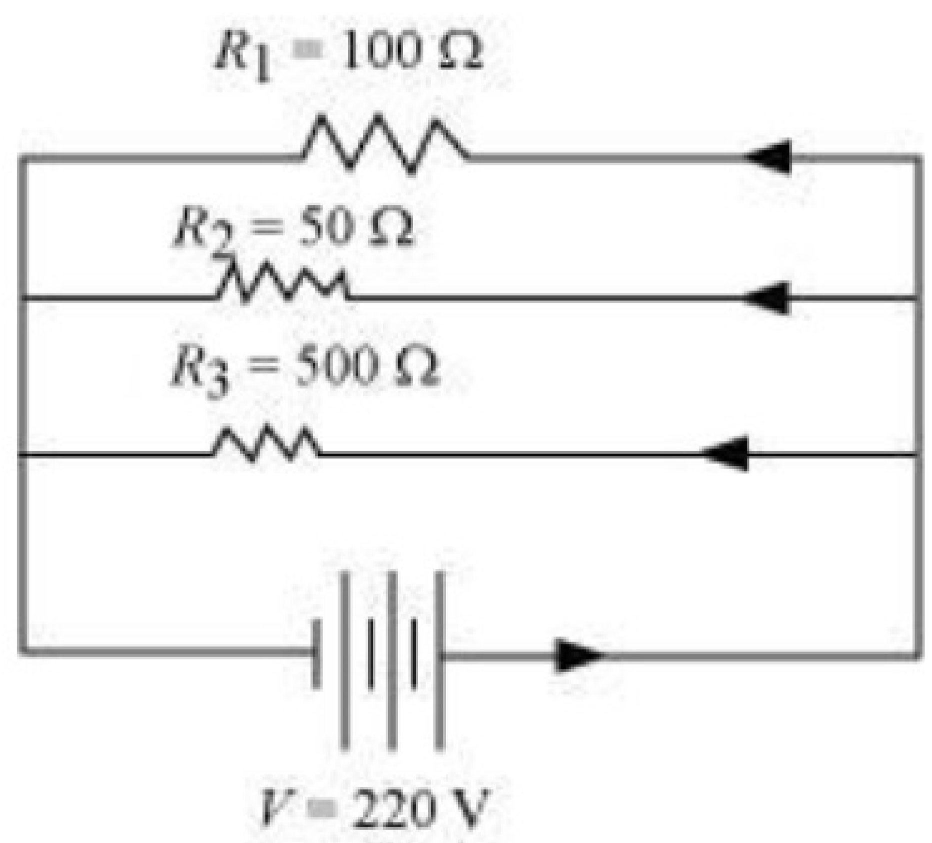
Question 2: An electric lamp of 100 Ω, a toaster of resistance 50 Ω, and a water filter of resistance 500 Ω are connected in parallel to a 220 V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?

Solution:

Resistance of electric lamp, 100Ω

Resistance of toaster, 50Ω

Resistance of water filter, 500Ω



Voltage of the source, $V = 220$ V

These are connected in parallel.

Let R be the equivalent resistance of the circuit.

$$\frac{1}{R}=\frac{1}{100}+\frac{1}{50}+\frac{1}{500}$$
$$\frac{1}{R}=\frac{16}{500}$$
$$R=\frac{500}{16}\Omega$$

According to Ohm's law,

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

where,

Current flowing through the circuit = I

$$I = \frac{220 \times 16}{500} = 7.04A$$

Hence, current drawn by an electric iron connected to the same source of potential 220 *V* = 7.04 *A*

Let R' be the resistance of the electric iron. According to Ohm's law,

$$V = IR'$$

$$R' = \frac{V}{I} = \frac{220}{7.04} = 31.25\Omega$$

Hence, the resistance of the electric iron is 31.25Ω and the current flowing through it is 7.04 *A*.

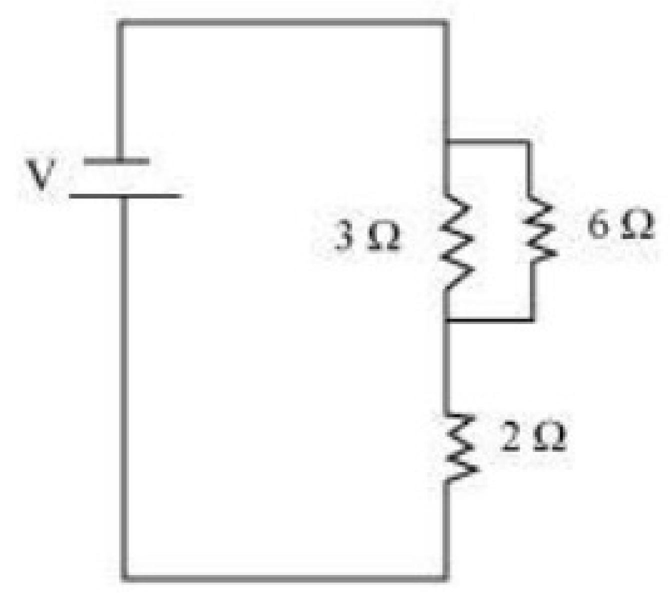
Question 3: What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

Solution: When connected in parallel, voltage doesn't divide. The potential difference across each appliance is equal to the supplied voltage. The total effective resistance of the circuit can be reduced by connecting electrical appliances in parallel.

Question 4: How can three resistors of resistances 2 Ω, 3 Ω and 6 Ω be connected to give a total resistance of (a) 4Ω, (b) 1 Ω?

Solution:

(a) The following circuit diagram shows the connection of the three resistors.



Here, 6 Ω and 3 Ω resistors are connected in parallel.

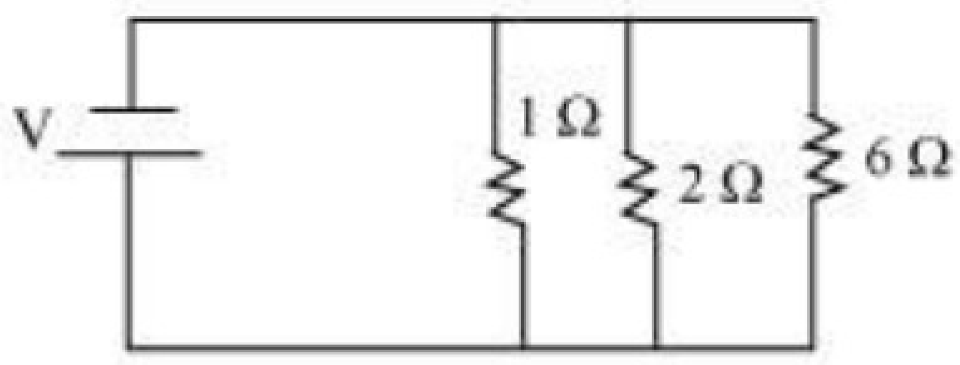
Therefore, their equivalent resistance will be given by

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

This equivalent resistor of resistance 2 Ω is connected to a 2 Ω resistor in series.

Therefore, equivalent resistance of the circuit = 2 Ω + 2 Ω = 4Ω

The following circuit diagram shows the connection of the three resistors.



All the resistors are connected in series. Therefore, their equivalent resistance will be given as

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

Therefore, the total resistance of the circuit is 1Ω.

Question 5: What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

Solution: If these coils are connected in series, then the equivalent resistance will be the highest, given by the sum 4 + 8 + 12 + 24 = 48Ω

If these coils are connected in parallel, then the equivalent resistance will be the lowest, given by

$$\frac{1}{\frac{1}{4}+\frac{1}{8}+\frac{1}{12}+\frac{1}{24}} = 2\Omega$$

Therefore, 2 Ω is the lowest total resistance.

On Page 218

Question 1: Why does the cord of an electric heater not glow while the heating element does?

Solution: The heating element of an electric heater is a resistor. Heat produced by it is directly proportional to its resistance. The resistance of the element of an electric heater is very high. As current flows through the heating element, it becomes too hot and glows red. On the other hand, the resistance of the cord is low. It does not become red when current flows through it.

Question 2: Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential difference of 50 V.

Solution: The amount of heat (H) produced is given by the Joule's law of heating as

$$H = VIt$$

Voltage, $V = 50$ V

Time, $t = 1$ h $= 1 \times 60 \times 60$ s

Amount of current, $I = \frac{96000}{1 \times 60 \times 60} = \frac{80}{3} A$

$$H = 50 \times \frac{80}{3} \times 60 \times 60$$
$$H = 4.8 \times 10^6 J$$

Therefore, the heat generated is $4.8 \times 10^6 J$.

Question 3: An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

Solution: The amount of heat (H) produced is given by the joule's law of heating as

$$H = VIt$$

where,

Current, $I = 5$ A

Time, $t = 30$ s

Voltage, V = Current × Resistance = 5 × 20 = 100 V

$$H = 100 \times 5 \times 30$$
$$H = 1.5 \times 10^4 J$$

Therefore, the amount of heat developed in the electric iron is $1.5 \times 10^4 J$.

On Page 220

Question 1: What determines the rate at which energy is delivered by a current?

Solution: The rate of consumption of electric energy in an electric appliance is called electric power. Hence, the rate at which energy is delivered by a current is the power of the appliance.

Question 2: An electric motor takes 5*A* from a 220*V* line. Determine the power of the motor and the energy consumed in 2*h*.

Solution:

Power (*P*) is:

$$P = VI$$

where,

Voltage, $V = 220$ V

Current, $I = 5$ A

$$P = 220 \times 5$$
$$P = 1100W$$

Energy consumed by the motor = Pt

where,

Time, $t = 2\ h = 2 \times 60 \times 60 = 7200$ s

$\therefore\ P = 1100 \times 7200 = 7.92 \times 10^6$ J

Therefore, power of the motor = 1100 W

Energy consumed by the motor = 7.92×10^6 J

On Page 221

Question 1: A piece of wire of resistance *R* is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is *R′*, then the ratio *R*/*R′* is

(a) $\frac{1}{25}$

(b) $\frac{1}{5}$

(c) 5

(d) 25

Solution: (d) Resistance of a piece of wire is proportional to its length. A piece of wire has a resistance *R*. The wire is cut into five equal parts.

Therefore, resistance of each part = $\frac{R}{5}$

All the five parts are connected in parallel.

Hence, equivalent resistance (R') is:

$$\frac{1}{R'} = \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R}$$
$$\frac{1}{R'} = \frac{25}{R}$$
$$\frac{R}{R'} = 25$$

Therefore, the ratio is 25.

Question 2: Which of the following terms does not represent electrical power in a circuit?

(a) I^2R

(b) IR^2

(c) VI

(d) $\frac{V^2}{R}$

Solution: Electrical power is given by:

$P = VI$ … (i)

According to Ohm's law, $V = IR$ … (ii)

V = Potential difference

I = Current

R = Resistance

$$P = VI$$

Now, from equation (i)

$$P = (IR) \times I$$

$$P = I^2 R$$

From equation (ii)

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

$$P = V \times \frac{V}{R}$$

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

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

Question 3: An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be:

(a) 100 W

(b) 75 W

(c) 50 W

(d) 25 W

Solution: (d)Energy consumed by an appliance is given by the expression,

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

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

where,

Power rating, P = 100 W

Voltage, V = 220 V

Resistance, $R = \frac{220^2}{100} = 484\Omega$

The resistance of the bulb remains constant if the supply voltage is reduced to 110 V.

If the bulb is operated on 110 V, then the energy consumed by it is given by the expression for power as

$$P' = \frac{(V')^2}{R} = \frac{110^2}{484} = 25W$$

Therefore, the power consumed will be 25 W.

Question 4: Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combinations would be:

(a) 1:2

(b) 2:1

(c) 1:4

(d) 4:1

Solution: (c) The Joule heating is given by, $H = i^2Rt$

Let, R = the resistance of the two wires.

The equivalent resistance of the series connection is $R_S = R + R = 2R$

If V is the applied potential difference, then it is the voltage across the equivalent resistance.

$$V = i_s \times 2R$$

$$i_s = \frac{V}{2R}$$

The heat dissipated in time *t* is,

$$H_s = i_s^2 \times 2R \times t$$

$$H_s = \left(\frac{V}{2R}\right)^2 \times 2R \times t$$

$$H_s = \frac{V^2 t}{2R}$$

The equivalent resistance of the parallel connection is, $R_P = \dfrac{1}{\frac{1}{R} + \frac{1}{R}} = \dfrac{R}{2}$

V is the applied potential difference across this R_P.

$$V = i_p \times \frac{R}{2}$$

$$i_p = \frac{2V}{R}$$

The heat dissipated in time *t* is,

$$H_p = i_p^2 \times \frac{R}{2} \times t$$

$$H_p = \left(\frac{2V}{R}\right)^2 \times \frac{R}{2} \times t$$

$$H_p = \frac{2V^2 t}{R}$$

So, the ratio of heat produced is,

$$\frac{H_s}{H_p} = \frac{1}{4}$$

Question 5: How is a voltmeter connected in the circuit to measure the potential difference between two points?

Solution: To measure the potential difference between two points, a voltmeter should be connected in parallel to the points.

Question 6: A copper wire has diameter 0.5 mm and resistivity of $1.6 \times 10^{-8}\ \Omega$ m. What will be the length of this wire to make its resistance 10 Ω? How much does the resistance change if the diameter is doubled?

Solution: Resistance (R) of a copper wire of length l and cross-section A is:

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

where,

$$\rho = 1.6 \times 10^{-8}\ \Omega m$$
$$A = \pi \left(\frac{d}{2}\right)^2$$
$$A = \pi (0.00025)^2$$

Resistance, $R = 10\ \Omega$

Hence, length of the wire,

$$l = \frac{RA}{\rho}$$
$$l = \frac{10 \times 3.14 \times 25}{4 \times 1.6}$$
$$l = 122.72 m$$

If the diameter of the wire is doubled, new diameter, $d = 2 \times 0.5 = 1 mm = 0.001 m$

Therefore, resistance $R' = \rho \frac{l}{A}$

$$R' = \rho \frac{l}{A}$$
$$R' = \frac{1.6 \times 10^{-8} \times 122.72 \times 4}{3.14 \times 10^{-6}}$$
$$R' = 2.5\Omega$$

Therefore, the length of the wire is 122.7 m and the new resistance is 2.5Ω

Question 7: 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

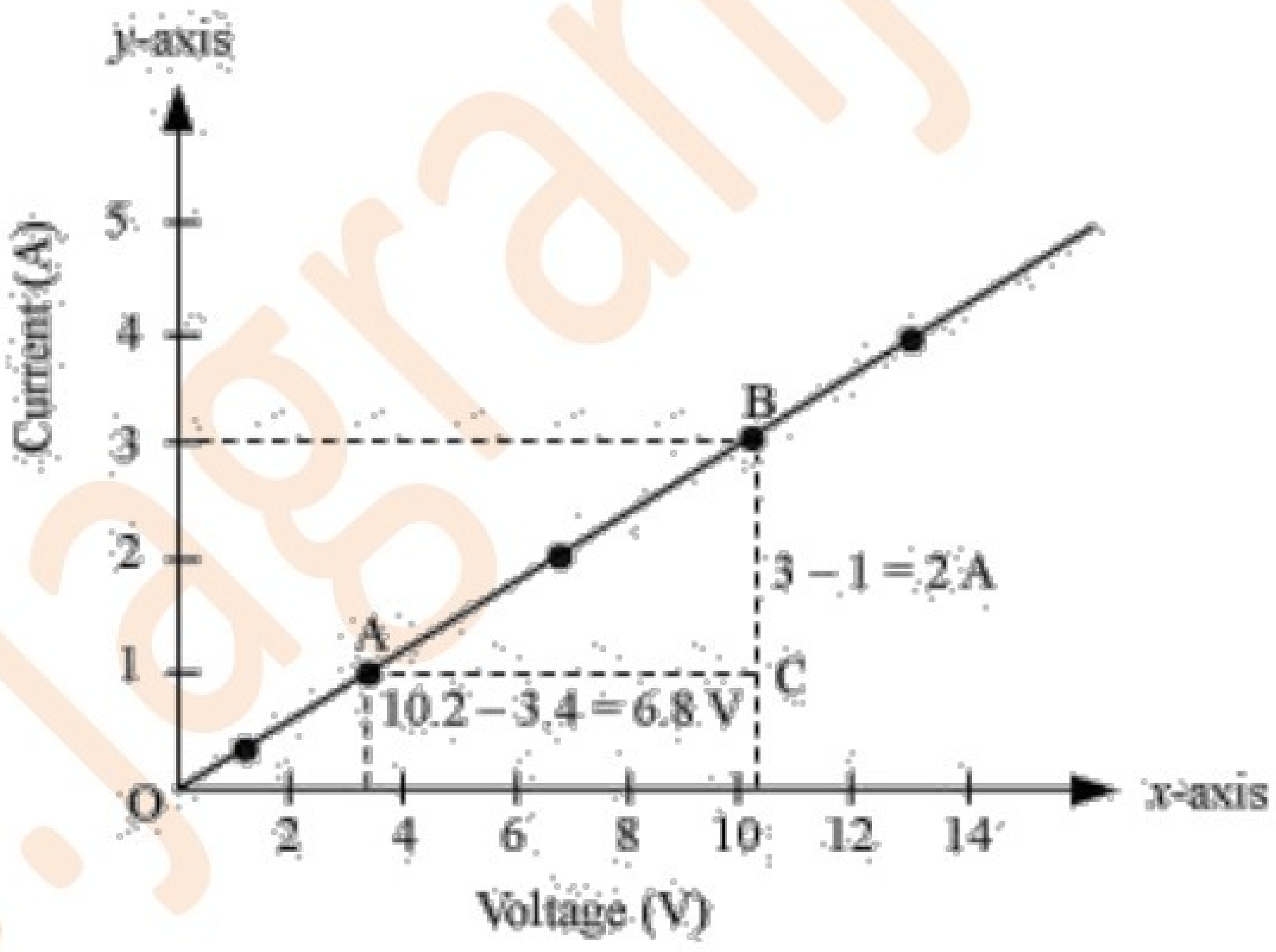
V (volts) 1.6 3.4 6.7 10.2 13.2

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

Solution: The plot between voltage and current is called *IV* characteristic. The voltage is plotted on x-axis and current is plotted on y-axis. The values of the current for different values of the voltage are shown in the given table.

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

The *IV* characteristic of the given resistor is plotted in the following figure.



The slope of the line gives the value of resistance (R)

$$\text{Slope} = \frac{1}{R} = \frac{BC}{AC} = \frac{2}{6.8}$$

$$R = \frac{6.8}{2} = 3.4\Omega$$

Therefore, the resistance of the resistor is 3.4Ω.

Question 8: When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.

Solution:

Resistance (R) of a resistor is given by Ohm's law as,

$$V = IR$$

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

where,

Potential difference, $V = 12$ V

Current in the circuit, $I = 2.5$ mA = $2.5 \times 10^{-3} A$

$$R = \frac{12}{2.5 \times 10^{-3}}$$

$$R = 4.8 k\Omega$$

Question 9: A battery of 9 V is connected in series with resistors of 0.2 Ω, 0.3 Ω, 0.4 Ω, 0.5 Ω and 12 Ω, respectively. How much current would flow through the 12 Ω resistors?

Solution: There is no current division occurring in a series circuit. Current flow through the component is the same, given by Ohm's law as

$$V = IR$$

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

where,

R is the equivalent resistance

$R = 0.2 + 0.3 + 0.4 + 0.5 + 12 = 13.4$ Ω

Potential difference, $V = 9$ V

$$I = \frac{9}{13.4} = 0.671 A$$

Therefore, the current that would flow through the 12 Ω resistor is 0.671 A.

Question 10: How many 176 Ω resistors (in parallel) are required to carry 5 A on a 220 V line?

Solution: For x number of resistors of resistance 176 Ω, the equivalent resistance of the resistors connected in parallel is given by Ohm's law as

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

where,

Supply voltage, $V = 220$ V

Current, $I = 5$ A

Equivalent resistance of the combination = R,

$$\frac{1}{R} = x \times \frac{1}{176}$$
$$R = \frac{176}{x}$$

From Ohm's law,

$$\frac{V}{I} = \frac{176}{x}$$
$$x = \frac{176 \times 5}{220}$$
$$x = 4$$

Therefore, four resistors of 176 Ω are required to draw the given amount of current.

Question 11: Show how you would connect three resistors, each of resistance 6 Ω, so that the combination has a resistance of (i) 9 Ω, (ii) 4 Ω.

Solution: If we connect the resistors in series, then the equivalent resistance will be the sum of the resistors, i.e., 6 Ω + 6 Ω + 6 Ω = 18 Ω, which is not desired. If we connect the resistors in parallel, then the equivalent resistance will be 3Ω

Hence, we should either connect the two resistors in series or parallel.

(i) Two resistors in parallel

Two 6 Ω resistors are connected in parallel. Their equivalent resistance will be

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

The third 6 Ω resistor is in series with 3 Ω. Hence, the equivalent resistance of the circuit is 6 Ω + 3 Ω = 9 Ω.

(ii) Two resistors in series

Two 6 Ω resistors are in series. Their equivalent resistance will be the sum $6+6=12\Omega$

The third 6 Ω resistor is in parallel with 12 Ω. Hence, equivalent resistance will be

$$\frac{1}{\frac{1}{12}+\frac{1}{6}}=4\Omega$$

Therefore, the total resistance is 4Ω.

Question 12: Several electric bulbs designed to be used on a 220 V electric supply line, are rated 10 W. How many lamps can be connected in parallel with each other across the two wires of 220 V line if the maximum allowable current is 5 A?

Solution:

Resistance R_1 of the bulb is:

$$P_1=\frac{V^2}{R_1}$$

$$R_1=\frac{V^2}{P_1}$$

where,

Supply voltage, V = 220 V

Maximum allowable current, I = 5 A

$$P_1 = 10W$$

$$R_1 = \frac{220^2}{10} = 4840\Omega$$

As per the Ohm's law,

$$V = I\,R$$

where,

R is the total resistance of the circuit for x number of electric bulbs

$$R = \frac{V}{I} = \frac{220}{5} = 44\Omega$$

Resistance of each electric bulb = 4840 Ω

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_1} + \frac{1}{R_1} + \ldots\ldots\ldots\ldots x \text{ times}$$

$$\frac{1}{R} = \frac{1}{R_1}x$$

$$x = \frac{R_1}{R} = \frac{4840}{44} = 110$$

Therefore, 110 electric bulbs are connected in parallel.

Question 15: Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply. What current is drawn from the line if the supply voltage is 220 V?

Solution: Both the bulbs are connected in parallel. Therefore, potential difference across each of them will be 220 V, because no division of voltage occurs in a parallel circuit.

Current drawn by the bulb of rating 100 W is given by,

$$P = V \times I$$

$$I = \frac{P}{V} = \frac{100}{220} A$$

Similarly, current drawn by the bulb of rating 60 W is given by,

$$I = \frac{P}{V} = \frac{60}{220} A$$

The current drawn from the line is:

$$\frac{100}{220} + \frac{60}{220} = 0.727A$$

Question 16: Which uses more energy, a 250 W TV set in 1 hr or a 1200 W toaster in 10 minutes?

Solution:

Energy consumed by an electrical appliance is given by the expression,

$$H = Pt$$

where,

Power of the appliance = P

Time = t

Energy consumed by a TV set of power 250 W in 1 h = 250 × 3600 = 9 × 10^5 J

Energy consumed by a toaster of power 1200 W in 10 minutes = 1200 × 600

= 7.2× 10^5 J

Question 17: An electric heater of resistance 8 Ω draws 15 A from the service mains 2 hours. Calculate the rate at which heat is developed in the heater.

Solution:

R = 8 Ω

I = 15 A

$$P = I^2R$$
$$P = 15 \times 15 \times 8$$
$$P = 1800J/s$$

Therefore, heat is produced by the heater at the rate of 1800 J/s.

Question 18: Explain the following.

(a) Why is the tungsten used almost exclusively for filament of electric lamps?

(b) Why are the conductors of electric heating devices, such as bread-toasters and electric irons, made of an alloy rather than a pure metal?

(c) Why is the series arrangement not used for domestic circuits?

(d) How does the resistance of a wire vary with its area of cross-section?

(e) Why are copper and aluminium wires usually employed for electricity transmission?

Solution:

The melting point and resistivity of tungsten are very high. It does not burn easily at high temperature. The electric lamps glow at very high temperatures. Thus, tungsten is mainly used as heating element of electric bulbs.

Because resistivity of an alloy is more than that of metals. It produces large amount of heat.

There is voltage division in series circuits. Each component of a series circuit receives a small voltage for a large supply voltage. As a result, the amount of current decreases and the device becomes hot. Hence, series arrangement is not used in domestic circuits.

Resistance of a wire is inversely proportional to its area of cross-section i.e., Copper and aluminium wires have low resistivity. They are good conductors of electricity. Hence, they are usually employed for electricity transmission.