CLASS X: SCIENCE
Chapter 11: Electricity

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Q1. What does an electric circuit mean ?

Ans. An electric circuit is a closed and continuous path consisting of many devices like resistors, electric bulbs, etc. through which an electric current flows.

Q2. Define the SI unit of current.

Ans. The SI unit of current is ampere (A). Current flowing through a conductor is said to be 1 ampere if 1 coulomb of charge flows through it in 1 second.

Q3. Calculate the number of electrons constituting one coulomb of charge.

Ans. Number of electrons constituting 1 coulomb is given by,

$n = \frac{Q}{e}$ Where, Q = 1 C and e = charge of a single electron = 1.6×10^{-19} C

or $n = \frac{1\,C}{1.6 \times 10^{-19}\,C} = \mathbf{6.24 \times 10^{18}}$ electrons.

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Q1. Name a device that helps to maintain a potential difference across a conductor.

Ans. A battery can be used to maintain a potential difference across a conductor.

Q2. What is meant by saying that the potential difference between two points is 1 V ?

Ans. Potential difference between two points is 1 volt if 1 joule of work is done to carry a charge of 1 coulomb from one point to the other.

Q3. How much energy is given to each coulomb of charge passing through a 6 V battery ?

Ans. Work done, W = QV where Q = 1 C ; V = 6 V

$W = 1\ C \times 6\ V = \mathbf{6\ J}$

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Q1. On what factors does the resistance of a conductor depend ?

Ans. The resistance (R) of a conductor depends upon

(1) Its length (ℓ): $R \propto \ell$

(2) Its cross-sectional area (A): $R \propto \frac{1}{A}$

(3) Nature of material i.e., resistivity (ρ) of its material: $R \propto \rho$

(4)Temperature: more the temperature, more will be its resistance.

Q2. Does current flow more easily through a thick wire or a thin wire of the same material when connected to the same source ? Why ?

Ans. The current flows more easily through a thick wire than through a thin wire. This is because, the resistance R of a thick wire (large area of cross-section) is less than that of a thin wire (small area of cross-section) as $R \propto \frac{1}{A}$.

Q3. Let the resistance of an electrical component remain constant while the potential difference across the two ends of the component decrease to half its former value. What change will occur in the current through it ?

Ans. We know that I = V/R, when potential difference becomes V/2, and resistance remains constant, then, current becomes 1/2 of its former value.

Q4. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal ?

Ans. This is because (i) resistivity of an alloy is generally higher than that of pure metals (ii) an alloy does not oxidise at high temperatures.

Q5. Use the data in Table 11.2 to answer the following?

(a) Which among iron and mercury is a better conductor? Given, $\rho_{iron} = 10.0 \times 10^{-8}\ \Omega m$ and $\rho_{mercury} = 94.0 \times 10^{-8}\ \Omega m$.

(b) Which material is the best conductor ?

Ans. (a) Iron is a better conductor than mercury as resistivity (ρ) for iron is less than that for mercury.

(b) Silver is the best conductor because its resistivity (ρ) is least.

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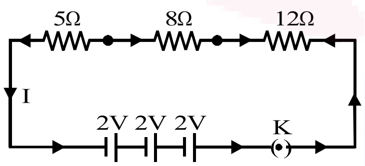
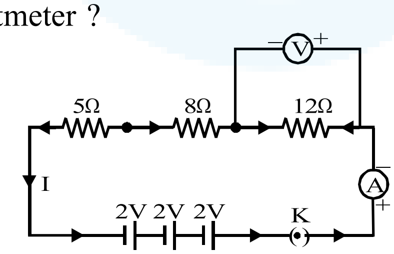
Q1. Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 ohm resistor, an 8 ohm resistor, and a 12 ohm resistor, and a plug key, all connected in series.

Ans.



Q2. Redraw the circuit of Q. 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the voltage across the 12 ohm resistor. What would be the readings in the ammeter and the voltmeter ?



Ans. Since all the three resistances are in series, total resistance in the circuit,

$R = 5 + 8 + 12 = 25\ \Omega$

Current in the circuit,

$I = \frac{V}{R} = \frac{2+2+2}{25} = \frac{6}{25} = 0.24\ A$, thus, ammeter will read 0.24 A.

Potential difference across 12 ohm resistor, $V = I \times R = 0.24 \times 12 = 2.88\ V$

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Q1. Judge the equivalent resistance when the following are connected in parallel

(a) $1\ \Omega$ and $10^6\ \Omega$ (b) $1\ \Omega$, $10^3\ \Omega$ and $10^6\ \Omega$.

Ans. (a) Approx. $1\ \Omega$ (slightly less than $1\ \Omega$) as other one ($10^6\ \Omega$) is very large as compared to $1\ \Omega$. In parallel combination of resistors, the equivalent resistance is lesser than the least resistance (in this case, $1\ \Omega$).

(b)Again, resistance is approx. $1\ \Omega$ (slightly less than $1\ \Omega$).

Q2. An electric lamp of $100\ \Omega$, a toaster of resistance $50\ \Omega$ and a water filter of resistance $500\ \Omega$ 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 in three appliances and what is current through it ?

Ans. Resistance of the electric lamp, $R_1 = 100\ \Omega$; resistance of toaster, $R_2 = 50\ \Omega$; resistance of water filter, $R_3 = 500\ \Omega$

Since R_1, R_2 and R_3 are connected in parallel, their equivalent resistance (R_p) is given by

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500}$$

$$= \frac{5+10+1}{500} = \frac{16}{500} = \frac{4}{125}$$

$$R_p = \frac{125}{4}\Omega$$

Current through the three appliances, i.e.,

$$I = \frac{V}{R_p} = \frac{220}{(125/4)} = 7.04\ A$$

Since the electric iron drawing the same current when connected to the same source (220 V), its resistance must be equal to R_p.

Thus, resistance of the electric iron, $\frac{125}{4} =$ **31.25 Ω**

Current through the electric iron, I = **7.04 A**

Q3. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series.

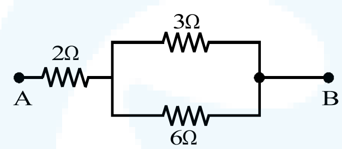
Ans. (a) In case of devices in parallel, if one device gets damaged (or open), all others will work as usual as the whole circuit does not break. This is not so with the devices connected in series because when one device fails, the circuit breaks and all devices stop working.

(b) Since potential difference across all devices is same in parallel circuit, they will draw required current according to their resistances. This is not so in series circuit where same current flows through all the devices, irrespective of their resistances.

Q4. How can three resistors of resistances 2 Ω, 3 Ω, and 6 Ω be connected to give a total resistance of

(a) 4 Ω (b) 1 Ω ?

Ans. (a) To get a total resistance of 4 Ω from resistors of resistances 2 Ω, 3 Ω and 6 Ω, the resistors are joined as shown below.

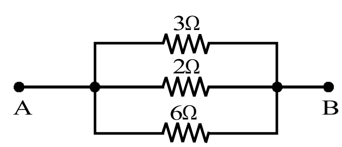


The resistors having resistances 3 Ω and 6 Ω are connected in parallel. This combination is connected in series with the resistor of resistance 2 Ω. Let us check it mathematically, equivalent resistance of 3 Ω and 6 Ω resistors is,

$$R_1 = \frac{3 \times 6}{3+6} = \frac{3 \times 6}{9} = 2\ \Omega$$

Now, R_1 and 2 Ω resistors are in series, their equivalent resistance is $R_e = R_1 + 2 = 2 + 2 = 4\ \Omega$.

(b) To get a resistance of 1 Ω from three given resistors of resistances 2 Ω, 3 Ω, 6 Ω, are joined as shown below.



They all are connected in parallel. Their equivalent resistance is given by,

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

Q5. What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistances 4 Ω, 8 Ω, 12 Ω, 24 Ω ?

Ans. (a) The highest resistance is secured when all the resistors are connected in series. The equivalent resistance is given by,

$R_e = 4\ \Omega + 8\ \Omega + 12\ \Omega + 24\ \Omega =$ **48 Ω.**

(2) The lowest resistance is secured when all the four coils are connected in parallel. The equivalent resistance is given by,

$$\frac{1}{R_e} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24} = \frac{6+3+2+1}{24} = \frac{12}{24} = \frac{1}{2} \quad \text{or} \quad R_e = \mathbf{2\ \Omega}$$

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Q1. Why does the cord of an electric heater not glow while the heating element does ?

Ans. The cord of an electric heater is made of thick copper wire and has much lower resistance than the heating element. For the same current (I) flowing through the cord and the element, heat produced in the element is much more than that produced in the cord. As a result, the element becomes very hot and glows whereas the cord does not become hot and as such does not glow.

Q2. Compute the heat generated while transferring 96000 coulombs of charge in one hour through a potential difference of 50 V.

Ans. Here, charge, Q = 96000 C ; time, t=1 hr

potential difference, V = 50 V.

Heat produced, $H = V\,I\,t = V \times Q \qquad [\because Q = I\,t]$

$= 96000\ C \times 50\ V =$ $\mathbf{4.8 \times 10^6\ J}$**.**

Q3. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

Ans. Here, resistance, R = 20 Ω, current, I = 5 A, time, t = 30 s.

Heat produced, $H = I^2 R\,t = (5)^2 \times 20 \times 30$

$= \mathbf{1.5 \times 10^4\ J}$**.**

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Q1. What determines the rate at which energy is delivered by a current ?

Ans. Electric power determines the rate at which energy is delivered by a current.

Q2. An electric motor takes 5 A from a 220 V. Determine the power and energy consumed in 2 hr.

Ans. Here, current, I = 5 A ; potential difference, V = 220 V ;
time, t = 2 hr = 2 × 60 × 60 = 7200 s.
Power, P = V × I = 220 × 5 = 1100 W
Energy consumed, H = V × I × t = 220 × 5 × 7200 $= \mathbf{7.92 \times 10^6\ J}$.

EXERCISES

Q1. 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

(1) $\frac{1}{25}$ (2) $\frac{1}{5}$ (3) 5 (4) 25

Ans. Resistance of each one of the five parts = $\frac{R}{5}$ Resistance of five parts connected in parallel is given by

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

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

or $$\frac{R}{R'} = \mathbf{25}$$

Thus, (4) is the correct answer.

Q2. Which of the following terms does not represent electrical power in a circuit ?

(1) I^2R (2) IR^2 (3) VI (4) V^2/R

Ans. Electrical power, $P = VI = (IR)\, I = I^2R$

$$P = V\,I = V\left(\frac{V}{R}\right) = \frac{V^2}{R}$$

Obviously, IR^2 does not represent electrical power in a circuit.

Thus, (2) is the correct answer.

Q3. An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be:

(1) 100 W (2) 75 W (3) 50 W (4) 25 W

Ans. Resistance of the electric bulbs, $R = \frac{V^2}{P}$ $\left(P = \frac{V^2}{R}\right)$

or $R = \frac{(220)^2}{100} = 484\ \Omega$

Power consumed by the bulb when it is operated at 110 V is given by

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

Thus, (4) is the correct answer.

Q4. Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then in parallel in an electric circuit. The ratio of the heat produced in series and parallel combinations would be

(1) 1 : 2 (2) 2 : 1 (3) 1 : 4 (4) 4 : 1

Ans. Since both the wires are made of the same material and have equal lengths and equal diameters, they have the same resistance. Let it be R.

When connected in series, their equivalent resistance is given by

$R_s = R + R = 2R$

When connected in parallel, their equivalent resistance is given by

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \text{ or } R_p = \frac{R}{2}$$

Further, electrical power is given by $P = \frac{V^2}{R}$

Power (or heat produced) in series, $P_s = \frac{V^2}{R_s}$

Power (or heat produced) in parallel, $P_p = \frac{V^2}{R_p}$

Thus, $\frac{P_s}{P_p} = \frac{V^2/R_s}{V^2/R_p} = \frac{R_p}{R_s} = \frac{R/2}{2R} = \frac{1}{4}$

or $P_s : P_p = \mathbf{1 : 4}$

Thus, (3) is the correct answer.

Q5. How is voltmeter connected in the circuit to measure potential difference between two points?

Ans. A voltmeter is always connected in parallel across the points between which the potential difference is to be determined.

Q6. A copper wire has a diameter of 0.5 mm and a resistivity of 1.6×10^{-6} ohm cm. How much of this wire would be required to make a 10 ohm coil? How much does the resistance change if the diameter is doubled?

Ans. We are given that, diameter of the wire,
$D = 0.5 \text{ mm} = 0.5 \times 10^{-3}$ m

Radius $r = \frac{D}{2} = \frac{0.5 \times 10^{-3}}{2} = 2.5 \times 10^{-4}$ m

Resistivity of copper, $\rho = 1.6 \times 10^{-6}$ ohm cm
$= 1.6 \times 10^{-8}$ ohm m

Required resistance, R = 10 ohm

As, $R = \frac{\rho\ell}{A}$, $\ell = \frac{RA}{\rho} = \frac{R(\pi r^2)}{\rho}$ $[A = \pi r^2]$

or $\ell = \dfrac{3.14 \times 10 \times (2.5 \times 10^{-4})^2}{1.6 \times 10^{-8}} = 112.7$ m

Since, $R = \dfrac{\rho\ell}{A} = \dfrac{\rho\ell}{\pi r^2} = \dfrac{\rho\ell}{\pi(D/2)^2} = \dfrac{4\rho\ell}{\pi D^2}$, $R \propto \dfrac{1}{D^2}$

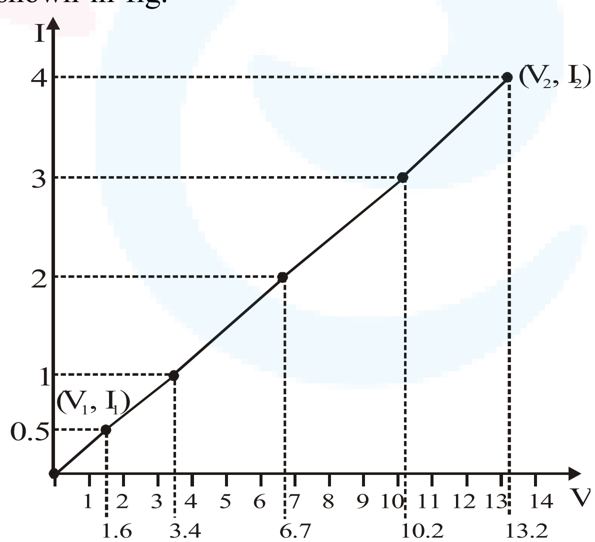
When D is doubled, R becomes $\dfrac{1}{4}$ times.

Q7. 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 (ampere) :	0.5	1.0	2.0	3.0	4.0
V (volt) :	1.6	3.4	6.7	10.2	13.2

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

Ans. The V-I graph is as shown in fig.



Here, the I – V graph is almost straight. The resistance of the resistor can be calculated as given below, $R = \dfrac{V_2 - V_1}{I_2 - I_1} = \dfrac{13.2 - 1.6}{4 - 0.5} = \dfrac{11.6}{3.5} = \mathbf{3.3\ \Omega}$

Q8. 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.

Ans. Here, V = 12 V, I = 2.5 mA = 2.5×10^{-3} A

Resistance of the resistor, $R = \frac{V}{I} = \frac{12}{2.5 \times 10^{-3}}$

$= 4800\ \Omega =$ **4.8 kΩ**

Q9. A battery of 9 V is connected with resistors of 0.2 Ω, 0.3 Ω, 0.4 Ω, 0.5 Ω and 12 Ω in series. How much current would flow through the 12 Ω resistor?

Ans. Since all the resistors are in series, equivalent resistance,

$R_s = 0.2 + 0.3 + 0.4 + 0.5 + 12 = 13.4\ \Omega$

Current, $I = \frac{V}{R_s} = \frac{9}{13.4} =$ **0.67 A**

In series, same current (I) flows through all the resistors. Thus, current flowing through 12 Ω resistor = 0.67 A

Q10. How many 176 Ω resistors (in parallel) are required to carry 5 A in 220 V line?

Ans. Here, I = 5 A, V = 220 V.

Resistance required in the circuit,

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

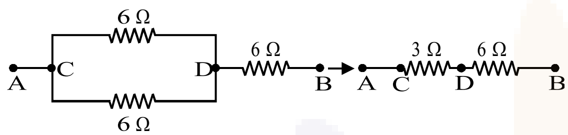
Resistance of each resistor, r = 176 Ω

If n resistors, each of resistance r, are connected in parallel to get the required resistance R, then

$R = \frac{r}{n}$ or $44 = \frac{176}{n}$ or $n = \frac{176}{44} = \mathbf{4}$

Q11. 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.

Ans. (i) In order to get a resistance of 9 Ω from three resistors, we connect two 6 Ω resistors in parallel and this parallel combination in series with the third 6 Ω resistor as shown in fig.



Two 6 Ω resistors are in parallel, their equivalent resistance is,

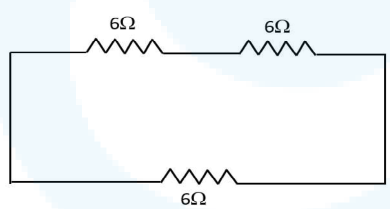
$$R_1 = \frac{6 \times 6}{6+6} = \frac{6 \times 6}{12} = 3\ \Omega$$

Now, R_1 and the third 6 Ω resistors are in series, their equivalent resistance is,

$R_e = R_1 + 6 = 3 + 6 =$ **9 Ω**

(ii) In order to get a resistance of 4 Ω, we connect all the three resistors in parallel as shown in fig. Their equivalent resistance is, $\frac{1}{R_p} = \frac{1}{12} + \frac{1}{6}$

$$R_p = \frac{12}{3} = 4\Omega$$



Q12. 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 ?

Ans. Resistance of each bulb, $R = \frac{V^2}{P} = \frac{(220)^2}{10} = 4840\,\Omega$

Total resistance in the circuit, $R_e = \frac{220}{5} = 44\ \Omega$

Let n be the number of bulb (each of resistance R) to be connected in parallel to obtain a resistance R_e.

Clearly, $R_e = \frac{R}{n}$ or $n = \frac{R}{R_e} = \frac{4840}{44} =$ **110**

Q13. A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of 24 Ω resistance, which may be used separately, in series, or in parallel. What are the currents in the three cases ?

Ans. Here, potential difference, V = 220 V

Resistance of each coil, R = 24 Ω

(i) When each of the coils A or B is connected separately, current through each coil, i.e.,

$$I = \frac{V}{R} = \frac{220}{24} = \mathbf{9.2\ A}$$

(ii) When coils A and B are connected in series, equivalent resistance in the circuit,

$R_s = R + R = 2R = 48\ \Omega$

Current through the series combination, i.e.,

$$I_s = \frac{V}{R_s} = \frac{220}{48} = \mathbf{4.6\ A}$$

(iii) When the coils A and B are connected in parallel, equivalent resistance in the circuit,

$$R_p = \frac{R}{2} = \frac{24\,\Omega}{2} = 12\,\Omega$$

Current through the parallel combination, i.e,

$$I_p = \frac{V}{R_p} = \frac{220}{12} = \mathbf{18.3\ A}$$

Q14. Compare the power used in the 2 Ω resistor in each of the following circuits :

(i) a 6 V battery in series with 1 Ω and 2 Ω resistors, and

(ii) a 4 V battery in parallel with 12 Ω and 2 Ω resistors.

Ans. (i) Since 6 V battery is in series with 1 Ω and 2 Ω resistors, current in the circuit,

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

Power used in 2 Ω resistor, $P_1 = I^2R = (2)^2 \times 2 = 8$ W

(ii) Since 4 V battery is in parallel with 12 Ω and 2 Ω resistors, potential difference across 2 Ω resistor, V = 4 V.

Power used in 2 Ω resistor, $P_2 = \frac{V^2}{R} = \frac{(4)^2}{(2)} = 8$ W

Clearly, $\frac{P_1}{P_2} = \frac{8}{8} = \mathbf{1}$.

Q15. Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to the electric mains supply. What current is drawn from the line if the supply voltage is 220 V ?

Ans. Resistance of first lamp,

$$R_1 = \frac{V^2}{P} = \frac{(220)^2}{100}$$

resistance of the second lamp,

$$R_2 = \frac{V^2}{P} = \frac{(220)^2}{60}$$

Since the two lamps are connected in parallel, the equivalent resistance is given by

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{100}{(220)^2} + \frac{60}{(220)^2} = \frac{160}{(220)^2}$$

or $R_P = \frac{(220)^2}{160} = \mathbf{302.5\ \Omega}$

Current drawn from the line, i.e.,

$$I = \frac{V}{R_p} = \frac{220\,V}{302.5\,\Omega} = \mathbf{0.727\ A}$$

Q16. Which uses more energy, a 250 W TV set in 1 h, or a 1200 W toaster in 10 minutes ?

Ans. Energy used by 250 W TV set in 1 h = 250 × 1 = 250 Wh
Energy used by 1200 W toaster in 10 min. (i.e., 1/6 h) = 1200 × (1/6) = 200 Wh
Thus, a 250 W TV set uses more energy in 1 h than a 1200 W toaster in 10 minutes.

Q17. An electric heater of resistance 8 Ω draws 15 A from the service mains for 2 hours. Calculate the rate at which heat is developed in the heater.

Ans. Here, I = 15 A, R = 8 Ω, t = 2 h
Rate at which heat is developed, i.e, electric power, $P = I^2 R = (15)^2 \times 8 =$ **1800 W**

Q18. Explain the following :
(1) Why is tungsten used almost exclusively for filament of incandescent lamps ?
(2) Why are the conductors of electric heating devices, such as toasters and electric irons, made of an alloy rather than a pure metal ?
(3) Why is the series arrangement not used for domestic circuits ?
(4) How does the resistance of a wire vary with its cross-sectional area ?
(5) Why are copper and aluminium wires usually employed for electricity transmission ?

Ans. (1) Tungsten has a high melting point (3380°C) and becomes incandescent (i.e., emits light) at a high temperature.

(2) The resistivity of an alloy is generally higher than that of pure metals and they do not oxidise readily at high temperatures.

(3) In series arrangement, if any one of the appliances fails or is switched off, all the other appliances stop working because the circuit breaks.

(4) The resistance of a wire (R) varies inversely as its cross-sectional area, $R \propto 1/A$.

(5) Copper and aluminium wires possess low resistivity, thus, they are generally used for electricity transmission.