12 ELECTRICITY

BASIC CONCEPTS – A FLOW CHART

ELECTRIC CURRENT (I)
- Rate of flow of electric charges
  $$I = \frac{\text{Net charge (Q)}}{\text{Time (t)}}$$
- Measured by ammeter

Essential requirement for current flow → **Potential difference (V)**
- Work done to move a unit charge from one point to other.
  $$V = \frac{\text{Work done (W)}}{\text{Charge (Q)}}\ \text{J/C}$$
- Measured by voltmeter.

Unit → **volt (V)**
$1\ V = 1\ JC^{-1}$
$1\ mV = 10^{-3}\ V$

Ohm's law
A relationship between V across a conductor and I through it.
$V \propto I$
i.e., $V = IR$

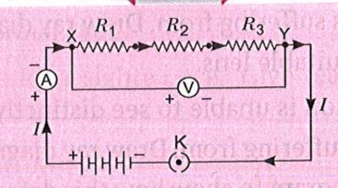
Opposition to passage of electric current → **Resistance (R)**
Ratio of potential difference across a conductor to current flowing through it.

Unit → **ohm (Ω)**
$1\ k\Omega = 10^{3}\ \Omega$
$1\ m\Omega = 10^{-3}\ \Omega$

Factors affecting resistance
- Length ($R \propto l$)
- Area of cross-section ($R \propto \frac{1}{A}$)
- Nature of material
- Temperature

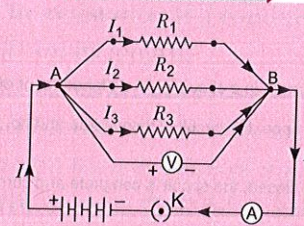
Combination of resistors

Resistors in series



- Current remains constant but voltage varies.
  $V = V_1 + V_2 + V_3$
- $R_s = R_1 + R_2 + R_3$

Resistors in parallel

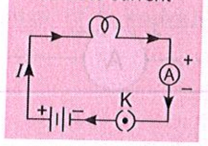


- Voltage remains constant but current varies.
- $I = I_1 + I_2 + I_3$
- $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Measure of current → **Electric power (P)**
Rate at which electric energy is dissipated or consumed in an electric circuit
$P = VI = I^2R = V^2/R$

Unit → **watt (W)**
$1\ W = 1\ Js^{-1}$
$1\ kW = 10^{3}\ W$

Representation of current flow → **Electric circuit**
Continuous and closed path for an electric current



Unit → **ampere (A)**
$1\ A = 1\ Cs^{-1}$
$1\ mA = 10^{-3}\ A$

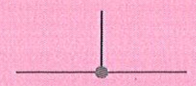
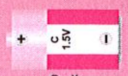
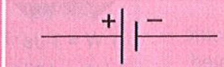
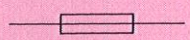
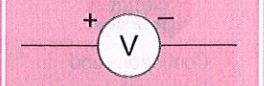
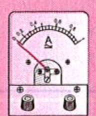
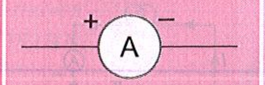
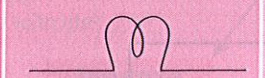
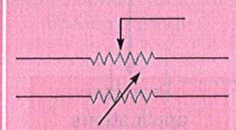
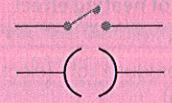
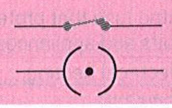
Heating effect
According to Joule's law of heating
$H \propto I^2$
$H \propto R$
$H \propto t$
∴ Heat produced,
$H = I^2Rt$

Practical applications of heating effect
- To produce light (electric bulb)
- Electric fuse that protects circuits and appliances.
- In electrical heating appliances (electric iron, toaster, room heater, etc.).

Commercial unit of electric energy is kilowatt hour (kWh), commonly known as 'unit'.
$1\ kWh = 3.6 \times 10^{6}\ J$

MORE POINTS TO REMEMBER

Commonly used Electrical Components

COMPONENT	CIRCUIT SYMBOL	FUNCTION OF COMPONENT
Wire		To conduct or pass current from one part of a circuit to another.
Wire joined		A 'blob' should be drawn where wires are connected (joined), but it is sometimes omitted. Wires connected to another wire should be staggered slightly to form two T-junctions, as shown. Such help to transmitted current to other paths.
Wires not joined		In diagrams, it is often necessary to draw wires crossing even though they are not connected. It is preferred to have the 'hump' symbol as shown because the simple crossing of the wire may be misread as a joint where you have forgotten to add a 'blob'.
 Cell		Supplies electrical energy. The larger terminal is marked as '+' to represent the anode and smaller terminal is marked as '–' to represent the cathode. A single cell is often interpreted and called a battery, but a battery is two or more cell joined together.
 Battery		Supplies electrical energy. A battery is more than cell.
 Fuse		A safety device, which will melt if the current flowing through it exceeds a specified value.
 Voltmeter		A voltmeter is used to measure voltage (potential difference).
 Ammeter		An ammeter is used to measure electric current.
 Bulb		A device, which converts electrical energy to light.
 Resistor		A fixed resistor limits the current in the circuit.
 Variable Resistor		A variable resistor allows the current in a circuit to be varied.
 Open switch		A switch enables current in a circuit to be switched on or off. When the switch is open, the circuit in incomplete and no current flows.
 Closed switch		When the switch in closed, the circuit is complete and current flows.

- **Electrical resistivity:** ρ (rho) is a constant of proportionality. The SI unit of resistivity is Ω m. It is a characteristic property of the material. The conductors have very low resistivity in the range of 10^{-8} Ω m to 10^{-6} Ω m. Insulators have resistivity of the order of 10^{12} to 10^{17} Ω m.
- The unit of power is watt (W). One watt of power is consumed when 1 A of current flows at a potential difference of 1 V.
- The electrical energy dissipated in a resistor is given by $W = V \times I \times t$

NCERT Intext Questions

Q. 1. What does an electric circuit mean?

Ans. A closed conducting path through which electric current may flow is called an electric circuit.

Q. 2. Define the unit of current.

Ans. The SI unit of electric current is ampere (A). When 1 coulomb of electric charge flows through any cross-section of a conductor in 1 second, the electric current flowing through it is said to be 1 ampere.

$$1 \text{ ampere(A)} = \frac{1 \text{ coulomb (C)}}{1 \text{ second (s)}}$$

Q. 3. Calculate the number of electrons constituting one coulomb of charge.

Ans. Charge on an electron = 1.6×10^{-19} C.

∵ If the value of charge is 1.6×10^{-19} C, then number of electron = 1

∴ If the value of charge is 1 C, then number of electrons

$$= \frac{1}{1.6\times10^{-19}} = \frac{1}{1.6}\times10^{19}$$

$$= 0.625 \times 10^{19} = \mathbf{6.25 \times 10^{18}}$$

Q. 4. Name a device that helps to maintain a potential difference across a conductor.

Ans. A cell or a battery.

Q. 5. What is meant by saying that the potential difference between two points is 1 V?

Ans. The potential difference between two points in a current carrying conductor is said to be 1 V when 1 joule of work is done to move a charge of 1 coulomb from one point to the other.

Therefore, $1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$

$1 \text{ V} = 1 \text{ JC}^{-1}$

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

Ans. Charge, $Q = 1$ C

Potential difference, $V = 6$ V

Work done, $W = VQ = 6 \text{ V} \times 1 \text{ C} = 6 \text{ J}$

The work done on each coulomb = **6 J**.

Therefore, the energy given to each coulomb of charge is also 6 J.

Q. 7. On what factors does the resistance of a conductor depend?

Ans. The resistance of a conductor depends:

(*i*) on its length,

(*ii*) on its area of cross-section,

(*iii*) on the nature of its material and

(*iv*) on temperature of the conductor.

Q. 8. Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?

Ans. Resistance, $R \propto \frac{1}{A}$

The resistance of a conductor is inversely proportional to its area of cross-section. A thick wire has a greater area of cross-section whereas a thin wire has a smaller area of cross section. Thus, a thick wire has less resistance and a thin wire has more resistance. Therefore, current will flow more easily through a thick wire.

Q. 9. Let the resistance of an electrical component remain 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?

Ans. We know that, $I = \dfrac{V}{R}$

Since the resistance remains constant, so the current is directly proportional to potential difference. If the potential difference is halved, the current also gets halved.

Q. 10. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?

Ans. Coils of electric toasters and electric irons are made of an alloy rather than a pure metal because

(*i*) the resistivity of an alloy is much higher than that of pure metal and

(*ii*) an alloy does not undergo oxidation easily even at high temperature.

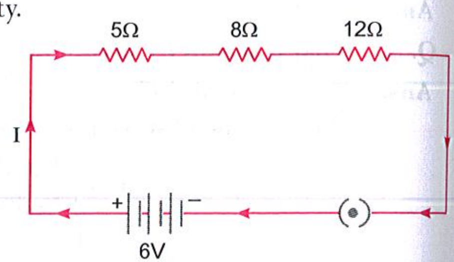
Q. 11. (*i*) Which among iron and mercury is a better conductor?

(*ii*) Which material is the best conductor?

Ans. (*i*) Among iron and mercury, iron is better conductor of electricity because resistivity of iron (10.0×10^{-8} Ω m) is less than that of mercury (94.0×10^{-8} Ω m).

(*ii*) We know that a good conductor of electricity should have a low resistivity and a poor conductor of electricity will have a high resistivity. Silver has the lowest resistivity of 1.60×10^{-8} Ω m, which means that silver offers the least resistance to the flow of current through it. So, silver is the best conductor of electricity.

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

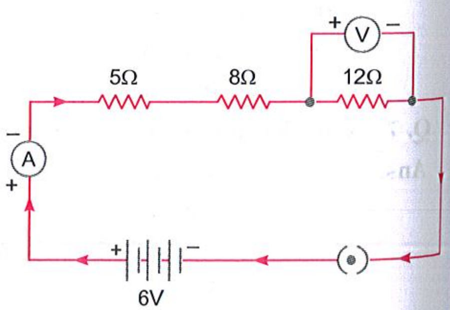


Ans. The potential difference of each cell = 2 V

The total potential difference (or voltage) of 3 cells

= 3 × 2 V = **6 V.**

Q. 13. Redraw the circuit of Q. 12, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter?



Ans. It is noted that the ammeter has been put in series with the circuit and the voltmeter has been put in parallel with the 12 Ω resistor.

(*i*) Calculation of current reading in the ammeter:

Here, $R_1 = 5\ \Omega$, $R_2 = 8\ \Omega$ and $R_3 = 12\ \Omega$

These three resistors are connected in series.

∴ Total resistance, $R = R_1 + R_2 + R_3$

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

Potential difference, $V = 6$ V

Current, $I = ?$

Applying Ohm's law,

$$V = IR$$

$$I = \frac{V}{R} = \frac{6}{25} = 0.24 \text{ A}$$

Therefore, ammeter will show a reading of 0.24 A.

(*ii*) Calculation of potential difference reading across 12 Ω resistor.

Current, $I = 0{\cdot}24$ A, Resistance, $R = 12\ \Omega$, Potential difference, $V = ?$

Applying Ohm's law

$$V = IR = 0{\cdot}24 \times 12 = \mathbf{2.88\ V}$$

Therefore, the voltmeter reading is 2.88 V.

Q. 14. Judge the equivalent resistance when the following are connected in parallel (*i*) 1 Ω and 10^6 Ω (*ii*) 1 Ω and 10^3 Ω and 10^6 Ω.

Ans. (*i*) When a number of resistance are connected in parallel, then their combined resistance is less than the smallest individual resistance. Therefore, equivalent resistance will be less than 1 Ω.

(*ii*) In this case, also the equivalent resistance will be less than 1 Ω.

Q. 15. 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?

Ans. Here, $R_1 = 100\ \Omega$, $R_2 = 50\ \Omega$, $R_3 = 500\ \Omega$

Equivalent resistance = R

Resistors are connected in parallel.

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

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500} \quad \Rightarrow \quad \frac{1}{R} = \frac{5 + 10 + 1}{500}$$

$$\frac{1}{R} = \frac{16}{500} = \frac{4}{125} \quad \Rightarrow \quad R = \frac{125}{4}\ \Omega$$

Current through all the three appliances, $I = \dfrac{V}{R} = \dfrac{220 \times 4}{125} = 7.04$ A

Since the electric iron connected to the same source that takes as much current as all the three appliances. So

Resistance of the electric iron $= \dfrac{125}{4}\ \Omega = 31.25\ \Omega$

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

Q. 16. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

Ans. (*i*) In parallel circuit, if one electrical appliance stops working due to some defect, then all other appliances keep working normally. In series circuit, if one electrical appliance stops working due to some defect, then all other appliances also stop working.

(*ii*) In parallel circuits, each electrical appliance gets the same voltage as that of the power supply line. In series circuit, appliances do not get the same voltage as that of the power supply line.

(*iii*) In the parallel connection of electrical appliances, the overall resistance of the household circuit is reduced due to which the current from the power supply is high. In the series connection, the overall resistance of the circuit increases too much due to which the current from the power supply is low.

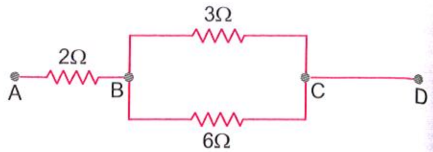
Q. 17. How can three resistors of resistance 2 Ω, 3 Ω and 6 Ω be connected to give a total resistance of (*i*) 4 Ω, (*ii*) 1 Ω?

Ans. (*i*) As the total resistance (equivalent resistance) is 4 Ω, the 6 Ω resistor cannot be in series. So, it must be in parallel with some other resistors.

In parallel connection, the equivalent resistance (4 Ω) has to be less than all the resistances.

So, the resistors of 2 Ω and 3 Ω cannot be in parallel at one time with 6 Ω.

So, the resistors have to be in a mixed combination. Let us consider the combination shown in the figure.



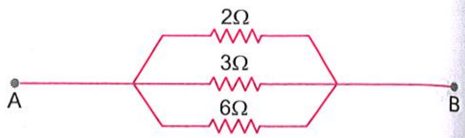
The equivalent resistance between B and C (which are in parallel)

$$= \frac{3\Omega \times 6\Omega}{3\Omega + 6\Omega} = \frac{18\Omega}{9\Omega} = 2\Omega$$

The resistance between A and D = 2 Ω + 2 Ω = 4 Ω.

So, the combination shown in the figure is true.

(*ii*) Here, $R_1 = 2\Omega$, $R_2 = 3\Omega$, $R_3 = 6\Omega$ and $R = 1\Omega$



Since the equivalent resistance of the combination is of lesser value than any of the resistors of the combination, it is clear that the resistors should be connected in parallel. It can be further confirmed by using the formula

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{3+2+1}{6} = \frac{6}{6} = 1$$

i.e., $R = 1$ ohm.

Therefore, resistors should be connected in parallel.

Q. 18. What is (*i*) the highest, (*ii*) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

Ans. (*i*) The highest can be secured by series combination and is equal to

$$R = 4\,\Omega + 8\,\Omega + 12\,\Omega + 24\,\Omega = \mathbf{48\,\Omega}$$

(*ii*) The lowest total resistance can be secured by parallel combination, which is given by

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24} \Rightarrow \frac{1}{R} = \frac{6+3+2+1}{24}$$

$$\Rightarrow \frac{1}{R} = \frac{12}{24} = \frac{1}{2} \qquad \therefore \quad R = 2\,\Omega$$

Q. 19. Why does the cord of an electric heater not glow while the heating element does?

Ans. The cord of the electric heater is made of copper. It does not glow because negligible heat is produced in it by the passing current due to its extremely low resistance.

The heating element of an electric heater is made of nichrome. It glows because large amount of heat is produced in it by the passing electric current due to its high resistance.

Q. 20. Compute the heat generated while transferring 96,000 coulombs of charge in one hour through a potential difference of 50 V.

Ans. Here, Q = 96,000 C, t = 1 hour = 60 × 60 s and V = 50 V

$$\text{Current, } I = \frac{Q}{t} = \frac{96{,}000}{60 \times 60} = \frac{80}{3}\text{A}$$

$$\text{Resistance, } R = \frac{V}{I} = \frac{50 \times 3}{80} = \frac{15}{8}\Omega$$

$$\text{Heat produced, } H = I^2 Rt$$

$$= \frac{80}{3} \times \frac{80}{3} \times \frac{15}{8} \times 60 \times 60$$

$$= 4800000$$

$$= \mathbf{4800\ kJ}$$

Q. 21. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

Ans. Here, $R = 20\,\Omega$, $I = 5$ A, $t = 30$ s

Heat developed $= I^2 Rt$

$= 5 \times 5 \times 20 \times 30$

$= 15{,}000$ J = **15 kJ**

Q. 22. What determines the rate at which energy is delivered by a current?

Ans. Electric power.

Q. 23. An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

Ans. Power, $P = VI$

$= 220 \times 5 = 1100$ W = 1.1 kW

Energy consumed, $E = P \times t$

$= 1.1$ kW × 2 h = **2.2 kWh**

NCERT Exercises

Q. 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 $\frac{R}{R'}$ is:

(*a*) $\frac{1}{25}$ (*b*) $\frac{1}{5}$ (*c*) 15 (*d*) 25

Ans. Resistance of this wire, $R = \rho\frac{l}{A}$

Resistance of a piece of length $\frac{l}{5} = \rho\frac{l}{5A} = \frac{R}{5}$ $\qquad \left(\because R = \rho\frac{l}{A}\right)$

The equivalent resistance of the 5 wires in parallel is R' Then

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

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

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

$$\therefore \quad \frac{R}{R'} = 25$$

Hence, the correct answer is (*d*).

Q. 2. Which of the following terms does not represent electrical power in a circuit?

(*a*) I^2R (*b*) IR^2 (*c*) VI (*d*) $\frac{V^2}{R}$

Ans. (*b*) IR^2.

Q. 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

Ans. We have, $P = \frac{V^2}{R}$

or $100 = \frac{(220)^2}{R}$ ...(1)

Let power consumed be P' when operated on 110 V. Then

$$P' = \frac{(110)^2}{R} \quad ...(2)$$

From (1) and (2), we have

$$\frac{P'}{100} = \left(\frac{110}{220}\right)^2 \quad \text{or} \quad P' = \frac{1}{4} \times 100$$

or $P' = 25$ W

Hence, the correct answer is (*d*).

Q. 4. 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. The ratio of heat produced in series and parallel combination would be:

(*a*) 1 : 2 **(*b*) 2 : 1** **(*c*) 1 : 4** **(*d*) 4 : 1**

Ans. Suppose the resistance of each one of the two wires is R.

The equivalent resistance of the series combination,

$$R_s = R + R = 2R$$

The heat produced in time t,

$$H_1 = \frac{V^2}{2R}t \quad \left(\because H = \frac{V^2}{R}t\right) \quad ...(1)$$

The equivalent resistance of the parallel combination is

$$R_P = \frac{R \times R}{R + R} = \frac{R^2}{2R} = \frac{R}{2}$$

Heat produced in time t,

$$H_2 = \frac{V^2}{R/2}t = \frac{2V^2 t}{R} \quad ...(2)$$

From (1) and (2), we have

$$\frac{H_1}{H_2} = \frac{V^2 t}{2R} \times \frac{R}{2V^2 t} \Rightarrow \frac{H_1}{H_2} = \frac{1}{4}$$

$$H_1 : H_2 = 1 : 4$$

Thus, the correct answer is (*c*).

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

Ans. A voltmeter is always connected in parallel in the circuit to measure the potential difference between two points.

Q. 6. A copper wire has diameter 0.5 mm and resistivity of 1.6 × 10^{-8} Ω 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?

Ans. (*i*) Diameter, d = 0.5 mm

$$\text{Radius, } r = \frac{0.5}{2}\text{ mm} = 0.25\text{ mm} = \frac{0.25}{100}\text{ m} = 0.25 \times 10^{-3}\text{ m}$$

$$\text{Area of cross-section, } A = \pi r^2 = \frac{22}{7} \times (0.25 \times 10^{-3})^2 = 0.1964 \times 10^{-6}\text{ m}^2$$

Resistance, R = 10 Ω, Resistivity, ρ = 1.6 × 10^{-8} Ω m, Length, l = ?

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

$$l = \frac{RA}{\rho} = \frac{10 \times 0.1964 \times 10^{-6}}{1.6 \times 10^{-8}} = \frac{1964}{16} = 122.75\text{ m}$$

(*ii*) The area of cross-section, $A_1 = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$

Its resistance, $R_1 = \frac{\rho l}{A_1} = \frac{4\rho l}{\pi d^2}$ ...(1)

When the diameter is doubled, area of cross-section,

$$A_2 = \pi\left(\frac{2d}{2}\right)^2 = \pi d^2$$

Its resistance, $R_2 = \frac{\rho l}{A_2} = \frac{\rho l}{\pi d^2}$ ...(2)

From (1) and (2), we have

$$\frac{R_2}{R_1} = \frac{\rho l}{\pi d^2} \times \frac{\pi d^2}{4\rho l} = \frac{1}{4}$$

or $R_2 = \frac{1}{4}R_1$

Thus, on doubling the diameter, the area of cross-section becomes 4 times and the resistance becomes one-fourth.

Q. 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.

Ans. Resistance of resistor

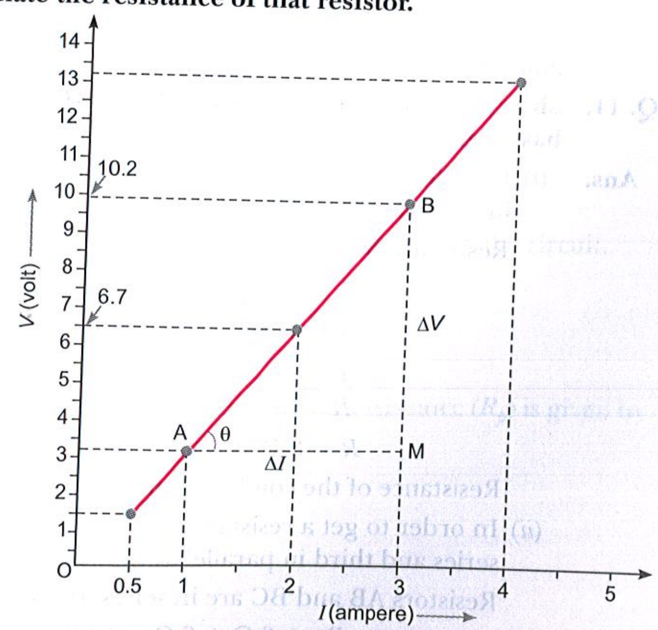
$$R = \frac{V}{I} = \text{slope of } V\text{-}I \text{ graph}$$

$$= \frac{\Delta V}{\Delta I} = \frac{BM}{AM}$$

$$= \frac{10.2 - 3.4}{3.0 - 1.0}$$

$$= \frac{6.8}{2.0}$$

$$= 3.4\ \Omega$$



Q. 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.

Ans. Potential difference, $V = 12$ V

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

We know that $V = IR$

or, $R = \frac{V}{I} = \frac{12}{2.5 \times 10^{-3}} = 4.8 \times 10^3\ \Omega = \mathbf{4.8\ k\Omega}$

Q. 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, resistor?

Ans. Resistors are connected in series.

So, equivalent resistance

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

Potential difference, $V = 9$ V

Current, through the circuit,

$$I = \frac{V}{R} = \frac{9}{13.4} = \mathbf{0.67\ A}$$

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

Ans. Current, $I = 5$ A

Potential difference, $V = 220$ V

Resistance of parallel circuit, $R = \frac{V}{I} = \frac{220}{5} = 44\ \Omega$

Let no. of resistors $= n$

In parallel, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots. + n$ times

$$\frac{1}{44} = \frac{1}{176} + \frac{1}{176} + \ldots. n \text{ times}$$

$$\frac{1}{44} = \frac{n}{176}$$

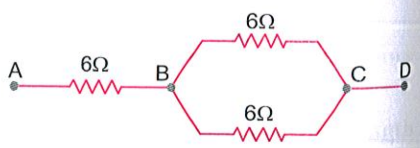
$$n = \frac{176}{44} \text{ or } n = 4$$

Number of required resistors = 4.

Q. 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.

Ans. (*i*) In order to get a resistance of 9 Ω, We connect the given resistors (each of resistance of 6 Ω) in the following way.

Resistance between B and C



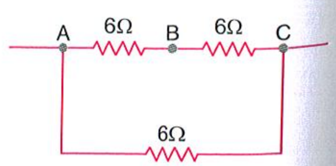
$$\frac{1}{R} = \frac{1}{6} + \frac{1}{6}$$

$$\frac{1}{R} = \frac{2}{6}$$

$$R = 3\ \Omega$$

Resistance of the combination $= 6\ \Omega + 3\ \Omega = 9\ \Omega$

(*ii*) In order to get a resistance of 4 Ω, we connect two resistors in series and third in parallel as shown in figure.



Resistors AB and BC are in series, therefore,

$$R_S = 6\ \Omega + 6\ \Omega = 12\ \Omega$$

Now, R_s is parallel with the third (6Ω).

∴ Equivalent resistance of combination (R_p) is given by

$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{12} = \frac{2+1}{12}$$

$$\frac{1}{R_p} = \frac{3}{12} = \frac{1}{4}$$

$$R_p = 4\ \Omega$$

Q. 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?

Ans. Potential difference, $V = 220$ V

Power of each bulb, $P = 10$ W

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

Total resistance in the circuit,

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

Let n be the number of bulbs to be connected in parallel to obtain resistance R'.

$$\frac{1}{R'} = \frac{1}{R} + \frac{1}{R} + \ldots. n \text{ times}$$

$$\frac{1}{R'} = \frac{n}{R}$$

$$n = \frac{R}{R'} = \frac{4840}{44} = \mathbf{110}$$

Required number of bulbs = 110

Q. 13. 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. Potential difference, $V = 220$ V

Resistance of each coil, $R = 24\ \Omega$

Case I: When coils A and B are used separately, current through each coil,

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

Case II: When coils A and B are connected in series, the equivalent resistance in the circuit.

$$R_s = 24 + 24 = 48\ \Omega$$

$$\text{Current, } I = \frac{V}{R_S} = \frac{220}{48} = 4.6\ \text{A}$$

Case III: When coils A and B are connected in parallel, the equivalent resistance (R_p) is given by

$$\frac{1}{R_p} = \frac{1}{24} + \frac{1}{24} = \frac{2}{24}$$

$$R_P = 12\ \Omega$$

$$\text{Current, } I = \frac{V}{R_p} = \frac{220}{12} = \mathbf{18.3\ A}$$

Q. 14. 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 12Ω and 2 Ω resistors.

Ans. (*i*) Equivalent resistance of 1 Ω and 2 Ω in series, R = 1 Ω + 2 Ω = 3 Ω

Potential difference, $V = 6$ V

Current, $I = \frac{V}{R} = \frac{6}{3} = 2A$

Current in series circuit is same.

∴ Current in 2 Ω resistor = 2 A

Power in 2 Ω resistor, $P = I^2 R = 2^2 \times 2 = 8$ W

(*ii*) Potential difference across 2 Ω resistor = 4 V

$$\text{Power, } P' = \frac{V^2}{R} = \frac{4^2}{2} = 8 \text{ W}$$

$P : P' = 8 \text{ W} : 8 \text{ W} = \mathbf{1 : 1}$

Q. 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?

Ans. We know that $P = \frac{V^2}{R}$

∴ $R = \frac{V^2}{P}$

Resistance of 1st lamp,

$$R_1 = \frac{V^2}{P} = \frac{220 \times 220}{100} = 484 \ \Omega$$

Resistance of 2nd lamp,

$$R_2 = \frac{220 \times 220}{60} = \frac{2420}{3} \ \Omega$$

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

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

$$= \frac{1}{484} + \frac{3}{2420} = \frac{8}{2420}$$

$$R = \frac{2420}{8} \ \Omega$$

Current drawn from the line

$$I = \frac{V}{R} = \frac{220 \times 8}{2420} = \mathbf{0.73 \ A}$$

Q. 16. Which uses more energy, a 250 W TV set in 1 h or a 1200 W toaster in 10 minutes?

Ans. Energy used by TV set

$$E_1 = P \times t$$

$$= 250 \text{ W} \times 1\text{h} = 250 \text{ Wh}$$

Energy used by toaster,

$$E_2 = P \times t$$

$$= 1200 \times \frac{10}{60} = 200 \text{ Wh}$$

Thus, TV set in one hour uses more energy than the toaster uses in 10 minutes.

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

Ans. Here, $R = 8 \ \Omega$

$I = 15$ A

The rate at which heat is developed is power, $P = I^2 R$

$$\text{Power} = \frac{\text{Heat developed } (I^2Rt)}{\text{Time taken } (t)}$$

$$= 15 \times 15 \times 8 = \mathbf{1800 \ J/s.}$$

Q. 18. Explain the following:

(*i*) Why is the tungsten used almost exclusively for filament of electric lamp?

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

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

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

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

Ans. (*i*) Pure tungsten has a high resistivity and a high melting point (nearly 3000°C). When an electric current is passed through the filament, the electric energy is converted to heat and light energy due to the heating of the filament to a very high temperature. Due to the high melting point of tungsten, the filament does not melt.

(*ii*) The resistivity of an alloy is generally higher than that of its constituent metals. Alloys do not oxidise (burn) readily at higher temperatures. Therefore, conductors of electric heating devices, such as toasters and electric irons, are made of an alloy rather than pure metal.

(*iii*) The series arrangement is not used for domestic circuits because:

(*a*) if connected in series total resistances will increase. Therefore, current flowing through the circuit will be low.

(*b*) if one appliance is switched off or gets damaged than all other appliances will also stop working because their electricity supply will be cut off.

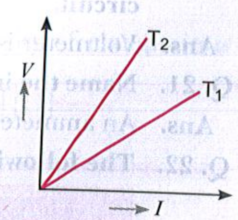
(*iv*) The resistance of a wire is inversely proportional to its cross-sectional area. Thus, a thick wire has less resistance, and a thin wire has more resistance.

(*v*) Copper and aluminium wires are usually employed for electricity transmission because copper and aluminium have very low resistivities.

VERY SHORT ANSWER QUESTIONS [1 mark]

Q. 1. The voltage-current (*V-I*) graph of a metallic conductor at two different temperatures T_1 and T_2 is shown in figure. At which temperature is the resistance higher?

Ans. At T_2.



Q. 2. Why is resistance less when resistors are joined in parallel?

Ans. We know that $R \propto \frac{1}{A}$

In parallel combination of resistors, the effective area of cross-section of the conductor increases, so the resistance decreases.

Q. 3. Why is resistance more in series combination?

Ans. We know $R \propto l$. In series combination of resistors, the effective length of the conductor increases, so the resistance increases.

Q. 4. **What are the special features of a heating wire?**

Ans. It must have high specific resistance and high melting point.

Q. 5. **What is the resistance of an ideal ammeter?**

Ans. Zero.

Q. 6. **What is the resistance of an ideal voltmeter?**

Ans. Infinite.

Q. 7. **Which one has more resistance 100 watt bulb or 60 watt bulb both operating at 220 V?**

Ans. The resistance of 60 watt bulb is greater than the resistance of 100 watt bulb.

Q. 8. **Write the expression for the heat energy produced in a wire of resistance *R* and carrying current *I*.**

Ans. Heat produced, $H = I^2 Rt$, where '*t*' stands for time, for which current *I* is passed through the conductor.

Q. 9. **Name the physical quantity whose unit is J/C.**

Ans. Electric potential.

Q. 10. **What is the resistance of an air gap?**

Ans. It is very large, almost infinite.

Q. 11. **What is the commercial unit of electric energy?**

Ans. The commercial unit of electric energy is kilowatt hour (kWh).

Q. 12. **What happens to the resistance of a wire if it is made thinner?**

Ans. The resistance of wire increases.

Q. 13. **In series combination which remains constant—current or voltage?**

Ans. Current.

Q. 14. **Which substance is used for making resistance coil of electric heater and why?**

Ans. Nichrome, due to its high resistivity.

Q. 15. **Which physical quantity remains constant when resistances are connected in parallel?**

Ans. Potential difference (voltage) remains constant.

Q. 16. **How is the ammeter connected in the circuit?**

Ans. An ammeter is connected in series in the circuit.

Q. 17. **Why is an ammeter connected in series in an electric circuit?**

Ans. It is connected in series so that whole of the electric current, which it has to measure, passes through it.

Q. 18. **Name two devices in which electricity is converted into heat.**

Ans. Electric heater and electric iron.

Q. 19. **Name the alloy which is used for making the filament of bulbs.**

Ans. Tungsten.

Q. 20. **Name the instrument used for measuring potential difference between two points in an electric circuit.**

Ans. Voltmeter is used for measuring potential difference.

Q. 21. **Name the instrument used for measuring electric current flowing in an electric circuit.**

Ans. An ammeter.

Q. 22. **The following table gives the value of electrical resistivity of some materials:**

Material	Copper	Silver	Constantan
Electrical resistivity (in Ω m)	1.62×10^{-8}	1.6×10^{-8}	49×10^{-6}

Which one of these materials is the best conductor of electricity?

Ans. Out of these three, silver has the lowest resistivity. Hence, silver is the best conductor of electricity.

SHORT ANSWER QUESTIONS–I [2 marks]

Q. 1. **Why does resistance of a metallic conductor increase with increase in temperature?**

Ans. When a metallic conductor is heated, the atoms in the metal vibrate with greater amplitude and frequency. Due to increase in temperature, the thermal velocities of free electrons also increases. Therefore, the number of collisions between free electrons and atoms increases. This increases the opposition to the movement of electrons and hence the resistance of the conductor.

Q. 2. **Why is it not advisable to handle high voltage electrical circuit with wet hands?**

Ans. The resistance of dry-skin human body is about 50,000 Ω. When the skin is wet, the resistance gets lowered to about 10,000 Ω. If a person with wet hands touches the electrical circuit, high current will flow through the body causing risk to life.

Q. 3. **Should the resistance of an ammeter be low or high? Give reason.** *[NCERT Exemplar]*

Ans. It should be as close to zero as possible. Ideally it should be zero ohm. If it is non-zero and substantial it will affect the true current.

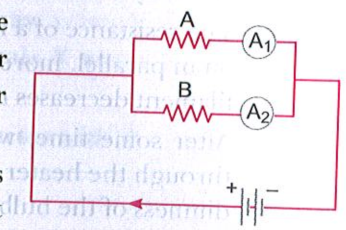
Q. 4. **Though the same current flows through line wires or the filament of a bulb, yet only the latter glows. Why?**

Ans. The filament of electric lamp has high resistance whereas the line wires are of negligible resistance. Since amount of heat generated is proportional to the resistance, the filament generates much more heat and it starts glowing.

Q. 5. **Heat is generated continuously in an electric heater but the temperature of its element becomes constant after some time. Why?**

Ans. When the temperature of the heater becomes greater than the temperature of the surrounding, some of the heat is lost to the surroundings in the form of thermal radiations. After some time, rate at which heat is being produced becomes equal to the rate at which heat is lost. Hence, the temperature of the element becomes constant.

Q. 6. **In the given circuit diagram, two resistance wires A and B are of same area of cross-section and same material, but A is longer than B. Which ammeter A_1 or A_2 will indicate higher reading for current? Give reason.**



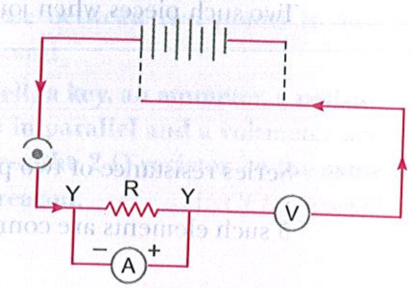
Ans. Ammeter A_2 shows higher reading. Since wire A_1 is longer, it has greater resistance and so draws lesser current. So more current flows through B and A_2 shows higher reading.

Q. 7. **Two wires of equal length, one of copper and the other of manganin (an alloy) have the same thickness. Which one can be used for (*i*) electrical transmission lines (*ii*) electrical heating devices? Why?**

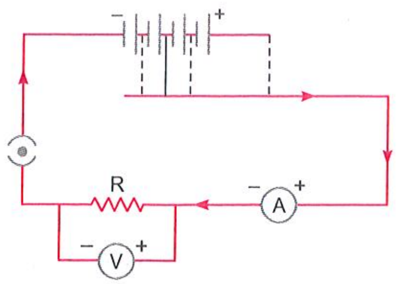
Ans. (*i*) Copper wire can be used for electrical transmission lines because copper has very low resistivity and hence it is very good conductor of electricity.

(*ii*) Manganin can be used for electrical heating devices because the resistivity of manganin is about 25 times more than that of copper and hence it produces a lot of heat on passage of current through it.

Q. 8. **A student has drawn the electric circuit to study Ohm's law as shown in figure. His teacher told that the circuit diagram needs correction. Study the circuit diagram and redraw it after making all corrections.** *[NCERT Exemplar]*



Ans.



Q. 9. What is electrical resistivity? In a series electrical circuit comprising of a resistor having a metallic wire, the ammeter reads 5 A. The reading of the ammeter decreases to half when the length of the wire is doubled. Why? *[NCERT Exemplar]*

Ans. The resistivity of a material is defined as the resistance of a conductor made of that material of unit length and unit cross-sectional area.

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

Also, $$V = RI$$

R is doubled while V remains unchanged. Hence, current becomes half.

Q. 10. How does use of a fuse wire protect electrical appliances? *[NCERT Exemplar]*

Ans. If a current larger than a specified value flows in a circuit, temperature of fuse wire increases to its melting point. The fuse wire melts and the circuit breaks.

SHORT ANSWER QUESTIONS–II [3 marks]

Q. 1. Why does an electric bulb become dim when an electric heater in parallel circuit is switched on? Why does dimness decrease after sometime?

Ans. The resistance of a heater coil is less than that of electric bulb filament. When heater is switched on in parallel, more current start flowing through the heater coil and current through the bulb filament decreases making it dim.

After some time, when heater coil becomes hot its resistance increases. As a result, current through the heater coil decreases and the current through the bulb filament increases and thus dimness of the bulb decreases.

Q. 2. A metallic wire of resistance R is cut into ten parts of equal length. Two pieces each are joined in series and then five such combinations are joined in parallel. What will be the effective resistance of the combination?

Ans. The resistance of a conductor is directly proportional to the length of the conductor. The resistance of the metallic wire, when it is cut into ten parts of equal length is

$$r = \frac{R}{10}$$

Two such pieces when joined in series, the equivalent resistance of these two parts

$$= r + r = 2r = \frac{2R}{10}.$$

$$\text{Series resistance of two parts} = 2 \times \frac{R}{10} = \frac{R}{5}$$

5 such elements are connected in parallel. Therefore the total resistance R' will be

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

Hence $$R' = \frac{R}{25}$$

Q. 3. A wire of length l and resistance R is stretched so that its length is doubled and the area of cross-section is halved. How will its:

(a) resistance change?

(b) resistivity change?

Justify your answer in each case.

Ans. (*a*) Here, length is doubled and area of cross-section is halved. Thus, a wire of length l and area of cross-section A becomes a wire of length $2l$ and area of cross-section $\frac{A}{2}$.

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

New resistance, $$R_1 = \rho\frac{2l}{A/2}$$

$$R_1 = \frac{4\rho l}{A} = 4 \times R$$

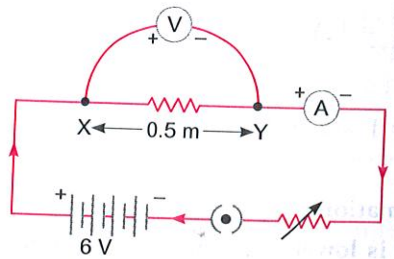
i.e., resistance becomes four times

(*b*) Resistivity of a substance does not depend on its length or area of cross-section. It depends on the nature of the material and temperature. Hence there is no change.

Q. 4. (*a*) The components of an electric circuit are 0.5 m long nichrome wire XY, an ammeter, a voltmeter, four cells of 1.5 V each, rheostat and a plug key. Draw a circuit diagram to study the relation between potential difference across the terminals X and Y of the wire and current flowing through it.

(*b*) State the law that relates potential difference across a conductor with the current flowing through it.

Ans. (*a*)

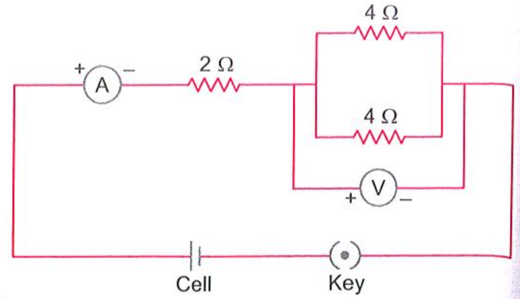


(*b*) Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference across the two points.

Q. 5. Draw a circuit diagram of an electric circuit containing a cell, a key, an ammeter, a resistor of 2 Ω in series with a combination of two resistors (4 Ω each) in parallel and a voltmeter across the parallel combination. Will the potential difference across the 2 Ω resistor be the same as that across the parallel combination of 4 Ω resistors? Give reason. *[NCERT Exemplar]*

Ans. The circuit is shown in figure. Effective resistance of combination of two resistors (4 Ω each) in parallel is

$$R_{eq} = \frac{4 \times 4}{4+4} = 2\ \Omega$$



Since the resistor of 2 Ω and parallel combination of two 4 Ω resistors are in series, same current will flow through these. Hence, the potential difference across 2 Ω resistor is same as that across combination of two resistors.

Q. 6. Three incandescent bulbs of 100 W each are connected in series in an electrical circuit. In another circuit another set of three bulbs of the same wattage are connected in parallel to the same source.

(a) Will the bulb in the two circuits glow with the same brightness? Justify your answer.

(b) Now let one bulb in both the circuits get fused. Will the rest of the bulbs continue to glow in each circuit? Give reason. *[NCERT Exemplar]*

Ans. (a) No.

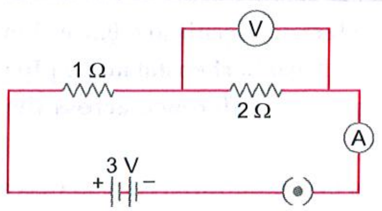
Reasons: Let R be the resistance of each bulb, then total resistance in series = $3R$

In series, current in each bulb is same.

So current drawn by each bulb connected in series is one-third as compared to the current in each bulb in parallel arrangement, so the bulbs connected in parallel combination glow more brightly.

(b) In series arrangement, if one bulb is fused; then current in the bulbs connected in series will become zero, so bulbs will stop glowing. In parallel arrangement, if one bulb is fused, the other two bulbs will continue to glow with same brightness.

Q. 7. What would be the reading of ammeter and voltmeter in the given circuit?



Ans. $R = R_1 + R_2 = 1 + 2 = 3\ \Omega$

$$I = \frac{V}{R} = \frac{3}{3} = 1\ \text{A}$$

Ammeter reading = 1 A

Voltmeter reading = $IR = 1 \times 2 = 2$ V

Voltmeter reading = 2 V

Q. 8. Read the following information:

(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, 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.

Ans. (a) Wire C has maximum resistance because it has maximum length, least thickness and highest resistivity.

(b) Wire F has the minimum resistance since it has least length, maximum thickness and least resistivity. (Using $R = \rho\frac{l}{A}$)

(c) $R_3 > R_5 > R_1$ (Using relation $R = \rho\frac{l}{A}$ and comparing)

LONG ANSWER QUESTIONS [5 marks]

Q. 1. (i) The potential difference between two points in an electric circuit is 1 volt. 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 below:

Silver	$1.60 \times 10^{-8}\ \Omega$ m
Copper	$1.62 \times 10^{-8}\ \Omega$ m
Tungsten	$5.2 \times 10^{-8}\ \Omega$ m
Iron	$10.0 \times 10^{-8}\ \Omega$ m
Mercury	$94.0 \times 10^{-8}\ \Omega$ m
Nichrome	$100 \times 10^{-6}\ \Omega$ m

Answer the following questions using above data:

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

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

Ans. (i) The potential difference between two points is 1 volt means that if a charge of 1 coulomb is moved from one point to the other, 1 joule of work is required.

The potential difference across a conductor is measured by means of an instrument called voltmeter.

(ii) The electric power P is given by

$$P = I^2R$$

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.

(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.

Q. 2. (a) Name an instrument that measures electric current in a circuit. Define the unit of electric current.

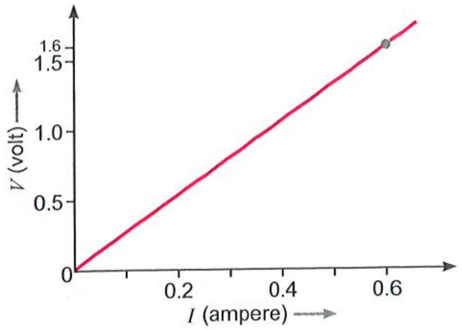
(b) What do the following symbols represent in a circuit diagram?

(i)  (ii) 

(c) An electric circuit consisting of a 0.5 m long nichrome wire XY, an ammeter, a voltmeter, four cells of 1.5 V each and a plug key was set up.

(i) Draw the electric circuit diagram to study the relation between the potential difference maintained between the points 'X' and 'Y' and the electric current flowing through XY.

(ii) Following graph was plotted between V and I values using above circuit:



What would be the values of $\frac{V}{I}$ ratios when the potential difference is 0.8 V, 1.2 V and 1.6 V respectively? What conclusion do you draw from these values?

Ans. (a) An instrument that measures electric current in a circuit is called "ammeter".

The unit of electric current is ampere (A). 1 ampere is constituted by the flow of 1 coulomb of charge through any point in an electric circuit in 1 second.

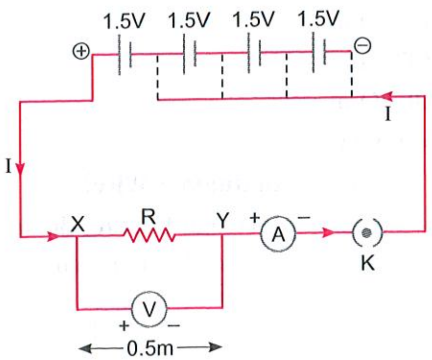
(i) 

Variable resistance or rheostat

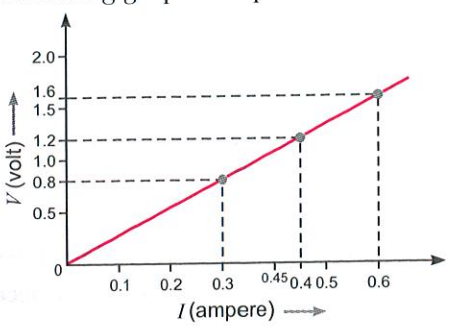
(ii) 

Plug key or switch (closed)

(c) (i)



(ii) Following graph was plotted between V and I values.



At potential difference 0.8V,

$$\frac{V}{I} = \frac{0.8}{0.3} = \frac{8}{3} \quad ...(1)$$

At potential difference 1.2 V,

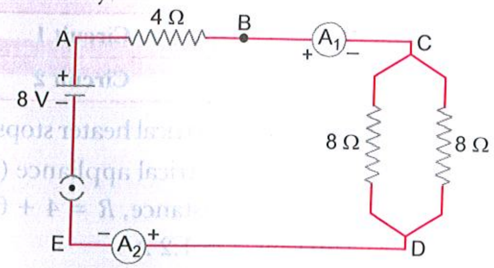
$$\frac{V}{I} = \frac{1.2}{0.45} = \frac{8}{3} \quad ...(2)$$

At potential difference 1.6 V, $\frac{V}{I} = \frac{1.6}{0.6} = \frac{8}{3}$ ...(3)

Conclusion: If I be the current through XY resistor and V be the potential difference across it, then the ratio $\frac{V}{I}$ = constant.

$\Rightarrow$ $V \propto I$ and Ohm's law is obeyed.

Q. 3. Find out the following in the electric circuit given in figure alongside:



(a) Effective resistance of two 8 Ω resistors in the combination

(b) Current flowing through 4 Ω resistor

(c) Potential difference across 4 Ω resistance

(d) Power dissipated in 4 Ω resistor

(e) Difference in ammeter readings, if any

[NCERT Exemplar]

Ans. (a) $R = \frac{R_1 R_2}{R_1 + R_2} = \left(\frac{8 \times 8}{8+8}\right) = 4\,\Omega$

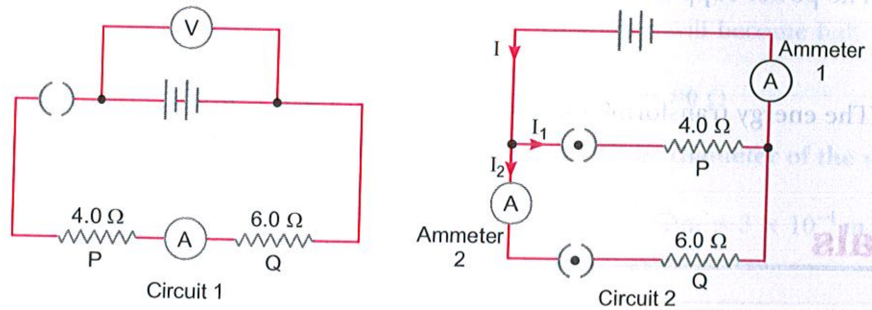
(b) $I = \frac{V}{R} = \frac{8}{4 + \left(\frac{8 \times 8}{8+8}\right)} = \frac{8}{8} = 1\text{A}$

(c) $V = IR = 1 \times 4 = 4\text{V}$

(d) $P = I^2R = 1^2 \times 4 = 4\text{W}$

(e) No difference, same current flows through each ammeter in the given circuit.

Q. 4. Figure shows two electrical circuits.



The batteries in circuit 1 and circuit 2 are identical.

(a) Put ticks in the table below to describe the connections of the two resistors P and Q.

	Series	Parallel
Circuit 1		
Circuit 2		

(b) The resistors P and Q are used as small electrical heaters. State two advantages of connecting them as shown in circuit 2.

(c) In circuit 1, the ammeter reads 1.2A when the switch is closed. Calculate the reading of the voltmeter in this circuit.

(*d*) **The two switches in circuit 2 are closed. Calculate the combined resistance of the two resistors in this circuit.**

(*e*) **When the switches are closed in circuit 2, ammeter 1 reads 5 A and ammeter 2 reads 2A.**

Calculate

(*i*) **the current in resistor P,**

(*ii*) **the power supplied to resistor Q,**

(*iii*) **the energy transformed in resistor Q in 300s.**

Ans. (*a*)

	Series	Parallel
Circuit 1	✓	
Circuit 2		✓

(*b*) (*i*) If one electrical heater stops working due to some defect then other keeps working normally.

(*ii*) Each electrical appliance (heater) gets the same voltage as that of the power supply line.

(*c*) Effective resistance, $R = 4 + 6 = 10\ \Omega$

Current, $I = 1.2$ A

$V = IR = 1.2 \times 10 = 12$ V

Voltmeter reading = 12 V

(*d*) Combined resistance,

$$R_p = \frac{R_1R_2}{R_1+R_2} = \frac{4\times6}{4+6} = \frac{24}{10} = 2.4\ \Omega$$

(*e*) Current I = 5A

$I_2 = 2$ A

(*i*) The current in resistor $P = I_1 = I - I_2$

$= 5\text{A} - 2\text{A}$

$= 3\text{A}$

(*ii*) The power supplied to resistor $Q = VI$

$= 12 \times 2$

$= 24\text{W}$

(*iii*) The energy transformed in resistor Q in 300 s $= E = P \times t$

$= 24 \times 300 \text{ s} = 7200$ J

Numericals

CURRENT AND POTENTIAL DIFFERENCE

Q. 1. A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through any point of the circuit.

Ans. It is given, $I = 0.5$ A; $t = 10$ min = 600 s.

We know that, $Q = It$

$= 0.5 \text{ A} \times 600 \text{ s} = \mathbf{300\ C}$

Q. 2. A current of 5 A is flowing through a resistor of 15 Ω. Calculate the potential difference between the ends of the resistor.

Ans. Given, Resistance (R) = 15 ohms,

Current (I) = 5 amperes,

Potential difference (V) according to Ohm's law

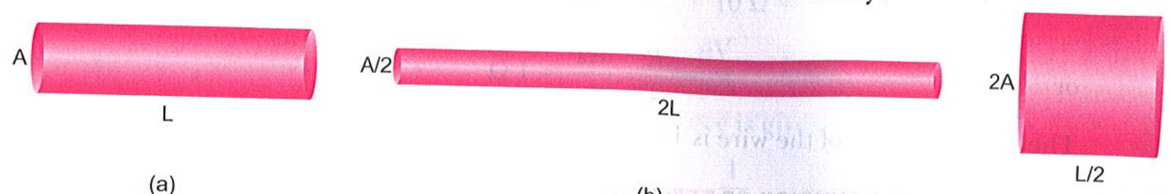
$V = IR$

$\Rightarrow$ $V = 5 \times 15 = 75$ volt

$\therefore$ $V = \mathbf{75\ volt}$

RESISTANCE AND RESISTIVITY

Q. 3. Figure (*a*), (*b*) and (*c*) show three cylindrical copper conductors alongwith their face areas and length. Which of the conductors will have highest resistance and why?



(a) (b) (c)

Ans. (*i*) $R_a = \rho\frac{l}{A}$

(*ii*) $R_b = \rho\left(\frac{2L}{A/2}\right) = \rho\left(\frac{4L}{A}\right) = 4R_a$

(*iii*) $R_c = \rho\left(\frac{L}{2(2A)}\right) = \frac{1}{4}\rho\left(\frac{L}{A}\right) = \frac{1}{4}R_a$

Hence, $R_b > R_a > R_c$. Thus, the conductor ***(b)*** will have the highest resistance.

Q. 4. A piece of wire of resistance 20 Ω is drawn out so that its length is increased to twice its original length. Calculate the resistance of the wire in the new situation.

Ans. Suppose the length of $R_1 = 20\ \Omega$ resistance wire is l, its area of cross-section is A and its resistivity is ρ. Then,

$$R_1 = \frac{\rho l}{A} = 20\ \Omega$$

When length becomes twice ($2l$), then its area of cross-section will become half $\left(\frac{A}{2}\right)$. The new resistance

$$R_2 = \frac{\rho\cdot 2l}{A/2} \quad\Rightarrow\quad R_2 = 4\frac{\rho l}{A} = 4 \times 20 = \mathbf{80\ \Omega}$$

Q. 5. Resistance of a metal wire of length 1 m is 26 Ω at 20°C. If the diameter of the wire is 0.3 mm, what will be the resistivity of the metal at that temperature?

Ans. Given the resistance of the wire $R = 26\ \Omega$ the diameter $d = 0.3$ mm $= 3 \times 10^{-4}$ m and the length of the wire $l = 1$ m.

The resistivity of the given metallic wire is

$$\rho = \frac{RA}{l} = \frac{R\pi d^2}{4l}$$

$$= \frac{26\times22\times3\times10^{-4}\times3\times10^{-4}}{7\times4\times1} = 183.857 \times 10^{-8}$$

$$= \mathbf{1.84 \times 10^{-6}\ \Omega\ m}$$

The resistivity of the metal at 20°C is $1.84 \times 10^{-6}\ \Omega$ m.

Q. 6. A 4 Ω resistance wire is doubled on it. Calculate the new resistance of the wire.

Ans. We are given, $R = 4\ \Omega$

When a wire is doubled on it, its length would become half and area of cross-section would be doubled. That is, a wire of length l becomes $\frac{l}{2}$ and area of cross-section $2A$.

We know that

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

$$R_1 = \rho\frac{l/2}{2A}, \quad \text{where } R_1 \text{ is the new resistance.}$$

Therefore,

$$\frac{R_1}{R} = \frac{\rho\frac{l/2}{2A}}{\rho\frac{l}{A}} = \frac{1}{4}$$

or

$$R_1 = \frac{R}{4} = \frac{4\Omega}{4} = \mathbf{1\ \Omega}$$

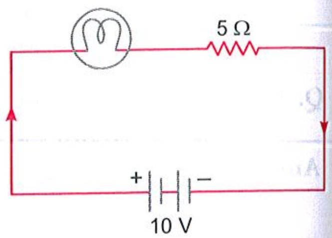
The new resistance of the wire is 1 Ω.

SERIES AND PARALLEL COMBINATION OF RESISTORS

Q. 7. A current of 1 ampere 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.

Now if a resistance of 10 Ω is connected in parallel with this series combination, what change (if any) in current flowing through 5 Ω conductor and potential difference across the lamp will take place? Give reason. *[NCERT Exemplar]*

Ans. (*i*) Let the resistance of the lamp = R_1



Resistance of conductor = R_2 = 5 Ω

Total resistance in series, $R_S = R_1 + R_2$

$= R_1 + 5$

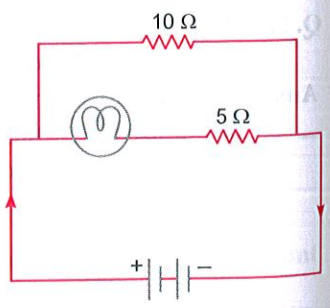
Current I = 1 A, Voltage, V = 10 V

Using Ohm's Law, $V = IR$

$10 = 1(R_1 + 5)$

⇒ $R_1 = \mathbf{5\ \Omega}$

(*ii*) Now, a resistance of 10 Ω is connected in parallel with the series combination. Therefore, the total resistance of the circuit is given by



$$\frac{1}{R_P} = \frac{1}{R_1 + 5} + \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{R_P} = \frac{1}{10} + \frac{1}{10}$$

$$\Rightarrow \quad R_P = 5\ \Omega$$

Hence, current flowing in the circuit,

$$I = \frac{V}{R} = \frac{10}{5} = \mathbf{2A}$$

Thus, 1 A current will flow through 10 Ω resistor and 1 A will flow through the lamp and conductor of 5 Ω resistance. Hence, there will be no change in current flowing through 5 Ω conductor. Also, there will be no change in potential difference across the lamp.

Q. 8. Two resistors, with resistances 5 Ω and 10 Ω respectively are to be connected to a battery of emf 6V so as to obtain:

(*i*) minimum current

(*ii*) maximum current

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

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

Ans. (*a*) (*i*) For obtaining minimum current, the two resistors should be connected in series.

(*ii*) For obtaining maximum current, the two resistors should be connected in parallel.

(*b*) (*i*) Given, R_1 = 5 Ω, R_2 = 10 Ω and V = 6 V

For series arrangement, the equivalent resistance,

$$R = R_1 + R_2$$

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

$$I = \frac{V}{R} = \frac{6V}{15\Omega} = \mathbf{0.4\ A}$$

(*ii*) For parallel arrangement, the equivalent resistance is given by

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

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

$$\Rightarrow \quad R = \frac{10}{3}\ \Omega$$

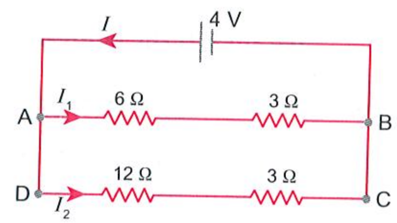
$$\therefore \quad I = \frac{V}{R} = \frac{6 \times 3}{10} = \mathbf{1.8\ A}$$

Q. 9. For the circuit shown in the given diagram:

What is the value of

(*i*) current through 6 Ω resistor?

(*ii*) potential difference across 12 Ω resistor?



Ans. Let the current through the circuit be I which is divided into I_1 and I_2 in the arms AB and CD respectively, then we have

$$I = I_1 + I_2$$

In the arm AB, the total resistance is

$$R_1 = 6\ \Omega + 3\ \Omega = 9\ \Omega$$

and the total resistance in the arm CD is

$$R_2 = 12\ \Omega + 3\ \Omega = 15\ \Omega$$

(*i*) Then current in the 6 Ω resistor *i.e.*,

$$I_1 = \frac{V}{R_1} = \frac{4}{9} = 0.44\ \text{A}$$

(*ii*) Now the current through CD is

$$I_2 = \frac{V}{R_2} = \frac{4}{15} = 0.27\ \text{A}$$

The potential difference across 12 Ω resistor is

⇒ $V_1 = I_2 \times 12\ \Omega$

∴ $V_1 = 0.27 \times 12$

$= \mathbf{3.24\ V}$

Q. 10. Two resistances when connected in parallel give resultant value of 2 ohm, when connected in series the value becomes 9 ohm. Calculate the value of each resistance.

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

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

Given, $R_P = 2\ \Omega$

$$2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$2(R_1 + R_2) = R_1 R_2 \quad \ldots(1)$$

Now, same resistances are in series

$$R_S = R_1 + R_2$$

Given, $R_S = 9$ ohm

$$9 = R_1 + R_2 \quad \ldots(2)$$

From (1) and (2), we get

$$R_1 R_2 = 18$$

Again using (2), we have

$$R_2 = 9 - R_1$$

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

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

$\Rightarrow$ $R_1^2 - 6R_1 - 3R_1 + 18 = 0$

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

Either $R_1 = 6$ or $R_1 = 3$

$R_2 = \mathbf{3\ \Omega}$ or $R_2 = \mathbf{6\ \Omega}$

Thus two resistances are 3 Ω and 6 Ω.

Q. 11. 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 find the ratio $\frac{R}{R'}$.

Ans. Resistance of a piece of length $\frac{l}{5} = \frac{R}{5}$

The equivalent resistance of the 5 wires in parallel is R'. Then

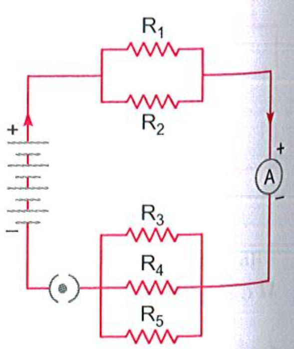
$$\frac{1}{R'} = \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5}$$

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

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

$$\therefore \quad \frac{R}{R'} = \mathbf{25}$$

Q. 12. If in the figure $R_1 = 10\ \Omega$, $R_2 = 40\ \Omega$, $R_3 = 30\ \Omega$, $R_4 = 20\ \Omega$, $R_5 = 60\ \Omega$, and a 12 V battery is connected to the arrangement, calculate (*i*) the total resistance in the circuit and (*ii*) the total current flowing in the circuit.



Ans. (*i*) Let the equivalent resistance of parallel resistors R_1 and $R_2 = R'$

The equivalent resistance of parallel resistors R_3, R_4 and $R_5 = R''$

Then, we have

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

$$\Rightarrow \quad \frac{1}{R'} = \frac{1}{10} + \frac{1}{40} = \frac{4+1}{40} = \frac{5}{40}$$

$$\Rightarrow \quad R' = 8\ \Omega$$

Similarly,

$$\frac{1}{R''} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

$$\Rightarrow \quad \frac{1}{R''} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60} = \frac{6}{60}$$

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

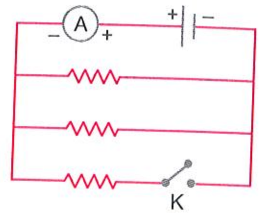
Thus, the total resistance

$$R = R' + R'' = 8\ \Omega + 10\ \Omega = 18\ \Omega$$

(*ii*) According to Ohm's law

$$I = \frac{V}{R} = \frac{12V}{18\Omega} = \mathbf{0.67\ A}$$

Q. 13. In the given circuit diagram, the cell and the ammeter, both have negligible resistance. The resistances are identical. With the switch K open, the ammeter reads 0.6 A. What will be the ammeter reading when the switch is closed?

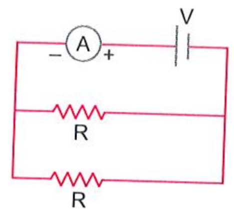


Ans. Let the value of each resistance be 'R'.

(*i*) When key 'K' is open the only two resistance are in circuit so resultant resistance in this case is parallel combination of two resistances.

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$$

$$\Rightarrow \quad R_1 = \frac{R}{2}$$



Let potential difference of cell = V volt

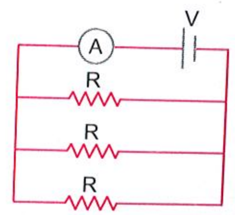
Current $I = 0.6$ A (given)

$$\therefore \quad V = IR_1 = 0.6 \times \frac{R}{2} = 0.3R$$

(*ii*) Now, when key 'K' is closed, all three resistances are parallel in the circuit. Therefore,

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

$$\Rightarrow \quad R_2 = \frac{R}{3}$$



Using Ohm's law $\quad V = IR_2$

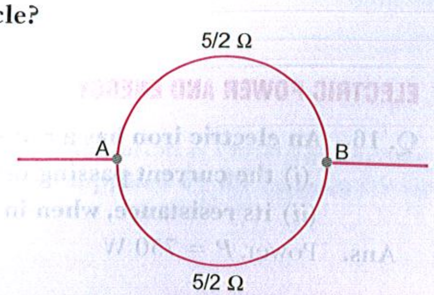
$$0.3R = I\left(\frac{R}{3}\right)$$

$$\Rightarrow \quad I = 0.3\ R \times \frac{3}{R} = \mathbf{0.9\ A}$$

Therefore, the ammeter reads 0.9 A.

Q. 14. A wire of resistance 5 ohms is bent in the form of a closed circle. What is the effective resistance between the two points at ends of any diameter of the circle?

Ans. The length of the wire between two points at the ends of a diameter of a circle is half of the whole wire. The resistance of a conductor is directly proportional to its length.



Thus, the two resistances $\frac{5}{2}$ Ω will be in parallel.

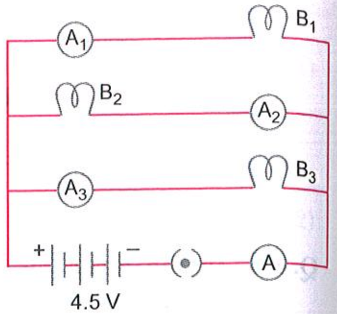
Let R is the effective resistance

$$\frac{1}{R} = \frac{2}{5} + \frac{2}{5}$$

$$\Rightarrow \quad \frac{1}{R} = \frac{4}{5}$$

$$\therefore \quad R = \frac{5}{4} = \mathbf{1.25\ \Omega}$$

Q. 15. B_1, B_2, B_3 are three identical bulbs connected as shown in figure. Ammeters A_1, A_2, A_3 are connected as shown. When all the bulbs glow, the current of 3A 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? [*NCERT Exemplar*]

Ans. 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

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

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

or, $$R = 3R_{eq} = 3 \times 1.5 = 4.5\ \Omega$$

Current in each bulb, $$I = \frac{V}{R} = \frac{4.5\ \text{V}}{4.5\ \Omega} = 1\ \text{A}$$

(*i*) When bulb B_1 gets fused, the currents in B_2 and B_3 remain same $I_2 = I_3 = 1A$, so their glow remains unaffected.

(*ii*) When bulb B_2 gets fused, the current in B_2 becomes zero and currents in B_1 and B_3 remains 1 A.

$$\text{Total current } I = I_1 + I_2 + I_3$$
$$= 1 + 0 + 1 = 2\text{A}$$

Current in ammeter A_1 = 1 A

Current in ammeter A_2 = 0

Current in ammeter A_3 = 1 A

Current in ammeter A = 2A

(*iii*) When all the three bulbs are connected.

$$\text{Power dissipitated, P} = \frac{V^2}{R_{eq}}$$

$$= \frac{(4.5)^2}{1.5} = \mathbf{13.5\ W}$$

ELECTRIC POWER AND ENERGY

Q. 16. An electric iron has a rating of 750 W, 220 V. Calculate

(*i*) the current passing through it, and

(*ii*) its resistance, when in use.

Ans. Power, P = 750 W

Potential, V = 220 V

$$\therefore \quad \text{I} = \frac{P}{V} = \frac{750\text{W}}{220\text{V}} = \mathbf{3.4\ A}$$

Now $$V = IR \quad \text{(Ohm's law)}$$

$$\text{R} = \frac{V}{I} = \frac{220\text{V}}{3.4\text{A}} = \mathbf{64.7\ \Omega}$$

Q. 17. Three 2 resistors *A*, *B* and *C* are connected as shown in figure. Each of them dissipates energy and can withstand a maximum power of 18W without melting. Find the maximum current that can flow through the three resistors. [*NCERT Exemplar*]

Ans. The current of resistor A is equally divided in resistors *B* and *C*; so maximum current can flow in resistor *A*.

$$\text{Power} = (\text{current})^2 \times \text{resistance}$$

$$\Rightarrow \quad 18\text{ W} = (I_A^2) \times 2\Omega$$

$$\therefore \quad = (I_A^2) = 9 \text{ or } I_A = 3\text{A}$$

Current in resistance A, I_A = 3A

So current in each of resistor *B* and *C*

$$I_B = I_C = \frac{3}{2}\text{A} = 1.5\text{A}$$

Q. 18. What is the commercial unit of electrical energy? Represent it in terms of joules.

Ans. The commercial unit of electrical energy is kilowatt hour.

Energy used = Power × time

$$1\text{ kWh} = 1\text{ kW} \times 1\text{h}$$
$$= 1000\text{W} \times 60 \times 60\text{s}$$
$$= 1000\text{ Js}^{-1} \times 60 \times 60\text{s}$$
$$= 3600000\text{ J}$$
$$= 3.6 \times 10^6\text{J}$$

Q. 19. A geyser is rated 1500 W, 250 V. It is connected to 250 V mains. Calculate (*i*) the current drawn, (*ii*) the energy consumed in 50 hours, and (*iii*) the cost of energy consumed at ₹ 2.20 per kWh.

Ans. Given, V = 250 V, P = 1500 W, t = 50 h = 50 × 60 × 60 s

(*i*) $$I = \frac{P}{V} = \frac{1500}{250} = \mathbf{6\ A}$$

(*ii*) $$\text{Energy consumed} = VIt \text{ joule}$$
$$= 250 \times 6 \times 50 \times 60 \times 60$$
$$= 27 \times 10^7\text{ J}$$
$$= \frac{27 \times 10^7}{3.6 \times 10^6}\text{ kWh}$$
$$= \mathbf{75\ kWh}$$

(*iii*) ∵ 1 kWh costs = ₹2.20

∴ 75 kWh cost = 2.20 × 75 = **₹165**

Q. 20. Two resistors of 4 Ω and 6 Ω are connected in parallel. The combination is connected across a 6 volt battery of negligible resistance. Calculate (*i*) the power supplied by the battery, (*ii*) the power dissipated in each resistor.

Ans. Here, $R_1 = 4\ \Omega$ and $R_2 = 6\ \Omega$

Both are in parallel. Hence

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

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

$$= \frac{4 \times 6}{4 + 6}$$

$$= \mathbf{2.4\ \Omega}$$

(*i*) Power dissipated, $P = \frac{V^2}{R} = \frac{36 \times 10}{24} = \mathbf{15\ W}$

(*ii*) For R_1, Power dissipated

$$P_1 = \frac{V^2}{R_1} = \frac{36}{4} = \mathbf{9\ W}$$

For R_2, $P_2 = \frac{V^2}{R_2} = \frac{6 \times 6}{6} = \mathbf{6\ W}$

Q. 21. An electric bulb is rated 220 V and 100 W. Calculate the power consumed when it is operated on 110 V.

Ans. We have, $P = \frac{V^2}{R}$

or $$100 = \frac{(220)^2}{R} \qquad ...(1)$$

Let power consumed will be P' when operated on 110 V. Then

$$P' = \frac{(110)^2}{R} \qquad ...(2)$$

From (1) and (2), we have

$$\frac{P'}{100} = \left(\frac{110}{220}\right)^2$$

or $$P' = \frac{1}{4} \times 100$$

or $$P' = \mathbf{25\ W}$$

Q. 22. 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. Suppose the resistance of each one of the two wires is R.

The equivalent resistance of the series combination,

$$R_s = R + R = 2R$$

The heat produced in time t,

$$H_1 = \frac{V^2}{2R}t \qquad \left(\because H = \frac{V^2}{R}t\right) \qquad ...(1)$$

The equivalent resistance of the parallel combination is

$$R_P = \frac{R \times R}{R + R} = \frac{R^2}{2R} = \frac{R}{2}$$

Heat produced in time t,

$$H_2 = \frac{V^2}{R/2}t = \frac{2V^2 t}{R} \qquad ...(2)$$

From (1) and (2), we have

$$\frac{H_1}{H_2} = \frac{V^2 t}{2R} \times \frac{R}{2V^2 t}$$

$$\Rightarrow \quad \frac{H_1}{H_2} = \frac{1}{4}$$

$$H_1 : H_2 = \mathbf{1 : 4}$$

Q. 23. Which has a higher resistance: a 50 W – 220 V lamp or a 25 W – 220 V lamp ? Calculate the ratio of their resistances.

Ans. Under a constant (fixed) applied voltage (V),

$$\text{Resistance} = \frac{(\text{Voltage})^2}{\text{Power}}$$

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

Resistance of the first bulb,

$$R_1 = \frac{V^2}{50}$$

Resistance of the second bulb

$$R_2 = \frac{V^2}{25}$$

$$\frac{R_2}{R_1} = \mathbf{2} \quad \text{or,} \quad R_2 = 2R_1$$

$R_2 > R_1$, 25 W bulb has higher resistance. Resistance of 25 W lamp bulb is twice the resistance of 50 W lamp bulb.

Q. 24. An electric iron consumes energy at a rate of 840 W when heating it at the maximum rate and 360 W when the heating it at the minimum. The applied voltage is 220 V. What is the value of current and the resistance in each case?

Ans. We know that the power input is

Thus the current, $I = \frac{P}{V}$

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

$$R = \frac{V}{I} = \frac{220\ \text{V}}{3.82\ \text{A}} = 57.59\ \Omega$$

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

$$R = \frac{V}{I} = \frac{220\ \text{V}}{1.64\ \text{A}} = \mathbf{134.15\ \Omega}$$

Q. 25. A heater coil is rated 100 W, 200 V. It is cut into two identical parts. Both parts are connected together in parallel to the same source of 200 V. Calculate the energy liberated per second in the new combination.

Ans. Resistance of heater coil,

$$R = \frac{V^2}{P} = \frac{(200)^2}{100} = \frac{200 \times 200}{100} = 400\ \Omega$$

After cutting, resistance of each part $= \frac{400}{2} = 200\ \Omega$

When connected in parallel, the net resistance is given by

$$\frac{1}{R_P} = \frac{1}{200} + \frac{1}{200}$$

$$\Rightarrow \quad \frac{1}{R_P} = \frac{2}{200}$$

$$\therefore \quad R_P = 100$$

Energy liberated $= P \times t$

$$= \frac{V^2}{R} \times t = \frac{(200)^2}{100} \times 1 = \mathbf{400\ joule}$$

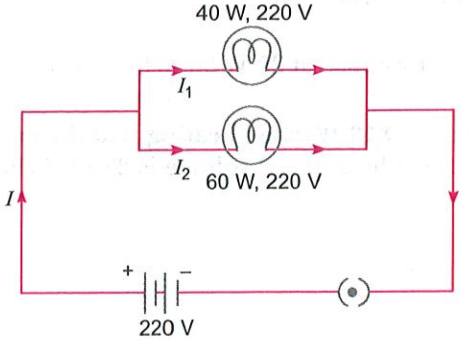
Q. 26. Two lamps, one rated at 40 W – 220 V and the other at 60 W – 220 V, are connected in parallel to the electric supply at 220 V.

(i) Draw a circuit diagram to show the connections.

(ii) Calculate the current drawn from the electric supply source.

(iii) Calculate the total energy consumed by the two lamps together when they operate for one hour.

Ans. (i)



(ii) Current drawn by 40 W bulb,

$$I_1 = \frac{P}{V} = \frac{40}{220}\ \text{A} = \frac{2}{11}\ \text{A} = 0.18\ \text{A}$$

Current drawn by 60 W bulb,

$$I_2 = \frac{P}{V} = \frac{60}{220}\ \text{A} = \frac{3}{11}\ \text{A} = 0.27\ \text{A}$$

Total current drawn from circuit,

$$I = I_1 + I_2 = 0.18\ \text{A} + 0.27\ \text{A} = \mathbf{0.45\ A}$$

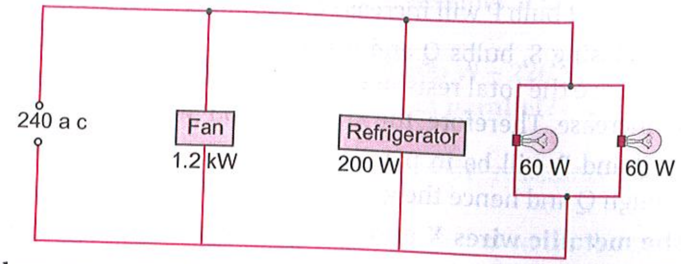
(iii) Energy consumed by 40 W bulb in 1 hour $= P \times t$

$= 40\ \text{W} \times 1\ \text{h} = 40\ \text{Wh}$

Energy consumed by 60 W bulb in 1 hour $= 60\ \text{W} \times 1\text{h} = 60\ \text{Wh}$

$\therefore$ Total energy consumed $= 40\ \text{Wh} + 60\ \text{Wh} = 100\ \text{Wh} =$ **0.1 kWh**

Q. 27. Figure shows a 240 V ac mains circuit to which a number of appliances are connected and switched on.



(a) Calculate the power supplied to the circuit.

(b) Calculate

(i) the current in the refrigerator,

(ii) the energy used by the fan in 3 hours,

(iii) the resistance of the filament of one lamp.

Ans. (a) Power supplied to the circuit

$= 1.2 \times 1000\ \text{W} + 200\ \text{W} + 60\ \text{W} + 60\text{W}$

$= 1200\ \text{W} + 200\ \text{W} + 60\ \text{W} + 60\ \text{W}$

$= 1520\ \text{W}$

$= 1.52\ \text{kW}$

(b) (i) Current in the refrigerator

$$= \frac{\text{Power}}{\text{Voltage}} = \frac{200\ \text{W}}{240\ \text{V}} = \mathbf{0.83\ A}$$

(ii) Energy used $=$ Power $\times$ Time

$= 1.2\ \text{kW} \times 3\text{h}$

$= 1.2 \times 1000\ \frac{\text{J}}{\text{s}} \times 3 \times 60 \times 60\text{s}$

$= 1200 \times 3 \times 3600\ \text{J}$

$= 12960000\ \text{J}$

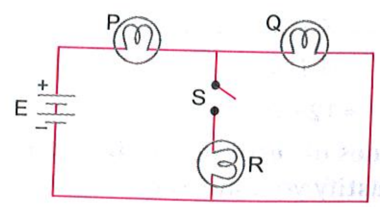
$= \mathbf{1.3 \times 10^7\ J}$

(iii) Current, $I = \frac{P}{V} = \frac{60}{240} = 0.25\ \text{A}$

Resistance $= \frac{V}{I} = \frac{240}{0.25} = \mathbf{960\ \Omega}$

HOTS (Higher Order Thinking Skills)

Q. 1. A battery E is connected to three identical lamps P, Q and R as shown in figure:



Initially the switch S is kept open and the lamp P and Q are observed to glow with some brightness.

Then switch S is closed.

How will the brightness of glow of bulbs P and Q will change? Justify your answer.

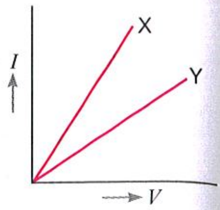
Ans. The brightness of glow of bulb P will increase and brightness of glow of bulb Q will decrease.

This is because on closing S, bulbs Q and R will be in parallel and the combination will be in series with bulb P. Hence the total resistance of the circuit will decrease and the current flowing in the circuit will increase. Therefore, the glow of bulb P will increase.

Also since bulbs Q and R will be in parallel in this case, the current gets divided and lesser current flows through Q and hence the glow of bulb Q will decrease.

Q. 2. V-I graph for the metallic wires X and Y at constant temperature are as shown in figure:

Assuming that the two wires have same length and same diameter, explain as to which of the two wires has higher resistivity and why?



Ans. The slope $\frac{I}{V}$ of the graph represents $\frac{1}{R}$. Since the graph marked Y has lesser slope, it represents higher resistance.

Since the length and diameter of the two wires is same, using the relation $R = \rho\frac{l}{A}$ the resistivity of wire Y will be higher.

Q. 3. Why is an ammeter likely to be burnt out if it is connected in parallel in a circuit?

Ans. The resistance of an ammeter is very low. If an ammeter is connected in parallel, the resultant resistance of the circuit decreases and excessive current passes through the instrument. Hence, the ammeter is likely to be burnt out.

Q. 4. Current *I* flowing through a resistor results in dissipation of power *P*. By what percentage will the power dissipated in the resistor increase if the current through the resistor is increased by 50%? Justify your answer with the help of mathematical calculations.

Ans. The power dissipated in the resistor will increase by 125%.

$$P = I^2Rt$$

When I is increased by 50%, I becomes $\frac{3}{2}I$.

Hence, $$P' = \left(\frac{3}{2}I\right)^2 Rt = \frac{9}{4}I^2Rt$$

$$\text{Increase in power dissipation} = \frac{9}{4}I^2Rt - I^2Rt$$

$$= \frac{5}{4}I^2Rt$$

$$\text{Percentage increase} = \frac{\text{Increase}}{\text{Original}} \times 100$$

$$= \frac{5}{4}\frac{I^2Rt}{I^2Rt} \times 100$$

$$= 125\%$$

Q. 5. What are the possible values of resistances which one can obtain by using resistors of values 2 Ω, 3 Ω and 6 Ω? Justify your answer.

Ans. The following combinations can be obtained:

(*i*) The individual resistances: 2 Ω, 3 Ω, 6 Ω

(*ii*) All in series: 11 Ω

(*iii*) All in parallel: 1 Ω

(*iv*) Three different possible mixed grouping of resistors: 4 Ω, $\frac{9}{2}$ Ω, $\frac{36}{5}$ Ω.

Q. 6. Out of two electric bulbs of 50 W – 220 V and 100 W – 220 V, which one will glow brighter when they are connected (*i*) in series, and (*ii*) in parallel?

Ans. The resistance of the bulb is defined as $R = \frac{V^2}{P}$. So the resistance of 50 W bulb is double than the resistance of 100 W bulb. When they are connected in series the current through both bulbs is same. Hence 50 watt bulb will be brighter because $P = I^2R$. In parallel, the voltage will be same in both bulbs. So, the 100 watt bulb will be brighter because $P = \frac{V^2}{R}$.

Q. 7. Given n resistors each of resistance *R*, how will you combine them to get the (*i*) maximum; and (*ii*) minimum effective resistance? What is the ratio of the maximum to minimum resistance?

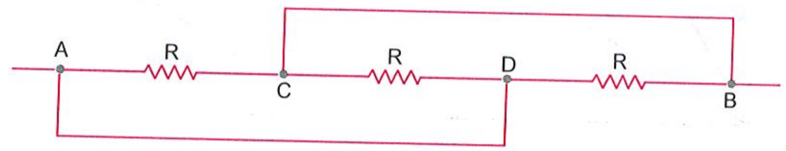
Ans. For maximum effective resistance, the resistors must be connected in series combination.

If there are n resistors each of resistance R, then the maximum effective resistance = nR

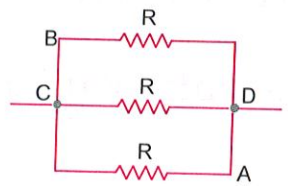
For minimum effective resistance, the resistors must be connected in parallel combination. So the minimum effective resistance = $\frac{R}{n}$

Ratio of the maximum to minimum resistance is $\frac{nR}{(R/n)} = n^2 : 1$.

Q. 8. What is the resistance from A to B in the network shown in the figure?



Ans. The point C is connected to B and the point D is connected to A. Therefore, three identical resistors, each having resistance R, are connected in parallel and the equivalent circuit diagram is shown in the figure.



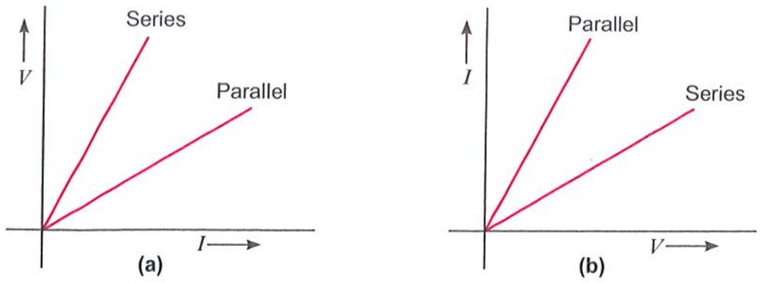
If the equivalent resistance is R' then

$$\frac{1}{R'} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R}$$

or $$R' = \frac{R}{3}$$

Q. 9. Two students perform the experiment on series and parallel combinations of two given resistors R_1 and R_2 and plot the following V-I graphs (*a*) and (*b*).

Which of the graphs is (are) correctly labelled in terms of the words 'series' and 'parallel'? Justify your answer.



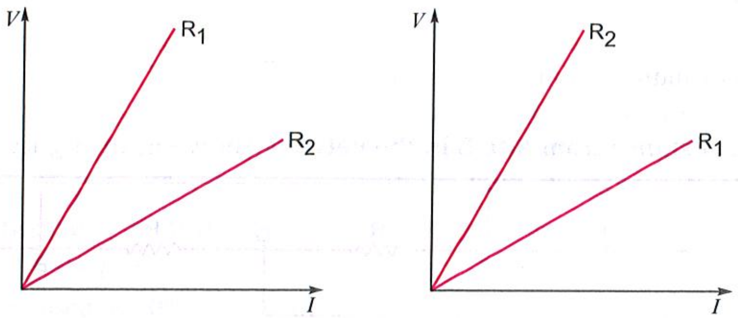
Ans. (*a*) Slope $\frac{V}{I}$ = Resistance R

As larger resistance represents series combination and smaller resistance the parallel combination. Therefore, graph of greater slope represents series combination and hence it is correctly labelled.

(*b*) Slope, $\frac{I}{V} = \frac{1}{R}$

As larger resistance represents series combination, so graph of smaller slope represents series combination and hence it is also correctly labelled.

Q. 10. Two students perform experiments on two given resistors R_1 and R_2 and plot the following V-I graphs. If $R_1 > R_2$ which of the two diagrams correctly represent the situation on the plotted curves? Justify your answer.



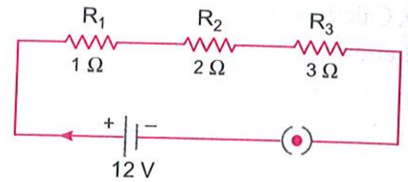
Ans. As $R_1 > R_2$

Therefore, figure (*a*) is correct. This is because R_1 is greater so the slope of V–I graph $\left(\frac{V}{I}\right)$ is greater in figure (*a*) and is correctly represented as R_1.

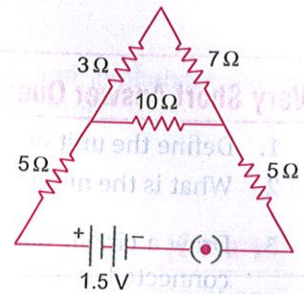
Some Important Numericals (For Practice)

1. A wire carries a current of 0.1 A and has a resistance of 120 milliohm per metre. What is the p.d. across 1 m of this wire? **[Ans.** 12 mV]
2. An electric iron draws a current of 4 A from 220 V supply line. When voltage of supply is changed, then iron draws a current of 2 A, what is the new voltage applied? [Ans. 110 V]
3. A copper wire has a diameter 0.5 mm and resistivity $1.6 \times 10^{-8}\ \Omega$ m.
   (*i*) What will be the length of this wire to make the resistance of 12 Ω?
   (*ii*) How much will be the resistance of another copper wire of same length but half the diameter? **[Ans.** (*i*) 147.3 m (*ii*) 48 Ω]
4. How can three resistances of 2, 3 and 6 ohms be connected so as to give a total resistance of 1 ohm? Justify your answer. **[Ans.** Parallel grouping]

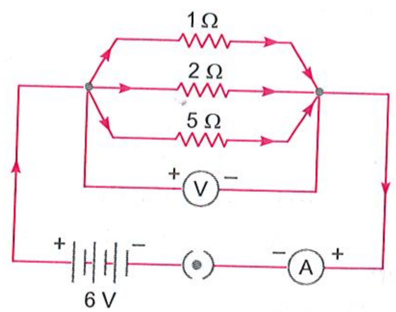
5. Three resistances of 5, 10 and 15 ohms are connected in series and a potential difference of 15 volts is applied across the combination. Calculate the current flowing through the circuit. **[Ans.** 0.5 A]
6. A voltmeter reads 24 V across a resistor and an ammeter reads a current of 3 A through it. Calculate R. What will be the current through the resistor if the voltage changes to 12 V? **[Ans.** 8 Ω, 1.5 A]
7. Three resistances are connected in electrical circuit as shown in the circuit diagram. Determine the potential difference across resistance R_2. **[Ans.** 4 V]



8. Five resistances are connected in the shape of letter A as shown in figure alongside. Determine the total resistance of the circuit. **[Ans.** 15 Ω]



9. A wire of uniform cross-section and length l has a resistance of 4 Ω. The wire is cut into four equal pieces. Each piece is then stretched to length 'l'. Thereafter, the four wires are joined in parallel. Calculate the net resistance. **[Ans.** Net resistance of combination = 4 Ω]
10. A cable of resistance 12 Ω carries electric power from a generator producing 250 kW at 10,000V. Calculate (*i*) the current in the cable, (*ii*) the power lost in the cable during transmission, and (*iii*) the p.d. across the ends of the cable. **[Ans.** (*i*) 25 A (*ii*) 7.5 kW (*iii*) 300 V]
11. Calculate the electrical energy produced in 5 minutes when a current of 2 A is sent through a conductor by a potential difference of 500 volts. [Ans. 3×10^5 joules]
12. Two bulbs have the following ratings: (*i*) 40 W at 220 V, and (*ii*) 40 W at 110 V. The filament of which bulb has a higher resistance? What is the ratio of their resistances? **[Ans.** (*i*) First bulb (*ii*) 4: 1]
13. A potential difference of 40V is applied across a resistance of 8 Ω for a period of 2 minutes.
    (*i*) What current is drawn?
    (*ii*) Calculate the charge which passes through the resistor. **[Ans.** (*i*) 5A (*ii*) 600 C]
14. For the given circuit diagram calculate:



(*i*) the current through each resistor.
(*ii*) the total current in the circuit.
(*iii*) the total effective resistance of the circuit. **[Ans.** (*i*) 6A, 3A, 1.2A (*ii*) 10.2 A (*iii*) 0.588 Ω]

15. An electric iron has a rating of 750 W, 220 V. Calculate
(*i*) the current passing through it.
(*ii*) its resistance, when in use. **[Ans.** (*i*) 3.4 A (*ii*) 64.5]

16. An electric heater draws a current of 10 A from a 220 V supply. What is the cost of using the heater 5 hours per day for 30 days if the cost of 1 unit is ₹ 2.50? **[Ans.** ₹ 825]

17. A torch bulb is rated 3V and 600 mA. Calculate its resistance if it is lighted for 4 hours. **[Ans.** 5 Ω]

18. In a household circuit, an electric bulb of 100 W is used for 10 hours and an electric heater of 1000 W for 2 hours everyday. Calculate the cost of using the bulb and the heater of 30 days if the cost of one unit of electrical energy is two rupees. **[Ans.** ₹ 180]

19. An electric bulb draws a current of 0.2 A when it operates at 220 V. Calculate the amount of electric charge flowing through it in 1 h. **[Ans.** 720 C]

Proficiency Exercise

Very Short Answer Questions [1 mark]

1. Define the unit of electric current.
2. What is the minimum resistance which can be made using five resistors each of $\frac{1}{5}$ Ω?
3. Draw a circuit diagram of a circuit consisting of a cell of 1.5V, 10 Ω resistor and a plug key all connected in series.
4. Write a mathematical expression for Joule's law of heating effect of current. Name one device which works on this principle.
5. Should the resistance of an ammeter be low or high? Give reason.

Short Answer Questions–I [2 marks]

6. In an experiment to study the relationship between the potential difference across a resistor and the current through it, a student recorded the following observations:

Potential difference (V)	2	3	4.5	5	6
Current (A)	0.08	0.12	0.15	0.20	0.24

Find in which one of the above sets of readings the trend is different from others and must be rejected. Calculate the mean value of resistance of the resistor based on the remaining sets of readings.

7. Two electric bulbs A and B are marked 40 W – 220 V and 60 W – 220 V respectively. Which one of the two has a greater resistance?

8. (*a*)Table gives the resistivity of three materials in (in Ω m) A, B, C.

Samples	A	B	C
Resistivity	1.6×10^{-8}	7.5×10^{17}	44×10^{-6}

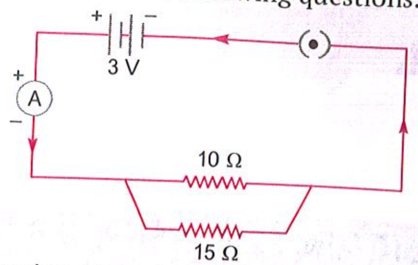
Which one of them is the best conductor? And which is an insulator and why?
(*b*)A wire of resistivity ρ is stretched to twice its length. What will be its new resistivity?

9. How can three resistance of 2, 3 and 6 ohms be connected so as to give a total resistance of 1 ohm? Show the working of your solution.

10. The resistance of a metal wire of length 1 m is 25 Ω at 20°C. If the diameter of the wire is 0.3 mm, what must be the resistivity of metal at that temperature?

Short Answer Questions–II [3 marks]

11. How is an ammeter and a voltmeter connected in a circuit and why?
12. Why does the cord of an electric heater not glow while the heating element does?
13. Study the following circuit and answer the following questions.



(*i*) State the type of combination of the two resistors in the circuit.
(*ii*) How much current is flowing through (*a*) 10 Ω and (*b*) 15 Ω resistor?
(*iii*) What is the ammeter reading?

14. Name two safety measures commonly used in domestic electric circuits and appliances. What precautions should be taken to avoid the overloading of domestic electric circuit?
15. How does use of a fuse wire protect electrical appliances?
16. Why is parallel arrangement used in domestic wiring?

Long Answer Questions [5 marks]

17. State Ohm's law? How can it be verified experimentally? Does it hold good under all conditions? Comment. *[NCERT Exemplar]*
18. What is electrical resistivity of a material? What is its unit? Describe an experiment to study the factors on which the resistance of conducting wire depends.
19. How will you conclude that the same potential difference (voltage) exists across three resistors connected in a parallel arrangement to a battery?
20. Three bulbs each having power P are connected in series in an electric circuit. In another circuit another set of three bulbs of same power are connected in parallel to the same source.
(*i*) Will the bulbs in both the circuits glow with the same brightness? Justify your answer.
(*ii*) Now let one bulb in each circuit get fused. Will the rest of the bulbs continue to glow in each circuit? Give reason.
(*iii*) Representing each bulb by a resistor, draw circuit diagram for each case.
21. How will you infer with the help of an experiment that the same current flows through every part of the circuit containing three resistances in series connected to a battery?
22. What is Joule's heating effect? How can it be demonstrated experimentally? List its four applications in daily life.