11 Electricity

Fastrack Revision

- **Electric Charge:** It is the property of matter due to which it produces and experience electrical and magnetic effects. There exist two types of charges in nature-(i) Positive charge and (ii) Negative charge. Like charges repel each other and unlike charges attract each other. SI unit of charge is coulomb (C).

  Electric charge $(Q) = ne$,

  where,

  n = number of electrons and

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

- **Coulomb:** One coulomb is defined as the amount of charge which repels an equal and similar charge with a force of 9×10^9 N when placed in vacuum at a distance of 1 metre from it.

- **Conductor:** It is a substance which allows passage of electric charges through it easily. It offers very low resistance to the flow of current. *e.g.*, copper, silver, aluminium, etc.

- **Insulator:** It is a substance that has finitely high resistance and does not allow electric current to flow through it. *e.g.*, rubber, glass, plastic, ebonite, etc.

- **Electric Current:** It is defined as the rate of flow of electric charge through any section of a conductor.

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

  The SI unit of electric current is ampere (A). Electric current is a scalar quantity. It is measured by an instrument called ammeter.

- **One Ampere:** When 1 coulomb of charge flows through a conductor in 1 second, then current passing through the conductor is 1ampere.

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

- **Electric Circuit:** It is a continuous and closed path along which electric current flows.

- **Electric Field:** It is the region around a charged body within which its influence can be experienced.

- **Electrostatic Potential:** It is the amount of work done in bringing a unit positive charge from infinity to that point. Its unit is volt.

- **Electric Potential Difference:** It is the amount of work done in bringing a unit positive charge from one point to another. SI unit of potential difference is volt (V).

$$\text{Potential difference} = \frac{\text{Work done}}{\text{Charge}} \text{ or } V = \frac{W}{Q}$$

- **One Volt:** When one joule work is done to move a unit charge from one point to another, then the potential difference between two points is one volt.

$$1\text{V} = \frac{1\text{ joule}}{1\text{coulomb}} \text{ or } 1\text{V} = \frac{1\text{J}}{1\text{C}}$$

- **Ammeter:** It is a device used to measure current in a circuit. It is always connected in series in a circuit.

- **Voltmeter:** It is a device used to measure potential difference. It is always connected in parallel to the component across which the potential difference is to be measured.

- **Ohm's Law:** This law states that the current passing through a conductor is directly proportional to the potential difference across its ends, provided the physical conditions like temperature, density, etc. remains unchanged.

$$V \propto I$$

or $$V = IR$$

where, R is the constant, called resistance of the conductor.

MNEMONICS

Concept : *Ohm's law*
Mnemonics: ***V****ampires* ***A****re* ***R****are*
Interpretation: *Voltage = Ampere × Resistance*

- **Resistance:** The resistance of a conductor is the ratio of the potential difference (p.d.) across its ends and the current flowing through it. It is a scalar quantity. SI unit of resistance is ohm (Ω).

$$\text{Resistance } (R) = \frac{\text{Potential difference } (V)}{\text{Current } (I)}$$

The factors on which the resistance of a conductor depends are:

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

i.e., $R \propto l$

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

i.e., $R \propto 1/A$

On combining, we get

$$R \propto l/A$$

or $$R = \rho\,(l/A)$$

or $$\rho = RA/l$$

where, ρ is called the electrical resistivity of the material of the conductor. Its SI unit is Ωm.

(iii) The resistance of conductor also depends on the nature of its material.

- **Ohm:** It is the SI unit of resistance. A conductor has a resistance of one ohm if the potential difference across the two ends of a conductor is 1V and the current through it is 1A.

$$1 \text{ ohm} = \frac{1 \text{volt}}{1 \text{ampere}} \text{ or } 1\Omega = \frac{1\text{V}}{1\text{A}}$$

- **Resistances in Series:** When two or more resistances are joined end-to-end so that the same current flows through each of them, it is called a series combination of resistances.
  Here, the total resistance is equal to the sum of the individual resistances.

$$R_S = R_1 + R_2 + R_3 + ...$$

- **Resistances in Parallel:** When two or more resistances are connected between two common points such that the same potential difference is applied across each of them, it is called a parallel combination of resistances.
  Here, the reciprocal of their combined resistance is equal to the sum of the reciprocals of the individual resistances.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

- **Joule's Law of Heating:** It states that the heat produced in a conductor is directly proportional to:
  (i) the square of the current 'I' through it,
  (ii) its resistance 'R' and
  (iii) the time 't', for which current is passed.
  It can be expressed as

$$H = I^2Rt \text{ joule} = \frac{I^2}{4.18} \text{ cal or } H = VIt \text{ joule } \frac{VIt}{4.18} \text{ cal}$$

- **Electric Power:** It is the rate at which electric energy is consumed by an appliance in an electric circuit.

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

- **Watt:** It is the SI unit of power. The power of an appliance is 1 watt if one ampere of current flows through it on applying a potential difference of 1 volt across its ends.

$$1 \text{ watt} = \frac{1 \text{joule}}{1 \text{second}} = 1 \text{volt} \times 1 \text{ampere}$$

or $1\ W = 1 Js^{-1} = 1\ V\text{-}A$

- **Kilowatt Hour:** It is the commercial unit of electric energy. One kilowatt hour is the electric energy consumed by an appliance of 1000 watts when used for one hour.

$$1 \text{ kilowatt hour (kWh)} = 3.6 \times 10^6 \text{ J}$$

- For commercial scale, $E = P \times t$
  where, power is in kilowatt and time is in hours.

Practice Exercise

Multiple Choice Questions

Q 1. Match the quantities given in Column (A) with their SI unit given in Column (B):

Column (A)		Column (B)	
A.	Electric potential difference	1.	Ohm
B.	Resistivity	2.	Volt
C.	Resistance	3.	Coulomb
D.	Electric charge	4.	Ohm-metre

	A	B	C	D
a.	2	1	4	3
c.	3	4	1	2

	A	B	C	D
b.	3	2	4	1
d.	2	4	1	3

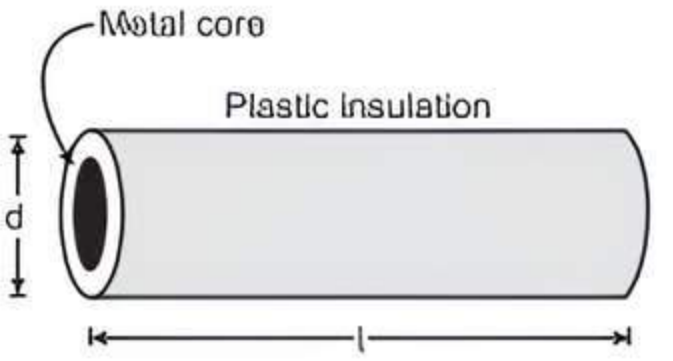
Q 2. For verifying Ohm's law, we design an electric circuit diagram in which we show the arrangement of different circuit components. We find that with respect to the resistor, the: *(CBSE 2023)*

a. ammeter is connected in parallel and the voltmeter in series.
b. ammeter is connected in series and the voltmeter in parallel.
c. ammeter and voltmeter are both connected in series.
d. ammeter and voltmeter are both connected in parallel.

Q 3. According to Ohm's law, the ends of a metallic wire is directly proportional to current, provided its ..... remains constant.

a. area b. volume
c. length d. temperature

Q 4. Plastic insulation surrounds a wire having diameter d and length l as shown in figure. A decrease in the resistance of the wire would be produced by an increase in the: *(CBSE SQP 2022-23)*



a. length l of the wire
b. diameter d of the wire
c. temperature of the wire
d. thickness of the plastic insulation

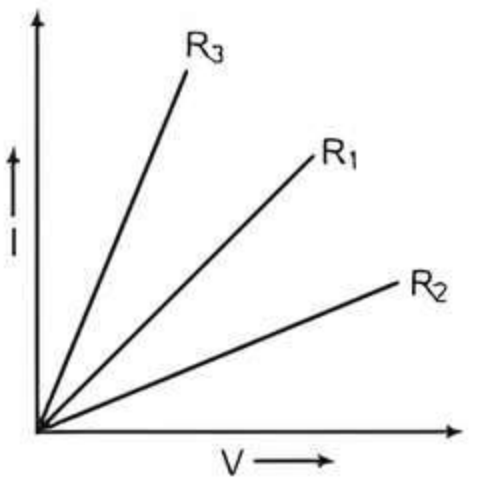
Q 5. A complete circuit is left on for several minutes, causing the connecting copper wire to become hot. As the temperature of the wire increases, the electrical resistance of the wire: *(CBSE SQP 2022-23)*

a. decreases
b. remains the same
c. increases
d. increases for some time and then decreases

Q 6. A cylindrical conductor of length l' and uniform area of cross-section A has resistance R. Another conductor of length 2.5 l and resistance 0.5 R of the same material has area of cross-section: *(CBSE 2020)*

a. 5 A b. 2.5 A c. 0.5 A d. (1/5) A

Q 7. A student plots *V-I* graphs for three samples of nichrome wire with resistances R_1, R_2 and R_3. Choose from the following statement that holds true for this graph: *(CBSE 2020)*



a. $R_1 = R_2 = R_3$ b. $R_1 > R_2 > R_3$
c. $R_3 > R_2 > R_1$ d. $R_2 > R_1 > R_3$

Q 8. When a 4 V battery is connected across an unknown resistor there is a current of 100 mA in the circuit. The value of the resistance of the resistor is:

a. 4 Ω b. 40 Ω c. 400 Ω d. 0.4 Ω

Q 9. Two LED bulbs of 12 W and 6 W are connected in series. If the current through 12 W bulb is 0.06 A the current through 6 W bulb will be:

a. 0.04 A b. 0.06 A
c. 0.08 A d. 0.12 A

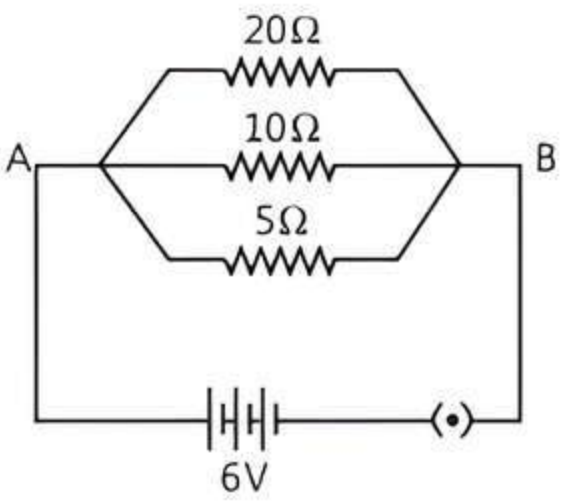
Q 10. The maximum resistance which can be made using four resistors each of resistance (1/2) Ω is: *(CBSE 2020)*

a. 2 Ω b. 1 Ω c. 2.5 Ω d. 8 Ω

Q 11. Three resistances of 2, 3 and 5 Ω are connected in parallel to a 10 V battery of negligible internal resistance. The potential difference across the 3 Ω resistance will be:

a. 2 V b. 3 V c. 5 V d. 10 V

Q 12. Calculate the current flowing through the 10 Ω resistor in the following circuit.



a. 1.2 A b. 0.6 A c. 0.2 A d. 2.0 A

Q 13. In an electrical circuit three incandescent bulbs *A*, *B* and *C* of rating 40 W, 60 W and 100 W respectively are connected in parallel to an electric source. Which of the following is likely to happen regarding their brightness? *(NCERT EXEMPLAR)*

a. Brightness of all the bulbs will be the same
b. Brightness of bulb *A* will be the maximum
c. Brightness of bulb *B* will be more than that of *A*
d. Brightness of bulb *C* will be less than that of *B*

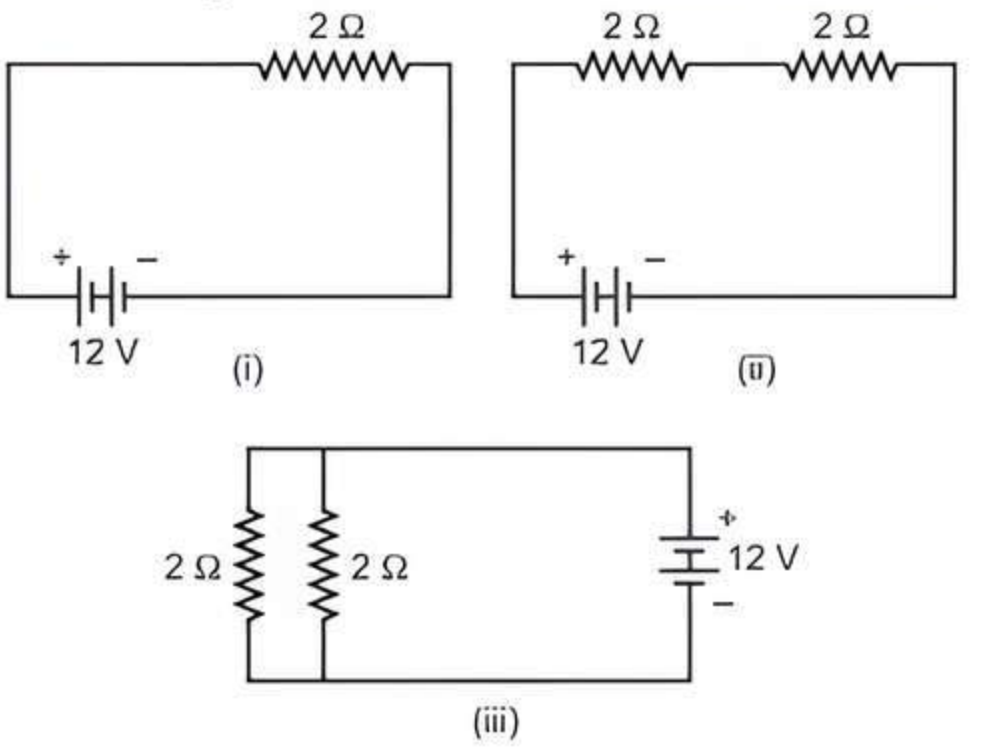
Q 14. The resistance of a resistor is reduced to half of its initial value. In doing so, if other parameters of the circuit remain unchanged, the heating effects in the resistor will become: *(CBSE 2020, 23)*

a. two times b. half
c. one-fourth d. four times

Q 15. In a resistive circuit, if the current is increased to two times, the percentage change in the amount of heat dissipated in the circuit would be: *(CBSE 2023)*

a. 400% b. 300%
c. 200% d. 100%

Q 16. In the following circuits, heat produced in the resistor or combination of resistors connected to a 12 V battery will be: *(NCERT EXEMPLAR)*



a. same in all the cases b. minimum in case (I)
c. maximum in case (II) d. maximum in case (III)

Q 17. At the time of short circuit, the electric current in the circuit:

a. vary continuously b. does not change
c. reduces substantially d. increases heavily

Q 18. A bulb is rated as 270 V, 0.5 A. Its power is:

a. 125 W b. 100 W c. 60 W d. 135 W

Q 19. An electric kettle consumes 1 kW of electric power when operated at 220 V. A fuse wire of ..... rating must be used for it.

a. 1 A b. 2 A c. 5 A d. 4 A

Q 20. Unit of electric power may also be expressed as:

a. volt-ampere b. kilowatt-hour
c. watt-second d. joule-second

Assertion & Reason Type Questions

Directions (Q. Nos. 21-28): *Each of the following questions consists of two statements, one is Assertion (A) and the other is Reason (R). Give answer:*

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
c. Assertion (A) is true but Reason (R) is false.
d. Assertion (A) is false but Reason (R) is true.

Q 21. Assertion (A): If a graph is plotted between the potential difference and the current flowing, the graph is a straight line passing through the origin.
Reason (R): The current is directly proportional to the potential difference.

Q 22. Assertion (A): When the length of a wire is doubled, then its resistance also gets doubled.
Reason (R): The resistance of a wire is directly proportional to its length.

Q 23. Assertion (A): Alloys are commonly used in electrical heating devices like electric iron and heater.
Reason (R): Resistivity of an alloy is generally higher than that of its constituent metals but the alloys have low melting points than their constituent metals. *(CBSE 2020)*

Q 24. Assertion (A): If ρ_1 and ρ_2 be the resistivity of the materials of two resistors of resistances R_1 and R_2 respectively and $R_1 > R_2$.

Reason (R): The resistance $R = \rho\frac{l}{A} \Rightarrow \rho_1 > \rho_2$ if $R_1 > R_2$.

Q 25. Assertion (A): At high temperatures, metal wires have a greater chance of short circuiting.
Reason (R): Both resistance and resistivity of a material vary with temperature. *(CBSE 2020)*

Q 26. Assertion (A): In a chain of bulbs, 50 bulbs are joined in series. One bulb is removed now and circuit is completed again. If the remaining 49 bulbs are again connected in series across the same supply, then light gets decreased in the room.
Reason (R): Net resistance of 49 bulbs will be less than 50 bulbs.

Q 27. Assertion (A): The 200 W bulbs glows with more brightness than 100 W bulbs.
Reason (R): A 100 W bulb has more resistance than a 200 W bulb.

Q 28. Assertion (A): Resistance of 50 W bulb is greater than that of 100 W.
Reason (R): Resistance of bulb is inversely proportional to rated power.

Answers

	A	B	C	D
1. (d)	2	4	1	3

2. (b) Ammeter is connected in series and the voltmeter in parallel

3. (d) temperature

4. (b) diameter d of the wire

5. (c) increases

6. (a) 5 A

Given,

length of first conductor = l

Area of first conductor = A

and resistance of first conductor = R

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

Now, length of another conductor = 2.5 l

and resistance of conductor = 0.5 R

$$\therefore \quad A' = \rho\left(\frac{2.5l}{0.5R}\right)$$

$$= \rho \times 5 \times \left(\frac{l}{R}\right)$$

Thus, $A' = 5A$ $\quad \left[\because A = \frac{\rho l}{R}\right]$

7. (d) $R_2 > R_1 > R_3$

8. (b) 40 Ω

Given that,

$V = 4$ Volt

$I = 100\ \text{mA} = 100 \times 10^{-3}\ \text{A}$

COMMON ERROR

Most of the students forget to convert 'mA' into 'A', which leads to wrong answer.

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

$$= \frac{4}{100 \times 10^{-3}} = 40\ \Omega$$

9. (b) 0.06A

In series combination, current is same in every part of the circuit.

10. (a) 2 Ω

To get maximum resistance, connect all four resistor in series combination,

$\therefore$ Equivalent resistance, $R = R_1 + R_2 + R_3 + R_4$

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

TiP

Students must remember that combining resistances in parallel reduces equivalent resistance whereas combining resistance in series increases equivalent resistance.

11. (d) 10 V

The potential difference across 3Ω resistance will be equal to the potential difference of 10 V.

TiP

In parallel combination of resistors, the potential difference across each resistor is same and equal to the total potential difference.

12. (b) 0.6 A

In parallel potential difference across each resistor will remain same. So, current through 10 Ω resistor

$$I = \frac{V}{R} = \frac{6}{10} = 0.6 \text{ A}$$

13. (c) Brightness of bulb B will be more than that of A.

TiP

Bulbs would glow according to their wattage.

14. (a) two times

15. (b) 300%

According to Joule's law of heating,

$H = I^2Rt$

When current is increased to two times,

$H' = (2I)^2Rt = 4I^2Rt$

$$\% \text{ change in heat dissipated} = \left(\frac{H' - H}{H}\right) \times 100$$

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

$$= \frac{3I^2Rt}{I^2Rt} \times 100$$

$= 300\%$

16. (d) Maximum in case (iii)

17. (d) increases heavily

18. (d) 135 W

Power = $VI = 270 \times 0.5 = 135$ W

19. (c) 5 A

20. (a) volt-ampere

21. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

22. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

23. (c) The element of electric iron and heater are made up of alloys having high melting point.

Hence, Assertion (A) is true but Reason (R) is false.

24. (c) ρ is the characteristic of the material of resistors. It does not depend on the length and cross-sectional area of resistors. But Resistance (R) depends on the length and the cross-sectional area of the resistor.

So, R_1 may be greater than R_2 even when $\rho_1 \leq \rho_2$.

25. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

26. (d) When one bulb is removed, the resistance is decreased, hence current flowing through each bulb is increased.

As, $H \propto I_2$, hence light get increased in the room.

27. (b) $R = \frac{V^2}{P}$, *i.e.*, $R \propto \frac{1}{P}$

i.e., higher is the wattage of a bulb, lesser is the resistance and so it will glow bright.

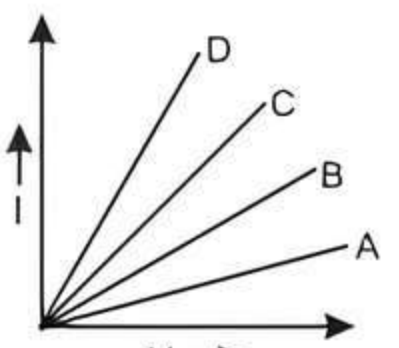
28. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).

Case Study Based Questions

Case Study 1

Ohm's law gives a relationship between current and potential difference. According to this law, at constant temperature, the current flowing through a conductor is directly proportional to the potential difference across its ends. The ratio of potential difference applied between the ends of a conductor and the current flowing through it is a constant quantity called resistance.

The following graph is obtained by a researcher while doing an experiment to study Ohm's law. The *I-V* graph for four conductors *A*, *B*, *C* and *D* having resistances R_A, R_B, R_C and R_D respectively are shown in the graph.



Read the above passage carefully and give the answer of the following questions:

Q 1. If all the conductors are of same length and same material, which is the thickest?

a. *C* b. *D* c. *A* d. *B*

Q 2. If all the conductors are of same thickness and of same material, which is the longest?

a. *B* b. *C* c. *A* d. *D*

Q 3. Which one of the following relations is true for these conductors?

a. $R_A > R_B > R_C > R_D$

b. $R_A = R_B < R_C < R_D$

c. $R_A < R_B < R_C < R_D$

d. $R_A = R_B = R_C = R_D$

Q 4. If conductors A and B are connected in series and *I-V* graph is plotted for the combination, its slope would be:

a. more than that of *A*

b. between *A* and *B*

c. more than that of *D*

d. less than that of *A*

Q 5. If conductors *C* and *D* are connected in parallel and *I-V* graph is plotted for the combination, its slope would be:

a. between *C* and *D*

b. lesser than that of *A*

c. more than that of *D*

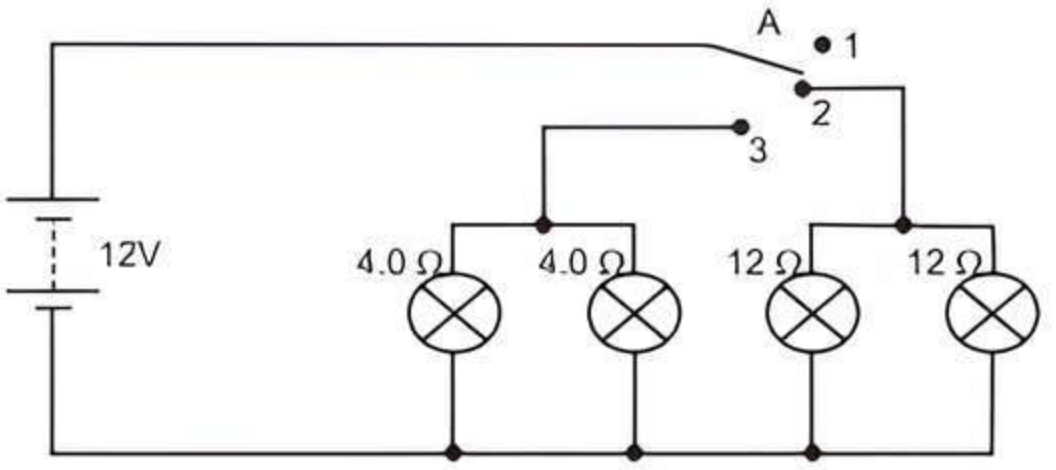
d. between *B* and *C*

Answers

1. (b) D
2. (c) A
3. (a) $R_A > R_B > R_C > R_D$
4. (d) less than that of A
5. (c) more than that of D

Case Study 2

Vinita and Ahmed demonstrated a circuit that operates the two headlights and the two sidelights of a car, in their school exhibition.



Based on their demonstrated circuit, answer the following questions:

Q 1. State what happens when switch A is connected to

(i) Position 2 (ii) Position 3

Q 2. Find the potential difference across each lamp when lit.

Q 3. Calculate the current:

(i) In each 12 Ω lamp when lit.

(ii) In each 4 Ω lamp when lit.

Or

Show, with calculations, which type of lamp, 4.0 Ω or 12 Ω, has the higher power. *(CBSE SQP 2023-24)*

Answers

1. (i) Only 12 Ω lamps will light up.
   (ii) Only 4 Ω lamps will light up.
2. 12 V for both sets of lamps as all of them are in parallel.
3. (i) Voltage across both 12 Ω lamps = 12 V.

   Using Ohm's law, $V = IR$

   $\Rightarrow \quad I = \frac{V}{R} = \frac{12}{12} = 1\ A.$

   (ii) Voltage across both 4 Ω lamps = 12 V.

   Using Ohm's law, $V = IR$

$\Rightarrow \quad I = \frac{V}{R} = \frac{12}{4} = 3\ A.$

Or

All lamps are in parallel and hence same V for all lamps.

Using, $P = V^2/R$

For 4 Ω lamps, $P = \frac{12 \times 12}{4} = 36\ W$

For 12 Ω lamps, $P = \frac{12 \times 12}{12} = 12\ W$

Hence, 4 Ω lamps will have higher power.

Case Study 3

When an electric current passes through a conductor (like a high resistance wire) the conductor becomes hot after some time and produces heat. This is called heating effect of electric current or joule heating or ohmic heating or resistive heating. The heating effect of electric current is widely used in our day-to-day life. The electric laundry iron, electric toaster, electric bulb, fuse and electric heater are some of the familiar devices based on Joule's heating.

Read the above passage carefully and give the answer of the following questions:

Q 1. Write the mathematical expression for Joule's law of heating.

Q 2. The following table gives the resistivity of three samples:

Sample	A	B	C
Resistivity	$1.6 \times 10^{-8}\ \Omega$ m	$5.2 \times 10^{-8}\ \Omega$ m	$100 \times 10^{-4}\ \Omega$ m

Which of them is suitable for heating elements of electrical appliances and why?

Q 3. Why does the cord of an electric heater not glow while the heating element does?

Q 4. State a difference between the wire used in the element of an electric heater and in a fuse wire.

Q 5. Tungsten is used almost exclusively for filaments of electric bulb. List two reasons.

Answers

1. The mathematical expression for Joule's law of heating is:

   Heat generated, $H = I^2Rt$

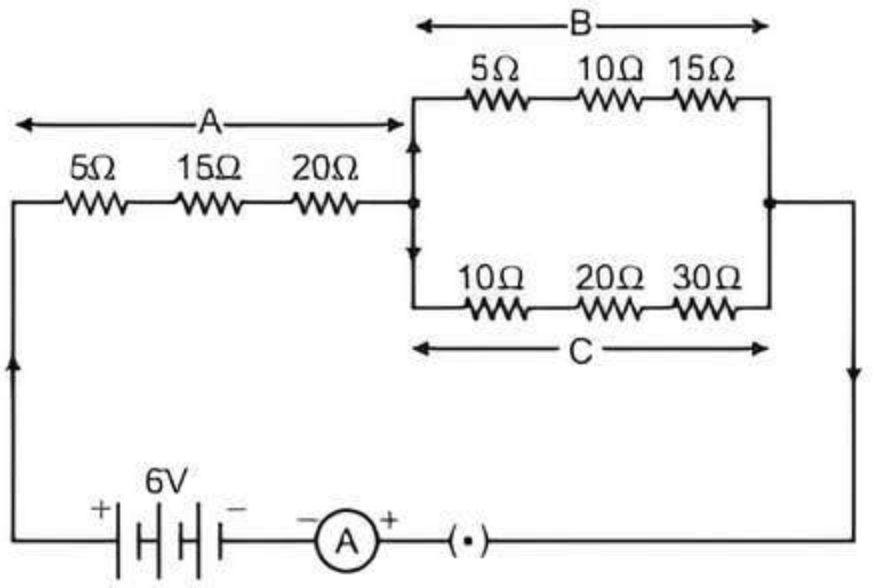
   where *I* is the amount of current flowing through the conductor, *R* is the resistance of conductor and *t* is the time for which the current has flown.
2. The resistivity of sample C is maximum so it is suitable for making heating elements of electrical appliances.
3. The cord of an electric heater is made up of copper with very low resistance whereas heating elements are made up of alloys which have very

high resistance. So, when current flows through the heating element, it becomes too hot and glows red due to heating effect of current.

4. The wire used in element of electric heater has high resistance and high melting point whereas a fuse wire has low resistance and low melting point.
5. Tungsten is used for making filaments of electric bulb because of the following reasons:
   (i) It has very high melting point
   (ii) It has high resistivity

Case Study 4

Study the following electric circuit in which the resistors are arranged in three arms A, B and C:



Study the above electric circuit carefully and give the answer of the following questions:

Q 1. Find the equivalent resistance of arm C.

Q 2. Calculate the equivalent resistance of the parallel combination of the arms B and C.

Q 3. (i) Determine the current that flows through the ammeter.

Or

(ii) Determine the current that flows in the ammeter when the arm B is withdrawn from the circuit.

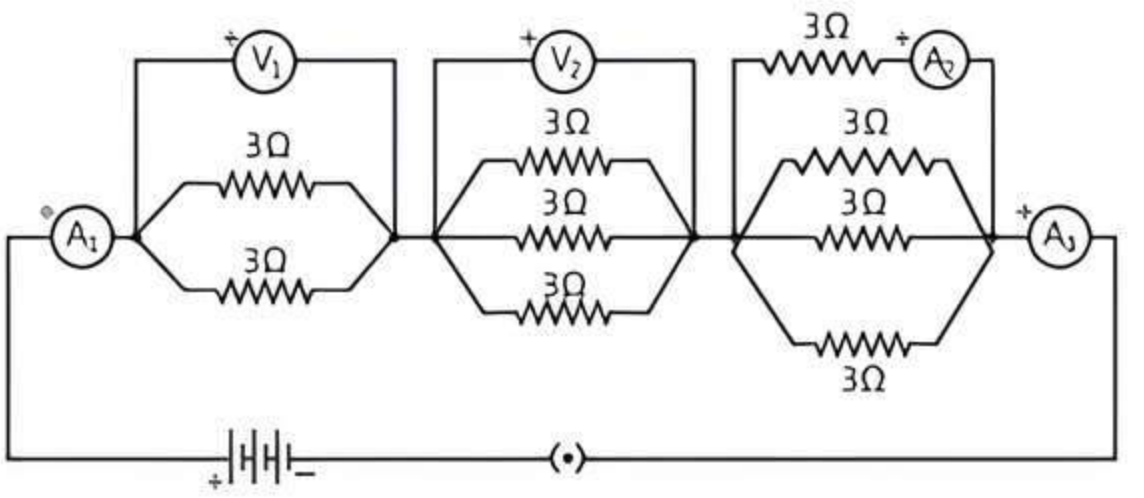
(CBSE 2022 Term-2)

Answers

1. In arm C, 10 Ω, 20 Ω and 30 Ω are in series.
   Thus, the equivalent resistance,
   $R_C = 10 + 20 + 30 = 60\ \Omega$
2. From the given circuit, the equivalent resistance of parallel combination of arm B and C
$$\frac{1}{R_{BC}} = \frac{1}{(5+10+15)} + \frac{1}{(10+20+30)}$$
$$= \frac{1}{30} + \frac{1}{60}$$
$$\frac{1}{R_{BC}} = \frac{2+1}{60} = \frac{3}{60}$$
$$R_{BC} = \frac{60}{3} = 20\ \Omega$$
3. (i) From the given circuit, the equivalent resistance of arm A (R_A) is combined in series with R_{BC}.
   ∴ Total resistance of the circuit $R = R_A + R_{BC}$
   $= (5 + 15 + 20) + 20$
   $= 40 + 20 = 60\ \Omega$
   Thus, the current flowing through ammeter,
$$I = \frac{V}{R} = \frac{6}{60}$$
$$= \frac{1}{10} = 0.1\ \text{A}$$
   Or
   (ii) When the arm B is withdrawn from the circuit, the equivalent resistance,
$$R = (5 + 15 + 20) + (10 + 20 + 30)$$
$$= 40 + 60 = 100$$
$$\therefore \text{Current } I = \frac{V}{R} = \frac{6}{100} = 0.06\ \text{A}$$

Case Study 5

Consider the following electrical circuit diagram in which nine identical resistors of 3 Ω each are connected as shown. The reading of the ammeter A_1 is 1 ampere.



Study the above electrical circuit carefully and give the answer of the following questions:

Q 1. What is the relationship between the readings of A_1 and A_3? Give reasons for your answer.

Q 2. What is the relationship between the readings of A_2 and A_3?

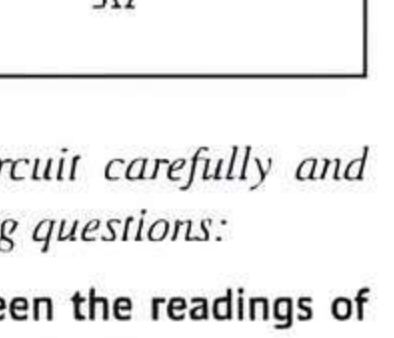
Q 3. Determine the reading of the voltmeter V_1.

Or

Find the total resistance of the circuit. *(CBSE 2023)*

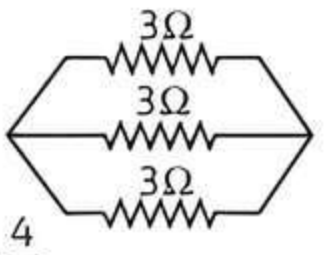
Answers

1. Reading of A_1 = Reading of A_3 because they are connected in series.
2. Reading of A_2 < Reading of A_3
3. $1/R_{eq} = \frac{1}{3} + \frac{1}{3}$
   or $R_{eq} = 3/2\ \Omega = 1.5\ \Omega$
   $V_1 = IR_{eq} = 1 \times \frac{3}{2} = 1.5\ \text{V}$



Or

$$1/R'_{eq} = \frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} = \frac{3}{3} = 1$$



or $R'_{eq} = 1\ \Omega$

Similarly, $1/R''_{eq} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{4}{3}$

or $R''_{eq} = \frac{3}{4}\Omega = 0.75\ \Omega$

Total resistance $= R'_{eq} + R'_{eq} + R''_{eq}$

$= 1.5\ \Omega + 1\ \Omega + 0.75\ \Omega$

$= 3.25\ \Omega$

Very Short Answer Type Questions

Q 1. Name and define the SI unit of current. *(CBSE 2019)*

Ans. The SI unit of current is ampere (A).

One ampere is defined as the flow of one coulomb of charge per second. *i.e.*, 1 A = 1 C/1 s.

Q 2. When is the potential difference between two points in a current carrying conductor said to be 1 volt? *(CBSE 2020)*

Ans. When one joule work is done to move a unit charge from one point to another, then the potential difference between two points is said to be one volt.

$$1\ \text{volt} = \frac{1\ \text{joule}}{1\ \text{coulomb}} \quad \text{or} \quad 1\ V = \frac{1\ J}{1\ C}$$

Q 3. Write the function of voltmeter in an electric circuit. *(CBSE 2019)*

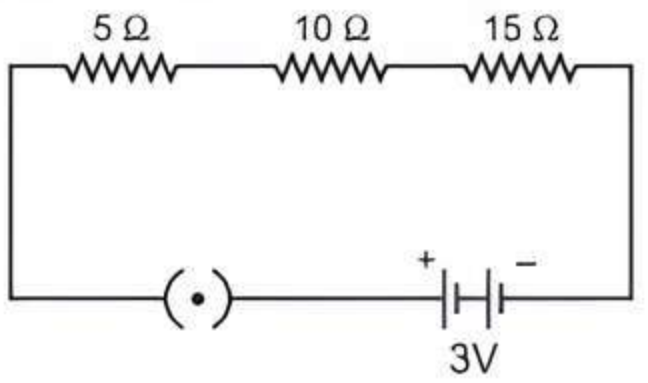
Ans. The function of voltmeter is to measure the potential difference across two points in a circuit.

Q 4. Should the resistance of a voltmeter be low or high? Give reason.

Ans. The resistance of a voltmeter should be high so that negligible current passes through it and it can measure the correct value.

Q 5. Draw a schematic diagram of an electric circuit consisting of a battery of two cells each of 1.5 V each, 5 Ω, three resistors of 10 Ω and 15 Ω respectively and a plug key, all connected in series.

Ans. Schematic diagram of electric circuit containing cells, key and three resistances.



Q 6. Define resistance. Give its SI unit. *(CBSE 2019)*

Ans. Resistance is the property of a conductor to resist the flow of current through it. Its SI unit is ohm.

Q 7. If the potential difference across the two ends of a conductor is 5 V and the current through it is 0.2 A, then what is the resistance of the conductor?

Sol. Given, $V = 5$ V and $I = 0.2$ A

We know that, $R = V/I = 5/0.2 = 25\ \Omega$

Thus, resistance of the conductor is 25 Ω.

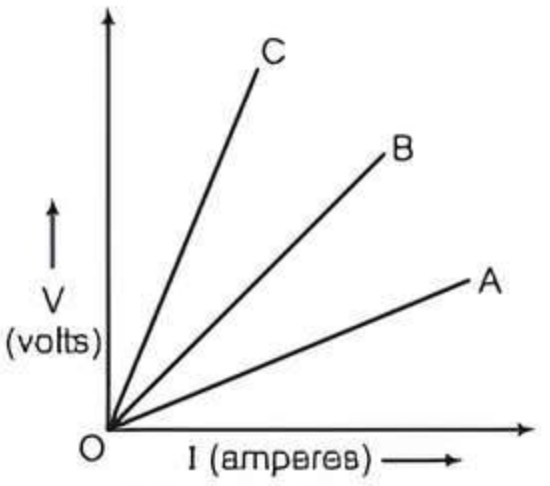
Q 8. Define the term electrical resistivity of a material.

Ans. We know that,

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

If $A = 1$, $l = 1$ then $\rho = R$ *i.e.*, resistivity of a material is the resistance of a conductor of this material whose length and area of cross-section both are unity.

Q 9. Three *V-I* graphs are drawn individually for two resistors and their series combination. Out of *A*, *B*, and *C* which one represents the graph for series combination of the other two. Give reason.



Ans. More slope of *V-I* graph means more resistance. Slope of *C* is maximum, hence its resistance is maximum. So, *C* represents the graph for series combination of *A* and *B*.

Q 10. Why is parallel arrangement used in domestic wiring? *(NCERT EXEMPLAR)*

Ans. Parallel arrangement is used in domestic wiring so as to provide the same potential difference across each electrical appliance. Moreover if fault or short circuit occurs in any circuit, it will not result in the disconnection to other circuits.

Q 11. Why are the heating elements of electric toasters and electric irons made of an alloy rather than a pure metal? *(CBSE 2019)*

Ans. They are made of an alloy due to high resistivity of alloys rather than its constituting metals.

Q 12. How does use of a fuse wire protect electrical appliances? *(NCERT EXEMPLAR)*

Ans. Fuse wire protects electrical appliances by breaking the circuit (melting the fuse wire) when a current larger than the specified value flows in the circuit.

Q 13. Define 1 kilowatt hour. Represent it in terms of joules.

Ans. 1 kilowatt hour is the energy consumed when 1000 watt of power is used for 1 hour.

$$1\ \text{kWh} = 1000\ \text{W} \times 60 \times 60\ \text{s} = 3.6 \times 10^6\ \text{J}$$

Short Answer Type-I Questions

Q 1. List in a tabular form two differences between a voltmeter and an ammeter.

Ans.

S. No.	Basis of Difference	Voltmeter	Ammeter
(i)	Purpose	It is used to measure P.D. across two points in an electric circuit.	It is used to measure electric current in an electric circuit.

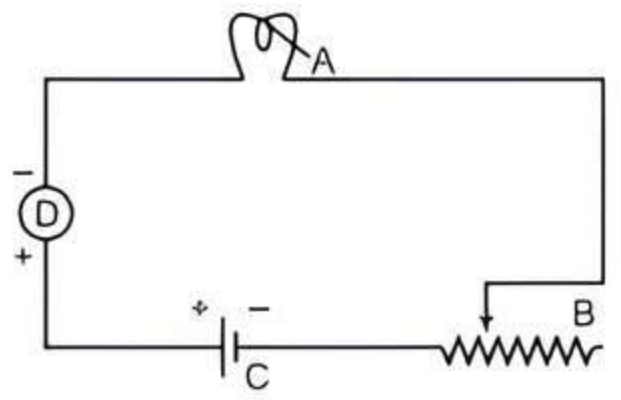
(ii)	Resistance	Its resistance is very high.	Its resistance is very low.
(iii)	Arrange-ment	An voltmeter is connected in parallel in an electric circuit.	An ammeter is connected in series in an electric circuit.

(Any two)

TiP

While understanding the concept of electric current and potential difference, lay stress on the definition and function of voltmeter and ammeter.

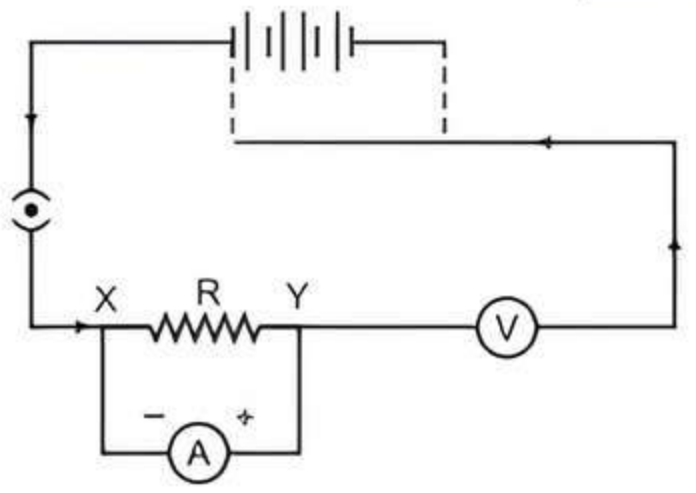
Q 2. Given below is a circuit showing current flowing in it. Identify each component *A*, *B*, *C*, *D* of this circuit:



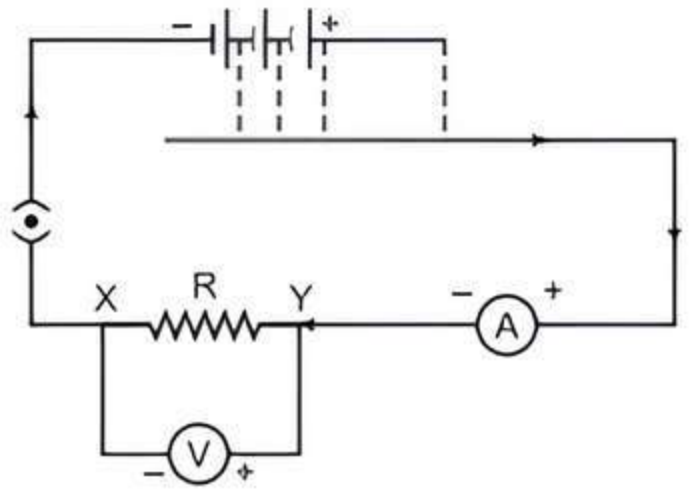
Ans. *A* is Electric Bulb; *B* is Rheostat or variable resistance; *C* is an electric cell and *D* is ammeter.

Q 3. A child 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. The correct circuit diagram is:



COMMON ERROR

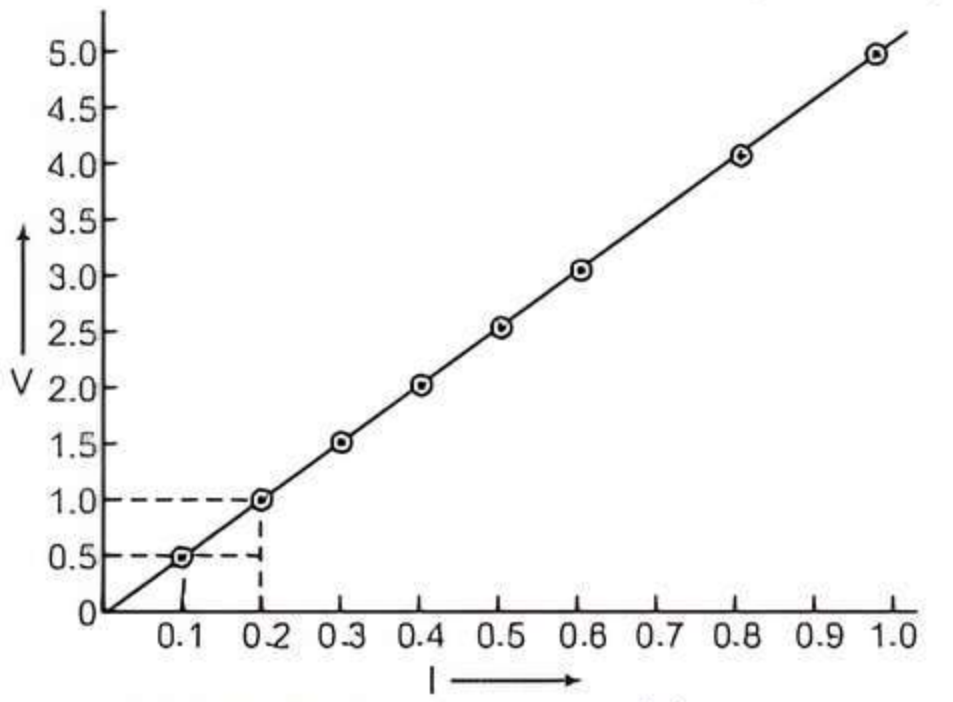
Many students fail to correct the direction of current in the given circuit.

Q 4. The values of current (*I*) flowing through a given resistor of resistance (*R*), for the corresponding values of potential difference (*V*) across the resistor are as given below:

V (volts)	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0
I (amperes)	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0

Plot a graph between current (*I*) and potential difference (*V*) and determine the resistance (*R*) of the resistor. *(CBSE 2018)*

Ans.



Slope of *V*-*I* graph gives resistance (*R*).

$$R = \frac{\Delta V}{\Delta I} = \frac{V_2 - V_1}{I_2 - I_1} = \frac{1.0 - 0.5}{0.2 - 0.1} = \frac{0.5}{0.1}$$

$\therefore \quad R = 5\ \Omega$

Q 5. Consider the circuit shown in the diagram. Find the current in 3 Ω resistor. *(CBSE 2011)*

Sol. 3 Ω and 6 Ω are connected in parallel.

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

$\therefore \quad R_p = 2\ \Omega$

R_p and 10 Ω are connected in series.

Hence, total amount of resistance, $R_s = R_p + 10$

$= 2 + 10 = 12\ \Omega$

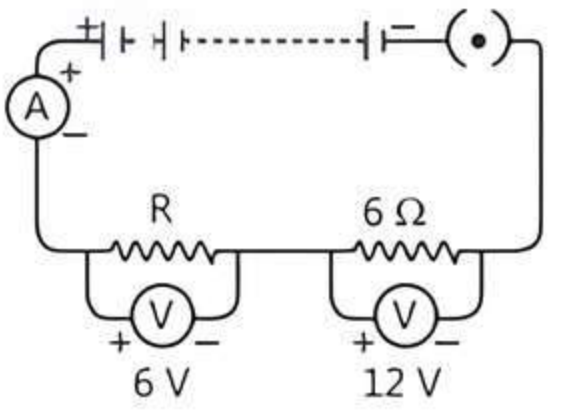
Total current in the circuit, $I = \frac{V}{R_s} = \frac{12}{12} = 1\ A$

Now, voltage drop across the parallel connection

$= 1 \times 2 = 2V$

So, current across the 3Ω resistance $= \frac{V}{R} = \frac{2}{3}\ A$

Q 6. A circuit is shown in the diagram given below:



(i) Find the value of R.

(ii) Find the potential difference across the terminals of the battery.

Sol. (i) Potential difference across 6 Ω = 12 V

Hence, current through 6 Ω.

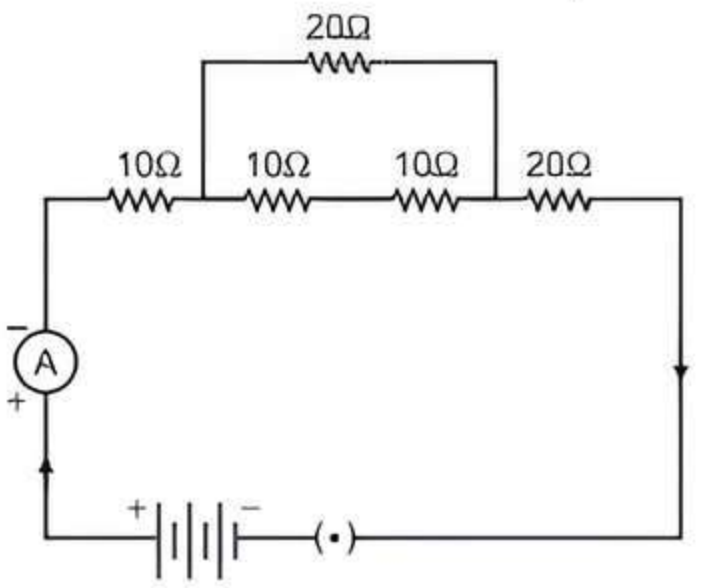
$$I = \frac{V}{R} = \frac{12}{6} = 2\,A$$

Since, R and 6 Ω are connected in series, therefore, the current through R will be 2 A. According to Ohm's law,

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

(ii) Potential difference across the terminals of the battery $V = V_1 + V_2 = 6 + 12 = 18$ V

Q 7. Calculate the equivalent resistance of the following electric circuit: *(CBSE 2022 Term-2)*



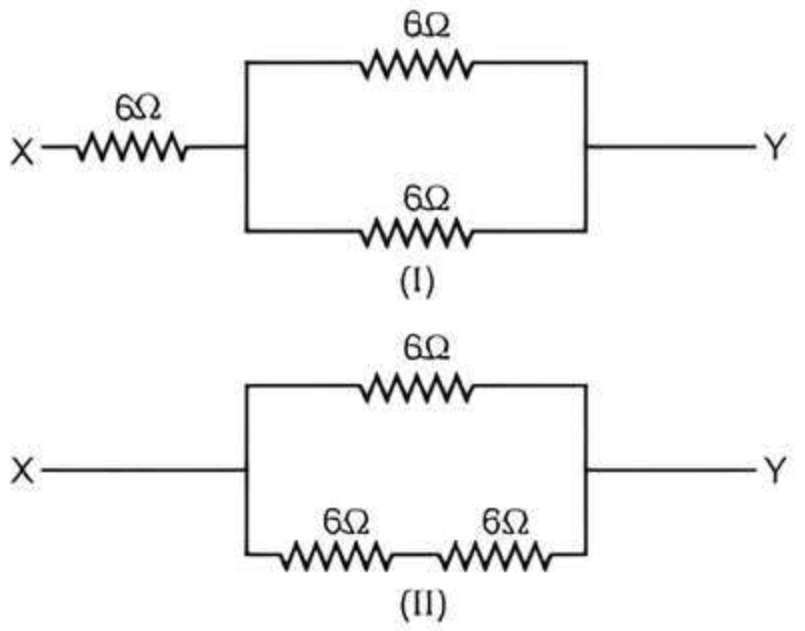
Sol. From the given electric circuit.

Equivalent resistance, $R_{eq} = 10 + \left(\frac{20 \times 20}{20 + 20}\right) + 20$

$= 10 + \frac{400}{40} + 20$

$= 40\ \Omega$

Q 8. A student shows two different ways in which three resistors of 6Ω each can be connected in a circuit. Show by calculation in which case is the equivalent resistance minimum.



Ans. Equivalent Resistance of Circuit (I):

$$R_I = 6 + \left(\frac{6 \times 6}{6 + 6}\right) = 6 + \frac{36}{12} = 6 + 3 = 9\,\Omega$$

Equivalent Resistance of Circuit (II):

$$R_{II} = \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4\,\Omega$$

Thus, circuit (II) has minimum resistance.

Q 9. A piece of wire of resistance R is cut into three equal parts. These parts are then connected in parallel. If the equivalent resistance of this parallel combination is R_1, what is the value of the ratio $R_1 : R$? *(CBSE SQP 2023-24)*

Sol. Resistance of each part $= \frac{R}{3}\Omega$ $(\because R \propto l)$

Equivalent resistance of parallel combination of these three parts $= R_1$

$$\Rightarrow \quad \frac{1}{R_1} = \frac{1}{(R/3)} + \frac{1}{(R/3)} + \frac{1}{(R/3)}$$

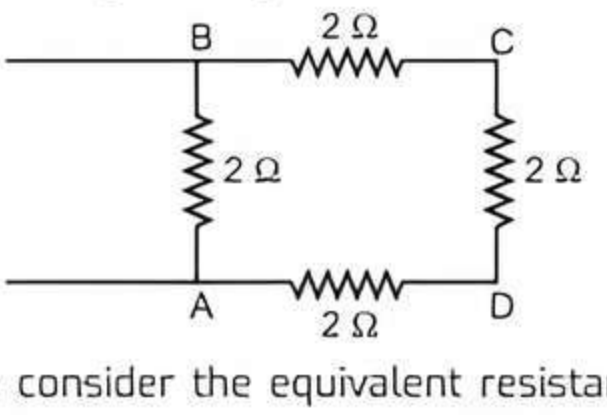
$$\Rightarrow \quad \frac{1}{R_1} = \frac{3}{R} + \frac{3}{R} + \frac{3}{R} = \frac{9}{R}$$

$$\Rightarrow \quad R_1 = \frac{R}{9}$$

$$\text{or} \quad \frac{R_1}{R} = \frac{1}{9}$$

Hence, $R_1 : R = 1 : 9$.

Q 10. A student has four resistors of 2Ω each which are joined end to end to form a square ABCD. Calculate the equivalent resistance of the combination between any two adjacent corners.



Sol. Let us consider the equivalent resistance between A and B. Here, three resistances of 2 Ω are in series and this combination is connected in parallel to another resistor of 2 Ω.

Equivalent resistance of three series resistors

$= 2 + 2 + 2 = 6\,\Omega$

$$\text{Required equivalent resistance} = \frac{1}{\frac{1}{6} + \frac{1}{2}} = \frac{1}{\frac{4}{6}} = 1.5\,\Omega$$

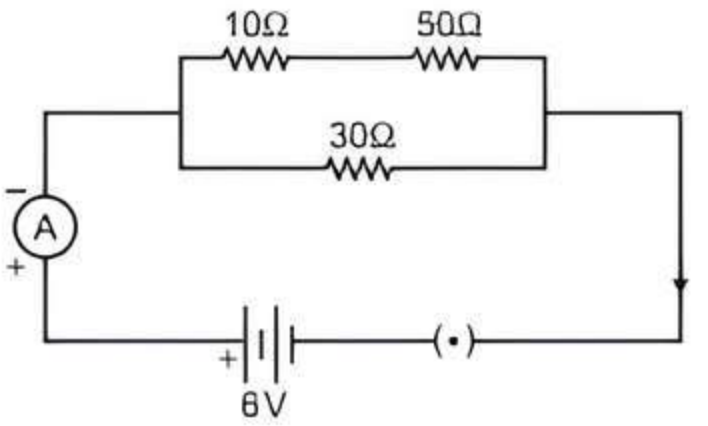
TiP

Clear your knowledge on finding total resistance in series and parallel circuit. It is advised to write the answer in SI unit.

Q 11. In the given circuit determine the value of:

(i) total resistance of the circuit

(ii) current flowing through the ammeter.



Sol. (i) From the given circuit, total resistance

$$= \frac{60 \times 30}{60 + 30} = \frac{1800}{90} = 20\ \Omega$$

(ii) From Ohm's law,

$$V = IR$$

$$I = \frac{V}{R} = \frac{6}{20} = 0.3\ \text{A}$$

Q 12. An electrical device of resistance *R* is connected across a source of voltage *V* and draws a current *I*. Derive an expression for power in terms of current and resistance. *(CBSE 2020)*

Ans. We know that, $V = W/Q$

$\Rightarrow$ $W = VQ$

Dividing both sides by 't', we get

$W/t = VQ/t$

$\Rightarrow P = VI \quad (\because W/t = P \text{ and } Q/t = I)$

$\Rightarrow P = IR.I \ (\because V = IR) \quad \Rightarrow P = I^2R$

Q 13. Find the resistance of bulb rated as 100 W-250 V.

Sol. We have, $P = 100$ W.

$V = 250$ V

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

$$R = \frac{(250)^2}{100} = \frac{250 \times 250}{100} = 625\ \Omega$$

Q 14. An electric heater rated 1100 W operates at 220 V. Calculate:
(i) its resistance and (ii) the current drawn by it.
(CBSE 2022 Term-2)

Sol. Given that,

$P = 1100$ W

$V = 220$ V

(I) As we know

$$P = \frac{V^2}{R} \quad \text{Or} \quad R = \frac{V^2}{P} = \frac{220 \times 220}{1100} = 44\ \Omega$$

(ii) From, $V = IR$

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

Short Answer Type-II Questions

Q 1. Define 1 V. Express it in terms of SI unit of work and charge. Calculate the amount of energy consumed in carrying a charge of 1 coulomb through a battery of 3 V.

Sol. When 1 joule of work is done in carrying 1 coulomb of charge, from infinity to a point in the electric field, then at that point, potential will be 1 volt.

Hence, $1\ \text{V} = 1\ \text{J/C}$

Potential difference between two points is

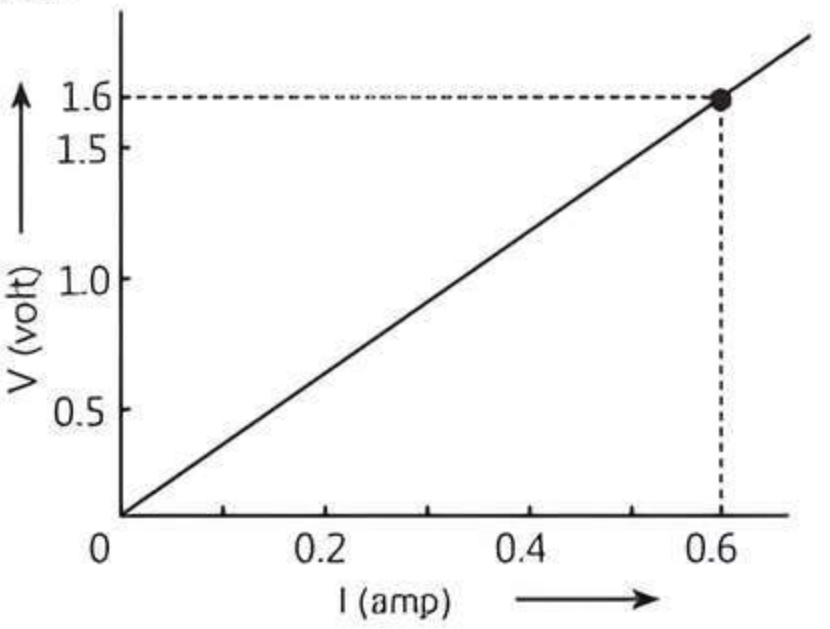
$$V = \frac{W}{q}$$

So, the amount of energy consumed,

$$W = q \times V = 1 \times 3 = 3\ \text{J}$$

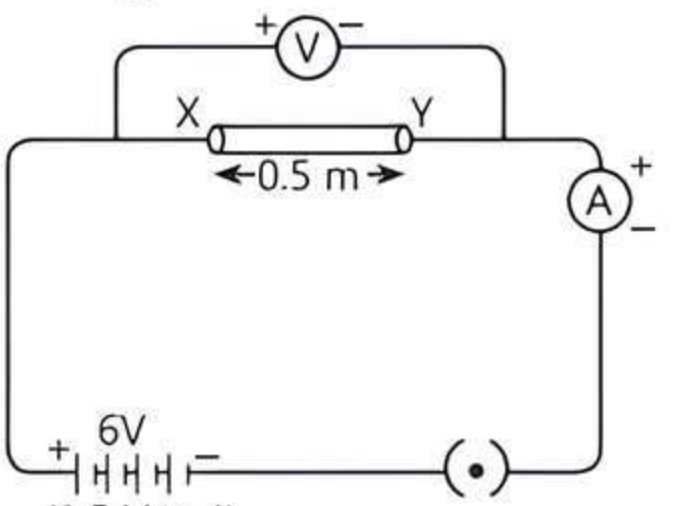
Q 2. (i) Draw a closed circuit diagram consisting of a 0.5 m long nichrome wire XY, an ammeter, a voltmeter, four cells of 1.5 V each and a plug-key.

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



What would be the values of *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? *(CBSE 2015)*

Ans. (i) **Circuit Diagram:**

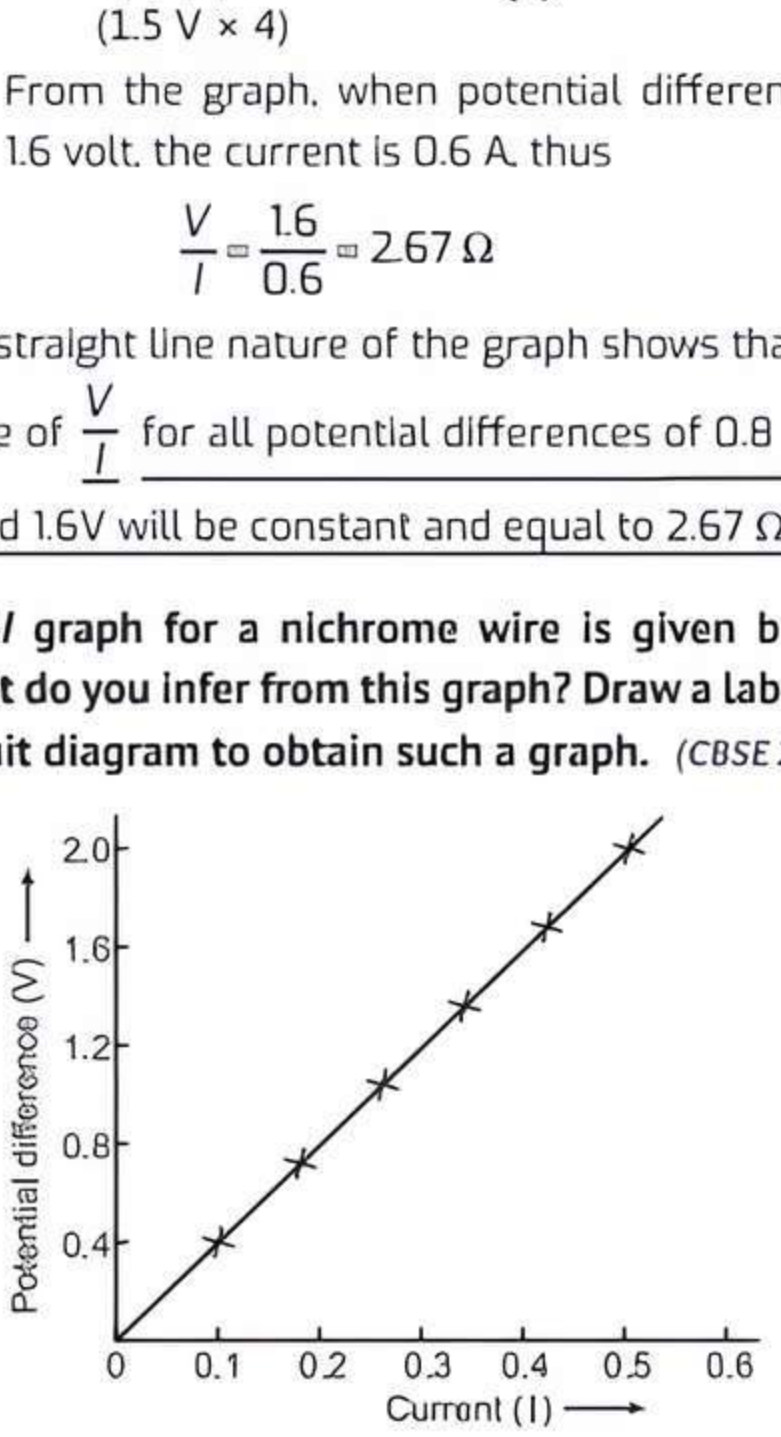


(ii) From the graph, when potential difference is 1.6 volt, the current is 0.6 A, thus

$$\frac{V}{I} = \frac{1.6}{0.6} = 2.67\ \Omega$$

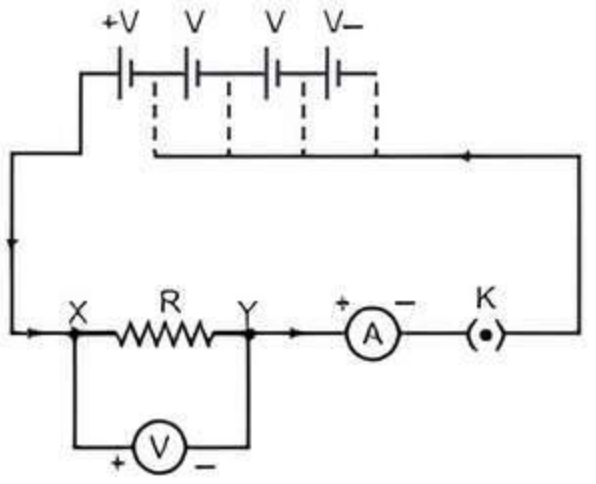
The straight line nature of the graph shows that the value of $\frac{V}{I}$ for all potential differences of 0.8 V, 1.2 V and 1.6V will be constant and equal to 2.67 Ω.

Q 3. A *V-I* graph for a nichrome wire is given below. What do you infer from this graph? Draw a labelled circuit diagram to obtain such a graph. *(CBSE 2020)*



Ans. The *V-I* graph of the nichrome wire is a straight line. So, we can conclude that current flowing through the wire is directly proportional to the potential difference across it. *i.e.*, $V \propto I$.

Circuit Diagram:



COMMON ERROR

Students fail to draw the electric circuit for studying Ohm's law.

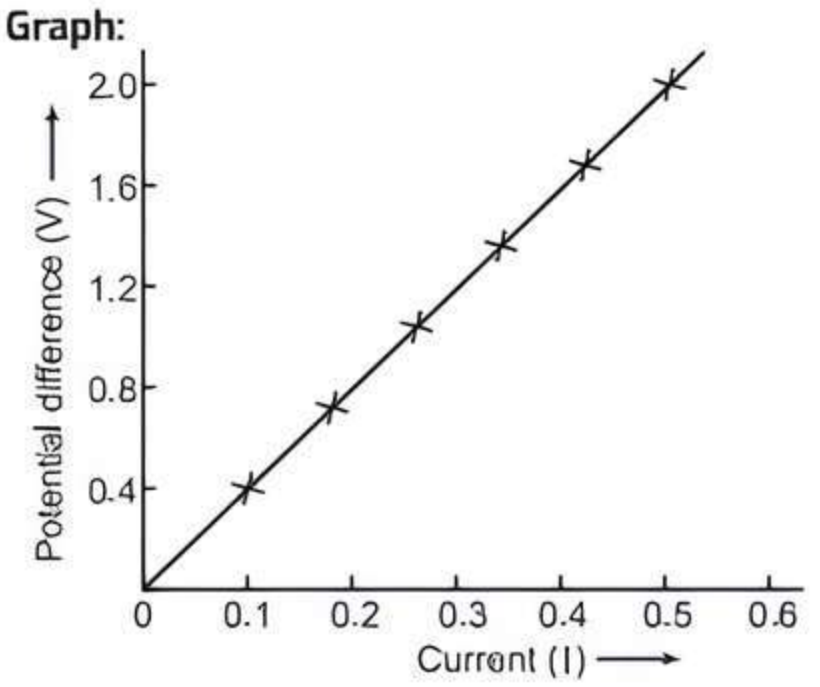
Q 4. (i) State the relation correlating the electric current flowing in a conductor and the voltage applied across it. Also draw a graph to show this relationship.

(ii) Find the resistance of a conductor if the electric current flowing through it is 0.35 A when the potential difference across it is 1.4 V. *(CBSE 2020)*

Ans. (i) The Ohm's law *i.e.*, potential difference across the ends of a conductor in an electric circuit is directly proportional to the current flowing through it. correlates electric current and voltage.

or $\frac{V}{I} = \text{constant}$

Graph:



(ii) Given, $I = 0.35$ A and $V = 1.4$ V

From Ohm's law,

$$R = \frac{V}{I} \Rightarrow R = \frac{1.4}{0.35} \Rightarrow \underline{R = 4\ \Omega}$$

Q 5. (i) List the factors on which the resistance of a conductor in the shape of a wire depends.

(ii) Why are metals good conductors of electricity whereas glass is a bad conductor of electricity? Give reason.

(iii) Why are alloys commonly used in electrical heating devices? Give reason. *(CBSE 2018)*

Ans. (i) Resistance of a conductor depends on the following factors:

(a) It is directly proportional to length (l) of the conductor.

$$R \propto l$$

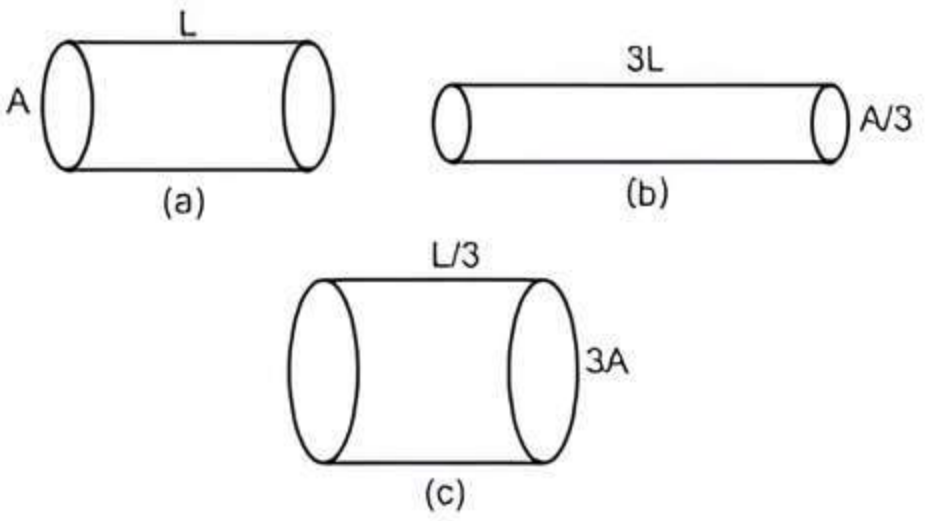
(b) It is inversely proportional to the area of cross-section of the conductor.

$$R \propto \frac{1}{A}$$

(ii) Metals are good conductors of electricity because they have free electrons to conduct electricity whereas glass does not have free electrons present in it hence it is a bad conductor of electricity.

(iii) Alloys are commonly used in electrical heating devices rather than pure metals as they have high resistivity as well as high melting point.

Q 6. The figure below shows three cylindrical copper conductors along with their face areas and lengths. Compare the resistance and the resistivity of the three conductors. Justify your answer:



Ans. In figure (a), the value of resistance,

$$R_a = \rho\frac{L}{A}$$

In figure (b), the value of resistance,

$$R_b = \rho\left(\frac{3L}{A/3}\right) = 9\left(\frac{\rho L}{A}\right) = 9R_a$$

In figure (c), the value of resistance,

$$R_c = \rho\left(\frac{L/3}{3A}\right) = \frac{1}{9}\left(\frac{\rho L}{A}\right) = \frac{1}{9}R_a$$

Hence, $R_b > R_a > R_c$

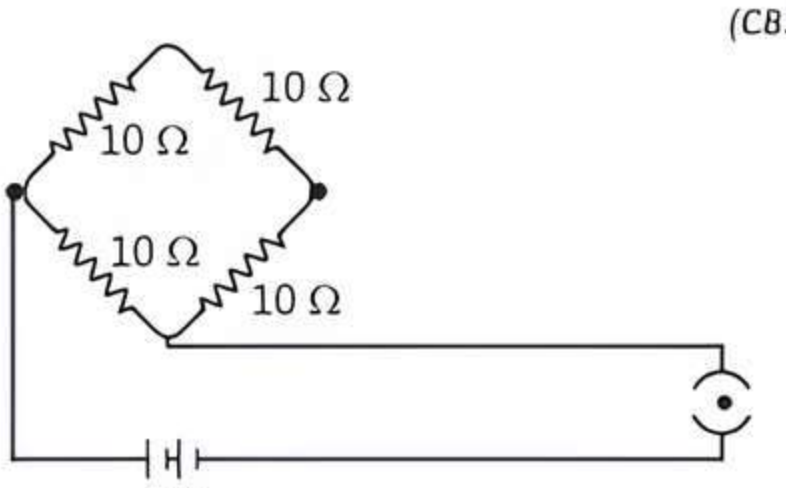
Also, $\underline{\rho_A = \rho_B = \rho_C}$ because all three conductors are of same material *i.e.*, copper.

COMMON ERROR

Many students commit errors in substituting the values in formulas. Some of them forget to answer the sub-part of this question i.e., compare the resistivity of three conductors.

Q 7. Find the current drawn from the battery by the network of four resistors as shown in the figure:

(CBSE 2015)



Sol. The given circuit shows a series combination of three 10 Ω resistors (let R_1, R_2, R_3) in parallel combination with one 10 Ω resistor (R_4). Hence, equivalent resistance of the given network is,

$$\frac{1}{R}=\frac{1}{R_4}+\frac{1}{R_1+R_2+R_3}$$

$$=\frac{1}{10}+\frac{1}{10+10+10}$$

$$=\frac{1}{10}+\frac{1}{30}=\frac{3+1}{30}=\frac{4}{30}$$

$$\Rightarrow \quad R=\frac{30}{4}=7.5\,\Omega$$

Now, the current drawn by the network,

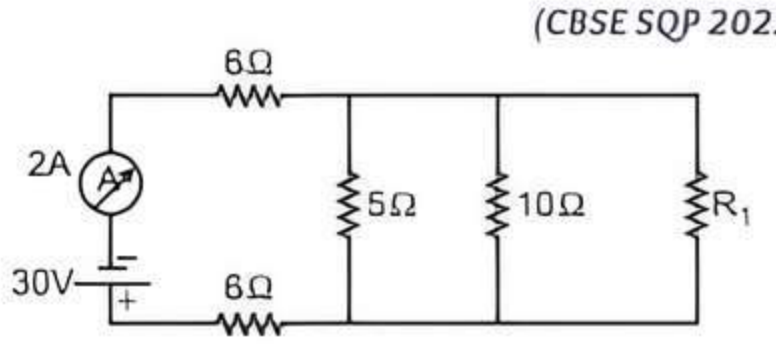
$$I=\frac{V}{R} \qquad (\because V=IR)$$

$$\Rightarrow \quad I=\frac{3}{7.5}=\underline{0.4\text{ A}}$$

Hence, the current drawn from the battery is <u>0.4 A</u>.

Q 8. In the given circuit, if the current reading in the ammeter *A* is 2A, what would be the value of R_1?

(CBSE SQP 2022 Term-2)



Sol. In the given circuit, resistances

5 Ω, 10 Ω and R_1 Ω are in parallel

$\therefore$ Resistance $\frac{1}{R}=\frac{1}{5}+\frac{1}{10}+\frac{1}{R_1}$

$$=\frac{2R_1+R_1+10}{10R_1}=\frac{3R_1+10}{10R_1}$$

$$\Rightarrow \quad R=\frac{10R_1}{3R_1+10}$$

Now, $\frac{10R_1}{3R_1+10}$, 6 Ω and 6 Ω are in series

$\therefore$ Equivalent resistance $R_{eq}=12+\frac{10R_1}{3R_1+10}$

$$=\frac{36R_1+10R_1+120}{3R_1+10}$$

As we know, $R=\frac{V}{I}$

$$\therefore \quad \frac{36R_1+10R_1+120}{3R_1+10}=\frac{30}{2} \Rightarrow 46R_1+120=45R_1+150$$

$$\therefore \quad R_1=30\,\Omega$$

Q 9. Show how would you join three resistors, each of resistance 9 Ω so that the equivalent resistance of the combination is (i) 13.5 Ω and (ii) 6 Ω.?

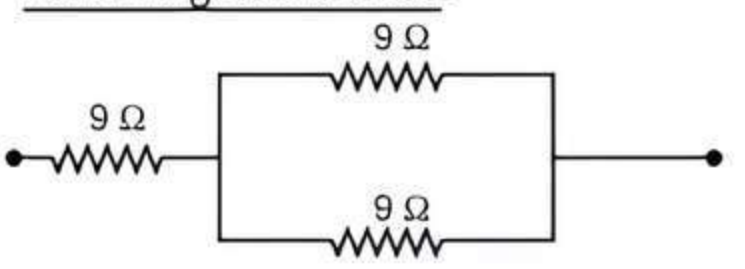
(CBSE 2018)

Ans.

TiP

Practice plenty of numericals based on finding the equivalent resistance of series and parallel circuits.

(i) To get equivalent resistance of 13.5 Ω, <u>two 9 Ω resistors are first connected in parallel and then their combination is connected in series with the remaining 9 Ω resistor.</u>

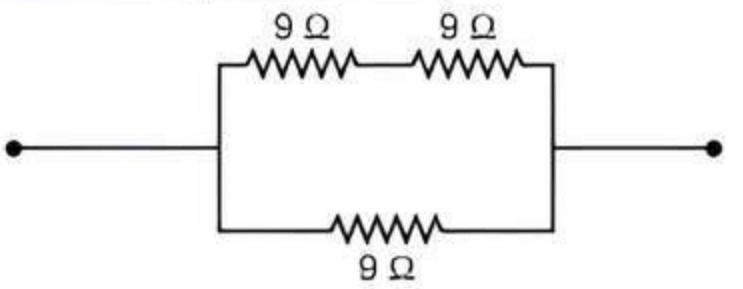


$$\frac{1}{R_p}=\frac{1}{9}+\frac{1}{9}=\frac{2}{9}$$

$$R_p=\frac{9}{2}=4.5\,\Omega$$

$$R=(9+4.5)\Omega=\underline{13.5\,\Omega}$$

(ii) To get equivalent resistance of 6 Ω, <u>two 9 Ω resistors are first connected in series and then this combination is connected in parallel with the remaining 9 Ω resistor.</u>



$$R_s=9\,\Omega+9\,\Omega=18\,\Omega$$

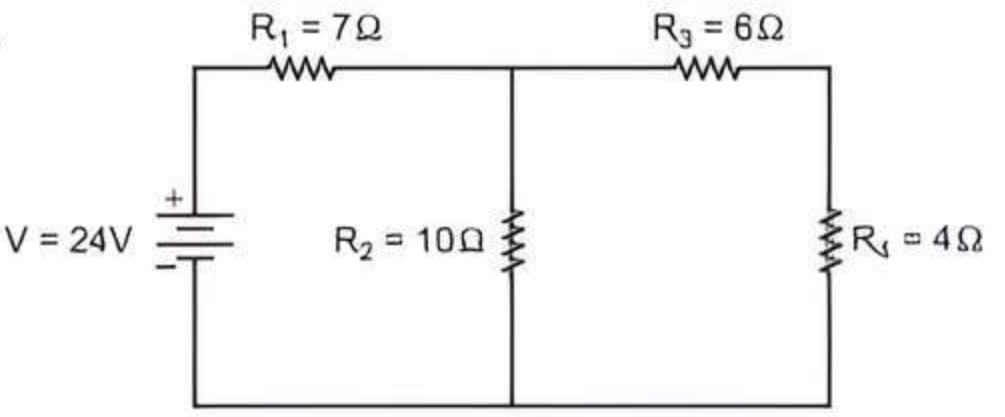
$$\frac{1}{R}=\frac{1}{18}+\frac{1}{9}=\frac{3}{18}$$

$$R=\frac{18}{3}=\underline{6\,\Omega}$$

COMMON ERROR

Most students show the circuit diagram and write theory part while answering this question, but do not show calculations due to which their marks will be deducted.

Q 10.



Calculate the total resistance of the circuit and find the total current in the circuit. *(CBSE SQP 2022 Term-2)*

Sol. In the given circuit, resistance are combined in following way

$$R = [(R_4 + R_3) \,||\, R_2] + R_1$$
$$= [(4 + 6) \,||\, 10] + 7$$
$$= \left[\frac{10 \times 10}{10 + 10}\right] + 7$$
$$= \frac{100}{20} + 7 = 12\ \Omega$$

Thus, the total resistance of the circuit = 12 Ω

Now, total current, $I = \frac{V}{R} = \frac{24}{12} = 2$ A

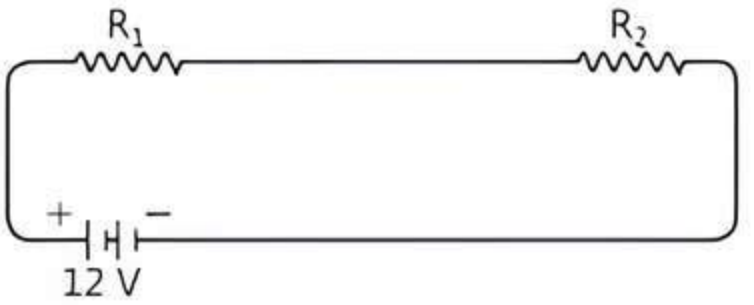
Q 11. Two resistors with resistance 10 Ω and 15 Ω are to be connected to a battery of emf 12 V so as to obtain:

(i) minimum current (ii) maximum current

Describe the mode of connecting the resistances in each case.

Calculate the strength of the total current in the circuit in each case. *(CBSE 2017)*

Ans. (i) The resistors are connected in series to obtain minimum current.



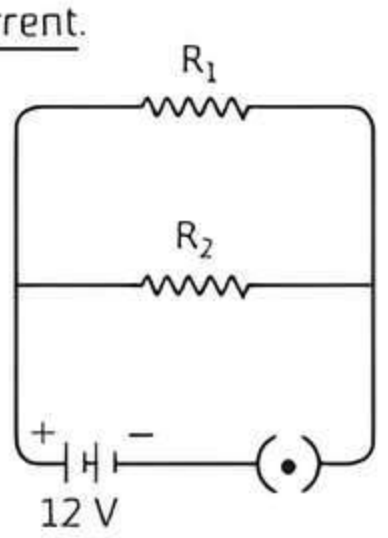
Given, $R_1 = 10\ \Omega$, $R_2 = 15\ \Omega$, $V = 12$ V, $I = ?$

$\therefore$ $R = R_1 + R_2 = 10 + 15 = 25\ \Omega$

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

$\Rightarrow$ $I = \frac{V}{R} = \frac{12}{25} = 0.48$ A

(ii) The resistors are connected in parallel to obtain maximum current.



Given: $R_1 = 10\ \Omega$, $R_2 = 15\ \Omega$, $V = 12$ V, $I = ?$

$\therefore$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{1}{R} = \frac{1}{10} + \frac{1}{15}$

$= \frac{3+2}{30} = \frac{5}{30}$

$\Rightarrow$ $\frac{1}{R} = \frac{1}{6}$ or $R = 6\ \Omega$

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

$\Rightarrow$ $I = \frac{V}{R} = \frac{12}{6} = 2$A

Q 12. (i) Write Joule's law of heating.

(ii) Compute the heat generated while transferring 96000 C of charge in two hours through a potential difference of 40 V. *(CBSE 2020)*

Ans. (I) **Joule's Law of Heating:** It states that the amount of heat produced in a conductor is:

(a) directly proportional to the square of current flowing through it. *i.e.*,

$$H \propto I^2$$

(b) directly proportional to the resistance of the conductor for a given current and time *i.e.*,

$$H \propto R$$

(c) directly proportional to the time for which current is flowing through it. *i.e.*,

$$H \propto t$$

Combining these, we get

$$H \propto I^2Rt$$

or

$$H = I^2Rt$$

(II) Given, $V = 40$ V, $Q = 96000$ C

Heat generated, $H = V.Q.$

$= 40 \times 96000 = 3.84 \times 10^6$ J

Q 13. (i) What is the meaning of electric power of an electrical device? Write its SI unit.

(ii) An electric kettle of 2 kW is used for 2h. Calculate the energy consumed in

(i) kilowatt hour and

(ii) joules *(CBSE 2022 Term-2)*

Ans. (i) Electric power is the rate at which electric energy is consumed by an electrical device in an electric circuit.

Its SI unit is Watt (W).

(ii) Given,

$P = 2$ kW

$t = 2$ h

We know that, Energy consumed, $E = P \times t$

(a) $E = 2 \times 2 = 4$ kWh

(b) $E = 4$ kWh $= 4 \times 3.6 \times 10^6$ J

$= 14.4 \times 10^6$ J

Long Answer Type Questions

Q 1. What is meant by electric current? Name and define its SI unit. In a conductor, electrons are flowing from B to A. What is the direction of conventional current? Give justification for your answer.

(CBSE 2015)

A steady current of 1 ampere flows through a conductor. Calculate the number of electrons that flows through any section of the conductor in 1 second. (Charge on electron $= -1.6 \times 10^{-19}$ coulomb)

Ans. Electric Current: Electric current is the amount of charge 'q' flowing through a particular area of cross-section in unit time 't'.

Electric current $I = \frac{q}{t}$

SI unit of electric current is ampere.

One ampere is the current which flows when one coulomb of electric charge flows through a particular area of cross section of the conductor in one second *i.e.*, $1A = 1\ Cs^{-1}$.

The direction of conventional current is from A to B *i.e.*, opposite to the direction of flow of electrons. Direction of flow of electrons gives the direction of electronic current. By convention, the direction of flow of positive charge is taken as the direction of conventional current.

We know that, $q = It = ne$

$\Rightarrow \quad It = ne$

$\Rightarrow \quad n = It/e$

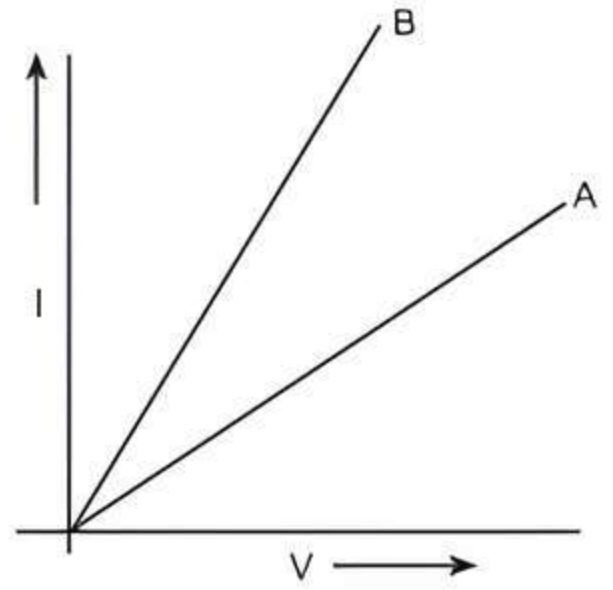
$\Rightarrow$ number of electrons,

$$n = \frac{1A \times 1s}{1.6 \times 10^{-19}C} = \frac{10^{19}}{1.6} = 6.25 \times 10^{18} \text{ electrons.}$$

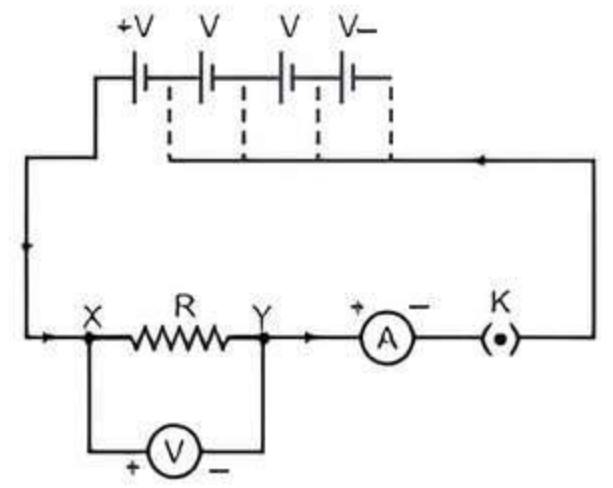
Q 2. (i) How is electric current related to the potential difference across the terminals of a conductor? Draw a labelled circuit diagram to verify this relationship.

(ii) Why should an ammeter have low resistance?

(iii) Two *V*-*I* graphs *A* and *B* for series and parallel combinations of two resistors are as shown. Giving reason state which graph shows (a) series, (b) parallel combination of the resistors. *(CBSE 2023)*



Ans. (i) The potential difference across the terminals of a conductor is directly proportional to the current flowing through it, provided its temperature remains the same.



TiP

Practice drawing circuit diagrams and remember the symbols of commonly used components in circuit diagrams.

(ii) An ammeter is used to measure the amount of current flowing in a circuit and is connected in series. Hence, its resistance adds to the total resistance of the circuit. If the resistance of the ammeter would be high, the total resistance would be high and this would decrease the amount of current flowing through the circuit. Hence, in order to measure the current appropriately, an ammeter has low resistance.

(iii) The slope of *I*-*V* graph gives (1/resistance). Since, straight line A is less steep, its resistance is more. We know that, in series combination, the equivalent resistance is more than in parallel combination. So, A represents series combination and B represents parallel combination of the resistors.

Q 3. (i) Write the relation between resistance and electrical resistivity of the material of a conductor in the shape of a cylinder of length *l* and area of cross-section *A*. Hence, derive the SI unit of electrical resistivity.

(ii) Resistance of a metal wire of length 5 m is 100 Ω. If the area of cross-section of the wire is $3 \times 10^{-7}\ m^2$, calculate the resistivity of the metal. *(CBSE 2019)*

Ans. (i) We know that, $R \propto l$ and $R \propto 1/A$

On combining, we get

$$R \propto \frac{l}{A}$$

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

or $$\rho = \frac{RA}{l} = \frac{\text{Ohm} \times m^2}{m}$$

$$= \text{Ohm} \times m$$

SI unit of electrical resistivity is Ohm-metre.

(ii) Given, $l = 5$ m, $R = 100\ \Omega$ and $A = 3 \times 10^{-7}\ m^2$

We know that,

$$\rho = \frac{RA}{l}$$

$$\rho = 100 \times 3 \times 10^{-7} / 5$$

$$\rho = 60 \times 10^{-7}\ \Omega\text{-m}$$

Q 4. (i) Find the ratio of resistances of two copper rods *X* and *Y* of lengths 30 cm and 10 cm respectively and having radii 2 cm and 1 cm respectively.

(ii) A current of 500 mA flows in a series circuit containing an electric lamp and a conductor of 10 Ω when connected to 6 V battery. Find the resistance of the electric lamp. *(CBSE 2020)*

Sol. (i) Given, $l_X = 30$ cm, $l_Y = 10$ cm,

$r_X = 2$ cm and $r_Y = 1$ cm

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

$$R_X = \rho\frac{l_X}{A_X} = \frac{30\ \rho}{\pi \times 2 \times 2} \qquad [\because A_X = \pi r_X^2]$$

$$= \rho\text{——} = \rho\frac{10}{\pi \times 1 \times 1} \qquad [\because A_Y = \pi r_Y^2]$$

$$\frac{R_X}{R_Y} = \frac{\rho.l_X}{A_x} \times \frac{A_Y}{\rho.l_Y}$$

$$= \frac{30}{\pi \times 2 \times 2} \times \frac{\pi \times 1 \times 1}{10}$$

$$\frac{R_X}{R_Y} = \frac{3}{4}$$

Hence, $R_X : R_Y = 3 : 4$

(ii) Here, $I = 500$ mA $= 0.5$ A:

Let Resistance of lamp be R_1

Given, Resistance of the conductor $(R_2) = 10\Omega$

and Potential difference $(V) = 6$ V

Net resistance of the circuit $= R = R_1 + R_2 = \frac{V}{I}$

$$\Rightarrow \quad R_1 + 10\,\Omega = \frac{6}{0.5}$$

$$\Rightarrow \quad R_1 + 10\,\Omega = 12\,\Omega$$

$$R_1 = (12 - 10)\,\Omega$$

$$= 2\,\Omega$$

COMMON ERR(!)R

Errors are commonly found in numericals. Students often forget to convert 'mA' to 'A'. This leads to incorrect answer and deduction of marks.

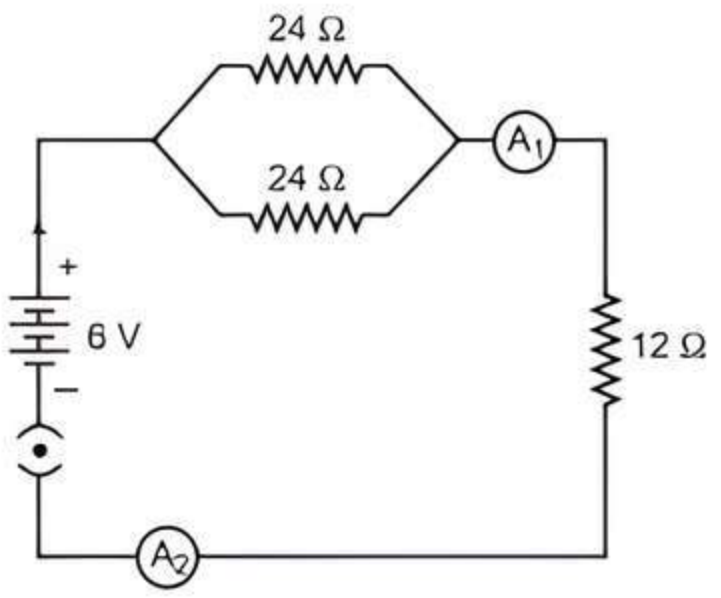
Q 5. (i) How will you infer with the help of an experiment that the same current flows through every part of the circuit containing three resistors R_1, R_2 and R_3 in series connected to a battery of V volts?

(ii) Study the following circuit and find out:

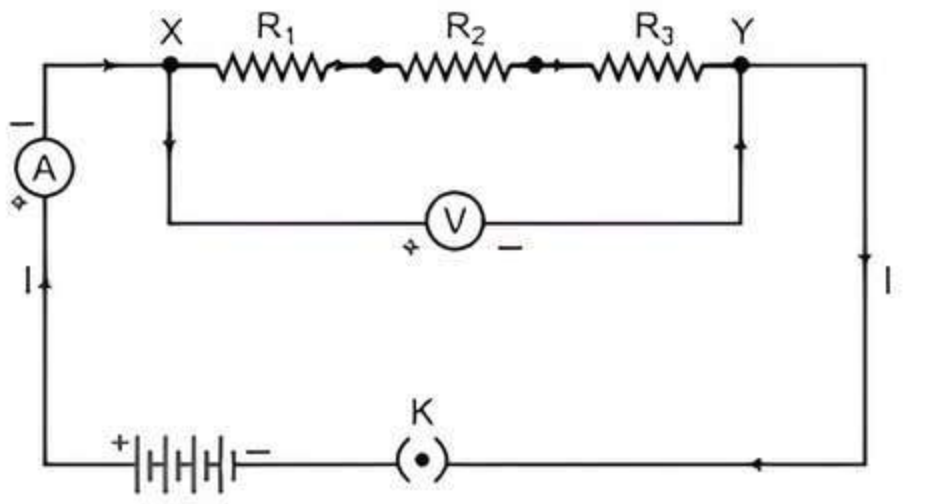
(a) Current in 12 Ω resistor.

(b) Difference in the readings of A_1 and A_2, if any.

(CBSE 2019)



Ans. (I)



(a) Three resistors R_1, R_2 and R_3 are connected in series.

(b) They are connected with a battery, an ammeter and a plug key as shown in figure.

(c) The ammeter reading is noted.

(d) Change the position of ammeter to anywhere in between the resistors.

(e) Note the ammeter reading each time.

(f) The value of the current in the ammeter is the same, independent of its position in the electric circuit.

It means that in a series combination of resistors, the current is the same in every part of the circuit or the same current flows through each resistor.

(II) 24 Ω and 24 Ω are connected in parallel.

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \left(\frac{1}{24}\right) + \left(\frac{1}{24}\right)$$

$R_p = 24/2 = 12\ \Omega$

Now, R_p and 12 Ω are connected in series.

Hence, total resistance $R_s = R_p + 12 = 12 + 12$

$= 24\ \Omega$

(a) Current passing through 12 Ω resistor.

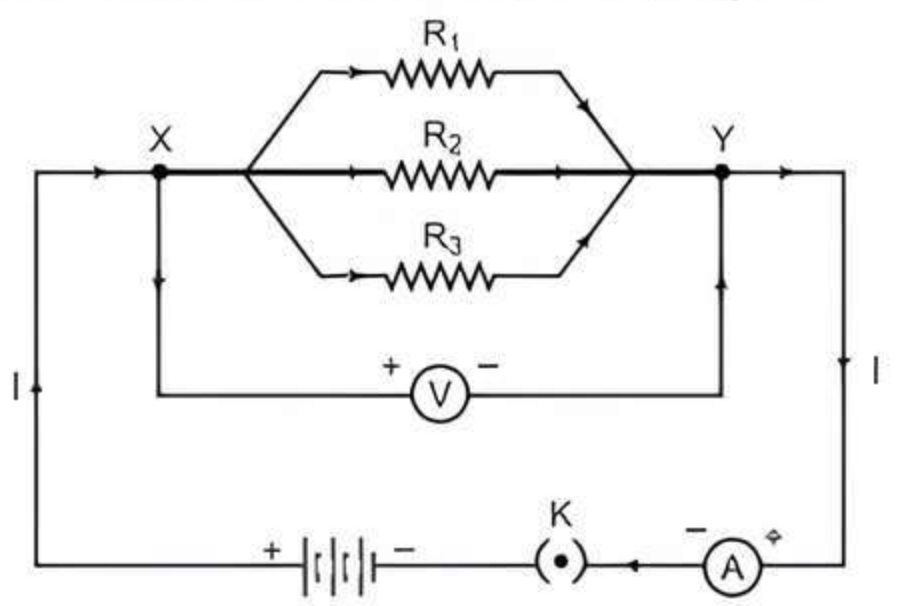
$I = V/R_s = 6/24 = 0.25$A

(b) There is no difference in the readings of A_1 and A_2 as they are connected in series.

Q 6. (i) With the help of a suitable circuit diagram, prove that the reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.

(ii) In an electric circuit, two resistors of 12 Ω each are joined in parallel to a 6 V battery. Find the current drawn from the battery. *(CBSE 2019)*

Ans. (i) Connect three resistors R_1, R_2 and R_3 in parallel between the point XY with a battery, a plug key and an ammeter in series shown in the figure.



Connect the voltmeter in parallel with these resistors between the terminals *X* and *Y*.

It is observed that the total current *I* is equal to the sum of the separate currents through each branch of the combination.

$$I = I_1 + I_2 + I_3$$

Let R_p be the equivalent resistance of the parallel combination of resistors. By applying Ohm's law to the parallel combination of resistors, we have

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

On applying Ohm's law to each resistor, we get

$$I_1 = \frac{V}{R_1};\ I_2 = \frac{V}{R_2};\ I_3 = \frac{V}{R_3}$$

Hence, $\frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$ or $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Thus, the reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.

TiP

The derivations of equivalent resistance of a group of resistances joined in series or parallel are important for the examination point of view.

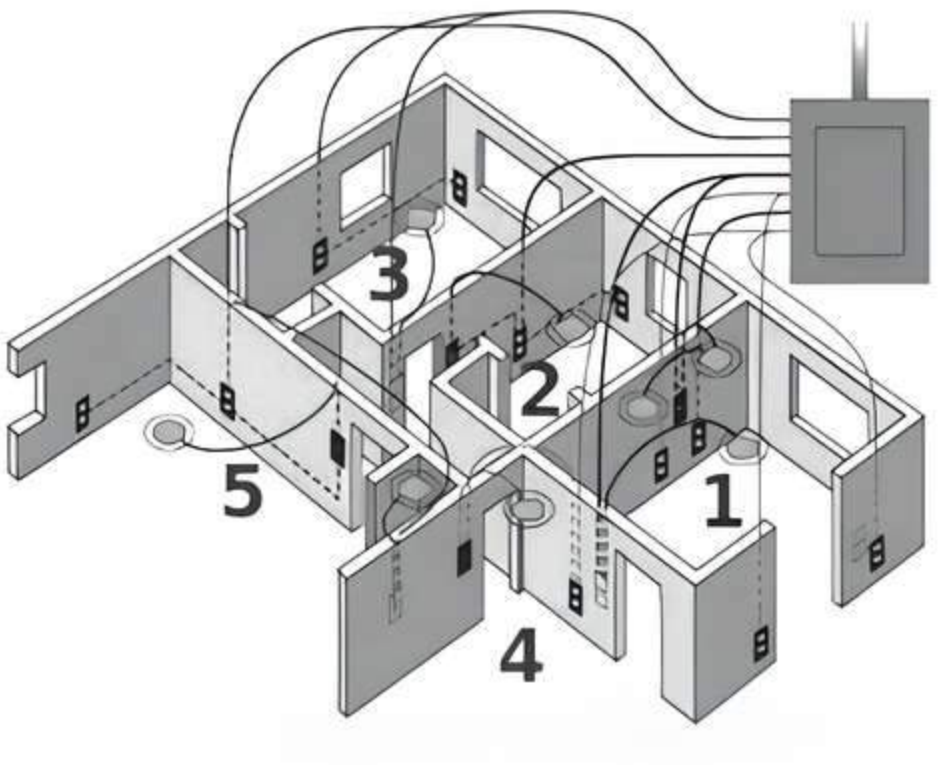
(ii) Given, $R_1 = R_2 = 12\,\Omega$, $V = 6$ V.

We know that

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{12} + \frac{1}{12} = \frac{2}{12} \quad \Rightarrow \quad R_{eq} = 6\,\Omega$$

$$\therefore \quad I = \frac{V}{R_{eq}} = \frac{6}{6} = 1\text{A}$$

Q 7.



The diagram above is a schematic diagram of a household circuit. The house shown in the above diagram has 5 usable spaces where electrical connections are made. For this house, the mains have a voltage of 220 V and the net current coming from the mains is 22 A.

(i) What is the mode of connection to all the spaces in the house from the mains?

(ii) The spaces 5 and 4 have the same resistance and spaces 3 and 2 have respective resistances of 20 Ω and 30 Ω. Space 1 has a resistance double that of space 5. What is the net resistance for space 5?

(iii) What is the current in space 3?

(iv) What should be placed between the main connection and the rest of the house's electrical appliances to save them from accidental high electric current? *(CBSE SQP 2022-23)*

Ans. (i) All spaces are connected in parallel.

(ii) Let resistance of space 5 and 4 be $R\Omega$ respectively.

Resistance of space 1 = $2R\,\Omega$

Resistance of space 2 = 30 Ω

Resistance of space 3 = 20 Ω

Current I = 22 A

V = 220 V

Total resistance $(R_{eq}) = V/I = \frac{220}{22} = 10\,\Omega$

$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{R_{eq}}$$

$$\Rightarrow \quad \frac{1}{2R} + \frac{1}{30} + \frac{1}{20} + \frac{1}{R} + \frac{1}{R} = \frac{1}{R_{eq}}$$

$$\Rightarrow \quad \frac{30 + 2R + 3R + 60 + 60}{60R} = \frac{1}{R_{eq}}$$

$$\Rightarrow \quad \frac{150 + 5R}{60R} = \frac{1}{R_{eq}}$$

$$R_{eq} = \frac{60R}{150 + 5R} = 10$$

$$60R = 10\,(150 + 5R)$$

$$60R = 1500 + 50R$$

$$10R = 1500$$

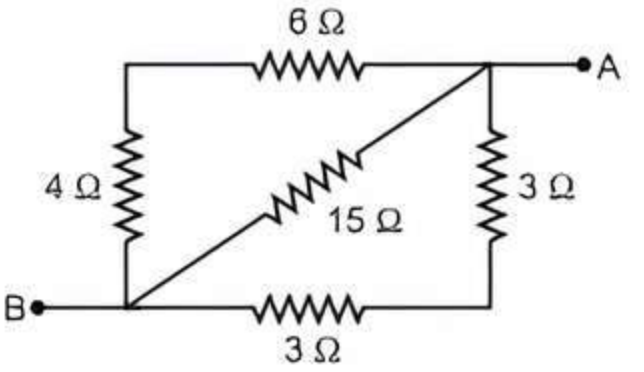
$$R = 150\,\Omega$$

(iii) Current in space 3 $= \frac{V}{R_3} = \frac{220}{20}$ A = 11 A

(iv) A fuse

Q 8. (i) List two disadvantages of using a series circuit in homes.

(ii) Calculate the effective resistance between *A* and *B* in the circuit given below: *(CBSE 2020)*



Ans. (i) Two disadvantages of using a series circuit at homes are as follows:

(a) Current is constant in series combination, so it is impractical to connect a bulb and an electric heater in series.

(b) If one electrical appliance stops working because of a serial circuit fault, then all devices will stop functioning.

(ii) 4 Ω and 6 Ω are connected in series, so, equivalent resistance $R_1 = 4 + 6 = 10\ \Omega$

Similarly, 3 Ω and 3 Ω are connected in series, so, equivalent resistance $R_2 = 3 + 3 = 6\ \Omega$ and $R_3 = 15\ \Omega$

R_1, R_2 and R_3 are connected in parallel.

So, effective resistance of the circuits is given by

$$\frac{1}{R} = \frac{1}{10\,\Omega} + \frac{1}{6\,\Omega} + \frac{1}{15\,\Omega}$$

$$= \frac{3+5+2}{30\,\Omega} = \frac{10}{30\,\Omega}$$

$$R = \frac{30}{10}\,\Omega = 3\,\Omega$$

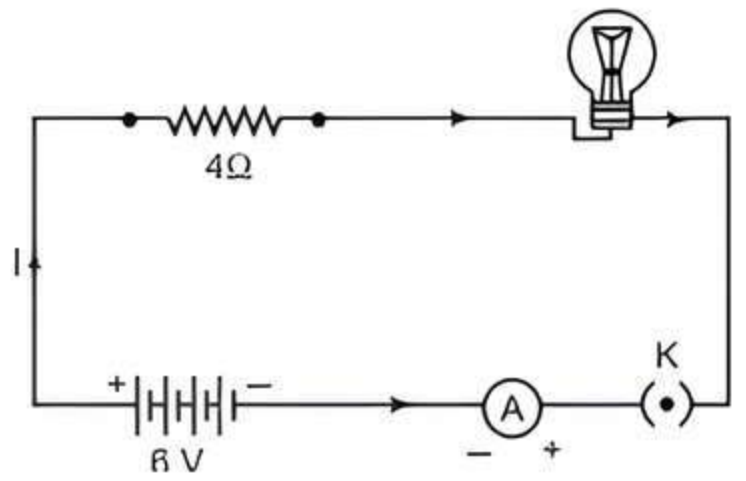
Q 9. An electric lamp of resistance 20 Ω and a conductor of resistance 4 Ω are connected to a 6 V battery as shown in the circuit. Calculate:

(i) the total resistance of the circuit,

(ii) the current through the circuit,

(iii) the potential difference across the (a) electric lamp and (b) conductor and

(iv) power of the lamp. *(CBSE 2019)*



Sol. Given, $R_1 = 20\ \Omega$, $R_2 = 4\ \Omega$ and $V = 6$ V

(i) Total resistance, $R = R_1 + R_2 = 20 + 4 = 24\ \Omega$

(ii) Current $I = \frac{V}{R} = \frac{6}{24} = \frac{1}{4} = 0.25$ A

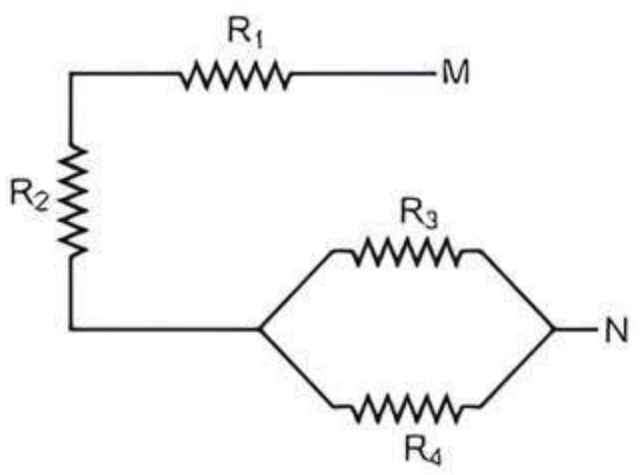
(iii) Potential difference across

(a) Electric lamp, $V_1 = IR_1 = 0.25 \times 20 = 5$ V

(b) Conductor, $V_2 = IR_2 = 0.25 \times 4 = 1$ V

(iv) Power of the lamp, $P = I^2R = (0.25)^2 \times 20 = 1.25$ W

Q 10. (i) For the combination of resistors shown in the following figure, find the equivalent resistance between *M* and *N*:



(ii) State Joule's law of heating.

(iii) Why we need a 5 A fuse for an electric iron which consumes 1 kW power at 220 V?

(iv) Why is it impracticable to connect an electric bulb and an electric heater in series? *(CBSE 2020)*

Sol. (I) R_3 and R_4 are in parallel connection.

$$\frac{1}{R'} = \frac{1}{R_3} + \frac{1}{R_4} = \frac{R_4 + R_3}{R_3R_4}$$

$$R' = \frac{R_3R_4}{R_4 + R_3}$$

Now R', R_1 and R_2 are in series connection, so

$$R_{eq} = R_1 + R_2 + \frac{R_3R_4}{R_4 + R_3}$$

(II) According to Joule's law of heating,

$$H \propto I^2$$

$$H \propto R$$

$$H \propto t$$

$$\therefore \quad \underline{H \propto I^2Rt}$$

or $\quad H = I^2Rt$.

where H is heat produced, I is current, R is resistance and t is time in seconds.

(III) Given, $P = 1$ kW $= 1000$ W, $V = 220$ V.

$\because \quad P = VI$

$I = \frac{P}{V} = \frac{1000}{220} = \frac{50}{11} = \underline{4.5\text{ A}}$, so 5 A fuse is needed.

(iv) In a series circuit, current is constant throughout the electric circuit. Thus, it is impracticable to connect an electric bulb and an electric heater in series, because they need current of widely different values to operate properly.

Q 11. (i) An electric bulb is rated at 200 V; 100 W. What is its resistance?

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

(iii) Calculate the total cost if the rate is ₹ 6.50 per unit. *(CBSE 2020)*

Sol. (i) Given, $V = 200$ V and $P = 100$ W

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

or $\quad R = \frac{V^2}{P} = \frac{(200)^2}{100\text{ W}} = \frac{40000}{100} = 400\ \Omega$

(ii) Electrical energy consumed, E = number of units × Power of each unit × time × total days

Here, $n = 3$, $P = 100$ W, $t = 10$ hours, Days = 30

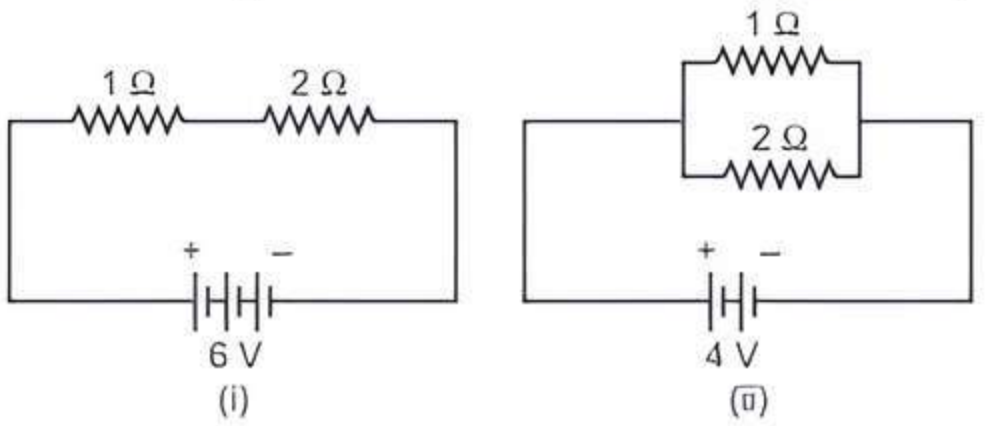
So, $\quad E = 3 \times 100\text{ W} \times 10\text{ h} \times 30 = 90{,}000$ Wh

$= 90$ kWh $= 90$ units

(iii) Total cost of electricity = Total unit of energy consumed × Cost per unit

$= 90$ units $\times$ 6.50 = ₹ 585

Q 12. Compare the power used in 2 Ω resistor in each of the following circuits: *(CBSE 2019)*



Sol. (i) 1 Ω and 2 Ω resistors are connected in series.

The equivalent resistance of the circuit.

$$R = 1 + 2 \text{ or, } R = 3\ \Omega$$

According to Ohm's law, $V = IR$, where, I = current through the circuit

$$\Rightarrow \quad I = \frac{6}{3} \quad \Rightarrow I = 2 \text{ A}$$

This current will flow through each component of the circuit because there is no division of current in series circuits. Hence, the current flowing through the 2 Ω resistor is 2 A.

We know that. $P = I^2R$

$$\Rightarrow \quad P = 2^2 \times 2$$

$$\Rightarrow \quad P = 8 \text{ W}$$

(ii) 1 Ω and 2 Ω resistors are connected in parallel.

The voltage across each component of a parallel circuit remains the same. Hence, the voltage across 2 Ω resistor will be 4 V.

Power consumed by 2 Ω resistor is given by.

$$P = V^2/R$$

$$\Rightarrow \quad P = \frac{4^2}{2} \quad \Rightarrow \quad P = 8 \text{ W}$$

Q 13. A bulb is rated 40 W; 220 V. Find the current drawn by it, when it is connected to a 220 V supply. Also find its resistance. If the given bulb is replaced by a bulb of rating 25 W; 220 V, will there be any change in the value of current and resistance? Justify your answer and determine the change. *(CBSE 2019)*

Sol. Given, $P = 40$ W and $V = 220$ V

We know that, $P = VI$

$$\Rightarrow \quad I = P/V = 40/220$$

$$\Rightarrow \quad I = 0.18 \text{ A}$$

We know that, $R = V^2/P$

$$\Rightarrow \quad R = (220 \times 220)/40$$

$$\Rightarrow \quad R = 1210\ \Omega$$

Now, $P = 25$ W and $V = 220$ V

We know that, $P = VI$

$$\Rightarrow \quad I = P/V = 25/220$$

$$\Rightarrow \quad I = 0.113 \text{ A}$$

We know that, $R = V^2/P$

$$\Rightarrow \quad R = (220 \times 220)/25$$

$$\Rightarrow \quad R = 1936\ \Omega$$

Yes, there is a change in the value of current and resistance.

Chapter Test

Multiple Choice Questions

Q 1. Two unequal resistances are connected in parallel. Which of the following statement is true?

a. Current is same in both
b. Current is higher in higher resistance
c. Voltage-drop is same across both
d. Voltage-drop is lower in lower resistance

Q 2. The relation between potential difference (V) and current (I) is:

a. $V \propto I^2$ b. $V \propto \frac{1}{I}$ c. $V^2 \propto I$ d. $V \propto I$

Q 3. If length of a conductor and it's radius, is increased twice, how the resistance will change?

a. Resistance will remain unchanged
b. Resistance increase twice
c. Resistance will become half
d. Resistance will increase 4 times

Q 4. How much energy is transferred when 10 A current flows through a resistor of 5 Ω for 30 minutes?

a. 0.25 kWh b. 1.2 kWh
c. 0.025 kWh d. 3.2 kWh

Assertion and Reason Type Questions

Directions (Q. Nos. 5-6): *Each of the following questions consists of two statements, one is Assertion (A) and the other is Reason (R). Give answer:*

a. Both Assertion (A) and Reason are true and Reason (R) is the correct explanation of Assertion (A).
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
c. Assertion (A) is true but Reason (R) is false.
d. Assertion (A) is false but Reason (R) is true.

Q 5. Assertion (A): When a wire is stretched to three times of its length, its resistance becomes 9 times.
Reason (R): Resistance is directly proportional to length of wire.

Q 6. Assertion (A): Two resistance having value R each.

Their equivalent resistances is —.

Reason (R): Given resistance is connected in parallel.

Case Study Based Question

Q 7. The relationship between potential difference and current was first established by George Simon Ohm called Ohm's law. According to this law, the current through a metallic conductor is proportional to the potential difference applied between its ends, provided the temperature remain constant *i.e.*, $I \propto V$ or $V = IR$; where R is constant for the conductor and it is called resistance of the conductor. Although Ohm's law has been found valid over a large class of materials, there do exist materials and devices used in electric circuits, where the proportionality of V and I does not hold.

Read the above passage carefully and give the answer of the following questions:

(i) If both the potential difference and the resistance in a circuit are doubled then what will be the current in the circuit?

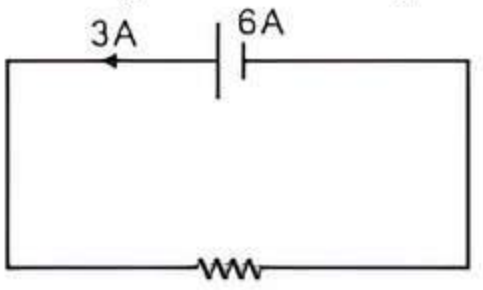
(ii) Draw *V-I* graph for a conductor.

(iii) What does the slope of *V-I* graph (*V* on *X*-axis and *I* on *Y*-axis) give?

(iv) When battery of 9 V is connected across a conductor and the current flows is 0.1 A. What will be the resistance?

Very Short Answer Type Questions

Q 8. How much charge flows through the resistor in 4s?



Q 9. Wire *A* and wire *B* has the following ratios

$$\frac{\text{length}(L_A)}{\text{length}(L_B)} = \frac{5}{18}, \quad \frac{\text{diameter}(D_A)}{\text{diameter}(D_B)} = \frac{2}{3}$$

and $$\frac{\text{resistivity}\ (\rho_A)}{\text{resistivity}\ (\rho_B)} = \frac{4}{9}$$

Calculate the ratio of the resistance of wire *A* to resistance of wire *B*.

Short Answer Type-I Questions

Q 10. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

Q 11. Name and define the SI unit of resistance. Calculate the resistance of a metal wire of length 2m and area of cross section $1.55 \times 10^{-6} m^2$, if the resistivity of the metal be $2.8 \times 10^{-8}\ \Omega m$.

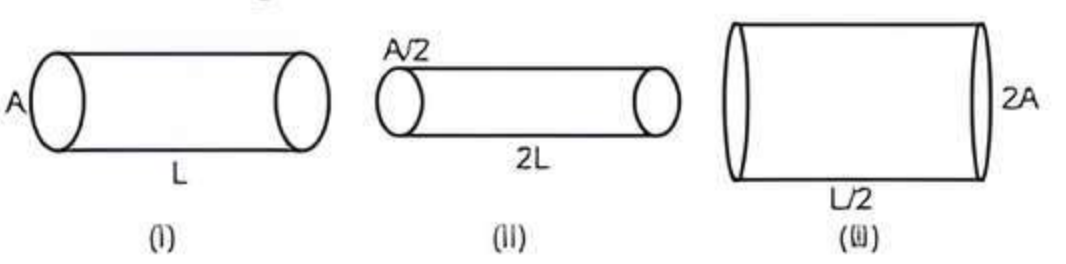
Q 12. Three incandescent bulbs of 100 W each are connected in series in an electric circuit. In another circuit, another set of three bulbs of the same wattage are connected in parallel to the same source.

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

(ii) Now let one bulb in both the circuits get fused. Will the rest of the bulbs continue to glow in each circuit? Give reason.

Short Answer Type-II Questions

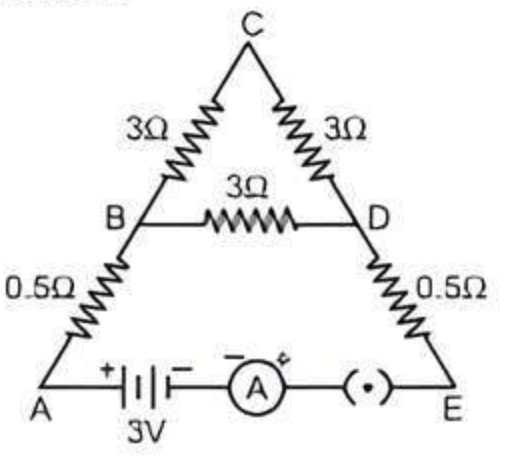
Q 13. The figure below shows three cylindrical copper conductors along with their face areas and lengths. Discuss in which geometrical shape, the resistance will be higher.



Q 14. Show four different ways in which three resistors of '*r*' Ohm each may be connected in a circuit. In which case is the equivalent resistance of the combination:

(I) Maximum (II) Minimum

Q 15. Five resistors are connected in a circuit as shown. Find the ammeter reading when circuit is closed.

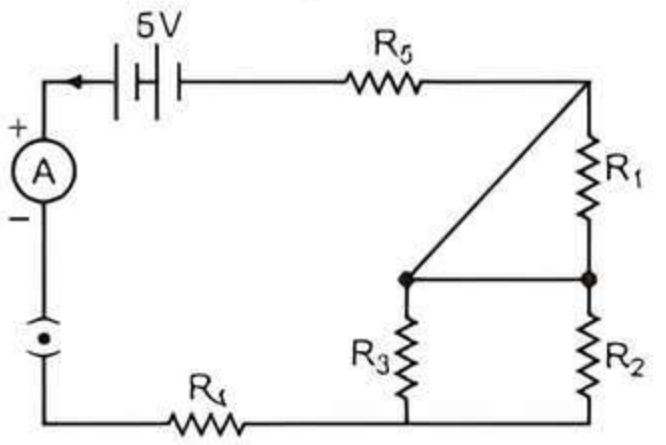


Long Answer Type Questions

Q 16. What is meant by electrical resistivity of a material? Derive its SI unit. Describe an experiment to study the factor on which the resistance of a conducting wire depends.

Q 17. (i) Deduce the expression for the equivalent resistance of the parallel combination of three resistors R_1, R_2 and R_3.

(ii) Consider the following electric circuit



(a) Which two resistors are connected in series?

(b) Which two resistors are connected in parallel?

(c) If every resistors of the circuit is of 2 Ω, what current will flow in the circuit?