CHAPTER - 12

ELECTRICITY

Electricity is a general term that encompasses a variety of phenomena resulting from the presence and flow of electric charge. These include many easily recognizable phenomena such as lightning and static electricity, but in addition, less familiar concepts such as the electromagnetic field and electromagnetic induction.

Electric charge

Electric charge is a fundamental conserved property of some subatomic particles, which determines their electromagnetic interaction. Electrically charged matter is influenced by, and produces, electromagnetic fields. The interaction between a moving charge and an electromagnetic field is the source of the electromagnetic force, which is one of the four fundamental forces. Electric charge is conserved, additive and quantised. The S.I. unit of electric charge is 'C' coulomb.
Any other charged body will have a charge Q

$$\mathbf{Q = ne}$$

where n is the number of electrons and e is the charge on electron = 1.6 x 10^{-19} coulombs.

Electric current

Electric current is a flow of electrons in a conductor such as a metal wire. Electric current is expressed by the amount of charge flowing through a particular area in unit time. In other words, it is the rate of flow of electric charges. In circuits using metallic wires, electrons constitute the flow of charges. However, electrons were not known at the time when the phenomenon of electricity was first observed. So, electric current was considered to be the flow of positive charges and the direction of flow of positive charges was taken to be the direction of electric current. Conventionally, in an electric circuit the direction of electric current is taken as opposite to the direction of the flow of electrons, which are negative charges.
The magnitude of electric current in a conductor is the amount of electric charge passing through a given point of conductor in 1 second.

$$I = \frac{Q}{t}$$

S.I. unit of electric current is 'A' (Ampere).
The electric current is expressed by a unit called ampere (A), named after the French scientist, Andre-Marie Ampere (1775–1836).

One Ampere

When 1 coulomb of charge flows through any cross-section of a conductor in 1 second, the electric charge flowing through it is said to be 1 ampere.
Smaller unit current is milliampere(mA) and microampere(μ A)

$$1 \text{ mA} = 10^{-3}\text{A}$$
$$1\ \mu\text{A} = 10^{-6}\text{A}$$

An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit through which the current is to be measured.
The direction of electric current is from positive terminal to negative terminal through the electric circuit.

INTEXT QUESTIONS PAGE NO. 200

1. **What does an electric circuit mean?**
   Ans. An electric circuit consists of electric devices, switching devices, source of electricity, etc. that are connected by conducting wires.

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

3. **Calculate the number of electrons constituting one coulomb of charge.**
   Ans. One electron possesses a charge of 1.6×10^{-19} C, i.e., 1.6×10^{-19} C of charge is contained in 1 electron.

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

   Therefore, 6.25×10^{18} electrons constitute one coulomb of charge.

Potential difference

Potential difference, $V_A - V_B$ between two points A and B is the work done per unit charge in taking a charge from B to A.

Potential difference, $V_A - V_B = \frac{work\ \ done}{charge}$, where V_A is potential at point A, V_B is potential at point B and S.I. unit of potential is volts (V), named after Alessandro Volta (1745–1827), an Italian physicist.

Electric Potential

Electric Potential at a point is defined as the work done per unit charge in bringing a charge from infinity to that point.

$$V = \frac{work\ \ done}{charge} = \frac{W}{Q}$$

The potential difference is measured by means of an instrument called the voltmeter. The voltmeter is always connected in parallel across the points between which the potential difference is to be measured.

One volt: The potential difference between two points is said to be 1 volt if 1 joule of work is done in moving 1 coulomb of electric charge from one point to the other.
Electrons always flow from lower potential to higher potential.

INTEXT QUESTIONS PAGE NO. 202

1. **Name a device that helps to maintain a potential difference across a conductor.**
   Ans. A source of electricity such as cell, battery, power supply, etc. helps to maintain a potential difference across a conductor.

2. **What is meant by saying that the potential difference between two points is 1 V?**
   Ans. If 1 J of work is required to move a charge of amount 1 C from one point to another, then it is said that the potential difference between the two points is 1 V.

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

Ans. The energy given to each coulomb of charge is equal to the amount of work required to move it. The amount of work is given by the expression,

$$\text{Potential difference} = \frac{\text{Work done}}{\text{Charge}}$$

$$\text{Work done} = \text{Potential difference} \times \text{Charge}$$

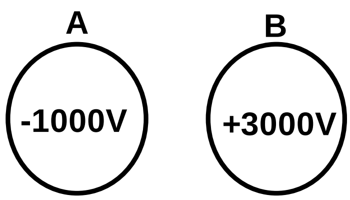
Where, Charge = 1 C and Potential difference = 6 V

$$\text{Work done} = 6 \times 1 = 6\ \text{J}$$

Therefore, 6 J of energy is given to each coulomb of charge passing through a battery of 6 V.

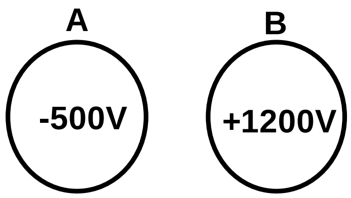
NUMERICAL PROBLEMS

1. Find the charge if the number of electrons is 4×10^{-18}.
2. Find the number of electrons constituting one coulomb of charge.
3. How much work done in moving a charge of 3 coulombs from a point at 118 V to a point at 128 volt?
4. How much work done in moving a charge of 2C across two points having a potential difference of 12V?
5. Calculate the amount of work done to carry 4C from a point at 100 V to a point at 120 volt?
6. How much work will be done in bringing a charge of 2×10^{-3} coulombs from infinity to a point P at which the potential is 5 V?
7. How much work will be done in bringing a charge of 3×10^{-2} coulombs from infinity to a point P at which the potential is 20 V?
8. How much energy is given to each coulomb of charge passing through a 6V battery?
9. How much energy is transferred by a 12 V power supply to each coulomb of charge which it moves around a circuit?
10. What is the potential difference between the terminals of a battery if 250 joules of work is required to transfer 20 coulombs of charge from one terminal of battery to the other?
11. What is the potential difference between the conductors A and B shown in below figure? If the conductors are connected by a length of wire, which way will electrons flow? When will this flow of electrons stop?



12. A particle of charge 2C is taken from a point at a potential of 100V to another point at a potential of 150V. Calculate the work done.

13. What is the potential difference between the conductors A and B shown in below figure? If the conductors are connected by a length of wire, which way will electrons flow? When will this flow of electrons stop?



14. A particle of charge 5 x 10^{-2} C is taken from a point at a potential of 50V to another point at a potential of 250V. Calculate the work done.

15. Three 2V cells are connected in series and used as a battery in a circuit.

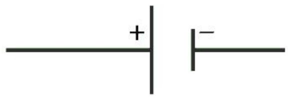
(a) What is the potential difference at the terminals of the battery?

(b) How many joules of electrical energy does 1 C gain on passing through (i)one cell (ii) all three cells.

CIRCUIT DIAGRAM

The Schematic diagram, in which different components of the circuit are represented by the symbols conveniently used, is called a circuit diagram. Conventional symbols used to represent some of the most commonly used electrical components are given below:

1. An electric cell

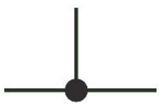


2. A battery or a combination of cells

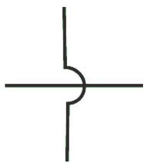
3. Plug key or switch (open)

4. Plug key or switch (closed)

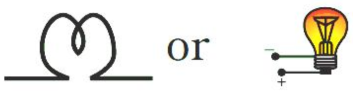
5. A wire joint



6. Wires crossing without joining

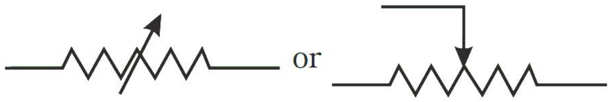


7. Electric bulb

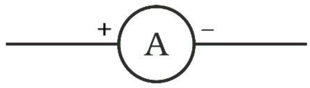


8. A resistor of resistance *R*

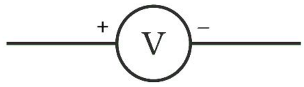
9. Variable resistance or rheostat



10. Ammeter



11. Voltmeter



Ohm's law

According to Ohm's law, "At constant temperature, the current flowing through a conductor is directly proportional to the potential difference across its ends."

$$I \propto V \quad \text{or } V \propto I \quad \text{at constant temperature}$$

$V = IR$ where R is constant of proportionally which is know as resistance.

Resistance

It is the ratio of potential difference applied between the ends of a conductor and the current flowing through it. The unit of resistance is ohm(Ω).

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

$$1 \ \ ohm = \frac{1 \ \ volt}{1 \ \ ampere}$$

One Ohm

One Ohm is the resistance of a conductor such that when a potential difference of 1 volt is applied to its ends, a current of 1 ampere flows through it.

If the resistance is doubled the current gets halved. In many practical cases it is necessary to increase or decrease the current in an electric circuit. A component used to regulate current without changing the voltage source is called variable resistance. In an electric circuit, a device called rheostat is often used to change the resistance in the circuit.

Factors on which the Resistance of a conductor depends

The resistance of the conductor depends (i) on its length, (ii) on its area of cross-section, and (iii) on the nature of its material.

Resistance depends on area of cross section: It is inversely proportional to the area of cross section (A)

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

Resistance depends on length of wire: It is directly proportional to the length of the wire (l)

$$R \propto l$$

Combining the above we get $R \propto \frac{l}{A}$

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

where ρ (rho) is a constant of proportionality which is called the resistivity or specific resistance of the material.

If l = 1m, A = 1m^2 then R = ρ

Resistivity of a material is the resistance of a unit length of the material having unit area of cross section.

INTEXT QUESTIONS PAGE NO. 209

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

Ans. The resistance of a conductor depends upon the following factors:

(a) Length of the conductor
(b) Cross-sectional area of the conductor
(c) Material of the conductor
(d) Temperature of the conductor

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

Ans. Resistance of a wire,

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

ρ =Resistivity of the material of the wire
l = Length of the wire
A = Area of cross-section of the wire

Resistance is inversely proportional to the area of cross-section of the wire.
Thicker the wire, lower is the resistance of the wire and vice-versa. Therefore, current can flow more easily through a thick wire than a thin wire.

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

Ans. The change in the current flowing through the component is given by Ohm's law as,

$V = IR$

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

Where,
Resistance of the electrical component = R
Potential difference = V
Current = I

The potential difference is reduced to half, keeping resistance constant.
Let the new resistance be R' and the new amount of current be I'.
Therefore, from Ohm's law, we obtain the amount of new current.

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

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

4. **Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?**
Ans. The resistivity of an alloy is higher than the pure metal. Moreover, at high temperatures, the alloys do not melt readily. Hence, the coils of heating appliances such as electric toasters and electric irons are made of an alloy rather than a pure metal.

5. **(a) Which among iron and mercury is a better conductor?**
(b) Which material is the best conductor?
Ans. (a) Resistivity of iron = $10.0\times10^{-8}\,\Omega m$
Resistivity of mercury = $94.0\times10^{-8}\,\Omega m$
Resistivity of mercury is more than that of iron. This implies that iron is a better conductor than mercury.

(b) It can be observed from Table 12.2 that the resistivity of silver is the lowest among the listed materials. Hence, it is the best conductor.

NUMERICAL PROBLEMS

1. What current must flow if 0.24 coulombs is to be transferred in 15 ms?
2. If a current of 10 A flows for four minutes, find the quantity of electricity transferred.
3. An electric bulb draws a current of 0.25A for 20 minutes. Calculate the electric charge that flows through the circuit.
4. If the amount of electric charge passing through a conductor in 10min is 300C, find the current.
5. How many electrons are flowing per second past a point in a circuit in which there is a current of 4A?
6. A lamp of resistance 80Ω draw a current of 0.75A. Find the line voltage. **7.**
A electric heater draw a current of 5A when connected to 220V mains. Calculate the resistance of its filament.
8. How much current will an electric bulb draw from a 200V source, if the resistance of the filament is 1200Ω?
9. How much current will an electric heater draw from a 200V source, if the resistance of the filament is 100Ω?
10. How much current does an electric heater draw from a 220V line, if the resistance of the heater (when hot) is 50Ω?
11. A bulb when cold has 1Ω resistance. It draws a current of 0.3A when glowing from a source of 3V. Calculate the resistance of the bulb when flowing and explain the reason for the difference in resistance.

12. Calculate the potential difference required across a conductor of resistance 5Ω to make a current of 1.5A flow through it.

13. What is the resistance of an electric are lamp when hot, if the lamp uses 20A when connected to a 220V line?

14. Calculate the amount of work done to draw a current of 8A from a point at 100V to a point at 120V in 2 seconds.

15. If 200C of charge pass a point in a circuit in 4 sec, what current is flowing?

16. A current of 4A flows around a circuit in 10 seconds. How much charge flows past a point in the circuit in this time? Also find the number of electrons passes in the circuit.

17. The current flowing through a resistor is 0.8 A when a p.d. of 20 V is applied. Determine the value of the resistance.

18. Determine the p.d. which must be applied to a 2 kΩ resistor in order that a current of 10 mA may flow.

19. A coil has a current of 50 mA flowing through it when the applied voltage is 12 V. What is the resistance of the coil?

20. A 100 V battery is connected across a resistor and causes a current of 5 mA to flow. Determine the resistance of the resistor. If the voltage is now reduced to 25 V, what will be the new value of the current flowing?

21. What is the resistance of a coil which draws a current of (a) 50 mA and (b) 200 μA from a 120 V supply?

22. If a current of 5 A flows for 2 minutes, find the quantity of electricity transferred.

23. 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 the circuit.

24. How much current will an electric bulb draw from a 220 V source, if the resistance of the bulb filament is 1200Ω?

25. How much current will an electric heater coil draw from a 220 V source, if the resistance of the heater coil is 100Ω?

26. The potential difference between the terminals of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is increased to 120 V?

27. 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.

28. An electric heater is connected to the 230 V mains supply. A current of 8A flows through the heater (a) How much charge flows around the circuit each second. (b)How much energy is transferred to the heater each second?

29. How many electrons are flowing per second past a point in a circuit in which there is a current of 5A?

30. An electric iron draws a current of 3.4A from the 220V supply line. What current will this electric iron draw when connected to 110V supply line?

31. A simple electric circuit has a 24V battery and a resistor of 60Ω. What will be the current in the circuit?

32. When a 4Ω resistor is connected across the terminal of 12V battery, find the number of coulombs passing through the resistor per second.

33. An electric room heater draw a current of 2.4A from the 120V supply line. What current will this room heater draw when connected to 240V supply line?

34. A current of 200mA flows through a 4kΩ resistor. What is the p.d. across the resistor?

35. A p.d. of 10V is needed to make a current of 0.02 A flow through a wire. What p.d. is needed to make a current of 250mA flow through the same wire?

36. A TV draws a current of 5 A from the 240V supply line. What current will this TV draw when it is connected to 100V supply line.

37. The potential difference between the terminals of an electric heater is 60V when it draw a current of 4A from the source. What current will the heater draw if the potential difference is increased to 120V?

38. A bulb of resistance 400Ω is connected to 220V mains. Calculate the magnitude of current.

39. A battery of two cells is used to light a torch bulb of resistance 5Ω. The cells maintain a potential difference of 3V across the bulb. How much current will flow through the bulb?

40. A steady current of 5A flows through a circuit for 30minutes. How much charge has circulated through the circuit in this time?

NUMERICAL PROBLEMS ON RESISTIVITY

1. Calculate the resistance of a copper wire of length 2m and area of cross section 10^{-6}m^2. Resistivity of copper is 1.7×10^{-8} Ω m

2. A copper wire of length 2m and area of cross section 1.7×10^{-6}m^2 has a resistance of 2×10^{-2} ohms. Calculate the resistivity of copper.

3. The amount of charge passing through a cell in 12 seconds is 3C. What is the current supplied by the cell?

4. A 12 V battery of a car is connected across a 4Ω resistor. Calculate the current passing through the resistor.

5. Resistivity of a given copper wire of length 2m is 1.7 x 10^{-8} Ωm. The wire is stretched so that its length becomes 4m. Find new resistivity of the copper wire.

6. Resistance of a given wire of length 'l' is 3Ω. The wire is stretched uniformly such that its length becomes $2l$. Find the new resistance of the stretched wire.

7. Resistance of a given wire of length 'l' is 4Ω. The wire is stretched uniformly such that its length becomes $3l$. Find the new resistance of the stretched wire.

8. A copper wire has a diameter of 0.5 mm and resistivity of 1.6 x 10¯8 Ωm. What will be the length of this wire to make its resistance 10Ω? How much does the resistance change if the diameter is doubled?

9. A 6Ω resistance wire is doubled up by folding. Calculate the new resistance of the wire.

10. Calculate the resistance of an aluminium cable of length 10km and diameter 20mm if the resistivity of aluminum is 2.7 x 10^{-8} Ωm.

11. Calculate the area of cross section of a wire if its length is 1.0m, its resistance is 23Ω and the resistivity of the material of the wire is 1.84 x 10^{-6} Ωm.

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

13. Two cylindrical wires of the same material have their lengths in the ratio of 4 : 9. What should be the ratio of their radii so that their resistances are in the ratio of 4 : 1?

14. Two wires of the same metal, have the same area of cross section but their lengths in the ratio of 3 : 1. What should be the ratio of current flowing through them respectively, when the same potential difference is applied across each of their length?

15. Two wires A and B of length 30m and 10m have radii 2cm and 1cm respectively. Compare the resistances of the two wires. Which will have less resistance?

16. Calculate the resistance of 1km long copper wire of radius 1mm. Resistivity of copper is 1.7 x 10^{-8} Ωm

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

18. What should be the length of the nichrome wire of resistance 4.5Ω, if the length of a similar wire is 60cm and resistance 2.5Ω?

19. A metal wire of resistivity 64 x 10^{-6} Ωm and length 198cm has a resistance of 7Ω. Calculate its radius.

20. Calculate the resistivity of the material of a wire 1.0m long, 0.4mm in diameter and having a resistance of 2.0Ω.

RESISTANCE OF A SYSTEM OF RESISTORS

RESISTORS IN SERIES

In a series circuit

(a) the current I is the same in all parts of the circuit, and

(b) the sum of the voltages V_1, V_2 and V_3 is equal to the total applied voltage, V, i.e.

$$\mathbf{V = V_1 + V_2 + V_3}$$

From Ohm's law:

$V_1 = IR_1$,

$V_2 = IR_2$,

$V_3 = IR_3$

and V = IR

where R is the total circuit resistance.

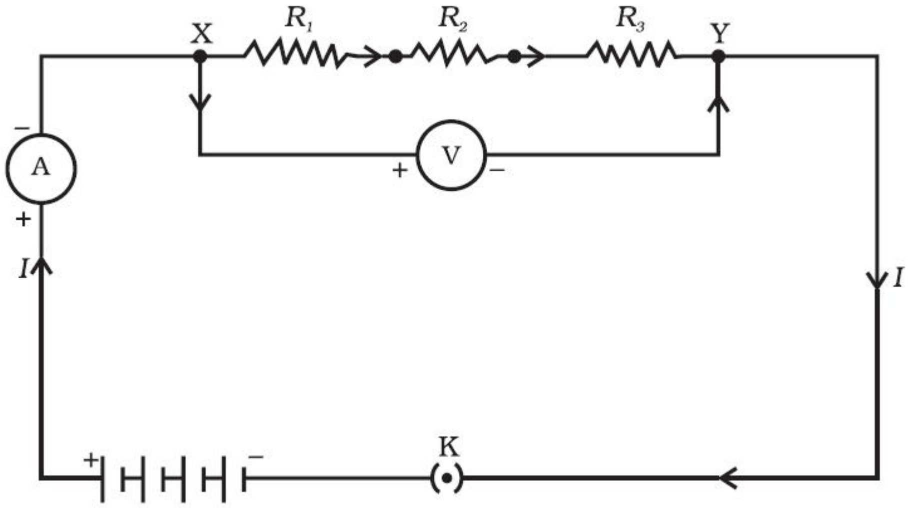
Since $\mathbf{V = V_1 + V_2 + V_3}$

then $IR = IR_1 + IR_2 + IR_3$

Dividing throughout by I gives

$\mathbf{R = R_1 + R_2 + R_3}$

Thus for a series circuit, the total resistance is obtained by adding together the values of the separate resistances.



When several resistors are connected in series, the resistance of the combination Rs is equal to the sum of their individual resistances R1, R2, R3 and is thus greater than any individual resistance.

RESISTORS IN PARALLEL

In a parallel circuit:

(a) the sum of the currents I_1, I_2 and I_3 is equal to the total circuit current, I, i.e. $\mathbf{I = I_1 + I_2 + I_3}$, and

(b) the source p.d., V volts, is the same across each of the resistors.

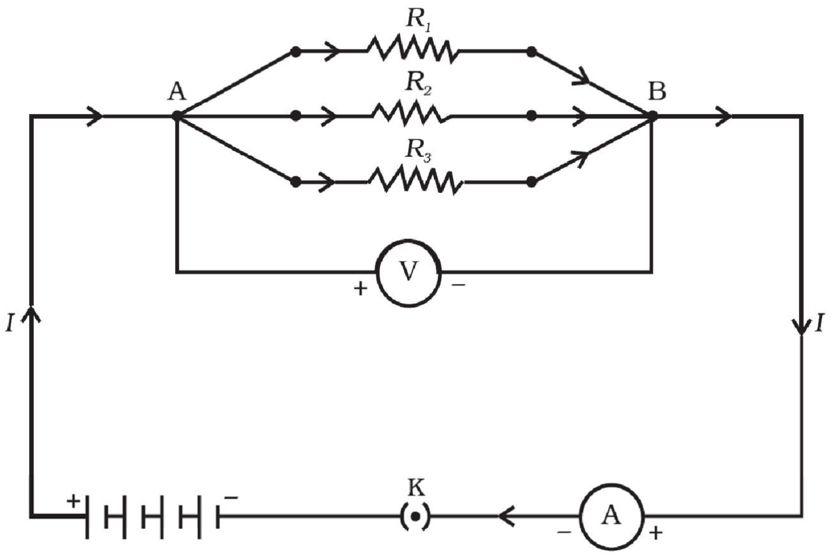
From Ohm's law:

$$I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}, \quad I_3 = \frac{V}{R_3} \quad and \quad I = \frac{V}{R}$$

where R is the total resistance of the circuit.

Since $\mathbf{I = I_1 + I_2 + I_3}$

then $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$



dividing throughout by V, we get

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

This equation must be used when finding the total resistance R of a parallel circuit. Thus the reciprocal of the equivalent resistance of a group of resistance joined in parallel is equal to the sum of the reciprocals of the individual resistance.

For the special case of **two resistors in parallel**

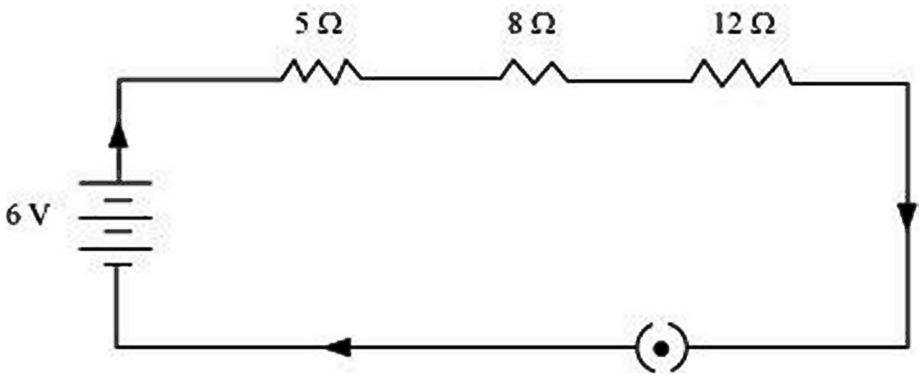
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2}$$

Hence $R = \frac{R_1 R_2}{R_1 + R_2}$ i.e. $\left(\frac{product}{sum}\right)$

INTEXT QUESTIONS PAGE NO. 213

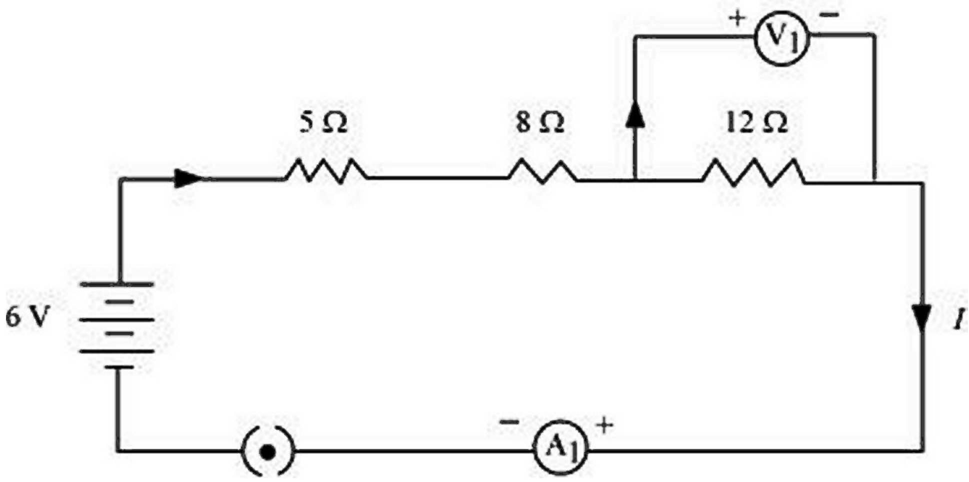
1. **Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.**

   Ans. Three cells of potential 2 V, each connected in series, is equivalent to a battery of potential 2 V + 2 V + 2 V = 6V. The following circuit diagram shows three resistors of resistances 5 Ω, 8 Ω and 12 Ω respectively connected in series and a battery of potential 6 V.



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

Ans. To measure the current flowing through the resistors, an ammeter should be connected in the circuit in series with the resistors. To measure the potential difference across the 12 Ω resistor, a voltmeter should be connected parallel to this resistor, as shown in the following figure.



The resistances are connected in series.

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

$V = IR$,

where, Potential difference, $V = 6$ V

Current flowing through the circuit/resistors = I

Resistance of the circuit, R = 5 + 8 + 12 = 25 Ω

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

Potential difference across 12 Ω resistor = V_1

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

Therefore, using Ohm's law, we obtain

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

Therefore, the reading of the ammeter will be 0.24 A.

The reading of the voltmeter will be 2.88 V.

INTEXT QUESTIONS PAGE NO. 216

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

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

Let R be the equivalent resistance.

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

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

Therefore, equivalent resistance = 1 Ω

(b) When 1 Ω, 10^3Ω and 10^6Ω are connected in parallel:

Let R be the equivalent resistance.

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

$$R=\frac{1000000}{1001001}=0.999\Omega$$

Therefore, equivalent resistance = 0.999 Ω

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

Ans. Resistance of electric lamp, R_1 = 100 Ω

Resistance of toaster, R_2 = 50 Ω

Resistance of water filter, R_3 = 500 Ω

Voltage of the source, V = 220 V

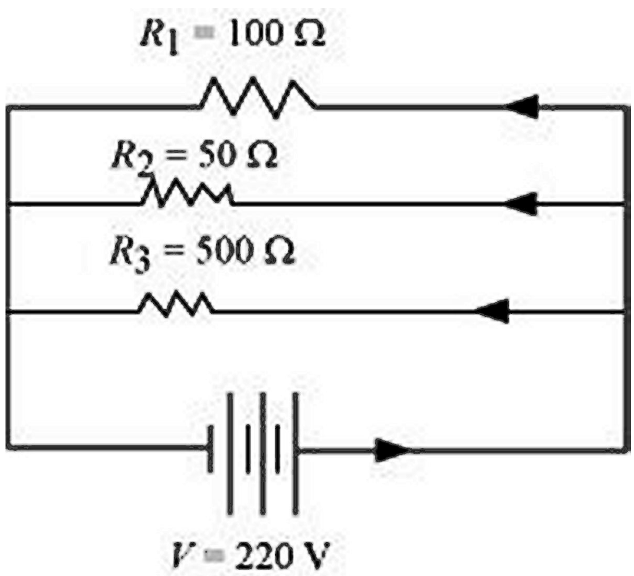
These are connected in parallel, as shown in the following figure.

Let R be the equivalent resistance of the circuit.

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

$$\Rightarrow \frac{1}{R}=\frac{5+10+1}{500}=\frac{16}{500}$$

$$\Rightarrow R=\frac{500}{16}\Omega$$



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

$I=\frac{V}{R}$ Where, Current flowing through the circuit = I

$$I=\frac{V}{R}=\frac{220}{500/16}=\frac{220\times16}{500}=7.04A$$

7.04 A of current is drawn by all the three given appliances.
Therefore, current drawn by an electric iron connected to the same source of potential 220 V = 7.04 A
Let R' be the resistance of the electric iron. According to Ohm's law,

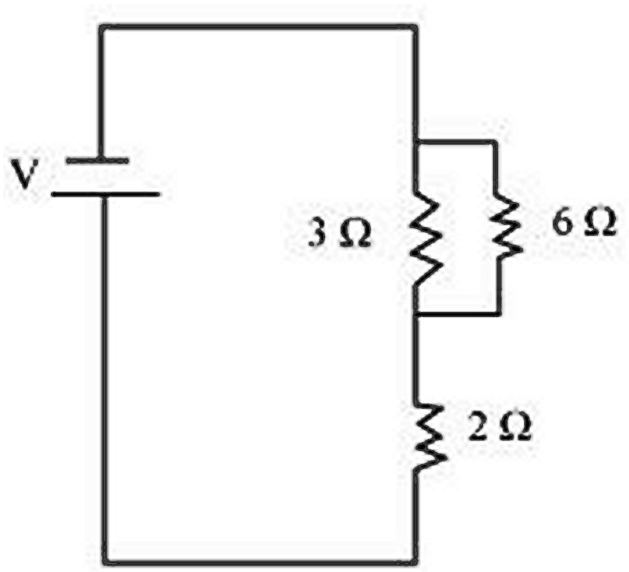
$$V = IR' \Rightarrow R' = \frac{V}{I} = \frac{220}{7.04} = 31.25\Omega$$

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

3. **What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?**
Ans. There is no division of voltage among the appliances when connected in parallel. The potential difference across each appliance is equal to the supplied voltage. The total effective resistance of the circuit can be reduced by connecting electrical appliances in parallel.
4. **How can three resistors of resistances 2 Ω, 3 Ω and 6 Ω be connected to give a total resistance of (a) 4 Ω, (b) 1 Ω?**
Ans. There are three resistors of resistances 2 Ω, 3 Ω, and 6 Ω respectively.
(a) The following circuit diagram shows the connection of the three resistors.
Here, 6 Ω and 3 Ω resistors are connected in parallel.
Therefore, their equivalent resistance will be given by

$$R = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}} = \frac{1}{\frac{1}{6}+\frac{1}{3}} = \frac{6\times3}{6+3} = 2\Omega$$

This equivalent resistor of resistance 2 Ω is connected to a 2 Ω resistor in series.
Therefore, equivalent resistance of the circuit = 2 Ω + 2 Ω = 4 Ω
Hence, the total resistance of the circuit is 4 Ω
The following circuit diagram shows the connection of the three resistors.



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

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

Therefore, the total resistance of the circuit is 1 Ω

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

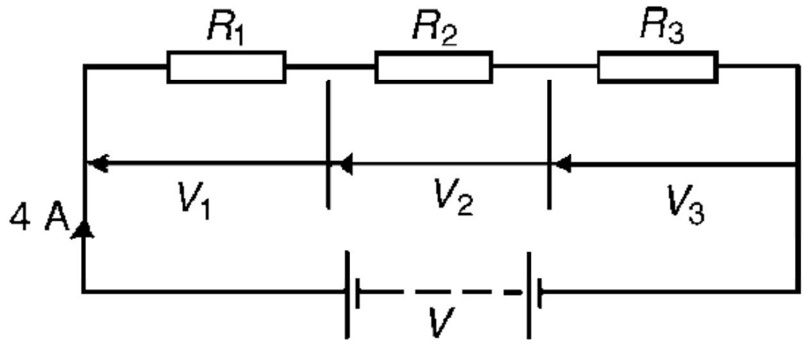
Ans. There are four coils of resistances 4 Ω, 8 Ω, 12 Ω and 24 Ω respectively
(a) If these coils are connected in series, then the equivalent resistance will be the highest, given by the sum 4 + 8 + 12 + 24 = 48 Ω
(b) If these coils are connected in parallel, then the equivalent resistance will be the lowest, given by

$$R = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}} = \frac{1}{\frac{1}{4}+\frac{1}{8}+\frac{1}{12}+\frac{1}{24}} = \frac{1}{\frac{6+3+2+1}{24}} = \frac{24}{12} = 2\Omega$$

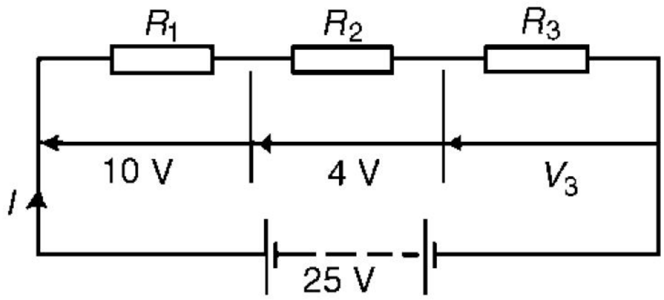
Therefore, 2 Ω is the lowest total resistance.

NUMERICAL PROBLEMS

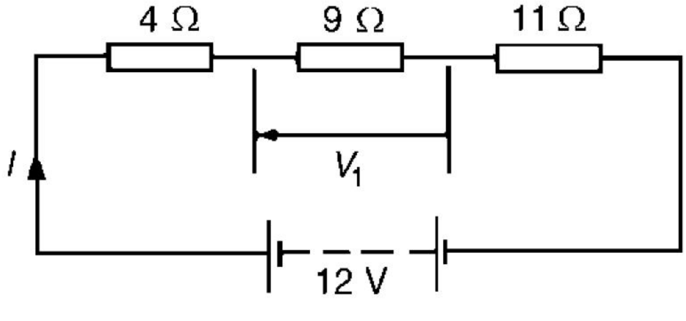
1. For the circuit shown in below Figure, determine (a) the battery voltage V, (b) the total resistance of the circuit, and (c) the values of resistance of resistors R1, R2 and R3, given that the p.d.'s across R1, R2 and R3 are 5 V, 2 V and 6 V respectively.



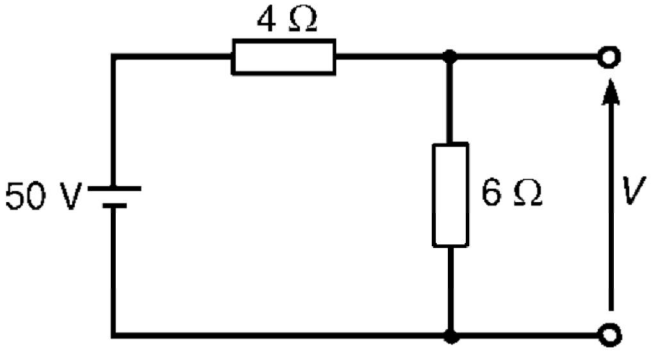
2. For the circuit shown in below Figure, determine the p.d. across resistor R_3. If the total resistance of the circuit is 100Ω, determine the current flowing through resistor R_1. Find also the value of resistor R_2



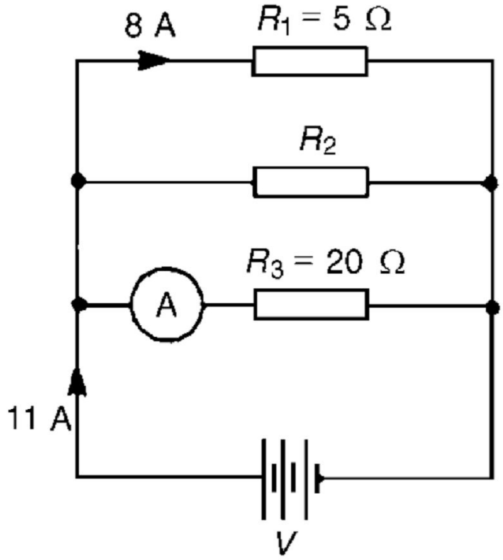
3. A 12 V battery is connected in a circuit having three series-connected resistors having resistances of 4Ω, 9Ω and 11Ω. Determine the current flowing through, and the p.d. across the 9Ω resistor.



4. Find the voltage V in the given figure.

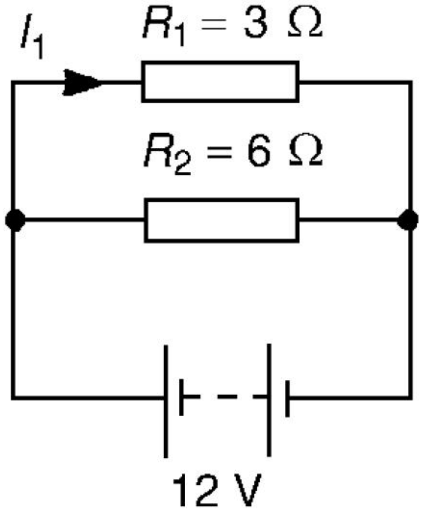


5. For the circuit shown in given Figure, determine (a) the reading on the ammeter, and (b) the value of resistor R_2



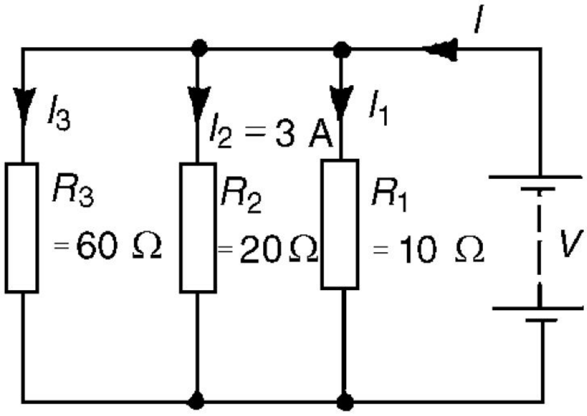
6. Two resistors are connected in series across a 24 V supply and a current of 3 A flows in the circuit. If one of the resistors has a resistance of 2Ω determine (a) the value of the other resistor, and (b) the p.d. across the 2Ω resistor. If the circuit is connected for 50 hours, how much energy is used?

7. Two resistors, of resistance 3Ω and 6Ω, are connected in parallel across a battery having a voltage of 12 V. Determine (a) the total circuit resistance and (b) the current flowing in the 3Ω resistor.

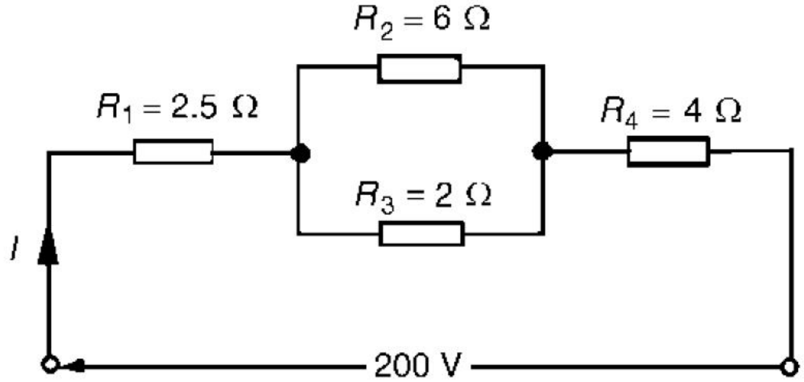


8. Given four 1 _ resistors, state how they must be connected to give an overall resistance of (a) $\frac{1}{4}\Omega$ (b) 1Ω (c) $1\frac{1}{3}\Omega$ (d) $2\frac{1}{2}\Omega$, all four resistors being connected in each case.

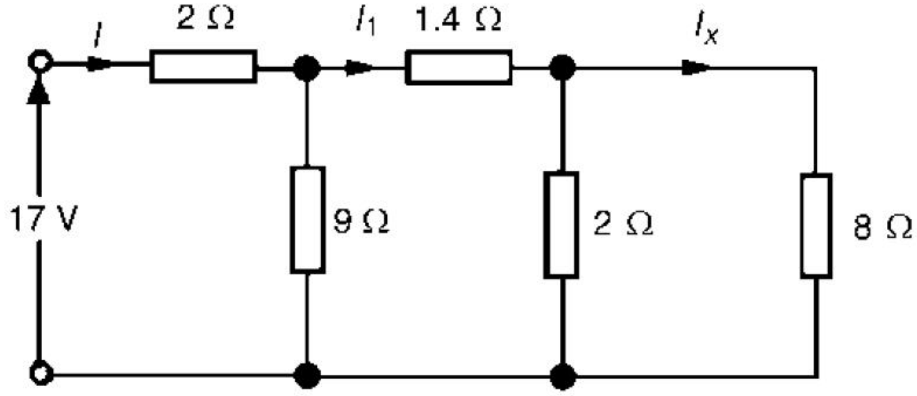
9. For the circuit shown in below Figure, find (a) the value of the supply voltage V and (b) the value of current I.



10. For the series-parallel arrangement shown in below Figure, find (a) the supply current, (b) the current flowing through each resistor and (c) the p.d. across each resistor.



11. For the arrangement shown in below Figure, find the current I_x.

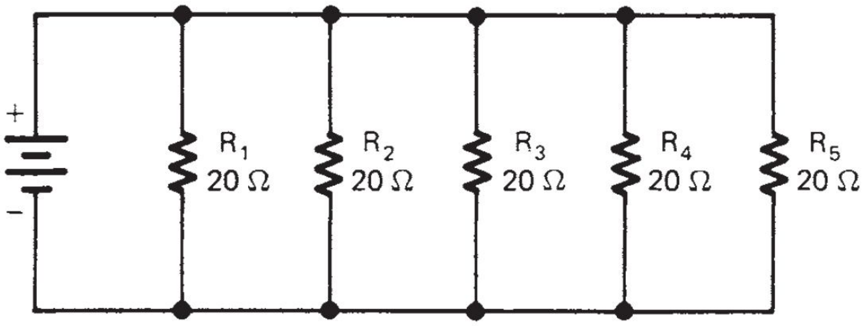


12. Four resistances of 16Ω each are connected in parallel. Four such combinations are connected in series. What is the total resistance?

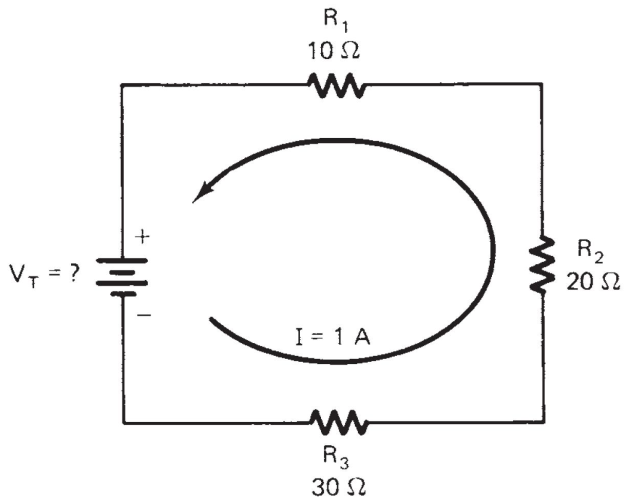
13. A battery of 9 V is connected in series with resistors of 0.2Ω, 0.3Ω, 0.4Ω, 0.5Ω and 12Ω. How much current would flow through the 12Ω resistor?

14. An electric bulb of resistance $20\,\Omega$ and a resistance wire of $4\,\Omega$ are connected in series with a 6V battery. Draw the circuit diagram and calculate: (a) total resistance of the circuit (b) current through the circuit (c) potential difference across the electric bulb (d) potential difference across the resistance wire.

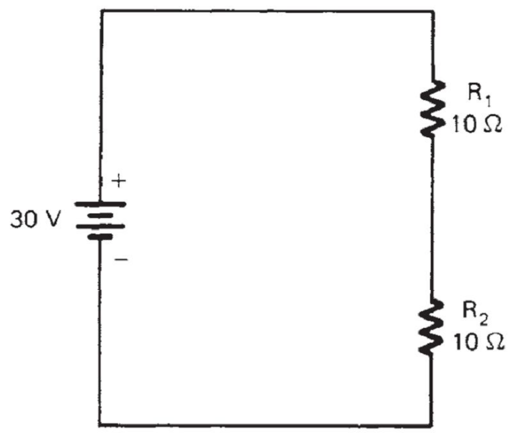
15. Find the equivalent resistance of the given circuit.



16. Find the value of V_T in the given circuit.



17. Find the voltage across each resistance in the given circuit.

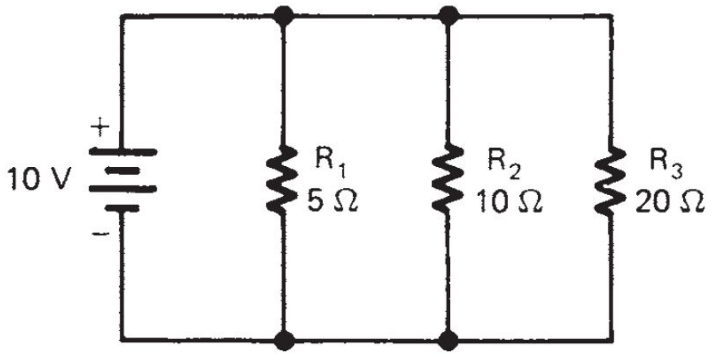


18. A potential difference of 4V is applied to two resistors of $6\,\Omega$ and $2\,\Omega$ connected in series. Calculate: (a) the combined resistance (b) the current flowing (c) the potential difference across the $6\,\Omega$ resistor

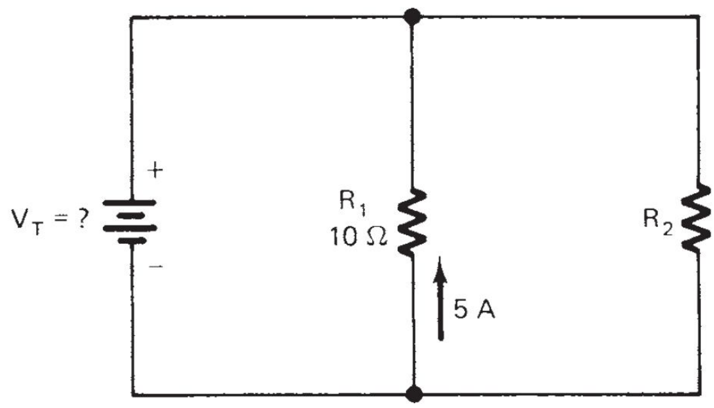
19. Resistors of 20Ω, 20Ω and 30Ω are connected in parallel. What resistance must be added in series with the combination to obtain a total resistance of 10Ω.

20. If four identical lamps are connected in parallel and the combined resistance is 100Ω, find the resistance of one lamp.

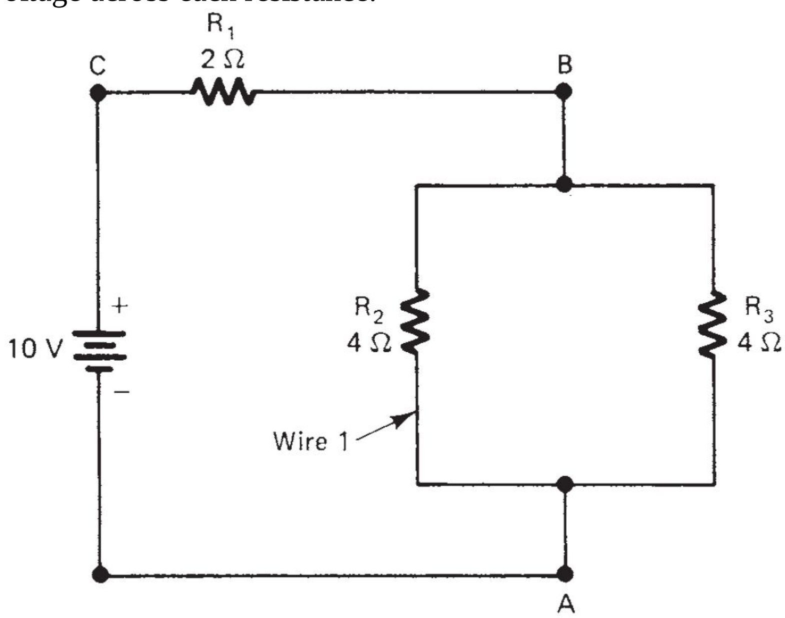
21. Find the current across the each resistance and total current flowing in the given circuit.



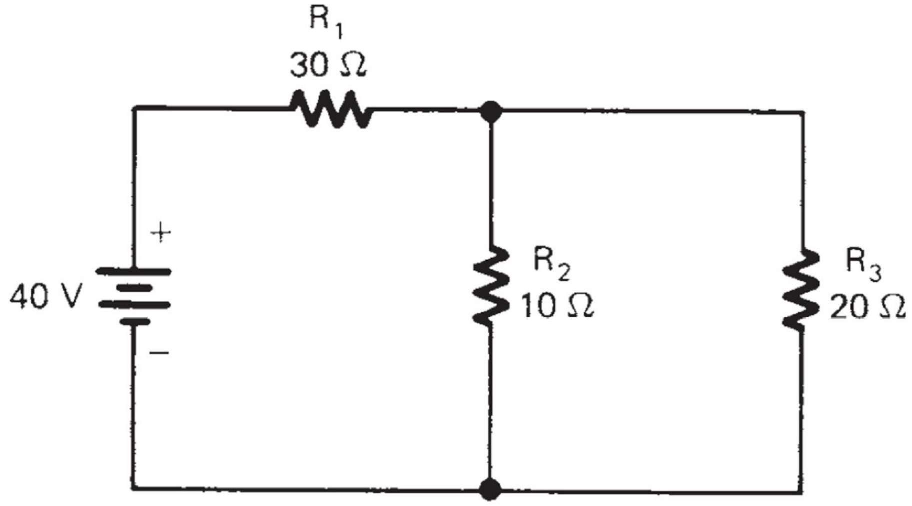
22. In the given circuit, the resistance R_1 and R_2 are connected in parallel. (i) Find the value of V_T. (ii) Find the total current and equivalent resistance in the circuit if resistance $R_2 = 10\,\Omega$



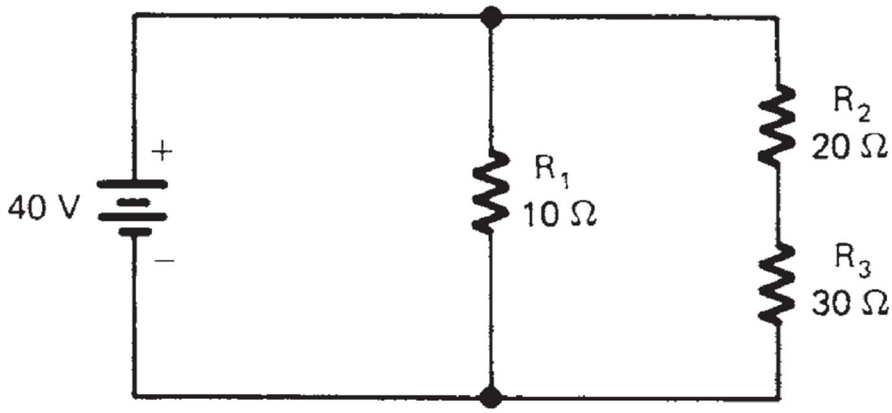
23. In the given circuit, (i) find the equivalent resistance of the circuit and total current flowing in the circuit. (ii) find the current flowing through R_2 and R_3. (iii) find the voltage across each resistance.



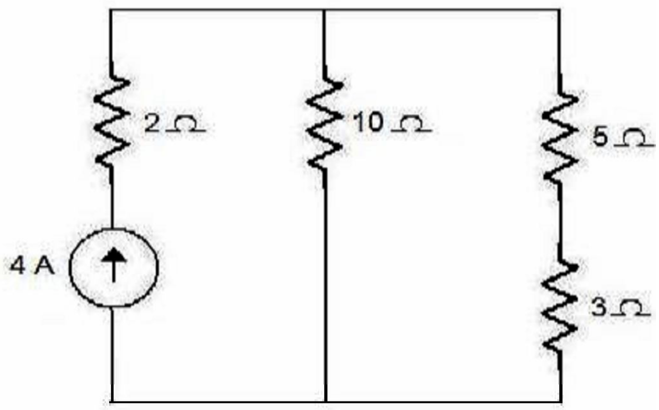
24. In the given circuit, (i) find the equivalent resistance and total current flowing in the circuit. (ii) find the voltage and current across each resistance in the circuit.



25. In the given circuit, (i) find the equivalent resistance and total current flowing in the circuit. (ii) find the voltage and current across each resistance in the circuit.

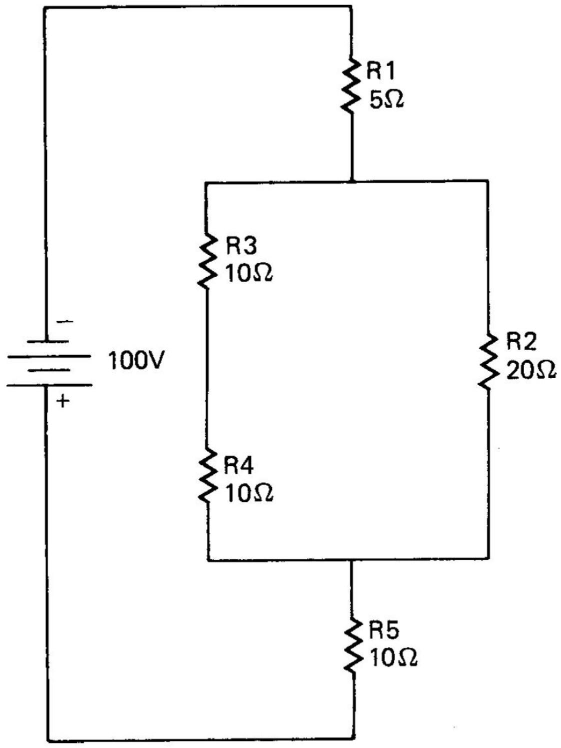


26. Find the current through 10 ohm resistor for the following circuit.



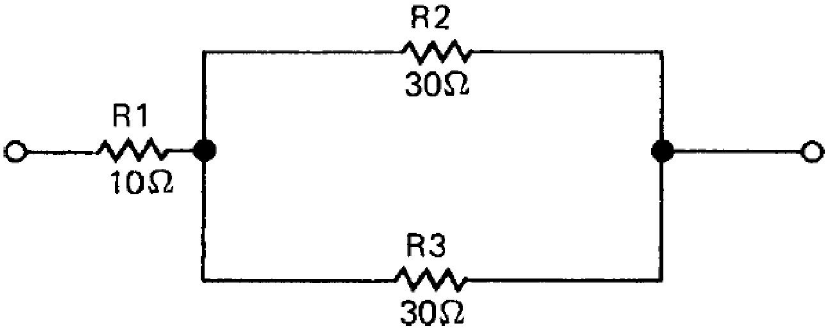
27. In the given circuit, (i) find the equivalent resistance and total current flowing in the circuit. (ii) find the voltage and current across each resistance in the circuit.

(iii)

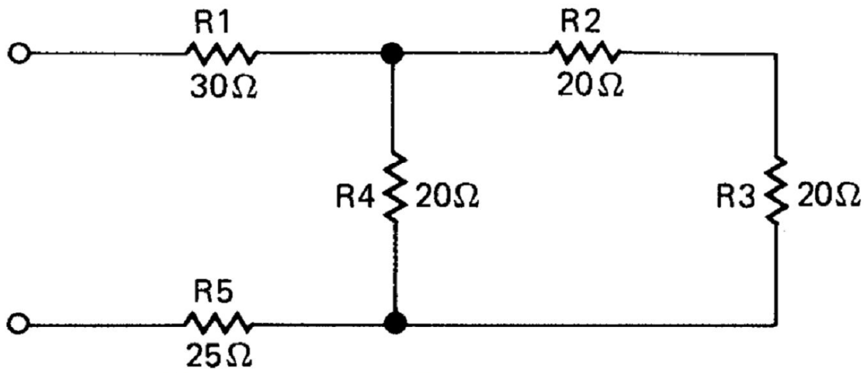


28. Find the equivalent resistance of the following circuits:

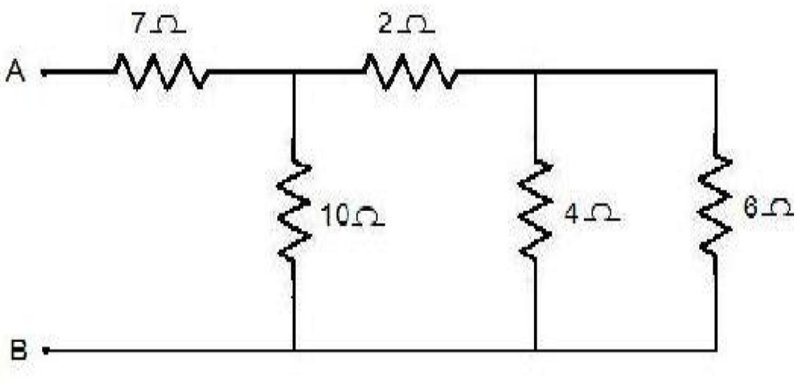
(i)



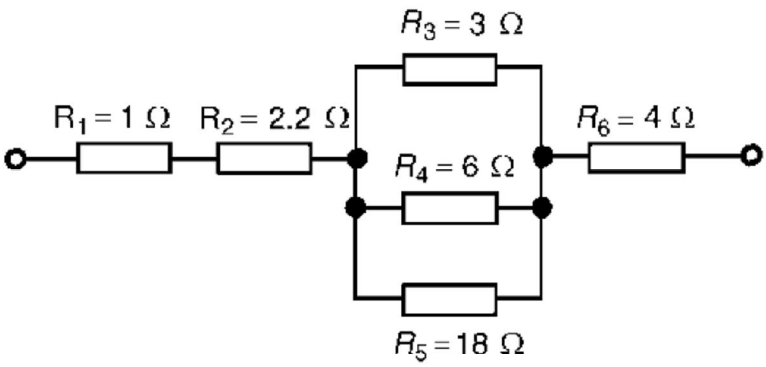
(ii)



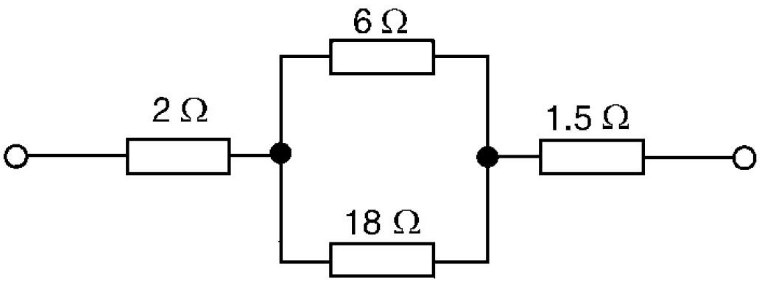
(iii)



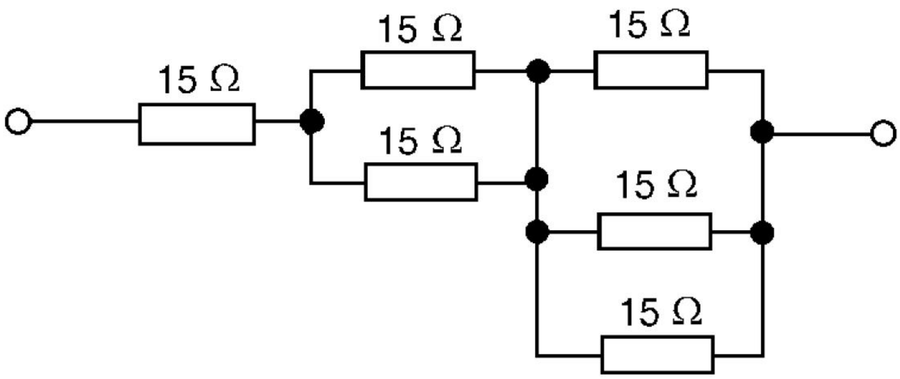
(iv)



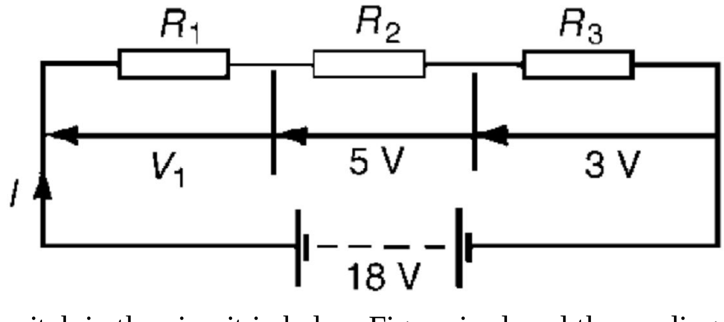
(v)



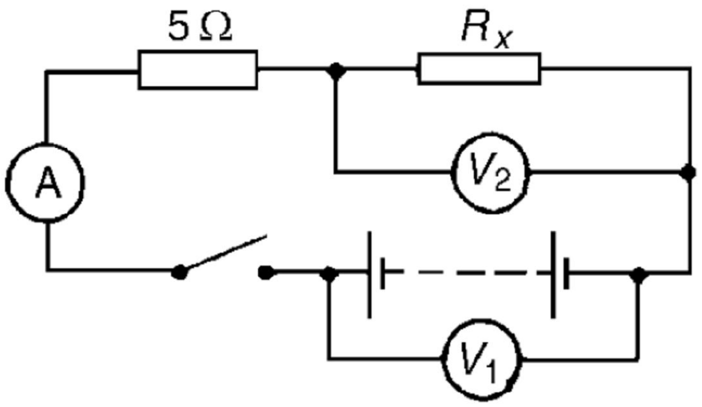
(v)



29. For the circuit shown in below Figure, determine the value of V1. If the total circuit resistance is 36Ω, determine the supply current and the value of resistors R1, R2 and R3.

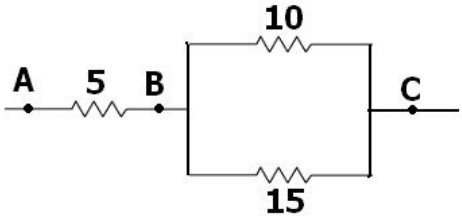


30. When the switch in the circuit in below Figure is closed the reading on voltmeter 1 is 30 V and that on voltmeter 2 is 10 V. Determine the reading on the ammeter and the value of resistor R_x.



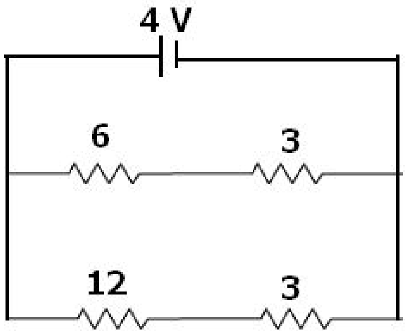
31. A potential difference of 6V is applied to two resistors of 3Ω and 6Ω connected in parallel. Calculate: (a) the combined resistance (b) the current flowing in the main circuit (c) the current flowing in the 3Ω resistor.

32. Three resistors are connected as shown in the diagram:



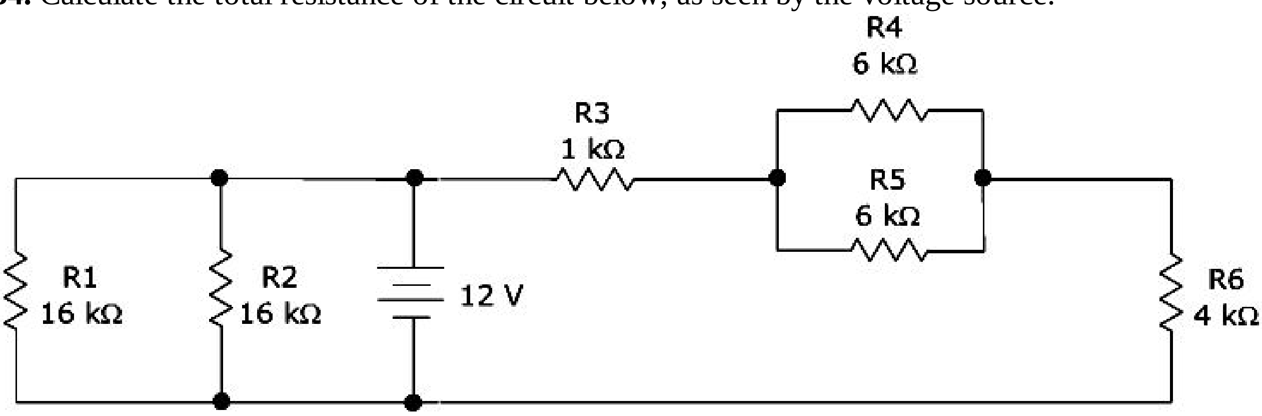
Through the resistor 5Ω ohm, a current of 1A is flowing.
(i) What is the current through the other two resistors?
(ii) What is the p.d. across AB and across AC?
(iii) What is the total resistance?

33. For the circuit shown in the diagram below:

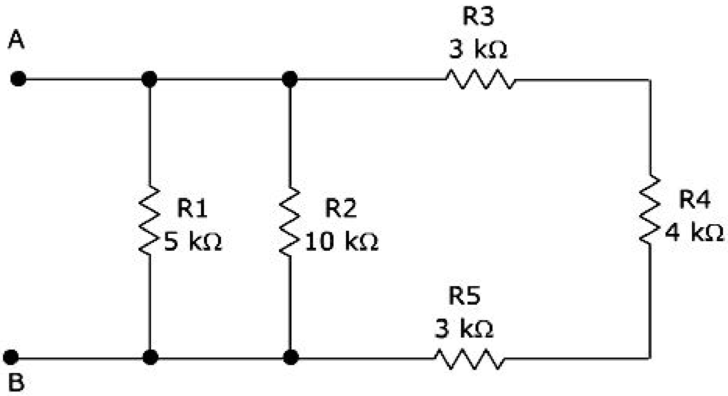


What is the value of: (i) current through 6Ω resistor? (ii) p.d. across 12Ω resistor?

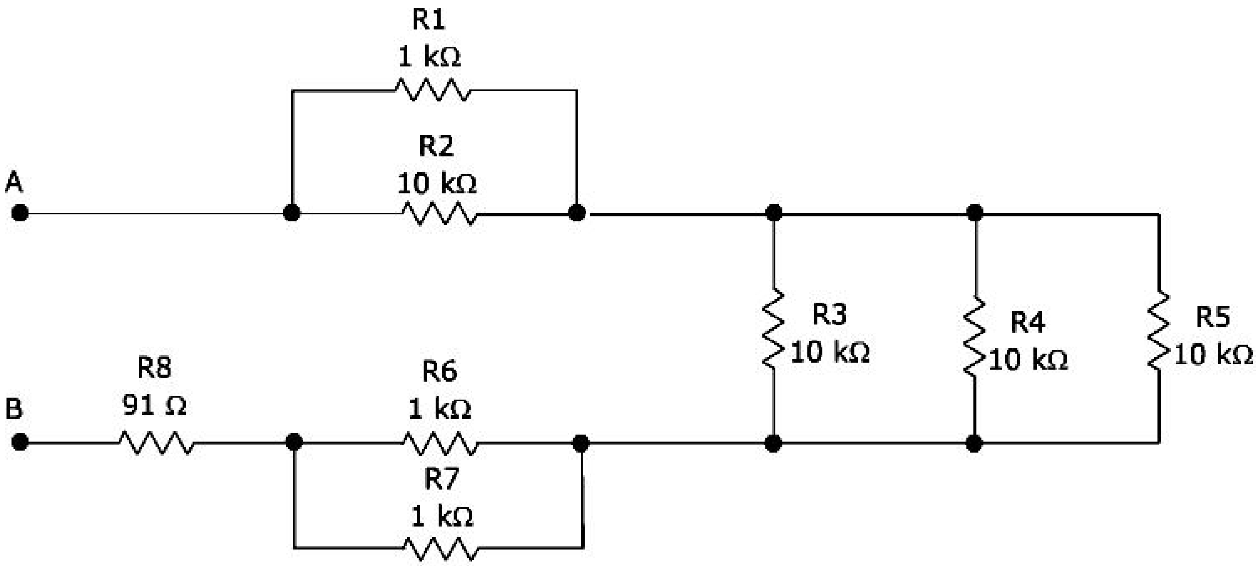
34. Calculate the total resistance of the circuit below, as seen by the voltage source.



35. What is the resistance between A and B in the given figure given below?



36. What is the resistance between A and B in the given figure given below?



37. Resistances of 4Ω and 12Ω are connected in parallel across a 9 V battery. Determine (a) the equivalent circuit resistance, (b) the supply current, and (c) the current in each resistor.

38. Three identical lamps A, B and C are connected in series across a 150 V supply. State (a) the voltage across each lamp, and (b) the effect of lamp C failing.

39. The p.d's measured across three resistors connected in series are 5 V, 7 V and 10 V, and the supply current is 2 A. Determine (a) the supply voltage, (b) the total circuit resistance and (c) the values of the three resistors.

40. If three identical lamps are connected in parallel and the combined resistance is 150Ω, find the resistance of one lamp.

HEATING EFFECT OF ELECTRIC CURRENT

If the electric circuit is purely resistive, that is, a configuration of resistors only connected to a battery; the source energy continually gets dissipated entirely in the form of heat. This is known as the heating effect of electric current. This effect is utilised in devices such as electric heater, electric iron etc

Workdone, $W = Q \times V$

$$I = \frac{Q}{t} \Rightarrow Q = I \times t$$

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

$$\therefore W = I \times t \times I \times R$$

$$\Rightarrow W = I^2 \times R \times t$$

$$\therefore Heat \quad produced, \; H = I^2 \times R \times t \quad joules$$

This is known as Joule's law of heating.

The law implies that heat produced in a resistor is (i) directly proportional to the square of current for a given resistance (I^2), (ii) directly proportional to resistance for a given current (R), and (iii) directly proportional to the time for which the current flows through the resistor (t).

INTEXT QUESTIONS PAGE NO. 218

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

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

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

   Ans. The amount of heat (*H*) produced is given by the Joule's law of heating as H=VIt

   Where, Voltage, *V* = 50 V, Time, *t* = 1 h = 1 × 60 × 60 s

   Amount of current, $I = \frac{\text{Amount of Charge}}{\text{Time of flow of charge}} = \frac{96000}{1 \times 60 \times 60} = \frac{80}{3} A$

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

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

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

   Ans. The amount of heat (*H*) produced is given by the Joule's law of heating as H=VIt

   Where,

   Current, *I* = 5 A

   Time, *t* = 30 s

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

   H = 100 x 5 x 30 = 1.5×10^4 J

   Therefore, the amount of heat developed in the electric iron is 1.5×10^4 J

Practical Applications of Heating Effect of Electric Current

The flowing of current through conductor produce heat. We are using this heat due to flow of current in our daily life as in electric iron, electric bulb, electric fuse, electric heater and more. Heating effect of electric current are below

(i) Electric iron: In an iron the upper part is grooved. In this groove a coil is placed. Mica as an insulator is placed between the metal part and the coil, so that there is no electrical connection between them. Mica is a bad conductor of electricity but it is a good conductor of heat. Due to the flow of current through the coil it becomes heated and the heat transferred to the metal part through mica. Finally the metal part becomes heated. Iron is used with the heating effect of an electric current.

(ii) Electric bulb: we see a thick metallic wire in the bulb. It is made of tangsten metal. In a glass vessel or bulb the tangsten wire is kept sealed. The glass bulb is filled with neutral gas or vacuum. Neutral gases are using now a days commonly. The tangsten wire is known as filament when the current flows through the tangsten wire or filament it becomes heated and emit of light. Due to the flow of current heating effect of an electric current used as the source of light.

(iii) Electric heater: In an electric heater one type of coil is used. A high resistance material like nichrome or same type of material is used as coil. The coil is wound in grooves on ceramic format or china clay. Flowing electric current through the coil it becomes heated. Due to high resistance the coil becomes red color forms.

(iv) Electric fuse: It protects circuits and appliances by stopping the flow of any unduly high electric current. The fuse is placed in series with the device. It consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc. If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases. This melts the fuse wire and breaks the circuit. The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends. The fuses used for domestic purposes are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc. For an electric iron which consumes 1 kW electric power when operated at 220 V, a current of (1000/220) A, that is, 4.54 A will flow in the circuit. In this case, a 5 A fuse must be used.

Electric Power: It is the electrical work done per unit time.

$$P = \frac{W}{t}$$

where W = work done and t = time

S.I. unit of power is watt

If W = 1 joule, t = 1 second then $Power = \frac{1\,joule}{1\,second} = 1\,watt$

One watt: The rate of working of 1 joule per second is the power of 1 watt.

Electric Energy: It is the total work done by a current in an electric circuit.

$$Electric\ \ power = \frac{work\ \ done\ \ by\ \ electric\ \ circuit}{time\ \ takem}$$

Work done by electric circuit = Electric Power x time taken

$$\Rightarrow E = P \times t$$

The electrical energy consumed by an electrical appliance is given by the product of its power rating and the time for which it is used.

Unit of Electrical consumed is watt-hour(Wh)

If P = 1 watt, t = 1 hr, then E = 1 watt x 1 hr = 1 watt-hour.

One watt-hour: It is the amount of electrical energy consumed when an electrical appliance of 1 watt power is used for an hour.

Commercial unit of Electrical energy is **kilowatt-hour(KWh)**

One Kilowatt-hour: It is the amount of electrical energy consumed when an electrical appliance having a power rating of 1 kilowatt is used in 1 hour.

1 kilowatt-hour = 36,00,000 joules or 3.6×10^6 J

INTEXT QUESTIONS PAGE NO. 220

1. **What determines the rate at which energy is delivered by a current?**
   Ans. The rate of consumption of electric energy in an electric appliance is called electric power. Hence, the rate at which energy is delivered by a current is the power of the appliance.

2. **An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.**
   Ans. Power (*P*) is given by the expression, P = VI
   Where,
   Voltage, $V = 220$ V
   Current, $I = 5$ A
   P = 220 x 5 = 1100 W
   Energy consumed by the motor = *Pt*
   Where,
   Time, $t = 2\ h = 2 \times 60 \times 60 = 7200$ s
   $\therefore P = 1100 \times 7200 = 7.92 \times 10^6$ J
   Therefore, power of the motor = 1100 W
   Energy consumed by the motor = 7.92×10^6 J

NUMERICAL PROBLEMS

1. What will be the current drawn by an electric bulb of 40 W when it is connected to a source of 220V?
2. A bulb is rated as 250V;0.4A. Find its power and resistance.
3. An electric bulb is connected to a 220V power supply line. If the bulb draw a current of 0.5A, calculate the power of the bulb.
4. An electric bulb is connected to a 250 V generator. The current is 0.50 A. What is the power of the bulb?
5. What current will be taken by a 920W appliance if the supply voltage is 230V? **6.** When an electric lamp is connected to 12V battery, it draws a current 0.5A.

Find

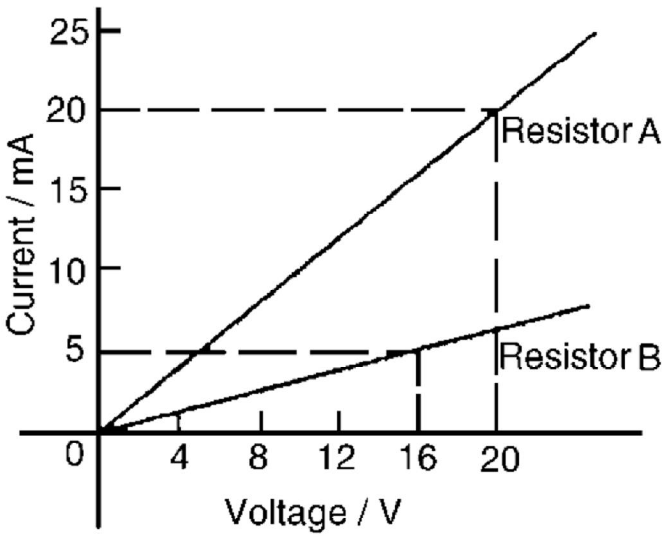
the power of the lamp.

7. Calculate the power used in 2Ω resistor in each (i) a 6V battery in series with 1Ω and 2Ω resistor (ii) a 4V battery in parallel with 12Ω and 2Ω resistor.
8. A 100 W electric light bulb is connected to a 250 V supply. Determine (a) the current flowing in the bulb, and (b) the resistance of the bulb.
9. Calculate the power dissipated when a current of 4 mA flows through a resistance

10. An electric kettle has a resistance of 30Ω. What current will flow when it is connected to a 240 V supply? Find also the power rating of the kettle.

11. A current of 5 A flows in the winding of an electric motor, the resistance of the winding being 100Ω. Determine (a) the p.d. across the winding, and (b) the power dissipated by the coil.

12. The current/voltage relationship for two resistors A and B is as shown in below Figure. Determine the value of the resistance of each resistor and also find the power dissipated through each resistor.



13. The hot resistance of a 240 V filament lamp is 960Ω. Find the current taken by the lamp and its power rating.

14. A 12 V battery is connected across a load having a resistance of 40Ω. Determine the current flowing in the load, the power consumed and the energy dissipated in 2 minutes.

15. A source of e.m.f. of 15 V supplies a current of 2 A for six minutes. How much energy is provided in this time?

16. Electrical equipment in an office takes a current of 13 A from a 240 V supply. Estimate the cost per week of electricity if the equipment is used for 30 hours each week and 1 kWh of energy costs 7p

17. An electric heater consumes 3.6 MJ when connected to a 250 V supply for 40 minutes. Find the power rating of the heater and the current taken from the supply.

18. Determine the power dissipated by the element of an electric fire of resistance 20Ω when a current of 10 A flows through it. If the fire is on for 6 hours determine the energy used and the cost if 1 unit of electricity costs 7p.

19. A business uses two 3 kW fires for an average of 20 hours each per week, and six 150 W lights for 30 hours each per week. If the cost of electricity is 7p per unit, determine the weekly cost of electricity to the business.

20. If 5 A, 10 A and 13 A fuses are available, state which is most appropriate for the following appliances which are both connected to a 240 V supply (a) Electric toaster having a power rating of 1 kW (b) Electric fire having a power rating of 3 kW

21. The hot resistance of a 250 V filament lamp is 625 . Determine the current taken by the lamp and its power rating.

22. Determine the resistance of a coil connected to a 150 V supply when a current of (a) 75 mA (b) 300 μA flows through it. Determine the power dissipated through it.

23. Determine the resistance of an electric fire which takes a current of 12A from a 240 V supply. Find also the power rating of the fire and the energy used in 20 h.

24. Determine the power dissipated when a current of 10 mA flows through an appliance having a resistance of 8 k.

25. 85.5 J of energy are converted into heat in nine seconds. What power is dissipated?

26. A current of 4 A flows through a conductor and 10 W is dissipated. What p.d. exists across the ends of the conductor?

27. Find the power dissipated when:

(a) a current of 5 mA flows through a resistance of 20 k

(b) a voltage of 400 V is applied across a 120 k resistor

(c) a voltage applied to a resistor is 10 kV and the current flow is 4 mA.

28. A battery of e.m.f. 15 V supplies a current of 2 A for 5 min. How much energy is supplied in this time?

29. In a household during a particular week three 2 kW fires are used on average 25 h each and eight 100 W light bulbs are used on average 35 h each. Determine the cost of electricity for the week if 1 unit of electricity costs 7p.

30. Calculate the power dissipated by the element of an electric fire of resistance 30 when a current of 10 A flows in it. If the fire is on for 30 hours in a week determine the energy used. Determine also the weekly cost of energy if electricity costs 7.2p per unit.

31. A television set having a power rating of 120 W and electric lawnmower of power rating 1 kW are both connected to a 240 V supply. If 3 A, 5 A and 10 A fuses are available state which is the most appropriate for each appliance.

32. For a heater rated at 4kW and 220V, calculate: (a) the current (b) the resistance of the heater (c) the energy consumed in 2 hours and (d) the cost if 1kWh is priced at Rs. 4.60

33. A radio set of 60W runs for 50hrs. How much electrical energy consumed?

34. A current of 4A flows through a 12V can headlight bulb for 10min. How much energy transfer occurs during this time?

35. Calculate the energy transferred by a 5A current flowing through a resistor of 2Ω for 30min.

36. A bulb is rated at 200V-100W. What is its resistance? 5 such bulbs burn for 4 hrs. What is the electrical energy consumed? Calculate the cost if the rate is Rs. 4.60 per unit.

37. A refrigerator having a power rating of 350W operates for 10hours a day. Calculate the cost of electrical energy to operate it for a month of 30days. The rate of electrical energy is Rs. 3.40 per KWh.

38. What will be the current drawn by an electric bulb of 40W when it is converted to a source of 220V?

39. An electric bulb is rated 220V and 100W. When it is operated on 110V, find the power consumed.

40. An electric heater draws a current of 10A from a 220V supply. What is the cost of using the heater for 5 hrs everyday for 30days if the cost of 1 unit is Rs. 5.20?

41. In house two 60W electric bulbs are lighted for 4 hrs and three 100W bulbs for 5 hrs everyday. Calculate the electrical energy consumed in 30days.

42. An electric motor takes 5A current from a 220V supply line. Calculate the power of the motor and electrical energy consumed by it in 2 hrs.

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

44. An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs 3.00 per kW h?

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

46. 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?

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

48. Two bulbs A and B are rated 100W – 120V and 10W – 120V respectively. They are connected across a 120V source in series. Which will consume more energy.

49. Two bulbs A and B are rated 100W – 120V and 10W – 120V respectively. They are connected across a 120V source in series. Find the current in each bulb. Which will consume more energy.

50. An electric kettle is rated at 230V, 1000W. What is the resistance of its element? What maximum current can pass through its element?

51. An electric geyser has the rating 1000W, 220V marked on it. What should be the minimum rating in whole number of a fuse wire that may be required for safe use with this geyser?

52. The mains power supply of a house is through a 5A fuse. How many 100W, 220V bulbs can be used in this house at the correct voltage?

53. An electrician puts a fuse of rating 5A in that part of domestic electrical circuit in which an electrical heater of rating 1.5kW, 220V is operating. What is likely to happen in this case and why? What change if any needs to be made/

54. Two bulbs of ratings 40W-220V and 60W-220V are connected in series and this combination is connected with a supply of 220V. Calculate the current from the supply line.

55. Two bulbs have the ratings 40W-200V and 20W-110V. What is the ratio of their resistances?

56. I can spend Rs. 9 per month (30days) on electric light. If power is 30paise per kWh and I use 5 identical bulbs for 5 hours a day, what should be the power of each bulb?

57. Compute the number of electrons passing through per minute through an electric bulb of 60W, 220V.

58. If electrical energy costs Rs.3 per unit, what is the total cost of leaving 4 light bulb rated at 100W each switched on for 8 hours.

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

60. 100 J of heat are produced each second in a 4 Ω resistance. Find the potential difference across the resistor.

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

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

63. A p.d. of 250V is applied across a resistance of 500 Ω in an electric iron. Calculate (i) current (ii) heat energy produced in joules in 10s.

64. Calculate the heat produced when 96000C of charge is transferred in 1 hour through a p.d. of 50V.

65. A resistance of 40 Ω and one of 60 Ω are arranged in series across 220V supply7. Find the heat in joules produced by this combination of resistances in half a minute?

66. When a current of 4A passes through a certain resistor for 10min, 2.88 x 10^4 J of heat are produced. Calculate (a) power of the resistor (b) the voltage across the resistor.

67. A heating coil has a resistance of 200 Ω. At what rate will heat be produced in it when a current of 2.5 Ω flows through it.

68. An electric heater of resistance 8 Ω takes a current of 15A from the mains supply line. Calculate the rate at which heat is developed in the heater.

69. A resistance of 25 Ω is connected to a 12V battery. Calculate the heat energy in joule generated per minute.

70. How much heat will an instrument of 12W produce in one minute if its is connected to a battery of 12V?

EXERCISE QUESTIONS PAGE NO. 221

1. A piece of wire of resistance *R* is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is *R′*, then the ratio *R*/*R′* is − (a) $\frac{1}{25}$ (b) $\frac{1}{5}$ (c) 5 (d) 25

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

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

All the five parts are connected in parallel. Hence, equivalent resistance (R') is given as

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

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

Therefore, the ratio $\frac{R}{R'}$ is 25.

2. Which of the following terms does not represent electrical power in a circuit?
(a) I^2R (b) IR^2 (c) VI (d) V^2/R
Ans. (b) Electrical power is given by the expression, $P = VI$ … (i)
According to Ohm's law, $V = IR$ … (ii)
where, V = Potential difference, I = Current and R = Resistance
$\therefore P = VI$
From equation (i), it can be written
$P = (IR) \times I$
$\therefore P = I^2R$
From equation (ii), it can be written

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

$$\therefore P = V \times \frac{V}{R} \Rightarrow P = \frac{V^2}{R}$$

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

Power P cannot be expressed as IR^2.

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

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

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

where, Power rating, P = 100 W , Voltage, V = 220 V

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

The resistance of the bulb remains constant if the supply voltage is reduced to 110 V. If the bulb is operated on 110 V, then the energy consumed by it is given by the expression for power as

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

Therefore, the power consumed will be 25 W.

4. Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combinations would be – (a) 1:2 (b) 2:1 (c) 1:4 (d) 4:1
Ans. (c) The Joule heating is given by, $H = i^2Rt$
Let, R be the resistance of the two wires.
The equivalent resistance of the series connection is $R_S = R + R = 2R$
If V is the applied potential difference, then it is the voltage across the equivalent resistance.

$$V = I_s \times 2R$$

$$\Rightarrow I_s = \frac{V}{2R}$$

The heat dissipated in time t is,

$$H = I_s^{\,2} \times 2R \times t = \left(\frac{V}{2R}\right)^2 \times 2R \times t \;\Rightarrow H = \frac{V^2 t}{2R}$$

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

V is the applied potential difference across this R_P.

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

$$\Rightarrow I_p = \frac{2V}{R}$$

The heat dissipated in time t is,

$$H' = I_p^{\,2} \times \frac{R}{2} \times t = \left(\frac{2V}{R}\right)^2 \times \frac{R}{2} \times t \;\Rightarrow H' = \frac{2V^2 t}{R}$$

So, the ratio of heat produced is, $\dfrac{H}{H'} = \dfrac{\frac{V^2 t}{2R}}{\frac{2V^2 t}{R}} = \dfrac{1}{4}$

5. How is a voltmeter connected in the circuit to measure the potential difference between two points?
Ans. To measure the potential difference between two points, a voltmeter should be connected in parallel to the points.

6. A copper wire has diameter 0.5 mm and resistivity of $1.6 \times 10^{-8}\ \Omega$ m. What will be the length of this wire to make its resistance 10 Ω? How much does the resistance change if the diameter is doubled?
Ans. Resistance (R) of a copper wire of length l and cross-section A is given by the expression,

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

Where,

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

Area of cross-section of the wire, $A = \pi \left(\dfrac{diameter}{2}\right)^2$

Diameter= 0.5 mm = 0.0005 m
Resistance, R = 10 Ω
Hence, length of the wire,

$$l = \frac{RA}{\rho} = \frac{10 \times 3.14 \times \left(\frac{0.0005}{2}\right)^2}{1.6 \times 10^{-8}} = \frac{10 \times 3.14 \times 25}{4 \times 1.6} = 122.72m$$

If the diameter of the wire is doubled, new diameter= 2 x 0.5 = 1 mm = 0.001m
Therefore, resistance R’

$$R' = \rho \frac{l}{A} = \frac{1.6 \times 10^{-8} \times 122.72}{\pi \left(\frac{1}{2} \times 10^{-3}\right)^2}$$

$$\Rightarrow R' = \frac{1.6 \times 10^{-8} \times 122.72 \times 4}{3.14 \times 10^{-6}} = 250.2 \times 10^{-2} = 2.5\Omega$$

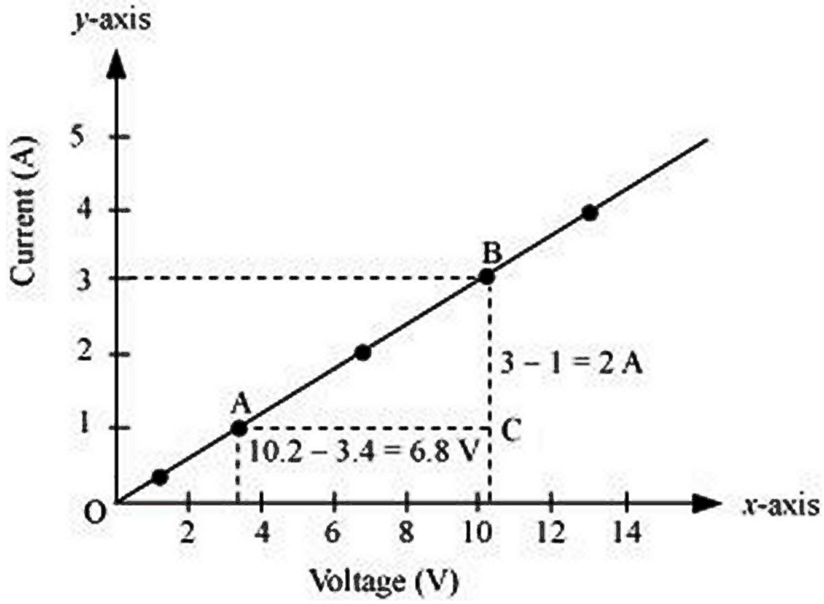
Therefore, the length of the wire is 122.7 m and the new resistance is 2.5 Ω

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. The plot between voltage and current is called IV characteristic. The voltage is plotted on x-axis and current is plotted on y-axis.



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

$$Slope = \frac{1}{R} = \frac{BC}{AC} = \frac{2}{6.8} \Rightarrow R = \frac{6.8}{2} = 3.4\Omega$$

Therefore, the resistance of the resistor is 3.4Ω

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

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

where, Potential difference, V = 12 V

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

$$V = IR \Rightarrow R = \frac{12}{2.5\times10^{-3}} = 4.8\times10^{3}\Omega = 4.8k\Omega$$

Therefore, the resistance of the resistor is $4.8k\Omega$

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

$V = IR \Rightarrow I = \frac{V}{R}$ where, R is the equivalent resistance of resistances 0.2 Ω, 0.3 Ω, 0.4 Ω, 0.5 Ω and 12 Ω. These are connected in series. Hence, the sum of the resistances will give the value of R.

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

Potential difference, V = 9 V

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

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

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

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

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

where, Supply voltage, V = 220 V, Current, I = 5 A

Equivalent resistance of the combination = R, given as

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

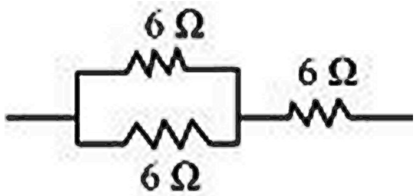
From Ohm's law, $\frac{V}{I} = \frac{176}{x} \Rightarrow x = \frac{176 \times I}{V} = \frac{176 \times 5}{220} = 4$

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

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. If we connect the resistors in series, then the equivalent resistance will be the sum of the resistors, i.e., 6 Ω + 6 Ω + 6 Ω = 18 Ω, which is not desired. If we connect the resistors in parallel, then the equivalent resistance will be $\frac{6}{2} = 3\Omega$, which is also not desired. Hence, we should either connect the two resistors in series or parallel.

(i) Two resistors in parallel

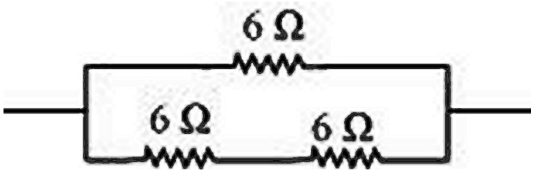


Two 6 Ω resistors are connected in parallel. Their equivalent resistance will be

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{1}{\frac{1}{6} + \frac{1}{6}} = \frac{6 \times 6}{6 + 6} = 3\Omega$$

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

(ii) Two resistors in series



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

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

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{1}{\frac{1}{12} + \frac{1}{6}} = \frac{12 \times 6}{12 + 6} = 4\Omega$$

Therefore, the total resistance is 4 Ω

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. Resistance R_1 of the bulb is given by the expression,

$P_1 = \frac{V^2}{R_1} \Rightarrow R_1 = \frac{V^2}{P_1}$ where, Supply voltage, V = 220 V; Maximum allowable current, I = 5 A

Rating of an electric bulb , P_1=10W

$$R_1 = \frac{(220)^2}{5} = 4840\Omega$$

According to Ohm's law, $V = I R$

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

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

Resistance of each electric bulb, R_1 = 4840 Ω

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \quad upto \;\; x \;\; times \Rightarrow \frac{1}{R} = \frac{1}{R_1} \times x$$

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

Therefore, 110 electric bulbs are connected in parallel.

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. Supply voltage, V = 220 V

Resistance of one coil, R =

(i) Coils are used separately

According to Ohm's law, $V_1 = I_1 R_1$ where, I_1 is the current flowing through the coil

$$I_1 = \frac{V}{R_1} = \frac{220}{24} = 9.166A$$

Therefore, 9.16 A current will flow through the coil when used separately.

(ii) Coils are connected in series

Total resistance, R_2 = 24 Ω + 24 Ω = 48 Ω

According to Ohm's law, $V_2 = I_2 R_2$ where, I_2 is the current flowing through the coil

$$I_2 = \frac{V}{R_2} = \frac{220}{48} = 4.58A$$

Therefore, 4.58 A current will flow through the circuit when the coils are connected in series.

(iii) Coils are connected in parallel

Total resistance, $R_3 = \frac{1}{\frac{1}{24} + \frac{1}{24}} = \frac{24}{2} = 12\Omega$

According to Ohm's law, $V_3 = I_3 R_3$ where, I_3 is the current flowing through the coil

$$I_3 = \frac{V}{R_3} = \frac{220}{12} = 18.33A$$

Therefore, 18.33 A current will flow through the circuit when coils are connected in parallel.

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 12 Ω and 2 Ω resistors.
Ans. (i) Potential difference, $V = 6$ V
1 Ω and 2 Ω resistors are connected in series. Therefore, equivalent resistance of the circuit, $R = 1 + 2 = 3\ \Omega$
According to Ohm's law, $V = IR$ where, I is the current through the circuit

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

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

$$P = (I)^2 R = (2)^2 2 = 8W$$

(ii) Potential difference, $V = 4$ V
12 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

$$P = \frac{V^2}{R} = \frac{4^2}{2} = 8W$$

Therefore, the power used by 2 Ω resistor is 8 W.

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

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

$$Power = Voltage \times Current$$

$$\Rightarrow Current = \frac{Power}{Voltage} = \frac{110}{220} A$$

Similarly, current drawn by the bulb of rating 100 W is given by,

$$Power = Voltage \times Current$$

$$\Rightarrow Current = \frac{Power}{Voltage} = \frac{60}{220} A$$

Hence, current drawn from the line = $\frac{110}{220} + \frac{60}{220} = 0.727A$

16. Which uses more energy, a 250 W TV set in 1 hr, or a 1200 W toaster in 10 minutes?
Ans. Energy consumed by an electrical appliance is given by the expression,
H = P x t
where, Power of the appliance = P, Time = t

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

Energy consumed by a toaster of power 1200 W in 10 minutes = 1200 × 600 = 7.2×10^5 J

Therefore, the energy consumed by a 250 W TV set in 1 h is more than the energy consumed by a toaster of power 1200 W in 10 minutes.

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

Ans. Rate of heat produced by a device is given by the expression for power as $P = I^2R$

where, Resistance of the electric heater, $R = 8\ \Omega$

Current drawn, $I = 15$ A

$P = 15^2 \times 8 = 225 \times 8 = 1800$ J/s

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

18. Explain the following.

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

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

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

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

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

Ans. (a) The melting point and resistivity of tungsten are very high. It does not burn readily at a high temperature. The electric lamps glow at very high temperatures. Hence, tungsten is mainly used as heating element of electric bulbs.

(b) The conductors of electric heating devices such as bread toasters and electric irons are made of alloy because resistivity of an alloy is more than that of metals. It produces large amount of heat.

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

(d) Resistance (R) of a wire is inversely proportional to its area of cross-section (A), i.e., $R \propto \frac{1}{A}$

(e) Copper and aluminium wires have low resistivity. They are good conductors of electricity. Hence, they are usually employed for electricity transmission.