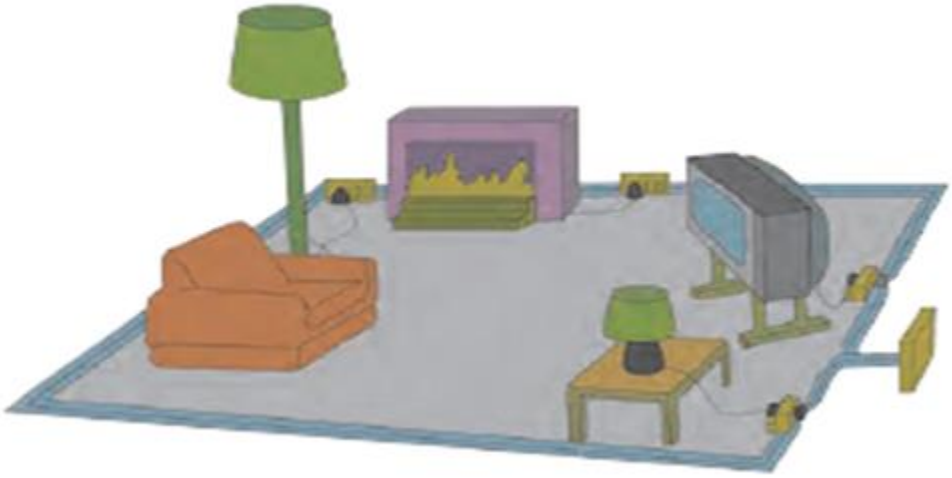
Current Electricity

Exercises

Q. 1. The accompanying figure shows some electrical appliances connected in a circuit in a house. Answer the following questions.

A. By which method are the appliances connected?
B. What must be the potential difference across individual appliances?
C. Will the current passing through each appliance be the same? Justify your answer.
D. Why are the domestic appliances connected in this way?
E. If the T.V. stops working, will the other appliances also stop working? Explain your answer.



Answer : A) The appliances are connected parallel to each other.

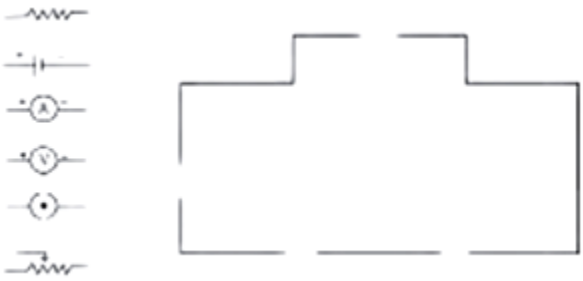
B) As the appliances are connected in parallel, the potential difference across individual appliances should be same. In India voltage ratings of all home appliances are constant i.e. 230V.

C) The current passing through each appliance won't be the same as the resistance of each appliance is different. (Current depends on both potential difference and resistance, I = V/R)

D) The domestic appliances are connected in this way as in a parallel circuit even if one of the appliance stops working, the rest would still be working but in case of series connection all the appliances stop working if one of them stops working.

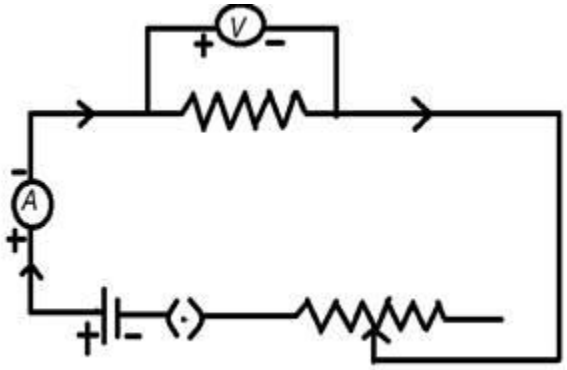
E) If the TV stops working, the other appliances do not stop working as they are connected in parallel. In parallel connection, the potential difference between the loads is the same and the total current in the circuit is the sum of current flowing through each path in the circuit.

Q. 2. The following figure shows the symbols for components used in the accompanying electrical circuit. Place them at proper places and complete the circuit.



Which law can you prove with the help of the above circuit?

Answer : The circuit with attached symbols is given below:



Ohm's law can be proved with the help of the above circuit.

Q. 3. Umesh has two bulbs having resistances of $15\ \Omega$ and $30\ \Omega$. He wants to connect them in a circuit, but if he connects them one at a time the filament gets burnt. Answer the following.

A. Which method should he use to connect the bulbs?
B. What are the characteristics of this way of connecting the bulbs depending on the answer of A above?
C. What will be the effective resistance in the above circuit?

Answer : Here we are assuming current to be constant and voltage to be varying.

A. The burning of filament is due to excessive heating when current passes through it. More the resistance of the wire, more is the heating. Therefore, the resistance of the circuit should be decreased which can be done if both the bulbs are connected in parallel.

We know that equivalent resistance in case of parallel combination of two resistances R_1 and R_2 is

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

In the above case, $R_{eq} = \frac{15 \times 30}{15 + 30} = 10 \Omega$ which is less than the individual resistances of both the wires.

Therefore, both the bulbs should be connected in parallel.

B. Characteristics of a parallel circuit:

1) A parallel circuit has two or more paths for current to flow through and the total current is equal to sum of currents flowing through these paths.

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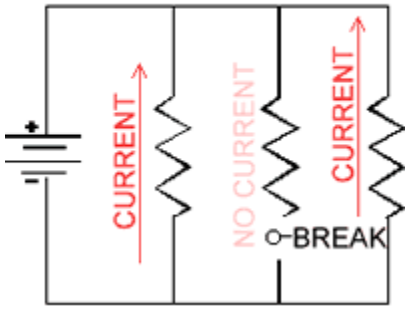
B. Characteristics of a parallel circuit:

1) A parallel circuit has two or more paths for current to flow through and the total current is equal to sum of currents flowing through these paths.

2) Voltage is same across each component of parallel circuit.

3) The current in all the branches is same. As shown in the figure:



C. The effective resistance in the above circuit is given as:

$$R_{effective} = \frac{1}{R_1} + \frac{1}{R_2}$$

Where R_1 and R_2 are the resistances connected in parallel.

or

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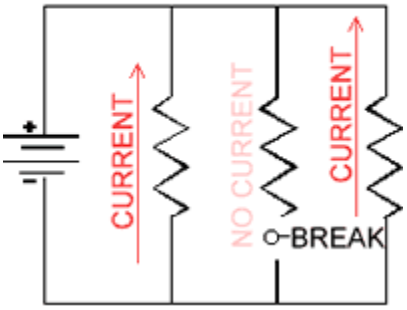

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Q. 4. The following table shows current in Amperes and potential difference in Volts.

A. Find the average resistance.
B. What will be the nature of the graph between the current and potential difference? (Do not draw a graph.)
C. Which law will the graph prove?

V(Volts)	I(Amp)
4	9
5	11.25
6	13.5

Answer : A. According to the equation V = IR

R = V/I

Resistance in the 1st case $R_1 = V_1/I_1$

= 4/9

= 0.444 Ω

Resistance in the 2nd case $R_2 = V_2/I_2$

= 5/11.25

= 0.444 Ω

Resistance in the 3rd case $R_3 = V_3/I_3$

= 6/13.5

= 0.444 Ω

$$\text{Average resistance } R_{avg} = \frac{R_1 + R_2 + R_3}{3}$$

= (0.444 + 0.444 + 0444)/3

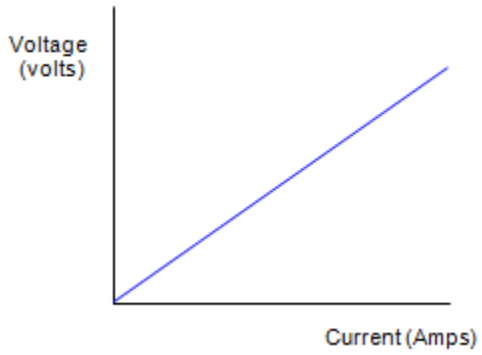
=0.444 Ω

B. In this case as R is constant, we can observe the increase in I as V increases.

We know that V = IR .

It represents a straight line starting from origin with a slope R. Therefore, the nature of graph between current and potential difference will be a straight line.

The graph is given below:



C. The graph proves Ohm's law.

According to Ohm's law the current passing through a conductor between two points is directly proportional to the voltage across the two points.

$I \propto V$

$I = V/R$

Q. 5. Match the pairs

'A' Group	**'B' Group**
1. Free electrons	a. V/ R
2. Current	b. Increases the resistance in the circuit
3. Resistivity	c. Weakly attached
4. Resistances in series	d. VA/LI

Answer :

Group A	Group B	Explanation
1. Free electrons	c. Weakly attached	The electrons which are very weakly attached to the ion/molecule and are free to move under the influence of applied electric or magnetic field are called free electrons
2. Current	a. V/R	From Ohm' law, we know that V = IR
3. Resistivity	d. VA/LI	Resistivity $\rho = RA/L$ $= VA/IL$
4. Resistance in series	b. Increases the resistance in the circuit	The effective resistance in case of series is the sum of resistances $R_{effective} = R_1 + R_2 + ...$

Q. 6. The resistance of a conductor of length x is r. If its area of cross section is a, what is its resistivity? What is its unit?

Answer : We know that Resistivity ρ = RA/L

where R = Resistance of the conductor

A = Cross sectional area of the conductor

L = Length of the conductor

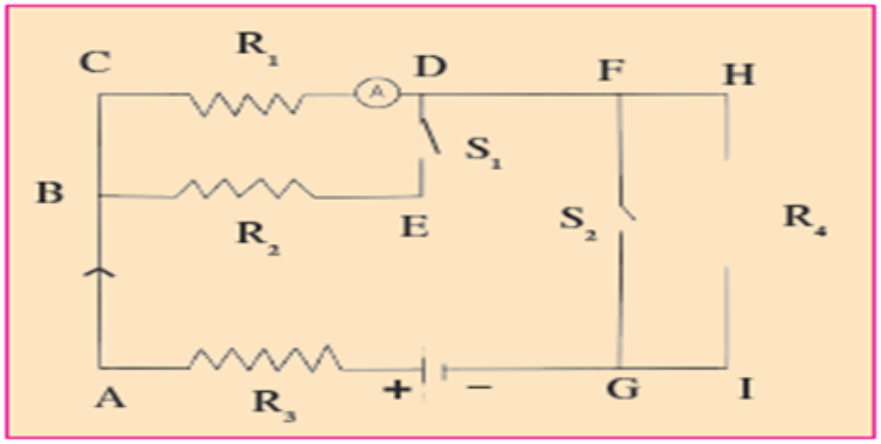
Here A = a and L = x

Therefore, Resistivity ρ = Ra/x

It's units are ohm.m^2/m = Ωm

Q. 7.

Resistances R_1, R_2, R_3 and R_4 are connected as shown in the figure. S1 and S2 are two keys. Discuss the current flowing in the circuit in the following cases.



A. Both S_1 and S_2 are closed.
B. Both S_1 and S_2 are open.
C. S_1 is closed but S_2 is open

Answer : A. When both S_1 and S_2 are closed, R_4 is short circuited.

R_3 and (R_1||R_2) are in series

Effective resistance of the circuit $R_{effective} = R_3 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$$\Rightarrow R_{effective} = R_3 + \frac{R_1 R_2}{R_1 + R_2}$$

Let the applied voltage be V.

$$\text{Current in the circuit } I = \frac{V}{R_{effective}}$$

$$\Rightarrow I = \frac{V}{R_3 + \frac{R_1 R_2}{R_1 + R_2}}$$

B. When both S_1 and S_2 are open, R_3 , R_1 and R_4 are in series.

The effective resistance of the circuit,

$R_{effective} = R_3 + R_1 + R_4$

Let the applied voltage be V.

Current in the circuit $I = V/R_{effective}$

$$I = \frac{V}{R_3 + R_1 + R_4}$$

C. When S_1 is closedbut S_2 is open, R_3, $(R_1||R_2)$ and R_4 are in series.

As S_1 is closed, R_1 and R_2 are parallel to each other.

The effective resistance of the circuit is

$$R_{effective} = R_3 + (R_1||R_2) + R_4 \left(\text{When } R_1||R_2 \text{ Req } = \frac{R_1 R_2}{R_1 + R_2} \right)$$

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

Let the applied voltage be V

Current in the circuit $I = V/R_{effective}$

$$I = \frac{V}{(R_3 + \frac{R_1 R_2}{R_1 + R_2} + R_4)}$$

Q. 8. Three resistances x_1, x_2 and x_3 are connected in a circuit in different ways. X is the effective resistance. The properties observed for these different ways of connecting x_1, x_2 and x_3 are given below. Write the way in which they are connected in each case. (I-current, V-potential difference, x-effective resistance)

A. Current I-flows through x_1, x_2 and x_3

B. x is larger than x_1, x_2 and x_3

C. x is smaller than x_1, x_2 and x_3

D. The potential across x_1, x_2 and x_3 is the same

E. $x = x_1 + x_2 + x_3$

F. $$x = \frac{1}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3}}$$

Answer : A. The same current flows through all the three conductors x_1, x_2 and x_3. So, all the three must be connected in series.

Because in series connection, the current in all the wires is same.

B. Effective resistance X is larger than x_1, x_2 and x_3 individually.

The only way in which this can be possible is if all the three conductors are connected in series.

In series combination of resistances,

$R_{effective} = R_1 + R_2 + R_3$

Therefore, the effective resistance is greater than the resistances taken individually.

C. Effective resistance X is smaller than x_1 , x_2 and x_3 taken individually. This can happen only when the three resistances are connected in parallel.

In parallel combination of resistances,

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Therefore, the effective resistance reduces when resistances are connected parallel to each other.

D. The potential across the conductors is same when they are connected in parallel.

E.

$$X = X_1 + X_2 + X_3$$

is the formula for calculating effective resistance of a circuit when conductors are connected in series

F.

$$X = \frac{1}{\frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3}}$$

is the formula for calculating effective resistance of a circuit when conductors are connected in parallel.

Q. 9 A. Solve the following problems.

The resistance of a 1m long nichrome wire is 6 W. If we reduce the length of the wire to 70 cm. what will its resistance be?

Answer : Given:

Resistance of a 1m(100cm) long(L_1) nichrome wire = 6 Ω (R_1)

We know that resistance is directly proportional to length of the conductor.

Therefore $R_1/R_2 = L_1/L_2$

$6/R_2 = 100/70$

$R_2 = 4.2$ Ω

Q. 9 B. Solve the following problems.
When two resistors are connected in series, their effective resistance is 80 Ω.

When they are connected in parallel, their effective resistance is 20 Ω. What are the values of the two resistances?

Answer : Given:

Effective resistance when two resistors are connected in series =80 Ω

Let us consider the resistances as R_1 and R_2 in series combination,
$V = V_1 + V_2$ and V=IR

As we know that in series connection current is constant, we get$R= R_1 + R_2 = 80\ \Omega$ ---(1)

Effective resistance when two resistors are connected in parallel combination = 20Ω

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

We get

$$R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2} = 20\ \Omega$$ .....(2)

putting the value of equation(1) in equation(2)

$$\frac{R_1 R_2}{80} = 20$$

$R_1R_2 = 1600$

$(R_1-R_2)^2 = (R_1 + R_2)^2 - 4R_1R_2$

$= 80^2 - (4\times1600)$

$= 0$

$R_1-R_2 = 0$ ---(3)

adding (1) and (3)

$R_1=40$

Subtracting (1) and(3)$R_2=40\Omega$

we get $R_1 = R_2 = 40\Omega$

Q. 9 C. Solve the following problems.

If a charge of 420 C flows through a conducting wire in 5 minutes what is the value of the current?

Answer : Given:

Charge (q) = 420C

Time for which the charge flows (t) = 5 min = 300 s

We know that current I = q/t

= 420/300

= 1.4 A

Therefore current flowing through the conductor is 1.4 A.