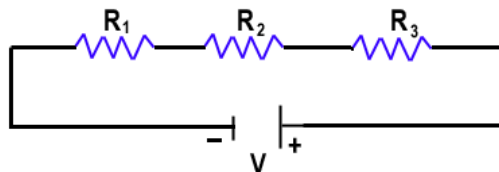




Combination of Resistance

Two or more resistance can be combined in more than one way. Equivalent resistance for the combination of resistance is the value of a single resistance that can replace the combination without changing the current and potential in the circuit. Let us try to find the equivalent resistance

Series Combination In this combination more than one resistance is connected one after the other as shown. In this type of circuit:



1. Equal current flows through each resistance.
2. Total voltage drop across the combination is equal to the sum of voltage drop across each resistance.
3. Voltage drop each resistance can be calculated using Ohm's Law and is proportional to the value of resistance. $V_1 = I R_1$.
4. Equivalent resistance can be calculated as follows:

$$V_1 = I R_1 \qquad V_2 = I R_2 \qquad V_3 = I R_3$$

$$V = V_1 + V_2 + V_3$$

Now, let us assume a resistance R_s which will have the same potential difference as the combination.

$$I R_s = I R_1 + I R_2 + I R_3$$

$$I R_s = I (R_1 + R_2 + R_3)$$

$$R_s = R_1 + R_2 + R_3$$

- **The sum of individual potential drop across the resistors connected in series is equal to the total potential difference across the series.**

Potential difference across R_1 i.e. $V_1 = V_a - V_b$

Potential difference across R_2 i.e. $V_2 = V_b - V_c$

Potential difference across R_3 i.e. $V_3 = V_c - V_d$

On adding the potentials across R_1, R_2 and R_3

$$V_1 + V_2 + V_3 = (V_a - V_b) + (V_b - V_c) + (V_c - V_d)$$

$$= V_a - V_d$$

i.e. equal to the potential difference between points L and M = V

Ex.1 Consider a circuit consisting three resistors having resistances $R_1 = 100 \Omega$, $R_2 = 150 \Omega$ and $R_3 = 200 \Omega$ in series combination with a voltage source 9 V as shown in fig. 4 below

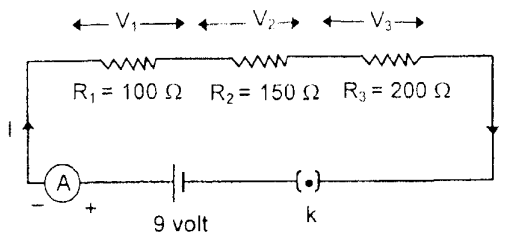


Figure (4)

Let us find the current passing through the circuit and the voltage drop across each resistor

Sol. As resistors are combined in series, therefore, the equivalent resistance R_s will be:

$$R_1 + R_2 + R_3 = (100 + 150 + 200)\Omega$$

$$R_s = 450 \Omega$$

Let the current through the circuit be I





Now, by Ohms Law, $V = IR_s$

$$\text{or } i = \frac{V}{R_s} = \frac{9V}{450\Omega} = 0.02 \text{ A}$$

Voltage drop across R_1 i.e, $V_1 = IR_1 = 0.02A \times 100\Omega$

or $V_1 = 2$ volt

Similarly, $V_2 = 0.02A \times 150 \Omega$

or $V_2 = 3$ volt

and $V_3 = 4$ volt

Try to see here that $V_1 + V_2 + V_3 = (2 + 3 + 4)$ volt = 9 volt

i.e. net potential difference is equal to the source voltage

Parallel Combination In this combination one end of all the resistors are connected to one end of the battery and the other end of all the resistance are connected to the other end of the battery as shown.

In this type of circuit

1. Potential difference is equal across each resistance.
2. Total Current in the circuit is equal to the sum of current flowing through each resistance.
3. Current in each resistance can be calculated using Ohm's Law and is inversely proportional to the value of resistance. $V = I_1 R_1$ or $I_1 = V/R_1$
4. Equivalent resistance can be calculated as follows:

$$I_1 = V/R_1 \quad I_2 = V/R_2 \quad I_3 = V/R_3$$

$$I = I_1 + I_2 + I_3$$

Now, let us assume a resistance R_p which will draw same amount of current from the battery as the combination.

$$V/R_p = V/R_1 + V/R_2 + V/R_3$$

$$V/R_p = V (1/R_1 + 1/R_2 + 1/R_3)$$

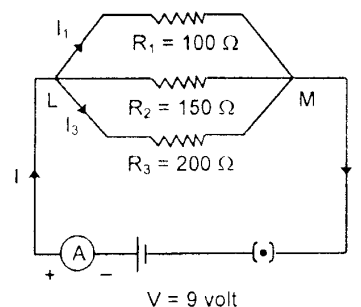
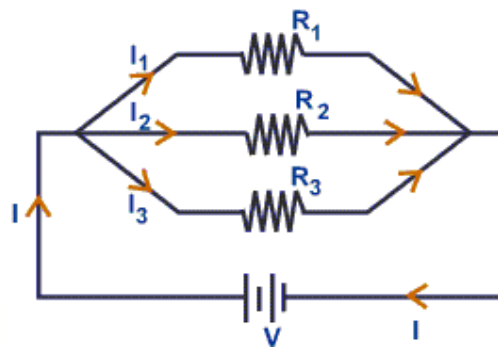
$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$$

Points to remember

- In parallel combination of resistors, the voltage across each resistor is the same
- In parallel combination, the electric current passing through each resistor is different and equal to
- In series combination, the current passing through each resistor is the same.
- In series combination, the voltage across each resistor is different and equal to IR

Ex,2 Consider a circuit consisting of three resistors $R_1 = 100\Omega$, $R_2 = 150\Omega$ and $R_3 = 200\Omega$ in parallel combination with a voltage source 9 V as shown below in the figure. Let's find the current passing through various resistors and total the current passing through the circuit.

Sol. As resistors are combined in parallel, equivalent resistance R_p can be calculated as:





$$\left(\frac{1}{R_p} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{100} + \frac{1}{150} + \frac{1}{200} + \frac{13}{600} \right) \text{ or } R_p = \frac{600}{13} \Omega = 46.15 \Omega$$

Let total current passing through the circuit be I.

By Ohm's Law, $V = IR_p$

$$I = \frac{V}{R_p} = \frac{9 \text{ volt}}{\frac{600 \Omega}{13}} = 0.195 \text{ A}$$

Also, we can calculate $I_1 = \frac{V}{R_1} = \frac{9 \text{ volt}}{100 \Omega} = 0.09 \text{ A}$

Similarly, $I_2 = \frac{V}{R_2} = \frac{9 \text{ volt}}{150 \Omega} = 0.06 \text{ A}$ and $I_3 = 0.045 \text{ A}$

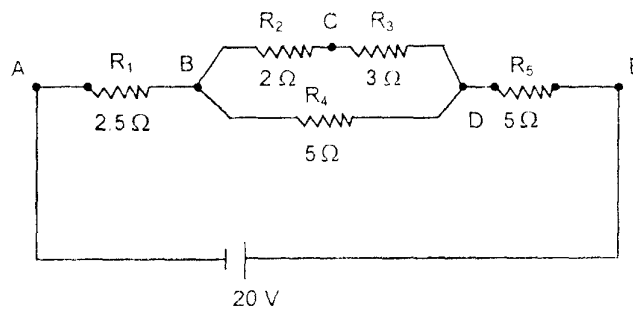
- Try to see here that $I_1 + I_2 + I_3 = (0.09 + 0.06 + 0.045) \text{ A} = 0.195 \text{ A}$ i.e. equal to the current through equivalent resistance R_p as calculated earlier.

Exercise - 1

Q.1 In case of parallel combination of resistors, current passing through each resistor is

- (a) The same (b) different (C) very low (d) very high

Q.2 Answer the following questions on the basis of the electrical circuit given below



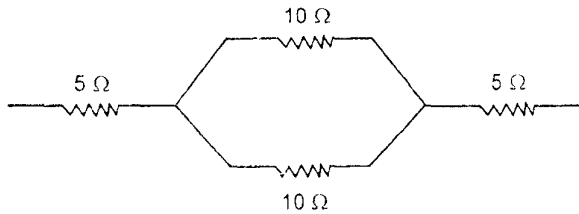
- In the above circuit diagram, R_2 and R_3 are in series. If the current passing through R_3 is 1 A, what is the current passing through R_2 ?
- Is the current passing through R_4 equal to the current passing through R_2 ? Why?
- If a current of 2 A is flowing through R_5 , what is the potential difference across it?
- If the current passing through R_3 is 1 A and current passing through R_4 is again 1A. What is the current passing through R_1 ?
- If the potential difference across B and D is 5 V and the potential difference across B and C is 2 V. Find the potential difference across C.

Q.3 A lamp of resistance R is connected in series with the two resistors of 5Ω and 10Ω and a voltage source of 21 V Current in the circuit is 1 A Calculate the value of R and the potential drop across the lamp.

Home Practice Questions:

1. Consider three resistors 10Ω , 20Ω and 40Ω . Calculate their equivalent resistance when they are combined in parallel. Check whether this equivalent resistance is more or less than each resistor in circuit

2. Calculate the equivalent resistance of parallel combination of three resistors of 1 Ω, 1 kΩ and 1 MΩ. What can you conclude from the answer?
3. Equivalent resistance of the circuit shown below is:

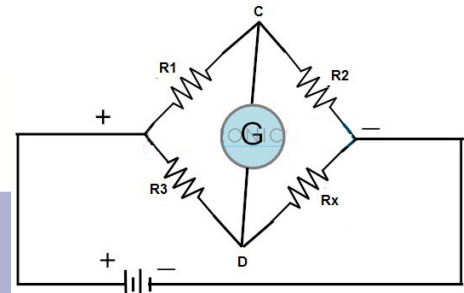


- (a) 30Ω (b) 5/3Ω (c) 15Ω (d) 3/5Ω
4. Take three equal resistors of 100 Ω each. In how many ways, can you combine these resistors to a 10 V battery? Find equivalent resistance in each case and draw the circuit diagram.
 5. Three resistors of 2Ω, 4Ω and 6Ω are combined to have the minimum possible resistance. Draw the diagram and calculate the equivalent resistance.
 6. Draw the various combination circuit diagram of four Resistance 10 Ω, each and find equivalent resistance in each case?

Wheatstone Bridge :-

A Wheatstone bridge consists of four resistors that are connected in the shape of a diamond with the supply source and indicating instruments as shown in figure.

The bridge is said to be balanced when the galvanometer shows no deflection, in this case:

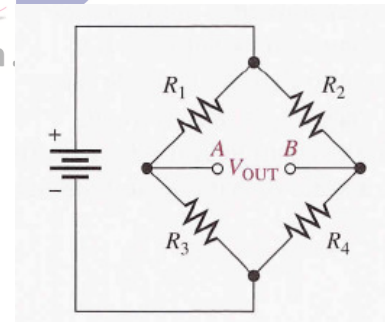


$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Learning With Innovation.

Example 1

In the given balanced Wheatstone bridge $R_1=10 \Omega$, $R_2=20 \Omega$, R_3 is unknown and $R_4=40\Omega$. Calculate R_3 .



Heating Effect of Current and Electric Power

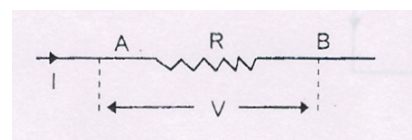
In 1841, Joule experimentally showed the heating effect of current by passing an electric current through the element of a heater.

Cause: When we connect a conductor to a voltage source, the electrons inside the conductor experience a force due to potential difference across the conductor and get accelerated towards the +ve terminal of the battery and hence their kinetic energy increases. With the increased velocities, these electrons undergo collisions with the ions or atoms of the conductor and lose their energy in the form of heat.

Let us find the expression for the amount of heat produced.

Consider a resistor of resistance R across which a potential difference V is applied as shown in the figure.

According to the Ohm's Law, the current I passing





through the resistor R is given by

$$V=IR \quad (i)$$

Suppose that a constant current I passes through the resistor for a time 't'. Then the total charge that flows through R in time 't' is given by

$$q = It \quad (ii)$$

If charge 'q' flows from A to B. energy dissipated across resistor, i.e. heat produced, is given as

$$H = V q$$

Using (i) and (ii)

$$H = I^2Rt$$

$$\text{or } H = VI t$$

$$\text{or } H = V^2t / R$$

Heat produced is measured in Joule. It is also measured in calories.

$$1 \text{ calorie} = 4.18 \text{ J}$$

Electric Power

Electric power is defined as the rate at which work is done by a potential source in maintaining the electric current in a circuit.

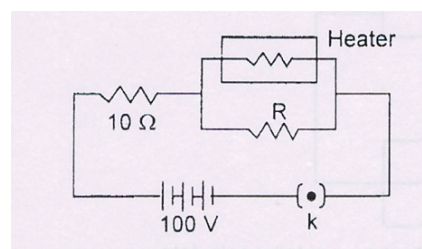
Or

Electric power is the rate at which the heat is produced in an electric circuit.

$$\text{Power} = H / t \quad \text{Power} = VI \quad \text{S.I. Unit of}$$

Power is Watt

$$1 \text{ Watt} = 1 \text{ Volt} \times 1 \text{ Ampere}$$



i.e. the electric power of a circuit or a device is said to be one watt, if one ampere of current passes through it when a constant potential difference of one volt is applied across it.

Larger units of power are Kilowatt (kW) and Megawatt (MW).

$$\text{Electric Energy} = \text{Power} \times \text{time} \quad \text{Units are Wh} \quad 1 \text{ Wh} = 3600 \text{ J}$$

Larger units are KWh. It is also called Board of Trade Unit. (B.O.T)

$$1 \text{ KWh} = 10^3 \text{ Wh} = 3.6 \times 10^6 \text{ J}$$

Ex.5 An electric heater and an electric lamp are rated at 500 W / 220 V and 100 W / 220 V respectively. Both are connected in series to a 220 V A.C mains. Calculate the power consumed by lamp and heater

Sol. Power of the heater, $P_H = 500 \text{ W}$

Operating voltage of the heater $V_H = 220 \text{ V}$

Let resistance of the heater be $=R_H$

$$P_H = V_H^2 / R_H \quad R_H = (220)^2 / 500 = 96.8 \Omega$$

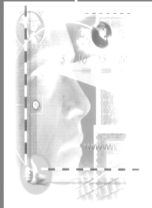
$$R_L = 484 \Omega$$

The lamp and the heater are combined in series

$$I = \frac{V}{R_H + R_L} = \frac{220}{96.8 + 484} = 0.38 \text{ A}$$

$$\text{Power consumed by heater} = I^2 R_H = (0.38 \text{ A})^2 \times 96.8 \Omega = 13.98 \text{ W}$$

$$\text{Power consumed by lamp} = I^2 R_L = (0.38 \text{ A})^2 \times 484 \Omega = 69.89 \text{ W}$$



Home Practice Questions

Q.1 A lamp of 100W works at 220 V. Resistance of the lamp is:

- (a) $22\ \Omega$ (b) $2.2\ \Omega$ (c) $484\ \Omega$ (d) $0.455\ \Omega$

Q.2 One kWh is equal to

- (a) 3600 J (b) 36000 J (c) 3600000 J (d) 3.6×10^3 J

Q.3 Which lamp has greater resistance, a 100 W or a 60 W lamp when connected to the same source of supply?

Q.4 A current of 5.0 A flows through an electric iron of resistance $11\ \Omega$. Calculate the energy consumed by the iron in 5 minutes. Express your answer in kWh.

Practice Sheet

1. A heater coil connected to a 220 V has a resistance of 150 Ohms. How long will it take for this coil to raise the temperature of 1 kg of water from 20°C to 60°C , assuming that all heat is taken up by water?

2. Three resistors R_1 , R_2 and R_3 are in parallel to a source V. Express how current and potential in them vary. Also, find equivalent resistance.

3. A uniform wire of resistance $15\ \Omega$ is cut into three pieces in the ratio 1:2:3 and the three pieces are connected to form a triangle. A cell of 10 V potential is connected across the highest of the three resistors, Calculate the current through each part of the circuit.

4. Three resistors $3\ \Omega$, $60\ \Omega$ and $90\ \Omega$ are connected to a battery. If they are all connected (i) in parallel (ii) in series, in which of them will the power dissipation be the maximum?

5. A heater is designed to operate at 1000 W in a 100 V line. It is connected to two resistances of $10\ \Omega$ and R as shown in the figure. The heater is now giving a power of 62.5 W. Calculate the value of the resistance R.

6. (i) Which has a higher resistance: a 50W lamp bulb or a 25W lamp bulb? Give reason.

(ii) Two bulbs are marked 50W / 220V and 100W / 220V. These are connected in parallel to 220V

mains. Which one of the two will glow brighter and why?

7. Two bulbs whose resistances are in the ratio 1 : 2, are connected in parallel to a source of constant voltage. What is the ratio of power dissipation of bulbs?