NEPAL ENGINEERING COUNCIL

Concept of Basic Electrical and Electronics Engineering

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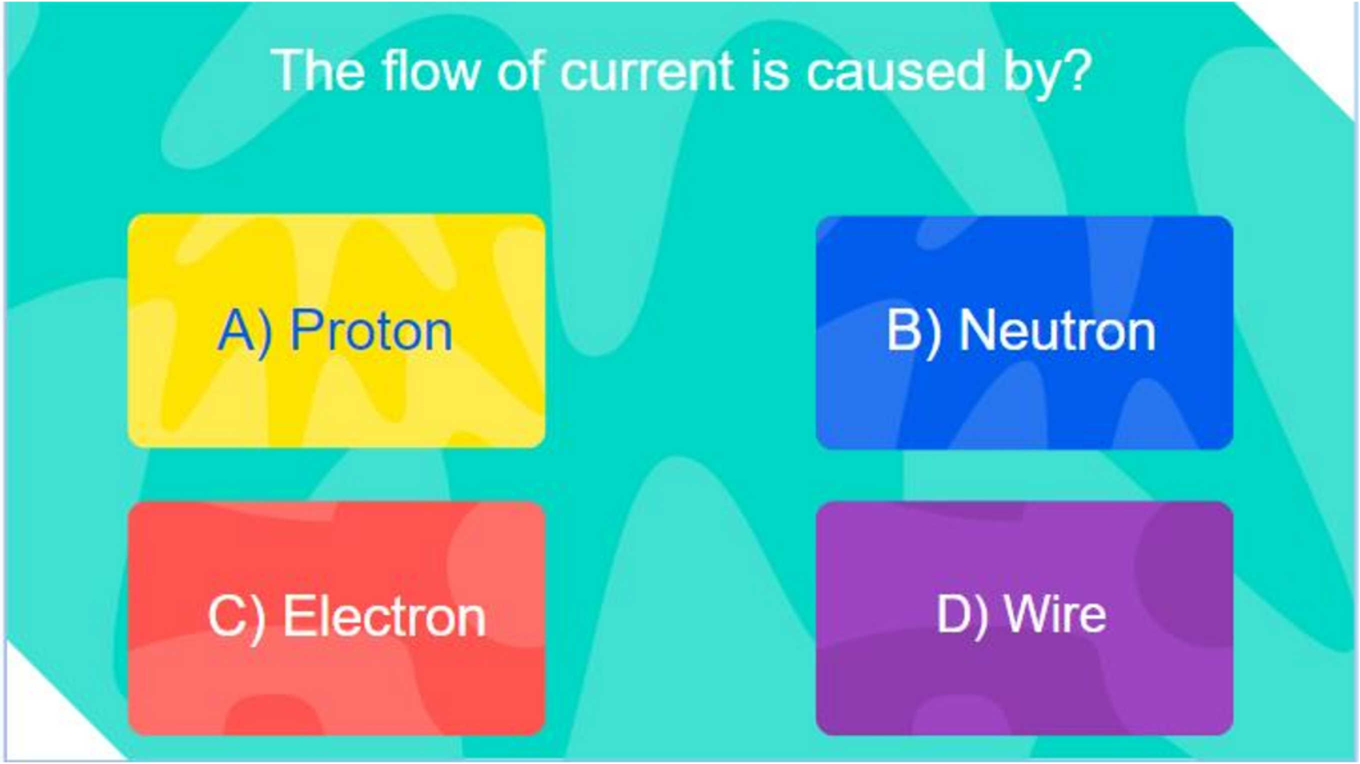
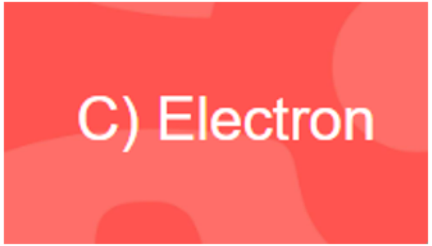
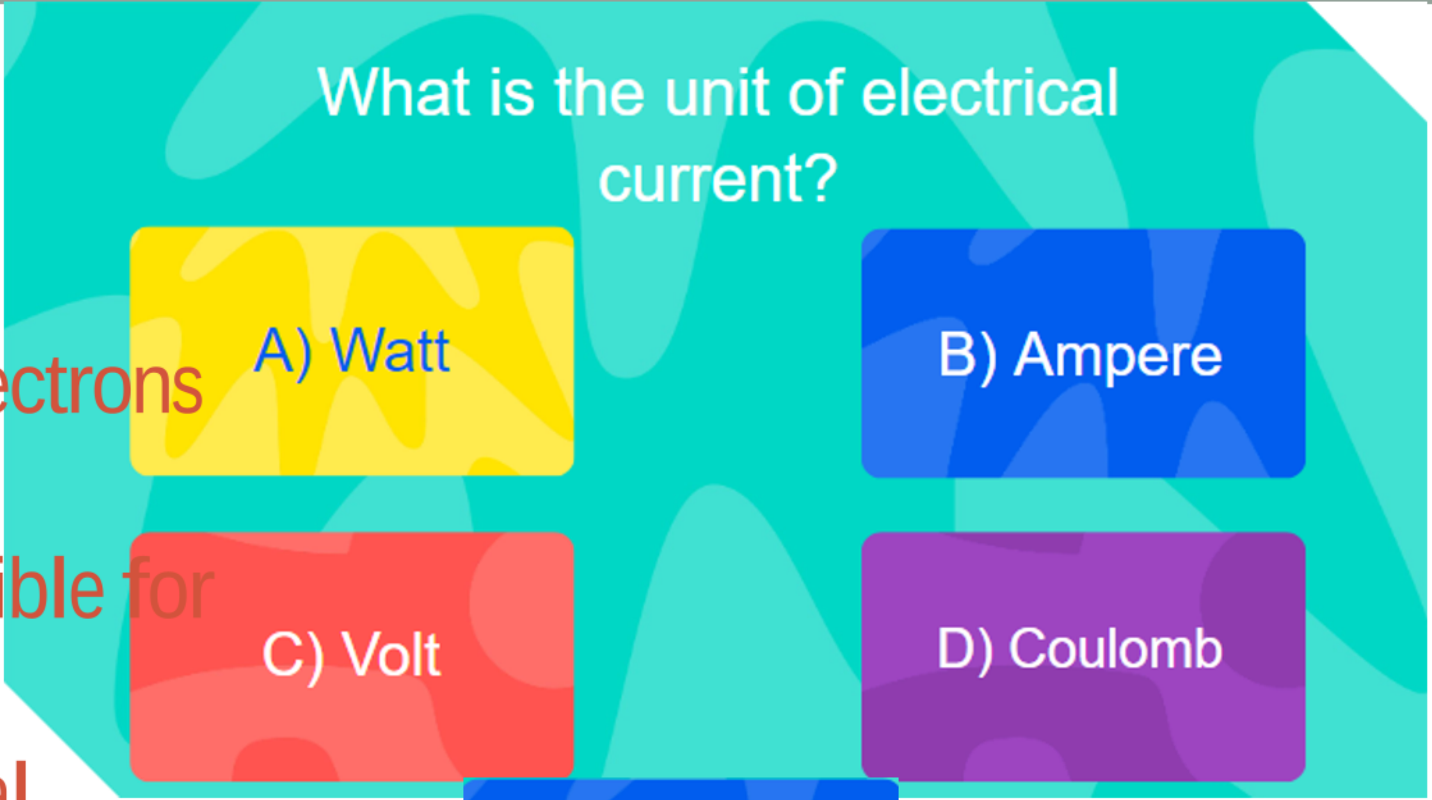
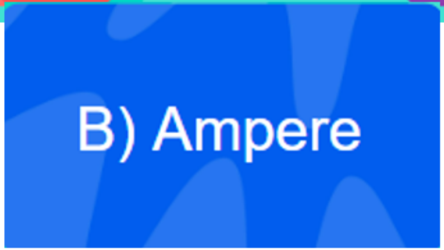

The flow of current is caused by?
A) Proton
B) Neutron
C) Electron
D) Wire


C) Electron



Free Electrons are responsible for flow of electrical currents in the circuit.



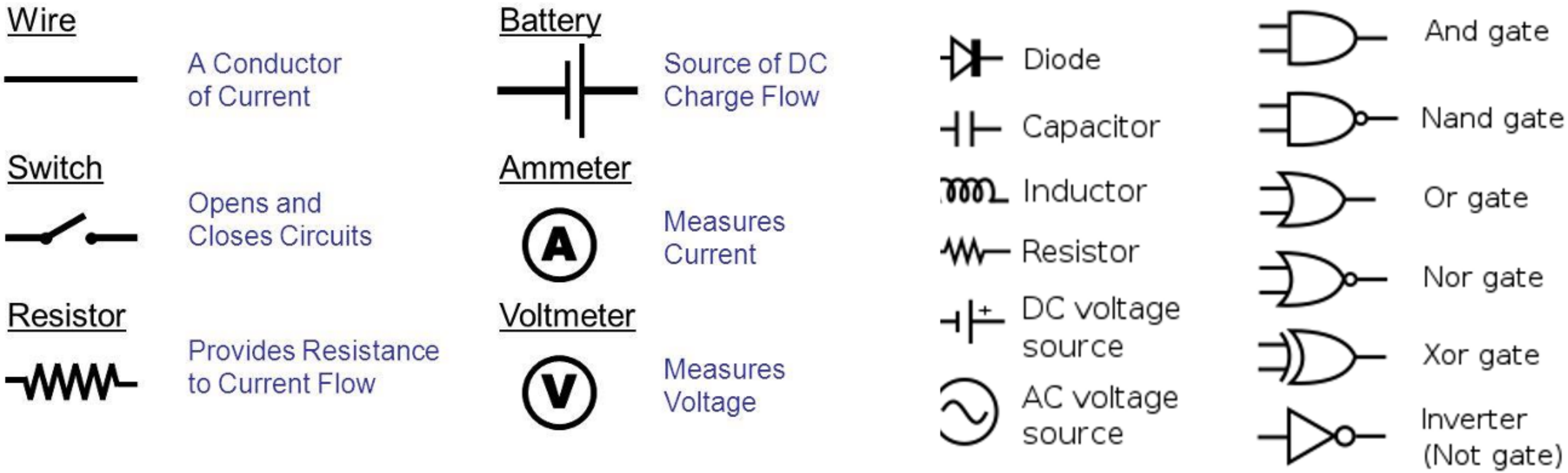
Terms and SI Units

Electrical Parameter	Measuring Unit	Symbol
Voltage	Volt	V or E
Resistance	Ohm	R or Ω
Capacitance	Farad	C
Charge	Coulomb	Q
Inductance	Henry	L or H
Power	Watts	W
Impedance	Ohm	Z
Frequency	Hertz	Hz
Conductance	Siemen	G or ℧
Current	Ampere	I or A
Energy	Watt-hr or Joules	E or W

SYMBOLS

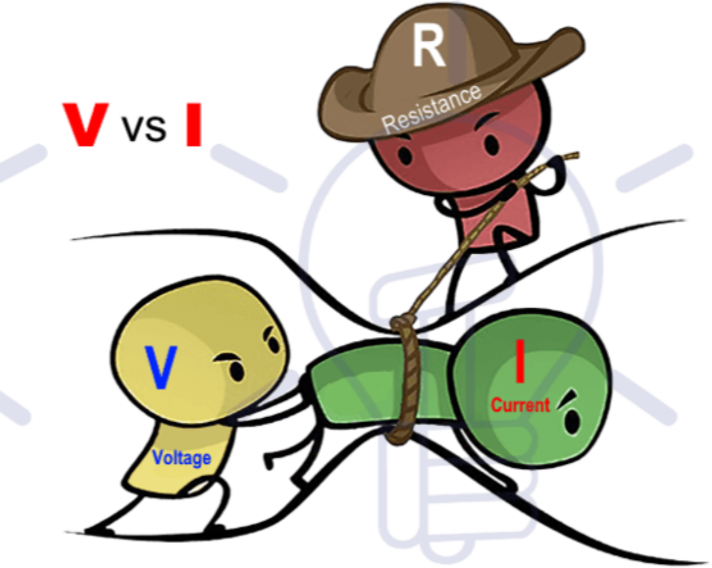
Circuit Symbols

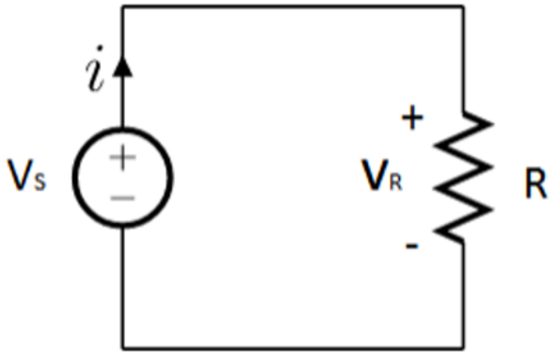
- Each circuit element has its own symbol.
- Common circuit symbols are shown below.



Electric voltage and current

- Voltage describes the "pressure" that pushes electricity/Current
- Here, Vs is source voltage(Cause) that results in flow of Current i (effect) through resistance R
- V_R is voltage across Resistor
- For ideal conducting wires, $Vs=V_R$





The rate of motion of charge in a conductor is current.
$I=q/t$

The relationship between electrical potential, electric current and Resistor is defined by which law?

A) Ohms Law

B) Coulomb Law

C) Kelvin Law

D) Thevenin Law

A) Ohms Law

Ohm’s Law

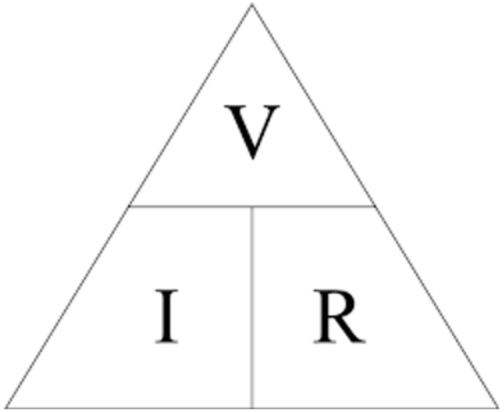
Statement: “The current (I) flowing through a conductor is directly proportional to the potential difference (V), provided that the **temperature and the other conditions are constant.**”

I is directly proportional to V

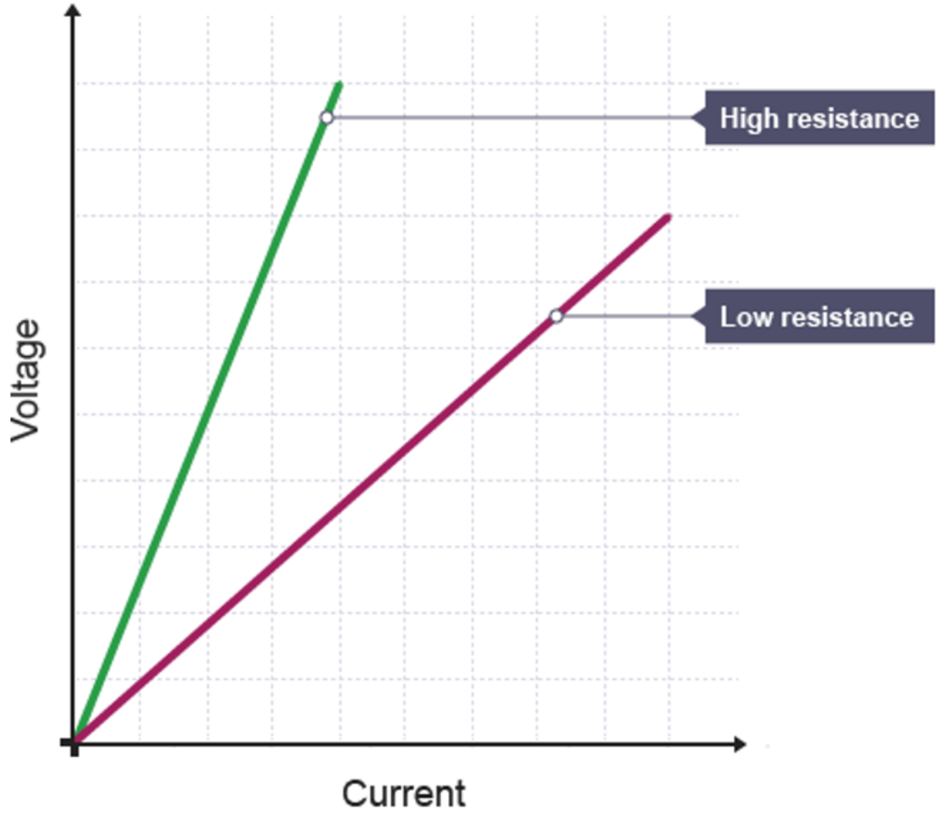
$$I \alpha V$$

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

$$V = IR \ \ here\ R\ is\ a\ constant$$



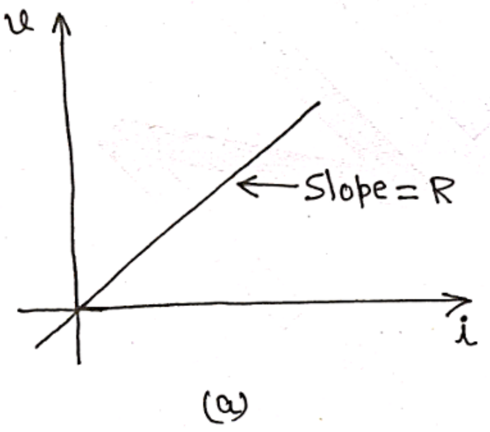
Ohm's Law

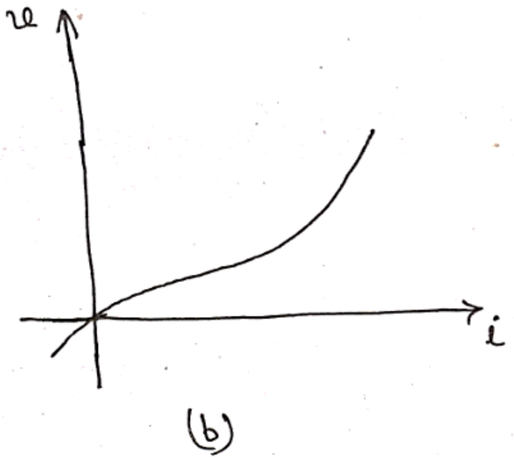


Y=mX, where m is slope

$V = IR$ *here R is a constant*

a) Ohmic b)Non ohmic conductor





The relationship between voltage and current is a straight line passing through the origin of the two coordinates. This type of relationship is called linear relationship.

Any Circuit element that has a linear relationship between voltage and current is known as **linear circuit element**. **Resistor** is a linear circuit element and other examples are **inductor and capacitor.** Some time inductor and capacitor might be considered non ohmic during sudden change in current and voltage respectively..

Application of Ohm's law

- To determine the voltage, resistance or current of an electric circuit.
- Ohm's law maintains the desired voltage drop across the electronic components.

Limitation of Ohm's law

- It is not applicable to nonlinear devices such as diodes, zener diodes, voltage regulators etc.
- It does not hold well for non-metallic conductors such as silicon carbide.

- It is not applicable for temperature varying condition

If the resistance of an electric iron is 50 Ω and a current of 3.2 A flows through the resistance. Find the voltage between two points.

$V = I \times R$

Substituting the values in the equation, we get

$V = 3.2\ A \times 50\ \Omega = 160\ V$

An EMF source of 8.0 V is connected to a purely resistive electrical appliance (a light bulb). An electric current of 2.0 A flows through it. Consider the conducting wires to be resistance-free. Calculate the resistance offered by the electrical appliance.

a) 2 Ω
b) 4 Ω
c) 8 Ω
d) 16 Ω

Resistance

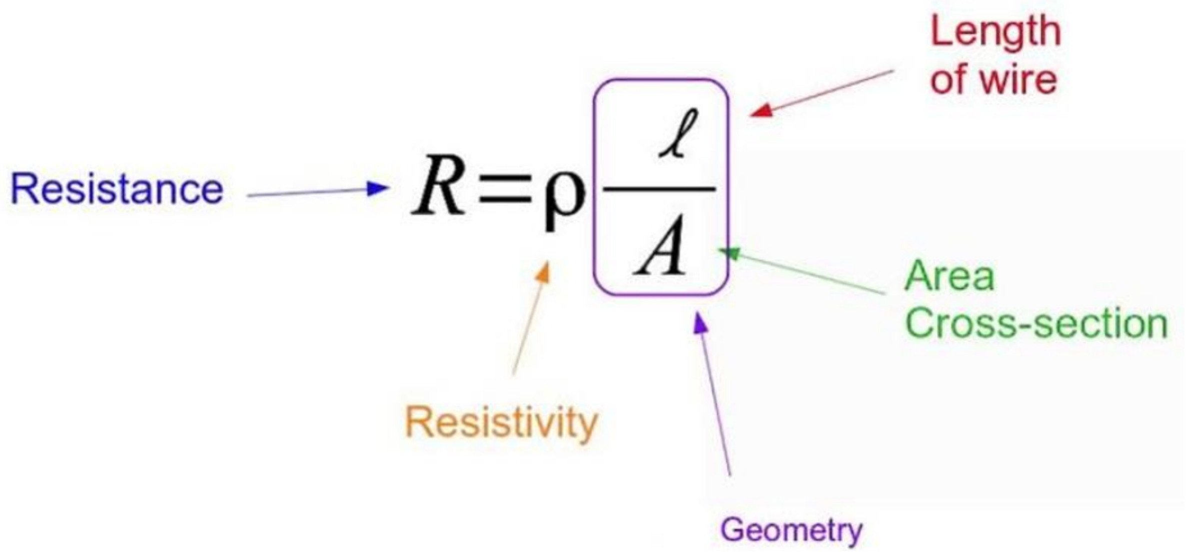
Resistance is defined as the **property of the conductor** which **opposes the flow of electric current**. It is also defined as the ratio of the voltage applied to the electric current flowing through it.

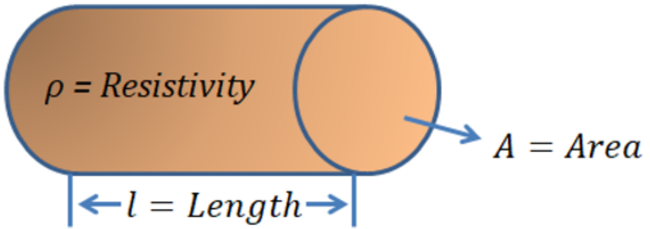
The electrical resistance of a conductor is dependent on the following factors:

- The cross-sectional area of the conductor
- Length of the conductor
- The material of the conductor
- The temperature of the conducting material

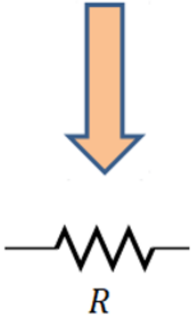
Electrical resistance is directly proportional to length (L) of the conductor and inversely proportional to the cross-sectional area (A). It is given by the following relation.

Resistance





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



$A = \pi r^2$ r (radius)

$A = \frac{\pi d^2}{4}$ d (diameter)

Resistivity

The electrical resistance offered per unit length and unit cross-sectional area at a specific temperature and is denoted by ρ.

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

$Where, R = Resistance$

$\rho = Material\ Resistivity$

$L = Length\ of\ Conductor$

$A = Cross\ Section\ Area$

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

Unit: Ω.m

Conductance (G) and Conductivity (σ)

$$G = \frac{1}{R} \quad \sigma = \frac{1}{\rho}$$

- Reciprocal of Resistance
- Reciprocal of Resistivity

Resistance of a material depends on…

a) Length
b) CSA
c) Type of Material
d) All of the above

Resistivity depends on…

a) Length
b) CSA
c) Type of Material
d) All of the above

Note: Temperature effect both Resistance and Resistivity

Q) What happens to the resistance of the conductor when

a. Length is Doubled?
b. Area is Doubled?
c. Length Doubled and Area halved?
d. Radius is doubled?

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

where, R – Resistance of conductor
L – length of conductor
ρ – resistivity
A – Area of cross section

a) If length is doubled

$$R = \frac{\rho(2L)}{A}$$

$$R = 2\left(\frac{\rho L}{A}\right)$$

If length is doubled resistance is doubled.

b) Area is doubled

$$R = \frac{\rho L}{2A}$$

$$R = \frac{1}{2}\left(\frac{\rho L}{A}\right)$$

If area is doubled, resistance gets halved.

Q) What happens when the resistance of the conductor when

a. Length is Doubled?
b. Area is Doubled?
c. Length Doubled and Area halved?
d. Radius is doubled?

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

where, R – Resistance of conductor
L – length of conductor
ρ – resistivity
A – Area of cross section

c) If length is doubled and area is halved

$$R = \frac{\rho(2L)}{\frac{A}{2}}$$

$$R = 4\left(\frac{\rho L}{A}\right)$$

If length is doubled and area is halved, resistance is 4 times that of original resistance

d) Radius is doubled

$$A = \pi r^2$$

$$R = \frac{\rho L}{\pi(2r)^2}$$

$$R = \frac{\rho L}{4\pi r^2}$$

$$Thus,\ R = \frac{1}{4}\left(\frac{\rho L}{A}\right)$$

Q) What will be the new resistance of the conductor with Resistance R when its Diameter is doubled?

a. 2R

b. R/2

c. 4R

d. R/4

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

where, $R -$ *Resistance of conductor*

$L -$ *length of conductor*

$\rho -$ *resistivity*

$A -$ *Area of cross section*

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

$$R = \frac{\rho L}{\pi\left(\frac{2d}{2}\right)^2}$$

$$R = \frac{\rho L}{\pi(d)^2}$$

$$d = 2r$$

$$Thus,\ R = \frac{\rho L}{4\pi r^2} = \frac{1}{4}\left(\frac{\rho L}{A}\right)$$

If diameter is doubled, resistance becomes 1/4 times the original resistance.

Power and energy

- Power delivered by the source is given by:

$P= I*V$ watt

- Power Consumed by the load(R) is given by:

$P=I^2*R$ watt

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

- Energy (Joules) is actually the work done while consuming power over a time period

$E=P*t$

$E=I^2*t = VI*t = (V^2/ R)*t$

Commercial Unit of Energy

If 1Kilowatt load is used for one hour then

Energy Consumed= 1KW*1 hr= 1Kw-hr =1 Unit (Commercial) of Energy

One unit of electrical energy is………. Joules

a. 3600000

b. 36000

c. 360

d. 3.6

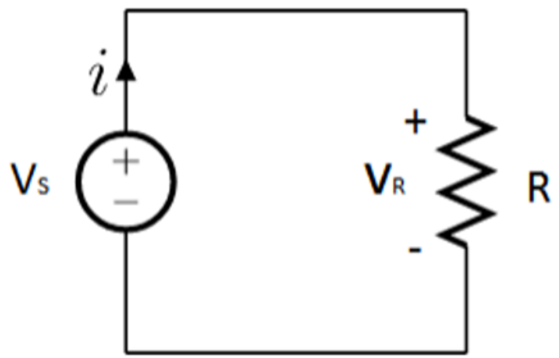
$$1\ \text{kWh} = 1\ \text{kW} \times 1\ \text{h}$$
$$1\ \text{kWh} = 1000\ \text{W} \times 3600\ \text{s}$$
$$1\ \text{kWh} = 3600000\ \text{J}$$
$$1\ \text{kWh} = 3.6 \times 10^6\ \text{J}$$

Q) Let the voltage across the source in the circuit diagram of Figure is 10V and resistance of the resistor is 5Ω. The current in the resistor and power consumed by it.

a. 2A and 10W
b. 2A and 20 W
c. 50A and 100 W
d. 50 A and 200W

$$i = \frac{v_s}{R} = \frac{10}{5} = 2A$$

$$p_R = i^2 R = 4 \times 5 = 20W$$

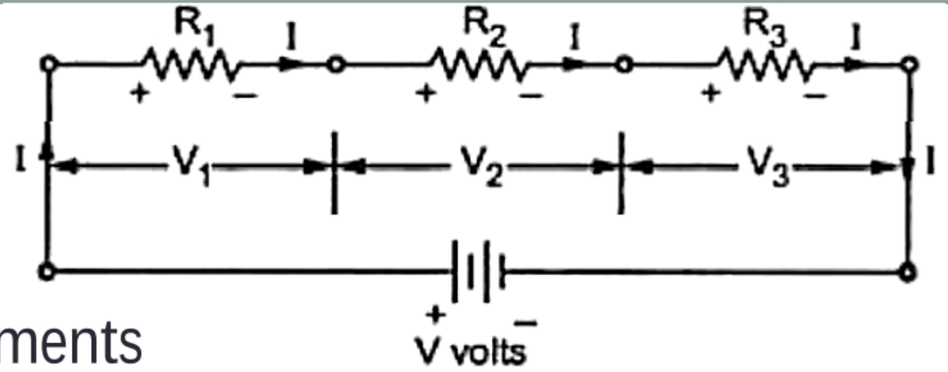


Conducting and insulating materials

Conductor	Insulator
Materials that permit electricity or heat to pass through it.	Materials that do not permit heat and electricity to pass through it.
A few examples of a conductor are silver, aluminium, and iron.	A few examples of an insulator are paper, wood, and rubber.
Electrons move freely within the conductor.	Electrons do not move freely within the insulator.

MCQs

Series electric circuits



- Current Same through each elements

  I

- Applied Voltage Division across each elements
  - V=V1+V2+V3,

$$\therefore \quad V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$

But $V = IR$

where R is the equivalent resistance of the series combination.

$$\therefore \quad IR = IR_1 + IR_2 + IR_3 \quad \text{or} \quad R = R_1 + R_2 + R_3$$

Characteristic of Series Circuit

The same current flows through each resistance.

The supply voltage V is the sum of the individual voltage drops across the resistances.

$$V = V1 + V2 + \ldots + Vn$$

The equivalent resistance is equal to the sum of the individual resistances.

$$R = R1 + R2 + \ldots + Rn$$

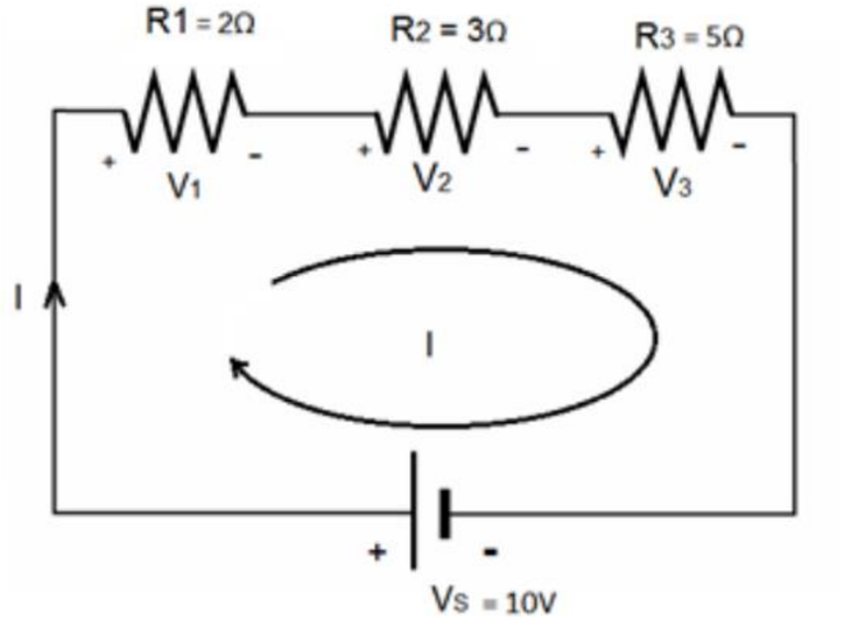
The equivalent resistance is the largest of all the individual resistances.

i.e $R > R1$, $R > R2$, …… $R > Rn$

Power are additive.

Q) Consider the series circuit as shown in Figure. The DC voltage source across this series combination is of 10V. The current, the voltage drop across each resistor and the power consumed by the entire circuit is……...respectively.

a. 1A, 2V, 3V, 5V and 10watt
b. 1A, 2V, 3V, 5V and 100watt
c. 2A, 4V, 6V,10 V, and 20watt
d. 2A, 4V, 6V,10 V, and 200watt



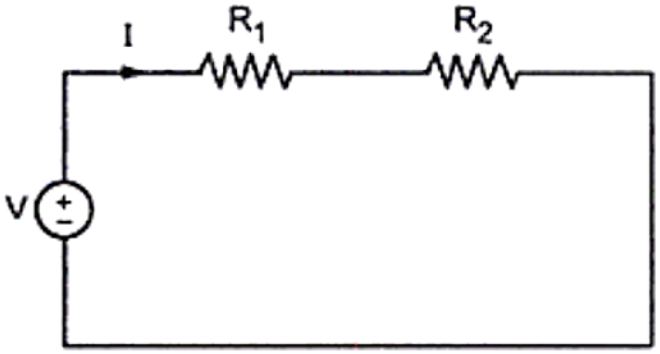
$$I = \frac{V_S}{R_1+R_2+R_3} = \frac{10}{10}$$

$$I = 1A$$

$$V_1 = IR_1 = 2V \qquad V_3 = IR_3 = 5V$$

$$V_2 = IR_2 = 3V \qquad P_S = V_s I = 10 \times 1 = 10W$$

Voltage Divider rule in Series circuit



$$V = I R_1 + I R_2$$

$$\therefore \quad I = \frac{V}{R_1 + R_2}$$

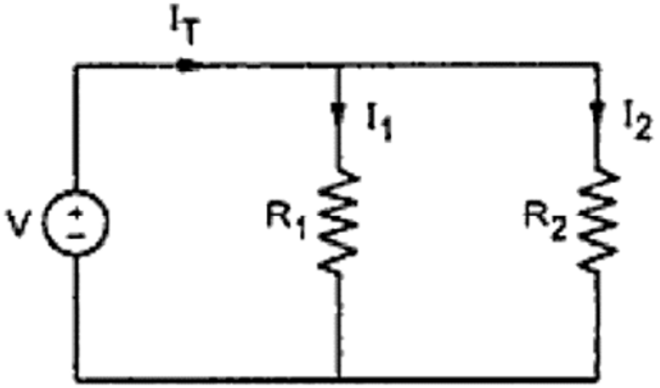
$$V_{R1} = I \cdot R_1$$

$$V_{R1} = \frac{V}{R_1 + R_2} \cdot R_1 = \left[\frac{R_1}{R_1 + R_2}\right] V$$

$$V_{R2} = I \cdot R_2$$

$$V_{R2} = \frac{V}{R_1 + R_2} \cdot R_2 = \left[\frac{R_2}{R_1 + R_2}\right] V$$

Current Divider rule in Parallel circuit



$$\therefore \quad I_T = I_1 + I_2$$

But $\quad I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}$

i.e. $\quad V = I_1 R_1 = I_2 R_2$

$$\therefore \quad I_1 = I_2 \left(\frac{R_2}{R_1}\right)$$

Substituting value of I_1 in I_T,

$$I_T = I_2 \left(\frac{R_2}{R_1}\right) + I_2 = I_2 \left[\frac{R_2}{R_1} + 1\right] = I_2 \left[\frac{R_1 + R_2}{R_1}\right]$$

$$\boxed{I_2 = \left[\frac{R_1}{R_1 + R_2}\right] I_T}$$

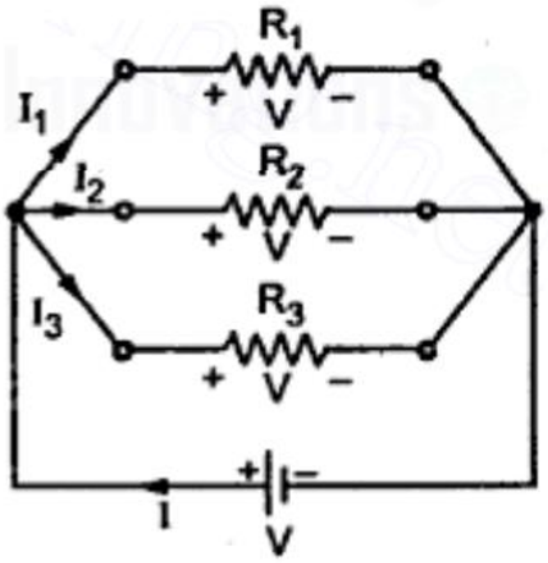
$$I_1 = I_T - I_2 = I_T - \left[\frac{R_1}{R_1 + R_2}\right] I_T$$

$$I_1 = \left[\frac{R_1 + R_2 - R_1}{R_1 + R_2}\right] I_T$$

$$\boxed{I_1 = \left[\frac{R_2}{R_1 + R_2}\right] I_T}$$

Parallel Circuit

- Applied Voltage and Voltage across each elements are Same V=V1=V2=V3,
- Current from sources divides across each elements I= I1+I2+I3



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

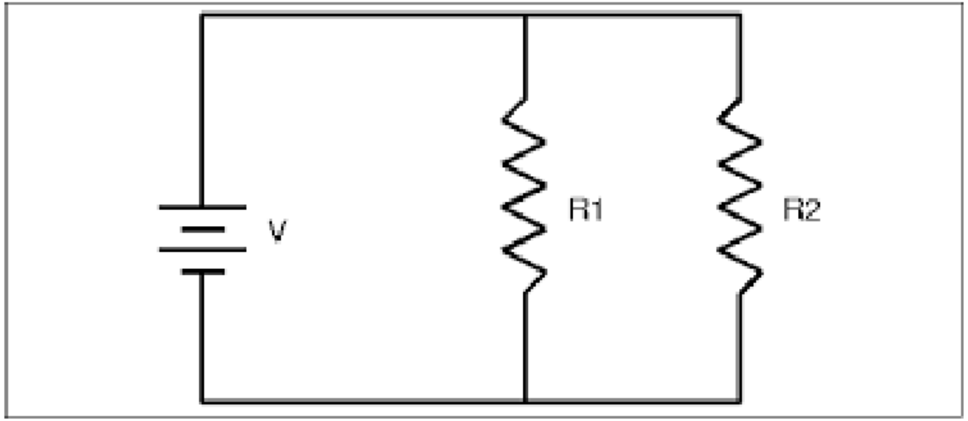
$$I = \frac{V}{R}$$ where V is the applied voltage.

R = equivalent resistance of the parallel combination.

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad \text{or} \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

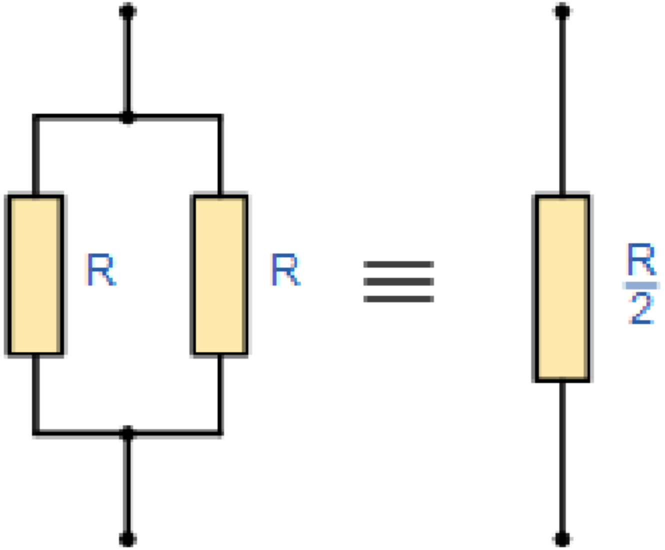
$$G = G_1 + G_2 + G_3$$

Parallel Circuit



Two resistors in parallel

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



Characteristics of Parallel Circuit

The same potential difference gets across all the resistances in parallel.

The total current gets divided into the number of paths equal to the number of resistances in parallel. The total current is always sum of all the individual currents.

$$I = I_1 + I_2 + I_3 + \ldots + I_n$$

The reciprocal of the equivalent resistance of a parallel circuit is equal to the sum of the reciprocal of the individual resistances.

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

The equivalent resistance is the smallest of all the resistances.

$$R < R_1, R < R_2 \ldots, R < R_n$$

The equivalent conductance is the arithmetic addition of the individual conductances.

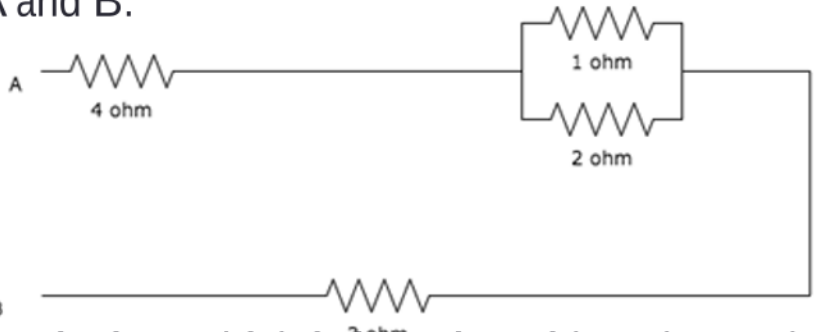
$$G = G_1 + G_2 + G_3 + \ldots + G_n$$

Power are additive.

- It is preferable to connect bulbs in series or in parallel?
  a) Series
  b) Parallel
  c) Both series and parallel
  d) Neither series nor parallel

(b->Bulbs are connected in parallel so that even if one of the bulbs blow out, the others continue to get a current supply by same voltage.)

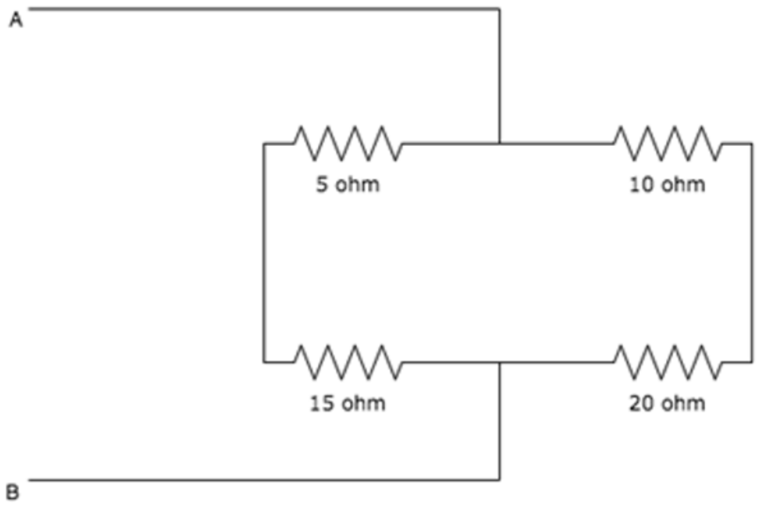
- Calculate the total resistance between the points A and B.
  a)7 ohm
  b) 9 ohm
  c) 7.67 ohm
  d) 8 ohm



(C->1 ohm in parallel with 2 ohm give 2/3 ohm equivalent which is in series with 4 ohm and 3 ohm so total resistance between A and B = 4 + 2/3 + 3 = 23/3 = 7.67 ohm.

Q) Calculate the equivalent resistance between A and B.

a) 60 ohm
b) 15 ohm
c) 12 ohm
d) 48 ohm



C->5 ohm and 15 ohm are connected in series to give 20 ohm.10ohm and 20 ohm are connected in series to give 30 ohm. Now both equivalent resistances (20ohm and 30 ohm) are in parallel to give equivalent resistance 20*30/(20+30) = 12 ohm.

In a _________ circuit, the total resistance is greater than the largest resistance in the circuit.

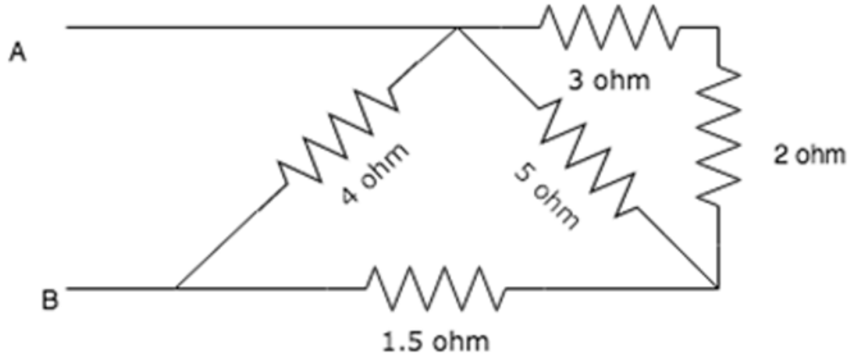
a) Series
b) Parallel
c) Either series or parallel
d) Neither series nor parallel

In a ____________ circuit, the total resistance is smaller than the smallest resistance in the circuit.

a) Series
b) Parallel
c) Either series or parallel
d) Neither series nor parallel

Q) Calculate the equivalent resistance between A and B.

a) 2 ohm
b) 4 ohm
c) 6 ohm
d) 8 ohm

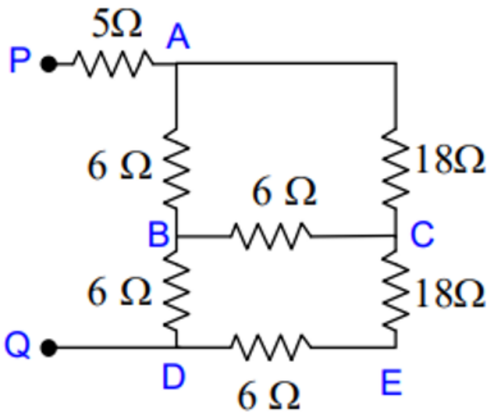


MCQs….

Series Parallel is not sufficient ☹

The equivalent resistance between point P and Q is……………..

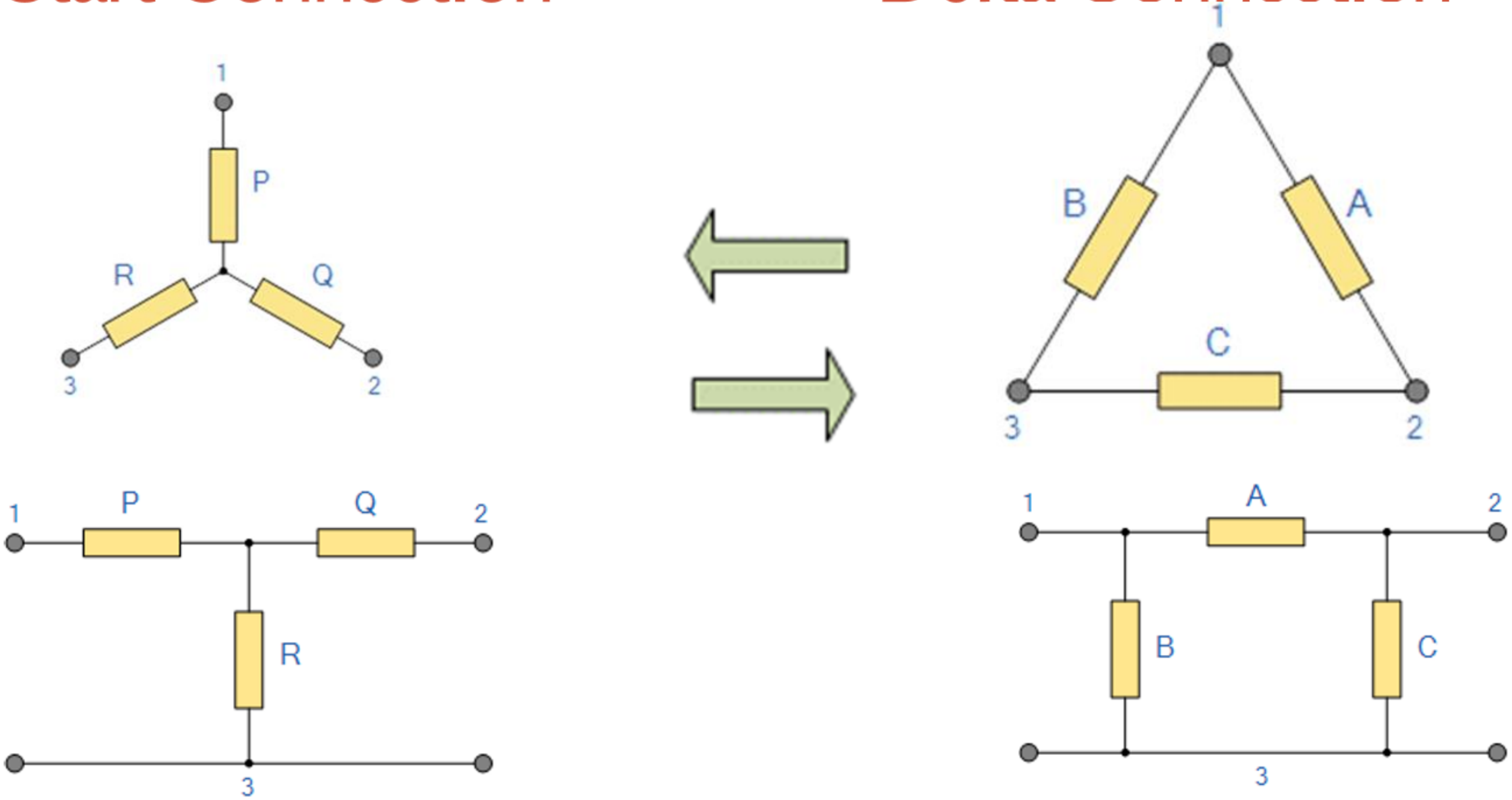
a. 14.31 ohm
b. 17.12 ohm
c. 12.24 ohm
d. 34.58 ohm



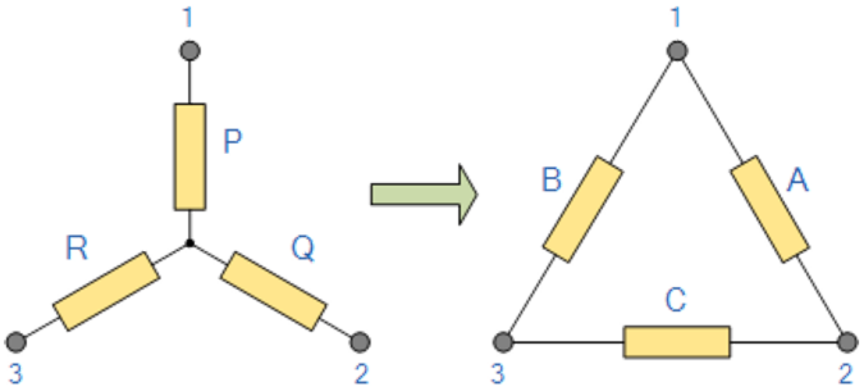
- To solve these we need the concept of Star and Delta transformation

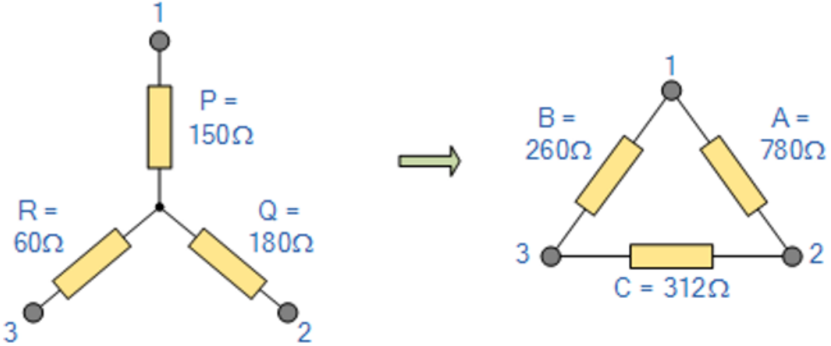
Start Connection

Delta Connection



Star to Delta





$$A = \frac{PQ + QR + RP}{R}$$

$$B = \frac{PQ + QR + RP}{Q}$$

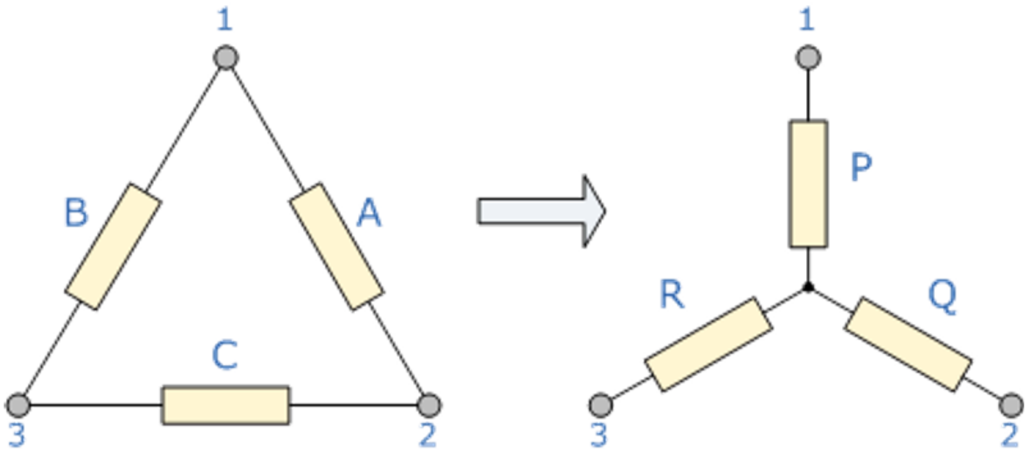
$$C = \frac{PQ + QR + RP}{P}$$

$$A = \frac{QP}{R} + Q + P = \frac{180 \times 150}{60} + 180 + 150 = 780\Omega$$

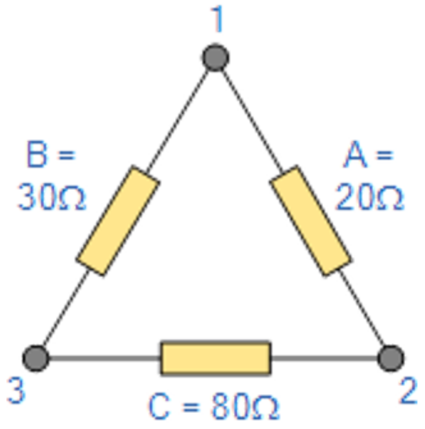
$$B = \frac{RP}{Q} + R + P = \frac{60 \times 150}{180} + 60 + 150 = 260\Omega$$

$$C = \frac{QR}{P} + Q + R = \frac{180 \times 60}{150} + 180 + 60 = 312\Omega$$

Delta to Star



$$P = \frac{AB}{A+B+C} \quad Q = \frac{AC}{A+B+C} \quad R = \frac{BC}{A+B+C}$$



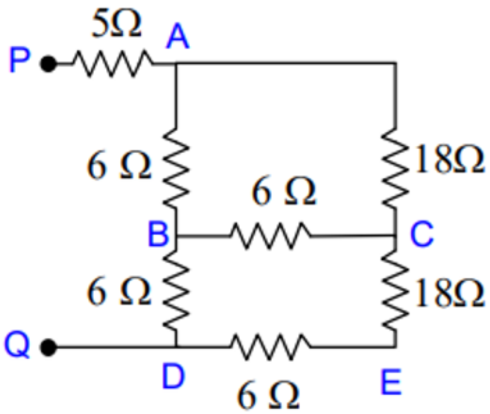
$$Q = \frac{AC}{A+B+C} = \frac{20\times 80}{130} = 12.31\Omega$$

$$P = \frac{AB}{A+B+C} = \frac{20\times 30}{130} = 4.61\Omega$$

$$R = \frac{BC}{A+B+C} = \frac{30\times 80}{130} = 18.46\Omega$$

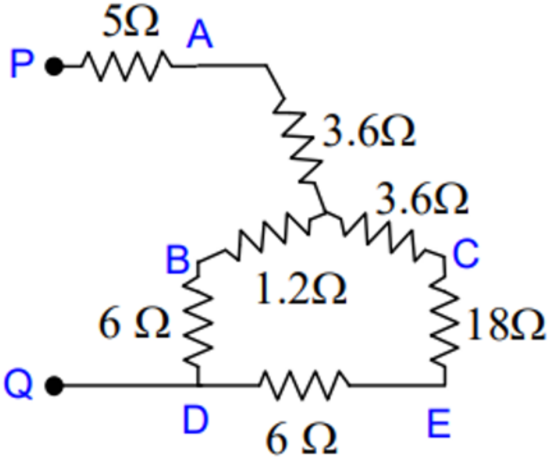
Q) The equivalent resistance between point P and Q is…………

a. 14.31 ohm
b. 17.12 ohm
c. 12.24 ohm
d. 34.58 ohm

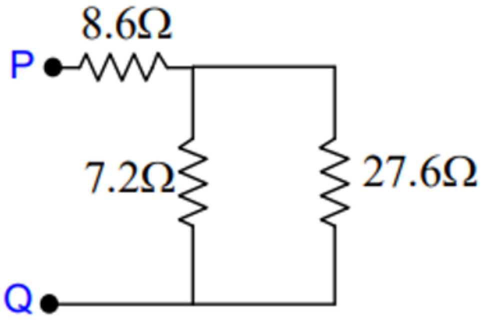


ABCA is Delta and can be converted to star

$$R_A = \frac{6 \times 18}{30} = 3.6\Omega$$
$$R_B = \frac{6 \times 6}{30} = 1.2\Omega$$
$$R_C = \frac{6 \times 18}{30} = 3.6\Omega$$



In the circuit 5 Ω and 3.6 Ω are in series, 6 Ω and 1.2 Ω are in series and 3.6 Ω 18 Ω and 6 Ω are in series.

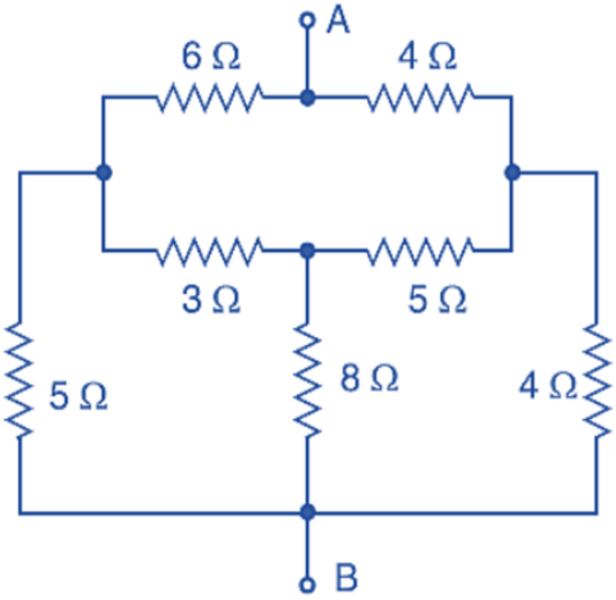


7.2 Ω 27.6 Ω are in parallel, which is in series with 8.6 Ω. The net resistance is.

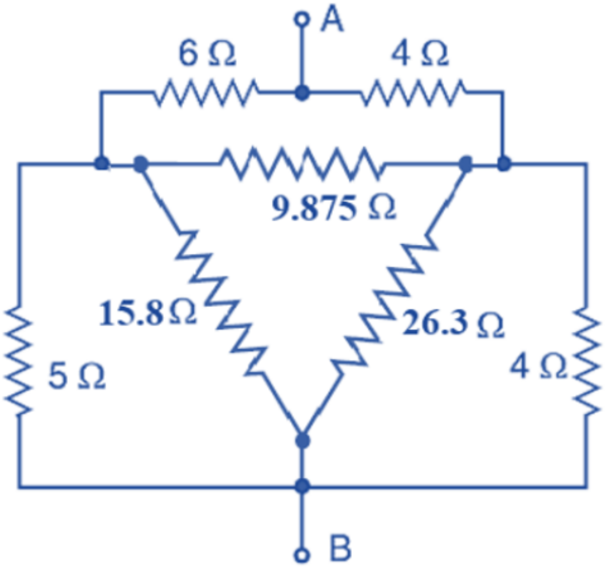
$$\begin{aligned} R_{PQ} &= 8.6 + \frac{7.2 \times 27.6}{7.2 + 27.6} \\ &= 8.6 + 5.71 \\ &= 14.31\Omega \end{aligned}$$

Q) Equivalent resistance across terminals A and B is………...

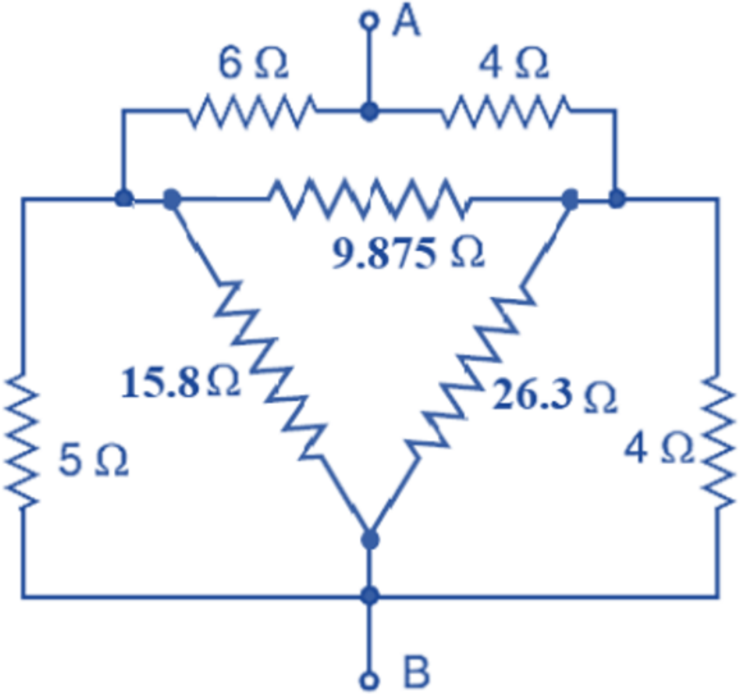
a. 2.23Ohm
b. 3.23 ohm
c. 4.23 oh
d. 5.23Oh

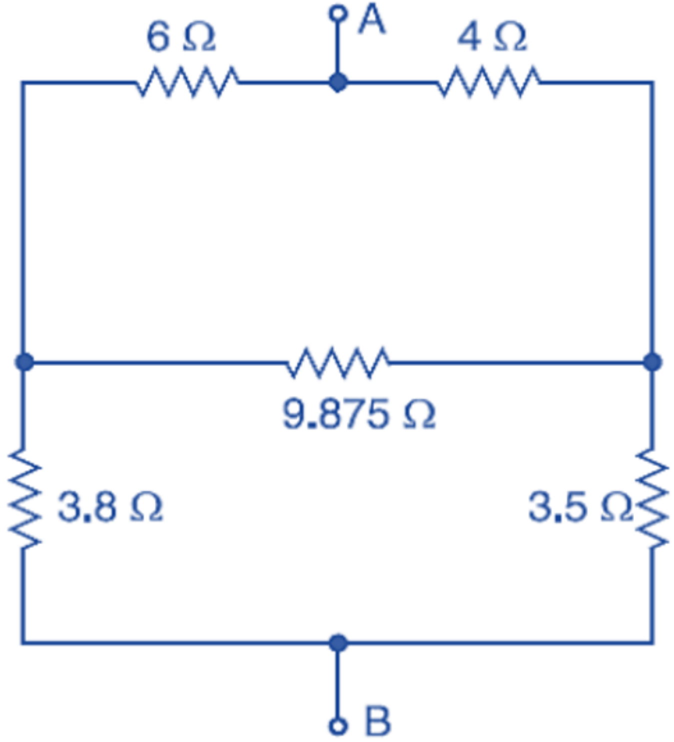


- Replacing inner STAR into DELTA.

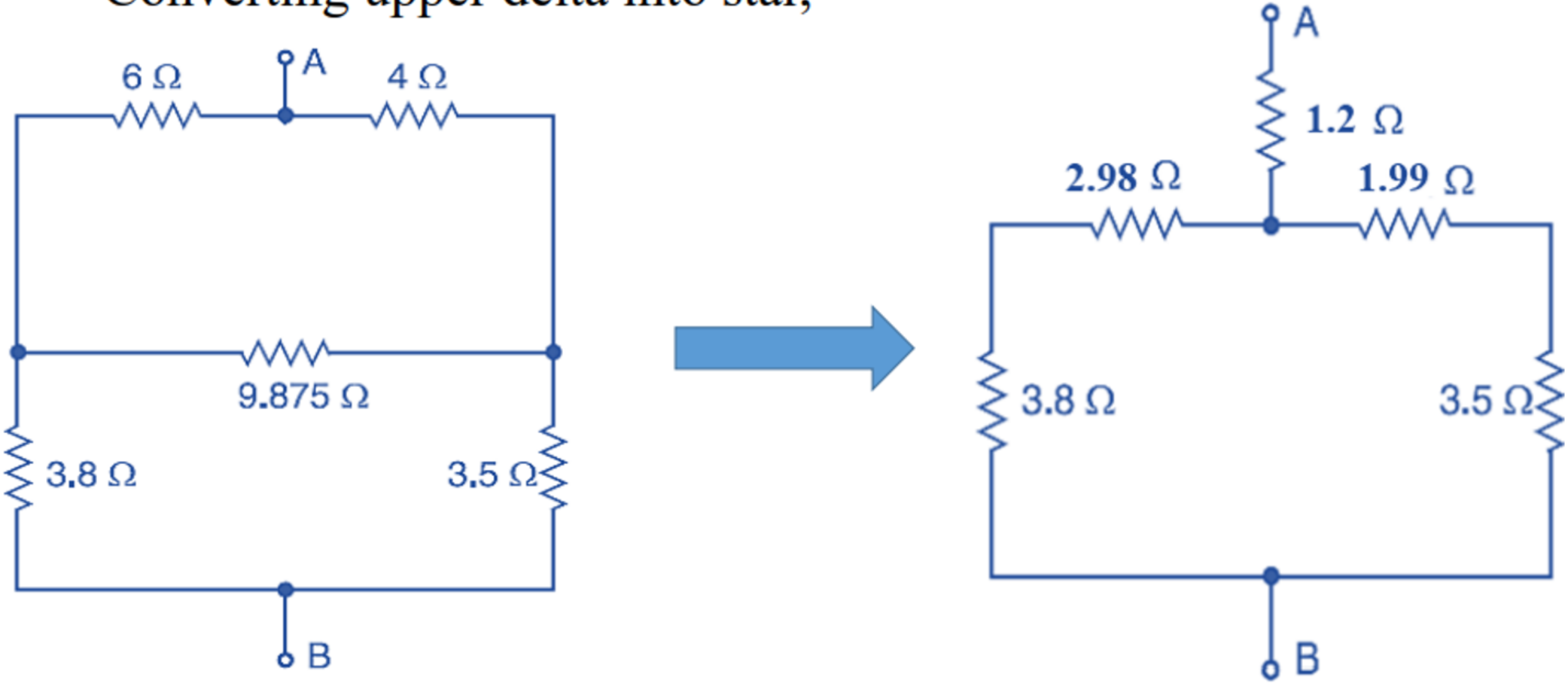


15.8 ohm is in parallel with 5 ohm and 26.3 ohm is in parallel with 4 ohm, circuit becomes

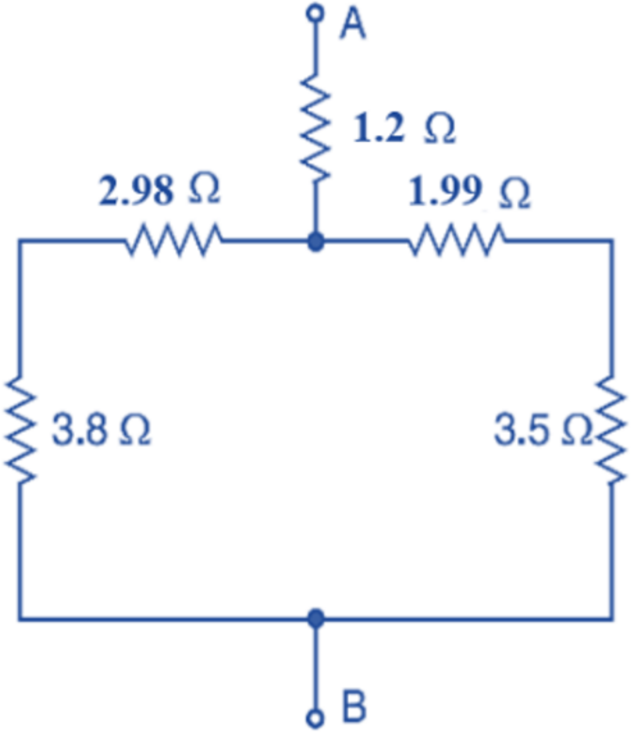




Converting upper delta into star,



Now equivalent resistance can be calculated as,



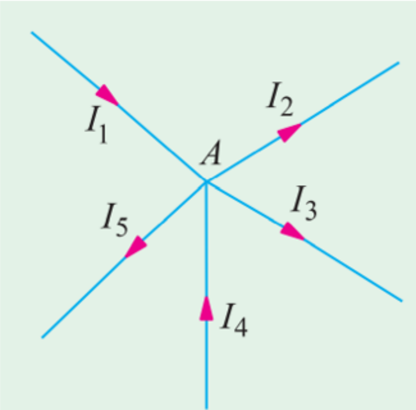
$$R_{eq} = (3 \cdot 8 + 2 \cdot 98) \,||\, (1 \cdot 99 + 3 \cdot 5) + 1 \cdot 2$$
$$= 4.23 \ ohms$$

Kirchhoff's law

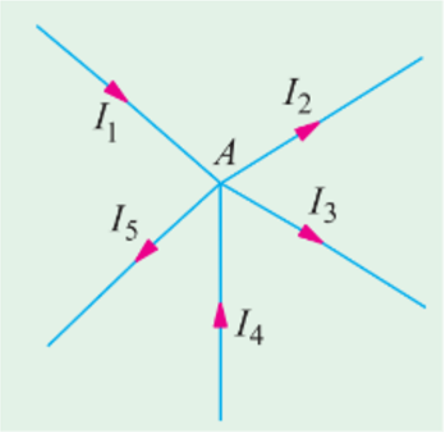
- In 1847, a German Physicist, Kirchhoff, formulated two fundamental laws of electricity.
    - Kirchhoff's Current Law (KCL)
    - Kirchhoff's Voltage Law (KVL)
- These laws are of tremendous importance from network simplification point of view.

KCL

- Kirchhoff's Law is based on the law of conservation of charge.
- Law of conservation of charge postulates that “ Charge is neither created nor destroyed”.
- Hence, When a charge enters a node in a network must either leave instantaneously or stored there.
- However, it cannot be stored because the node is an infinitesimal mathematical point, and the charge possesses a finite mass and size. Hence, the charge which arrives at a node must leave immediately.
- In term of current, total current entering a node must be equal to total current leaving the node.



KCL



$$I_1 + (-I_2) + (-I_3) + (+I_4) + (-I_5) = 0$$

$$I_1 + I_4 - I_2 - I_3 - I_5 = 0$$

or $$I_1 + I_4 = I_2 + I_3 + I_5$$

incoming currents = outgoing currents

Hence,
The total current leaving a junction is equal to the total current entering that junction.
i.e. **incoming currents=outgoing currents**

KCL

Kirchhoff's current law **(KCL)** is applicable to networks that are:

- Kirchhoff's law is applicable to both AC and DC circuits. **It is not applicable for time-varying magnetic fields**.
- Unilateral or bilateral
- Active or passive
- **Linear or non-linear**
- Lumped network

KVL

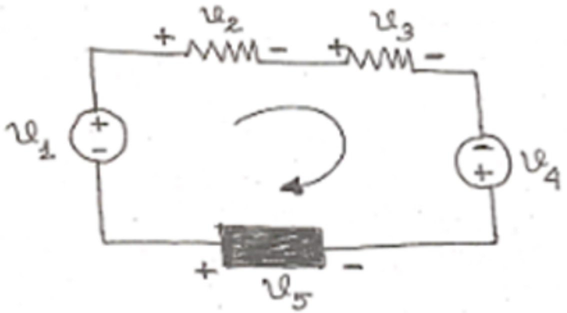
- Kirchhoff's Voltage Law is based on the law of conservation of energy.

Statement

The algebraic sum of all voltages in any closed path (or mesh) in a network is zero.

Mathematically,

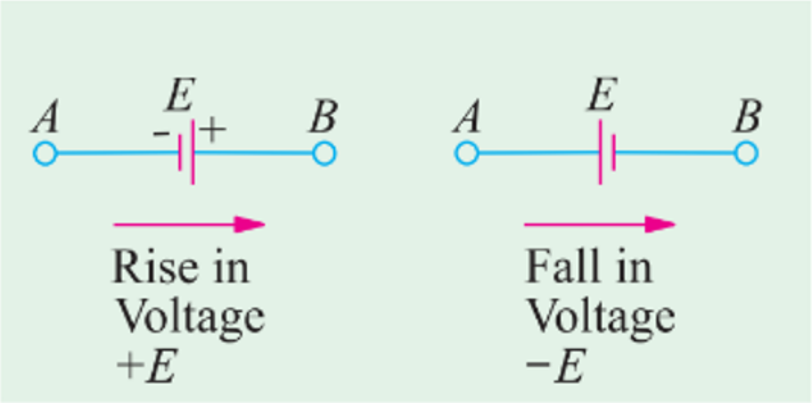
$$\Sigma IR + \Sigma e.m.f. = 0$$



The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs. in that path is zero.

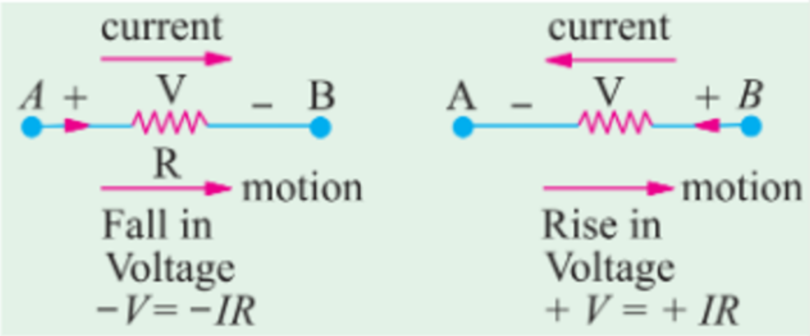
Sign Convention

- Sign of Battery E.M.F.



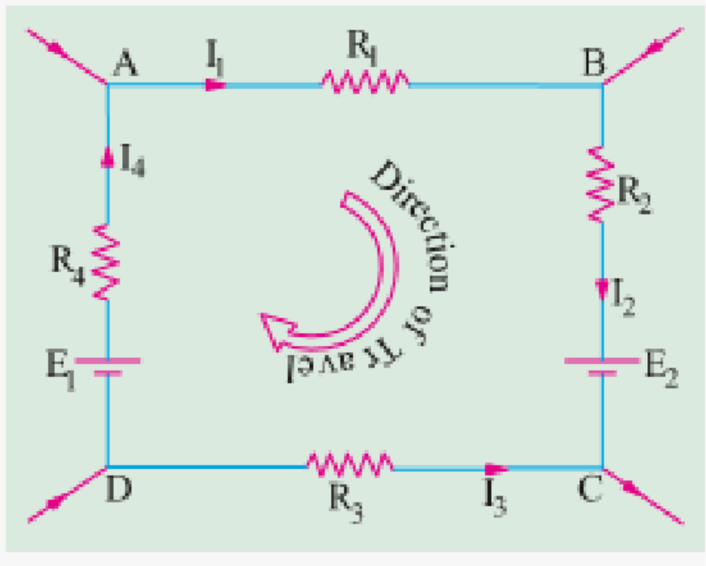
It is important to note that the sign of the battery e.m.f. is independent of the direction of the current through that branch

- Sign of Voltage Drop



It is clear that the sign of voltage drop across a resistor depends on the direction of current through that resistor but is independent of the polarity of any other source of e.m.f. in the circuit under consideration.

KVL



I_1R_1	is	$-$ve	(fall in potential)
I_2R_2	is	$-$ve	(fall in potential)
I_3R_3	is	$+$ ve	(rise in potential)
I_4R_4	is	$-$ve	(fall in potential)
E_2	is	$-$ve	(fall in potential)
E_1	is	$+$ ve	(rise in potential)

Using Kirchhoff's voltage law, we get

$$-I_1R_1 - I_2R_2 + I_3R_3 - I_4R_4 - E_2 + E_1 = 0$$

or $$I_1R_1 + I_2R_2 - I_3R_3 + I_4R_4 = E_1 - E_2$$

Linear and Non-Linear Network

Linear Network :

- A circuit or network whose parameters i.e. elements like resistances, inductances and capacitances are always constant irrespective of the change in time, voltage, temperature etc. is known as linear network.
- The **Ohm's law can be applied** to such network.
- The mathematical equations of such network can be obtained by using the law of **superposition.**

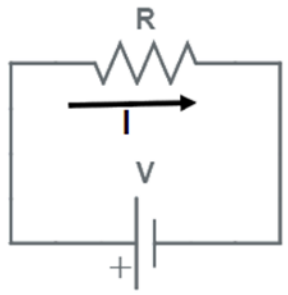
Non linear Network :

- A circuit whose parameters change their values with change in time, temperature, voltage etc. is known as non linear network .
- The Ohm's law may not be applied to such network.
- Such network does **not** follow the law of **superposition.**

Bilateral and Unilateral network

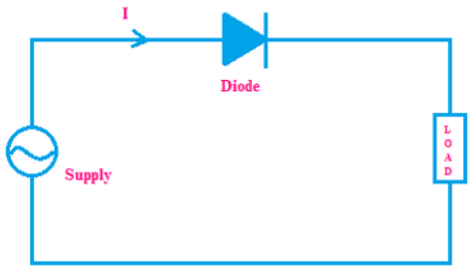
Bilateral Network :

- A circuit whose characteristics, behavior is same irrespective of the direction of current through various elements of it, is called bilateral network.
- Network consisting only resistances is good example of bilateral network.



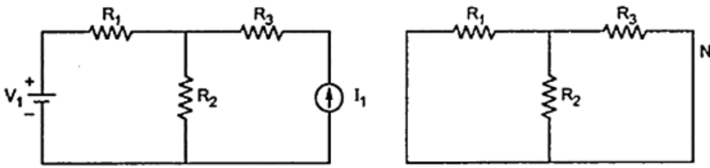
Unilateral Network :

- A circuit whose operation, behavior is dependent on the direction of the current through various elements is called unilateral network.
- Circuit consisting diodes, which allows flow of current only in one direction is good example of unilateral circuit.



Active and Passive Component

BASIS	ACTIVE COMPONENTS	PASSIVE COMPONENT
Nature of source	Active components deliver power or energy to the circuit.	Passive elements utilizes power or energy from the circuit.
Examples	Diodes, Transistors, SCR, Integrated circuits etc.	Resistor, Capacitor, Inductor etc.



(a) Active network (b) Passive network

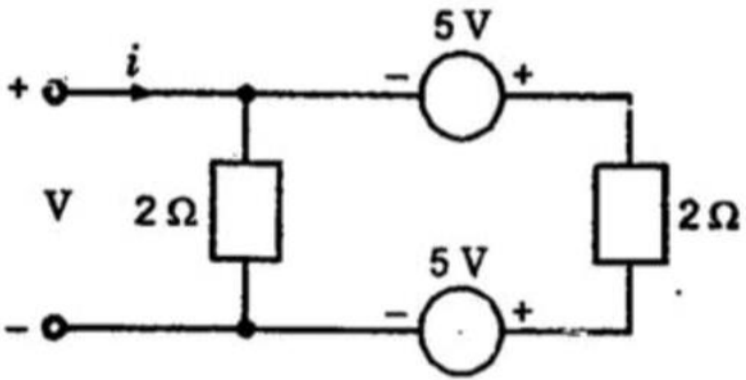
Active Network :

- A circuit which contains at least one source of energy is called active.
- An energy source may be a voltage or current source.

Passive Network :

- A circuit which contains no energy source is called passive circuit.

Which one of the following statements is correct ?



(a) Passive and linear. (b) Active and linear.
(c) Passive and nonlinear. (d) Active and nonlinear.