

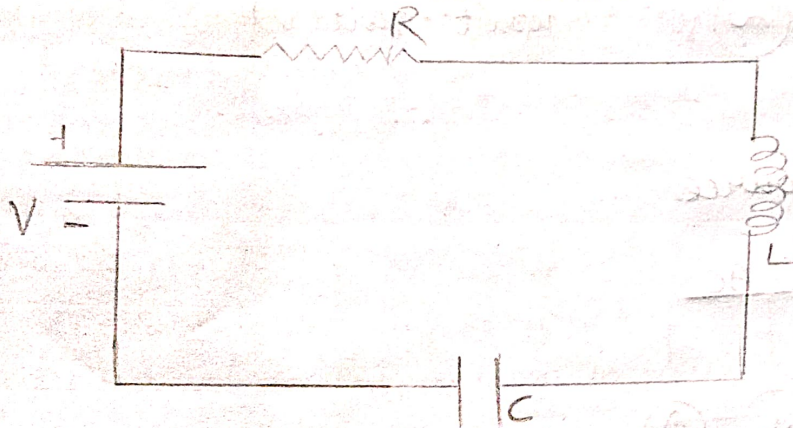
**ELECTRIC CIRCUIT
NETWORK
CLASS NOTES
BY
SIDHARTH SEKHAR
MALICK**

CHAPTER 1

Date 23/07/2025

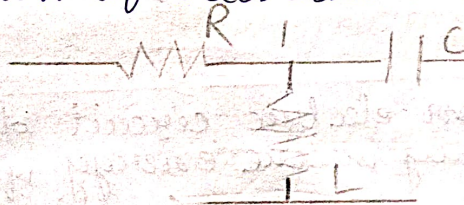
What is Circuit ?

An electrical circuit is a specific type of types of electrical Networks that provides a closed path for the flow of the electric current.



What is electric Network ?

An electrical Network is the most general term for any inter connection of electrical component



1.1 Component of circuit Active Component Passive Component
Circuit Component

Active
component

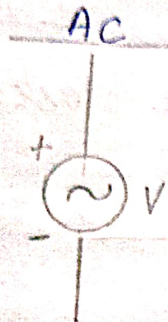
Passive
component

Active component :-

The Active elements are the elements of an circuit which possess energy of their own and can transform it to the other element of the circuit

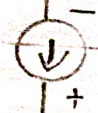
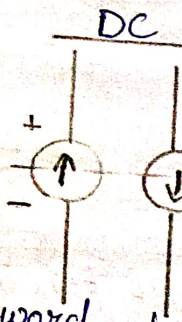
Example :- Voltage source
Current source

Voltage source are two types



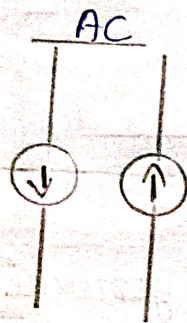
volt - volt (V)

Current source



up word

down word



Passive component:-

The passive elements of an electric circuit does not pass energy of their own. They receive energy from the sources.

Example: Resistor ————— (ohm)

Inductor ————— (Henry)

Capacitor ————— (Faraday)

1.2 Application, Specification of carbon Resistor. Idea of Potentiometer, Preset, Multi turn Potentiometers.

Application specification of carbon Resistor. Idea of Potentiometer Preset, Multi turn

Carbon Resistance:-

Carbon Resistor are a common type of fixed resistor used in electronics circuits to limit current flow.

Carbon Resistor are made from a solid cylindrical resistor the element (Mixture of carbon powder)

Application of carbon Resistor

- It is used to limit the flow of electric current
- There also used for voltage dropping in circuit.
- Carbon resistor are suitable for high frequency circuit

Resistor:-

which opposes the flow of current that called resistance

Law of Resistance:-

$$R = f \cdot \frac{L}{A}$$

f = Resistivity of material

L = length of conductor or wire

A = cross sectional area of conductor

$R \propto \frac{1}{A}$ - inverse to Proportion to resistivity

$L \uparrow \propto R \uparrow$ - Direct Relation

- when the length of conductor increase then resistance of the conductor increase
- when area of conductor increases resistance of the conductor increase

Specification of carbon Resistor Range:- 1 ohm to 10 mega Ohm

Tolerance:- $\pm 2\%$, $\pm 5\%$.

deviation in resistor $\pm 10\%$, $\pm 20\%$.

Example:- $10 \Omega \rightarrow \pm 2\%$.

$$10 \times \frac{2}{100} = 0.2$$

$$10 \pm 0.2$$

$$10.2 \rightarrow 10 + 0.2$$

$$9.8 \rightarrow 10 - 0.2$$

$$9.8 \Omega \text{ to } 10.2 \Omega$$

→ Temperature Range: -55°C to 155°C

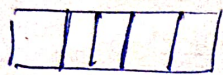
→ Colour code:-

- 0 - B - Black
- 1 - Br - Brown
- 2 - R - Red
- 3 - O - Orange
- 4 - Y - Yellow
- 5 - G - Grey
- 6 - B - Blue
- 7 - V - Violet
- 8 - Gr - Green
- 9 - W - White

Gold and Silver

15%, 10%

Tolerance.



(Tolerance, Gold)

21 X → Multiplication

21 $\times 10^4 \pm 5\%$

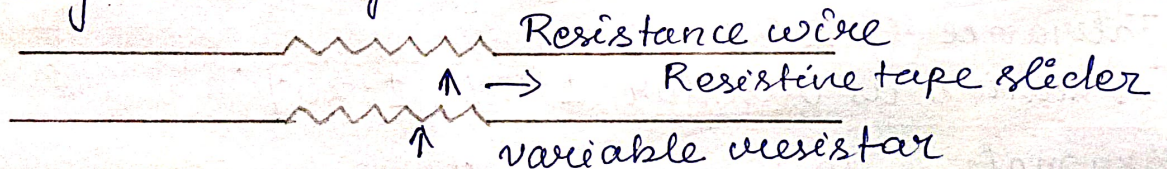
R 21 $\times 10000$

= 2,10,000 = 210 K Ω

Potentiometer:-

Date 24/07/2025

A Potentiometer is a three terminal variable resistor functioning as a voltage divider.



→ It is called as variable resistor

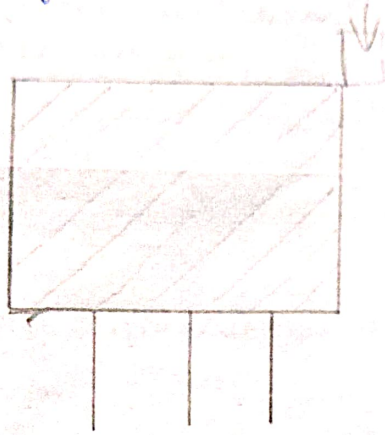
→ Carbon Resistor are called fixed resistor

Application:-

- Volume control in Audio system
- Tuning circuits
- Calibration of Instrument
- Position sensing
- Light dimmers

Preset Potentiometer:-

Preset or trim pots are small Potentiometer designed for frequency adjustment to fine tune a circuit Performed.

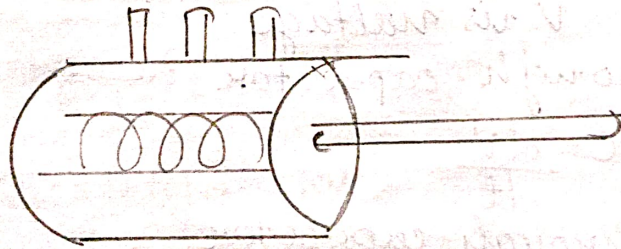


Application:-

- fine tuning current and voltage
- tuning filtering
- Controlling screen brightness or audio volume

Multi-turn Potentiometer:-

This Potentiometers offers enhanced precision by equating Multiple turn typically 3 to 20 rotation to travel one ohm to maximum resistor.

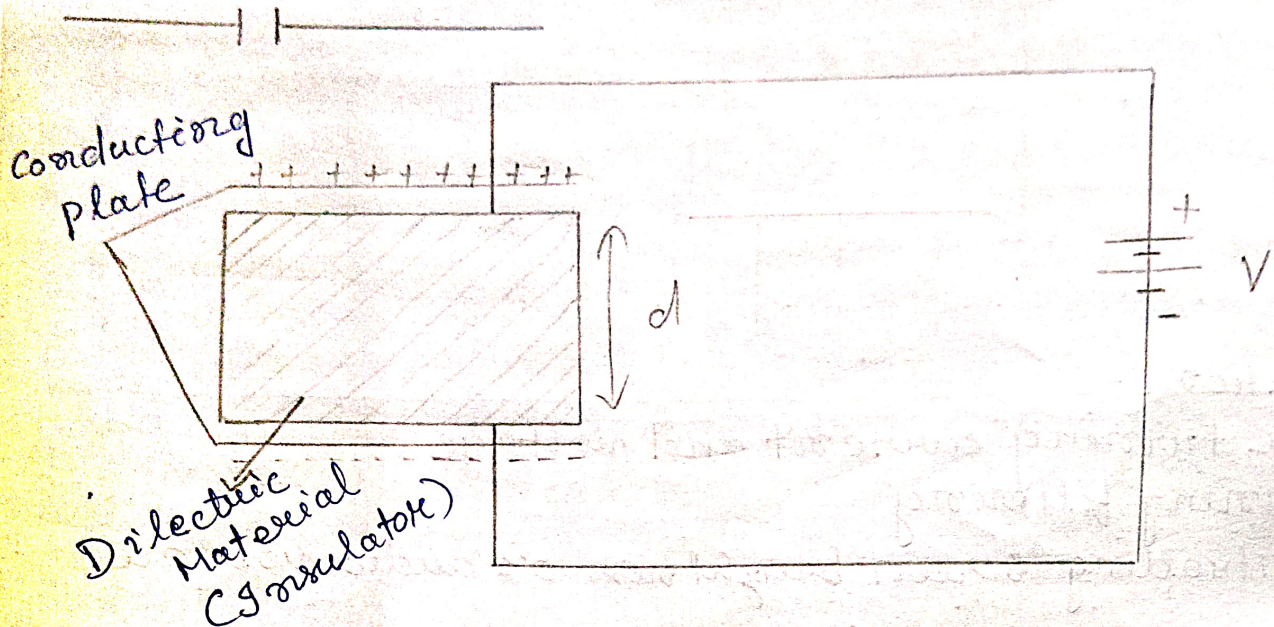


Application

- use for calibration equipment sensitive sensor. tuning high frequency circuits industrial control system.

1.3 Application, specification of Paper Capacitor, Mica capacitor, ceramic capacitor, Plastic film capacitor, electrolytic capacitor.

Capacitor (C)
unit (f)



→ Capacitor is a two terminal electrical device that stores electrical energy in a electric field in terms of charge

$$C = \frac{Q}{V} \quad \text{where } Q \text{ is charge}$$

V is voltage

Current through capacitor

$$I = C \frac{dV}{dt}$$

voltage through capacitor

$$V = \frac{1}{C} \int i \cdot dt$$

law of capacitor

$$C = \frac{\epsilon A}{d}$$

$\epsilon = \epsilon_0 \cdot \epsilon_r$ = permittivity of dielectric Material

$$\epsilon_0 = 8.85 \times 10^{-12}$$

$$\epsilon_r = 1 \text{ (air)}$$

d = distance between two plate

A = Overlapping area of plate

1. Paper Capacitor

Paper is used as dielectric Material

Specification

- Capacitance Range = 1 nF to $1\text{ }\mu\text{F}$
- Voltage range up to 2000 V
- These are fixed capacitor

Application :

Noise filtering, coupling and dc-coupling system.

Car Audio System

Capacitor Blocking DC signal to pass AC signal

High voltage and High Current

Mica Capacitor

Date 28/07/2025

Application :-

- High frequency circuit, resonant circuit and tuning circuit
- Blocking DC signal and allowing AC signal
- It is used for high voltage and high current

Specification

- Capacitance range - A few pF to a few thousand pF.
- Low loss (High Quality factor)
- High stability and accuracy

Ceramic capacitor

Dielectric Material - ceramic Material

(Titanium dioxide, barium titanate)

Application

- It is used for high frequency application and noise reduction.
- It is used in filter circuit coupling circuit and by passing circuit

→ It is used in circuit breaker and induction furnaces

Specification:-

→ Capacitance range - 1 pf to 100 mf

It is small size and light weight

voltage rating - 100 to 50000

Negative:-

Milli = 10^{-3} mf = 10^{-3} f

Micro = 10^{-6} uf = 10^{-6} f

Nano = 10^{-9} nf = 10^{-9} f

Pico = 10^{-12} pf = 10^{-12} f

Positive:-

10^3 = kilo

10^6 = Mega

10^9 = Giga

10^{12} = Tera

Plastic film capacitor

→ Dielectric - Thin diameter of plastic film

(Example - polyester, polypropylene, poly styrene)

Application

→ It is used in the circuit required low loss high insulation resistance and stability

→ It is used in filter circuit A/D Analog or Digital converter ~~specification~~

Specification

→ Capacitance range:- 1 nf to 30 mf

→ voltage range:- 50 to above 2000V

Electrolytic capacitor

Dielectric (liquid gel, or solid)

(Manganese dioxide)

Application

→ power supply used in filtering and smoothing

→ Tuning circuit and motor starting

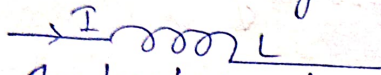
Specification

High capacitance values in a compact size

1.4 Fundamental Idea of Inductor Application and Specification of Ferri te core Inductor, Pat core Inductor, Air core Inductor, Self and Mutuals Inductance.

→ Inductor (L)

unit - Henry (H)



→ An Inductor stores energy in the form of a magnetic field when current passes through it

→ Voltage across Inductor $= V_L = L \cdot \frac{di}{dt}$

→ Law of Inductance $= L = \mu \cdot \frac{N^2 a}{l}$

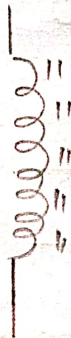
where L - Inductance

μ = permeability

a = cross sectional area

l = length of the coil

Ferri te core Inductor



Ferri te (Ceramic with iron oxide and metal)

Specification

High permeability (μ)

Frequency range 20 kilo Hz to mega Hz)

Application

→ ~~RF~~ RF (Radio frequency) Transformer

→ SMPS (Switched Mode power supply)

→ used in chok

Pot core Inductor :-



Application

used in transformer, filter, signal processing.

Air core Inductor :-

This conductor with no magnetic core



It is only a coil or wire

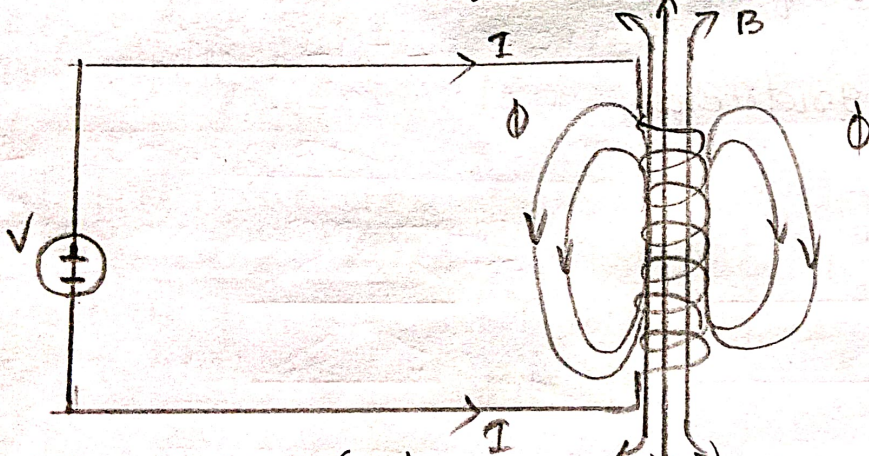
Application

→ RF circuit

→ Tuned circuit

→ Antennas

Self Inductance and Mutual Inductance



Coil consisting of 'N' no of turns

Property of a loop in which its own magnetic field oppose any change in current oppose any change in current is called self inductance and the EMF Generated it is called as self induced EMF or back EMF.

Mathematically 'C' $\frac{N \phi}{I}$

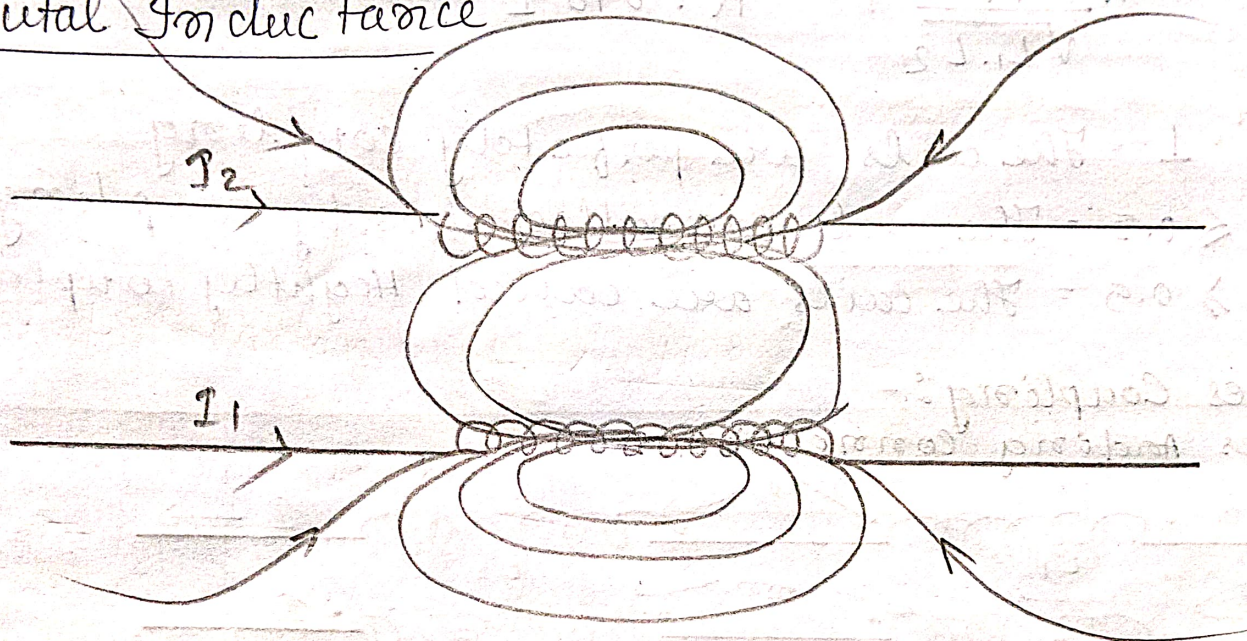
Where L is self inductance

N is No of turns of coil

ϕ = flux

I = current

Mutal Inductance



$$M_{12} = N_1 \cdot \frac{d\phi_{21}}{dt}$$

N_1 = No of turns of L_1 coil

$\frac{d\phi_{21}}{dt}$ = Rate of change of flux with respect to time

$$M = K \sqrt{L_1 \cdot L_2}$$

M = Mutual Inductance

K = Co-efficient of coupling (constant)

L_1 = Inductor '1'

~~L_2 = Co-efficient of couple~~

L_2 = Inductor '2'

Co-efficient of coupling

The degree to which the mutual inductance approaches its maximum value is given by the co-efficient of coupling

$$M = K\sqrt{L_1 \cdot L_2} \quad 0 < K < 1$$

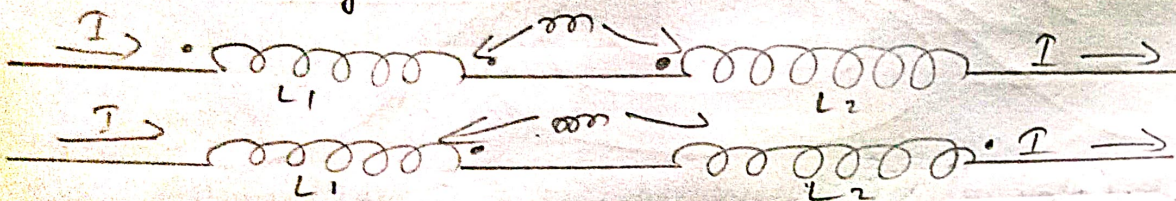
$$K = \frac{M}{\sqrt{L_1 \cdot L_2}}$$

K . 0 to 1

- (i) $K = 1$ - The coils are perfectly coupling
- (ii) $K \leq 0.5$ - The coils are called loosely coupling
- (iii) $K \geq 0.5$ - The coils are called Highly coupling

Series Coupling:-

Series Aiding connection

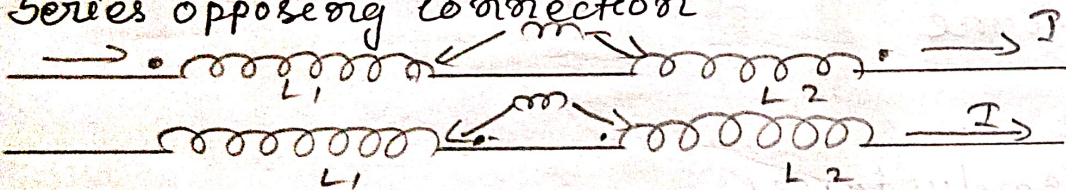


$$\text{Total Inductance} = L_1 + L_2 + 2M$$

Where M = Mutual Inductance

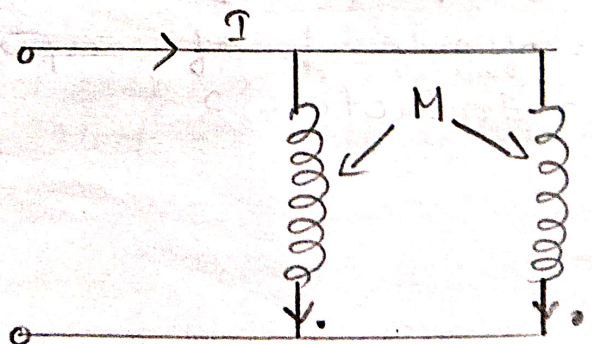
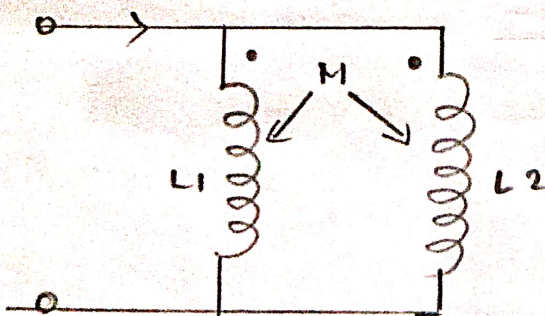
L_1 = Inductor value coil 1 or coil 2

Series opposing connection



$$\text{Total Inductance} = L_1 + L_2 - 2M$$

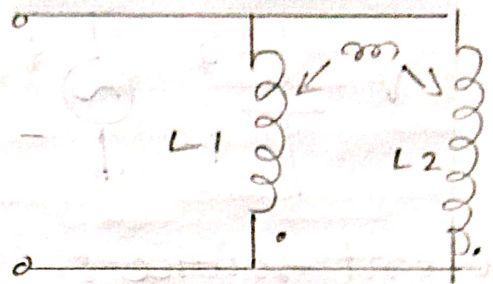
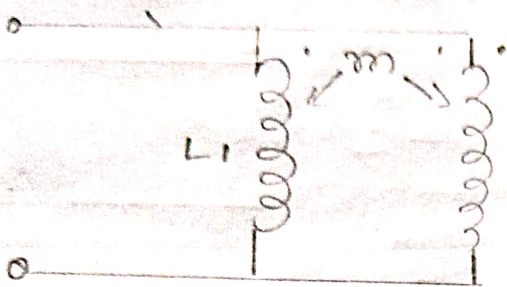
Parallel Aiding



Total Inductance = $L_1 + L_2 - 2M$

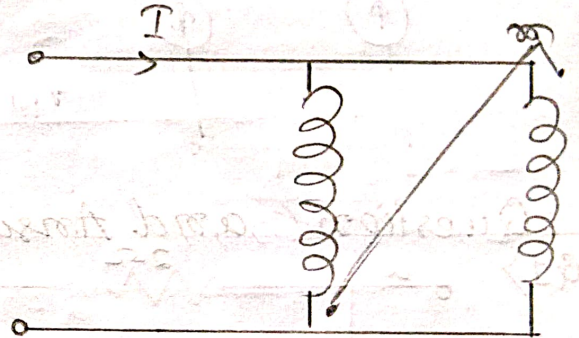
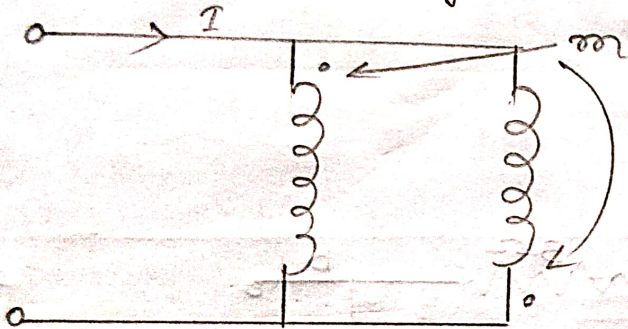
Parallel Connection

Parallel aiding



Total Inductance = $\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 - 2M}$
(L equivalent)

Parallel opposing



Total Inductance = $\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 + 2M}$
(L equivalent)

Date 31/07/2025

1.5 Energy sources, current and voltage sources and their transformation

Energy source :-

→ The energy source are the component in circuit which provides electrical energy for operation

→ Energy source are two types

(a) DC energy source

(b) AC energy source

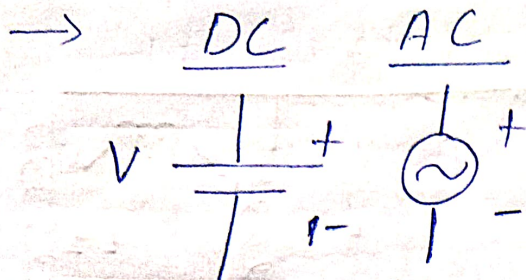
→ Energy sources classified by 2 types

(a) voltage source

(b) current source

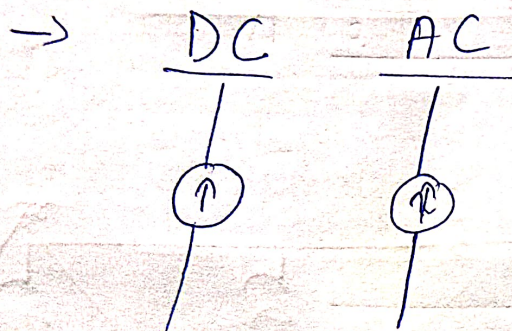
Voltage source :-

→ Which provide voltage to the circuit

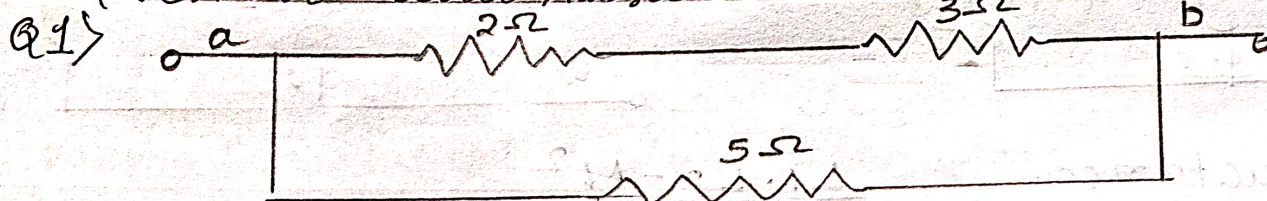


Current source :-

→ It provide current to the electric circuit



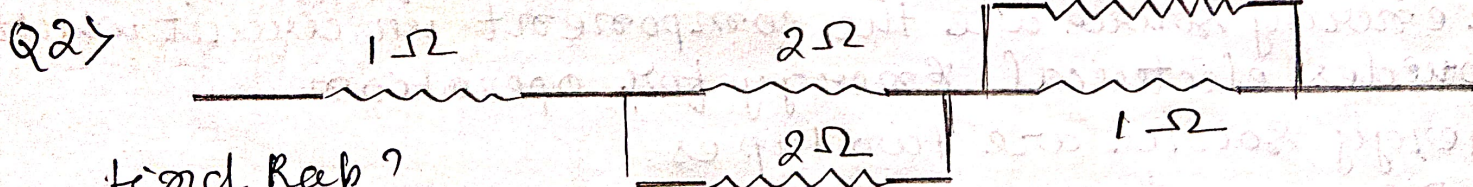
Question and Answer



find R_{ab} ?

Ans $\frac{1}{R_{ab}} = \frac{1}{5} + \frac{1}{5} = \frac{2}{5}$

$R_{ab} = \frac{5}{2} = 2.5 \Omega$



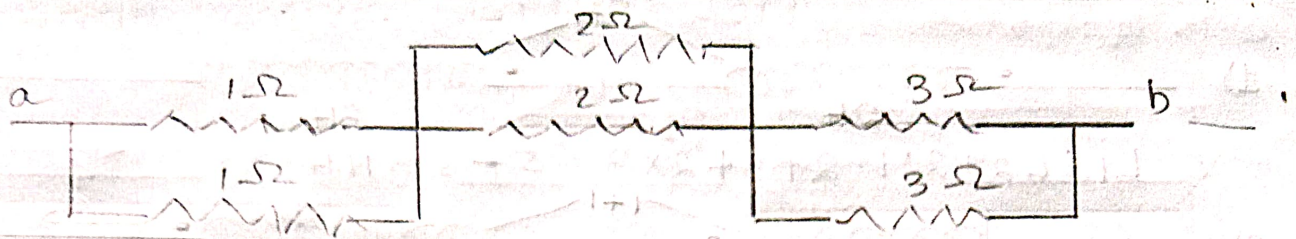
find R_{ab} ?

Ans $\frac{1}{R} = \frac{1}{1} + \frac{1}{1} = 2$

$R = 0.5 \Omega$

$1 + 2 + 2 + 0.5 = 5.5 \Omega$

Q3)

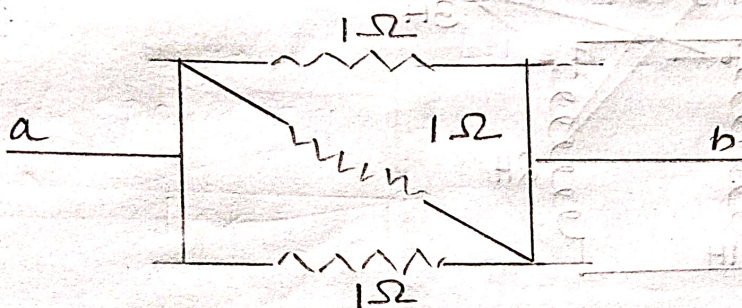


Ans) $\frac{1}{R} = \frac{1}{2} + \frac{1}{3} = \frac{5}{6}$

$R = \frac{6}{5} = 1.2 \Omega$

$1 + 2 + 1.2 = 4.2 \Omega$

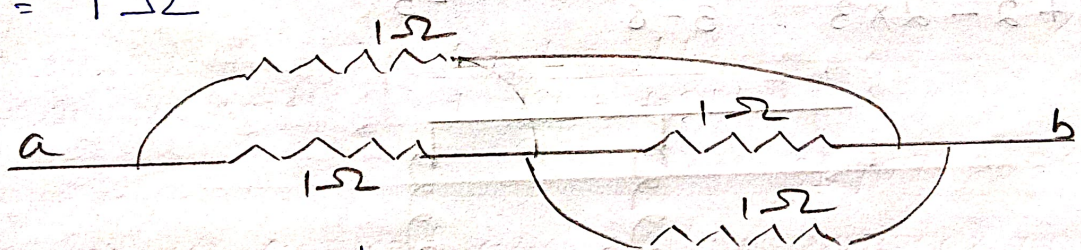
Q4)



Ans) $\frac{1}{R_{ab}} = \frac{1}{2} + \frac{1}{2} = 1$

$R_{ab} = 1 \Omega$

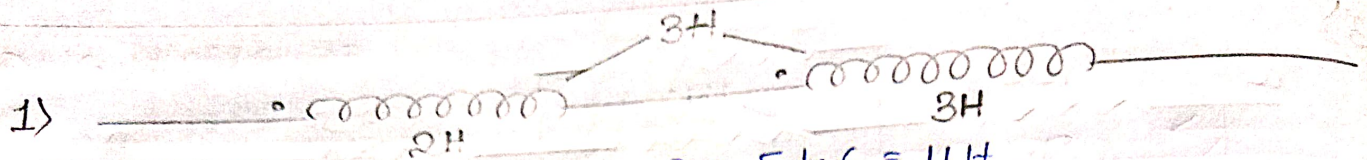
Q5)



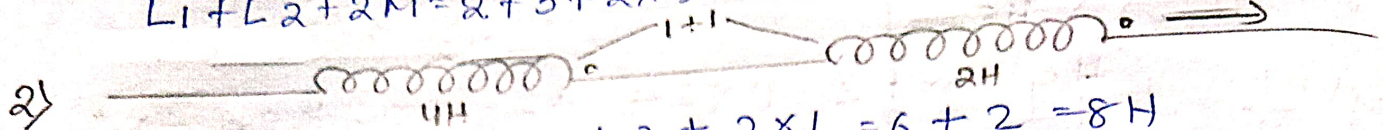
$\frac{1}{R} = \frac{1}{1} + \frac{1}{1}$
 $= 2$

$R = 0.5 \Omega$

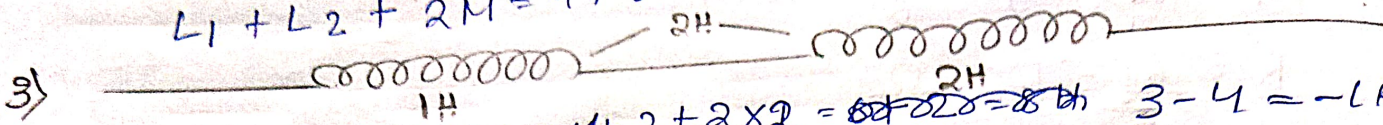
$1 + 0.5 + 1 = 2.5 \Omega$



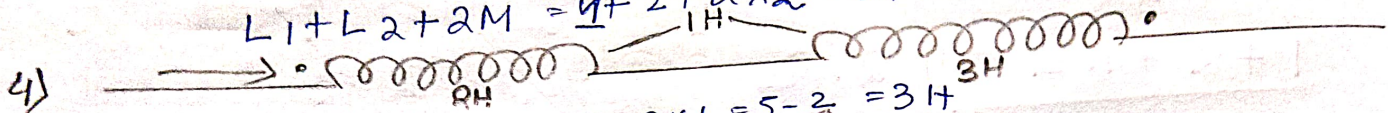
$$L_1 + L_2 + 2M = 2 + 3 + 2 \times 3 = 5 + 6 = 11H$$



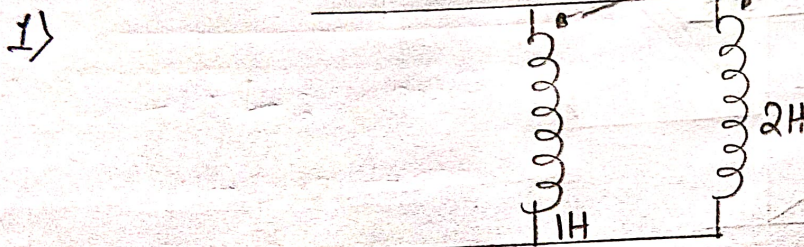
$$L_1 + L_2 + 2M = 4 + 2 + 2 \times 1 = 6 + 2 = 8H$$



$$L_1 + L_2 + 2M = 1 + 2 + 2 \times 2 = 5 + 4 = 9H \quad 3 - 4 = -1H$$

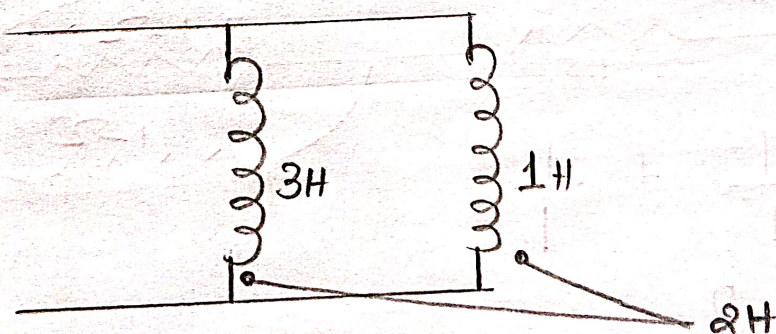


$$L_1 + L_2 - 2M = 2 + 3 - 2 \times 1 = 5 - 2 = 3H$$



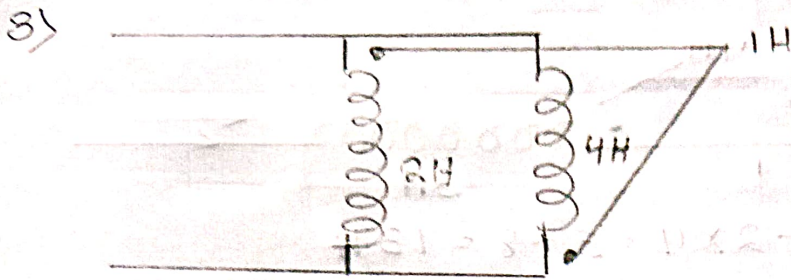
$$\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 - 2M}$$

$$\Rightarrow \frac{1 \times 2 - 3^2}{1 + 2 - 2 \times 3} = \frac{2 - 9}{3 - 6} = \frac{-7}{-3} = 2.3H$$



$$\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 - 2M}$$

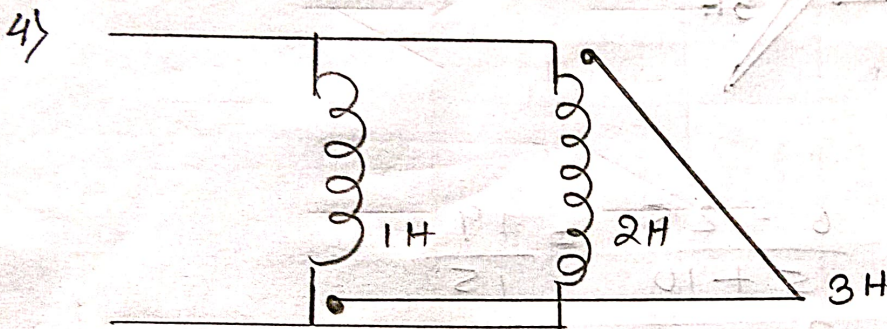
$$\Rightarrow \frac{3 \times 1 - 2^2}{3 + 1 - 2 \times 2} = \frac{3 - 4}{4 - 4} = \frac{-1}{0} = 0(H)$$



$$\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 + 2M}$$

$$L_1 + L_2 + 2M$$

$$\Rightarrow \frac{2 \times 4 - 1^2}{2 + 4 + 2 \times 1} = \frac{8 - 1}{6 + 2} = \frac{7}{8} = 0.8H$$



$$\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 + 2M}$$

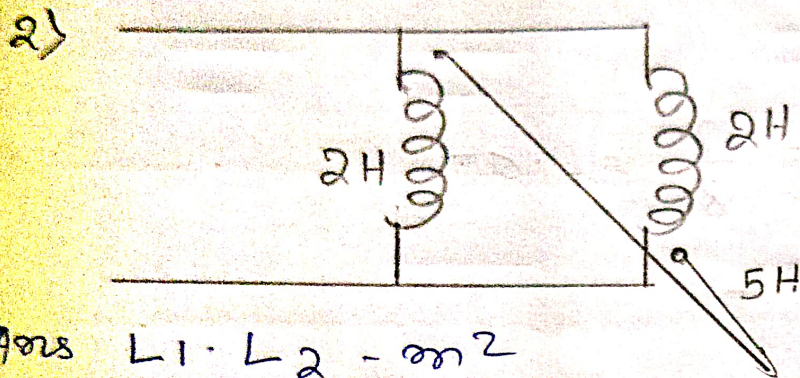
$$L_1 + L_2 + 2M$$

$$\Rightarrow \frac{1 \times 2 - 3^2}{1 + 2 + 2 \times 3} = \frac{2 - 9}{3 + 6} = \frac{7}{9} = 0.7H$$

Date 04/08/2025

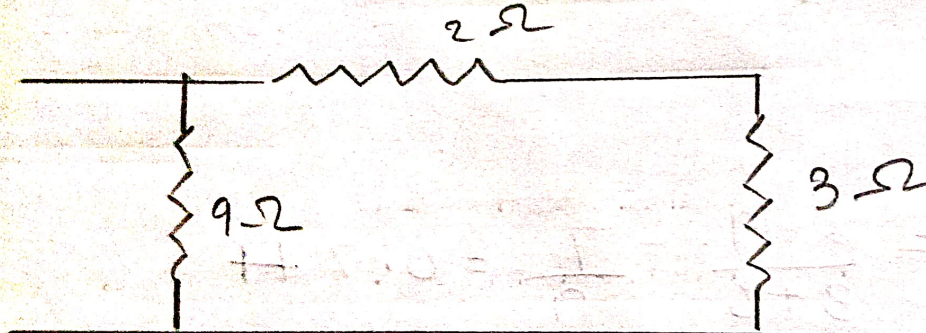


$$L_1 + L_2 + 2M = 2 + 3 + 2 \times 4 = 5 + 8 = 13 \text{ H}$$



Ans $\frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 + M}$

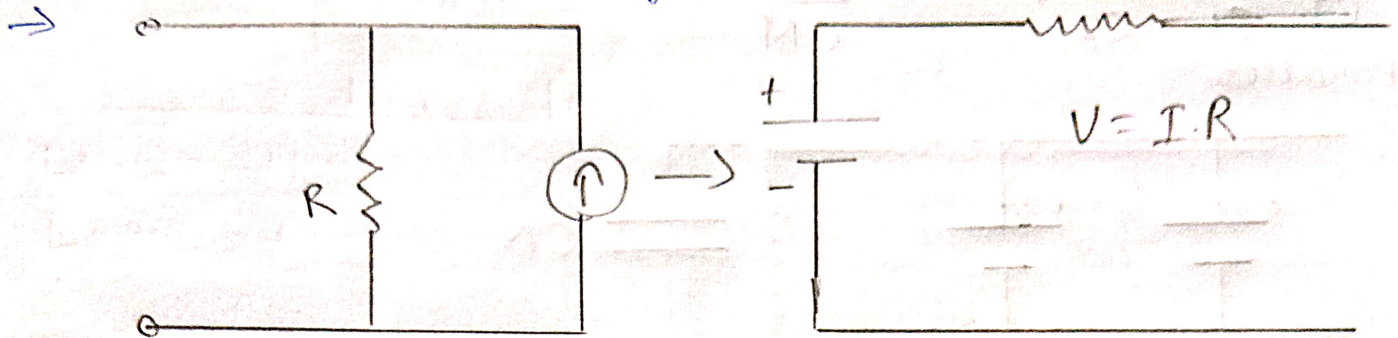
$$\Rightarrow \frac{2 \times 2 - 5^2}{2 + 2 + 2 \times 5} = \frac{4 - 25}{4 + 10} = \frac{-21}{14} = -\frac{3}{2}$$



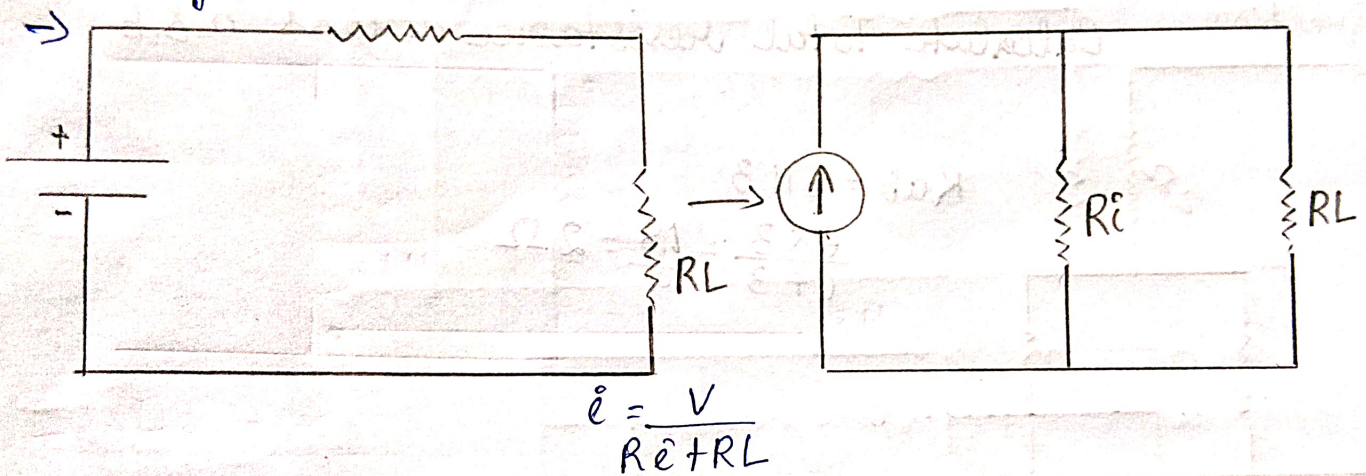
Date : 4/08/2020

Source Transformation

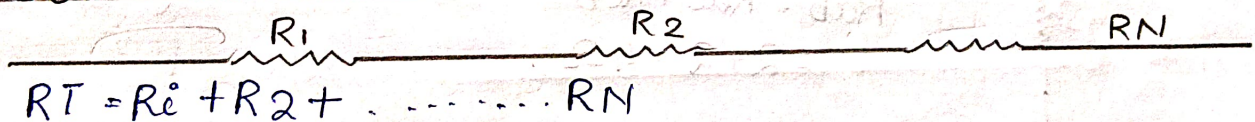
→ Current source to voltage source conversion



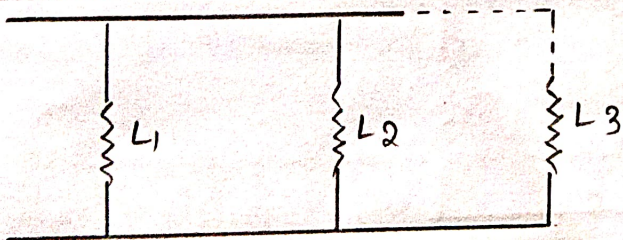
→ Voltage source to current source transformation



1.6 Series and Parallel circuits Resistors (R)



Parallel



$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_N}$$

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}}$$

$$R_T = \frac{1}{\frac{1}{2} + \frac{1}{2} + \frac{1}{2}} = \frac{1}{1.5} = 0.67 \Omega$$

$$R_T = 2 + 2 + 2 = 6 \Omega$$

$$R_T = 1 \Omega$$

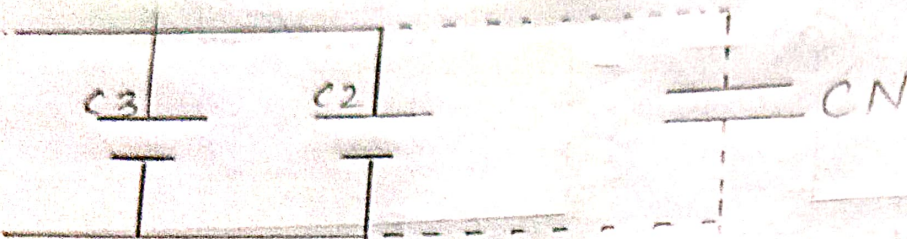
Capacitance :-

Series



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N}$$

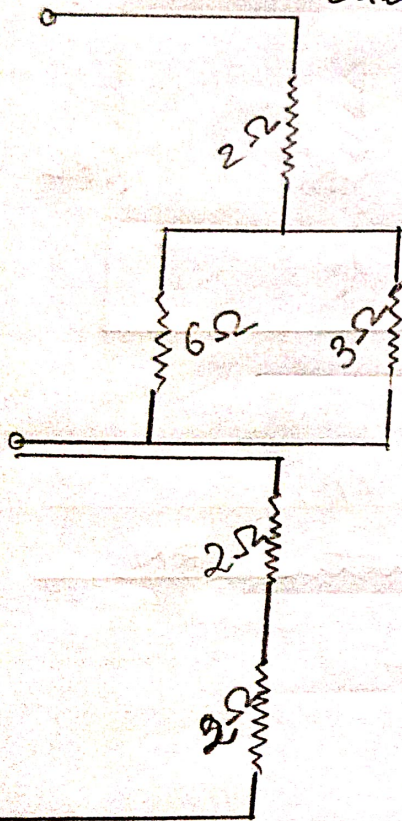
Parallel



$$C_T = C_1 + C_2 + \dots + C_N$$

Question

Calculate Total resistance across a & b



$$R_{ab} = 6 \parallel 3$$

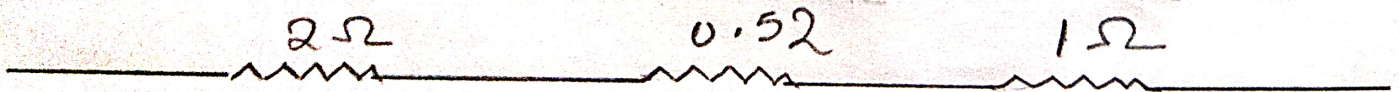
$$\frac{6 \times 3}{6 + 3} = \frac{18}{9} = 2 \Omega$$

$$R_{ab} = R_{ac} + R_{cb}$$

$$= 2 + 2 = 4 \Omega$$

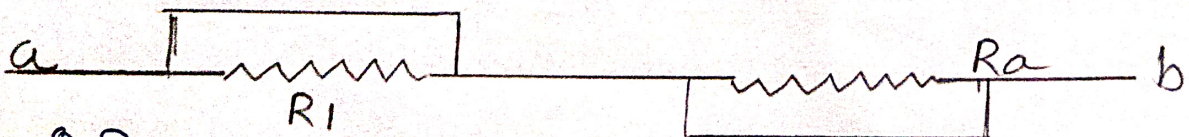
$$2 \cdot 2 \parallel 2 = 2 \times 2 = \frac{4}{2} = 1 \Omega$$

$$\text{Ans } ||| = \frac{1 \times 1}{1 + 1} = \frac{1}{2} = 0.5 \Omega$$



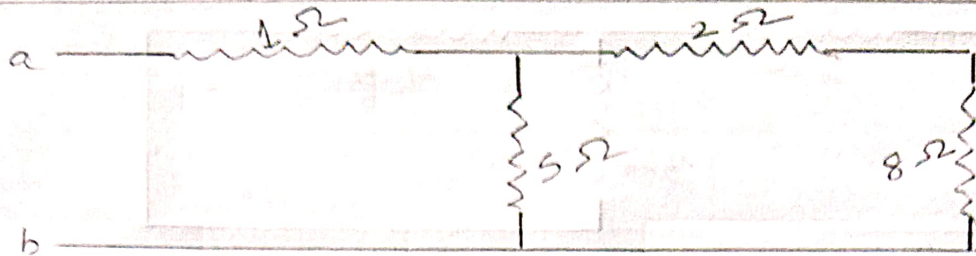
$$R_{ab} = 2 + 0.5 + 1 = 3.5 \Omega$$

3.

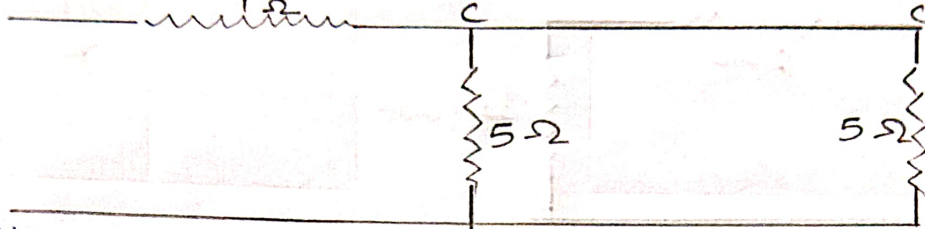


$$\text{Ans } R_T = 0 \Omega$$

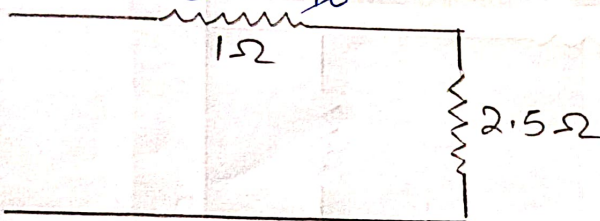
4.



$$R_{ab} = R_{dc} + R_{cb} = 2 + 3 = 5 \Omega$$

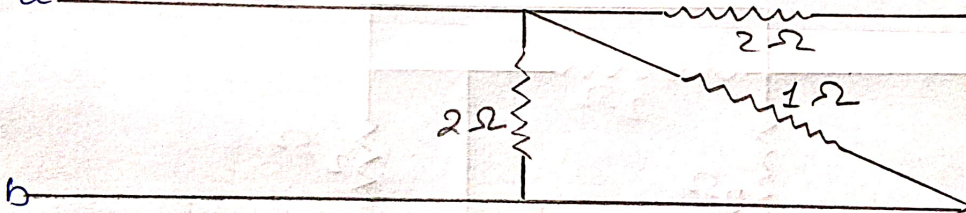


$$5 || 10 = \frac{5 \times 10}{5 + 10} = \frac{50}{15} = 2.5 \Omega$$

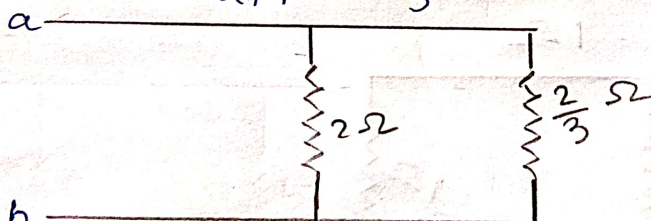


$$R_{ab} = 1 + 2.5 = 3.5 \Omega$$

5

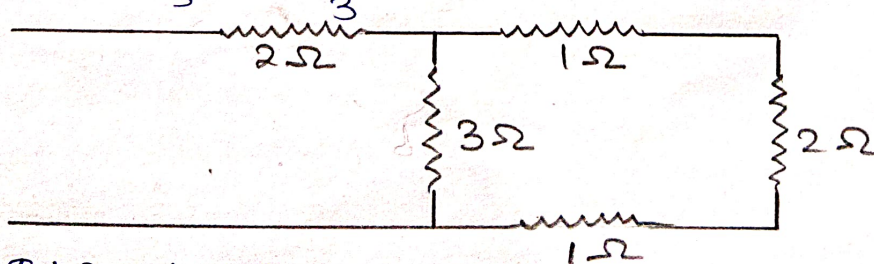


$$Ans \quad 2 || 2 = \frac{2 \times 2}{2 + 2} = \frac{4}{4} = 1$$

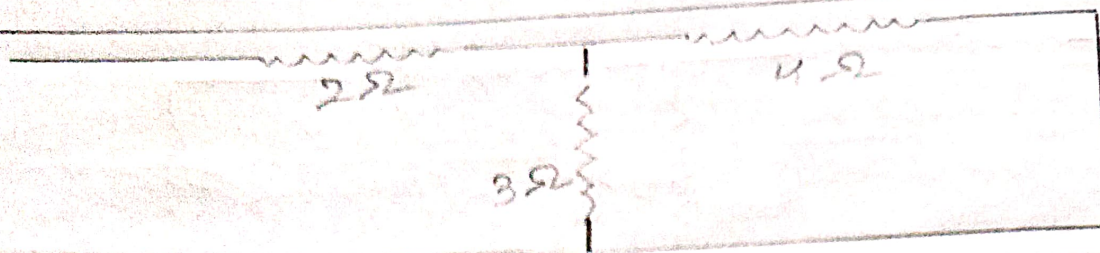


$$2 || \frac{2}{3} = \frac{2 \times \frac{2}{3}}{2 + \frac{2}{3}} = \frac{\frac{4}{3}}{\frac{6+2}{3}} = \frac{4}{8} = \frac{1}{2}$$

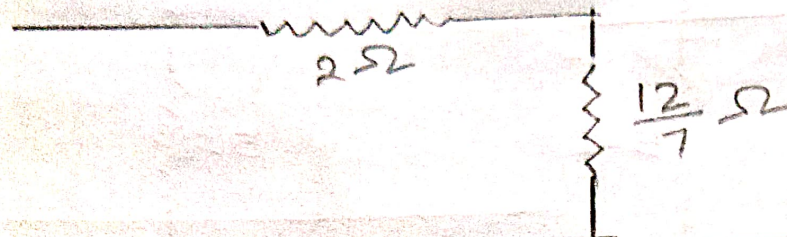
6



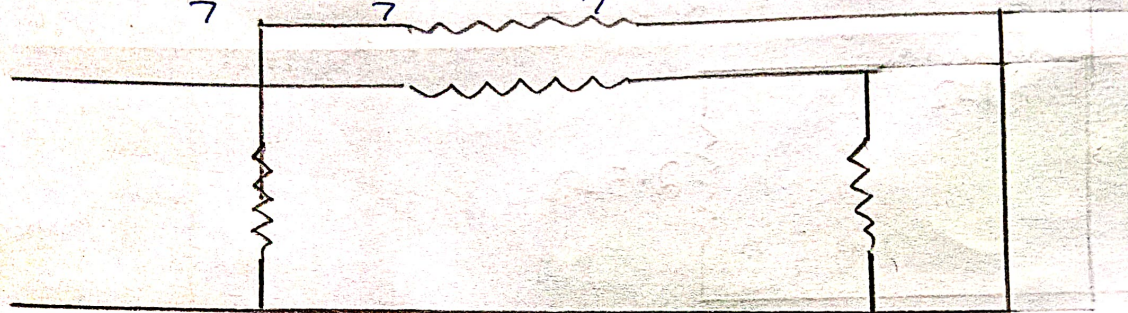
$$Ans \quad 1 + 2 + 1 = 4$$



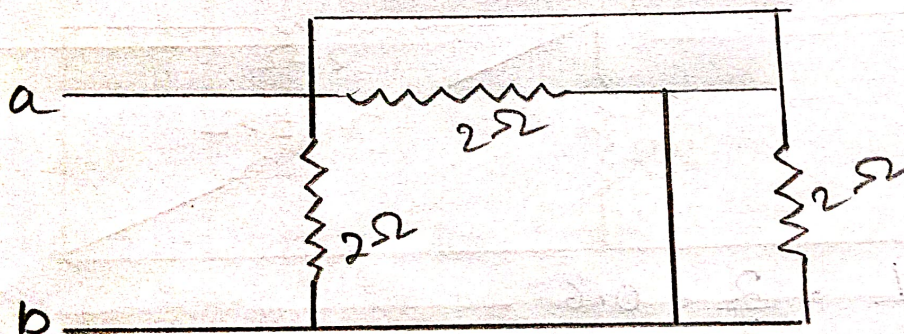
$$3 \parallel 4 = \frac{3 \times 4}{3 + 4} = \frac{12}{7} \Omega$$



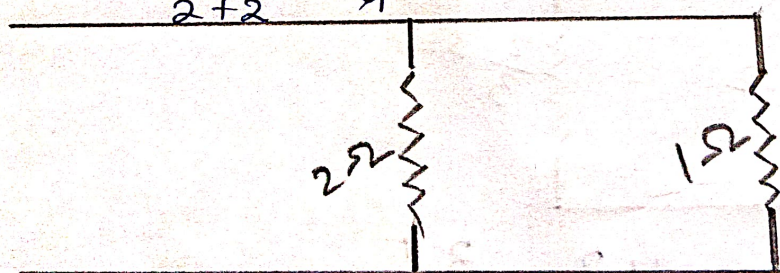
$$2 + \frac{12}{7} = \frac{14 + 12}{7} = \frac{26}{7} \Omega$$



$$1 + 1 = 2$$



$$2 \parallel 2 = \frac{2 \times 2}{2 + 2} = \frac{4}{4} = 1 \Omega$$



Date:- 13/08/2025

Chapter- 2

Network Theoram in DC Circuit

201

Node and Mesh Analysis

Mesh Analysis KVL and Ohm's

⇒ Mesh is defined as a loop which does not contain any other loop within it and it does not include loop.

Node :-

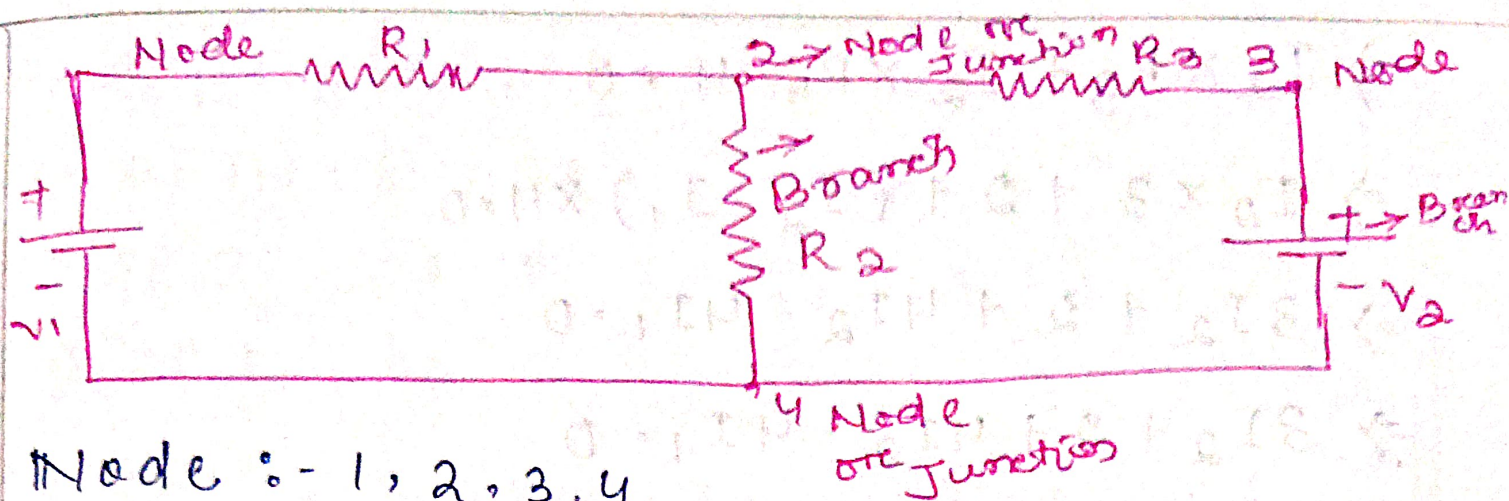
⇒ It is a equipotential point at which two or more circuit elements are joined together that is called node.

Junction :-

⇒ It is that a point of a network where three or more circuit elements are joined.

Branch :-

⇒ It is a part of a network lies between Junction point.



Node :- 1, 2, 3, 4

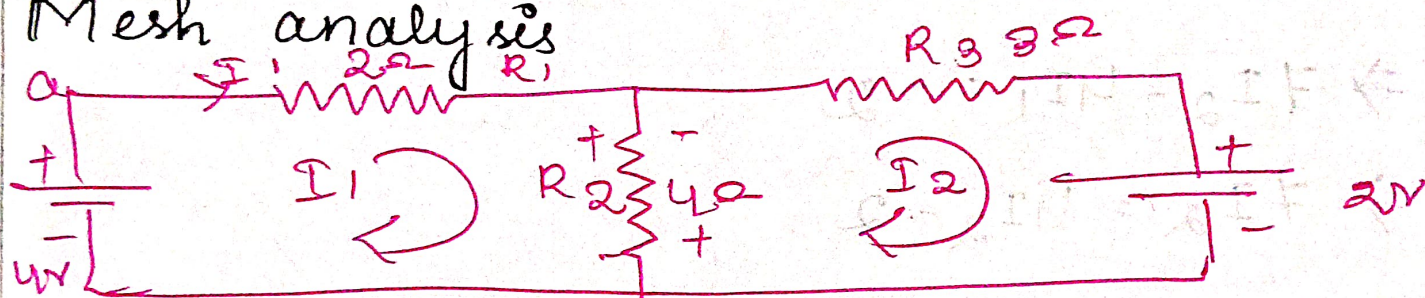
Junction - 2, 4

Branch = (1, 2), (1, 4), (2, 3), (3, 4), (2, 4)

Mesh = 2 (1, 2, 4) (2, 3, 4)

loop = 3 (1, 2, 4) (2, 3, 4) (1, 2, 3, 4)

Mesh analysis



A $\rightarrow$ Mesh -

apply KVL in Mesh-1 (a-b-d-a)

$$I_1 \times R_1 + I_1 \times R_2 - V = 0$$

$$\Rightarrow I_1 \times 2 + (I_1 - I_2) 4 - 4 = 0$$

$$\Rightarrow 2I_1 + 4I_1 - 4I_2 - 4 = 0$$

$$\Rightarrow 6I_1 - 4I_2 = 4 \quad \text{--- (1)}$$

apply KVL in Mesh-2 (b-c-d-b)

$$\Rightarrow I_2 \times R_3 + I_2 \times R_4 - 4 = 0$$

$$\Rightarrow I_2 \times 3 + 2 + (I_2 - I_1) \times 4 = 0$$

$$\Rightarrow 3I_2 + 2 + 4I_2 - 4I_1 = 0$$

$$\Rightarrow 3I_2 + 2 + 4I_2 - 4I_1 = 0$$

$$\Rightarrow 7I_2 - 4I_1 + 2 = 0$$

$$\Rightarrow 7I_2 - 4I_1 = -2 \quad \text{--- (ii)}$$

Consider eqn (ii)

$$7I_2 - 4I_1 = -2$$

$$\Rightarrow 7I_2 - 4I_1 = -2$$

$$\Rightarrow 7I_2 = 4I_1 - 2$$

$$\Rightarrow I_2 = \frac{4I_1 - 2}{7} \quad \text{--- (iii)}$$

Put the value of I_2 in eqn (i)

$$6I_1 - 4 \times \frac{4I_1 - 2}{7} = 4$$

$$\Rightarrow 6I_1 - \frac{16I_1 + 8}{7} = 4$$

$$\Rightarrow \frac{42I_1 - 16I_1 + 8}{7} = 4$$

$$\Rightarrow 42 I_1 - 16 I_1 + 8 = 28$$

$$\Rightarrow 26 I_1 + 8 = 28$$

$$\Rightarrow 26 I_1 = 28 - 8$$

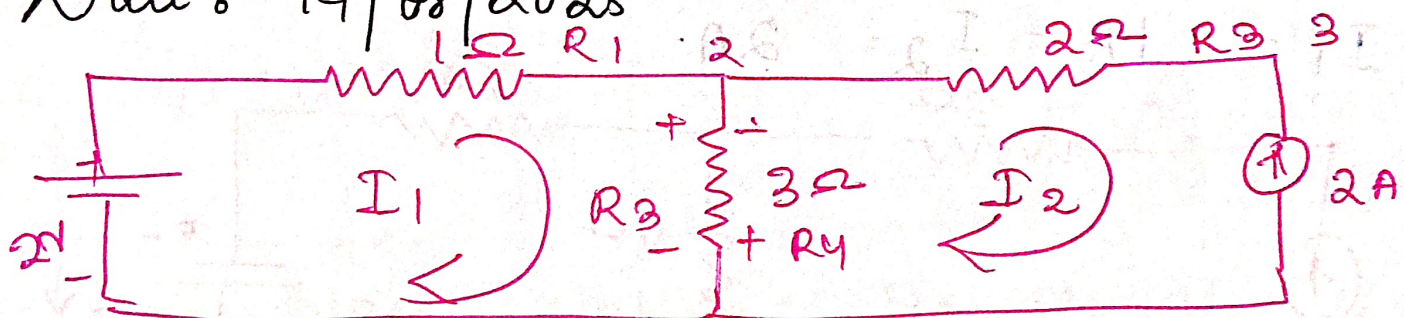
$$\Rightarrow 26 I_1 = 20$$

$$I = \frac{20}{26} \text{ A} = 0.76 \text{ A}$$

Put the value of I_1 in eqⁿ (iii)

$$I_2 = \frac{4 \times 0.76 - 2}{7} = \frac{3.04 - 2}{7} = \frac{1.04}{7} = 0.14 \text{ A}$$

Date: 14/08/2025



Apply KVL in Mesh - 1

$$\Rightarrow I_1 \times 1 + (I_1 - I_2) 3 - 2 = 0$$

$$\Rightarrow 1 I_1 + 3 I_1 - 3 I_2 - 2 = 0$$

$$\Rightarrow 4 I_1 - 3 I_2 = 2 \quad \text{--- (i)}$$

Apply KVL in Mesh - 2

$$\Rightarrow I_2 = -2 \text{ A} \quad \text{--- (ii)}$$

Put the Value of I_2 in Eqⁿ - ①

$$4I_1 - 3I_2 = 2$$

$$\Rightarrow 4I_1 - 3(-2)A = 2$$

$$\Rightarrow 4I_1 + 6 = 2$$

$$\Rightarrow 4I_1 + 6 = 2$$

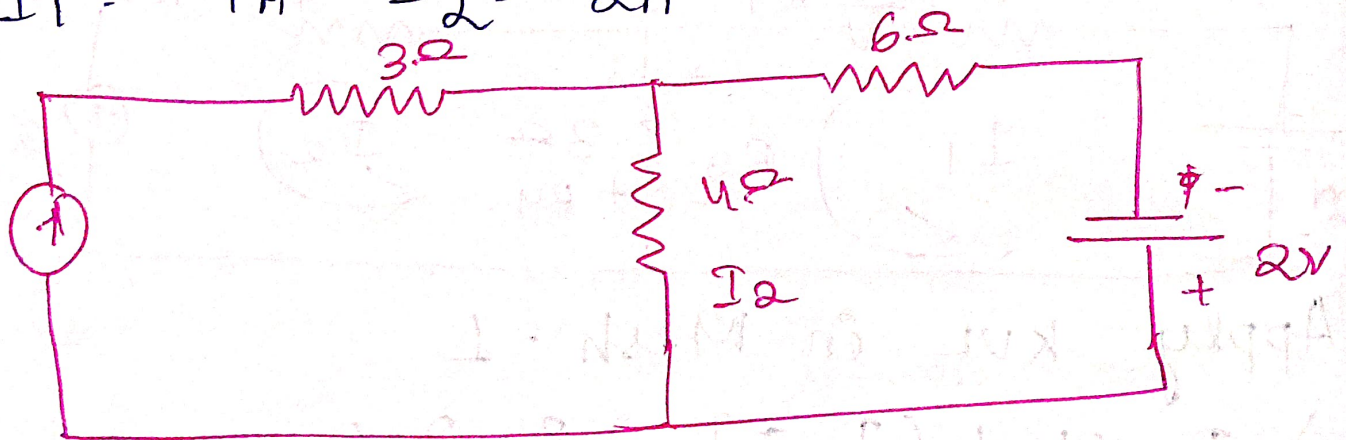
$$\Rightarrow 4I_1 = 2 - 6$$

$$\Rightarrow 4I_1 = -4$$

$$\Rightarrow I_1 = \frac{-4}{4} = -1A$$

$$I_1 = -1A - I_2 = -2A$$

2)



Apply KVL in Mesh - ①

$$\Rightarrow I_1 = 3A \quad \text{--- ①}$$

Apply KVL in Mesh - ②

$$\Rightarrow I_2 \times 6 = 2 + (I_2 - I_1) \times 4$$

$$\Rightarrow 6I_2 - 2 + 4I_2 - 4I_1 = 0$$

$$\Rightarrow 10I_2 - 4I_1 = 2 \quad \text{--- ②}$$

Putting the value of I_1 in Eqn ⑪

$$10 I_2 - 4(3) = 2$$

$$\Rightarrow 10 I_2 - 12 = 2$$

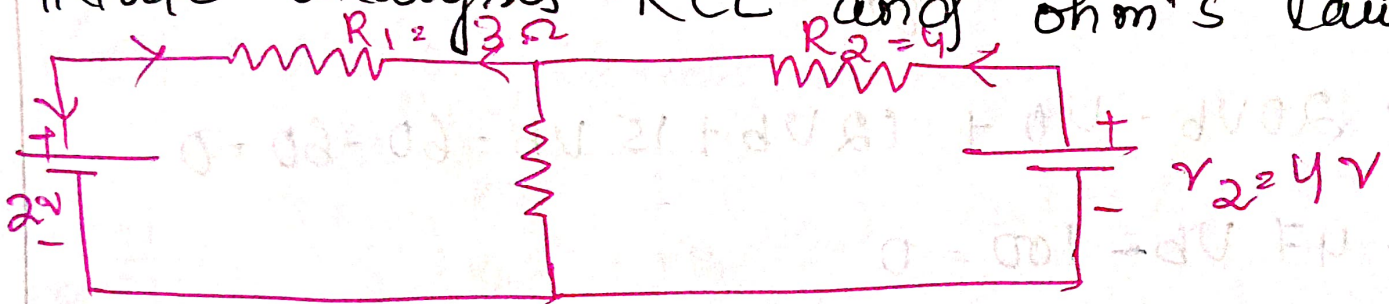
$$\Rightarrow 10 I_2 - 12 = 2$$

$$\Rightarrow 10 I_2 = 2 + 12$$

$$\Rightarrow 10 I_2 = 14$$

$$\Rightarrow I_2 = \frac{14}{10} = 1.4 \text{ A.}$$

Node analysis KCL and ohm's law



find Node voltage V_a, V_b, V_c using
Nodal analysis.

No of Node = 4

apply Nodal at ' V_a ' Node

$$V_a = V_1$$

apply Nodal at ' V_c ' Node

$$V_c = 4 \text{ V}$$

$$V_c = 4V$$

apply Nodal at ' V_b '

$$\frac{V_b - V_a}{R_1} + \frac{V_b - 0}{R_3} + \frac{V_b - V_c}{R_2} = 0$$

$$\Rightarrow \frac{V_b - 2}{3} + \frac{V_b}{5} + \frac{V_b - 4}{4} = 0$$

$$\Rightarrow \frac{20(V_b - 2) + 12V_b + 15(V_b - 4)}{60} = 0$$

$$\Rightarrow 20V_b - 40 + 12V_b + 15V_b - 60 - 60 = 0$$

$$\Rightarrow 47V_b - 100 = 0$$

$$\Rightarrow 47V_b = 100$$

$$\Rightarrow V_b = \frac{100}{47} = 2.12V$$

2.2

Network Theorem :-

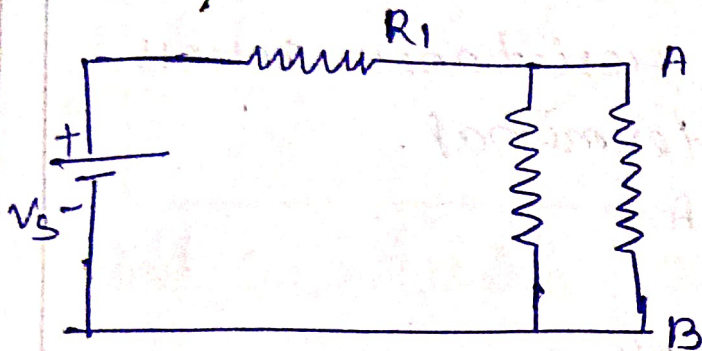
Thevenin's Theorem :-

Statement :-

$\Rightarrow$ Any two terminal by lateral linear DC circuit can be replaced by an equivalent circuit consisting

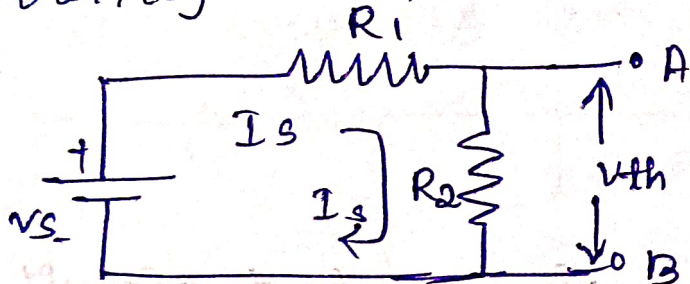
of a voltage source and a series resistance.

Explanation: $\rightarrow$



Step - 1

Remove load Resistance ' R_L ' and calculate open circuit or Thevenin's equivalent voltage ' V_{th} ' across A & B.



apply KVL in the close loop

$$I_s \times R_1 + I_s \times R_2 - V_s = 0$$

$$\Rightarrow I_s R_1 + I_s R_2 = V_s$$

$$\Rightarrow I_s (R_1 + R_2) = V_s$$

$$\Rightarrow I_s = \frac{V_s}{R_1 + R_2}$$

$$R_2 \parallel V_{th}$$

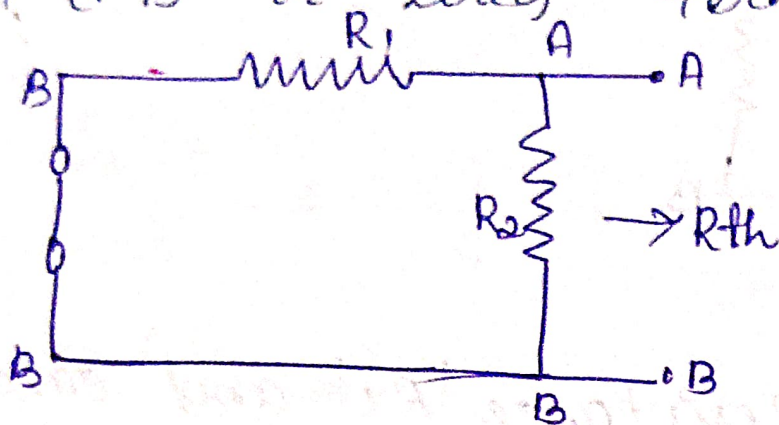
So voltage is same

$$V_{th} = I_s \times R_2$$

$$V_{th} \rightarrow \frac{V_s}{R_1 + R_2} \times R_2$$

Step-2

Calculate equivalent resistance across A & B or load terminal.

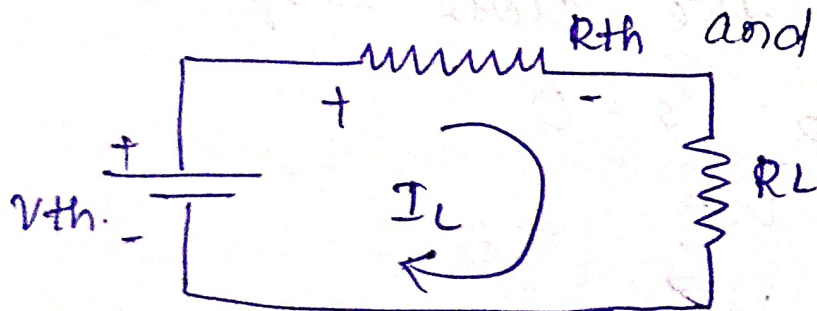


$$R_{th} = R_1 \parallel R_2$$

$$R_{th} = \frac{R_1 \times R_2}{R_1 + R_2}$$

Step-3

Draw the thevenin's equivalent circuit and connect the RL across load.



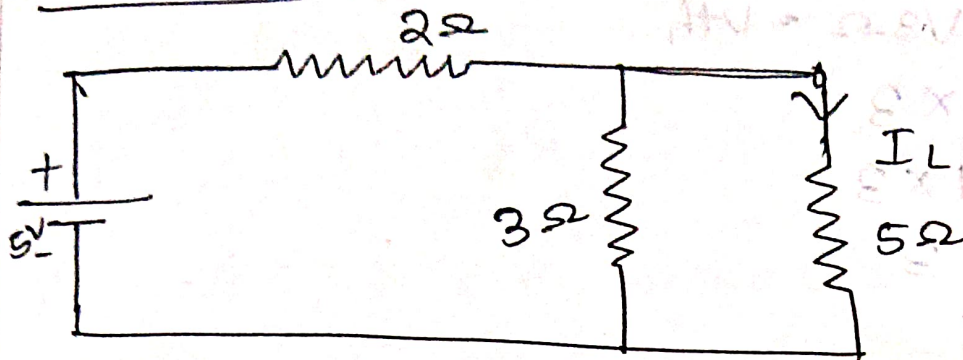
Apply KVL

$$I_L R_{th} + I_L R_L - V_{th} = 0$$

$$\Rightarrow I_L (R_{th} + R_L) = V_{th}$$

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

Question :-

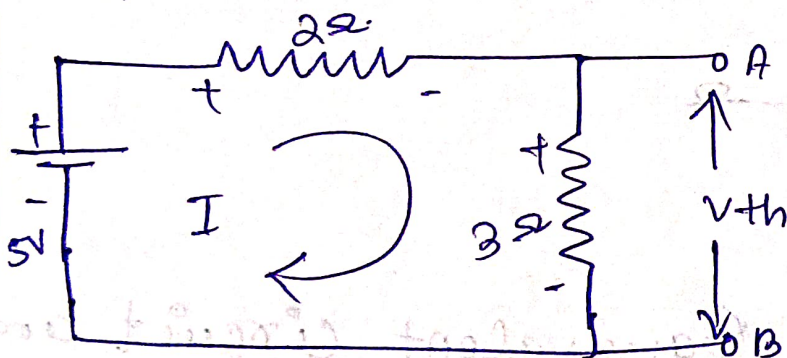


Find I_L Using Thevenin's Theorem?

Apply KVL in the clo

A → Step - 1

Remove load resistance ' R_L ' and calculate open circuit or Thevenin's equivalent voltage ' V_{th} ' across A and B.



Apply KVL in the close loop

$$I \times R_1 + I \times R_2 - V = 0$$

$$\Rightarrow I \times 2 + I \times 3 - 5 = 0$$

$$\Rightarrow 2I + 3I - 5 = 0$$

$$\Rightarrow 2I + 3I - 5 = 0$$

$$\Rightarrow 5I - 5 = 0$$

$$\Rightarrow 5I = 5$$

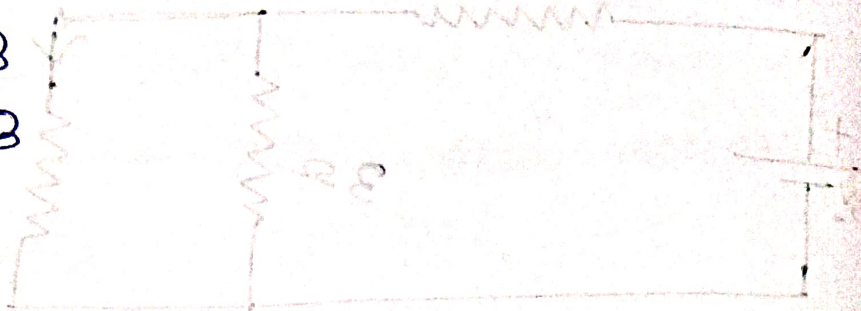
$$\Rightarrow I = \frac{5}{5} = 1$$

$$V_{th} = \sqrt{3} \Omega$$

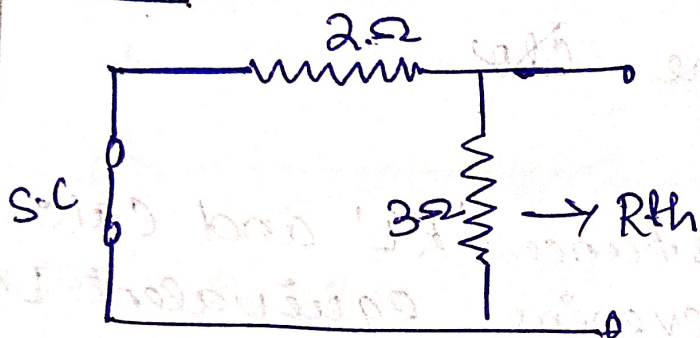
$$V_{3\Omega} \parallel V_{th} = V_{3\Omega} = V_{th}$$

$$\begin{aligned} \text{So } V_{th} &= I \times 3 \\ &= 1 \times 3 \\ &= 3 \end{aligned}$$

$$V_{th} = 3V$$



Step - 2 Draw thevenin equivalent circuit

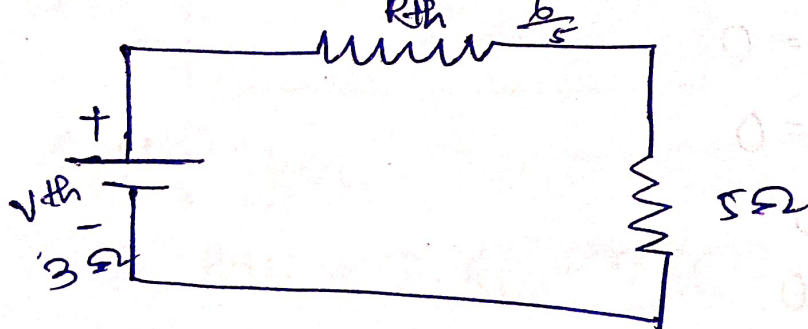


$$\begin{aligned} R_{th} &= 2 \parallel 3 \\ &= \frac{2 \times 3}{2 + 3} = \frac{6}{5} \Omega \end{aligned}$$

Step - 3

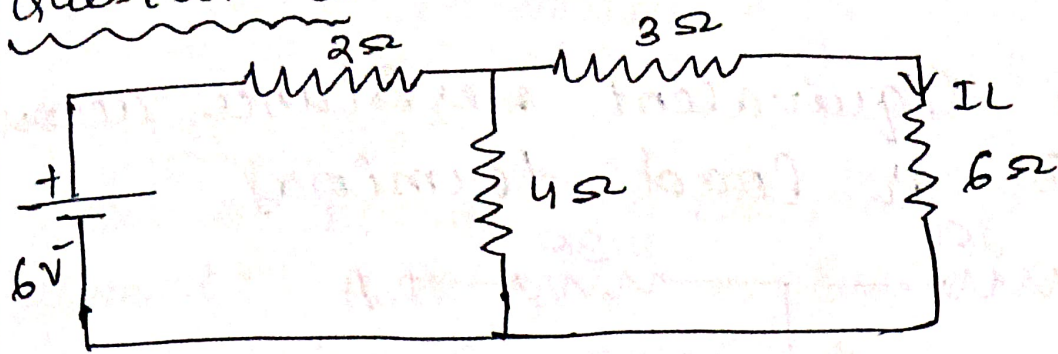
Draw Thevenin's Equivalent circuit and

Calculate I_L



$$\begin{aligned} I_L &= \frac{V_{th}}{R_{th} + R_L} = \frac{3}{\frac{6}{5} + 5} = \frac{3}{1.2 + 5} = \frac{3}{6.2} = \frac{3}{6.2} \\ &= 0.48A \end{aligned}$$

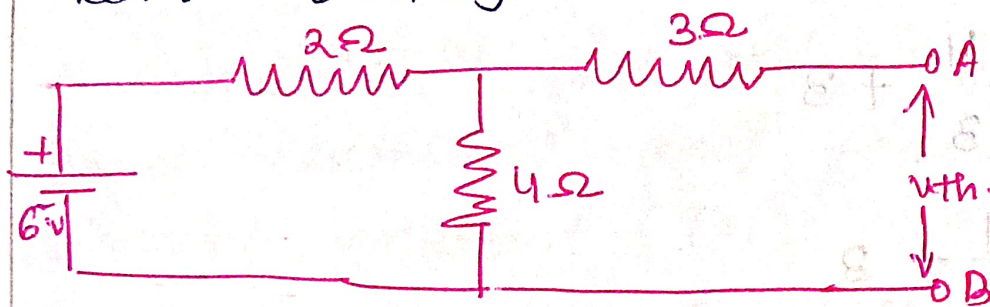
Question-2



Calculate I_L or current through 6Ω resistance using Thevenin's Theorem?

Step-1

Remove load resistance ' R_L ' and calculate open circuit or Thevenin's equivalent voltage ' V_{th} ' across A & B.



Apply KVL

$$I \times 2 + I \times 4 - 6 = 0$$

$$\Rightarrow 2I + 4I - 6 = 0$$

$$\Rightarrow 6I = 6$$

$$\Rightarrow I = \frac{6}{6} = 1A$$

$$R_2 \parallel V_{th}$$

$$\Rightarrow V_{4\Omega} = V_{th}$$

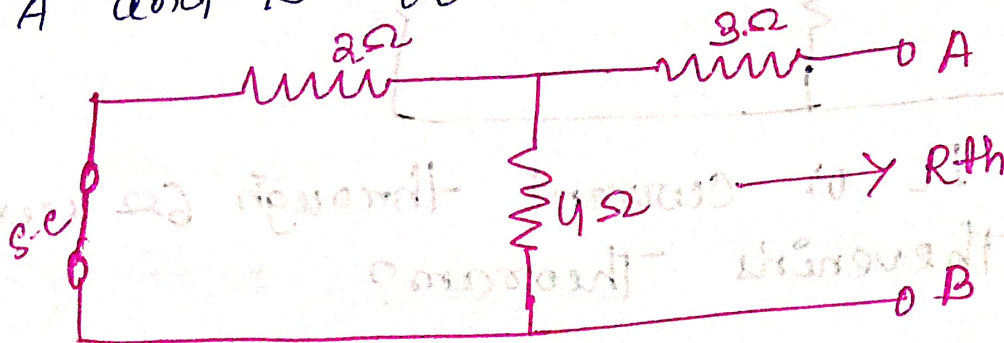
$$\Rightarrow V_{4\Omega} = I \times 4$$

$$\Rightarrow 1 \times 4 = 4V$$

$$V_{th} = 4V$$

Step - 2

Calculate equivalent resistance across A and B or load terminal



$$R_{th} \Rightarrow (2 \parallel 4) + 3$$

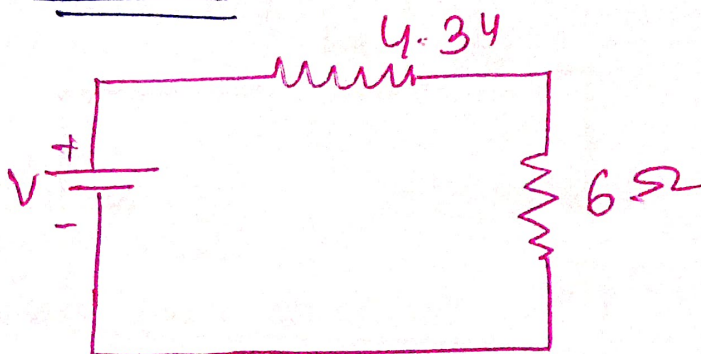
$$\Rightarrow \frac{2 \times 4}{2 + 4} + 3$$

$$\Rightarrow \frac{8}{6} + 3$$

$$\Rightarrow \frac{4}{3} + 3$$

$$\Rightarrow 1.34 + 3 = 4.34\Omega$$

Step - 3



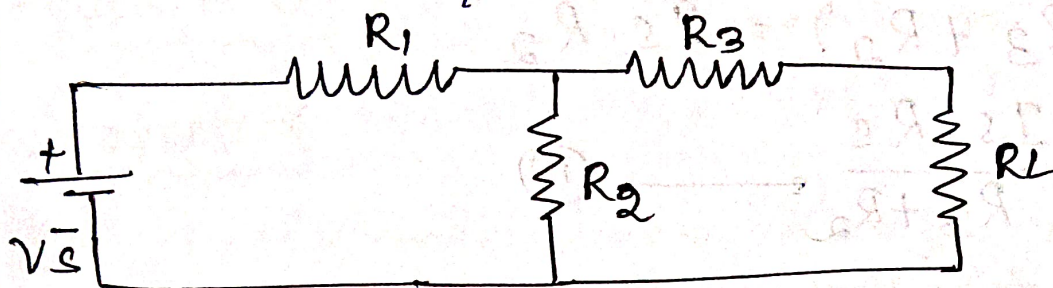
$$I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{4}{4.34 + 6} = \frac{4}{10.34} = 0.34$$

$$I_L = 0.34A$$

Norton's Theorem :-

Statement :-

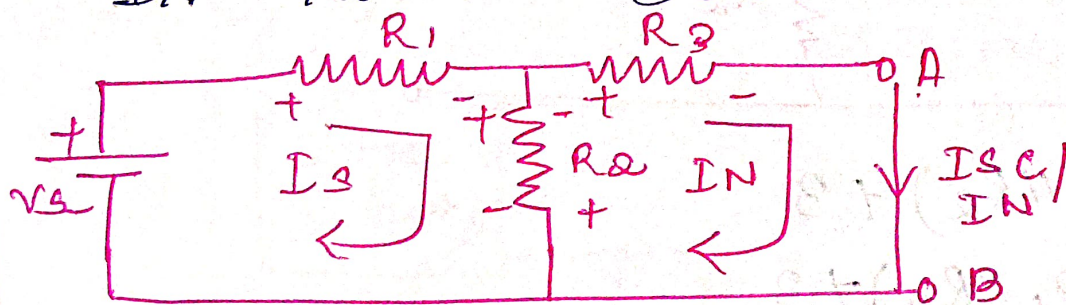
→ In a linear bilateral DC Network elements can be replaced by an equivalent circuit consisting of a current source in parallel with a resistance.



Step-1

Remove ' R_L ' and short circuit the load terminal and calculate short circuit current (I_N)

I_N = Norton's Current



apply KVL in Mesh - 1

$$I_s R_1 + (I_s - I_N) R_2 - V_s = 0$$

$$\Rightarrow I_s R_1 + I_s R_2 - I_N R_2 = V_s$$

$$\Rightarrow I_s (R_1 + R_2) - I_N R_2 = V_s$$

$$\Rightarrow I_s (R_1 + R_2) = V_s + I_N R_2$$

$$\Rightarrow I_s = \frac{V_s + I_N R_2}{R_1 + R_2} \quad \text{--- (1)}$$

apply KVL in Mesh-2

$$I_N \cdot R_3 + (I_N - I_s) \cdot R_2 = 0$$

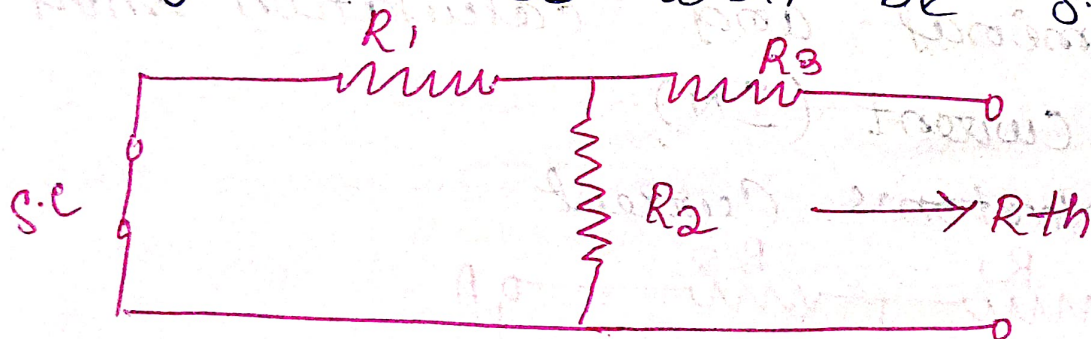
$$\Rightarrow I_N \cdot R_3 + I_N \cdot R_2 - I_s \cdot R_2 = 0$$

$$\Rightarrow I_N (R_3 + R_2) = I_s \cdot R_2$$

$$\Rightarrow I_N = \frac{I_s \cdot R_2}{R_3 + R_2} \quad \text{--- (11)}$$

Step-2

Calculate equivalent resistance R_{th}
voltage source will be s.c.

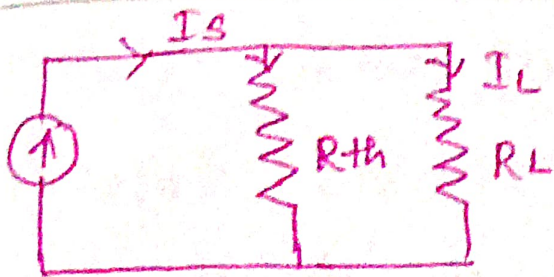


$$R_{th} = (R_1 \parallel R_2) + R_3$$

$$R_{th} = (R_1 \parallel R_2) + R_3$$

Step-3

Draw the Norton's equivalent circuit



$$I_L = I_S \times \frac{R_{Th}}{R_{Th} + R_L}$$

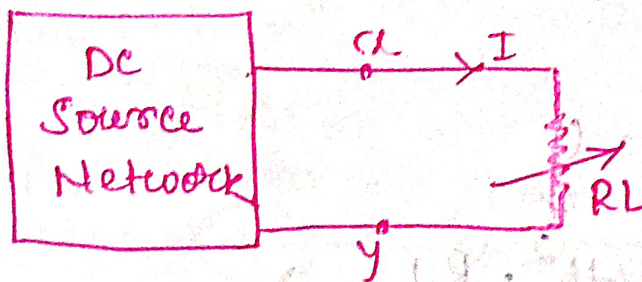
Maximum Power Transfer Theorem

Statement

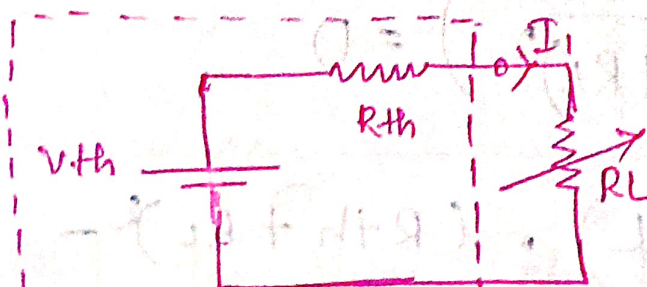
⇒ A resistance load being connected to a dc network receives maximum power when the load resistance is equal to the internal resistance of the source network as seen from the load terminals.

$$R_{Th} = R_L$$

Explanation ⇒



R_L = Variable resistance



$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

$$P_L = I_L^2 \cdot R_L$$

$$\Rightarrow \left(\frac{V_{th}}{R_{th} + R_L} \right)^2 \cdot R_L$$

$$R_L = \frac{V_{th}^2 \cdot R_L}{(R_{th} + R_L)^2} \quad \text{--- (1)}$$

$$V = I \cdot R \quad \text{Power}$$

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

$$P = I \cdot V$$

$$= I \cdot R \cdot I$$

$$P = I^2 R$$

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

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

P_L can be maximum by varying R_L and maximum power can be delivered when.

$$\frac{dP_L}{dR_L} = 0$$

$$\Rightarrow \frac{d}{dR_L} \left(\frac{V_{th}^2 \cdot R_L}{(R_{th} + R_L)^2} \right) = 0$$

$$\Rightarrow \frac{d}{dR_L} \left(V_{th}^2 \cdot R_L \right) \cdot (R_{th} + R_L)^2 - \frac{V_{th}^2 \cdot R_L \cdot \frac{d}{dR_L} (R_{th} + R_L)^2}{((R_{th} + R_L)^2)^2} = 0$$

$$\Rightarrow V_{th}^2 (R_{th} + R_L)^2 - V_{th}^2 \cdot R_L \cdot 2(R_{th} + R_L) = 0$$

$$\Rightarrow V_{th}^2 (R_{th} + R_L) [(R_{th} + R_L) - 2R_L] = 0$$

$$\Rightarrow R_{th} + R_L - 2R_L = 0$$

$$\Rightarrow R_{th} - R_L = 0 \Rightarrow \boxed{R_{th} = R_L}$$

Maximum power can be obtained

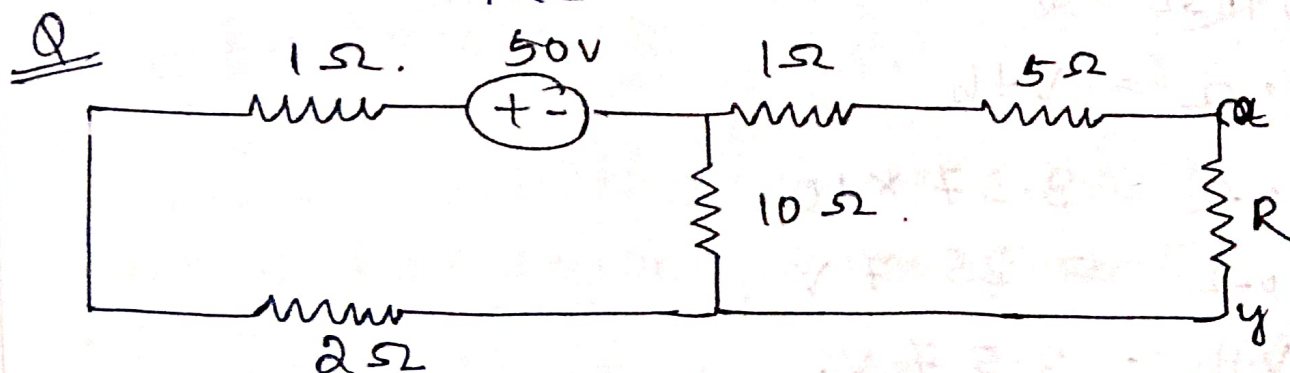
$$P_{max} = \frac{V_{th}^2 \cdot R_L}{(R_{th} + R_L)^2}$$

$$\Rightarrow \frac{V_{th} \cdot R_L}{(R_L + R_L)^2}$$

$$\Rightarrow \frac{V_{th}^2 \cdot R_L}{(2R_L)^2}$$

$$\Rightarrow \frac{V_{th}^2 \cdot R_L}{4 \cdot R_L^2}$$

$$P_{max} = \frac{V_{th}^2}{4R_L}$$

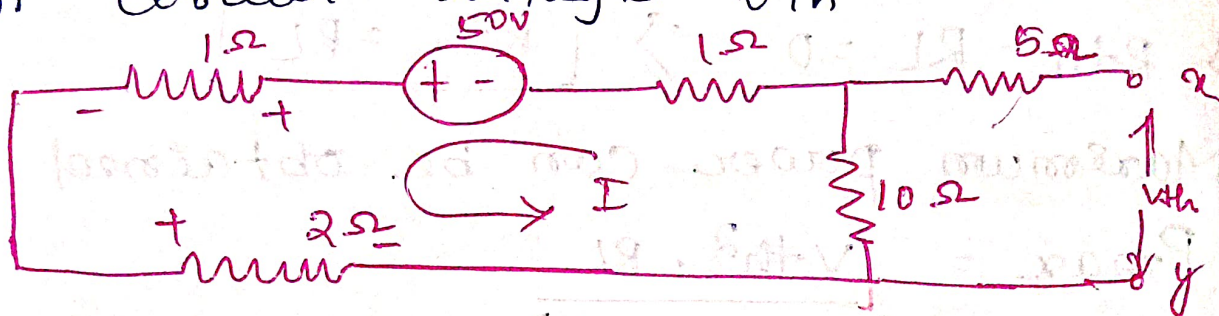


Find the Value of R and maximum power to be transfer source to load?

A $\rightarrow$ $R_L = R$ load resistance

Step - 1

Remove load resistance ' R_L ' & calculate open circuit voltage ' V_{th} '



apply KVL

$$\Rightarrow I \times 1 + 2 \cdot I + 10 \cdot I + I \cdot 1 - 50 = 0$$

$$\Rightarrow I + 2I + 10I + I = 50$$

$$\Rightarrow 14I = 50$$

$$\Rightarrow I = \frac{50}{14}$$

$$I = 3.57 \text{ A}$$

~~$V_{10\Omega} = V_{th}$~~

~~$V_{10\Omega} = V$~~

$$V_{10\Omega} = V_{th}$$

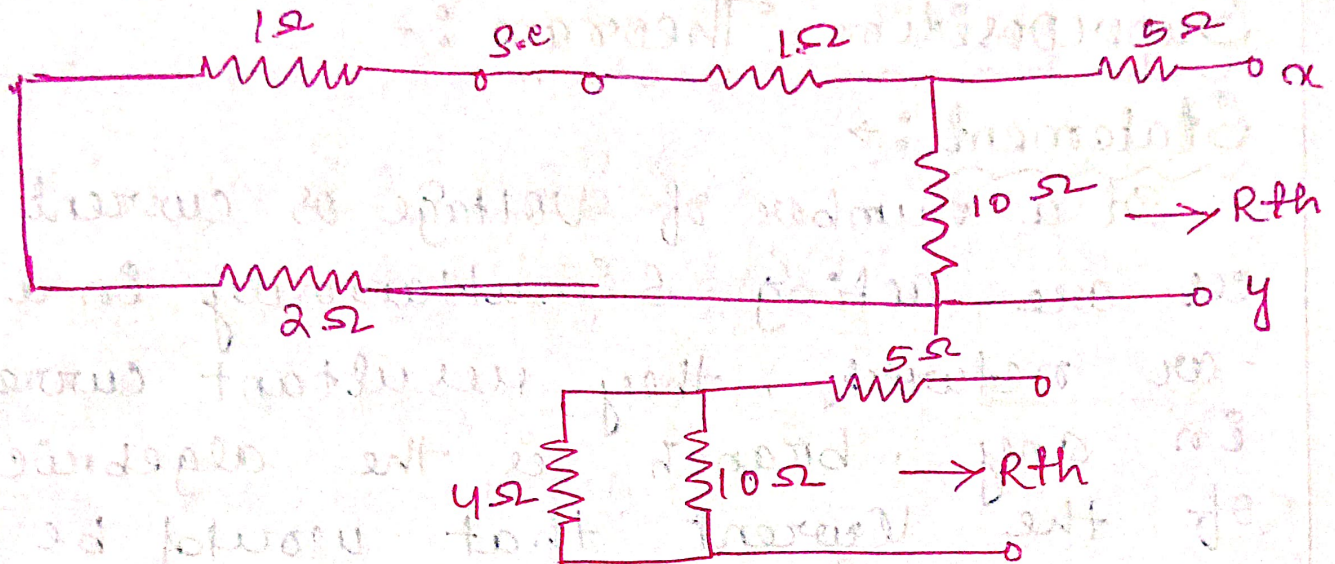
$$V_{10\Omega} = 3.57 \times 10$$

$$V_{10\Omega} = 35.7 \text{ V}$$

$$V_{th} = 35.7 \text{ V}$$

Step-2

Calculate Total equivalent resistance R_{th} across the load and Voltage Source will S.C.



$$R_{th} = (4 \parallel 10) + 5 \Omega$$

$$\Rightarrow \frac{4 \times 10}{4 + 10} + 5$$

$$\Rightarrow \frac{40}{14} + 5$$

$$\Rightarrow 2.85 + 5$$

$$R_{th} = 7.85 \Omega$$

Step-3

apply maximum power Transfer Theorem
-fore $R_{th} = R_L$

$$R = 7.85 \Omega$$

$$P_{max} = \frac{V_{th}^2}{4 \cdot R_L} = \frac{(3.5.7)^2}{4 \times 7.85}$$

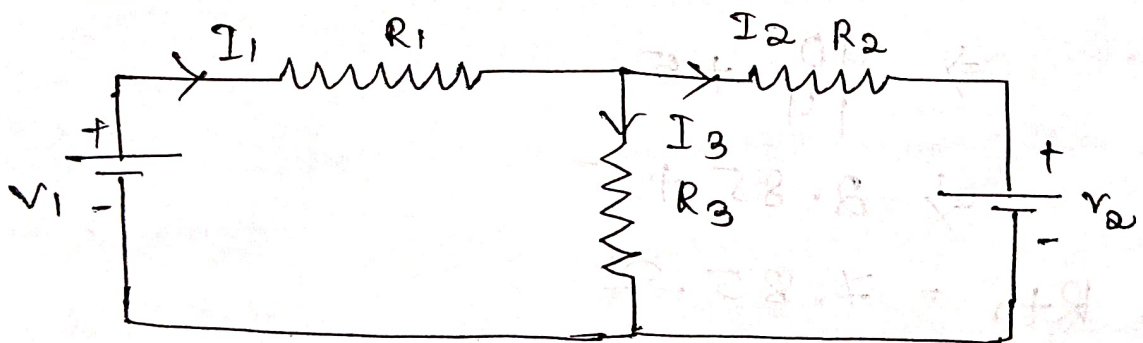
$$\Rightarrow \frac{1274 \cdot 49}{31.4} = 40.50 \text{ watt}$$

$$P_{\text{max}} = 40.58 \text{ watt}$$

Superposition Theorem :-

Statement :->

If a number of Voltage or current sources are acting simultaneously in a linear network, the resultant current in any branch is the algebraic sum of the current that would be produced in it, when each source acts alone replacing all other independent source by their internal resistance.



find the current flowing through ' R_3 ' resistance using Superposition theorem?

A $\Rightarrow$ Consider the voltage ' V_1 ' & ' V_2 ' will be short circuit.

apply KVL in Mesh (1)

$$I_1' \cdot R_1 + (I_1' - I_2') \cdot R_3 - V_1 = 0$$

$$\Rightarrow I_1' \cdot R_1 + I_1' \cdot R_3 - I_2' R_3 = V_1$$

$$\Rightarrow I_1' (R_1 + R_3) - I_2' R_3 = V_1 \quad \text{--- (1)}$$

Apply KVL in Mesh (2)

$$I_2' \cdot R_2 + (I_2' - I_1') \cdot R_3 = 0$$

$$\Rightarrow I_2' \cdot R_2 + I_2' \cdot R_3 - I_1' \cdot R_3 = 0$$

$$\Rightarrow I_2' (R_2 + R_3) - I_1' \cdot R_3 = 0 \quad \text{--- (2)}$$

$$\boxed{I_3' = I_1' - I_2'}$$

Consider the Voltage ' V_2 ' & ' V_1 ' voltage Source will be short circuit

Apply KVL in Mesh - (1)

$$I_1'' \cdot R_1 + (I_1'' - I_2'') \cdot R_3 = 0$$

$$\Rightarrow I_1'' \cdot R_1 + I_1'' \cdot R_3 - I_2'' \cdot R_3 = 0$$

$$\Rightarrow I_1'' \cdot (R_1 + R_3) - I_2'' \cdot R_3 = 0 \quad \text{--- (1)}$$

Apply KVL in Mesh - ②

$$I_2'' \cdot R_2 + (I_2'' - I_1'') \cdot R_3 - V_2 = 0$$

$$I_2'' \cdot R_2 + I_2'' \cdot R_3 - I_1'' \cdot R_3 = V_2$$

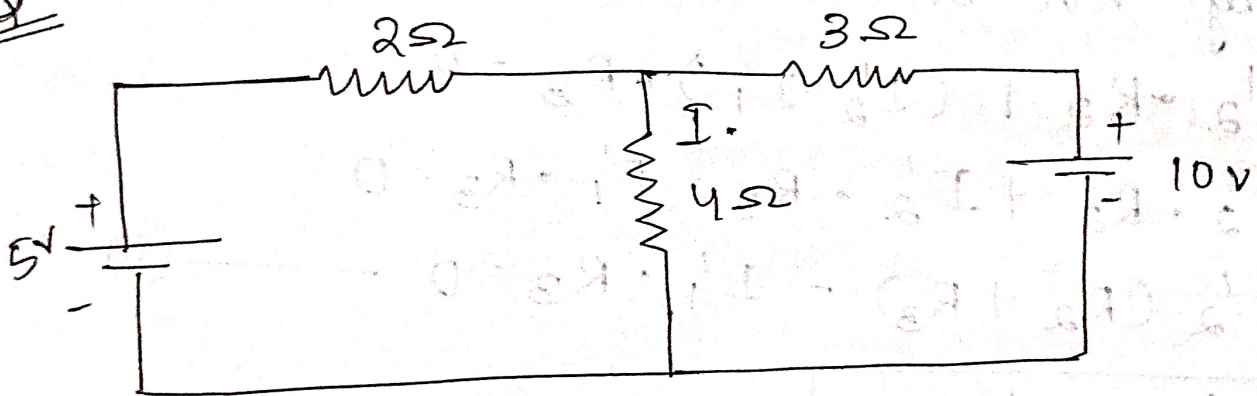
$$\Rightarrow I_2'' (R_2 + R_3) - I_1'' \cdot R_3 = V_2 \quad \text{--- ③}$$

$$I_3'' = I_2'' - I_1''$$

As super position theorem

$$I_2 = I_2' + I_2''$$

Q



Find the current through 4Ω resistance using Superposition Theorem?

A $\Rightarrow$ Consider the 5V voltage source then 10V voltage source will be short circuit.

apply KVL in Mesh - ①

$$I_1 \cdot 2 + (I_1 - I_2) \cdot 4 - 5 = 0$$

$$\Rightarrow 2I_1 + 4I_1 - 4I_2 = 5$$

$$\Rightarrow 6I_1 - 4I_2 = 5 \quad \text{--- ①}$$

apply KVL in Mesh - ②

$$I_2 \cdot 3 + (I_2 - I_1) \cdot 4 = 0$$

$$\Rightarrow 3I_2 + 4I_2 - 4I_1 = 0$$

$$\Rightarrow 7I_2 - 4I_1 = 0 \quad \text{--- ②}$$

Compare eqn ① & eqn ②

$$4 \times 6I_1 - 4I_2 = 5$$

$$6 \times 4I_1 + 7I_2 = 0$$

add eq ① & ②

$$\begin{array}{r} 24I_1 - 16I_2 = 20 \\ -24I_1 + 42I_2 = 0 \\ \hline \end{array}$$

$$26I_2 = 20$$

$$I_2 = \frac{20}{26}$$

$$\boxed{I_2 = 0.76 \text{ A}}$$

Put the Value of I_2 in eqn ②

$$7I_2 - 4I_1 = 0$$

$$\Rightarrow 7 \times 0.76 - 4I_1 = 0$$

$$\Rightarrow 4I_1 = 5.32 \Rightarrow I_1 = \frac{5.32}{4} \quad \boxed{I_1 = 1.33 \text{ A}}$$

apply KCL at 'O'

$$\sum \text{outgoing} = \sum \text{incoming}$$

$$I_2 + I' = I_1$$

$$I'_2 = (I_1 - I_2)$$

$$= 1.33 - 0.76$$

$$\boxed{I' = 0.57 \text{ A}}$$

Consider 10 V voltage source & 5V voltage source will be short circuit.

apply KVL in Mesh - ①

$$I_4 \cdot 2 + (I_4 - I_2) \cdot 4 = 0$$

$$\Rightarrow 2I_4 + 4I_4 - 4I_2 = 0$$

$$\Rightarrow 6I_4 - 4I_2 = 0 \quad \text{————— ①}$$

apply KVL in Mesh - ②

$$I_3 \cdot 3 + (I_3 - I_4) \cdot 4 - 10 = 0$$

$$\Rightarrow 3I_3 + 4I_3 - 4I_4 = 10$$

$$\Rightarrow 7I_3 - 4I_4 = 10$$

$$\Rightarrow -4I_4 + 7I_3 = 10 \quad \text{————— ②}$$

compare eqn ① & ②

$$4 \times (6I_4 - 4I_3 = 0)$$

$$6 \times (4I_4 + 7I_3 = 10)$$

$$24I_4 - 16I_3 = 0$$

$$+ \quad -24I_4 + 42I_3 = 10$$

$$+ 26I_3 = 10$$

$$I_3 = \frac{10}{26} = 0.38$$

$$\boxed{I_3 = 0.38 \text{ A}}$$

Put the value of I_3 in Eqn ① — ①

$$6I_4 - 4 \times 0.38 = 0$$

$$\Rightarrow 6I_4 - 1.52 = 0$$

$$\Rightarrow 6I_4 = 1.52$$

$$\Rightarrow I_4 = \frac{1.52}{6}$$

$$\boxed{I_4 = 0.25 \text{ A}}$$

apply KCL

$$I_3 = I_4 + I''$$

$$I'' = I_3 - I_4$$

$$= 0.38 - 0.25$$

$$\boxed{I'' = 0.13}$$

apply Superposition Theorem

$$I = I' + I''$$
$$= 0.57 + 0.77$$

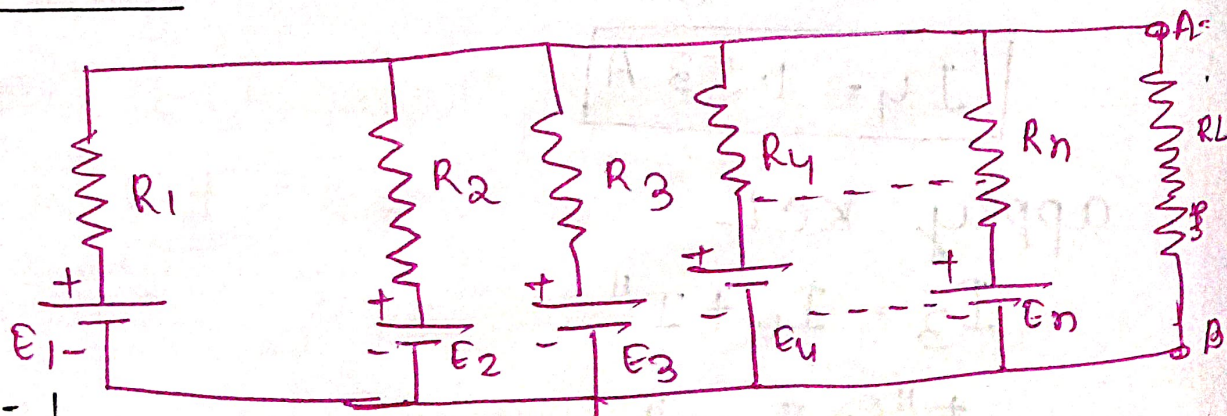
$$I = 1.34 \text{ A}$$

Millman's Theorem :-

Statement :-

When a no. of Voltage Source ($V_1, V_2, \dots, V_n$) are in parallel having internal resistance ($R_1, R_2, \dots, R_n$) respectively the arrangement can be replaced by a single equivalent voltage source ' V ' in series with an equivalent voltage source ' V ' in series with an equivalent series resistance ' R ' as given below.

Explanation

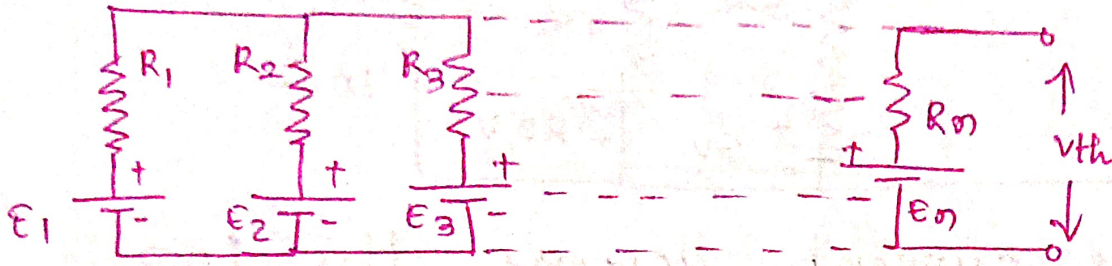


Step - 1

Remove Load Resistance R_L

Step-2

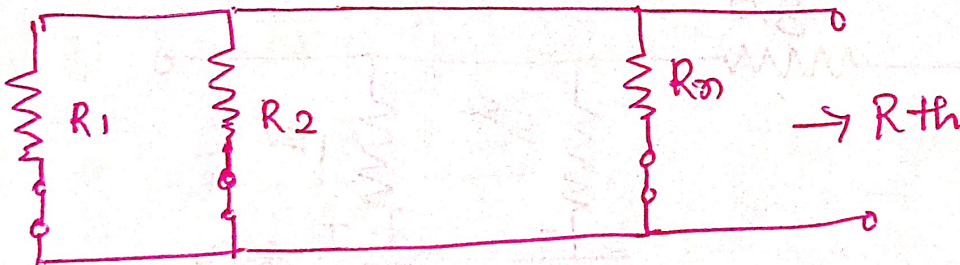
Calculate open circuit voltage ' V_{th} '



$$V_{th} = \pm \frac{E_1}{R_1} \pm \frac{E_2}{R_2} \pm \frac{E_3}{R_3} + \dots + \frac{E_n}{R_n}$$
$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

Step-3

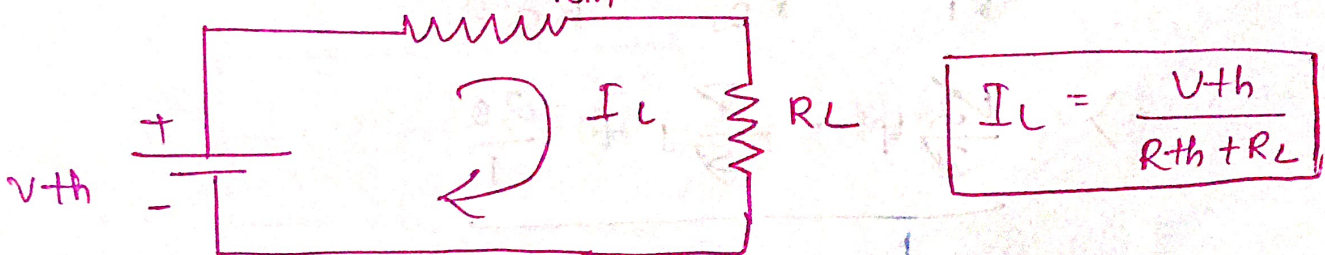
Find the equivalent Resistance across load terminal.



$$\frac{1}{R_{th}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

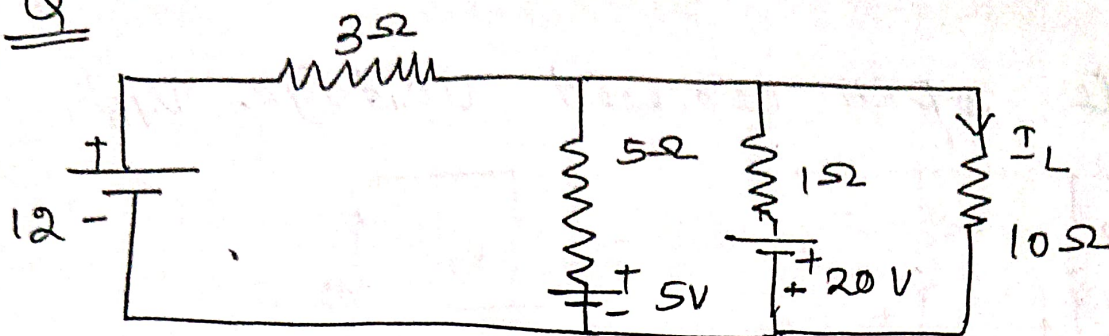
Step-4

Draw thevenin's equivalent circuit



$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

Q



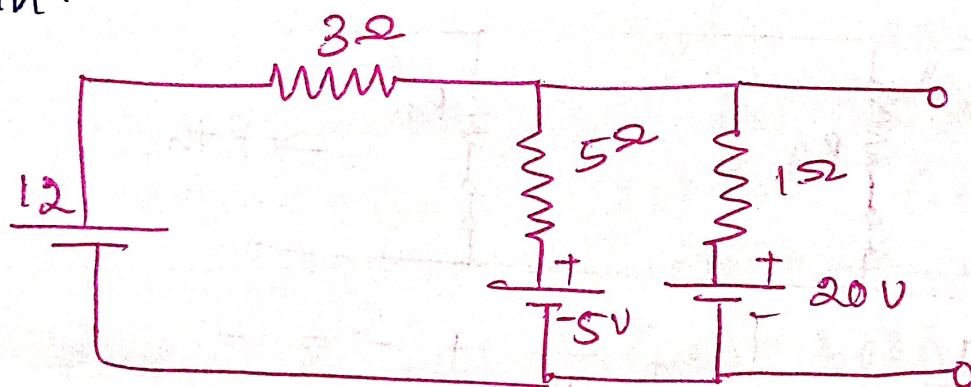
Find the current across the 10 ohm resistance using Millman's Theorem

Ans:-

$$R_L = 10$$

Step-1

Remove load Resistance R_L & calculate V_{th} .



$$V_{th} = \frac{\frac{E_1}{R_1} \pm \frac{E_2}{R_1} \pm \frac{E_3}{R_3} \dots}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots}$$

$$\Rightarrow \frac{\frac{12}{3} - \frac{5}{5} + \frac{20}{1}}{\frac{1}{3} + \frac{1}{5} + \frac{1}{1}}$$

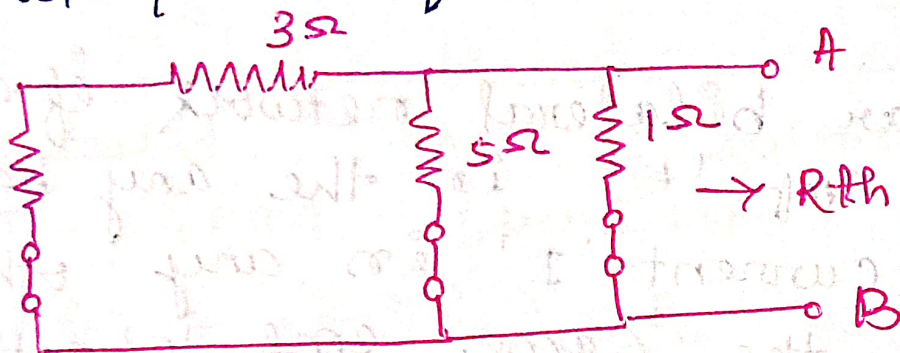
$$\Rightarrow \frac{4 - 1 + 20}{5 + 3 + 15} = \frac{23}{23}$$

$$= \frac{23}{23} = 1$$

$$V_{th} = 15V$$

Step-2

Calculate equivalent resistor



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

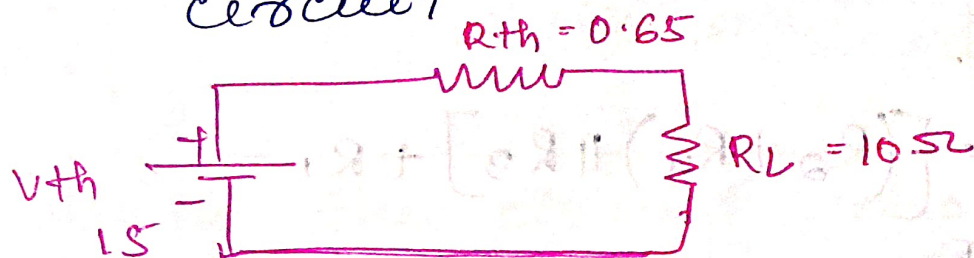
$$\frac{1}{R_{th}} = \frac{1}{3} + \frac{1}{5} + \frac{1}{1}$$

$$\frac{1}{R_{th}} = \frac{5 + 3 + 15}{15}$$

$$\frac{1}{R_{th}} = \frac{23}{15} \quad R_{th} = \frac{15}{23} = 0.65 \Omega$$

Step-3

Draw the thevenin's equivalent circuit



$$R_L = \frac{V_{th}}{R_{th} + R_L} = \frac{15}{0.65 + 10} = \frac{15}{10.65}$$

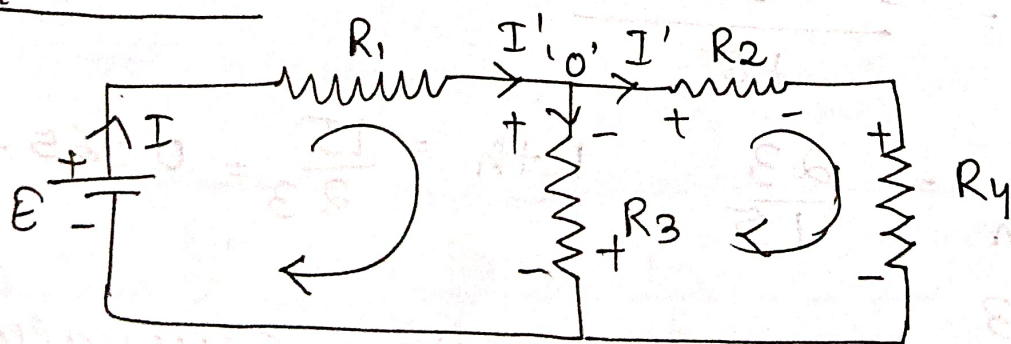
$$I_L = 1.40 \text{ A}$$

Reciprocity Theorem

Statement

In a linear bilateral network if a source of emf 'E' in the any branch produce a current 'I' in any other branch then the same emf 'E' acting in the second branch would produce the same current 'I' in the first branch.

Explanation



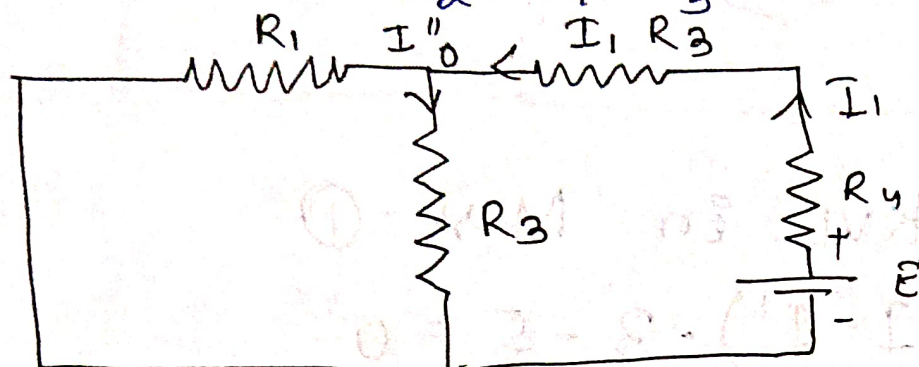
Total equivalent Resistance across Source terminal.

$$R_{eq} = [(R_2 + R_4) \parallel R_3] + R_1$$

$$I = \frac{E}{R_{eq}}$$

Apply current division Rule at 'O'

$$I' = I \times \frac{R_3}{R_2 + R_4 + R_3} \quad \text{--- ①}$$



Calculate Total equivalent Resistance across the load terminal.

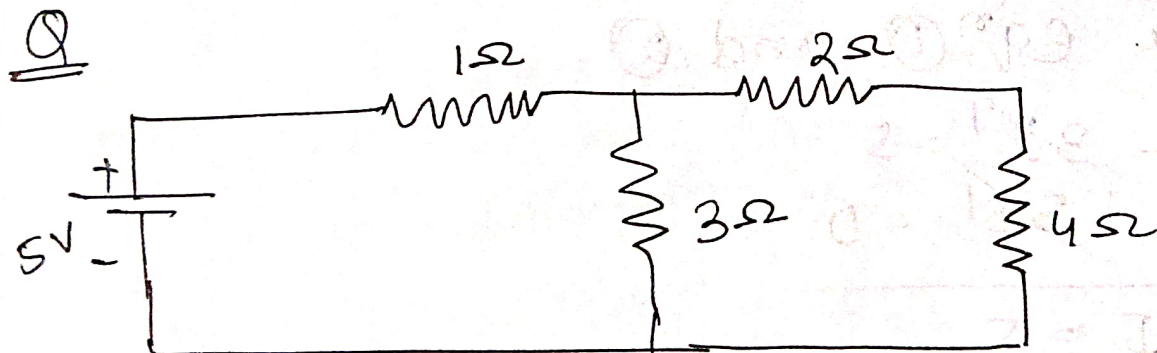
$$R_{eq}' = (R_1 \parallel R_3) + R_2 + R_4$$

$$I_1 = \frac{E}{R_{eq}'}$$

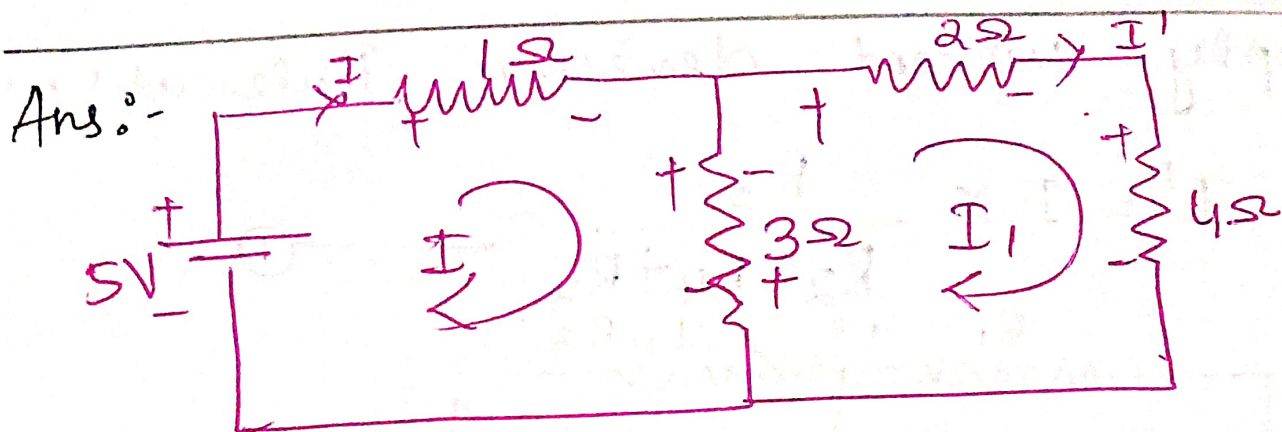
Apply current division Rule at 'O'

$$I'' = I_1 \times \frac{R_3}{R_1 + R_3}$$

According Reciprocity theorem $I' = I''$



Verify the circuit what the Satisfy Reciprocity theorem or not.



apply KVL in Mesh-①

$$I \cdot 1 + (I - I') \cdot 3 - 5 = 0$$

$$\Rightarrow I + 3I - 3I' = 5$$

$$\Rightarrow 4I - 3I' = 5 \quad \text{--- ①}$$

apply KVL in Mesh-②

$$+ 2 \cdot I' + 4 \cdot I' + (I' - I) \cdot 3 = 0$$

$$\Rightarrow 6I' + 3I' - 3I = 0$$

$$\Rightarrow 9I' - 3I = 0$$

$$\Rightarrow 3(3I' - I) = 0$$

$$\Rightarrow 3I' - I = 0 \quad \text{--- ②}$$

Compare eqⁿ ① and ②

$$4I - 3I' = 5$$

$$-I + 3I' = 0$$

$$3I = 5$$

$$I = 5/3 \text{ A}$$

Put the Value of I in eqn ①

$$4I - 3I' = 5$$

$$\Rightarrow 4 \times \frac{5}{3} - 3I' = 5$$

$$\Rightarrow \frac{20}{3} - 3I' = 5$$

$$\Rightarrow 3I' = \frac{20}{3} - 5$$

$$\Rightarrow 3I' = \frac{20 - 15}{3}$$

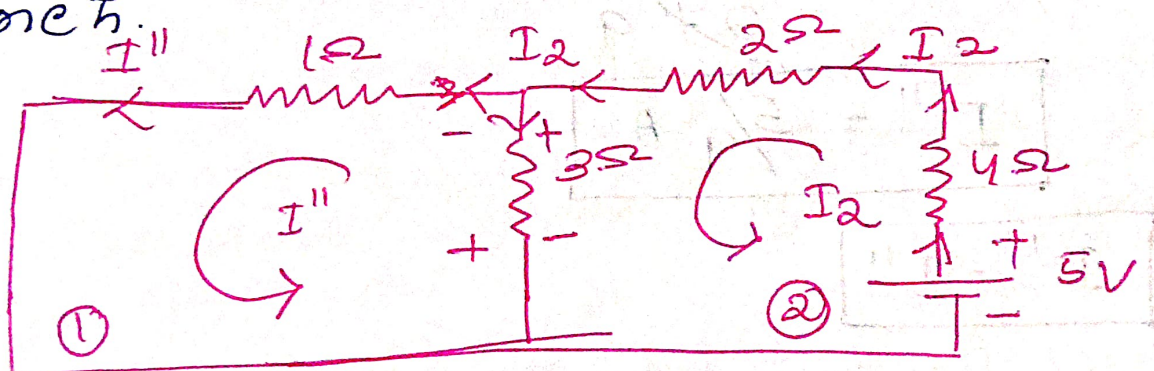
$$\Rightarrow 3I' = \frac{5}{3}$$

$$\Rightarrow I' = \frac{5}{3 \times 3}$$

$$I' = 5/9 \text{ A}$$

Step-2

Interchange the source ($5V$) to Second branch.



apply KVL in Mesh ①

$$I'' \cdot 1 + (I'' - I_2) \cdot 3 = 0$$

$$\Rightarrow I'' + 3I'' - 3I_2 = 0$$

$$\Rightarrow 4I'' - 3I_2 = 0 \quad \text{--- ①}$$

apply KVL in Mesh (2)

$$+4I_2 + 2I_2 + (I_2 - I'') \cdot 3 - 5 = 0$$

$$\Rightarrow 6I_2 + 3I_2 - 3I'' = 5$$

$$\Rightarrow 9I_2 - 3I'' = 5 \quad \text{--- (11)}$$

Compare eqn (1) & (11)

$$3 \times 4I'' - 3I_2 = 0$$

$$4 \times 3I'' + 9I_2 = 5$$

$$\underline{36I'' - 27I_2 = 0}$$

$$\underline{9I'' + 27I_2 = 15}$$

$$27I'' + 0 = 15$$

$$27I'' = \frac{15}{27} \times 15$$

$$I'' = \frac{15}{27} \times 5$$

$$\boxed{I'' = 5/9 \text{ A}}$$

$$\boxed{I' = I''}$$

Hence this circuit satisfy the Reciprocity theorem.