Jaipur Engineering College & Research Centre, Jaipur

Session 2020-21

Subject Notes

Unit-I

Basic Electrical Engineering (2FY3-08)

Name of Faculty Ritu Soni
Designation Asst. Professor
Department Electrical Engineering

Syllabus

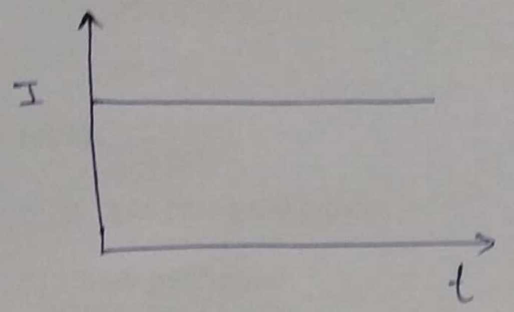
1FY3-08/ 2FY3-08: Basic Electrical Engineering

SN	CONTENTS
1	**DC Circuits:** Electrical circuit elements (R, L and C), voltage and current sources, Kirchhoff current and voltage laws, ~~Series-Parallel circuits~~, Node voltage method, Mesh current method, Superposition, Thevenin"s, Norton"s ~~and Maximum power transfer~~ theorems.
2	**AC Circuits:** Representation of sinusoidal waveforms, peak and r.m.s values, phasor representation, real power, reactive power, apparent power, power factor. Analysis of single-phase AC circuits consisting of R, L, C, RL, RC and RLC combinations (series and parallel), resonance. ~~Three phase balanced circuits, voltage and current relations in star and delta connections.~~
3	**Transformers:** Ideal and practical transformer, EMF equation, equivalent circuit, losses in transformers, ~~regulation and~~ efficiency.
4	**Electrical Machines:** Generation of rotating magnetic fields, Construction and working of a three-phase induction motor, ~~Significance of torque-slip characteristic.~~ Starting and speed control of induction motor, ~~single-phase induction motor.~~ Construction, working, torque-speed characteristic and speed control of separately excited DC motor. ~~Construction and working of synchronous generators.~~
5	**Power Converters:** Semiconductor PN junction diode and transistor (BJT). Characteristics of SCR, power transistor and IGBT. Basic circuits of single phase rectifier with R load, ~~Single phase Inverter, DC-DC converter.~~
6	**Electrical Installations:** Layout of LT switchgear: Switch fuse unit (SFU), MCB, ~~ELCB, MCCB, Type of earthing.~~ Power measurement, elementary calculations for energy consumption.
	TOTAL

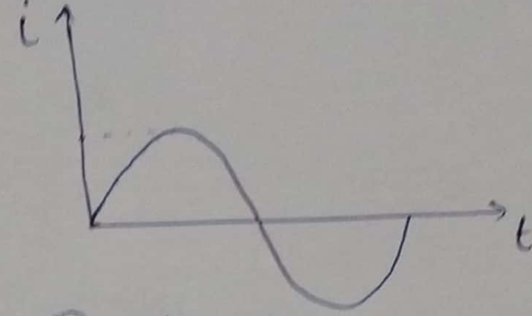
Electric current ⇒

it is defined as flow of charges (Coulomb) Per unit time (sec.)

$$I = \frac{dq}{dt} \quad A$$



ⓐ Direct Current.



ⓑ Alternating current

Electric Potential ⇒

The electric Potential of a Point may be defined as amount of work done to bring a unit Posi-tive charge from infinity to that Point.

mathematically,

$$V = \frac{W}{Q}$$

where W is workdone in transporting Positive Q charge from infinity to the Point when $Q = +1$ Coulomb

$V = W$ (amount of work done)

The unit of Potential is Volt (V)

The difference of Potential b/w two Point is also Called as Potential difference.

Electric Power =>

In an electric circuit, when flow of Charges takes Place, some amount of work is done. The electric Power (P) is defined as amount of work done Per unit time.

mathematically, $P = \frac{W}{t}$ $\quad \because V = \frac{W}{q}$

$$W = VQ$$

$$P = \frac{VQ}{t} \quad \because I = Q/t$$

$$P = VI \text{ watt}$$

Ohm's law =)

The relationship b/w Voltage (V) and current (I) through a conductor is given by Ohm's law which may be stated as follows:

"The current (I) passing through a conductor is directly proportional to the potential difference (V) across the ends of the conductor, provided the physical conditions (i.e, temp, resistivity, dimensions) remain the same."

mathematically

$$I \propto V$$

or $$I = \left(\frac{1}{R}\right) V$$

or $$V = IR$$

The constant R is called resistance of conductor. it's unit is ohm.

→ Resistance is a property of conductor which opposes the flow of current.

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

where, ρ = resistivity of conductor material

l = length of the conductor in meter

a = cross-sectional area of conductor (m^2)

and $$G = \frac{1}{R}$$

→ reciprocal of R is called Conductance G in mho

Electric circuit ⇒

An electric circuit is an interconnection of physical electrical devices (elements).

There are two types of element in electric circuit.

① Active elements

② Passive elements.

① **Active element** – The element which supply energy to the network are known as active elements.

ex. – Voltage source – batteries, dc generators, ac generators

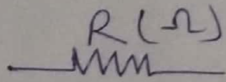
Current source – Photoelectric cells, operational amplifiers

② **Passive element** – The components which dissipate or stores energy are known as passive components.

ex – Resistor, inductor, capacitor

Resistor – A resistor is a passive element which opposes the flow of electric current.

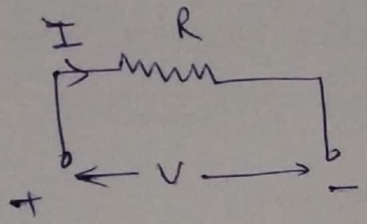
$$R = \rho \cdot \frac{l}{a}$$



ρ = resistivity, l = length of conductor (meter)

a = area of cross section of conductor (m^2)

~~Inductor~~ -

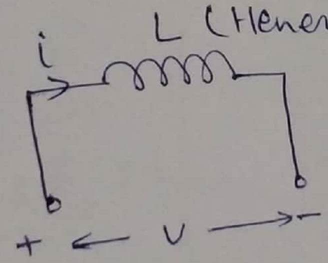


$V = IR$ (by ohm's law)

$P = VI = I^2 R$ watt

E or $W = I^2 R t$ Joules

Inductor - An inductor is an element which can store electrical energy in the form of electromagnetic energy.



" inductance is a property of a circuit element which opposes change of electronic current."

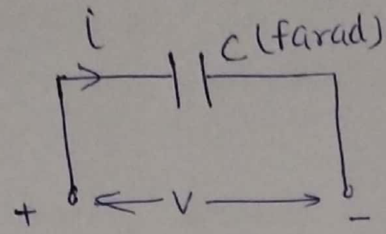
Voltage across inductor $V = L \frac{di}{dt}$; $i = \frac{1}{L} \int V\,dt$

Power in inductor $P = Vi = L \frac{di}{dt} \cdot i$

$$P = Li \frac{di}{dt}$$

and energy in inductor $W_L = \frac{1}{2} L I^2$ Joules

Capacitor — A capacitor is that element which can store electrical energy in the form of electrostatic energy.



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

Current through the capacitor, $i = C \frac{dV}{dt}$

Power, $P = Vi = VC\frac{dV}{dt} = CV\frac{dV}{dt}$

Energy, $W_c = \frac{1}{2} CV^2$

"capacitance is a property of circuit element which opposes change of applied voltage."

Linear and nonlinear elements —

The elements in which response is directly proportional to applied excitation are called linear elements

ex. - Pure resistors, inductors and capacitors.

The elements which are not linear are called non-linear elements

ex. - diode, transistors. etc.

Bilateral and unilateral elements -

The elements whose input to output relationship is independent of the direction of applied input. are called bilateral element
ex. - Resistor, inductor, Capacitor.

The elements whose response (o/p) to excitation (i/p) relationship is dependent on the direction of applied i/p are called unilateral element.
eg. - transistor, diode etc.

Lumped and distributed elements =>

Lumped elements are the elements which are pure and Physically separable.
for ex- Pure resistors, inductors and Capacitors.

Distributed elements are the elements which are not pure and can not be physically seperated
ex. - Transmission line.

Sources =>

A Source is a basic network element which supplies energy to the n/w. There are two classes of sources -

(i) Independent sources (ii) Dependent sources

(i) Independent Sources -

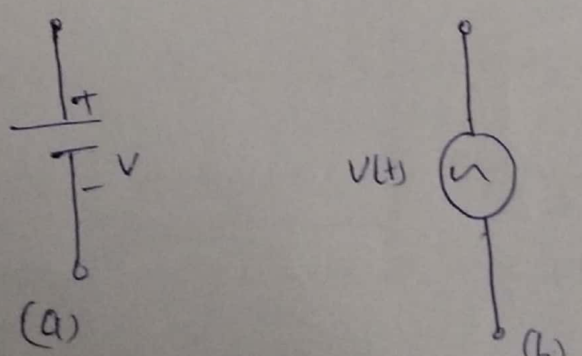
O/P characteristics of independent sources are not dependent on any network variable such as a current or voltage.

ⓐ Independent Voltage source

ⓑ Independent current source

ⓐ Independent Voltage source -

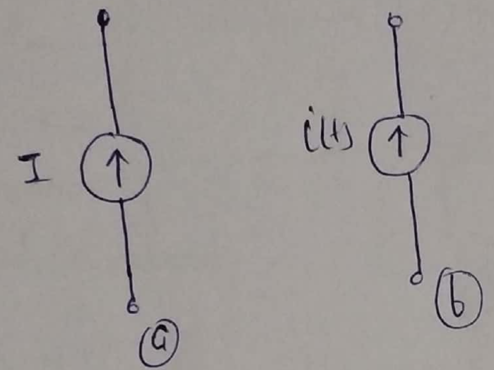
An independent voltage source is a two terminal n/w element that establishes a specified voltage across it's terminals.
The value of this voltage at any instant is independent of the value or direction of the current that flows through it.



independent voltage sources

(b) Independent current sources -

An independent current source is a two-terminal n/w element which produces a specified current. The value and direction of this current at any instant of time is indepent of the value or direction of the Voltage that appears across the terminals of the ~~sour~~ source.



Independent current source

(ii) Dependent sources =>

If the voltage or current of a source depends in turn upon some other voltage or current, it is called as dependent or controlled source.

(a) Voltage dependent Voltage source

(b) Voltage dependent current source

(c) Current dependent voltage source

(d) Current dependent current source

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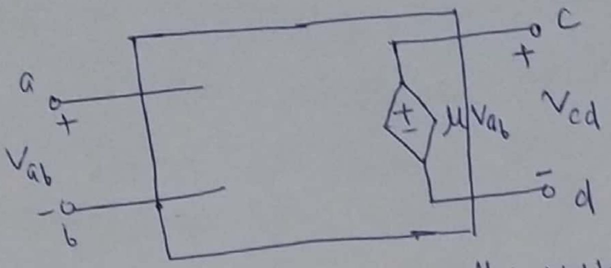
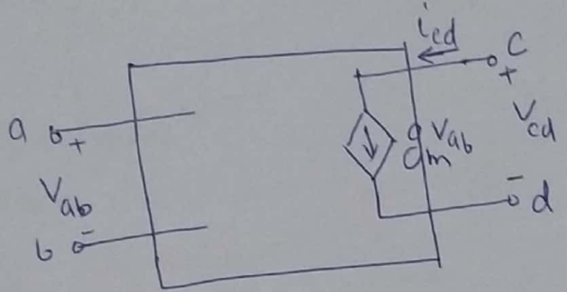
(a) Voltage controlled (dependent) voltage source –



$V_{cd} = \mu V_{ab}$; μ = dimensionless constant called voltage gain.

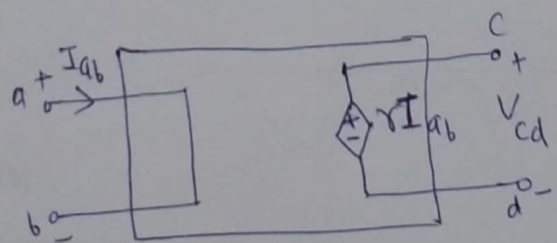
(b) Voltage dependent current source –



$i_{cd} = g_m V_{ab}$

g_m = mutual conductance in A/V or Siemens (S)

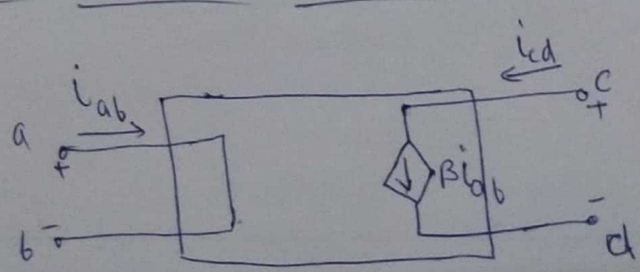
(c) Current dependent voltage source →



$V_{cd} = r I_{ab}$

r = constant called mutual resistance in V/A or Ohm

(d) Current dependent current source →

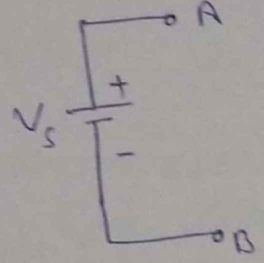


$i_{cd} = \beta i_{ab}$

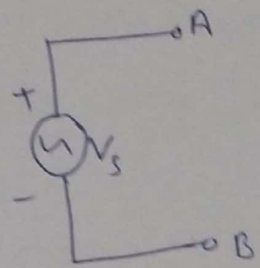
β = constant called current gain is dimensionless.

Ideal Voltage source and Practical Voltage source:

An ideal Voltage source is an Constant voltage source capable of supplying any current at a given voltage. If the internal resistance of of a voltage source is zero, the terminal voltage is equal to the voltage across the source, and is independent of the load current.



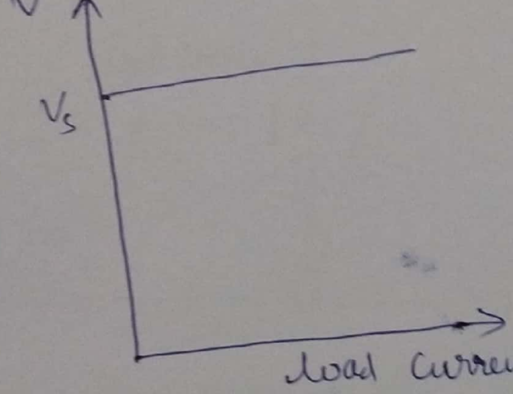
(a)

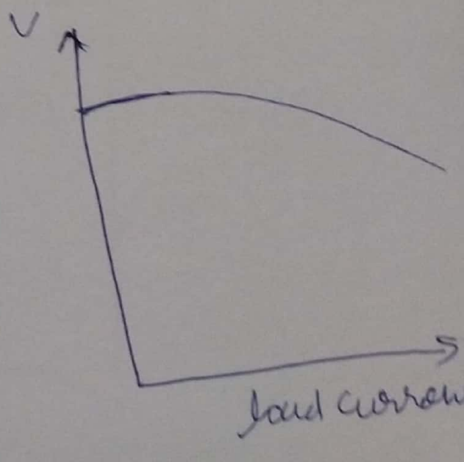


(b)

Symbolic representation of DC and AC ideal voltage sources.

→ ideal voltage source can not be short circuited
→ two ideal voltage sources of unequal O/P voltage can not be placed in parallel.
→ An ideal voltage source is not practically possible





(a) for ideal voltage source

(b) for practical voltage source

fig- VI characteristics of voltage sources.

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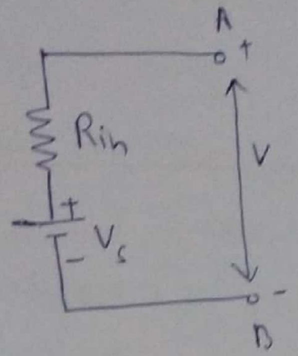
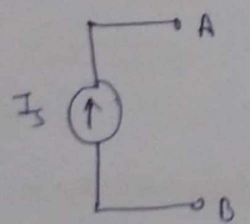


Practical voltage source

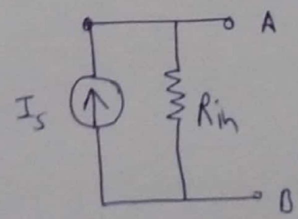
→ A Practical Voltage source have an internal resistance in series with it.

ideal and Practical current sources ⇒

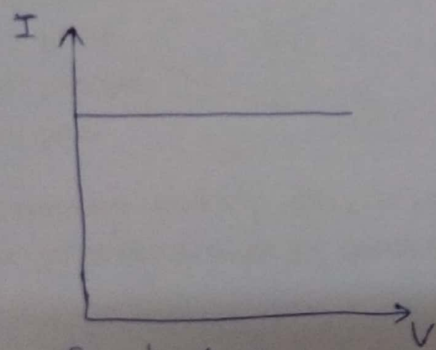
An ideal current source supplies a constant current to a load even if it's impedance varies. ideally, the current supplied by such a source should ~~be~~ remain constant irrespective of the load impedance.



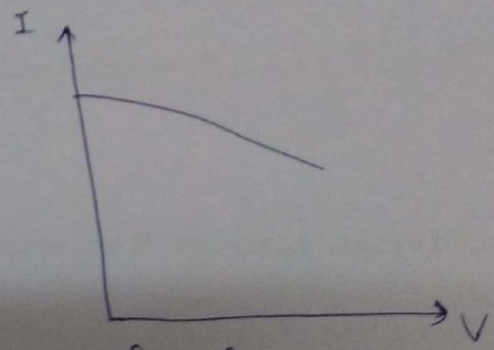
ideal current Source



Practical current Source



for ideal current source



for Practical current source

V-I characteristics of ideal current source.

→ internal resistance of an ideal current source is infinity

→ ideal current source can not be open circuited

→ Two ideal currents of different O/P currents can not be placed in series.

→ An ideal current source is not practically possible.

→ A internal resistance is connected in ~~parralel~~ parallel with a practical current source.

Kirchhoff's laws ⇒ KCL and KVL

① Kirchhoff's current law ⇒

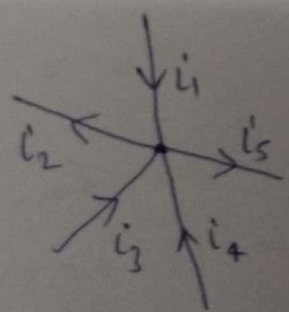
KCL states that the algebric sum of currents entering a node ~~tor~~ is zero

mathematically,

$$\sum_{n=1}^{N} i_n = 0$$

N = no. of branches connected to the node

i_n = nth current entering or leaving the node



$$i = -i_1 + i_2 - i_3 - i_4 + i_5$$

or

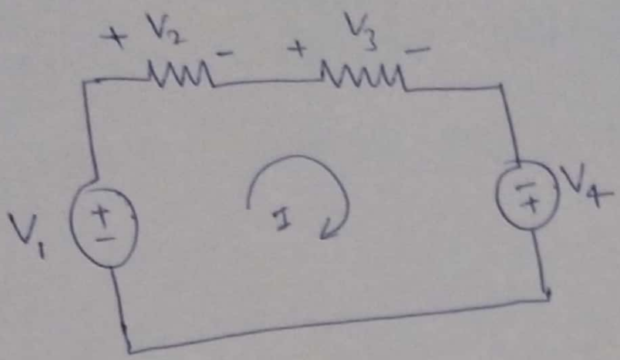
$$i_1 + i_3 + i_4 = i_2 + i_5$$

incomming current = outgoing current

② Kirchhoff's Voltage law ⇒ (KVL)

it states that the algebric sum of all voltages arround a closed path (or loop) is zero

$$\sum V = 0$$



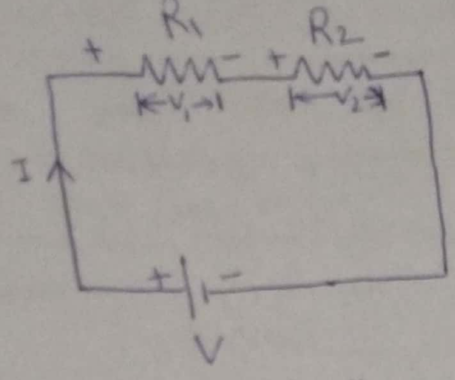
$$-V_1 + V_2 + V_3 - V_4 = 0$$

$$V_2 + V_3 = V_1 + V_4$$

Sum of Voltage drop = sum of voltages rises

Series circuit ⇒

Resistors R_1 and R_2 are said to be connected in series when the same current flows through each resistor.



Series circuit

Voltage drop across $R_1 = V_1 = I R_1$

" " " $R_2 = V_2 = I R_2$

by KVL

$$V = V_1 + V_2$$

$$V = R_1 I + R_2 I$$

$$= I(R_1 + R_2)$$

$$V = R_T I \quad \text{where } R_T = R_1 + R_2$$

hence, when a no. of resistors are connected in series, the equivalent resistance is the sum of all individual resistances.

Note -

1- Same current flows through each resistor

2- Voltage drop are additive

3- Resistances are additive

4- Power is additive

5- Applied voltage equals the sum of different voltage drops.

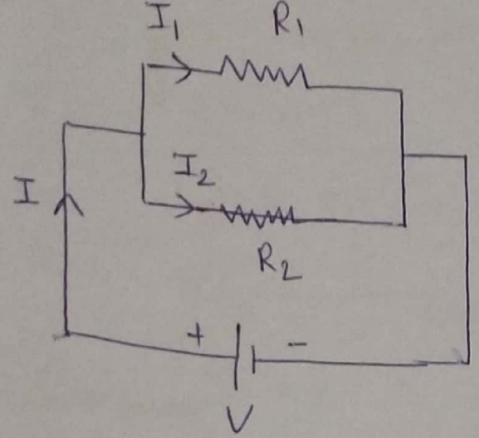
Voltage division in a series circuit -

$$I = \frac{V}{R_T} = \frac{V}{R_1 + R_2}$$

Hence, Voltage across $R_1 = V_1 = R_1 I = R_1 \frac{V}{R_1+R_2} = \frac{R_1}{R_1+R_2} V$

Similarly, Voltage across $R_2 = V_2 = R_2 I = R_2 \cdot \frac{V}{R_1+R_2} = \frac{R_2}{R_1+R_2} V$

Parallel Circuit ⇒ Resistors R_1 and R_2 are said to be connected in parallel when the potential difference across each resistor is same. and both terminals of both resistances are connected to each other.



$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

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

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$I = \frac{V}{R_T}, \text{ when } \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

Hence, when a number of resistors are connected in parallel, the reciprocal of the total resistance is equal to the sum of reciprocal of individual resistances.

Note –
1. Same voltage appear across all resistors
2. Branch current are additive
3. Conductances are additive
4. Power is additive

Current division in a Parallel Circuit-

1- When two resistances are connected in parallel,

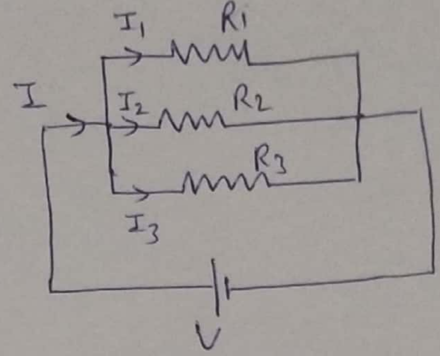
$$R_T = \frac{R_1 R_2}{R_1 + R_2}, \text{ also, } V = R_T I = R_1 I_1 = R_2 I_2$$

Current through $R_1 = I_1 = \frac{V}{R_1} = \frac{R_T I}{R_1} = \frac{R_2}{R_1+R_2} I$

Similarly, current through $R_2 = I_2 = \frac{V}{R_2} = \frac{R_T I}{R_2} = \frac{R_1}{R_1+R_2} I$

2- When three resistances are connected in parallel,

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



$$= \frac{R_2R_3 + R_3R_1 + R_1R_2}{R_1 R_2 R_3}$$

$$R_T = \frac{R_1R_2R_3}{R_2R_3 + R_3R_1 + R_1R_2}$$

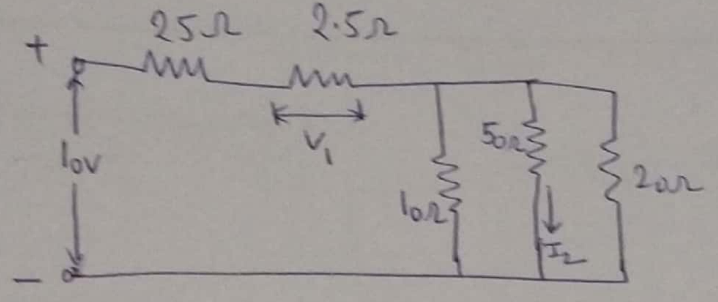
also, $V = R_T I = R_1 I_1 = R_2 I_2 = R_3 I_3$

Current through $R_1 = I_1 = \frac{V}{R_1} = \frac{R_T I}{R_1} = \frac{R_2 R_3}{R_1R_2 + R_2R_3 + R_3R_1} I$

Current through $R_2 = I_2 = \frac{V}{R_2} = \frac{R_T I}{R_2} = \frac{R_3 R_1}{R_1R_2 + R_2R_3 + R_3R_1} I$

Current through $R_3 = I_3 = \frac{V}{R_3} = \frac{R_T I}{R_3} = \frac{R_1 R_2}{R_1R_2 + R_2R_3 + R_3R_1} I$

Q.1- for the circuit shown in fig, using the method of series parallel combintion, find V_1 and I_2



R_T =

$$R_T = (25+2.5) + \frac{1}{\frac{1}{10}+\frac{1}{50}+\frac{1}{20}}$$

$$= 27.5 + \frac{100}{10+2+5} = 33.38\,\Omega$$

Current drawn by supply $I = \frac{V}{R_T} = \frac{10}{33.38} = 0.299\text{A}$

Voltage drop across 2.5Ω, $V_1 = I \times 2.5 = 0.299 \times 2.5 = 0.75\text{ V}$

Voltage drop across parallel combination –

$$V_2 = I \cdot \frac{100}{17} = 0.299 \times \frac{100}{17} = 1.76\text{V}$$

Current through 50Ω resistor $I_2 = \frac{V_2}{50} = 0.0352\text{ A}$

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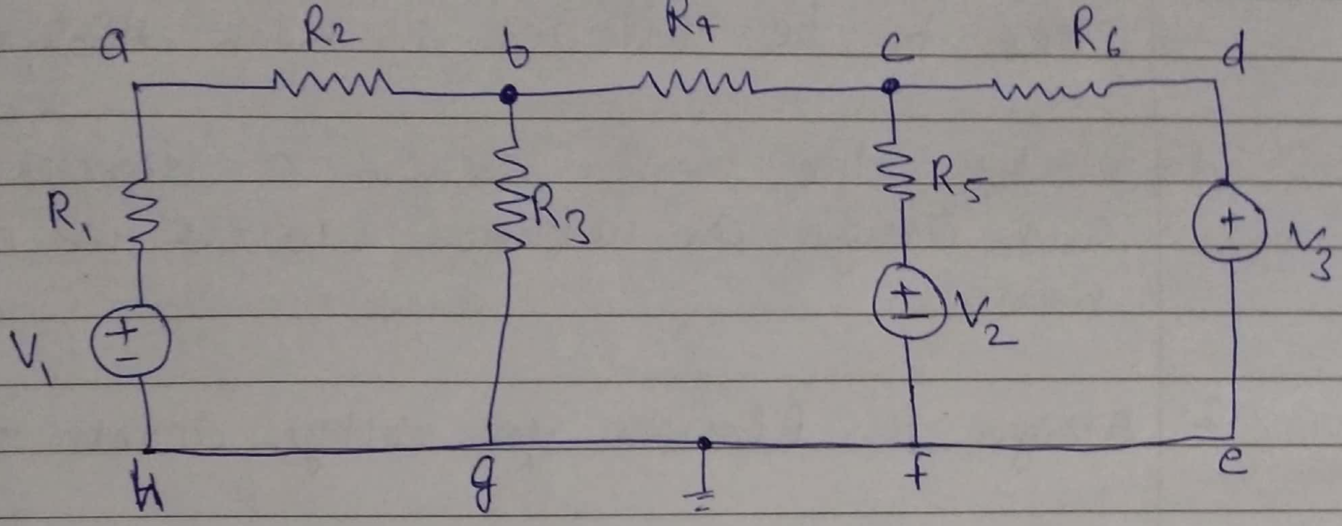
Some basic terminologies -

(I)



(1) Loop → Loop is a closed Path.
ABGHA, bcfgb, cdefc, abcfgha, bcdefgb, abcdefgha.

(2) mesh → mesh is also a closed Path, mesh is most elementary form of loop, it does not Contain any other loop with in it.
abgha, bcfgb, cdefc

(3) Node ⇒ Node is a Point where two or more than two branches are Connected.
a, b, c, d, g

Junction ⇒ Junction is a Point where three or more than three branches are Connected.
b, c, g.

(4) Branch - Branch is a Part of the network which is Connected between two Junction.
ex- bg, cf, cde, bc, bah etc.

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Mesh Analysis ⇒ (mesh, KVL)

→ Steps to be followed in mesh Analysis-

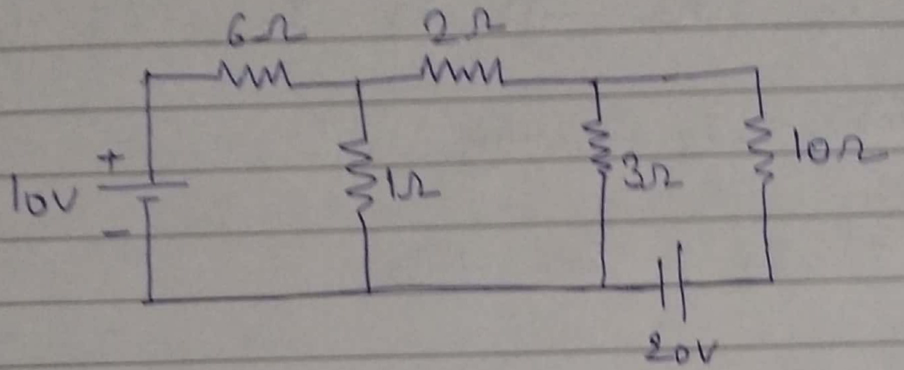
1- Identify the mesh, assign a direction to it and assign an unknown current in each mesh.

2- Assign the Polarities for voltage across the branches

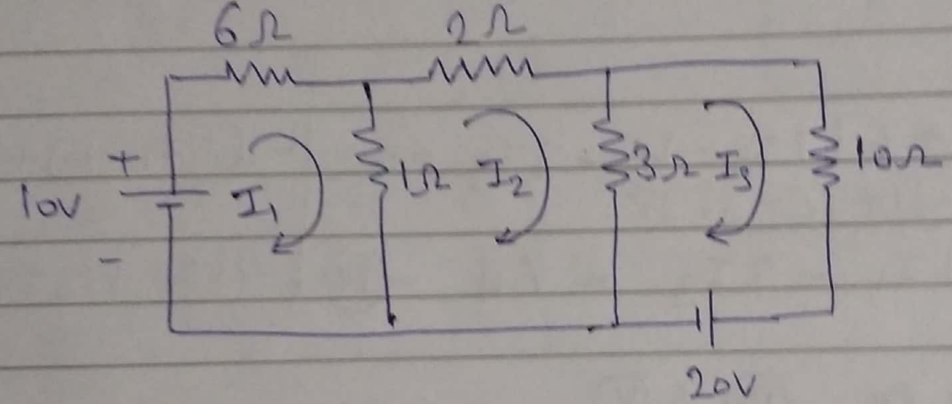
3- Apply KVL around the mesh and use Ohm's law to express the branch voltages in terms of unknown mesh currents and the resistance

4- Solve the simultaneous equation for unknown mesh currents.

Q. find the value of current flowing through the $2\,\Omega$ resistor.



Solution-



Applying KVL to mesh-1

$6I_1 + 1(I_1 - I_2) - 10 = 0$

$7I_1 - I_2 = 10 \quad -(1)$

Applying KVL to mesh-2

$2I_2 + 3(I_2 - I_3) + (I_2 - I_1) = 0$

$-I_1 + 6I_2 - 3I_3 = 0 \quad -(2)$

Applying KVL to mesh-3

$10I_3 + 20 + 3(I_3 - I_2) = 0$

$-3I_2 + 13I_3 = -20 \quad -(3)$

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Solving eq. (I), (II) & (III)

$7I_1 - I_2 = 10$ — (I) $\Rightarrow$ $I_2 = 7I_1 - 10$

$-I_1 + 6I_2 - 3I_3 = 0$ — (II)

$-3I_2 + 13I_3 = -20$ — (III)

from eq. (I), $I_2 = 7I_1 - 10$, Put this value in eq (II) & (III)

$-I_1 + 6(7I_1 - 10) - 3I_3 = 0$

$41I_1 - 3I_3 = 60$ — (IV)

$-3(7I_1 - 10) + 13I_3 = -20$

$-21I_1 + 13I_3 = -50$ — (V)

from eq. (IV) & (V)

$41I_1 - 3I_3 = 60 \quad \times 13$

$-21I_1 + 13I_3 = -50 \quad \times 3$

$533I_1 - 39I_3 = 780$

$-63I_1 + 39I_3 = -150$

$470I_1 = 630$

$I_1 = \frac{630}{470} = 1.34A$

$I_2 = 7I_1 - 10$

$= (7 \times 1.34) - 10$

$I_2 = -0.62\ A$

from eq. (III)

$-3I_2 + 13I_3 = -20$

$13I_3 = -20 + 3(-0.62) = -21.86$

$I_3 = -1.68\ A$

Current in 2Ω resistance - I_2

$$I_{2\Omega} = I_2 = -0.62\,A$$

or

Writing eq. in matrix form

$$\begin{bmatrix} 7 & -1 & 0 \\ -1 & 6 & -3 \\ 0 & -3 & 13 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ -20 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 7 & -1 & 0 \\ -1 & 6 & -3 \\ 0 & -3 & 13 \end{vmatrix} = 7(78-9) + 1(-13) + 0 = 470$$

$$\Delta_1 = \begin{vmatrix} 10 & -1 & 0 \\ 0 & 6 & -3 \\ -20 & -3 & 13 \end{vmatrix} = 10(78-9) + 1(0-60) + 0 = 630$$

$$\Delta_2 = \begin{vmatrix} 7 & 10 & 0 \\ -1 & 0 & -3 \\ 0 & -20 & 13 \end{vmatrix} = 7(-60) + 10(-13) + 0 = -290$$

$$\Delta_3 = \begin{vmatrix} 7 & -1 & 10 \\ -1 & 6 & 0 \\ 0 & -3 & -20 \end{vmatrix} = 7(-120) + 1(20) + 10(3) = -790$$

$$I_1 = \frac{\Delta_1}{\Delta} = 1.34\,A$$

$$I_2 = \frac{\Delta_2}{\Delta} = -0.62\,A$$

$$I_3 = \frac{\Delta_3}{\Delta} = -1.68$$

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Nodal Analysis => (node, KCL)

Steps to be followed in nodal Analysis -

① Assuming that a network has n nodes, assign a reference node and the reference directions, and assign a current and a voltage name for each branch and node respectively.

② Apply KCL at each node except for the reference node and apply ohm's law to ~~be~~ the branch currents

③ Solve the simultaneous equations for the unknown node voltages.

④ Using these voltages, find any branch currents required.

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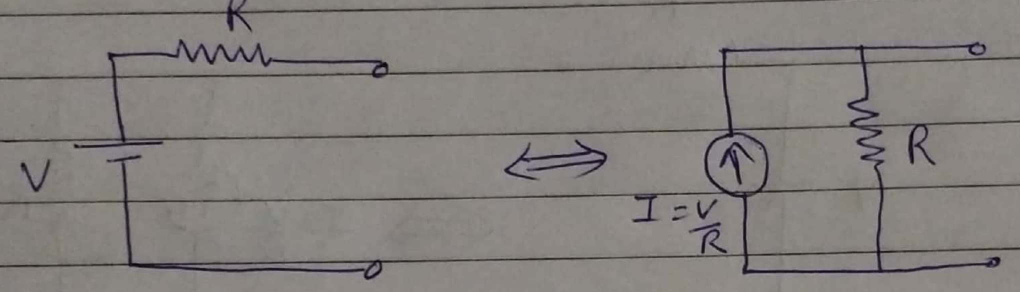
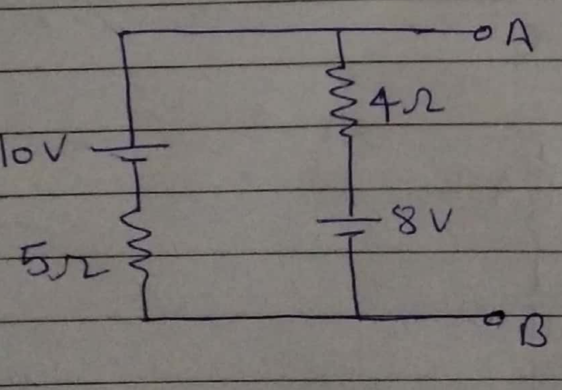
Sourse transformation =)

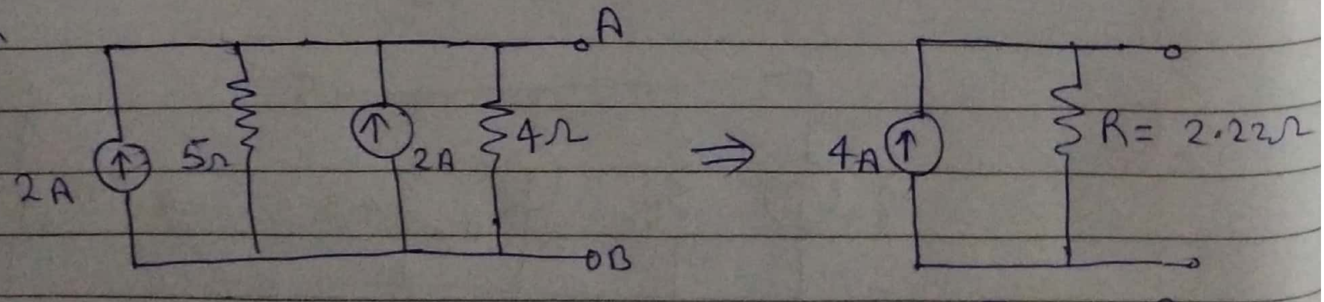
A voltage source with a series resistor can be converted into an equivalent current source with a parallel resistor. Conversely, a current source with a parallel resistor can be converted into a voltage source with a series resistor.



Example- Convert the given circuit into a single current source in parallel with a single resistance b/w points A and B.



Solution



$$R = \frac{5 \times 4}{5+4} = \frac{20}{9} = 2.22$$

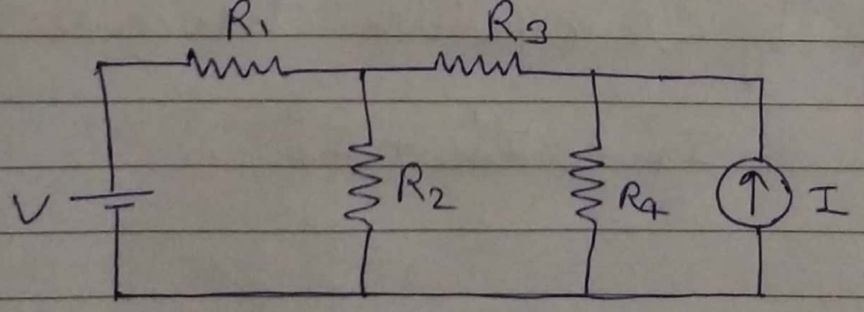
Superposition theorem =)

It states that " In a linear network containing more than one independent sources, the resultant current in any ~~branch~~ element is the algebraic sum of the currents that would be produced by each independent source acting alone, all the other independent sources being represented meanwhile by their respective internal resistances".

The independent voltage source → short circuit
Independent current source → open circuit.

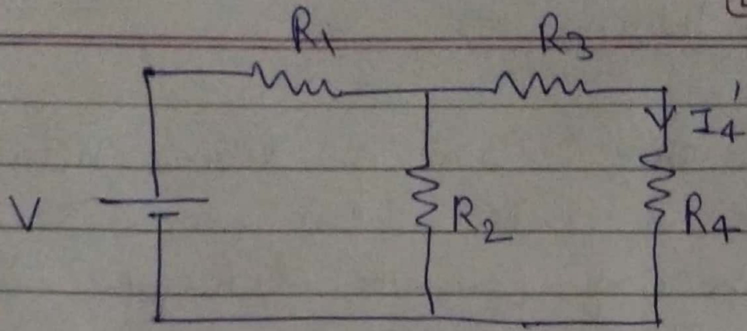
Explanation :-

Consider the circuit shown in fig.
Suppose we have to find current I_4 flowing through R_4.

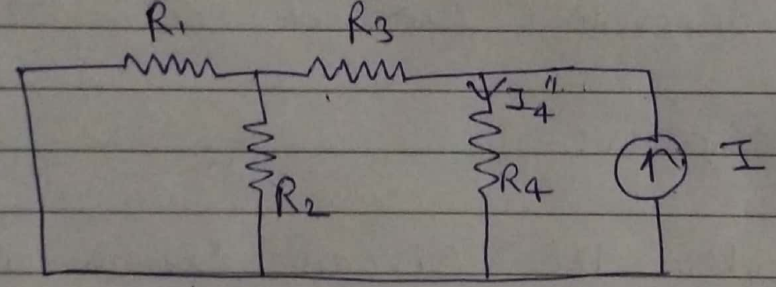


Steps to be followed in superposition theorem

① Find the current I_4' flowing through R_4 due to independent voltage source 'V' representing independent current source with infinite resistance, i.e. open circuit



② Find the Current I_4'' flowing through R_4 due to independent current source 'I' representing the independent Voltage source with Zero resistance or short circuit.



③. Find the resultant current I_4 through R_4 by superposition theorem

$$I_4 = I_4' + I_4''.$$

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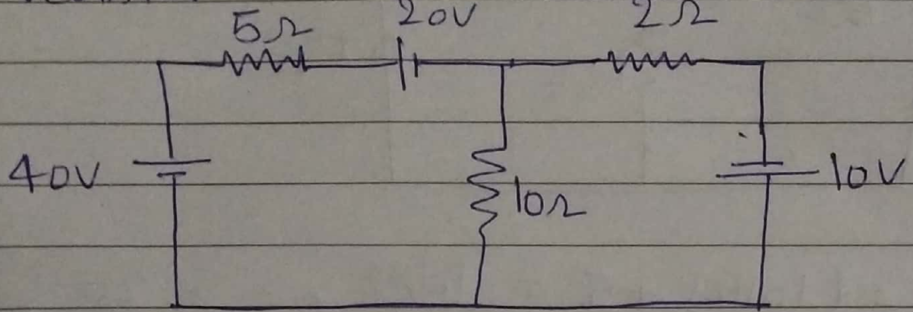
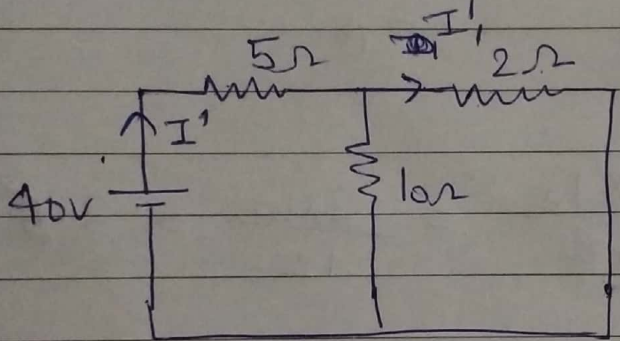
Q.1- Find the value of Current flowing through 2Ω resistor.



Solution-

Step I- When 40 V source acting alone



$$R_{eq}' = (10 \| 2) + 5 = \frac{10 \times 2}{10+2} + 5 = \frac{20}{12} + 5$$

$$= 1.67 + 5 = 6.67\,\Omega$$

$$I' = \frac{40}{6.67} = 6A$$

by current division rule

$$I_1' = \frac{I' \times 10}{10+2} = \frac{6 \times 10}{12} = 5A$$

Step-II- When 20V source is acting alone

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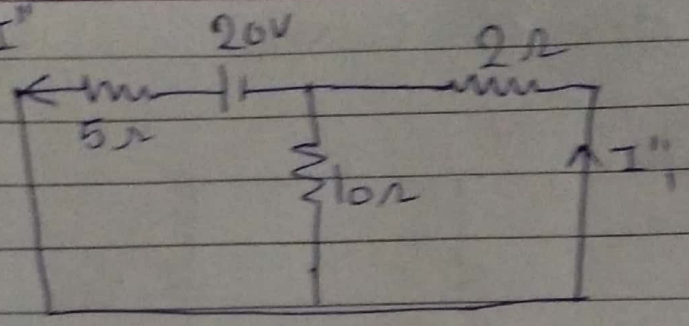


$$R_{eq}'' = (10 \| 2) + 5 = \frac{10 \times 2}{10+2} + 5 = \frac{20}{12} + 5$$

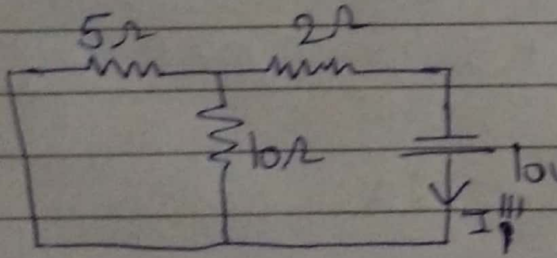
$$R_{eq}'' = 6.67\ A$$

$$I'' = \frac{20}{6.67} = 3A$$

$$I_1'' = \frac{I'' \times 10}{10+2} = \frac{3 \times 10}{12} = 2.5\ A$$

Step-III -

When 10V source is acting alone



$$R_{eq}''' = \frac{5 \times 10}{5+10} + 2 = \frac{50}{15} + 2 = 5.33\ \Omega$$

$$I''' = \frac{10}{5.33} = 1.88A$$

~~Seven~~ Step IV - by superposition theorem

$$I_1 = I_1' - I_1'' + I_3'' = 5 - 2.5 + 1.88$$
$$= 4.38A$$

Thevenin's theorem ⇒

Thevenin's theorem states that "Any linear, active, bilateral circuit can be replaced by an equivalent circuit consisting a voltage source V_{th} in series with a resistor R_{th}, where V_{th} is the open-circuit voltage across the open circuited load terminals. and R_{th} is the equivalent resistance at the open circuited load terminals when the independent sources are replaced by their internal resistances.

Explanation —

let any circuit be given in fig (a)

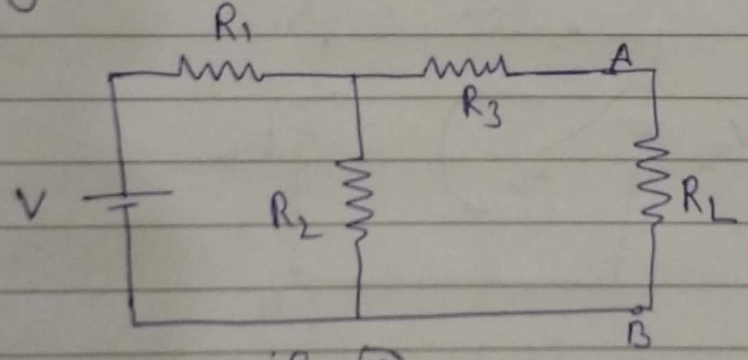


fig (a)

Step 1 - Remove the load resistance R_L and find open circuit voltage V_{th} across point A & B -

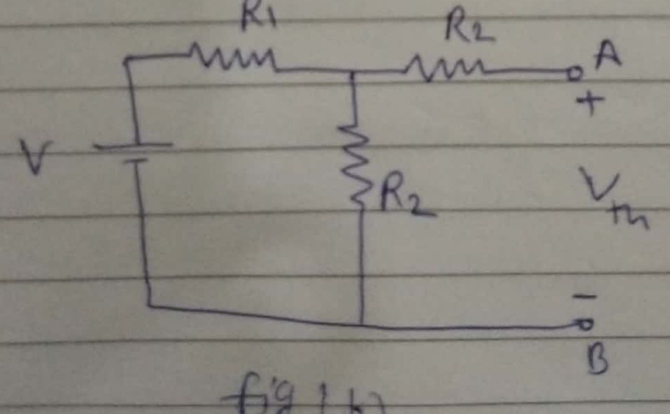


fig (b)

Step II - Find the resistance R_{th} as seen from points A & B with all independent sources are replaced by their internal resistances.

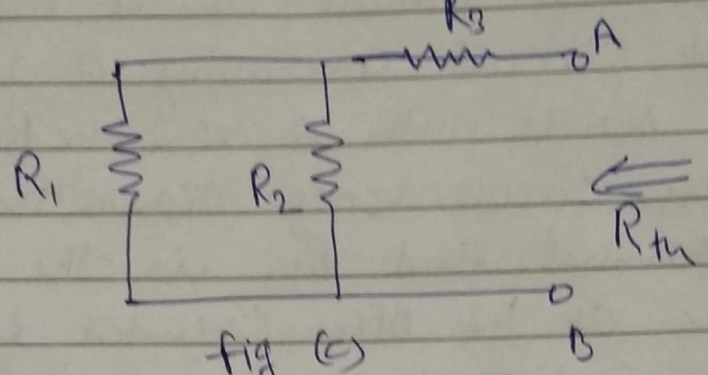


fig (c)

Step-III - Replace the network by a voltage source V_{th} in series with resistance R_{th}.

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

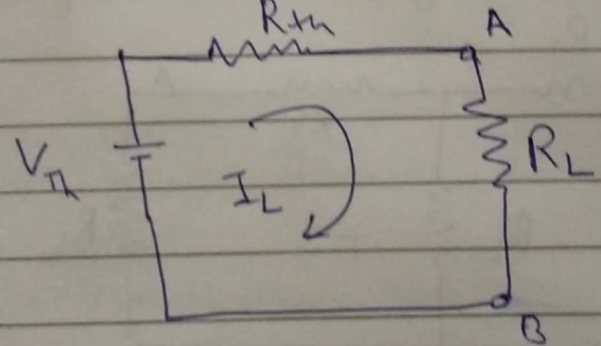
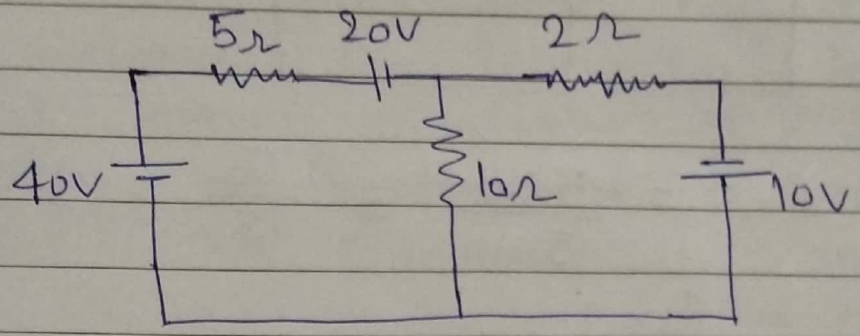


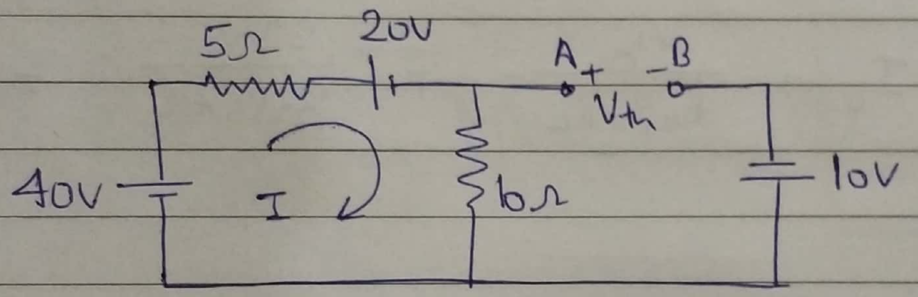
fig (d)

Q. Find the value of current flowing through 2Ω using thevenin's theorem.



Solution =>

Remove load resistance and find V_{th}



Apply KVL in mesh

$$-40 + 5I + 20 + 10I = 0$$
$$15I = 20$$
$$I = 1.33\,A$$

$$V_{th} = 10I + 10 = 10 \times 1.33 + 10$$
$$V_{th} = 23.33V$$

Replace voltage sources by their internal resistance and find R_{th}

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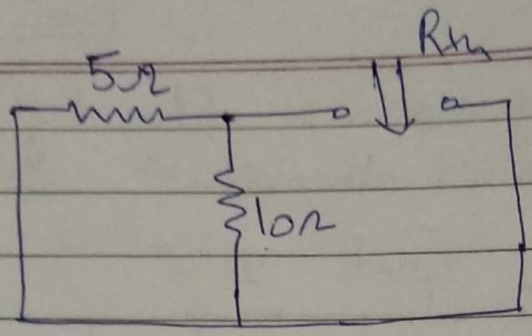
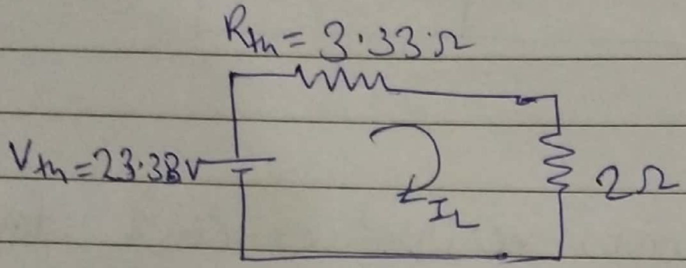


$$R_{th} = \frac{5 \times 10}{5+10} = \frac{50}{15} = 3.33\,\Omega$$



$$I_L = \frac{V_{th}}{R_{th}+R_L} = \frac{23.33}{3.33+2} = 4.38\,A$$

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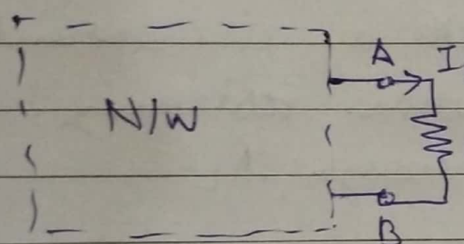
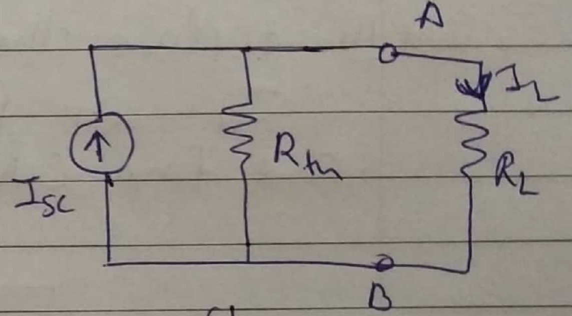
Norton's theorem ⇒

Norton's theorem states that - " Any linear, active, bilateral network, can be replaced by an equivalent circuit consisting of a current sorce I_{sc} in parallel with a resitance R_{th}: where I_{sc} is the short circuit current through the load terminals and R_{th} is the equivalent resistance across the load terminals when all independent sources are replaced by their internal resistances".



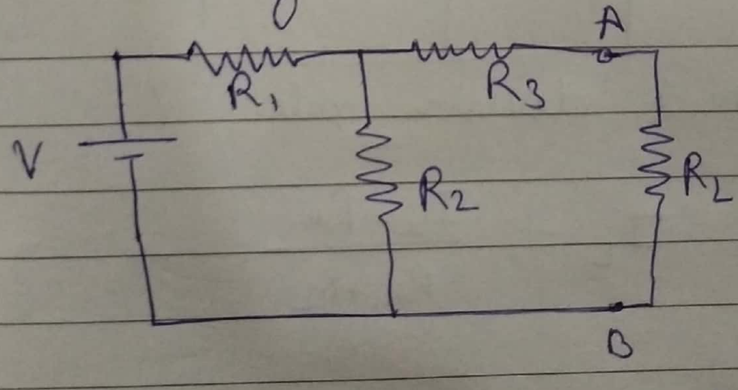
(a)



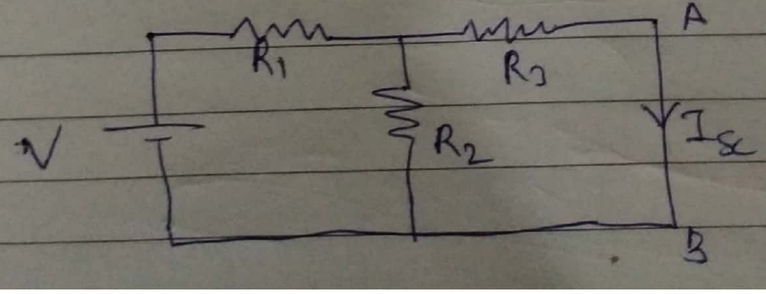
(b)

Explanation ⇒

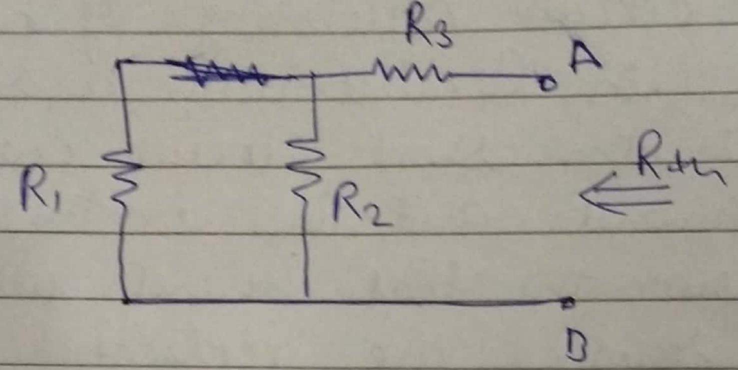
let any circuit be given



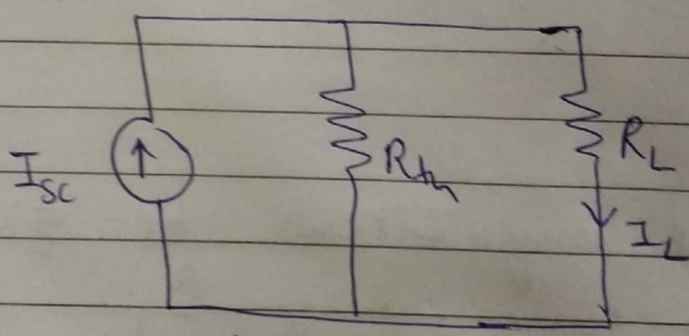
Step I - Remove the load resistance R_L and put a short circuit across the terminals. and find I_{sc}.



Step II - Find the resistance R_{th} as seen from points A and B by replacing the voltage source and current sources by internal resistances



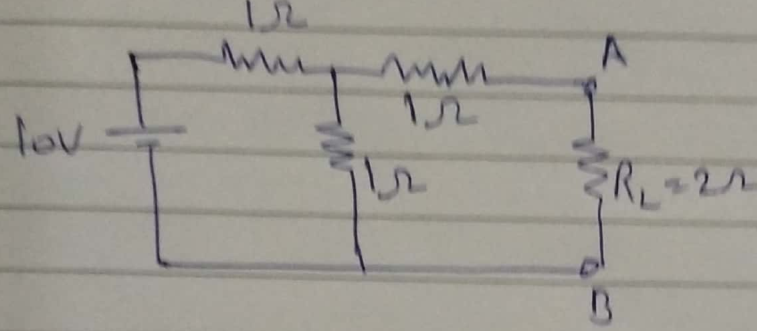
Step III Replace the network by a current source I_{sc} in parallel with resistance R_{th} and find current through R_L.



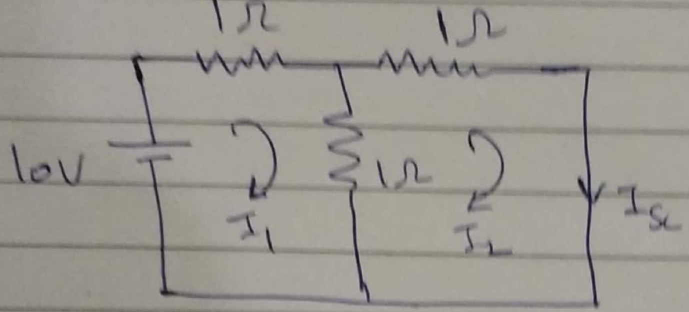
by current division rule

$$I_L = \frac{I_{sc} \cdot R_{th}}{R_{th} + R_L}$$

Q. For the given circuit find the Norton equivalent b/w point A & B.



Solution



Apply KVL in mesh 1

$-10 + I_1 + (I_1 - I_2) = 0$

$2I_1 - I_2 = 10 \quad -(1)$

Apply KVL in mesh 2

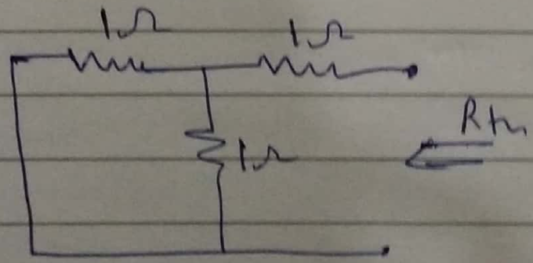
$I_2 + (I_2 - I_1) = 0$

$2I_2 - I_1 = 0 \quad -(ii)$

by solving eq. (1) & (2)

$I_1 = 6.67\,A$

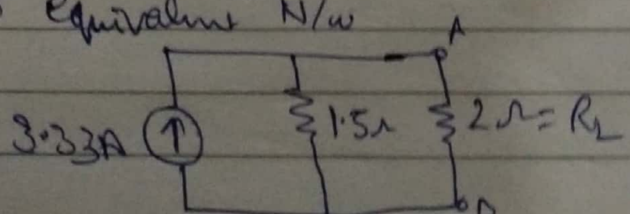
$I_2 = I_{sc} = 3.33\,A$



$R_{th} = (1 \| 1) + 1$

$= \frac{1 \times 1}{1+1} + 1 = 1.5\,\Omega$

Norton's equivalent N/w



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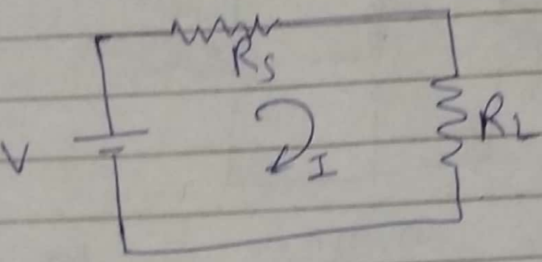
Maximum Power transfer theorem ⇒

It states that 'the maximum Power is delivered from a source to a load when the load resistance is equal to the source resistance."



$$I = \frac{V}{R_S + R_L}$$

Power delivered to the load $R_L = P = I^2 R_L$

$$P = \frac{V^2 R_L}{(R_S+R_L)^2}$$

To determine the value of R_L for maximum power to be transferred to the load,

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

$$\frac{dP}{dR_L} = \frac{d}{dR_L}\left[\frac{V^2}{(R_S+R_L)^2} R_L\right]$$

$$= \frac{V^2\left[(R_S+R_L)^2 - (2R_L)(R_S+R_L)\right]}{(R_S+R_L)^4}$$

$$(R_S+R_L)^2 - 2R_L(R_S+R_L) = 0$$

$$R_S^2 + R_L^2 + 2R_SR_L - 2R_LR_S - 2R_L^2 = 0$$

$$\boxed{R_L = R_S}$$

hence. the maximum Power will be transfe-red to the load when load resistance is equal to source resistance.

Steps to be followed in max. Power transfer theorem =>

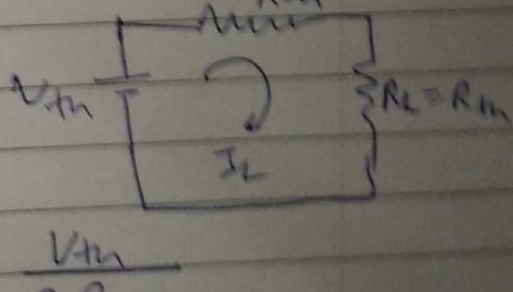
① Remove the variable load resistor R_L.

② Find open circuit voltage V_{th} across Point A & B.

③ Find the resistance R_{th} as seen from Point A & B with voltage source and current source replaces by internal resistances.

④ find resistance R_L for max. Power transfer

$$R_L = R_{th}$$



⑤ find max. Power

$$I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{V_{th}}{2R_{th}}$$

$$P_{max.} = I_L^2 R_L = \frac{V_{th}^2}{4R_{th}^2} \times R_{th} = \frac{V_{th}^2}{4R_{th}}$$

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