

Basic Electrical & Electronics Engineering

Part A: Basic Electrical Engineering

UNIT- I: DC & AC Circuits

DC Circuits:

- **Electrical circuit elements (R, L and C)**
- **Ohm's Law and its limitations**
- **KCL & KVL, series**
- **parallel, series-parallel circuits**
- **Super Position theorem**
- **Simple numerical problems.**

BEEE - PART-A - UNIT-1 : DC & AC CIRCUITS

DC CIRCUITS

Basic Definitions

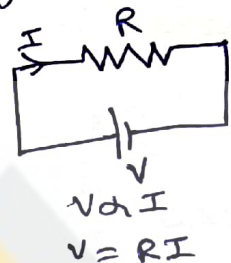
Electric Network: "The interconnection of two or more circuit elements ^{connected} in any manner"

Electric circuit: "Any electrical network consisting of at least one closed path to flow the current"

Electrical circuit Elements: R, L, C

① Resistor: "which element opposes the flow of current"

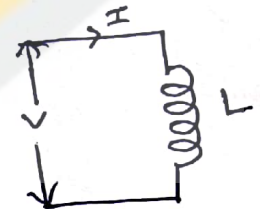
→ If the voltage across the element is directly proportional to the current flowing through it, then that element is a Resistor (R) -



→ Resistor dissipates energy in the form of heat into the air around the component. It does not store energy.

② Inductor: "which element does not allow the sudden change in current"

→ If terminal voltage is proportional to the time derivative of current through it then that element is an inductor (L) - units Henry.



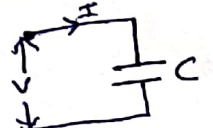
$$V \propto L \frac{di}{dt}; \quad V = L \frac{di}{dt}$$

→ An inductor stores energy in magnetic form. $E = \frac{1}{2} LI^2$

→ The average power absorbed by it is zero.

③ Capacitor: "which element does not allow the sudden change in voltage"

→ If the terminal voltage is proportional to the integral of current through it then that element is Capacitor (C) - units Farads.



$$V \propto \int i dt; \quad V = \frac{1}{C} \int i dt$$

→ The capacitor stores energy in an electric field. $E = \frac{1}{2} CV^2$

→ The average power absorbed by it is zero.

OHM'S Law: [1826 - George Simon ohm]

Statement: "At constant temperature, the current flowing through a conductor is directly proportional to the applied voltage across the same conductor."

mathematical representation: $V \propto I$

$$V = R I$$

Here V - is applied voltage (or) potential difference between two points. in volts.

I is resulting current in Amperes.

R is resistance of the conductor.

Limitations of ohm's law's

- Ohm's law can not be applied to the Vacuum and Gas filled devices and thermionic devices because they are not linear devices.
- It can not be applied to semiconducting devices which are known to be non linear devices.
- It can not be applied to arcing devices.
- It can not be applied to those electrolytes in which gases are liberated on the electrodes.
- It can not be applied to those conductors whose temperature changes due to the flow of current through them.

Laws of Resistance

"The resistance of a conducting wire depends upon the physical dimensions, nature of the material and temperature. Laws of resistance explain these facts, namely,

- The resistance of a conducting wire is directly

proportional to its length, l i.e., $R \propto l$

where l - is the length of the conducting wire.

→ The resistance of a conducting wire is inversely proportional to its area of cross-section, 'a' i.e.,

$$R \propto \frac{1}{a}$$

→ The resistance of a conducting wire will depend upon the nature of the material with which it is made.

→ The resistance of the conducting wire will depend upon its working temperature. Hence, from the above factors, we have

$$R \propto \frac{l}{a}$$

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

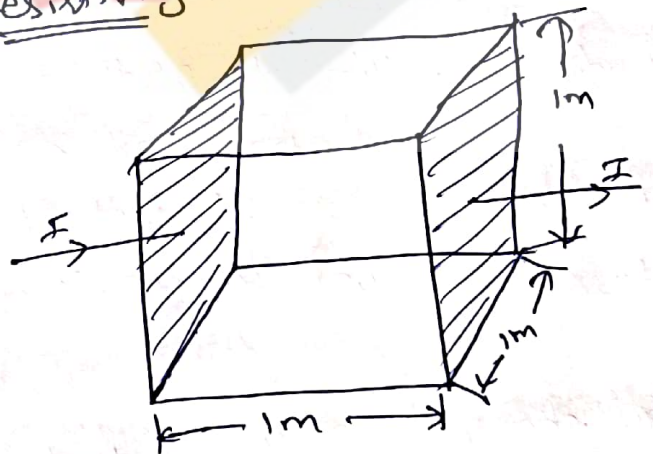
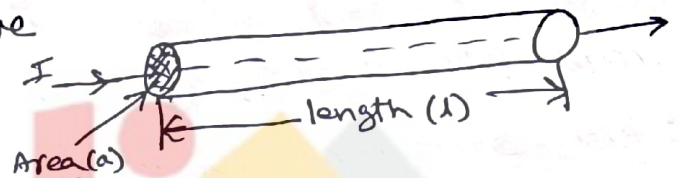
where ρ - (ρ_{ho}) is the constant and it is called specific resistance (ρ) resistivity of the conducting wire.

Specific resistance (ρ) Resistivity :-

specific resistance of a material is defined as the resistance offered between the opposite faces of a unit cube of that material.

$$\rho = \frac{R \cdot a}{l} \text{ (ohm-m)}.$$

The units of specific resistance is "ohm-metre".



Basic Definitions

- ① Active element: The sources may be voltage/current sources, which supply energy to a circuit/network.
Ex: generator, battery, voltage source, current source, etc.
- ② Passive element: The various elements like resistance, inductance and capacitance are called passive elements or circuit parameters, which are utilized or consumed energy. The parameters may be lumped or distributed.

(i) Lumped parameters: Those which are effectively connected at a single point.

Ex: R, L, C used in electric circuits.

(ii) Distributed parameters: Those which are spread out over an electrically significant length (or) area.
Ex: R, L, C of transmission line. Here R, L, C represented per unit length.

③ Linear circuit: A linear circuit is one whose parameters are constant, i.e. they do not change with voltage or current. [R, L, C]

④ Non-linear circuit: A circuit in which the parameters change with voltage and current is known.
ex: Diode, SCR, Transistors etc.

⑤ Unilateral circuit: A circuit whose properties (or) characteristics change with the change of direction of its operating current.

ex: A rectifier, Diode, Transistors etc.

⑥ Bilateral circuit: A circuit whose properties or characteristics are same in either current direction.
Ex: R, L, C , Transmission line, etc.

- ⑦ Active circuit: A closed electric circuit in which active elements like voltage or current sources are found along with passive elements.
- ⑧ Passive circuit: A closed electric circuit in which only passive elements are present.

⑨ Junction or Node

In a circuit a point at which two or more elements are connected and where division of current takes place is known as a junction or node. Junctions are represented by thick dot's.

- ⑩ Branch: A part of the network/circuit connected between two junctions.

- ⑪ Loop: It is a closed path in a circuit in which no element or node is encountered more than once.

- ⑫ Mesh: It is a loop that contains no other loop within it.

- ⑬ Current: "Flow of energy from one electron to beside electron". It is called current, units are amperes.

- ⑭ Voltage (or) Potential Difference (or) Electric pressure (or) Electric tension (or) Electromotive force :-

Voltage is measure of electrical energy per unit charge between two points in an electrical circuit.

→ voltage was thought of as an electric force pushing charges through conductors

$$V = \text{Energy} / \text{charge} ; \text{units} = \frac{\text{Joule}}{\text{Coulomb}} \text{ (or) Volts.}$$

(15) Work: we know work done = Force $\times$ Distance

In electrical units work is said to be done in a electric circuit when a current of one ampere per second flows due to a potential difference of one volt across the circuit.

$$\text{work done} = \text{voltage} \times \text{current} \times \text{time}$$

$$= V I t \quad (\text{watt-sec})$$

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

(16) Power: The rate of doing work.

$$P = \frac{\text{work done}}{\text{time}} = \frac{VIt}{t} = VI \quad \begin{matrix} \text{watt} \\ \text{Joules/sec.} \end{matrix}$$

$$\therefore 1 \text{ watt} = 1 \text{ Joule/second}$$

$$1 \text{ kW} = 1000 \text{ W} = 1000 \text{ Joule/sec.}$$

(17) Energy: The capacity to do work.

$$\text{Energy} = \text{Rate of doing work} \times \text{time} = \text{watt-hour}$$

$$= \frac{\text{Joule}}{\text{sec}} \times 3600 \text{ sec} = 3600 \text{ Joule.}$$

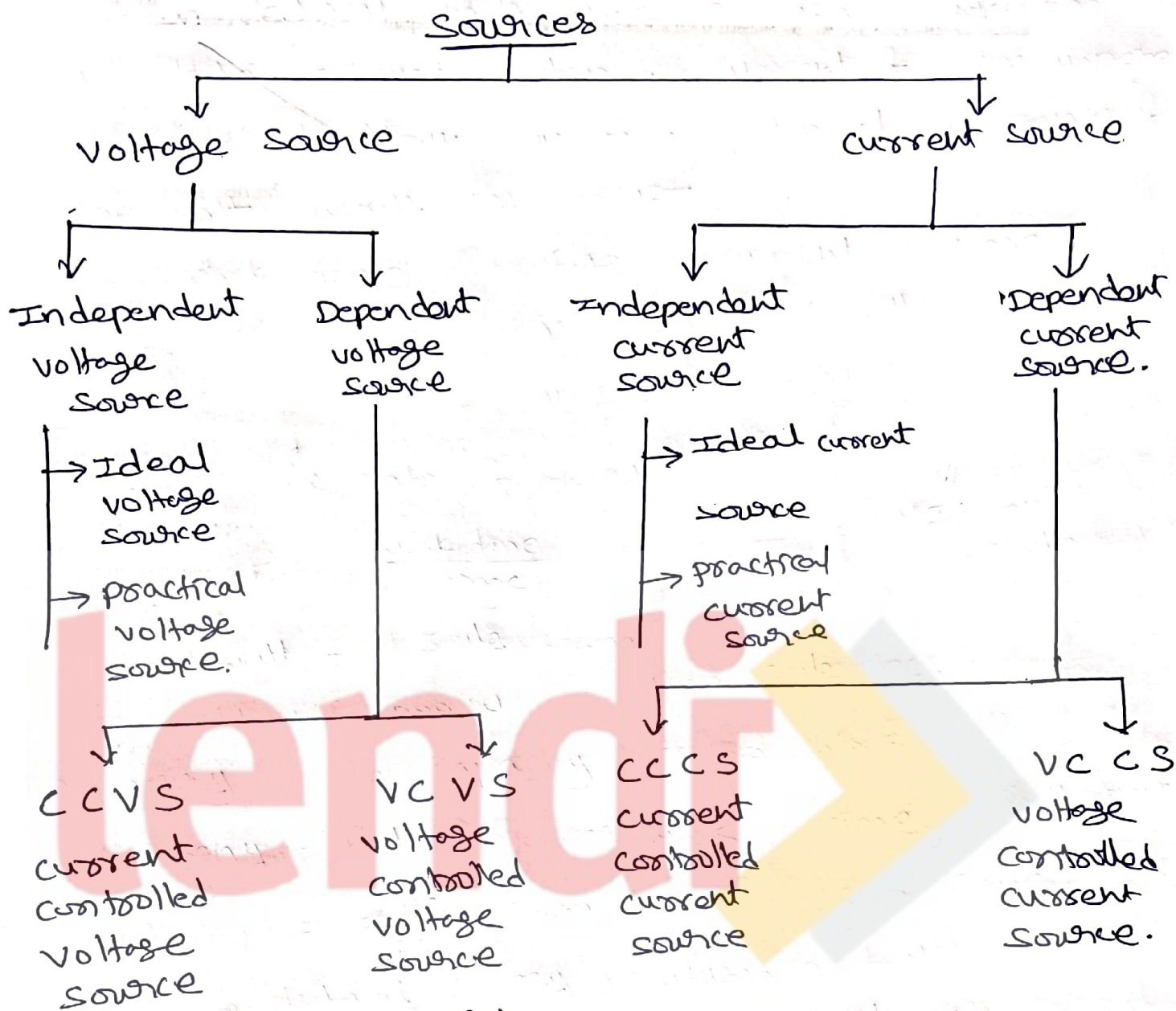
$\therefore$ The electrical energy measured in kWh

$$1 \text{ kilo watt hour (kWh)} = 1000 \text{ watt hour}$$

$$= 1000 \times 3600 \text{ sec}$$

$$1 \text{ kWh} = 36 \times 10^5 \text{ Joule.}$$

classification of Sources



Independent Sources

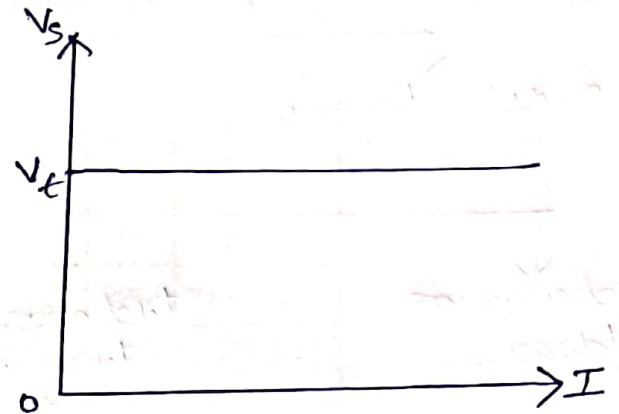
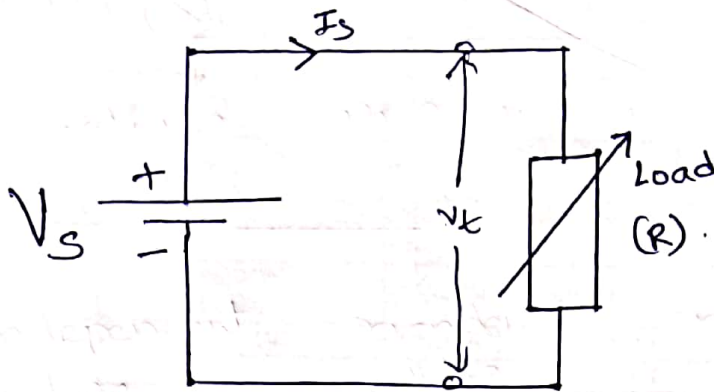
These sources maintain a constant voltage or constant current regardless of the circuit load.

Ideal independent voltage source

The voltage across the voltage source is constant and is independent of the current flows through its terminals to the load.

If current varies or load varies, then the source maintain constant voltage is called ideal voltage source.

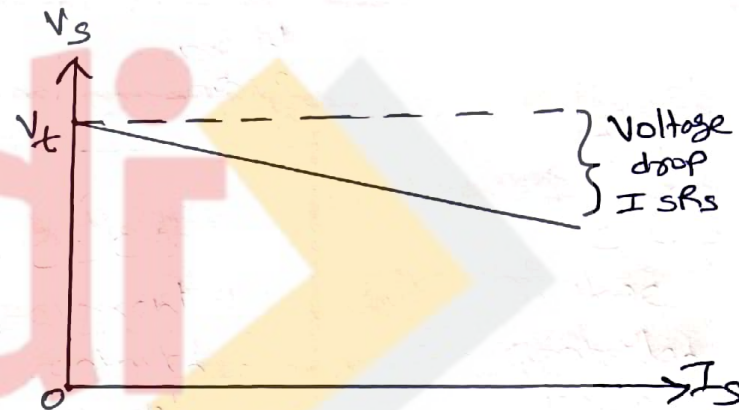
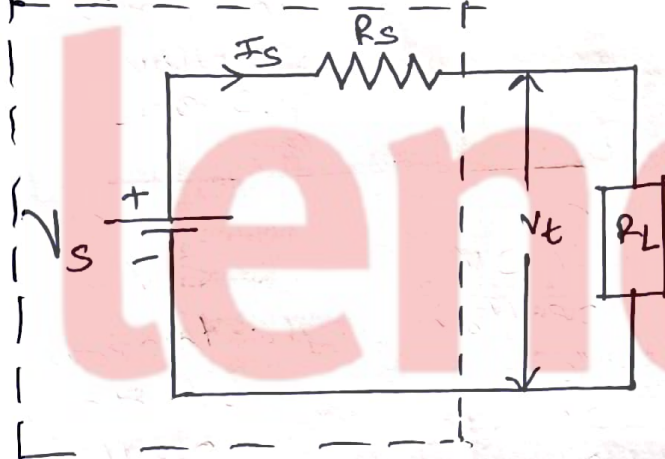
→ Internal resistance " r " of voltage source is zero. ($R_{int} = 0$).



Practical voltage sources

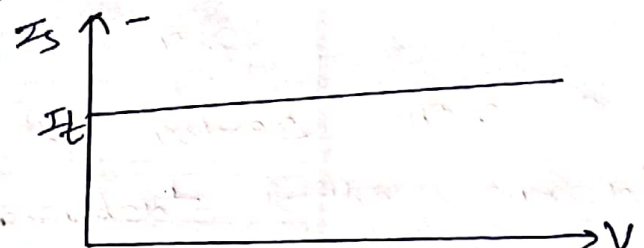
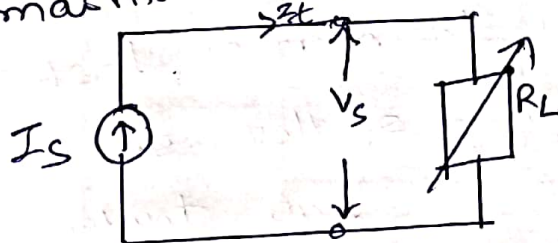
voltage source have some internal resistance (R_s)

in series with voltage source.



Ideal independent current source

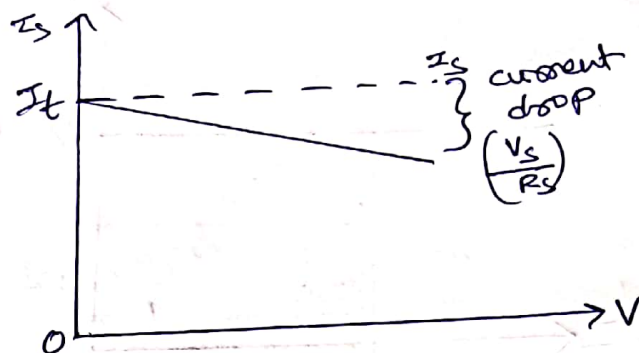
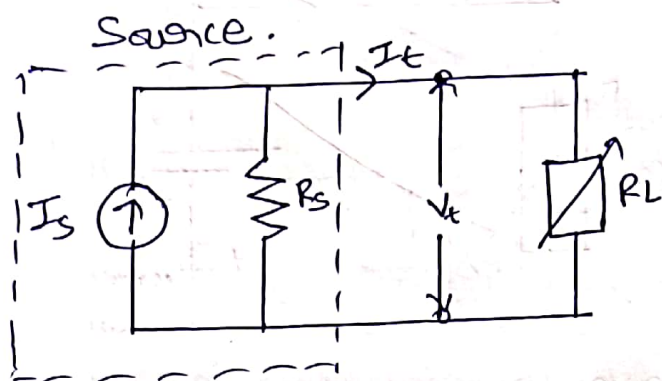
The current in current source is completely independent of the voltage across its terminals and maintain constant current in current source.



If voltage varies or load varies, then the source maintain constant current is called ideal current source. The internal resistance of current source is ∞ , $R_{int} = \infty$.

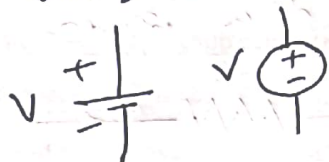
Practical current Source

→ current source have some internal resistance
 R_s is connected in parallel with current

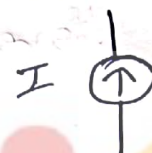


Symbols of Independent sources

voltage source



current source



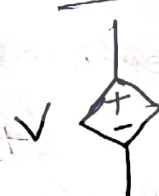
Dependent (or) Controlled Sources

Their output is controlled by a voltage or current at another point in the circuit.

Symbols are

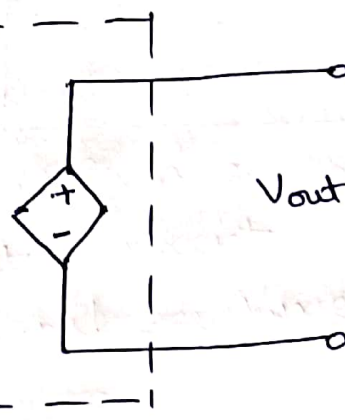
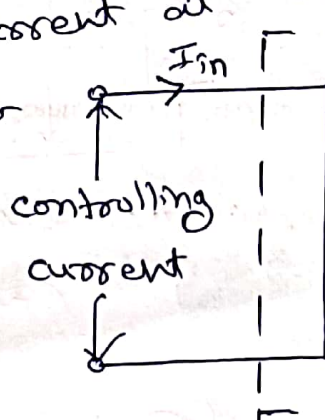
voltage source

current source



① CCVS : Current Controlled Voltage Source
 → voltage source controlled by the input current
 or current at another point in a circuit.

symbol



$$V_{out} = \rho I_{in}$$

→ CCVS have 4 terminals.

→ If control input current, the voltage at output is controlled.

Here e is constant (or) scaling factor (or) multiple factor.

$$\therefore V_{out} = e I_{in}$$

$$\therefore e = \frac{V_{out}}{I_{in}} \Omega.$$

$\therefore$ Here ' e ' is also called Trans Resistance (or) Trans impedance.

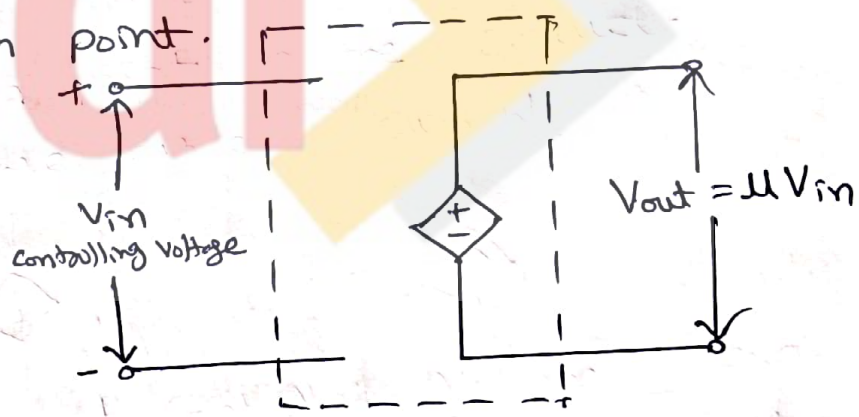
→ CCVS is a current to voltage converter (or) trans impedance amplifier.

② VCVS: Voltage Controlled Voltage source

→ voltage source controlled by voltage input or voltage at another point.

→ VCVS have 4 terminals.

→ If output is controlled by input voltage (or) depends on voltage input.



→ Here ' μ ' is proportionality constant.

$$V_{out} = \mu V_{in} \Rightarrow \mu = \frac{V_{out}}{V_{in}}$$

μ have no units,

→ Here μ is scaling factor (or) multiple factor.

→ Here μ is Voltage gain.

→ VCVS is a voltage to voltage converter (or) voltage amplifier.

③ CCCS : Current Controlled Current Source

→ current source controlled by the input current or current at another point.

→ It has 4 terminals.

→ I_{out} is controlled or depends on I_{in}

→ Here β is proportional constant.

$$I_{out} = \beta I_{in} \Rightarrow \beta = \frac{I_{out}}{I_{in}} \text{ (scaling factor).}$$

→ β is current gain

→ It is current to current converter (cc) current amplifier

④ VCCS : Voltage Controlled Current Source

→ current source controlled by the input voltage.

→ It has 4 terminals.

→ I_{out} is controlled or depends on V_{in}

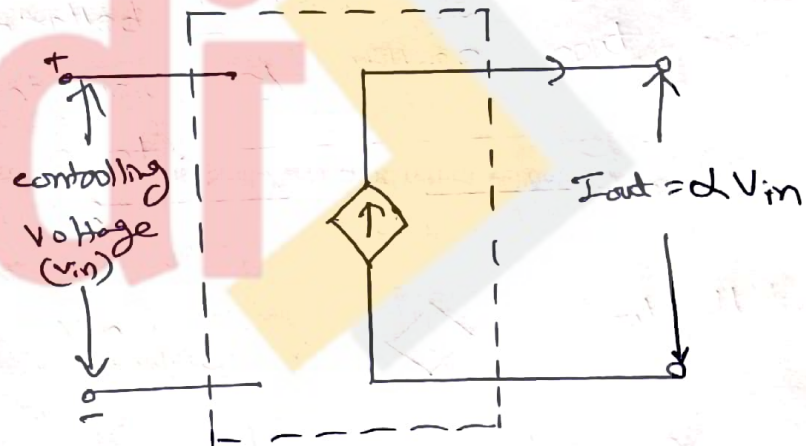
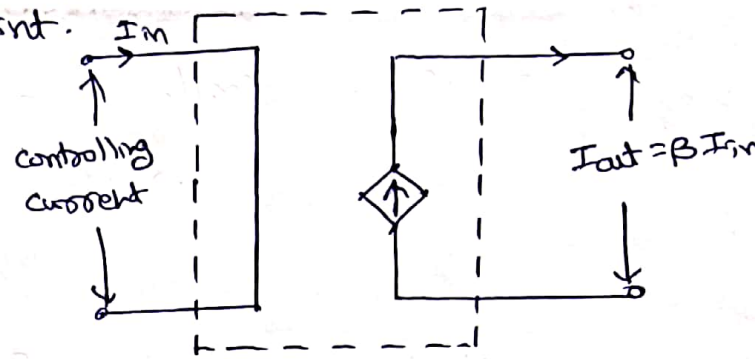
→ Here α is proportional constant.

$$I_{out} = \alpha V_{in}$$

$$\alpha = \frac{I_{out}}{V_{in}} ; \alpha \text{ is scaling factor.}$$

→ Here α is Trans conductance

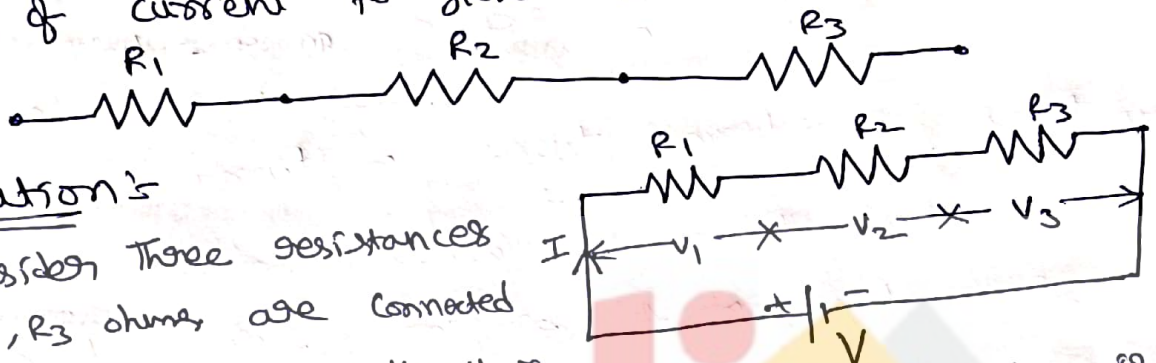
→ It is voltage to current converter (vc) trans conductance amplifier.



Resistance in Series end of resistance.

we know that, each resistance has two ends, and is as shown in above figure.

If one end of a resistance is joined with one end of another resistance and finally two ends are brought out from the combination, then they are said to be connected in series. So, that there is only one path of current to flow and shown in below figure.



Derivation:

Consider Three resistances R_1, R_2, R_3 ohms are connected in series across a battery of voltage of 'V' volts as shown in above figure.

There is only one path for current 'I' i.e., current is same throughout the circuit.

By applying ohm's law the voltage across the resistance are $V_1 = IR_1$, $V_2 = IR_2$; $V_3 = IR_3$

$$\text{we have } V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

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

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

But $\frac{V}{I}$ is the total resistance "R"

$\therefore$ 'R' is called total or equivalent resistance of the three resistance.

$$R = R_1 + R_2 + R_3.$$

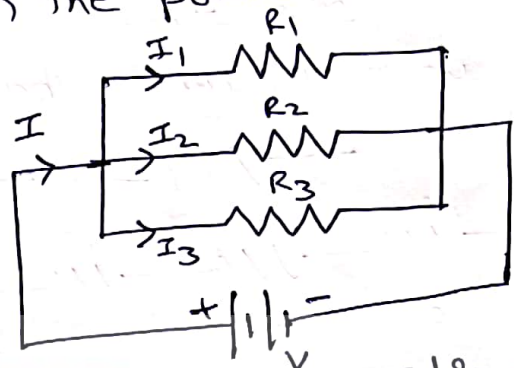
Hence from the above, when a number of resistance are connected in series, total resistance is equal to the sum of the individual resistances.

Resistance in parallel:-

If one end of each resistance is joined to a common point and the other end of each resistance is joined to another common point such type of connection is called parallel connection. In this type the number of paths for current flow will be equal to number of resistance in the parallel circuit.

Derivation}

Consider Three resistances R_1, R_2, R_3 ohms are connected in parallel across a battery of 'V' volts.



The total current 'I' divides into 3 parts, i.e. I_1 flowing through R_1 , I_2 flowing through R_2 , I_3 flowing through R_3 .

The voltage across each resistance is the same. By applying ohm's law

The current flowing through each resistance is

$$I_1 = \frac{V}{R_1} ; \quad I_2 = \frac{V}{R_2} ; \quad I_3 = \frac{V}{R_3}$$

Total current $I = I_1 + I_2 + I_3$

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

$$I = V \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right]$$

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

but we know that $\frac{V}{I} = \text{equivalent resistance 'R'}$

$$\therefore \frac{I}{V} = \frac{1}{R} ; \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If n-no-of resistance are connected in parallel then the equivalent resistance

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

KIRCHHOFF'S LAWS

- ① Kirchhoff's current law (a) Point law (b) K-C-L

"The algebraic sum of all the currents meeting at a point or junction in a network is zero."

(a)

"In any electric network, the sum of all currents coming towards the junction is equal to the sum of all currents going away from the junction (same junction)"

$$\sum I = 0.$$

Apply KCL at Junction 'O'

$$I_1 - I_2 + I_3 - I_4 + I_5 - I_6 = 0$$

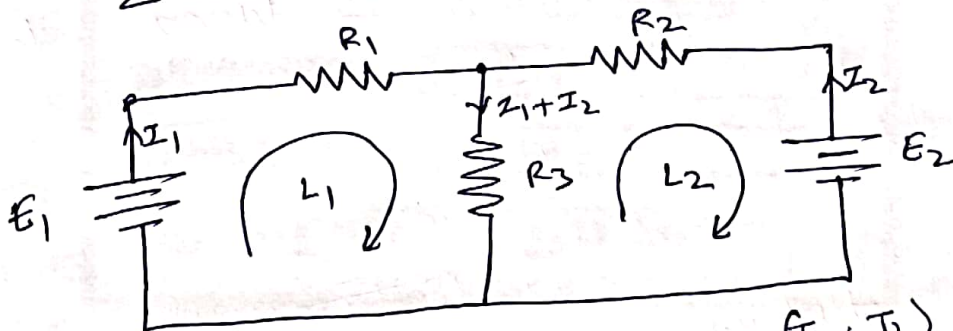
(b)

$$I_1 + I_3 + I_5 = I_2 + I_4 + I_6$$

- ② Kirchhoff's voltage law (a) mesh law (b) loop law

In any closed electrical circuit (a) mesh, the algebraic sum of all the voltage sources (e.m.f's) and the voltage drops is equal to zero.

$$\sum \text{e.m.f} + \sum I \cdot R = 0$$



From the figure let I_1 , I_2 & $(I_1 + I_2)$ be the assumed currents in branches. and applying KVL to the loop 1 (L_1)

$$E_1 - I_1 R_1 - (I_1 + I_2) R_3 = 0 \quad \text{--- (1)}$$

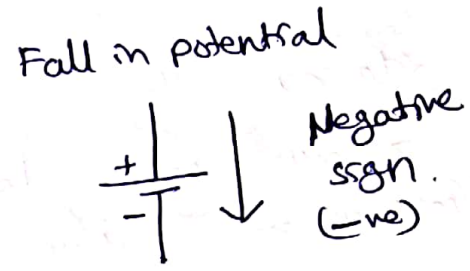
similarly applying KVL to loop 2 (L_2).

$$I_2 R_2 - E_2 + (I_1 + I_2) R_3 = 0 \quad \text{--- (2)}$$

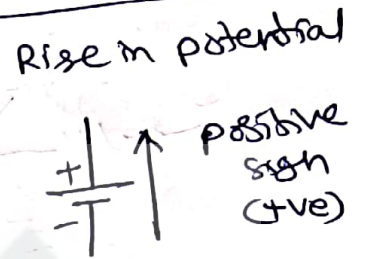
solving the equations (1) & (2) we get the values of currents I_1 & I_2 .

Sign Convention for E.M.F.:

(i) If we consider the circuit from positive terminal of a battery to negative terminal, caused there is a fall in potential and the emf is assigned by "-"ve sign.

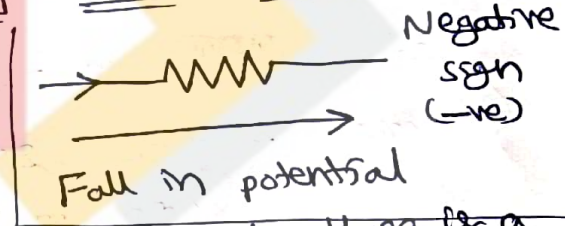


(ii) If we consider the circuit from negative terminal of a battery to positive terminal, there is a rise in potential and hence the emf is assigned by "+"ve sign.

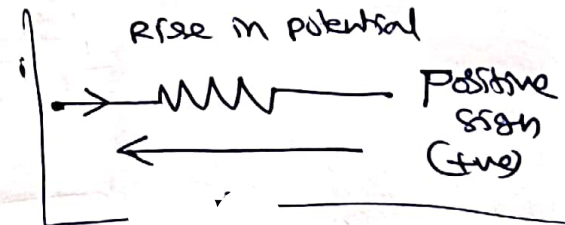


Sign Convention for voltage drop across Resistance:

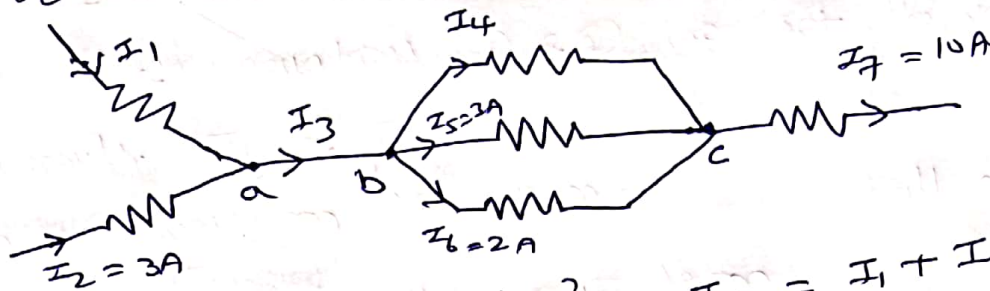
(i) when the current flows through a resistor, there is a voltage drop across it. If we go through the resistor in the same direction as the current, there is a fall in potential because current flows from higher potential to lower potential. Hence voltage drop represented by Negative sign (-ve). It is represented in above figure.



(ii) If the current flows from lower potential to higher potential caused there is a rise in potential hence, the voltage drop is represented by positive sign (+ve) and is represented in above figure.



① Find the current I_1, I_3, I_4 in the circuit shown in the fig by using KCL.



Sol: Apply KCL at node 'a' $\Rightarrow I_3 = I_1 + I_2$
 $I_3 = I_1 + 3$ ——— ①

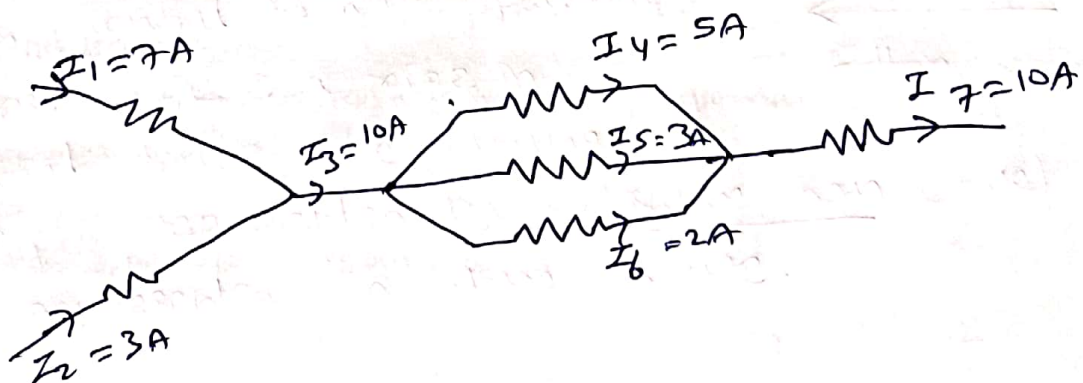
Apply KCL at node 'b' $\Rightarrow I_3 = I_4 + I_5 + I_6$
 $I_3 = I_4 + 3 + 2$
 $I_3 = I_4 + 5$ ——— ②

Apply KCL at node 'c' $\Rightarrow I_7 = I_4 + I_5 + I_6$
 $I_7 = I_4 + 3 + 2$
 $10 = I_4 + 5$
 $\therefore I_4 = 10 - 5 = 5A$ ——— ③

Substitute eq ③ in equation ②
 $I_3 = I_4 + 5 = 5 + 5 = 10A$ ——— ④

Substitute eq ④ in equation ①
 $I_3 = I_1 + 3$

$10 = I_1 + 3$
 $I_1 = 10 - 3 = 7A$ ——— ⑤

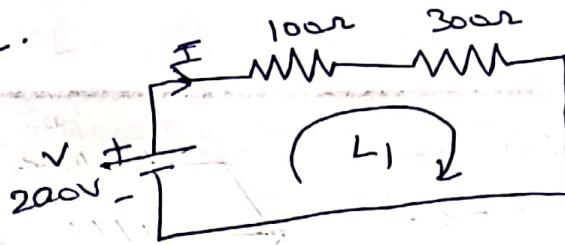


② Find the voltage drops and current flowing in the given circuit by using KVL.

Given $V = 200V$

$$R_1 = 100\Omega$$

$$R_2 = 300\Omega$$



Apply KVL to the circuit for Loop 1

$$200 - I(100) - I(300) = 0$$

$$200 - 100I - 300I = 0$$

$$200 = 400I$$

$$\therefore I = \frac{200}{400} = 0.5A$$

$\therefore$ Voltage across 100Ω resistor $V_1 = 100 \times I = 100 \times 0.5 = 50 \text{ Volts}$.

$\therefore$ Voltage across 300Ω resistor $V_2 = 300 \times I = 300 \times 0.5 = 150 \text{ Volts}$.

as per KVL statement

$$\text{Sum} = \text{voltage drops}$$

$$200 = V_{100\Omega} + V_{300\Omega}$$

$$= 50 + 150 = 200$$

Voltage Division Rule

The voltage across a individual resistor in a series circuit calculated by using voltage division rule without calculate the current value.

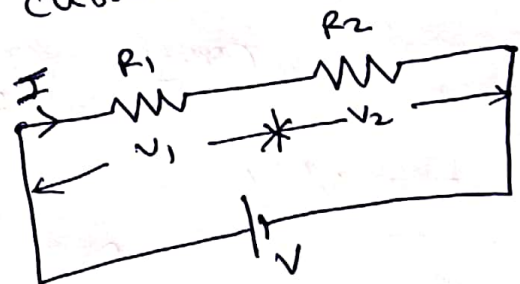
$$\text{Total Resistance } R = R_1 + R_2$$

$$\text{Total Current } I = \frac{V}{R}$$

$$\text{Voltage across resistor } R_1 \Rightarrow V_1 = I \cdot R_1$$

$$= \frac{V}{R} \cdot R_1$$

$$\therefore V_1 = \frac{V \cdot R_1}{R_1 + R_2}$$



Similarly voltage across R_2 $V_2 = I R_2$
 $= \frac{V}{R} \cdot R_2$

$$V_2 = \frac{V \cdot R_2}{R_1 + R_2}$$

Hence the voltage division rule states that the voltage across a resistor in series circuit is equal to the value of the supply voltage times of corresponding resistance value divided by total equivalent resistance of the circuit.

Current division rule

The current flowing through an individual resistor in a parallel circuit is determined by using current division rule without calculating value.

Let us consider parallel circuit.

$$\text{Total Resistance } R = \frac{R_1 R_2}{R_1 + R_2}$$

$$\text{Total voltage } V = I R$$

Voltage across the R_1 resistor is V_1 .

In parallel circuit voltage across each parallel branch is equal. i.e. $V = V_1 = V_2$.

$$V = V_1$$

$$I R = I_1 R_1$$

$$I_1 R_1 = I \cdot \left(\frac{R_1 R_2}{R_1 + R_2} \right)$$

$$I_1 = I \cdot \left(\frac{R_1 R_2}{R_1 + R_2} \right) \frac{1}{R_1} = \frac{I \cdot R_2}{R_1 + R_2}$$

so, current in R_1 resistor is

$$I_1 = \frac{I \cdot R_2}{R_1 + R_2}$$



Similarly,

$$V = V_2$$

$$I R = I_2 R_2$$

$$\therefore I_2 R_2 = I \cdot \frac{R_1 R_2}{R_1 + R_2}$$

$$I_2 = \frac{I \cdot R_1}{R_1 + R_2}$$

Hence, the current division rule states that, the current flowing through any branch in parallel circuit is equal to the product of total current supplied by the source and opposite branch resistance divided by the total resistance.

NODAL ANALYSIS

Node voltages can be computed from which any desired response can be calculated. Nodal analysis is based on KCL and it is applicable to any network for which KCL & KVL are true.

Note:- given circuit principle nodes are "n".

The no. of nodal equations are "(n-1)"
→ one of the node in the network is taken as reference.

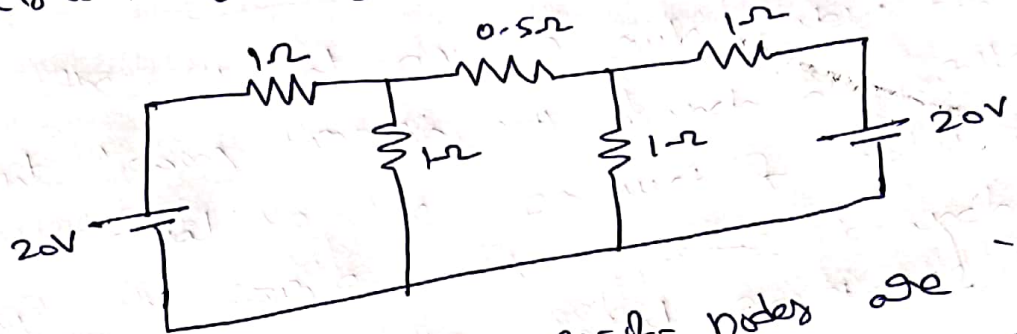
Steps to be followed in nodal analysis

- ① Assuming that a network has 'n' nodes, assign a reference node and assign a voltage name for each node.
- ② Apply KCL at each node except for the reference node and apply ohm's law to the branch current and

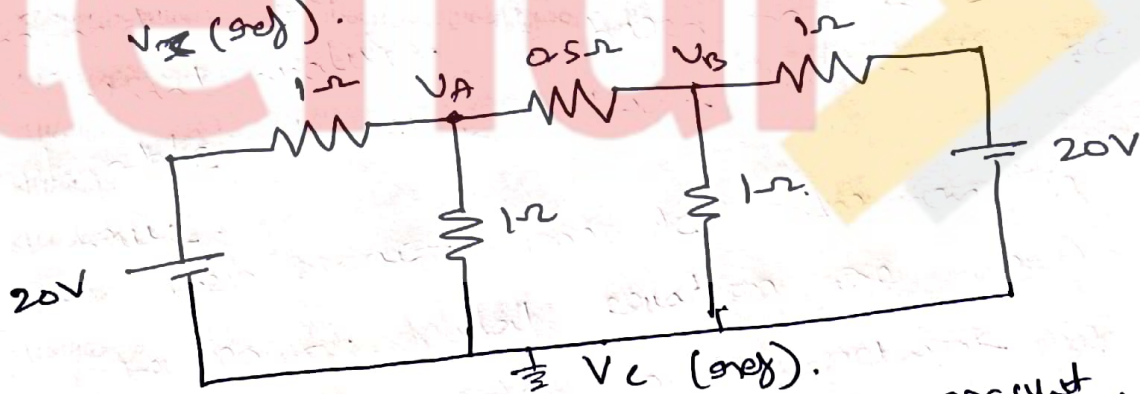
frame the equations for each node.

- ③ solve the simultaneous equations for the unknown node voltages. and also find any branch currents.

Exr To find the current through 2Ω resistor for the given circuit by using Nodal analysis.



Soln: For the given circuit no. of nodes are '3'
 so, no. of equations are $n-1 = 3-1 = 2$.
 assume the nodes V_A, V_B , and reference node V_C (ref).



Apply KCL at node V_A to above circuit.

$$\frac{V_A - 20}{1} + \frac{V_A}{1} + \frac{V_A - V_B}{0.5} = 0$$

$$V_A \left(1 + 1 + \frac{1}{0.5} \right) - \frac{V_B}{0.5} = 20$$

$$V_A (1 + 1 + 2) - 2V_B = 20$$

$$2V_A - V_B = 10 \quad \text{--- (1)}$$

Apply KCL at node $-V_B$

$$\frac{V_B - V_A}{0.5} + \frac{V_B}{1} + \frac{V_B - 20}{20} = 0$$

$$V_B \left(\frac{1}{0.5} + \frac{1}{2} + 1 \right) - \frac{V_A}{0.5} = 20$$

$$-2V_A + V_B(3.5) = 20 \quad \text{--- (2)}$$

By solving equations (1) & (2)

we get $V_A = 11V$, $V_B = 12V$.

Current through the 2Ω resistor is $\frac{V_B}{2}$
 $= \frac{12}{2} = 6A$.

MESH Analysis

This method is used to find the individual currents in each mesh and thereby current, voltage & power in every branch of the network can be estimated.

Limitation:- The network should be planar, it can be drawn on a plane surface without cross over.

In this method, the current in different meshes are assigned continuous paths, so that they do not split at a junction into branch currents.

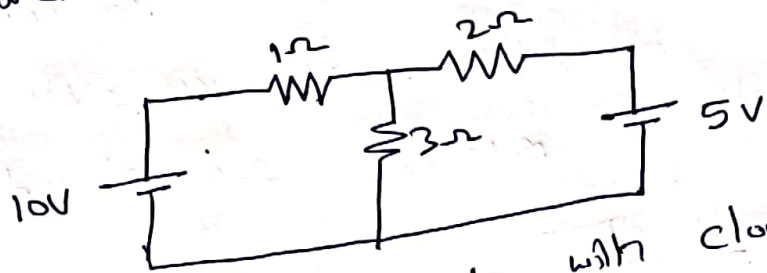
mesh analysis based on KVL to write equations.

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 resistances.
- ④ Solve the simultaneous equations for unknown mesh currents.

prob Find the current through 3Ω resistor by using mesh analysis.



→ mention the current's in mesh with clockwise direction. i.e



Apply KVL to the mesh I1

$$10V - I_1(1) - (I_1 - I_2)3 = 0$$

$$10 - I_1 - 3I_1 + 3I_2 = 0$$

$$4I_1 - 3I_2 = 10 \quad \text{--- (1)}$$

Apply KVL to the I2 mesh.

$$-5 - 3(I_2 - I_1) - I_2(2) = 0$$

$$-5 - 3I_2 + 3I_1 - 2I_2 = 0$$

$$3I_1 - 5I_2 = 5 \quad \text{--- (2)}$$

By solving equations (1) & (2) then get the I_1 & I_2 values. Then substitute the these values in the current flowing through 3Ω resistor is $I_1 - I_2$.

SUPER POSITION THEOREM

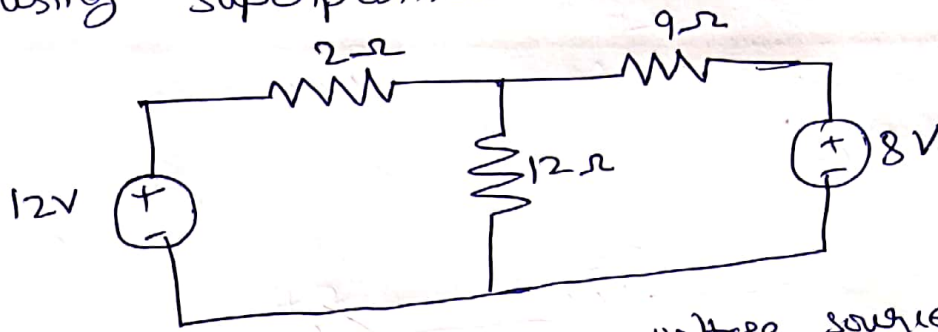
"In any linear bilateral resistive network having two or more voltage sources, the current through any branch is the algebraic sum of the currents produced by each source acting alone at a time" when all other sources are replaced by their internal resistances".

Note: It is applicable only to voltage & current responses but not for power.

Steps to be followed in super position theorem

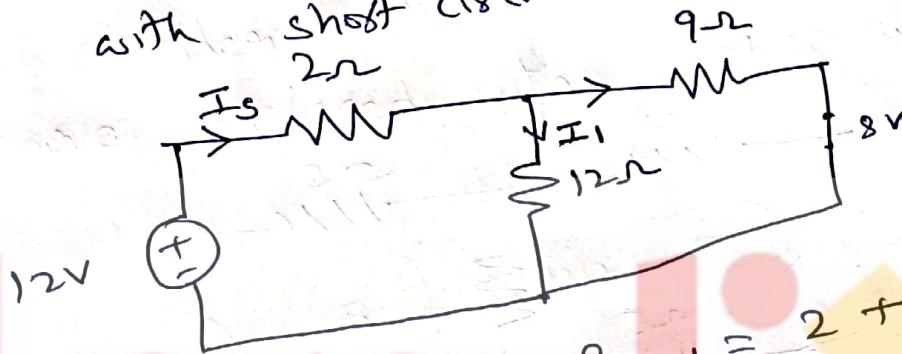
- Identify independent sources: List all independent voltage or current sources.
- Select one active source: choose one independent source to remain active while deactivating others. voltage sources are replaced by short circuit (0V) (∞) replaced with internal resistance, and current sources are replaced by open circuit (0A) (∞) replaced with internal resistance.
- calculate the response: Determine the voltage or current due to the single active source using circuit analysis techniques like ohm's law or KVL, KCL, loop analysis, nodal & mesh analysis.
- Repeat for all sources above three steps.
- Algebraic summation: combine all individual responses, considering the direction of current and polarity of voltage, to find the total response.

Prob: Find the current in 12Ω resistance by using superposition.



Sol: Given circuit has two voltage sources 12V, 8V.

Step 1 consider 12V source, 8V source is replaced with short circuit.



From above circuit $R_{Total} = 2 + \left[\frac{9 \times 12}{9 + 12} \right] = 7.142$

Total input current $\Rightarrow I_s = \frac{12}{7.142} = 1.68 \text{ Ams.}$

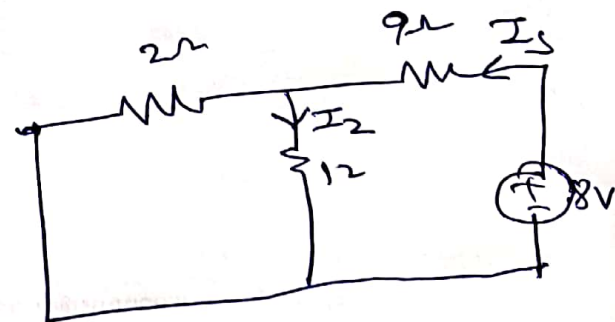
Apply current division rule. $I_1 = \frac{I_s \cdot 9}{9 + 12}$

$\therefore I_1 = \frac{(1.68) \cdot 9}{21} = 0.72 \text{ Ams.} \quad \text{--- (1)}$

Step 2 consider 8V source, 12V source is replaced with short circuit.

$R_{Total} = 9 + \left(\frac{2 \times 12}{2 + 12} \right)$
 $= 9 + \frac{24}{14}$

$R_{Total} = 11\Omega$



$$\text{Total input current } I_s = \frac{8}{11} = 0.727 \text{ Am.}$$

Apply current division rule.

$$I_2 = \frac{I_s \cdot 2}{2+9} = \frac{0.727(2)}{11} = 0.132 \text{ Am} \quad \text{--- (2)}$$

So, the current flowing through a 12Ω resistor when we consider both voltage source $12V$ & $8V$

I_s = addition of I_1 & I_2

$$= I_1 + I_2$$

$$= 0.72 + 0.132$$

$$I_{12\Omega} = 0.852 \text{ Am.}$$

$I_{12\Omega} = 0.852$ Amperes of current flowing through 12Ω resistor when the both sources are acting alone at a time.