# Electrical Engineering

→ Any arrangement of various electrical energy sources along with different circuit element is known as Network.

→ Any individual circuit element with two terminals which can be connected to other circuit element is called network element.

It is of 2 types:-

- Active Elements - Elements which supply power or energy to network
  Eg:- Voltage & Current source
- Passive Elements - Elements which either store or dissipate energy in form of heat. Eg:- Resistors, Inductors, Capacitors

→ A part of network which connects the various points of network with one another is called branch.

→ A point where three or more branches meet is called Junction point.

→ A point at which two or more elements are joined together is Node.

→ Mesh (or loop) is a set of branches forming a closed path in a network such that if one branch is removed then remaining branches dont form a closed path.

Electrical Circuits or Networks

Active | Passive | Linear | Nonlinear | Unilateral | Bilateral | Lumped | Distributed

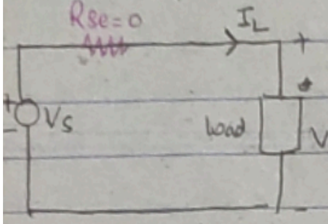
- Linear - A circuit or network whose parameters are always constant irrespective of change in time, voltage, temperature. Ohm's law can be applied
- Non linear - A circuit whose parameter change with change in temp, time voltage. Ohm's law & law of superposition not followed.
- Bilateral - A circuit whose characteristics, behaviour is same irrespective of current through various elements of it. Eg:- Network consisting only resistances
- Unilateral - A circuit whose characteristics, behaviour is dependent of direction of current through it. Eg:- Network consisting of diodes
- Active - A circuit which contains atleast one energy source
- Passive - A circuit which contains no energy source.

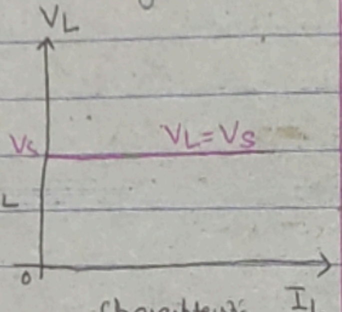
- Lumped - A network in which all network elements are physically seperable.
- Distributed - A network in which circuit elements like resistance, inductance cannot be physically seperable for analysis purpose

Eg: Transmission line where elements (R, C, & L) are distributed along its length.

## ($R_{se} = 0$) Ideal Voltage Source

- Energy source which gives constant voltage across its terminals irrespective of current drawn through its terminals.

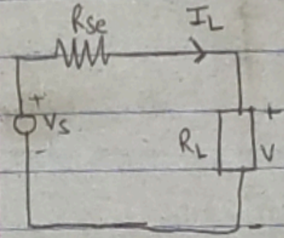


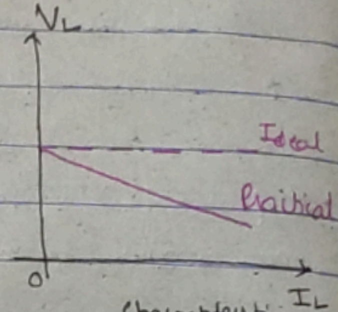




Characteristic

## Practical Voltage Source

- Energy source in which voltage across its terminal decreases slightly with increase in current




Characteristic

- When there is no load $I_L = 0$, $V = V_S$

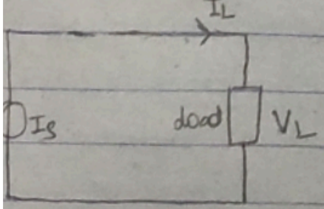
$$\boxed{V_L = -(R_{se}) I_L + V_S = V_S - I_L R_e}$$

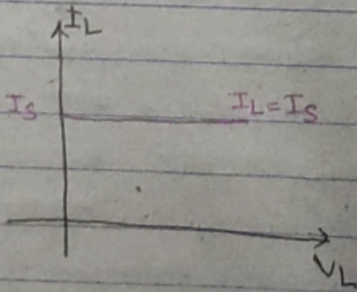
## Current / Voltage Source

| Time Invariant Sources | Time Variant Sources |
| --- | --- |
| Source in which voltage/current is not varying with time | Source in which current / voltage is varying with time |
| Eg: DC | Eg: AC |

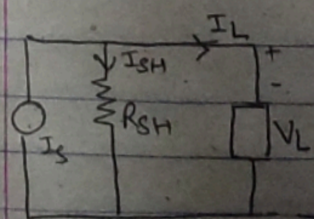
## Ideal Current Source

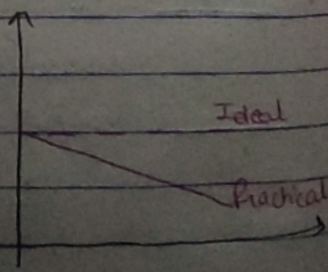
$\boxed{R_{SH} = \infty}$




## Non-Ideal Current Source




$I_L + I_{SH} = I_S$

$I_L < I_S$

Dependent Sources

1. Voltage Dependent Voltage source - Voltage as a function of voltages elsewhere in given circuit.

2. Current Dependent Current Source

3. Current Dependent Voltage Source

4. Voltage Dependent Current source

Ohm's Law - Current flowing through electric circuit is directly proportional to potential difference across circuit & inversely proportional to resistance of circuit.

Ohm's Law can be either applied to entire circuit or part of circuit. If it is applied to entire circuit the voltage across entire circuit and resistance of entire circuit should be taken into account. & if it is applied to part of circuit then resistance of that part and potential across that part should be used.

Limitations

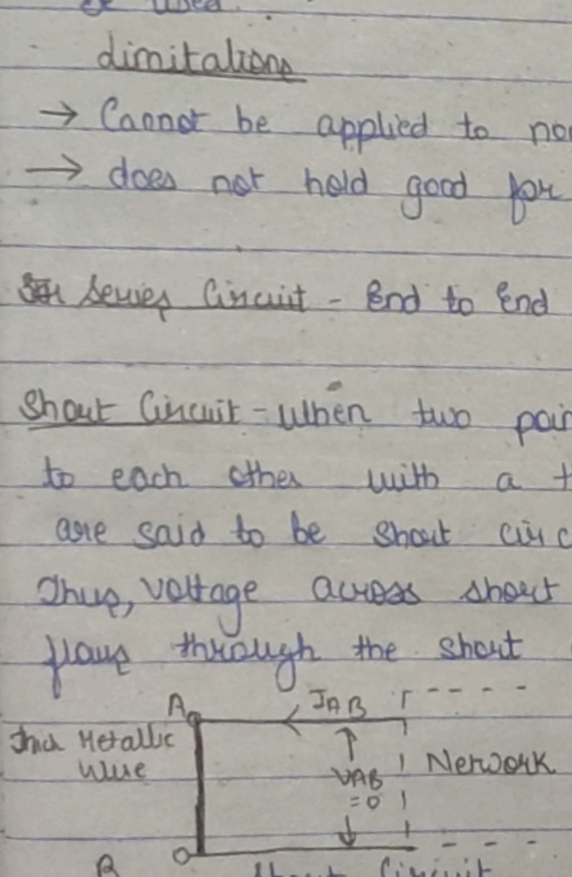
→ Cannot be applied to non-linear devices such as diodes, voltage regulator.

→ does not hold good for metallic conductors such as silicon carbide.

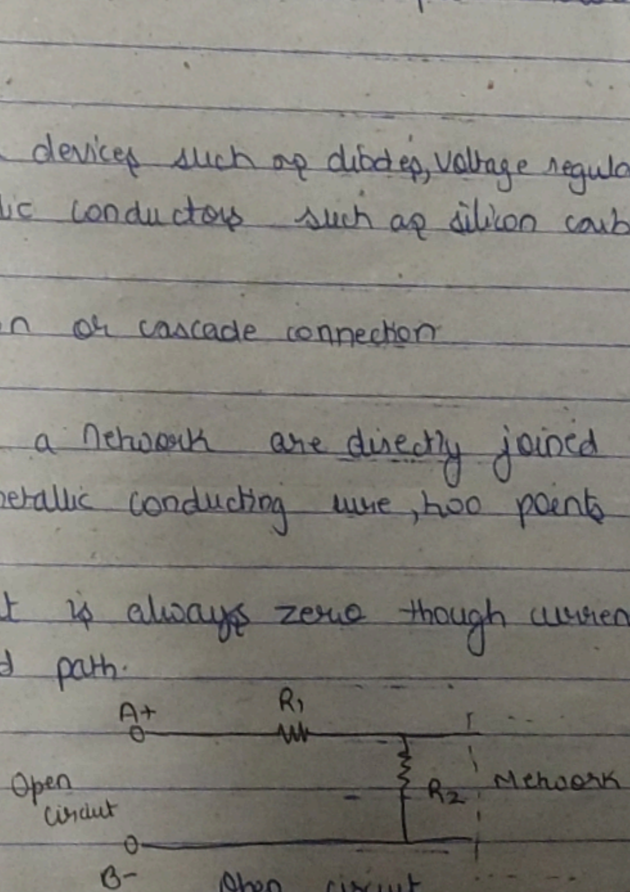
~~Ser~~ Series Circuit - End to End connection or cascade connection

Short Circuit - When two points in a Network are directly joined to each other with a thick metallic conducting wire, two points are said to be short circuited.

Thus, voltage across short circuit is always zero though current flows through the short circuited path.



Short Circuit



Open circuit

Open Circuit when there is no connection between the points of a network having some voltage across the two points then the two points are said to be open circuited.

## Redundant Branches & Combinations

Redundant means excessive & unwanted.

If in a circuit there are branches or combinations of elements which do not carry any current then such branches and combinations are called redundant from circuit point of view.

Two important situations of redundancy:→

Situation 1 → Any branch or combination across which there exists a short circuit, becomes redundant as it does not carry any current.

Situation 2 → If there is open circuit in a branch or combination, it cannot carry any current and becomes redundant.

## Source Transformation

Two sources are said to be equivalent, if they supply equal load current to the load with same load connected across its terminals.

- If voltage source is converted to current source, then current source $I = V/R_{se}$ with parallel internal resistance equal to $R_{se}$
- If current source is converted to voltage source, then voltage source $V = IR_{SH}$ with series internal resistance equal to $R_{SH}$.

→ Voltage sources to be connected in series must have same current ratings though their voltage ratings must be same or different.

→ Voltage sources to be connected in parallel must have same voltage ratings though their current rating may be same or different.

→ Current sources to be connected in series must have same current ratings though their voltage ratings must be same or different.

→ Current sources to be connected in parallel must have same voltage rating though their current ratings may be same or different.

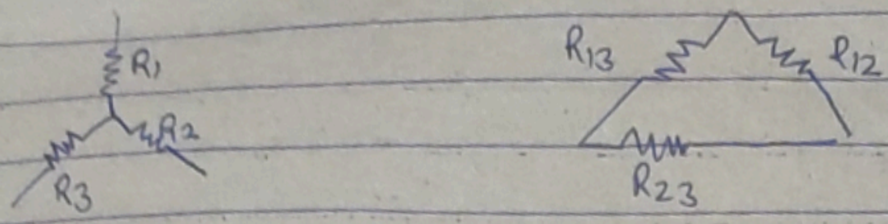
Kirchhoff's Current Law $\Sigma I$ at junction point $= 0$

Current flowing towards junction point are assumed to be positive which currents flowing away from junction point are assumed to be negative.

Kirchhoff's Voltage Law Around a closed path $\Sigma V = 0$

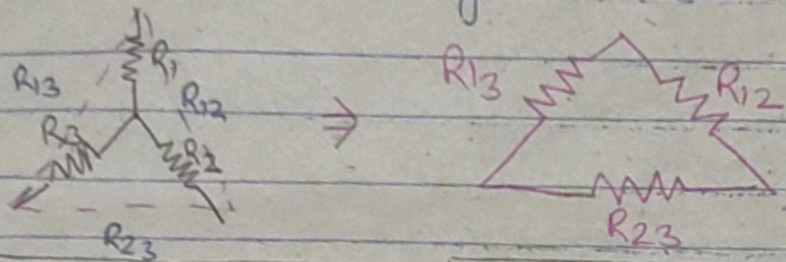
In any network algebraic sum of voltage drop across the circuit elements of any closed path (loop or mesh) is equal to algebraic sum of emf's in path

## Star-Delta Transformation




Star

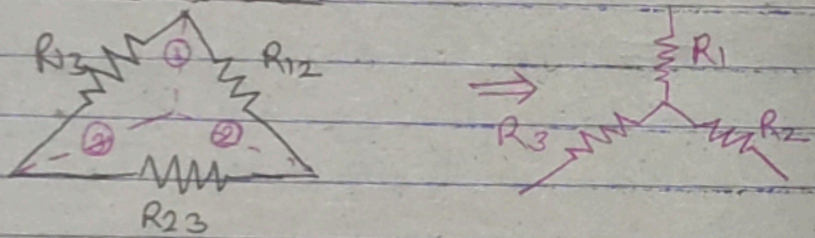
1→ Star to Delta: First join the outer ends




$$\boxed{R_{12} = R_1 + R_2 + \frac{R_1 \times R_2}{R_3}} \quad \boxed{R_{23} = R_2 + R_3 + \frac{R_2 \times R_3}{R_1}} \quad \boxed{R_{13} = R_1 + R_3 + \frac{R_1 \times R_3}{R_2}}$$

$$\boxed{R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}} \quad \boxed{R_{23} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}} \quad \boxed{R_{13} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}}$$

2→ Delta to Star




$$\boxed{R_1 = \frac{R_{12} \cdot R_{13}}{R_{12} + R_{23} + R_{13}}} \quad \boxed{R_2 = \frac{R_{12} \cdot R_{23}}{R_{12} + R_{23} + R_{13}}} \quad \boxed{R_3 = \frac{R_{13} \cdot R_{23}}{R_{12} + R_{23} + R_{13}}}$$

[Multiplication of adjacent sides devided by 3 teeno ka addition

5 Rules for solving problem

Rule 1: Sabse pehle series parellel solve krenge jb tak wo nhi honge tb tak ~~series~~ star ~~parell~~ delta ko hath nhi lgaenge

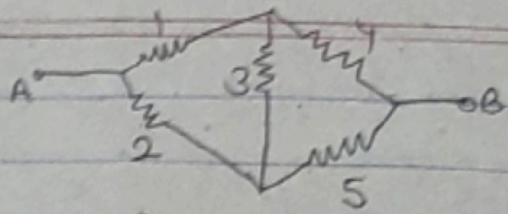
Rule 2: Jab bhi 2 ~~se jyada~~ delta samne aaenge tb kewal ek hi delta solve krenge.

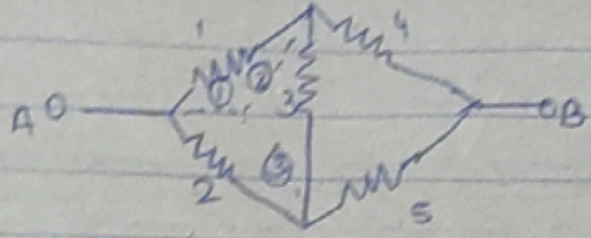
Rule 3: Jab bhi 3 delta aaenge to beech wale star ko solve krenge

Rule 4: Jab bhi 4 delta aae to opp wale 2 delta solve krenge

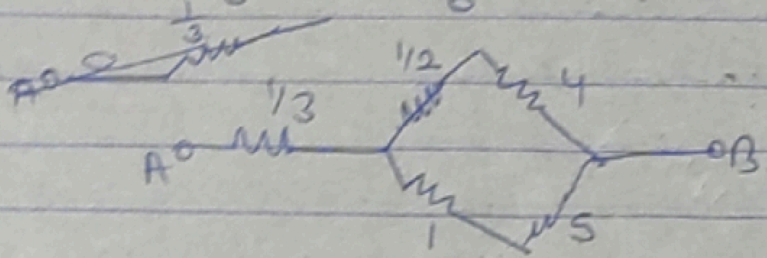
Rule 5: Jab bhi 6 delta aae to any 3 alternate delta solve krenge

Q Find total resistance b/w A&B

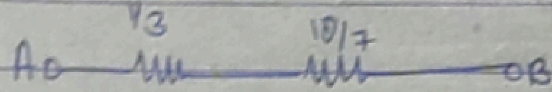



① ⇒ $\frac{2}{6}$ ② ⇒ $\frac{3}{6}$ ③ ⇒ $\frac{6}{6}$ Now redrawing



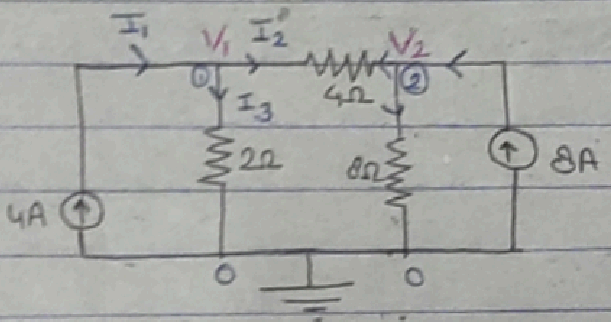

$$\frac{\frac{9}{2}\times 6}{\frac{9}{2}+6} = \frac{54}{21} \Rightarrow \frac{18}{7}$$




$$R_{AB} = \frac{1}{3}+\frac{18}{7} = \frac{7+54}{21} \Rightarrow \frac{61}{21}$$

Q→ Question for KCL

| |
|---|
| Enter → -ve |
| Leave → +ve |




Applying KCL at node ① $I_2 + I_3 - I_1 = 0$

$$\frac{V_1 - V_2}{4} + \frac{V_1 - 0}{2} - 4 = 0 \Rightarrow \boxed{3V_1 - V_2 = 16} \text{ — ①}$$

Applying KCL at node ② $\frac{V_2 - V_1}{4} + \frac{V_2 - 0}{8} - 8 = 0$ $\boxed{3V_2 - 2V_1 = 64}$ — ②

Solving ① & ② simultaneously,

$$6V_1 - 2V_2 = 32$$
$$9V_2 - 6V_1 = 192$$
$$7V_2 = 224 \quad V_2 = \frac{224}{7} = 32V$$

$3V_1 = 16 + 32$ $\boxed{V_1 = 16V}$

Hence $V_1 = 16V$ $V_2 = 32V$

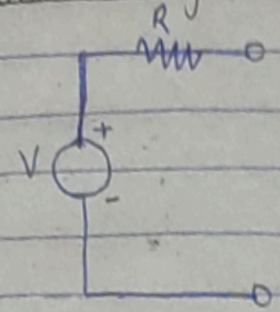
Current in 4Ω branch = 4A

Current in 2Ω branch = 8A

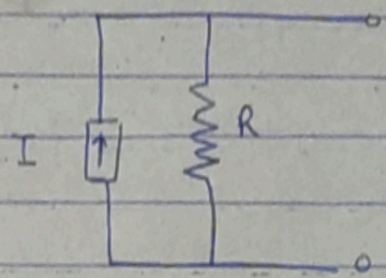
Current in 8Ω branch = 4A

# Source Transformation

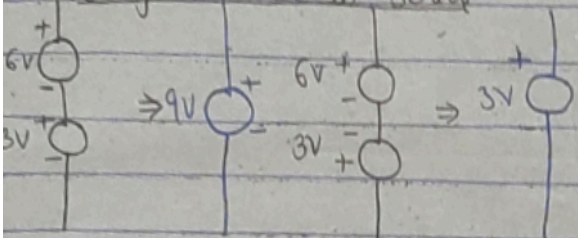
Practical Voltage Source



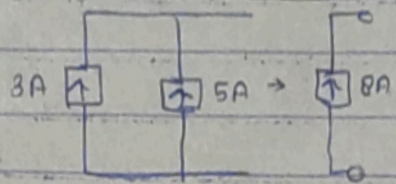

Practical Current Source

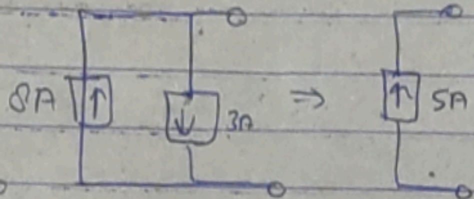



Voltage Source in Series

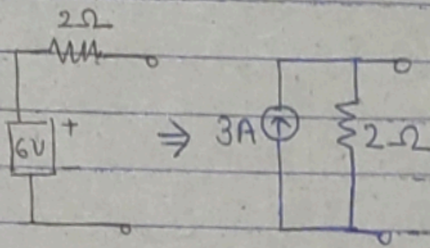



Current source in Parellel

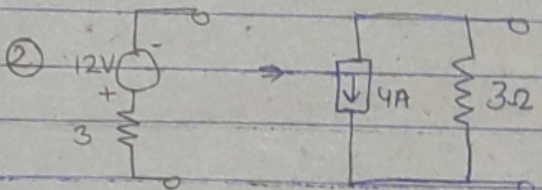


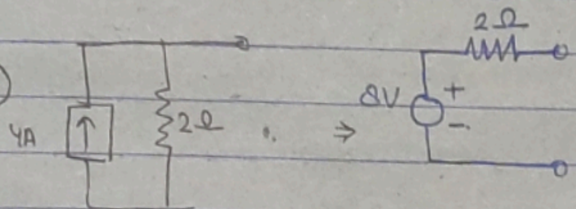

Examples ①



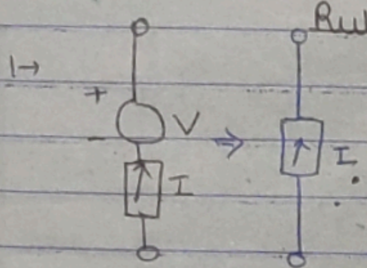

②




③




1→



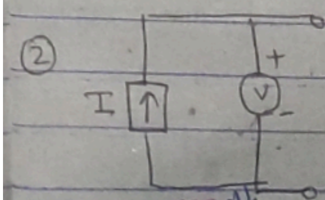

Rules

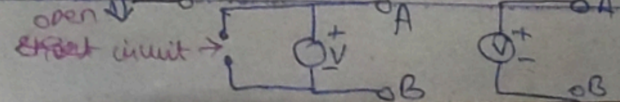
- If voltage source & current source are in series deactivate the voltage source ( as in 1)
- If voltage source & current source are in parellel deactivate the current source ( as in 2

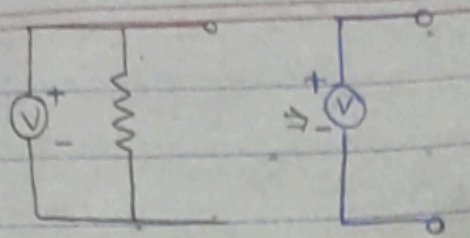
For Deactivating

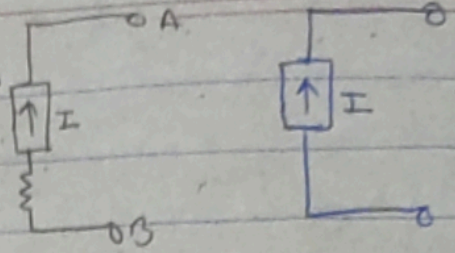
- Voltage source → Make in short circuit
- Current source - Make it open circuit

②



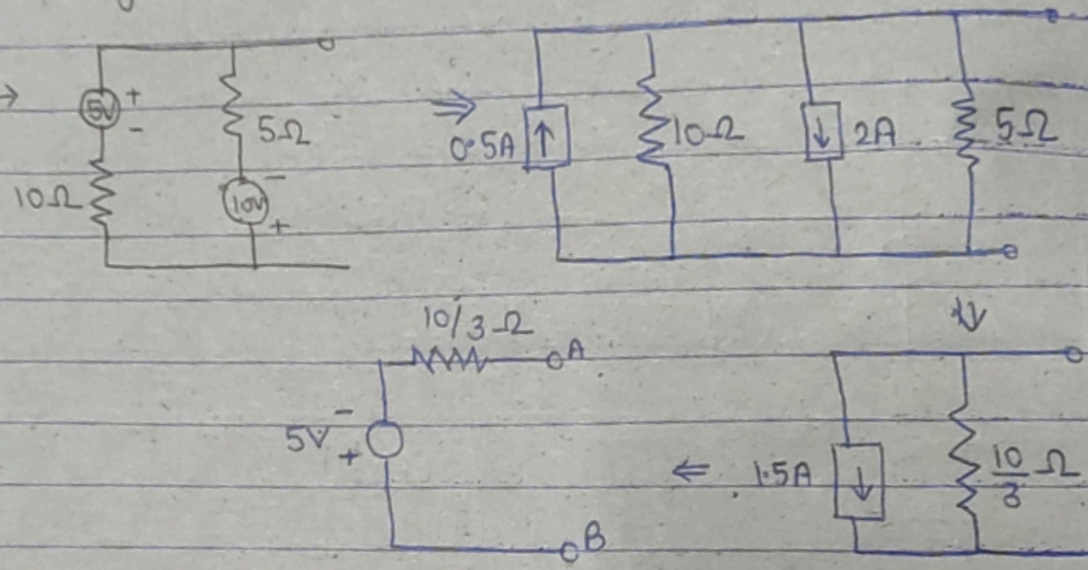



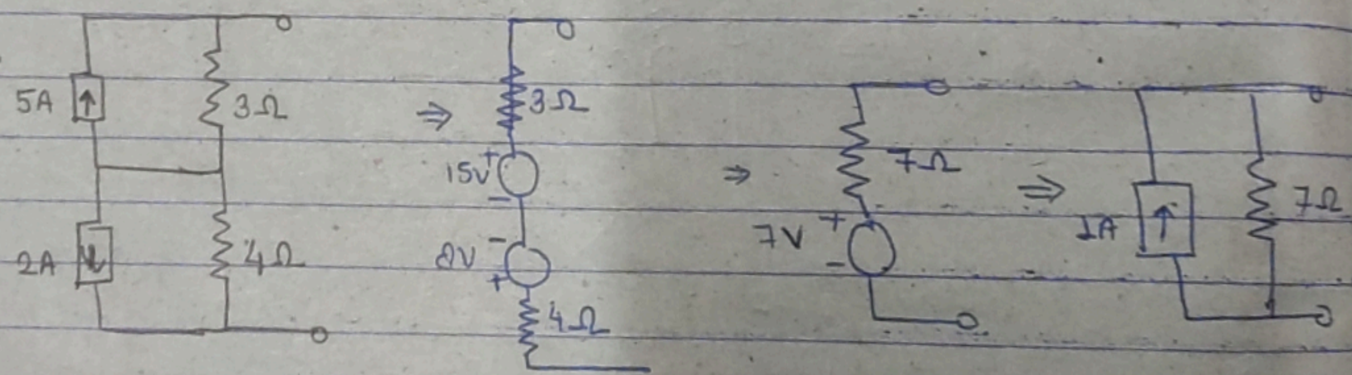


4→ 


Make resistance as dummy element & remove it

Ques Reduce the network shown in figure to a single voltage source in series with a single element

1→ 


2→ 

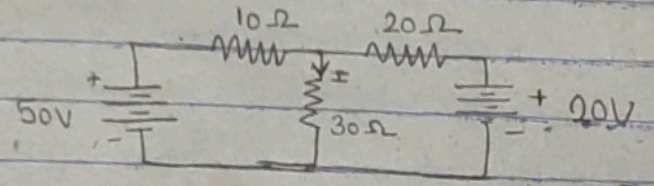
→ Applicable for linear and bilateral networks

Superposition Theorm: In any multisource complex network consisting of linear bilateral elements, the voltage across or current through any given element of network is equal to algebraic sum of the individual voltages or currents, produced independently across or in that element by each source acting independantly, when all remaining sources are replaced by their respective internal resistances.

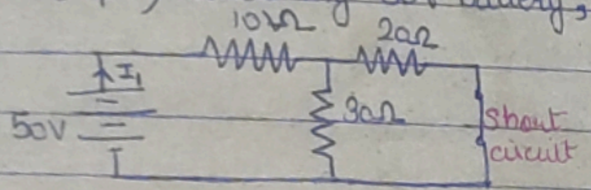
NOTE:- If the internal resistance of the sources are unknown then the independent voltage source must be replaced by short circuit while the independent current source must be replaced by an open circuit.

★ There must be more than 1 source.

Ques



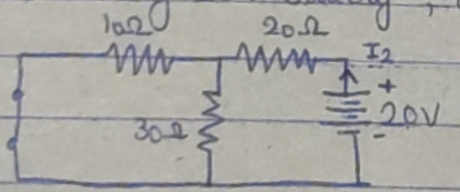

Ans Step 1) Considering 50V battery, deactivating 20V battery




$$I_1 = \frac{50}{\frac{30\times20}{30+20}+10} = \frac{50}{12+10} = \frac{50}{22} = 2.272A$$

Current through 30Ω branch $= 2.272 \times \frac{2}{5} = 0.9088\,A\ (\downarrow)$

Step 2) Considering 20V battery, deactivating 50V battery




$$I_2 = \frac{20}{\frac{30\times10}{30+10}+20} = 0.727\,A$$

Current through 30Ω branch $= 0.727 \times \frac{10}{40} = 0.1818\,A\ (\downarrow)$

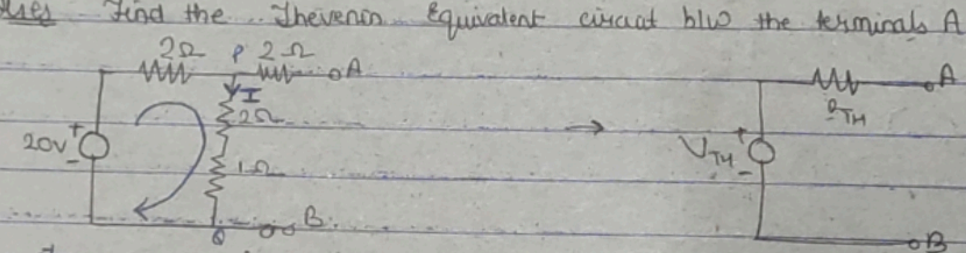
Step 3) Total current through 30Ω resistance $= 0.9088 (\downarrow) + 0.1818 (\downarrow) = \boxed{1.09A (\downarrow)}$

Superposition Theorm doesn't work for power calculation Because power calculations involve either the product of voltage and current

**Thevinin's Theorm** Any combination of linear bilateral circuit elements and active sources, regardless of the connections or complexity, connected to a given load $R_L$ may be replaced by a simple two terminal network consisting of a single voltage source of $V_{TH}$ volts and a single resistance $R_{eq}$ in series with voltage source, across two terminals of ~~Read~~ load $R_L$. The voltage $V_{TH}$ is the open circuit voltage measured at the two terminal of intrest with load resistance $R_L$ removed.
This voltage is also called Thevenin's Equivalent Voltage.
$R_{eq}$ is the equivalent resistance of given network as viewed through terminals where $R_L$ is connected but with $R_L$ removed and all active sources are replaced by their internal resistance.

NOTE:- If internal resistance are not known the independant voltage sources are to be replaced by short circuit while the independent current sources must be replaced by open circuit.

**Ques** Find the Thevenin Equivalent circuit b/w the terminals A & B

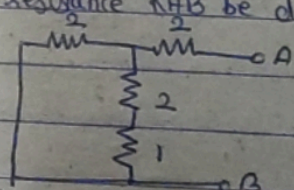



- For calculation of $V_{th}$ Calculation $V_{PQ}$

Applying KVL loop $\Rightarrow -20 + 5I_1 = 0$ $\therefore I_1 = 4A$

$\therefore V_{PQ} = 4 \times 3 = 12\,V$ $\therefore V_{PQ} = V_{TH}$

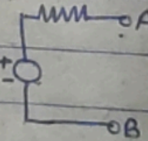
- For calculation of $R_{th}$ $\Rightarrow$ Calculating Resultant resistance $R_{AB}$ be deactivating all sources




$$R_{AB} = \frac{3 \times 2}{3+2} + 2 = \frac{5}{5} + 2 = 3.2\,\Omega$$

$R_{th} = 3.2\,\Omega$

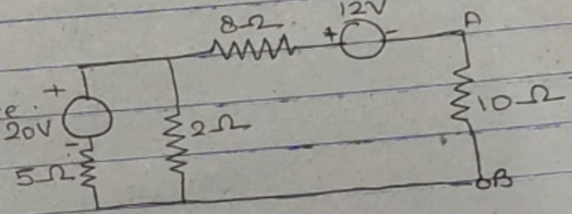
- Now thevenin Equivalent circuit b/w A & B



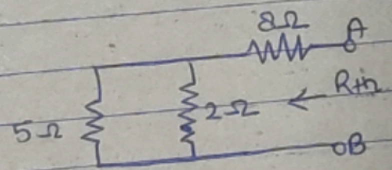

Limitations:-
1) Not applicable to unilateral networks
2) Not applicable to circuit consisting of non linear elements.
3) There shouldn't be magnetic coupling between the load and circuit ~~to~~ to be replaced by Thevenin's Theorm.
4) In the load side, there should not be controlled sources, controlled from other part of circuit.

**Norton Theorem:→** ~~Ay~~ Any combination of linear bilateral circuit elements and active sources, regardless of the connection or complexity, connected to a given load $R_L$ can be replaced by a simple two terminal network consisting of a single current source of $I_N$ amperes and a single impedance $R_{eq}$ ~~with~~ in parallel with it across the two terminals of load $R_L$. The $I_N$ is the short circuit current flowing through short circuited path replaced instead of $R_L$. It is also called Norton's current. $R_{eq}$ is the equivalent impedance of given network as viewed through the load terminals, with $R_L$ removed and all active sources are replaced by their internal impedances.
If the internal impedances are unknown then the independent voltage source must be replaced by short circuit while the independent current sources must be replaced by open circuit, while calculating $R_{eq}$. and its value remain same.
NOTE:→ Infact the calculation of $R_{eq}$ is Thevenin or Norton as long as wether the theorm applied to network is same. terminal of interest remains same.

Ques Find the current through 10 Ω Resistance.

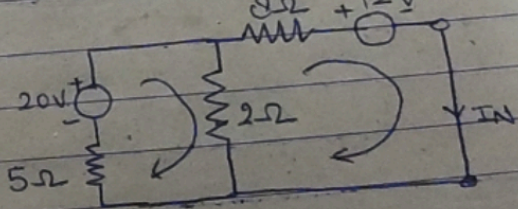



Step 1) Calculating $Z_{th}$




$R_{th} = (5 \| 2) + 8$

$= \frac{5\times 2}{5+2} + 8 = 9.428\ \Omega$



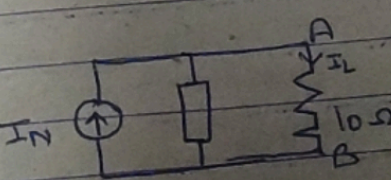

Step 2) Calculation of $I_N$, shorting the load resistance
Applying KVL,

$-20 + 5I_1 + 2(I_1 - I_2) = 0 \quad 7I_1 - 2I_2 = 20$ (loop 1)

$12 + 2I_2 - 2I_1 + 8I_2 = 0 \quad 10I_2 - 2I_1 = -12$ (loop 2)

$\therefore I_2 = 0.666A = I_N$

Step 3) Norton Equivalent circuit




$\therefore I_L = -0.323A\ (\downarrow)$

$= 0.323A\ (\uparrow)$

Maximum Power Transfer Theorm

In an active resistive network, maximum power transfer to the load resistance takes place when load resistance equals to equivalent resistance of network as viewed from terminals of load.