UNIT - I

S.I UNITS: The international System of units, Known as S.I units.

Quantity	Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	S
Temperature	Kelvin	K
Luminous intensity	Candela	cd
Electric Current	Ampere	A
Amount of Substance	Mole	mol

ELECTRIC CURRENT (I):

* Electric Current is defined as rate of flow of electric charge.

$\boxed{i = \frac{dq}{dt}}$ ampere, where 'q' is the charge in Coulombs

* The charge of an electron is, $e = 1.6 \times 10^{-19}$ coulombs and is negative. $\boxed{\text{UNIT} = \text{AMPERE}}$

ELECTRIC POTENTIAL (E or V):

Electric Potential is defined as the work done in moving One Coulomb of charge between the two Points is one joule, then the Potential of one point with reference to the Second Point is One Volt.

$\boxed{V \text{ or } E = \frac{dW}{dQ}}$, where 'W' is the work done in joules.

$\boxed{\text{UNIT} = \text{VOLT}}$

ELECTRICAL RESISTANCE (R):

Electrical resistance is defined as the Opposition to the flow of electric charges in the Circuit.

$\boxed{R = \frac{\rho l}{a}}$, where 'l' is the length of the material
'a' is the area of Cross Section
'ρ' is the resistivity of the material

$\boxed{\text{UNIT} = \text{Ohm}, \Omega}$

ELECTRICAL CONDUCTANCE (G):

The reciprocal of resistance is called Conductance.

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

UNIT = SIEMEN

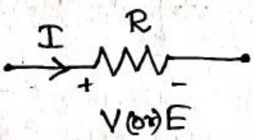
Similarly, the reciprocal of resistivity is called Conductivity (σ).

$$\boxed{\sigma = \frac{1}{\rho}} \quad \boxed{\text{UNIT} = \frac{\text{Siemen}}{\text{metre}}}$$

BASIC CIRCUIT COMPONENTS:

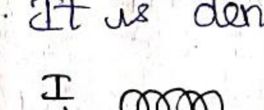
The three basic circuit components are,
1. Resistor (R)
2. Capacitor (C)
3. Inductor (L)

RESISTOR: Resistor is an electrical component made from the material which opposes the flow of current through it. It is denoted by 'R'. Unit is ohm 'Ω'



$$\boxed{R = \frac{V}{I}} \ \text{Ohm}, \Omega$$

CAPACITOR: Capacitor is a storage element which can store and deliver energy in an electrostatic field. It is denoted by 'C'. Unit is Farad 'F'



$$\boxed{C = \frac{Q}{V}} \ \text{Farad}$$

INDUCTOR: Inductor is an element in which energy can be stored in the form of electromagnetic field. It is denoted by 'L'. Unit is Henry 'H'

$$\boxed{L = \frac{\phi}{I}} \ \text{Henry}$$

③ NETWORK DEFINITIONS:

NETWORK: Any arrangement of the Various electrical energy Sources along with the different Circuit elements is Called an electrical network.

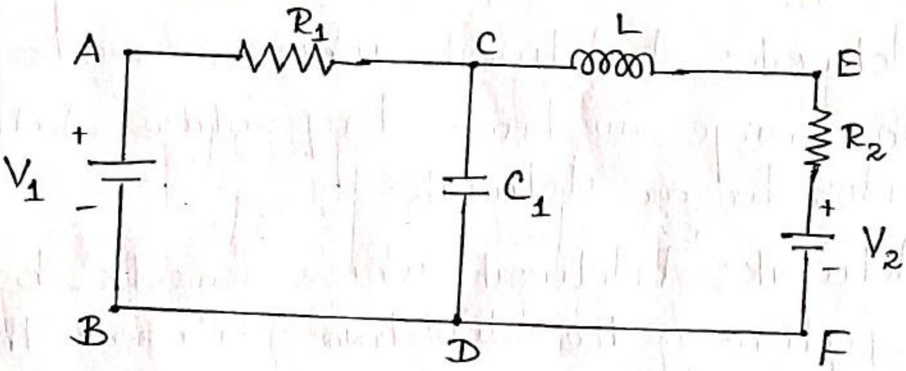


Fig: An electrical Network

NETWORK ELEMENT: Any individual Circuit element with two terminals which Can be Connected to other Circuit element, is Called a network element.

Network element

ACTIVE ELEMENTS	PASSIVE ELEMENTS
Eg:- Voltage Source, Current Source	Eg: Resistor, Inductor and Capacitor.

BRANCH: *A Part of the Network which Connects the Various Points of the network with one another is Called branch.

*In fig, AC, C-E, E-F, C-D, A-B are the Various branches.

JUNCTION POINT: *A Point where three (or) more branches meet is Called a junction Point.

*Point C and D are the junction Points in the network.

NODE: * A Point at which two (or) more elements are joined together is Called node.

*The junction Points are also the nodes of the network. In fig., A, B, C, D, E&F are the nodes of the network.

MESH (or) LOOP: *A Set of branches forming a closed Path in a network.

*In fig., ACDBA, CEFDC and ACEFDBA are the loops of the network.

CLASSIFICATION OF ELECTRICAL NETWORKS:

Linear Network: A network whose elements like resistors, inductors and Capacitors are always Constant irrespective of the change in time, Voltage, temperature etc., is known as linear Network.

Non-Linear Network: A Network whose elements change their Values with change in time, temperature, Voltage etc., is known as Non-Linear Network.

Bilateral Network: A Network whose elements, behaviour is Same irrespective of the direction of Current through Various elements of it, is Called Bilateral Network.

Unilateral Network: A Network whose elements, behaviour is dependent on the direction of the Current through Various elements of it, is Called unilateral Network.

Active Network: A Network which Contains a Source of energy is Called active network.

Eg:- Voltage Sources and Current Sources.

Passive Network: A Network which Contains no energy Sources is Called passive network.

Eg:- A network Contains resistor, inductor and Capacitor.

Lumped Network: * A network in which all the network elements are Physically Separable is known as lumped Network.

* Most of the electrical networks are lumped N/ws.

Distributed Network: A network in which all the network elements are not Physically Separable is known as distributed Network.

⑤ **OHM'S LAW:** When the temperature remains Constant, Current flowing through a Conductor is directly Proportional to the Potential difference across the Circuit and inversely Proportional to the resistance of the Circuit.

$$I \propto V$$

$$\therefore I = \frac{V}{R} \Rightarrow \boxed{V = IR}$$ where, R is the Constant of Proportionality

Limitations of ohm's Law:

* It is not applicable to non-linear devices Such as diodes, Zener diode, Voltage regulator etc.,
* It is true for metal Conductors at Constant temperature. If the temperature changes, the law is not applicable.

ELECTRICAL POWER: The rate at which electrical work is done in an electric Circuit is Called an electrical Power.

$$\text{Electrical Power, } P = \frac{\text{Electrical work}}{\text{Time}} = \frac{W}{t} = \frac{VIt}{t} = VI$$

$$\boxed{P = VI} \text{ Watts}$$

ELECTRICAL WORK: It means movement of electrons in an electric Circuit.

$$\boxed{\text{Unit} = \text{Joule}}$$

$$\text{Electrical work, } W = V \times Q \text{ Joule}$$
$$= V \times It \text{ Joule}$$
$$\boxed{W = VIt} \text{ Joule}$$

where, $I = \frac{Q}{t}$ = Rate of flow of charge
t = Time in Sec.
Q = charge in Coulomb

ELECTRICAL ENERGY: An electrical energy is the total amount of Work done in an electric Circuit.

$$\text{Electrical energy, } E = \text{Power} \times \text{time}$$
$$= VI \times t$$
$$\boxed{E = VIt} \text{ joules (or) KWh}$$

Problem 1: A 5Ω resistor has a Voltage rating of 100V, What is its Power rating?

Solution: $R = 5\Omega$, $V = 100V$

$P = VI$

$= V \times \frac{V}{R} = \frac{V^2}{R} = \frac{100^2}{5} = 2000$ Watts

Problem 2: What will be the Current drawn by a lamp rated at 230V, 40 Watts Connected to a 230V Supply?

Solution: $P = 40W$, $V = 230V$ To find, I?

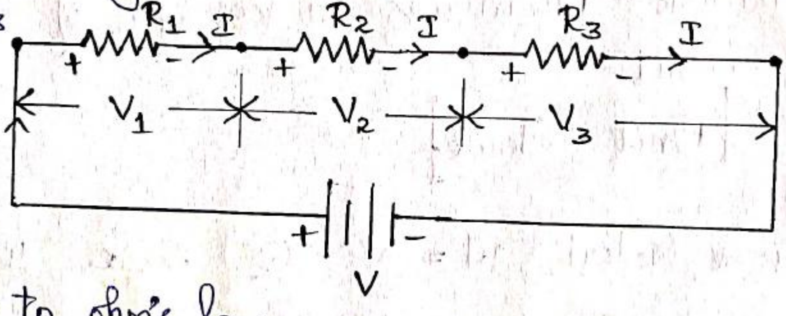
$P = \frac{V^2}{R}$ $I = V/R$

$R = \frac{V^2}{P} = \frac{230^2}{40} = 1562.5\ \Omega$

Current drawn by a lamp, $I = \frac{V}{R} = \frac{230}{1562.5} = 0.1472\ A$

RESISTORS IN SERIES:

When resistors are Connected in Series, the Current flowing through all resistors are Same and the Voltage in each resistor is different.



According to ohm's law, $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

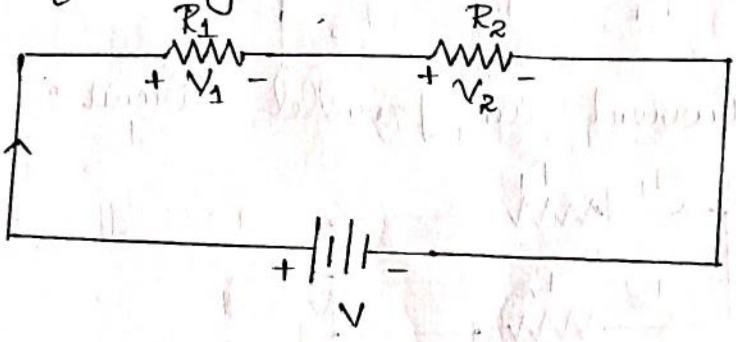
$V = V_1 + V_2 + V_3$

$V = IR_1 + IR_2 + IR_3$

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

Equivalent Resistance }, $\boxed{R_{eq} = R_1 + R_2 + R_3}$

(7). Division of Voltage in Series Circuit:



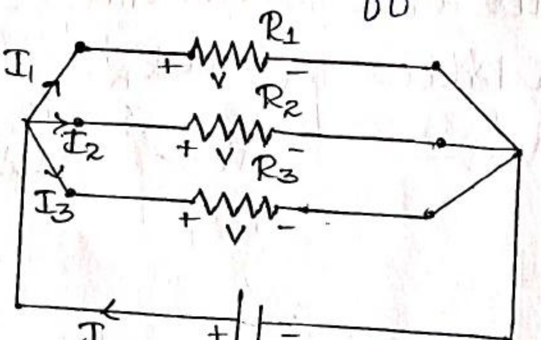
Voltage across one of the resistors } = (Total Voltage across Series Circuit × Value of the Particular resistor) / Sum of the individual resistors.

$$V_1 = V \times \frac{R_1}{R_1+R_2}$$

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

RESISTORS IN PARALLEL:

When resistors are connected in Parallel and Combination is connected across a source of Voltage v, the voltage across all resistor is same and the current flowing through each resistor is different.



According to ohm's law, $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$, $I_3 = \frac{V}{R_3}$

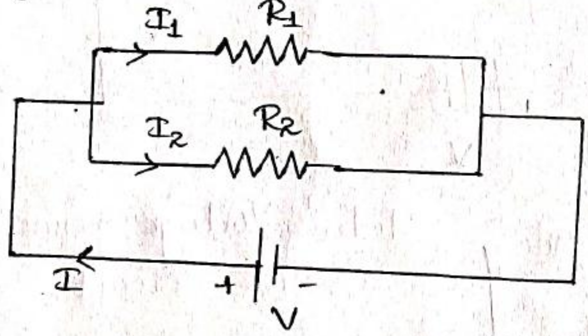
$$I = I_1 + I_2 + I_3$$

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

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

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

Division of Current in Parallel Circuit:

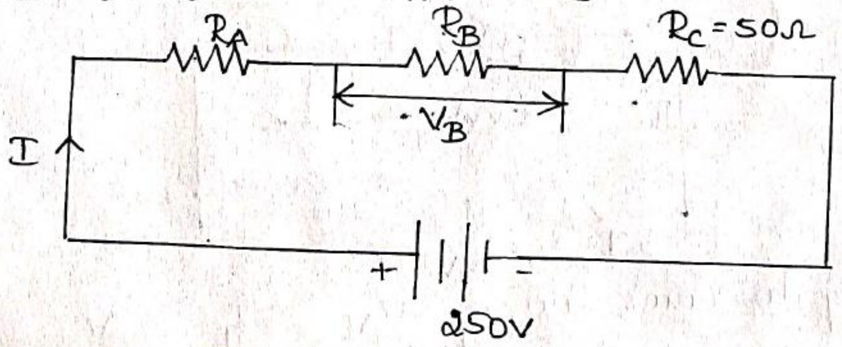


Current through one of the resistors = (Total Current flows through Parallel Circuit × Value of the Opposite resistor) / Sum of the Individual resistors.

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

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

PROBLEM 1: The Three Resistors R_A, R_B and R_C Connected in Series to a 250V Source. Given $R_C = 50\Omega$ and $V_B = 80$ Volts when the Current is 2 amperes. Calculate the resistances R_A and R_B.



Solution: Current flowing through the Circuit, $I = 2A$

Voltage across resistor R_B, $V_B = 80V$

$$V_B = I R_B$$

$$\therefore R_B = \frac{V_B}{I} = \frac{80}{2} = 40\ \Omega$$

$\therefore V = IR$

$$R = \frac{V}{I} = \frac{250}{2} = 125\,\Omega$$

Total resistance, $R = R_A + R_B + R_C$

$$125 = R_A + 40 + 50$$

$$R_A = 125 - 90 = 35\,\Omega$$

$$\boxed{R_A = 35\,\Omega}$$

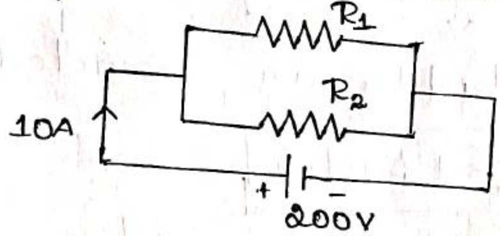
PROBLEM:2 Two resistors Connected in Parallel across 200V Supply take 10A from the mains. If the Power dissipated in one resistor is 800 W. Find the Value of the other resistor.

Solution:

Total Power, $P = VI$

$$= 200 \times 10 = 2000\ W$$

Power dissipated in one resistor, $P_1 = 800\,W$



$\therefore$ Power dissipated in the other resistor, $P_2 = P - P_1$

$$= 2000 - 800$$

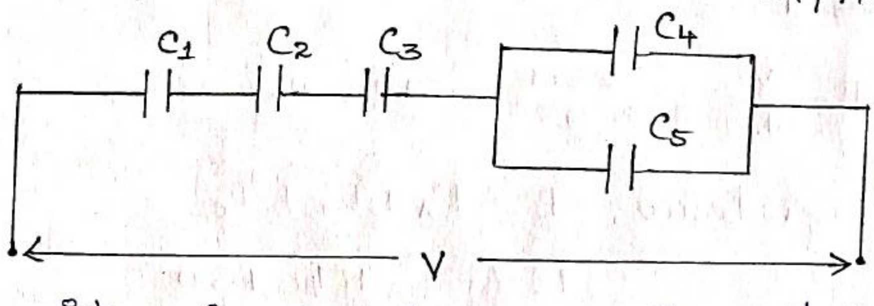
$$= 1200\,W$$

$$P_2 = VI_2 = \frac{V_2^2}{R_2} \Rightarrow R_2 = \frac{V_2^2}{P_2} = \frac{200 \times 200}{1200}$$

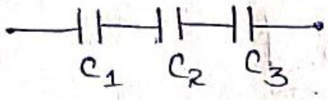
$$= 33.33\,\Omega$$

$$\boxed{R_2 = 33.33\,\Omega}$$

SERIES AND PARALLEL CIRCUIT WITH CAPACITIVE NETWORK:-

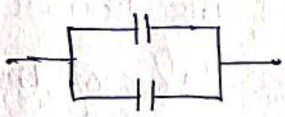


Here, Capacitor C_1, C_2 and C_3 are Connected in Series.



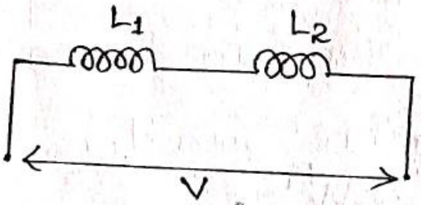
$$\boxed{C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

Capacitor C_4 and C_5 are Connected in Parallel.



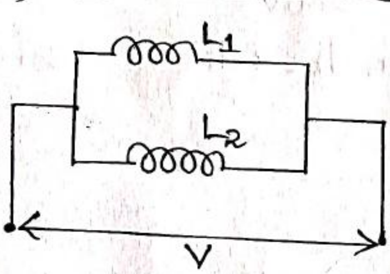
$$\boxed{C_{eq} = C_4 + C_5}$$

SERIES AND PARALLEL CIRCUIT WITH INDUCTIVE NETWORK:-



Here, Inductance L_1 & L_2 are Connected in Series.

Equivalent Inductance, $\boxed{L_{eq} = L_1 + L_2}$



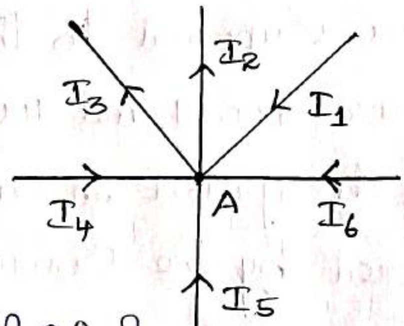
Now the inductance are Connected in Parallel.

Equivalent inductance, $\boxed{L_{eq} = \frac{L_1 L_2}{L_1 + L_2}}$

KIRCHHOFF'S LAW:

Kirchhoff's Current Law (I-Law):

The Sum of the Currents flowing towards a junction is equal to the Sum of the Currents flowing away from it.



According to Kirchhoff's law,

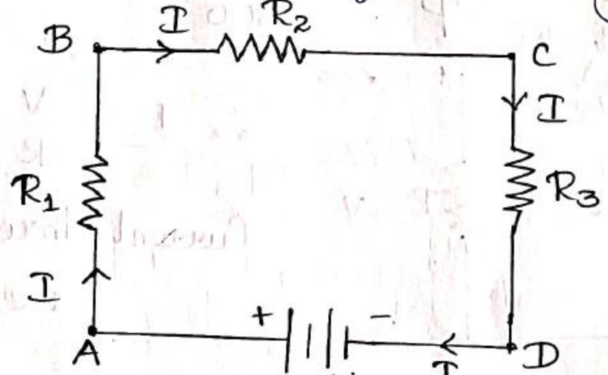
Sum of entering Current = Sum of leaving Current.

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

The Current at node A is equal to Zero.

Kirchhoff's Voltage Law (II-Law)

In a closed Circuit, the sum of the Voltage drop is equal to the sum of the Voltage rises.



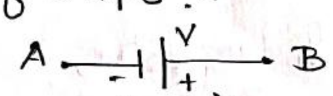
In fig, ABCDA form a closed Circuit. Assuming the Current direction from A to B, we have Voltage drop of IR_1 and further,

Sum of Voltage drops $= IR_1 + IR_2 + IR_3$

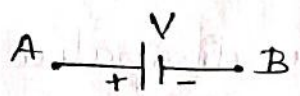
Voltage rise from D to A $= V$

$$\therefore V = IR_1 + IR_2 + IR_3.$$

Sign of EMFs :-

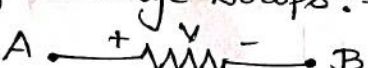


Rise in Voltage (+V)



Fall in Voltage (−V)

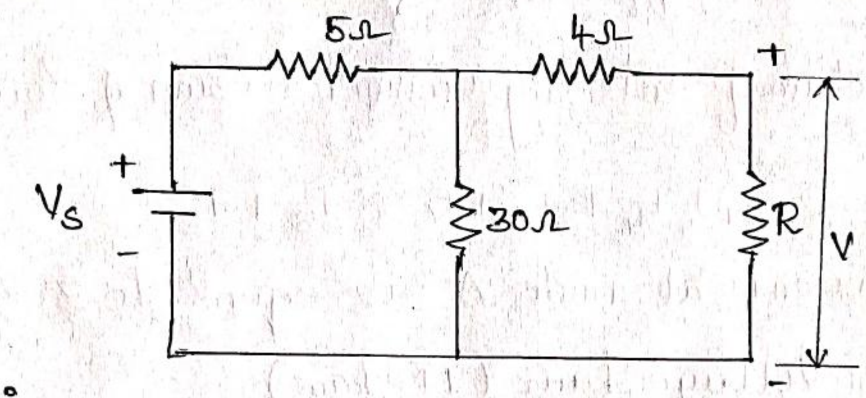
Sign of Voltage Drops :-



Fall in Voltage (−V)

Rise in Voltage (+V)

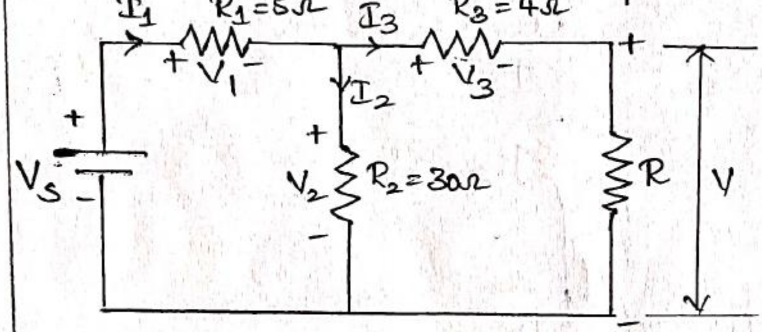
(12) PROBLEM 1: The Power Supplied to the load R and the Voltage across it in figure are 500 W and 100V. Determine (i). The Value of the V_s (ii). the Power dissipated in each resistor. Also Confirm that the Power delivered by the Source equals the total power dissipated elsewhere.



Solution:

Gn. (i). P = 500W (ii) V = 100V

The resistance, $R = \frac{V^2}{P} = \frac{100^2}{500} = 20\Omega$



$\therefore I_3 = \frac{V}{R} = \frac{100}{20} = 5A$

Current through 4Ω is also I_3 i.e., 5A.

Voltage drop across 4Ω, $V_3 = I_3 R_3 = 5 \times 4 = 20V$

Voltage drop across 30Ω, $V_2 = V_3 + V = 20 + 100 = 120V$

Current through 30Ω, $I_2 = \frac{V_2}{R_2} = \frac{120}{30} = 4A$

Current through 5Ω, $I_1 = I_2 + I_3 = 4 + 5 = 9A$

Voltage drop across 5Ω, $V_1 = I_1 R_1 = 9 \times 5 = 45V$

$\therefore V_s = V_1 + V_2 = 45 + 120 = 165V$ (i). $\boxed{V_s = 165V}$

The Power dissipated in each resistor,

$$P = V_1 I_1 + V_2 I_2 + V_3 I_3 + V I_3$$
$$= (45 \times 9) + (120 \times 4) + (20 \times 5) + (100 \times 5) = 1485W$$

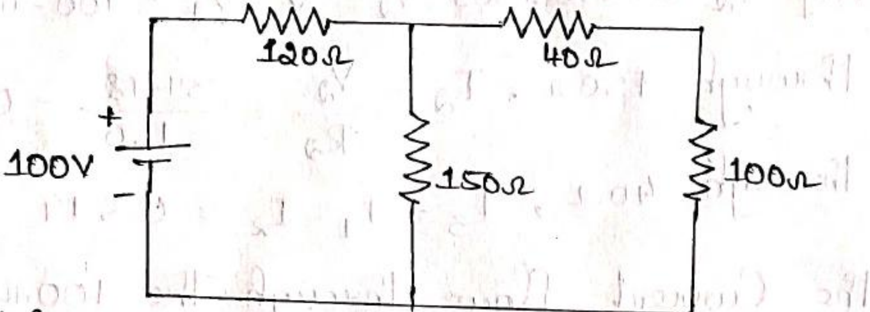
(ii). $\boxed{P = 1485\ W}$

The Power delivered by the Source $= V_S I_1$

$= 165 \times 9 = \boxed{1485 W}$

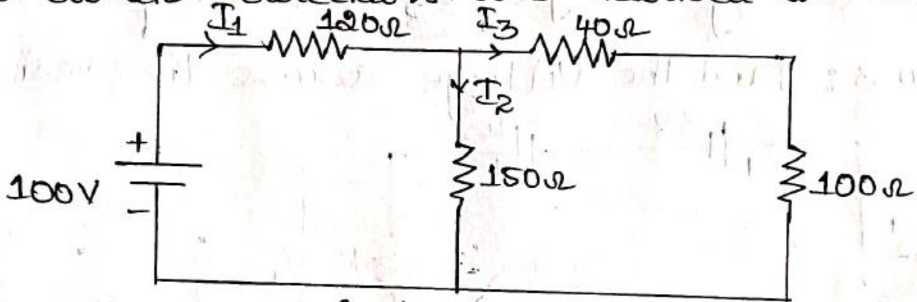
$$\boxed{\text{Power delivered by the Source} = \text{Power dissipated in all resistors}}$$

PROBLEM 2: In the Circuit Shown in figure, find the Value of Current through 100Ω



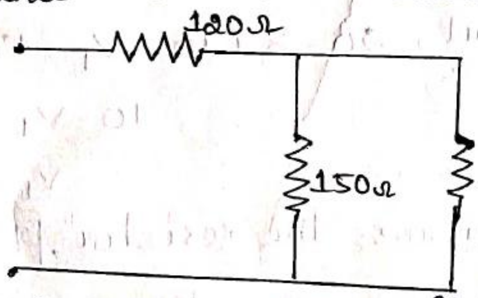
Solution:

The Current directions are marked as Shown in the figure.

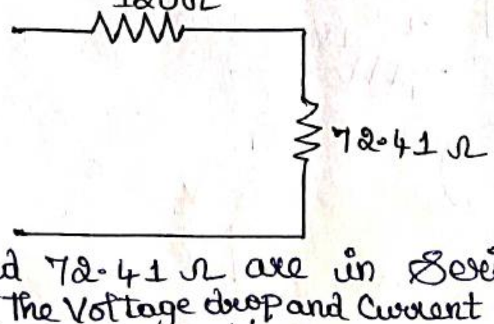


First, find the equivalent resistance of the Circuit, Req.

40Ω and 100Ω are Connected in Series. ∴ $40 + 100 = 140\Omega$



150Ω and 140Ω are in parallel, ∴ $\dfrac{150 \times 140}{150 + 140} = 72.41\Omega$

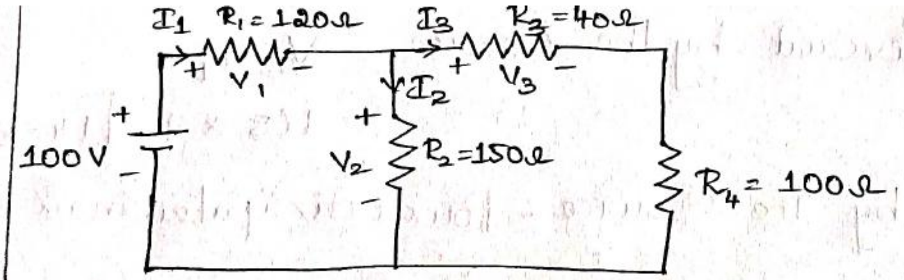


120Ω and 72.41Ω are in Series, ∴ $120 + 72.41 = 192.41\Omega$

Second, find the Voltage drop and Current through each resistor, $\boxed{R_{eq} = 192.41\Omega}$

$$I_1 = \frac{V}{R_{eq}} = \frac{100}{192.41} = 0.519\,A$$

∴ I_1 is the Current flows through 120Ω resistor.



Voltage drop across 120Ω, $V_1 = I_1 R_1 = 0.519 = 120 = 62.28\,V$

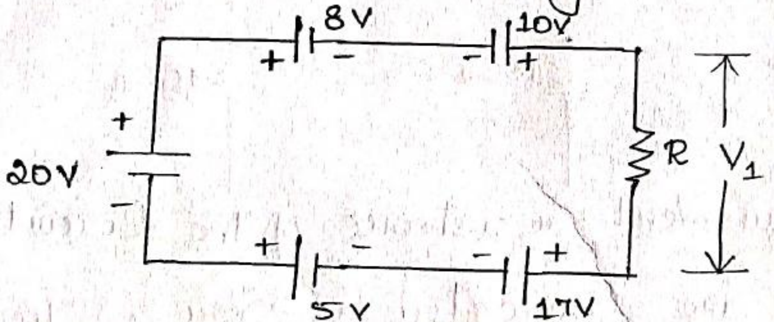
Voltage drop across 150Ω, $V_2 = V - V_1 = 100 - 62.28 = 37.72\,V$

Current through 150Ω, $I_2 = \frac{V_2}{R_2} = \frac{37.72}{150} = 0.251\,A$

Current through 40Ω, $I_3 = I_1 - I_2 = 0.519 - 0.251 = 0.268\,A$

$\therefore$ I_3 is the Current flows through the 100Ω resistor which is given by, $\boxed{I_3 = 0.268\,A}$

PROBLEM 3: Find the Voltage across the resistor 'R' in figure.



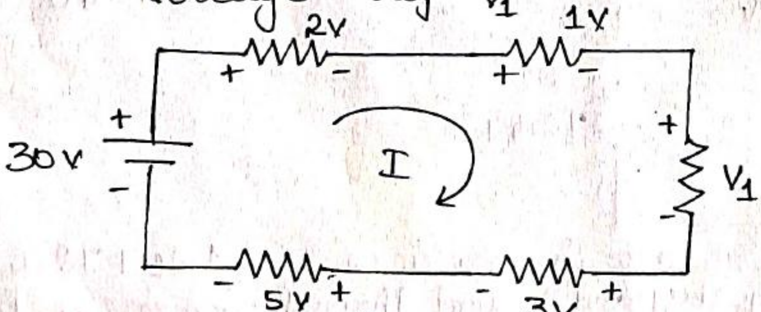
Applying KVL in the Circuit, $20 - 8 + 10 - V_1 - 17 + 5 = 0$

$$10 - V_1 = 0$$

$$V_1 = 10$$

$\therefore$ Voltage across the resistor, $\boxed{R = 10V}$

PROBLEM 4: For the Circuit shown in figure, determine the unknown Voltage drop V_1.



Applying KVL in the above circuit, $-2 - 1 - V_1 - 3 - 5 + 30 = 0$

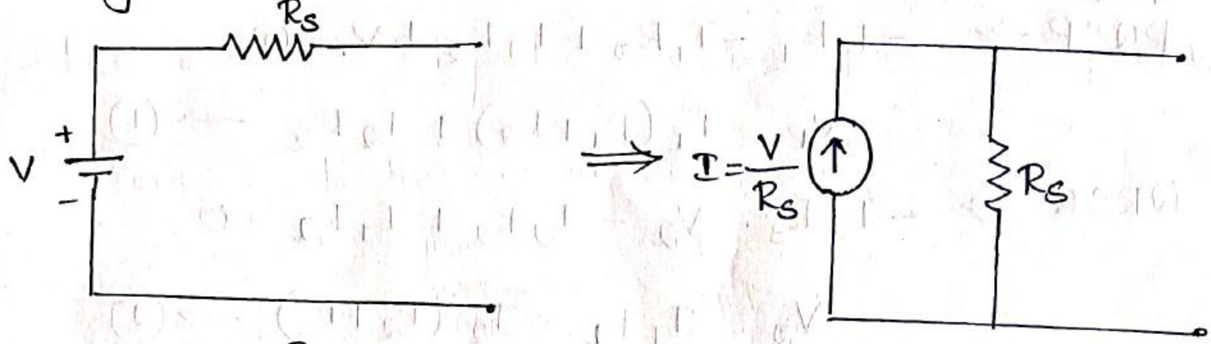
$$-V_1 + 19 = 0$$

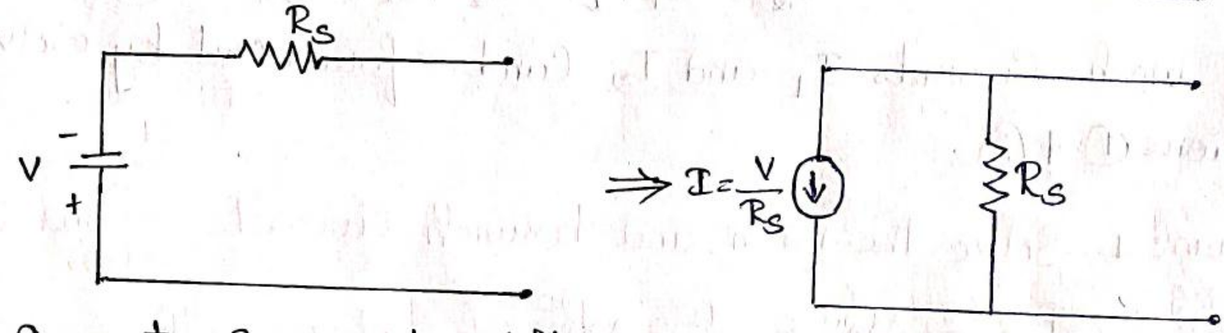
$$\boxed{V_1 = 19\,V}$$

15

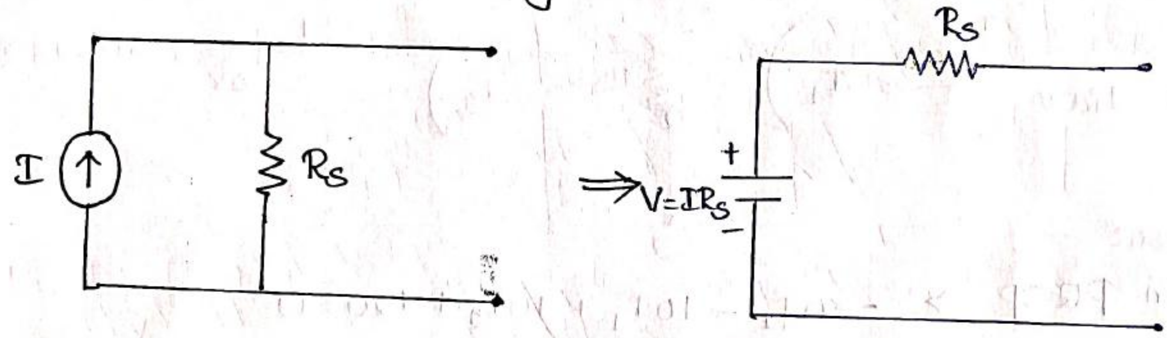
SOURCE TRANSFORMATION:

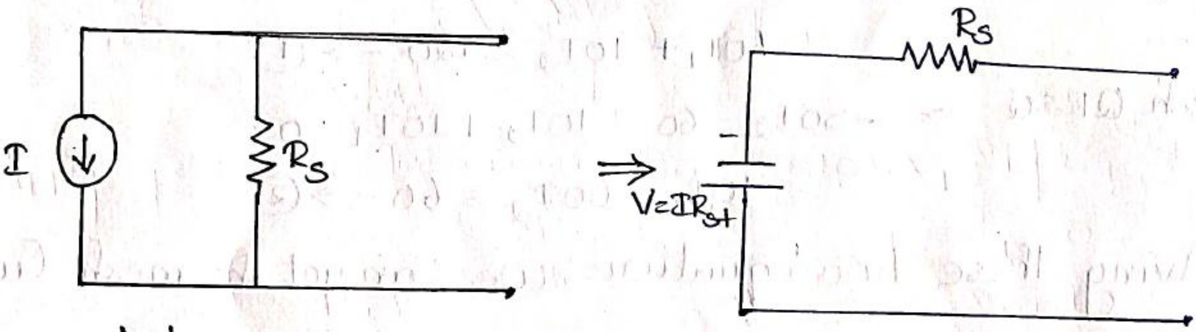
Voltage Source to Current Source:-



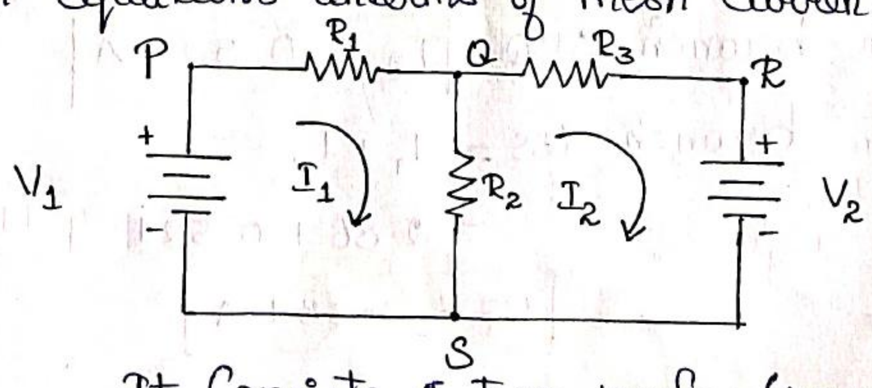


Current Source to Voltage Source:-





MESH ANALYSIS: In mesh method, Kirchhoff's Voltage Law (KVL) is applied to a network. For this network, we have to write mesh equations interms of mesh currents.



It consists of two meshes (PQSP and QRSQ) and each mesh is assigned a separate mesh current. Therefore it consists of two mesh Currents (I_1 and I_2).

By applying KVL to the above Circuit, we get two equations.

Mesh PQSP $\Rightarrow$ $-I_1R_1 - I_1R_2 + I_2R_2 + V_1 = 0$

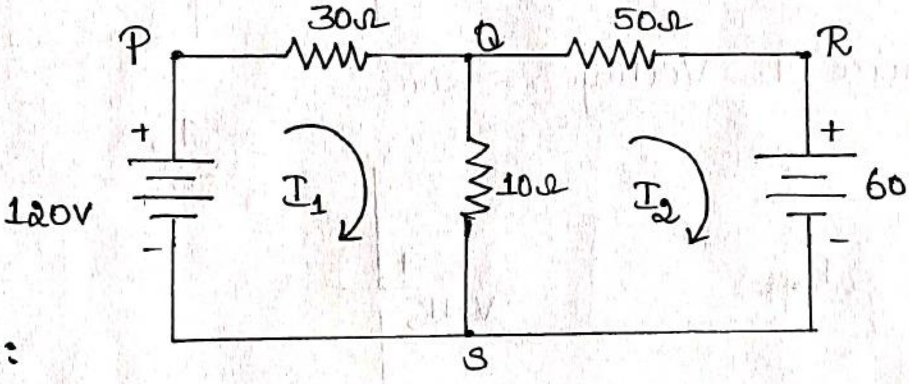
$$V_1 = I_1(R_1+R_2) + I_2R_2 \rightarrow (1)$$

Mesh QRSQ $\Rightarrow$ $-I_2R_3 - V_2 - I_2R_2 + I_1R_2 = 0$

$$V_2 = I_1R_2 - I_2(R_2+R_3) \rightarrow (2)$$

The mesh Currents I_1 and I_2 Can be found out by Solving equations (1) & (2).

PROBLEM: 1 Solve the mesh and branch Currents shown in fig.



Solution:

Mesh PQSP $\Rightarrow$ $-30I_1 - 10I_1 + 10I_2 + 120 = 0$

$$40I_1 - 10I_2 = 120 \rightarrow (1)$$

Mesh QRSQ $\Rightarrow$ $-50I_2 - 60 - 10I_2 + 10I_1 = 0$

$$10I_1 - 60I_2 = 60 \rightarrow (2)$$

Solving these two equations, we Can get the mesh Currents.

$$I_1 = 2.86\,A, \quad I_2 = -0.521\,A$$

Current in branch SPQ, $\boxed{I_1 = 2.86\,A}$

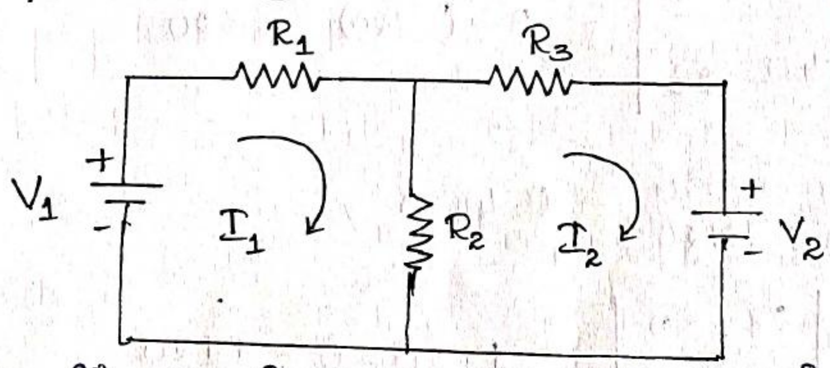
Current in branch SRQ, $\boxed{I_2 = 0.521\,A}$

Current in branch QS $= I_1 + I_2$

$$= 2.86 + 0.521$$

$$\boxed{QS = 3.381\,A}$$

MESH EQUATIONS BY INSPECTION METHOD:

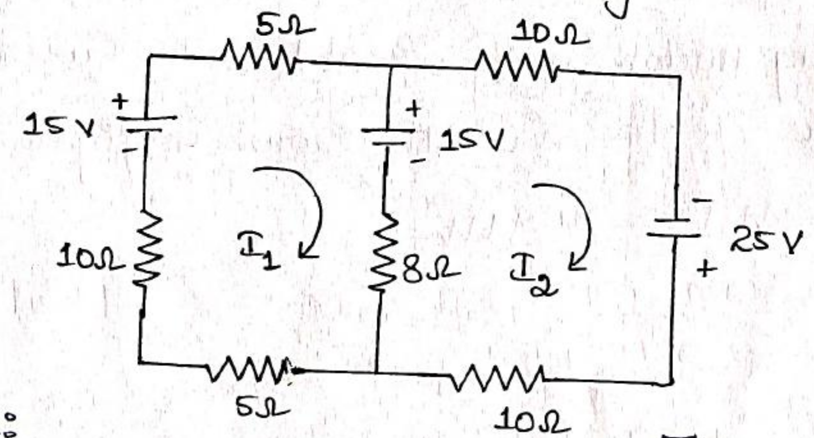


Here, the Circuit Consists of two loops. The general matrix form of mesh equation is,

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2 & R_2+R_3 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ -V_2 \end{bmatrix}$$

Using Cramer's rule, we can find mesh (or) loop Currents I_1 and I_2.

PROBLEM: 2 Find the Current through the 8Ω resistor shown in fig.



Solution:

By using mesh inspection method, $\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$

$$\begin{bmatrix} 5+8+5+10 & -8 \\ -8 & 10+10+8 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 15-15 \\ 25+15 \end{bmatrix}$$

$$\begin{bmatrix} 28 & -8 \\ -8 & 28 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 40 \end{bmatrix}$$

By applying Cramer's rule, we can find out Current through 8Ω resistor,

$$\Delta = \begin{vmatrix} 28 & -8 \\ -8 & 28 \end{vmatrix} = 784 - 64 = 720$$

$$\Delta I_1 = \begin{vmatrix} 0 & -8 \\ 40 & 28 \end{vmatrix} = 0 - (-320) = 320$$

$$I_1 = \frac{\Delta I_1}{\Delta} = \frac{320}{720} = 0.44 \text{ A}$$

$$\Delta I_2 = \begin{vmatrix} 28 & 0 \\ -8 & 40 \end{vmatrix} = 1120 - 0 = 1120$$

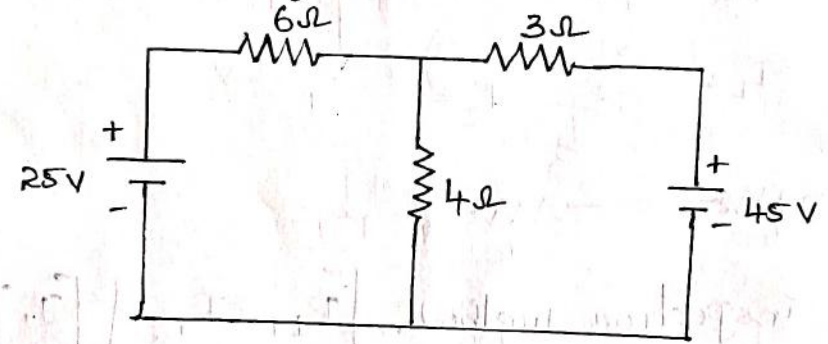
$$I_2 = \frac{\Delta I_2}{\Delta} = \frac{1120}{720} = 1.55 \text{ A}$$

Current through 8Ω resistor $= I_2 - I_1$

$= 1.55 - 0.44 = 1.11$ A

NODAL ANALYSIS:

PROBLEM: 1 Using nodal analysis, obtain the Currents flowing in all the resistors of the Circuit shown in figure.



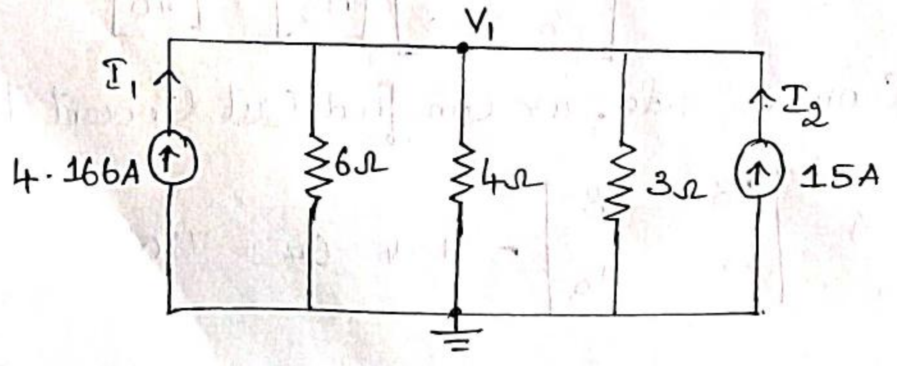
Solution:

Convert all the Voltage Sources into their equivalent Current Sources.

$$I_1 = \frac{25}{6} = 4.166\text{A}$$

$$I_2 = \frac{45}{3} = 15 \text{ A}$$

Now, the Circuit becomes,



Then apply KCL to node V_1

$$4.166+15 = \frac{V_1}{6} + \frac{V_1}{4} + \frac{V_1}{3}$$

$$V_1\left[\frac{1}{6}+\frac{1}{4}+\frac{1}{3}\right] = 19.166$$

$$V_1 = \frac{19.166}{0.75} = 25.55\ V$$

Current through 6Ω resistor $= \frac{V_1}{6} = 4.25\ A$

Current through 4Ω resistor $= \frac{V_1}{4} = 6.38\ A$

Current through 3Ω resistor $= \frac{V_1}{3} = 8.51\ A$

NETWORK THEOREMS:

(i). Superposition Theorem

(ii). Thevenin's Theorem

(iii). Norton's Theorem

(iv). Maximum Power Transfer Theorem.

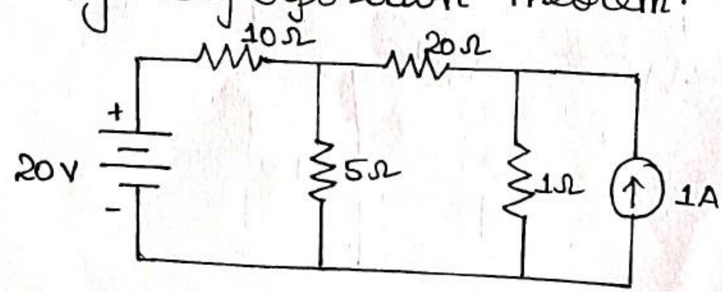
SUPERPOSITION THEOREM: "STATEMENT"

"In a linear bilateral network, the response of a circuit having more than one independent sources equals the algebraic sum of the responses caused by each independent sources acting alone, where all the other independent sources are replaced by their internal resistance".

→ Replacing all other independent voltage sources with a short circuit.

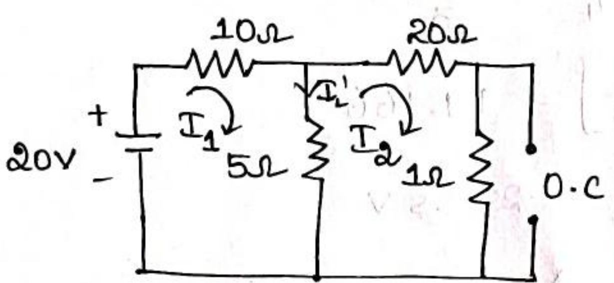
→ Replacing all other independent current sources with an open circuit.

PROBLEM 1: Solve for current through 5Ω resistor by Principle by Superposition theorem.



(20) Solution:

STEP 1: 20 V Source is acting : Current Source becomes O.C



$$[R]\,[I] = [V]$$

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} 15 & -5 \\ -5 & 26 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \end{bmatrix}$$

$$15I_1 - 5I_2 = 20 \rightarrow (1)$$

$$-5I_1 + 26I_2 = 0 \rightarrow (2)$$

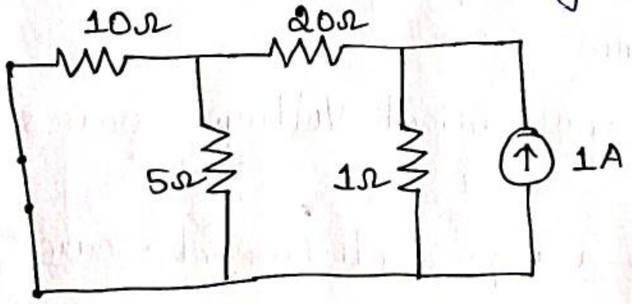
Solving (1) & (2)

$$I_1 = 1.424\,A \quad I_2 = 0.273\,A$$

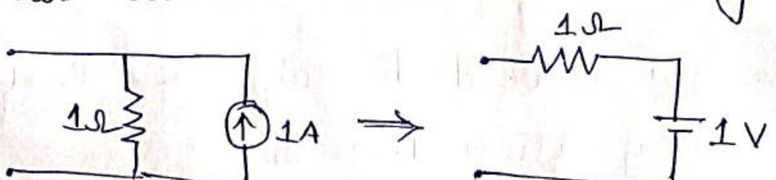
Load Current, $I_L' = I_1 - I_2$

$$\boxed{I_L' = 1.151 A}$$

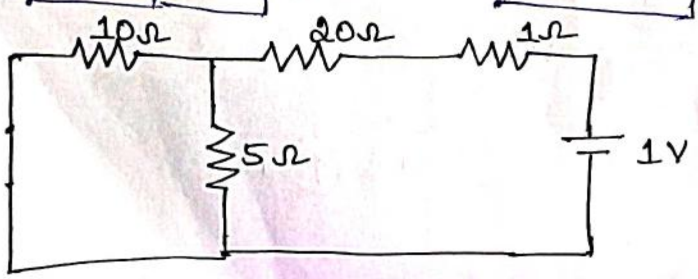
STEP 2: 1 A Source is acting . Voltage Source becomes S.C

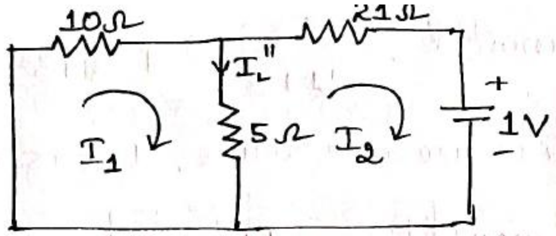


Convert this Current Source into Voltage Source,



$\therefore V = IR$
$= 1 \times 1$
$V = 1V$





$$\begin{bmatrix} 15 & -5 \\ -5 & 26 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}$$

$15I_1 - 5I_2 = 0 \rightarrow (3)$

$-5I_1 + 26I_2 = -1 \rightarrow (4)$

Solving (1) & (2)

$I_1 = -0.013A \quad I_2 = -0.041A$

$I_L'' = I_1 - I_2$

$\boxed{I_L'' = 0.028A}$

STEP 3:

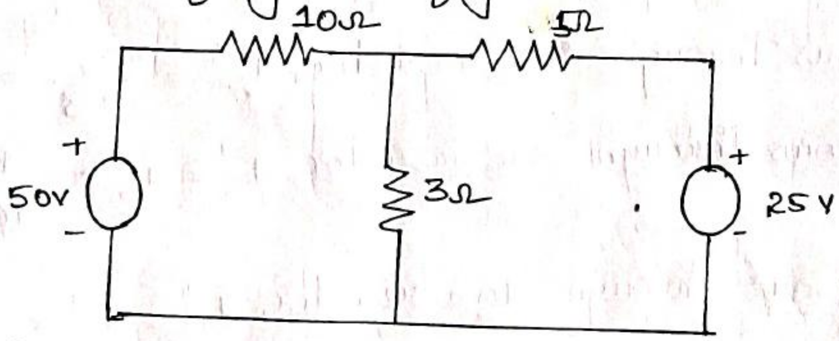
According to Superposition theorem Current Passing through 5Ω resistance due to 20V and 1V Sources is

$I_L = I_L' + I_L''$

$= 1.151 + 0.028$

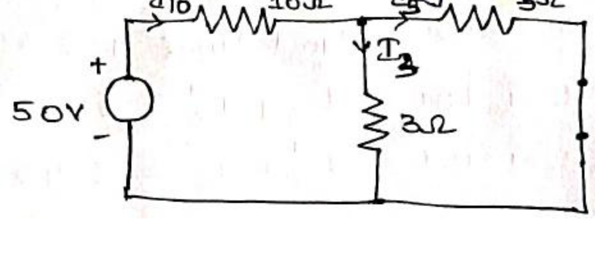
$\boxed{I_L = 1.179 \text{ A}}$

PROBLEM 2: Using Superposition Principle, find the Current in each resistor of given figure.



Solution:

STEP 1: 50V Source is acting. 25V Source is S.C



$\therefore$ 5Ω and 3Ω are in Parallel, $\frac{5\times 3}{5+3} = 1.875\Omega$

1.875Ω and 10Ω resistors are in Series, $1.875 + 10 = 11.9\Omega$

Total resistance, $\boxed{R_{eq} = 11.9\Omega}$

Current flows through 10Ω resistor, $I_{10} = \frac{50}{11.9} = 4.2\,A$

Apply Current division rule to find I_2 and I_3,

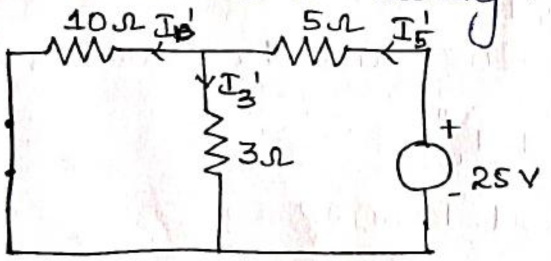
Current flows through 3Ω resistor, $I_3 = I_{10} \times \frac{5}{5+3}$

$$= 4.2 \times \frac{5}{8} = 2.62\,A$$

Current flows through 5Ω resistor, $I_5 = I_{10} \times \frac{3}{5+3}$

$$= 4.2 \times \frac{3}{8} = 1.58\,A$$

STEP 2: 25V Source is acting. 50V Source is S.C



$\therefore$ 10Ω and 3Ω resistors are in parallel, $\frac{10\times 3}{10+3} = 2.3\Omega$

2.3Ω and 5Ω resistors are in Series, $2.3 + 5 = 7.3\Omega$

Total resistance, $\boxed{R_{eq} = 7.3\Omega}$

Current flows through 5Ω resistor, $I_5' = \frac{25}{7.3} = 3.42\,A$

Current flows through 3Ω resistor, $I_3' = I_5' \times \frac{10}{10+3} = 3.42 \times \frac{10}{13}$

$$= 2.63\,A$$

Current flows through 10Ω resistor, $I_{10}' = I_5' \times \frac{3}{10+3} = 3.42 \times \frac{3}{13}$

$$= 0.79\,A$$

STEP 3:

According to Superposition theorem,

Current in 10Ω resistor $= I_{10} - I_{10}' = 4.2 - 0.79 = 3.41\,A$

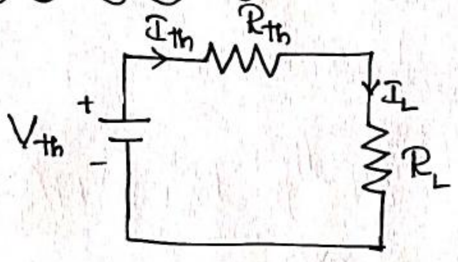
Current in 3Ω resistor $= I_3 + I_3' = 2.62 + 2.63 = 5.25\,A$

Current in 5Ω resistor $= I_5' - I_5 = 3.42 - 1.58 = 1.84\,A$

THEVENIN'S THEOREM: "STATEMENT"

"Any two terminal Linear network having a number of Voltage Sources, Current Sources and resistances Can be replaced by a Simple equivalent Circuit having Single Voltage Source and a resistance in Series".

Thevenin's Equivalent Circuit:



where, V_{Th} = thevenin's Voltage

R_{Th} = thevenin's resistance

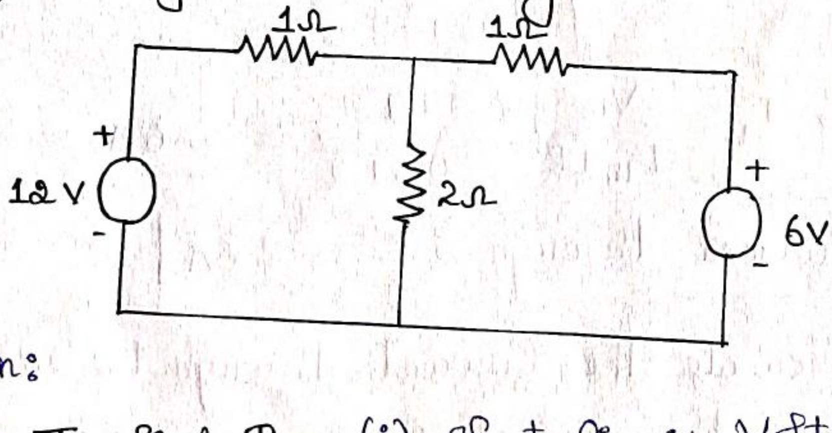
I_{Th} = thevenin's Current

R_L = Load resistance (the resistance given in the qn).

I_L = Load Current

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

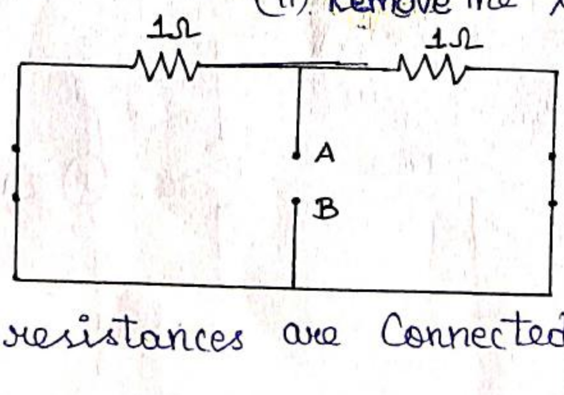
PROBLEM 1: Determine the Current through the 2Ω resistor in the following network using thevenin's theorem.

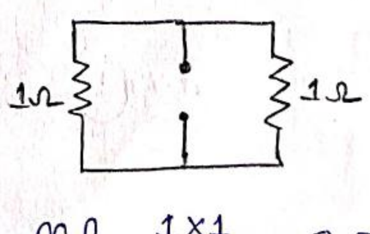


Solution:

STEP 1: To find R_{Th}, (i). Short Circuit Voltage Source

(ii). Remove the load resistance, R_L (Gn in qn)

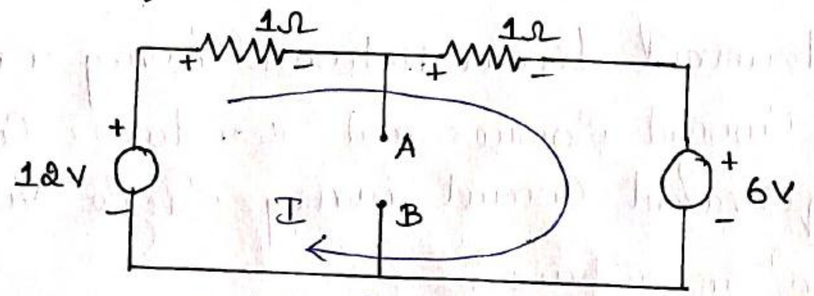




The two resistances are Connected in Parallel, $\frac{1 \times 1}{1+1} = 0.5$

$$\boxed{R_{Th} = 0.5\ \Omega}$$

STEP 2: To find V_{th}, (i). Remove the load resistance, R_L



Applying KVL in the above Circuit, we get.

$$-1I - 1I - 6 + 12 = 0$$

$$-2I + 6 = 0$$

$$I = 6/2 = 3A$$

Voltage across 1Ω, $V_1 = 3 \times 1 = 3V$

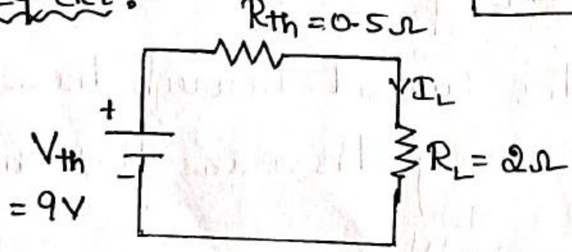
Voltage across 1Ω, $V_2 = 3 \times 1 = 3V$

Thevenin's Voltage, $V_{th} = V_{AB} = 12 - 3 = 9V$

STEP3:

$$\boxed{V_{th} = 9V}$$

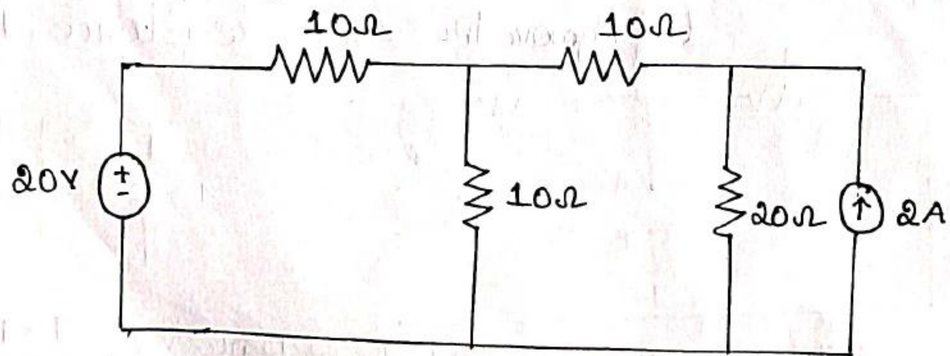
Thevenin's Eq. ckt:



Load Current, $I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{9}{0.5 + 2} = 3.6A$

$$\boxed{\text{Current through } 2Ω \text{ is } 3.6A}$$

PROBLEM 2: Calculate the Current through the 20Ω resistor using thevenin's theorem.

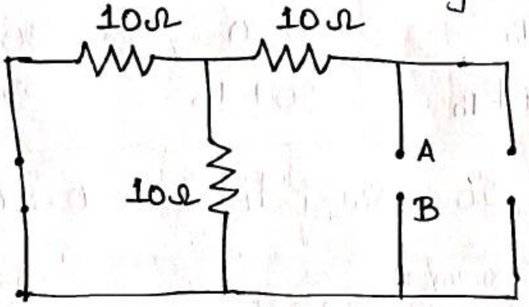


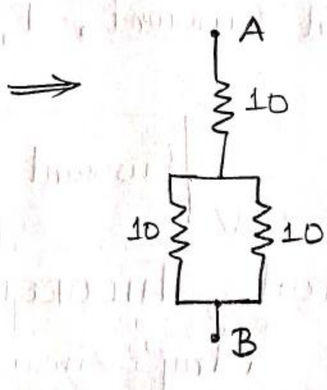
Solution:

STEP 1: To find R_{th}, (i). Remove the load resistance, R_L

(ii). Short Circuit the Voltage Source.

(iii). Open Circuit the Current Source.





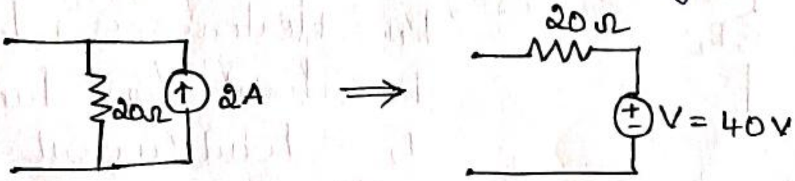
$$\Rightarrow \frac{10 \times 10}{10+10} = 5\Omega$$

5Ω and 10Ω resistors are in Series, $5 + 10 = 15\Omega$

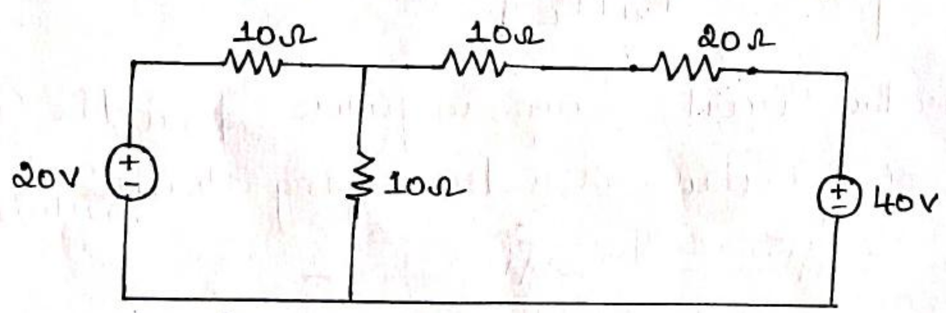
$$\therefore \boxed{R_{th} = 15\Omega}$$

STEP 2: To find V_{th}, (i). Remove the load resistance, R_L

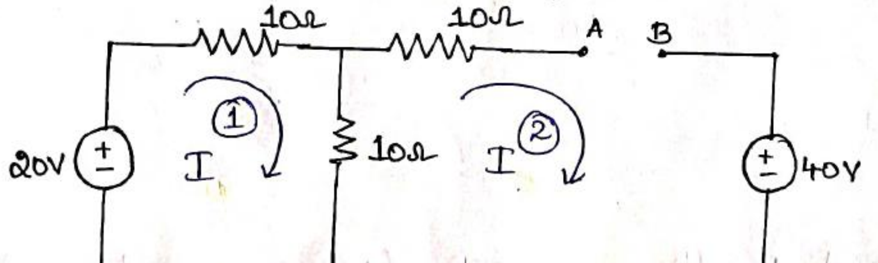
Convert Current Source into Voltage Source.



By ohm's Law, $V = IR = 2 \times 20 = 40V$



Remove the load resistance, $R_L = 20\Omega$



Apply KVL to loop ①

$$-10I - 10I + 20 = 0$$

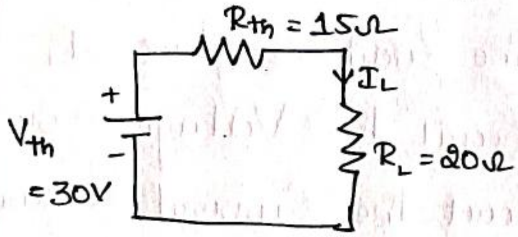
$$I = 1A$$

Apply KVL to loop ② to find V_{th},

$$10I - V_{th} - 40 = 0$$

$$\boxed{V_{th} = -30V}$$

STEP 3: Thevenin's Eq. ckt:



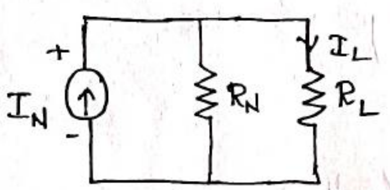
Load Current, $I_L = \frac{V_{th}}{R_L + R_{th}} = \frac{-30}{20+15} = \frac{-30}{35} = -0.86A$

Current through 20Ω resistor is $-0.86A$

NORTON'S THEOREM: "STATEMENT"

"Any linear network having a number of Voltage Sources, Current Sources and resistances Can be replaced by a Simple equivalent Circuit having Single Current Source and a resistance Connected in Parallel".

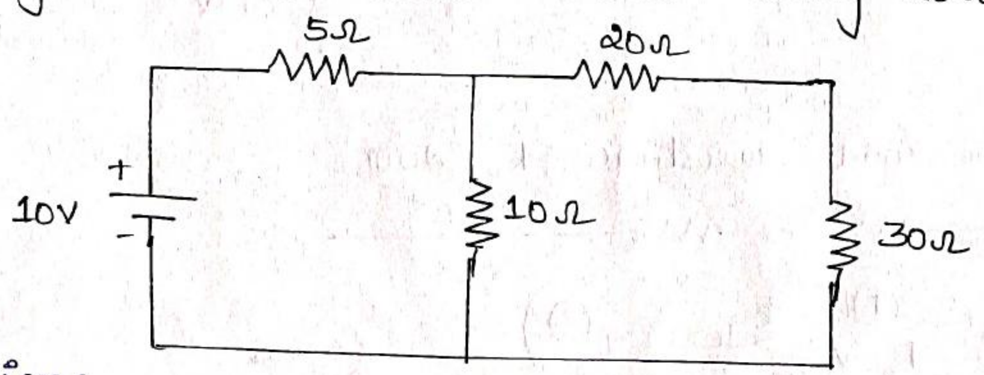
Norton's Equivalent Circuit:



where, I_N = Norton's Current
R_N = Norton's resistance
R_L = Load resistance
I_L = Load Current.

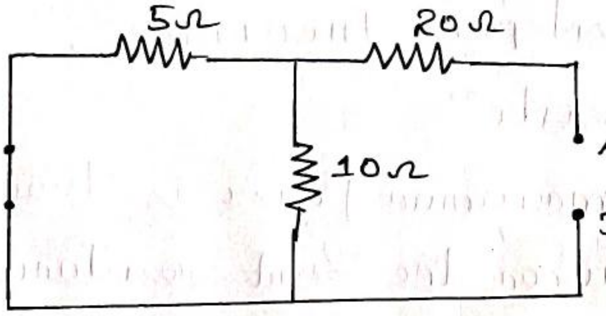
$$\boxed{I_L = I_N \frac{R_N}{R_N + R_L}}$$

PROBLEM 1: For the Circuit Shown in figure, find the Current through the 30Ω load resistor using Norton's theorem.

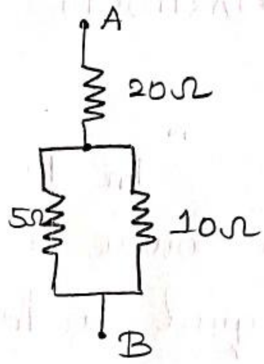


Solution:

STEP 1: To find R_N (i) remove R_L (Load resistance)
(ii) Short Circuit the Voltage Source.



$\Rightarrow$



5Ω and 10Ω are in Parallel,

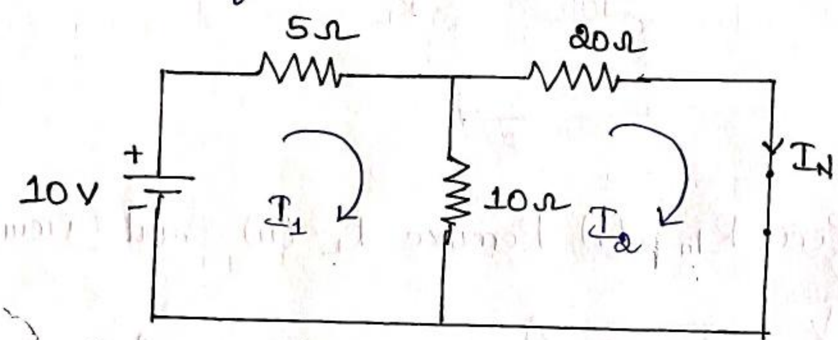
$$\frac{5 \times 10}{5+10} = 3.33\,\Omega$$

3.33Ω and 20Ω are in Series,

$$3.33 + 20 = 23.33\,\Omega$$

$$\therefore \boxed{R_N = 23.33\,\Omega}$$

STEP 2: To find I_N, Short Circuit the Load resistance (R_L).



By mesh inspection,

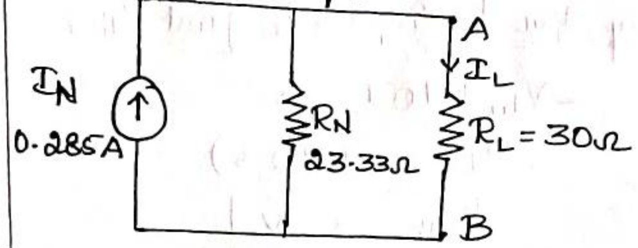
$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{bmatrix} 15 & -10 \\ -10 & 30 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 15 & -10 \\ -10 & 30 \end{vmatrix} = 450 - 100 = 350$$

$$\Delta I_2 = \begin{vmatrix} 15 & 10 \\ -10 & 0 \end{vmatrix} = 0 - (-100) = 100$$

$$I_2 = \frac{\Delta I_2}{\Delta} = \frac{100}{350} = 0.285\,A = I_N$$

STEP 3: Norton's Eq.ckt:



$$I_L = I_N \cdot \frac{R_N}{R_N + R_L}$$

$$= 0.285 \left[\frac{23.33}{23.33 + 30}\right] = 0.125\,A$$

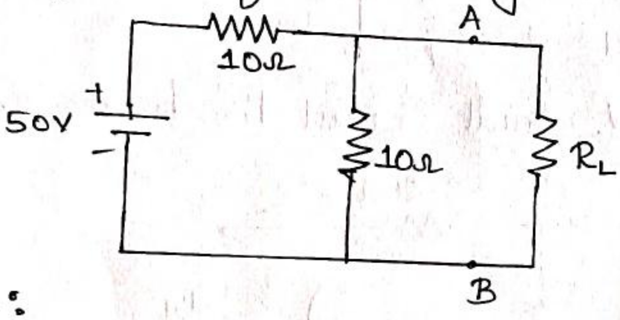
$\boxed{\text{Current through } 30\Omega \text{ is } 0.125\,A}$

MAXIMUM POWER TRANSFER THEOREM:-

"STATEMENT"

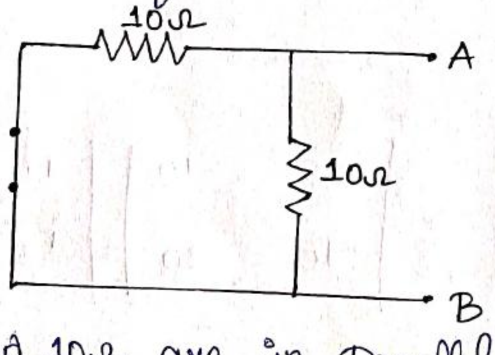
"In DC Circuits, maximum Power is transferred from a Source to the load when the load resistance is made equal to the resistance of the network as Viewed from the load terminals with load removed and all the Sources are replaced by their internal resistance".

PROBLEM 1: Calculate the Value of R_L, So that maximum Power is transferred from battery.



Solution:

STEP-1: To find R_{th}, (i) Remove R_L (ii) Short Circuit Voltage Source.



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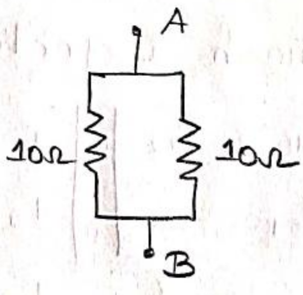
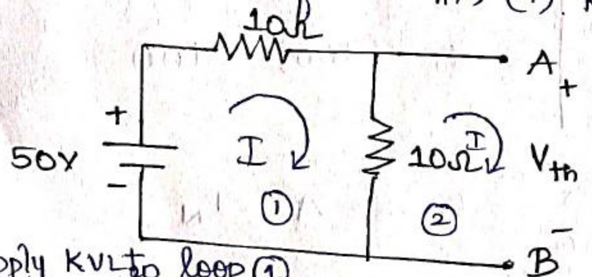


10Ω and 10Ω are in Parallel, $\frac{10\times10}{10+10} = 5\Omega$ $\therefore \boxed{R_{th} = 5\Omega}$

STEP-2: To find V_{th}, (i) Remove the R_L,



Apply KVL to loop ①

$$-10I - 10I + 50 = 0$$

$$I = 2.5\,A$$

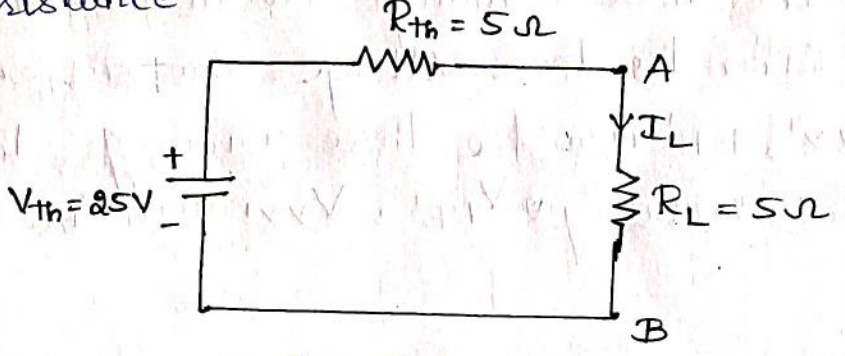
Apply KVL to loop ② to find V_{th},

$$-V_{th} + 10I = 0$$

$$-V_{th} = -10(2.5)$$

$$\boxed{V_{th} = 25\,V}$$

The maximum Power is transferred to the load resistor only when the load resistance is equal to the Thevenin's resistance.



$\therefore R_L = R_{Th} = 5\Omega$

Maximum Power, $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}}$

$= \dfrac{25^2}{4 \times 5}$

$\boxed{P_{max} = 31.25\ W}$

THREE PHASE CIRCUITS:

A Small Consumers (domestic applications), we use 1ϕ AC Supply (230V, 50Hz). But big Consumers (industrial applications) are Consuming large amount of Power. Single phase is not Sufficient for Producing large amount of Power. The large amount of power Can be obtained from three phase AC Supply (440V, 50 Hz).

Several advantages of using three phase Supply System:-

The total Power is more nearly uniform unlike in a Single Phase Circuit, where the Power Varies widely.

Three phase machines have better Power factor and efficiency.

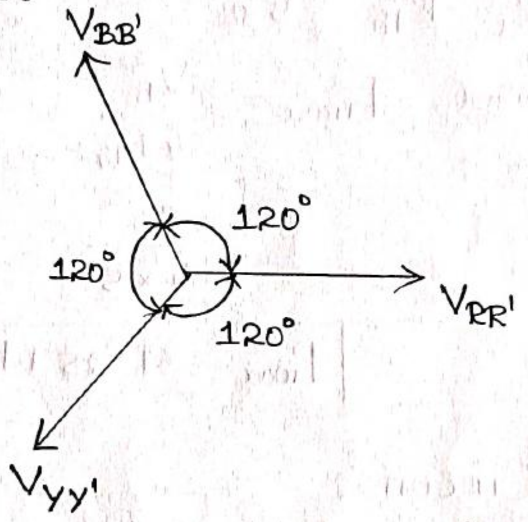
Generation, transmission and utilization of Power is more economical in three Phase Systems Compared to Single phase Systems.

Generation of Three phase Voltage System:-

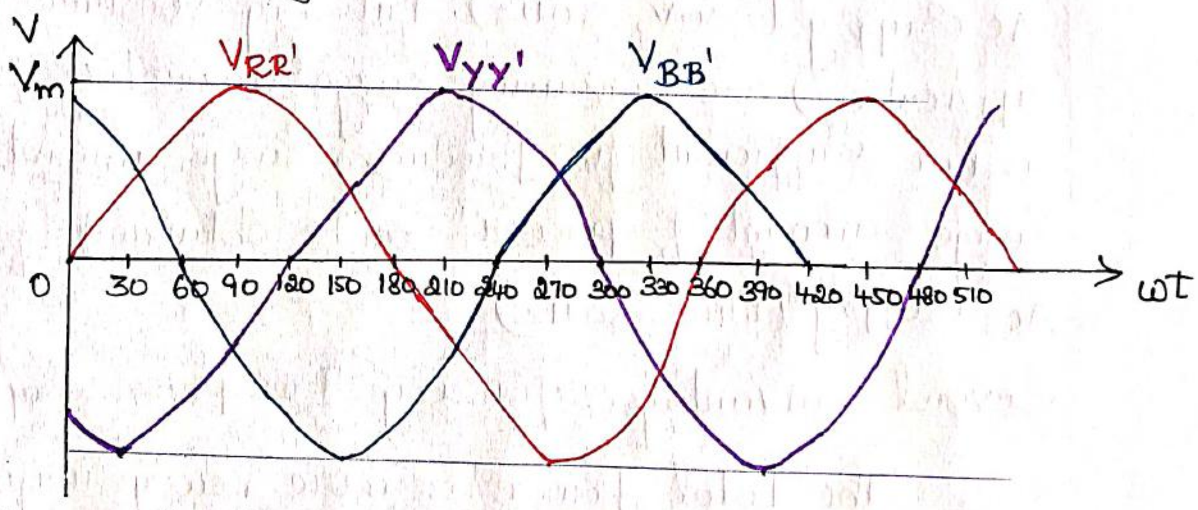
A three phase alternator has three Separate windings in its Stator. The three windings are displaced from one another by 120°. Then the three Voltages are differ by 120°.

If RR', YY', BB' are the three windings, then the Voltages in the winding are $V_{RR'}$, $V_{YY'}$ and $V_{BB'}$ differ by 120° each.

Phasor diagram:



3φ Sinusoidal Voltage Waveform:-



The Equations for the induced Voltages are,

$$V_{RR'} = V_m \sin \omega t \rightarrow (1)$$

$$V_{YY'} = V_m \sin(\omega t - 120°) \rightarrow (2)$$

$$V_{BB'} = V_m \sin(\omega t - 240°) \rightarrow (3)$$

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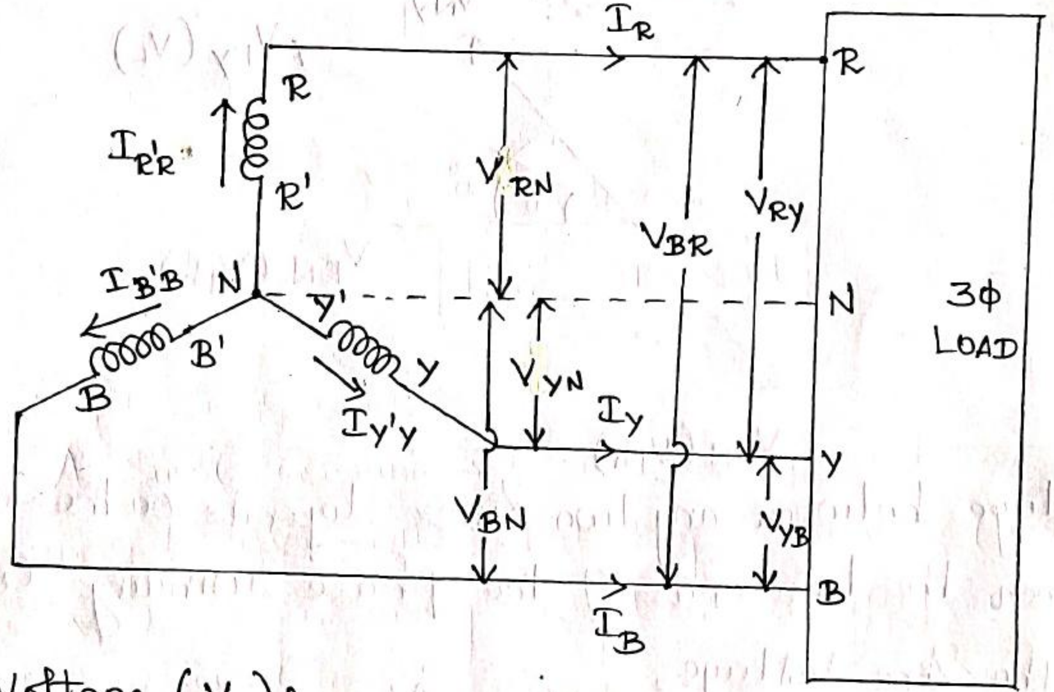
STAR CONNECTION (or) Wye CONNECTION:

The three windings are Connected in Star. The terminals R', Y' and B' are Connected together to form the Star Point, also Called the Neutral (N). The Lines R, Y, B are Connected to the Load.

If the neutral is Connected to the neutral of the load, it becomes a 3-phase, 4-Wire System. otherwise it is a 3-ϕ, 3-Wire System.



Line Voltage (V_L):-

Voltage across any two lines is Called the Line Voltage. V_{RY}, V_{YB} and V_{BR} are the Line Voltages.

phase Voltage (V_{ph}):-

Voltage across the winding is Called phase Voltage. V_{RN}, V_{YN} and V_{BN} are the phase Voltages.

Line Current (I_L):

Current flows through the line is Called line Current. I_R, I_Y and I_B are the line Currents.

Phase Current (I_{ph}):

Current flows through any phase winding is Called phase Current. $I_{R'R}$, $I_{Y'Y}$ and $I_{B'B}$ are the phase Currents.

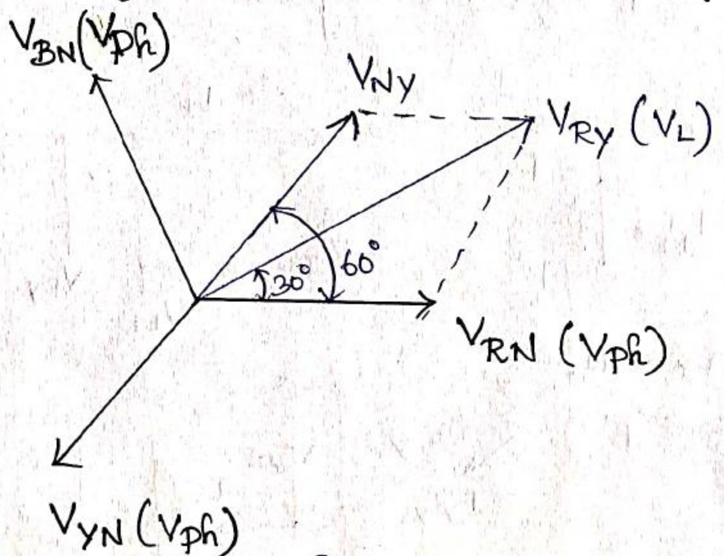
Current Equation:

In a Star Connected System, the Same Phase Current $I_{R'R}$ flows through the line R. Hence, $I_R = I_{R'R}$

$$\boxed{\text{Line Current}, I_L = \text{Phase Current}, I_{ph}}$$

Voltage Equation:

phasor diagram of 3-ϕ Star Connected System.



Voltage between any two lines depends on the Voltage between the two ends of the phase windings Concerned.

The line Voltage, $V_{RY} = V_{RN} + V_{NY}$

$$V_{RY} = V_L = 2 V_{ph} \cos 30° = 2 V_{ph} \frac{\sqrt{3}}{2} = \sqrt{3} V_{ph}$$

$$\therefore \boxed{V_L = \sqrt{3} V_{ph}}$$

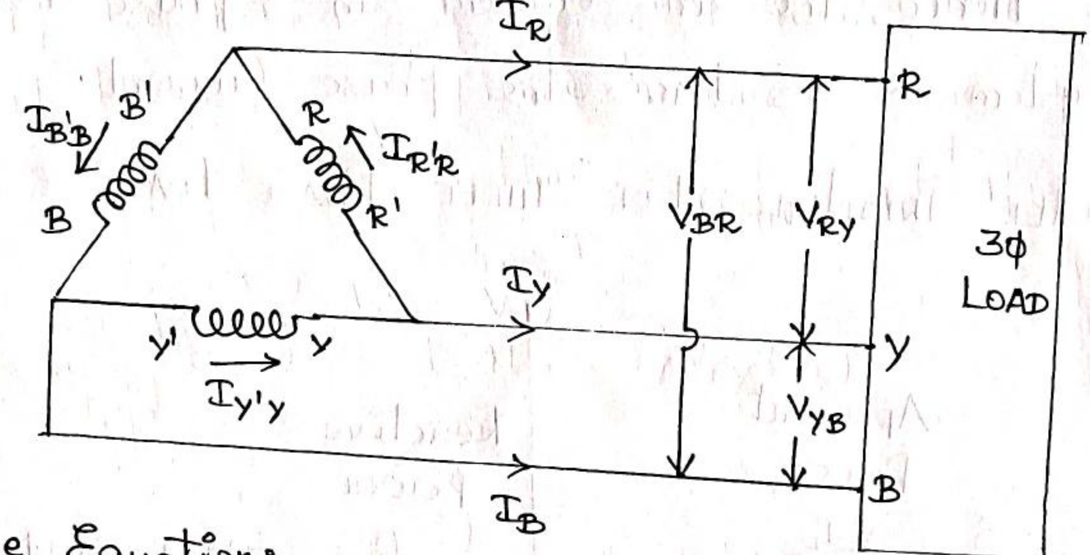
Hence, the line Voltage in 3-ϕ Star Connected System is $\sqrt{3}$ times the phase Voltage.

DELTA CONNECTION:

The three windings are Connected in delta. The end of R phase winding R' is Connected to the Start of the next phase winding Y. The end of the Y phase winding

Y' is Connected to the Start of the next Phase winding B. B' and R terminals are Connected.

This type of Connections form delta Connection. This delta Connection gives 3-phase 3-wire System only.



Voltage Equation:

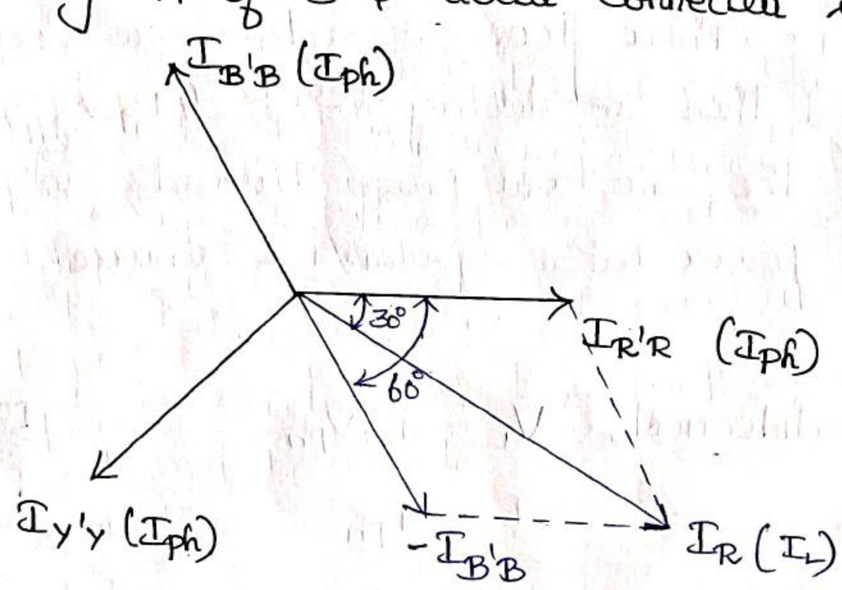
The phase Voltage $V_{RR'}$ is same as the line Voltage V_{RY}. Hence, in delta Connection, the line Voltage is equal to phase Voltage.

$$V_{RY} = V_{RR'}$$

$$\therefore \boxed{V_L = V_{ph}}$$

Current Equation:

Phasor diagram of 3-φ delta Connected System.



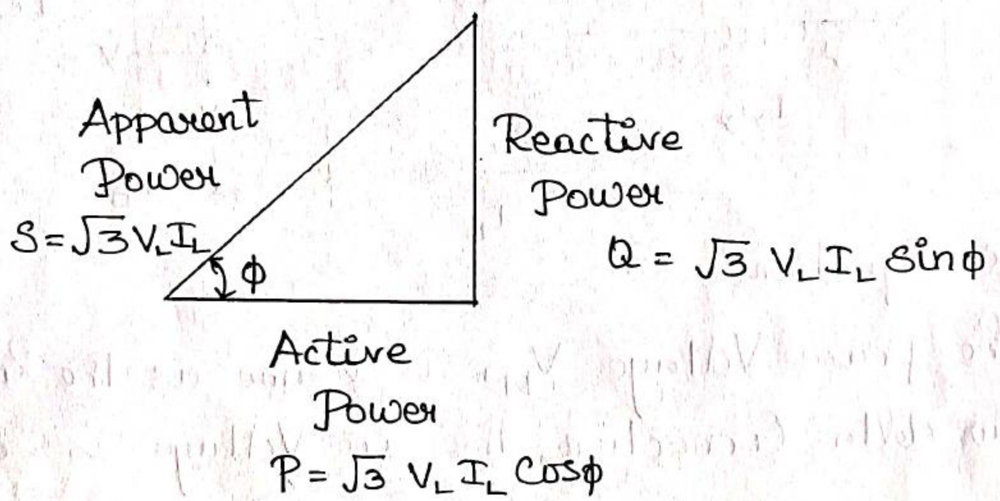
The Line Current, $I_R = I_{R'R} + (-I_{B'B})$

$$I_L = I_R = 2 I_{ph} \cos 30^\circ = 2 I_{ph} \frac{\sqrt{3}}{2} = \sqrt{3}\, I_{ph}$$

$$\therefore \boxed{I_L = \sqrt{3}\, I_{ph}}$$

Hence, the line Current in 3-phase delta Connected System is $\sqrt{3}$ times the phase Current.

POWER TRIANGLE FOR THREE PHASE LOAD:-



Total Apparent Power, $S = \sqrt{3}\, V_L I_L$ [VA (or) KVA]

Total Active Power, $P = \sqrt{3}\, V_L I_L \cos\phi$ [W (or) KW]

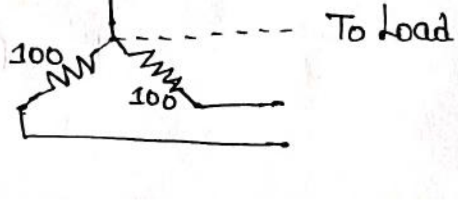
Total Reactive Power, $Q = \sqrt{3}\, V_L I_L \sin\phi$ [VAR (or) KVAR]

PROBLEM 1: Three 100Ω resistors are Connected first in Star and then in delta across 415 V, 3-phase Supply. Calculate the line and phase Currents in each Case and also the Power taken from the Source.

Solution:

STAR CONNECTION, $V_L = \sqrt{3}\, V_{ph}$

$I_L = I_{ph}$



$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6 \text{ V}$$

$$I_{ph} = \frac{V_{ph}}{R} = \frac{239.6}{100} = 2.396 \text{ A}$$

Line Current, $\boxed{I_L = I_{ph} = 2.396 \text{A}}$

Power taken from the Source, $P = \sqrt{3}\, V_L I_L$

$= \sqrt{3} \times 415 \times 2.396$

$\boxed{P = 1722.2 \text{ W}}$

DELTA CONNECTION, $V_L = V_{ph}$

$I_L = \sqrt{3}\, I_{ph}$

∴ Line Voltage, $V_L = 415 \text{ V} = V_{ph}$

$V_{ph} = 415 \text{ V}$

∴ Phase Current, $I_{ph} = \frac{V_{ph}}{R} = \frac{415}{100} = 4.15 \text{A}$

Line Current, $I_L = \sqrt{3} \times 4.15$

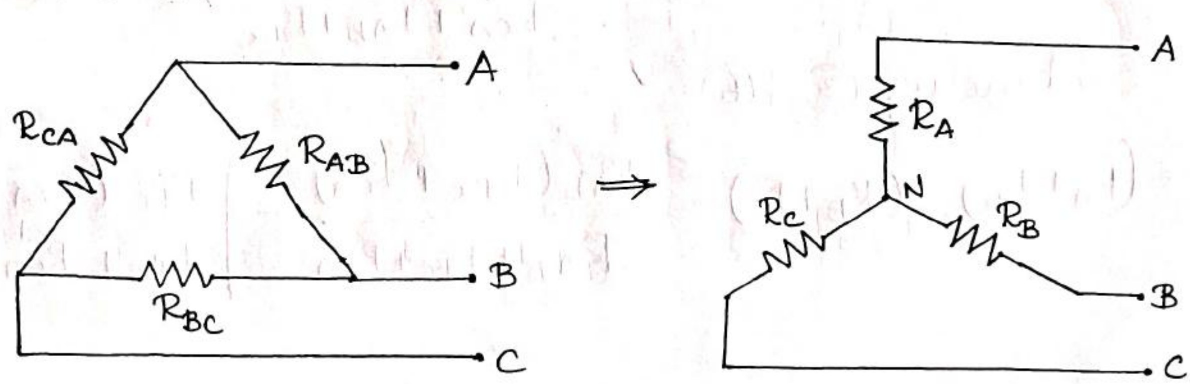
$\boxed{I_L = 7.188 \text{A}}$

Power taken from the Source, $P = \sqrt{3}\, V_L I_L$

$= \sqrt{3} \times 415 \times 7.188$

$\boxed{P = 5166.7 \text{ W}}$

DELTA TO STAR CONVERSION:



(36) Let the three resistors R_{AB}, R_{BC} & R_{CA} from a Δ is Converted into Y Consisting of R_A, R_B and R_C.

In Delta Connection, the equivalent resistance between A and B is R_{AB}.

$$R_{AB} = \frac{R_{AB}(R_{BC}+R_{CA})}{R_{AB}+R_{BC}+R_{CA}} \rightarrow (1)$$

In Star Connection, the equivalent resistance between A & B is,

$$R_A+R_B \rightarrow (2).$$

(1) = (2).

$$R_A+R_B = \frac{R_{AB}(R_{BC}+R_{CA})}{R_{AB}+R_{BC}+R_{CA}} \rightarrow (3)$$

|||ly.

In Delta Connection, the equivalent resistance between B and C is R_{BC}

$$R_{BC} = \frac{R_{BC}(R_{CA}+R_{AB})}{R_{BC}+R_{CA}+R_{AB}} \rightarrow (4)$$

In Star Connection, the equivalent resistance b/w B & C is,

$$R_B+R_C \rightarrow (5)$$

(4) = (5).

$$R_B+R_C = \frac{R_{BC}(R_{CA}+R_{AB})}{R_{BC}+R_{CA}+R_{AB}} \rightarrow (6).$$

|||ly.

$$R_C+R_A = \frac{R_{CA}(R_{AB}+R_{BC})}{R_{CA}+R_{AB}+R_{BC}} \rightarrow (7).$$

Subtracting, (3) − (6)

$$(R_A+R_B)-(R_B+R_C) = \frac{R_{AB}(R_{BC}+R_{CA})}{R_{AB}+R_{BC}+R_{CA}} - \left[\frac{R_{BC}(R_{CA}+R_{AB})}{R_{BC}+R_{CA}+R_{AB}}\right]$$

$$R_A + \cancel{R_B} - \cancel{R_B} - R_C = \frac{R_{AB}\cancel{R_{BC}} + R_{AB}R_{CA} - R_{BC}R_{CA} - R_{BC}\cancel{R_{AB}}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_A - R_C = \frac{R_{AB}R_{CA} - R_{BC}R_{CA}}{R_{AB} + R_{BC} + R_{CA}} \longrightarrow (8)$$

Add , (7) + (8)

$$(\cancel{R_C} + R_A) + (R_A - \cancel{R_C}) = \frac{R_{CA}R_{AB} + R_{CA}\cancel{R_{BC}} + (R_{AB}R_{CA} - \cancel{R_{BC}R_{CA}})}{R_{AB} + R_{BC} + R_{CA}}$$

$$2R_A = \frac{2R_{AB}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

$$\boxed{R_A = \frac{R_{AB}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}} \longrightarrow (9)$$

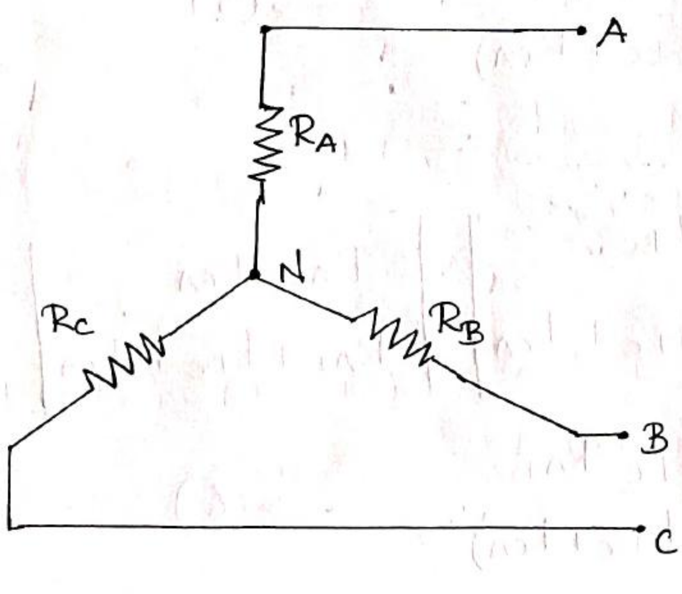
|||ly

$$\boxed{R_B = \frac{R_{BC}R_{AB}}{R_{AB} + R_{BC} + R_{CA}}} \longrightarrow (10)$$

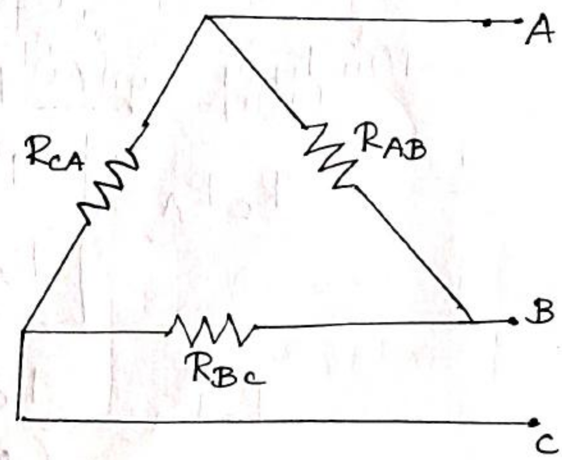
$$\boxed{R_C = \frac{R_{CA}R_{BC}}{R_{AB} + R_{BC} + R_{CA}}} \longrightarrow (11)$$

AB BC CA
Start with B
End with B.

STAR TO DELTA CONVERSION:



$\Rightarrow$



(38) We Know that,

$$R_A = \frac{R_{AB}\ R_{CA}}{R_{AB} + R_{BC} + R_{CA}} \longrightarrow (1)$$

AB BC CA

$$R_B = \frac{R_{BC}\ R_{AB}}{R_{AB} + R_{BC} + R_{CA}} \longrightarrow (2)$$

$$R_C = \frac{R_{CA}\ R_{BC}}{R_{AB} + R_{BC} + R_{CA}} \longrightarrow (3).$$

Multiply eqn (1) & (2)

$$R_A R_B = \left[\frac{R_{AB}\ R_{CA}}{R_{AB} + R_{BC} + R_{CA}}\right]\left[\frac{R_{BC}\ R_{AB}}{R_{AB} + R_{BC} + R_{CA}}\right]$$

$$R_A R_B = \frac{R_{AB}^2\ R_{BC}\ R_{CA}}{(R_{AB} + R_{BC} + R_{CA})^2} \longrightarrow (4)$$

Multiply eqn (2) & (3)

$$R_B R_C = \left[\frac{R_{BC}\ R_{AB}}{R_{AB} + R_{BC} + R_{CA}}\right]\left[\frac{R_{CA}\ R_{BC}}{R_{AB} + R_{BC} + R_{CA}}\right]$$

$$R_B R_C = \frac{R_{BC}^2\ R_{AB}\ R_{CA}}{(R_{AB} + R_{BC} + R_{CA})^2} \longrightarrow (5)$$

Multiply eqn (3) & (1)

$$R_C R_A = \left[\frac{R_{CA}\ R_{BC}}{R_{AB} + R_{BC} + R_{CA}}\right]\left[\frac{R_{AB}\ R_{CA}}{R_{AB} + R_{BC} + R_{CA}}\right]$$

$$R_C R_A = \frac{R_{CA}^2\ R_{BC}\ R_{AB}}{(R_{AB} + R_{BC} + R_{CA})^2} \longrightarrow (6)$$

39 Add Equations 4, 5 & 6, we get,

$$R_A R_B + R_B R_C + R_C R_A = \frac{R_{AB} R_{BC} R_{CA} (R_{AB} + R_{BC} + R_{CA})}{(R_{AB} + R_{BC} + R_{CA})^2}$$

$$= \frac{R_{AB} R_{BC} R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_A R_B + R_B R_C + R_C R_A = R_{AB} \cdot R_C$$

$$\therefore R_C = \frac{R_{BC} R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

We can write,

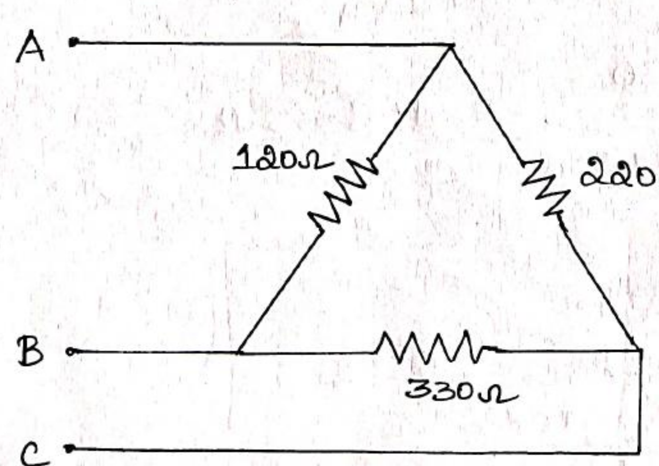
$$\boxed{R_{AB} = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}} \rightarrow (7)$$

lll^ly

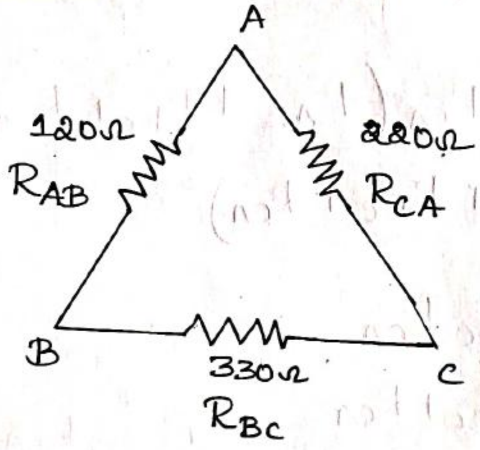
$$\boxed{R_{BC} = \frac{R_B R_C + R_C R_A + R_A R_B}{R_A}} \rightarrow (8)$$

$$\boxed{R_{CA} = \frac{R_C R_A + R_A R_B + R_B R_C}{R_B}} \rightarrow (9)$$

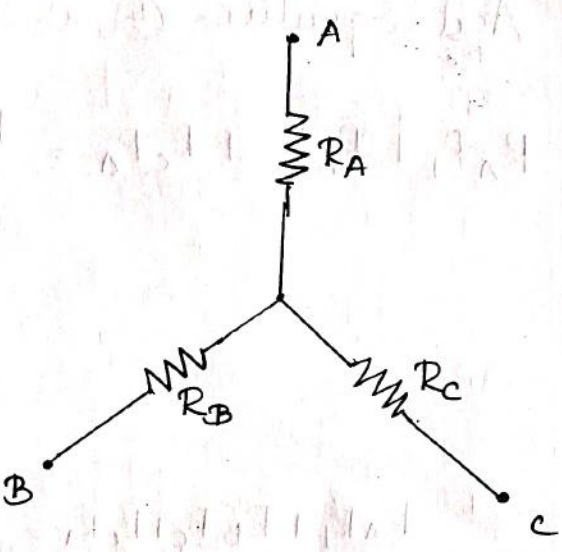
PROBLEM 1: Convert the given Δ network into Star Connection.



Solution:



$\Rightarrow$



AB BC CA.

$$R_A = \frac{R_{AB}\ R_{CA}}{R_{AB}+R_{BC}+R_{CA}}$$

$$= \frac{220 \times 120}{120+330+220} = 39.4\ \Omega$$

$$R_B = \frac{R_{BC}\ R_{AB}}{R_{AB}+R_{BC}+R_{CA}}$$

$$= \frac{330 \times 120}{120+330+220} = 59.1\ \Omega$$

$$R_C = \frac{R_{CA}\ R_{BC}}{R_{AB}+R_{BC}+R_{CA}}$$

$$= \frac{220 \times 330}{120+330+220} = 108.35\ \Omega$$