UNIT-1

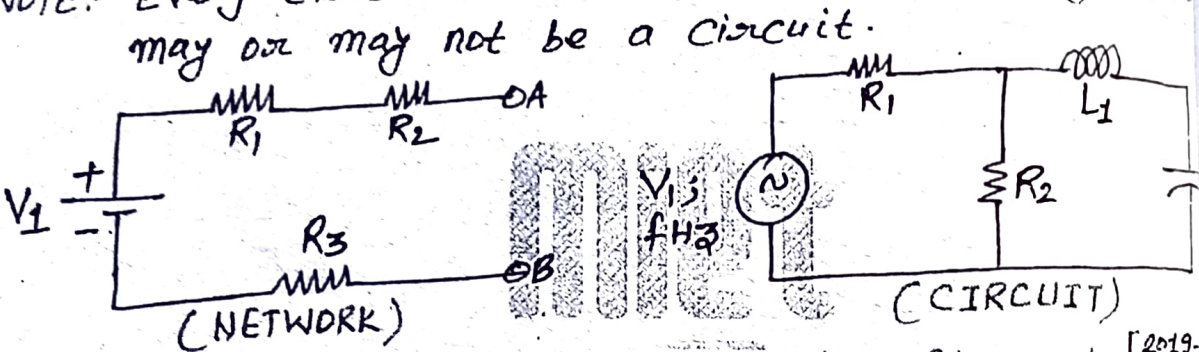
DC CIRCUIT ANALYSIS

Question:- Define Network and Circuit. [2020-21, 2018-19, 2016-17, 2015-16]

Answer:- Any combination of electrical elements such as "voltage sources, current sources, resistances, inductance & capacitance" is called a "Network". It may be opened or closed.

→ Any closed path formed by the voltage / current sources, resistance, inductance and capacitance results in a flow of current is known as a "Circuit".

NOTE:- Every circuit is a Network but every Network may or may not be a circuit.



Question:- Define Active and passive Elements. [2019-, 2017-, 2015-]

Answer:- Active Elements :- Elements that are capable delivering electrical energy are called "Active Elements"

eg :- Voltage source, current source, Batter

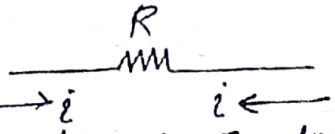
Passive Elements :- The elements which ar capable of receiving and storing or dissi the electrical energy are called "passive elements"

Eg:- Resistance, Inductance, Capacitance

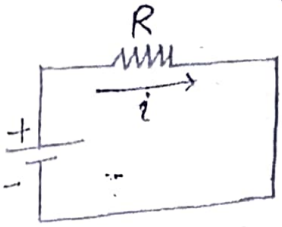
Question:- Define Unilateral and Bilateral Elements. [2019-20, 2018-19, 2017-18, 2016-17]

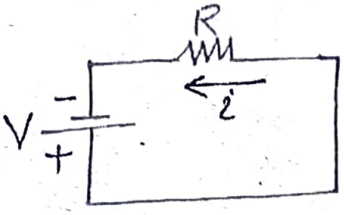
Answer:- Bilateral Elements :- If the V-I characteristics, behaviour of elements remains unchanged on changing the direction of current is known as "Bilateral element".

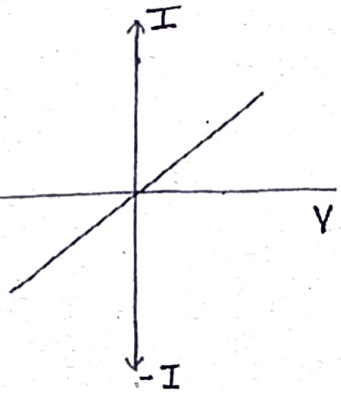
eg:- Resistance, Inductance, Capacitance



Property of R doesn't change with change in direction of current

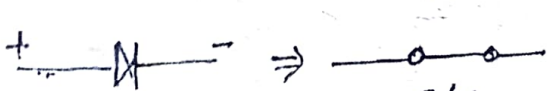


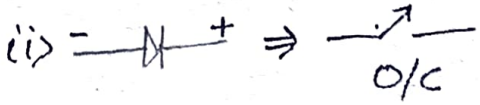


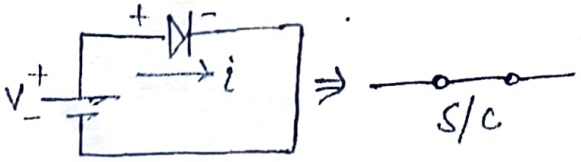


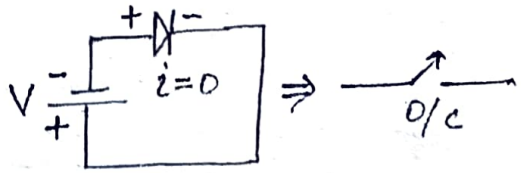
Unilateral Elements :- If the V-I characteristics, behaviour of element changes on changing the direction of current is known as "Unilateral Element".

eg:- Diode



(i) 





Question:- Define Linear and Non-Linear Element.

Answer:- A system is said to be linear if it follows the principles of "superposition and homogeneity".

Linear Element :- If a element follows the principle of superposition and homogeneity, it is said to be "linear". $y = mx$ is a "linear system."

* A Linear element follows Ohm's Law.

for eg:- R, L, C

Non-Linear Element :- If an element doesn't follow the principle of superposition and homogeneity, it is said to be Non-Linear Element. $y = mx + c$ is a "Non-linear system".

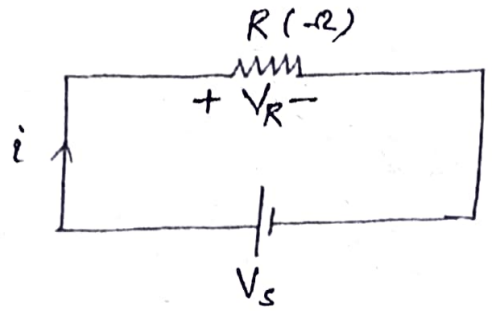
* A Non-linear element doesn't follow ohm's law.

for eg:- Diode, transistor.

Question:- Explain Ohm's Law.

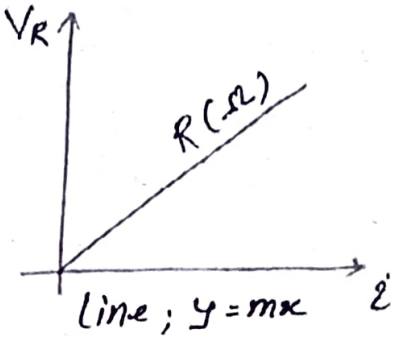
Answer:- Statement :- Voltage drop across a conductor is directly proportional to the current passing through that elements if atmospheric condition like temperature, pressure and humidity etc. kept constant.

Explanation :-



$V_R \propto i$

$V_R = i.R$

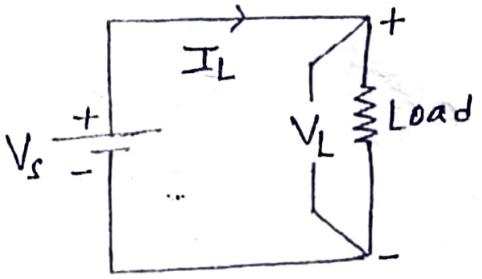


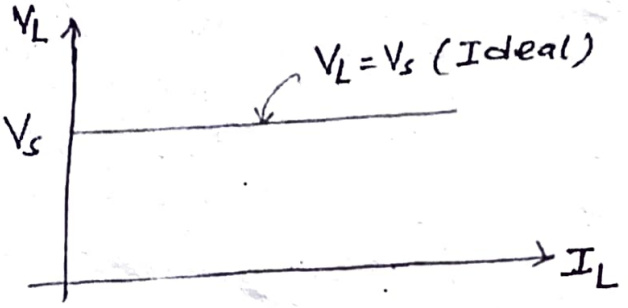
→ Here R is linear element.

→ Ohm's law is not applicable to non-linear elements like diode and transistor.

Question :- Explain ideal & practical voltage source. [2020-21, 2018-19, 2017-18]

Answer :- Ideal voltage source →



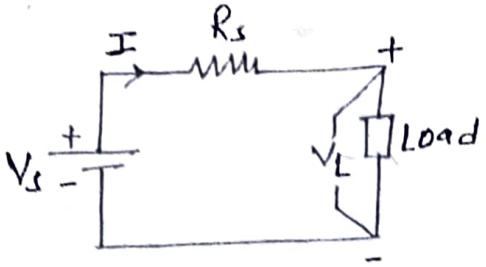


→ It gives constant voltage across its terminals irrespective of current drawn through its terminals.

$$V_L \text{ (load)} = V_s \text{ (source)}$$

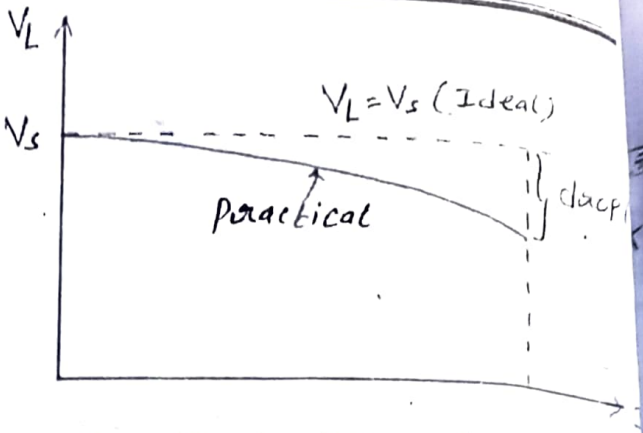
→ Internal resistance $(R_s = 0)$

Practical voltage source → practically every voltage source has small internal resistance in series.



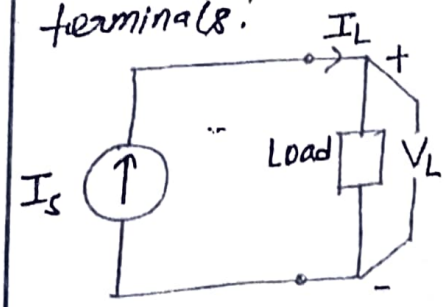
By KVL:-

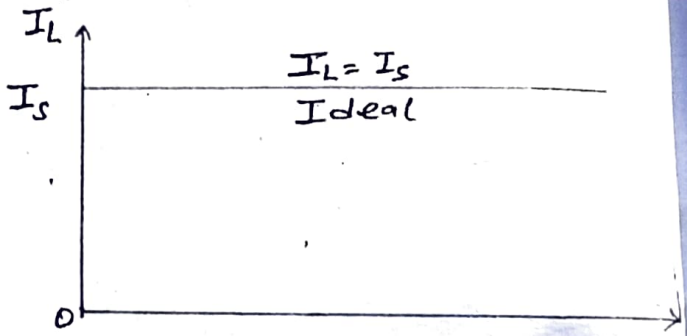
$$V_L = V_s - I \cdot R_s$$



Question:- Explain ideal & practical current source [2020-21, 2018-19, 2017

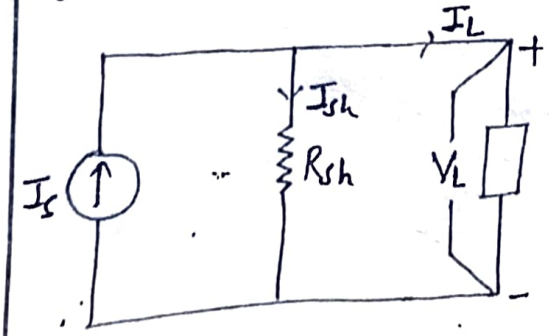
Answer:- Ideal current source :- It is the source which gives constant current at its terminals or irrespective of the voltage appearing across its terminals.

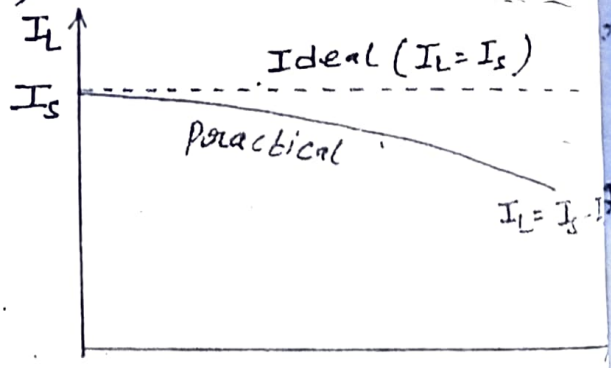




for ideal current source $(R_{sh} = \infty)$.

Practical current source :- It has high internal resistance in parallel. (R_{sh})





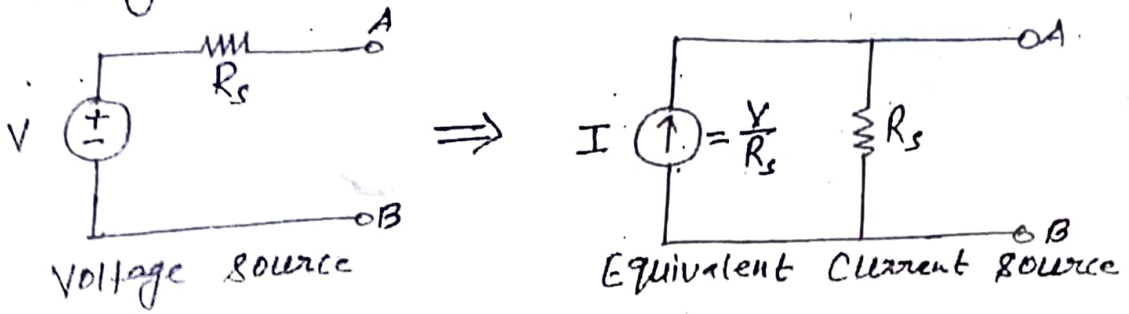
By KCL:-

$$I_s = I_{sh} + I_L$$

$$I_L = I_s - I_{sh}$$

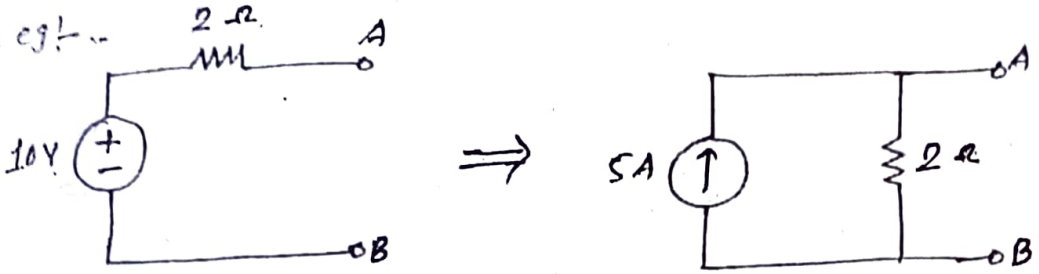
5 Source transformation :-

Voltage source → Current source

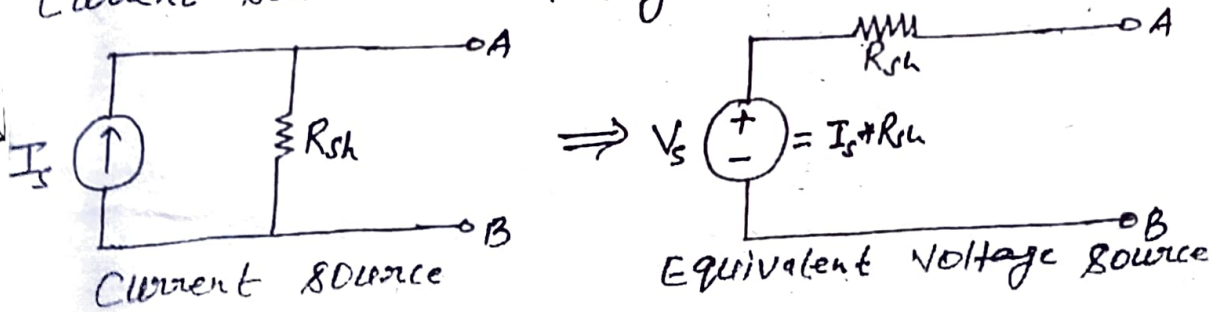


Voltage source — Equivalent Current source

eg :-

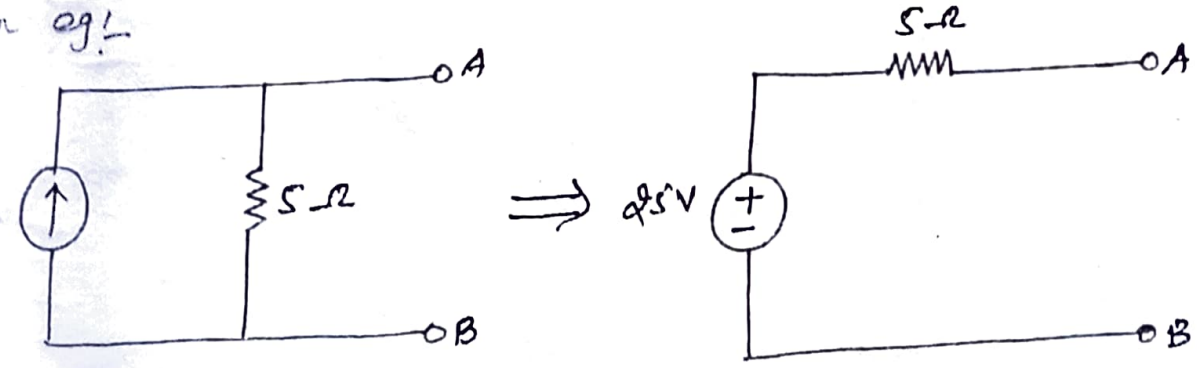


Current source → Voltage source



Current source — Equivalent Voltage source

eg :-



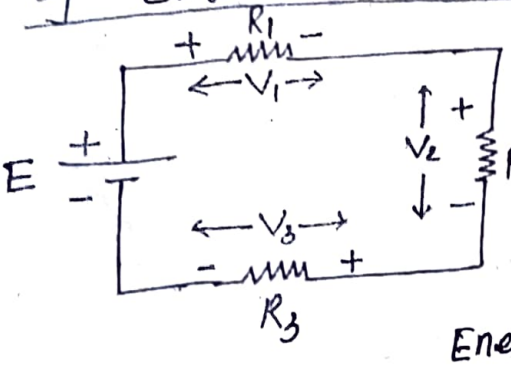
Question :- Explain Kirchhoff's voltage law (KVL) with their applications & limitations. [2016-17]

Answer :- "At any time instant the sum of voltages in a closed circuit is zero".

$$\sum_{j=1}^{K} V_j = 0$$

V_j = Voltage drop of the j^{th} element in a closed circuit and there are K elements.

Concept :- This law is a restatement of the "Law of conservation energy."



The energy supplied by the Battery is dissipiated by the resistance. so

$$W = W_1 + W_2 + W_3$$

W : Energy supplied from E
W_1 : Energy dissipates through R_1
W_2 : R_2
W_3 : R_3

furthermore, if we denote by Q the total charge which moves throughout the circuit during same interval of time, it follows that the work per unit charge may be written as :-

$$\frac{W}{Q} = \frac{W_1}{Q} + \frac{W_2}{Q} + \frac{W_3}{Q} \quad \text{---(A)}$$

work done per unit charge is voltage ; $\frac{W}{Q} = V$ so eqn A can be written as :-

$$E = V_1 + V_2 + V_3 \quad \text{or} \quad E - V_1 - V_2 - V_3 = 0 \quad \text{---(B)}$$

This eq^n (B) is a direct mathematical statement of Kirchhoff's Voltage Law.

NOTE:- All voltage drop are treated as a negative sign and voltage rise are treated as a positive sign or vice-versa.

* Application :-

1) In Mesh analysis (To determine a Mesh or Branch current)

2) To determine a voltage across an electrical element.

* Limitations :-

1) only applicable in a Lumped Network.

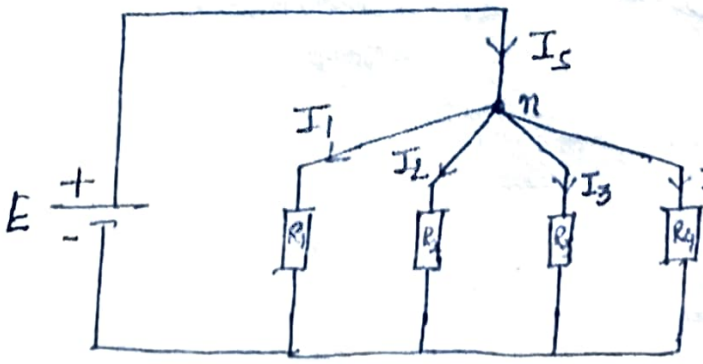
2) There should be a close path.

Question :- Explain Kirchhoff's Current Law (KCL) with their applications & limitations.

Answer :- "KCL states that the sum of currents entering or leaving the junction point at any instant is equal to zero."

$$\sum_{j=1}^{K} I_j = 0$$

K → No. of elements connected to the node.



* At Node n by KCL :-

$I_5 = I_1 + I_2 + I_3 + I_4$

$\therefore I_5 - I_1 - I_2 - I_3 - I_4 = 0$

Concept → It is the restatement of the "principle of conservation of charge".

→ This principle states that the num of electrons passing per second must be for all points in the circuit.

→ Therefore it is proper to conclude that for every charged particle that enter the node there is another charged particle that leaves.

$$\frac{dq_5}{dt} - \frac{dq_1}{dt} - \frac{dq_2}{dt} - \frac{dq_3}{dt} - \frac{dq_4}{dt} = 0$$

$$\boxed{dq_5 - dq_1 - dq_2 - dq_3 - dq_4 = 0}$$

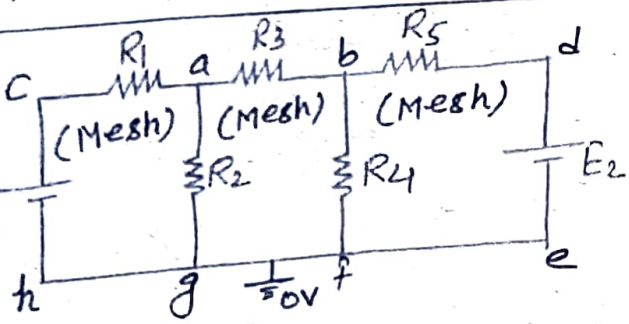
Application :-

1) In Nodal analysis
2) To determine a branch current

Limitations :-

1) Only applicable at a Node where more than two branches are connect.
2) only applicable in a Lumped Network.

BASIC CONCEPT RELATED TO NODE, JUNCTION, BRANCH, MESH AND LOOP



★ NODE :- A Node of a Network is an equipotential surface at which two or more circuit elements are joined.

a, b, c, d, g, f are nodes. $N = 5$

★ Junctions :- It is that point in the Network where three or more circuit elements are joined.

b, f, a are junction. $J = 3$

★ Branch :- It contains element. It is that part of a Network which lies between junction points.

$B = 7$

★ MESH :- It is the most elementry part of the loops. Every Mesh is a loop but every loop is not a Mesh. $M = 3$

★ LOOP :- It is any closed path of the network.

eg:- { cdehc ; abdefga ; cabfghc ; agfca ; abfga ; bdefb }

$L = 6$

NOTE :- $M = B - N + 1$ where :-

M → No. of Mesh

B → No. of Branch

N → No. of Node

MESH ANALYSIS

Step 1 :- Identify the No. of Mesh in the circuit.

Step 2 :- Assume current in each Mesh. (Any direction)

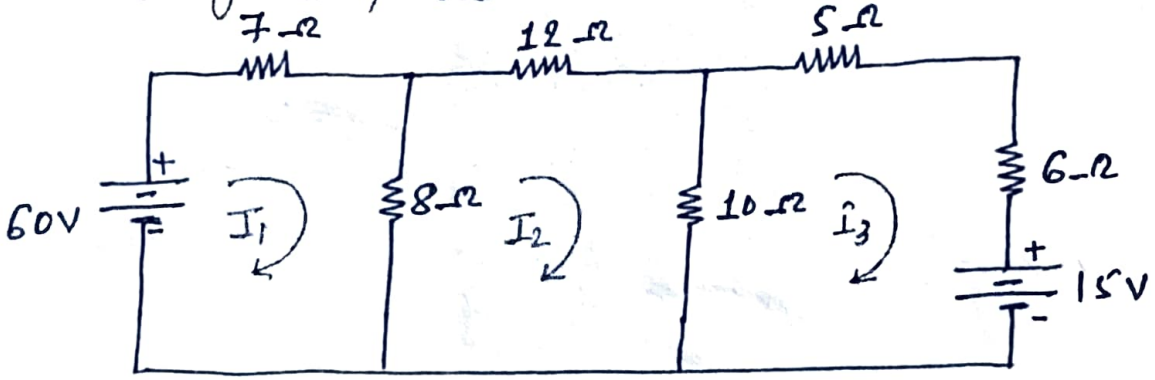
Step 3 :- Apply KVL in each Mesh and write equation of each Mesh.

Step 4 :- Solve the equations and Find Mesh current.

Step 5 :- Find Current in each branch. Voltage drop ($V=IR$)

Step 6 :- Power in any branch is $P = I^2R$ (Watt)

Question :- Find the currents in all the branches and Voltage drop across 5 Ω.



Solution :- Apply KVL in each Mesh :-

Mesh (1) :-

$$60 - 7I_1 - 8(I_1 - I_2) = 0$$

$$15I_1 - 8I_2 + 0 \cdot I_3 = 60 \quad \text{——— (i)}$$

Mesh (2) :-

$$-12I_2 - 10(I_2 - I_3) - 8(I_2 - I_1) = 0$$

$$8I_1 - 30I_2 + 10I_3 = 0 \quad \text{——— (ii)}$$

Mesh (3) :-

$$-15 - 10(I_3 - I_2) - 5I_3 - 6I_3 = 0$$

$$0 \cdot I_1 + 10I_2 - 21I_3 = 15 \quad \text{——— (iii)}$$

By solving equation (i), (ii) & (iii) we get :-

* Mesh Currents :-

$$I_1 = 4.632A \; ; \quad I_2 = 1.185A \; ; \quad I_3 = -0.15A$$

* Branch Currents :-

$I_{7\Omega} = I_1 = 4.632\,A$

$I_{8\Omega} = (I_1 - I_2) = 3.447\,A \downarrow$

$I_{12\Omega} = I_2 = 1.185A \rightarrow$

$I_{10\Omega} = (I_2 - I_3) = 1.335A \downarrow$

$I_{5\Omega} = I_3 = +0.15A \leftarrow$

$I_{6\Omega} = I_3 = +0.15A \leftarrow$

Ans.

* Voltage drop :-

$V_{5\Omega} = I_{5\Omega} * 5 = I_3 *$

$V_{5\Omega} = -0.15 * 5$

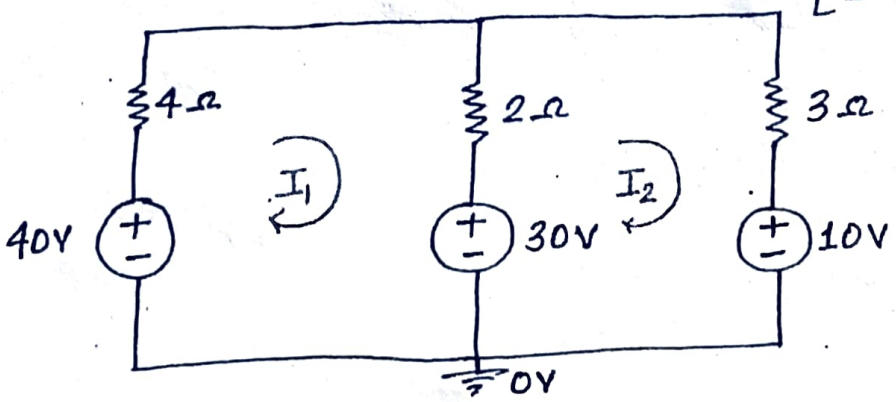
$V_{5\Omega} = -0.75\,V$

* Power Loss :-

$P_{5\Omega} = I^2_{5\Omega} * 5 = (-0.$

$P_{5\Omega} = 0.1125\,W$

Question :- Find out the current in 2 Ω resistance in the given figure using Loop analysis. [2015-16 EVEN



Solution :- Apply KVL in each mesh :-

Mesh (1) :-

$$40 - 4I_1 - 2(I_1 - I_2) - 30 = 0$$

$$6I_1 - 2I_2 = 10 \quad \text{——— (i)}$$

Mesh (2) :-

$$30 - 2(I_2 - I_1) - 3I_2 - 10 = 0$$

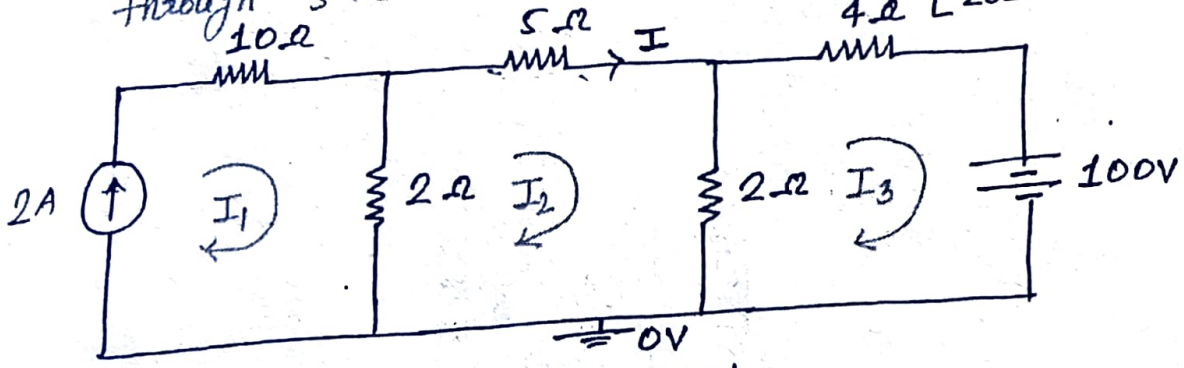
$$-2I_1 + 5I_2 = 20 \quad \text{—— (ii)}$$

By solving equation (i) & (ii) we get :-

$$\boxed{I_1 = 3.46A \; ; \; I_2 = 5.38A}$$

$$\boxed{I_{2\Omega} = I_1 - I_2 = -1.92A}$$ Answer.

Question :- Apply Mesh analysis and obtain the current (I) through 5 Ω resistor in the given circuit. [2020-21 ODD SEM]



Solution :- Apply KVL in each Mesh :-

Mesh (1) :-

$$\boxed{I_1 = 2A}$$

Mesh (2) :-

$$-5I_2 - 2(I_2 - I_3) - 2(I_2 - 2) = 0$$

$$9I_2 - 2I_3 = -4 \quad \text{—— (i)}$$

Mesh (3) :-

$$-100 - 2(I_3 - I_2) - 4I_3 = 0$$

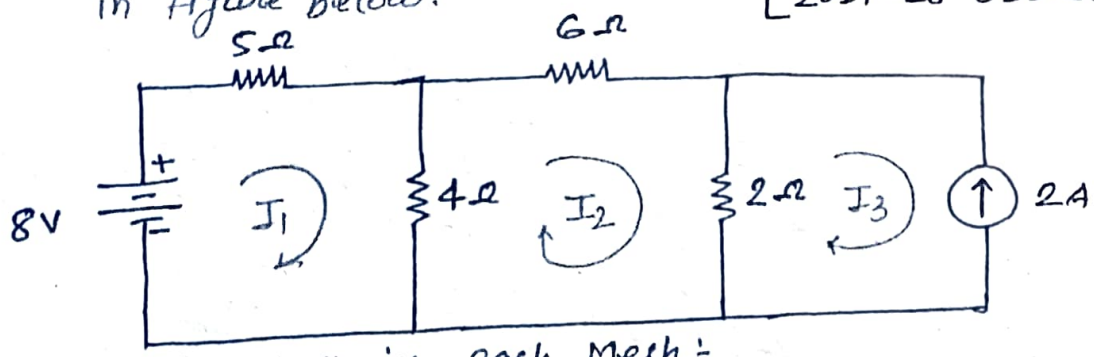
$$2I_2 - 6I_3 = 100 \quad \text{—— (ii)}$$

By solving equation (i) & (ii) we get :-

$$\boxed{I_2 = -3.52A \; ; \; I_3 = -17.84A.}$$

$$\boxed{I = I_{5\Omega} = I_2 = -3.52A}$$ Answer

Question:- Determine current in 4Ω resistor by using Mesh analysis in the circuit shown in figure below. [2017-18 ODD SEM]



Solution:- Apply KVL in each Mesh:-

Mesh (3):-

$$I_3 = -2A$$

Mesh (1):-

$$8 - 5I_1 - 4(I_1 - I_2) = 0$$

$$9I_1 - 4I_2 = 8 \quad \text{---- (i)}$$

Mesh (2):-

$$-6I_2 - 2(I_2 + 2) - 4(I_2 - I_1) = 0$$

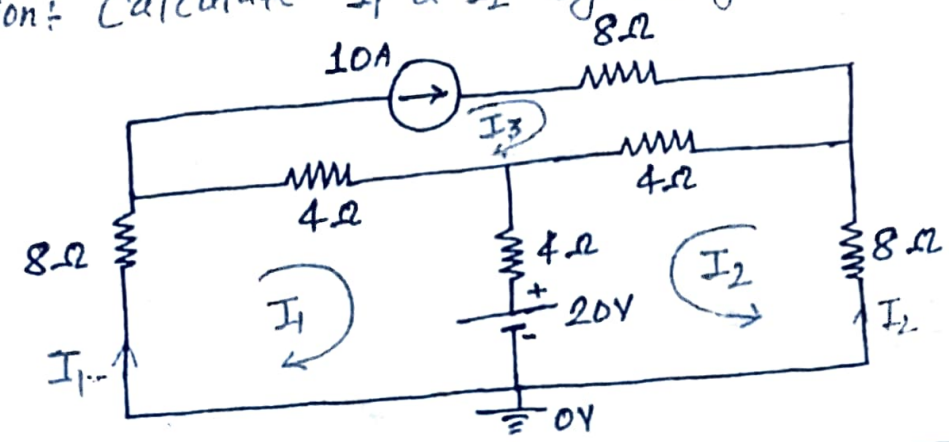
$$4I_1 - 12I_2 = 4 \quad \text{---- (ii)}$$

By solving equation (i) & (ii) we get:-

$$I_1 = 0.869A \; ; \; I_2 = -0.043A$$

$$I_{4\Omega} = I_1 - I_2 = 0.1299A$$ Answer.

Question:- Calculate I_1 & I_2 by using Mesh analysis:-



Solution:- Apply KVL in each Mesh :-

Mesh (3) :-

$$I_3 = 10A$$

Mesh (1) :-

$$-20 - 8I_1 - 4(I_1 - 10) - 4(I_1 + I_2) = 0$$

$$16I_1 + 4I_2 = 20 \quad \text{——— (i)}$$

Mesh (2) :-

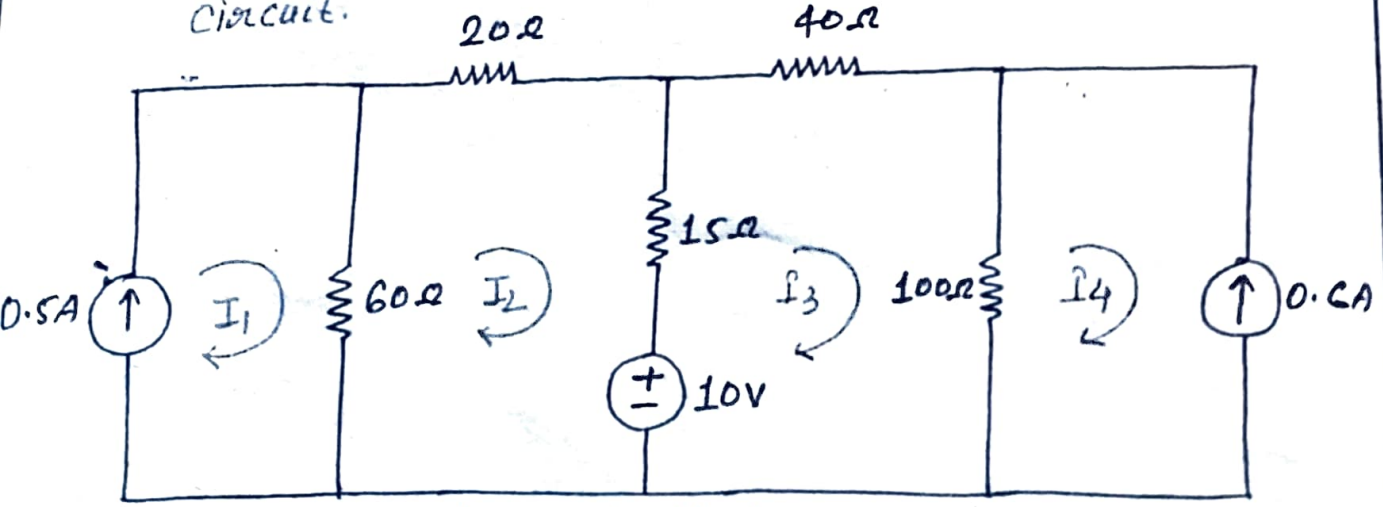
$$-20 - 8I_2 - 4(I_2 + 10) - 4(I_1 + I_2) = 0$$

$$4I_1 + 16I_2 = -60 \quad \text{——— (ii)}$$

By solving equation (i) & (ii) we get :-

$$I_1 = 2.33A \; ; \; I_2 = -4.33A$$ Answer.

Question:- Using Mesh analysis find out the current in 20 Ω, 40 Ω & 15 Ω resistor in the given circuit. [2016-17 ODD SEM]



Solution:- Apply KVL in each Mesh :-

Mesh (1) :-

$$I_1 = 0.5A$$

Mesh (4) :-

$$I_4 = -0.6A$$

Mesh (2) :-

$$-10 - 60(I_2 - 0.5) - 20I_2 - 15(I_2 - I_3) = 0$$

$$-95I_2 + 15I_3 = -20 \quad \text{——— (i)}$$

Mesh (3) :-

$$10 - 15(I_3 - I_2) - 40I_3 - 100(I_3 + 0.6) = 0$$

$15I_2 - 15I_3 = 50$ ——— (ii)

By solving eqn (i) & (ii) we get :-

Mesh Currents:-

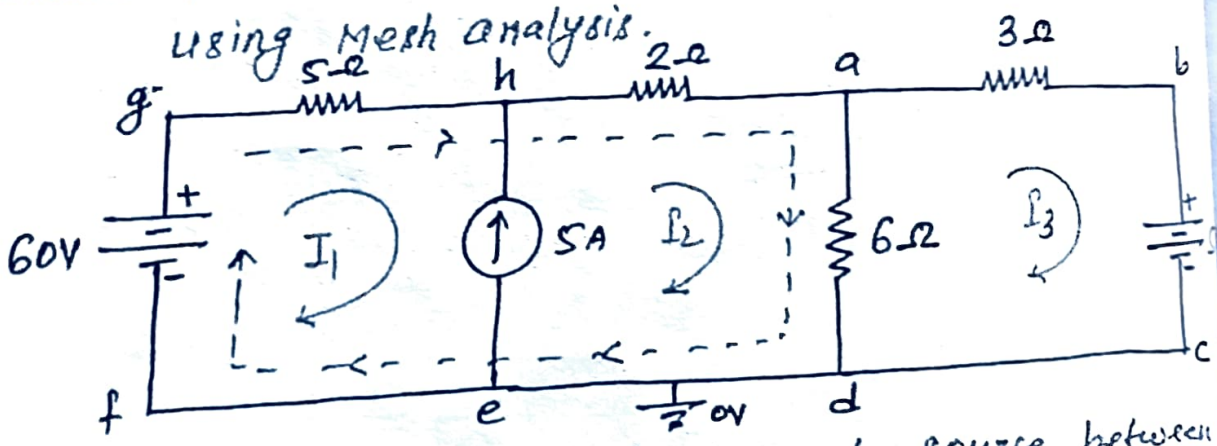
$I_2 = 0.162A$; $I_3 = -0.306A$

Branch Currents:-

$I_{20\Omega} = I_2 = 0.162A$	Answer
$I_{40\Omega} = I_3 = -0.306A$	Answer
$I_{15\Omega} = (I_2 - I_3) = 0.468A$	Answer

☞ SUPERMESH → If a current source is common between two loops then don't directly apply KVL in both loops. Apply KVL to the "supermesh" (combined loop) and apply KCL at common node to establish the relation between Mesh currents and current source.

Question:- Find out the Mesh Current in the given circuit using Mesh analysis.



Solution:- Branch h-e consist current source between Mesh-1 & Mesh-2. That's why it is a super-Mesh.

Now apply KVL to super-Mesh (g-h-a-d-c-f-g) :-

$60 - 5I_1 - 2I_2 - 6(I_2 - I_3) = 0$

$$5I_1 + 8I_2 - 6I_3 = 60 \quad \text{——(i)}$$

To express 5A Current source in terms of loop currents, apply KCL at h.

$$I_1 + 5 = I_2$$

$$-I_1 + I_2 + 0 \cdot I_3 = 5 \quad \text{——(ii)}$$

Apply KVL in Mesh(3) :-

$$-50 - 6(I_3 - I_2) - 3I_3 = 0$$

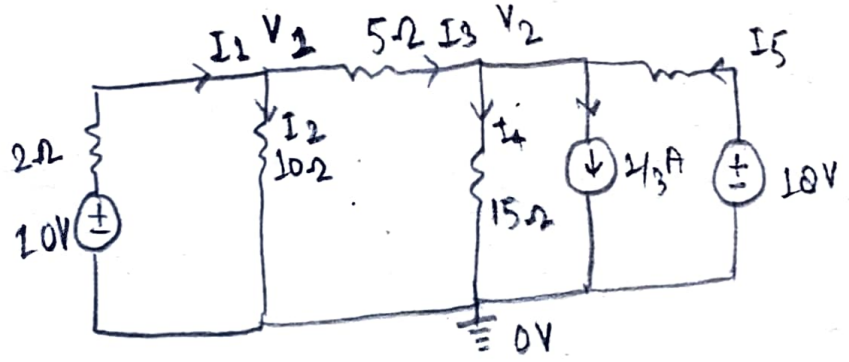
$$0 \cdot I_1 + 6I_2 - 9I_3 = 50 \quad \text{—— (iii)}$$

By solving equation (i), (ii) & (iii) we get :-

Mesh Currents :-

$$I_1 = 0.74A \; ; \; I_2 = 5.74A \; ; \; I_3 = -1.72A$$

Answer.



$$I_1 = I_2 + I_3 \quad \text{—(i)}$$

$$I_3 = I_4$$

NODAL ANALYSIS

Step 1 :- Take a reference Node at generally ground (V=0)

Step 2 :- Identify number of Nodes.

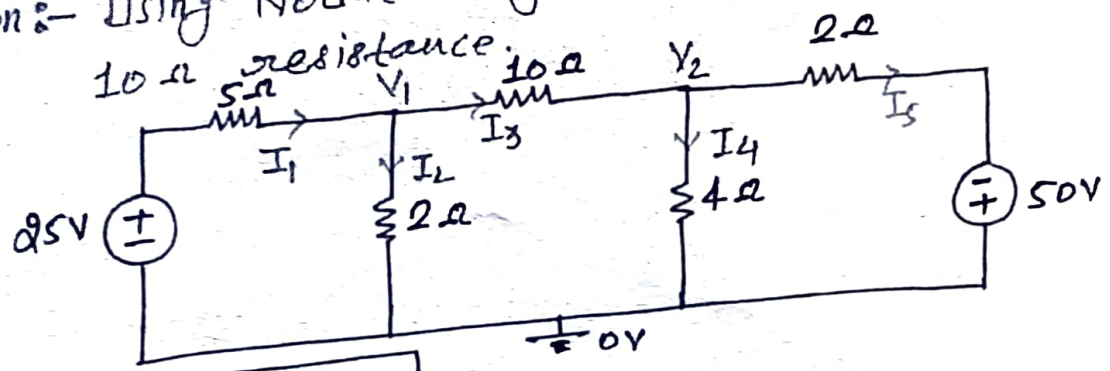
Step 3 :- Assume current in each branch (Any direction)

Step 4 :- Apply KCL at each Node and make equations (N-1) ; where N is a principal Node (Junction)

Step 5 :- Solve equations to find Node Voltages.

Step 6 :- put Node voltages in equations to find branch currents. Then find voltage drop and power in each branch.

Question :- Using Nodal analysis find out current in 10 Ω resistance.



Solution :-

Node (N) = 3

No. of Nodal eq^n = N-1 = 2

Apply KCL at Node-1 :-

$$I_1 = I_2 + I_3$$

$$I_1 - I_2 - I_3 = 0$$

$$\frac{85 - V_1}{5} - \frac{V_1}{2} - \frac{V_1 - V_2}{10} = 0$$

$$-8V_1 + V_2 = -50 \quad \text{—(i)}$$

Apply KCL at Node-2 :-

$$I_3 = I_4 + I_5$$

$$I_3 - I_4 - I_5 = 0$$

$$\frac{V_1 - V_2}{10} - \frac{V_2}{4} - \frac{V_2 + 56}{2} = 0$$

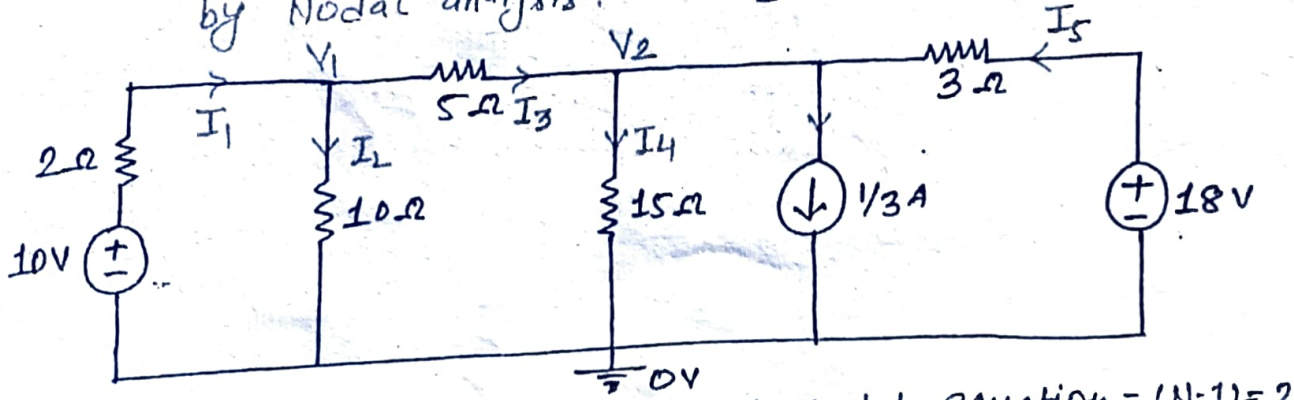
$$2V_1 - 17V_2 = 500 \quad \text{——— (ii)}$$

By solving equation (i) & (ii) we get :-

$$\boxed{V_1 = 2.61\,V \;;\; V_2 = -29.10\,V}$$

$$\boxed{I_3 = \frac{V_1 - V_2}{10} = 3.171\,A}$$ Answer

Question :- Determine current through 15 Ω resistance by Nodal analysis. [2018-19 ODD SEM]



Soln :- Node (N) = 3 ; So No. of Nodal equation = (N-1) = 2

Apply KCL at Node-1 :-

$$I_1 = I_2 + I_3$$

$$I_1 - I_2 - I_3 = 0$$

$$\frac{10 - V_1}{2} - \frac{V_1}{10} - \frac{V_1 - V_2}{5} = 0$$

$$8V_1 - 2V_2 = 50 \quad \text{——— (i)}$$

Apply KCL at Node-2 :-

$$I_3 + I_5 = I_4 + 1/3$$

$$I_3 - I_4 - I/3 + I_5 = 0$$

$$\frac{V_1 - V_2}{5} - \frac{V_2}{15} - \frac{1}{3} + \frac{18 - V_2}{3} = 0$$

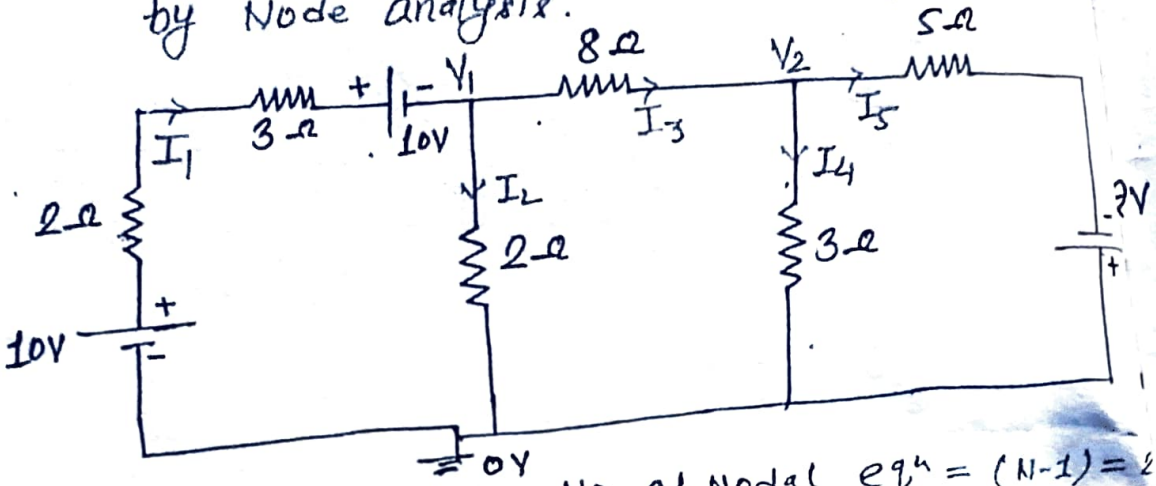
$$3V_1 - 9V_2 = -85 \quad \text{——— (ii)}$$

By solving equation (i) & (ii) we get :-

$$\boxed{V_1 = 9.39\ V \ ; \quad V_2 = 12.57\ V}$$

$$\boxed{I_{15\Omega} = I_4 = \frac{V_2}{15} = 0.838\ A}$$ Answer

Question:- Determine Current through 8Ω resistan estio
[2017-18 EVEN
by Node analysis.



Solution:- Node(N) = 3 ; No. of Nodal eqⁿ = (N-1) = 2

Apply KCL at Node-1 :-

$$I_1 = I_2 + I_3$$

$$I_1 - I_2 - I_3 = 0$$

$$\frac{10 - 10 - V_1}{5} - \frac{V_1}{2} - \frac{V_1 - V_2}{8} = 0$$

$$33V_1 - 5V_2 = 0 \quad \text{——— (i)}$$

Apply KCL at Node-2 :-

$$I_3 = I_4 + I_5$$

$$I_3 - I_4 - I_5 = 0$$

$$\frac{V_1 - V_2}{8} - \frac{V_2}{3} - \frac{V_2 + 25}{5} = 0$$

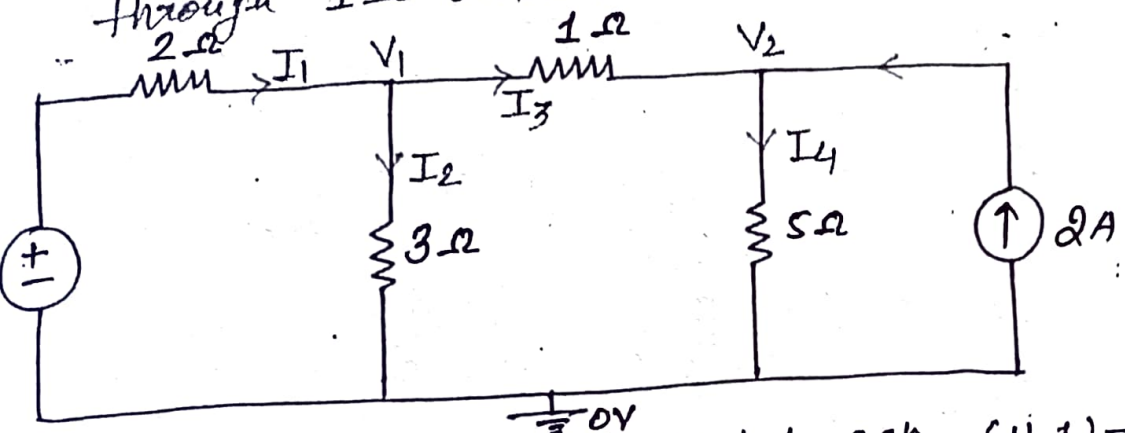
$$15V_1 - 79V_2 = 600 \quad \text{——— (ii)}$$

Solving equation (i) & (ii) we get :-

$$\boxed{V_1 = -1.184\,V \;;\; V_2 = -7.819\,V}$$

$$\boxed{I_{8\Omega} = I_3 = \frac{V_1 - V_2}{8} = 0.829A}$$ Answer.

Que :- Using Nodal analysis find the Current through 1Ω resistance. [2016-17 EVEN SEM]



Node (N) = 3 ; No. of Nodal eq^n = (N-1) = 2

Apply KCL at Node-1 :-

$$I_1 = I_2 + I_3$$

$$I_1 - I_2 - I_3 = 0$$

$$\frac{2 - V_1}{2} - \frac{V_1}{3} - \frac{V_1 - V_2}{1} = 0$$

$$11V_1 - 6V_2 = 6 \quad \text{——— (i)}$$

Apply KCL at Node-2 :-

$$I_3 + 2 = I_4$$

$$I_3 - I_4 + 2 = 0$$

$$\frac{V_1 - V_2}{1} - \frac{V_2}{5} + 2 = 0$$

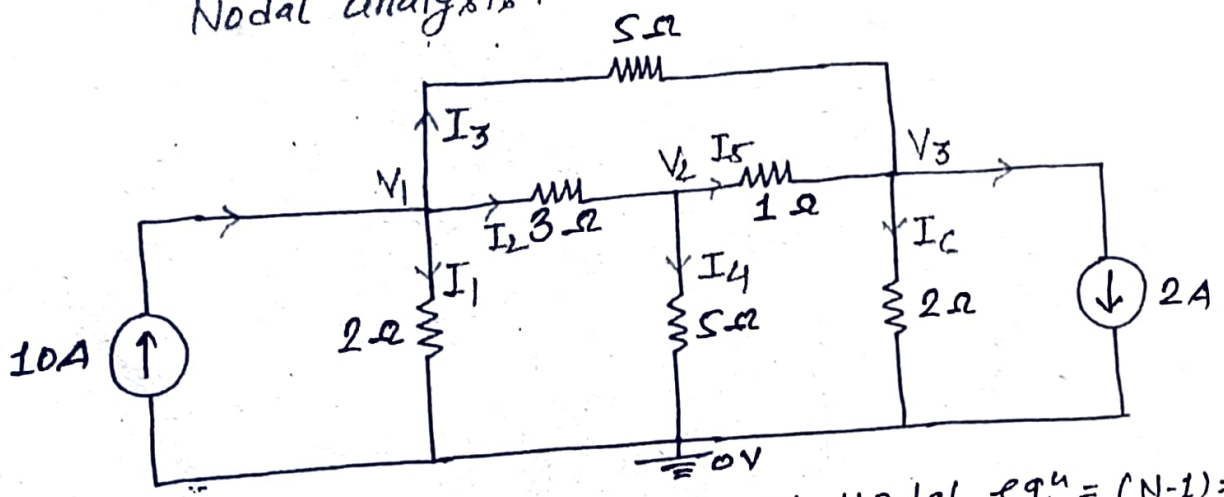
$$-5V_1 + 6V_2 = 10 \quad \text{——(ii)}$$

By solving eq^n (i) & (ii) we get :-

$$V_1 = 2.66\ V \ ; \quad V_2 = 3.88\ V$$

$$I_{1\Omega} = I_3 = \frac{V_1 - V_2}{1} = -1.22A$$ Answer.

Question :- Find the current in all resistances using Nodal analysis.



Solution:- Node(N) = 3 ; No. of Nodal eq^n = (N-1) = 2

Apply KCL at Node-1 :-

$$10 = I_1 + I_2 + I_3$$

$$10 - I_1 - I_2 - I_3 = 0$$

$$10 - \frac{V_1}{2} - \frac{V_1 - V_2}{3} - \frac{V_1 - V_3}{5} = 0$$

$$31V_1 - 10V_2 - 6V_3 = 300 \quad \text{——(i)}$$

Apply KCL at Node-2 :-

$$I_2 = I_4 + I_5$$

$$I_2 - I_4 - I_5 = 0$$

$$\frac{V_1 - V_2}{3} - \frac{V_2}{5} - \frac{V_2 - V_3}{1} = 0$$

$$5V_1 - 23V_2 + 15V_3 = 0 \quad \text{---(ii)}$$

Apply KCL at Node-3 :-

$$I_3 + I_5 = I_6 + 2$$

$$I_3 + I_5 - I_6 - 2 = 0$$

$$\frac{V_1 - V_3}{5} + \frac{V_2 - V_3}{1} - \frac{V_3}{2} - 2 = 0$$

$$2V_1 + 10V_2 - 17V_3 = 20 \quad \text{---(iii)}$$

By solving eq^n (i), (ii) & (iii) we get :-

$V_1 = 11.58\,V$; $V_2 = 4.28\,V$; $V_3 = 2.70\,V$

$$I_1 = \frac{V_1}{2} = 5.79A$$

$$I_2 = \frac{V_1 - V_2}{3} = 2.43A$$

$$I_3 = \frac{V_1 - V_3}{5} = 1.77A$$

$$I_4 = \frac{V_2}{5} = 0.856A$$

$$I_5 = \frac{V_2 - V_3}{1} = 1.58A$$

$$I_6 = \frac{V_3}{2} = 1.35A$$

Answer.