GANDAKI COLLEGE OF ENGINEERING AND SCIENCE

Bachelor of Engineering in Computer Engineering

Chapter-2: DC Circuit Analysis

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Contents

Objectives of all theorems:

- To find the current flowing
- To find the voltage
- To find the power consumption

Application of Kirchhoff's Laws in network solution

Nodal Analysis

Application of Kirchhoff's Laws in network solution

Nodal Analysis

We solve for finding "Voltage"

- Find the possible **number of nodes**
- **Assign the variable** at each of the nodes which is unknown
- Select **the reference node**, generally ground/ common point
- For each of the unknown, form **an equation based on KCL**
- If there are **voltage sources between two unknown junction**, join the two nodes as **super node**. The currents of the two nodes are combined in a single equation and a new equation for the voltage is formed.
- **Solve** the equations for each **unknown voltage**.

Application of Kirchhoff's Laws in network solution

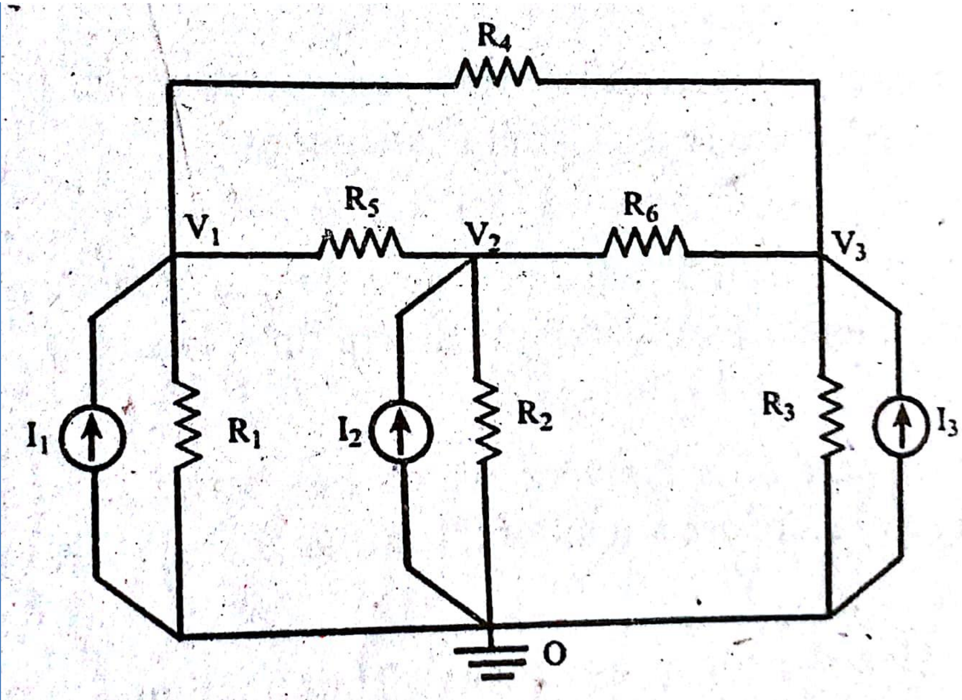
Nodal Analysis Conditions

1. Circuit containing **only current source**
2. Circuit containing **voltage source in addition to current source**
   i. Voltage source **transformable into current source**
   ii. Voltage source **not transformable into current source**
      a. Voltage source **involving reference node**
      b. Voltage source **not involving reference node**

1. Circuit containing only current source

Nodal Analysis

- Find the possible number of **nodes**
- Select the **reference node**, generally ground/ common point
- **Assign the variable** at each of the nodes which is unknown
- For each of the unknown, form an **equation** based on KCL
- Identify if there are any **super node**. Then combine two nodes in a single equation and a new equation for the voltage is formed.
- **Solve** the equations for each unknown voltage.



Applying KCL at node 1,

$$\frac{V_1 - 0}{R_1} + \frac{V_1 - V_2}{R_5} + \frac{V_1 - V_3}{R_4} = I_1$$

Applying KCL at node 2,

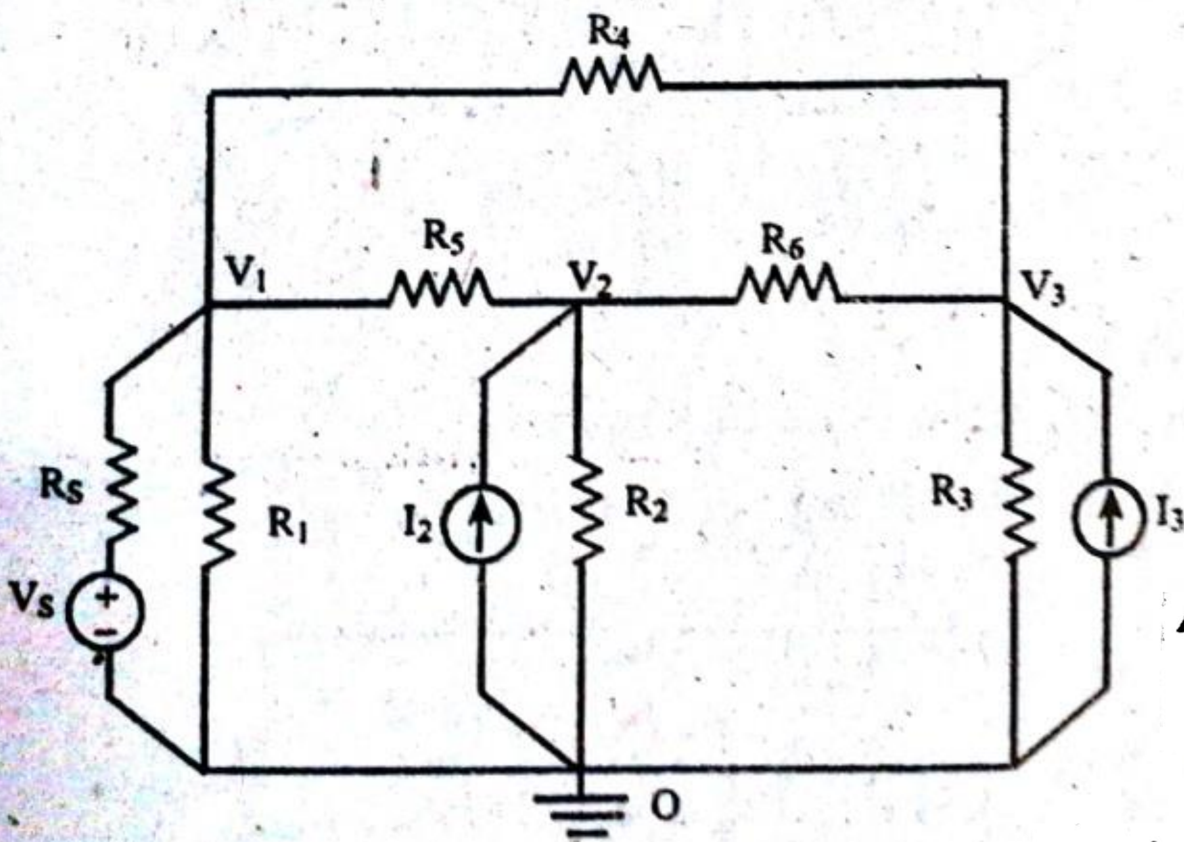
$$\frac{V_2 - 0}{R_2} + \frac{V_2 - V_1}{R_5} + \frac{V_2 - V_3}{R_6} = I_2 .$$

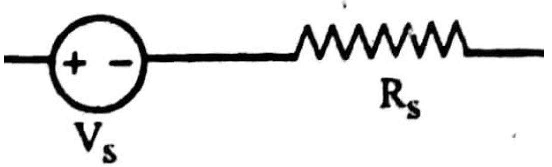
Applying KCL at node 3,

$$\frac{V_3 - 0}{R_3} + \frac{V_3 - V_2}{R_6} + \frac{V_3 - V_1}{R_4} = I_3 .$$

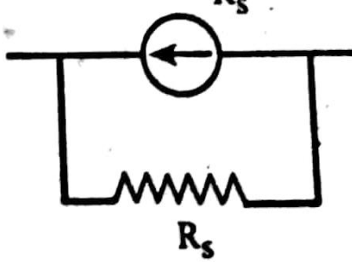
2. Circuit containing voltage source in addition to current source

Voltage source transformable into current source





$$I_s = \frac{V_s}{R_s}$$



Applying KCL at node 2,

$$\frac{V_2 - 0}{R_2} + \frac{V_2 - V_1}{R_5} + \frac{V_2 - V_3}{R_6} = I_2 .$$

Applying KCL at node 3,

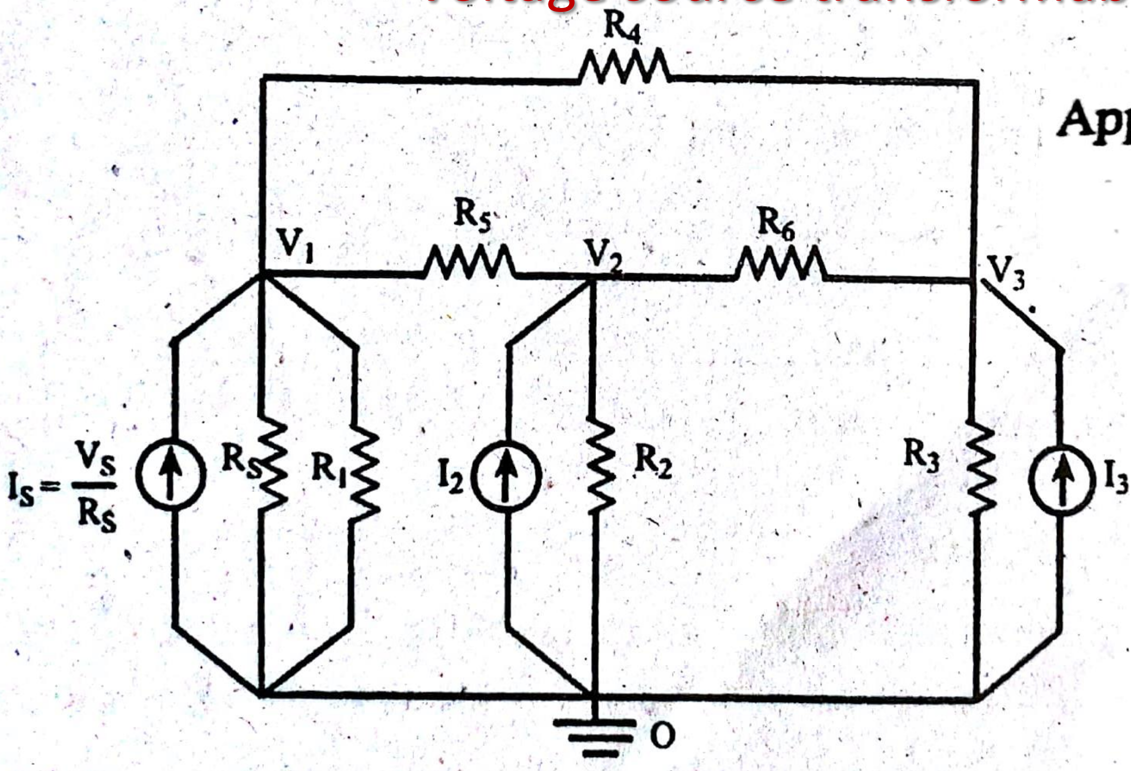
$$\frac{V_3 - 0}{R_3} + \frac{V_3 - V_2}{R_6} + \frac{V_3 - V_1}{R_4} = I_3 .$$

Applying KCL at node 1,

$$\frac{V_1 - V_2}{R_5} + \frac{V_1 - V_3}{R_4} + \frac{V_1 - V_S}{R_S} + \frac{V_1 - 0}{R_1} = 0 .$$

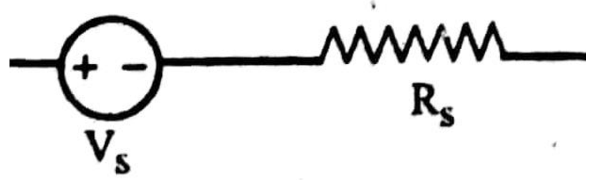
2. Circuit containing voltage source in addition to current source

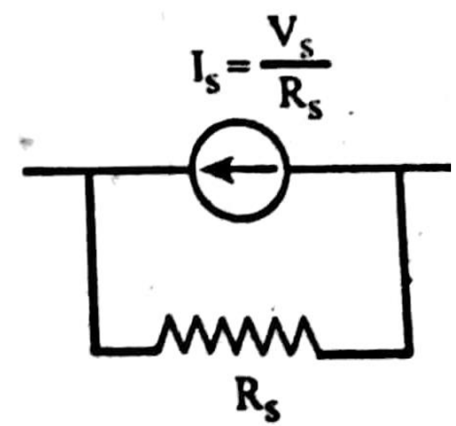
Voltage source transformable into current source



Applying KCL at node 2,

$$\frac{V_2 - 0}{R_2} + \frac{V_2 - V_1}{R_5} + \frac{V_2 - V_3}{R_6} = I_2 .$$





Applying KCL at node 1,

$$\frac{V_1 - V_2}{R_5} + \frac{V_1 - V_3}{R_4} + \frac{V_1 - 0}{R_S} + \frac{V_1 - 0}{R_1} = \frac{V_S}{R_S}$$

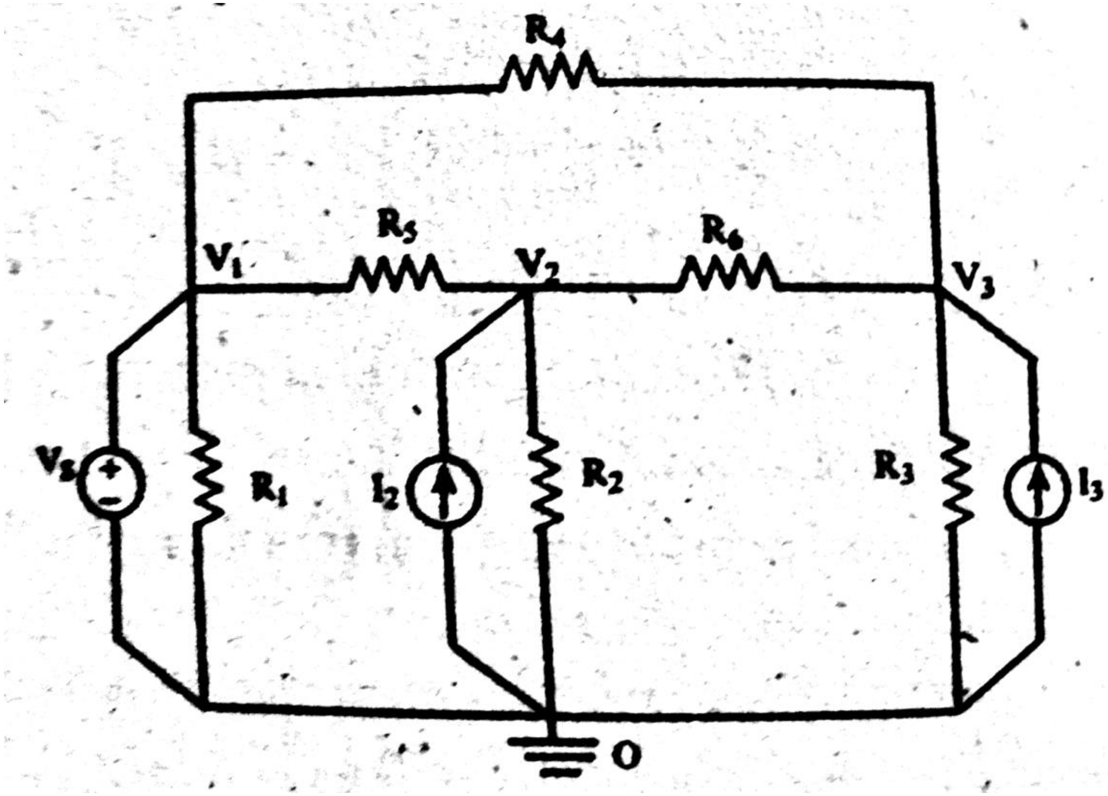
Applying KCL at node 3,

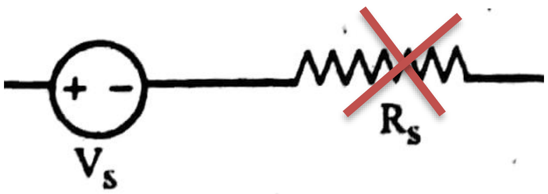
$$\frac{V_3 - 0}{R_3} + \frac{V_3 - V_2}{R_6} + \frac{V_3 - V_1}{R_4} = I_3 .$$

2. Circuit containing voltage source in addition to current source

Voltage source not transformable into current source

Voltage source involving reference node





Here, $V_S = V_1 - 0$

or, $V_1 = V_S$ ....

Applying KCL at node 2,

$$\frac{V_2 - 0}{R_2} + \frac{V_2 - V_1}{R_5} + \frac{V_2 - V_3}{R_6} = I_2 .$$

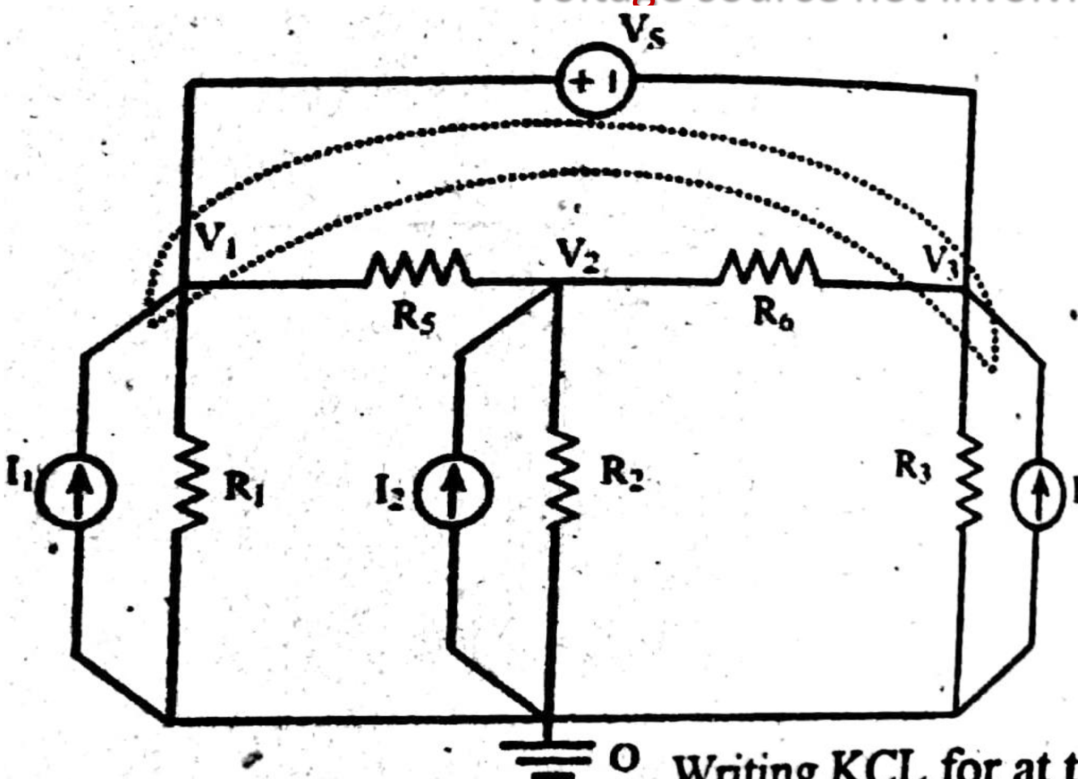
Applying KCL at node 3,

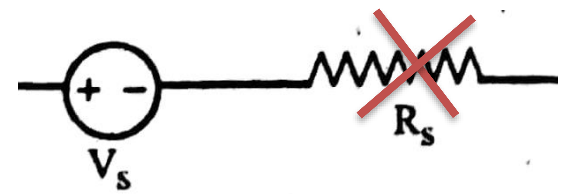
$$\frac{V_3 - 0}{R_3} + \frac{V_3 - V_2}{R_6} + \frac{V_3 - V_1}{R_4} = I_3 .$$

2. Circuit containing voltage source in addition to current source

Voltage source not transformable into current source

Voltage source not involving reference node





Super nodes

$$V_1 - V_3 = V_s$$

Writing KCL for at the supernode 1 and 3,

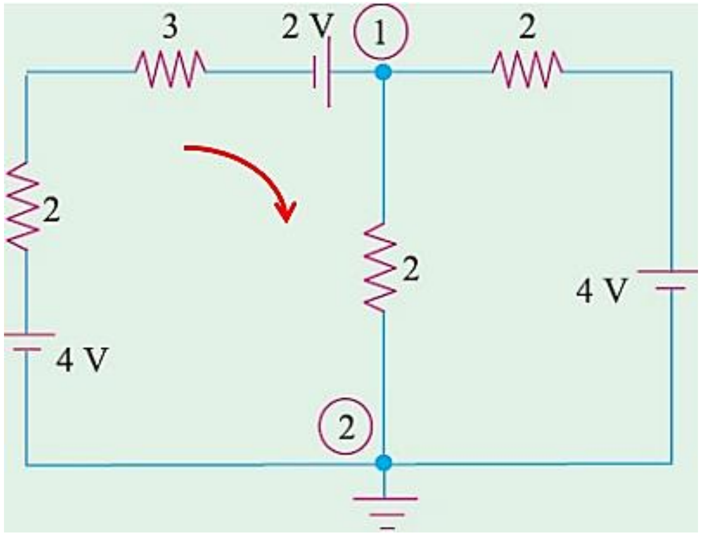
$$\frac{V_1 - 0}{R_1} + \frac{V_1 - V_2}{R_5} + \frac{V_3 - 0}{R_3} + \frac{V_3 - V_2}{R_6} = I_1 + I_3$$

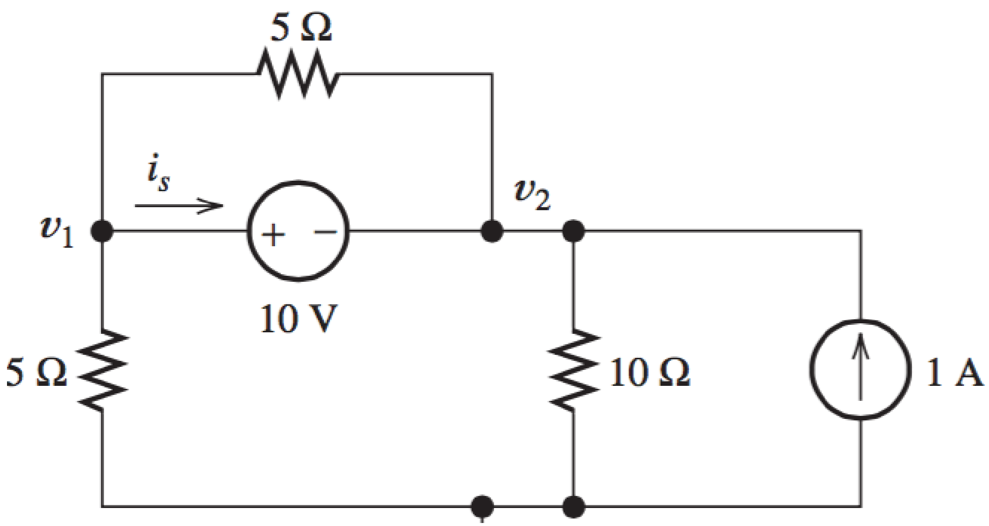
Applying KCL at node 2,

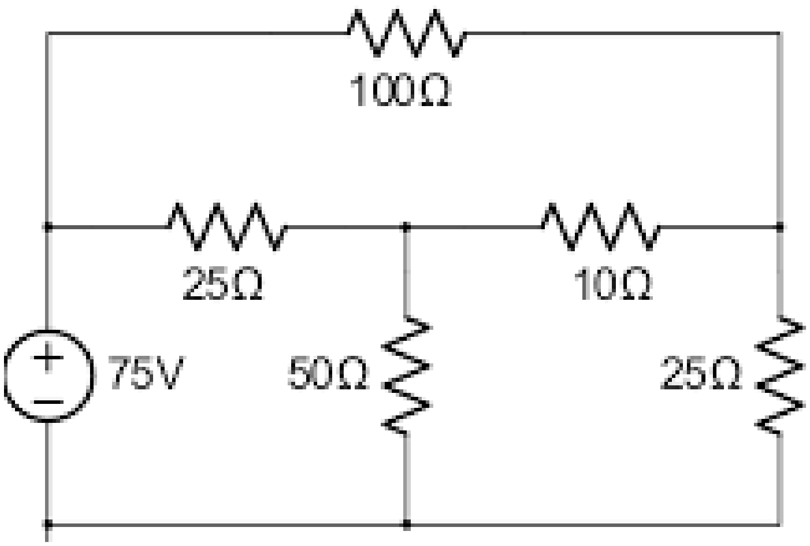
$$\frac{V_2 - 0}{R_2} + \frac{V_2 - V_1}{R_5} + \frac{V_2 - V_3}{R_6} = I_2 \cdot$$

Classwork

Q. Use nodal analysis to find the current through 3 ohm resistor in the circuit.
Ans: 2/3 A







Application of Kirchhoff's Laws in network solution

Mesh Analysis

Application of Kirchhoff's Laws in network solution

Mesh Analysis

- Find the possible **number of mesh**.
- Assume the smallest number of **mesh currents** so that at least one mesh current links every element. As a matter of convenience, all mesh currents can be assumed to have clockwise direction
- For each mesh, write **KVL equation**. When **more than one mesh current flows** through an element the **algebraic sum of currents** should be used. The algebraic sum of mesh currents may be the sum or the difference of the currents flowing through the element depending on the **direction of mesh currents**.
- **Solve** the above equations and from the mesh currents find the **branch currents**.

We solve for finding "Current"

Application of Kirchhoff's Laws in network solution

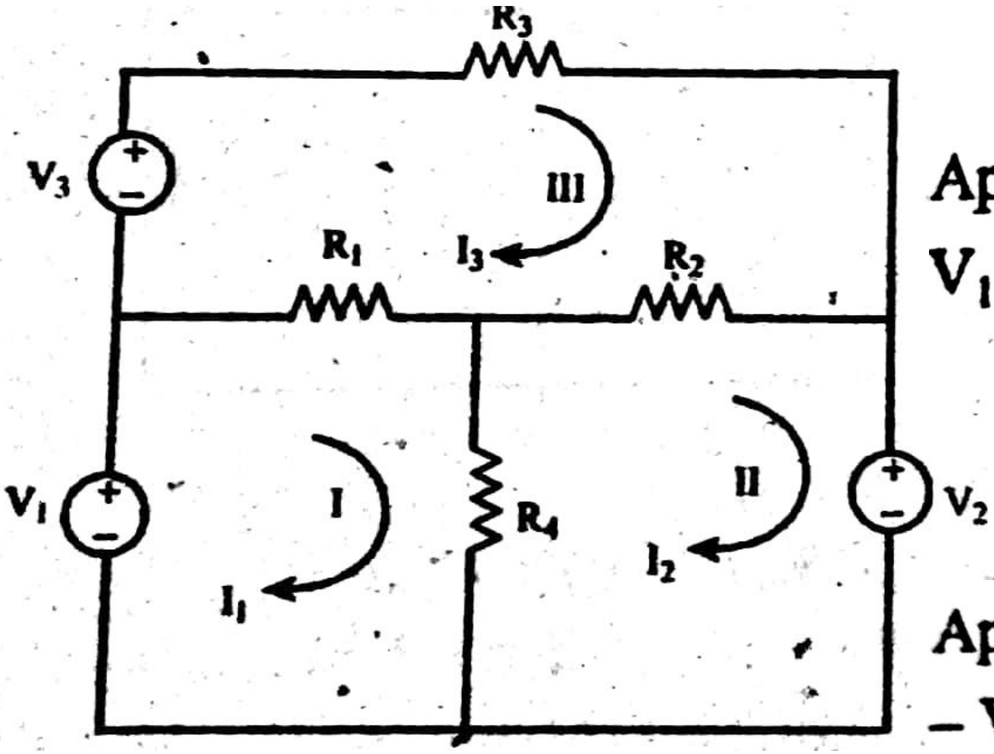
Mesh Analysis

1. Circuit containing **only voltage sources**

2. Circuit containing **current source + Voltage source**
   i. Current source **transformable into voltage source**
   ii. Current source **not transformable into voltage source**
      a. Current source present in the **perimeter of any individual loop**
      b. Current source present in the **common branch of any two loops**

Mesh Analysis

1. Circuit containing only voltage sources



Applying KVL to the loop I, we get

$$V_1 - (I_1 - I_3)R_1 - (I_1 - I_2)R_4 = 0$$

Applying KVL to the loop II , we get

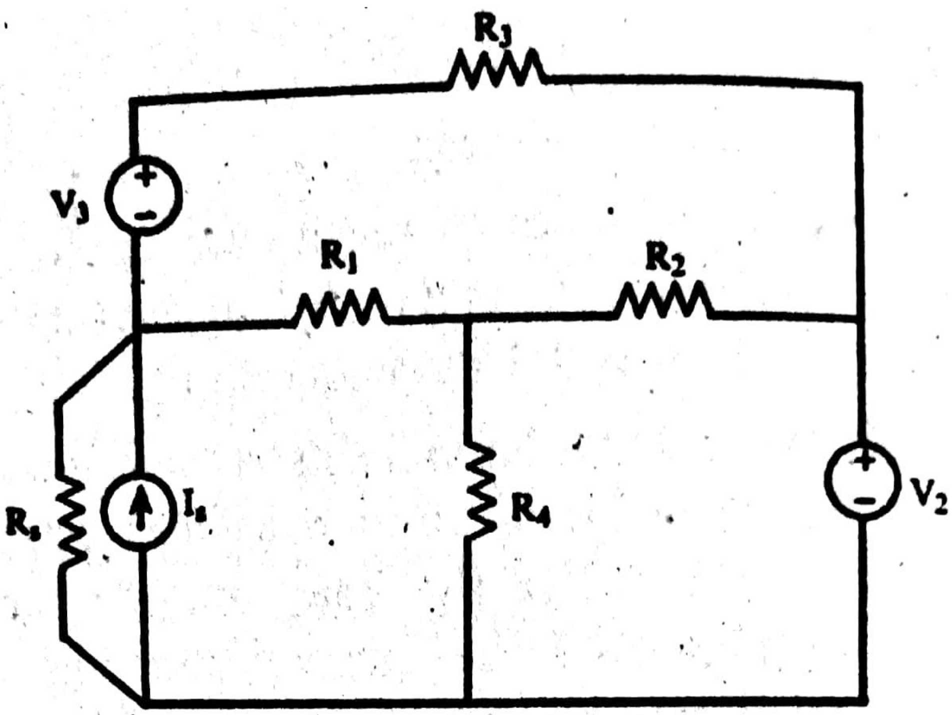
$$-V_2 - (I_2 - I_1)R_4 - (I_2 - I_3)R_2 = 0$$

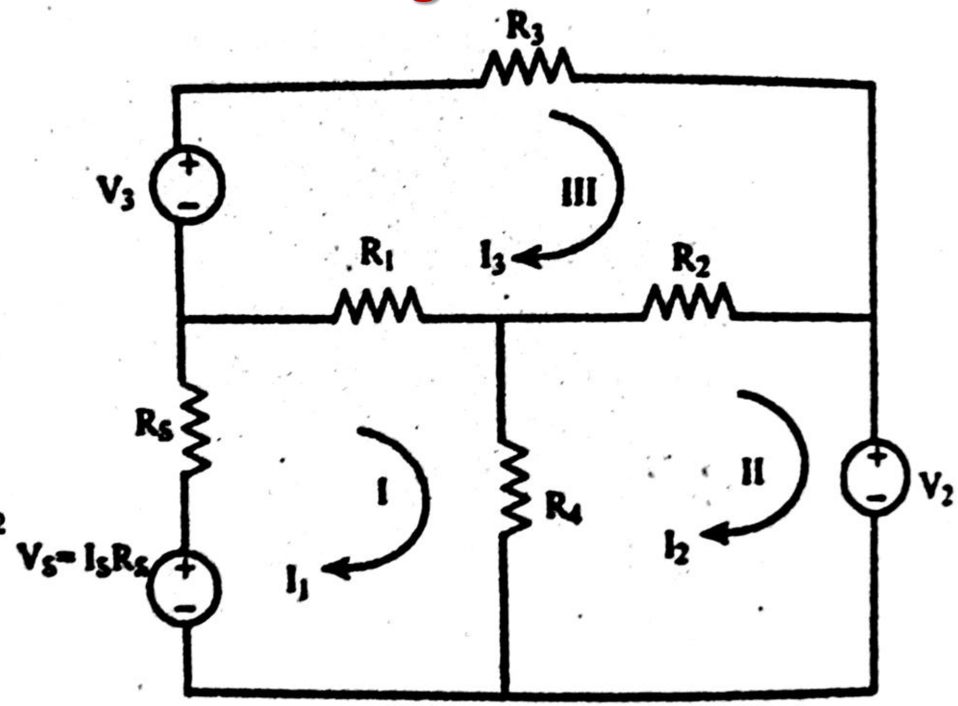
Applying KVL to the loop III, we get

$$V_3 - I_3R_3 - (I_3 - I_2)R_2 - (I_3 - I_1)R_1 = 0$$

2. Circuit containing current source + Voltage source

Current source transformable into voltage source





Applying KVL to the loop I, we get

$$I_S R_S - I_1 R_S - R_1 (I_1 - I_3) - R_4 (I_1 - I_2) = 0$$

Applying KVL to the loop II , we get

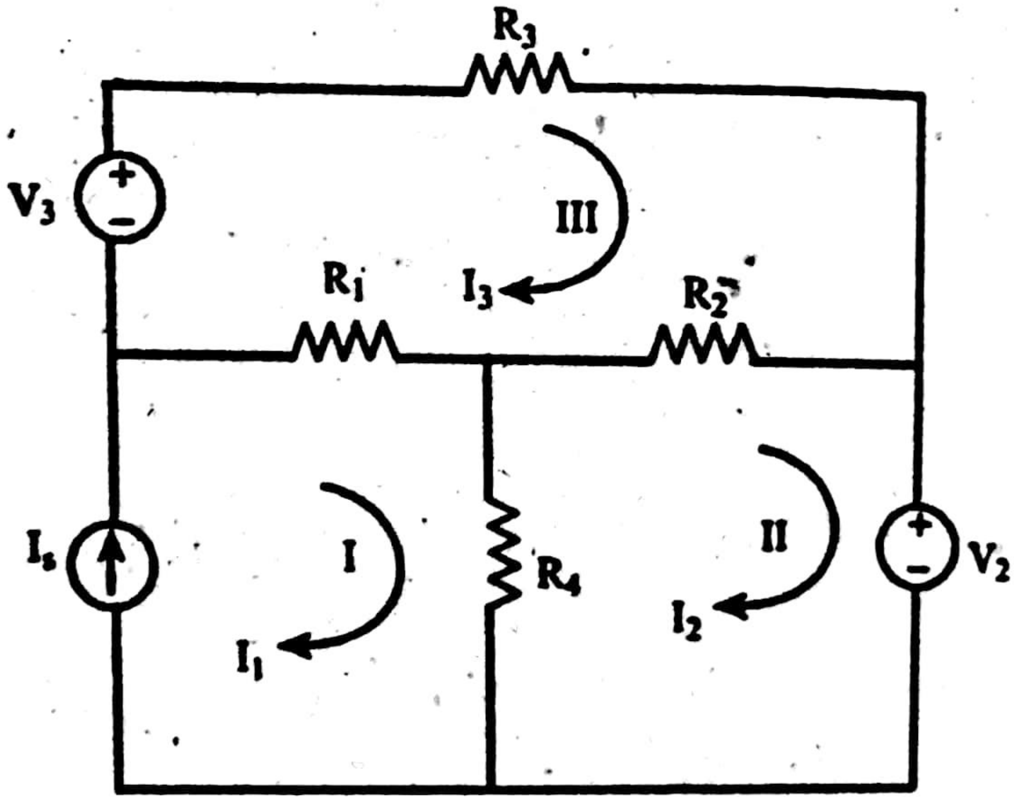
$$-V_2 - (I_2 - I_1)R_4 - (I_2 - I_3)R_2 = 0$$

Applying KVL to the loop III, we get

$$V_3 - I_3R_3 - (I_3 - I_2)R_2 - (I_3 - I_1) R_1 = 0$$

2. Current source not transformable into voltage source

i. Current source present in the perimeter of any individual loop



$$I_1 = I_S \ldots$$

Applying KVL to the loop II , we get

$$-V_2 - (I_2 - I_1)R_4 - (I_2 - I_3)R_2 = 0$$

Applying KVL to the loop III, we get

$$V_3 - I_3R_3 - (I_3 - I_2)R_2 - (I_3 - I_1)R_1 = 0$$

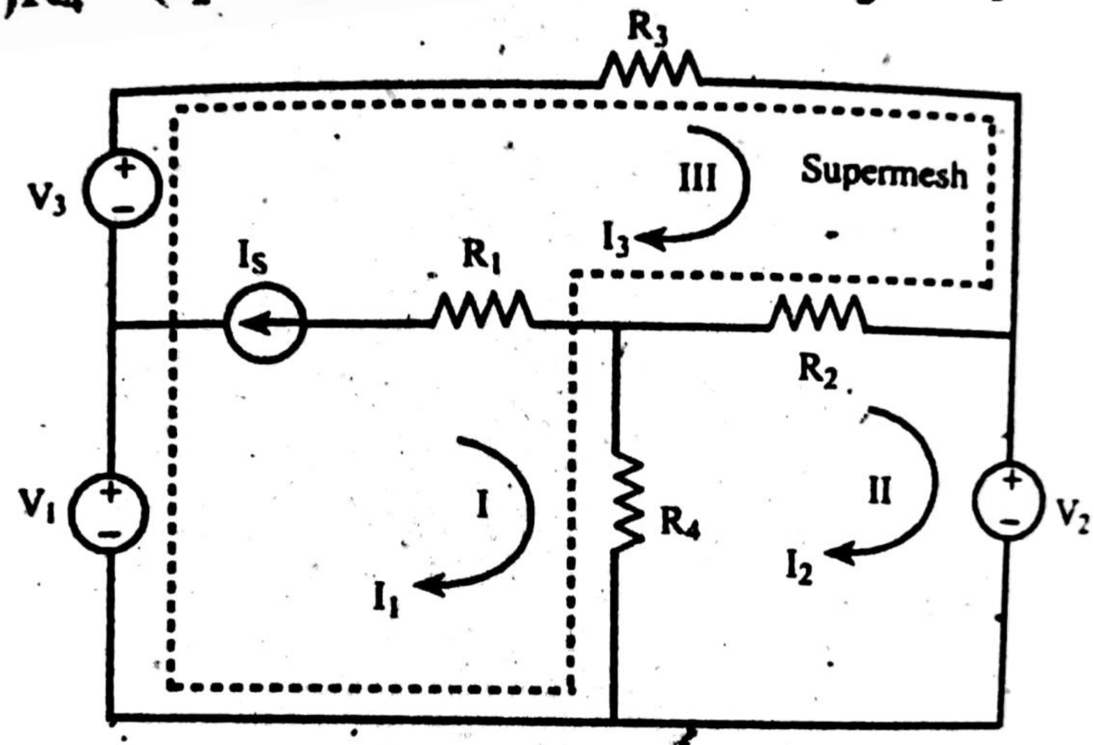
2. Current source not transformable into voltage source

ii. Current source present in the common branch of any two loops

Applying KVL to the loop II , we get

$$-V_2 - (I_2 - I_1)R_4 - (I_2 - I_3)R_2 = 0$$

$$I_3 - I_1 = I_S \ldots$$

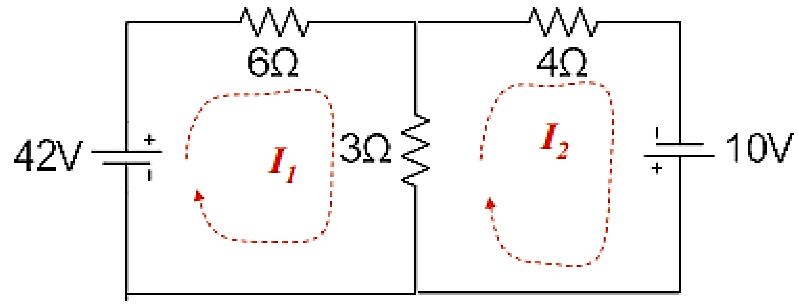


Applying KVL for supermesh I and III, we get

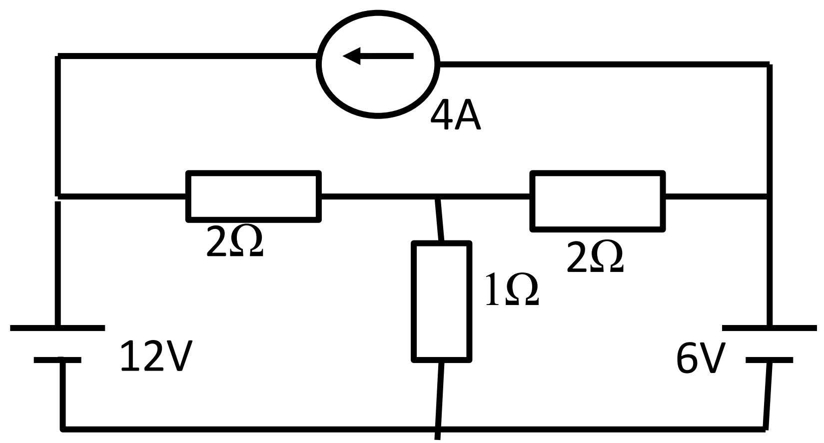
$$V_3 - I_3R_3 - R_2\,(I_3 - I_2) - R_4\,(I_1 - I_2) + V_1 = 0$$

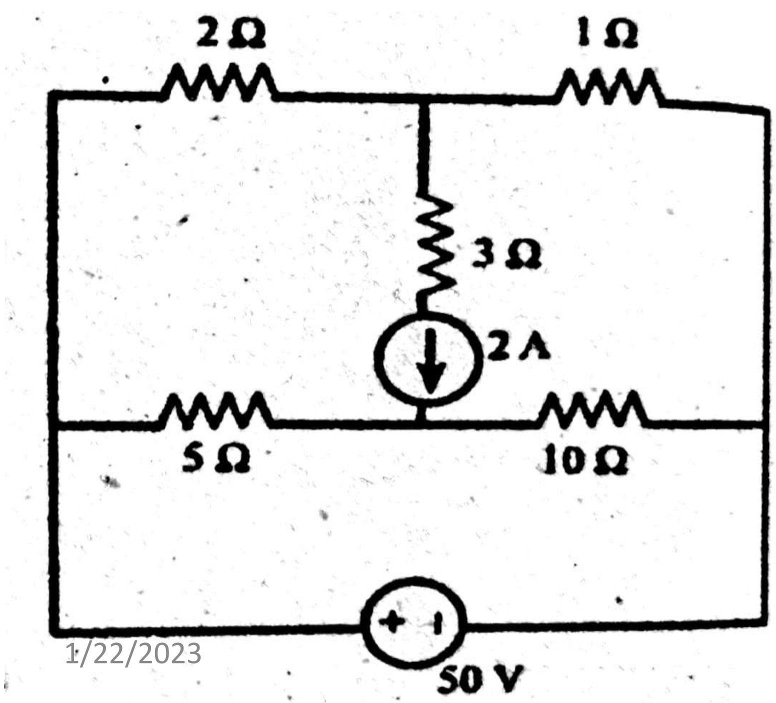
Classwork

Q. Use mesh analysis to find the power consumption in the resistor 3 ohm?



Q. Find the current through 1 ohm resistor using mesh/ loop analysis.





Q. Determine the current in the 5 ohm resistor in the network shown, using loop formulation method.