Network Analysis

Important Definitions:

Circuit: It is a conducting path through which an electric current either flows or is intended to flow.

Parameters: The elements of an electric circuit such as resistance, inductance, capacitance. (Parameters may be lumped i.e. they can be represented independently from the circuit or distributed i.e. they can not be represented separately.)

Linear Circuit/element: If the parameters of a circuit/element are constant, i.e. they do not change with voltage/current, the circuit is known as linear circuit. (e.g. Resistor, inductor, capacitor)

Nonlinear Circuit/element: If the parameters of a circuit/element are not constant, i.e. they change with voltage/current, the circuit is known as nonlinear circuit. (e.g. Diode, Transistor, capacitor)

Network Analysis

Important Definitions:

Bilateral Circuit/element:

The circuit/element whose properties or characteristics are same in both directions. (e.g. Transmission lines or resistors)

Unilateral Circuit/element:

The circuit/element whose properties or characteristics are not same in both directions. (e.g. diode, Transistors)

Electric Network: It is combination of various electrical elements connected in any manner.

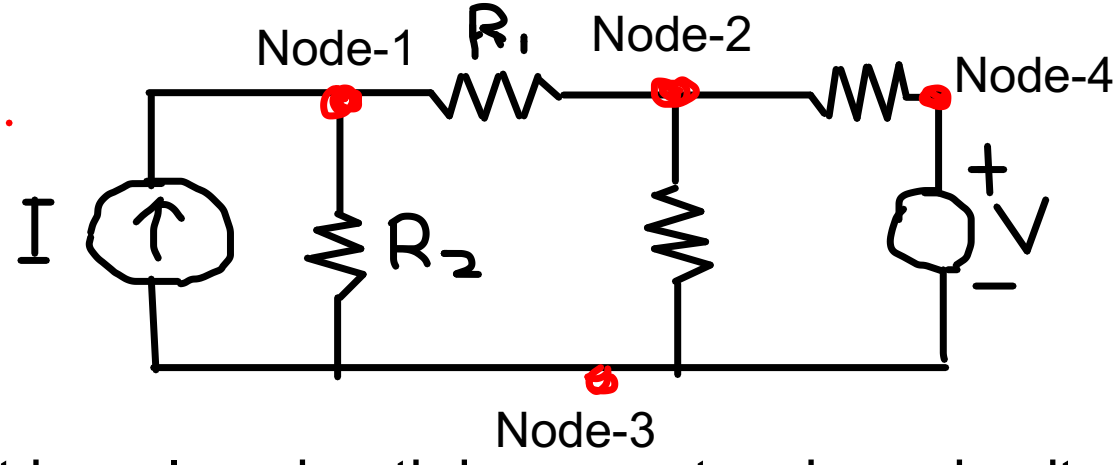
Passive Network: It is a network which does not contain any source of energy.

Active Network: It is a network which contains atleast one source of energy.

Network Analysis using Mesh current Method

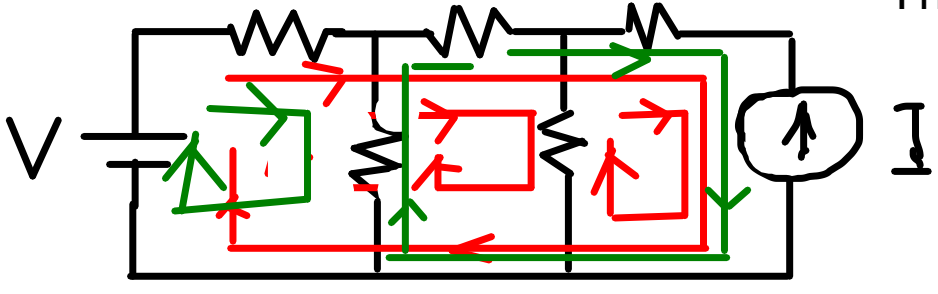
Important Definitions:

Node: It is a junction where two or more circuit elements are connected.



Loop: It is a closed path in any network or circuit.

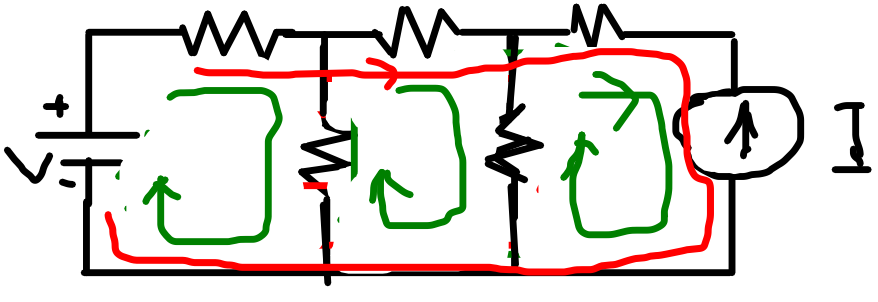
There are many loops.



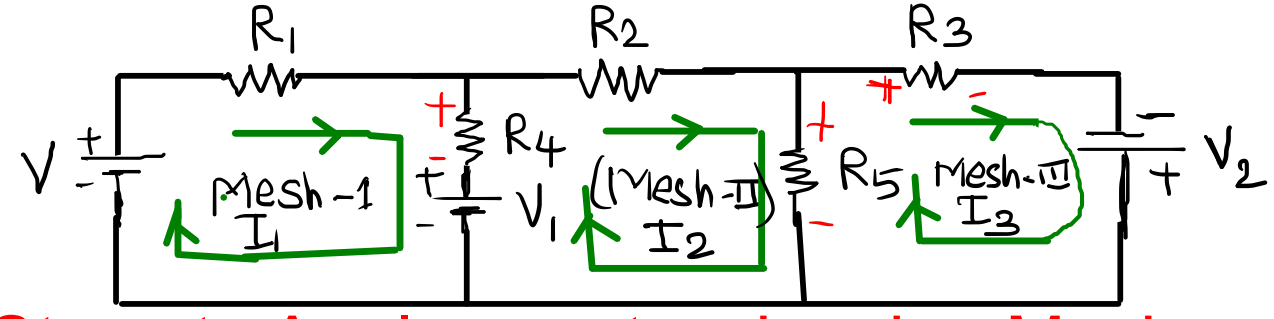
Mesh : It is a loop which does not have loop inside it.

Only loops marked with green are Mesh.

The loops marked with red is not a Mesh.



Network Analysis using Mesh current Method (Mesh analysis)



Steps to Analyze network using Mesh analysis:

1. Identify mesh and mark Mesh Currents
2. Write potential drops across every mesh using KVL.

KVL to mesh (I) $V - I_1R_1 - R_4(I_1 - I_2) - V_1 = 0$ OR $(R_1+R_4)I_1 - R_4I_2 = V - V_1$ --- (I)

KVL to mesh (II) $-R_2I_2 - R_5(I_2 - I_3) + V_1 - R_4(I_2 - I_1) = 0$ OR

$R_4I_1 - (R_2 + R_4 + R_5)I_2 + R_5I_3 = -V_1$ --- (II)

KVL to mesh (III) $-R_3I_3 + V_2 - R_5(I_3 - I_2) = 0$ OR

$R_5I_2 - (R_3 + R_5)I_3 = -V_2$ --- (III)

3. Solve the mesh equations simulteneously to find every mesh current.

I_1, I_2 & I_3

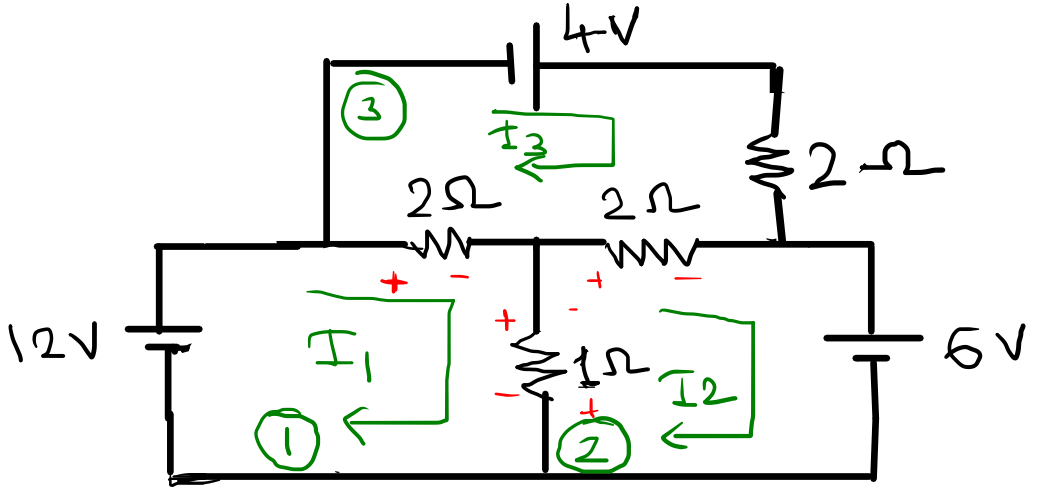
4. Use mesh currents to find current/voltage in any branch of the network.

e.g. Current through R_4 is $I_{R_4} = (I_1 - I_2)$ ↓ & $I_{R_1} = I_1$ etc.

Voltage across $R_3 = V_{R_3} = I_3R_3$

Network Analysis using Mesh Current Method

Example:- 1. Find current flowing through all batteries and 1 ohm resistor.



Applying KVL to mesh (1)

$$12 - 2(I_1 - I_3) - 1(I_1 - I_2) = 0$$

$$3I_1 - I_2 - 2I_3 = 12 \quad \text{---} (1)$$

Applying KVL to mesh (2)

$$-1(I_2 - I_1) - 2(I_2 - I_3) - 6 = 0$$

$$I_1 - 3I_2 + 2I_3 = 6 \quad \text{---} (2)$$

Applying KVL to mesh (3)

$$4 - 2I_3 - 2(I_3 - I_2) - 2(I_3 - I_1) = 0$$

$$2I_1 + 2I_2 - 6I_3 = -4 \quad (3)$$

Solving (1) (2) & (3)

$I_1 = 8.75\text{A}$ ✓

$I_2 = 4.25\text{A}$ ✓

$I_3 = 5\text{A}$ ✓

$I_{1\Omega} = (I_2 - I_1) \uparrow$

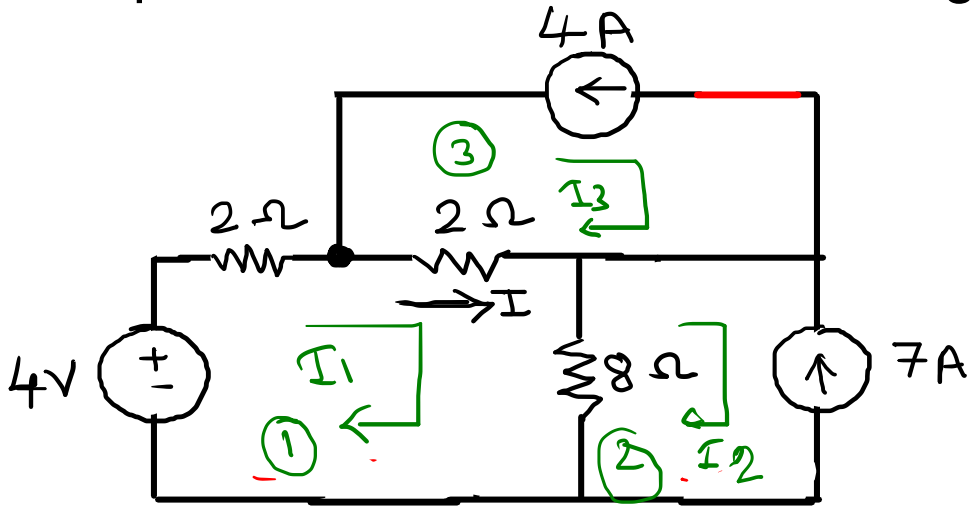
$= -4.5\text{A} \uparrow$

$I_{1\Omega} = (I_1 - I_2) \downarrow$

$= 8.75 - 4.25 = 4.5\text{A} \downarrow$ ✓

Network Analysis using Mesh Current Method

Example:- 2. Find current I in following network.



Since 4A & 7A current sources appears on uncommon branch of mesh ③ & ② so

So $I_3 = -4A$ $I_2 = -7A$

No need to apply KVL to mesh ② & ③

Applying KVL to mesh ①

$4 - 2I_1 - 2(I_1 - I_3) - 8(I_1 - I_2) = 0$

$4 - 2I_1 - 2(I_1 + 4) - 8(I_1 + 7) = 0$

$4 - 2I_1 - 2I_1 - 8 - 8I_1 - 56 = 0$

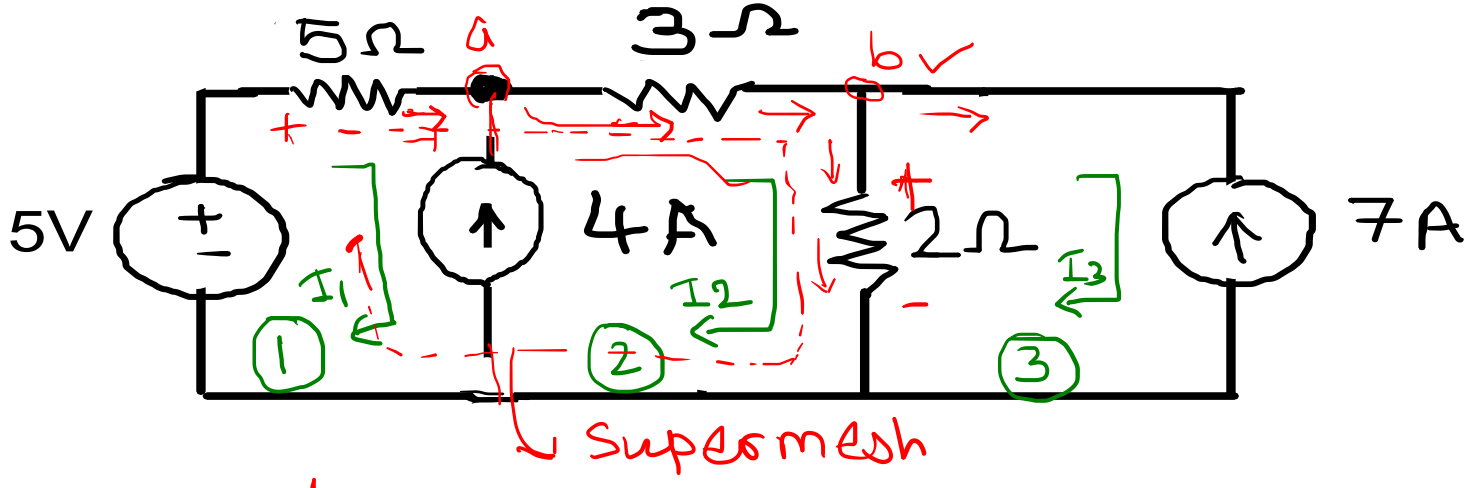
$-12I_1 = 60$

$\boxed{I_1 = -5A}$

$I = (I_1 - I_3)(\rightarrow) = -5 + 4 = -1A(\rightarrow)$

Network Analysis using Mesh Current Method

Example:- 3. Find voltage across 2 Ohm resistor in the following network.



Current source 7A appears on uncommon branch of mesh ③

$\therefore I_3 = -7A$ ✓

Current source 4A appears on common branch of mesh ① & ②

So write 4A in terms of I_1 & I_2 using KCL

$I_1 + 4 = I_2$ & $I_1 - I_2 = -4$ --- ① ✓

✓ $I_2 - I_1 = 4$ & $I_1 - I_2 = -4$

KVL to supermesh keeping I_1 & I_2 intact

$5 - 5I_1 - 3I_2 - 2(I_2 - I_3) = 0$

$I_{2\Omega} = (I_2 - I_3)$ ↓

$5I_1 + 5I_2 = -9$ --- ②

$V_{2\Omega} = 2(I_2 - I_3)$ ✓

$I_1 = -2.9$, $I_2 = 1.1A$

$I_3 = -7A$

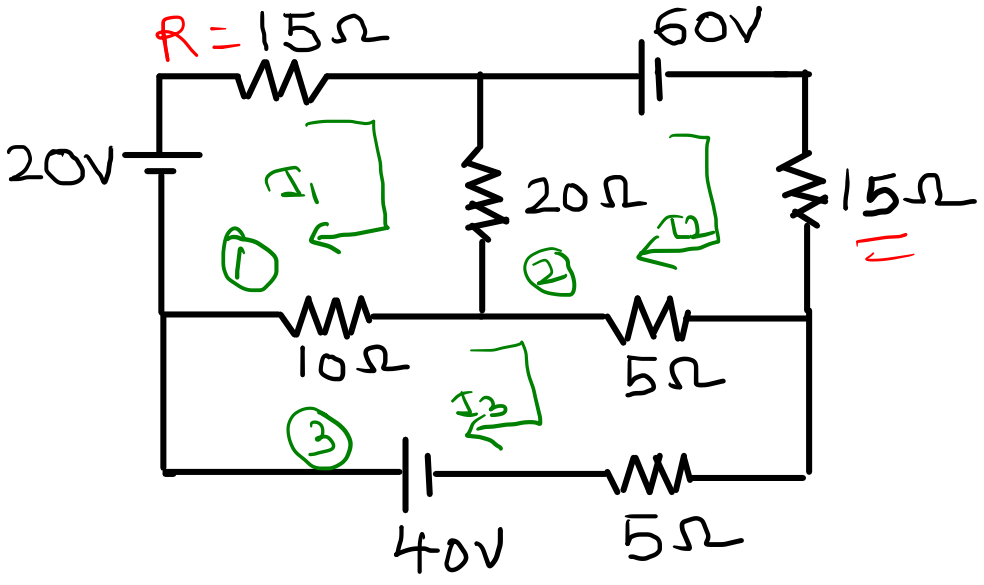
$V_{2\Omega} = (1.1 + 7) \times 2$

$V_{2\Omega} = 16.2V$

$I_{2\Omega} = (I_3 - I_2)$ ↑

Network Analysis using Mesh Current Method

Example:- 4. Find current through R = 15 Ohm resistor in the following network.



KVL to mesh (3)

$40 - 10(I_3 - I_1) - 5(I_3 - I_2) - 5I_3 = 0$

$10I_1 + 5I_2 - 20I_3 = -40$ — (3)

Solving (1), (2) & (3)

$I_1 = \frac{68}{167} = 0.407$

$I_2 = -1.053A$ & $I_3 = 1.94A$

$I_{15\Omega} = I_1 = 0.407A$

KVL to mesh (1)

$20 - 15I_1 - 20(I_1 - I_2) - 10(I_1 - I_3) = 0$

$45I_1 - 20I_2 - 10I_3 = 20$ — (1)

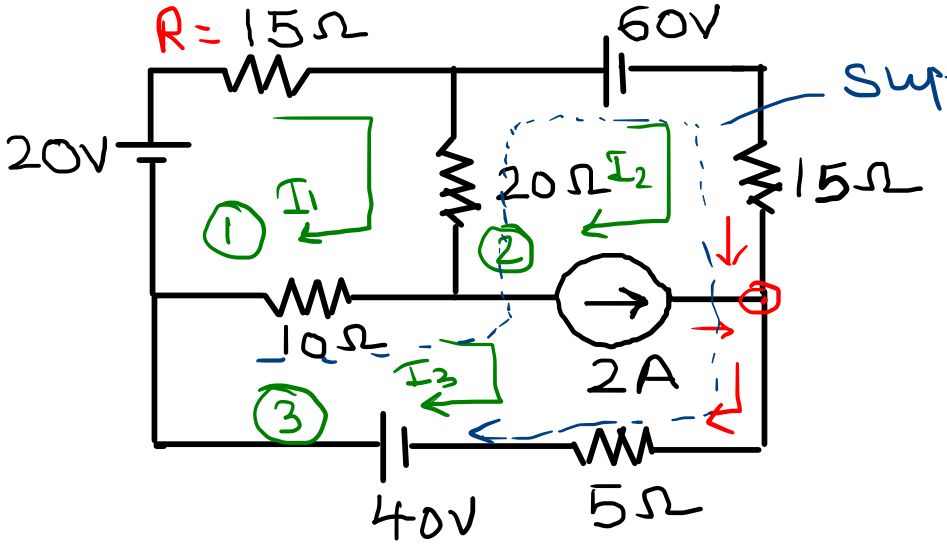
KVL to mesh (2)

$-60 - 15I_2 - 5(I_2 - I_3) - 20(I_2 - I_1) = 0$

$20I_1 - 40I_2 + 5I_3 = 60$ — (2)

Network Analysis using Mesh Current Method

Example:- 5. Find current through R = 15 Ohm resistor in the following network.



Current source 2A appears on Common branch of mesh ② & ③ So its a supermesh problem.

Writing 2A in terms of I_2 & I_3

$I_3 - I_2 = 2$ ---(I) ✓

KVL to mesh (1)

$20 - 15I_1 - 20(I_1 - I_2) - 10(I_1 - I_3) = 0$

$45I_1 - 20I_2 - 10I_3 = 20$ ---(II)

KVL to Supermesh

$-10(I_3 - I_1) - 20(I_2 - I_1) - 60 - 15I_2 - 5I_3 + 40 = 0$

$30I_3 - 35I_2 - 15I_3 = 20$ ---(III)

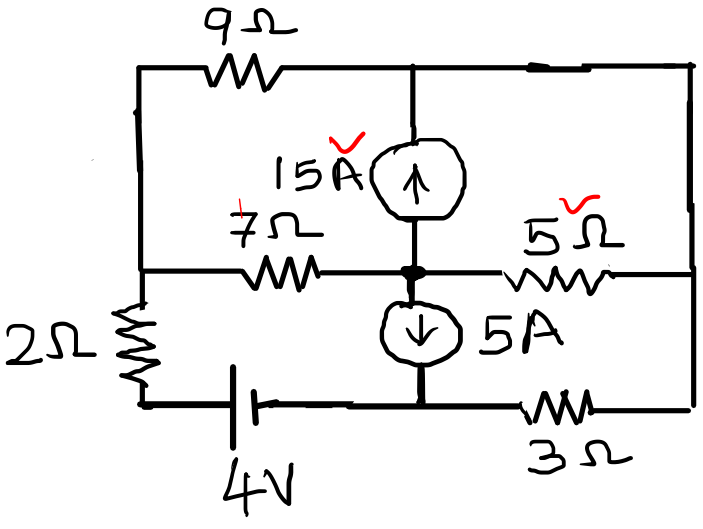
Solving (I), (II) & (III)

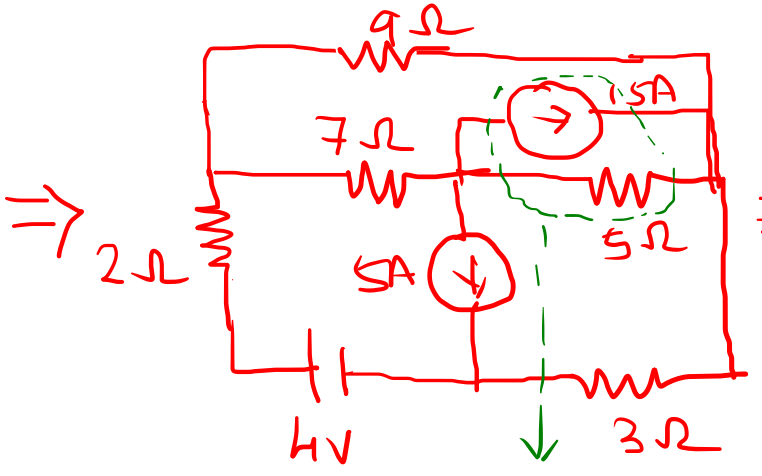
$I_1 = 0.37A, I_2 = -0.7A, I_3 = 1.22A$

$I_{15\Omega} = I_1 = 0.37A$

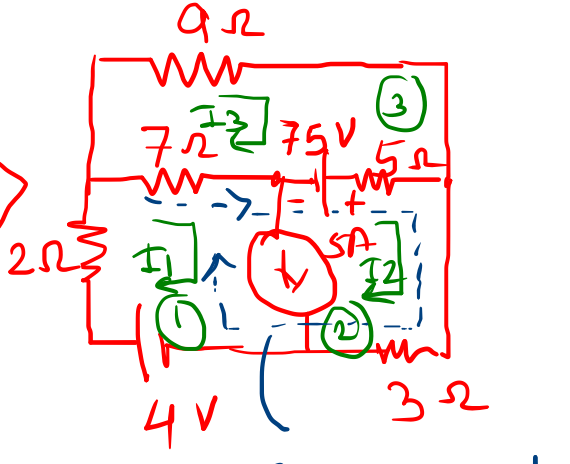
Network Analysis using Mesh Current Method

Example:- 6. Find current through 3 Ohm resistor in the following network.





Source transformation



Supermesh

→ 5A current source appears on common branch of mesh ① & ②

→ The current source in terms of I_1 & I_2 is $I_1 - I_2 = 5$ --- ①

→ KVL to super mesh

$4 - 2I_1 - 7(I_1 - I_3) + 75 - 5(I_2 - I_3) - 3I_2 = 0$

$9I_1 + 8I_2 - 12I_3 = -79$ --- ⑪

→ KVL to mesh ③

$-9I_3 - 5(I_3 - I_2) - 75 - 7(I_3 - I_1) = 0$

$7I_1 + 5I_2 - 21I_3 = 75$ --- ⑪

Solving ①, ⑪ & ⑪

$I_1 = 6.09A$, $I_2 = 1.09A$, $I_3 = 1.28A$

$I_{3\Omega} = I_3 = 1.09A$