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Subject: Basic Electrical Engineering **Class/ Sem: I-I/I**

Subject code: ES301EE

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BEE Unit Wise Important Questions

UNIT-I

1. State and Explain Ohm's Law.
2. State and Explain Kirchoff's Laws.
3. Write the expressions for stored energy in Inductor and Capacitor.
4. Explain Nodal analysis with an example.
5. Explain Mesh analysis with suitable example.
6. State and explain Thevenin's Theorem with help of neat circuit diagrams and their related Expressions & Problems
7. State and explain Norton's Theorem with help of neat circuit diagrams and their related Expressions & Problems
8. State and explain Super position Theorem with help of neat circuit diagrams and their related expressions & Problems

1. Ohm's Law:

Statement:
Ohm's Law states that the current (I) through a conductor is directly proportional to the voltage (V) across it, provided temperature remains constant.

Formula:

$$V = IR$$

Explanation:
If you increase the voltage, the current also increases, assuming resistance (R) stays the same. This law helps in calculating any one of the three quantities (V, I, or R) if the other two are known.

2. Kirchhoff's Laws:

(a) Kirchhoff's Current Law (KCL):

Statement:
The total current entering a junction is equal to the total current leaving the junction.

Formula:

$$\sum I_{in} = \sum I_{out}$$

Explanation:
This is based on conservation of charge. No current is lost at a junction—it only splits or combines.

(b) Kirchhoff's Voltage Law (KVL):

Statement:

The sum of voltages around any closed loop in a circuit is zero.

Formula:

$$\sum V = 0$$

Explanation:

As you go around a closed loop, the energy supplied by sources (like batteries) is exactly used up by the resistors and other components. This is energy conservation in action.

3. Stored Energy in Inductor and Capacitor:

Inductor:

$$E_L = \frac{1}{2}LI^2$$

Explanation:
An inductor stores energy in the form of a magnetic field when current flows through it.

Capacitor:

$$E_C = \frac{1}{2}CV^2$$

Explanation:
A capacitor stores energy in the form of an electric field when a voltage is applied across its plates.

4)

Nodal Analysis Statement:

*Nodal analysis is a method used in electrical circuit analysis to determine the voltage at each node relative to a reference node (usually ground) by applying **Kirchhoff's Current Law (KCL)**, which states that the sum of currents leaving or entering a node is zero.*

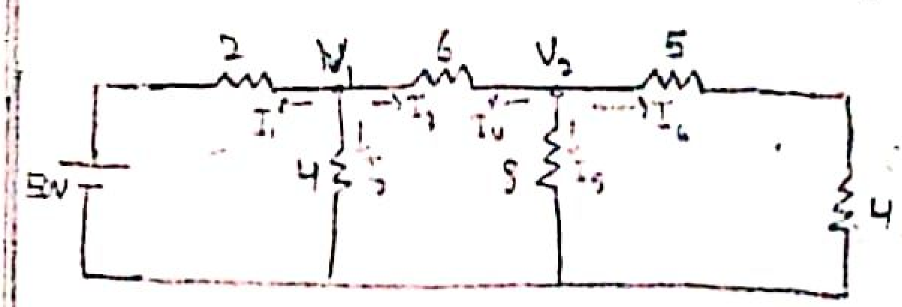
Key Steps in Nodal Analysis:

1. **Choose a reference node (ground).**
2. **Label the node voltages at all other essential nodes.**
3. **Apply KCL at each node** (except the reference), expressing currents in terms of node voltages.
4. **Solve the resulting system of equations** to find the unknown node voltages.

$I_3 = -2.65A$

4) Nodal Analysis

1. Identify the No. of Nodes.
2. Give the current direction outward/away from the Node.



$I_{6\Omega} = ?$

$$\frac{V_1 - 50}{2} + \frac{V_1 - 0}{4} + \frac{V_1 - V_2}{6} = 0$$

$$\frac{V_2 - V_1}{6} + \frac{V_2 - 0}{8} + \frac{V_2 - 0}{9} = 0$$

$$\frac{V_1}{2} + \frac{V_1}{4} + \frac{V_1}{6} - \frac{V_2}{6} = 25$$

$$\frac{V_2}{6} - \frac{V_1}{6} + \frac{V_2}{8} + \frac{V_2}{9} = 0$$

$$V_1\left[\frac{1}{2} + \frac{1}{4} + \frac{1}{6}\right] - V_2\left[\frac{1}{6}\right] = 25$$

$$-V_1\left[\frac{1}{6}\right] + V_2\left[\frac{1}{6} + \frac{1}{8} + \frac{1}{9}\right] = 0$$

$$V_1\left[\frac{11}{12}\right] - V_2\left[\frac{1}{6}\right] = 25$$

$$-V_1\left[\frac{1}{6}\right] + V_2\left[\frac{29}{72}\right] = 0$$

$$\begin{bmatrix} 0.91 & -0.16 \\ -0.16 & 0.40 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 25 \\ 0 \end{bmatrix}$$

$V_1 = \cancel{2500V}$ 29.5 V

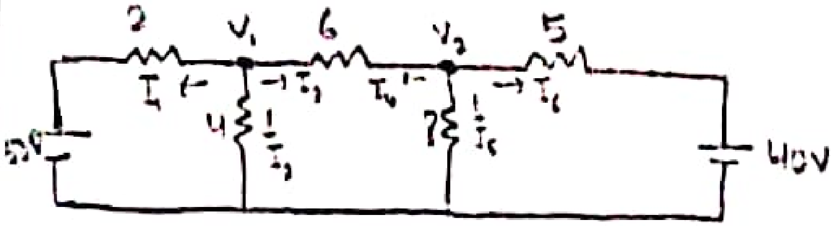
$V_2 = \cancel{3750V}$ 11.8 V

$$I_{6\Omega} = \frac{V_1 - V_2}{6}$$

$$\cancel{\frac{2500 - 3750}{6}}$$

$$= \frac{29.5 - 11.8}{6}$$

$$= 2.95\,A$$



$I_{5\Omega} = ?$

$$\frac{V_1 - 50}{2} + \frac{V_1}{4} + \frac{V_1 - V_2}{6} = 0$$

$$\frac{V_2 - V_1}{6} + \frac{V_2}{8} + \frac{V_2 - 40}{5} = 0$$

$$\frac{V_1}{2} + \frac{V_1}{4} + \frac{V_1}{6} - \frac{V_2}{6} = 25 \Rightarrow V_1\left[\frac{1}{2} + \frac{1}{4} + \frac{1}{6}\right] - V_2\left[\frac{1}{6}\right] = 25$$

$$-\frac{V_1}{6} + \frac{V_2}{6} + \frac{V_2}{8} + \frac{V_2}{5} = 8 \Rightarrow -V_1\left[\frac{1}{6}\right] + V_2\left[\frac{1}{6} + \frac{1}{8} + \frac{1}{5}\right] = 8$$

$$V_1\left[\frac{11}{12}\right] - V_2\left[\frac{1}{6}\right] = 25 \Rightarrow$$

$$-V_1\left[\frac{1}{6}\right] + V_2\left[\frac{59}{120}\right] = 8 \Rightarrow$$

$$\begin{bmatrix} 0.91 & 0.16 \\ -0.16 & 0.49 \end{bmatrix}\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 25 \\ 8 \end{bmatrix}$$

$V_1 = 23.2$

$V_2 = 23.9$ //

$$I_{5\Omega} = \frac{V_2 - 40}{5} = \frac{23.9 - 40}{5} = -3.22 \text{ A}$$

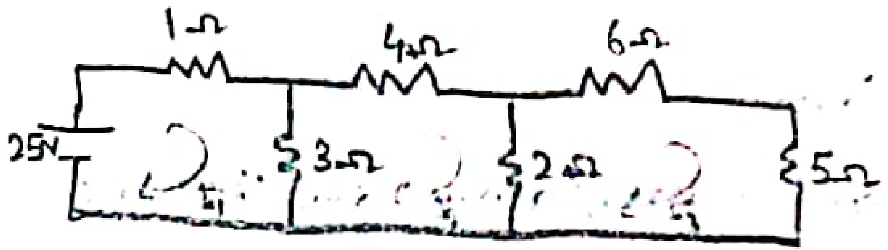
5)

Mesh Analysis Statement:

Mesh analysis is a method used in circuit analysis to determine the unknown currents flowing in the loops (meshes) of a planar circuit by applying ***Kirchhoff's Voltage Law (KVL)****, which states that the algebraic sum of voltages around any closed loop is zero.*

Key Steps in Mesh Analysis:

1. **Identify all meshes** (independent loops) in a planar circuit.
2. **Assign a mesh current** to each loop (usually in clockwise direction).
3. **Apply KVL** to each mesh, summing voltage drops and rises.
4. **Form equations** using Ohm's law and solve them to find the mesh currents.



$I_{6\Omega}$, $I_{4\Omega}$

$$1I_1 + 3(I_1 - I_2) = 25$$
$$4I_2 + 3(I_2 - I_1) + 2(I_2 - I_3) = 0$$
$$6I_3 + 2(I_3 - I_2) + 5I_3 = 0$$

$$4I_1 - 3I_2 = 25$$
$$-3I_1 + 9I_2 - 2I_3 = 0$$
$$-2I_2 + 13I_3 = 0$$

$$\begin{bmatrix} 4 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 13 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 25 \\ 0 \\ 0 \end{bmatrix}$$

$X = I_1 = 8.432\ A$ $\qquad$ $I_{6\Omega} = 0.447\ A$

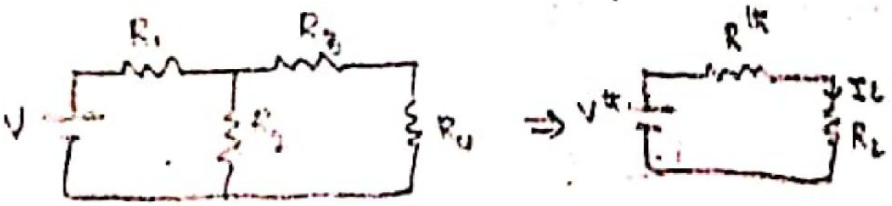
$Y = I_2 = 2.910\ A$ $\qquad$ $I_{4\Omega} = 2.910\ A$

$Z = I_3 = 0.447\ A$

$I_{4\Omega} = 15 + 20 = 35A$

6) Thevenins Theorem

In a linear bilateral resistive network consisting of voltage sources (or) current sources ~~with the multiple~~ can be replaced by single voltage source in series with a resistor



~~where~~
~~Vth – Thevenin's volt~~

where

V^{th} – Thevenin's Voltage (V)

R^{th} – Thevenin's Resistance (Ω)

R_L – Load Resistance (Ω)

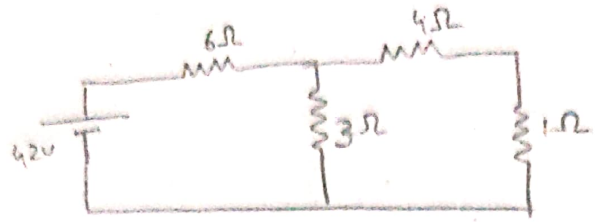
I_L : Load current (A)

$$\boxed{I_L = \frac{V^{th}}{R^{th} + R_L}}$$

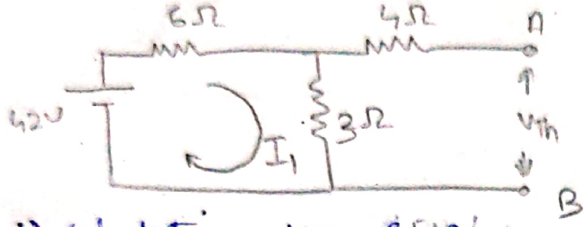
Steps to apply Thevenin's Theorem:

1. **Remove the load resistor** from the circuit.
2. **Find the open-circuit voltage** across the terminals — this is V_{th}.
3. **Find the Thevenin resistance** R_{th} by:
   - Deactivating all independent sources:
     - Replace voltage sources with short circuits.
     - Replace current sources with open circuits.
   - Then, calculate the equivalent resistance seen from the open terminals.
4. **Draw the Thevenin equivalent circuit:** V_{th} in series with R_{th}, and reconnect the load.

example problem for Thevenin's theorem



i) let $1\Omega = R_L$,



i) Calculating V_{Th} & R_{Th}:

$6I_1 + 3I_1 = 42$

$9I_1 = 42$

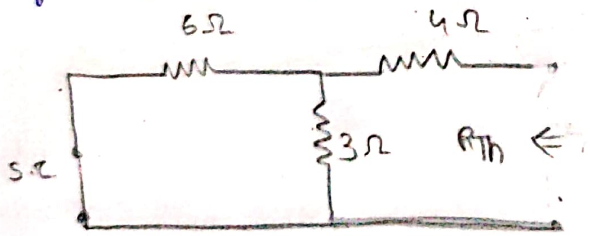
$I_1 = 4.66$

$V_{Th} = I \times R$

$= 4.66(4)$

$V_{Th} = 18.66$

for R_{Th}



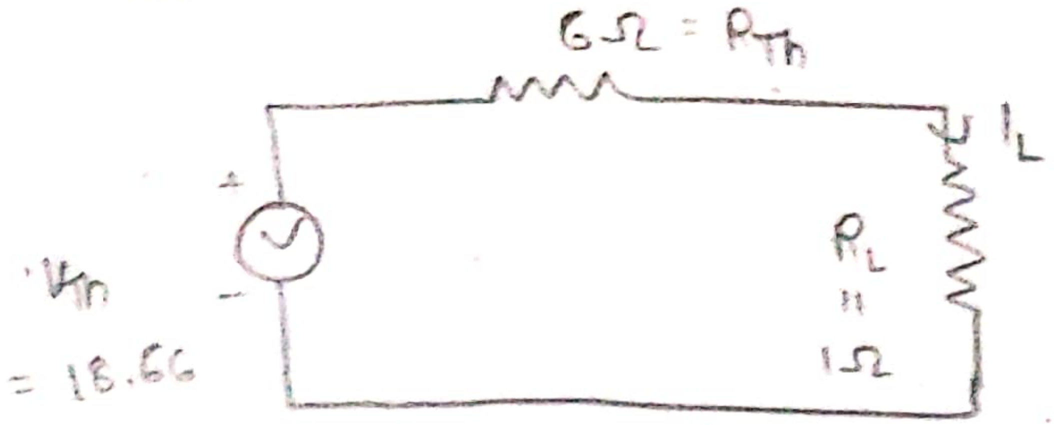
$R_{Th} = (6 \parallel 3) + 4$

$= \frac{6 \times 3}{6+3} + 4$

$= \frac{\cancel{18}^{2}}{\cancel{9}_{1}} + 4 = 6$

$R_{Th} = 6\Omega$

ii) drawing equivalent Thevenins circuit



The current flowing through 1Ω resistor

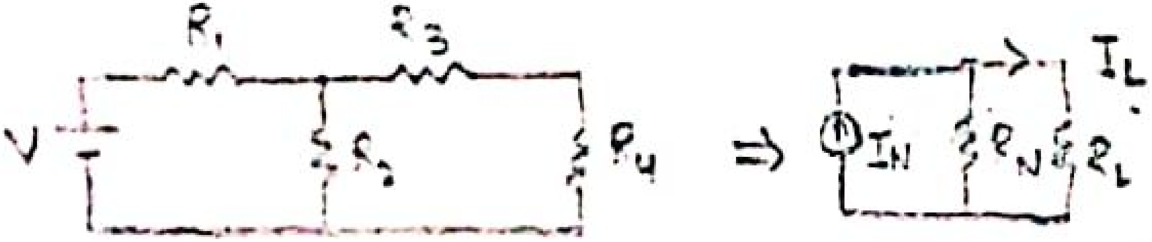
$$I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{18.66}{6+1} = \frac{18.66}{7} = 2.66\,A$$

∴ The current flowing through 1Ω resistor is 2.66A

Norton's Theorem

7) Norton's Theorem

In a Linear bilateral resistive network consisting of v.s (or) c.s with multiple resistors can be replaced by single c.s in parallel with a resistor.



I_N = Norton's current

R_N = Norton's Resistor

R_L = load Resistance

I_L = load current

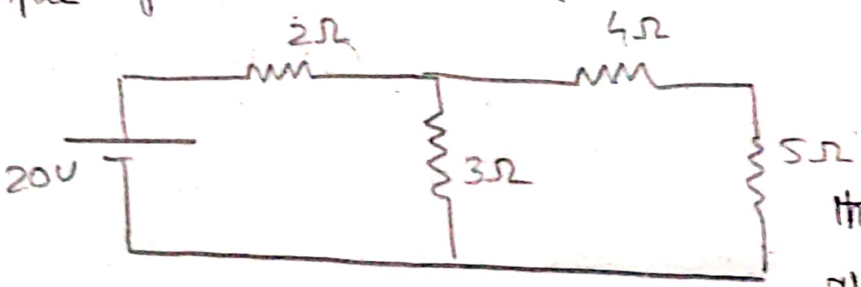
$$\boxed{I_L = \frac{I_N \times R_N}{R_N + R_L}}$$

Steps to apply Norton's Theorem:

1. **Remove the load resistor** from the circuit.
2. **Find the short-circuit current** across the terminals — this is I_N.
3. **Find the Norton resistance** R_N by:
   - Deactivating all independent sources (same method as in Thevenin's).
   - Calculating the equivalent resistance seen from the terminals.
4. **Draw the Norton equivalent circuit:** I_N in parallel with R_N, and reconnect the load.

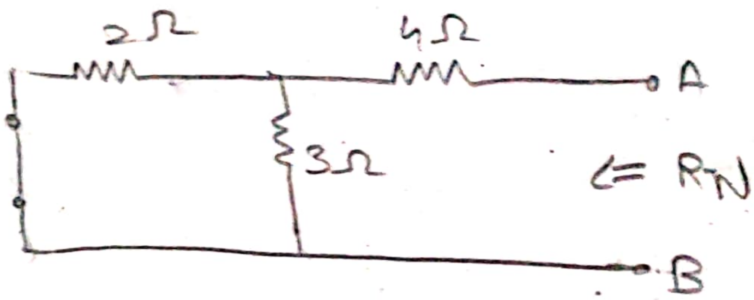
Example for Norton's Theorem

ex:



Find current flowing through 5Ω using Norton's Theorem

sol Step 1: Find R_N by s.c all sources and open circuit the load resistance

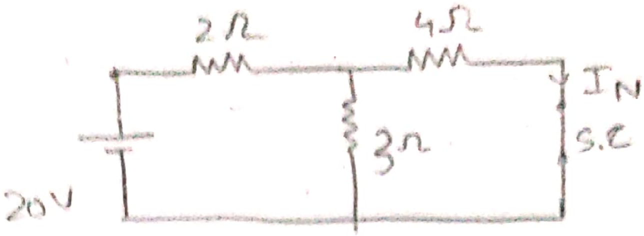


$R_L = 5\Omega$

$R_N = (2 \| 3) + 4$

$= \frac{2 \times 3}{2+3} + 4 = \frac{6}{5} + 4 = 1.2 + 4 = 5.2\Omega$

Step 2: Finding I_N



$$I = \frac{V}{R}$$

$$= \frac{20}{2 + \frac{4 \times 3}{4+3}}$$

$$= \frac{20}{2 + \frac{12}{7}} = \frac{20}{2 + 1.71}$$

$$= \frac{20}{3.71} = 5.39$$

I_N = flowing through 4Ω

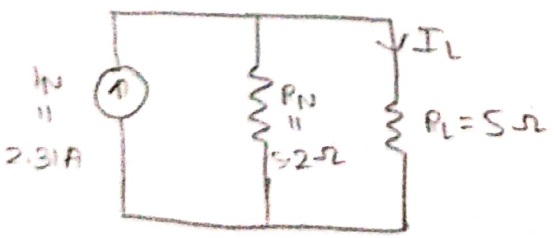
$$I_N = I \times \frac{3}{3+4} \quad \text{(current division rule)}$$

$$= 5.39 \times \frac{3}{7} =$$

$$= \frac{16.17}{7} = 2.31\,A$$

Step 3: Finding load current (I_L)

Nortons' equivalent circuit



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

$$= \frac{2.31 \times 5.2}{5.2 + 5}$$

$$= \frac{12.01}{10.2} = 1.17\,A$$

∴ The current flowing through 5Ω resistor is 1.17A.

Network Reduction Techniques

Sol

1.8) Super position Theorem:-

In a linear by lateral resistive network consisting of two or more voltage source or current source can be replaced with short circuit if it is a voltage source and open circuit if it is a current source considering a single source alone in order to calculate the value of current.

Voltage Source $\longrightarrow$ Short Circuit.

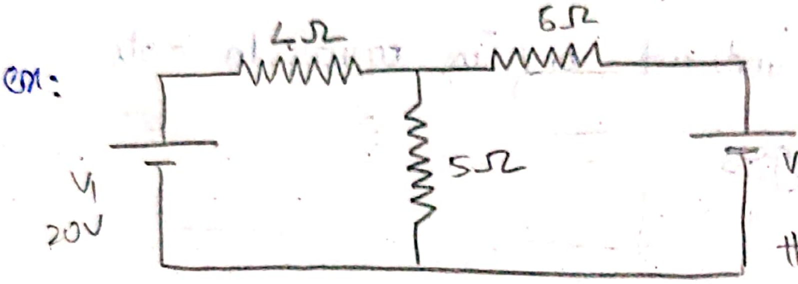
Open ~~Source~~ Circuit $\longrightarrow$ Current Source

Part B

2a.) State and explain Super Position Theorem

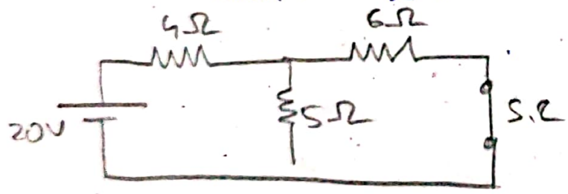
In a linear bi lateral resistive network consisting of two or more voltage sources or current sources can be replaced by short circuit if its a voltage source and open circuit if its a current source considering a single source alone.

ex:



Calculate the value of current flowing through 15Ω using super position Theorem

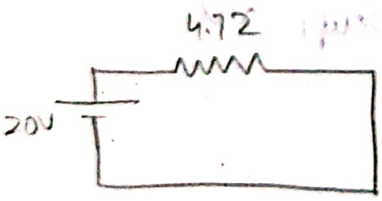
Sol step 1: Considering 20 V.S alone and S.C 15V



$$R = \frac{6 \times 5}{6+5} + 4$$

$$= \frac{30}{11} + 4 = 2.72 + 4$$

$$= 6.72$$



$V = IR$

$I = V/R$

$= 20/6.72 = 2.97$

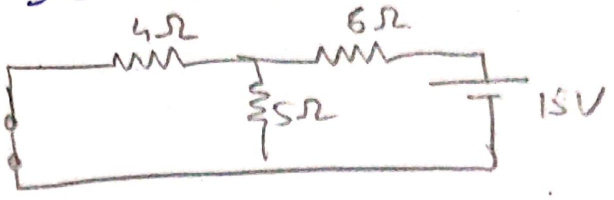
$$I'_{5\Omega} = \frac{\text{total current} \times \text{OPP R}}{\text{OPP Res} + \text{current R}}$$

$$= \frac{2.97 \times 6}{6+6} = 1.62\,A$$

$I'_{5\Omega} = 1.62\,A$

Step 2: Considering 15 V.S alone

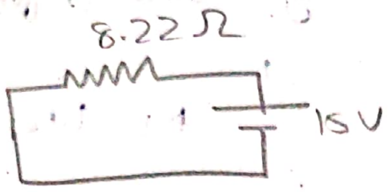
S.C 20 V.S



$R = \frac{4 \times 5}{4+5} + 6$

$= \frac{20}{9} + 6 = 2.22 + 6$

$= 8.22\ \Omega$



$I = V/R$

$= 15/8.22 = 1.82\ A$

$I_{5\Omega}'' = \frac{\text{total current} \times \text{OPP R}}{\text{OPP R} + \text{Current R}} = \frac{1.82 \times 4}{4+5} = 0.8\ A$

Step 3: Sum of $I_{5\Omega}'$ & $I_{5\Omega}''$

$I_{5\Omega} = I_{5\Omega}' + I_{5\Omega}''$

$I_{5\Omega} = 1.62 + 0.8$

$I_{5\Omega} = 2.42\ A$

∴ The current flowing through 5Ω = 2.42 A