

Subject Name & Code:

ELECTRICAL CIRCUIT ANALYSIS- BE03009031

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Assignment – 1

1. Maximum Power Transfer Theorem

Statement: In a linear bilateral network, maximum power is transferred from a source to a load when the load resistance equals the internal resistance of the source (DC). For AC, maximum power is transferred when the load impedance is the complex conjugate of the source impedance.

DC derivation:

Let Thevenin voltage = V_{th} , Thevenin resistance = R_{th} , load resistance = R_L .

$$I = \frac{V_{th}}{R_{th} + R_L}, P = I^2 R_L = \frac{V_{th}^2 R_L}{(R_{th} + R_L)^2}$$

For maximum power, $\frac{dP}{dR_L} = 0$:

$$\begin{aligned} \frac{dP}{dR_L} &= V_{th}^2 \frac{(R_{th} + R_L)^2 - 2R_L(R_{th} + R_L)}{(R_{th} + R_L)^4} = 0 \\ (R_{th} + R_L) - 2R_L &= 0 \Rightarrow R_L = R_{th} \\ P_{\max} &= \frac{V_{th}^2}{4R_{th}} \end{aligned}$$

AC derivation:

Let $Z_{th} = R_{th} + jX_{th}$, $Z_L = R_L + jX_L$.

$$P = \frac{|V_{th}|^2 R_L}{(R_{th} + R_L)^2 + (X_{th} + X_L)^2}$$

For maximum power:

$$X_L = -X_{th}, R_L = R_{th}$$

Thus,

$$\begin{aligned} Z_L &= Z_{th}^* = R_{th} - jX_{th} \\ P_{\max} &= \frac{|V_{th}|^2}{4R_{th}} \end{aligned}$$

2. Reciprocity Theorem

Statement: In a linear, passive, bilateral network, if a single voltage source V in branch A produces a current I in branch B, then the same voltage source shifted to branch B will produce the same current I in branch A. For a current source, the dual statement holds: a current source I in branch A producing voltage V in branch B will produce the same voltage V in branch A when placed in branch B.

Conditions: Applicable to linear, passive, bilateral networks with a single independent source. It is not valid for networks containing dependent sources or nonlinear elements.

3. Compensation Theorem

Statement: In a linear bilateral network, if the impedance of a branch carrying current I is changed by ΔZ , the change in branch current/voltage can be obtained by replacing the change with a compensating voltage source $V_c = I\Delta Z$ in series with the branch, with all other sources replaced by their internal resistances.

Steps:

1. Find the original current I in the branch to be changed.
2. Replace the actual impedance change by a compensating voltage source $V_c = I\Delta Z$.
3. Kill all independent sources, i.e. replace voltage sources by short and current sources by open.
4. Find the additional current/voltage due to V_c alone.
5. Superimpose the original and additional quantities to get the final result.

4. Thevenin's Theorem and Norton's Theorem

Thevenin's Theorem: Any linear two-terminal network can be replaced by an equivalent voltage source V_{th} in series with an equivalent resistance R_{th} .

- V_{th} = open-circuit voltage across the terminals.
- R_{th} = equivalent resistance seen from the terminals with all independent sources killed.

Norton's Theorem: Any linear two-terminal network can be replaced by an equivalent current source I_N in parallel with a resistance R_N .

$$I_N = \frac{V_{th}}{R_{th}}, R_N = R_{th}$$

Norton equivalent is the source transformation of the Thevenin equivalent.

5. Duality

Concept: Two networks are dual if the mesh equations of one have the same mathematical form as the node equations of the other. The dual is obtained by interchanging voltage and current, resistance and conductance, inductance and capacitance, series and parallel, node and mesh, etc.

Analogous quantities:

Original	Dual
Voltage V	Current I
Current I	Voltage V
Resistance R	Conductance G
Inductance L	Capacitance C
Capacitance C	Inductance L
Series branch	Parallel branch
Mesh	Node
KVL	KCL
Short circuit	Open circuit
Voltage source	Current source
Impedance Z	Admittance Y

6. Dot Convention Rule for Magnetically Coupled Network

Dot convention: A dot is placed at one terminal of each coupled coil. If current enters both dotted terminals, the mutual flux aids the self-flux. If current enters one dotted terminal and leaves the other, the mutual flux opposes the self-flux.

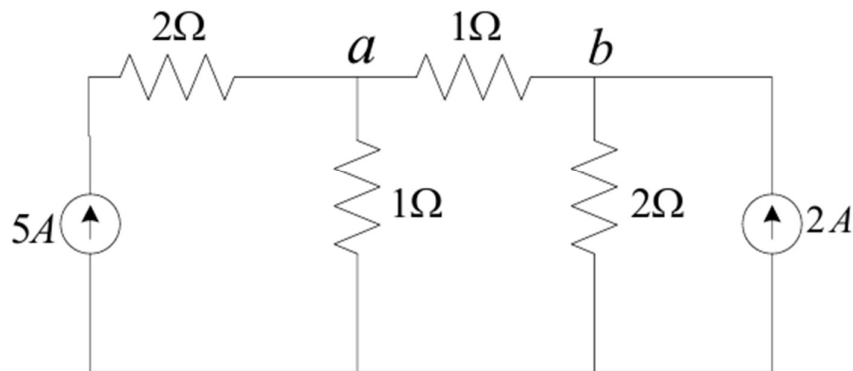
The sign of mutual voltage is positive if both currents enter the dotted terminals; otherwise negative.

Method to place dots:

1. Assume a current direction in one coil.
2. Determine the direction of flux using the right-hand rule.
3. For the second coil, determine which terminal current must enter to produce flux in the same direction.
4. Mark that terminal with a dot.

Example: Two coils on a common core. If current enters the top terminal of coil 1 and produces clockwise flux, then for coil 2 to produce clockwise flux, current must enter its bottom terminal. Hence the dot is placed at the bottom of coil 2.

7. Using the Node Voltage analysis, find the current in all resistors in given figure.



For Q7, using **Node Voltage Analysis**:

Given

- Left current source: 5 A
- Left series resistor: $2\ \Omega$
- Node a : $1\ \Omega$ to ground, $1\ \Omega$ to node b
- Node b : $2\ \Omega$ to ground, 2 A current source from ground

To Find

Current in all resistors: $2\ \Omega$, $1\ \Omega$, $1\ \Omega$, $2\ \Omega$

Solution

Let the bottom node be the reference ground.

Let node voltages be:

V_a = voltage at node a , V_b = voltage at node b

KCL at node a

$$5 = \frac{V_a}{1} + \frac{V_a - V_b}{1}$$

$$5 = 2V_a - V_b \quad (1)$$

KCL at node b

$$\frac{V_a - V_b}{1} + 2 = \frac{V_b}{2}$$

Multiplying by 2:

$$2(V_a - V_b) + 4 = V_b$$

$$2V_a - 2V_b + 4 = V_b$$

$$2V_a - 3V_b = -4 \quad (2)$$

Solving equations (1) and (2):

$$2V_a - V_b = 5$$

$$2V_a - 3V_b = -4$$

Subtracting:

$$2V_b = 9 \Rightarrow V_b = 4.5 \text{ V}$$

Substitute in (1):

$$2V_a - 4.5 = 5 \Rightarrow 2V_a = 9.5 \Rightarrow V_a = 4.75 \text{ V}$$

Currents in all resistors

1. 2Ω left series resistor

It carries the source current:

$$I_{2\Omega, \text{left}} = 5 \text{ A}$$

2. 1Ω vertical resistor at node a

$$I_{1\Omega, a} = \frac{V_a}{1} = 4.75 \text{ A}$$

Direction: downward from node a to ground.

3. $1\ \Omega$ horizontal resistor between a and b

$$I_{1\Omega,ab} = \frac{V_a - V_b}{1} = 4.75 - 4.5 = 0.25\text{ A}$$

Direction: from a to b .

4. $2\ \Omega$ vertical resistor at node b

$$I_{2\Omega,b} = \frac{V_b}{2} = \frac{4.5}{2} = 2.25\text{ A}$$

Direction: downward from node b to ground.

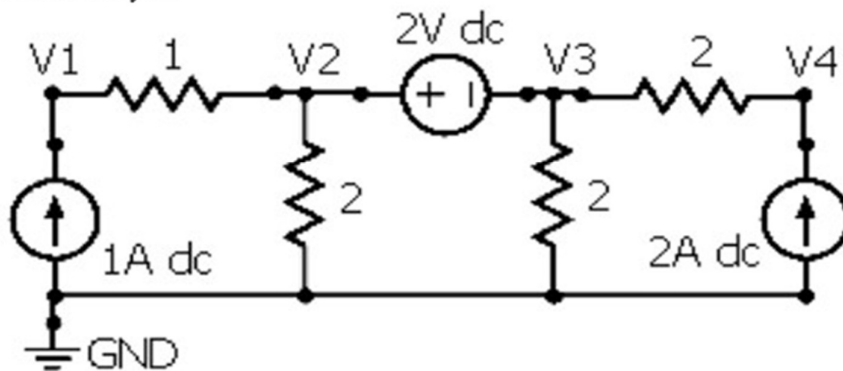
Final Answer

$I_{2\Omega,\text{left}} = 5\text{ A}$ $I_{1\Omega,a} = 4.75\text{ A}$ $I_{1\Omega,ab} = 0.25\text{ A}$ $I_{2\Omega,b} = 2.25\text{ A}$
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Node voltages:

$V_a = 4.75\text{ V}, V_b = 4.5\text{ V}$

8. Solve for the nodal voltages V_1, V_2, V_3 and V_4 as shown in the network in given figure, using the nodal analysis.



For Q8, using Nodal Analysis:

Given

- Node V_1 : 1 A current source from ground into V_1
- $1\ \Omega$ resistor between V_1 and V_2

- $2\ \Omega$ resistor from V_2 to ground
- 2 V DC voltage source between V_2 and V_3 , with positive terminal at V_2
- $2\ \Omega$ resistor from V_3 to ground
- $2\ \Omega$ resistor between V_3 and V_4
- 2 A current source from ground into V_4
- Ground at bottom

To Find

$$V_1, V_2, V_3, V_4$$

Solution

Step 1: KCL at node V_1

Current leaving V_1 through $1\ \Omega$ resistor:

$$\frac{V_1 - V_2}{1}$$

Current entering from 1 A source is 1 A . Therefore,

$$\begin{aligned} \frac{V_1 - V_2}{1} - 1 &= 0 \\ V_1 - V_2 &= 1 \end{aligned} \quad (1)$$

Step 2: Voltage source constraint between V_2 and V_3

The 2 V source has positive terminal at V_2 :

$$V_2 - V_3 = 2 \quad (2)$$

Step 3: Supernode KCL at V_2 and V_3

Form a supernode containing V_2 and V_3 . The internal voltage source branch current does not appear.

Currents leaving the supernode:

$$\begin{aligned} \frac{V_2 - V_1}{1} + \frac{V_2}{2} + \frac{V_3}{2} + \frac{V_3 - V_4}{2} &= 0 \\ (V_2 - V_1) + \frac{V_2}{2} + \frac{V_3}{2} + \frac{V_3 - V_4}{2} &= 0 \end{aligned} \quad (3)$$

Step 4: KCL at node V_4

Current leaving V_4 through $2\ \Omega$ resistor:

$$\frac{V_4 - V_3}{2}$$

Current entering from 2 A source is 2 A:

$$\begin{aligned}\frac{V_4 - V_3}{2} - 2 &= 0 \\ V_4 - V_3 &= 4\end{aligned}\quad (4)$$

Solving Equations

From (2):

$$V_2 = V_3 + 2$$

From (1):

$$V_1 = V_2 + 1 = (V_3 + 2) + 1 = V_3 + 3$$

From (4):

$$V_4 = V_3 + 4$$

Substitute into (3):

$$\begin{aligned}(V_2 - V_1) + \frac{V_2}{2} + \frac{V_3}{2} + \frac{V_3 - V_4}{2} &= 0 \\ V_2 - V_1 &= (V_3 + 2) - (V_3 + 3) = -1 \\ \frac{V_2}{2} &= \frac{V_3 + 2}{2} = \frac{V_3}{2} + 1 \\ \frac{V_3 - V_4}{2} &= \frac{V_3 - (V_3 + 4)}{2} = -2\end{aligned}$$

Therefore,

$$\begin{aligned}-1 + \left(\frac{V_3}{2} + 1\right) + \frac{V_3}{2} - 2 &= 0 \\ V_3 - 2 &= 0 \\ V_3 &= 2\text{ V}\end{aligned}$$

Now,

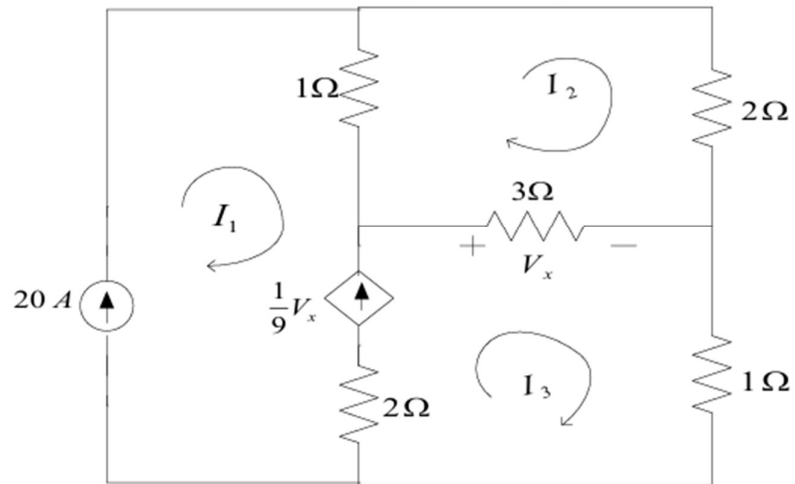
$$\begin{aligned}V_2 &= V_3 + 2 = 4\text{ V} \\ V_1 &= V_3 + 3 = 5\text{ V}\end{aligned}$$

$$V_4 = V_3 + 4 = 6 \text{ V}$$

Final Answer

$$V_1 = 5 \text{ V}, V_2 = 4 \text{ V}, V_3 = 2 \text{ V}, V_4 = 6 \text{ V}$$

9. Determine the mesh currents in a network using mesh analysis.



For Q9, using **Mesh Analysis**:

Given

- Mesh 1: left loop containing 20 A current source
- Mesh 2: upper right loop current I_2
- Mesh 3: lower right loop current I_3
- 3 Ω resistor has voltage V_x with positive polarity at left node
- Dependent current source in lower branch: $\frac{1}{9}V_x$ upward

To Find

Mesh currents I_1, I_2, I_3

Solution

Step 1: Mesh 1 current

The 20 A current source lies only in mesh 1 and its direction is upward. Therefore,

$$I_1 = 20 \text{ A}$$

Step 2: KVL for mesh 2

Traversing mesh 2 counterclockwise:

- $2\ \Omega$ resistor: voltage drop $2I_2$
- $3\ \Omega$ resistor: current is $I_2 + I_3$ from right to left, voltage drop $3(I_2 + I_3)$
- $1\ \Omega$ resistor: downward current is $I_1 - I_2 = 20 - I_2$, so upward current is $I_2 - 20$, voltage drop $1(I_2 - 20)$

Thus,

$$\begin{aligned} 2I_2 + 3(I_2 + I_3) + (I_2 - 20) &= 0 \\ 6I_2 + 3I_3 &= 20 \quad (1) \end{aligned}$$

Step 3: Constraint from dependent current source

The $3\ \Omega$ resistor current from right to left is $I_2 + I_3$. Hence,

$$V_x = -3(I_2 + I_3)$$

The dependent current source is $\frac{1}{9}V_x$ upward. In mesh 3, the branch direction is downward, so

$$I_3 = -\frac{1}{9}V_x$$

Substitute V_x :

$$\begin{aligned} I_3 &= -\frac{1}{9}[-3(I_2 + I_3)] \\ I_3 &= \frac{1}{3}(I_2 + I_3) \\ 3I_3 &= I_2 + I_3 \\ I_2 &= 2I_3 \quad (2) \end{aligned}$$

Step 4: Solve equations

Substitute (2) into (1):

$$\begin{aligned} 6(2I_3) + 3I_3 &= 20 \\ 12I_3 + 3I_3 &= 20 \\ 15I_3 &= 20 \\ I_3 &= \frac{4}{3}\text{ A} \end{aligned}$$

Then,

$$I_2 = 2I_3 = \frac{8}{3} \text{ A}$$

$$I_1 = 20 \text{ A}$$

Final Answer

$$I_1 = 20 \text{ A}$$

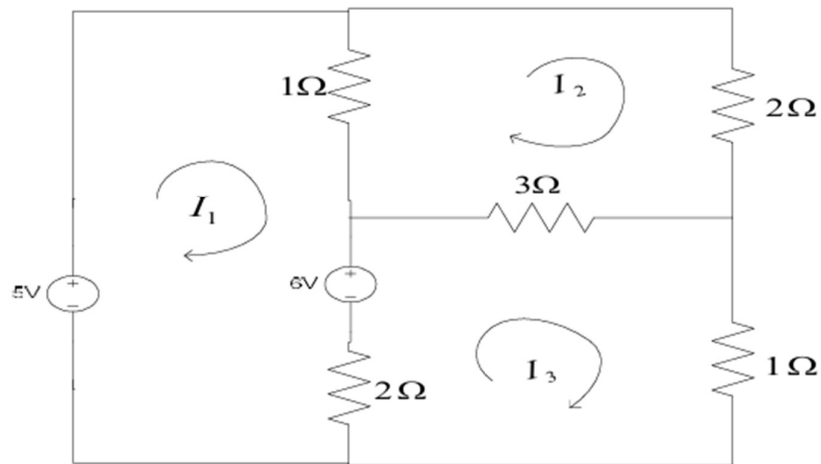
$$I_2 = \frac{8}{3} \text{ A} \approx 2.67 \text{ A}$$

$$I_3 = \frac{4}{3} \text{ A} \approx 1.33 \text{ A}$$

The mesh currents are therefore:

$$I_1 = 20 \text{ A}, I_2 = \frac{8}{3} \text{ A}, I_3 = \frac{4}{3} \text{ A}$$

10. Determine the mesh current in the given network of figure.



Given

- Left source: 5 V, positive terminal at top
- Middle vertical source: 6 V, positive terminal at top
- Resistors: 1 Ω (top left), 2 Ω (top right), 3 Ω (middle horizontal), 2 Ω (middle vertical), 1 Ω (bottom right)
- Mesh currents I_1, I_2, I_3 assumed clockwise

To Find

$$I_1, I_2, I_3$$

Solution**Mesh 1 KVL**

Clockwise loop:

$$\begin{aligned} 5 &= 1I_1 + 6 + 2(I_1 + I_3) \\ 3I_1 + 2I_3 &= -1 \end{aligned} \quad (1)$$

Mesh 2 KVL

Clockwise loop through $2\ \Omega$ and $3\ \Omega$:

$$\begin{aligned} 2I_2 + 3(I_2 + I_3) &= 0 \\ 5I_2 + 3I_3 &= 0 \end{aligned} \quad (2)$$

Mesh 3 KVL

Clockwise loop through middle vertical, $1\ \Omega$, and $3\ \Omega$:

$$\begin{aligned} 6 + 2(I_1 + I_3) + 1I_3 + 3(I_2 + I_3) &= 0 \\ 2I_1 + 3I_2 + 6I_3 &= -6 \end{aligned} \quad (3)$$

Solving (1), (2), (3):

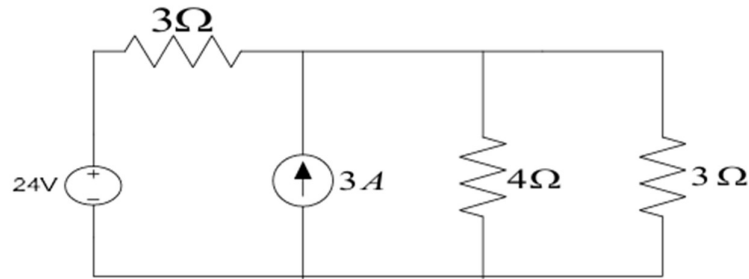
$$\begin{aligned} I_3 &= -\frac{80}{43}\text{ A} \\ I_2 &= \frac{48}{43}\text{ A} \\ I_1 &= \frac{39}{43}\text{ A} \end{aligned}$$

Final Answer

$\begin{aligned} I_1 &= \frac{39}{43}\text{ A} \approx 0.907\text{ A} \\ I_2 &= \frac{48}{43}\text{ A} \approx 1.116\text{ A} \\ I_3 &= -\frac{80}{43}\text{ A} \approx -1.860\text{ A} \end{aligned}$
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The negative sign on I_3 means the actual current in the lower-right mesh flows **counterclockwise**, opposite to the assumed clockwise direction.

11. Find the current in the 4-ohm resistor in given figure using Thevenin's Theorem.



For Q11, using **Thevenin's Theorem**:

Given

- 24 V DC source in series with 3 Ω resistor
- 3 A current source in parallel with 4 Ω and 3 Ω resistors
- Need current through 4 Ω resistor

To Find

$$I_{4\Omega}$$

Solution

Step 1: Remove the 4 Ω resistor and find V_{th}

Let the top node voltage be V .

At the node, KCL:

$$\begin{aligned}\frac{V - 24}{3} + \frac{V}{3} - 3 &= 0 \\ \frac{2V - 24}{3} &= 3 \\ 2V - 24 &= 9 \\ 2V &= 33 \\ V &= 16.5 \text{ V}\end{aligned}$$

Thus,

$$V_{th} = 16.5 \text{ V}$$

Step 2: Find R_{th}

Kill the independent sources:

- 24 V source $\rightarrow$ short circuit

- 3 A source $\rightarrow$ open circuit

The remaining resistors seen from the open terminals are:

$$R_{th} = 3\ \Omega \parallel 3\ \Omega = 1.5\ \Omega$$

Step 3: Connect the 4 Ω load

$$I_{4\Omega} = \frac{V_{th}}{R_{th} + 4}$$

$$I_{4\Omega} = \frac{16.5}{1.5 + 4} = \frac{16.5}{5.5}$$

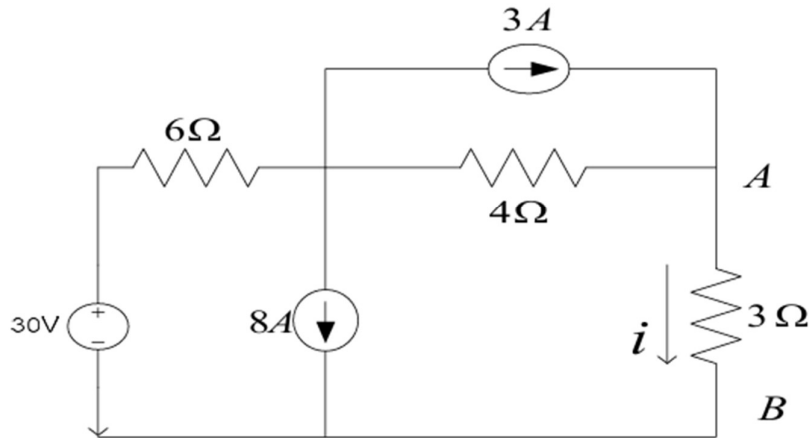
$$I_{4\Omega} = 3\ \text{A}$$

Final Answer

$$I_{4\Omega} = 3\ \text{A}$$

The current in the 4 Ω resistor is 3 A.

12. Find Voltage across 3 Ω in figure using Superposition Theorem



For Q12, using **Superposition Theorem**:

Given

- 30 V voltage source in series with 6 Ω
- 8 A current source from node C to ground
- 3 A current source from node C to node A
- 4 Ω resistor between node C and node A

- $3\ \Omega$ resistor between node A and ground

To Find

Voltage across the $3\ \Omega$ resistor, i.e. V_A

Superposition Method

1. Effect of 30 V source only

Open 8 A and 3 A sources.

The circuit becomes a single series loop:

$$R_{\text{total}} = 6 + (4 + 3) = 13\ \Omega$$

$$I = \frac{30}{13}\ \text{A}$$

Voltage across $3\ \Omega$:

$$V_{A1} = I \times 3 = \frac{30}{13} \times 3 = \frac{90}{13}\ \text{V}$$

2. Effect of 8 A source only

Short the 30 V source, open the 3 A source.

The $6\ \Omega$ resistor is now connected from node C to ground.

KCL at nodes:

$$\frac{V_C}{6} + 8 + \frac{V_C - V_A}{4} = 0$$

$$\frac{V_C - V_A}{4} = \frac{V_A}{3}$$

Solving:

$$V_{A2} = -\frac{144}{13}\ \text{V}$$

3. Effect of 3 A source only

Short the 30 V source, open the 8 A source.

The 3 A source injects current into node A .

KCL equations:

$$\frac{V_C}{6} + 3 + \frac{V_C - V_A}{4} = 0$$

$$3 + \frac{V_C - V_A}{4} - \frac{V_A}{3} = 0$$

Solving:

$$V_{A3} = \frac{36}{13} \text{ V}$$

Total Voltage

$$V_A = V_{A1} + V_{A2} + V_{A3}$$

$$V_A = \frac{90}{13} - \frac{144}{13} + \frac{36}{13}$$

$$V_A = \frac{-18}{13} \text{ V}$$

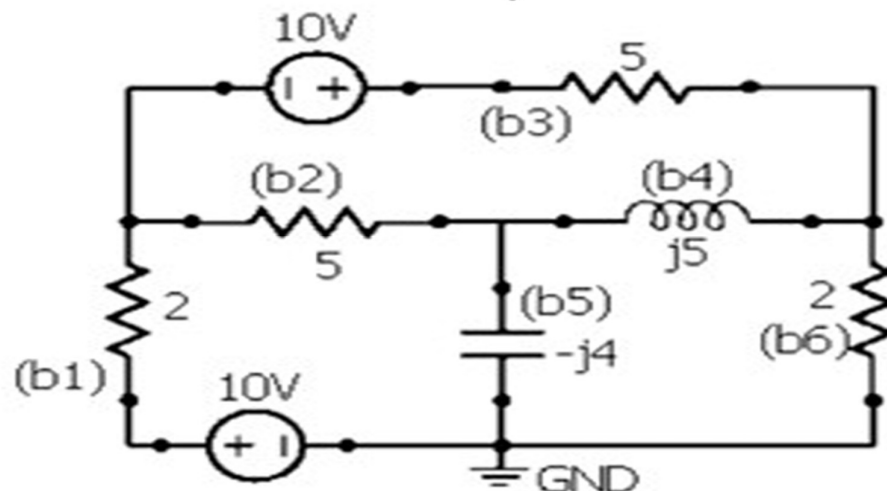
$$V_A \approx -1.385 \text{ V}$$

Final Answer

$$V_{3\Omega} = -\frac{18}{13} \text{ V} \approx -1.385 \text{ V}$$

The negative sign indicates that node A is at a lower potential than ground. The magnitude of the voltage across the 3Ω resistor is:

13. Draw the dual of the network shown in figure



For **Q13**, the dual network is obtained by applying the principle of duality:

- Mesh $\leftrightarrow$ Node
- Resistance $R \leftrightarrow$ Conductance $G = 1/R$
- Inductance $L \leftrightarrow$ Capacitance C
- Capacitance $C \leftrightarrow$ Inductance L
- Voltage source $V \leftrightarrow$ Current source I
- Series $\leftrightarrow$ Parallel
- KVL $\leftrightarrow$ KCL

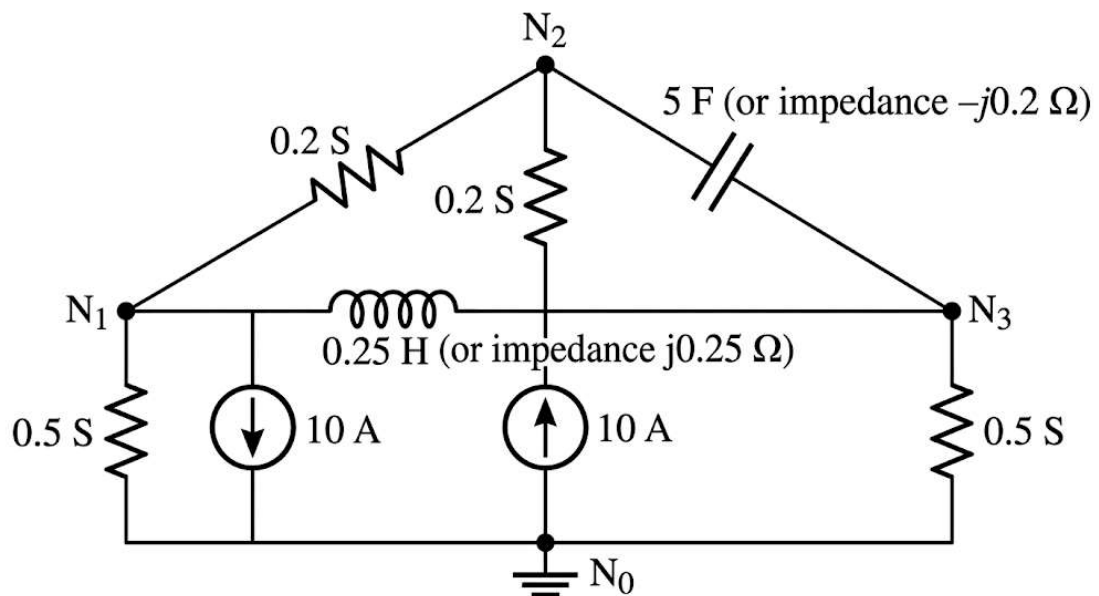
Dual Network Construction

Identify the three meshes of the original network and the outer region. Assign dual nodes:

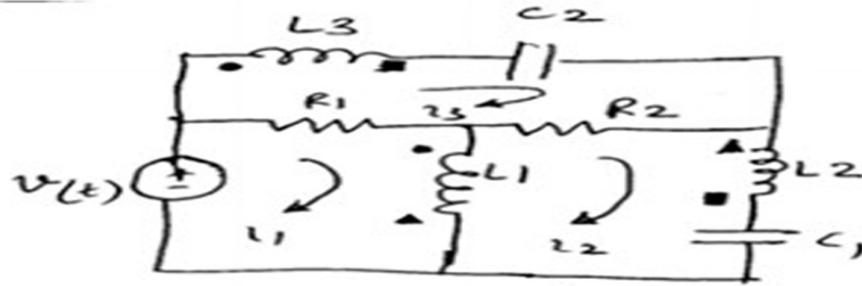
- **N1** for left mesh
- **N2** for top mesh
- **N3** for right mesh
- **N0** = reference ground (outer region)

For each original branch, place the dual element between the corresponding dual nodes:

Diagram:



14. Formulate the Loop equations for Network shown in figure



For **Q14**, the network has magnetically coupled inductors L_1 , L_2 , and an uncoupled inductor L_3 in the top branch. Let the loop currents be:

- i_1 : left mesh, clockwise
- i_2 : right mesh, clockwise
- i_3 : top mesh, clockwise (through L_3, C_2, R_2, R_1)

Dot convention: L_1 and L_2 have dots at their top terminals, so currents entering the top terminals aid each other.

KVL Equations

Loop 1 (left mesh):

$$v(t) = R_1(i_1 - i_3) + L_1 \frac{d}{dt}(i_1 - i_2) + M \frac{di_2}{dt}$$

Loop 2 (right mesh):

$$0 = R_2(i_2 - i_3) + L_2 \frac{di_2}{dt} + M \frac{d}{dt}(i_1 - i_2) + \frac{1}{C_1} \int i_2 dt - L_1 \frac{d}{dt}(i_1 - i_2) - M \frac{di_2}{dt}$$

Simplifying the mutual terms in Loop 2:

$$0 = R_2(i_2 - i_3) + L_2 \frac{di_2}{dt} + M \frac{di_1}{dt} - 2M \frac{di_2}{dt} + \frac{1}{C_1} \int i_2 dt - L_1 \frac{d}{dt}(i_1 - i_2)$$

Loop 3 (top mesh):

$$0 = L_3 \frac{di_3}{dt} + \frac{1}{C_2} \int i_3 dt + R_2(i_3 - i_2) + R_1(i_3 - i_1)$$

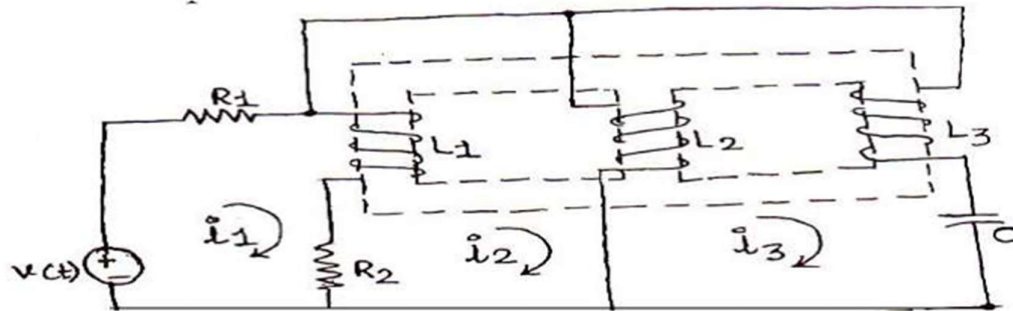
If the top branch is not considered and only the two main loops i_1, i_2 are required, set $i_3 = 0$. The first two equations then reduce to the standard two-loop coupled-circuit equations.

$$v(t) = R_1 i_1 + L_1 \frac{d}{dt}(i_1 - i_2) + M \frac{di_2}{dt}$$

$$0 = R_2 i_2 + L_2 \frac{di_2}{dt} + M \frac{d}{dt}(i_1 - i_2) + \frac{1}{C_1} \int i_2 dt - L_1 \frac{d}{dt}(i_1 - i_2) - M \frac{di_2}{dt}$$

For the full three-loop network, include the third equation as given above.

15. For magnetically coupled network shown in Figure, find dot-convention and write equations.



For **Q15**, the magnetically coupled network has three loops with mesh currents i_1, i_2, i_3 assumed **clockwise**. The coupled coils are L_1, L_2, L_3 with mutual inductances M_{12}, M_{23}, M_{13} . From the winding directions shown in the figure:

- L_1 : dot at the **top** terminal
- L_2 : dot at the **top** terminal
- L_3 : dot at the **bottom** terminal

Dot Convention

- If currents enter the dotted terminals of two coils, the mutual voltage aids the self-voltage $\rightarrow$ use $+M$.
- If one current enters the dotted terminal and the other leaves it, the mutual voltage opposes $\rightarrow$ use $-M$.

Thus:

- L_1 and L_2 : both dotted at top. Currents $(i_1 - i_2)$ and $(i_2 - i_3)$ enter the top dotted terminals when positive downward. Hence M_{12} is **positive**.
- L_2 and L_3 : L_2 dot at top, L_3 dot at bottom. Current $(i_2 - i_3)$ enters top dot of L_2 ; current i_3 enters bottom dot of L_3 . Both enter dotted terminals $\rightarrow M_{23}$ is **positive**.
- L_1 and L_3 : L_1 dot at top, L_3 dot at bottom. Current $(i_1 - i_2)$ enters top dot of L_1 ; current i_3 enters bottom dot of L_3 . Both enter dotted terminals $\rightarrow M_{13}$ is **positive**.

KVL Equations

Let:

- R_1 = top series resistor
- R_2 = left vertical resistor
- L_1 = coupled inductor between loop 1 and loop 2
- L_2 = coupled inductor between loop 2 and loop 3
- L_3 = coupled inductor in the right branch
- C = capacitor in the right branch

Loop 1 (left mesh):

$$v(t) = R_1 i_1 + R_2 i_1 + L_1 \frac{d}{dt}(i_1 - i_2) + M_{12} \frac{d}{dt}(i_2 - i_3) + M_{13} \frac{di_3}{dt}$$

Loop 2 (middle mesh):

$$0 = L_1 \frac{d}{dt}(i_2 - i_1) + M_{12} \frac{d}{dt}(i_1 - i_2) + L_2 \frac{d}{dt}(i_2 - i_3) + M_{23} \frac{di_3}{dt}$$

Loop 3 (right mesh):

$$0 = L_2 \frac{d}{dt}(i_3 - i_2) + M_{23} \frac{d}{dt}(i_2 - i_3) + L_3 \frac{di_3}{dt} + M_{13} \frac{d}{dt}(i_1 - i_2) + \frac{1}{C} \int i_3 dt$$

Final Answer

$$\begin{aligned} v(t) &= R_1 i_1 + R_2 i_1 + L_1 \frac{d}{dt}(i_1 - i_2) + M_{12} \frac{d}{dt}(i_2 - i_3) + M_{13} \frac{di_3}{dt} \\ 0 &= L_1 \frac{d}{dt}(i_2 - i_1) + M_{12} \frac{d}{dt}(i_1 - i_2) + L_2 \frac{d}{dt}(i_2 - i_3) + M_{23} \frac{di_3}{dt} \\ 0 &= L_2 \frac{d}{dt}(i_3 - i_2) + M_{23} \frac{d}{dt}(i_2 - i_3) + L_3 \frac{di_3}{dt} + M_{13} \frac{d}{dt}(i_1 - i_2) + \frac{1}{C} \int i_3 dt \end{aligned}$$

Note: If the dots are marked opposite to the above assumption, change the signs of the corresponding mutual inductance terms.
