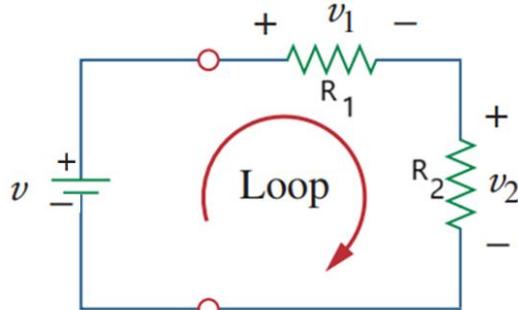


## Section-B

### 1. State and explain Kirchoff's laws

- **Kirchhoff's Voltage Law (KVL)** states that the total voltage around any closed loop in a circuit is zero.
- The algebraic sum of voltages around each loop is zero.

$$\Sigma \text{ Voltage Drops} - \Sigma \text{ Voltage Rises} = 0$$



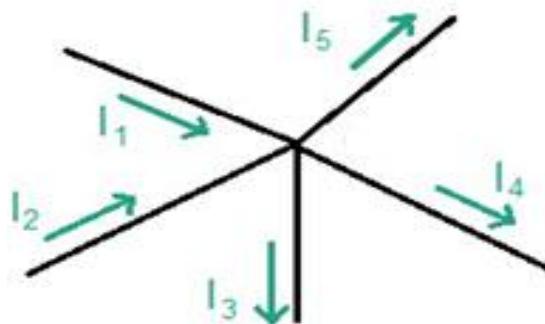
According to KVL:

$$\sum v = 0$$

$$-v + v_1 + v_2 = 0$$

- **Kirchhoff's Current Law (KCL)** states that the total current entering a node in an electrical circuit is equal to the total current leaving the node.
- The algebraic sum of currents entering a node is zero.

$$\Sigma \text{ Currents In} - \Sigma \text{ Currents Out} = 0$$



According to KCL:

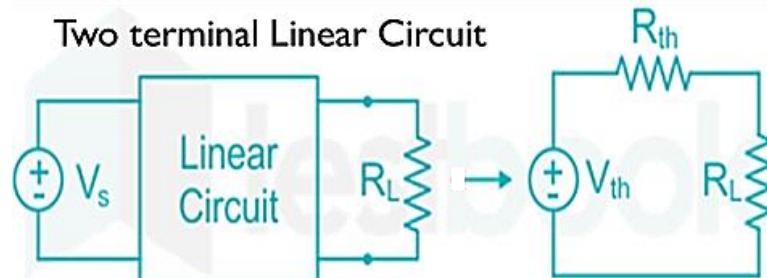
$$\sum I = 0$$

$$I_1 + I_2 - I_3 - I_4 - I_5 = 0$$

$$I_1 + I_2 = I_3 + I_4 + I_5$$

2. State and explain Maximum Power transfer theorem

The maximum power transfer theorem states that maximum power is transferred (delivered) from a source to a load when the load resistance ( $R_L$ ) is equal to the Thevenin's equivalent resistance ( $R_{th}$ ) of the source circuit.



Consider a Thevenin equivalent circuit consisting of a voltage source  $V_{th}$  with an internal resistance  $R_{th}$ , connected to a load resistance  $R_L$ .

Power delivered to the load is given by

$$\begin{aligned} P_L &= I_L^2 R_L \\ &= \frac{V_{th}^2}{(R_{th}+R_L)^2} R_L \end{aligned}$$

To maximize power, differentiate  $P_L$  with respect to  $R_L$  and set it to zero

$$\frac{dP_L}{dR_L} = 0$$

Which leads to  $R_{th} - R_L = 0$

$$\begin{aligned} \therefore R_L &= R_{th} \\ &= \frac{V_{th}^2}{(R_{th}+R_{th})^2} R_{th} \end{aligned}$$

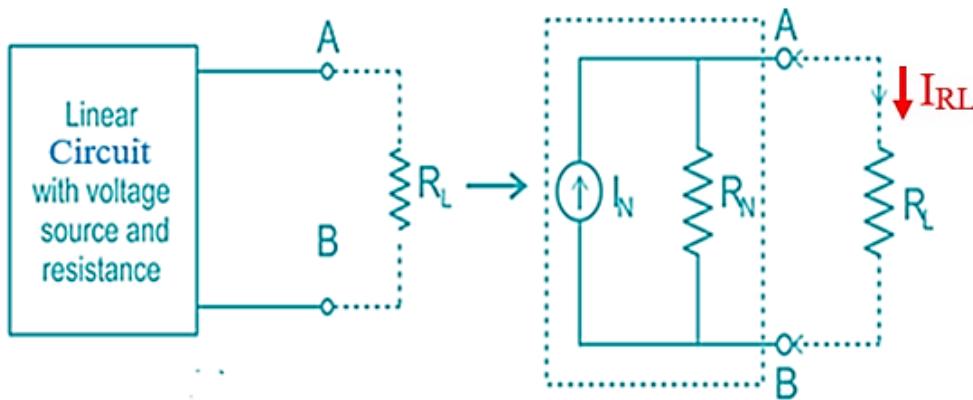
Maximum power delivered to the load is

$$P_{max} = \frac{V_{th}^2}{4R_L} = \frac{V_{th}^2}{4R_{th}}$$

### 3. State and explain Norton's theorem

Any two-terminal linear circuit having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a Norton current source ( $I_N$ ) in parallel with a resistance ( $R_N$ ).

#### Two terminal Linear Circuit



The equivalent **Norton current**  $I_N$  is the **short-circuit current** between the two terminals, and the **Norton resistance**  $R_N$  is the same as the Thevenin resistance  $R_{th}$  which is found by deactivating all independent sources and calculating the equivalent resistance seen from the terminals.

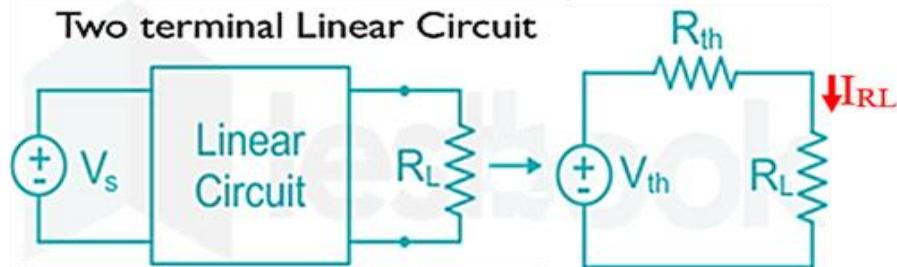
Simple Steps/Procedure to analyze electric circuit through Norton's Theorem and determine  $I_N$ ,  $R_N$ , and  $I_{RL}$ :

1. Remove the load resistor ( $R_L$ ) and replace it with a short circuit ( $I_{SC}=I_N$ ).
2. Calculate the Norton current ( $I_N$ )-the current through the short circuit.
3. All voltage sources are replaced with short circuits, and all current sources are replaced with open circuits. Calculate the Norton resistance ( $R_N$ )-the total resistance between the open circuit connection points.
4. Now, Redraw the circuit with the Norton current source ( $I_N$ ) in parallel with the Norton resistance ( $R_N$ ). The load resistor ( $R_L$ ) re-attaches between the two open points of the equivalent circuit. Now find the total current flowing through the load resistor by using  

$$I_{RL} = I_N \frac{R_N}{(R_N + R_L)}$$

#### 4. State and explain Thevenin's theorem

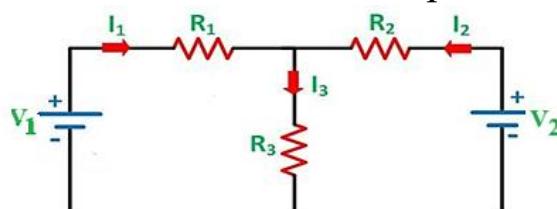
Any two-terminal linear circuit having a number of voltage current sources and resistances can be replaced by a simple equivalent circuit consisting of a single voltage source ( $V_{th}$ ) in series with a resistance ( $R_{th}$ ).



Simple Steps/Procedure to analyze electric circuit through Thevenin's Theorem and determine  $V_{th}$ ,  $R_{th}$  and  $I_{RL}$ :

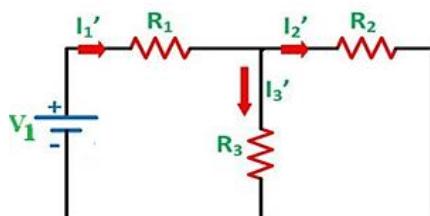
1. Open/remove the load resistor ( $R_L$ ).
2. Calculate the Thevenin Voltage ( $V_{th}$ ) (Open Circuit Voltage).
3. Open Current Sources and Short Voltage Sources. Calculate the Thevenin Resistance ( $R_{th}$ ) (Open Circuit Resistance).
4. Now, Redraw the circuit with ( $V_{th}$ ) in Step (2) as voltage Source and ( $R_{th}$ ) in step (3) as a series resistance and connect the load resistor ( $R_L$ ) which we had removed in Step (1). This is the Equivalent Thevenin Circuit. Now find the total current flowing through load resistor by using the Ohm's Law  $I_{RL} = \frac{V_{th}}{(R_{th} + R_L)}$ .
5. State and explain Superposition theorem

The response in any two-terminal linear circuit with multiple independent sources is the sum of the individual responses, considering one source at a time while the other sources are non-operative.

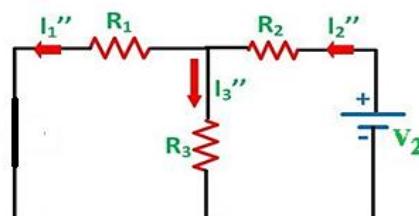


Circuit Diagram A

**Transferred to Circuit Diagrams B and C**



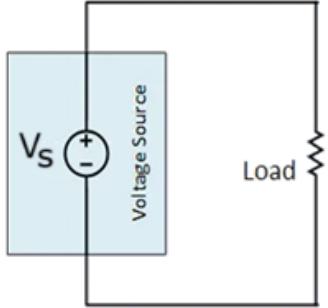
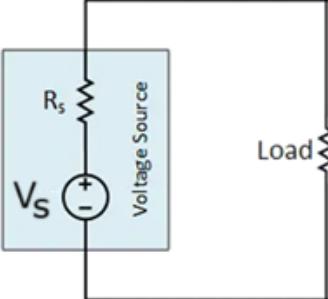
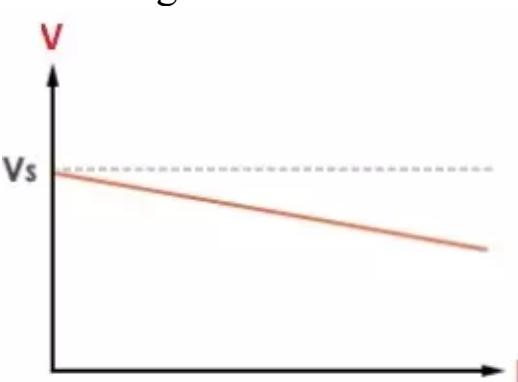
Circuit Diagram B



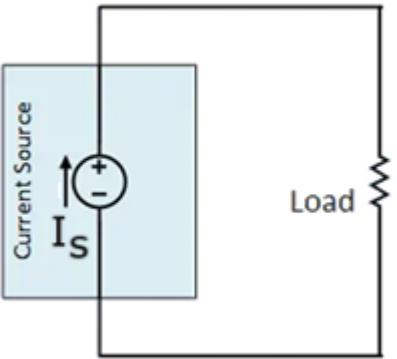
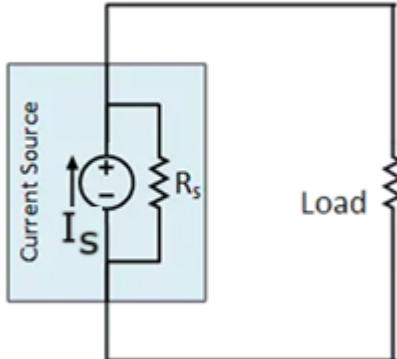
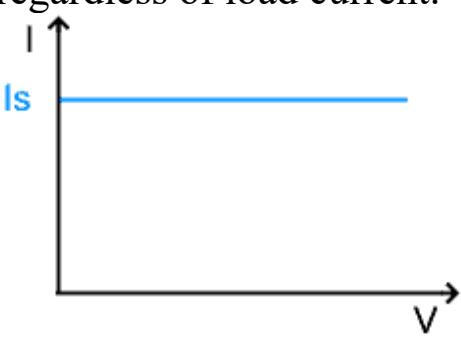
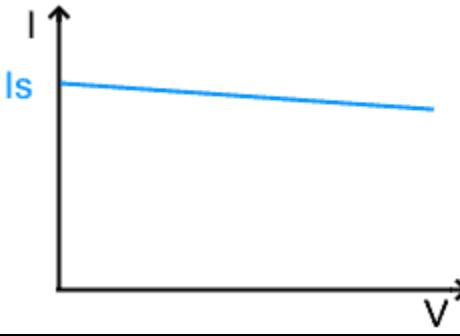
Circuit Diagram C

## Steps of Applying Superposition Principle:

1. Deactivate all independent sources except one source. If the internal resistance of the sources is neglected then the deactivated voltage source is replaced with a “Short Circuit” ( $R = 0 \Omega$ ) and the deactivated current source is replaced with an open circuit ( $R = \infty$ ) respectively then find the corresponding ( $V$  or  $I$ ) due to that active source.
2. Repeat step (1) for each of the other independent sources.
3. Find the total contribution ( $V$  or  $I$ ) by adding algebraically all the voltages or currents due to the independent sources.
6. List out difference between ideal and real voltage sources.

Ideal voltage sources	Real voltage sources
<p>Ideal voltage sources are perfect models used for theoretical analysis.</p> 	<p>Real voltage sources have limitations due to internal resistance, leading to voltage drops and power losses in practical applications.</p> 
<p>Maintains a constant voltage regardless of load current.</p> 	<p>Provides voltage that decreases with increasing load due to internal resistance.</p> 
<p>Internal Resistance (<math>R_s</math>) is zero. causing no voltage drop.</p>	<p>Small but nonzero (<math>R_s &gt; 0</math>) causing voltage drop.</p>
<p>Voltage remains constant under any load condition.</p>	<p>Voltage drops as current increases.</p>
<p>No internal power loss.</p>	<p>Some power is lost due to internal resistance (<math>P = I^2 R_s</math>).</p>

7. List out difference between ideal and real current sources.

Ideal current sources	Real current sources
<p>The ideal current source provides the same current to any load resistance and doesn't change its current by changing a load resistance.</p> 	<p>Ideal current source is connected in parallel with the internal resistance, and the current flowing through it depends on the load.</p> 
<p>Maintains a constant current regardless of load current.</p> 	<p>Provides current that decreases with increasing load due to internal resistance.</p> 
<p>Source resistance is infinite.</p>	<p>Source resistance is high.</p>
<p>Current remains constant under any load condition.</p>	<p>Current drops as voltage increases.</p>
<p>No internal power loss.</p>	<p>Some power is lost due to internal resistance (<math>P = I^2 R_s</math>).</p>

## 8. List out the differences between Mesh and Nodal Analysis.

Aspect	Mesh Analysis	Nodal Analysis
<b>Basis</b>	Based on Kirchhoff's Voltage Law (KVL).	Based on Kirchhoff's Current Law (KCL).
<b>Unknown Variables</b>	Solves for mesh currents (currents flowing in closed loops).	Solves for node voltages (voltages at circuit nodes).
<b>Applicability</b>	Best suited for circuits with many series elements and fewer current sources.	Best suited for circuits with many parallel elements and fewer voltage sources.
<b>Complexity</b>	Easier to use when the circuit has fewer meshes (loops).	Easier to use when the circuit has fewer nodes.
<b>Equations</b>	Equations are formed by applying KVL to each mesh.	Equations are formed by applying KCL at each node.
<b>Preferred Use</b>	Preferred for planar circuits (circuits that can be drawn on a plane without overlapping wires).	Preferred for both planar and non-planar circuits.

### Key Points:

- Mesh analysis uses **KVL** and solves for **mesh currents**.
- Nodal analysis uses **KCL** and solves for **node voltages**.
- Mesh analysis is simpler for circuits with fewer loops, while nodal analysis is simpler for circuits with fewer nodes.

## 9. List out the steps followed in Mesh analysis.

- a) Identify Meshes:
  - Identify all the independent closed loops (meshes) in the circuit. A mesh is a loop that does not contain any other loops within it.
- b) Assign Mesh Currents:
  - Assign a current variable to each mesh. The direction of the current can be chosen arbitrarily (clockwise or counterclockwise).
- c) Apply Kirchhoff's Voltage Law (KVL):
  - Write KVL equations for each mesh by summing the voltage drops and rises around the loop. For each mesh, the algebraic sum of voltages is set to zero.
- d) Solve the Equations:
  - Solve the system of linear equations obtained from the KVL equations to find the mesh currents.
- e) Determine Branch Currents:
  - Use the mesh currents to determine the currents in individual branches of the circuit. If a branch is shared by two meshes, the branch current is the algebraic sum or difference of the mesh currents.

## 10. List out the steps followed in Nodal analysis.

- a) Identify Nodes:
  - Identify all the principal nodes in the circuit. A node is a point where two or more circuit elements are connected.
- b) Select a Reference Node:
  - Choose one node as the reference node (usually the one with the most connections) and assign it a potential of zero volts.
- c) Assign Node Voltages:
  - Assign voltage variables to the remaining non-reference nodes. These voltages are measured with respect to the reference node.
- d) Apply Kirchhoff's Current Law (KCL):
  - Write KCL equations for each non-reference node by summing the currents leaving the node and setting the sum to zero. Express the currents in terms of the node voltages using Ohm's Law ( $I = V/R$ ).
- e) Solve the Equations:
  - Solve the system of linear equations obtained from the KCL equations to find the node voltages.
- f) Determine Branch Currents and Voltages:
  - Use the node voltages to determine the currents and voltages in individual branches of the circuit.

## 11. List out the steps followed to find Thevenin's theorem.

**Statement:** Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source  $V_{Th}$  in series with a resistor  $R_{Th}$ , where  $V_{Th}$  is the open-circuit voltage at the terminals and  $R_{Th}$  is the input or equivalent resistance at the terminals when the independent sources are turned off.

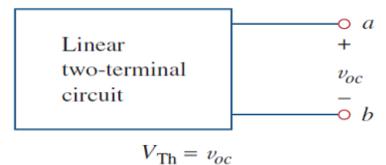
Step 1: Open the load resistor.

Step 2: Calculate the open circuit voltage. This is the Thevenin Voltage ( $V_{Th}$ ).

Step 3: Open current sources and short voltage sources.

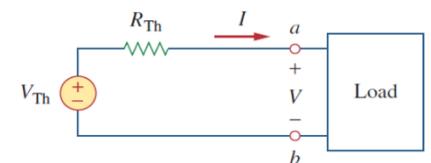
Step 4: Calculate the Open Circuit Resistance. This is the Thevenin Resistance ( $R_{Th}$ ).

Step 5: Now, redraw the circuit with a series combination of open circuit Voltage ( $V_{Th}$ ) calculated in Step (b), open circuit resistance ( $R_{Th}$ ) calculated in step (d) with load resistor  $R_L$  which we had removed in Step (a). This is the equivalent Thevenin circuit of the linear electric network.



Step 6: Now find the Total current flowing through the load resistor by using the Ohm's Law:

$$I_T = V_{Th} / (R_{Th} + R_L).$$



## 12. List out the steps followed to find Norton's theorem.

**Statement:** Norton's theorem states that any linear, bilateral electrical network with voltage and current sources and resistances can be replaced by an equivalent circuit consisting of a single current source in parallel with a single resistor. The current source is called the Norton equivalent current ( $I_N$ ), and the resistor is called the Norton equivalent resistance ( $R_N$ ).

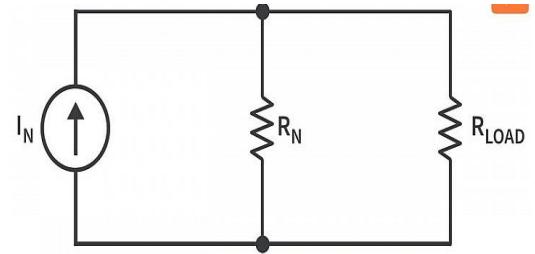
Step 1: Remove the load resistor and replace it with a short circuit.

Step 2: Calculate the Norton current—the current through the short circuit.

Step 3: All voltage sources are replaced with short circuits, and all current sources are replaced with open circuits.

Step 4: Calculate the Norton resistance —the total resistance between the open circuit connection points after all sources have been removed.

Step 5: Draw the Norton equivalent circuit, with the Norton current source in parallel with the Norton resistance. The load resistor re-attaches between the two open points of the equivalent circuit.



(13)  $i_1 = 100 \sin(100t)$   
 $i_2 = 200 \cos(100t + 30^\circ)$   
Find  $i_1 + i_2$

Ans:  $i_1 = 100 \sin(100t) = 100 \cos(100t - 90^\circ)$   
 $i_2 = 200 \cos(100t + 30^\circ)$

Phasor form  $\begin{cases} i_1 = 100 [-90^\circ] \\ i_2 = 200 [30^\circ] \end{cases}$

Rectangular form  $\begin{cases} i_1 = 100 [\cos(-90^\circ) + j \sin(-90^\circ)] = 100 [-j] = -j100 \\ i_2 = 200 [\cos 30^\circ + j \sin 30^\circ] = 173.2 + j100 \end{cases}$

$$\begin{aligned} i_1 + i_2 &= -j100 + 173.2 + j100 = 173.2 + j(0) \\ &= 173.2 [0^\circ] \\ &= 173.2 \cos(100t) \end{aligned}$$

(14)  $i_1 = 100 \cos(100t)$   
 $i_2 = 200 \sin(100t + 30^\circ)$  } Find  $(i_1 - i_2)$

$i_1 = 100 \cos(100t)$

$i_2 = 200 \sin(100t + 30^\circ) = 200 \cos(100t + 30^\circ - 90^\circ) = 200 \cos(100t - 60^\circ)$

Phasor form  $\begin{cases} i_1 = 100 [0^\circ] \\ i_2 = 200 [-60^\circ] \end{cases}$

Rectangular form  $\begin{cases} i_1 = 100 + j(0) \\ i_2 = 200 [\cos(-60^\circ) + j \sin(-60^\circ)] \\ = 100 - j173.2 \end{cases}$

$$\begin{aligned} i_1 - i_2 &= 100 - 100 + j173.2 = j173.2 \\ &= 173.2 [90^\circ] \\ &= 173.2 \cos(100t + 90^\circ) \end{aligned}$$

$$\textcircled{15} \quad \left. \begin{array}{l} i_1 = 100 \sin(100t) \\ i_2 = 200 \sin(100t + 30^\circ) \end{array} \right\} \text{Find } i_1 * i_2$$

$$i_1 = 100 \sin(100t) = 100 \cos(100t - 90^\circ)$$

$$i_2 = 200 \sin(100t + 30^\circ) = 200 \cos(100t + 30^\circ - 90^\circ) = 200 \cos(100t - 60^\circ)$$

$$\text{Phasor} \left\{ \begin{array}{l} i_1 = 100 \angle -90^\circ \\ i_2 = 200 \angle -60^\circ \end{array} \right.$$

$$i_1 * i_2 = 100 \angle -90^\circ * 200 \angle -60^\circ = 20000 \angle -150^\circ \\ = 20000 \cos(100t - 150^\circ)$$

$$\textcircled{16} \quad \left. \begin{array}{l} i_1 = 100 \cos(100t) \\ i_2 = 200 \cos(100t + 30^\circ) \end{array} \right\} \text{Find } i_1 \div i_2$$

$$\text{Phasor} \left\{ \begin{array}{l} i_1 = 100 \angle 0^\circ \\ i_2 = 200 \angle 30^\circ \end{array} \right.$$

$$\frac{i_1}{i_2} = \frac{100 \angle 0^\circ}{200 \angle 30^\circ} = \frac{1}{2} \angle -30^\circ = 0.5 \angle -30^\circ \\ = 0.5 \cos(100t - 30^\circ)$$

$$\textcircled{17} \quad \left. \begin{array}{l} i_1 = 100 \sin(100t) \\ i_2 = 200 \cos(100t + 30^\circ) \end{array} \right\} \text{Find } (i_1 * i_2)^3$$

$$i_1 = 100 \sin(100t) = 100 \cos(100t - 90^\circ)$$

$$i_2 = 200 \cos(100t + 30^\circ) \cancel{\neq 200}$$

$$\text{Phasor} \left\{ \begin{array}{l} i_1 = 100 \angle -90^\circ \\ i_2 = 200 \angle 30^\circ \end{array} \right.$$

$$i_1 * i_2 = 100 \angle -90^\circ * 200 \angle 30^\circ = 20000 \angle -60^\circ$$

$$(i_1 * i_2)^3 = (20000 \angle -60^\circ)^3 = 8 \times 10^{12} \angle -180^\circ$$

$$= 8 \times 10^{12} \cos(100t - 180^\circ)$$

### 18. Show that in pure resistor ac current and voltages are in same phase.

Consider the function  $i(t) = I_m \sin \omega t = I_m \cos(\omega t - 90^\circ)$

Phasor representation  $I = I_m \angle -90^\circ$

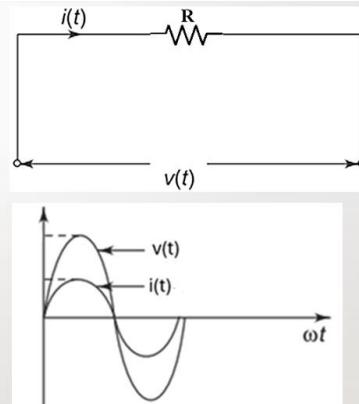
The voltage current relation in the case of an **resistor** is given by

$$v(t) = i(t)R = I_m R \cos(\omega t - 90^\circ)$$

Phasor representation  $V = RI_m \angle -90^\circ$

$$Z = \frac{V}{I} = \frac{RI_m \angle -90^\circ}{I_m \angle -90^\circ}$$

$$\therefore Z = R$$



Voltage wave form follows current wave form. Voltage and current phasor are in phase.

### 19. Show that in pure inductor ac current lags over voltage by $90^\circ$ phase.

Consider the function  $i(t) = I_m \sin \omega t = I_m \cos(\omega t - 90^\circ)$

Phasor representation  $I = I_m \angle -90^\circ$

The voltage current relation in the case of an **inductor** is given by

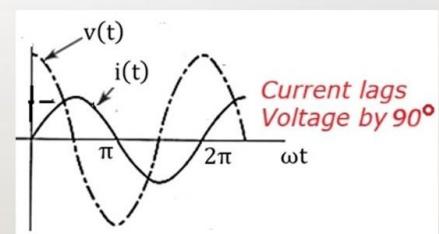
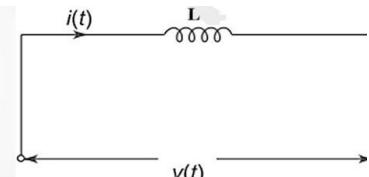
$$v(t) = L \frac{di(t)}{dt} = L \frac{d}{dt} (I_m \cos(\omega t - 90^\circ)) = -L\omega I_m \sin(\omega t + 90^\circ) = L\omega I_m \cos(\omega t - 90^\circ + 90^\circ)$$

Phasor representation  $V = L\omega I_m \angle 0^\circ$

$$Z = \frac{V}{I} = \frac{L\omega I_m \angle 0^\circ}{I_m \angle -90^\circ} = L\omega \angle +90^\circ = j\omega L$$

$$\therefore Z = j\omega L = jX_L$$

Where  $X_L = \omega L$  and is called inductive reactance.



The current lags behind the voltage by  $90^\circ$ .

### 20. Show that in pure capacitor ac current lags over voltage by $90^\circ$ phase.

Consider the function  $i(t) = I_m \sin \omega t = I_m \cos(\omega t - 90^\circ)$

Phasor representation  $I = I_m \angle -90^\circ$

The voltage current relation in the case of an **capacitor** is given by

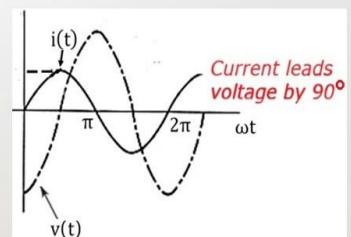
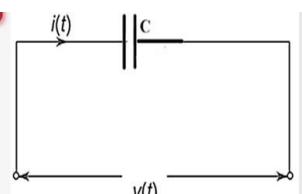
$$v(t) = \frac{1}{C} \int i(t) dt = \frac{I_m}{C} \int \cos(\omega t - 90^\circ) dt = \frac{I_m}{\omega C} \sin(\omega t - 90^\circ) = \frac{I_m}{\omega C} (\cos \omega t - 90^\circ - 90^\circ)$$

$$\text{Phasor representation } V = \frac{I_m}{\omega C} \angle -180^\circ$$

$$Z = \frac{V}{I} = \frac{\frac{I_m}{\omega C} \angle -180^\circ}{I_m \angle -90^\circ} = \frac{1}{\omega C} \angle -90^\circ = \frac{-j}{\omega C}$$

$$\therefore Z = \frac{-j}{\omega C} = -jX_C$$

Where  $X_C = \frac{1}{\omega C}$  and is called capacitive reactance.



The current leads the voltage by  $90^\circ$ .

## SECTION-C

1. A  $50\mu F$  capacitor is connected across a  $230V$ ,  $50Hz$  supply. Calculate (a) the reactance offered by the capacitor (b) the maximum current (c) the r.m.s. value of the current drawn by the capacitor (d) the maximum energy stored in the capacitor and (e) plot the current and voltage waveforms.

Given that  $C = 50\mu F$ ,  $f = 50Hz \therefore \omega = 2\pi f = 100\pi$  and

$$V_m = 230\sqrt{2} V$$

$$\text{Capacitive reactance } X_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 50 \times 10^{-6}} = 63.66 \Omega$$

$$\text{The capacitive reactance is } -jX_C = -j63.66 = 63.66 \angle -90^\circ$$

$$\text{The maximum current } I_m = \frac{V_m}{|X_C|} = \frac{230\sqrt{2}}{63.66} = 5.109 A$$

$$\text{The rms value of the current} = \frac{I_m}{\sqrt{2}} = 0.707 \times 5.109 = 3.613$$

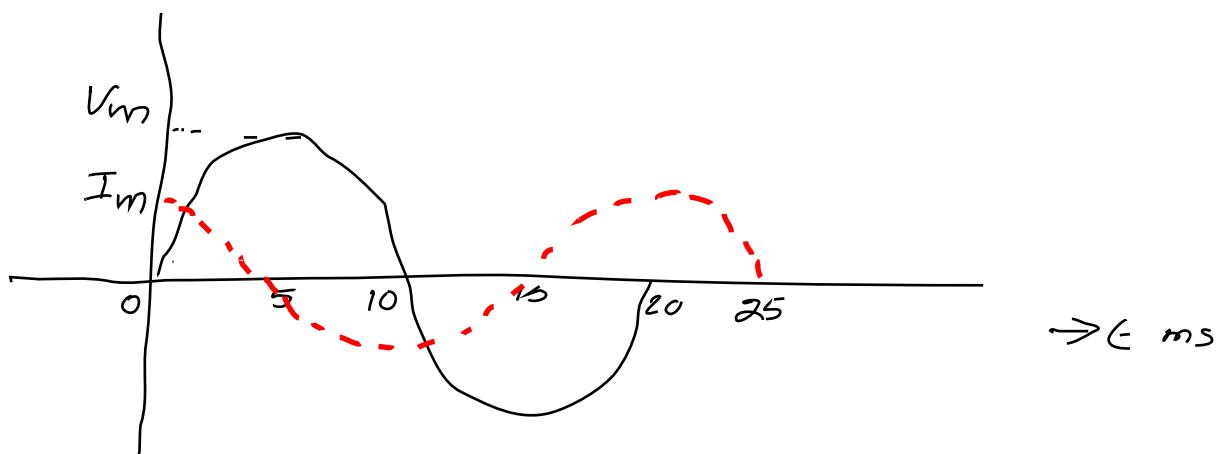
$$\text{The maximum energy stored } E = \frac{1}{2} CV_m^2 = \frac{1}{2} \times 50 \times 10^{-6} (230\sqrt{2})^2 \\ = 2.645 \text{ Joules}$$

$$\text{Here } V = 230\sqrt{2} \sin 100\pi t$$

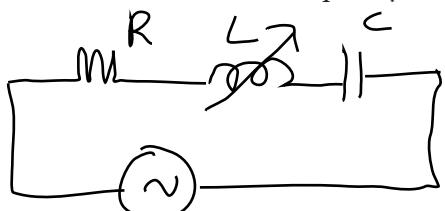
$$V = 230\sqrt{2} \angle -90^\circ ; I = \frac{230\sqrt{2} \angle -90^\circ}{63.66 \angle -90^\circ} = 5.109 \angle 0^\circ$$

$$\therefore i = 5.109 \cos 100\pi t = 5.109 \sin(100\pi t + 90^\circ)$$

$$\text{Here } f = 50Hz \therefore T = \frac{1}{f} = 20ms$$



2. For a series R-L-C circuit the inductor is variable. Source voltage is  $283\sin 100\pi t$ . Maximum current obtainable by varying the inductance is 0.314 A and the voltage across the capacitor then is 300V. Find the circuit element values, resonance frequency, Q-factor and bandwidth of the circuit.



$$\text{Here } V(t) = 283\sin 100\pi t \text{ V}$$

$$\omega = 100\pi.$$

Since 'L' varied at one instant  
current is maximum means, the circuit is in resonance and the resonance frequency  $\omega_0 = \omega$   
 $\Rightarrow \omega_0 = 100\pi \Rightarrow f_0 = \frac{100}{2\pi} = 50\text{Hz}$

at resonance current is maximum

$$I = I_0 = \frac{V_m}{|Z|} \quad \text{. Here } Z = R + jX$$

$$\text{where } X = 0 \Rightarrow X_L = X_C$$

$$\therefore I_0 = \frac{V_m}{R} = \frac{283}{R} \Rightarrow R = \frac{283}{0.314} = 901.27\Omega$$

$$\text{at resonance } |jX_L| = |-jX_C|$$

$$\text{and } |V_L| = |V_C| = 300$$

$$\text{but } |V_L| = |jX_L I_0| = \omega_0 L I_0 = 300$$

$$\therefore L = \frac{300}{\omega_0 I_0} = \frac{300}{100\pi \times 0.314} = 3.041 \text{ H}$$

$$\text{but } |V_C| = |-jX_C I_0| = \frac{I_0}{\omega_0 C} = 300$$

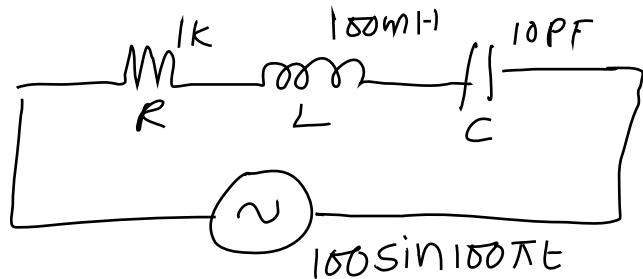
$$\Rightarrow C = \frac{I_0}{300\omega_0} = \frac{0.314}{300 \times 100\pi} = 3.332 \mu\text{F}$$

$$\text{The Q-factor} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 R C} = \frac{1}{R} \sqrt{\frac{L}{C}} = 1.06$$

$$\text{Bandwidth } \Delta f = \frac{R}{2\pi L} = 47.17 \text{ Hz}$$

$$\text{or } \Delta f = \frac{f_0}{Q} = \frac{50}{1.06} = 47.17 \text{ Hz}$$

3. A series circuit with  $R = 1\text{k}\Omega$ ,  $L = 100 \text{ mH}$  and  $C = 10 \mu\text{F}$  is supplied with 100V, 50 Hz. Determine the impedance, current, power factor, resonance frequency, Q-factor and bandwidth of the circuit.



$$\begin{aligned} \text{Here } JX_L &= JW_L \\ &= J 100\pi \times 100 \times 10^{-3} \\ &= J 10\pi \sqrt{2} = 10\pi \angle 90^\circ \end{aligned}$$

$$-J X_C = -\frac{J}{\omega C} = -\frac{J}{100\pi \times 10 \times 10^{-6}} = -J 318.31 \Omega$$

$$\begin{aligned} \text{The impedance } Z &= R + JX_L - JX_C = 1000 + j10\pi - J318.31 \\ &= 1000 - J286.9 \Omega = 1040 \angle -16^\circ \end{aligned}$$

$$\text{At resonance } Z = R = 1000 \Omega$$

$$\text{Current } I_0 = \frac{V_m}{R} = \frac{100}{1000} = 0.1 \text{ A}$$

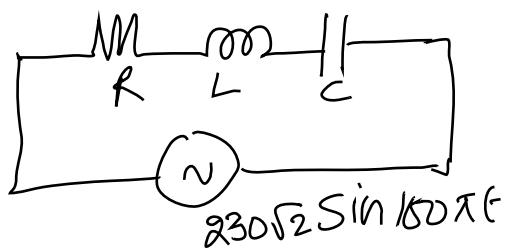
$$\text{Power factor PF} = \cos 0^\circ = 1$$

$$\text{Resonance frequency } f_0 = \frac{1}{2\pi\sqrt{LC}} = 159.15 \text{ Hz}$$

$$\text{Q-factor} = \frac{\omega_0 L}{R} = \frac{2\pi \times 159.15 \times 100 \times 10^3}{1000} \approx 0.1$$

$$\text{Bandwidth } \Delta f = \frac{R}{2\pi L} = 1591.5 \text{ Hz} = \frac{f_0}{Q}$$

4. A series circuit with  $R = 100\Omega$ ,  $L = 10 \text{ mH}$  and  $C = 10 \mu\text{F}$  is supplied with 230V, 50 Hz. Determine the impedance, current, power factor resonance frequency, Q-factor and bandwidth of the circuit.



$$\begin{aligned} \text{Impedance } Z &= R + jX_L + jX_C \\ &= 100 + j(100\pi \times 10 \times 10^{-3}) \\ &= 100 + j314 \Omega \end{aligned}$$

$$\begin{aligned} -jX_C &= -\frac{j}{\omega C} = -\frac{j}{100\pi \times 10 \times 10^{-6}} \\ &= -j318.3 \Omega = 318.3 \angle -90^\circ \Omega \end{aligned}$$

$$\begin{aligned} Z &= R + jX \\ &= 100 + j314 - j318.3 = 100 - j315.17 = 100 \angle -72.4^\circ \end{aligned}$$

The impedance at resonance  $Z = R$   $\therefore X = 0$

$$\therefore Z = 100\Omega ; \text{ current } I_0 = \frac{V_m}{|Z|} = \frac{230\sqrt{2}}{100} = 3.253 \text{ A}$$

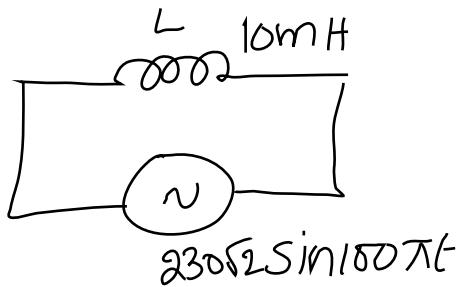
$$\text{power factor} = \cos 0^\circ = 1$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10 \times 10^{-3} \times 10 \times 10^{-6}}} = 503.3 \text{ Hz}$$

$$\begin{aligned} \text{Q-factor (Q)} &= \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R} = \frac{2\pi \times 503.3 \times 10 \times 10^{-3}}{100} \\ &= 0.316 \end{aligned}$$

$$\text{Bandwidth } \Delta f = \frac{R}{2\pi L} = \frac{f_0}{Q} = \frac{100}{2\pi \times 10 \times 10^{-3}} = 1591.5 \text{ Hz}$$

5. A 10mH inductor is connected across a 230V, 50Hz supply. Calculate (a) the reactance offered by the inductor (b) the maximum current and (c) the rms value of the current drawn by the inductor (d) the maximum energy stored in the inductor and (e) plot the current and voltage waveform.



The Reactance  $\Im X_L$

$$= \Im \omega L$$

$$= 3100\pi \times 10 \times 10^{-3}$$

$$= 31\pi \Omega = \pi \boxed{90^\circ}$$

$$V = 230\sqrt{2} \sin 100\pi t$$

$$\therefore V = 230\sqrt{2} \boxed{-90^\circ} \quad \text{Hence current } I_m = \frac{V}{\Im X_L}$$

$$= \frac{230\sqrt{2} \boxed{-90^\circ}}{\pi \boxed{90^\circ}} = 103.54 \boxed{-180^\circ} A$$

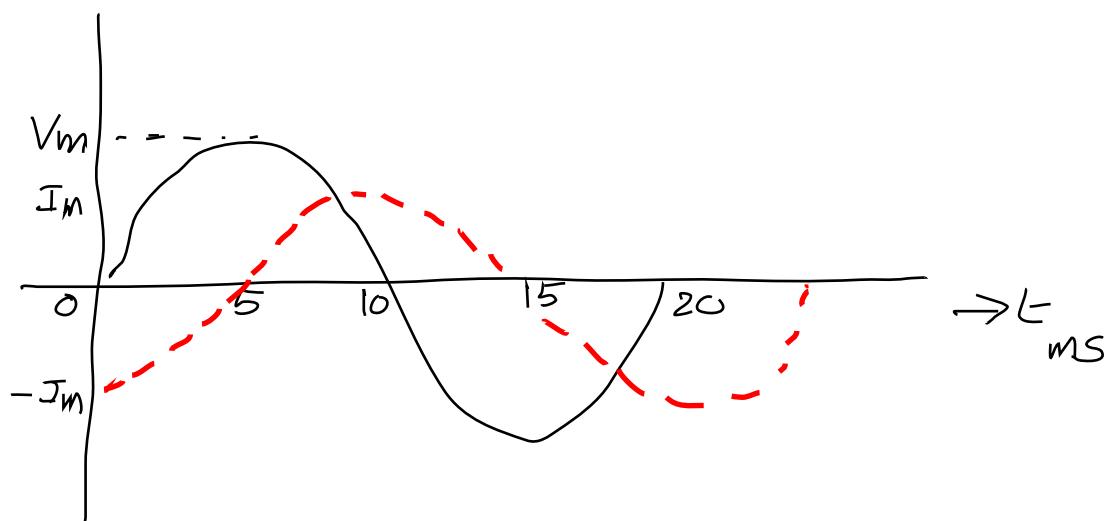
i.e.  $i = 103.54 \sin(100\pi t - 90^\circ)$

$$\text{The rms current} = \frac{I_m}{\sqrt{2}} = 103.54 \times 0.707 = 73.21 A$$

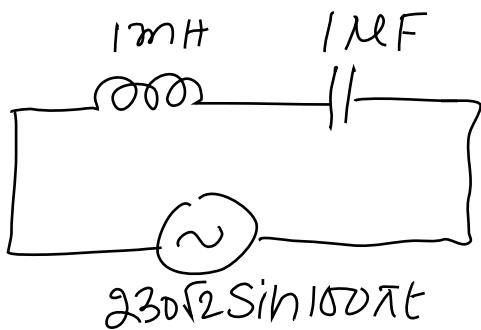
The maximum Energy stored in the inductor

$$\text{is } E = \frac{1}{2} L I_m^2 = \frac{1}{2} \times 10 \times 10^{-3} \times 103.54^2$$

$$= 53.60 \text{ Joules}$$



6. A 1mH inductor and a  $1\mu\text{F}$  capacitor are connected in series with a 230V, 50Hz supply. Calculate (a) the reactance offered by the inductor (b) the maximum current and (c) the rms value of the current drawn by the inductor (d) the maximum energy stored in the inductor and (e) plot the current and voltage waveform.



$$\text{Here } \omega = 100\pi$$

$$V = 230\sqrt{2} \sin 100\pi t$$

$$V = 230\sqrt{2} \angle -90^\circ$$

$$\text{Inductive reactance } JX_L = JW = J100\pi \times 1 \times 10^{-3} \\ = J0.314\sqrt{2} = 0.314 \angle 90^\circ$$

$$\text{Capacitive reactance } -JX_C = \frac{-J}{\omega C} = \frac{-J}{100\pi \times 10^{-6}} \\ = -J3183 \Omega = 3183 \angle -90^\circ \Omega$$

$$\text{Now } Z = JX_L + JX_C = J0.314 - J3183 \\ = -J3182.7 \Omega = 3182.7 \angle -90^\circ \Omega$$

$$\text{Hence current } i = \frac{V}{Z} = \frac{230\sqrt{2} \angle -90^\circ}{3182.7 \angle -90^\circ} = 102 \angle 0^\circ \text{ mA}$$

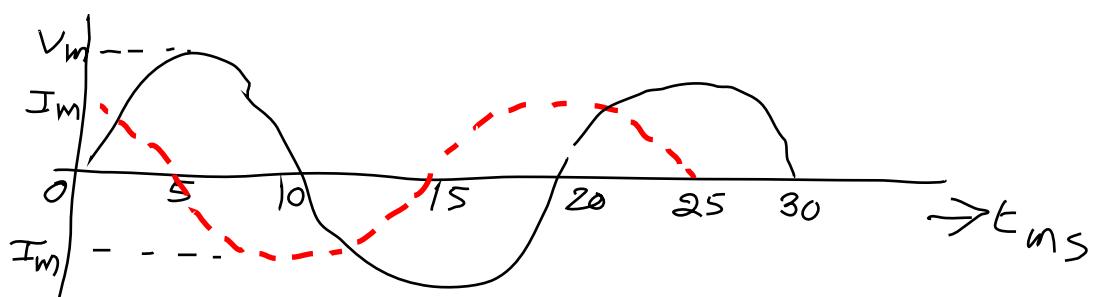
$$\text{Hence } i = 102 \sin(100\pi t + 90^\circ) \text{ mA}$$

$$\text{maximum current (in the inductor)} = 102 \text{ mA}$$

$$\text{rms current} = 102 \times 0.707 = .723$$

maximum energy stored in the inductor is

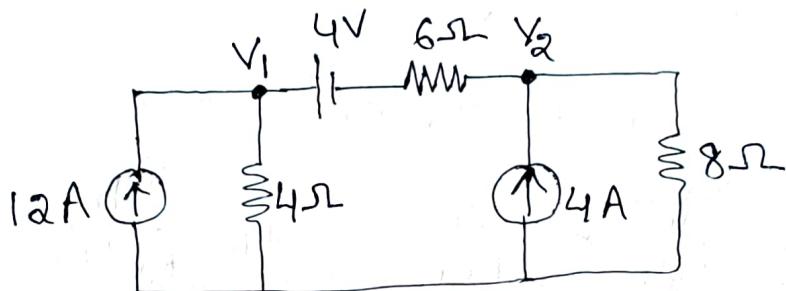
$$E = \frac{1}{2} L I_m^2 = \frac{1}{2} \times 10^{-3} (102 \times 10^{-3})^2 \\ = 5.202 \mu \text{ Joules}$$



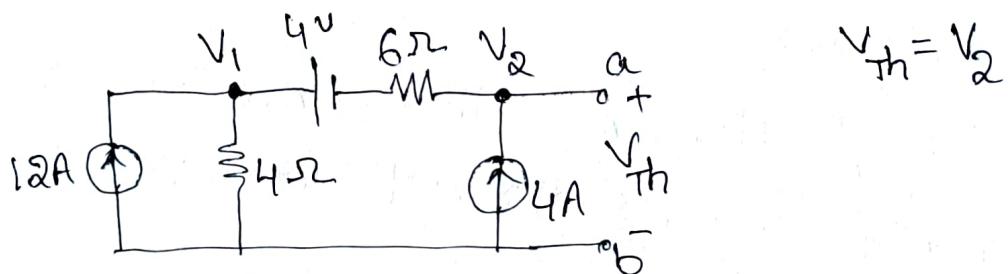
(1)

## Section-C

7. Using Thévenin's theorem, find the current flowing through the  $8\Omega$  resistor of the network shown.



Sol:- (i) To find  $V_{th}$ : Remove  $R_L = 8\Omega$



By nodal analysis,

$$\text{At node-1: } \frac{V_1}{4} + \frac{V_1 - 4 - V_2}{6} = 12$$

$$3V_1 + 2V_1 - 8 - 2V_2 = 144$$

$$5V_1 - 2V_2 = 152 \rightarrow ①$$

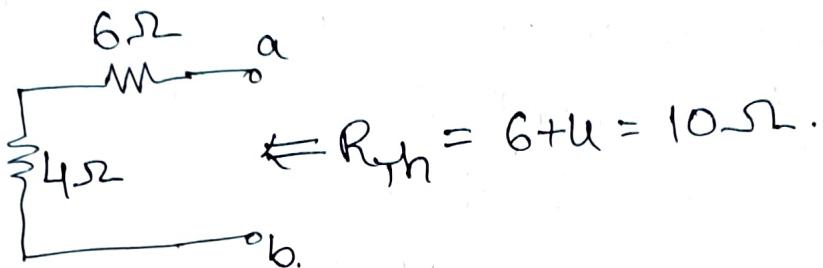
$$\text{At node-2: } \frac{V_2 + 4 - V_1}{6} = 4$$

$$-V_1 + V_2 = 20 \rightarrow ②$$

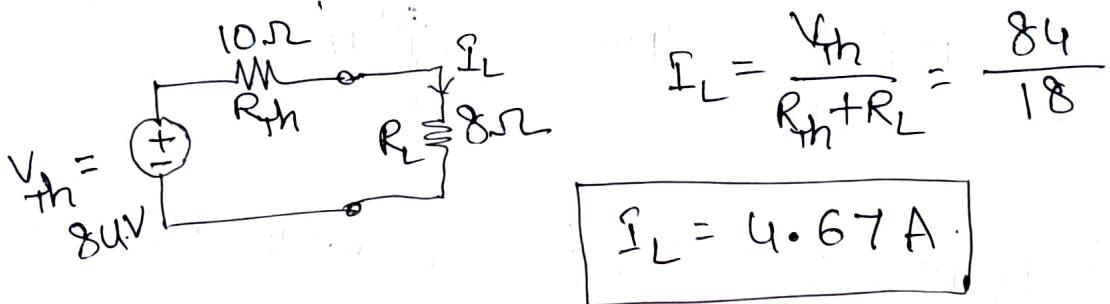
Solving eq- ① & ②, we get

$V_1 = 64V$	$V_{th} = V_2 = 84V$
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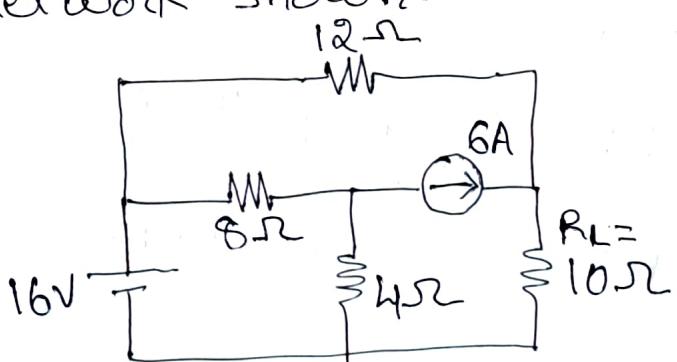
ii) To find  $R_{th}$ :



(iii) To find current in 8 ohm resistor:



⑧ Using Norton's theorem, find the current flowing through 10 ohm resistor in the network shown.



Sol: (i) To find short circuit current  $I_N$



Current through 12 ohm is

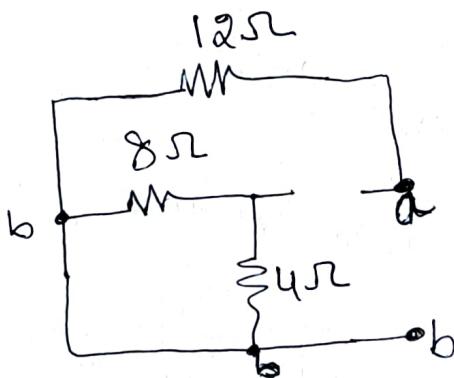
$$I_{12\Omega} = \frac{16}{12} = 1.33 \text{ A}$$

(2)

By KCL at node-a,

$$I_N = 6 + I_{12\Omega} = 6 + 1.33 = \underline{\underline{7.33A}}$$

(ii) To find  $R_N$ :

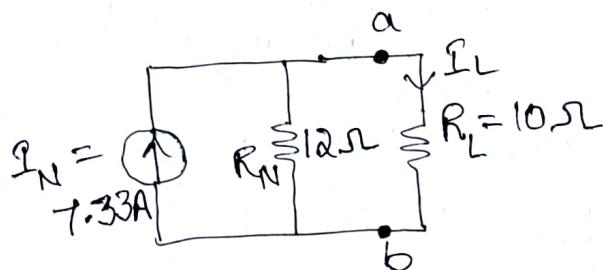


$R_N$  = Resistance between node-a and node-b.

$$R_N = 12\Omega$$

[ $\because (8+4)$  is parallel with short circuit]

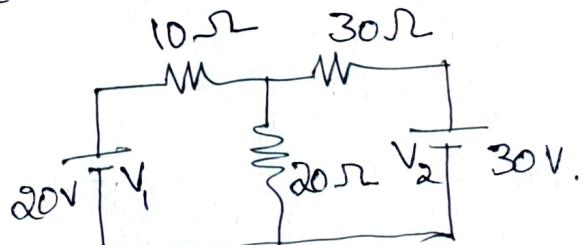
(iii) To find current in  $10\Omega$  resistor:



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

$$I_L = 7.33 \times \frac{12}{22} = 4A$$

⑨ Using superposition theorem, find the current flowing through the  $20\Omega$  resistor of the network shown.



Sol: (i) with only 20V source in the network,



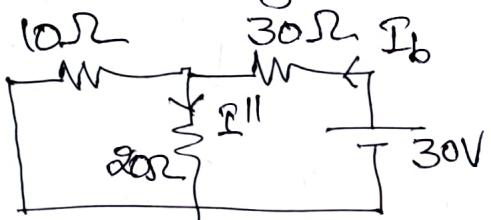
$$I_a = \frac{20}{10 + \frac{20 \times 30}{20 + 30}} = \frac{20 \times 50}{1100}$$

$$I_a = \frac{10}{11} = 0.91 \text{ A.}$$

then

$$I^I = I_a \times \frac{30}{30 + 20} = \underline{\underline{0.55 \text{ A.}}}$$

(ii) with only 30V source in the network,



$$I_b = \frac{30}{30 + \frac{10 \times 20}{10 + 20}} = 0.82 \text{ A}$$

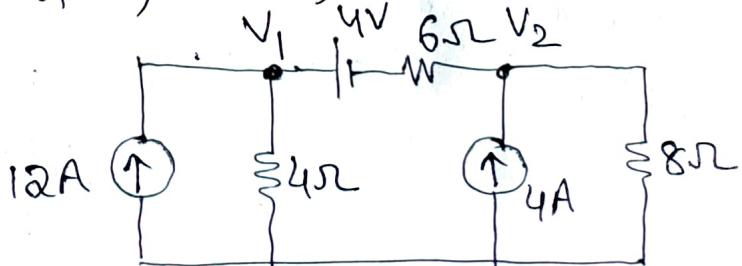
then

$$I^{II} = I_b \times \frac{10}{10 + 20} = \underline{\underline{0.27 \text{ A}}}$$

(iii) By superposition theorem, the current flowing through 20Ω resistor is

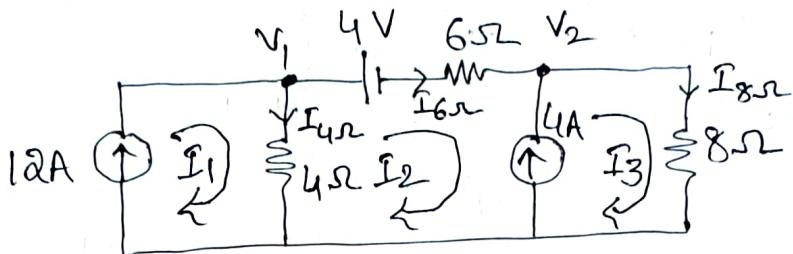
$$I = I^I + I^{II} = 0.55 + 0.27 = \underline{\underline{0.82 \text{ A}}}$$

- 10) Using mesh analysis, determine the currents in 4Ω, 6Ω & 8Ω of the network shown.



(3)

Sol:- Let the mesh currents are  $I_1, I_2$  and  $I_3$  as shown



From mesh-1:  $I_1 = 12 \text{ A}$ .

from mesh-2 & 3 form a super mesh, then

$$4(I_2 - I_1) + 4 + 6I_2 + 8I_3 = 0$$

$$10I_2 + 8I_3 = 44 \rightarrow ① \quad [\because I_1 = 12]$$

From 4A current source branch,

$$\begin{array}{c} I_2 \\ \downarrow \\ \textcircled{2} \end{array} \quad \begin{array}{c} \textcircled{1} \\ \uparrow 4\text{A} \\ \downarrow \end{array} \quad -I_2 + I_3 = 4 \rightarrow ②$$

Solving eq-① & ②, we get

$$I_2 = 0.67 \text{ A} \quad \text{and} \quad I_3 = 4.67 \text{ A}$$

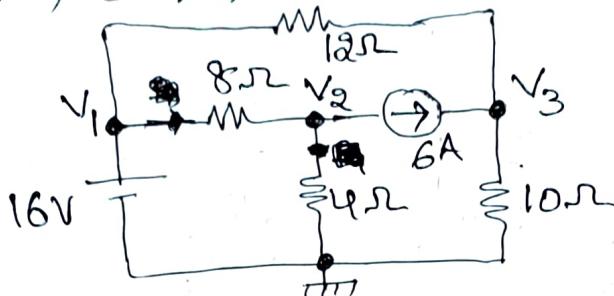
Now,

$$I_{4\Omega} = I_1 - I_2 = 12 - 0.67 = \underline{\underline{11.33 \text{ A}}}$$

$$I_{6\Omega} = I_2 = \underline{\underline{0.67 \text{ A}}}$$

$$I_{8\Omega} = I_3 = \underline{\underline{4.67 \text{ A}}}$$

⑪ using nodal analysis, determine the currents in  $4\Omega$ ,  $8\Omega$ ,  $12\Omega$  &  $10\Omega$  in the network shown.



Sol: Let  $V_1$ ,  $V_2$  and  $V_3$  are the node voltages at node-1, 2, & 3, respectively, w.r.t ground.

From node-1 :  $V_1 = 16 \text{ V.}$

From node-2, by KCL :

$$\frac{V_2 - V_1}{8} + \frac{V_2}{4} + 6 = 0.$$

$$-V_1 + 3V_2 = -48 \rightarrow ① \quad \therefore V_2 = -10.67 \text{ V.}$$

From node-3, by KCL

$$\frac{V_3 - 16}{12} + \frac{V_3}{10} = 6 \Rightarrow 11V_3 = 280.440$$

$$\therefore \boxed{V_3 = 25.45 \text{ V.}}$$

$$\boxed{V_3 = 40 \text{ V}}$$

Then,

$$I_{8\Omega} = \frac{V_1 - V_2}{8} = 3.33 \text{ A.}$$

$$I_{4\Omega} = \frac{V_2}{4} = -2.67 \text{ A}$$

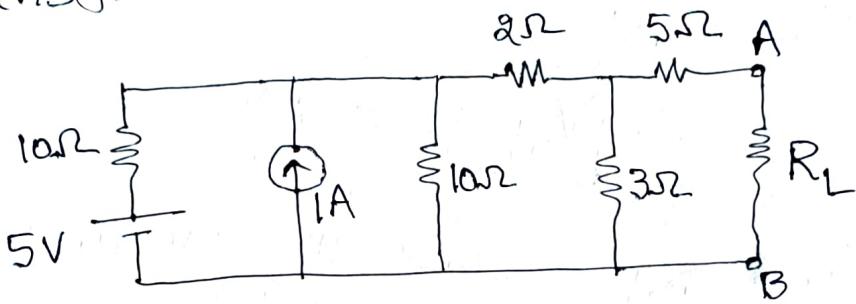
$$I_{10\Omega} = \frac{V_3}{10} = 4 \text{ A}$$

$$I_{12\Omega} = \frac{V_3 - V_1}{12} = \frac{24}{12} = 2 \text{ A.}$$

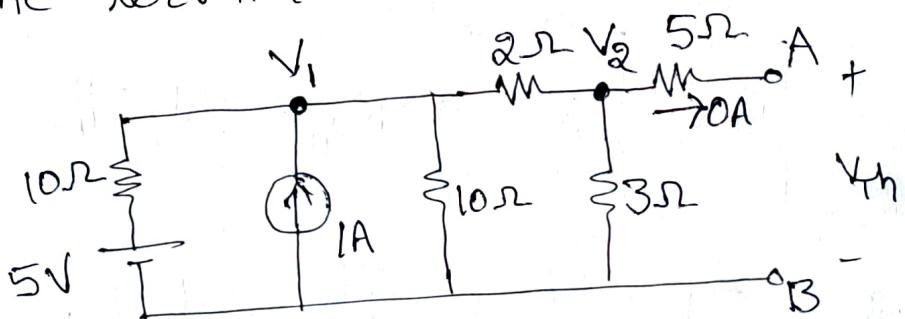
$$\boxed{I_{12\Omega} = 2 \text{ A.}}$$

(4)

- (12) In the circuit shown, (a) obtain the condition for maximum power transfer to the load  $R_L$ . (b) Hence determine the maximum power transferred.



Sol: (i) To find thevenin's voltage across the terminals A-B:



By nodal analysis; at node-1,

$$\frac{V_1 - 5}{10} + \frac{V_1}{10} + \frac{V_1 - V_2}{2} = 1$$

$$7V_1 - 5V_2 = 15 \rightarrow ①$$

at node-2:

$$\frac{V_2 - V_1}{2} + \frac{V_2}{3} = 0 \Rightarrow -3V_1 + 5V_2 = 0 \rightarrow ②$$

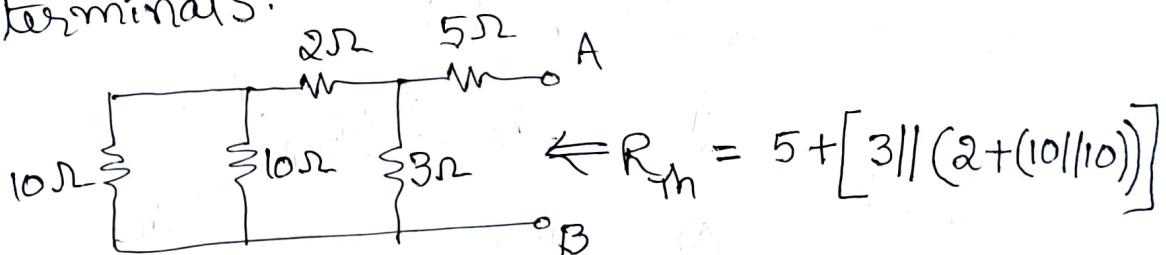
Solving eq-① & ②, we get

$$V_1 = 3.75V \text{ and } V_2 = 2.25V.$$

As no current flows through  $5\Omega$  when load terminals are open, the Thevenin's voltage  $V_{Th}$  across A-B terminals is equal to  $V_2$  only.

$$\therefore V_{Th} = 2.25V$$

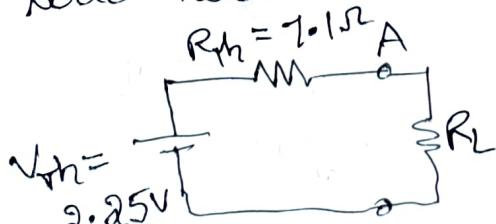
(ii) To find  $R_{Th}$ , short the 5V and open the 1A sources and calculate  $R_{Th}$  between load terminals.



$$R_{Th} = 5 + \frac{3 \times 7}{3+7} = \frac{71}{10} = 7.1\Omega.$$

$$R_{Th} = 7.1\Omega$$

(iii) the Thevenin's equivalent circuit across load terminals is



According to maximum power transfer theorem, for max. power transfer is possible when  $R_L = R_{Th}$ .

$$\therefore R_L = 7.1\Omega$$

(5)

(iv) The value of max. power transferred to the load  $P_{L,\max}$  is,

$$P_{L,\max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(2.25)^2}{4 \times 7.1}$$

$$\boxed{P_{L,\max} = 0.18 \text{ W.}}$$