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

Aspect	Mesh Analysis	Nodal Analysis
Basis	Based on Kirchhoff's Voltage Law (KVL).	Based on Kirchhoff's Current Law (KCL).
Unknown Variables	Solves for mesh currents (currents flowing in closed loops).	Solves for node voltages (voltages at circuit nodes).
Applicability	Best suited for circuits with many series elements and fewer current sources.	Best suited for circuits with many parallel elements and fewer voltage sources.
Complexity	Easier to use when the circuit has fewer meshes (loops).	Easier to use when the circuit has fewer nodes.
Equations	Equations are formed by applying KVL to each mesh.	Equations are formed by applying KCL at each node.
Preferred Use	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 VTh in series with a resistor RTh, where VTh is the open-circuit voltage at the terminals and RTh 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:

$$I_T = V_{TH} / (R_{TH} + R_L).$$
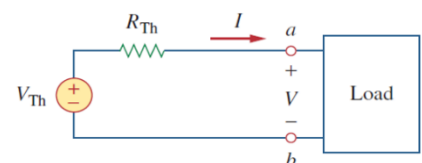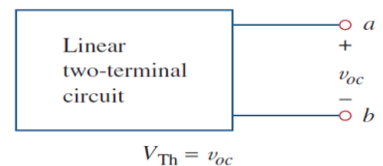
12. List out the steps followed to find Norton's theorem.

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.
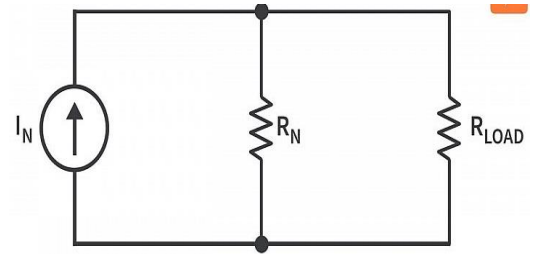
(13) $i_1 = 100 \sin(100t)$

$i_2 = 200 \cos(100t + 30°)$

Find $i_1 + i_2$

Ans: $i_1 = 100 \sin(100t) = 100 \cos(100t - 90°)$

$i_2 = 200 \cos(100t + 30°)$

Phasor form $\begin{cases} i_1 = 100 \angle -90° & ; \quad i_2 = 200 \angle 30° \end{cases}$

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

$i_1 + i_2 = -j100 + 173.2 + j100 = 173.2 + j(0)$

$= 173.2 \angle 0°$

$= 173.2 \cos(100t)$

(14) $\left. \begin{array}{l} i_1 = 100 \cos(100t) \\ i_2 = 200 \sin(100t + 30°) \end{array} \right\}$ Find $(i_1 - i_2)$

$i_1 = 100 \cos(100t)$

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

Phasor form $\begin{cases} i_1 = 100 \angle 0° \\ i_2 = 200 \angle -60° \end{cases}$

Rectangular form $\begin{cases} i_1 = 100 + j(0) \\ i_2 = 200[\cos(-60°) + j\sin(-60°)] \\ \quad = 100 - j 173.2 \end{cases}$

$i_1 - i_2 = 100 - 100 + j173.2 = j173.2$

$= 173.2 \angle 90°$

$= 173.2 \cos(100t + 90°)$

(15)

$i_1 = 100 \sin(100t)$
$i_2 = 200 \sin(100t + 30°)$ } Find $i_1 * i_2$

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

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

Phasor form }
$i_1 = 100 \angle{-90°}$
$i_2 = 200 \angle{-60°}$

$i_1 * i_2 = 100 \angle{-90°} * 200 \angle{-60°} = 20000 \angle{-150°}$

$= 20000 \cos(100t - 150°)$

(16)

$i_1 = 100 \cos(100t)$
$i_2 = 200 \cos(100t + 30°)$ } Find $\dfrac{i_1}{i_2}$

Phasor form {
$i_1 = 100 \angle{0°}$
$i_2 = 200 \angle{30°}$

$\dfrac{i_1}{i_2} = \dfrac{100 \angle{0°}}{200 \angle{30°}} = \dfrac{1}{2} \angle{-30°} = 0.5 \angle{-30°}$

$= 0.5 \cos(100t - 30°)$

(17)

$i_1 = 100 \sin(100t)$
$i_2 = 200 \cos(100t + 30°)$ } Find $(i_1 * i_2)^3$

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

$i_2 = 200 \cos(100t + 30°)$ ~~IABO~~ :

Phasor form {
$i_1 = 100 \angle{-90°}$
$i_2 = 200 \angle{30°}$

$i_1 * i_2 = 100 \angle{-90°} * 200 \angle{30°} = 20000 \angle{-60°}$

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

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

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

Consider the function $i(t)=I_m \sin \omega t = I_m \cos(\omega t - 90°)$
Phasor representation $I = I_m \angle -90°$
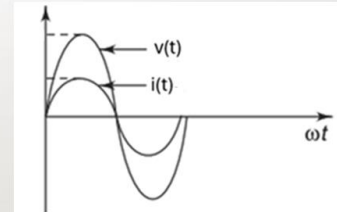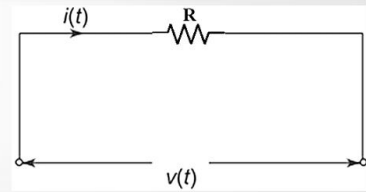The voltage current relation in the case of an **resistor** is given by
$v(t) = i(t)R = I_m R \cos(\omega t - 90°)$
Phasor representation $V = RI_m \angle -90°$

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

$$\boxed{\therefore Z = R}$$

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° phase.

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

Phasor representation $I = I_m \angle -90°$

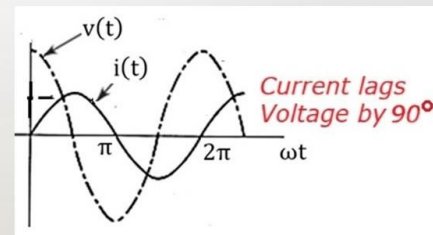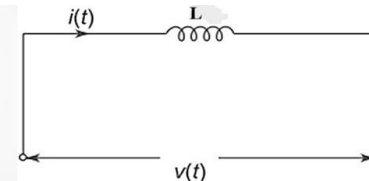The voltage current relation in the case of an **inductor** is given by

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

Phasor representation $V = L\omega I_m \angle 0°$

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

$$\boxed{\therefore Z = j\omega L = jX_L}$$

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

Current lags Voltage by 90°

The current lags behind the voltage by 90°.

20. Show that in pure capacitor ac current lags over voltage by 90° phase.

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

Phasor representation $I = I_m \angle -90°$

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

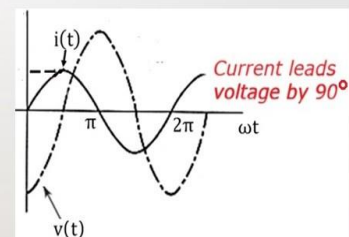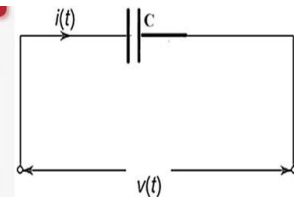$v(t) = \frac{1}{C}\int i(t)dt = \frac{I_m}{C}\int \cos(\omega t - 90°)dt = \frac{I_m}{\omega C}\sin(\omega t - 90°) = \frac{I_m}{\omega C}(\cos \omega t - 90° - 90°)$

Phasor representation $V = \frac{I_m}{\omega C} \angle -180°$

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

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

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

Current leads voltage by 90°

The current leads the voltage by 90°.