Quiz 3 - PrequizReview

Chapters 9 – 10

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9. Sinusoidal Steady State Analysis

10. Sinusoidal Steady-State Power Calculations

Chapter 9 – Sinusoidal Steady-State Analysis

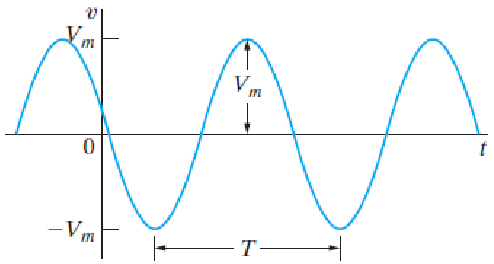
Main ideas:

- The Sinusoidal Source

$$v = V_m \text{Cos}(\omega t + \phi)$$

$$f = \frac{1}{T}$$

$$\omega = 2\pi f$$

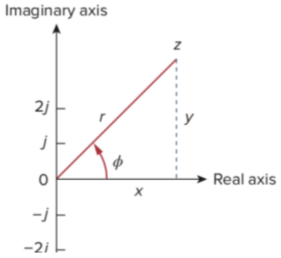


- Complex Numbers

$z = x + jy$ Rectangular form

$z = r\underline{/\phi}$ Polar form

$z = re^{j\phi}$ Exponential form



Complex number arithmetic

- The Phasor

$$v(t) = V_m \cos(\omega t + \phi) \qquad \mathbf{V} = V_m\underline{/\phi}$$

(Time-domain representation)

x jy

Circuit Element	Impedance	Reactance
Resistor	R	—
Inductor	$j\omega L$	ωL
Capacitor	$j(-1/\omega C)$	$-1/\omega C$

- Passive Circuit Elements in the Frequency Domain

$$\boldsymbol{V} = R\boldsymbol{I} \qquad \boldsymbol{V} = j\omega L\boldsymbol{I} \qquad \boldsymbol{I} = j\omega C\boldsymbol{V}$$

- KVL & KCL, Series-Parallel Equivalent

$$\mathbf{Z}_{eq} = \frac{\mathbf{V}}{\mathbf{I}} = \mathbf{Z}_1 + \mathbf{Z}_2 + \cdots + \mathbf{Z}_N \qquad \frac{1}{\mathbf{Z}_{eq}} = \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} + \cdots + \frac{1}{\mathbf{Z}_N}$$

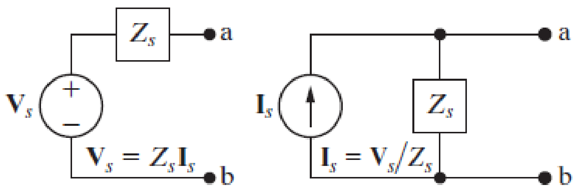
$$\mathbf{V}_1 + \mathbf{V}_2 + \cdots + \mathbf{V}_n = 0$$

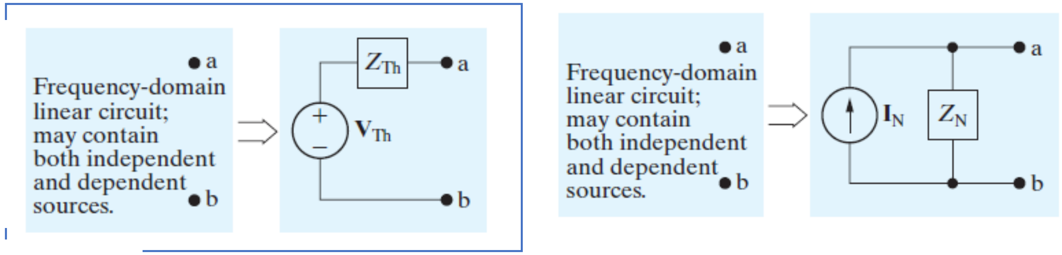
$$\mathbf{I}_1 + \mathbf{I}_2 + \cdots + \mathbf{I}_n = 0$$

Chapter 9 – Sinusoidal Steady-State Analysis

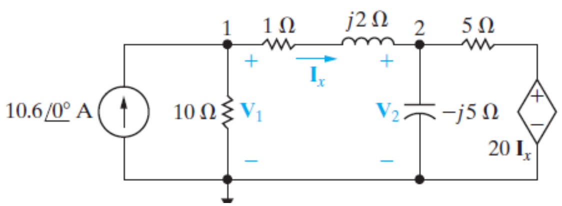
Main ideas:

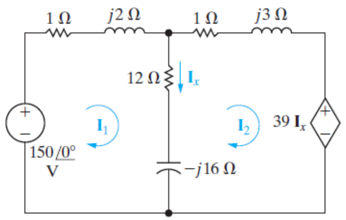
- Source Transformations,
  Thevenin & Norton Equivalents



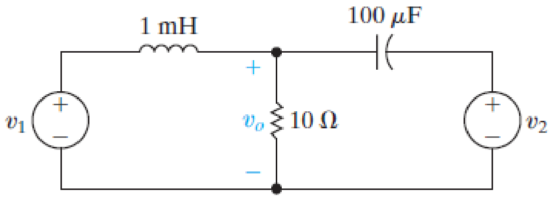


- Node Voltage & Mesh Current Methods



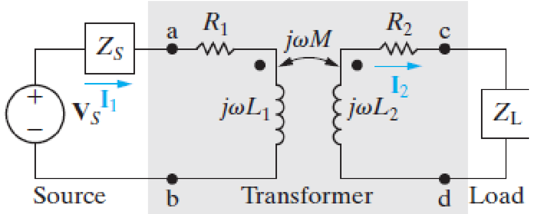


- Superposition



Sources with different ω

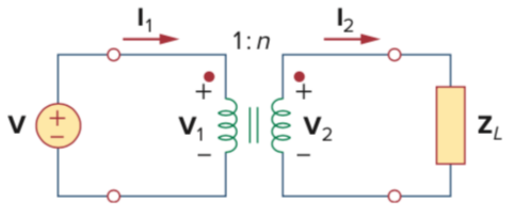
- The Transformer (Linear & Ideal)



$$Z_{in} = \frac{V}{I_1} = R_1 + j\omega L_1 + \frac{\omega^2 M^2}{R_2 + j\omega L_2 + Z_L}$$

$$Z_{in} = R_1 + j\omega L_1 + Z_R$$

$$\boxed{Z_R = \frac{\omega^2 M^2}{R_2 + j\omega L_2 + Z_L}}$$



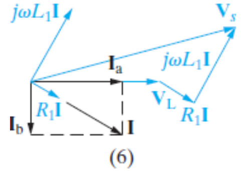
$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1} = n}$$

$$\boxed{Z_R = \frac{1}{n^2} Z_L}$$

Max power

$$a^2 = \frac{Z_L}{Z_S}$$

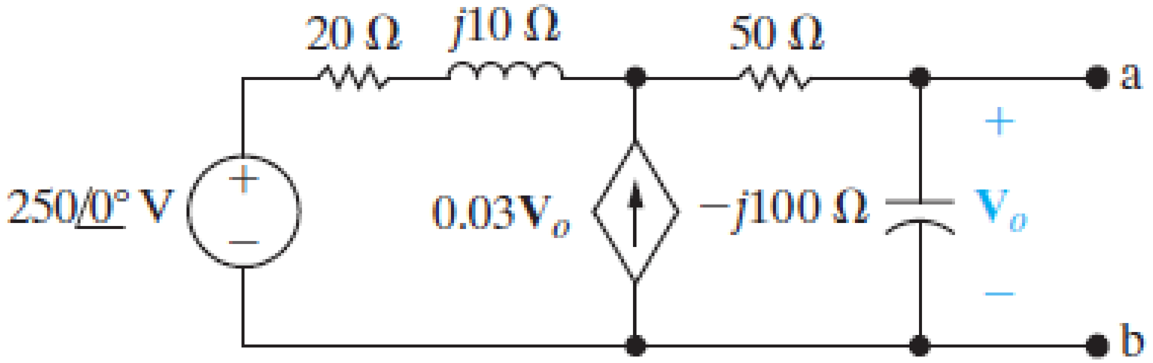
- Phasor Diagrams



Problem: Thevenin's Equivalent

Problem 9.50

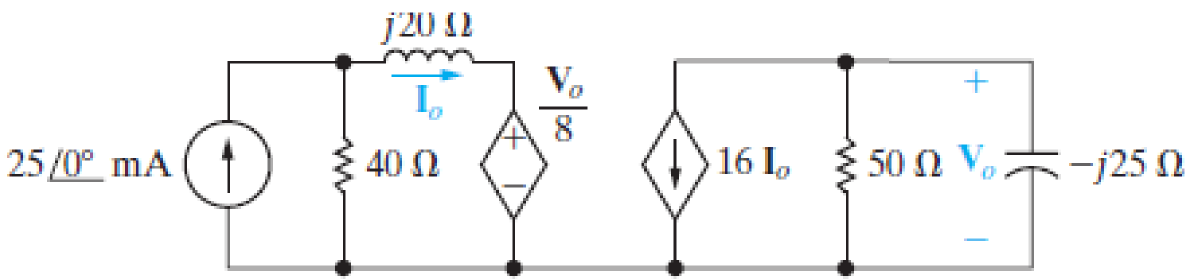
Find the Thevenin equivalent circuit with respect to terminals a, b.



Problem: Node Voltage Method

Problem 9.57

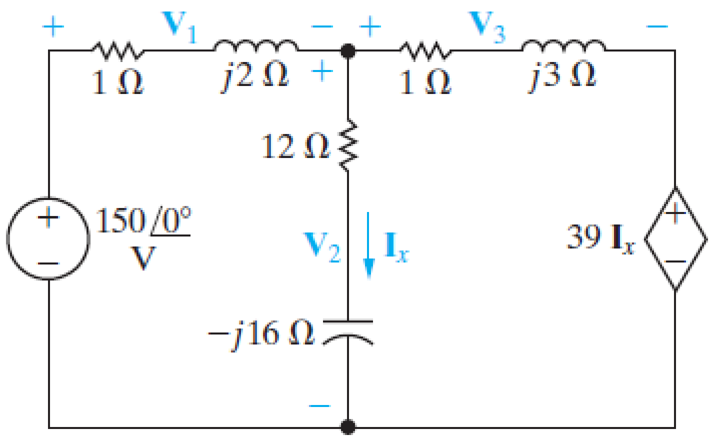
Find $\boldsymbol{V_o}$ $\boldsymbol{I_o}$

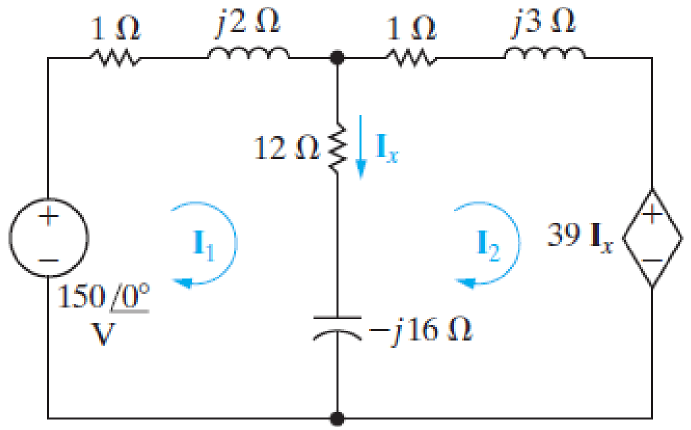


9.9 The Mesh Current Method
Example 9.14

Example 9.14:

Find $\boldsymbol{V_1}$ $\boldsymbol{V_2}$ $\boldsymbol{V_3}$

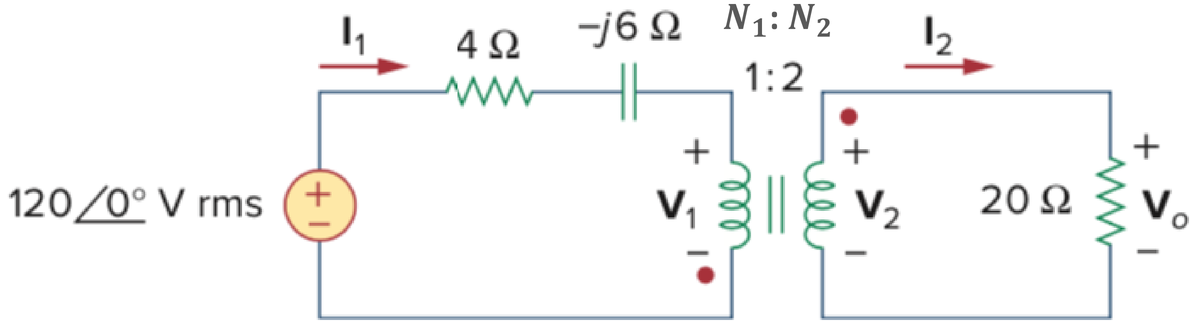




9.11 The Transformer, Ideal Transformer

Problem – Currents & Voltages

Find $\boldsymbol{I}_1$ & $\boldsymbol{V_O}$



$$\frac{N_2}{N_1} = n$$

$$\boxed{Z_R = \frac{1}{n^2} Z_L}$$

$$\boxed{\frac{\mathbf{V}_2}{\mathbf{V}_1} = \frac{N_2}{N_1} = n}$$

$$\boxed{\frac{\mathbf{I}_2}{\mathbf{I}_1} = \frac{N_1}{N_2} = \frac{1}{n}}$$

Chapter 10 – Sinusoidal Steady-State Power

Main ideas:

- Instantaneous Power

$$p(t) = \frac{1}{2}V_m I_m \cos(\theta_v - \theta_i) + \frac{1}{2}V_m I_m \cos(2\omega t + \theta_v - \theta_i)$$

- Average (or Real) and Reactive Power

$P = \frac{1}{2} V_m I_m Cos(\theta_v - \theta_i)$ ⟶ *REAL POWER, in Watts*

$Q = \frac{1}{2} V_m I_m Sin(\theta_v - \theta_i)$ ⟶ *REACTIVE POWER, in VARs*

+ve VARS for Inductance

-ve VARS for Capacitance

Also:

$\theta = \theta_v - \theta_i$ ⟶ POWER FACTOR ANGLE

$Cos\ (\theta_v - \theta_i)$ ⟶ POWER FACTOR

- Rms Value and Power Calculations

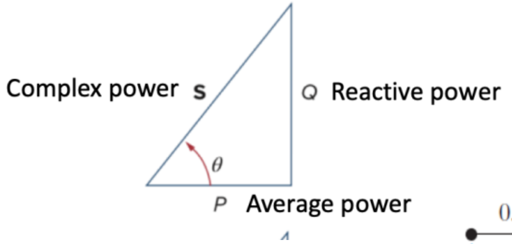
$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

(Real) $P = \frac{1}{2} V_m I_m Cos(\theta_v - \theta_i)$ becomes $P = V_{rms} I_{rms} Cos(\theta_v - \theta_i)$

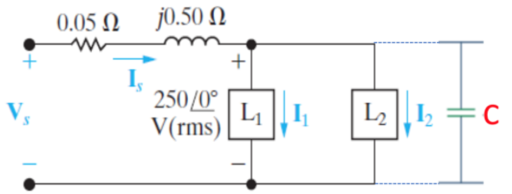
(Reactive) $Q = \frac{1}{2} V_m I_m Sin(\theta_v - \theta_i)$ becomes $Q = V_{rms} I_{rms} Sin(\theta_v - \theta_i)$

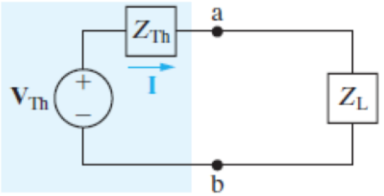
- Complex Power

$$\text{Complex Power} = \mathbf{S} = P + jQ = \mathbf{V}_{\text{rms}}(\mathbf{I}_{\text{rms}})^*$$
$$= |\mathbf{V}_{\text{rms}}|\,|\mathbf{I}_{\text{rms}}| \angle \theta_v - \theta_i$$
$$\text{Apparent Power} = S = |\mathbf{S}| = |\mathbf{V}_{\text{rms}}|\,|\mathbf{I}_{\text{rms}}| = \sqrt{P^2 + Q^2}$$
$$\text{Real Power} = P = \text{Re}(\mathbf{S}) = S\cos(\theta_v - \theta_i)$$
$$\text{Reactive Power} = Q = \text{Im}(\mathbf{S}) = S\sin(\theta_v - \theta_i)$$
$$\text{Power Factor} = \frac{P}{S} = \cos(\theta_v - \theta_i)$$



- Power factor correction, Max Power Transfer



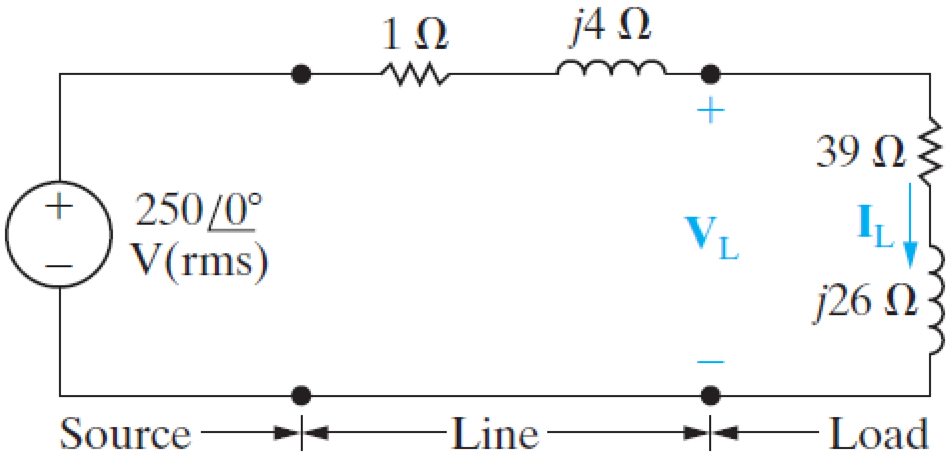


$$\mathbf{Z}_L = R_L + jX_L = R_{\text{Th}} - jX_{\text{Th}} = \mathbf{Z}^*_{\text{Th}}$$

10.5 Power Calculations

Example 10.6 Calculating Average & Reactive Power

a) Calculate phasors $\boldsymbol{V_L}$ & $\boldsymbol{I_L}$
b) Calculate the reactive & average powers delivered to the load
c) Calculate the reactive & average powers delivered to the line
d) Calculate the reactive & average powers supplied by the source



$$\mathbf{S} = \mathbf{V}_{rms}(\mathbf{I}_{rms})^*$$

$$\mathbf{S} = P + jQ$$

$$\mathbf{S} = |\boldsymbol{I}_{rms}|^2\,\mathbf{Z}$$

10.5 Power Calculations
HW problem 3

Problem 3:

When connected to a 120 V (rms), 60-Hz power line, a load absorbs 4kW at a lagging power factor of 0.8. Find the value of Capacitance, C, necessary to raise the power factor to 0.95 lagging.

$$\text{So } X_C = \frac{120^2}{1685.6} = 8.54\,\Omega.$$

Maximum Power Transfer

Problem 10.44

a) What is the maximum average power transferred to Z_L ?
b) What percentage of the total power developed is transferred to the load impedance found above?