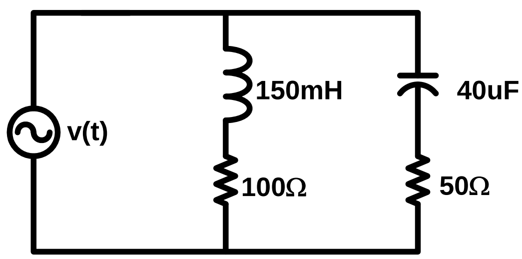
ECET 2111

Circuits II – Exam I **Sample Problems**

Instructions: Show all of your work… no credit will be given for illegible or illogical work, or for final answers that are not justified by the work shown. This exam is closed book except for one 8½"x11", single sheet of handwritten notes that may NOT contain any numerically-solved problems.

Note – Express all voltages and currents as phasors written in "polar" form. (I.e. – $100\angle 45°$ **or** $100e^{\frac{\pi}{4}rad}$)

Problem #1) Given the following (steady-state) AC circuit:

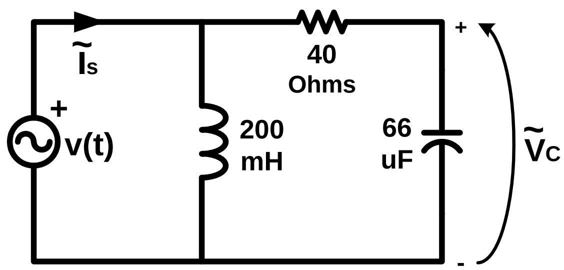


$$v(t) = 24 \cdot \sin(\omega \cdot t + 45°)$$
$$f = 60\ Hz$$

Express all of the loads in their impedance form and then determine the impedance seen by the source if the entire network is simplified into a single complex impedance expressed in "rectangular" form.

$Z_{eq} =$ ________________ **Ω**

Problem #2) Given the following (steady-state) AC circuit:

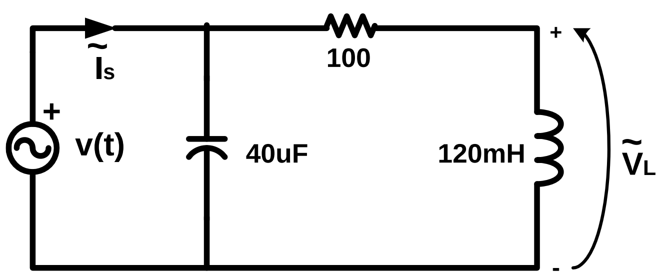


$$v(t) = 24 \cdot \sin(\omega \cdot t + 60°)$$
$$f = 60\ Hz$$

Determine the ***source current*** $\tilde{I}_S$ and the capacitor voltage $\tilde{V}_C$, both in phasor form.

$\tilde{I}_S =$ ________________ **A** $\tilde{V}_C =$ ________________ **V**

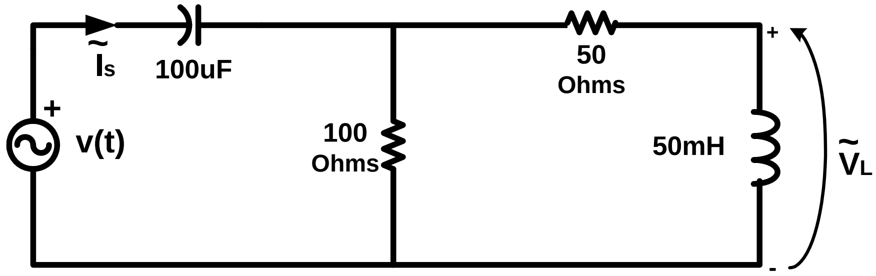
Problem #3) Perform a steady-state AC analysis of the circuit shown below in order to determine the source current, $\tilde{I}_S$, and the voltage across the inductor, $\tilde{V}_L$, both in phasor form.



$$v(t) = 10 \cdot \sin(\omega t)$$
$$\omega = 2\pi \cdot f$$
$$f = 60\ Hz$$

$\tilde{I}_S =$ ________________ **A** $\tilde{V}_L =$ ________________ **V**

Problem #4) Given the following (steady-state) AC circuit:

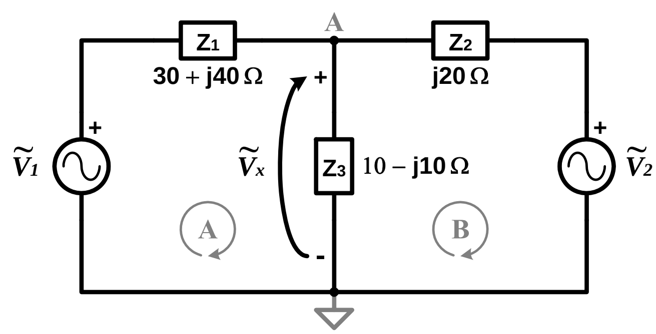


$$v(t) = 60 \cdot \sin(\omega t - 45°)$$
$$\omega = 2\pi \cdot f = 1000 \ {}^{rad}/_{sec}$$

Determine the ***source current*** $\tilde{I}_S$ and the ***inductor voltage*** $\tilde{V}_L$, both in "polar" form.

$\tilde{I}_S =$ ________________________ **A** $\qquad$ $\tilde{V}_L =$ ________________________ **V**

Problem #5) Given the following (steady-state) AC circuit:



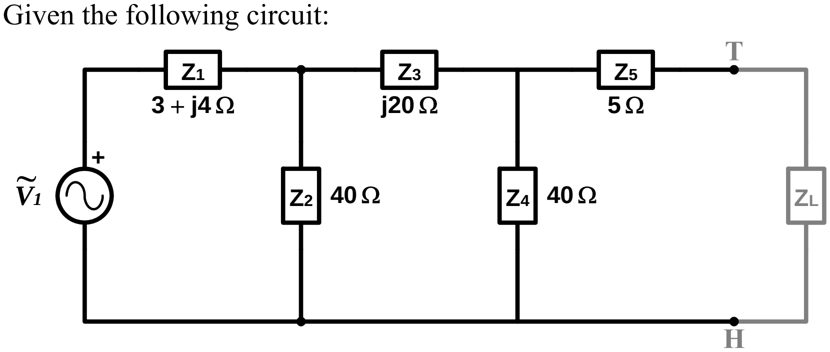
$$\tilde{V}_1 = 120\angle 0° \text{ volts}$$
$$\tilde{V}_2 = 60\angle -30° \text{ volts}$$

a) Determine the voltage $\tilde{V}_x$ across the (10-j10)Ω impedance using the **Superposition Theorem**.

b) Write out the minimum set of equations required to perform a ***Nodal Analysis*** of the circuit and utilize the results in order to determine the voltage $\tilde{V}_x$.

c) Write out the minimum set of equations required to perform a ***Mesh Analysis*** of the circuit and utilize the results in order to determine the voltage $\tilde{V}_x$.

Problem #6) Given the following circuit:



$$\tilde{V}_1 = 24\angle 0° \text{ volts}$$

a) Determine the ***Thevenin's Equivalent Circuit*** parameters for the circuit shown above with respect to terminals "T" and "H".

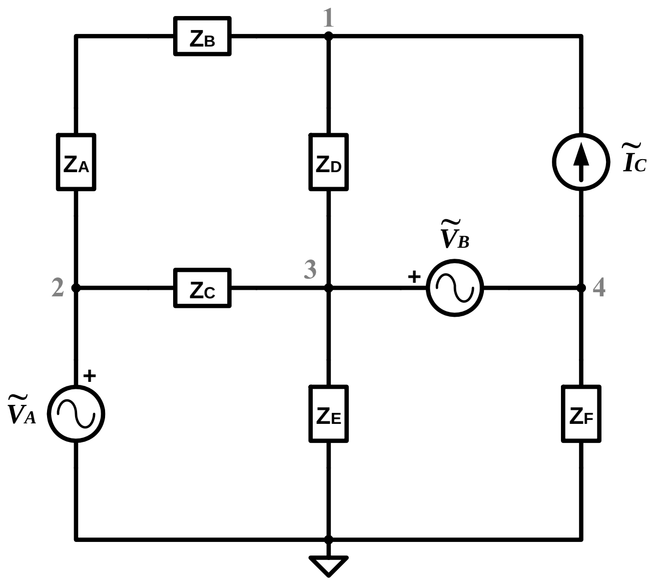
b) If an arbitrary impedance $\boldsymbol{Z_L}$ is connected between terminals "T" and "H", determine the value of $\boldsymbol{Z_L}$, expressed in rectangular form ($\boldsymbol{Z_L = R_L + jX_L}$) that will result in maximum power being transferred from the circuit to the load.

c) If the load impedance is constrained to be purely resistive ($\boldsymbol{Z_L = R_L}$), determine the value of $\boldsymbol{Z_L}$ that will result in maximum power being transferred from the circuit to the load.

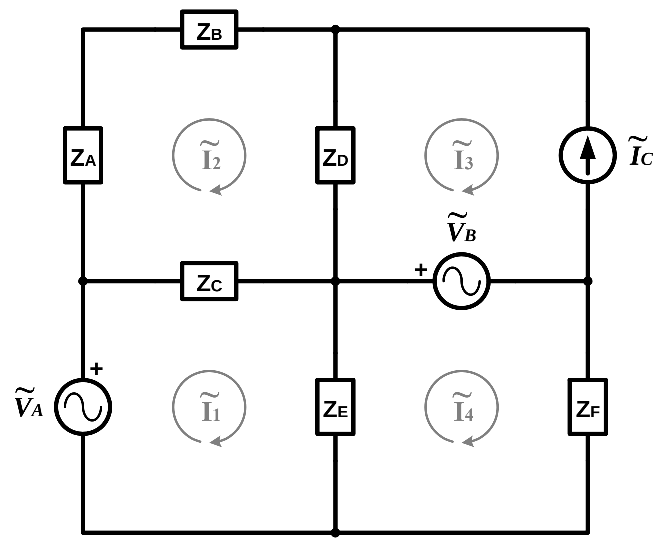
Problem #7) Given the circuit shown below:

a) Write out the minimum set of equations required to perform a ***Nodal Analysis*** of the network. If you assign an "unknown" node voltage, utilize the numbers provided in the figure. (I.e. – $\tilde{V}_1$)

b) Write out the minimum set of equations required to perform a ***Mesh Analysis*** of the network. If you assign an "unknown" mesh current, utilize the numbers provided in the figure. (I.e. – $\tilde{I}_1$)

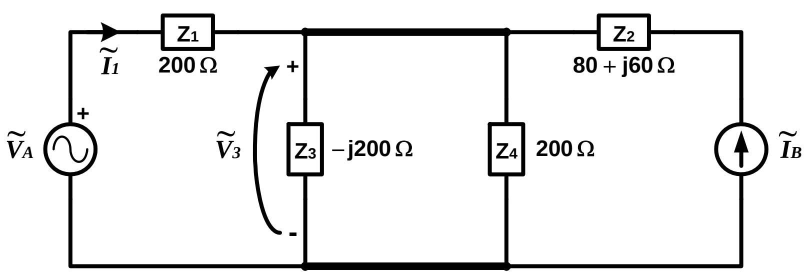


Circuit Diagram for Nodal Analysis



Circuit Diagram for Mesh Analysis

Problem #8) Given the following AC circuit:



$\tilde{V}_A = 120\angle 0°$ volts

$\tilde{I}_B = 2\angle 90°$ amps

a) Write out the minimum set of node equations required to perform a ***Nodal Analysis*** of the circuit.

b) Write out the minimum set of mesh equations required to perform a ***Mesh Analysis*** of the circuit.

c) Solve for the voltage $\tilde{V}_3$ and the current $\tilde{I}_1$ **using the Superposition Theorem.**

Problem T/F) Specify whether each of the statements are **TRUE** or **FALSE**.

___________ Given a circuit containing both an AC voltage source and a ***resistor***, the magnitude of the ***impedance*** of the resistor will increase if the frequency of the source is increased.

___________ Given a circuit containing both an AC voltage source and an ***inductor***, the magnitude of the ***impedance*** of the inductor will increase if the frequency of the source is increased.

___________ Given a circuit containing both an AC voltage source and an ***capacitor***, the magnitude of the ***impedance*** of the capacitor will increase if the frequency of the source is increased.

___________ An ***ideal voltage source*** looks like an ideal wire when it is "turned-off".

___________ A positive, purely "imaginary" impedance relates to a ***capacitive load***.

___________ The magnitude of the ***impedance*** of a specific capacitor will be greater when it is connected to a 60Hz voltage source compared to when it is connected to a 50Hz voltage source.

___________ The ***impedance*** of a resistor will increase as the source frequency increases.

___________ Setting a load resistor connected to a single-port network equal to the network's Thevenin's Equivalent Resistance will result in ***maximum power*** delivered to the load resistor.

___________ When expressed in ***phasor form***, a sinusoidal voltage source's magnitude and phase angle are shown but the frequency of the source is not.

___________ The magnitude of the impedance of a capacitor supplied by an AC source will decrease as the source frequency increases.

___________ Given the ***Thevenin's Equivalent*** for a circuit, the Thevenin's Equivalent may be used to determine the current that would flow through an ideal wire if the wire is connected directly from node "t" to node "h" of the original circuit.

1) $Z_{eq} = 59.7 - j21.5\,\Omega$

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2)
$\tilde{I}_S = 0.3\angle 56.5^\circ\ amps$
$\tilde{V}_C = 17.0\angle 15.1^\circ\ volts$

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3)
$\tilde{V}_L = 4.12\angle 65.7^\circ\ volts$
$\tilde{I}_S = 0.14\angle 53.76^\circ\ amps$

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4) $\tilde{I}_S = 1.455\angle -59.04^\circ$ amps $\quad \tilde{V}_L = 46.02\angle 12.53^\circ$ volts

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5a) $\tilde{V}_x = 70.6\angle -76.3^\circ\ volts$

b) $\dfrac{\tilde{V}_A - 120\angle 0^\circ}{30 + j40} + \dfrac{\tilde{V}_A - 0}{10 - j10} + \dfrac{\tilde{V}_A - 60\angle -30^\circ}{j20} = 0$ → $\tilde{V}_A = 70.6\angle -76.3^\circ\ volts$

c)
$$(10 - j10)\cdot \tilde{I}_A + (30 + j40)\cdot \tilde{I}_A - (10 - j10)\cdot \tilde{I}_B = 120\angle 0^\circ$$
$$-(10 - j10)\cdot \tilde{I}_A + (10 - j10)\cdot \tilde{I}_B + (j20)\cdot \tilde{I}_B = -60\angle -30^\circ$$

$$\tilde{V}_x = \tilde{I}_x \cdot Z_3 = \left(\tilde{I}_A - \tilde{I}_B\right)\cdot Z_3$$

6a) $\tilde{V}_{TH} = 18.1\angle -33.8^\circ$ volts $\quad Z_{TH} = 16.35 + 15.57\,\Omega$

b) $Z_L = R_L + jX_L = Z_{TH}^* = 16.35 - 15.57\,\Omega$

c) $Z_L = R_L = |Z_{TH}| = \sqrt{R_{TH}^2 + X_{TH}^2} = 22.6\,\Omega$

7a)
Node 1: Unknown Voltage Assigned Variable $\tilde{V}_1$
Node 2: Known Voltage → $\tilde{V}_2 = \tilde{V}_A$
Node 3: Known Voltage (if node 4 is assigned variable $\tilde{V}_4$) → $\tilde{V}_3 = \tilde{V}_4 + \tilde{V}_B$
Node 4: Unknown Voltage Assigned Variable $\tilde{V}_4$

Node 1 Eqn:
$$\frac{\tilde{V}_1 - \tilde{V}_A}{Z_A + Z_B} + \frac{\tilde{V}_1 - \tilde{V}_3}{Z_D} + \left(-\tilde{I}_C\right) = 0$$

Super Node 3+4 Eqn:
$$\frac{\left(\tilde{V}_4 + \tilde{V}_B\right) - \tilde{V}_1}{Z_D} + \frac{\left(\tilde{V}_4 + \tilde{V}_B\right) - \tilde{V}_A}{Z_C} + \frac{\left(\tilde{V}_4 + \tilde{V}_B\right) - 0}{Z_E} + \frac{\tilde{V}_4 - 0}{Z_F} + \tilde{I}_C = 0$$

7b) Mesh 1: Unknown Current Assigned Variable $\tilde{I}_1$

Mesh 2: Unknown Current Assigned Variable $\tilde{I}_3$

Mesh 3: Known Current → $\tilde{I}_3 = -\tilde{I}_C$

Mesh 4: Unknown Current Assigned Variable $\tilde{I}_4$

Mesh 1 Eqn: $(Z_C + Z_E)\cdot\tilde{I}_1 - (Z_C)\cdot\tilde{I}_2 - (Z_E)\cdot\tilde{I}_4 = \tilde{V}_A$

Mesh 2 Eqn: $-(Z_C)\cdot\tilde{I}_1 + (Z_A + Z_B + Z_C + Z_D)\cdot\tilde{I}_2 = (Z_D)\cdot\left(-\tilde{I}_C\right)$

Mesh 4 Eqn: $-(Z_E)\cdot\tilde{I}_1 + (Z_E + Z_F)\cdot\tilde{I}_4 = -\tilde{V}_B$

8a) If bottom node grounded and top node assigned variable $\tilde{V}_3$:

$$\frac{\tilde{V}_3 - 120\angle 0°}{200} + \frac{\tilde{V}_3 - 0}{-j200} + \frac{\tilde{V}_3 - 0}{200} + (-2\angle 90°) = 0$$

b) Note: Mesh Current #3 is defined by the source $\tilde{I}_B$ → $\tilde{I}_3 = -\tilde{I}_B$

Mesh 1 Eqn: $(200 - j200)\cdot\tilde{I}_1 - (-j200)\cdot\tilde{I}_2 = \tilde{V}_A$

Mesh 2 Eqn: $-(-j200)\cdot\tilde{I}_1 + (200 - j200)\cdot\tilde{I}_2 - (-j200)\cdot\left(-\tilde{I}_B\right) = 0$

c) **Source A ON:** $\tilde{V}_{3A} =$ $\tilde{I}_{1A} =$

Source B ON: $\tilde{V}_{3B} =$ $\tilde{I}_{1B} =$

Actual Values: $\tilde{V}_3 =$ $\tilde{I}_1 =$

<u>Answers to True/False Questions</u>

True/False) Specify whether each of the statements are **TRUE** or **FALSE**.

___**False**___ Given a circuit containing both an AC voltage source and a ***resistor***, the magnitude of the ***impedance*** of the resistor will increase if the frequency of the source is increased.

___**True**___ Given a circuit containing both an AC voltage source and an ***inductor***, the magnitude of the ***impedance*** of the inductor will increase if the frequency of the source is increased.

___**False**___ Given a circuit containing both an AC voltage source and an ***capacitor***, the magnitude of the ***impedance*** of the capacitor will increase if the frequency of the source is increased.

___**True**___ An ***ideal voltage source*** looks like an ideal wire when it is "turned-off".

___**False**___ A positive, reactance value relates to a ***capacitive load***.

___**False**___ The magnitude of the ***impedance*** of a specific capacitor will be greater when it is connected to a 60Hz voltage source compared to when it is connected to a 50Hz voltage source.

___**False**___ The ***impedance*** of a resistor will increase as the source frequency increases.

___**True**___ Setting a load resistor connected to a single-port network equal to the network's Thevenin's Equivalent Resistance will result in ***maximum power*** delivered to the load resistor.

___**True**___ When expressed in ***phasor form***, a sinusoidal voltage source's magnitude and phase angle are shown but the frequency of the source is not.

___**True**___ The magnitude of the impedance of a capacitor supplied by an AC source will decrease as the source frequency increases.

___**True**___ Given the ***Thevenin's Equivalent*** for a circuit, the Thevenin's Equivalent may be used to determine the current that would flow through an ideal wire if the wire is connected directly from node "t" to node "h" of the original circuit.