Name: ___________________________ ECE 3600 homework # 1 **Due: Fri, 1/13/23** e

Base your answers on class lecture & discussion, books and/or internet research. Some possible sources:
http://www.nerc.com/
http://en.wikipedia.org/wiki/Electricity_generation
http://www.energy.gov/energysources/electricpower.htm
http://en.wikipedia.org/wiki/Relative_cost_of_electricity_generated_by_different_sources

1. What is the name of the organization which ensures the reliability of power in North America?

2. Electric Utilities have been forced to break up into two separate companies responsible for:
   a.
   b.

3. What does deregulation provide for independent power producers (IPPs)?

4. The current bottleneck to overall system capacity.

5. What are the advantages of a highly interconnected system? (List at least 2). Also give a disadvantage.

6. Rank the sources of electrical energy in the US (highest to lowest %)
   1.
   2.
   3.
   4.
   5. Other

7. List 3 of the "Other" sources.
   1.
   2.
   3.

8. Rank the sources of electrical energy in the US by environmental and social negatives (worst to best). Assume "Other" is all the 3 you listed above. Consider petroleum just a little worse than natural gas (due to the danger of spills). Also give (in your opinion) the worst environment or social negative of each. Your answers here may be subjective.
   1.
   2.
   3.
   4.

9. Rank the sources of electrical energy in the US cost per kWh.

   List Nat gas twice, once for single cycle and once for combined-cycle. Choose one of the "Other" that you listed above. Initial costs are amortized over the life of the generation facility. You will have to make some guesses and may qualify your answers.

   1. (cheapest)
   2.
   3.
   4.
   5.
   6. (most expensive).

10. Give the approximate efficiencies of each type of power plant:

    a. Hydroelectric

    b. Rankine-cycle steam turbine plants, regardless of the source of heat.
    (coal, oil, gas-steam, nuclear, solar-steam, geothermal)

    c. Single-cycle (Brayton-cycle) gas turbine

    d. Combined-cycle (Brayton-cycle flowed by Rankine-cycle)

11. In nuclear fission reactions, what is particle is crucial to the chain reaction and is used to control the reaction rate?

12. a) Why can't a wind turbine's coefficient of performance (conversion of wind energy to rotational mechanical energy) be 100%?

    b) What two things can be controlled to maximize the coefficient of performance?

    c) What is the biggest single problem of wind power?

13. a) Do photovoltaic cells produce AC or DC power?

    b) What are the 2 biggest problems of photovoltaic cells?

14. What is cogeneration?

15. Some power sources are used to supply base loads and some are used to supply peak loads. Give some reasons to differentiate the sources in this way.

    <u>Base loads</u> <u>Peak loads</u>

16. Requirements of the power system
    1.
    2.
    3.
    4.
    5.

17. What two things are constantly monitored by the power company to assure that they meeting the demand.
    1.
    2.

18. Sensors placed around the network can let operators know if these requirements are being met What is the name of this system:

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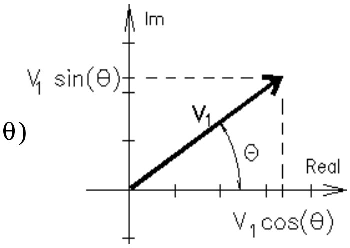
9/3/08
rev,

Review of Phasors

ECE 3600

For steady-state sinusoidal response ONLY

Phasors



Time domain

$$v(t) = \sqrt{2}\cdot V_1\cdot\cos(377\cdot t+\theta)$$

Phasor, frequency domain (RMS)

$$\mathbf{V_1} = V_1\cdot e^{j\cdot\theta} = V_1 \underline{/\theta} = V_1\cdot\cos(\theta)+j\cdot V_1\cdot\sin(\theta)$$

Impedances,

AC impedance

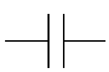
Inductor

$$v_L = L\cdot\frac{d}{dt}i_L = L\cdot\frac{d}{dt}I_p\cdot e^{j\cdot(\omega\cdot t+\theta)} = j\cdot\omega\cdot L\cdot\left[I_p\cdot e^{j\cdot(\omega\cdot t+\theta)}\right]$$

$$\mathbf{V_L}(\omega) = j\cdot\omega\cdot L\cdot\mathbf{I}(\omega)$$

$$\mathbf{Z_L} = j\cdot\omega\cdot L$$

Capacitor



$$i_C = C\cdot\frac{d}{dt}v_C = C\cdot\frac{d}{dt}V_p\cdot e^{j\cdot(\omega\cdot t+\theta)} = j\cdot\omega\cdot C\cdot\left[V_p\cdot e^{j\cdot(\omega\cdot t+\theta)}\right]$$

$$\mathbf{I_C}(\omega) = j\cdot\omega\cdot C\cdot\mathbf{V}(\omega) \qquad \mathbf{V_C}(\omega) = \frac{1}{j\cdot\omega\cdot C}\cdot\mathbf{I}(\omega)$$

$$\mathbf{Z_C} = \frac{1}{j\cdot\omega\cdot C} = \frac{-j}{\omega\cdot C}$$

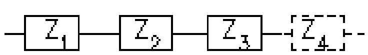
Resistor

$$v_R = i_R\cdot R \qquad \mathbf{V_R}(\omega) = R\cdot\mathbf{I}(\omega)$$

$$\mathbf{Z_R} = R$$

You can use impedances just like resistances as long as you deal with the complex arithmetic.
ALL the DC circuit analysis techniques will work with AC.

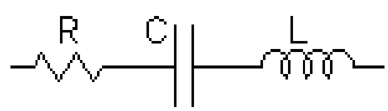
series:



$$\mathbf{Z_{eq}} = \mathbf{Z_1}+\mathbf{Z_2}+\mathbf{Z_3} + \ldots$$

$f := 60\cdot Hz \qquad \omega := 2\cdot\pi\cdot f \qquad \omega = 377\cdot\frac{rad}{sec}$

Example:



$R := 20\cdot\Omega \qquad L := 80\cdot mH$

$C := 60\cdot\mu F \qquad j\cdot\omega\cdot L = 30.159j\cdot\Omega$

$$\frac{1}{j\cdot\omega\cdot C} = -44.21j\cdot\Omega$$

$$\mathbf{Z_{eq}} := R+\frac{1}{j\cdot\omega\cdot C}+j\cdot\omega\cdot L = 20\cdot\Omega - 44.21\cdot j\cdot\Omega + 30.16\cdot j\cdot\Omega = 20 - 14.05j\cdot\Omega$$

$$\sqrt{(20\cdot\Omega)^2+(14.05\cdot\Omega)^2} = 24.44\cdot\Omega \qquad \operatorname{atan}\left(\frac{-14.05\cdot\Omega}{20\cdot\Omega}\right) = -35.09\cdot deg$$

$$\mathbf{Z_{eq}} = 24.44\Omega \underline{/-35.1}^{o}$$

If: $\mathbf{V} := 120\cdot V\cdot e^{j\cdot 0\cdot deg} \qquad \mathbf{I} := \frac{\mathbf{V}}{\mathbf{Z_{eq}}} = \frac{120\cdot V}{24.44\cdot\Omega} = 4.91\cdot A \qquad \underline{/}\ 0 - -35.1 = 35.1\ deg$

$4.91\cdot\cos(35.1\cdot deg) = 4.017 \qquad 4.91\cdot\sin(35.1\cdot deg) = 2.823 \qquad \mathbf{I} = 4.017+2.822j\cdot A$

slight roundoff error

Voltage divider:

$$\mathbf{V}_{Zn} = \mathbf{V}_{total}\cdot\frac{\mathbf{Z}_n}{\mathbf{Z}_1+\mathbf{Z}_2+\mathbf{Z}_3+\ldots}$$

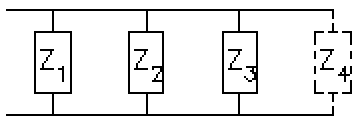
Eg: $$\mathbf{V}_C := \mathbf{V}\cdot\frac{\frac{1}{j\cdot\omega\cdot C}}{\mathbf{Z}_{eq}} = 120\cdot V\cdot e^{j\cdot 0\cdot deg}\cdot\frac{44.21\cdot e^{-j\cdot 90\cdot deg}\cdot\Omega}{24.44\cdot e^{-j\cdot 35.1\cdot deg}\cdot\Omega}$$

$$120\cdot V\cdot\frac{44.21\cdot\Omega}{24.44\cdot\Omega} = 217.07\cdot V \qquad \angle\ 0 + -90 - -35.1 = -54.9\ deg$$

$$\mathbf{V}_C = 217.1V\ \underline{/-54.9}^o \qquad \mathbf{V}_C = 124.771 - 177.604j\ \cdot V$$

$$217.1\cdot\cos(-54.9\cdot deg) = 124.8 \qquad 217.1\cdot\sin(-54.9\cdot deg) = -177.6$$

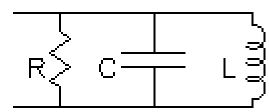
parallel:



$$\mathbf{Z}_{eq} = \frac{1}{\frac{1}{\mathbf{Z}_1}+\frac{1}{\mathbf{Z}_2}+\frac{1}{\mathbf{Z}_3}+\ldots}$$

Example:

$$f := 60\cdot Hz \qquad \omega := 2\cdot\pi\cdot f \qquad \omega = 377\cdot\frac{rad}{sec}$$



$$L := 80\cdot mH \qquad j\cdot\omega\cdot L = 30.159j\cdot\Omega$$

$$R := 20\cdot\Omega \qquad C := 60\cdot\mu F \qquad \frac{1}{\omega\cdot L} = 3.316\cdot 10^{-2}\cdot\frac{1}{\Omega}$$

$$\frac{1}{j\cdot\omega\cdot C} = -44.21j\cdot\Omega \qquad \omega\cdot C = 2.262\cdot 10^{-2}\cdot\frac{1}{\Omega}$$

$$\mathbf{Z}_{eq} := \frac{1}{\frac{1}{R}+\frac{1}{\left(\frac{1}{j\cdot\omega\cdot C}\right)}+\frac{1}{j\cdot\omega\cdot L}} = \frac{1}{\frac{1}{R}+j\cdot\omega\cdot C-\frac{j}{\omega\cdot L}} = \frac{1}{\frac{1}{20\cdot\Omega}+2.262\cdot 10^{-2}\cdot j\cdot\frac{1}{\Omega}-3.316\cdot 10^{-2}\cdot j\cdot\frac{1}{\Omega}} = \frac{1}{\left(5\cdot 10^{-2}-1.054\cdot 10^{-2}\cdot j\right)\cdot\frac{1}{\Omega}}$$

$$= \frac{1}{\left(5\cdot 10^{-2}-1.054\cdot 10^{-2}\cdot j\right)\cdot\frac{1}{\Omega}}\cdot\frac{5\cdot 10^{-2}+1.054\cdot 10^{-2}\cdot j}{\left(5\cdot 10^{-2}+1.054\cdot 10^{-2}\cdot j\right)} = 19.149 + 4.037j\ \cdot\Omega$$

$$\sqrt{\left(5\cdot 10^{-2}\cdot\frac{1}{\Omega}\right)^2+\left(1.054\cdot 10^{-2}\cdot\frac{1}{\Omega}\right)^2} = 5.11\cdot 10^{-2}\cdot\frac{1}{\Omega} \qquad \operatorname{atan}\left(\frac{-1.054\cdot 10^{-2}\cdot\Omega}{5\cdot 10^{-2}\cdot\Omega}\right) = -11.9\cdot deg$$

$$\frac{1}{5.11\cdot 10^{-2}\cdot\frac{1}{\Omega}} = 19.569\cdot\Omega \qquad \angle\ 0 - -11.9 = 11.9\ deg \qquad \mathbf{Z}_{eq} = 19.57\Omega\ \underline{/11.9}^o$$

If: $$\mathbf{V} := 120\cdot V\cdot e^{j\cdot 0\cdot deg} \qquad \mathbf{I} := \frac{\mathbf{V}}{\mathbf{Z}_{eq}} = \frac{120\cdot V}{19.57\cdot\Omega} = 6.132\cdot A \qquad \angle\ 0 - 11.9 = -11.9\ deg$$

$$6.132\cdot\cos(-11.9\cdot deg) = 6 \qquad 6.132\cdot\sin(-11.9\cdot deg) = -1.264 \qquad \mathbf{I} = 6 - 1.265j\ \cdot A$$

slight roundoff error

Current divider:

$$\mathbf{I}_{Zn} = \mathbf{I}_{total}\cdot\frac{\frac{1}{\mathbf{Z}_n}}{\frac{1}{\mathbf{Z}_1}+\frac{1}{\mathbf{Z}_2}+\frac{1}{\mathbf{Z}_3}+\ldots}$$

Eg: $$\mathbf{I}_L := \mathbf{I}\cdot\frac{\frac{1}{j\cdot\omega\cdot L}}{\frac{1}{R}+j\cdot\omega\cdot C+\frac{1}{j\cdot\omega\cdot L}} = \mathbf{I}\cdot\frac{\left(\frac{1}{j\cdot\omega\cdot L}\right)}{\left(\frac{1}{\mathbf{Z}_{eq}}\right)} = \mathbf{I}\cdot\frac{\mathbf{Z}_{eq}}{j\cdot\omega\cdot L}$$

$$= 6.132\cdot A\cdot e^{j\cdot -11.9\cdot deg}\cdot\frac{19.57\cdot e^{j\cdot 11.9\cdot deg}\cdot\Omega}{30.159\cdot e^{j\cdot 90\cdot deg}\cdot\Omega}$$

$$\mathbf{I}_L = 6.132\cdot A\cdot\frac{19.57\cdot\Omega}{30.159\cdot\Omega} = 3.979\cdot A \qquad \angle\ -11.9 + 11.9 - 90 = -90\ deg \qquad \mathbf{I}_L = -3.979\cdot 10^3 j\ \cdot mA$$

Duh... $$\frac{\mathbf{V}}{j\cdot\omega\cdot L} = -3.979\cdot 10^3 j\ \cdot mA$$

ECE 3600 Phasor Examples

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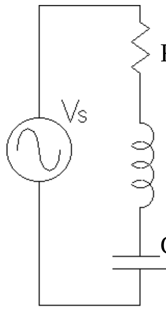
Ex. 1 Find $\mathbf{V_R}$, $\mathbf{V_L}$, and $\mathbf{V_C}$ in polar phasor form. $f := 2\cdot kHz$

$\mathbf{V}(j\omega)$

$6\cdot V\cdot e^{j0}$

$f := 2\cdot kHz$

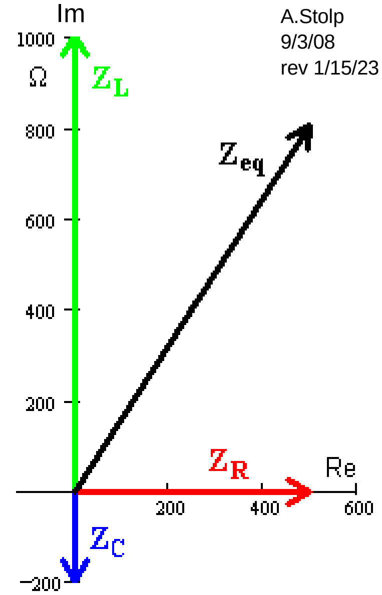


$R := 500\cdot\Omega \qquad \omega := 2\cdot\pi\cdot f \qquad \omega = 12566\cdot\frac{rad}{sec}$

$L := 80\cdot mH \qquad \mathbf{Z_L} := j\cdot\omega\cdot L \qquad \mathbf{Z_L} = 1.005j\cdot k\Omega$

$C := 0.4\cdot\mu F \qquad \mathbf{Z_C} := \frac{1}{j\cdot\omega\cdot C} \qquad \mathbf{Z_C} = -0.199j\cdot k\Omega$

$\mathbf{Z_{eq}} := R + j\cdot\omega\cdot L + \frac{1}{j\cdot\omega\cdot C} \qquad \mathbf{Z_{eq}} = 500 + 806.366j\ \cdot\Omega$



$\sqrt{500^2 + 806^2} = 948.491 \quad \text{atan}\left(\frac{806}{500}\right) = 58.187\cdot deg \qquad \mathbf{Z_{eq}} = 948.5\Omega\ \underline{/\ 58.2^o}$

find the current: $\mathbf{I} := \frac{6\cdot V\cdot e^{j\cdot 0}}{\mathbf{Z_{eq}}}$ magnitude: $\frac{6\cdot V}{948.5\cdot\Omega} = 6.326\cdot mA$ angle: $0\cdot deg - 58.2\cdot deg = -58.2\cdot deg$

$\mathbf{I} = 6.326mA\ \underline{/{-58.2}^o}$

	<u>find the magnitude</u>	<u>find the angle</u>	
$\mathbf{V_R} := \mathbf{I}\cdot R$	$6.326\cdot mA\cdot 500\cdot\Omega = 3.163\cdot V$	$-58.2\cdot deg + 0\cdot deg = -58.2\cdot deg$	$\mathbf{V_R} = 3.163V\ \underline{/{-58.2}^o}$
$\mathbf{V_L} := \mathbf{I}\cdot\mathbf{Z_L}$	$6.326\cdot mA\cdot 1005\cdot\Omega = 6.358\cdot V$	$-58.2\cdot deg + 90\cdot deg = 31.8\cdot deg$	$\mathbf{V_L} = 6.358V\ \underline{/\ 31.8^o}$
$\mathbf{V_C} := \mathbf{I}\cdot\mathbf{Z_C}$	$6.326\cdot mA\cdot(-199)\cdot\Omega = -1.259\cdot V$	$-58.2\cdot deg + (90)\cdot deg = 31.8\cdot deg$	$\mathbf{V_C} = -1.259V\ \underline{/\ 31.8^o}$
OR:	$6.326\cdot mA\cdot(199)\cdot\Omega = 1.259\cdot V$	$-58.2\cdot deg + (-90)\cdot deg = -148.2\cdot deg$	$\mathbf{V_C} = 1.259V\ \underline{/{-148.2}^o}$

OR, you can also find these voltages directly, using a voltage divider. I.E. to find $\mathbf{V_C}$ directly:

$$\mathbf{V_C} := \frac{\frac{1}{j\cdot\omega\cdot C}}{R + j\cdot\omega\cdot L + \frac{1}{j\cdot\omega\cdot C}}\cdot 6\cdot V = \frac{1}{R\cdot(j\cdot\omega\cdot C) + j\cdot\omega\cdot L\cdot(j\cdot\omega\cdot C) + 1}\cdot 6\cdot V = \frac{1}{R\cdot(j\cdot\omega\cdot C) - \omega^2\cdot L\cdot C + 1}\cdot 6\cdot V$$

$$= \frac{1}{\left(1 - \omega^2\cdot L\cdot C\right) + j\cdot\omega\cdot R\cdot C}\cdot 6\cdot V \qquad \left(1 - \omega^2\cdot L\cdot C\right) = -4.053 \qquad j\cdot\omega\cdot R\cdot C = 2.513j$$

$$= \frac{6\cdot V}{-4.053 + 2.513\cdot j}\cdot\frac{(-4.053 - 2.513\cdot j\ )}{(-4.053 - 2.513\cdot j\ )} = \frac{6\cdot V\cdot(-4.053 - 2.513\cdot j\ )}{(-4.053)^2 + 2.513^2}$$

$6\cdot V\cdot(-4.053 - 2.513\cdot j\ ) = -24.318 - 15.078j\ \cdot V$

$(-4.053)^2 + 2.513^2 = 22.742$

$$= \left(\frac{-24.318}{22.742} - \frac{15.078\cdot j}{22.742}\right)\cdot V = -1.069 - 0.663j\ \cdot V$$

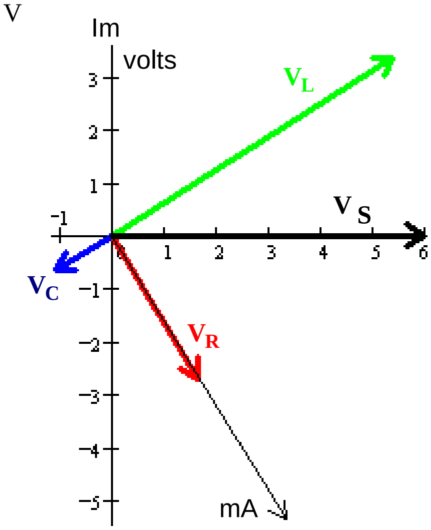
magnitude: $\sqrt{1.069^2 + 0.663^2} = 1.258$

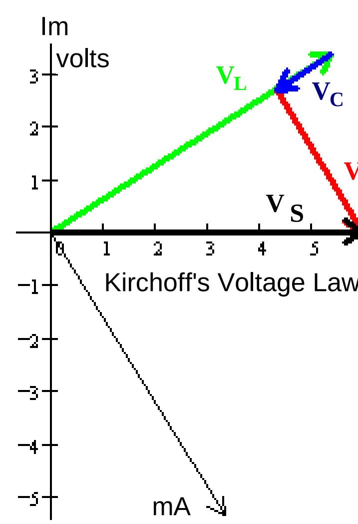
angle: $\text{atan}\left(\frac{-0.663}{-1.069}\right) = 31.81\cdot deg$

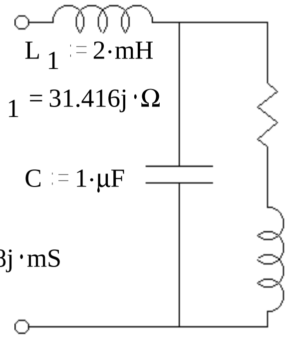
but this is actually in the third quadrant,
so modify your calculator's results:

$31.81\cdot deg - 180\cdot deg = -148.19\cdot deg$

$= 1.258V\ \underline{/{-148.2}^o}$







$L_1 := 2 \cdot mH$ $\quad j\cdot\omega\cdot L_1 = 31.416j \cdot \Omega$ $\quad R := 200 \cdot \Omega$ $\quad C := 1 \cdot \mu F$ $\quad L_2 := 8 \cdot mH$ $\quad j\cdot\omega\cdot L_2 = 125.664j \cdot \Omega$

Ex. 2 a) Find $\mathbf{Z_{eq}}$. $\quad f := 2.5 \cdot kHz \quad \omega := 2\cdot\pi\cdot f \quad \omega = 15708 \cdot \frac{rad}{sec}$

$$\mathbf{Z_{eq}} = j\cdot\omega\cdot L_1 + \frac{1}{\frac{1}{R + j\cdot\omega\cdot L_2} + \frac{1}{\frac{1}{j\cdot\omega\cdot C}}} = j\cdot\omega\cdot L_1 + \frac{1}{\frac{1}{R + j\cdot\omega\cdot L_2} + j\cdot\omega\cdot C}$$

$$j\cdot\omega\cdot C = 15.708j \cdot mS$$

$$\mathbf{Z_{eq}} := j\cdot\omega\cdot L_1 + \frac{1}{\frac{1}{R + j\cdot\omega\cdot L_2} + j\cdot\omega\cdot C} = 31.416\cdot j \cdot \Omega + \frac{1}{\frac{1}{(200 + 125.664\cdot j)\cdot\Omega} + 15.708\cdot j \cdot mS}$$

$$= 31.416\cdot j \cdot \Omega + \frac{1}{(3.585 - 2.252\cdot j + 15.708\cdot j)\cdot mS} = 31.416\cdot j \cdot \Omega + (18.487 - 69.391\cdot j)\cdot\Omega = 18.487 - 37.975j \cdot \Omega$$

$$\left|\mathbf{Z_{eq}}\right| = 42.238 \cdot \Omega \qquad \arg\left(\mathbf{Z_{eq}}\right) = -64.043 \cdot deg$$

b) $\mathbf{V_{in}} := 12\cdot V\cdot e^{j\cdot 20\cdot deg}$ Find $\mathbf{I_{L1}}$, $\mathbf{V_C}$

$$\mathbf{I_{L1}} := \frac{\mathbf{V_{in}}}{\mathbf{Z_{eq}}} \qquad \frac{12\cdot V}{42.24\cdot\Omega} = 284.1 \cdot mA \qquad 20\cdot deg - (-64.04)\cdot deg = 84.04 \cdot deg$$

$$\mathbf{I_{L1}} = 284.1mA\ \underline{/\ 84.04^o} = 284.1\cdot mA\cdot e^{j\cdot 84.04\cdot deg} \qquad \mathbf{I_{L1}} = 29.485 + 282.569j \cdot mA$$

$$\mathbf{V_C} := \mathbf{I_{L1}}\cdot(18.486 - 69.384\cdot j)\cdot\Omega \qquad 284.1\cdot mA\cdot\sqrt{18.486^2 + 69.384^2}\cdot\Omega = 20.4 \cdot V \qquad 84.04\cdot deg + atan\left(\frac{-69.384}{18.486}\right) = 8.959 \cdot deg$$

$$\mathbf{V_C} = 20.4V\ \underline{/\ 8.96^o}$$

To find $\mathbf{V_C}$ directly:

$$\mathbf{V_C} := \frac{\frac{1}{\frac{1}{R + j\cdot\omega\cdot L_2} + j\cdot\omega\cdot C}}{j\cdot\omega\cdot L_1 + \frac{1}{\frac{1}{R + j\cdot\omega\cdot L_2} + j\cdot\omega\cdot C}}\cdot\mathbf{V_{in}} = \frac{1}{j\cdot\omega\cdot L_1\cdot\left(\frac{1}{R + j\cdot\omega\cdot L_2} + j\cdot\omega\cdot C\right) + 1}\cdot\mathbf{V_{in}} \qquad \mathbf{V_C} = 20.153 + 3.178j \cdot V$$

You could then use another voltage divider to find $\mathbf{V_R}$ or $\mathbf{V_{L2}}$.

c) Find $\mathbf{I_{L2}}$

$$\mathbf{I_{L2}} := \frac{\mathbf{V_C}}{R + j\cdot\omega\cdot L_2} = \frac{20.4\cdot V\cdot e^{j\cdot 8.96\cdot deg}}{236.202\cdot\Omega\cdot e^{j\cdot 32.142\cdot deg}} = \frac{20.4\cdot V}{236.202\cdot\Omega}\ \underline{/\ 8.96 - 32.142^o} = 86.4mA\ \underline{/-23.18}$$

Or, directly by Current divider:

$$\mathbf{I_{L2}} := \frac{\frac{1}{R + j\cdot\omega\cdot L_2}}{j\cdot\omega\cdot C + \frac{1}{R + j\cdot\omega\cdot L_2}}\cdot\mathbf{I_{L1}} = \frac{1}{j\cdot\omega\cdot C\cdot\left(R + j\cdot\omega\cdot L_2\right) + 1}\cdot\mathbf{I_{L1}} = 79.404 - 34.001j \cdot mA$$

d) How about $\mathbf{I_C}$?

$$\mathbf{I_C} := \frac{\mathbf{V_C}}{\left(\frac{1}{j\cdot\omega\cdot C}\right)} = \mathbf{V_C}\cdot j\cdot\omega\cdot C = 20.4V\ \underline{/\ 8.96^o}\ 15.708mS\ \underline{/\ 90^o} = 320mA\ \underline{/\ 98.96^o}$$

Or, directly by Current divider:

$$\mathbf{I_C} := \frac{j\cdot\omega\cdot C}{j\cdot\omega\cdot C + \frac{1}{R + j\cdot\omega\cdot L_2}}\cdot\mathbf{I_{L1}}$$

This current is greater than the input current. What's going on?

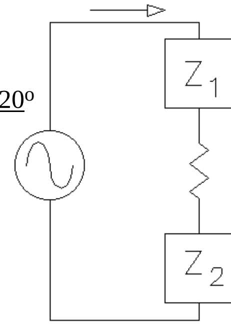
The angle between $\mathbf{I_C}$ & $\mathbf{I_{L2}}$ is big enough that they somewhat cancel each other out, partial resonance.

Check Kirchoff's Current Law: $\mathbf{I_C} + \mathbf{I_{L2}} = 29.485 + 282.569j \cdot mA = \mathbf{I_{L1}} = 29.485 + 282.569j \cdot mA$

ECE 3600 Phasor Examples p3

$i(t) = 25\cdot mA\cdot\cos\left(377\cdot\frac{rad}{sec}\cdot t + 10\cdot deg\right)$

Ex. 3 a) Find $\mathbf{Z_2}$.



$\mathbf{V_{in}}$ = 10V /-20º

$\mathbf{Z_1} := (80 - 60\cdot j)\cdot\Omega$

$R := 50\cdot\Omega$

$\mathbf{Z_2}$ = ?

$\mathbf{I} := 25\cdot mA\cdot e^{j\cdot 10\cdot deg}$

$\mathbf{V_{in}} := 10\cdot V\cdot e^{-j\cdot 20\cdot deg}$

$\mathbf{Z_T} := \frac{\mathbf{V_{in}}}{\mathbf{I}} = \frac{10\cdot V}{25\cdot mA}$ $\underline{/ -20 - 10^o}$ = 400Ω $\underline{/ -30^o}$

$\mathbf{Z_T} = 346.41 - 200j \cdot\Omega$

$\mathbf{Z_2} := \mathbf{Z_T} - R - \mathbf{Z_1} = (346.41 - 200\cdot j)\cdot\Omega - 50\cdot\Omega - (80 - 60\cdot j)\cdot\Omega = 216.41 - 140j \cdot\Omega$

b) Circle 1: i) The source current leads the source voltage <--- answer, because 10º > -20º.

ii) The source voltage leads the source current

Ex. 4 a) The impedance $\mathbf{Z_1}$ (above) is made of two components in series. What are they and what are their values?

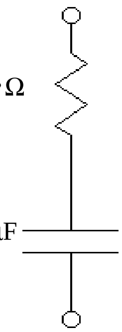
$\mathbf{Z_1} = 80 - 60j \cdot\Omega$ $\qquad \omega := 377\cdot\frac{rad}{sec}$

Must have a resistor because there is a real part.

$R := Re(\mathbf{Z_1})$ $\qquad R = 80\cdot\Omega$

Must have a capacitor because the imaginary part is negative.

$Im(\mathbf{Z_1}) = -60\cdot\Omega = \frac{-1}{\omega\cdot C}$ $\qquad C := \frac{-1}{\omega\cdot Im(\mathbf{Z_1})}$ $\qquad C = 44.21\cdot\mu F$



b) The impedance $\mathbf{Z_1}$ is made of two components in <u>parallel</u>. What are they and what are their values?

$\mathbf{Z_1} = 80 - 60j \cdot\Omega$

Must have a resistor because there is a real part.

Must have a capacitor because the imaginary part is negative.

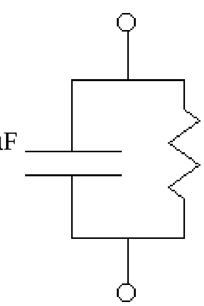
$$\mathbf{Z_1} = \frac{1}{\frac{1}{R} + j\cdot\omega\cdot C} \qquad \frac{1}{\mathbf{Z_1}} = \frac{1}{(80 - 60\cdot j)\cdot\Omega}\cdot\left(\frac{80 + 60\cdot j}{80 + 60\cdot j}\right) = \frac{80 + 60\cdot j}{80^2 + 60^2} = \frac{80 + 60\cdot j}{10,000}\cdot\frac{1}{\Omega}$$

$80^2 + 60^2 = 10000$

$$\frac{1}{\mathbf{Z_1}} = 8 + 6j \cdot mS = 0.008 + 0.006\cdot j\ \frac{1}{\Omega} = \frac{1}{R} + j\cdot\omega\cdot C$$

$\frac{1}{R} = 0.008\cdot\frac{1}{\Omega}$ $\qquad R := \frac{1}{0.008\cdot\frac{1}{\Omega}}$ $\qquad R = 125\cdot\Omega$

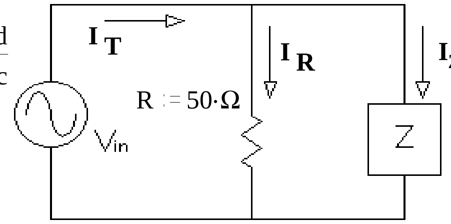
$\omega\cdot C = 0.006\cdot\frac{1}{\Omega}$ $\qquad C := \frac{0.006\cdot\frac{1}{\Omega}}{\omega}$ $\qquad C = 15.915\cdot\mu F$



$R = 125\cdot\Omega$

Ex. 5 a) Find $\mathbf{V_{in}}$ in polar form.

$\omega := 1000 \cdot \frac{rad}{sec}$



$\mathbf{I_Z} = 100\ \underline{/\ 0^o}\ mA$ $\qquad \mathbf{Z} := (40 + 60 \cdot j) \cdot \Omega$

$\mathbf{I_Z} := 100 \cdot mA \qquad \mathbf{Z} := (40 + 60 \cdot j) \cdot \Omega$

$\mathbf{V_{in}} := \mathbf{I_Z} \cdot \mathbf{Z} \qquad \mathbf{V_{in}} = (4 + 6j) \cdot V$

$\sqrt{4^2 + 6^2} = 7.211 \qquad \operatorname{atan}\left(\frac{6}{4}\right) = 56.31 \cdot deg \qquad \mathbf{V_{in}} = 7.21V\ \underline{/ \text{-}56.3^o}$

b) Find $\mathbf{I_T}$ in polar form.

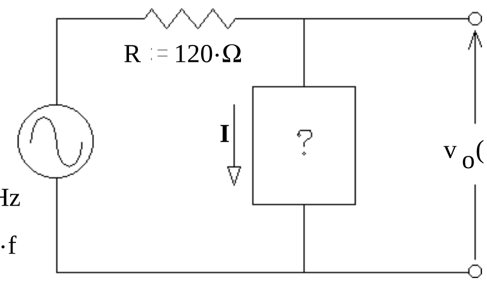
$\mathbf{I_R} := \frac{\mathbf{V_{in}}}{R} = \frac{(4 + 6 \cdot j) \cdot V}{50 \cdot \Omega} = \frac{4 \cdot V}{50 \cdot \Omega} + \frac{6 \cdot j \cdot V}{50 \cdot \Omega} = (80 + 120j) \cdot mA$

$\mathbf{I_T} := \mathbf{I_R} + \mathbf{I_Z} = (80 + 120 \cdot j) \cdot mA + 100 \cdot mA = (180 + 120j) \cdot mA$

$|\mathbf{I_T}| = 216.3 \cdot mA \qquad \arg(\mathbf{I_T}) = 33.69 \cdot deg \qquad \mathbf{I_T} = 216.3mA\ \underline{/\ 33.7^o}$

c) Circle 1: i) $\mathbf{I_T}$ leads $\mathbf{V_{in}}$ ii) $\mathbf{V_{in}}$ leads $\mathbf{I_T}$ answer ii), $56.3^o > 33.7^o$

Ex. 6 You need to design a circuit in which the the "output" voltage leads the input voltage ($v_S(t)$) by 30º of phase.



$v_S(t)$

$f := 1 \cdot kHz$

$\omega := 2 \cdot \pi \cdot f$

$\omega = 6.283 \cdot 10^3 \cdot \frac{rad}{sec}$

a) What should go in the box: R, L, C?

$$\mathbf{V_o} = \frac{\mathbf{Z_{box}}}{R + \mathbf{Z_{box}}} \cdot \mathbf{V_S}$$

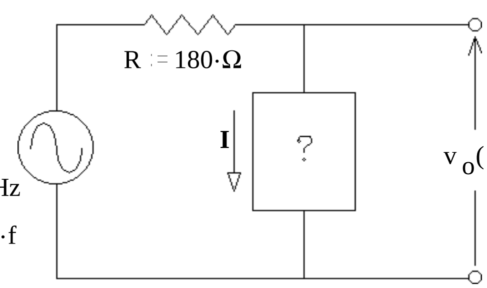
angle of $\frac{\mathbf{Z_{box}}}{R + \mathbf{Z_{box}}}$ is 30º.

This can only happen if the angle of $\mathbf{Z_{box}}$ is positive, so $\mathbf{Z_{box}}$ is a inductor

b) Find its value. $\mathbf{V_o} = \quad \mathbf{V_o} = \frac{j \cdot \omega \cdot L}{R + j \cdot \omega \cdot L} \cdot \mathbf{V_S}$ angle: $\frac{j \cdot \omega \cdot L}{R + j \cdot \omega \cdot L}$ is $90 - \operatorname{atan}\left(\frac{\omega \cdot L}{R}\right) = 30^o$ so $\operatorname{atan}\left(\frac{\omega \cdot L}{R}\right) = 60^o$.

$\frac{\omega \cdot L}{R} = \tan(60 \cdot deg) = 1.732 \qquad L := \frac{R \cdot 1.732}{\omega} \qquad L = 33.1 \cdot mH$

Ex. 7 You need to design a circuit in which the the "output" voltage lags the input voltage ($v_S(t)$) by 40º of phase.



$v_S(t)$

$f := 1 \cdot kHz$

$\omega := 2 \cdot \pi \cdot f$

a) What should go in the box: R, L, C?

$$\mathbf{V_o} = \frac{\mathbf{Z_{box}}}{R + \mathbf{Z_{box}}} \cdot \mathbf{V_S}$$

angle of $\frac{\mathbf{Z_{box}}}{R + \mathbf{Z_{box}}}$ is -40º.

This can only happen if the angle of $\mathbf{Z_{box}}$ is negative, so $\mathbf{Z_{box}}$ is a capacitor

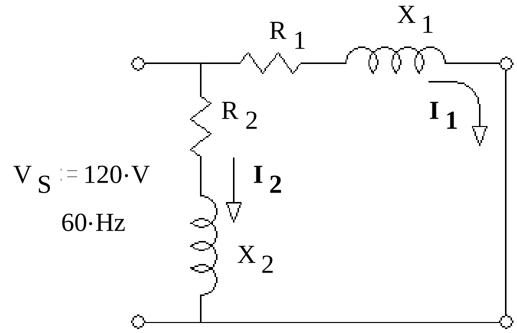
b) Find its value.

$$\mathbf{V_o} = \frac{\frac{1}{j \cdot \omega \cdot C}}{R + \frac{1}{j \cdot \omega \cdot C}} \cdot \mathbf{V_S}$$

angle: $\frac{\frac{1}{j \cdot \omega \cdot C}}{R + \frac{1}{j \cdot \omega \cdot C}}$ is $-90 - \operatorname{atan}\left(\frac{-\frac{1}{\omega \cdot C}}{R}\right) = -90 - \operatorname{atan}\left(-\frac{1}{\omega \cdot C \cdot R}\right)$ so $\operatorname{atan}\left(-\frac{1}{\omega \cdot C \cdot R}\right) = \text{-}50^o$

$-\frac{1}{\omega \cdot C \cdot R} = \tan(-50 \cdot deg) = -1.192 \qquad C := \frac{1}{\omega \cdot R \cdot 1.192} \qquad C = 0.742 \cdot \mu F$

Ex. 8 The magnitudes of $\mathbf{I_1}$ and $\mathbf{I_2}$ are 3A and 2A. They lag the supply voltage by 20° and 30°. respectively.



a) Find the values of R_1, R_2, X_1 and X_2.

$$\mathbf{Z_1} := \frac{120\cdot V}{3\cdot A\cdot e^{-j\cdot 20\cdot deg}} \qquad \mathbf{Z_1} = 37.588 + 13.681j \ \cdot\Omega$$

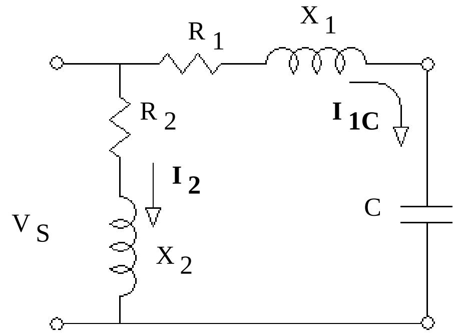
$$R_1 := \mathrm{Re}(\mathbf{Z_1}) \qquad R_1 = 37.588\cdot\Omega$$

$$X_1 := \mathrm{Im}(\mathbf{Z_1}) \qquad X_1 = 13.681\cdot\Omega$$

$$\mathbf{Z_2} := \frac{120\cdot V}{2\cdot A\cdot e^{-j\cdot 30\cdot deg}} \qquad \mathbf{Z_2} = 51.962 + 30j \ \cdot\Omega \qquad R_2 := \mathrm{Re}(\mathbf{Z_2}) \qquad R_2 = 51.962\cdot\Omega \qquad X_2 := \mathrm{Im}(\mathbf{Z_2}) \qquad X_2 = 30\cdot\Omega$$

b) Add C to the circuit such that $\mathbf{I_{1C}}$ leads $\mathbf{I_2}$ by 90°. Find the value of C.

$\omega := 2\cdot\pi\cdot 60\cdot Hz$



$$\mathbf{I_{1C}} = \frac{120\cdot V}{R_1 + j\cdot X_1 + j\cdot X_C}$$ needs to be at an angle of + 50°

So: $$\mathrm{atan}\left(\frac{X_1 + X_C}{R_1}\right) = -50\cdot deg$$

$$\frac{X_1 + X_C}{R_1} = \tan(-50\cdot deg)$$

$$X_C := R_1\cdot\tan(-50\cdot deg) - X_1 \qquad X_C = -58.476\cdot\Omega = \frac{-1}{\omega\cdot C} \qquad C := \frac{-1}{\omega\cdot X_C} \qquad C = 45.4\cdot\mu F$$

c) Change C so that the magnitudes of $\mathbf{I_{1C}}$ and $\mathbf{I_2}$ are the same. Find the new C.

$$\left|\mathbf{I_{1C}}\right| = \left|\frac{120\cdot V}{R_1 + j\cdot X_1 + j\cdot X_C}\right|$$ needs to be 2A So: $$\left|R_1 + j\cdot X_1 + j\cdot X_C\right| = 60\cdot\Omega$$

$$\sqrt{R_1^{\,2} + \left(X_1 + X_C\right)^2} = 60\cdot\Omega$$

$$\left(X_1 + X_C\right) = \sqrt{(60\cdot\Omega)^2 - R_1^{\,2}} = 46.767\cdot\Omega$$

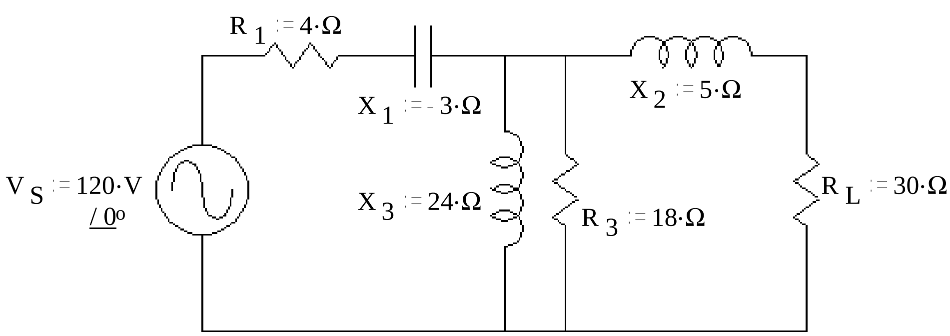
$$X_C := \sqrt{(60\cdot\Omega)^2 - R_1^{\,2}} - X_1 \qquad X_C = 33.086\cdot\Omega = \frac{-1}{\omega\cdot C}$$ NOT POSSIBLE

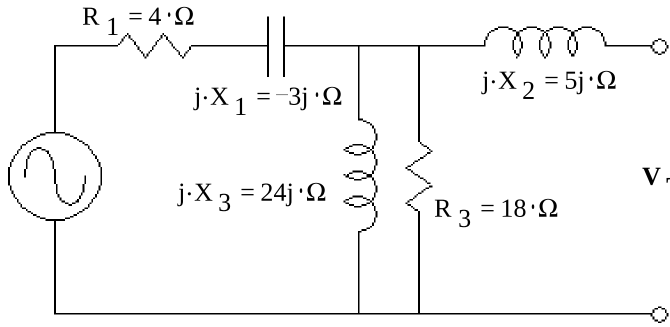
So: $$\left(X_1 + X_C\right) = -46.767\cdot\Omega$$

And: $$X_C := -\sqrt{(60\cdot\Omega)^2 - R_1^{\,2}} - X_1 \qquad X_C = -60.448\cdot\Omega = \frac{-1}{\omega\cdot C} \qquad C := \frac{-1}{\omega\cdot X_C} \qquad C = 43.9\cdot\mu F$$

You'll use a very similar method to find start- and run- capacitors for single-phase induction motors.

Ex. 9 a) In the circuit below R_L is the load resistor. Find and draw the Thevenin equivalent of the rest of the circuit.



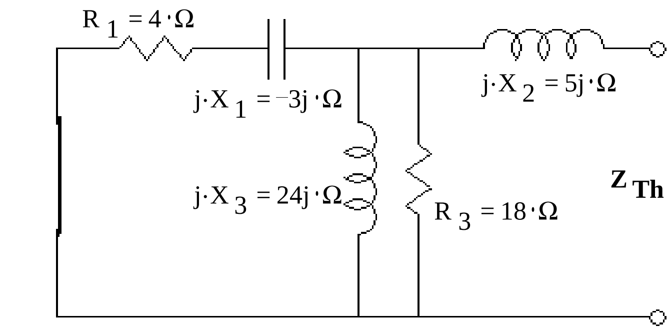


$$\mathbf{V_{Th}} := V_S \cdot \frac{\left(\dfrac{1}{\dfrac{1}{j\cdot X_3} + \dfrac{1}{R_3}}\right)}{R_1 + j\cdot X_1 + \left(\dfrac{1}{\dfrac{1}{j\cdot X_3} + \dfrac{1}{R_3}}\right)}$$

$\left|\mathbf{V_{Th}}\right| = 104.645\cdot V$

$\arg\left(\mathbf{V_{Th}}\right) = 16.899\cdot deg$

$\mathbf{V_{Th}} = 100.126 + 30.418j\ \cdot V$



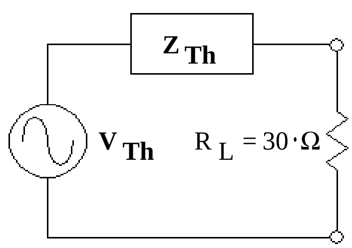
$$\mathbf{Z_{Th}} := \frac{1}{\dfrac{1}{R_1 + j\cdot X_1} + \dfrac{1}{j\cdot X_3} + \dfrac{1}{R_3}} + j\cdot X_2$$

$\left|\mathbf{Z_{Th}}\right| = 5.3962\cdot\Omega$

$\arg\left(\mathbf{Z_{Th}}\right) = 40.587\cdot deg$

$\mathbf{Z_{Th}} = 4.098 + 3.511j\ \cdot\Omega$

b) Use the Thevenin equivalent to find the current through the load resistor and the voltage across the load resistor.



$$\mathbf{I_{RL}} := \frac{\mathbf{V_{Th}}}{\mathbf{Z_{Th}} + R_L}$$

$\mathbf{I_{RL}} = 2.997 + 0.584j\ \cdot A$

$\left|\mathbf{I_{RL}}\right| = 3.053\cdot A$ $\arg\left(\mathbf{I_{RL}}\right) = 11.02\cdot deg$

$\mathbf{V_{RL}} := \mathbf{I_{RL}}\cdot R_L$ $\mathbf{V_{RL}} = 89.895 + 17.507j\ \cdot V$

$\left|\mathbf{V_{RL}}\right| = 91.584\cdot V$ $\arg\left(\mathbf{V_{RL}}\right) = 11.02\cdot deg$

c) Find a replacement for R_L in order to maximize the power delivered to R_L.

$R_L := \left|\mathbf{Z_{Th}}\right|$

$R_L = 5.396\cdot\Omega$

d) Find the new current and voltage for the load resistor.

$$\mathbf{I_{RL}} := \frac{\mathbf{V_{Th}}}{\mathbf{Z_{Th}} + R_L}$$

$\mathbf{I_{RL}} = 10.32 - 0.612j\ \cdot A$ $\left|\mathbf{I_{RL}}\right| = 10.338\cdot A$ $\arg\left(\mathbf{I_{RL}}\right) = -3.395\cdot deg$

$\mathbf{V_{RL}} := \mathbf{I_{RL}}\cdot R_L$ $\mathbf{V_{RL}} = 55.687 - 3.303j\ \cdot V$ $\left|\mathbf{V_{RL}}\right| = 55.785\cdot V$ $\arg\left(\mathbf{V_{RL}}\right) = -3.395\cdot deg$

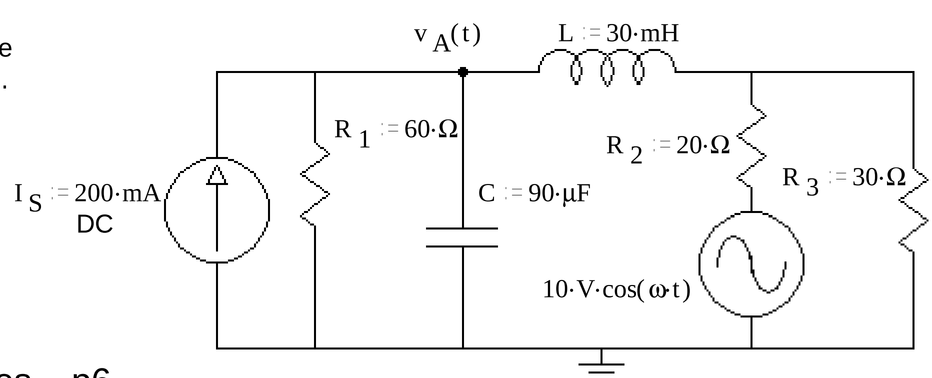
You'll use a Thevenin equivalent circuit to analyze induction motors.

Ex. 10 The circuit shown has two sources. The current source is DC and the voltage source is 60Hz.

Using superposition, find the nodal voltage $v_A(t)$. Be sure to redraw the circuit twice as part of your solution.

$v_A(t) = ?$

$\omega := 2\cdot\pi\cdot 60\cdot Hz$

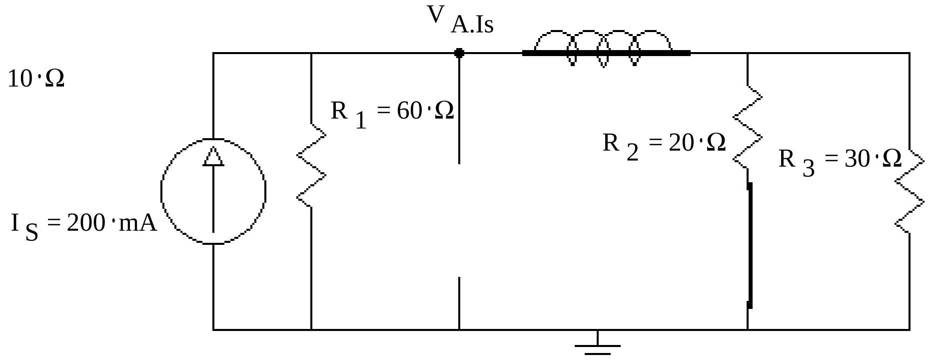


Eliminate voltage source

$$R_{eq} := \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} \qquad R_{eq} = 10\cdot\Omega$$

$$V_{A.Is} := I_S \cdot R_{eq}$$

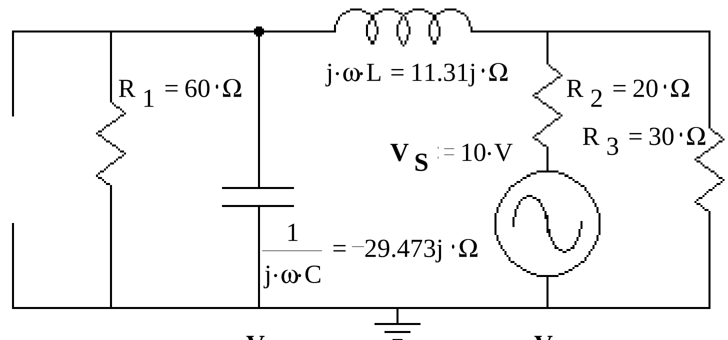
$$V_{A.Is} = 2\cdot V$$



Eliminate current source

Let's use nodal analysis

node A



$$\mathbf{I_L} = \mathbf{I_1} + \mathbf{I_C}$$

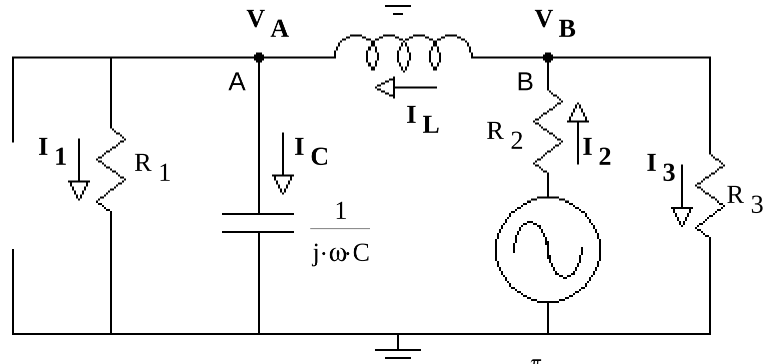
$$\frac{\mathbf{V_B}-\mathbf{V_A}}{j\cdot\omega\cdot L} = \frac{\mathbf{V_A}}{R_1} + \mathbf{V_A}\cdot j\cdot\omega\cdot C$$

$$\mathbf{V_B}-\mathbf{V_A} = \left(\frac{\mathbf{V_A}}{R_1} + \mathbf{V_A}\cdot j\cdot\omega\cdot C\right)\cdot(j\cdot\omega\cdot L)$$

$$j\cdot\omega\cdot L = 11.31j\cdot\Omega$$

$$\mathbf{V_B} = \left(\frac{\mathbf{V_A}}{R_1} + \mathbf{V_A}\cdot j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L + \mathbf{V_A}$$

$$j\cdot\omega\cdot C = 33.929j\cdot mS$$



node B

$$\mathbf{I_2} = \mathbf{I_L} + \mathbf{I_3}$$

$$\frac{\mathbf{V_S}-\mathbf{V_B}}{R_2} = \frac{\mathbf{V_B}-\mathbf{V_A}}{j\cdot\omega\cdot L} + \frac{\mathbf{V_B}}{R_3}$$

$$\frac{\mathbf{V_S}}{R_2} + \frac{\mathbf{V_A}}{j\cdot\omega\cdot L} = \mathbf{V_B}\cdot\left(\frac{1}{j\cdot\omega\cdot L}+\frac{1}{R_3}+\frac{1}{R_2}\right) = \mathbf{V_B}\cdot(83.333-88.419\cdot j)\cdot mS = \mathbf{V_B}\cdot 121.5\cdot mS\cdot e^{-46.696\cdot\frac{\pi}{180}\cdot j}$$

$$\mathbf{V_B} = \frac{\mathbf{V_S}}{R_2\cdot\left(\frac{1}{j\cdot\omega\cdot L}+\frac{1}{R_3}+\frac{1}{R_2}\right)} + \frac{\mathbf{V_A}}{j\cdot\omega\cdot L\cdot\left(\frac{1}{j\cdot\omega\cdot L}+\frac{1}{R_3}+\frac{1}{R_2}\right)} = \left(\frac{\mathbf{V_A}}{R_1} + \mathbf{V_A}\cdot j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L + \mathbf{V_A}$$

Equate to node A equation:

$$\frac{\mathbf{V_S}}{R_2\cdot\left(\frac{1}{j\cdot\omega\cdot L}+\frac{1}{R_3}+\frac{1}{R_2}\right)} = \left(\frac{\mathbf{V_A}}{R_1} + \mathbf{V_A}\cdot j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L + \mathbf{V_A} - \frac{\mathbf{V_A}}{1+j\cdot\omega\cdot L\cdot\left(\frac{1}{R_3}+\frac{1}{R_2}\right)}$$

$$1+j\cdot\omega\cdot L\cdot\left(\frac{1}{R_3}+\frac{1}{R_2}\right) = 1+0.942j$$

$$= \mathbf{V_A}\cdot\left[\left(\frac{1}{R_1}+j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L + 1 - \frac{1}{1+j\cdot\omega\cdot L\cdot\left(\frac{1}{R_3}+\frac{1}{R_2}\right)}\right]$$

$$\left(\frac{1}{R_1}+j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L = -0.384+0.188j$$

$$\mathbf{V_A} := \frac{\mathbf{V_S}}{R_2\cdot\left(\frac{1}{j\cdot\omega\cdot L}+\frac{1}{R_3}+\frac{1}{R_2}\right)}\cdot\frac{1}{\left[\left(\frac{1}{R_1}+j\cdot\omega\cdot C\right)\cdot j\cdot\omega\cdot L + 1 - \frac{1}{1+j\cdot\omega\cdot L\cdot\left(\frac{1}{R_3}+\frac{1}{R_2}\right)}\right]}$$

$$\mathbf{V_A} = 4.796-3.5j\cdot V$$

$$\left|\mathbf{V_A}\right| = 5.938\cdot V \qquad \arg\left(\mathbf{V_A}\right) = -36.12\cdot deg$$

$$V_{A.Vs} = 5.938\cdot V\cdot\cos(377\cdot t - 36.1\cdot deg)$$

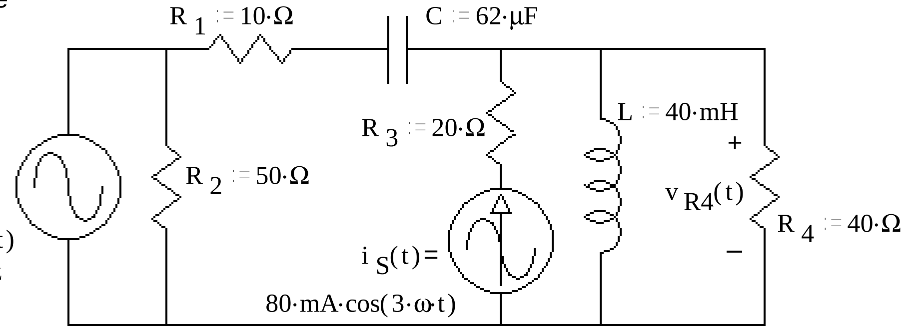
$$= \frac{\mathbf{V_S}}{R_2\cdot 121.5\cdot mS\cdot e^{-j\cdot 46.696\cdot deg}\cdot\left[(-0.384+0.188\cdot j)+1-\frac{1}{1+0.942\cdot j}\right]}$$

Add the results $v_A(t) = 2\cdot V + 5.938\cdot V\cdot\cos(377\cdot t - 36.1\cdot deg)$

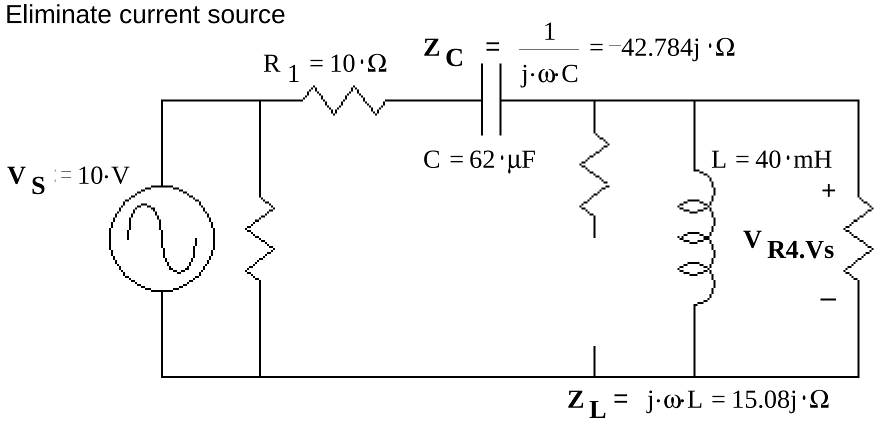
Ex. 11 The circuit shown has two sources. The frequency of the current source is the third harmonic of the voltage source.

Using superposition, find the voltage across R_4. Be sure to redraw the circuit twice as part of your solution.

$v_{R4}(t) = ?$



Eliminate current source



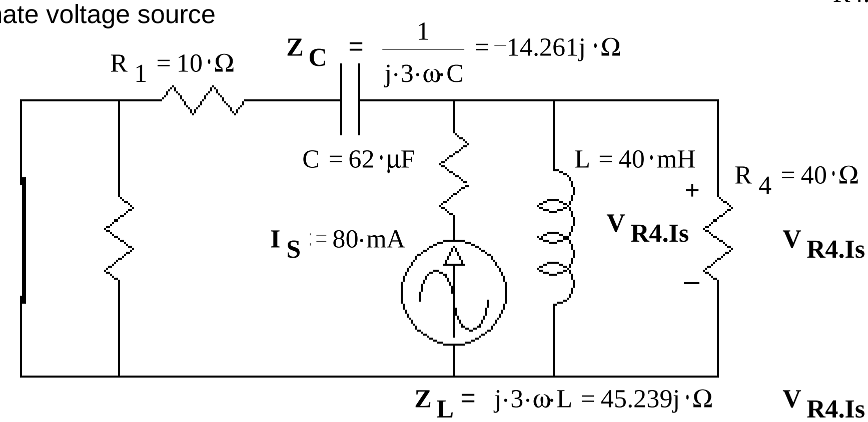
$$\mathbf{V_{R4.Vs}} := \mathbf{V_S}\cdot\frac{\dfrac{1}{\left(\dfrac{1}{j\cdot\omega\cdot L}+\dfrac{1}{R_4}\right)}}{R_1+\dfrac{1}{j\cdot\omega\cdot C}+\dfrac{1}{\left(\dfrac{1}{j\cdot\omega\cdot L}+\dfrac{1}{R_4}\right)}}$$

$\mathbf{V_{R4.Vs}} = -2.875 + 3.138j \cdot V$

$\left|\mathbf{V_{R4.Vs}}\right| = 4.256\cdot V \quad \arg(\mathbf{V_{R4.Vs}}) = 132.5\cdot deg$

$v_{R4.Vs}(t) := 4.256\cdot V\cdot\cos(\omega\cdot t + 132.5\cdot deg)$

Eliminate voltage source



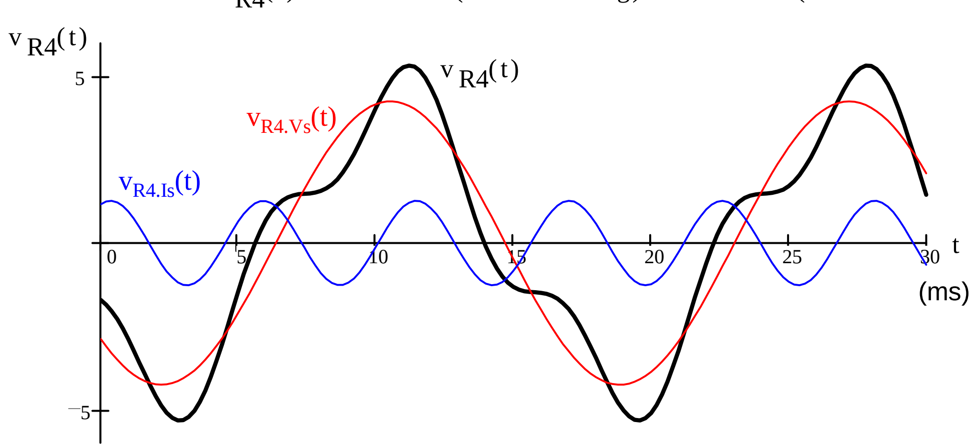
$$\mathbf{V_{R4.Is}} := \mathbf{I_S}\cdot\frac{1}{\left(\dfrac{1}{R_1+\dfrac{1}{j\cdot 3\cdot\omega\cdot C}}+\dfrac{1}{j\cdot 3\cdot\omega\cdot L}+\dfrac{1}{R_4}\right)}$$

$\mathbf{V_{R4.Is}} = 1.165 - 0.501j \cdot V$

$\left|\mathbf{V_{R4.Is}}\right| = 1.268\cdot V \quad \arg(\mathbf{V_{R4.Is}}) = -23.25\cdot deg$

$v_{R4.Is}(t) := 1.268\cdot V\cdot\cos(3\cdot\omega\cdot t - 23.25\cdot deg)$

Add the results $\quad v_{R4}(t) := 4.256\cdot V\cdot\cos(\omega\cdot t + 132.5\cdot deg) + 1.268\cdot V\cdot\cos(3\cdot\omega\cdot t - 23.25\cdot deg) \qquad t := 0, .2 .. 30$



3rd harmonics like this are caused by iron cores used in transformers and motors.

Nodal anaysis is used in power flow calculations

A variation of superposition is used to analyze faults on transmission lines.

ECE 3600 homework 2A

Due: Tue, 1/17/23

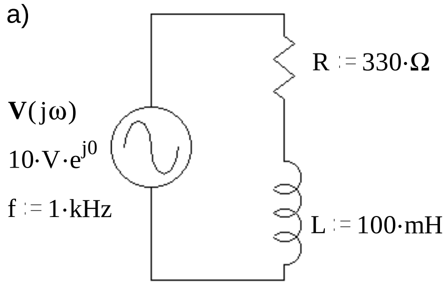
c

1. Express the impedance of a 5.2mH inductor at 60 Hz in polar form.

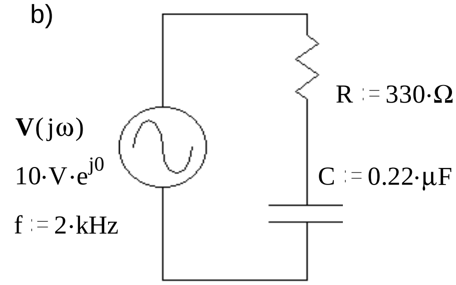
2. A capacitor impedance has a magnitude of 240Ω at a frequency of 1.8kHz. What is the value of capacitor?

3. Find $\mathbf{Z_{eq}}$ in each case.

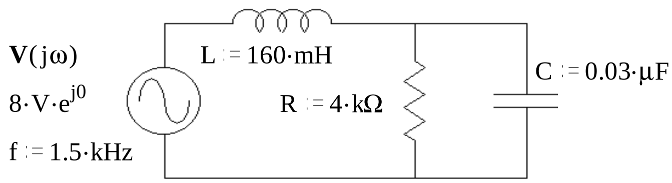
a)



b)



c)



4. Find the current **I**(jω) in each case above.

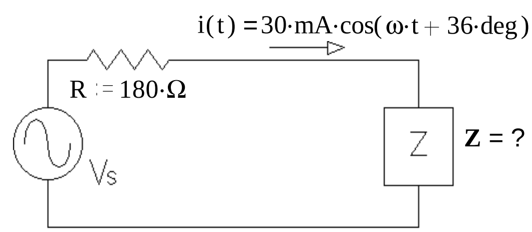
5. a) Find **Z**. Hint: Find the total impedance (R+**Z**) first.

   b) Which leads, current or voltage?

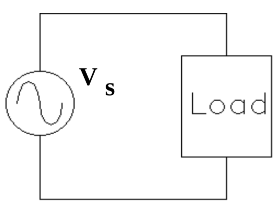
   $\omega := 377$

   $v_S(t) = 14 \cdot V \cdot \cos(\omega \cdot t + 16 \cdot deg)$

   c) By how much?
   I.E. what is the phase angle between the voltage and current?



6. The phasor diagram at right shows the voltage and current in the circuit below

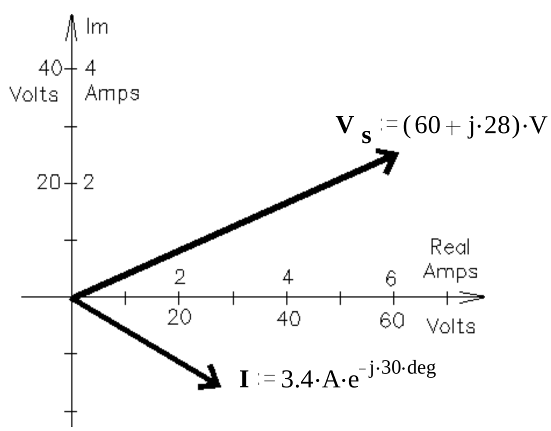


Assume the load consists of a resistor in series with a reactive component and the frequency is 60 Hz.

   a) What is the magnitude of the impedance?

   b) What is the value of the resistor?

   c) What is the reactive component (type and value)?



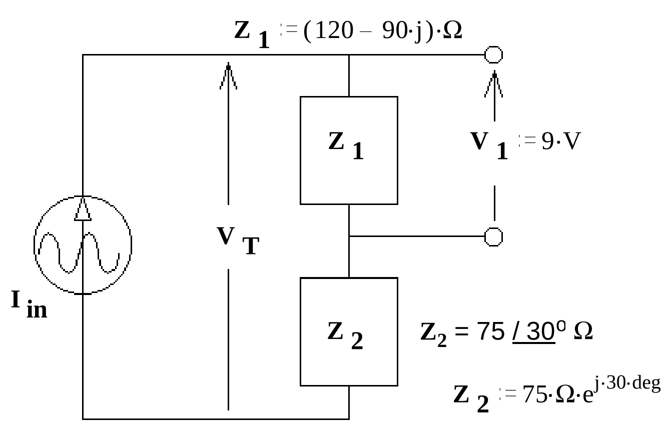
7. a) Find the AC current source, $\mathbf{I_{in}}$ in polar form.

   b) Find $\mathbf{V_T}$.

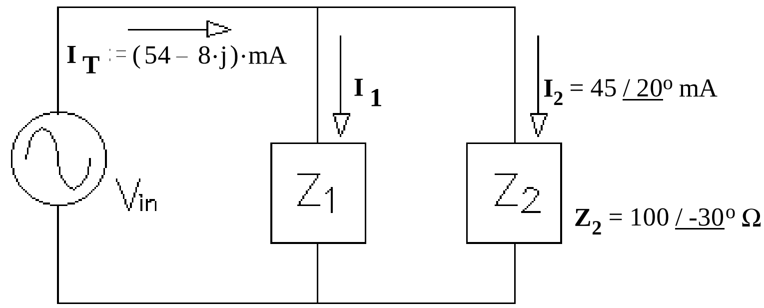
   c) Choose one:

      i) The source current leads the source voltage.

      ii) The source current lags the source voltage.



8. a) Find $\mathbf{Z_1}$.



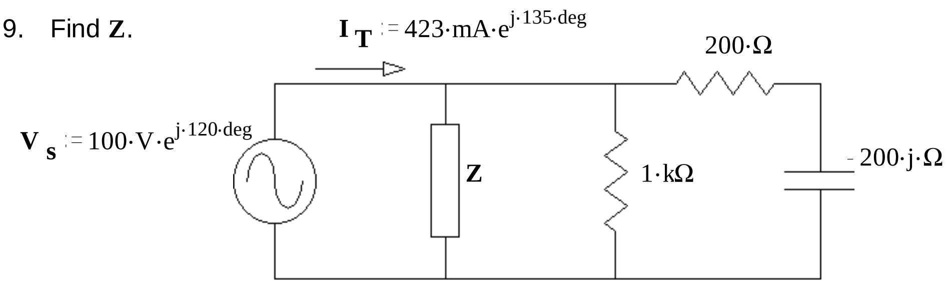
b) To make $\mathbf{Z_1}$ in the simplest way, what part(s) would you need? Just determine the needed part(s) from the list below and state why you made that choice, don't find the values.

resistor   capacitor   inductor   power supply   current source
Thevenin resistor   Ideal transformer   voltmeter   ammeter   scope

c) Choose one: i) $\mathbf{I_2}$ leads the source voltage ($\mathbf{V_{in}}$)   ii) $\mathbf{I_2}$ lags the source voltage ($\mathbf{V_{in}}$)

d) Choose one: i) $\mathbf{I_1}$ leads $\mathbf{I_2}$ ii) $\mathbf{I_1}$ lags $\mathbf{I_2}$

9. Find $\mathbf{Z}$.



Answers

1. $1.96\ \Omega \angle 90^o$
2. $0.368 \cdot \mu F$
3. a) $(330 + 628.3 \cdot j) \cdot \Omega = 709.7\Omega \angle 62.29^o$ b) $(330 - 361.7 \cdot j) \cdot \Omega = 489.6\Omega \angle -47.63^o$ c) $1.82k\Omega \angle -15.2^o$
4. a) $(6.6 - 12.5 \cdot j) \cdot mA = 14.1mA \angle -62.29^o$ b) $(13.8 + 15.1 \cdot j) \cdot mA = 20.4mA \angle 47.63^o$ c) $4.4mA \angle 15.2^o$
5. a) $259 - 160 \cdot j$ b) The current leads the voltage   c) 20^o
6. a) $19.5 \cdot \Omega$ b) $11.2 \cdot \Omega$ c) inductor $42.3 \cdot mH$
7. a) $60 \angle 36.87^o$ mA   b) $11.54 \angle 21^o$ V   c) i)
8. a) $172 \angle 53.4^o\ \Omega$ b) phase angle > 0, resistor and inductor   c) i)   d) ii)
9. $657\ \Omega \angle 67.4^o$

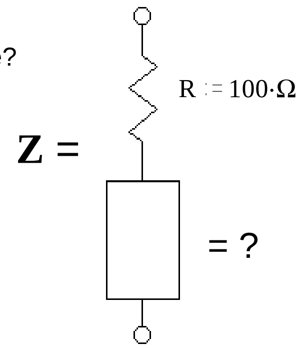
ECE 3600 homework 2B

Due: Fri, 1/20/23

1. $\mathbf{Z} = |\mathbf{Z}| \cdot e^{-j \cdot 30 \cdot deg}$ We don't know its magnitude, but its phase angle is -30º.

   $\mathbf{Z}$ is made of a 100Ω resistor in series with one other part. What is the part? type and value?

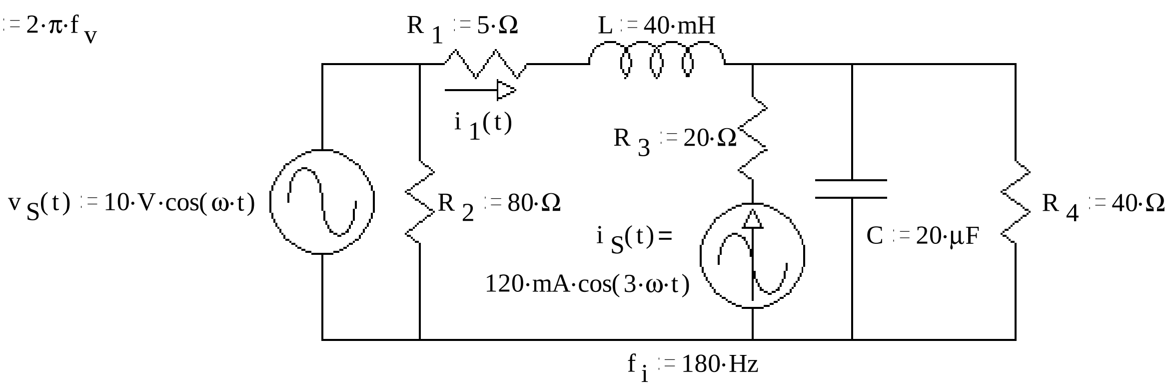
   $f := 60 \cdot Hz$ $\omega := 2 \cdot \pi \cdot 60 \cdot Hz$



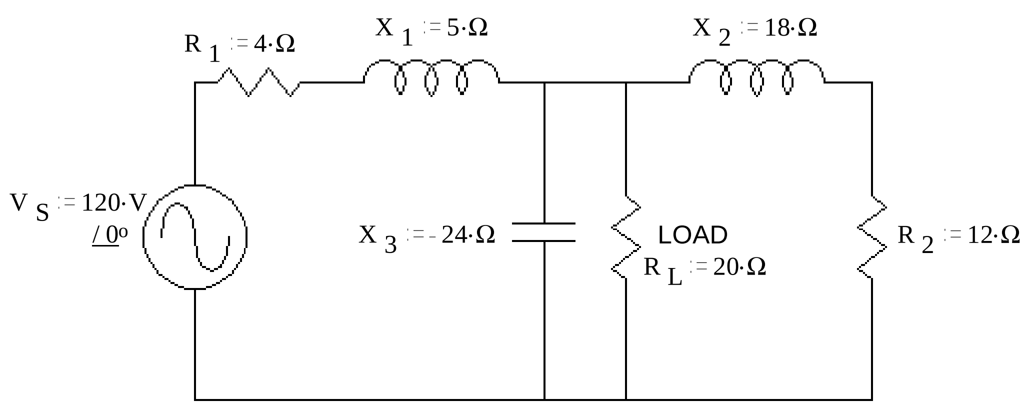
2. The circuit shown has two sources. The frequency of the current source is the third harmonic of the voltage source. Using superposition, find the current $i_1(t)$. Be sure to redraw the cicuit twice as part of your solution. $i_1(t) = ?$

   $f_v := 60 \cdot Hz$

   $\omega := 2 \cdot \pi \cdot f_v$



3. a) In the circuit below R_L is the load resistor. Find and draw the Thevenin equivalent of the rest of the circuit.



   b) Use the Thevenin equivalent to find the current through the load resistor and the voltage across the load resistor.

   c) Find a replacement for R_L in order to maximize the power delivered to R_L.

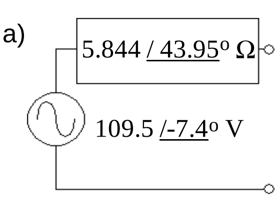
   d) Find the new current and voltage for the load resistor.

Answers

1. 45.9·μF

2. $i_1(t) := 239 \cdot mA \cdot \cos(\omega \cdot t - 5.5 \cdot deg) + 96.1 \cdot mA \cdot \cos(3 \cdot \omega \cdot t + 94.7 \cdot deg)$

3. a)



   b) 4.46 /-16.9º A

   89.2 /-16.9º V

   c) 5.844 Ω

   d) 10.1 /-29.4º A

   59.1 /-29.4º V