1. Choose an R, an L, or a C to be placed in the dashed-line box to make

\[ i(t) = I_0 \cos(25kt + 135^\circ) \]

where \( I_0 \) is a positive, (i.e., nonzero), real constant. State the value of the component you choose.

Hint: Use a Thevenin equivalent.

In the frequency domain, we represent the source with a phasor and use an impedance for the \( C \).

\[ I_g = 24 \text{mA} \angle 90^\circ, \quad I = I_0 \angle 135^\circ \]

\[ I_R = 24 \text{mA} \angle 90^\circ \cdot 10\text{k}\Omega - 240 \angle 90^\circ \text{V} \approx V_g \]

\[ Z_C = \frac{1}{j \omega C} = -\frac{j}{25 \cdot 1 \text{nF}} = -\frac{j}{25 \mu} \]

\[ Z_C = -j 40 \text{k}\Omega \]

\[ I_g = 24m e^{j90} \]

The resultant circuit is a current divider:

\[ I = \frac{I_g \cdot 10k}{10k - j 40k + Z_{box}} = \frac{24m \cdot 10k \cdot e^{j90^\circ}}{10k - j 40k + Z_{box}} \]

The desired output is:

\[ I = I_0 e^{j135^\circ} \]

In order for the above two equations to match, their angles need to match:

\[ I = \frac{\angle(24m \cdot 10k \cdot e^{j90^\circ})}{\angle(10k - j 40k + Z_{box})} = \angle I_0 e^{j135^\circ} \]
\[ \angle (10k - j40k + Z_{\text{box}}) = \angle 135^\circ \]

In order for this equation to be satisfied, the angle on the bottom has to equal

\[ \angle (90^\circ - 135^\circ) = \angle -45^\circ \]

To achieve -45 degrees, the bottom has to have the real = -imaginary so that \( \tan^{-1}(-1) = -45 \)

If an R,
10k+R=40k so R=30k. This is a valid value.

If an L,
10k=(40k-25kL) \Rightarrow L=(40k-10k)/25k=1.2H which is a valid value but large.

Therefore, an \textbf{R=30k or L=1.2H} will work to achieve the desired value.

2. With your component from problem 1 in the circuit, calculate the resulting value of \( I_0 \).

\[ I_0 = \left| I_1 \right| = \left| V_0 / Z_{\text{tot}} \right| = \left| V_0 / Z_{\text{tot}} \right| \]

\[
\begin{align*}
\text{For } \text{R } &= 30k \Omega , \quad I_0 = 240V/40k-j40k \Omega = 2.40A = 342\text{mA}. \\
\text{For } \text{L } &= 1.2H , \quad I_0 = 210V/10k-j10k \Omega = 21.00A = 125\text{mA}. \\
\end{align*}
\]

3. \( i_0(t) = 6\sin(1Mt) \text{A} \)

Choose an R, an L, or a C to be placed in the dashed-line box to make \( i(t) = I_0 \cos(1Mt - 120^\circ) \)

where \( I_0 \) is a positive, (i.e., nonzero and non-negative), real constant. State the value of the component you choose.

The phasor for the current source becomes: \( I_g = 6e^{j90^\circ} \) \{Note the -90 because \( \cos(\pi-90^\circ)=\sin(\pi)\)\}

And the desired phasor becomes: \( I = I_g e^{j(-120^\circ)} \)

An equation can be written for the desired phasor by observing that it is a current divider:

\[
I = \frac{I_g \cdot 4}{4 + Z_{\text{box}}} = \frac{6 \cdot e^{j90^\circ}}{4 + Z_{\text{box}}}
\]
In order for the above two equations to match, their angles need to match:

\[ I = \angle \left( \frac{24e^{j\cdot90^\circ}}{4 + Z_{\text{box}}} \right) = \angle I_e e^{j\cdot120^\circ} \]

\[ \frac{\angle -90^\circ}{\angle (4 + Z_{\text{box}})} = \angle -120^\circ \]

In order for this equation to be satisfied, the angle on the bottom has to equal \( \frac{\angle -90^\circ}{\angle -120^\circ} = \angle \left(-90^\circ + 120^\circ\right) = \angle +30^\circ \)

To get the bottom to equal +30 degrees the Zbox needs to be an inductor because a R will only result in an angle of 0; a capacitor will only result in angles (because of the -) between 0 and -90 (not a +angle):

\[
\tan^{-1} \left( \frac{1 \times 10^6 L}{4} \right) = 30^\circ
\]

\[
\frac{1 \times 10^6 L}{4} = \tan \left(30^\circ\right)
\]

\[
L = \frac{\tan \left(30^\circ\right) \cdot 4}{1 \times 10^6} = 2.3 \mu H
\]

4. With your component from problem 3 in the circuit, calculate the resulting value of \( I_o \).

\[
I = \frac{24 \cdot e^{j\cdot90^\circ}}{4 + j(1 \times 10^6) \cdot 2.3 \times 10^{-6}} = 5.2 \cdot e^{j\cdot120^\circ}
\]

So \( I_o = 5.2 A \)

5. \( i_s(t) = 4 \cos(20Mt) mA \)

Draw a frequency-domain equivalent of the above circuit. Show a numerical phasor value for \( i_s(t) \), and show numerical impedance values for R, L, and C. Label the dependent source appropriately.
6. Find the Thevenin equivalent (in the frequency domain) for the circuit from Problem 6. Give the numerical phasor value for $V_{Th}$ and the numerical impedance value of $Z_{Th}$.

We can replace the dependent source with an equivalent impedance since the voltage drop across the dependent source is $V_x$.

$$Z_{eq} = \frac{V_x}{2V_x} = \frac{3k\Omega}{2} = 1.5\, k\Omega$$

Note: We are using Ohm's law: $V = I \cdot Z$.

Note: This equivalent impedance is valid regardless of what is connected from $a$ to $b$.

We may combine $7.5k\Omega$ and $2\Omega$ in parallel.

$$7.5k\Omega \parallel 1.5k\Omega = 1.5k\Omega \cdot \frac{2}{1} = 1.25k\Omega$$
Now we combine the \( z_c \) and \( z_L \) in parallel.

\[
\frac{1}{z_{c||z_L}} = \frac{1}{j2k\Omega} = j2k\left(\frac{1}{2}\right) = -j1k\Omega
\]

\[\text{since no current can flow through the \(-j1k\Omega\),}
\]
\[\text{owing to the lack of a complete circuit,}
\]
\[\text{\( I_g \) must flow through the 1.25 k\Omega and}
\]
\[\text{the voltage drop across the \(-j1k\Omega\) must}
\]
\[\text{be zero.}
\]
\[\therefore V_{Th} = I_g \times 1.25k\Omega
\]

\[\text{\( V_{Th} = 5V 20^\circ\)}
\]

To find \( z_{Th} \), we turn off \( I_g \), (which becomes an open circuit), and look into the circuit from the \( a,b \) terminals.

\[z_{Th} = 1.25k\Omega - j3k\Omega
\]

\[V_{Th} = 5V 20^\circ
\]
7. Draw a frequency-domain equivalent of the above circuit. Show a numerical phasor value for \( i_s(t) \), and show numerical impedance values for \( R, L, \) and \( C \). Label the dependent source appropriately.

\[
\begin{align*}
    j\omega L &= j2k \cdot 50m = j100 \\
    I_s &= 5e^{j90^\circ}
\end{align*}
\]

8. Find the Thevenin equivalent (in the frequency domain) for the circuit from Problem 8. Give the numerical phasor value for \( V_{Th} \) and the numerical impedance value of \( z_{Th} \).

Using node-voltage with \( V_1 \) at the node above the current source. \( V_{th} \) is the open circuit voltage between a-b:

\[
\begin{align*}
-5e^{j90^\circ} + \frac{V_1}{-j200} + \frac{V_1 - v_s}{j100 + 100} &= 0 \\
v_s &= V_1 \\
-5e^{j90^\circ} + \frac{V_1}{-j200} + 0 &= 0 \\
V_1 &= -j200(5j) = 1kV \\
V_{Th} &= V_1 = 1kV
\end{align*}
\]
To find $Z_{th}$, short a-b and label it $I_{sc}$. The new circuit becomes a current divider:

$$I_2 = \frac{5e^{j90^\circ} \cdot (-j200)}{-j200 + j100} = -j200 \cdot \frac{5e^{j90^\circ}}{-j100} = 10e^{j90^\circ} = 10j$$

$$I_1 = \frac{V_S}{100} = \frac{10j \cdot j100}{100} = -10$$

$$I_{sc} = I_1 + I_2 = -10 + j10 = 10 \cdot \sqrt{2}e^{j135^\circ}$$

$$Z_{th} = \frac{V_{th}}{I_{sc}} = \frac{1k}{10 \cdot \sqrt{2}e^{j135^\circ}} = 70e^{-j135^\circ}$$

a) Draw a frequency-domain equivalent of the above circuit. Show a numerical phasor value for $V_S(t)$, and show numerical impedance values for R, L, and C. Label the dependent source appropriately.
b) Find the Thevenin equivalent (in the frequency domain) for the above circuit. Give the numerical phasor value for $V_{Th}$ and the numerical impedance value of $z_{Th}$.

\[ V_{Th} \left( \frac{j}{1000} + \frac{j}{10k} - \frac{j}{1666.7} + \frac{j}{2k} \right) = \frac{4\sqrt{2}e^{j45^\circ}}{2k} \]

\[ V_{Th} \left( (1m + 0.1m - 0.6m)j + 0.5m \right) = 4\sqrt{2}e^{j45^\circ} \]

\[ V_{Th} \left( 0.5(0.5 + 1) \right) = \frac{4\sqrt{2}e^{j45^\circ}}{2k(0.5m(0.5)e^{j45^\circ})} = 4V \]

\[ T_{sc} = \frac{4\sqrt{2}e^{j45^\circ}}{2k} \]

\[ V_x = 0 \]

\[ R_{Th} = \frac{V_{Th}}{I_{sc}} = \frac{4(2k)}{4\sqrt{2}e^{j45^\circ}} = \frac{2k}{4\sqrt{2}e^{j45^\circ}} = \sqrt{2}k e^{-j45^\circ} \]
10.

(a) Choose an \( R \), an \( L \), or a \( C \) to be placed in the dashed-line box to make

\[ i(t) = I_0 \cos(100t - 240^\circ) \]

where \( I_0 \) is a positive real constant (with units of Amps). State the value of the component you choose.

(b) Calculate the resulting value of \( I_0 \).
Need to get a phase of 60° from the following quantity \( \Rightarrow \)

\[
(1,000 - 1,000j + z)
\]

If \( z = R \) then \([This is just Imaginary] \)

\[
\tan^{-1}\left(\frac{-1,000}{1,000 + R}\right) = 60°
\]

\[
\frac{-1,000}{1,000 + R} = \tan 60°
\]

\[
R = \frac{-1,000}{\tan(60°)} - 1,000 = \Theta 151\Omega
\]

\[ \therefore \text{ No! } R \text{ can not be negative! (NOT AN R)} \]

If \( z = C \) then

\[
\tan^{-1}\left(\frac{-1,000 - \frac{1}{100C}}{1,000}\right) = 60°
\]

\[
\frac{-1}{100C} = \tan(60°) + 1,000 + 1,000
\]

\[
C = \frac{1}{100 \times 2732} = 8.66 \mu F
\]

\[ \therefore \text{ No! } C \text{ can not be a negative value! (NOT AN C)} \]

If \( z = L \) then

\[
\tan^{-1}\left(\frac{-1,000 + 100L}{1,000}\right) = 60°
\]

\[
L = \left(\tan 60° \times 1,000 + 1,000\right) = 27.32 \mu H
\]

\(2) \quad I_f = I_s \frac{Z}{Z_c + Z_l + R}
\]

using magnitude only

\[
I_0 = 20 \times 1K \frac{1K}{2K} = 10 \text{ mA}
\]