University of Jordan
School of Engineering
Electrical Engineering Department

EE 374
Electrical Engineering and machines Lab

EXPERIMENT 5

INDUCTIVE REACTANCE

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OBJECTIVE

Inductive reactance will be examined in this experiment. In particular, its relationship to the AC source frequency will be investigated, including a plot of inductive reactance versus frequency. In addition, AC power and power factor calculations will be introduced.

DISCUSSION

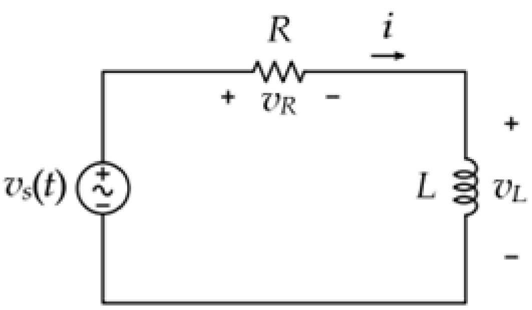
The AC current-voltage characteristic of the inductor, known as inductive *reactance* X_L, which is directly proportional to frequency. Hence, the *impedance* of an inductor (Z_L) (in units of Ohm). The inverse of the impedance is *admittance* $Y = 1/Z = G + jB$, which has the real part G called *conductance*, and the imaginary part B called *susceptance*. All three quantities have units of Siemens (S).

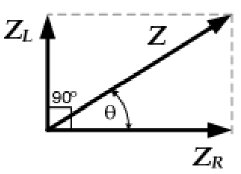
The inductive reactance may be determined experimentally by applying a known AC voltage across the inductor, measuring the resulting current, and dividing the two. This process may be repeated across a range of frequencies in order to obtain a plot of inductive reactance versus frequency.

AC-excited series RL circuit

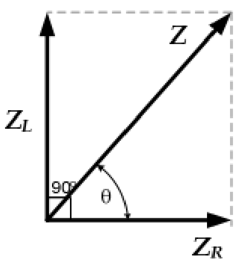
The series RL circuit is shown below, the inductor impedance Z_L changes with the frequency of the source, the total impedance Z changes with frequency as well, as shown in the following phasor diagram. Notice how the resistor impedance remains constant with frequency.

The following phasor diagram shows how the above impedance change affects the inductor voltage V_L and resistor voltage V_R, both of which now change with frequency for a constant V_S due to the voltage divider rule. The current I also changes along with its phase shift compared to the source voltage V_S, but the current remains lagging compared to the source voltage. Notice that complex numbers are added like vectors, not like scalars.

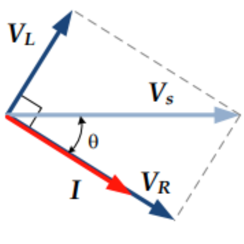




f_1



$f_2 > f_1$



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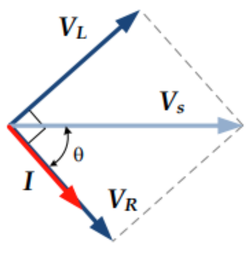


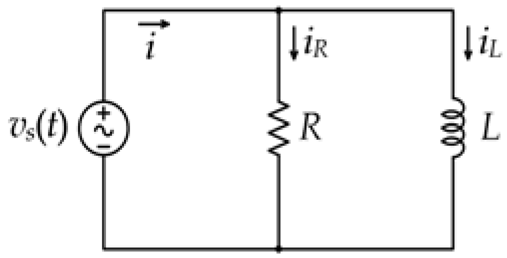
$f_2 > f_1$

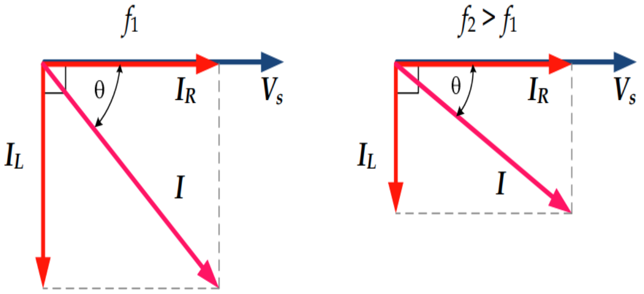
- **Some important equations to find the needed quantities in the tables:**

Quantity	Practically	Theoretically
Total current	$I = V_R/R = \|I\| \measuredangle I$	$\frac{Vs}{\|Z\|\measuredangle Z}$
Inductor Reactance	$X_L = \|V_L\|/\|I\|$	ωL
Total impedance magnitude	$\|Z\| = \|V_S\| / \|I\|$	$\sqrt{R^2 + (\omega L)^2}$
Total impedance phase	$\measuredangle Z = \measuredangle V_S - \measuredangle I$	$tan^{-1}(\frac{\omega L}{R})$

AC-excited parallel RL circuit

For the parallel RL circuits shown below, the phasor diagram shows how the inductive admittances change with frequency affects the inductor currents (I_L), which change with increasing frequency for a constant source voltage V_S. The resistance current I_R, however, stays constant, which means that the total current I changes (due to phasor addition) along with its phase shift compared to the source voltage V_S. Of course, the current lags the source voltage in case of RL circuit.





- Some important equations to find the needed quantities in the tables:

Quantity	Practically	Theoretically
Total current	$I = V_{R'} / R' = \| I \| \measuredangle I$	$\frac{Vs}{\|Z\|\measuredangle Z}$
Resistor and Inductor voltage	$V_R = Vs - V_{R'} = V_L = \| V_R \| \measuredangle V_R$	$V_R = I_R * R = V_L$
Resistor current	$I_R = V_R / R = \| I_R \| \measuredangle I_R$	$I_R = V_R / R$
Inductor current	$I_L = I - I_R = \| I_L \| \measuredangle I_L$	$I_L = V_L / Z_L$
Inductor Susceptance	$B_L = \|I_L\| / \|V_L\|$	$(\frac{1}{\omega L})$
Total admittance magnitude	$\|Y\| = \|I\| / \|V_S\|$	$\sqrt{\frac{1}{R^2} + \frac{1}{(\omega L)^2}}$
Total admittance phase	$\measuredangle Y = \measuredangle I - \measuredangle V_S$	$-tan^{-1}(\frac{R}{\omega L})$

Power and Power Factor

The average *complex power* $\boldsymbol{S}$ (units of VA) is given by the combination of the average *real power* P and the average *reactive power* Q as follows:

$$\boldsymbol{S} = P + jQ = V_{rms} I_{rms} \measuredangle(\measuredangle V - \measuredangle I) = \frac{1}{2} V_p I_p \measuredangle(\measuredangle V - \measuredangle I)$$

Hence, the real power P (units of W) is given by:

$$P = V_{rms} I_{rms} \cos(\measuredangle V - \measuredangle I) = \frac{1}{2} V_p I_p \cos(\measuredangle V - \measuredangle I)$$

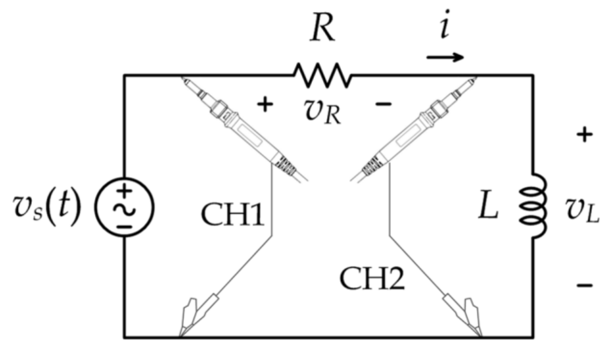
And the reactive power Q (units of VAR) is given by:

$$Q = V_{rms} I_{rms} \sin(\measuredangle V - \measuredangle I) = \frac{1}{2} V_p I_p \sin(\measuredangle V - \measuredangle I)$$

where the $\cos(\measuredangle V - \measuredangle I)$ quantity is known as the *power factor* (PF), which is lagging for inductive loads, and leading for capacitive loads. Finally the *apparent power* is given by $|\boldsymbol{S}| = V_{rms} I_{rms} = 0.5 \times V_p \times I_p$.

PROCEDURE A – AC-EXCITED SERIES RL CIRCUIT

1. Construct the circuit shown below. Use ***R* = 820 Ω and *L* = 10 mH**.



2. Set the function generator to produce a **sinusoidal** waveform (AC) with frequency of **5100 Hz**, and peak to peak voltage of $\mathbf{V_{pp} = 6\ V}$.

3. Use the oscilloscope to measure the **peak to peak** values of the voltage V_L and V_R and their phase shift compared to V_S. Record the measurements in Table 1 in the report.

4. Measure total current I in (RMS) and record the results in Table 1 in the report.

5. Can we just subtract the magnitudes of $|V_S|$ - $|V_L|$ to obtain the magnitude $|V_R|$? Why?

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6. What is the relationship between the periods T of the two signals V_S and V_R?

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7. Evaluate the reactance of the inductor X_L and the total impedance Z of the series *R* and *L* components, and record them in Table 2 in the report.

8. Evaluate the apparent power S (magnitude and phase), real power P, and reactive power Q generated by the source (function generator), the power factor (PF) and state whether it is leading or lagging and record them in Table 3 in the report.

9. Plot the following versus source frequency using the measured values in Table 1, 2 and 3:

(1) X_L and |Z| on the same plot.

(2) ∡Z.

(3) V_L and V_R on the same plot.

(4) P and Q on the same plot

10. From Table 3, at what frequency the real power P and the magnitude of the reactive power |Q| is maximum?

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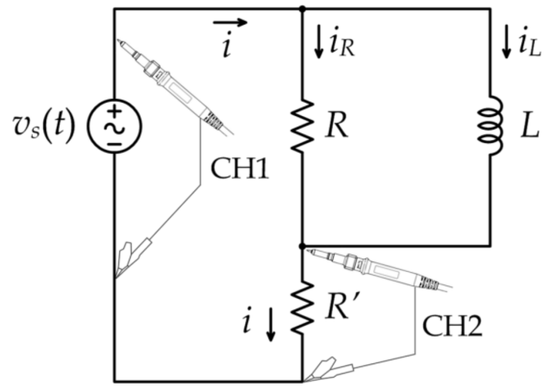
PROCEDURE B – AC-EXCITED PARALLEL RL CIRCUIT

1. Construct the circuit shown below. Use ***R* = 820 Ω, *L* = 10 mH, and *R′* = 10 Ω**. Make sure you use the correct resistor values.



2. Set the function generator to produce a **sinusoida**l waveform (AC) with frequency of **250 Hz**, and peak to peak voltage of **V_{pp}= 6 V**.

3. Use the oscilloscope to measure the **peak to peak** value of the voltage $V_{R'}$ and its phase shift compared to V_S and record the measurements in Table 4 in the report.

4. Measure the currents: the total current I, the resistor current I_R and the inductor current I_L. Record them in table 5 in the report.

5. Can we just subtract the magnitudes of $|I|$ - $|I_R|$ to obtain the magnitude $|I_L|$? Why?

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6. Evaluate the susceptance of the inductor B_L and the total admittance Y (magnitude and phase), and record them in Table 6 in the report.

7. Plot the following figures versus source frequency using the measured values in Table 5 and 6:
(1) B_L and $|Y|$ on the same plot.
(2) $\measuredangle Y$ versus source frequency.
(3) I_L and I_R on the same plot.