PHY222 **RCL Circuit**

Objectives

After completing this laboratory, a student will be able to:

1. Calculate the reactance of a capacitor or inductor based on the circuit current
2. Calculate the reactance of a capacitor or inductor based on the driving frequency
3. Choose a capacitor or inductor which will have a specified reactance at a specified frequency.
4. Show the phase relationship between the current and the voltage in a capacitor of inductor.

RCL Theory

The ratio of voltage to current in a resistor is called resistance, R = V/I where V is the voltage across the resistor and I is the current passing through it. The unit of resistance is an Ohm and 1 ohm = 1 Volt/1 Amp. The value of R is the same for AC or DC currents and is independent of frequency.

When there is an alternating current in a capacitor or an inductor, the voltage and current are 90^o out of phase with each other. These phase relationships can be represented by two-dimensional vectors called **phasors**. In a purely resistive alternating current circuit, the potential difference across the resistor is in phase with current (see Figure 1).

In other words, when the voltage across the resistor is zero, the current across the resistor is also zero. If the voltage across the resistor is at its maximum, then so is the current. This is not true for an inductor or capacitor. If the voltage across an inductor is at a maximum, then the current is at zero. The relationship for an inductor is: voltage leads the current by 90^o (see Figure 2). In a capacitor the voltage lags the current by 90^o (see Figure 3).

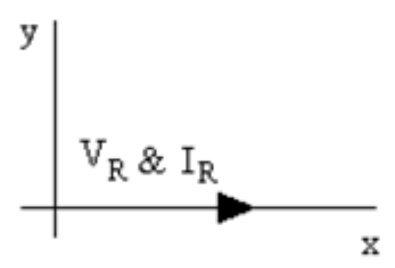

Figure 1

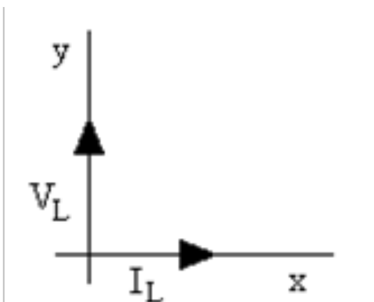

Figure 2

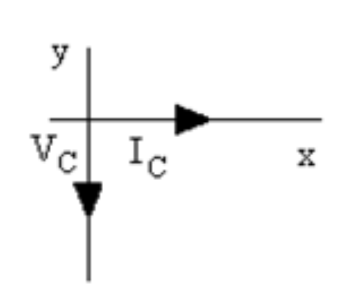

Figure 3

Most AC ammeters and voltmeters are designed to measure root-mean-square (rms) values of current and voltage rather than the maximum or peak-to-peak values. The rms value of the voltage is defined by $V_{rms} = V_{pp} / \sqrt{2} = 0.707\ V_{pp}$

V_{rms} is equal to the constant (DC) voltage which would dissipate the same average power in a resistor. Similarly,

$$I_{rms} = I_{max} / \sqrt{2} = 0.707\ I_{max}$$

Both inductance and capacitance are very important aspects of circuits. Inductors and capacitors both exhibit Ohm's law type relationships between voltage and current. The ratio of the rms voltage to the rms current is defined as the reactance, X, of a capacitor or an inductor.

Capacitive reactance is given by $\mathbf{X_C} = \frac{V_c}{I_c}$ and inductive reactance is given by $\mathbf{X_L} = \frac{V_L}{I_L}$

The units for both capacitive reactance and inductive reactance are ohms (Ω).

The dependence of reactance on frequency is different in inductors and capacitors. Inductive reactance is directly proportional to frequency, capacitive reactance is inversely proportional to frequency. The theoretical relationships are:

$X_C = \frac{1}{\omega_d C}$ and $X_L = \omega_d L$

where C is the capacitance and L is the inductance, and recall $\omega_d = 2\pi f_d$, where f_d is the driven (Function Generator) frequency.

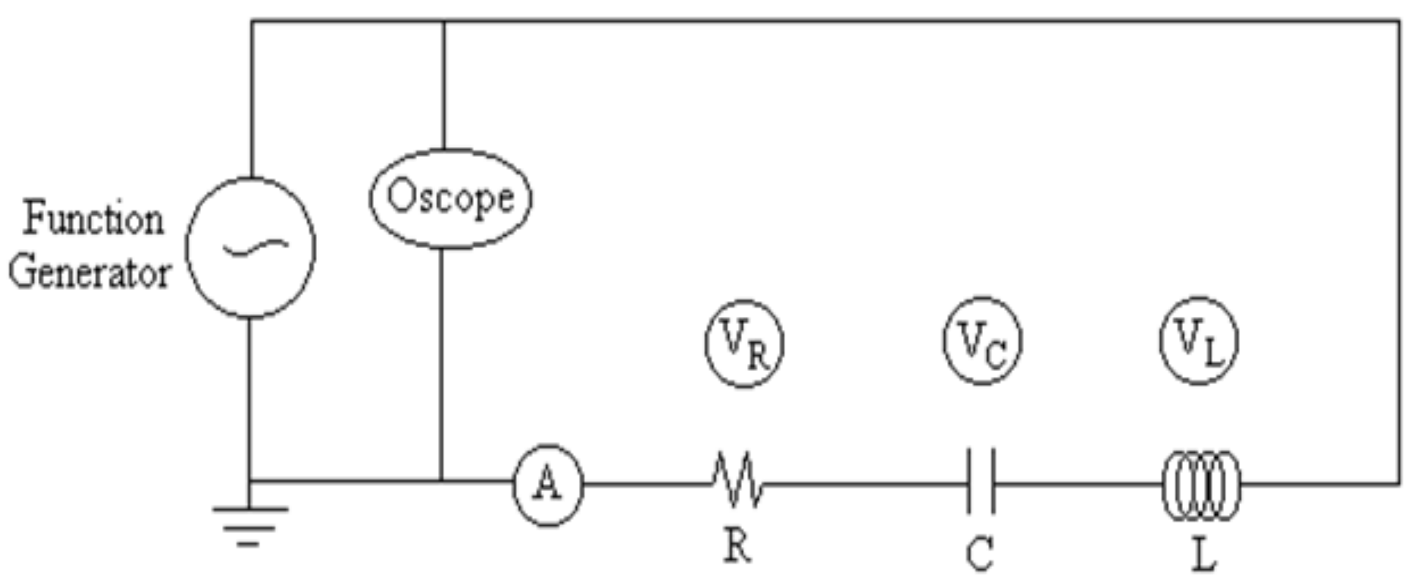

Figure 4

RCL Circuit

1. Create a series circuit that includes a function generator, an AC ammeter (the orange multimeter) a resistor box set at 7500Ω, a capacitor box set at 0.018μF and the 0.5 H inductor. Then, connect the o-scope in parallel with the function generator. Recall that the current is the same for all components connected in series: $I = I_R = I_C = I_L$.
2. Before you turn on the circuit, use the red multimeter to measure the exact resistance and the exact capacitance and record those values here: R = __________Ω   C = __________nF
3. Be sure the ammeter is set to AC and is on the micro-amp scale initially
4. Set the function generator for a *sine* wave with an initial frequency of 100 Hz (and determine the corresponding ω_d frequency). Adjust the horizontal scale on the o-scope until you can see 2-3 crests of the sine wave. Dial the amplitude adjustment on the Function Generator to the maximum setting. Now, use the red multimeter to measure the AC voltage at the function generator. Record that maximum voltage here:___________V
5. Use the CH1 vertical scale (including fine adjustment) on the o-scope to fill the screen top to bottom with the sine wave. **DO NOT** use the function generator amplitude to make this fill-the-screen adjustment because you have already set your maximum voltage with that!
6. Use an AC voltmeter to measure the rms voltage across the resistor, V_R, the capacitor, V_C, and the inductor, V_L. Remember to always use the smallest voltage scale on the meter that will give you a value in order to record the most precise data! Record these voltage values along with the ammeter current in the table below.
7. Repeat this procedure six more times for the frequencies shown in the table below
8. Record your data in the table below for each trial.

Data Table

f (Hz)	ω_d (rad/s)	I (A)	V_R (V)	V_C (V)	V_L (V)	X_C (Ω)	X_L (Ω)
100							
500							
900							
1300							
1950							
2500							
3100							
Resonant = ______							

9. The frequency at which the maximum current is achieved is called the Resonant frequency. Adjust the frequency setting until the current is maximized, and record the frequency in the table above, including the corresponding current, voltage and reactance values.

10. In addition to monitoring the ammeter for maximum current, what other measurements could you take in your circuit to verify that the resonant frequency has been achieved? (Hint: consider Ohm's Law for the capacitor and inductor and what their reactance values should be at resonance).

11. Besides monitoring the ammeter for maximum current and taking the additional measurements suggested in #10, how else can you predict what the resonant angular frequency should be? Show your work for this predicted resonant frequency below, and compare your predicted (**A**ctual) value with your experimental (**O**bserved) value using $E_R = \frac{O-A}{A}(100)\%$.

To complete the lab, go get a set of unknown RLC from your instructor.

PHY222 **Names: __________________________**

RCL Unknown Challenge **__________________________________**

Collect from your instructor an unknown Resistor, Capacitor, Inductor set. Utilizing your knowledge of how to measure and interpret RCL information, determine the unknown values of R, C and L. SHOW ALL OF YOUR WORK BELOW, including the information you gathered and/or calculated in order to determine the unknown values. Record the values in the spaces below.

R = ________________Ω C = ________________F L = _______________H

Now, using the red multimeter, measure the actual resistance and capacitance of the unknown R and C and record those values below.

R_{actual} = __________________Ω C_{actual} = ________________F

Calculate (and show your work) for the percent error between your experimental (**O**bserved) values for R and C and the **A**ctual values using $E_R = \frac{O-A}{A}(100)\%$. Record your E_R values below.

E_R for resistor = _____________% E_R for capacitor = _______________%

Now, set up an RL circuit with the unknown inductor and any resistor you need to get a good looking RL decay curve on your oscilloscope. Using the RL decay curve with the known resistor, calculate the inductance of the inductor. SHOW YOUR WORK BELOW for the calculating the inductance value from the RL decay graph. Now, ask your instructor for the actual inductance value, and calculate the percent error for both of your experimental inductance results. Show your work for these E_R calculations and record them below.

E_R for inductor from RCL calculation = _____________%
E_R for inductor from RL decay calculation = _______________%

******* If the percent errors for the R and C are < 1.50% and if either of the percent errors for the L are < 10%, then you will get *<u>5 extra credit points</u>* added to your RCL quiz score, but you DO NOT get the extra credit points unless you SHOW ALL YOUR WORK for all steps above!!!**

HAND IN THIS PAGE ONLY TODAY.
THE REST OF YOUR LAB HANDOUT MAY BE USED DURING YOUR LAB QUIZ.