LRC Circuit

PHYS 296

Your name_________________ **Lab section___________________**

PRE-LAB QUIZZES

1. What will we investigate in this lab?

2. Figure 1 on the following page shows an LRC circuit with the resistor of *10* Ω, the capacitor of *330* μF, and the inductor of *8.2* mH.

(a) Calculate the resonance frequency in radian/s for the LRC circuit.

(b) If the angular frequency of the applied AC source is *628* radian/s, calculate

The impedance of the resistor =

The impedance of the capacitor =

The impedance of the inductor =

(c) If the current is measured as $I(t) = 0.1\times \cos[(628$ radian/s$) t]$ (A), calculate

$V_R(t) =$

$V_C(t) =$

$V_L(t) =$

The LRC Series Circuit
PHYS 296

Name______________________________ **Lab section**_______________________

Lab partner's name(s)____

Objective

In this lab, we investigate the property of LRC circuit and learn how to measure the resonance frequency.

Background

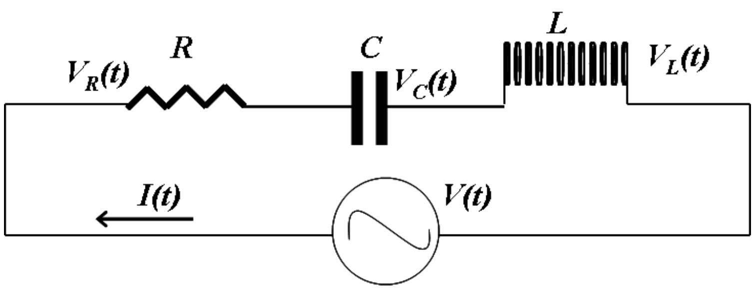


Figure 1. The LRC series circuit.

The basic AC circuit shown in Figure 1 consists of a resistor, an inductor, and a capacitor. The balance between the associated resistance, inductance, and capacitance is critical for how the AC circuit functions. Assume the applied AC voltage is described by

$$V(t) = V_0 \cos(\omega t). \tag{1a}$$

We write the to-be-determined current in the circuit as

$$I(t) = I_0 \cos(\omega t - \phi). \tag{1b}$$

Comparing Equations (1a) and (1b), *V(t)* leads *I(t)* by a phase of ϕ.

Because the impedance of the resistor is *R*, the potential drop over the resistor is:

$$V_R(t) = I(t)R = I_0 R \cos(\omega t - \phi). \tag{2a}$$

For the capacitor, the capacitive impedance is $1/\omega C$ and the potential drop over the capacitor lags the passing current by $90°$. Thus, the potential drop over the capacitor is:

$$V_C(t) = \frac{I_0}{\omega C}\cos(\omega t - \phi - 90°) = \frac{I_0}{\omega C}\sin(\omega t - \phi). \tag{2b}$$

For the inductor, the inductive impedance is ωL and the potential drop over the inductor leads the passing current by 90°. Thus, the potential drop over the inductor is:

$$V_L(t) = I_0 \omega L \cos(\omega t - \phi + 90°) = -I_0 \omega L \sin(\omega t - \phi). \tag{2c}$$

Because *V(t)* equals the sum of $V_R(t)$, $V_C(t)$, and $V_L(t)$, combining Equations (1a), 2(a), 2(b), and 2(c) leads to

$$V_0 \cos(\omega t) = I_0 [R\cos(\omega t - \phi) + (\frac{1}{\omega C} - \omega L)\sin(\omega t - \phi)]. \tag{3a}$$

Expanding the two terms on the right side of Equation (3a), we obtain:

$$V_0 = I_0 [R\cos\phi + (\omega L - \frac{1}{\omega C})\sin\phi]; \tag{3b}$$

$$0 = R\sin\phi - (\omega L - \frac{1}{\omega C})\cos\phi . \qquad (3c)$$

Hence, the phase of the AC circuit is given by

$$\tan\phi = (\omega L - \frac{1}{\omega C})/R , \qquad (4)$$

and the total impedance of the AC circuit is given by

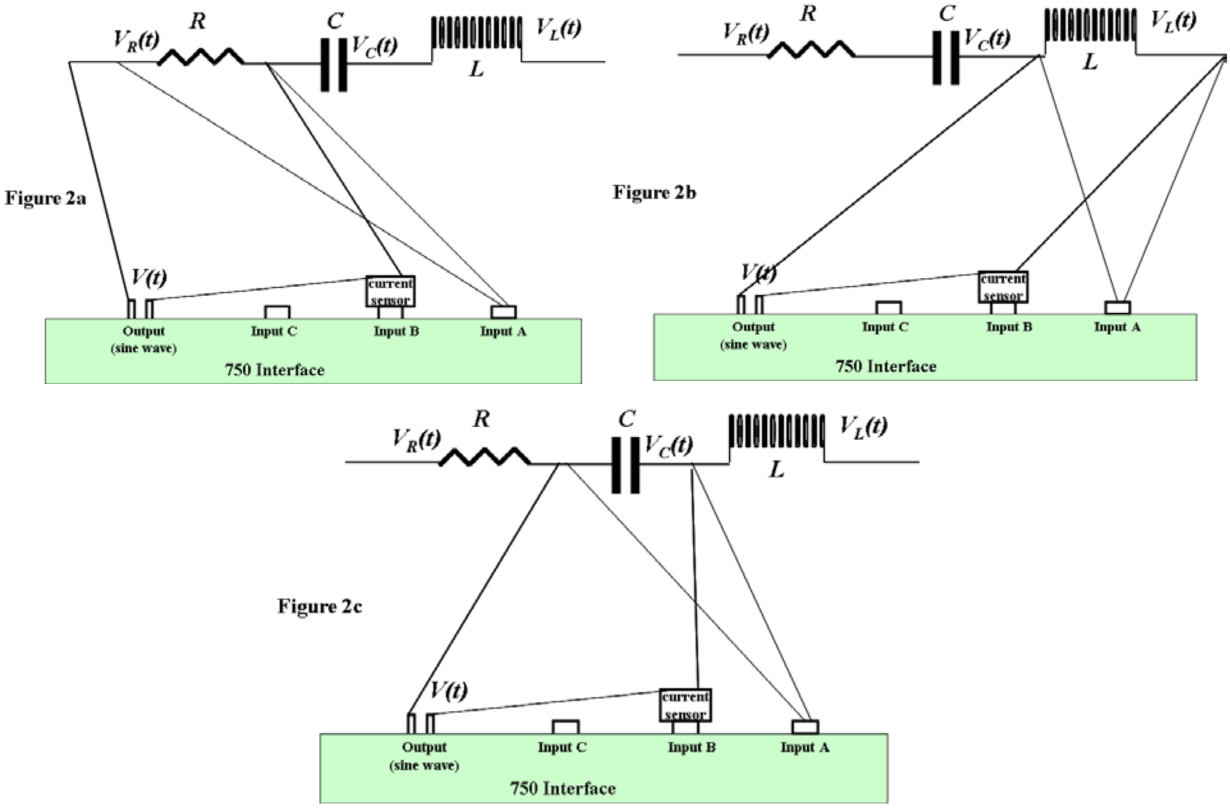
$$Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} . \qquad (5)$$

Inspecting Equations (4) and (5), **the zero phase and the minimum impedance both occur at the resonance angular frequency** which is given by

$$\omega_0 = \sqrt{\frac{1}{LC}} . \qquad (6)$$

In this experiment, we should always keep in mind that $\omega = 2\pi f$. For example, when we say the frequency of the applied AC voltage is 50 Hz, $\omega = 2\pi \times 50 rad/s$.

PART I The Properties of the LRC Circuit



(A) The Phase Properties of the Resistor, Capacitor and Inductor

In Part I(A), we measure the phases between the current and the potential drop over the resistor, the capacitor, and the inductor.

PROCEDURES

1. Set up the LRC circuit shown in Figure 2a using the capacitor of *330 μF*, the resistor of about *10 Ω*, and the inductor of *8.2 mH*. Proper connections between ***Interface 750*** and the circuit are shown in Figure 2a. Calibrate the current sensor!
2. In ***Data Studio***, select *input channel A* for the potential drop over the resistor and select *input channel B* for the current in the circuit. For all the following measurements, you should appropriately adjust the sensitivities for both channels. Using *signal generator*, select *Sine Wave* as the output, set the frequency to *10 Hz*, and set the amplitude to *2.0 V* (must below 3.0 V).
3. In ***Data Studio***, open *scope display*. Choose *analog input channel A* as input 1 and choose *analog input channel B* as input 2 for *Scope display*. To enable *scope* to display the current, you should artificially set the *input channel B* to measure Voltage (if you forget how to set it up, ask the TA). Set the trigger level at “zero, rising” for *Scope display*. Select 20 ms/div for the horizontal display scale. You should change the scale of the y- axis for each input such that you can display both traces clearly.
4. Click on *start* button. Use the smart tool to determine the amplitude for the current trace, I_0 and the amplitude for the voltage trace, V_0.

Data Analysis

1. Determine the phase difference between the potential drop over the resistor and the current in the circuit =

2. Determine the amplitude of the potential drop over the resistor =

   Determine the amplitude of the current in the circuit =

3. Calculate the impedance of the resistor by dividing the former by the latter.

   Z_R =

PROCEDURES

5. Now, set up the circuit as shown in Figure. 2b. Repeat steps 1-4, except that the frequency of *Sine Wave* is set to *2000 Hz* and select *0.1* ms/div for the horizontal display scale. Change the vertical scale for each trace such that both traces can be clearly displayed.

Data Analysis

4. Determine the phase difference between the potential drop over the inductor and the current in the circuit =

5. Determine the amplitude of the potential drop over the inductor =

   Determine the amplitude of the current in the circuit =

6. Calculate the impedance of the inductor by dividing the former by the latter.

   Z_L (*2000* Hz) =

   Assuming that the impedance is completely inductive, use $Z_L = \omega L$ to calculate the inductance

   L =

PROCEDURES

6. Now, set up the circuit as shown in Figure 2c. Repeat steps 1-4, except that the frequency of *Sine Wave* is set to *10 Hz* and select *20* ms/div for the horizontal display scale. Change the vertical scale for each trace such that you can display both traces clearly.

Data Analysis

7. Determine the phase difference between the potential drop over the capacitor and the current in the circuit =

8. Determine the amplitude of the potential drop over the capacitor =

   Determine the amplitude of the current trace in the circuit =

9. Calculate the impedance of the capacitor by dividing the former by the latter.

   Z_C (10 Hz) =

   Assuming that the impedance is completely capacitive, use $Z_C = \frac{1}{\omega C}$ to calculate the capacitance

   C =

QUESTIONS

1. Using the measured capacitance and inductance, calculate the resonance frequency of the LRC circuit.

$f_0 =$

2. What is the observed phase difference between the potential drop over the capacitor and the current in the circuit? To measure the capacitance, why do we use low frequency?

3. What is the observed phase difference between the potential drop over the inductor and the current in the circuit? To measure the inductance, why do we use high frequency?

PART II The Resonance Frequency of the LRC Circuit

In Part II, we measure the resonance frequency of the LRC circuit.

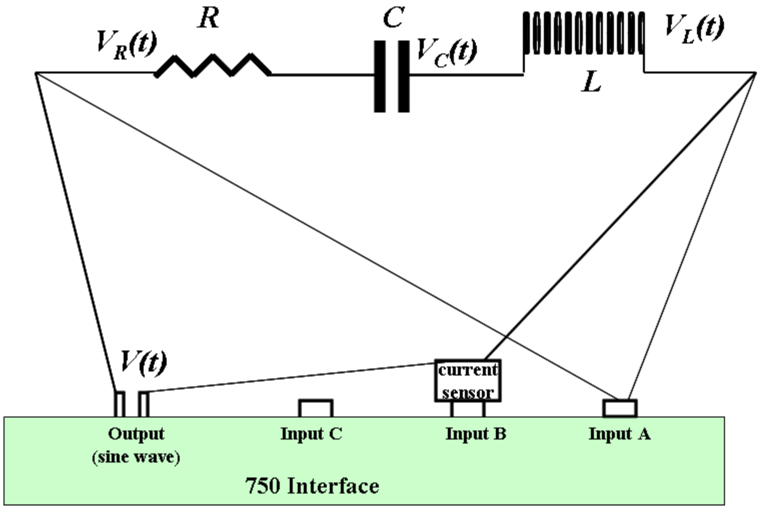


Figure 3. The LRC circuit.

PROCEDURES

1. Set up the LRC circuit as shown in Figure 3.
2. In ***Data Studio***, select *input channel B* to measure the current in the circuit and select *analog input channel A* to measure the potential drop over the circuit. Using *signal generator*, select *Sine Wave* as the AC source and set the amplitude to *2.0 V*.
3. In ***Data Studio***, open *scope display*. Choose *analog input channel A* as input 1 and *analog input channel B* as input 2. Set the trigger level to zero for *Scope*. Select 50 ms/div for the horizontal display scale. You should change the scale of the y- axis for each trace such that you can display all traces clearly. Set *scope display* to continuously update the traces.
4. Click on the *start* button.
5. Use *signal generator* to vary the frequency of *Sine Wave* between *10 – 300* Hz and determine when *input channel A* (voltage) and *input channel B* (current) are on phase. The corresponding frequency (f_{01}) is the resonance frequency. Note: when you change the frequency, you must accordingly change the scale for the horizontal display and you may also need to change the scale of the y- axis for the current trace. Determine f_{01} as accurately as you could and with the uncertainty no larger than *10* Hz.

   Record f_{01} =

QUESTIONS

1 Calculate the percent error between f_{01} and the calculated f_0.

PROCEDURES

6. Now display only the current trace for the listed frequencies in Table 1. When changing frequency, you must accordingly change the horizontal scale of display and you may also need to change the vertical scale for the current trace. But between 40-150 Hz, do not change the scales such that you can clearly see how the amplitude changes when you change the frequency. Using *Smart Tool* to determine the amplitude of the current for each frequency and record it in Table 1.

TABLE 1

f (Hz)	The amplitude of $I(t)$ (A)
10	
20	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
170	
200	
250	
300	

QUESTIONS

1 Plot I_0-versus-f. Print out the graph. Is the calculated f_0 close to the peak of the I_0-versus-f curve?