E15a: AC Circuits with Resistors, Inductors & Capacitors

Introduction:

The initial circuit experiments conducted used only resistors and DC current for investigating the behavior of voltage and current with different resistor configurations. For this lab new circuit components, namely the capacitor and inductor, will be introduced together with AC current. AC stands for alternating current, meaning the current is changing with time. AC circuits are generally considered more complex than the DC circuits initially studied. Complex is a particularly appropriate term since the mathematics of complex variables is typically used for analyses as these circuits get more advanced. This experiment will keep a simpler approach, not requiring complex variables, and introduce some of the circuit components frequently used in AC circuits. The characteristics and behavior of these components when combined together will be examined experimentally. Initially an RLC meter will be used to measure individual properties of each component. Next several different combinations will be constructed and again measured with the RLC meter. Afterwards each of these combinations will be constructed in a circuit with a function generator power supply and sensors for monitoring voltages and current. The data collected via computer software will be used to determine time constants, capacitive reactance, inductive reactance, and impedance. Finally a resonance circuit composed of a resistor, capacitor and inductor will be constructed and data collected to graphically determine the peak resonance frequency.

Apparatus:

- Circuit Breadboard
- RLC Meter
- Pasco 850 Interface
- Pasco Current Sensor
- 3 Pasco Voltage Sensors
- Hook-Up Wires & Connectors
- 2 Resistors, 5 & 10 Ohm
- 2 Inductors, 5 & 10 milliHenry
- 2 Capacitors, 1000 & 2 microFarad

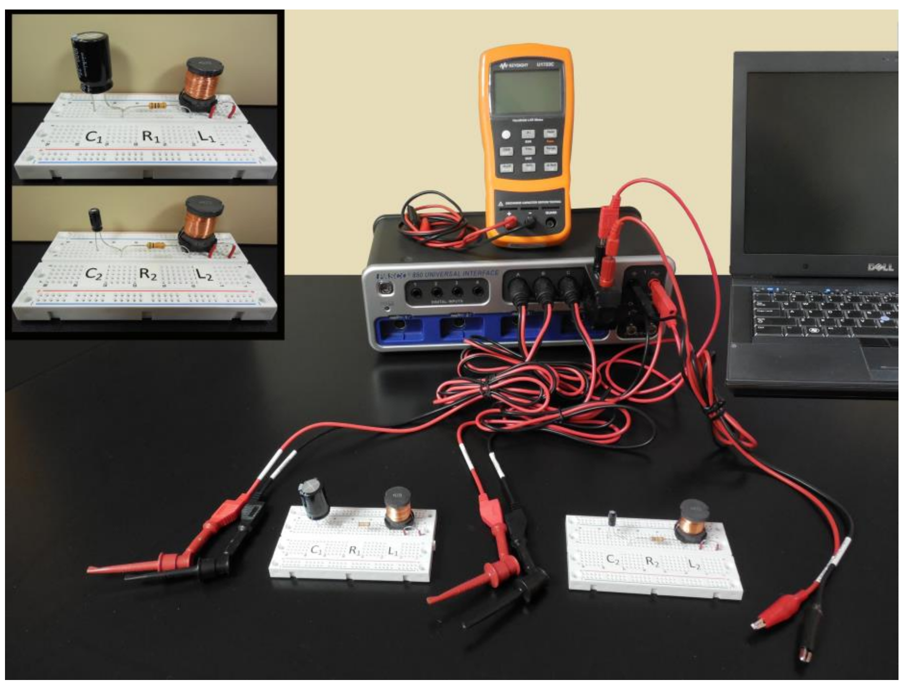


Figure 1

Discussion:

I. Capacitors and RC circuits

A capacitor is a circuit element which stores electric potential energy by storing electric charge. They can be made by insulating two conductors from one another and transferring charge from one conductor to the other, until one is negatively charged and the other is positively charged. Work is done moving the charges from one plate to the other creating a potential difference between the conductors. The result is stored electric potential energy with a total charge Q on one conductor and $-Q$ on the other conductor. When a battery is used to move the charges, eventually it results in a fixed potential difference between the two conductors that is equal to the voltage of the battery. If a larger battery is used more charges are stored on each conductor but again it reaches a fixed potential difference between the conductors. It follows then that the potential difference between the two conductors must be proportional to the total charge Q; if we were to double the charge magnitude on each conductor, the potential difference would also double, however, the *ratio* between the two remains the same. This ratio of charge to potential difference is called the capacitance of the capacitor:

$$C=\frac{Q}{V} \qquad (1).$$

A simple circuit for charging a capacitor is the RC Circuit, which features a resistor and capacitor connected in series to a power supply, see **Figure 2**.

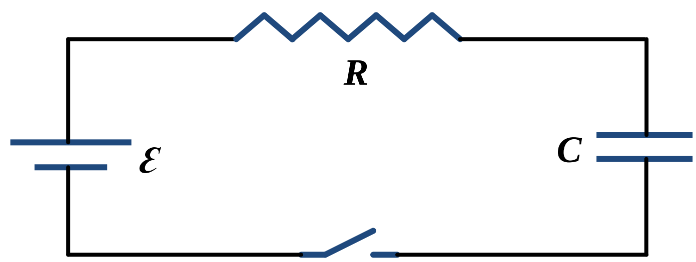


Figure 2 Diagram of an RC circuit

Initially the capacitor is uncharged, and the voltage across it is zero, whereas the voltage across the battery is equivalent to the battery electromotive force (emf) $\mathcal{E}$. When the switch in the circuit is closed the capacitor begins to charge and the voltage across it increases. At the same time the voltage across the resistor decreases. The voltage across either component can be represented in the usual way:

for the resistor $\qquad v_R = iR \qquad$ (2a),

for the capacitor $\qquad v_C = \frac{q}{C} \qquad$ (2b).

The lowercase letters used for current and charge, represent variables which are changing in time. Now using Kirchhoff's loop rule on **Figure 2** we find,

$$\varepsilon - iR - \frac{q}{C} = 0 \qquad (3a).$$

Noting that current and charge are related by,

$$i = \frac{dq}{dt} \qquad (3b),$$

and substituting this into equation (3a),

$$\varepsilon = R\frac{dq}{dt} + \frac{q}{C} \qquad (3c).$$

This is a differential equation for q and can be solved yielding the following result:

$$q = C\varepsilon\left(1 - e^{-\frac{t}{RC}}\right) \qquad (4).$$

Substituting this result in to equation (2b) we are able to find an equation for the voltage across the capacitor as a function of time,

$$v_C = \varepsilon\left(1 - e^{-\frac{t}{RC}}\right) \qquad (5).$$

The denominator in the exponent, *RC*, is a characteristic value of the circuit known as the *time constant*, typically denoted by τ. The time constant is a measure of how quickly the capacitor charges. For small τ, the capacitor will charge quickly and for larger τ, it will take more time.

$$\tau_C = RC \qquad (6).$$

II. Inductors and RL circuits

Another new circuit component you will be introduced to in this lab is the inductor. A simple inductor can be constructed from a coil of wire. When a current is run through an inductor, in this case the coil of wire, a magnetic field is produced. This also means there is a magnetic flux through the inductor. As the current changes through the wire, correspondingly the magnetic flux changes through the inductor. The changing magnetic flux gives rise to an induced electromotive force (emf) also called self-induced emf or self-induction. It is described by the following relationship:

$$\varepsilon_L = -L\frac{di}{dt} \qquad (7).$$

In this equation *L* is the coefficient of proportionality, called self-inductance; it depends on the geometry and characteristics of the material. In a circuit, inductors are typically used to resist rapid changes in current. In equation (7) we see that the larger the change in current the greater the self-induced emf, and thus the greater the potential difference between inductor terminals.

The second circuit in this lab is an RL circuit, which features a resistor and an inductor connected in series to a power supply, see **Figure 3**.

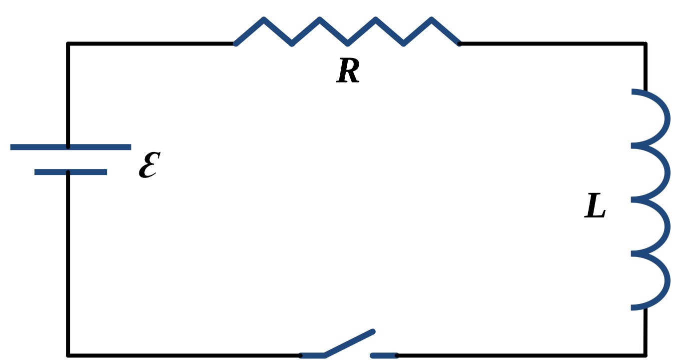


Figure 3 Diagram of an RL circuit

The initial analysis is similar to the RC circuit, using Kirchhoff's loop rule. In the RL circuit, when the switch is closed, the voltage across each component is given by:

for the resistor $\quad v_R = iR \quad$ (8a),

for the inductor $\quad v_L = L\frac{di}{dt} \quad$ (8b).

Now applying Kirchhoff's loop rule to **Figure 3** we find,

$$\varepsilon - iR - L\frac{di}{dt} = 0 \qquad (9a).$$

Solving for ε we find,

$$\varepsilon = iR + L\frac{di}{dt} \qquad (9b).$$

This is again a differential equation where the current i can be solved for:

$$i = \frac{\varepsilon}{R}(1 - e^{-\frac{R}{L}t}) \qquad (10).$$

Taking the derivative and substituting this in to equation (8b) we find the voltage across the inductor as a function of time is given by:

$$v_L = \varepsilon e^{-\frac{R}{L}t} \qquad (11).$$

In this case the time constant τ is equal to L/R and is a measure of how quickly the current builds to reach its final value. For small τ, the current will rise quickly, whereas for larger τ, it will take more time.

$$\tau_L = \frac{L}{R} \qquad (12).$$

III. AC Circuits with RLC

One type of simple AC circuit consists of a resistor, an inductor and a capacitor connected in series to a power supply, see **Figure 4**.

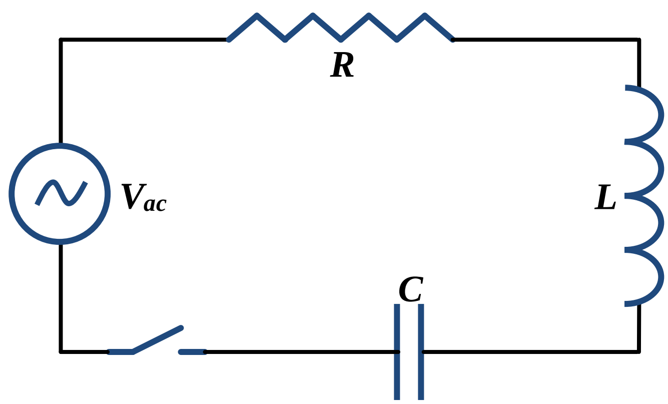


Figure 4 Diagram of an RLC circuit

In an AC circuit the voltage delivered to the circuit is a sinusoidal function of time. Therefore, the current is represented with a sine and/or cosine function, such as:

$$i = I\cos(\omega t) \qquad (13),$$

where I is the peak amplitude of the current and ω is the angular frequency of the power supply. From the RC circuit before, equation (3b) indicates that equation (13) can be integrated to solve for q. Next, substituting this expression for q back into equation (2b) we find the voltage across the capacitor is given by:

$$v_c = \frac{I}{\omega C}\sin(\omega t) \qquad (14).$$

Where I is the maximum amplitude of the current, ω is the angular frequency, and C is the capacitance. This indicates the maximum amplitude of the voltage is therefore,

$$V_C = \frac{I}{\omega C} \qquad (15a).$$

This expression can be written in a form similar to the voltage and current relationship for a resistor:

$$V_C = IX_C \qquad (15b),$$

where X_C is known as the capacitive reactance and given by the following equation:

$$X_C = \frac{1}{\omega C} \qquad (16).$$

Notice in equation (16) that the higher the frequency or capacitance results in the lower capacitive reactance; and the smaller the frequency or capacitance results in the higher capacitive reactance. This property gives capacitors the tendency to pass high-frequency current and block low-frequency and DC currents.

For inductors, a similar type of analysis can be done. Once again starting with equation (13) and finding the derivative with respect to time, the result can be substituted into equation (7) to find the voltage across the inductor:

$$v_L = -I\omega L sin(\omega t) \qquad (17).$$

This expression indicates the maximum amplitude of the inductor's voltage is:

$$V_L = I\omega L \qquad (18a).$$

Where L is the inductance of the inductor, I is the maximum amplitude of the current and ω is the angular frequency. Equation (18a) can also be written in a similar form to the voltage and current relationship for a resistor:

$$V_L = IX_L \qquad (18b),$$

where X_L is known as the inductive reactance and given by the following equation:

$$X_L = \omega L \qquad (19).$$

Notice for inductors that higher frequency or larger inductance results in a larger inductive reactance; and lower frequency or smaller inductance results in smaller inductive reactance; which is opposite to the behavior of capacitors. Inductors have a tendency to block high-frequency current and allow low-frequencies or DC currents through.

Examining the relationship between the current through the series RLC circuit and the voltages across each component indicates that the voltage peaks across each component occurs at different times. In other words the voltages have different phases.

The current through circuit: $i = Icos(\omega t)$ (13),

voltage across the resistor: $v_R = IRcos(\omega t)$ (20),

voltage across the inductor: $v_L = -I\omega Lsin(\omega t) = I\omega Lcos(\omega t + \frac{\pi}{2})$ (21),

voltage across the capacitor: $v_c = \frac{I}{\omega C}\sin(\omega t) = \frac{I}{\omega C}\cos(\omega t - \frac{\pi}{2})$ (22).

Notice that the voltage across the resistor is in phase with the current through the circuit. The voltage across the inductor is out of phase with the current by $+\frac{\pi}{2}$; this voltage across the inductor peaks before the current peaks and is said to *lead* the current by 90°. The voltage across the capacitor is out of phase with the current by $-\frac{\pi}{2}$; this voltage across the capacitor peaks after the current peaks and is said to *lag* the current by 90°.

Applying Kirchhoff's voltage loop rule to **Figure 4** produces the following equations:

$$\mathrm{v}_{ac} - v_R - v_L - v_c = 0 \qquad (23),$$

where:

$$v_{ac} = V\cos(\omega t + \varphi) \qquad (24).$$

In equation (24), V represents the maximum amplitude of the voltage from the AC power supply; ω corresponds to the angular frequency of the power supply, and φ is the phase shift between the current in the circuit and the voltage of the power supply. Substituting into equation (23) for: v_R equation (2a) & (3b), v_L equation (8b), v_C equation (2b), gives:

$$v_{ac} = R\frac{dq}{dt} + L\frac{d^2q}{dt^2} + \frac{q}{C} \qquad (25a).$$

This can also be expanded by substituting into equation (23) for the voltages using equations (24), (20), (21) and (22) giving a longer expression:

$$V\cos(\omega t + \varphi) = IRcos(\omega t) + \ I\omega Lcos\left(\omega t + \frac{\pi}{2}\right) + \frac{I}{\omega C}\cos(\omega t - \frac{\pi}{2}) \qquad (25b).$$

The phase differences of the voltages for each component in the RLC circuit means solving this expression is a more complicated process frequently done with trigonometry, vectors and phasors. The solution can be expressed in a few different forms:

$$V = I\sqrt{\left(R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right)} \quad (26a),$$

$$V = I\sqrt{(R^2 + (X_L - X_C)^2)} \quad (26b).$$

This expression can also be written in a similar form as the voltage current relationship for a resistor:

$$V = IZ \qquad (26c),$$

where Z is called the impedance and given by:

$$Z = \sqrt{(R^2 + (X_L - X_C)^2)} \qquad (27).$$

The impedance of a circuit is defined as the ratio of the maximum voltage across the circuit to the maximum current through the circuit. In an AC circuit, impedance plays the same role as resistance in a DC circuit; just as direct current follows the path of least resistance, alternating current follows the path of least impedance.

Another useful form of this equation solves for the current amplitude:

$$I = \frac{\varepsilon_{ac}}{\sqrt{(R^2 + (X_L - X_C)^2)}} \quad (28).$$

Examining this form of the expression, notice that because both X_L and X_C depend on the source's angular frequency ω, the impedance also depends on angular frequency ω. Also notice that the maximum current is obtained when the impedance is at a minimum. The minimum impedance occurs when X_L=X_C.

$$X_L = X_C \rightarrow \omega L = \frac{1}{\omega C} \quad (29),$$

$$\therefore \quad \omega = \frac{1}{\sqrt{LC}} \quad (30).$$

The angular frequency from equation (30) is called the natural resonance frequency of the circuit. It corresponds to a minimum in the impedance and therefore a maximum in the current's amplitude. The phenomenon is known as resonance in an AC circuits.

When measuring the inductive reactance experimentally the effect of the internal resistance of the inductor itself cannot be removed from the measurement. In the data tables it's being labeled as the effective inductance reactance. In order to compare the measured values to the predicted value from theory an additional calculation will be required. This is true for both the measurement made with the RLC meter and the measurements made from the oscilloscope graphs of voltage and current. For the RLC meter the explanation goes as follows:

Using the RLC meter and measuring in the impedance setting Z, the effective voltage obtained through the measurement is a combination of two factors. This measurement is the sum of the potential difference V_{RL} (due to current in the resistor of the inductor) and V_L (a potential difference due to induced emf in the inductor). Because the maximum voltages of V_{RL} and V_L are out of phase by 90°, the effective potential difference is given by:

$$V_{L_{(eff)}} = \sqrt{(V_L^2 + V_{RL}^2)} \quad (31),$$

and the actual inductive reactance is given by:

$$X_L = \sqrt{\left(X_{L_{(eff)}}^2 - R_L^2\right)} \quad (32).$$

The explanation for the inductive reactance determined from the oscilloscope graphs of voltage and current is similar. Use equation (32) for calculating the inductive reactance from the effective inductive reactance measurements.

For additional information on these concepts please read/review the following sections in your textbook.

RC Circuit:

Young & Freedman. **Sears & Zemansky's University Physics,** *Chapter* 26 *section* 4

RL Circuit:

Young & Freedman. **Sears & Zemansky's University Physics,** *Chapter* 30 *sections* 4

Resistance, Reactance & Impedance:

Young & Freedman. **Sears & Zemansky's University Physics,** *Chapter* 31 *sections* 2 & 3

Resonance in AC Circuit:

Young & Freedman. **Sears & Zemansky's University Physics,** *Chapter* 31 *sections* 5

Procedures:

Part I Measuring RLC Components with RLC Meter

Measure the following components using the RLC Meter. Turn on the meter; press the Freq. button to cycle through until you reach the 100 Hz setting; press the ZLCR button to select the component type being measured; R for resistance, L for inductance, C for capacitance, Z for impedance.

Data for Table 1

1. Using the RLC Meter measure the individual resistance of R_1 and R_2.
2. Using the RLC Meter measure the individual capacitance of C_1 and C_2.
3. Using the RLC Meter measure the individual inductance of L_1 and L_2.
4. Using the RLC Meter measure the individual resistance of L_1 and L_2.
5. Using the RLC Meter measure the total resistance of R_1 connected in series with L_1 and the total resistance of R_2 connected in series with L_2.
6. Using the RLC Meter measure the total inductance of R_1 connected in series with L_1 and the total inductance of R_2 connected in series with L_2.

Data for Table 2 (*These measurements use the Z-impedance setting on the RLC Meter at 100 Hz.*)

7. Measure the effective Inductive Reactance of L_1 by using the meter in the impedance setting. Now calculate the Inductive Reactance using the effective measurement just made and the measured total resistance of L_1; see equation (32).
8. Measure the Capacitive Reactance of C_1 by using the meter in the impedance setting.
9. Connect R_1, L_1 and C_1 together in series; use the breadboard to hold the components; measure across the combination using the meter to determine the impedance.
10. Using the measured values from Table 1 calculate the theoretically predicted Inductance Reactance, equation (19); Capacitive Reactance, equation (16); and Impedance, equation (27). For the Impedance calculation the resistance must include the resistance in the inductor, use $R_{(R_1L_1)}$.

Part II Determining the Time Constant of a RC Circuit

Activate the Capstone software start-up routine for the experiment E15a. Connect the Pasco 850 interface to the computer with the attached USB cable and turn on the interface.

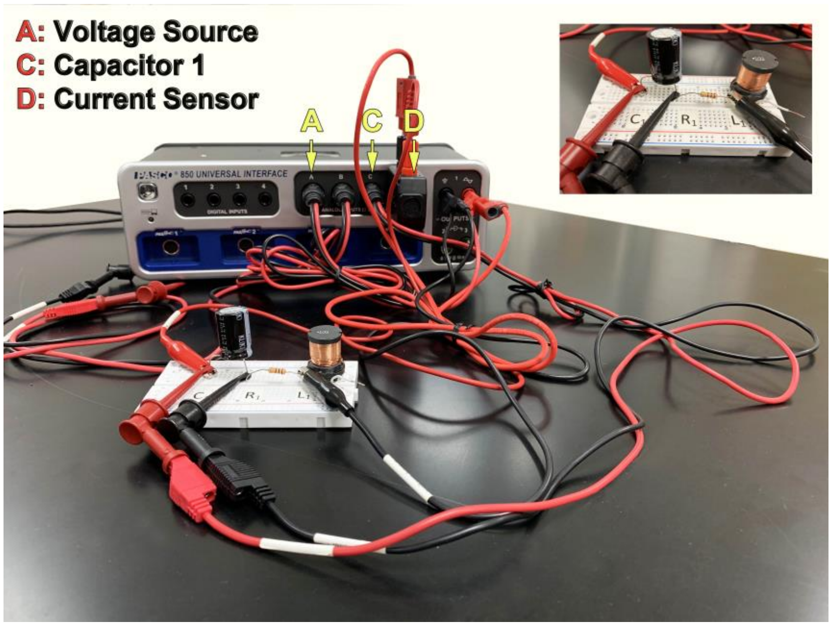


Figure 5

1. Connect the RC Circuit together using R_1, C_1 and the interface as in **Figure 5**. The AC source is from Output 1 of the interface. The current sensor, attached to Input D on the interface, is wired in series from the positive side of the source to the capacitor C_1. The voltage sensor, attached to Input C on the interface, is connected across the capacitor C_1.
2. On the Scope tab of the software there is a signal generator control labeled 850 Output 1. Click on the drop down menu next to Waveform and select Square as the waveform. Set the Frequency to 100 Hz and the Amplitude to 1 Volt. Also check that the Auto button is pressed. At the bottom of the display is a Monitor button with a drop menu next to it; select the Fast Monitor Mode from the menu.
3. To start collecting data click on the Monitor button. Watch the scope screen for the waveforms to appear. If needed the axis can be auto scaled or manually scaled so that a few complete cycles can be viewed. Only 30 seconds of data collection is necessary; click on the Monitor button again to stop the data collection.
4. Move to the Time Constant display by clicking on the tab. At the top of the graph are icons that activate different features on the graph. Click on the down arrow next to the triangle icon that represents data controls  ; now click on Monitor Run to bring the data from the Scope tab into this graph. The voltage data from the sensor connected across the capacitor (V, C) will be displayed on the y-axis as a function of time.

5. Click on the (V, C) data label on the graph. If needed scale the graph so that at least one complete cycle is displayed. Click on the curve-fit icon and the down arrow next to the icon;  select Inverse Exponent as the fit from the drop down menu. Click on the icon for highlight range of data  ; move and resize the highlight box to enclose a region of data where the capacitor is charging; the fit line will automatically respond to the data enclosed; adjust the highlight box until the fit line best conforms to match the data.

Data for Table 3

6. Document the Inverse Exponent fit equation. Use the value of "B" to determine the time constant for the RC circuit; see equation (5).
7. Calculate the time constant for the RC circuit predicted, equation (6), using R_1 and C_1. Compare the results for the two calculations.

Part III Determining the Time Constant of a RL Circuit

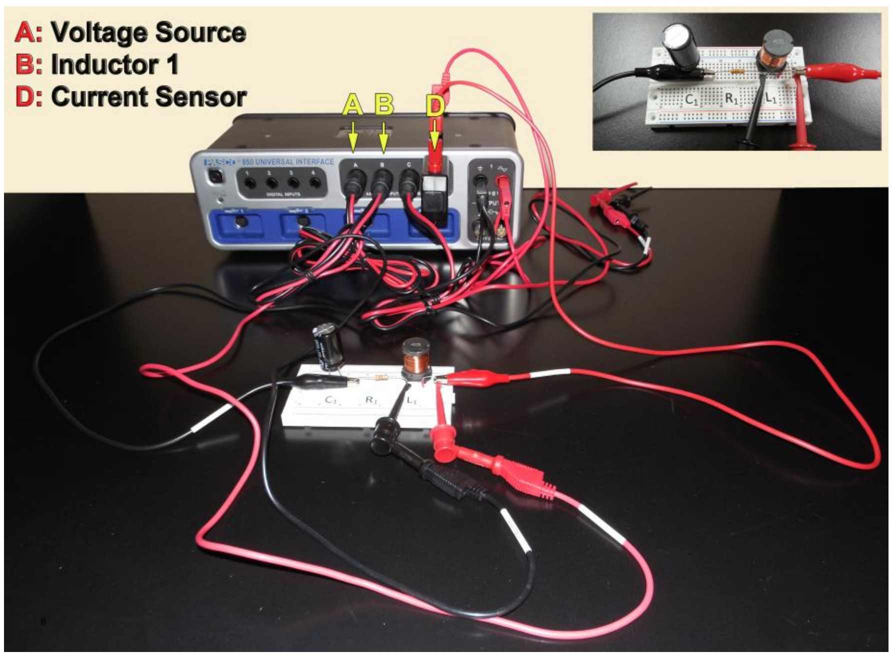


Figure 6

1. Connect the RL Circuit together using R_1, L_1 and the interface as in **Figure 6**. The AC source is from Output 1 of the interface. The current sensor, attached to Input D on the interface, is wired in series from the positive side of the source to the inductor L_1. The voltage sensor, attached to Input B on the interface, is connected across the inductor L_1.
2. On the Scope tab of the software there is a signal generator control labeled 850 Output 1. Click on the drop down menu next to Waveform and select Square as the waveform. Set the Frequency to 100 Hz and the Amplitude to 1 Volt. Also check that the Auto button is pressed. At the bottom of the display is a Monitor button with a drop menu next to it; select the Fast Monitor Mode from the menu.

3. To start collecting data click on the Monitor button. Watch the scope screen for the waveforms to appear. If needed the axis can be auto scaled or manually scaled so that a few complete cycle can be viewed. Only 30 seconds of data collection is necessary; click on the Monitor button again to stop the data collection.
4. Move to the Time Constant display by clicking on the tab. At the top of the graph are icons that activate different features on the graph. Click on the down arrow next to the triangle icon that represents data controls; now click on Monitor Run to bring the data from the Scope tab into this graph. The current data (I, D) from the sensor connected in series with the inductor will be displayed on the y-axis as a function of time.
5. Click on the (I, D) data label on the graph. If needed scale the graph so that at least one complete cycle is displayed. Click on the curve-fit icon and the down arrow next to the icon; select Inverse Exponent as the fit from the drop down menu. Click on the icon for highlight range of data; move and resize the highlight box to enclose a region of data where the inductor's current is increasing; the fit line will automatically respond to the data enclosed; adjust the highlight box until the fit line best conforms to match the data.

Data for Table 4

6. Document the Inverse Exponent fit equation. Use the value of "B" to determine the time constant for the RL circuit; see equation (10).
7. Calculate the time constant for the RL circuit predicted, equation (12), using $R_{(R1L1)}$ and $L_{(R1L1)}$. Compare the results for the two calculations.

Part IV Investigating the Characteristics of a Series RLC Circuit

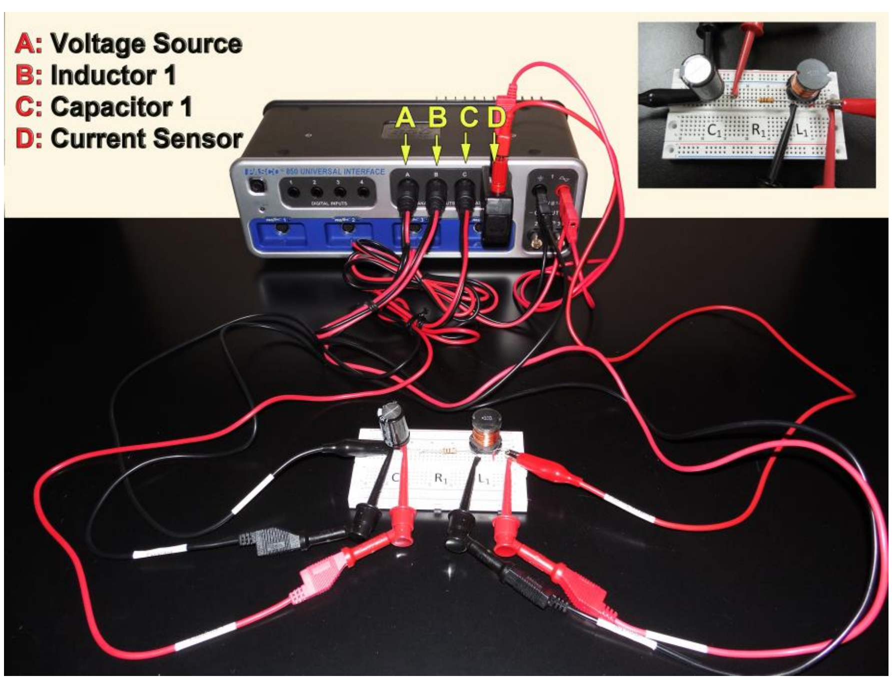


Figure 7

1. Connect the RLC Circuit together using R_1, L_1, C_1 and the interface as in **Figure 7**. The AC source is from Output 1 of the interface. The current sensor, attached to Input D on the interface, is wired in series from the positive side of the source to the inductor L_1. The voltage sensor, attached to Input C on the interface, is connected across the capacitor C_1. The voltage sensor, attached to Input B on the interface, is connected across the inductor L_1. The voltage sensor, attached to Input A on the interface, is connected across the source from Output 1.
2. On the Scope tab of the software there is a signal generator control labeled 850 Output 1. Click on the drop down menu next to Waveform and select Sine as the waveform. Set the Frequency to 100 Hz and the Amplitude to 1 Volt. Also check that the Auto button is pressed. At the bottom of the display is a Monitor button with a drop menu next to it; select the Fast Monitor Mode from the menu.
3. To start collecting data, click on the Monitor button. Watch the scope screen for the waveforms to appear. If needed the axis can be auto scaled or manually scaled so that a few complete cycle can be viewed. Only 30 seconds of data collection is necessary; click on the Monitor button again to stop the data collection.
4. Move to the Max Voltage Max Current display by clicking on the tab. At the top of the graph are icons that activate different features on the graph. Click on the down arrow next to the triangle icon that represents data controls; now click on Monitor Run to bring the data from the Scope tab into this graph. The voltage and current data from all the sensors will be displayed on the y-axis as a function of time.
5. If needed scale the graph so that at least one complete cycle is displayed. Click on the statistics icon and the down arrow next to the icon ; select Maximum from the drop down menu.

Data for Table 5

6. Click on the (V, A) data label on the graph; the maximum voltage across the source, Output 1, will be displayed on the graph. Document this maximum voltage.
7. Click on the (V, B) data label on the graph; the maximum voltage across the inductor L_1 will be displayed on the graph. Document this maximum voltage.
8. Click on the (V, C) data label on the graph; the maximum voltage across the capacitor C_1 will be displayed on the graph. Document this maximum voltage.
9. Click on the (I, D) data label on the graph; the maximum current through the RLC series circuit will be displayed on the graph. Document this maximum current.
10. Calculate, using the maximum voltages and maximum current, the effective Inductive Reactance, equation (18b); Capacitive Reactance, equation (15b); and the RLC Impedance, equation (26c). Compare these to the values determined with RLC Meter in Table 2. Note as indicated before, calculate the Inductive Reactance using the effective value just determined and the measured total resistance of the series connected L_1, equation (32). Also compare these values to the theoretically calculated X_L, X_C and Z at 100 Hz in Table 2.

Part V Examining Resonance in a Series RLC Circuit

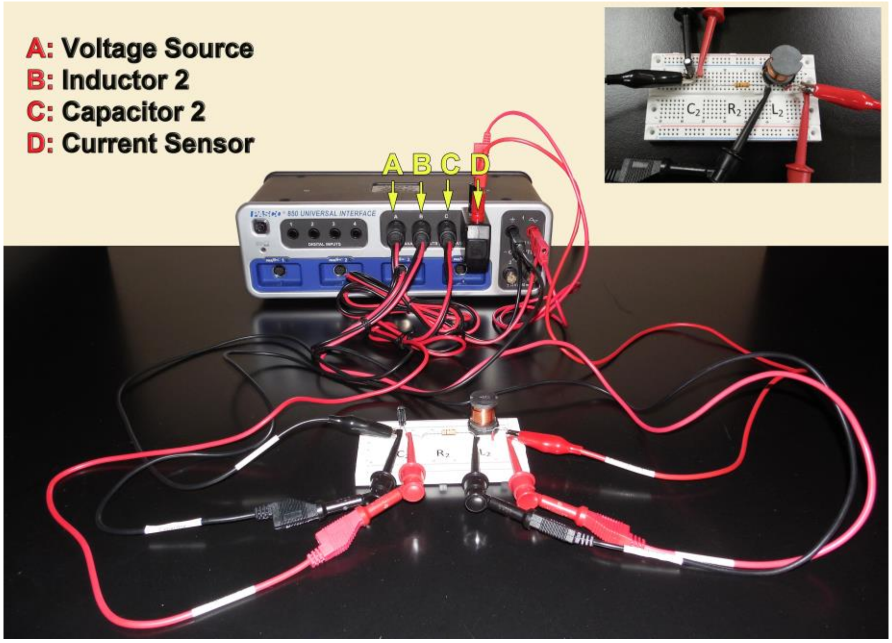
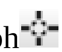


Figure 8

1. Connect the RLC Circuit together using R_2, L_2, C_2 and the interface as in **Figure 8**. The AC source is from Output 1 of the interface. The current sensor, attached to Input D on the interface, is wired in series from the positive side of the source to the inductor L_2. The voltage sensor, attached to Input C on the interface, is connected across the capacitor C_2. The voltage sensor, attached to Input B on the interface, is connected across the inductor L_2. The voltage sensor, attached to Input A on the interface, is connected across the source from Output 1.
2. On the Scope tab of the software there is a signal generator control labeled 850 Output 1. Click on the drop down menu next to Waveform and select Sine as the waveform. Set the Frequency to 300 Hz and the Amplitude to 1 Volt. Also check that the Auto button is pressed. At the bottom of the display is a Monitor button with a drop menu next to it; select the Fast Monitor Mode from the menu.
3. To start collecting data click on the Monitor button. Watch the scope screen for the waveforms to appear. If needed the axis can be auto scaled or manually scaled so that a few complete cycle can be viewed. Only 15 seconds of data collection is necessary; click on the Monitor button again to stop the data collection.
4. Move to the Max Voltage Max Current display by clicking on the tab. At the top of the graph are icons that activate different features on the graph. Click on the down arrow next to the triangle icon that represents data controls; now click on Monitor Run to bring the data from the Scope tab into this graph. The voltage and current data from all the sensors will be displayed on the y-axis as a function of time.

5. If needed scale the graph so that at least one complete cycle is displayed. Click on the statistics icon and the down arrow next to the icon; select Maximum from the drop down menu.
6. Click on the (I, D) data label on the graph; the maximum current through the RLC series circuit will be displayed on the graph. Document this maximum current together with the corresponding frequency of the AC source in data Table 6.
7. Next click on the Resonance Graph tab. In the data table to the left side of the graph, enter using the appropriate columns, the frequency and maximum current just measured.
8. Return to the Scope tab and change the Frequency to 400 Hz. Repeat the sequence for collecting the data from Step 3 thru Step 7.
9. Continue repeating the sequence (Steps 3 thru 7) increasing the frequency by 100 Hz each trial until completing the 1300 Hz frequency.
10. Examine the graph on the Resonance Graph tab to determine the frequency (F_c) that correlates with the highest current. This frequency will be close to the resonance frequency but not it. In order to fill in the additional data needed to find the resonance frequency, collect measurements from 200 Hz below this frequency (F_c) to 200 Hz above this frequency (F_c) at 25 Hz intervals. As an example if the highest current correlated to 700 Hz then you would collect measurements from 525 Hz thru 975 Hz at 25 Hz intervals.
11. Continue repeating the sequence (Steps 3 thru 7) from 200 Hz below the frequency (F_c) to 200 Hz above (F_c) using 25 Hz intervals for each trial.
12. After completing the additional trials there should be about 20 to 25 data points on the resonance graph. The peak area of the graph should be well defined with data points. Activate the coordinate tool by clicking on its icon located along the tool at the top of the graph. Using the coordinate tool locate the frequency that produced the highest current. This peak current occurs at the resonance frequency. Document your value of the resonance frequency (F_R) in Table 6.
13. Calculate the predicted resonance frequency from theory using the measure values of L_2 and C_2, equation (30). Compare the results between the resonance frequency predicted by theory and the one determined from the graph.

E15a: AC Circuits with Resistors, Inductors & Capacitors

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor______________________________________

Experiment Start Date__________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheet 1: E15a: AC Circuits with Resistors, Inductors & Capacitors

NAME: ______________________________ **DATE:** __________________

Table 1

Component	RLC Meter (measurement)
R_1	
R_2	
C_1	
C_2	
L_1	
L_2	
$R_{(L_1)}$	
$R_{(L_2)}$	
$R_{(R_1L_1)}$	
$R_{(R_2L2)}$	
$L_{(R_1L_1)}$	
$L_{(R_2L_2)}$	

Table 2

Component	RLC Meter (measurement)
X_L - Inductive Reactance @100 Hz	
X_{L1} (effective)	
X_{L1} (calculated)	
X_C - Capacitive Reactance @100 Hz	
X_{C1}	
Z - Impedance @100 Hz	
$Z_{(R_1L_1C_1)}$	
Theoretical Calculations @ 100 Hz	
X_{L1}	
X_{C1}	
$Z_{(R_1L_1C_1)}$	

Data Sheet 2: E15a: AC Circuits with Resistors, Inductors & Capacitors

NAME: ______________________________ DATE: __________________

Table 3

RC circuit	Square Wave @100 Hz
Curve-Fit Equation	$V_t = A\left(1 - e^{-B(t-t_0)}\right) + C$ A = B = t_0 = C = RMSE =
Time Constant from Curve-Fit Equation	
Time Constant from Theory using R_1C_1	

Table 4

RL circuit	Square Wave @100 Hz
Curve-Fit Equation	$I_t = A\left(1 - e^{-B(t-t_0)}\right) + C$ A = B = t_0 = C = RMSE =
Time Constant from Curve-Fit Equation	
Time Constant from Theory using $L_{(R_1L_1)} / R_{(R_1L_1)}$	

Data Sheet 3: E15a: AC Circuits with Resistors, Inductors & Capacitors

NAME: ____________________________   **DATE: _________________**

Table 5

RLC Circuit	Sine Wave @100 Hz
Maximum Source Voltage (measured)	
Maximum Inductor Voltage (measured)	
Maximum Capacitor Voltage (measured)	
Maximum Current (measured)	
X_{L1} - Inductive Reactance @100 Hz (effective)	
X_{L1} - Inductive Reactance @100 Hz (calculated)	
X_{C1} - Capacitive Reactance @100 Hz (calculated))	
$Z_{(R1L1C1)}$ - Impedance @100 Hz (calculated)	

Data Sheet 4: E15a: AC Circuits with Resistors, Inductors & Capacitors

NAME: ____________________________ DATE: _________________

Table 6

RLC Circuit and Resonance	
Frequency (Hz)	Maximum Current (A)
300	
400	
500	
600	
700	
800	
900	
1000	
1100	
1200	
1300	

Resonance Frequency from Graph	
Resonance Frequency from Theory	