RLC Circuit

Name:	Teammates:

Introduction

Recall the concept of a simple harmonic oscillator, a device whose oscillation when disturbed from equilibrium can be described by a as a sine function. As it moves from one extreme to another, the energy of the simple harmonic system constantly changes from potential to kinetic and back. Examples of simple harmonic motion are a pendulum and a mass on a spring. The electrical version of a harmonic oscillator is the RLC circuit. A circuit consisting of a resistor (R), an inductor (L), and a capacitor (C).

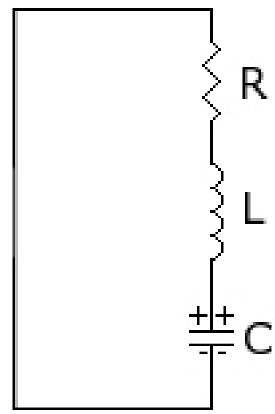


Fig. 1: RLC circuit

To see how an RLC circuit works, consider the circuit in Figure 1 with the capacitor initially charged. Since there is a conducting wire connecting the negative side of the capacitor to the positive, a current will begin to flow in the counterclockwise direction. As it does, several things happen. The first is that the resistor will begin to strip energy from the current and convert it to thermal energy. The second is that the current through the inductor will result in a magnetic field. However, since the current is transient (not constant), the magnetic flux through the inductor is not constant, resulting in an emf across the inductor, pointing in the opposite direction of the voltage across the capacitor.

Once the capacitor is discharged, the emf in the inductor, in trying to prevent the change in magnetic flux, will result in a current in the opposite direction. This causes an opposite charge to start building up on the capacitor. The negative charge will be on the upper plate. This transient current will continue to flow until the capacitor is charges and the magnetic flux through the inductor becomes zero. At this point, the capacitor current starts discharging and the current flowing in the clockwise direction.

This process would continue forever if it were not for the resistor. Each time the current flows through the resistor, some of the electrical energy changes into thermal energy. Eventually, all of the electrical energy changes into thermal energy and the charges will stop from flowing.

To visualize some of what was discussed in the previous paragraphs consider running this simulation:
http://physci.kennesaw.edu/physlets/electricity/RLCharmonic.html

Resonance

The oscillation of the RLC circuit can be maintained by injecting electrical energy into the system. However, just like with mechanical systems, this energy must be injected at the right frequency; the frequency at which the system naturally oscillates. Think of the example of a swing, if someone tries to push the swing or try to pump it at a frequency that is not the natural frequency of the swing, the swing will not respond as well as you expect, and the oscillation amplitude will not increase as high as it can. The same thing applies to this electrical system. To get the RLC circuit to oscillate at high amplitude, you need to drive (inject energy) the circuit at its natural frequency.

As one could guess, the frequency at which an RLC circuit oscillates, the resonant frequency of the circuit, depends solely on the values of the capacitor and the inductor. The resistor's only function in the circuit is to remove energy from the system and to limit how large of an oscillation will be achieved. The larger the capacitor, the more charge it can store, which means the longer it takes for the capacitor to become fully charged. Similarly, the larger the inductor results in a greater the induced emf. The resonance frequency is given by

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

If the system is driven at a frequency that is either above or below this one, the current flowing will be less than that at f_o. In fact, the amount of power that the system has falls off exponentially from what it has at the resonant frequency.

This makes the RLC circuit very useful as a tuning device for television, radio and mobile phone sets. A tuned RLC circuit results in a higher oscillation amplitude when subject to a radio signal at its resonant frequency.

Procedure

In this week's activity, we are going to measure the power curve for two RLC circuits in order to find the resonant frequency. To do this, you will need a signal (function) generator, Pasco's RLC circuit board, wires, and a voltmeter.

The Pasco RLC circuit board provides us with the resistor and the inductor we will use for this analysis. We will use external smaller capacitors instead of the ones provided. The following table provides the values we use for each of the runs. For all runs except Run 4, use the last column to calculate the theoretical resonant frequency of the circuit. Note that the Capacitor values are precise to only 20%!

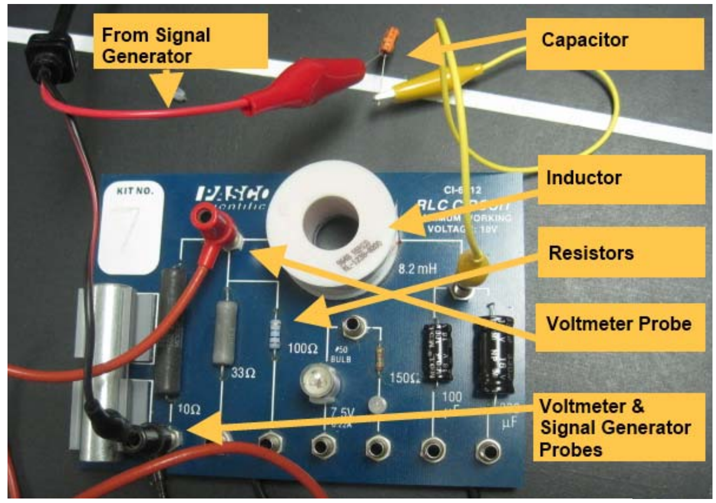
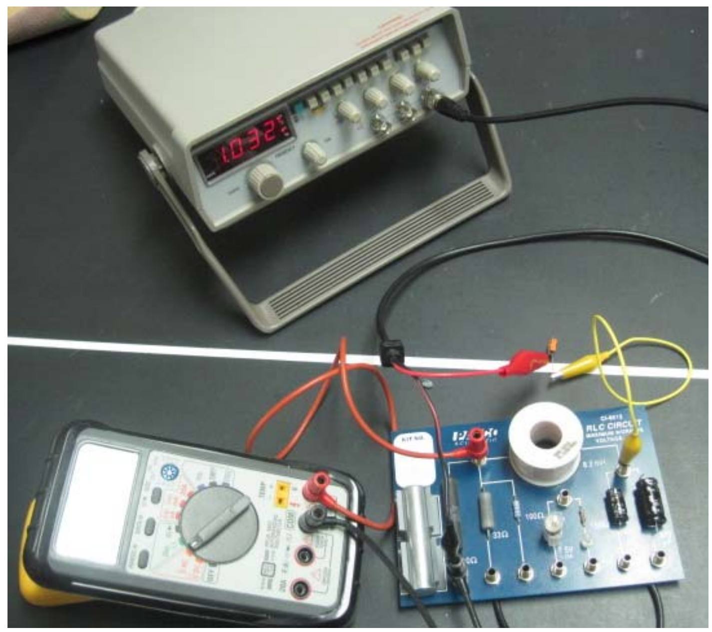


Fig 2: RLC circuit set-up



	C (μF)	L (mH)	R (Ω)	f_o (Hz)
Run 1	2.2	8.2	100	
Run 2	2.2	8.2	10	
Run 3	1	8.2	10	
Run 4	1		10	

1. Complete the circuit as shown in Figure 2. The positive output of the signal generator (red alligator clip) should be connected the positive lead of the capacitor, the ground should be connected to the resistors lead. The voltmeter should be connected across the resistor and should be set to read AC voltages. Note that under this mode, the voltmeter reads RMS (root mean square) voltage values. That is the peak value of the sine shaped voltage over square root of two.

$$V_{RMS} = \frac{V_p}{\sqrt{2}}$$

2. Start the signal generator and set the controls for a sine wave output.
3. Set the signal amplitude at about its half way value.
4. For Runs 1-3, measure the voltage across the resistor, for the various frequencies as indicated in the table.
5. Don't worry about having exact frequency values, remember the error associated with the capacitor values.

Run 1:

Frequency (Hz)	f_o-2000	f_o-1000	f_o-700	f_o-600	f_o-500	f_o-400	f_o-300	f_o-200	f_o-100
Voltage (V)									
Frequency	f_o-80	f_o-60	f_o-40	f_o-20	f_o	f_o+20	f_o+40	f_o+60	f_o+80
Voltage (V)									
Frequency	f_o+100	f_o+200	f_o+300	f_o+400	f_o+500	f_o+600	f_o+700	f_o+1000	f_o+2000
Voltage (V)									

Run 2:

Frequency (Hz)	f_o-2000	f_o-1000	f_o-700	f_o-600	f_o-500	f_o-400	f_o-300	f_o-200	f_o-100
Voltage (V)									
Frequency	f_o-80	f_o-60	f_o-40	f_o-20	f_o	f_o+20	f_o+40	f_o+60	f_o+80
Voltage (V)									
Frequency	f_o+100	f_o+200	f_o+300	f_o+400	f_o+500	f_o+600	f_o+700	f_o+1000	f_o+2000
Voltage (V)									

Run 3:

Frequency (Hz)	f_o-2000	f_o-1000	f_o-700	f_o-600	f_o-500	f_o-400	f_o-300	f_o-200	f_o-100
Voltage (V)									
Frequency	f_o-80	f_o-60	f_o-40	f_o-20	f_o	f_o+20	f_o+40	f_o+60	f_o+80
Voltage (V)									
Frequency	f_o+100	f_o+200	f_o+300	f_o+400	f_o+500	f_o+600	f_o+700	f_o+1000	f_o+2000
Voltage (V)									

6. Turn off the signal generator.
7. Graph the voltage vs. the frequency for all sets of data.
8. Use the graph to determine the resonant frequency for each of the runs:

Run 1: Measured f_o = _______ Hz Theoretical f_o = _______ Hz Percent Difference = _____

Run 2: Measured f_o = _______ Hz Theoretical f_o = _______ Hz Percent Difference = _____

Run 3: Measured f_o = _______ Hz Theoretical f_o = _______ Hz Percent Difference = _____

9. Placing the iron core inside the inductor coil increases the inductance of the coil. Our goal now is to find the new inductance L.
10. The goal is to repeat the same experiment as we did for the previous runs, use the data to determine the resonance value, and use that value to determine the new inductance. The only difference is that we don't know what frequencies to use.
11. Turn on the signal generator.
12. Think of how an increase of inductance might impact the resonance frequency and use that knowledge, and the circuit to approximately identify the approximate value of the resonant frequency.
13. Complete your table based on that approximate value.

Run 4:

Frequency (Hz)									
Voltage (V)									
Frequency									
Voltage (V)									
Frequency									
Voltage (V)									

14. Graph your data then provide the following.

Run 4: Measured f_o = _______ Hz L = _____

1. What was the effect on the resonant frequency of placing the metal cylinder in the solenoid?

2. What is the effect of the resistance on an RLC circuit?

3. What are the factors that affect the resonant frequency of an RLC circuit?

4. Which voltage did you measure during this experiment? (voltage across what device)

5. How does the shape of this voltage compare to the shape of the current flowing in the circuit?