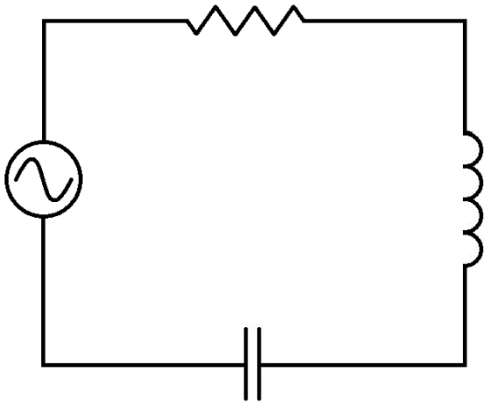


Impedance & Resonance in an RLC Circuit

equipment needed	qty.
function generator	1
100 nF capacitor	1
1 mH inductor	1
multimeter	2
LRC meter	1
BB wires	mult.

AC circuits are electric circuits with alternating voltages and currents. Some important applications are electrical power distribution, radio communication, and audio equipment. In this exercise, you'll study an important phenomenon, **AC resonance** in a circuit.

The notion of **impedance** is a critical concept. Impedance is an extension of resistance,



The circuit above is a simple AC circuit. The symbol to the left represents an AC voltage source. You recognize the symbols for an **inductor** and a **capacitor**. The **resistor** shown has resistance R to a DC or an AC current in the circuit, but for AC currents, the inductor & capacitor also limit the current through

properties that are likewise measured in ohms. These are **capacitive reactance** and **inductive reactance**.

$$X_L = \omega L \quad eq. 1$$

$$X_C = \frac{1}{\omega C} \quad eq. 2$$

ω is the angular frequency of the AC current ($\omega = 2\pi f$) Notice that X_L increases with frequency but X_C decreases. A quantity called impedance totals the effects of R , X_L & X_C :

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad eq. 3$$

The RMS current in the circuit is then given by Ohm's Law:

$$V = IZ \quad eq. 4$$

V is the RMS voltage of the AC voltage source.

Side note: More complete analysis of an AC circuit can be done using complex variables (a variable with a real & an imaginary component). In this type of analysis:

$$Z_L = j\omega L \quad Z_C = \frac{1}{j\omega C}$$

$$Z = R + Z_L + Z_C$$

Here, $j = \sqrt{-1}$. All the values for the circuit (voltages, currents, and impedances) are represented by complex numbers (which really represent sinusoidal functions). In today's exercise, we won't use this more sophisticated complex analysis.

In eq. 3, Z is a minimum when:

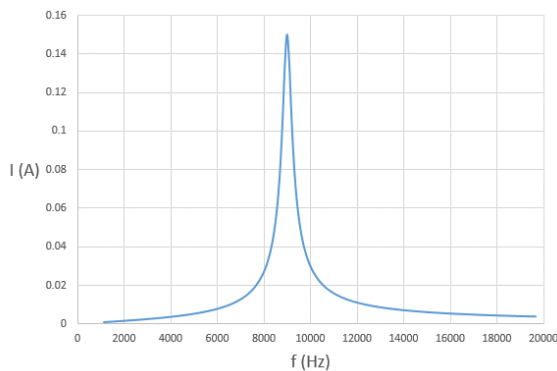
$$X_L - X_C = 0$$

$$\omega L - \frac{1}{\omega C} = 0$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega_r = \frac{1}{\sqrt{LC}} \quad (\text{eq. 5})$$

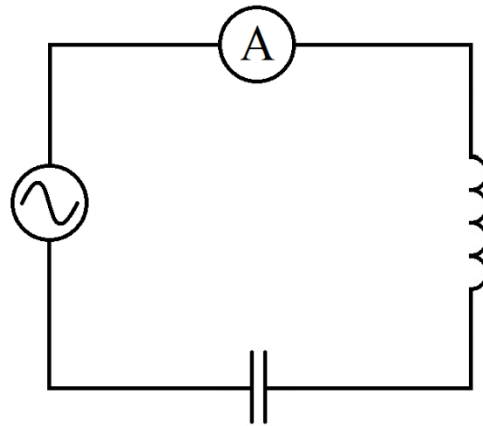
ω_r is the so called **resonant frequency** of the circuit, the frequency that manifests the highest current. You'll put together a circuit like the one above, and then expose it to a sinusoidal voltage of variable frequency. You'll measure current for numerous frequencies and plot current as a function of frequency. The resonant frequency will be apparent in your plot, which will look something like the one below.



Procedure

- Using the LRC meter, measure the capacitance of your capacitor and the inductance of your inductor.
 $C = \underline{\hspace{2cm}} F$
 $L = \underline{\hspace{2cm}} H$
- Calculate the resonant angular frequency according to eq 5.
 $\omega_r = \underline{\hspace{2cm}} Hz$
- Calculate the resonant cyclic frequency f_r , according to $\omega_r = 2\pi f_r$. The frequency display on the function generator reads cyclic frequency.
 $f_r = \underline{\hspace{2cm}} Hz$
- Assemble the circuit below. The AC source symbol represents the function generator. Note that we won't include a resistor, but the circuit will have a few

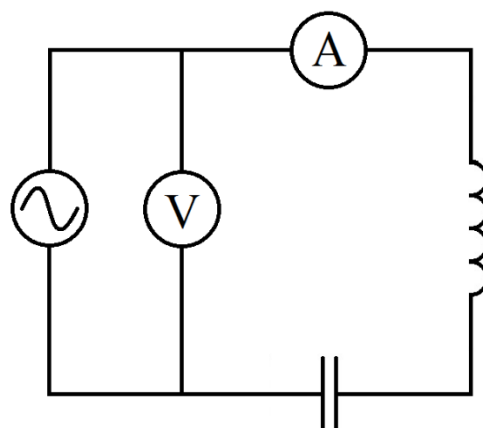
ohms of resistance due to the components. Set the ammeter on the 200mA AC setting.



- Remove the function generator from the circuit and replace it with an ohmmeter. This will allow you to measure the resistance of the circuit. You must also connect a shorting wire across the capacitor.

$$R = \underline{\hspace{2cm}} \Omega$$

- Now reinstall the function generator in the circuit. Switch the ohmmeter to a voltmeter and include it in the circuit as in the figure below.



- Make a table to record the current I for many values of f .
- Switch on the function generator, and set the frequency to 1000 Hz. Set its

voltage knob so that the voltmeter reads 1.0 V. **Even if your function generator has a voltage readout, do not rely on this value. It will not display the correct voltage.**

9. Record I in your table.
10. Change f to 1500 Hz. Now reset the function generator's voltage so that the voltmeter again reads 1.0 V.
11. Record I for this new setting.
12. Continue raising the frequency in increments of 500 Hz. For each frequency, reset the voltage to 1.0 V, and record I .
13. Plot I as a function of f .
14. From your graph, estimate the frequency of the peak.

$$\omega_r = \text{_____ Hz}$$

15. Calculate the percent error of your measured peak frequency, using the theoretical value as the accepted value.

$$\% \text{ error} = \text{_____ \%}$$

Activity 2

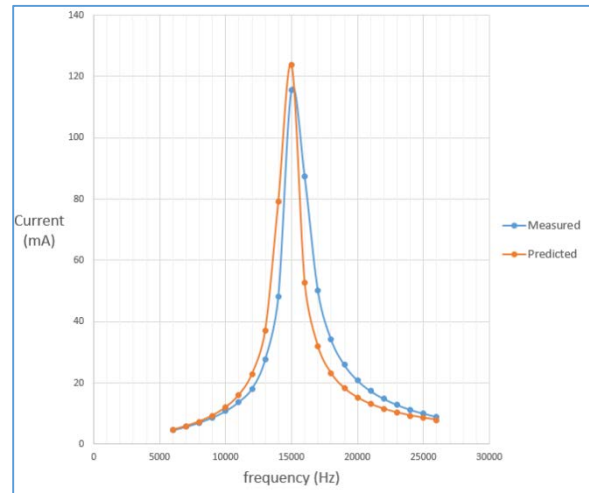
1. Using MS Excel or graphing software, make a plot of the theoretical frequency response like the one on the previous page. In Excel, you can make a spreadsheet something like the one shown below (this one also contains a

	A	B	C	D	E	F	G	H
1	V	f	ω	I_{meas}	X_L	X_C	Z	I_{calc}
2	1	6000	37699	4.55	42.90	258.06	215.27	4.65
3	1	7000	43982	5.66	50.05	221.19	171.28	5.84
4	1	8000	50265	7	57.20	193.54	136.52	7.32
5	1	9000	56549	8.67	64.35	172.04	107.91	9.27
6	1	10000	62832	10.77	71.50	154.84	83.63	11.96
7	1	11000	69115	13.77	78.65	140.76	62.50	16.00
8	1	12000	75398	18.1	85.80	129.03	43.79	22.84
9	1	13000	81681	27.6	92.95	119.10	27.07	36.94
10	1	14000	87965	48.2	100.10	110.60	12.61	79.28
11	1	15000	94248	115.6	107.25	103.22	8.08	123.80

column for the measured current values). For each frequency, ω is calculated from f , X_L is calculated from L & ω , X_C from C & ω , Z from R , X_L & X_C , and I from Z & $V = 1.0V$.

Remember that X_L , X_C & Z are all frequency dependent, and so must be recalculated in each row of the spreadsheet.

2. Make a plot of I vs. f . In Excel, it's called a "scatter plot."
3. You now have a theoretical curve of I vs f . Your measured I values can be plotted on the same graph as a test of the theory. Such a plot is shown below.



4. Comment on differences between the two curves (measured vs theoretical current). Try to think of reasons for any systematic differences. For example, how might the circuit's measured parameters differ from your values, and what effects would the differences have?