**7.** As described in the "theory" section, the resonant frequency depends on the values of the inductance and the capacitance. Using Eq. (6), your measured resonant frequency, and the value $C = 100\mu\text{F}$, deduce the value of the inductance $L$.

| | |
|---|---|
| Measured inductance, $L$: | |

| frequency $f$ | angular frequency $\omega$ | peak voltage across resistor |
|---|---|---|
| 300 Hz | | |
| 250 Hz | | |
| 225 Hz | | |
| 200 Hz | | |
| 175 Hz | | |
| 150 Hz | | |
| 125 Hz | | |
| 100 Hz | | |
| 90 Hz | | |
| 80 Hz | | |
| 70 Hz | | |
| 60 Hz | | |
| 50 Hz | | |
| 45 Hz | | |
| 40 Hz | | |
| 35 Hz | | |
| 30 Hz | | |

**Q1.** Approximately at what frequency do you obtain a maximum voltage amplitude? (This is the resonant frequency of the circuit.)

| Measured resonant frequency, $f_0$: | |
|---|---|

The current flowing in the circuit will be smaller at frequencies which are either larger or smaller than $f_0$.

In general, the current flowing through the circuit will be out of phase with the voltage driving the circuit. The phase angle $\phi$ is given by

$$\tan \phi = \frac{\mathcal{X}_L - \mathcal{X}_C}{R} \tag{7}$$

where $R$ is the total resistance in the circuit (including the resistance in the inductor coil!!).

1. Select the output of the Science Workshop interface box to have an amplitude of 1 volt and a frequency of 300 hertz. You can do this by clicking on the button labelled "sample $V$" and entering the desired voltage and frequency. Click the "on" button to turn the generator on.

2. Connect the interface box across a series combination of the 10 Ω resistor, the inductor and the 100 $\mu$F capacitor. Essentially, the black lead (ground) goes to the free end of the resistor and the red lead (phase) goes to the free end of the capacitor. To increase the inductance of the inductor insert the steel core attached to the circuit board into the hole through the center of the inductor.

3. Making sure that you keep the polarities right, connect the voltage sensor input leads across the 10 Ω resistor.

4. Tell ScienceWorkshop about the voltage senstor. Select the "Scope" icon and drag it to the input channel (A, B, or C) which you have connected to the voltage sensor.
   - You can adjust the vertical scale of the scope display by clicking on the icons at the upper right corresponding to the green trace (which is color used to plot the signal received by the voltage sensor). Likewise, the time scale (horizontal) may be adjusted using the buttons at the lower left.
   - To measure the amplitude of the voltage across the resistor, use the cross-hairs (click on the icon and then position the pointer so that the horizontal line just barely brushes the top of the waveform) and read off the numerical value of the amplitude.

5. Your aim is to measure the amplitude of the voltage across the resistor as a function of the frequency of the output voltage. Vary the frequency from 300 hertz down to 30 hertz in the following steps, measuring the amplitude of the voltage across the resistor at every frequency: 300 Hz, 250 Hz, 225 Hz, 200 Hz, 175 Hz, 150 Hz, 125 Hz, 100 Hz, 90 Hz, 80 Hz, 70 Hz, 60 Hz, 50 Hz, 45 Hz, 40 Hz, 35 Hz, 30 Hz. You will have to adjust both the horizontal and vertical scales of the scope output as you do this to keep a good view of the waveform as you go through this measurement.

6. Using an Excel spreadsheet (or drawing one by hand), make a plot of the voltage amplitude versus frequency. Include a copy of the printout of this graph with your lab writeup.

MAD 03/97
rev. 03/03/03, 02/25/04

# Experiment 16
# AC Series Circuits

## Objective

In this experiment, we are going to study the behavior of series $RLC$ circuits, concentrating on the resonance phenomenon.

## Equipment

- ScienceWorkshop 750 Interface box.
- ScienceWorkshop software.
- Voltage sensor CI-6053.
- RLC circuit board CI-6512.
- Banana wires.

## Theory

To describe AC circuits, we generalize Ohm's Law to include capacitors and inductors in addition to resistors. In a purely resistive circuit,

$$V_R = IR; \tag{1}$$

in a purely inductive circuit,

$$V_L = I\mathcal{X}_L; \quad \mathcal{X}_L \equiv 2\pi f L; \tag{2}$$

in a purely capacitive circuit,

$$V_C = I\mathcal{X}_C; \quad \mathcal{X}_C \equiv \frac{1}{2\pi f C}. \tag{3}$$

Finally, if all three of these elements are connected in series the result is

$$V = I\mathcal{Z}; \quad \mathcal{Z} \equiv \sqrt{R^2 + (\mathcal{X}_L - \mathcal{X}_C)^2}, \tag{4}$$

where $\mathcal{Z}$ is called the **impedance** of the circuit. Because of Ohm's Law, the voltage across the resistor is simply related to the current flowing in the circuit. This voltage in a $RLC$ circuit is found to be

$$V_R = IR = \frac{V}{\mathcal{Z}}R. \tag{5}$$

The voltage (and hence the current) will be a maximum when $\mathcal{Z}$ is a minimum; in other words, at the frequency where $\mathcal{X}_C = \mathcal{X}_L$ the current flowing through the circuit will be the largest. This condition is known as **resonance**, and the resonance frequency is

$$f_0 = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}. \tag{6}$$