Name: ____________________

Partner(s): ____________________

____

Date: ____________________

AC Circuits

Purpose:

In this lab, we examine the behavior of various circuit elements in an alternating current circuit.

Theory:

In previous labs, we have investigated a number of circuits where the current always flowed in one direction; such currents were known as *direct currents*. There is a second type of current, where the flow of electrons will occasionally switch directions. This type of current is referred to as an *alternating current*. A typical AC source produces a voltage, or current, that varies sinusoidally in time, described by Equation 1.

$$V(t) = V_o \sin(\omega t) \tag{1}$$

where $V(t)$ is the voltage at some time t, V_o is the peak voltage produced and ω is the angular frequency; equal to 2π times the *oscillation frequency*, f.

Any interesting device, when connected to a power supply in a circuit, will have a voltage across it that depends on its instantaneous "condition," as we will see. If we think of this voltage as that circuit element's "passive" response to its environment, *e.g.* the rest of the circuit, then most devices can be modeled as a combination of resistors, R, capacitors, C, and inductors, L.

The voltage across a capacitor is proportional to charge that has built up on the plates, *i.e.* the "accumulated" current; the voltage across a resistor is proportional to the change of charge, or current, that flows through it; the voltage across an inductor is proportional to the change of current. Each of these elements has a tendency to resist a change in the quantity that determines the voltage across it, a sort of inertia. The quantity that describes the inertia that these circuit elements have in an AC circuit is known as *reactance*. Reactance, which is denoted by the symbol X, is the average voltage that is required to obtain a unit of current. Symbolically, one would state this using Equation 2.

$$X = \frac{V_{average}}{I_{average}} \tag{2}$$

When an AC source, such as a power supply or a wall socket, is connected to any of these passive circuit elements, one would expect that the circuit element would respond in different ways. In this experiment, we will examine how each of these circuit elements responds to a sinusoidal applied voltage. We will also examine how the response depends on the frequency of the signal applied.

Procedure:

To investigate the frequency dependence of various circuit elements, you will wire the circuit depicted in Figure 1. The circle with a "squiggle" in the middle is variable frequency AC signal generator. The resistor, *R*, should be 50 Ω. By measuring the voltage drop across the resistor, you can determine the current that is entering the circuit element that is being investigated.

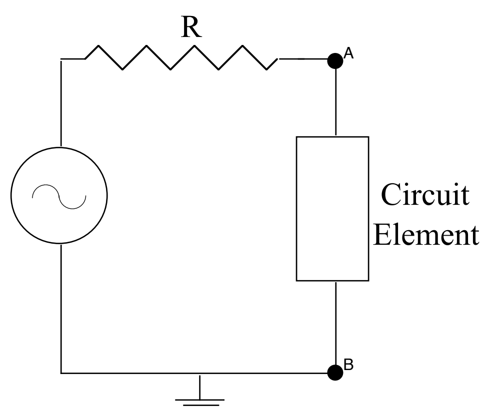

Figure 1

The voltages that we are interested in, namely the voltage drop across the resistor and the circuit element vary with time. To measure voltages that vary with time, one traditionally uses an instrument known as an oscilloscope. As you have seen previously, Data Studio has a "Scope" option for display of such data.

The Science Workshop 750 interface box can also be used as a function generator, which will be used as the AC source in this lab. On the interface box, you should see two banana plug receptacles to the right of the analog inputs. This is the output of the signal generator. You can control it using the Data Studio software clicking the output on the virtual interface.

Part 1: The Resistor

Using a 1 kΩ resistor as the device to be investigated, vary the frequency from 10 Hz to 10 kHz. You will need to record the voltage across the 1 kΩ resistor, V_R, as well as the voltage from the signal generator, V_{source}. Record as much data as you need to clearly see what is going on.

Frequency (Hz)	V_{source} ( )	V_R ( )	I_R ( )	V_R / V_{source}	X_R ( )
10					

Create the following plots: I vs. V_R / V_{source} , X vs. AC frequency and V_R / V_{sourec} vs. AC frequency. In the space below, comment on what your data is telling you. Affix any plots, which you consider meaningful to the lab.

Is the resistor an ohmic device in an AC circuit? Is this what you expected? Why or why not?

Does the behavior of the resistor depend on the frequency? Is this what you expect? Why or why not?

Does the voltage drop across the resistor depend on the frequency? Is this what you expected? Why or why not?

Is there an observed ***phase shift*** between the current entering the 1kΩ resistor and the voltage across the 1 kΩ resistor? Does the phase shift depend on the frequency of the source?

Part 2: The Capacitor

Using a 10 μF capacitor as the device to be investigated, repeat the experiment from part 1. Record as much data as you need to clearly see what is going on. You can record your data below.

Frequency (Hz)	V_{source} ( )	V_C ( )	I_C ( )	V_C / V_{source}	X_C ( )
10					

Create the plots that you made for the resistor and affix any plots, which you consider meaningful to the lab.

Is the capacitor an ohmic device in an AC circuit? Is this what you expected? Why or why not?

Does the behavior of the capacitor depend on the frequency? Is this what you expect? Why or why not? *Hint*: Does the effective resistance of the capacitor depend on the frequency?

Does the voltage drop across the capacitor depend on the frequency? Is this what you expected? Why or why not?

Is there an observed phase shift between the current entering the capacitor and the voltage across the capacitor? Does the phase shift depend on the frequency of the source?

Part 3: The Inductor

We know look at the behavior of an inductor, which is nothing more than a coil of wires.

What is the resistance of the 2.5 mH inductor?

Using the 2.5 mH inductor as the circuit element, repeat the experiment from part 1. Record as much data as you need to clearly see what is going on. You can record your data on the next page.

Frequency (Hz)	V_{source} ( )	V_L ( )	I_L ( )	V_L / V_{source}	X_L ( )
10					

Create the plots that you have previously made and affix any plots which you consider meaningful to the lab.

Is the inductor an "ohmic" device in an AC circuit? Is this what you expect? Why or why not?

Does the behavior of the inductor depend on the frequency? Is this what you expect? Why or why not? *Hint*: Does the effective resistance of the inductor depend on the frequency?

Does the voltage drop across the inductor depend on the frequency? Is this what you expected? Why or why not?

Is there an observed phase shift between the current entering the inductor and the voltage across the inductor? Does the phase shift depend on the frequency of the source?

Part 4: Choose your own Adventure

Option 1: The LC Circuit

Figure 3 shows a circuit with an inductor, a capacitor and a resistor. Wire the circuit shown in Figure 3 and repeat what you have done in the previous parts of this lab. Your data can be recorded below.

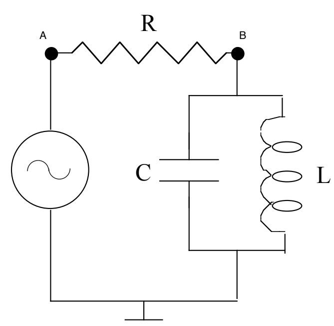

Figure 3

Frequency (Hz)	V_{source} ( )	V_{AB} ( )	V_{AB} / V_{source}
10			

Create a plot of V_{AB} / V_{source} vs. AC frequency and attach it to the lab.

What is this circuit doing? Support your statement with your data.

Using the previous parts of this lab, explain your observed data.

Option 2: The LRC Circuit

Figure 4 shows an LRC circuit, where the resistor, inductor and capacitor are wired in series.

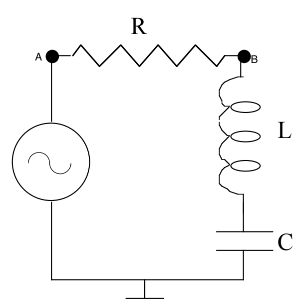

Figure 5

Wire the circuit shown in Figure 4, with R = 50 Ω, L = 2.5 mH and C = 100 μF, and repeat what you have done in the previous parts of this lab. Your data can be recorded on the next page.

Frequency (Hz)	V_{source} ( )	V_{AB} ( )	V_{AB} / V_{source}
10			

Create a plot of V_{AB} / V_{source} vs. AC frequency and attach it to the lab.

Does this look like a phenomenon that you have studied before? Discuss the similarities.

Using the previous parts of this lab, explain your observed data.

Measure the ***root mean square*** voltage drop across each circuit element. Do they sum to the voltage from the signal generator? Explain what you find.

Option 3: The Transformer

Connect the primary side of a transformer to the signal generator and measure the voltage on the secondary side. Vary the frequency of the signal generator from 10 Hz to 10 kHz and record the voltage across the primary side of the transformer, V_p, and the voltage across the secondary side of the transformer, V_s. You can record your data below.

Frequency (Hz)	V_p ( )	V_s ( )	V_p / V_s
10			

Does the ratio of the primary voltage to the secondary voltage depend on the frequency? Is this what you expect? Why or why not?

Is there an observed phase shift between the primary voltage to the secondary voltage? Does it depend on the frequency?

What is the turn ratio?

Repeat this experiment, but connect the signal generator to the secondary side. Is the primary voltage consistent with what you would expect? Explain.

Questions:

1. Repeat part 2, but apply a square wave instead. Explain what you observe. (*Hint*: what calculus operations do these suggest?)

Initiative:

Possible ideas:

1. Apply a triangle wave to the circuit from part 2 and carefully interpret the results.

Conclusions: