LR & LC Circuit Lab

04/16/2018

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Abstract

This lab report presented students with the task of applying their knowledge of a previously discussed topic within an experimental setting. The students were to utilize equations that had been given to them in the past to theorize on the behavior of the circuits they were currently studying. These theories presented calculated values that would be compared with the values measured during the experiment. After collecting data, the students were able to compare their theoretical values with their measured values. It was discovered that the calculated values were inaccurate, but were calculated correctly. Ultimately, this showed that the students had been able to grasp their understanding on *RL* and *LC* circuits by displaying their knowledge during the lab.

Objectives

The objective of the lab was to have students implement previous concepts in order to formulate an experiment in which the behavior of the current within *RL* and *LC* circuits can be observed. Previously obtained knowledge on resistors (*R*), capacitors (*C*), and inductors (*L*) was consistently utilized throughout the experiment to theorize and explain the behavior of the current. The students tasked themselves with theorizing the behavior of the current by using the given resistor, capacitor, and inductor values. Their theoretical calculations would then be compared to the data that was recorded when measuring the current within the *RL* and *LC* circuits. In the end, the students were expected to receive a deeper understanding on how *RL* and *LC* circuits function by utilizing an experimentational process.

Introduction / Background

Once given the task of devising an experiment and finding lab partners, the students established their goal by analyzing their understanding of *RL* and *LC* circuits. After an analysis of their given materials, the students concluded that the formulas for a charging *RL* circuit

$$(\,i(t)_{RL} \;=\; i_{max}\,[1 - e^{\,-t/RL}]\,) \tag{1}$$

And a charging / discharging *LC* circuit

$$(\,i(t)_{LC} \;=\; (C \times V\,)\,(1 \div \sqrt{(LC)}\,)sin((1 \div \sqrt{(LC)}\,)\,t)\,) \tag{2}$$

would need to be utilized for studying the behavior of the current over time.

Knowing which formulas to implement and having been given sufficient components, the group hypothesized that they could predict the behavior of the current by using the formulas as functions to create theoretical graphs. If the calculations and understanding on the topic are accurate, then the theoretical graphs should depict a similar behavior as the data collected. To calculate the time constant,

$$(\tau_{RL} = R \times L) \tag{3}$$

the maximum current,

$$(i_{max} = \varepsilon / R) \tag{4}$$

and max charge

$$(Q_0 = C \times V). \tag{5}$$

The given resistor, inductor, capacitor, and emf values were used to create functions for the *RL* and *LC* circuits. The students assumed that their functions and calculated constants (time constant and maximum current) would be similar to the graphs and values recorded from an actual charging and discharging *RL* and *LC* circuit.

Materials

The group was given a variety of materials to construct both an *RL* and *LC* circuit and to measure the current overtime in both circuits. Tools such as a chromebook, LabQuest, power supply, and ammeter were used on both circuit types. To construct the *RL* circuit, all of the following were used: a breadboard, a battery, a resistor, an inductor, wires, and clipper wires. The *LC* circuit was created with the same materials aside for the resistor being interchanged with a capacitor. Images for both the tools and materials used throughout the experiment are located and labeled below.

Figure 1 - LabQuest

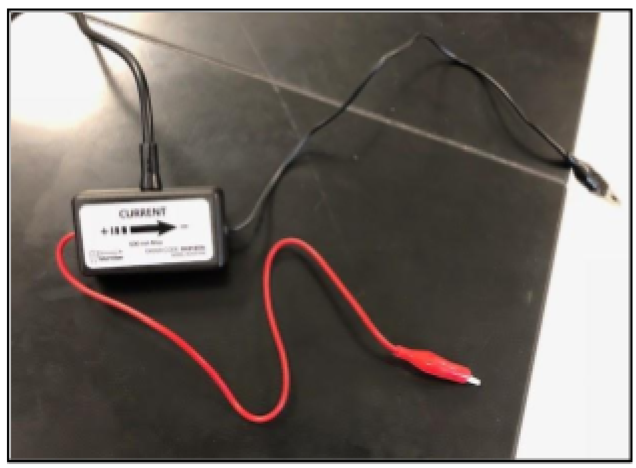

Figure 2 - Ammeter

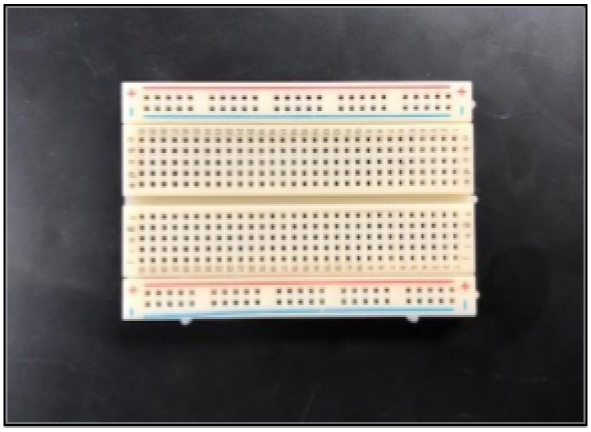

Figure 3 - Breadboard

Figure 4 - Wire

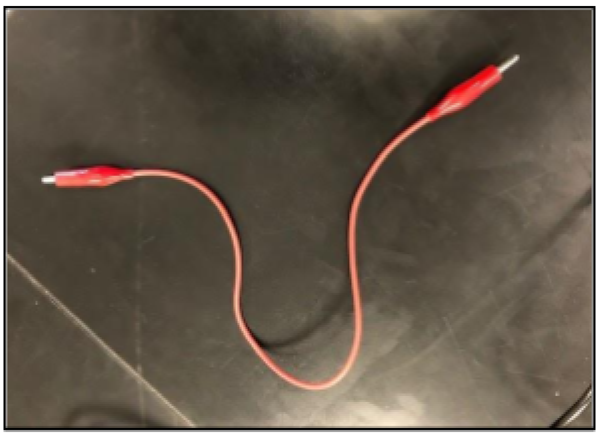

Figure 5 - Clipper Wires

Figure 6 - Inductor

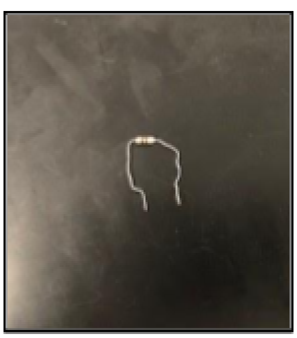

Figure 7 - Resistor

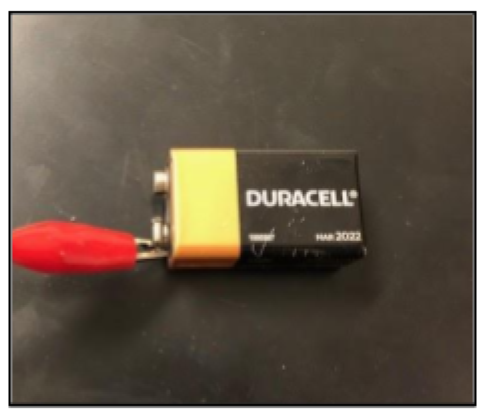

Figure 8 - Battery

Procedure

The *RL* circuit was constructed and measured before the *LC* circuit. First, the inductor and resistor were implemented in a series circuit on the breadboard. Clipper wires would attach the battery to the circuit and allowed for the battery to quickly be disconnected from the circuit. The ammeter probes are attached in series with the circuit to record the current's behavior. Once the tools are ready to collect data, one student would connect the battery to the circuit. Another student would begin recording the data right before the battery was disconnected. By doing this, the students were able to observe and record the current decreasing until the recording was stopped. For the *LC* circuit, a similar procedure was performed in which no resistor was used; instead, a capacitor was used in its place. The data was recorded once the power supply was turned on and was stopped after the power supply had been turned off the circuit. With the recorded data, the LabQuest presented students with graphs that would be used for comparing them to the theoretical graphs.

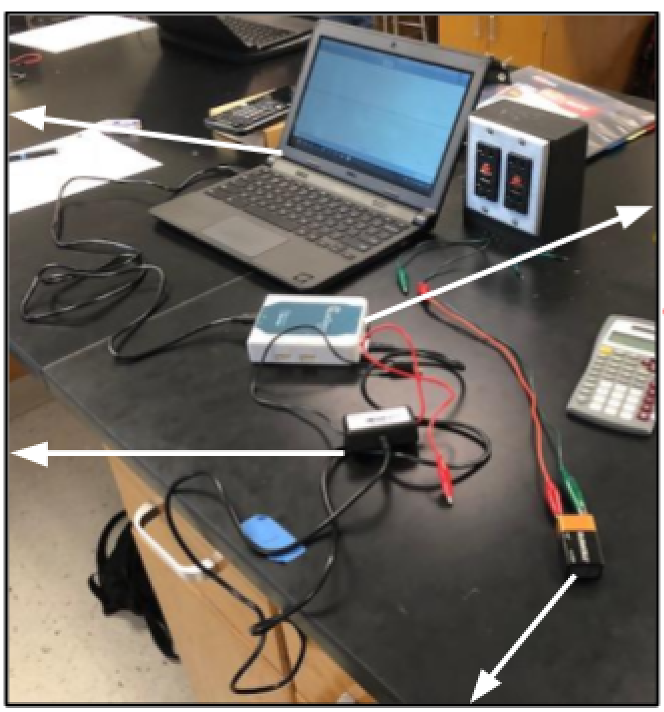

Figure 9 - Lab Setup

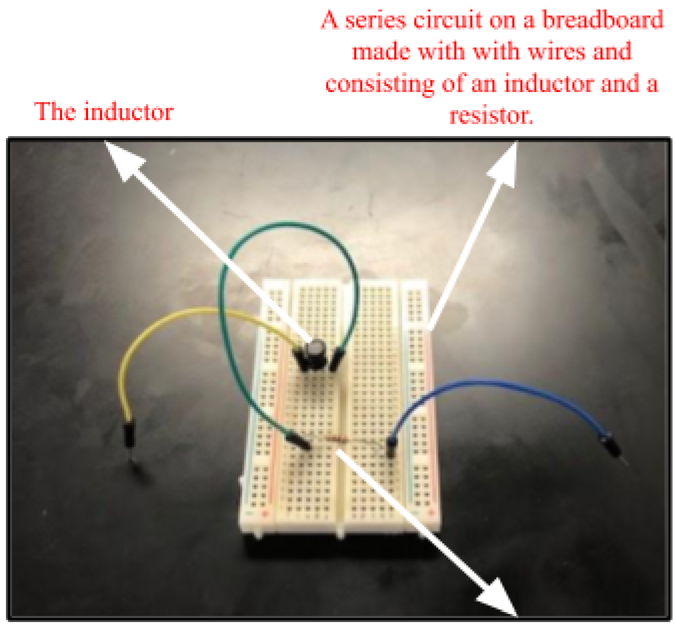

Figure 10 -
Lab Setup: RL Circuit

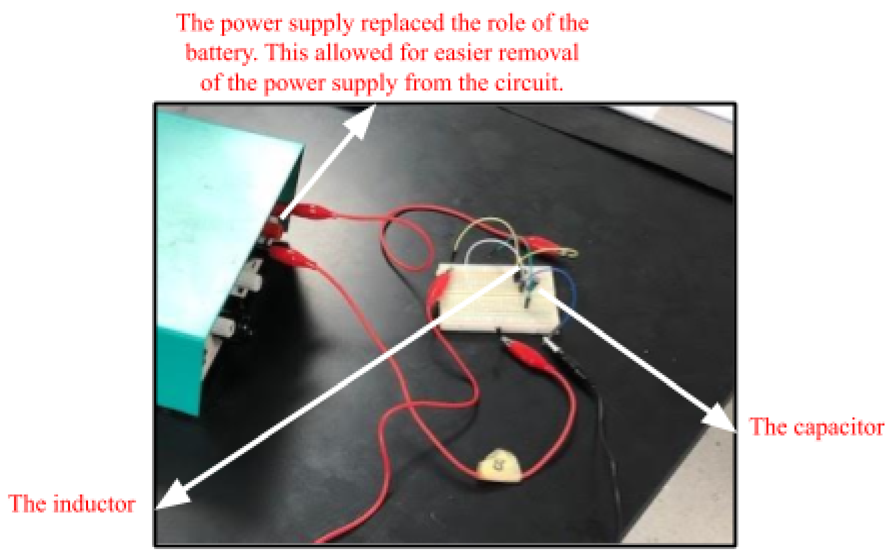

Figure 11 -
Lab Setup: LC Circuit

<u>Labs Steps</u>

1. Setup tools by connecting the ammeter, LabQuest, and computer with one another
2. Construct an *RL* circuit on a breadboard consisting of a resistor and an inductor in series
3. Connect both the battery and ammeter probes to the circuit in series
4. Began recording data on the computer's software and, after some time, remove the battery from the circuit.
5. Stop recording data once enough information is collected
6. After dismantling the previous circuit, construct an *LC* circuit consisting of an inductor and a capacitor in series
7. Attach the ammeter probes in series to the circuit
8. Begin recording data and, after some time, attach the battery in series to the circuit. Once the capacitor is charged, disconnect the battery and stop recording once enough information is collected

Data / Results

Before experimenting, the group had calculated and plotted a function for both *RL* and *LC* circuits. This included using the given resistor and inductor values to find the time constant (3). The theoretical graphs, along with the *RL* time constant value, were saved in order to be used later to compare with the experimental graphs. Both the theoretical graphs and calculations are shown below.

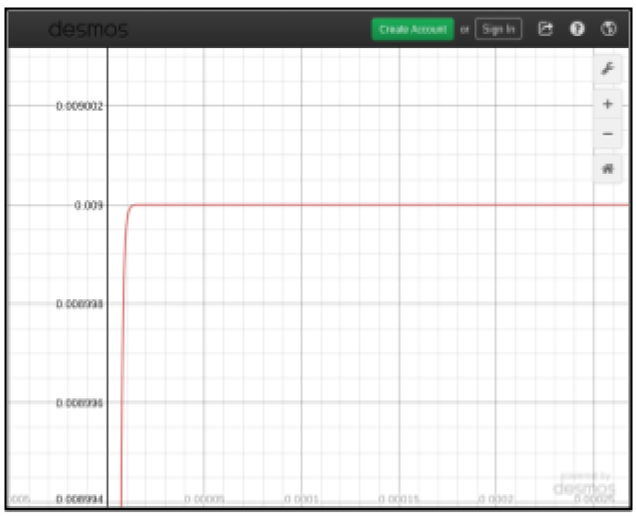

Figure 12 - Theoretical Graph: RL Circuit

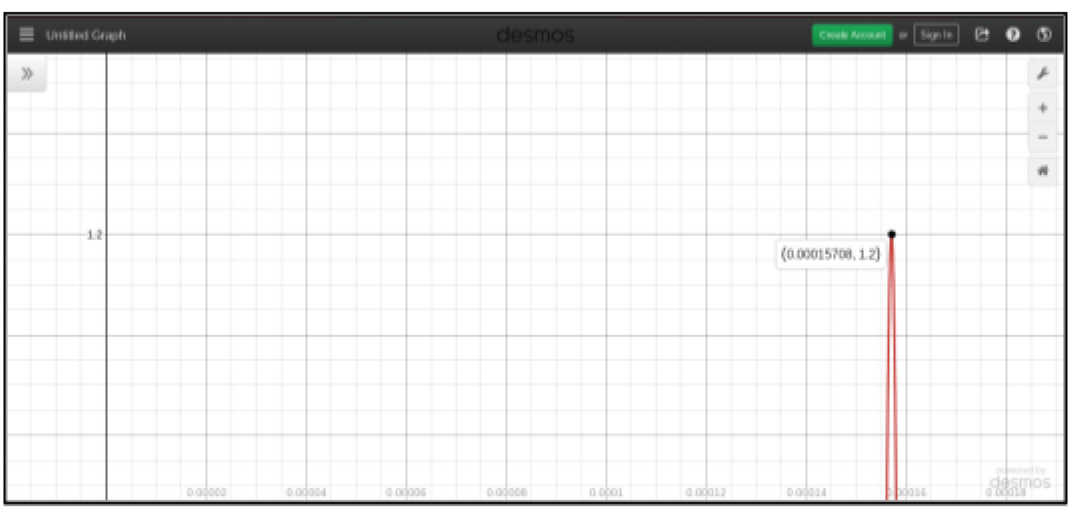

Figure 13 - Theoretical Graph: LC Circuit

Calculations

*** Given Variables ***

$R = 1000\Omega$

$C = .00001\text{F}$

$L = .001\text{H}$

$V_{battery} = 9\text{V}$

$V_{power\ supply} = 12\text{V}$

*** RL ***

τ *found with RL equation for time constant*

$\tau = .001H/1000\Omega \rightarrow \tau = .000001\ sec$

I_{max} *found with ohm's law equation for current*

$I_{max} = 9V/1000\Omega \rightarrow I_{max} = .009\ A$

The theoretical function for the charging RL circuit turns out to be:

$I(t) = .009\ A(1 - e^{-t/.000001\ sec})$

*** LC ***

Q_0 *found with equation for charge*

$Q_0 = .00001F * 12V \rightarrow Q_0 = .00012\ C$

The theoretical function for the charging / discharging LC circuit turns out to be:

$I(t) = (.00012C) * (1 \div \sqrt{((.001H) * (.00001F))}) * (sin((1 \div \sqrt{((.001H) * (.00001F))})\ t)$

Given a resistor value of 1000 Ω, an inductor value of .001 H, and a voltage of 9 V, the maximum current was calculated to be .009 A. The *RL* time constant, using the previously mentioned values, was found to be .000001 sec. Using the same inductor value, a capacitor value of .00001 F, and a voltage of 12 V, the maximum charge was calculated to be .00012 C. These results allowed for the creation of functions of time for both circuits. The theoretical graph for the *RL* circuit was eventually compared to the experimental *RL* circuit graph, which is depicted below. The experimental graph for the *LC* circuit was never created due to complications and lack of time.

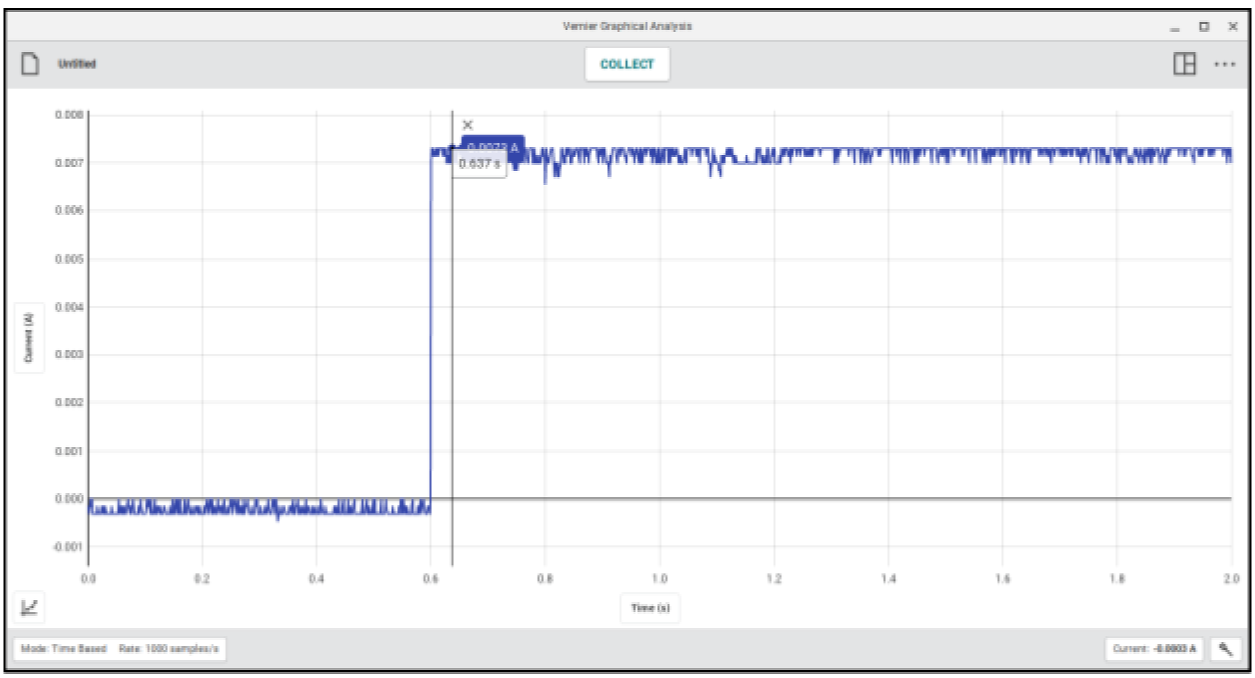

Figure 14 - Experimental Graph: RL Circuit

After collecting data, the students noticed that the experimental graph displayed a smaller value for the maximum current when compared to their calculations. In this case, the maximum current was shown to be .0073 A. The calculated and experimental time constants could not be compared because the data would not show the value.

Conclusion

The calculated maximum current was, in the end, proven to be inaccurate when compared to the measured maximum current. This finding does not make the students' calculations incorrect; instead, it shows that other variables that were not considered had an effect on the circuit. The group believes that the battery was old and did not actually have 9 V. Also, the resistor's tolerance was not implemented in the calculations. The comparison between the experimental and the calculated *RL* time constants could not be done because the circuit produced a time constant value that was too small and would not allow for an accurate comparison. During the experimentation process, difficulties were encountered when attempting to measure the *LC* circuit. For example, the battery was being used to measure the circuit when the emf was removed and then reapplied. Later, the students discovered that using the battery would not lead to correct results and that a power supply would be needed. Because of this, the group ran out of time and was unable to experiment with the *LC* circuit. Given more time, the group would be able to complete the *LC* circuit experiment in order to also approve or disapprove of their *LC* circuit calculations. The extra time could be used to improve the *RL* circuit experiment to produce data that would allow for the experimental time constant to be compared. While the theoretical *LC* circuit function could not be proven to be accurate, the information on *RL* circuits was sufficient in showing that the students could apply their knowledge of *LC* and *RL* circuits in a given task.