EXPERIMENT 2: DC *RC* CIRCUITS and AC *LRC* CIRCUITS

LEARNING OUTCOMES:

The purpose of this experiment:

PART A: Investigate how the voltage across a capacitor, V_c varies as it charges and to find the capacitive time constant, τ in a *DC RC* circuits.

PART B: Study resonance in an AC inductor-capacitor circuit (AC *LRC* circuit) by examining the current through the circuit as a function of the frequency of the applied voltage.

PART A: DC RC circuit

THEORY

Fig. 1 shows a DC *RC* circuit. When a DC voltage source is connected across an uncharged capacitor, the rate at which the capacitor charges up decreases with times.

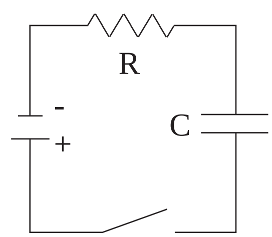


Fig. 1: A *DC RC* circuit

The capacitor charges exponentially and the charge on the plates at any time is given by:

$$q = q_o\left(1 - e^{-t/\tau}\right)$$

where q_o is maximum charge on the plates and τ is the capacitive time constant (τ = *RC*). The time it takes to charge the capacitor to half full is called the half-life and is related to the capacitive time constant in the following way:

$$t_{1/2} = \tau \ \ln 2$$

In this activity the charge on the capacitor will be measured indirectly by measuring the voltage across the capacitor since these two values are proportional to each other: $q = CV$.

APPARATUS

- Computer and Science Workshop Interface Universal Interface (UI-5000) 850
- 2 Voltage Sensor
- AC/DC Electronics Board; Inductor coil & Core
- 100 Ω Resistor, 10 Ω Resistor
- 330 μF, 100 μF capacitor
- Wire leads
- Banana plug patch cords

PROCEDURE

(i) Fig. 2 shows the experimental setup:

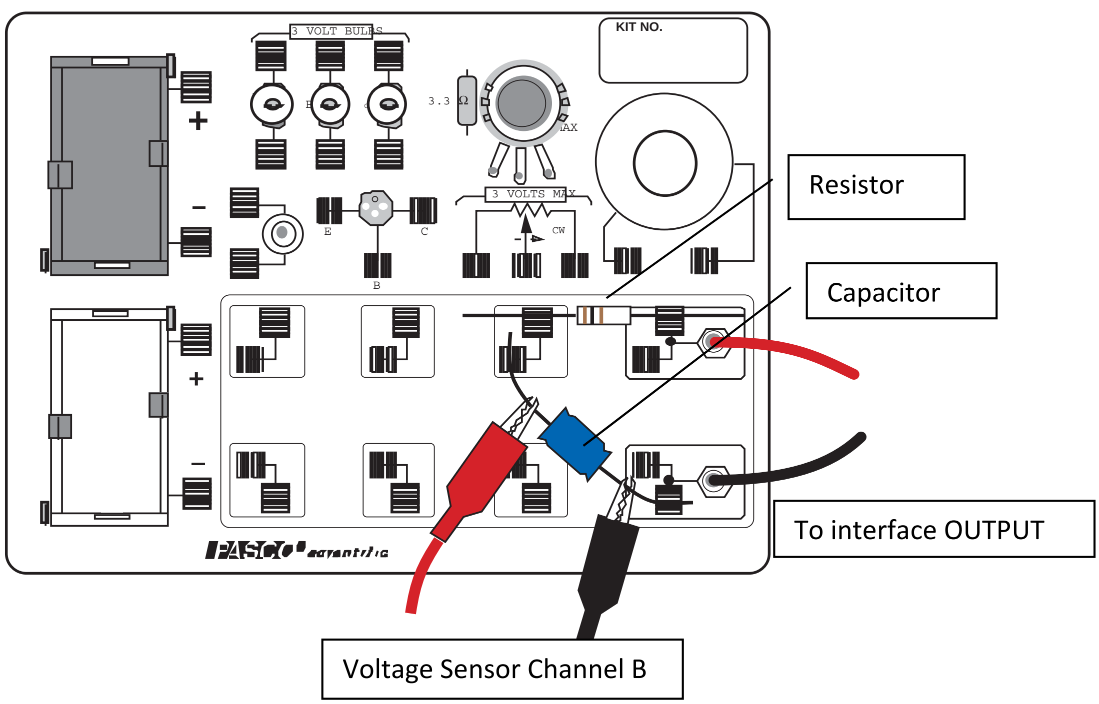


Fig. 2: experimental setup

(ii) Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

(iii) Connect the Voltage Sensor DIN plug into Analog Channel B.

(iv) Connect banana plug patch cords into the 'OUTPUT' ports on the interface.

(v) Open the document titled **EXPT2_RC and LRC CIRCUITS.**

(vi) You do not need to calibrate the Voltage Sensor.

(vii) Place a **100-ohm (Ω)** resistor (brown, black, brown) in the pair of component springs nearest to the top banana jack at the lower right corner of the AC/DC Electronics Lab Board.

(viii) Connect a **330 microfarad (μF)** capacitor between the component spring on the left end of the**100-Ω** resistor and the component spring closest to the bottom banana jack.

(ix) Put alligator clips on the Voltage Sensor banana plugs. Connect the alligator clips to the wires at both ends of the **330 μF** capacitor.

(x) Connect banana plug patch cords from the 'OUTPUT' ports of the interface to the banana jacks on the AC/DC Electronics Lab Board.

DATA

- Beginning Time = __________s
- Time to 2 Volt = __________s
- Time to half max (t_{12}) = __________s

- Use $t_{1/2} = \tau \ln 2 = 0.693RC$ alculate the capacitance (C) of the capacitor.

Capacitance = ___________Farad

- If a capacitance meter is available, use it to measure the capacitance of the capacitor. Using the percent different method, compare the measured value to the experimental value. (Remember, the stated value of a capacitor may vary by as much as +/- 20% from the actual measured value).
- If capacitance meter is not available, use the percent error method and compare the stated value (e.g.; 330 μF to the experimental value).

QUESTION:

1. Capacitor also have what is known as the capacitive time-constant. Calculate this constant based on your result for this experiment.

   Ans:

2. The time to half-maximum voltage is the time taken for the capacitor to charge halfway. Based on your experiment result, how long does it take to charge to 75% of its maximum?

   Ans: What is the maximum charge for the capacitor in this experiment?

   Ans:

PART B: AC *LRC* circuit

THEORY

The amplitude of the AC current (I_0) in a series *LRC* circuit is dependent on the amplitude of the applied voltage (V_0) and the impedance (Z).

$$I_0 = \frac{V_0}{Z}$$

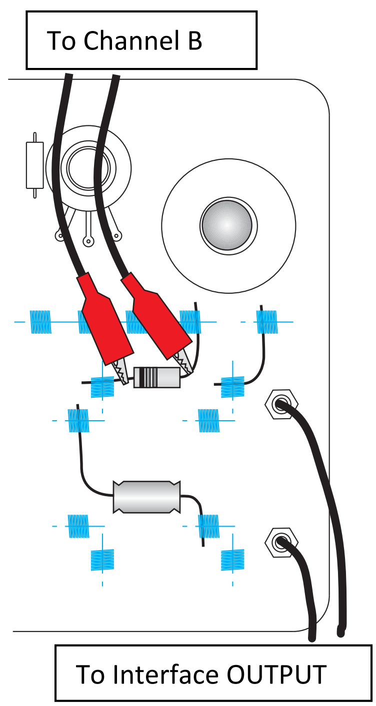
Since the impedance depends on frequency, the current varies with frequency:

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)}$$

where X_L = inductive reactance = ωL, X_C = capacitive reactance = $\frac{1}{\omega C}$, R = resistance, and ω = angular frequency = $2\pi f$ (f = linear frequency). The current will be maximum when the circuit is driven at its resonant frequency:

$$\omega_{res} = \frac{1}{\sqrt{LC}}$$

One can show that, at resonance, $X_L = X_C$ and thus the impedance (Z) is reduced to R. At resonance, the impedance is the lowest value possible and the current will be the largest value possible.



PROCEDURE

(i) You do not need to calibrate the Voltage Sensors. The following setup shows the AC/DC Electronics Board (EM-9656).

(ii) Connect a 5-inch wire lead between a component spring next to the top banana jack, and the component spring at the right hand edge of the inductor coil. Put the iron core inside the inductor coil.

(iii) Connect the 10-Ω resistor (brown, black, black) between the component spring at the left-hand edge of the inductor coil, and the second component spring to the left of the top banana jack.

(iv) Connect the 100-μF capacitor between the component spring nearest to the one in which one end of the 10-Ω resistor is connected, and a component spring nearest to the bottom banana jack at the lower right corner of the AC/DC Electronics Lab circuit board.

(v) Put alligator clips on the banana plugs of the Voltage Sensor connected to Analog Channel B. Connect the alligator clips of the Voltage Sensor to the wires at both ends of the 10-Ω resistor. The voltage measured at Analog Channel B is related to the current through the resistor by $I = V_R/R$.

(vi) Connect banana plug patch cords from the banana jacks on the edge of the AC/DC Electronics Lab Board to the 'OUTPUT' ports on the *ScienceWorkshop/ Universal* interface

ANALYSING THE DATA

- Calculate the current through the resistor for each increment of frequency and record the values in the Data Table.
- Graph the current versus the linear frequency. You can use the software or graph paper. (NOTE: The function generator frequency is the linear frequency.)
- Using the resonant frequency found from the Scope display, calculate the resonant angular frequency and record the value in the Data Table:

$$\omega_{res} = 2\pi f$$

- Calculate the theoretical resonant angular frequency using the values of the inductance and capacitance:

$$\omega_{res} = \frac{1}{\sqrt{LC}}$$

Data Table

Freq (Hz)	V_R (V)	Current = V_R/R (A)	Freq (Hz)	V_R (V)	Current = V_R/R (A)
50			110		
60			120		
70			130		
80			140		
90			150		
100					

Plot the graph using MS-Excel.

Parameter	**Value**
Inductance, L, (mH)	18.9
Resistance, R, (Ω)	
Capacitance, C, (μF)	
Resonant frequency, f_{res}, (Hz)	
Resonant angular frequency, ω_{res}, (rad)	
Theoretical resonant angular frequency, ω_{res}, (rad)	
% error of $\omega_{res} = \frac{\lvert TheoreticalValue - ExperimentalValue \rvert}{TheoreticalValue} \times 100\%$	

QUESTION:

1. From your result, explain the use of the resonant frequency and how do you determine the value.
   Ans:
2. Explain how energy is stored in a capacitor and inductor.
   Ans: