Name _____   Class _____   Date _____

RC Circuit Lab

Objectives:

Students will be able to …

- Use the *ScienceWorkshop* interface to investigate the relationship between the voltage remaining across a capacitor and the time taken for the discharge of the capacitor in an RC circuit;

- Calculate the capacitance based on the time to "half-max";

- Calculate the capacitive time constant based on the capacitance and resistance of the circuit;

- Compare the measured capacitance to the theoretical value as stated by the manufacturer.

Equipment Needed	Qty	From AC/DC Electronics Lab*	Qty
Voltage Sensor	1	Capacitor, 330 microfarad	1
Patch Cords	2	Resistor, 100 ohm	1

What Do You Think?

The voltage across a capacitor varies as it charges. How can you investigate this relationship? Capacitors also have what is known as the capacitive time constant. How can this constant be calculated?
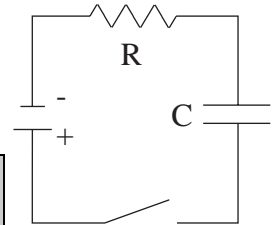
Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

When a DC voltage source is connected across an uncharged capacitor, the rate at which the capacitor charges up decreases as time passes. At first, the capacitor is easy to charge because there is very little charge on the plates. But as charge accumulates on the plates, the voltage source must "do more work" to move additional charges onto the plates because the plates already have charge of the same sign on them. As a result, the capacitor charges exponentially, quickly at the beginning and more slowly as the capacitor becomes fully charged. The charge on the plates at any time is given by:

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

,

where q_o is the maximum charge on the plates and τ is the capacitive time constant ($\tau = RC$, where R is resistance and C is capacitance). NOTE: The stated value of a capacitor may vary by as much as ±20% from the actual value. Taking the extreme limits, notice that when t = 0, q = 0 which means there is not any charge on the plates initially. Also notice that when t goes to infinity, q goes to q_o which means it takes an infinite amount of time to <u>completely</u> charge the capacitor.

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: $q = CV$.

SAFETY REMINDER	THINK SAFETY ACT SAFELY BE SAFE!
• Follow all safety instructions.	

For You To Do ++

Use the 'Output' feature of the *ScienceWorkshop* interface to supply a voltage to the resistor-capacitor circuit. Use the Voltage Sensor to measure the voltage across the capacitor as it charges and discharges. Record the voltage in the secondary coil for two configurations: one with an iron core inside the inner coil, and one without the iron core inside the inner coil.

Use *DataStudio* to control the voltage output of the interface and to record and display the voltage across the capacitor. Finally, measure the time for the capacitor to charge to the 'half-maximum' voltage. Use the half-time constant and the known value of the resistance to calculate the capacitance of the capacitor.

Compare the calculated value of the capacitor to the stated value of the capacitor.

In this activity, the interface outputs a low frequency 'positive-only' square wave (0 to 4 V). This waveform imitates the action of charging and then discharging a capacitor by connecting and then disconnecting a DC voltage source.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the Voltage Sensor DIN plug into Analog Channel B.

3. Connect banana plug patch cords into the 'OUTPUT' ports on the interface.

4. Open the document titled RC Circuit Lab.

• The *DataStudio* document has a Graph display of voltage versus time and the Signal Generator window for controlling the 'Output' of the interface. The document also has a Workbook display. Read the instructions in the Workbook.

• Data recording is set to stop automatically at 4 seconds.

- The Signal Generator is set to output a 4 volt, "positive only" square wave at 0.40 Hz. The Signal Generator is set to 'Auto' so it will start and stop automatically when you start and stop measuring data.

PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Voltage Sensor.

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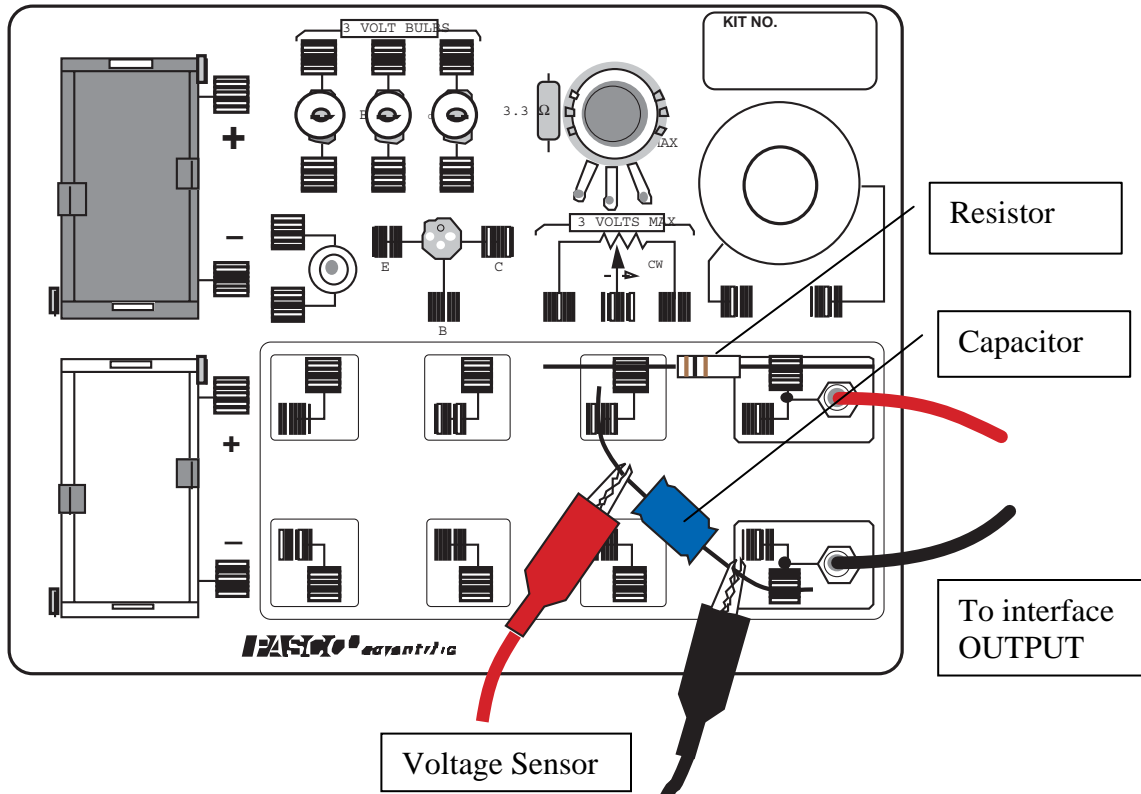
nearest to the top banana jack at the lower right corner of the AC/DC Electronics Lab Board.

2. 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.
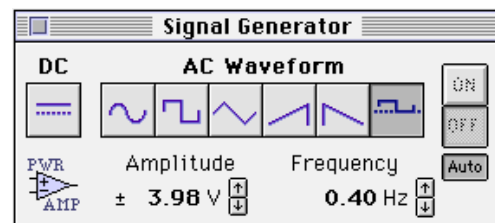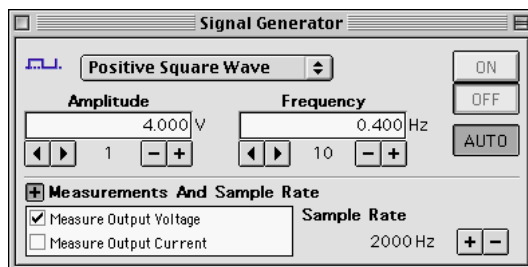

3. Put alligator clips on the Voltage Sensor banana plugs. Connect the alligator clips to the wires at both ends of the 330 µF capacitor.

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

Part III: Data Recording

1.   Start measuring data. (Hint: Click 'Start' in *DataStudio*.) The Signal Generator output will automatically start when data recording begins.

•   Watch the plot of voltage versus time in the Graph display.

2.   Data recording will continue for <u>four seconds</u> and then stop automatically.
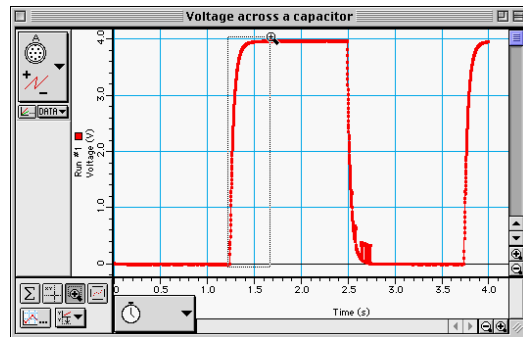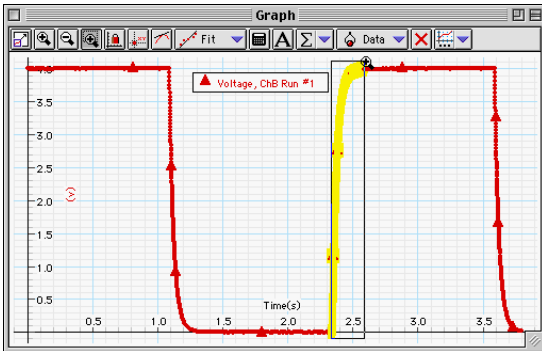
•   'Run #1' will appear in the Data list.

Analyzing the Data

1.   Rescale the Graph display if needed.

2.   Expand a region of the Graph display. Use the 'Zoom Select' tool in *DataStudio* () to click-and-draw a rectangle over a region of the plot of Voltage versus Time that shows the voltage rising from zero volts to the maximum volts.

•   **Result**: Your selected region expands to fill the Graph display.

3.   Use the built-in analysis tools in the Graph display to find the time to 'half-max'.

•   In *DataStudio*, click the 'Smart Tool'. Move the cursor to the point on the plot where the voltage begins to rise. Drag the corner of the 'Smart Tool' to the point where the voltage is about 2 volts. The time to 'half-max' is the 'x-coordinate'.

4.   Use $\mathbf{t}_{\frac{1}{2}} = \boldsymbol{\tau}\,\mathbf{ln2} = 0.693$ RC to calculate the capacitance (C) of the capacitor.

Put your results in the Lab Report section

Lab Report: RC Circuit Lab

What Do You Think?

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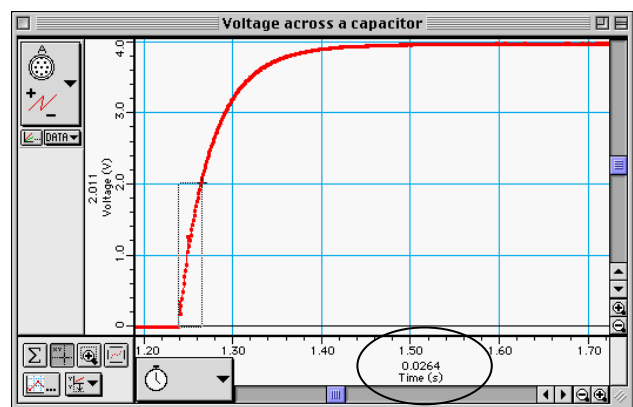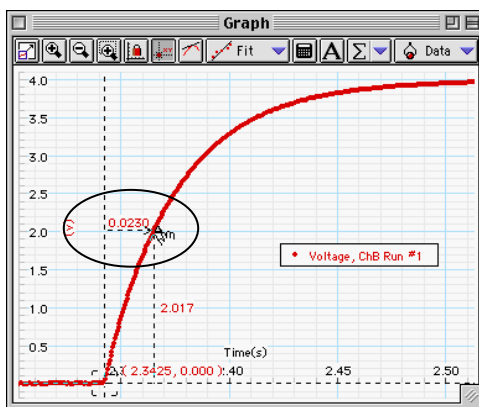### Data

Time to half-max ($t_{1/2}$)   = _____ s

Capacitance = _____ F   = _____ µF

(Remember, $C = \dfrac{t_{\frac{1}{2}}}{\ln 2} \div R$)

Percent Difference between stated capacitance value of 330 microfarad = _____

1. The time to half-maximum voltage is how long it takes the capacitor to charge halfway. Based on your experimental results, how long does it take for the capacitor to charge to 75% of its maximum?

2. After four "half-lifes" (i.e., time to half-max), to what percentage of the maximum charge is the capacitor charged?

3. What is the maximum charge for the capacitor in this experiment?

4. What are some factors that could account for the percent difference between the stated and experimental values?

5. Show that the capacitive time constant, RC, has the dimensions of time in *seconds* when R is in ohms and C is in farads.

6. During the initial charging of this capacitor up to the max voltage, V_o, the initial energy stored in the capacitor is $\frac{1}{2}CV_o^2$. Show mathematically that this energy is equal to the total energy dissipated as heat in the resistance through which discharging the current flows. (You may attach a separate sheet).

7. A charged 2-μF capacitor is connected in parallel with 0.5-MΩ resistor. (a) How long after the connection is made will the voltage across the capacitor fall to 75% of its maximum value? (b) How much thermal energy will be dissipated across the resistance after three time constants?