Name ____________________ Class ______________ Date _________

Activity P50: RC Circuit
(Power Output, Voltage Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Circuits	P50 RC Circuit.DS	(See end of activity)	(See end of activity)

Equipment Needed	**Qty**	**From AC/DC Electronics Lab***	**Qty**
Voltage Sensor (CI-6503)	1	**Capacitor, 330 microfarad**	1
LCR Meter (SB-9754)	1	**Resistor, 100 ohm**	1
Patch Cords (SE-9750)	2		

(*The AC/DC Electronics Lab is PASCO Model EM-8656)

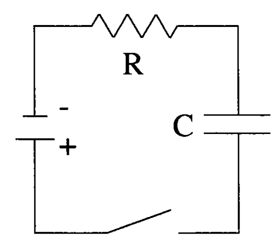
What Do You Think?

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:



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

where $\mathbf{q_o}$ is the maximum charge on the plates and τ is the capacitive time constant (τ = 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 completely 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:

$$\mathbf{t}_{1/2} = \tau\,\mathbf{ln2}$$

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**
• Follow all safety instructions.	**ACT SAFELY** **BE SAFE!**

For You To Do

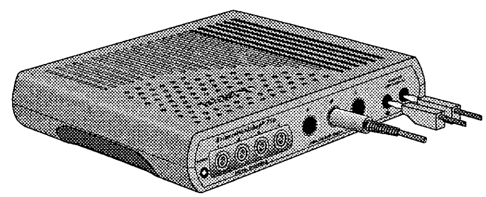
Use the 'Output' feature of the *ScienceWorkshop* interface to supply a voltage to the resistor-capacitor circuit. Use the Voltage Sensor to measure the voltage across the capacitor as it charges and discharges. Record the voltage in the secondary coil for two configurations: one with an iron core inside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

Use *DataStudio* or *ScienceWorkshop* 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.

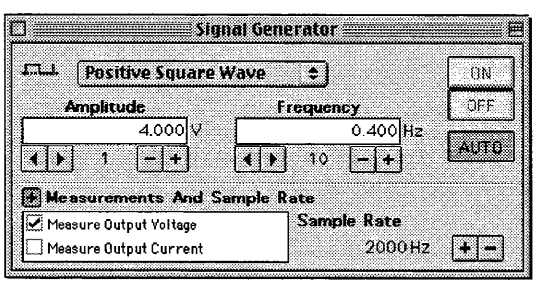
PART I: Computer Setup

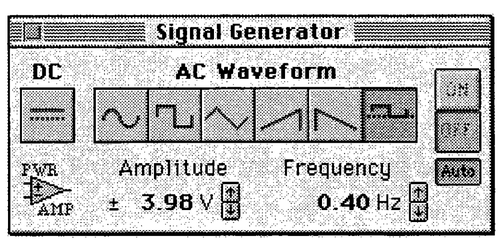


1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel B.
3. Connect banana plug patch cords into the 'OUTPUT' ports on the interface.
4. Open the document titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
P50 RC Circuit.DS	(See end of activity)	(See end of activity)

- 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.
- See the pages at the end of this activity for information about modifying a *ScienceWorkshop* file.
- 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.



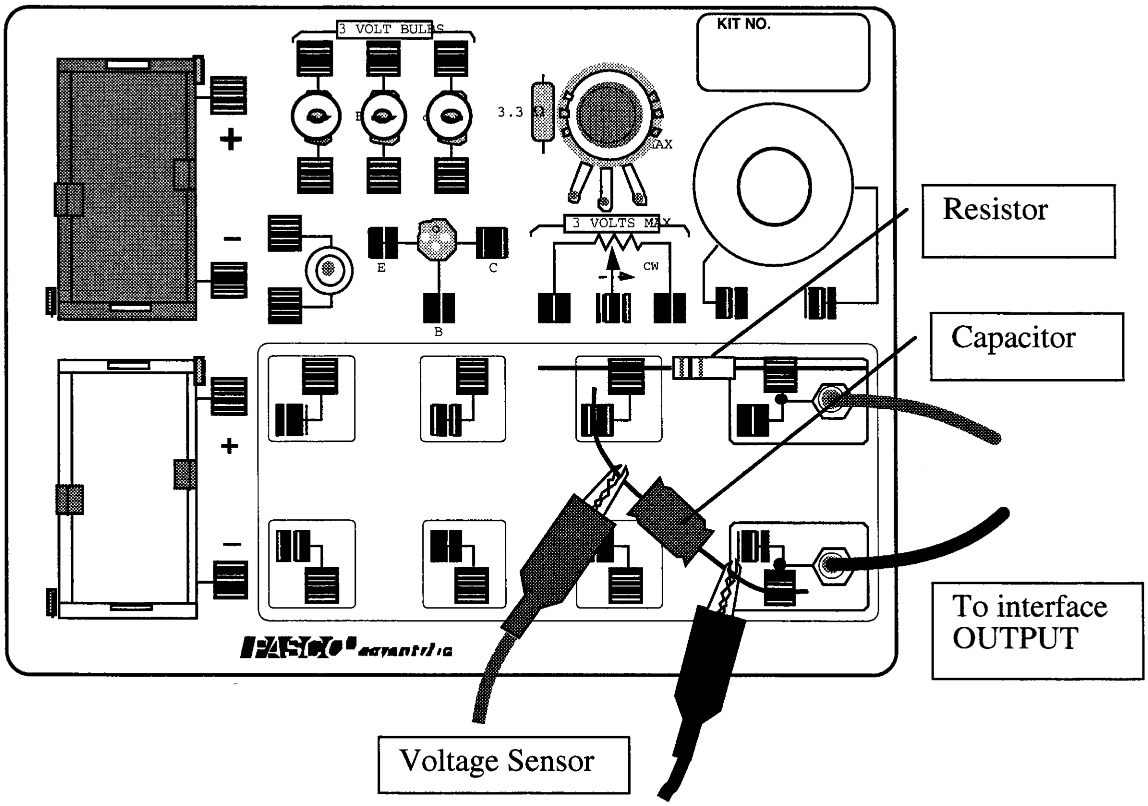


Name ____________________ Class ______________ Date _________

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* or 'REC' in *ScienceWorkshop*.) The Signal Generator output will automatically start when data recording begins.

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

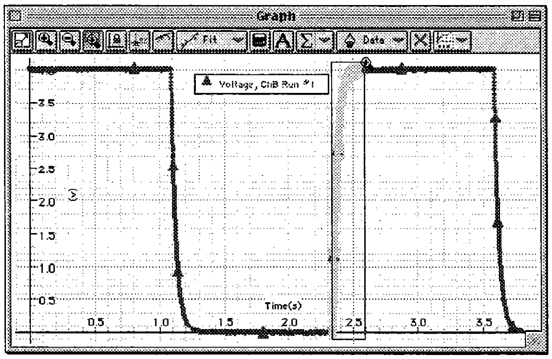
2. Data recording will continue for <u>four seconds</u> and then stop automatically.

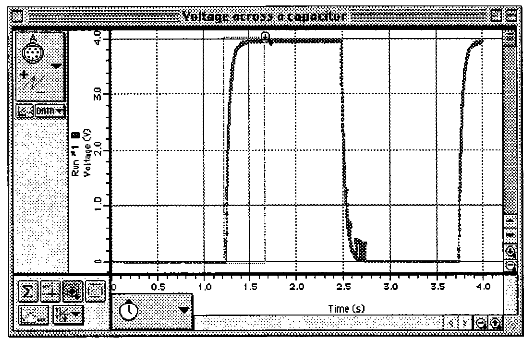
- 'Run #1' will appear in the Data list.

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* () or the 'Magnifier' tool in *ScienceWorkshop* () 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.

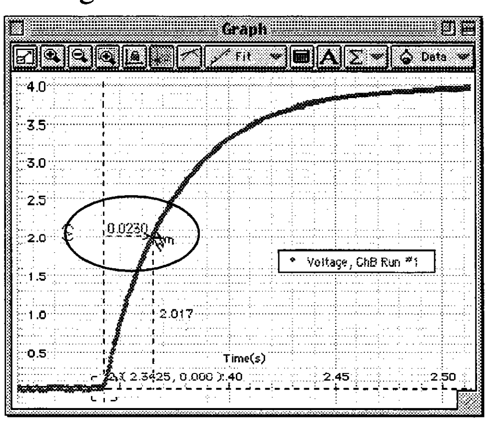


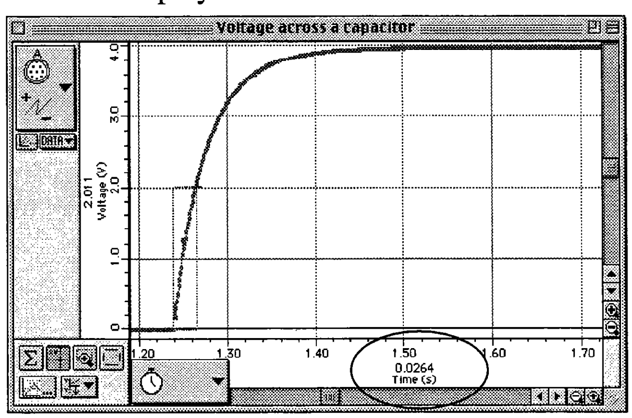


- **Result**: Your selected region expands to fill the Graph display.

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'.
- In *ScienceWorkshop*, click the 'Smart Cursor'. The cursor changes to a cross hair when you move the cursor into the display area of the Graph. Move the cursor to the point on the plot where the voltage begins to rise. Click-and-drag the cursor to the point where the voltage is about 2 volts. The time to 'half-max' is displayed under the horizontal axis.





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

Put your results in the Lab Report section

Name ____________________ Class ______________ Date _________

Lab Report- Activity P50: RC Circuit

What Do You Think?

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Data

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

Capacitance = __________ F = __________ μF

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

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?