CAPACITORS

(L-23)

A capacitor is a circuit element that stores charge and, in doing so, stores electrical energy. The relationship between the voltage V_c across a capacitor's plates and the charge Q on each plate is $C = Q/V_c$, where C is called the *capacitance* of the capacitor. In an RC circuit (i.e., a circuit in which there is a resistor and a capacitor), a fully charged capacitor will discharge at a rate governed by the size of the capacitor and the size of the resistor. The *time constant*--the amount of time required for the capacitor to discharge 63% of its initial charge (and, hence, drop to 37% of its initial voltage)--is numerically equal to the product of R and C, where R must be in ohms and C in farads.

This lab will be concerned with capacitors in general and, more specifically, with the charging and discharging characteristics of capacitor combinations.

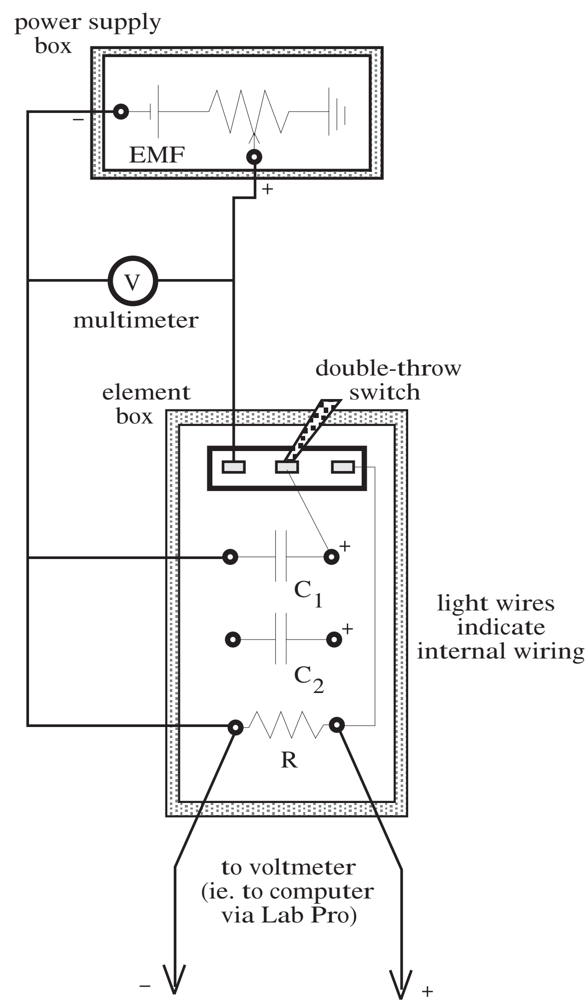
PROCEDURE--DATA

Part A: (C_1 circuit)

a.) Plug your *voltage probe* into the Lab Pro and open the Logger Pro program. Once open, calibrate the *voltage probe* by opening up EXPERIMENT and clicking on ZERO.

b.) Set your vertical axis to *2 volts* and the horizontal axis to *10 seconds*.

c.) In the circuit shown to the right, wire the circuit box and power supply together first, *then* wire in the voltmeter (use a MULTIMETER set on its *2.5 volt* scale) and the computer voltage probes. Connect the probes to the underside of the circuit box and be careful to get your polarities right.



d.) After having your circuit checked, turn on the POWER SUPPLY and set the voltage across the capacitor at exactly 2.0 volts as measured using the MULTIMETER.

e.) To CHARGE the capacitor, simply throw the double-pole switch to the LEFT. The charging shouldn't take more than a few seconds. Once charged, hit COLLECT, wait for the icon to change to STOP, then throw the switch completely to the RIGHT to put the capacitor in parallel with the resistor and allow the capacitor to discharge through the resistor. If the MULTIMETER is calibrated accurately, the voltage across the resistor will shoot up to 2.0 volts and the scope will present *in real time* a graph of the voltage across the resistor as the capacitor discharges through it.

Note: If the MULTIMETER is not accurately calibrated, one of two things will happen:

If the trace's initial voltage is less than or greater than 2.0 volts, forget the MULTIMETER (you used it solely as a first step, anyway), tweak the POWER SUPPLY'S voltage down a bit, recharge the capacitor, discharge the capacitor, and watch to see if the graph begins at exactly 2.0 volts. Continue this fine tuning until your discharge begins at EXACTLY 2.0 volts.

f.) Once you a plot that starts EXACTLY at the 2.0 volt crux, print it

g.) At some point in time, you will need to use the IMPEDANCE BRIDGE to determine:

--R;

--C_1;

--HAVE ME CHECK YOUR VALUES BEFORE LEAVING LAB.

CALCULATIONS

Part A: (Capacitance and *time constant* for RC_1 circuit.)

1.) For amusement, let's see if our theoretical and experimental *time constants* match. To find out:

a.) Use your graph to determine the experimental *time constant* for R and C_1 (this will be the *time* when the voltage has dropped to .37 of its original value).

b.) Using your Impedance Bridge values for R and C_1, determine the theoretical *time constant* for your circuit.

c.) Do a % comparison between the theoretical and experimental *time constants*. Comment briefly.

2.) We would like to determine a theoretical expression for the capacitance C_1.

a.) To do this, consider the following: It is possible to show from Kirchoff's Laws and a little calculus that the voltage at time t across a discharging capacitor is:

$$V(t) = V_o e^{-t/RC},$$

where t is the time in question, $V(t)$ is the voltage across the capacitor at time t, V_o is the initial voltage across the capacitor, C is the capacitor's capacitance, and R is the resistance of the resistor.

Use this information to derive an expression for the theoretical capacitance C_1. DON'T PUT NUMBERS IN YET, JUST DO THE DERIVATION.

b.) Consider your data (i.e., the graph). Look specifically at time $t = 2$ *seconds*. Use the equation derived in *Part 2a*, your graph's voltage value at $t = 2$ *seconds*, and your Impedance Bridge value for R to determine the capacitance of C_1. Call this $C_{1,exp}$ (this is being tagged "experimental" because we are using experimentally determined data from the graph to determine $V(t = 2)$).

c.) Do a % comparison between $C_{1,exp}$ and your Impedance Bridge value for C_1. Comment.

Part B: (parallel versus series)

3.) You had the computer create a *Voltage versus Time* graph for the discharge of C_1 during the data taking part of this lab. Cut out the graph you generated during the data-taking part of the lab. On a clean piece of Engineering paper, paste the graph.

4.) Draw a grid similar to the one you pasted into Part 3. If the circuit had been of two capacitors in *series* with both of the size equal to C_1:

a.) What would the time constant be?

b.) What (to a good approximation) would the trace look like. This should be a sketch. You don't need to actually plot number. Just give a general look that is true, relative to what you have in Part a.

5.) Draw a grid similar to the one you pasted into Part 3. If the circuit had been of two capacitors in *parallel* with both of the size equal to C_1:

a.) What would the time constant be?

b.) What (to a good approximation) would the trace look like. This should be a sketch. You don't need to actually plot number. Just give a general look that is true, relative to what you have in Part a.

QUESTION

I.) What was the initial energy stored in the capacitor C_1 (i.e., just after it was charged)? Show equation(s) used and put in numbers appropriately.