PHYSICS 1040L LAB

LAB 4: R.C. TIME CONSTANT LAB

OBJECT: To study the discharging of a capacitor and determine the time constant for a simple circuit.

APPARATUS: Capacitor (about 24 µF), two resistors (about 25,000 Ω and 100 Ω), DC power supply, double throw switch, computer and voltage sensor.

THEORY: Capacitor is a useful device for storing charge and energy, which consists of a pair of parallel conducting sheets, closely spaced but insulated from each other. The magnitude of the charge on either conductor is proportional to the voltage across the two conductors. The ratio of the charge to the voltage is called the capacitance:

$$C = \frac{Q}{V} \quad (1)$$

Capacitors have many uses ranging from storage of energy and charge, electronic tuning in AM Radios, filtering of high frequencies in power supplies, constructing delay lines in coaxial cables, oscillation tanks, pulse shaping, voltage doubling, AC coupling and so on.

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When a capacitor is charged up to a particular voltage, and then allowed to discharge through a resistor (Fig. 2), the voltage does not go to zero immediately but decreases exponentially with time. If the resistor is connected across the terminals of a capacitor at t = 0 and the voltage is V_o, the voltage at any time later, V_t will be given by the following expression:

$$V_t = Q(t) / C = V_o \, e^{(-t/RC)} \quad (2)$$

Where R is the resistance in Ohms and C is the capacitance in Farads. The combination RC= τ (The Time Constant) has units of time (seconds). It is the time for the voltage across the capacitor to reduce to 1/e =(0.368) of its original value. After 3 time constants, only 5% of voltage is left. The voltage is practically zero after 10 time constants.

Figure 2: Capacitor Discharging through a Resistor

A similar expression may be written for charging the capacitor through a resistor (Figure 3). If the capacitor is originally discharged and a voltage, V_o applied at t = 0, the voltage at subsequent times will be:
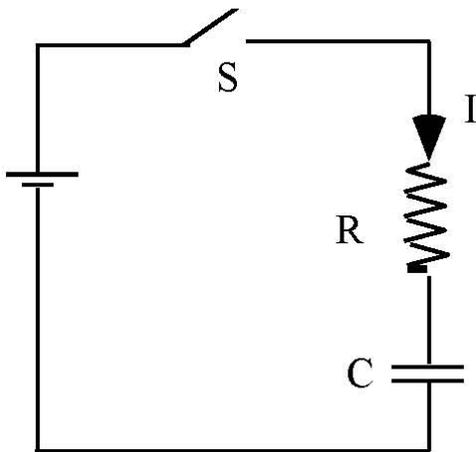
$$V_t = Q_t/C = V_0(1 - e^{-(t/\tau)}) \quad (3)$$

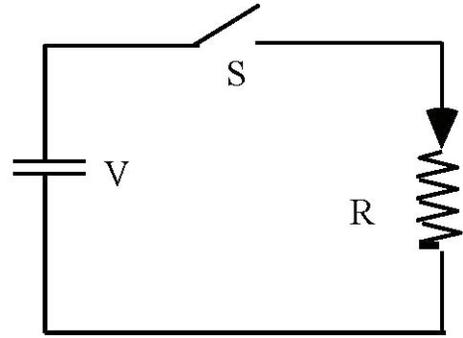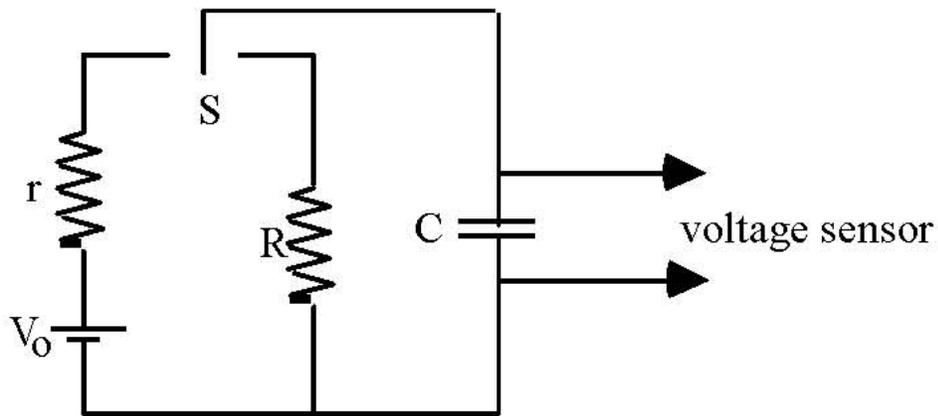**Figure 3 Capacitor Charging up through a Resistor**

Figure 4: Circuit Diagram. Note: The parts of the circuit diagram marked S represents the 3 connectors on the DPDT Switch. See Figure 7.
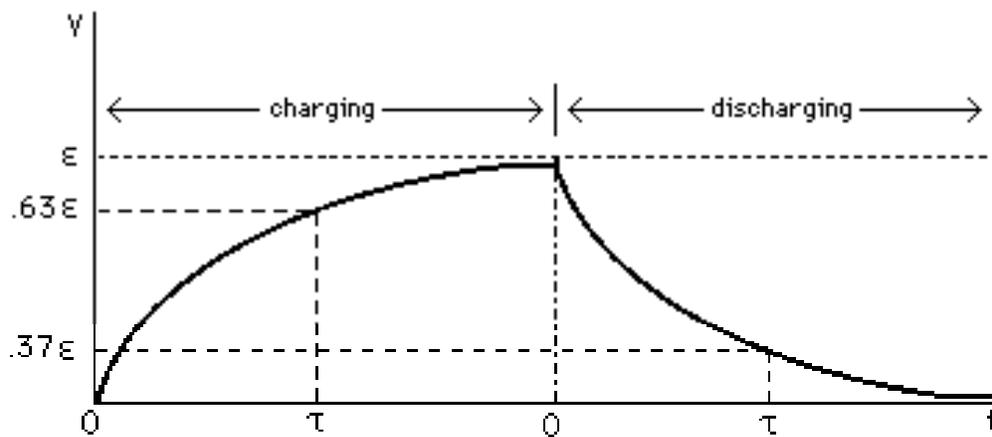

Fig. 1. Graph of voltage vs. time for charging and discharging in an RC circuit.

PROCEDURE:

1. Construct a circuit (fig. 4). Connect the voltage sensor as a voltmeter.

Figure 5: Capacitor

Figure 6: Voltage Probe

Figure 7: Double Pole Double Throw Switch

2. On the desktop OPEN Vernier LoggerPro 3.8.*

3. In the LoggerPro program click FILE – OPEN – Physics with VERNIER – Exp 24 "RC time constant/Capacitors".

4. Set the voltage axis to 5 V and the time axis to 60 seconds. You can always change both the voltage and time ranges such that the exponential decay curve fills up the whole screen.

5. Click on the Insert menu and choose table.

6. Click onto the Page menu and choose Auto Arrange. You will see three columns. Time(s), Potential V (volts) and Ln V.

7. Turn on the power supply and set the voltage to about 4 V. Flip the DPDT switch to the power supply position to charge the capacitor. The charging resistor, r , has a small resistance (about a few k Ω). It should take only a split second to charge up the capacitor to the full voltage of the power supply.

8. Click the green "Start" or "collect" button to start collecting data. Then quickly flip the DPDT switch so that the capacitor is now discharging through the large resistor. An exponential curve should show the voltage across the capacitor as a function of time. When the voltage is less than 5% or so, click "Stop" button.

9. Click on the graph window so that it is the active window.

7. Click on the Analyze Menu and choose curve fit. Y = A*exp(-Ct)+ B

8. Click on the button "Try Fit". The curve fitting parameters will appear in the little white boxes.

9. Click on the OK button and the fitting parameters will appear in a pop up window on top of your graph,

10. Record the fitting parameter C, from the computer fit, in your first data table.

11. Repeat this process 5 more times for a total of 6 trials.

12. Find and average value for C from the computer data.

13. Find the decay constant τ from C$_{average}$.

15. Calculate the resistance. The capacitance can be read from the side of the capacitor.

16. Get a hard copy of one of the plots for one of the six trials for each person to turn in with their report.

17. For one of your trials you will choose 12 Voltage and Time data points to graph. These data points should cover the whole range of your data. Record these data points in a second data table

Data analysis

1. **By hand make a graph of V(t) vs. (t) on linear graph paper(The green stuff or something similar) using your data** (you should choose about 10 to 12 points from your set of data ; choose points thruought the data set. Not just at the beginning or the end of the data set); (make a separate table in your report). Visually compare it to the graph you got from your LoggePro computer fit of the experimental data. (Natural Exponential graph.)
2. Plot your chosen points BY HAND on semi-logarithmic graph paper. Semi-logarithmic graph paper automatically takes the log of the y-value of the function because of the scale. Find the slope of the best fit line. [See the handout on how to use Log-Log and Semi-Log paper.]
3. In Excel, or in Vernier's Logger Pro or Graphical Analysis, plot V vs. t and make another graph. Choose a logarithmic scale for the y-axis. You will get a straight line. Find the equation of the line. You must fit the data to the Natural exponential fit of the form Y=Ae(-Cx)+B . A linear Fit will not work when using a logarithmic scale for the Y axis.
4. In a new column in Excel, or Vernier's Logger Pro or Graphical Analysis calculate a new column (If you have nor already done so) of ln (Vt) and plot ln(Vt) versus t on

linear graph paper (linear graph in Excel, Logger Pro or Graphical Analysis). Calculate the slope of the line. The absolute value of the slope of the graph is equal to 1/RC.

5. In a new column in Excel, or Vernier's Logger Pro or Graphical Analysis calculate a new column ln (V_t/V_0) and plot ln(V_t/V_0) versus t on linear graph paper (linear graph in Excel, Logger Pro or Graphical Analysis). Calculate the slope of the line. The absolute value of the slope of the graph is equal to 1/RC.

6. Make sure you record correct units. Assuming the value of capacitor C is correct, calculate the experimental resistance.

7. Find the % difference between the calculated value for the resistor and the given value.

Reminder: Check your math, check the units, check your graphs, and do not forget to follow the format for your lab report (see syllabus). Also the value of C obtained from the computer *IS NOT THE CAPACITANCE*.