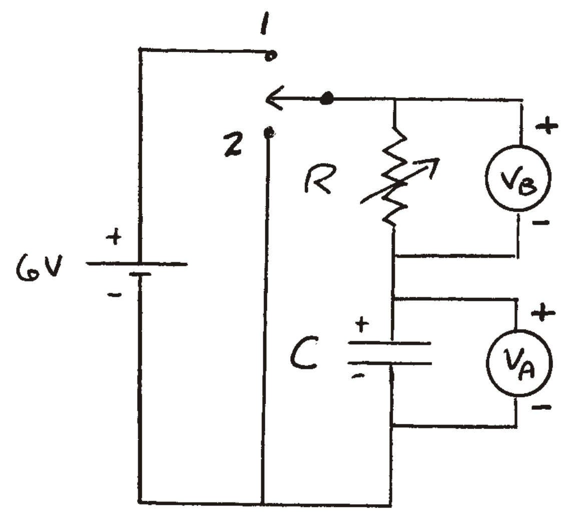
Physics NYB

Experiment: Capacitor Charge and Discharge

Objective: To study the charging and discharging of capacitors.

Part A: Charging and Discharging Curve

Procedure:



1) Connect the circuit as shown. ***C = 1000 μF*** and **R** is a decade resistance box set initially for ***1 kΩ*** . The single pole double throw switch allows you to change the connection from position 1 to position 2. In position 1, the ***6 volt battery*** charges the capacitor C through the resistor R. In position 2, the capacitor discharges through the same resistor. V_A is a voltage probe connected to input A and V_B is a probe connected to input B on the Science Workshop interface.

Important: *TURN ON THE INTERFACE BEFORE CONNECTING WIRES AND USING DATASTUDIO.*

2) After you have set up the two voltage probes in DataStudio, double click on either one of the "Voltage Sensor" labels in the setup window. Make sure that the sample rate is *at least 20 Hz* in the dialogue box. To record more points you may adjust till 100Hz.

3) Set up a graph to display V_A as a function of time.

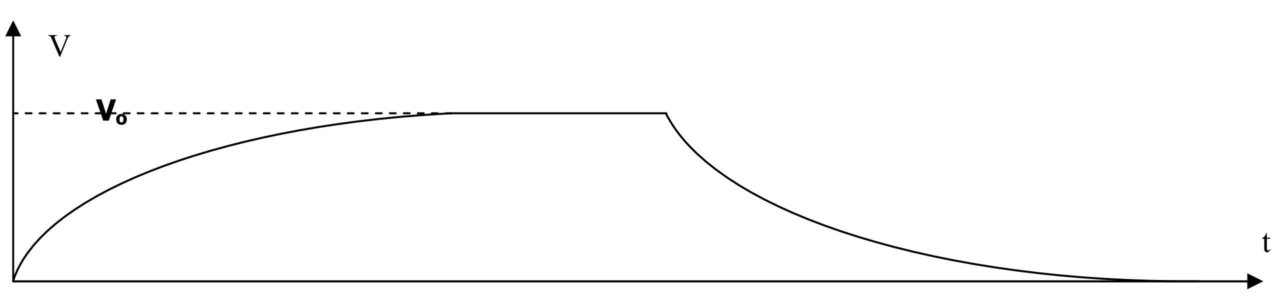
CHARGING C

4) Put the switch in position 2 and wait for a few seconds to make sure that capacitor is not charged.

5) Then, **click on Start** to begin collecting data. **Immediately**, move the switch to position 1. The potential of capacitor will increase. After a while V_A reaches a value $\mathbf{V_o}$ and remains constant.

DISCHARGING C

6) Move the switch back to position 2 and wait until V_A has returned to zero, **then click Stop**. You will see on the screen a graph similar to that shown here.



Analysis

Observing the time evolution of $V_C=V_C(t)$ and $I=I(t)$

1) Calculate the current. Open by clicking the calculator. Use the CALCULATOR to calculate the current flowing through the resistor. Enter the ***function*** $I = V/R$. Identify V as the measurement V_B (***enter*** $V=V_B$ ***).*** Identify R as a constant ***and enter R=1000***.

2) Add a graph of current I vs time inside to the opened graph window. Lock the time scales of the two graphs and adjust the other scales. You will see the two graphs $\mathbf{V_A=V(t)}$ and $\mathbf{I=I(t)}$ in the same window. Print the two graphs together.

Measuring the time characteristics

3) In the graph of V_A vs t, use the SMART TOOL to determine the maximum value of the voltage across the capacitor ($\mathbf{V_O}$). Then use the ZOOM SELECT or manually adjust the scales to display only the **part of the graph** where the capacitor ***is discharging*** *(decreasing part)*. Use the SMART TOOL to determine the time it takes for the voltage across the capacitor to drop to half its original value. This is called the half life ($T_{½}$). Also find the time it takes to drop from **½ $\mathbf{V_O}$** to **1/4 of $\mathbf{V_O}$** and from **1/4 of $\mathbf{V_O}$** to **1/8 of $\mathbf{V_O}$**. Write these time intervals in a table on your data sheet.
   N.B. The "Smart Tool" has the habit of jumping over to a data point when you get near it. This can be annoying when you are trying to read values in between points. This is a property called "gravity" in DataStudio. To disable this feature, click the SETTINGS button in the graph window. Select **TOOLS** and set the "**data point gravity**" **to zero**.

4) Adjust the scales again so that you are looking only at the ***part of the graph*** where the ***capacitor is charging.*** Use the smart tool to determine ***the time it takes*** to get from ***0*** to **½ $\mathbf{V_O}$**, from ***½ V_O to 3/4 V_O***, and from ***3/4 V_O to 7/8 V_O***.

Measuring the time constant from the discharging graph

5) Use the calculator to calculate ***ln(V)*** and ***enter*** the V=(V_A). Plot this data in a graph in a new graph window along with V_A. Lock the time axes and zoom in to the part of the lnV graph showing the discharge of the capacitor. Click on the FIT button in the graph window and select "Linear". Then on the graph, *click and drag* to select the *points starting with the first point after the capacitor starts to discharge* and including data point for about $\mathbf{3*T_{1/2}}$. (It is very important to select the correct part of the data; otherwise, the computer will attempt to fit a straight line to the entire data set which may introduce errors.) When satisfied, print this graph. Note the value of **the slope** which is shown in the box beside the fit line. The time constant is τ ***= -1/slope***. Calculate the half life of the discharging curve from the time constant as $T_{1/2} = 0.693 * \tau$. Compare this value to $\mathbf{T_{1/2}}$ measured directly on the recorded graph.

Conclusions:

1) Comment on all the time intervals measured in steps 3 and 4. Is the half-life for the discharging part of the curve the same as for the charging part?
2) Compare the maximum current to V_O/R. Is this what you expect?
3) Does the discharging part of the V_A vs t graph follow an exponential decay? How do you know? Do the data start to deviate from the exponential decay at any point? Where?
4) Does the half-life calculated from the time constant agree with the half-life measurements in steps 2 and 3 of the analysis?
5) What is the relationship between the current and voltage of the capacitor? (Think about how each of these is related to the charge on the capacitor, Q.) Do your graphs demonstrate this relationship? How?

Part B: **<u>Dependance of Time Constant on R and C</u>**

Measuring time constant for different R values keeping C =1000 **μF**

1) Change the resistance of decade resistance box to ***300 Ω*** and collect a new set of data for charging and discharging the capacitor. Measure the time constant for the discharge part of the curve by using the SMART TOOL to find ***the time*** it takes the voltage to drop from V_0 to V_0/e. Write the value in a table on your data sheet but **do not print the graph**. Include the Run# of each set of data in your table so you can check values later if necessary.

2) Change the resistance decade resistance box to 100 Ω and repeat.

Measuring time constant for different R values keeping C =100 **μF**

3) Change the capacitance to **100 μF** and measure the time constants for **R = 1 kΩ, 3 kΩ** and **10 kΩ**.

Analysis:

1) Construct a table showing the values of R, C, and time constant for all data sets. Calculate the product RC and enter it in the table as well.

Conclusions:

1) Do the data confirm the relationship $\tau = RC$ to at least two significant figures?