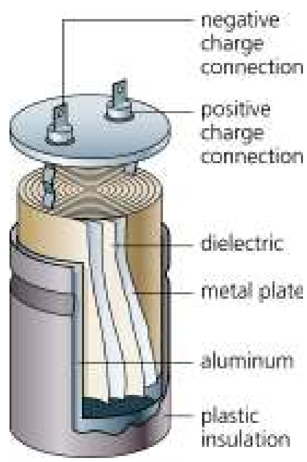
Max Shapiro
2/5/2006
AP Physics C / 2* / Philhour

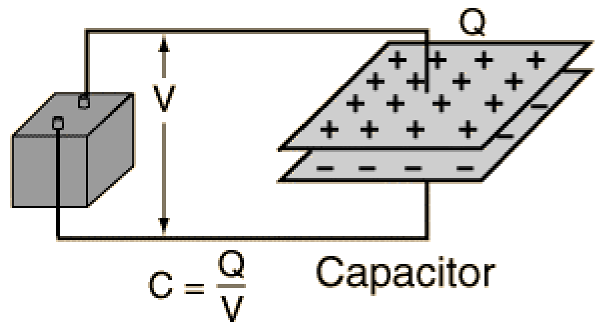
RC Circuits Lab

Abstract

The purpose of the lab was to determine the resistance of a resistor (for this experiment, a small lamp) for a given capacitor-powered circuit. This objective involved an understanding of the basic relationship between charge, resistance, capacitance, current, and voltage. Based on our calculations and introduction to the theory, we expect an exponential decay of voltage with time. Physically discharging the capacitor and measuring the voltage drop with volt probes will either verify or contradict this hypothesis.

I. Introduction and Procedure

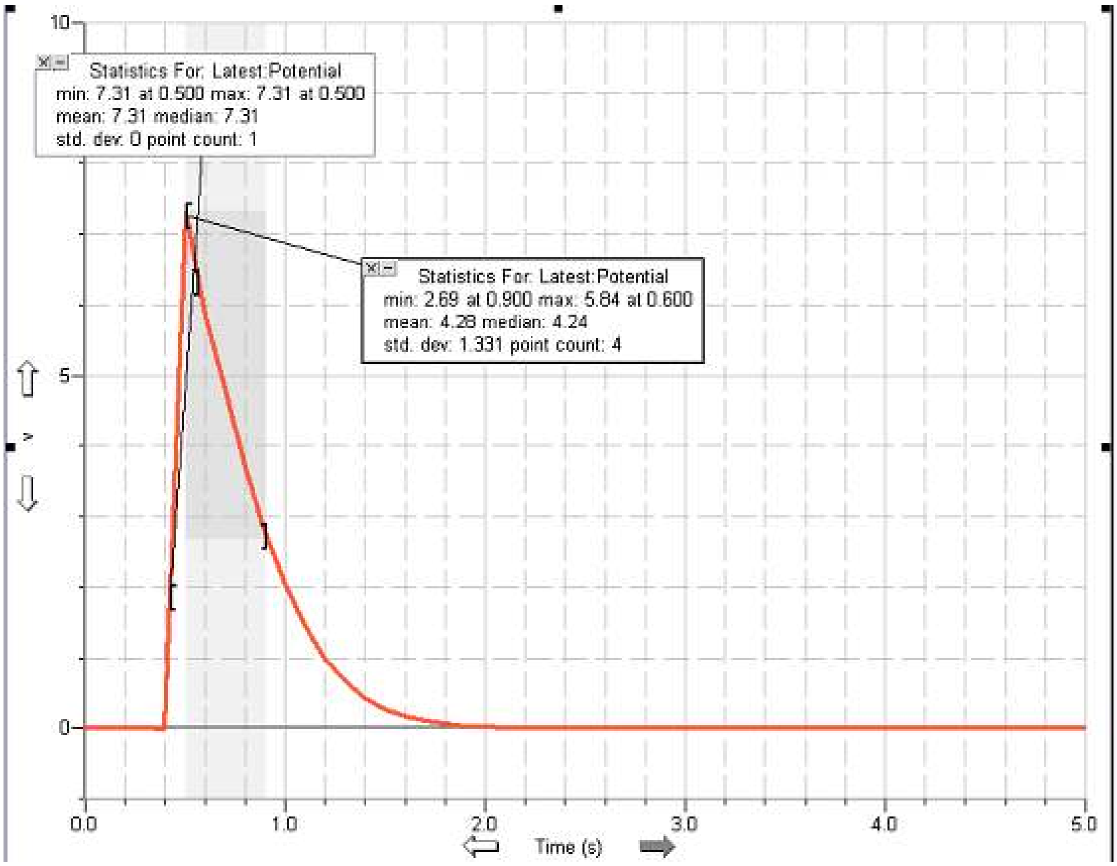




Since the commencement of the "Age of Electricity," man has desired a means in which to harness the potential of electricity (electrical potential, if you will) towards practical ends. An overarching question that arises from this question is how to store charge long enough in order to connect it to devices that we wish to power electrically; furthermore, once connected, what should we expect of the discharge of electrons and subsequent current flow? In an attempt to gain a hands-on appreciation for the physics behind our computers and televisions, we sought to charge and discharge a known capacitance, quantitatively observe the variance of electric potential with time, and solve for the time constant (which would allow us to predict future voltage for this circuit).

Prior to beginning the experiment, we reviewed our background knowledge. For a closed circuit, $V_1 + V_2 = 0$. Using the definition of capacitance and Ohm's Law allows us to write IR = -Q/C. Since current is the time rate-of-change of charge, (dQ/dt)RC = -Q, which means that dQ/Q = -dt/RC. Solving the differential equation yields $Q(t) = Q_0e^{-t/RC}$. Taking the time derivative gives that $I(t) = I_0e^{-t/RC}$, which allows us to use Ohm's Law again to find that $V(t) = V_0e^{-t/RC}$. This is an exponential curve with a negative exponent, leading us to believe that the electric potential decreases with time (a reasonable conclusion). Observing this will provide a graphical check to our experimental results. The key to this equation is that if we allow $t = \tau = RC$, then $V(\tau) = V_0/e$. Measuring the time between when the curve is at V_0 and when it is at V_0/e will allow us to solve for the total resistance of the circuit (i.e., the resistance of the miniature lamp).

II. Results



The following table sums up the given and ascertained data, as well as the accompanying thought process:

Quantity	Numerical Value	Reason Obtained
$V(t_0)$; Value of the electric potential at $t = t_0$	7.31 V	Point easily observable; makes t_0 easy to compute for the expression $\tau - t_0 = RC$
$V(\tau)$; Value of the electric potential at $t = \tau$	2.69 V	Point easily observable; makes τ easy to compute for the expression $\tau - t_0 = RC$
C; Capacitance	3900 μF = 3.900×10^{-3} F	The electric potential measured depends on how much charge the capacitor can hold
R; Resistance	Unknown (Units of Ohms, Ω)	Value easily obtained from the values above; objective of the experiment

Following the procedure outlined above, we first observe that V(t = .5 s) = 7.31 V. Because this is the instant where we graphically view V_0, we will designate t = .5s as t_0 from now on. Since we also care about where $V(t) = V_0/e$, that point is indicated on the graph above. Since $7.31/e \approx 2.69$, observe that $V(\tau) = 2.69$ V when $\tau = .900$ s. Therefore, the interval $\tau - t_0 = .900\text{ s} - .500\text{ s} = .400$ s. This number should equal RC. Thus, given that C = 3900 μF, $R_{Lamp} = \tau - t_0 / C = (.400\text{ s}) / (3.900 \times 10^{-3}\text{ F}) \approx 102\ \Omega$.

III. Sources of Error

Significant Figures – As with any experiment, our results are only as reliable as the measuring capabilities of our tools. For the sake of scientific precision, we rounded our results regularly to two or three decimal places; however, this could have produced a slight problem in the accuracy of our data. To combat excessive inaccuracy, we only rounded at the end of a particular calculation, leaving the only approximation in the final answer.

Resistance and Temperature – As we learned last year, the resistance of an object varies with the temperature of the surrounding environment. Due to a number of trial runs, our light bulb heated up enough to where it was tactilely noticeable. This may or may not have affected the resistance that we measured.

Determining when the Capacitor was Fully Charged – Learning from experience, we found that it was impossible to determine exactly when the capacitor was filled to its capacity. Although this does not change the accuracy of our procedure or the integrity of our results, disconnecting the capacitor too soon results in a much quicker drop in electric potential. Trivial measurement errors become increasingly more important as the objects being measured decrease in size; however, we limited this factor by conducting the experiment a few times to gain a sense of when the capacitor was full.