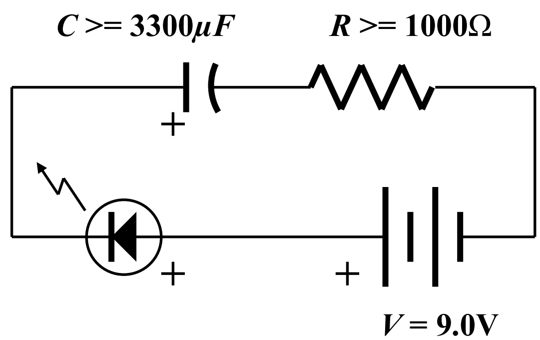
Lab: RC Circuits   AP Physics

Background
An RC circuit is one that includes a resistor and a capacitor in series. The resistor governs the flow of charge (current) in the circuit, and increases the amount of time that it takes for the capacitor to charge.

Objectives
To examine the behavior—qualitatively and quantitatively—of an RC circuit.

Equipment
Resistor (1000Ω or more), electrolytic capacitor (3300 μF or more), Light-Emitting Diode (LED), 9V battery, breadboard, multimeter, leads, alligator clips, stopwatch/timer

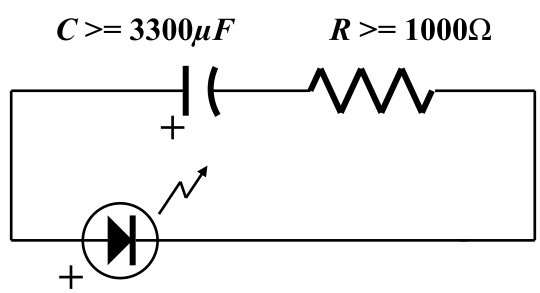
Procedure

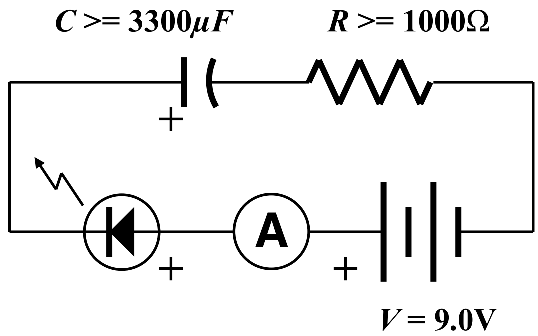


1. Build the circuit shown here. Note that capacitor and the LED both have one longer lead that indicate their *anodes*, which need to be connected to the positive (+) end of the circuit. If using a breadboard, you may find it convenient to refer to the photo at the end of this handout.

2. **Qualitative Observations—Charging**
   Complete the circuit and observe the behavior of the LED. *Describe what you observe, and explain this behavior in terms of your understanding of RC circuits.*

3. **Qualitative Observations—Discharging**
   Remove the battery from the circuit, and insert a jumper wire where the battery used to be. This would ordinarily allow the capacitor to discharge through the circuit, but in our case, the LED only allows current to flow in one direction. Swap the wires on the LED so that the charge stored in the capacitor can flow through the circuit. *Describe what you observe, and explain this behavior in terms of your understanding of RC circuits.*





4. **Quantitative Observations—Charging:**
Based on the behavior of the LED in procedure steps 2-3, we can deduce that current flow decreases over time in an RC circuit, but what is the quantitative relationship that describes this? We'll use an ammeter inserted into the circuit to collect current vs. time data that can be used to identify an empirical time constant for this circuit.
   a. Rebuild the original circuit *without a capacitor*, and insert an ammeter into the circuit so that current flow can be measured. **Be sure to use the appropriate setting on the ammeter!** Complete the circuit and identify the current flowing in the circuit. This will be I_0.

   b. Disconnect the circuit from the battery. Rebuild the circuit with the capacitor again inserted. Connect the battery at time $t = 0$, and collect instantaneous current data in the circuit as the battery charges over some period of time. *Record your current and time data in a data table.*

   c. The data collected here should be sufficient for us to graph the results and perform a regression to identify an empirical time constant for this circuit.

5. Use the impedance bridge to directly measure the actual resistance R of the resistor and the actual capacitance C of the capacitor. Are these values within the expected range for those devices?

6. Calculate a theoretical time constant $\tau_{theoretical} = RC$ based on these directly measured values.

7. Plot your data for I as a function of time for your data points using a spreadsheet. (See notes at end for further instructions.)

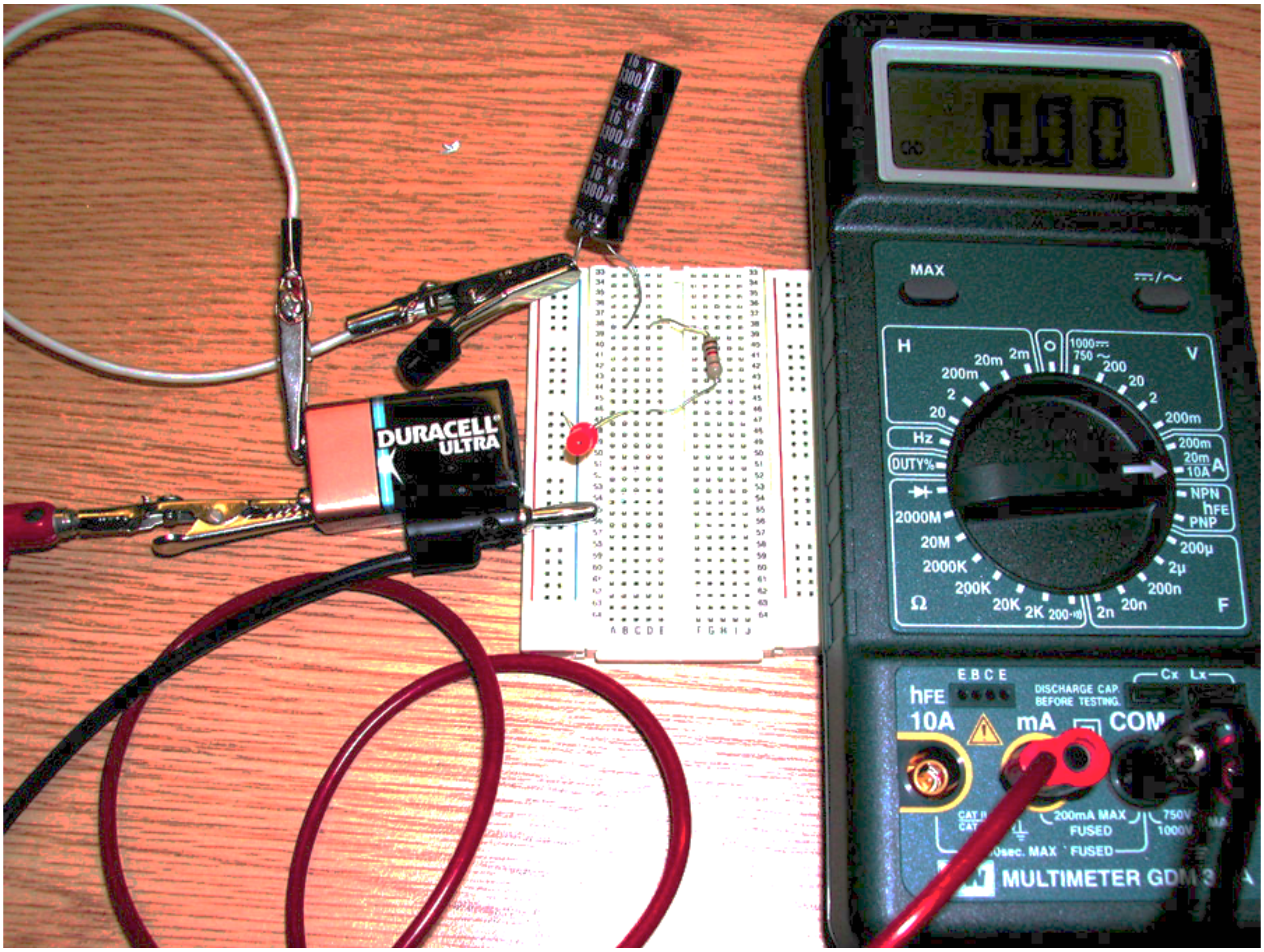
8. Perform an *exponential regression* of your data to determine an experimental time constant for your circuit, $\tau_{experimental}$.

9. Look on your graph to determine the time at which the current has dropped out 63% of its maximum (that is, to the point where its current is 37% of its maximum). At what time does this happen? It should equal your time constant. Does it?

10. Compare this experimental time constant determined from your graph with the theoretical time constant RC. Determine the percentage difference between the two values. Which value do you think is more realistic, and why?

Additional Notes

1. Experimental set-up



2. Example of using Microsoft Excel to record data, graph data, and perform exponential regression.

   Based on the regression given in the spreadsheet below, what is the *time constant* for the circuit?

$$I = I_0 e^{-t/RC}$$

$$-t/RC = -0.219x \text{ (where t = x)}$$

$$-1/RC = -0.219$$

$$RC = \tau = \frac{1}{0.219} = 4.566\,\text{sec}$$