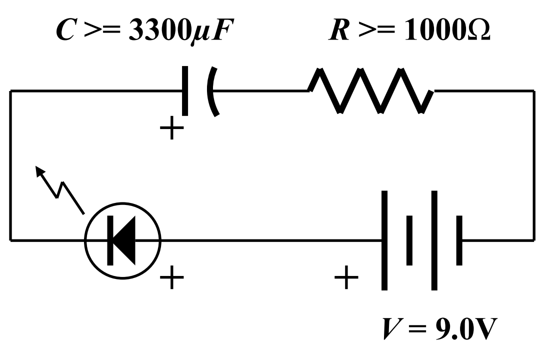
Lab: RC Circuits AP Physics

Background
An RC circuit is one that includes a resistor and a capacitor in series. The resistor reduces 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

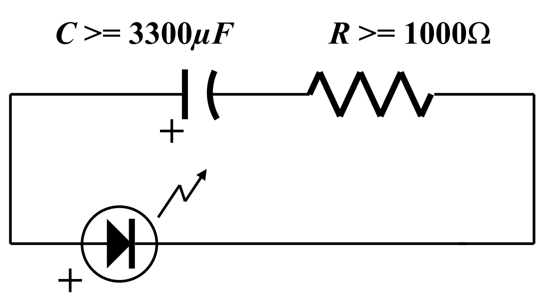
Procedure

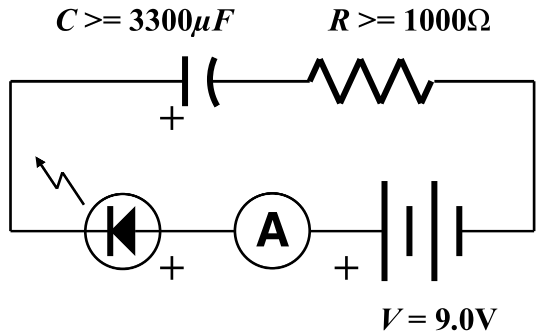


1. Build the circuit shown here. Note that capacitor and the LED have long wires that indicate their *anodes*, which need to be connected to the positive (+) end of the circuit. If using a breadboard, you may find it convenient to refer to the photo at the end of this handout.

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 with an ammeter inserted into the circuit so that current can be measured. **Be sure to use the appropriate setting on the ammeter!** Complete the circuit and verify that the LED behaves as it did before—slowly dimming over time as the capacitor charges—and that the multimeter is indicating a decreasing current.

    b. When you're ready to record current and time data, take a spare alligator clip and hold it across the two leads of the capacitor. This will discharge the capacitor, and allow current to travel through the circuit without accumulating charge. Record this initial current as I_0 for time $t = 0$.

    c. Simultaneously release the alligator clip from the capacitor and begin timing the circuit. Collect instantaneous current data in the circuit as the capacitor charges over some period of time. Record these current and time values in a data table.

    d. 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 a multimeter to directly determine 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. Compare this experimental time constant with the theoretical time constant. Determine the percentage difference between the two values. Which value do you think is more realistic, and why?

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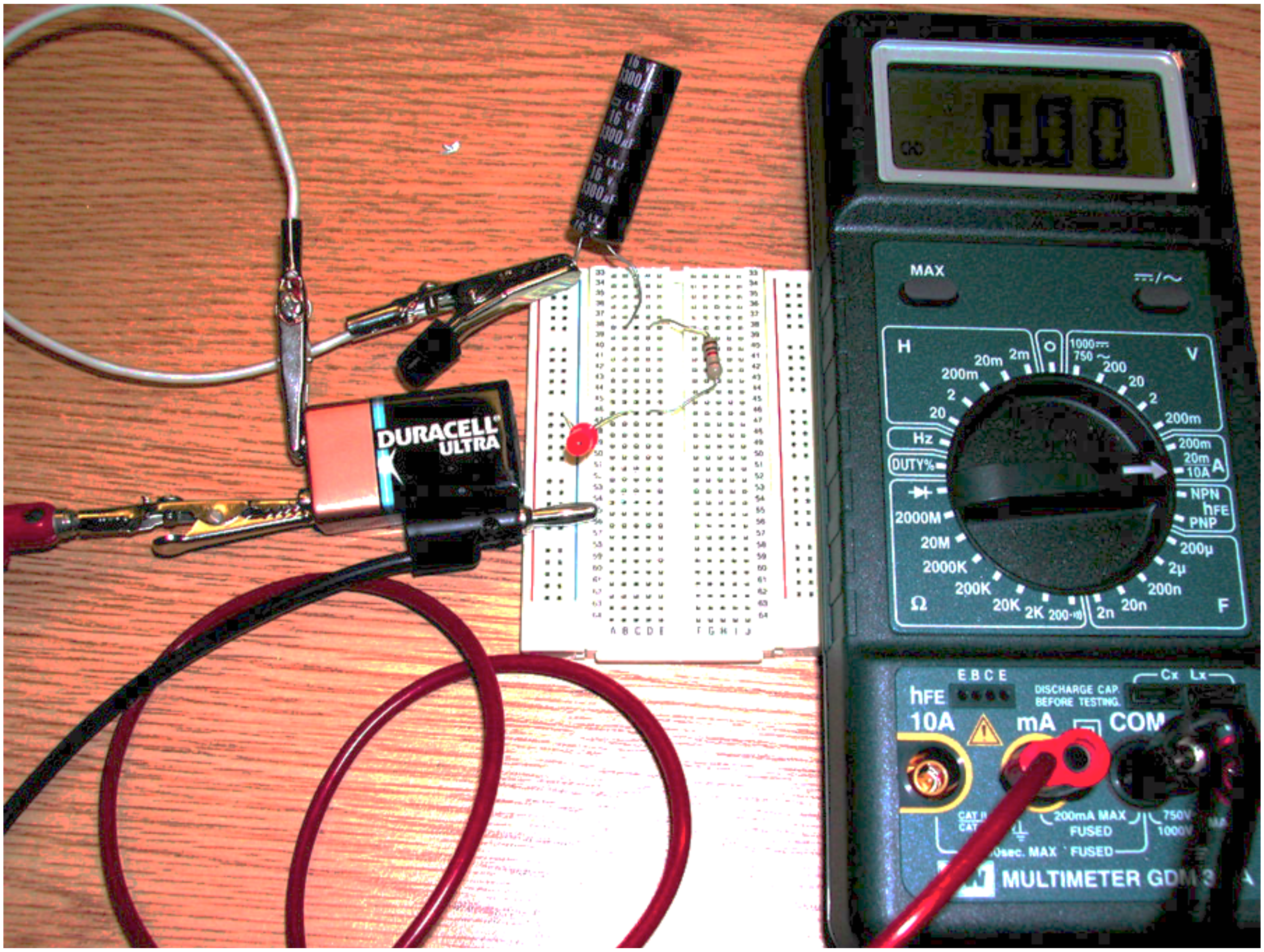
Additional Notes

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?

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

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

$$-1/RC = -0.219$$

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