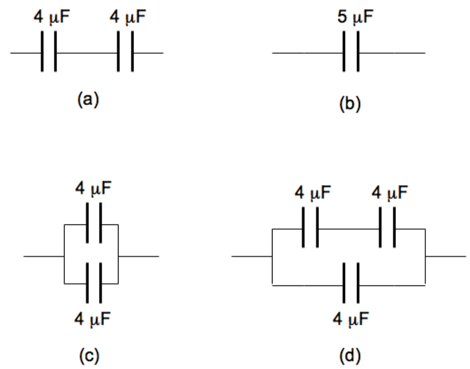
Introduction

In this lab you will explore ideas about electric circuits using batteries, wires, a light bulb, and one or more capacitors. Read all the steps in each part before you start. Please read sections 16.1 to 16.9 of Serway & Faughn before coming to lab.

Pre-Lab

1. Rank in order, from largest to smallest, the equivalent capacitance $(C_{eq})_a$ to $(C_{eq})_d$ of circuits a to d (as shown to the right). Explain your reasoning.



2. You have two capacitors, one is 3.0 μF the other is 6.0 μF. You also have some wires and a 9.0 V battery.

a. Using the schematic symbols on page 2, draw a diagram of a circuit with the two capacitors connected in series with the battery. Draw a diagram of a circuit using the same battery and capacitors with the capacitors now connected in parallel. Find the equivalent capacitance for each circuit.
b. For each of the two circuits drawn in part (a) determine the charges on each capacitor.
c. For each of the circuits from part (a) determine the total energy stored by the capacitors. Which configuration stores the greater amount of energy? Which configuration stores the greater amount of charge?

3. Suppose a parallel plate capacitor (with capacitance C_1) is fully charged (to a value Q_o) by a battery. The battery (which supplies a potential difference of V_o) is then disconnected from the capacitor. If the plates of the capacitor are then moved farther apart (the separation distance d between the plates is doubled), describe ***quantitatively*** what happens to:

a. the capacitance of the capacitor.
b. the potential difference between the plates.
c. the energy stored in the capacitor.
d. the charge on the plates.

A. Group Activity

A1. Suppose you are given a battery, a capacitor, two switches, a light bulb and several pieces of connecting wire. Design a single circuit that will do both of the following: (a) When switch 1 is closed and switch 2 is open, the capacitor charges but no current moves through the light bulb, and (b) when switch 1 is open and switch 2 is closed, the light bulb is connected to the capacitor but not the battery. Draw your circuit on the white board and get your TA to check it before you go on to the next section.

A2. Suppose you set up this circuit with both switches open and no charge on the capacitor. Describe the motion of charge in the circuit when you close switch 1 (leaving switch 2 open). Is energy being stored on the capacitor? What measurements could you make to discover how much energy is stored, if any? What (if anything) happens to the light bulb?

A3. After switch 1 has been closed for a while, you open it. Then you close switch 2. What will happen to the light bulb now? What happens to it as time passes? What happens to the capacitor? How could you confirm your predictions?

A4. After class discussions, use the equipment available to make the circuit. Experiment with various switch positions. Be sure you can understand all the combinations of positions of switches 1 and 2. (Note: Capacitors need to be wired with the correct polarity. Your TA can show you the correct way to do this.)

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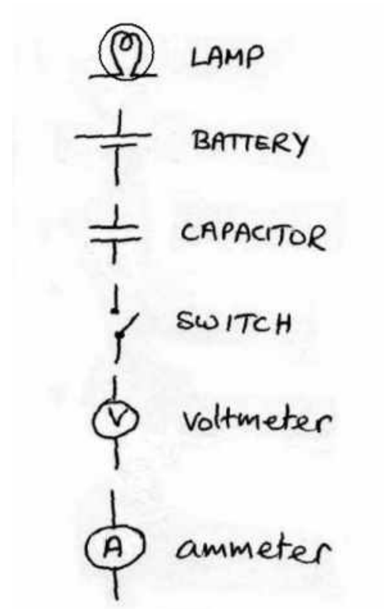
B: Two Batteries in Series with One Bulb



B1. In your group, make two circuits. You should have enough components such that both circuits can be operational at the same time so that you can compare them.

(a) Circuit #1: Connect one battery, a switch and a light bulb. Close the switch to make the bulb light.

(b) Circuit #2: Connect two batteries *in series* with the switch and light bulb. Close the switch to light the bulb.

B2. Check with your TA to make sure you have the series circuits set up properly before answering the questions.

B3. Draw a circuit diagram for the two batteries in series. What voltage would you expect to measure across two batteries in series? (This is known as the "equivalent voltage" for the battery combination).

B4. Measure the voltages:

- Use a DMM set to the 20V scale to measure the voltage drop across the bulb, and the voltage across the two batteries. (DMM stands for digital multi-meter and is another name for the electrical multi-meter you used in the circuits lab).
- How do these measurements compare to your value for the equivalent voltage of the batteries from B3 above?
- Draw a circuit to show how the DMM is connected. Use the "V" symbol to represent the DMM when it is used as a ***voltmeter***.

B5. Which bulb is brighter, the bulb in the circuit with one battery or the bulb in the circuit with two batteries in series?

B6. Now remove the DMM from your circuit and switch it to measure current.

- To measure current you need to do ***two*** things: (1) change to the 10A scale, and (2) ***move the red probe to the socket marked 10A on the meter***. Now your DMM will function as an ***ammeter***. Set the second DMM to measure current in the same way.
- Using circuit #2 (two batteries), connect one ammeter *in series* in the circuit between the battery's positive terminal and the light bulb. Connect the other ammeter in series in the

same circuit between the bulb and the negative battery terminal. Check with your TA to be sure you have the ammeters connected correctly.

- Draw the circuit diagram with both the ammeters connected.
- Close the switch, measure the currents on each side of the light bulb. Are they the same?
- Does the light bulb “use up” the current? If not, what makes the light bulb light?
- Do you need to use two ammeters to measure the current around a loop?

B7. Measure the current in each of your circuits (the single-battery and the two-battery circuits). How does the current through the light bulb correlate with the brightness of the bulb? Compare numerically the current supplied by the battery in the series circuit to the circuit with just one battery.

B8. Review your work with your TA before going on to section C.

C: Two Batteries in Parallel with One Bulb

C1. Modify the two-battery circuit you made above so that the batteries are connected in parallel. Leave the single battery circuit the same as in part B.

- Check with your TA to make sure you have the parallel circuit set up properly before answering the questions.
- Draw a circuit diagram for the parallel battery set-up and derive a mathematical expression for the equivalent voltage for this combination of batteries.

C2. Measure voltages:

- Use a DMM to measure the voltage drop across the bulb in each circuit. (Remember to set the DMM dial to the voltage setting, and to put the red probe back into the socket marked on the meter. This is the opposite of the changes you made to the DMM in B6)
- For the single-battery circuit, compare the voltage across the bulb with the battery voltage.
- For the parallel circuit, how does the voltage drop across the bulb compare to the expression you derived for the voltage of two in-series batteries?

C3. Compare the brightness of the bulbs in the two different circuits.

- Are the bulbs equally bright? Is one brighter than the other? If so, which is brighter?

C4. Measure the currents in each circuit using a similar procedure as in B6 and *B7 (make sure to move the red probe to the the 10A socket.*) This time connect one ammeter in series with one of the batteries (it doesn’t matter which) and connect the other ammeter in series with the light bulb. Compare the current through the light bulb in the two- battery parallel circuit to the circuit with one battery.

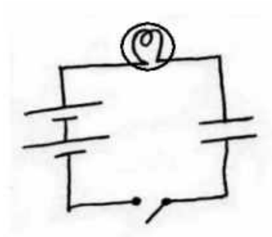
- What do you notice about the current through one of the two batteries in the two battery circuit vs. the current through the one battery in the single battery circuit.
- Can you explain your observations of the bulbs’ brightnesses in terms of the currents and voltages through the bulbs?

C5. Are there any situations in which the ‘*two or more batteries in parallel’* type of circuit is desirable or advantageous?

C6. In what situations is the circuit in Experiment B (batteries in series) advantageous?

D: Circuits with One Capacitor and One Bulb

Be sure you have the following components: one capacitor (1F), two batteries, one light bulb, several wires, one switch, two DMMs, and a stop watch.



D1. Connect the two batteries (in series), the bulb, the *uncharged* capacitor, and the switch together *with the switch OPEN*. Note that the capacitors are polarized. This means that it matters how it is placed in the circuit with respect to the batteries[1]. So make sure that the positive end of the battery is connected to the positive terminal of the capacitor. Have a TA check your circuit before you close the switch. (Note: To fully discharge your capacitor take the positive lead to the capacitor and touching it directly to the negative lead of the capacitor. This is called short-circuiting the capacitor.)

D2. Predict what will happen to the brightness of the bulb when you close the switch. Explain.

D3. Now close the switch and observe how the brightness of the bulb changes over time. Measure the time the bulb is alight with the stop watch.

D4. From you observation of the bulb's brightness, how does the charge flowing through the bulb change over time?

D5. Now observe the voltages in the circuit.

- Open the switch and hook the DMMs into the circuit to see how the voltages across the capacitor and light bulb change with time. Take the first DMM and connect it across the capacitor. This means that the DMM must be in *parallel* with the capacitor. Take the second DMM and connect it across the light bulb. Make sure both DMM's are set to read voltage and that they are on an appropriate scale.
- To return to the original starting conditions make sure that the capacitor is fully discharged.
- Close the switch and observe how the voltages across the capacitor and the light bulb change with time. You may need to repeat this a few times to confirm your results (remember to completely discharge the capacitor between each run.)
- From your observations, sketch two graphs of voltage verses time for the capacitor and the light bulb.

D6. Now we will use the DMM to measure current in the circuit. Current is measured by connecting the DMM *in series* in the circuit.

- Open the switch and discharge the capacitor. Connect one DMM in-series with the bulb and the other DMM in series with the capacitor. Change both DMMs to measure current. Make sure you are using an appropriate measurement scale. Have the TA check your circuit before you close the switch.
- Close the switch and observe how the current changes with time.
- Draw a quantitative graph of current verses time for this circuit.

D7. Explain how the changing voltage and current in these circuits relate to the changing brightness of the bulb.

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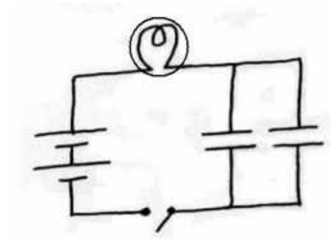
[1] You will hear the term "polarized" used in many different contexts in physics. In electrical circuits, a polarized circuit element is one that needs to have its "positive" end at higher potential than its "negative" end.

E: Circuits with Two Capacitors and one Bulb.

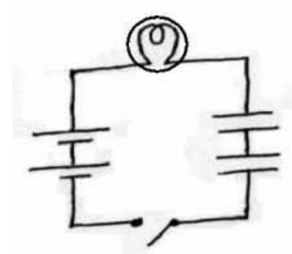


Be sure you have the following components: two capacitors of equal capacitance, two batteries, one light bulb, a switch, several wires, and a stop watch.

E1. Connect the two capacitors *in parallel* as shown in the circuit. (Remember the polarity of the capacitors.)

- What is the equivalent capacitance for this arrangement of capacitors?
- Discharge the capacitors, then close the switch and observe how the bulb's brightness changes with time.
- Measure using a stopwatch how long it takes for the bulb to dim completely.

E2. Next connect the capacitors *in series,* and connect them to the batteries, light bulb and switch.



- Write an expression for the equivalent capacitance for this capacitor arrangement.
- Discharge the capacitors, then close the switch and observe how the bulb's brightness changes over time.
- Measure using a stopwatch how long it takes for the bulb to dim completely.

E3. Compare your dimming-time measurements from the parallel set-up to the series set-up. How does the equivalent capacitance of the capacitors relate to the dimming time?

E4. Is there more charge stored on the capacitors in the series or the parallel setup? (Calculate the actual charge stored for the actual circuits you used in each case). Does the dimming time correspond to the amount of stored charge?

Conclusion:

1. Please do a write-up for the section of the lab that your TAs specified.