Lab 9: Energy Conservation in Circuits & Charge on a Capacitor

Part (1) Energy Conservation in Circuits

OBJECTIVES

In this part of the lab you will
- Write the energy conservation equation (loop rule) for several pairs of circuits
- Predict the relation between the currents in each circuit pair
- Learn the proper use of an ammeter (a multimeter in current mode)
- Check your predictions of the current relations

1) Warm-up Problem:

Problem (1) The electron current is $i = nA\bar{v} = nAuE$
What are the units of electron current?
What is n?
What are its units?
What is A? What are its units?
What is $\bar{v}$? What are its units?
What is u? What are its units?

CHECKPOINT 1: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

2) Current Predictions

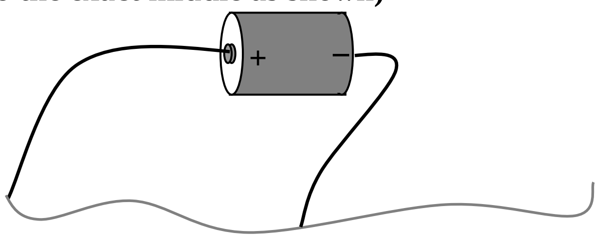
a) **Get out the following items for this part of the lab**
- **2 batteries with battery holder**
- **3 alligator clips**
- **1 multimeter**
- **1 piece of thick nichrome wire**
- **1 piece of thin nichrome wire, equal in length to the thick. You may need to role the wires in your fingers to feel the difference between thick and thin.**

b) **Put away everything else (except your lab manual), so your table is neat and clear.**

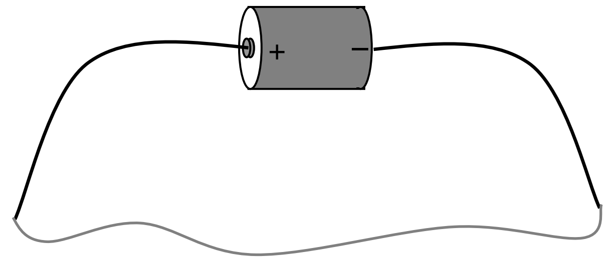
The potential difference around any closed path must be zero. If you make the path to be the path current takes through a circuit, this simple fact becomes a powerful tool for analyzing circuits. You will analyze three pairs of circuits. In each pair, the two circuits will only differ in one way. You must analyze the circuit and determine how this difference affects the current in each circuit.

The first pair of circuits:

Circuit 1: Thin nichrome wire of length L/2
(**Do not cut the wire! Connect the clip lead to the exact middle as shown)**



Circuit 2: Thin nichrome wire of length L.



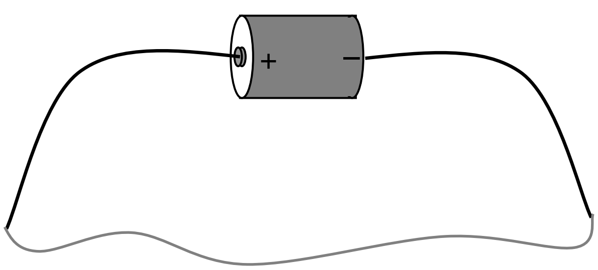
c) **Write the energy conservation equation for each circuit. Do this entirely in symbols i.e. the voltage difference across the battery should be ΔV_{bat} not 1.5 V.**

d) **Solve for the electric fields in each of these nichrome wires (E_1 and E_2).**

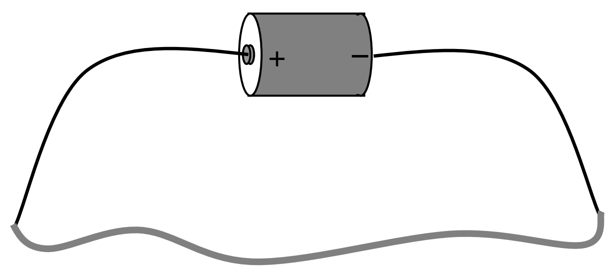
e) **Calculate the relation between the currents in each of these circuits.**

The second pair of circuits:

Circuit 3: Entire length of thin Nichrome wire



Circuit 4: Same length of Thick Nichrome wire.



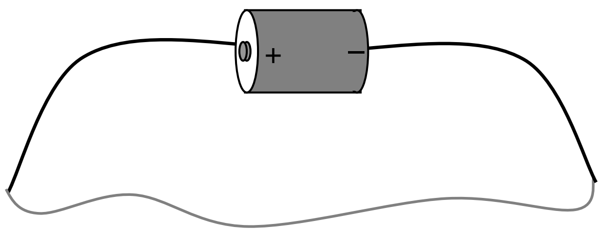
f) **Write the energy conservation equation for each circuit. Do this entirely in symbols i.e. the voltage difference across the battery should be ΔV_{bat} not 1.5 V.**

g) **Solve for the electric fields in each of these nichrome wires (E_3 and E_4).**

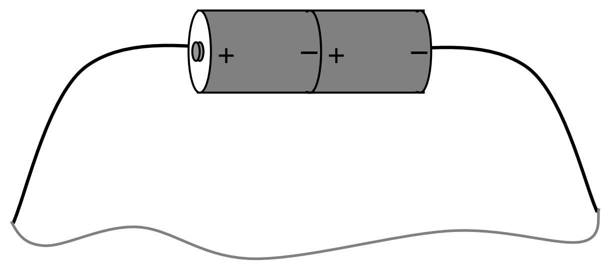
h) **Calculate the relation between the currents in each of these circuits.**

The third pair of circuits:

Circuit 1: Thin nichrome wire of length L with one battery



Circuit 2: Thin nichrome wire of length L with two batteries



i) **Write the energy conservation equation for each circuit. Do this entirely in symbols i.e. the voltage difference across the battery should be ΔV_{bat} not 1.5 V.**

j) **Solve for the electric fields in each of these nichrome wires (E_1 and E_2).**

k) **Calculate the relation between the currents in each of these circuits.**

3) Current Measurements

You can now take measurements of the current in each circuit with your ammeter. First we will explain how to use it.

Since you will be measuring currents larger than 200 mA, it is important to set up the meter correctly, so you do not blow a fuse and render the meter useless.

a) **Connect the black wire to COM**

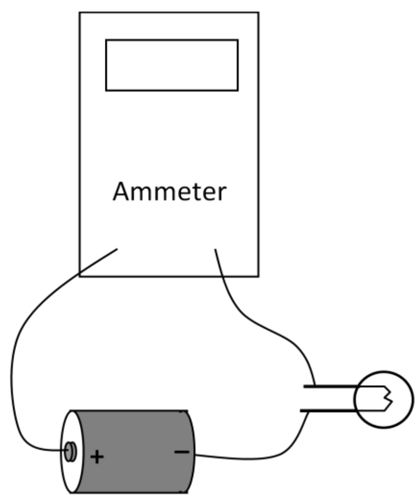
b) **Connect the red wire to the leftmost connector, labeled 10A.**

c) **Set the dial to 10A .**

Don't use other functions than 10A at this time (you could blow a fuse in the meter).

An ammeter must be inserted into a circuit.

d) Set up the following circuit to test your ammeter, using one battery and one round bulb, BUT DO NOT MAKE THE FINAL CONNECTION UNTIL AN INSTRUCTOR HAS CHECKED YOUR SETUP.



You may want to use clip leads to connect the ammeter probe wires to the circuit.

e) If you see your ammeter works you may proceed to make your measurements.

f) Record your measurements of current in each of the three pairs of circuits.

   i. Did your predictions agree with your measurements?

CHECKPOINT 2: Ask an instructor to check your work for credit. **You may proceed while you wait to be checked off**

Part (2) Charge on a Capacitor

Objectives

In this part of the lab you will

- Charge and discharge a capacitor through various circuits
- Use your results to fully explain why the circuits behave the way you observe.

1) Charging and Discharging Capacitors

a) Get out the following items for this part of the lab

- **1 capacitor**
- **1 short bulb and holder**
- **1 long bulb and holder**
- **2 batteries and holder**
- **1 stop watch or timing device**
- **Put away everything else (except your lab manual), so your table is neat and clear.**

When a capacitor is connected across a voltage difference it gains charge up to a limit. If a light bulb is wired in series with the capacitor it will glow, so long as the capacitor is gaining charge i.e. current is flowing. In these experiments you will charge and discharge a capacitor in a variety of ways.

To charge the capacitor:

Make sure it is fully discharged by connecting the leads for several seconds, and then wire the capacitor in series with the stated type of light bulb and the stated number of batteries.

To discharge the capacitor:

Connect it to the stated type of light bulb.

Each time you charge or discharge you should measure the amount of time the process takes i.e. the amount of time it takes for the light to go out. The long bulb will continue to glow very softly for several seconds after it has stopped shining. Before you stop the time, look very closely at the long bulb to make sure it has stopped glowing entirely. Any glow, no matter how slight, is a sign that current is still flowing.

We have provided a table in which to record your data.

b) Perform these experiments.

Charging # of Batteries	Charging Bulb	Discharging Bulb	Charge Time (s)	Discharge Time (s)
2	Short	Short		
2	Short	Long		
2	Long	Short		
2	Long	Long		
1	Short	Short		
1	Short	Long		
1	Long	Short		
1	Long	Long		

a) From your observations write any conclusions you can draw. Some questions you may consider are:

i. *How does the long vs. short bulb affect the circuit*

ii. *How does the long vs. short bulb affect the capacitor?*

iii. *How does the number of batteries affect the capacitor?*

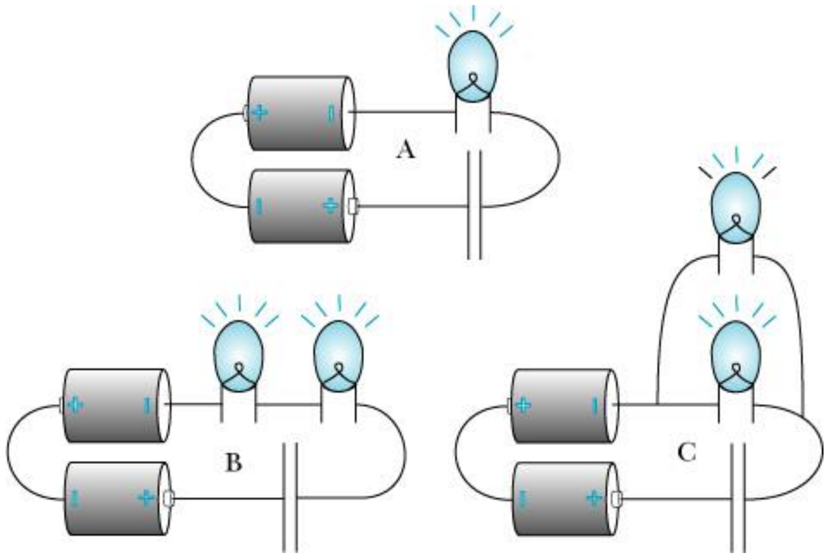
Use your knowledge of the energy in circuits to aid in drawing conclusions.

When you wish to be checked off you should be able to explain to your instructor what is happening in each circuit and why.

CHECKPOINT 3: Ask an instructor to check your work for credit.
You may proceed while you wait to be checked off

2) Final Problem

Problem (2) Here are three circuits labeled A, B, and C. All the long bulbs, capacitors, and batteries are identical, and are like equipment you used in lab. The capacitors are initially uncharged. In each circuit the batteries are connected for a short time T and then disconnected. The time T is only ten percent of the charge time through a single long bulb, so that the bulb brightness doesn't change much during the time T.



(a) In which circuit does the capacitor now have the most charge? Explain.

(b) In which circuit does the capacitor now have the least charge? Explain.

CHECKPOINT 4: Ask an instructor to check your work for credit.