

## **LABORATORY 4 ELECTRIC CIRCUITS I**

### **Objectives**

- to be able to discuss potential difference and current in a circuit in terms of electric field, work per unit charge and motion of charges
- to understand that current is constant throughout a simple closed circuit
- to be able to demonstrate Kirchoff's Second Law in a simple closed circuit
- to be able to connect current and voltage probes properly
- to be able to demonstrate Ohm's Law for linear resistors
- to understand that not all resistors are linear resistors
- to be able to determine the resistivity of a piece of metal experimentally

**Overview:** In this lab, you will study the concept of electric potential within a circuit and use that concept to explain the motion of charges. You will examine current and potential in a simple circuit. You will learn how to connect ammeters (current probes) and voltmeters (voltage probes) to measure current and voltage through and across different elements in a circuit. You will learn how currents and voltages in different parts of a circuit are related and study Kirchoff's Second Law. You will demonstrate Ohm's Law for non-linear resistors and observe the relationship of potential and current for non-linear resistors. You will devise an experiment to measure the resistivity of metals.

### **Equipment:**

- 2 current probes
- 2 voltage probes
- Computer-based laboratory system

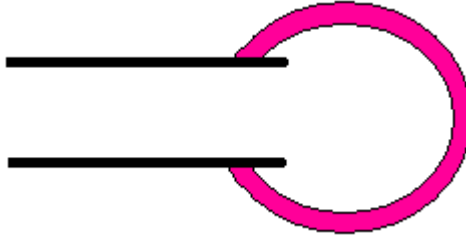
### **Exploration 1 Current and potential difference**

**Exploration 1.1** Take the pretest for Circuits I.

### Exploration 1.2 Potential difference

Consider a capacitor with charge  $+Q$  on one plate and charge  $-Q$  on the other plate.

a. If a wire is now connected, as in the diagram below, would charge flow in the wire?



- i) If so, explain why charge would flow in terms of the electric field. If not, explain why not.
  
- ii) If charge does flow, would it flow continuously always in the same direction? Would it flow for a period of time and then stop? Or would it flow and then switch direction? Describe the flow as a function of time. Explain your reasoning.
  
- iii) Would the potential difference between the plates change or remain constant? Would it increase or decrease? Explain.

b. If you could keep a constant charge  $+Q$  on one plate and charge  $-Q$  on the other plate, while the wire in the figure above is connected, would charge flow through the wire?

- i) Would the charge flow continuously? Explain.
  
- ii) Would the potential difference between the plates change or remain constant? Explain.

A battery is a mechanism for keeping two plates continuously charged and the potential difference between the two plates constant. In the batteries we will use, it is a chemical process that keeps the plates charged and at a constant potential difference.

When working with circuits, the potential difference between the two ends of the battery is called the voltage of the battery. The symbol for voltage is V. Voltage is measured using an instrument called a voltmeter. Voltmeters are connected in parallel.

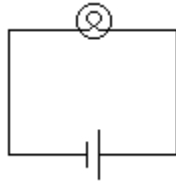
### Exploration 1.2 Current

When the battery and other circuit elements, such as bulbs or wires are connected in a closed loop, charge can flow through the wires. The amount of charge per unit time passing a cross-sectional area of a wire is called the current. The symbol for current is I. Mathematically,

$$I = \frac{\Delta Q}{\Delta t}$$

The unit of current is the Ampere (A). One Ampere is equal to one Coulomb per second:  $1\text{A} = 1\text{C/s}$ . Current is measured using an instrument called an ammeter. Ammeters are connected in series.

Set up a simple circuit with one battery, one bulb, and two wires. A circuit diagram is shown below.



- a. Is the amount of current flowing through each of the wires the same or is it different? Are any of the models below correct models for current flow? Explain.

Model A Current flows from the battery to the bulb and is completely used up in the bulb. None of the current returns to the battery.

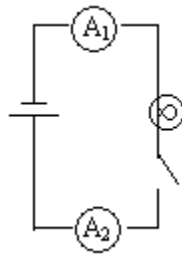
Model B Current flows from the battery to the bulb. Some of it is used up in the bulb. The rest flows back to the battery. There is less current in the circuit after the bulb than before the bulb.

Model C Current flows from the battery through the bulb and back to the battery. The same amount of current would be measured before and after the bulb. It is not used up in the bulb.

Model D The current flows from the positive end of the battery to the bulb and current flows from the negative end of the battery to the bulb. The bulb lights when the two currents meet. There is the same amount of current in each wire, but it travels in different directions to each side of the bulb.

Current is measured with an ammeter. We will use ammeters (current probes) that connect to the computer and show the amount of current on a graph.

- b.** To test to see, if your answer in part **a** is correct, we will use an ammeter to measure the current in each of the wires. Set up the circuit shown below, with two current probes. Do not close the switch, until you are ready to test your prediction. Determine how the readings on the current probes would compare for each of the cases in part **a**. Then close the switch and test your prediction.

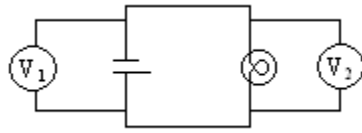


Which model is correct?

### **Exploration 2 Potential difference and Kirchoff's Second Law**

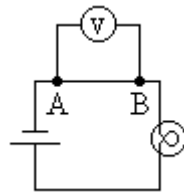
**Exploration 2.1** Potential difference is measured using a voltmeter. A voltmeter is connected in parallel to the circuit element whose voltage is being measured. We will use voltmeters (voltage probes) that connect to a computer.

- a. Set up the circuit shown in the diagram below and measure the potential difference across the battery and the bulb.

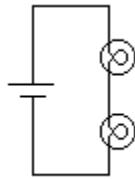


How do the potential differences compare? Explain in terms of the work done by the electric field or other forces. Discuss which end of each element is at a higher potential and which forces are doing work in each element.

- b. Measure the potential difference across a wire, by connecting the voltmeter in parallel with a wire. Compare the magnitude of this potential difference with that of the battery and the bulb. How do they compare? How does the work per unit charge to move through a wire compare with the work per unit charge to move through the battery or the bulb?



- c. Add a second bulb to the circuit, in series with the first, as in the picture below. Again measure the voltage across each bulb and across the battery.



How does the voltage across the battery compare to that across the bulbs?

Kirchhoff's Second Rule says that the sum of the potential differences around a closed loop is zero. If you add up all the potential differences across the elements around the circuit, counting them as positive when the potential energy is increasing and negative when the potential energy is decreasing, the net potential difference is zero.

It can also be stated as follows: The voltage across the battery in a current loop is equal to the sum of the voltages across the other elements.

Is this consistent with your data?

- d. Replace the bulbs with  $22\Omega$  resistors and check Kirchhoff's Second Rule again.

- e. Is Kirchhoff's Second Rule still valid when the resistors are not identical? (Try it out.)

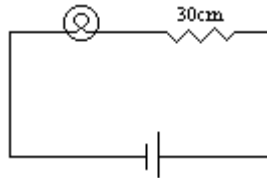
**Equipment:**

- 4-5 batteries
- 1 30cm length of nichrome wire
- 1 bulb
- alligator clips

**Investigation 1 Ohm's Law**

When more than one battery is added to the circuit in series with a bulb or a resistor, voltage across the circuit elements and the current through the circuit elements will change.

Set up the circuit in the diagram below. It consists of a battery, a bulb and a 30cm length of nichrome wire.



- a. Measure the current through the bulb and the potential difference across the bulb. Measure the current through the nichrome wire and the potential difference across the nichrome wire. Record your results in the table below.

Add a battery to the circuit, and again record the current through and the potential difference across the bulb and the nichrome wire in the table below.

Continue to add batteries and record the current through and the potential difference across both the bulb and the nichrome wire in the table below, up to four or five batteries.

Voltage across bulb	Current through bulb	Voltage across nichrome wire	Current through nichrome wire

In Excel, plot the potential difference vs. the current for both the nichrome wire and the bulb.

Should the point  $V = 0, I = 0$  be on your plots? Explain.

Circuit elements for which a plot of potential difference vs. current is a straight line are called linear resistors.

**b.** Are either of the elements (the bulb or the nichrome wire), linear resistors?

**c.** Write an equation for the potential difference vs. the current for the nichrome wire.



For linear resistors, the slope of the line is called the resistance. The potential difference and the current are related by a constant:

$$\Delta V = IR$$

The constant is the resistance measured in ohms. The symbol for ohms is  $\Omega$ .

- d.** Test one of the carbon resistors at your table to see if it is linear resistor. Record your data in the table below.


In Excel, plot the potential difference vs. the current for the resistor. Determine the resistance of the resistor.

Carbon resistors are color-coded. They have colored bands on them that indicate the value of the resistor. The first two bands are the first two digits of the resistance value. The third band indicates the power of ten multiplier. The fourth band is the tolerance. The table below tells what numerical value corresponds to each color.

Bands 1-3	
color	value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9
Band 4	
None	+/-20%
Silver	+/-10%
Gold	+/-5%

For example, if the strips are violet, green, brown, gold, the value of the resistance is  $75 \times 10^2 \pm 5\%$ .

Practice reading the values of some of the resistors at your table and ask your TA, if you are correct.

- e. Does the value of the resistance you determined in part **d.** agree with the color-coding for that resistor? Explain.



iv) how you will calculate the resistivity from your measurements and graphs

Clearly describe your experiment to your TA.

Carry out the experiment. Record your results below. Show your calculations clearly.  
Print out any graphs you create.



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