**D.C. Circuits – Ohm’s Law and Kirchhoff’s Laws**

# Notes:

1. ***This is a two-week long lab, done Face-to-Face in the lab.***
2. This lab will be done with your three lab partners, in the Lab Room in the basement of LD.
3. **You will submit a report on Activity 1 of this lab, and your lab notes for Activity 2. Your TA might (not always) provide feedback which you should incorporate into your later lab reports and/or lab summaries.**
4. Turning in your report:
   1. Collaborate with your partners on data collection, analysis, and report.
   2. Turn in only one report but be sure it lists all group members as authors.
   3. Lab reports should be uploaded to Canvas by the deadline in the course calendar.
   4. Do not include raw spreadsheets in the reports. You may want to use figures in your report that can contain snapshots of spreadsheet(s).
5. Getting help:
   1. Your lab TA can answer questions during the lab or after the lab by email or at their office hour (listed in the syllabus).
   2. You can also ask advice from lab partner(s) and/or other students.

# Objectives of this lab:

In this lab, you will use Ohm’s law to determine the internal resistance of a battery that will be provided to you. The Ohm’s Law states that the potential difference across a battery, V, is proportional the current, I, through it, and the proportionality constant is the resistance, R, , i.e. V=IR. All batteries have some internal resistance, r, and the goal of this lab is to measure this internal resistance.

Consider the circuit below, in which the battery of voltage, V, has an internal resistance, r (not shown). The battery voltage is now “distributed” across the internal resistance, r, and the external resistor, R. If there is a current, I, in the circuit, the voltage across the internal resistance is Ir, and the voltage across R is given by V’=IR, such that V = V’ + Ir. In your lab, you will measure V’, the voltage across R, and the current I, and plot V’ vs I. You should get a straight line that fits the equation V’ = -Ir + V. Then, from the slope of the graph, you can get the internal resistance.

These are things you will do:

1. Construct a circuit with a battery and resistor.
2. Measure current and voltage using appropriate instruments, connected in a proper manner.
3. Use Ohm’s Law to determine internal resistance of a battery.
4. Construct a more sophisticated circuit with multiple batteries and resistors.
5. Measure current and voltages at different points in circuits and compare to your predictions from formulas you obtain via Kirchhoff’s Laws.
6. Identify possible errors that can occur in your experiment.
7. Minimize those errors.

# What you will learn:

Please review the learning goals for the semester in lab in the handout from the first week. In addition, this lab has several specific goals:

1. You will practice keeping lab notes in a paper notebook, computer file, or other format.
2. You will enhance the data analysis skills you learned previously, by applying them to real data.
3. You will learn to distinguish between two types of errors that occur in data: systematic errors and random errors.
4. You will enhance your understanding of how noise arises in data, and how to account for that noise when interpreting experimental results.
5. You will practice scientific communication skills by preparing graphs and writing a formal lab report.

## What goes in my lab notes, and what about my report/summary?

The purpose of personal lab notes is to enable you or a colleague to reconstruct what was done and why.

* They don’t have to be neat, in complete sentences, etc., but they do have to be useful.
* In a case like this, they should include things like what was the circuit setup.
* Did you try different setups or take multiple data sets for same setup?
* If you store multiple files, record what filenames correspond to what conditions.

The purpose of a **report** is to explain what you learned and how you learned it. The sorts of things that belong here are

* A description of each step you did as part of the Activities.
* Any graphs or drawings to show to your results.
* Explain how you determined your results.
* Explain differences between calculated (theory) and the actual (measured) values.
* Your conclusions about any relevant and useful information you were able to extract.
* An analysis of the errors of the in your experiment.

# EQUIPMENT

For this lab, the following are available for use: A multimeter (or voltmeter, ammeter), battery pack, multiple resistors, connecting cables.

**DOs & DON’Ts**

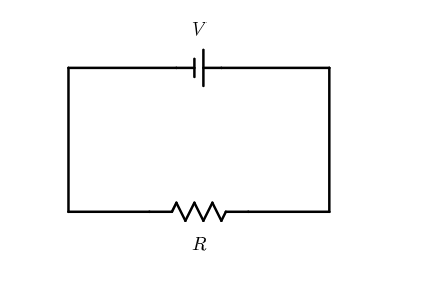
* + ***Don’t*** break the equipment.
  + ***Do*** consult with your Lab TA about the techniques you may want to consider as you design your particular experiment.
  + ***Don’t*** forget to record all data runs
  + ***Do*** use your imagination and have fun.

# ACTIVITY 1: Determine internal resistance of a battery using Ohm’s Law

# NOTE: Submit lab report for this activity.

* Connect the battery to a resistor, R, in series. The circuit diagram is below:

2

**V (battery with an internal resistance**) 

* Connect a voltmeter in parallel across the battery to measure voltage, V, of the battery.
* Construct the circuit above by connecting an external resistor, R, in series with battery.
* Connect an ammeter in series with R to measure current through the circuit.
* For a given R, measure V’ across R, and current, I, in the circuit.
* Repeat for several different resistor values of R (at least 8 different resistors).
* Plot V’ vs I. The slope and intercept of this plot contain useful information. Think about what the information is and use it to determine the internal resistance of the battery.
* Can you set up the equations for your circuit and derive an expression for the internal resistance as a function of battery voltage, external resistance and current in the circuit?
* Does your predicted value of internal resistance agree with the measured value? Why, or why not?

# ACTIVITY 2: Test predictions of Kirchhoff’s Laws

# NOTE: Submit your lab notes for the activity.

* Build the circuit shown in the figure below:

Diagram, schematic

Description automatically generated

* Measure currents in top branch, middle branch, and bottom branch of the circuit.
* Measure voltage between points (1,2), (3,4) and (5,6).
* Measure voltages across the two batteries, and the resistance of the three resistors.
* Set up the equations for your circuit using Kirchhoff’s Laws?
* Use these equations to predict currents and voltages at the points that you measured experimentally and compare the values. Do they agree? Why, or why not?