Ohm's Law

Purpose

In this lab you will apply Ohm's Law ($V = IR$) to experimentally determine the resistances of three circuits and compare your results to theoretical values, which you will either directly measure or calculate.

Pre-Lab Exercises

Read through this handout carefully before attempting the pre-lab quiz and prepare a spreadsheet for recording data.

Introduction

In this lab, we will explore different ways that resistors can be connected in a circuit. Most complicated circuits can be reduced to sub-units where the resistors are connected in one of two basic ways: series and parallel. In a series connection, the current must flow through one resistor and then through the next; there is no alternate path (see Figure 1). In a parallel connection, the current can split into two or more paths and may be different for the different paths. The current then recombines on the other side.

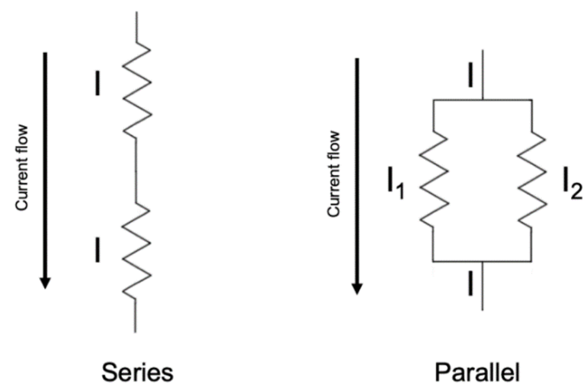

Figure 1: Series and parallel connections.

Three important facts to note about resistors in series:

1. In a series connection, the current I is the same in all parts of the circuit (to within the uncertainty of the measuring device).
2. The potentials V across two resistors in series are not necessarily equal.
3. Resistors in series act like one resistor with resistance

$$R_{series} = R_1 + R_2 + \cdots$$

Eq. 1

Three important facts to note about resistors in parallel:

1. In a parallel connection, the potentials V across all resistors are the same (to within the uncertainty of the measuring device).
2. The currents I through resistors in parallel are not necessarily equal, and their sum equals the total current flowing into the parallel connections. In Figure 1, $I = I_1 + I_2$.
3. Resistors in parallel act like one resistor with resistance

$$R_{parallel} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots\right)^{-1}$$

Eq. 2

Procedure

You will need to gather one of each of the following resistors from the gray component drawers: "unknown" resistance, $24\ \Omega$, $100\ \Omega$.

⚠ In every part of the lab, have each lab partner check over the circuit carefully before hooking it up to the power supply. Always have both power supply voltage knobs turned fully counterclockwise (to zero) before turning it on; set the "coarse" current knob to about halfway and leave it there for the entire lab. If you smell smoke at any point, unplug everything from the power supply immediately– *then* blame your lab partner.

Part I: Resistor of unknown resistance

⚠ The voltage on the power supply should not exceed $\sim 10\ \mathrm{V}$ during Part I of this lab.

1. Begin by setting up the circuit shown in Figure 3 using the resistor of unknown resistance wrapped with black electrical tape. Note that the voltmeter probes are placed *in parallel with* the resistor whereas the ammeter (current meter) must be *in series with* the resistor– we measure voltage/potential *across* and current *through*.

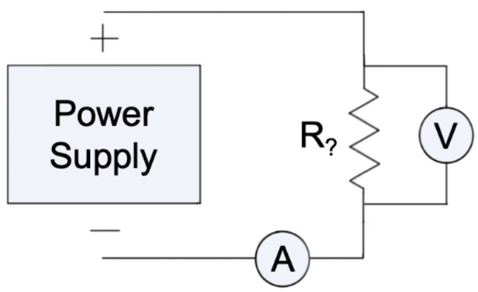

Figure 2: Circuit #1 with "unknown" resistor.

2. Slowly increase the voltage to $\sim 0.25\ \mathrm{V}$.
3. Use one of your digital multimeters (DMM's) with alligator-clip cables as a voltmeter to measure the potential across the resistor and record the value V, including the uncertainty.
4. Use another DMM with alligator-clip cables as an ammeter to measure the current through the resistor and record the value I.
5. Repeat steps 3 and 4 for voltages of approximately: $0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0$ (in V)
6. Use the provided Python plotting template to plot V vs. I, where δV is determined by the precision of the voltmeter.
7. Calculate your experimental result for the resistor's resistance $R_{experimental}$ using Ohm's Law and the slope of your best fit line.
8. Using one of your DMM's as an ohmmeter, directly measure and record the resistance $R_{theoretical}$ of the resistor. Completely remove the resistor from your circuit and use alligator clips to attach to the resistor legs for this measurement.

Part II: Resistors in series

⚠ Turn the voltage knobs on your power supply fully counterclockwise before proceeding and DO NOT EXCEED $\sim 5\ \mathrm{V}$ from the power supply for the remainder of this lab.

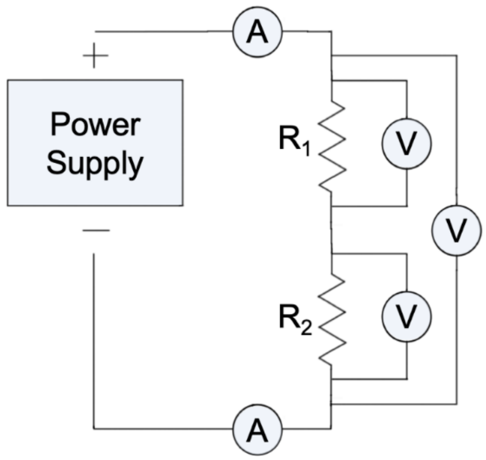

*Figure 3: Circuit #2 with resistors in series. Note that **you will NOT have 3 voltmeters hooked up at once**; the diagram is simply indicating the locations of the measurements to be taken.*

1. Use your $100\ \Omega$ resistor and your $24\ \Omega$ resistor to set up the circuit shown in Figure 4, with the **resistors in series** with each other.
2. Connect two ammeters in series with, and on either side of, the resistors. Use the alligator-clip cables for these connections.
3. Slowly increase the voltage to $\sim 5\ \mathrm{V}$.
4. Connect the voltmeter (using probes) first across one resistor to measure and record V_1, then across the second resistor to measure and record V_2, and finally across both resistors to measure and record the total voltage V_{total}.
5. Record the ammeter readings as I_1 and I_2.
6. Calculate R_1 from your measurements of V_1 and I_1. Calculate R_2 from your measurements of V_2 and I_2. Calculate R_{total} from your measurement of V_{total} and what you know about resistors in series for I_{total}.
7. Use one of your DMM's as an ohmmeter to directly measure and record the accepted resistances $R_{1,theoretical}$ and $R_{2,theoretical}$, as in Step 8 of Part I. Calculate R_{series} (i.e., the theoretical value for R_{total} in Part II) using Eq. 1.

Part III: Resistors in parallel

1. Use your $100\ \Omega$ resistor and your $24\ \Omega$ resistor to set up the circuit shown in Figure 5, with the **resistors in parallel** with each other.

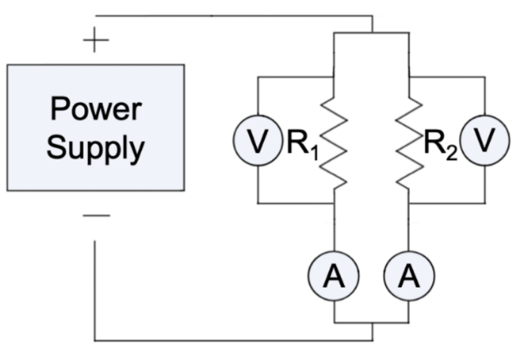

Figure 4: Circuit #3 with resistors in parallel.

2. Connect each resistor in series with its own ammeter (the ammeters must be in parallel with each other as are the resistors) to measure the amount of current flowing through each resistor individually. Use the alligator-clip cables for these connections.
3. Supply the circuit with $\sim 5\ \mathrm{V}$ of power.

4. Connect the voltmeter (using probes) first across one resistor to measure V_1, then across the second to measure and record V_2.
5. Record the ammeter readings as I_1 and I_2.
6. Calculate R_1 from your measurements of V_1 and I_1. Calculate R_2 from your measurements of V_2 and I_2. Calculate R_{total} from what you know about resistors in parallel for V_{total} and I_{total}.
7. Calculate $R_{parallel}$ (i.e., the theoretical value for R_{total} in Part III) using Eq. 2.

Error Analysis

Note that the "brute force" method will be required to determine $\delta R_{parallel}$ in Part III. *(Hints given below)*

$$\delta R_{parallel} = \sqrt{\left(\delta R_{p,1}\right)^2 + \left(\delta R_{p,2}\right)^2}$$

$$\delta R_{p,1} = \left|\left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} - \left(\frac{1}{[R_1 + \delta R_1]} + \frac{1}{R_2}\right)^{-1}\right|$$

List of all measurements & calculations

PART I

Measure:

- $V \pm \delta V$
- I

x 12

- $R_{theo} \pm \delta R_{theo}$

Calculate:

- $R_{exp} \pm \delta R_{exp}$

PART II

Measure:

- $R_{1,theo} \pm \delta R_{1,theo}$
- $R_{2,theo} \pm \delta R_{2,theo}$
- $I_1 \pm \delta I_1$
- $I_2 \pm \delta I_2$
- $V_1 \pm \delta V_1$
- $V_2 \pm \delta V_2$
- $V_{total} \pm \delta V_{total}$

Calculate:

- $R_{total,theo} \pm \delta R_{total,theo}$
- $R_{1,exp} \pm \delta R_{1,exp}$
- $R_{2,exp} \pm \delta R_{2,exp}$
- $R_{total,exp} \pm \delta R_{total,exp}$

PART III

Measure:

- $I_1 \pm \delta I_1$
- $I_2 \pm \delta I_2$
- $V_1 \pm \delta V_1$
- $V_2 \pm \delta V_2$

Calculate:

- $R_{total,theo} \pm \delta R_{total,theo}$
- $R_1 \pm \delta R_1$
- $R_2 \pm \delta R_2$
- $R_{total,exp} \pm \delta R_{total,exp}$

Final Considerations

Be prepared to show your work and to state and compare your experimental and theoretical results from each part of the lab.

Don't forget to upload your plot's GitHub hyperlink to Canvas before the post-lab quiz.