**Laboratory Manual**

**for**

**Physics 216: Electronics**

**Matt Trawick**

*University of Richmond*

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# Review Lab i: An introduction to electric circuits

**Current, voltage, and series and parallel circuits**

**Materials:**

2 digital multimeters

DC power supply

three light bulbs

various wires and alligator clips

scissors

**Introduction:**

In this lab, you will measure both electric currents and potential differences using your digital multimeters (DMMs). Your instructor will show you how to set up your DMM for each kind of measurement.

To measure the electric current in a circuit, you will need to break the circuit, reconnecting it so that current is forced to flow through the meter, as shown below. (The “A” is the symbol for a current meter, or ammeter.)

*To measure current in this wire:*

*…and reconnect through the ammeter.*

*Break the circuit somehow…*

A

Your DMM can also measure the potential difference, in volts between any two points in the circuit. For this measurement, keep your circuit intact, and simply touch the two leads of the DMM to the two places in the circuit you want to measure between.

***For all parts of this lab, keep your power supplies set to a voltage of 3.0 volts, and use the 10A or 20A range of your DMM for measuring currents. Otherwise we’ll blow out lots of bulbs and fuses.***

**Activity 1: current and voltage measurements.**

a. The circuit below consists of a power supply, two ammeters, and a single lightbulb. For the following circuit, predict which of the two ammeters will measure the larger current. (Or will they be the same?)

Prediction:

A

A

b. Build the circuit above, using your two DMMs to measure the current that flows at the two points in the circuit shown. Record your measurements. Was your prediction correct?

c. Remove one of your two DMMs from the circuit, and use it to measure some voltage differences in the circuit as shown. Hold the black lead at point a, and move the red lead to b, c, and d, recording the results.

A

a

b

c

d

V

*Measuring potential difference between points a and b.*

d. Predict the voltage difference between the two points c and d in the circuit above. Test your prediction with a measurement. Do they agree?

Prediction:

Measurement:

e. How big is the voltage difference between the two ends of a typical wire in your circuit?

f. How big is the voltage difference across your ammeter?

g. Is it reasonable to approximate either or both of the voltage differences in (e) and (f) as zero?

**Activity 2: Two light bulbs in parallel**

a. Add a second light bulb to your circuit, as shown. These bulbs are connected “in parallel.” Make a prediction: If you add the second light bulb to your circuit as shown, will the current in the first light bulb increase, decrease, or stay about the same? Build the circuit and test your prediction.

A

Prediction:

Measurement:

b. In the circuit you have just built, how much current is flowing from the power supply? Make a prediction, and use a second ammeter to test your prediction.

Prediction:

Measurement:

*This is a good time to check with your instructor to be sure your measurements are on the right track.*

c. What is the voltage difference across each of the two light bulbs in the circuit above? Use one of your DMMs as a voltmeter to test your prediction.

Prediction:

Measurement:

d. Here’s a neat way to visualize electric potential, using an analogy with gravitational potential energy. For the simple circuit that you made in activity one, imagine the circuit drawn on a piece of paper shaped like a loop, with the paper folded so that height above the table corresponds to electric potential as shown below.

On the last pages of this lab are some big circuit diagrams for you to cut out. First, find the diagram of the circuit with two light bulbs, and use scissors to cut it into a shape with two loops. Then fold your paper so that the height above the table corresponds to changes in potential energy. Discuss your figure with your instructor. Yes, you REALLY have to do this.

e. Is your power supply acting more like a source of fixed current, or a source of fixed voltage? (What changes and what stays the same when you connect one or two bulbs to your power supply?) Explain.

**Activity 3: Two light bulbs in series:**

a. The circuit below shows two light bulbs connected to the power supply in series. Make predictions for the current in each of the bulbs, and the voltage difference across each bulb. Then build the circuit and test your predictions with measurements.

Predictions: Measurements:

A

A

b. Cut out the picture of this circuit from the final pages of your lab, and fold it so that height above the table represents electric potential. Discuss your figure with your instructor.

(A quick note: for those who have studied circuits before. You may have expected the current in each of the bulbs to be exactly half of the current through a bulb in the previous exercises. That would be true if the bulbs were regular resistors. But in fact, the “resistance” of these bulbs change as they get hot, so they don’t obey Ohm’s law.)

**Activity 4: Bulbs in series and in parallel:**

a. The circuit shown below includes light bulbs in series and in parallel with each other. Predict the values of the currents and voltage differences for each bulb, and then test your predictions. Which bulb or bulbs will be brightest?

Predictions: Measurements:

A

A

a

b

c

e

d

Brightest Brightest

Bulb? Bulb?

b. What is the relationship between bulb brightness and current through the bulb?

c. What is the relationship between bulb brightness and voltage difference across the bulb?

d. If we define the electric potential at the negative terminal of the power supply to be at Volts, what is the potential at each of the points a, b, c, d, and e in the circuit drawing above?

**Homework:**

Problem 1: consider the following circuit:

a

b

c

f

e

d

g

3 volts

a. If we define the electric potential at the negative terminal of the power supply to be at Volts, what is the potential at each of the points a, b, c, d, e, f, and g?

b. Rank from smallest to largest the current at each of the lettered points in the circuit. (You can write “” or something like that.)

c. Which bulb or bulbs will be brightest? Which bulb or bulbs will be least bright?

Problem 2: Consider the following circuit:

a

b

c

e

d

f

3 volts

a. Which is greater, or ? Why?

b. Which bulb is brighter, the one between a and b, or the one between e and f? Why?

c. Which is greater, or ? Why?

d. Which is greater, or ? Why?

e. Which is greater, or ?

f. Cut out the circuit on the last page of this lab, and fold it so that height above the table represents electric potential. Now that you have folded it, are there any answers above you’d like to change? Bring your folded paper to class, and prepare to discuss your figure with your instructor.

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# Review Lab ii: More on electric circuits:

**Resistance, Ohm’s law, resistors in series and parallel, and equivalent resistances**

**Materials:**

digital multimeters (2)

DC power supply

one light bulb

1k Ω resistors (2)

2.2 k Ω resistor (1)

various wires and alligator clips

scissors

**Introduction:**

In this lab, you will measure both electric currents and potential differences using your digital multimeters (DMMs). Your instructor will show you how to set up your DMM for each kind of measurement.

***For all parts of this lab, keep your power supplies set to a voltage of 3.0 volts or less. Otherwise we’ll blow out lots of bulbs and fuses.***

**Activity 1: relationship between current and voltage**

a. *For the current measurements in this part, be sure your DMM is using the 10 Amp or 20 Amp range.* Connect a single light bulb to your power supply, and measure both the current through it and the voltage across it as you vary the voltage of the power supply from 0 to 3.0 volts. Make a graph of *vs.* . Is the relationship between the two linear?

A

V

b. *For the current measurements in this part, change your DMM to a range between 40 mA and 400 mA.* Repeat the measurements in part (a), replacing the light bulb with a resistor with bands colored brown, black, red, and gold. Make a graph of *vs.* . Is the relationship between the two linear?

c. Ohm’s law says that for some circuit elements, the current through them is proportional to the voltage across them. The ratio between the two is the resistance, . (The unit of resistance is an Ohm (Ω), where 1 Ohm = 1 Volt / 1 Amp.) Which one of the two things you measured in (a) and (b) follows Ohm’s law, and what is its resistance?

d. Your DMM allows you to measure resistance directly, without using your power supply. Disconnect the resistor from your circuit *completely*, and use your DMM to measure its resistance. (The leads go in the same holes you used to measure voltage, and the function selector should be turned to “”.) What is its resistance?

e. The light bulb is designed to glow white hot when current flows in it, and the resistivity of the tungsten filament depends strongly on temperature. That’s why the bulb doesn’t follow Ohm’s law. From your measurements in (a) does the filament’s resistivity increase or decrease with temperature?

**Activity 2: Two equal resistors in series**

a. Build the circuit shown below, which has two 1 kΩ resistors connected in series. If your power supply is set to 3 volts, what will be the voltage drop across each resistor? Make a prediction, and test your prediction with a measurement.

Prediction:

Measurement:

b. You saw in Activity 1 that the voltage difference across a resistor is proportional to its current, . Make a prediction for the current through the resistors in the circuit. Test your prediction by inserting a current meter into your circuit and measuring it.

Prediction:

Measurement:

c. We can think of the two resistors in series as being equivalent to a single resistor , . What value single resistor would we have to replace the two 1k Ω resistors with in order to draw the same current (about 1.5 mA) from the power supply?



Equivalent to

****

**Activity 3: Two different resistors in series**

a. The circuit below shows a 1kΩ and 2.2kΩ resistor connected in series. Which resistor carries the larger current? (Or are they the same?) Check yourself with a measurement. The 2.2 kΩ resistor has bands colored red, red, red, gold.

 Prediction:

Measurement:

b. Which resistor in the circuit above has a larger voltage drop across it? Why? Check yourself with a measurement.

Prediction:

Measurement:

c. Imagine replacing the two resistors in series with a single equivalent resistor . We can write in terms of the voltage drops across the resistors as

Use the equation above as a start to writing an expression for in terms of and for two resistors in series.

For resistors in series:

**Activity 4: two resistors in parallel**

a. The circuit drawn below shows two resistors in parallel. Which is bigger, or ? (Or are they the same?)



b. Which resistor in the circuit above has a larger current through it? Why? Check yourself with a measurement.

c. What are the currents and through the resistors, in terms of , , and ?

d. Imagine replacing the two resistors in parallel with a single equivalent resistor . We can write the current through the equivalent resistor as . Using the definition , write an expression for in terms of and , for two resistors in parallel. (It’s not the same as for resistors in series.)

Equivalent to



For Resistors in Parallel,

**Activity 5: using equivalent resistances to solve problems:**

The circuit to the right shows four resistors connected to a power supply.

a. The last page of this lab is a large picture of this circuit. Cut it out and fold it so that height above the table at each point of the circuit corresponds to electric potential.

b. Which two resistors have the same ? Which two resistors carry the same current ?

c. Use the idea of equivalent resistances to find the current that flows in each of the resistors in the circuit. The flow chart on the following page will guide you through it.



2. Find the equivalent resistance for and in parallel (numerical answer, in Ohms):

4. Find the equivalent resistance for resistors , and in series:

5. Find the current through the equivalent resistor :

6. Given the current , find the voltage difference across each of the resistors , :

7. Given , find the current through resistors and :

1. Identify a group of resistors in parallel or in series; redraw as an equivalent resistance.

3. Identify a group of resistors in parallel or in series; redraw as an equivalent resistance.

(Back to previous drawing.)

(Back to previous drawing.)



**Homework Questions:**

a. If two resistors are connected in series, do they always carry the same current through them? If not, which one will have the larger current?

b. If two resistors are connected in series, do they always have the same voltage difference across them? If not, which one will have the larger voltage difference across it?

c. If two resistors are connected in parallel, do they always carry the same current through them? If not, which one will have the larger current?

d. If two resistors are connected in parallel, do they always have the same voltage difference across them? If not, which one will have the larger voltage difference across it?



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