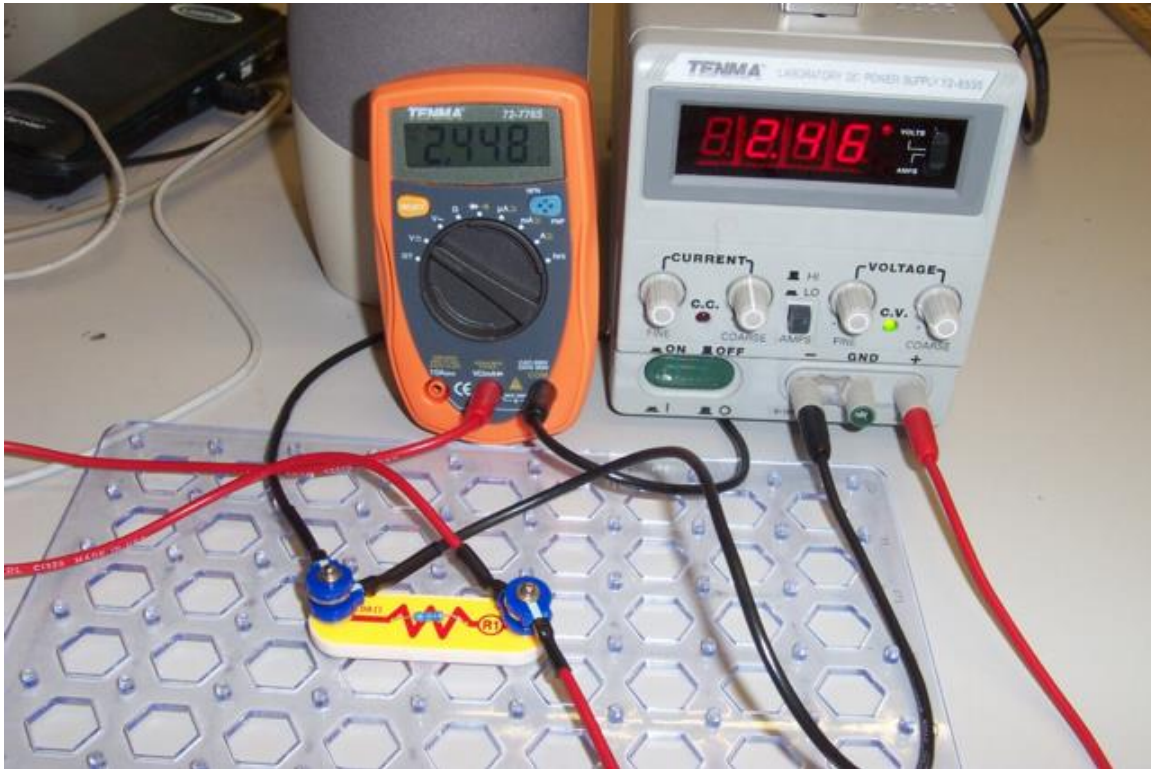


DC Circuits



Objective: To learn how to build and run an electrical circuit. To measure current and voltage anywhere in the circuit. To determine the relationships between Current, Voltage and Resistance. To learn Kirchoff's Rules

Apparatus: SnapCircuits board and connectors, 100Ω resistors (2), banana-to-snap cables (4), DC power supply, multimeter (combination voltmeter/ammeter/ohmmeter), light bulbs (two, **8V limit – do not exceed for a single bulb in series**).

Introduction

So far our labs have focused on electrical fields that have macroscopic effects – a charged rod that attracts bits of paper or foil, two charged copper spheres or scotch tape strips that attract or repel each other. Now we will examine the microscopic effects of electrical fields in wires that conduct electricity. You will build simple circuits and learn to measure Voltage, Current and Resistance (both directly and from the slope of V vs. I).

Theory

The following summarizes what you have already learned in lecture about circuits:

Electric Potential

The electric field E is related to the rate of change of electric potential V . If the electric potential

changes by the amount ΔV , the electric field in the direction of the displacement is:

$$E = -\frac{\Delta V}{\Delta s}$$

Current

Current I is defined as the flow of charge Q per unit time:

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

Power

Power P is the rate of energy flow per unit time through a circuit or circuit element:

$$P = VI = I^2 R$$

Ohm's Law

For many a material, the current I through it is proportional to the potential difference across it, with the resistance R being the constant of proportionality, as well as the slope of the V vs. I graph:

$$V = IR$$

Materials that behave this law are known as *ohmic* materials; those that do not are *non-ohmic*.

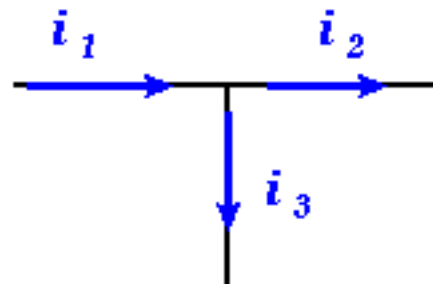
The power that is dissipated through a resistor also obeys $P = I^2 R$.

Kirchoff's Junction Rule

The current entering any point in a circuit must equal the current leaving that point. This ensures that there is no charge buildup anywhere, which would violate conservation of charge and energy:

A *junction* is where roads or paths meet or connect. In the junction on the right, the current I_1 splits up into I_2 and I_3 . So that there is no excess buildup of charge or current in the circuit, this condition must be fulfilled:

$$I_1 = I_2 + I_3 \quad \text{or} \quad I_1 - I_2 - I_3 = 0$$

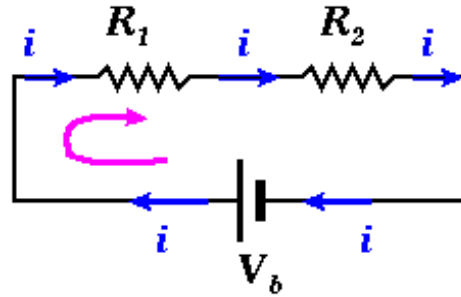


Kirchoff's Loop Rule

The algebraic sum of all potential differences around any closed loop in a circuit is zero:

Starting from the battery V_b and proceeding counterclockwise, the gains or losses in potentials are:

$$+V_b - IR_1 - IR_2 = 0$$



Procedure

You will build a series of circuits using SnapCircuit circuit elements and connectors, which will be connected to a DC power supply. A DC (Direct Current) power supply supplies a steady potential difference (voltage), as opposed to the AC (Alternation Current) power which comes out of an electrical outlet at home or in lab. A typical flashlight battery is another example of a DC power source.

Circuit elements, including light bulbs and power supplies/batteries, have two terminals: plus (+) and minus (-). Current enters through one and leaves through the other. So a closed circuit (as in the circuit containing two resistor and one battery, above) should be one continuous, closed loop (or series of loops).

On your power supply, there is a green Power button. Make sure that, before you push it, the “Coarse” and “Fine” Current knobs are set to the middle position, and that the “Coarse” Voltage knob is set to the minimum position. After you press the Power button, you can slowly adjust the Voltage with the two Voltage knobs. **Do not exceed 8V on the power supply if you are using a single light bulb in series with it.** The voltage (or current) is displayed on the red LED display on the face of the power supply, with a lever that lets you select Voltage or Current. Remember, this is the voltage (or current) reading *through the power supply* and not necessarily at every point in the circuit.

IMPORTANT: A voltmeter *must be connected in parallel* with the circuit element across which you are measuring the voltage; that is, the current forks out to enter both the element and the voltmeter, then recombines after it has passed through both. In contrast, an ammeter *must be connected in series* with the circuit element through which you are measuring the current; this means that the ammeter must be directly in-line with the circuit element. In the labs, we will be using measuring devices called *multimeters*, which can serve as a voltmeter, ammeter or ohmmeter. If you are using the multimeter as an ohmmeter, you should not have a power supply or battery in the circuit – the only thing in between the ohmmeter's terminals should be the circuit element (resistor or bulb).



See the multimeter on the left. Its large function dial is set to V~, which measures DC voltage; you will not use V~, which measures AC voltage, in this lab. The next function is Ω which measures resistance. The middle setting is for diodes, which you will not use, and the next three – μA, mA and A – measure current.

You will use two cables, banana-to-button, to connect the multimeter to various parts of the circuits that you will build, or circuit elements. On the multimeter, one of these cables stays on the COM jack at bottom left. The other cable is to be plugged into the VΩmA jack on bottom center if measuring voltage or resistance, or the 10A jack on bottom left if measuring current.

Remember that the multimeter cables are to be connected to a circuit in parallel if measuring voltage. If you're measuring current, the cables are to be connect to the circuit in series!

Again, as with all your work this semester, your lab report will consist of a created Google Docs document shared amongst the lab partners, your TA and your LA. Note that you can do your plotting and curve-fitting in Google Sheets and include a link to that document on your Google Docs lab report.

0. Connect the cables of an ohmmeter (select this function on your multimeter) to the terminals of a 100 Ohm resistor and **confirm that the resistor's rating is approximately correct by listing both values (labeled and measured) in your lab report.** (3 pts)
1. The power supply has a selectable current limiter; this is a feature that limits the current, and hence the power (from $P = I^2 R$ in the circuit). This prevents the device being powered (light bulb, amplifier,

etc.) from being overloaded. Activate the current limiter by doing the following:

- a. With the green Power button OFF, turn all Current and Voltage knobs to their minimum position (fully counterclockwise). Then press the Power button ON.
- b. SHORT the two lead wires (+ and -) coming out of the power supply by connecting the button-snap ends to each other.
- c. With the two lead wires still snapped together, rotate the COARSE Voltage knob about 1/8 turn clockwise from its minimum position and set the Volts/Amps selector switch on the LED read-out to AMPS.
- d. Adjust the Current knobs until the read-out indicates 0.150 Amps (this corresponds to roughly 8V when the bulb is fully lit, the bulb's maximum rating). This power supply will make sure that this value is not exceeded. You can now proceed to hook up the light bulb in the next step.

2. Build a simple circuit where a flashlight bulb is powered by a DC power supply. Slowly raise the voltage to between 7 and 8 Volts. **Remember, do not exceed 8V on the power supply if you are using a single light bulb in series with it.**

- a. Draw the circuit in pictorial form so that your TA can see exactly how you connected things when he/she grades your work, and include in your lab report; alternatively, you can take a photo of your circuit and include in your lab report. (3 pts)
- b. You should also draw its representation in schematic form; if it's more convenient, you can hand-draw this on a piece of paper and take photo of it, also for lab report inclusion. (3 pts) For a light bulb, you can use this as its schematic representation:



3. Measure the voltage across the bulb. Do this two different ways, describe each one, and record the two values. (5 pts) Hint – you have more than one multimeter at your disposal.
4. Measure the current through the light bulb. Do this two different ways, describe each one, and record the two values. (5 pts) Remember how an ammeter is connected to a circuit.
5. Using only the power supply's built-in multimeter, vary the voltage across the light bulb from zero to the maximum rating of the light bulb at 11 evenly-spaced values of voltage (the first data point will be at $V=0$, the last should be $V=8.0V$). At each value, record the current (this involves the mere flip of the Current/Voltage switch on the power supply's meter). Plot your data (Google Sheets is recommended) and include in your lab report, labeling axes and list units. (5 pts)

You will now repeat Activities 2-5 above, but this time for a 100 Ohm resistor; do not use any light bulbs. For the single resistor, **use the current limiter to keep the current to under 0.07 A** (this corresponds to the rating of the resistor – about 0.5 W). Please note that the resistor might be hot enough to burn you!

6. Build a simple circuit where 100 Ohm resistor is powered by a DC power supply. **Draw the circuit in pictorial form or take a photo of it. Also, draw its representation in schematic form (using symbols for resistor, battery, etc).** (3 pts) As with before, you can take photos of the constructed circuit or a hand-drawn schematic diagram

7. Measure the voltage across the resistor. **Do this two different ways, describe each one, and record the two values.** (5 pts)

8. Measure the current through the resistor. **Do this two different ways, describe each one, and record the two values.** (5 pts)

9. Using only the power supply's built-in multimeter, vary the voltage across the resistor from zero to the maximum voltage allowed by the power supply, with its current now limited to 0.07A, at 11 evenly-spaced values of voltage. At each value, **record the current (this involves the mere flip of the Current/Voltage switch on the power supply's meter).** Plot your data and include in your lab report, **labeling axes and list units.** (8 pts)

For the resistor, **find a value for the slope of the V vs. I graph. How does this value compare to the resistance value as labeled on the resistor? (3 pts) Is the resistor an ohmic device? (3 pts) Is the bulb an ohmic device? (3 pts)**

10. Connect two 100Ω resistors in **series** and connect to the power supply.

a. **Predict (calculate) the voltage across each one and the current through each one.** (5 pts) Note that you should first decide on a voltage setting for the power supply, e.g. 2V, and calculate the voltages and currents through each circuit element based on that value. (5 pts)

b. Then actually **measure these values using multimeter(s) and record them.** (3 pts)

c. **How close (give a percentage difference) were your predicted values to your measured ones? (2 pts)**

d. **Draw a schematic of the complete circuit and indicate the current through and voltage drop across each circuit element (including the power supply). Are Kirchoff's Rules obeyed (do the numbers add up)? (5 pts)**

11. Connect two 100Ω resistors in **parallel** and connect to the power supply. *If you have trouble visualizing what it would look like on your SnapCircuits board, draw it out in schematic form first.*

- a. Predict (calculate) the voltage across each one and the current through each one, after you've decided on a voltage setting for the power supply (4V is a good starting value). (5 pts)
- b. Then, actually measure and record these values using multimeter(s). (5 pts)
- c. How close (give a percentage difference) were your predicted values to your measured ones? (2 pts)
- d. Draw a schematic of the complete circuit and indicate the current through and voltage drop across each circuit element (including the power supply). Are Kirchoff's Rules obeyed (do the numbers add up)? (5 pts)

Assessment and Presentation (Hand-in Sheet/Lab Notebook)

After entering results from Activities 1-10 above in the hand-in sheet, answer the following questions:

1. Resistance is often a function of temperature. How does the temperature of the light bulb influence its resistance? (3 pts)
2. Christmas Tree light bulbs are connected in parallel, not series. Can you think of a practical reason for this? (3 pts)
3. Connect a light bulb in series with a 100 Ohm resistor and connect to a power supply. Are you able to make the bulb light up? If not, or if the bulb lights quite dimly, explain why. (3 pts)