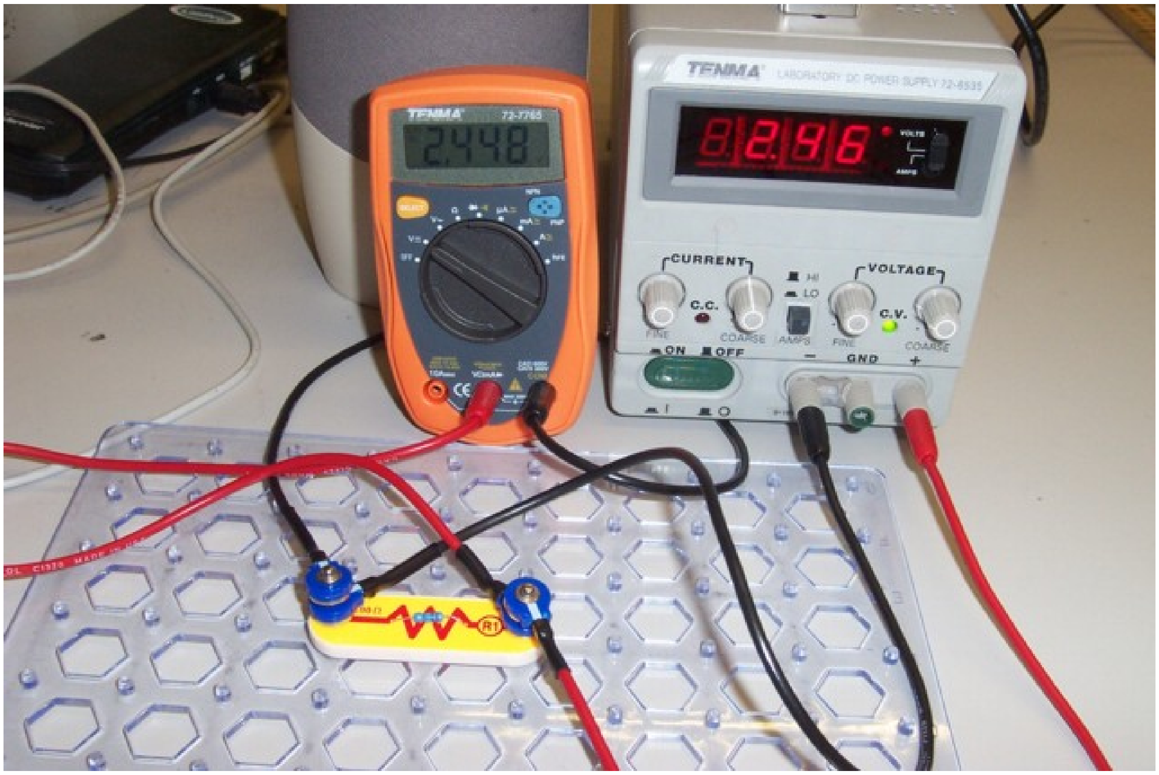
DC Circuits



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, circuit elements, cables, DC power supply, multimeter (combination voltmeter/ammeter/ohmmeter), light bulb (**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 have already learned in lecture about circuits:

<u>Electric Potential</u>

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 until 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.*

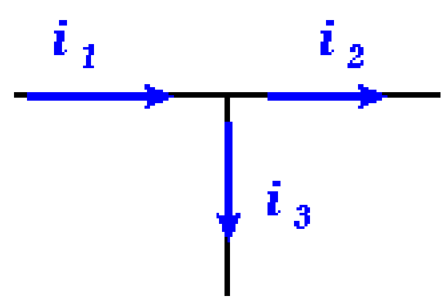
The power that is dissipated through a resistor also obeys

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:

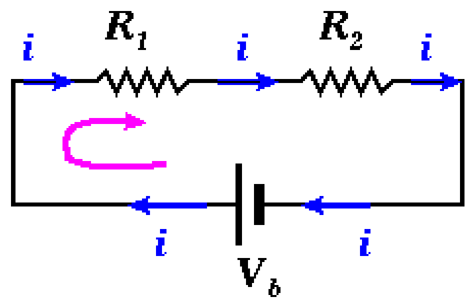
A *junction* is where roads or paths meet or connect. In the junction on the right, the current I_1 splits up into I_2 and I_3. So that there is no excess buildup of charge or current in the circuit, this condition must be fulfilled:

$I_1 = I_2 + I_3$.   or $I_1 - I_2 - I_3 = 0$



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 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 knows. **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.

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).

Record all drawings, observations and calculations in the hand-in sheet and submit.

<u>Activity 0</u>

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..

<u>Activity 1</u>

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 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. 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.

Activity 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.** Draw the circuit in pictorial form, and draw its representation in schematic form (using symbols for resistor, battery, etc).

Activity 3

Measure the voltage across the bulb. Do this two different ways. (Hint – you have more than one multimeter at your disposal.)

Activity 4

Measure the current through the light bulb. Do this two different ways.

Activity 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. At each value, record the current (this involves the mere flip of the Current/Voltage switch on the power supply's meter).

Activity 6-9

Repeat Activities 2-5 above, but this time for a 100 Ohm resistor 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).

Plot V vs. I for both bulb and resistor; you can use Graphical Analysis if you wish (recommended). Is there a difference between the shapes of their graphs?

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? Is the resistor an ohmic device? Is the bulb an ohmic device?

Activity 10

Connect two resistors of known value in **series** and connect to the power supply. Choose resistors of low resistance value. Predict (calculate) the voltage across each one and the current through each one. Then actually measure these values using multimeter(s). How close (give a percentage error) were your predicted values to your measured ones? Draw 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)?

Activity 11

Connect two resistors of known value in **parallel** and connect to the power supply. Choose resistors of low resistance value. Predict (calculate) the voltage across each one and the current through each one. Then actually measure these values using multimeter(s). How close (give a percentage error) were your predicted values to your measured ones? Draw 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)?

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 is resistance?

2. Christmas Tree light bulbs are connected in parallel, not series. Can you think of a practical reason for this?

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? **DO NOT EXCEED 8V!** If not, explain why.