Name: ________________________ Partner(s): ________________________

Investigation #11 ________________________

ELECTRIC CIRCUITS & OHM'S LAW

The purpose of this investigation is multifaceted. With minimal background information and using a "trial-and-error" approach, you will become familiar with the concept of an electric circuit, distinguish between series and parallel circuits, and determine the relationship between voltage and electric current through different electrical devices.

Part I
Creating a Simple Circuit

Your group will need the following materials/equipment for this part (per person):

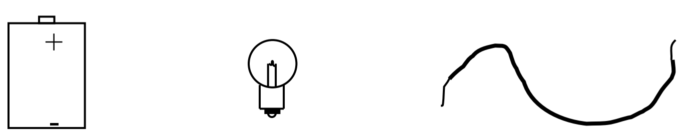
- 1 D-cell battery
- 1 minilamp
- 1 piece of copper wire

Procedure

1. Using <u>only</u> the three items provided, come up with a configuration that will make the lamp light. Talk to your partner(s), but experiment individually.
2. As initial trials, try the configuration shown in the examples below. Indicate whether or not these arrangements provided light by indicating the actual result.
3. Record <u>each</u> of your attempts (successful or not!) by sketching (neatly!) the arrangement tested in the space provided on the next page. Make your sketches in a similar fashion as those shown in the examples below.

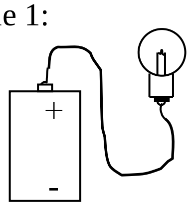
CAUTION: Hold the wire at the insulation. If at any time you notice the wire or battery getting hot with the lamp unlit, STOP what you are doing, record that configuration as unsuccessful, and then try something else!

4. Label the sketches as to whether there was LIGHT or NO LIGHT.
5. Once you have found a configuration that works, note the connections that you have made and then come up with <u>three more configurations</u> that light the lamp for a **total of four** working configurations. Each configuration must be different.



Battery Minilamp Wire

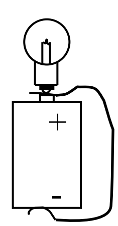
Example 1:



______ Light

______ No light

Example 2:



______ Light

______ No light

Sketches:

Question: Look carefully at your sketches. Come up with a general set of rules that when followed will ALWAYS lead to a successful lighting of the bulb. Be careful in your wording. (Hint: Do not take anything for granted. You should make reference to what component touches what component and where contacts on each component are made!)

Checkpoint: Consult with your instructor before proceeding. **Instructor's OK:** ______

Part II
Series and Parallel Circuits

By now, you may be developing the concept of an electric circuit. Once you have successfully made your lamp light using the four different configurations found in **Part I**, you can now use the battery and lamp holder to construct a circuit. In the sections that follow, you will be given a variety of "circuit problems." Your challenge is to find a "solution" to each of the situations described.

Your group will need the following materials/equipment for this part:

- 1 "D-cell" battery and 1 battery holder
- 2 minilamps (should be identical make and model) and 2 bulb holders
- 2 contact switches
- several pieces of copper wire

Procedure

1. Be sure that each of your batteries and each of your bulbs are functioning by using the procedures of **Part I**.
2. For each situation described, construct a circuit that performs the specified task.
3. In each case, make a neat circuit diagram of your solution. (To save time in your sketches, you may use the symbols shown below.)
4. If your circuit doesn't work, again check to make sure that your batteries and lamps are all functioning. If all your equipment is working and your solution doesn't work, then you will need to develop an alternative solution. (Suggestion: Keep the sketch of the nonfunctioning circuit to help you avoid repeating what doesn't work.)

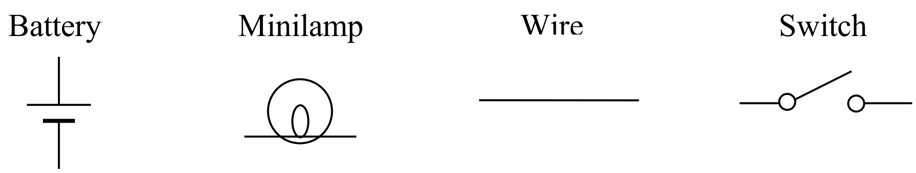
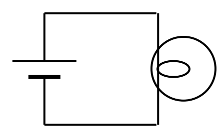


Fig. 2: Standard symbols for some basic electrical components

As an example of a circuit diagram, consider any of the four successful circuits constructed in **Part I**. Using the standard electronic symbols, any of those four circuits can be represented by the circuit diagram shown at right.



Circuit Problem #1: Design, construct, and sketch a circuit with one battery and two lamps (initially unlit) that both light when a switch is closed. If either lamp is removed from its holder, the other lamp goes out. This circuit is called a *series circuit*.

Sketch(es):

Question: How did the brightness of the two simultaneously lit lamps in *Circuit Problem #1* compare to each other? (Pick one.)

______ One of the lamps was definitely brighter that the other.

______ Both of the lamps had about the same brightness.

Question: How does the brightness of the two simultaneously lit lamps in *Circuit Problem #1* compare to a successful circuit in **Part I**?

______ The two lamps were definitely brighter than the lamp in **Part I**.

______ The two lamps had about the same brightness as the lamp in **Part I**.

______ The two lamps were definitely dimmer than the lamp in **Part I**.

Circuit Problem #2: Design, construct, and sketch a circuit with one battery and two lamps (initially unlit) that both light when a switch is closed. If either lamp is removed from its holder, the other lamp stays lit. This circuit is called a *parallel circuit*.

Sketch(es):

Question: How did the brightness of the two simultaneously lit lamps in circuit problem #2 compare to each other?

______ One of the lamps was definitely brighter that the other.

______ Both of the lamps had about the same brightness.

Question: How does the brightness of the two simultaneously lit lamps in *Circuit Problem #2* compare to the successful circuit in **Part I**?

______ The two lamps were definitely brighter than the lamp in **Part I**.

______ The two lamps had about the same brightness as the lamp in **Part I**.

______ The two lamps were definitely dimmer than the lamp in **Part I**.

Questions: Consider the arrangements of the lamps in successful circuits constructed in *Circuit Problems #1* and *#2*. What feature of the series circuit makes it behave the way it does? What feature of the parallel circuit makes it behave the way it does?

Circuit Problem #3: Design, construct, and sketch a circuit with one battery, one lamp, and two switches such that if both switches are closed, the lamp will light, but if either switch is open, the lamp will not light.

Sketch(es):

Circuit Problem #4: Design, construct, and sketch a circuit with one battery, one lamp and two switches such that if either switch is closed, the lamp will light, but if both switches are open, the lamp will not light.

Sketch(es):

Questions: Consider the arrangements of the switches in successful circuits constructed in *Circuit Problems #3* and *#4*. One is a *series* arrangement and the other is a *parallel* arrangement. Which do you think is which? Why do you think that?

Checkpoint: Consult with your instructor before proceeding. **Instructor's OK:** _______

Part III
Battery Combinations

The role of the battery in an electric circuit is similar to that of a pump in a water line. In a water line, the pump produces the "push" necessary to make the water flow through the pipes. The pump provides a pressure difference across its two ends to force the water to flow. In an electric circuit, the battery produces the push necessary to make electricity flow through the wires. Conceptually, the battery exerts an "electrical pressure" to force the electric charge to flow through the circuit. However, one must be careful using this analogy. This "electrical pressure" is not really a pressure because it is not measured in N/m^2. Rather, the battery provides a *potential difference* or more familiarly, a *voltage* across its two ends to force the electric charge to flow through the circuit. Voltage is measured in units called *volts*. The flow of electric charge is called a *current* and is measured in units called *amperes* (or "amps" for short). These concepts will be explored further in **Part IV**.

To examine the voltages of battery combinations, you will employ a device called a voltmeter. As the name implies, a voltmeter measures the potential difference (voltage) across its two leads. By convention, the red lead goes to the expected higher potential and the black lead goes to the expected lower potential to read a positive value.

Your group will need the following materials/equipment for this part:

- 3 "D-cell" batteries
- 1 digital voltmeter

Procedure

1. Keep track of each battery: label each battery with a piece of tape or use an erasable marker.
2. Start by measure the voltage of each individual D-cell battery using the voltmeter. Measure with the red lead on the (+) side of the battery and the black lead on the (–) side. Record these values below.

Voltage of Battery 1: V_1 = ________ V

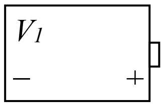
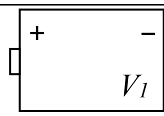
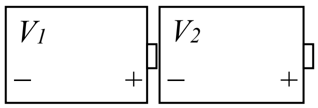
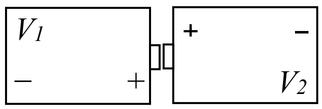
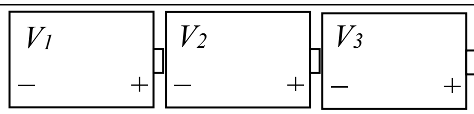
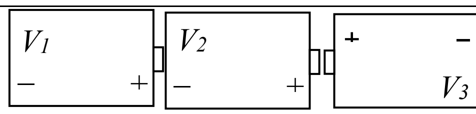
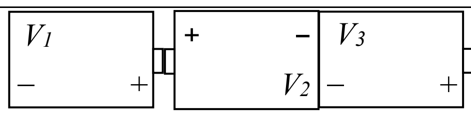
Voltage of Battery 2: V_2 = ________ V

Voltage of Battery 3: V_3 = ________ V

3. Measure the voltage across each battery combination shown in Table 1 on the next page. For consistency, measure the voltages with the red lead of the voltmeter on the right side of the combination and the black lead of the voltmeter on the left side for each combination shown in Table 1.

Note: Make sure that the voltmeter is set on the direct current (DC) setting and that the range is set to 20V full scale. Be sure to turn the voltmeter off when you are finished.

Table 1

Battery Combination		Measured Voltage (V)
1		
2		
3		
4		
5		
6		
7		

Question: Based on these results, explain why the measured voltages of the battery combination are what they are.

Suppose a lamp was connected across each end of the battery Combinations 2-7 shown in Table 1. Use your results in Table 1 and from **Part II** to answer the following questions.

Question: For which of Combinations 2-7 (if any) would you expect the lamp to light with the about the same brightness as Combination 1? Why?

Question: For which of Combinations 2-7(if any) would you expect the lamp to light more brightly than Combination 1? Why?

Question: For which of Combinations 2-7 (if any) would you expect the lamp to not appear to light at all? Why?

Checkpoint: Consult with your instructor before proceeding. **Instructor's OK:** _______

Part IV
Ohm's Law

In this section, you will measure the *voltage* and *current* in a simple circuit in order to deduce the relationship between them. This relationship, known as *Ohm's law*, relates voltage, current through a quantity called *resistance*.

Your group will need the following materials/equipment for this part:

- 1 variable (low voltage) DC power supply
- 1 ammeter (variable scale)
- 2 resistors (different values) and 1 minilamp with holder
- 3 wires with "banana" plugs and/or "alligator" clips

Procedure

1. Set up the circuit as per your instructor's directions. Your circuit should look like the one shown in Fig. 1 on the next page.

IMPORTANT: DO NOT TURN ON THE POWER SUPPLY UNTIL YOUR INSTRUCTOR HAS INSPECTED YOUR CIRCUIT. BE SURE TO TURN OFF THE POWER WHILE CHANGING COMPONENTS IN THE CIRCUIT.

2. Once cleared to proceed, vary the applied voltage so that the voltage across the first resistor is exactly 0.5 Volt. Record the current reading from the ammeter in Table 2 on the next page for the first resistor. Increase the voltage in increments of 0.5 V up to 5.0 V while recording the current reading each time.
3. Repeat Step 2 for the second resistor and for the lamp. Complete Table 2.

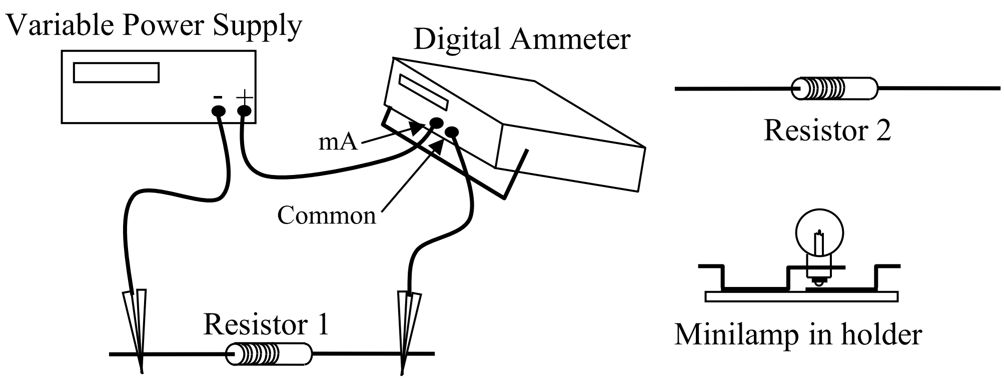


Fig. 1: Schematic layout for voltage and current measurements.

Table 2

Resistor 1		Resistor 2		Lamp	
Voltage (V)	Current ($\times 10^{-3}$A)	Voltage (V)	Current ($\times 10^{-3}$A)	Voltage (V)	Current ($\times 10^{-3}$A)
0.5		0.5		0.5	
1.0		1.0		1.0	
1.5		1.5		1.5	
2.0		2.0		2.0	
2.5		2.5		2.5	
3.0		3.0		3.0	
3.5		3.5		3.5	
4.0		4.0		4.0	
4.5		4.5		4.5	
5.0		5.0		5.0	

Note: The current values read from the digital multimeter will typically be in units of milliamperes (mA) rather than amperes. Note that 1 A = 1000 mA. In other words,
1 mA = 10^{-3} A.

Note: In the **Homework Questions**, you will be asked to make a graph voltage vs. current for both of the resistors and the lamp using graph paper or a plotting program and then use the graphs to answer additional questions.

Question: For each component, what are the independent variable and the dependent variable for the data in Table 2?

IV = ______________ DV = _____________

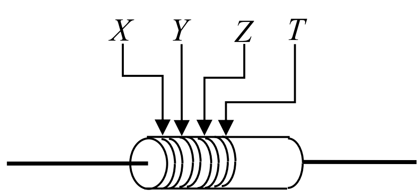
Questions: Is (0, 0) a valid data point for each component? In other words, what current would expect to measure if the applied voltage is set to zero?

In order to concisely identify the resistance of your resistors, you will use the standard resistor color code described in Chart 1 below. The standard unit of resistance is the *Ohm* and is designated by the symbol, Ω. A numerical example is also provided below.

Chart 1: The Standard Resistor Color Code used to identify the value (in Ω) of resistors.

$R = XY \times 10^{Z} \pm T\%\ (\Omega)$									
Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

Tolerance Band (T):	Red	Gold	Silver	(None)
	± 2%	± 5%	± 10%	± 20%



Example: Suppose the color bands on the resistor shown at left are:

X	*Y*	*Z*	*T*
Yellow	Violet	Red	Gold
4	7	2	± 5%

Then this resistor has a value of $47 \times 10^2\ \Omega \pm 5\ \%$ or 4700 Ω ± 235 Ω. Thus, this resistor can have minimum of 4465 Ω and a maximum of 4935 Ω and still be within tolerance.

Note: *XY* are NOT multiplied together. *XY* are the first two digits of the resistor value! In the example above, the "*X* = 4" and the "*Y* = 7" combine to give "47" (not "28").

Questions: Use the resistor color code above to determine the values of your resistors.

Resistor 1	*X*	*Y*	*Z*	*T*
Band Color				
#				

Resistor 1 = $XY \times 10^{Z} \pm T\%$ = ____________ ± __________ Ω

R_{min} = _____________ Ω and R_{max} = _____________ Ω

Resistor 2	*X*	*Y*	*Z*	*T*
Band Color				
#				

Resistor 2 = $XY \times 10^{Z} \pm T\%$ = ____________ ± __________ Ω

R_{min} = _____________ Ω and R_{max} = _____________ Ω

Checkout: Consult with you instructor before leaving the lab. **Instructor's OK:** ______