Lab 5:
Circuit Fundamentals-
Electric Potential and Electric Current

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The first part of this lab is for us to get acquainted with circuits. In particular, we will introduce (1) constructing circuits and (2) diagramming circuits. The second part of this lab is quantitative. There, we will endeavor to answer two research questions: What functions can be determined to relate the three fundamental circuit variables [potential, current, resistance]? Second, what measurable tendencies distinguish devices in line from multiple paths?

Part I: Qualitative Experimentation

As stated above, the first part of this experiment is for pure exploration of circuits. There are no measurements to be made at this step, only qualitative observation and notation. The goal here is not to determine mathematical relationships but to have an understanding of how charge flows and the different ways devices can be arranged.

1) Locate the power source. This is the large black box. This will act as the "battery" for your circuit. Note the two knobs, one labeled current and one labeled voltage. For our purposes, the current knob may be turned all the way up. The **voltage**, however, **should NOT exceed half way**. When creating a circuit and powering it for the first time, the voltage knob should be on the lowest and then gradually raised until a dim light emanating from the bulb. On the bottom right-hand side of the power supply is a switch for voltage range. On side is 0 - 15 V, the other is 15 - 30 V. For this lab the switch is to be set to **0 - 15 V**

2) Locate your resistors. These devices are the small cylinders with metal wire attached to them. Note the coloration of the bands on the cylinder. These colors are code for the resistance. Determine the resistance (in Ohms- [Ω]) of the supplied resistors by consulting a resistor color code chart found through your local google search or wherever you find images on the internet. Record their respective resistances.

Please note: when in the circuit, these resistors can get hot. Use the needle nose pliers to remove them from the circuit.

3) Locate your light bulb. These devices emit light when enough current passes through them (~.18 A). Locate your bulb holder. This blue circle has a place to screw in your bulb, as well as two metal hooks. These two hooks are what needs to be connected into the circuit via wire.

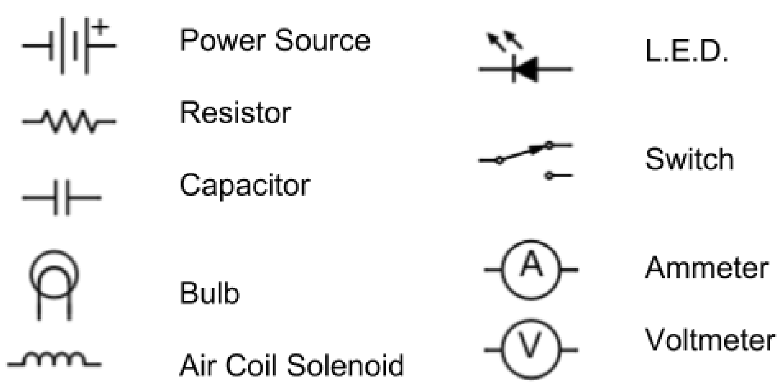
4) Now that you have an understanding of the devices in the circuits you will be building, you will build your first circuit (Now known as C1). For this introduction we will not be using the "breadboard." Instead you will create the circuit using alligator clips.

   The parameters of circuit one is as follows:

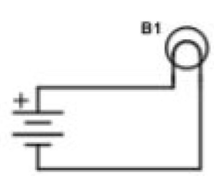
   a) This circuit must consist of 3 bulbs and no resistors.
   b) This circuit should be designed in such a way that when any bulb is unscrewed, all other bulbs turn off. This should be true for any and all bulbs.

GO!

5) Now that you have created the circuit as described above, create a circuit diagram of the circuit (C1). A circuit diagram is a simple and concise representation of your circuit using standard symbols to represent devices. Some common and useful symbols:



Example:



6) The next step is to create a different type of circuit (This will be known as C2). For this circuit we will also be using alligator clips.

The parameters of circuit two is as follows:

a) This circuit must consist of 3 bulbs and no resistors.
b) This circuit should be designed in such a way that when any bulb is unscrewed, all other bulbs stay on. This should be true for any and all bulbs.

GO!

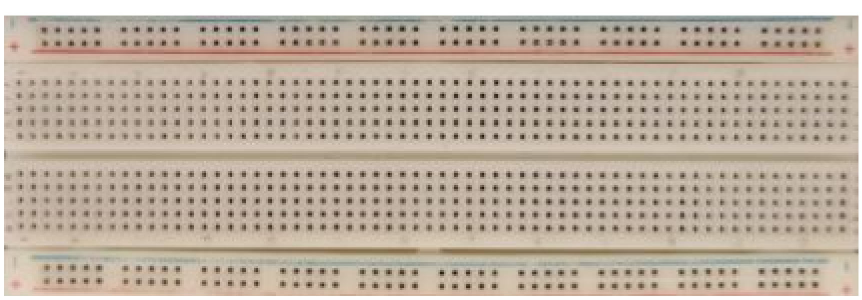
7) Create a circuit diagram for circuit 2 (C2)

8) We have created two unique types of circuits. What differentiates these two circuits? For each diagram, take a pencil and trace the path of current from the positive end of the battery to the negative end. What makes these circuits different?

9) Now that we have a clear distinction in our minds of the difference between C1 and C2, our last dive into the realm of qualitative analysis will be of the elusive "breadboard." Your task is to determine how the metal strips inside the breadboard are arranged. The way in which they are arranged is in a pattern, but this pattern is not necessarily uniform

Using 3 bulbs, try to recreate both C1 and C2. Use this experimentation to determine the configuration of the metal tracks underneath the holes of the breadboard. Label the diagram below (or draw your own) indicating this configuration.

DO NOT CONTINUE TO PART II
UNTIL YOU HAVE A CLEAR UNDERSTANDING
OF THIS CONFIGURATION



Part II: Quantitative Experimentation

This is where the measurements will be made. From here on out, we are less concerned with strict observation than we are concerned with inference gleaned from experimental data. In this section we will be deriving formulas and equations from data collected and fostering an understanding of the mathematical relationships of circuits.

1) At this point, the "breadboard" is no longer a mystery (If for you it still is, then please return to P.I-9). A new mystery is on the horizon. This mystery is that of the **ammeter** and **voltmeter**. These two instruments measure **current** (in amperes- [A]) and **voltage**, A,K,A, potential difference (measured in volts- [V]) respectively.

   For all measurements of current and voltage **DO NOT** use the power source's built in moving-coil meters. They are not accurate nor precise.

   a) To start: The ammeter. As mentioned, the ammeter measures current, which is the "flow" of charge through a device. This must be measured like the devices in C1 are arranged. That is, the ammeter must be in line or **series** to the devices.

      The question now being posed to you and MUST be answered is:

      Why?

      Why does an ammeter, which measures "flow" through a device, need to be in line with a device?

   b) To end: The voltmeter. Also already mentioned, the voltmeter measures voltage, which is the difference of potential across a device. This voltage is a comparison of the potential of one side of a device to the other. This must be measured like the devices in C2 are arranged. That is, the voltmeter must be in around or **parallel** to the devices.

      The question now being posed to you and MUST be answered is:

      Why?

      Why does a voltmeter, which measures potential difference of a device, need to be around a device?

2) Now that we can officially make measurements with a level of accuracy with a level of confidence, we can now start this quantitative analysis. Our first tasks is as follows:

> Determine a relationship between Current (I), Voltage (ΔV) and Resistance (R). That is, more specifically, I as a function of ΔV { $f(\Delta V)$ } with a given R.

<u>The Experiment:</u>

a) Using a 100 Ω resistor only, create a simple circuit in the breadboard (For all Quantitative Analysis, we will **not** be using the alligator clips).

b) Draw a circuit diagram of this circuit.

c) Collect data and analyse (that is graph) to determine the relationship. (Keep in mind that there is a constant in your experiment and there should be a constant in your relationship. The hardest part of this analysis is determining how YOUR constant relates to THE constant.)

This relationship is, and will now be known as, **Ohm's Law**.

3) Ohm's Law will be the key to the remaining analysis at hand. Please insure you understand Ohm's law and have determined it, correctly, from the analysis of your data. The next step is to collect quantitative data from the types of circuits you created in P.I-4,6. First we will tackle a C1 type circuit.

<u>The Experiment:</u>

a) Using the **other** 3 resistors (NOT the 100 Ω) and a bulb, create a C1 type circuit. That is, create a circuit where all devices are in line, or **Series**, with each other.

b) Draw a circuit diagram of this circuit.

c) Collect voltage and current readings for each device, including the power source.

d) Fill out (or recreate) the following table. Some information needs to be measured, some needs to be calculated, other known values must be determined by other means.

Device	Resistance (Ω)	Current (A)	Voltage (V)
Device	Equivalent Resistance (Ω)	Current Output (A)	Voltage (V)
Power Source			

4) With the data collected and values calculated, we analyse. What measure remained relatively **consistent** from device to device?

All devices that are in line will, in fact, always share a common 1)_____________.
(This is the part where you fill in the answer to the previous question)

5) Now we look at the source and, more specifically, the **Equivalent Resistance**, or $\mathbf{R_{EQ}}$. You are most likely wondering, "What is R_{EQ}" or something to that effect. Good, because R_{EQ} is a perceived resistance. A collection of resistors may have individual resistances, but as a whole there is a total resistance that can be determined. A circuit may be a complicated configuration of devices, but to a power source or battery a circuit has a single resistance. It is this **Equivalent Resistance** that, given a voltage, will determine the current output of the source.

The question still remains: What determines the R_{EQ} for devices that are in line? From the data collected and calculations, you may be able to determine it. Promised: it is a simple relationship for devices in line.

6) If you were not able to determine this relationship, the following will allow you to do so algebraically. If you were able to, you <u>must</u> derive it algebraically and the following will help you do so.
   a) First recall what measure remains consistent.
      Fill in here 1)______________ or make an annotation in your notes.
      This measure will now be known as "***1)***"

   b) Second, determine what measure is different from device to device.
      i) Fill in here 2)______________ or make an annotation in your notes.
         This measure will now be known as "***2)***"
      ii) How is the 2)______________ of the source related to the 2)______________ across all the devices (also known as 2)______________ **drops**)

   c) Write down this relationship (This is simple as well).

   d) Rearrange Ohm's law so that 2)______________ is a function of 1)______________. Rewrite this equation for the power source and each of the devices

      <u>For example:</u>
      i) For the source, the equation will be in terms of R_{EQ}, I_B and ΔV_B.
      ii) For the first resistor, R_1, I_1 and ΔV_1.
      iii) Etc.

   e) For the equation determined in part "*c)*" substitute **all** values of 2)______________ for what we determined they are equal to in part "*d)*"

   f) With this new equation you can factor out a common value and use the division property of equality to simplify.

   g) You should now have an equation that relates R_{EQ} to the resistance of the devices in the circuit. This equation can be generalized and can be used to determine the equivalent resistance of any number of devices that are in line

7) That concluded the analysis of a C1 type circuit. Next is a similar analysis of a C2 type circuit.

<u>The Experiment:</u>

e) Using the **other** 3 resistors (NOT the 100 Ω) and a bulb, create a C2 type circuit. That is, create a circuit where each device is within its own path, or **Parallel** to each other.

f) Draw a circuit diagram of this circuit.

g) Collect voltage and current readings for each device, including the power source.

h) Fill out (or recreate) the following table. Some information needs to be measured, some needs to be calculated, other known values must be determined by other means.

Device	Resistance (Ω)	Current (A)	Voltage (V)
Device	Equivalent Resistance (Ω)	Current Output (A)	Voltage (V)
Power Source			

8) With the data collected and values calculated, we analyse. What measure remained relatively (and for this case we mean RELATIVELY) **consistent** from device to device?
All devices that are in line will, in fact, always share a common
)___________.

(This is the part where you fill in the answer to the previous question)

9) Now we pose the question: How do we determines the R_{EQ} of multiple paths? When evaluating resistors in multiple paths, it is more beneficial to discuss the paths themselves then the resistors within. From the data collected and calculations, you may find this quite difficult to determine it. Promised: it is **NOT** a simple relationship for devices between paths.

10) If you were not able to determine this relationship, the following will allow you to do so algebraically. If you were able to, congratulations BUT you <u>must</u> derive it algebraically and the following will help you do so.
    a) First recall what measure remains consistent.
       Fill in here ١)_____________ or make an annotation in your notes.
       This measure will now be known as "**١)**"

    b) Second, determine what measure is different from device to device.
       i) Fill in here ٢)_____________ or make an annotation in your notes.
          This measure will now be known as "**٢)**"
       ii) How is the ٢)_____________ from the source related to the ٢)_____________ through all of the paths.

    c) Write down this relationship (This is a simple one).

    d) Rearrange Ohm's law so that ٢)_____________ is a function of ١)_____________. Rewrite this equation for the power source and each of the paths.

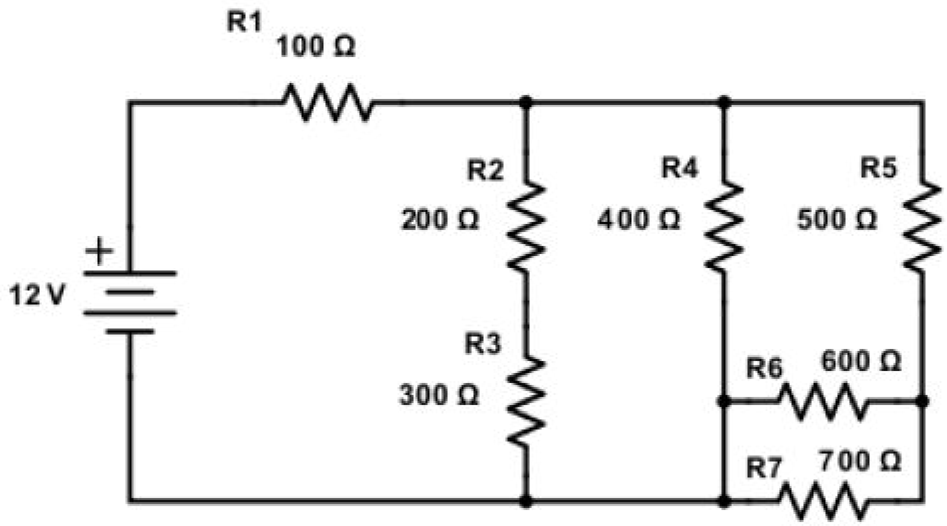
       <u>For example:</u>
       i) For the source, the equation will be in terms of R_{EQ}, I_B and ΔV_B.
       ii) For the first path, R_z, I_z and ΔV_z.
       iii) For the second path, R_y, I_y and $\Delta V_{y,}$
       iv) Etc.

    e) For the equation determined in part "*c)*" substitute **all** values of ٢)_____________ for what we determined they are equal to in part "*d)*"

    f) With this new equation you can factor out a common value and use the division property of equality to simplify.

g) You should now have an equation that relates R_{EQ} to the resistance within each of the paths in the circuit. This equation can be generalized and can be used to determine the equivalent resistance between any number of paths.

11) With the knowledge gained and formulas and equations derived, the final step is to put your understanding of the concepts to the test.



a) For the circuit above, determine the equivalent resistance (R_{EQ}) for the entire circuit.

b) Determine the amount of current output by the battery.

c) Determine the voltage of and current through each device.