Department of Physics

Electronics Safety and Introduction to Circuits

112X Lab 1

Last Edited January 11, 2024

Written by Dana

Lab Objectives

- Begin building electronics safety habits
- Understand the common components of a circuit
- Basics of drawing and reading circuits

Equipment

- Power Supply (from 0 to 3 volts)
- Vernier circuit board with lightbulb on board
- Vernier current meter (ammeter)
- Vernier differential voltage meter (voltmeter)
- 3 banana cables
- 2 aligator cables

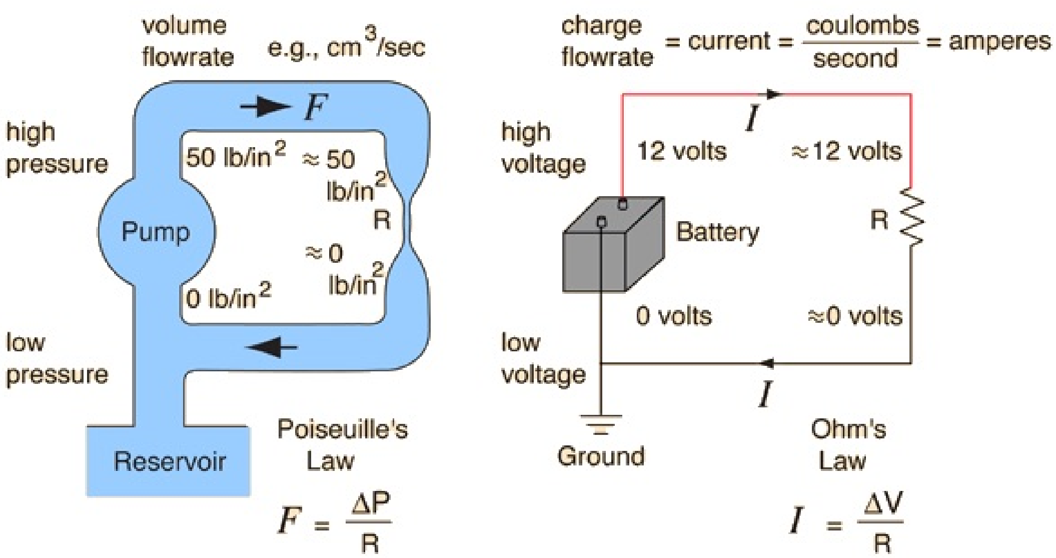


Figure 1: Example of the water analogy for circuits. For more details please see Hyper Physics's Page, from where the diagram came.

What are Voltage and Current?

When electricity is stationary and not moving we refer to that as static. When you switch on a light, however, your electricity is allowed to flow through the wires. That flows through wires has a motion, which we call its current. Current is measured in Amps (from the scientist Ampere, 1775-1836). Ampere also began the convention of saying electrical currents flow from positive to negative poles, which we now understand to be the opposite. Electrical current flow from negative to positive poles, but this matters for just a small number of phenomenon so the field keeps Ampere's convention. Current is measured with an Ammeter, as discussed elsewhere.

The easiest visual metaphor for current is that the rate of flow of water in a pile is completely analogous to the current of an electrical system.

Voltage is the potential energy difference between two points on a circuit. That is why one always measures the voltage of a circuit somewhat removed from the item you are measuring the potential difference across. Volt is named after Alessandro Volta, and is defined as "the difference of potential between two points when one joule of work is required to carry one coulomb from one point to the other".

Resistance, if we continue with the water flowing metaphor, restricts the amount of water that can flow through at that point. The water analogy will break down if you move outside of DC circuits, and it does not account for magnetism, but it is extremely useful for our circuit today. Please see Fig. 1 for an example of this.

Safety Rules

Safety is essential to this course, and your lab instructors will be making sure to remind you of these safety rules every lecture. Your quiz 1 will include many questions on these safety rules because we think they are important. You will not work with circuits that can hurt you in this class, but if you go to another class that begins working with higher voltage and current systems you need to know these rules.

1. Never Work On A Circuit While The Power Is Applied.
2. Always Turn The Power Down Before Switching Off A Power Supply.
3. If You Smell Anything Burning (Or Your Resistor Is Warm To The Touch) Turn The Power Off At Once.
4. Never Work Alone.

For more information on these rules please see the Appendix.

Question 1 *Why should you never work alone? What questions might you have about that rule? (3 sentence)*

The LoggerPro Board

Looking at the board before you, you can hopefully see the labels on it. If not perhaps you can see the labels on Fig. 7. Please see the Appendix for a more in-depth overview.

Question 2 **Getting Used to The Circuit Board**

Take a picture of your circuit board, or use the blank board on your worksheet, and label all the components you will be using or analyzing today. Include that picture in your worksheet, and include your labels on the circuit board. [a] *Those components includes:*

- *positive power input*
- *negative power input*
- *One 10 Ω resistor*
- *Lightbulb*
- *The Fuse*
- *The LED*
- *The Capacitor (to be used in Lab 3)*

[a] For a point breakdown, and some common mistakes, of each lab question, please see the rubric under the Canvas assignment for Lab 1: Safety. Also lab partners may not submit the same labeled diagram.

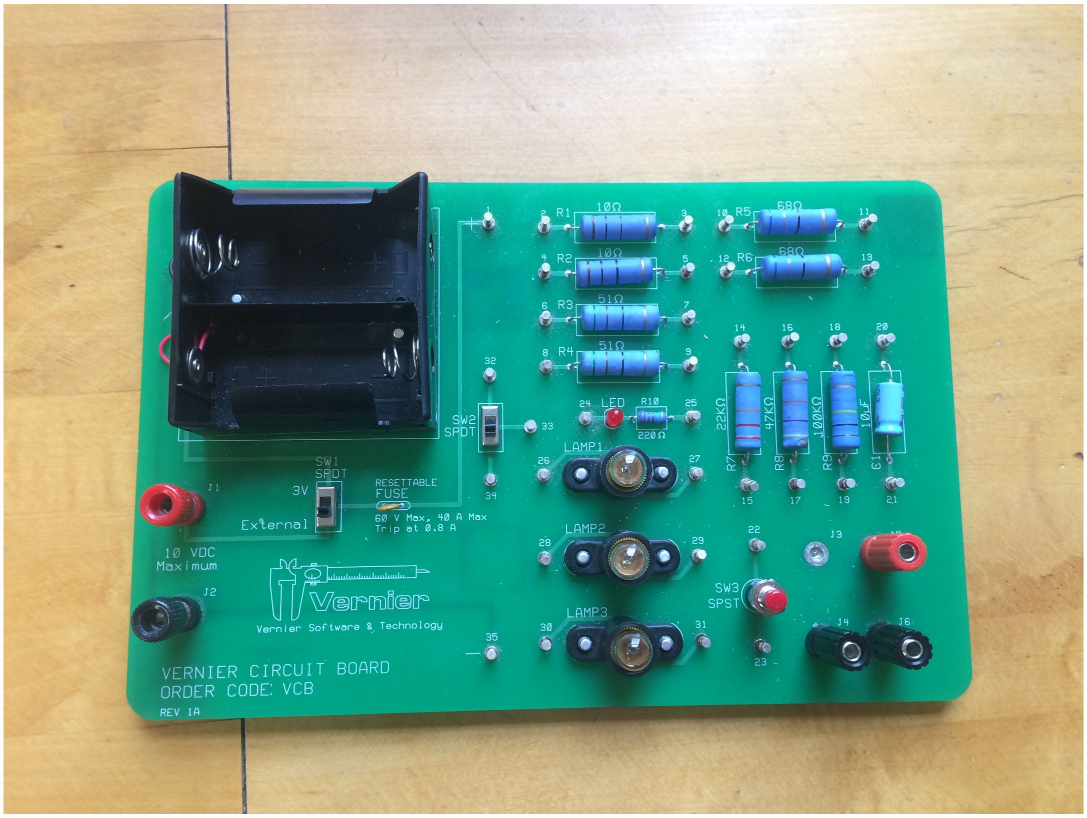
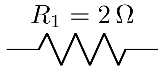


Figure 2: Example Vernier circuit board that we will use in all our experiments.

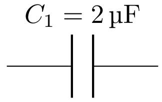
Drawing Circuits

$R_1 = 2\,\Omega$



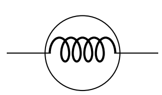
Resistors are drawn as in image above with the label $R_1 = 2\,\Omega$. The unit of resistance is the Ω symbol, which is called an ohm. It's SI base unit is $kgm^2s^{-3}A^{-2}$.

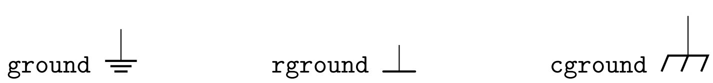
$C_1 = 2\,\mu\text{F}$



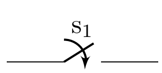
Capacitor's are drawn as in image above with the label $C_1 = 2\mu F$. The μF symbol is called an micro Farad. It's SI base unit is $1kg^{-1}m^{-2}s^4A^2$.

This is the symbol for a lightbulb, and we will be using this a lot today. Today you will work with the lightbulb to plot their voltage vs current curves (also known as an I-V) curve.



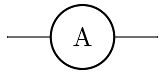


The symbols above are all possible symbols for 'ground'. On your power supplies you will often see the 'ground' or GND marking. They are often green on your power supplies.

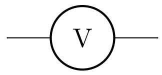


The diagram above is a switch. When a switch is 'open' the circuit is off and current cannot flow through a circuit. When a switch is 'closed' the circuit can run.

Measurement symbols



The A above represents where an Ammeter should be placed. Ammeters measure current, and should always be placed in series (interrupting the connection between two components) on a circuit. You will learn more about series versus parallel connections later in this lab.



Above is the symbol of a voltmeter. Voltmeters measure voltage, and should always be placed parallel (or around) to the component being tested. As you can see in Fig. 3 the voltmeter symbol is placed such that it spans the 10 Ω resistor. The voltmeter should always be placed around the component you are trying to measure the voltage of because otherwise it will interfere with the system, and will not be recording the voltage in the system.

The full circuit diagram for a resistor under test would be

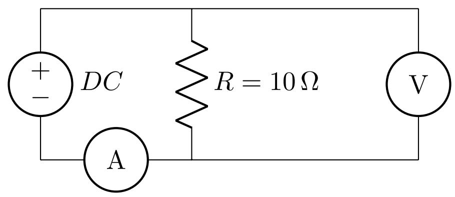


Figure 3: This is an example circuit diagram. On the left we have the DC power supply input. In the middle is the lightbulb. On the right is the voltmeter, which is parallel to the lightbulb. Then on the bottom of the circuit is the ammeter, which is in series with the lightbulb and DC power supply.

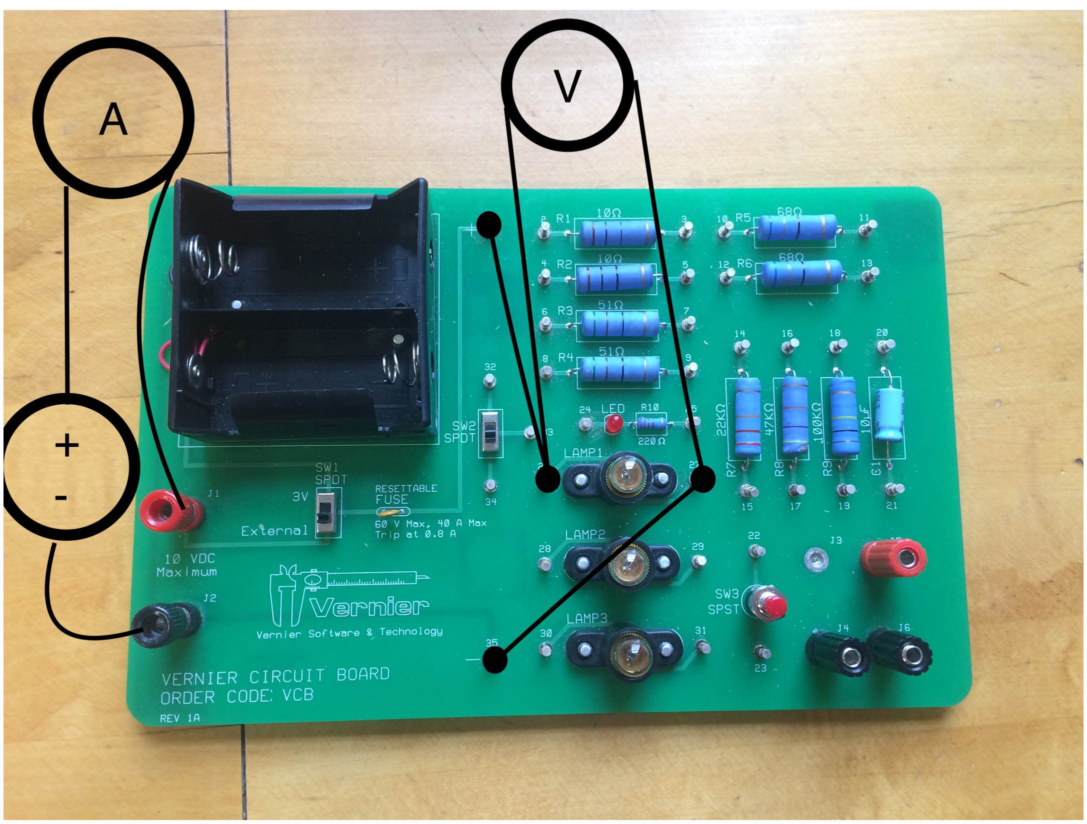


Figure 4: Detailed view of the connections with a lightbulb as the device under test.

Question 3 Practice drawing a circuit: Lightbulb

Looking at Fig. 4 which shows (from bottom left to right)

1. *The negative side of the DC power supply connected to the black connector, J2.*
2. *The DC power supply (positive side) is connected to an ammeter.*
3. *Then from the other side of the ammeter is connected to the the red connector (J1)*
4. *Then there is an internal connection to the + connector*
5. *In parallel with the lightbulb is the voltmeter*
6. *which then that is finally connected to the negative input of the DC power supply*

Please re-draw Fig. 4 with the appropriate symbols used above in the style of Fig. 3. [a]

[a] You may draw it by hand, or using the Word Scribble function, but please make sure the quality is high enough for your lab instructor to read. Lab partners may not submit the exact same circuit diagram.

Measurement tools for Voltage and Current

Your voltmeter (sometimes labeled 'Differential Voltage') will measure the voltage of the system. Voltmeters measure the potential difference between two parts of a circuit. That electrical difference is measured in 'volts'. Voltmeters often have a high internal resistance, which means they draw less current from the circuit, and therefore affect the system less.

The ammeter (also labeled current meter) will measure current. Ammeters are always placed in series (see Fig. 3, as items in series will experience the same current as the other components. Your LoggerPro ammeter and voltmeter will be connected to your LoggerPro box, much like the motion sensor was in 111X. Then you can open Logger Pro, which will record your Current and Voltage for you.

Testing and Experimenting with the Circuit Board

There are number of resistors and other components on the Vernier circuit board that you each have at your lab station. We will be using the light bulb.

On either side of the bulb holders are small metal posts, these are connected via a circuit board trace. You can use the posts to more easily connect your wires.

While the DC power supply that you have is capable of outputting 15 volts at 1 amp, it is important that you do not exceed the limits of the voltmeter and ammeter and wires. If your resistor feels warm, or you smell something burning, shut of your supply and ask an instructor to help check your circuit! **The limits of the sensors are *0.6 amps (600mA)* and *6 volts*.**

You should start by trying to turn on the lightbulb! Then if that works you can move onto taking the voltage vs current measurements for the lightbulb.

Data Collection

1. Open Logger Pro on the computer and make sure that both the current and voltage probes are recognized. While the current probe is disconnected from the circuit, connect the leads of the voltage probe together and zero the sensors in the Logger Pro software, this procedure will help minimize any systematic error. You should repeat this process often, certainly if you notice any odd measurements.
2. With the power supply off, connect the circuit as shown above in Figure 4.
3. **Turn down the voltage and current knobs on the power supply, then turn on the power switch.** While watching the display on both the computer and the power supply, slowly adjust the supply so you are outputting *3 volts*, you will have to adjust both the voltage and the current control as the output will be limited by the lowest setting. If your voltage or current is stuck, try changing the other knob! This is referred to as a 'current or voltage limited' situation. Often we set the current then change the voltage.
4. At *3 volts* the light bulb they should be visibly lit. If you do not see illumination at 3V, double check your circuit and then ask your TA to help. This is why we are starting with the lightbulb circuit, because you can so easily check that

it is working. Please remember to turn down the current and voltage when moving wires around. You do not need to turn the power supply completely off, but at least dial down the voltage and current.

5. When you are confident that your circuit is performing properly, collect data in logger pro for *10 seconds*, you should end up with 100 data points. You can change how data is collected by going to the menu item `Experiment > Data Collection` and changing the collection time.

6. Use the statistics feature to find the mean and the standard deviation for each graph (Click on the graph you want to get statistics for, then under the Analyze menu, select **Statistics**). Use the standard deviation as the uncertainty for the current and voltage.

7. Collect 10 data points in the same manner as above. Each data point should be at a different voltage between *0.1* and *3 Volts*. If you cannot take data at exactly 0.1V or 3.00 V that is fine, just try your best.

Clean Up Procedure

Once you have collected all your data, and before you leave for the day please make sure to

1. **Turn off power supplies.** You may leave them plugged into the walls, but make sure they are off.

2. Leave Voltage and Current probes (Ammeter and Voltmeter's) plugged in to the logger pro, but please make sure none of the wires are touching the ground. Please also leave your green box plugged into your computer and at your station.

3. Unhook your wires from your circuit boards, and place the circuit board back in their white boxes.

4. Put wires back in the white box, or if there is no room in the white box then put them in the communal wire box that is near the front of each room.

5. If you used a capacitor and attached it to the board **please do not remove it from the board after connecting it**. Too much connecting and unconnecting will weaken or break the wires eventually.

Question 4 **Data Visualization and Analysis**

Please graph your data you have taken for your lightbulb. You can use LoggerPro, Excel or Python, but your graph should follow all proper graphing rules, have error bars[a] *and a trend line. That includes a descriptive caption of what you looked at, and in that caption include what shape you think your graph follows, with that trend line applied.*

If you wish to use Logger Pro to graph these values the information on how to do that is below, in the Appendix. You will need create a scatter plot of the values from your table of Voltage vs Current of a lightbulb with error bars.

[a] Those error bars need to be formatted to the error you took, not a constant

Question 5 **Lab Modus Operandi**

Communicate the steps that you took when collecting and analyzing your data.

Pretend you are writing this so a fellow student that missed this lab could take and analyze the data using only this section. For example, you do not need to tell them to press start in Logger Pro or open the program, but you would want to tell them what sensors you used to collect data and if there are any special settings that you used. (3-4 sentences)

Question 6 **Conclusion**

In your own words, please reflect on what we worked through today, and write 3-4 sentences on what you think you learned during this lab. What further questions do you have about this lab? Please do not copy any of the lab instructions. [a]

[a] Please try to use physics terminology to address this question.

Graph and Data Checklist:

You should have written an answer for each section highlighted by the gray boxes. Make sure that you used complete sentences and that your conclusions match your results. You should also have **1 table** and **1 graph** showing your data.

You also have a lab quiz on Canvas that will focus on safety and lab rules. That quiz is untimed, and you have as many tries to pass it as you wish. The quiz is worth 6 points of your final lab grade.

Question 7 *For up to 1 point of extra credit please draw out a circuit of an LED under test.*

Question 8 **Extra Credit: Creative Safety Rules Reinforcement**

For up to 3 points of extra credit please create your own Electronics Safety Meme! They do not have to be good (see Fig. 5), but please integrate one of our four safety rules, and state which rules you're trying to convey.

Lab Instructor's have final discretion if your meme makes sense or not. But again, you just have to be as good as or better than Fig. 5. Please include a comment in your figure caption for the meme that includes these two things. First, what safety rule you are trying to demonstrate, and secondly, if we are allowed, or not allowed, to post your meme on our lab instagram page. If you are fine with us posting your meme, please include how you'd want to be attributed.

Partners cannot submit the same meme.

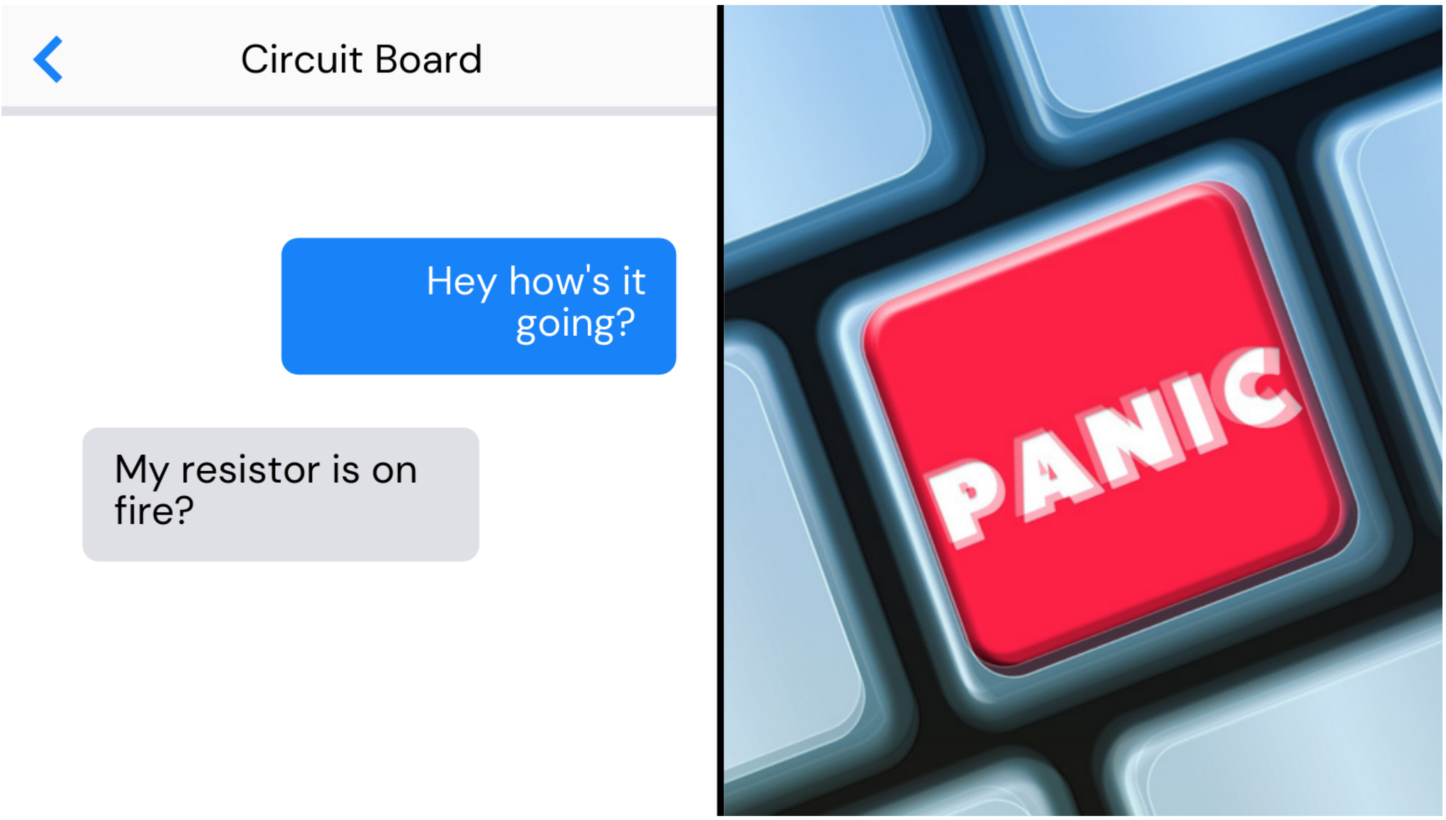


Figure 5: Here you can see a meme, indicating one of the four safety rules of electronics lab. This one is meant to exemplify rule number 3 (IF YOU SMELL ANYTHING BURNING OR YOUR RESISTOR IS WARM TO THE TOUCH TURN THE POWER OFF AT ONCE.). As it says, once the circuit board's resistor is on fire one can Panic, but then turn off the power supply and let my Lab Instructor know. // You can use this meme on the instagram page, but anonymously

Appendix

Safety Overview

Never Work On A Circuit While The Power Is Applied

This was written for much higher voltages and currents than the ones we will use, but the rule remains because you should always practice good safety so to maintain the habit when it matters. These habits are learned through repetition, and one of the learning objectives of this class is that you can practice good electronics safety without conscious thought.

To quote the Canadian Center for Occupational Health and Safety, (Canadian OSHA),

> People are injured when they become part of the electrical circuit. Humans are more conductive than the earth (the ground we stand on) which means if there is no other easy path, electricity will try to flow through our bodies...
>
> These injuries can happen in various ways:
>
> Direct contact with exposed energized conductors or circuit parts. When electrical current travels through our bodies, it can interfere with the normal electrical signals between the brain and our muscles (e.g., heart may stop beating properly, breathing may stop, or muscles may spasm).

Always Turn The Power Down Before Switching Off A Power Supply

Similar to the concern above when you work with high enough voltages those power supplies are not always equipped to handle large changes in power. Thus, if you were to switch the power supply off quickly the quickest path from the power supply to ground could be through your hand turning the dial down, harming you in the process. When you approach a power supply you make sure the power is all the way down before switching it on.

If You Smell Anything Burning (Or Your Resistor Is Warm To The Touch) Turn The Power Off At Once.

Resistors limits the flow of electricity through a circuit. Part of that process means slowing down the current as it travels through the resistor. When the current slows down it produces heat as the electrons meet resistance.

Resistors are equipped to handle only so much power (Voltage time Current). That is indicated in their voltage rating, and when a resistor is under their voltage rating they should be cool to the touch.

When a resistor encounters too much power, however, they warm up. If they warm up too much they can catch on fire. If they catch on fire, or **feel warm to the touch** please turn the power down and leave your circuit alone until either it feels cool to the touch or your Lab Instructor says it is fine. Resistors are cheap, and so at one point in the lab your Lab Instructor might set one on fire so you all know what burning plastic smells like.

Link to an article on the physics behind this.

Never Work Alone In A Room

For the three reasons outlined above please never work alone in our labs with electronics. You should always have your Lab Instructor, Dana (ldana@wpi.edu), or peer's who are trained in basic electronic safety while working on electronics. If something goes wrong you need someone else there to help out.

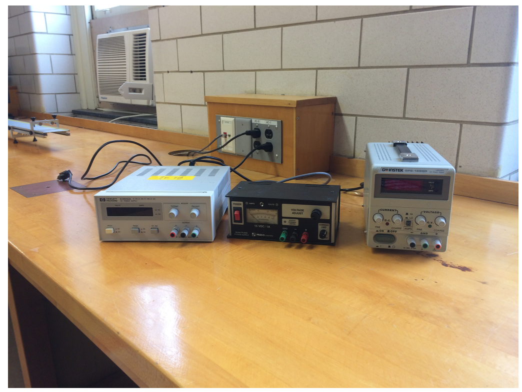


Figure 6: Example of three of the power supplies you may find in lab. Before turning the power supply on please turn the current or voltage knob all the way down (counter-clockwise). If you are just approaching the power supply you should never assume that the previous student did the correct thing and turned the power down themselves. If you were the last person to turn the power supply off it is still useful to check and make sure you turned the voltage or current down before turning the power switch on.

Detailed overview of LoggerPro Board

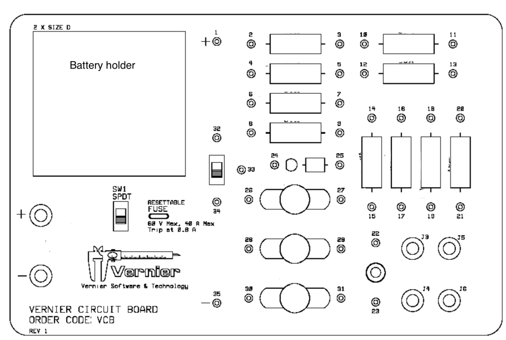


Figure 7: Diagram from Vernier of circuit board. You will find your boards similarly labeled.

For a brief overview

- J1 (red) on the far left of the board is where you input the positive voltage from your DC power supply.

- J2 (black) is where you put in your grounded voltage from your DC power supply.
- SW1 or SPDT is a switch. If it is up, or towards '3V' your circuit is expecting power from the battery holders in the top left of your boards. If it is down closer to 'External', as we will typically keep it, it is expecting power from your external DC power supply.
- R refers to resistors, with the value of the resistor written on top of the resistors.
- LAMP refers to lightbulbs
- C refers to capacitors, and there is only one on the boards with a value of $10\mu F$ (the F refers to Farads). Sometimes your capacitor will not be exactly that value, so it is useful to check the labeling on the capacitor for it's real capacitance.
- LED refers to the light-emitting diode, commonly called a LED. You will notice there is a resistor next to it (on the right if you are looking at your board the same direction that Fig. 2 is orientated). That resistor helps protects the LED. The LED will only turn on if you have the positive voltage on the same side as the resistor.
- Resettable Fuse is a fuse through which your current will flow. This fuse will stop power flowing through the circuit if the current or voltage becomes too large, which is helpful in preventing the resistors from catching on fire (see section If You Smell Anything Burning Turn The Power Off At Once).

Example Table for Data Collection

The Figures and Caption Rules

There are a few very important aspects to creating a proper figure and caption. If you follow these rules, not only will you get points on your physics lab grades, you will impress your instructors and peers in the future.

The Caption

- The caption should start with a label so you can reference the figure from other places in your paper/report. For this course you should use "Figure 1", "Figure 2", etc.
- The caption should allow the figure to be standalone, that is to say, by reading the caption and looking at the figure, it should be clear what the figure is about and why it was included without reading the whole paper.
- The caption should contain complete sentences and be as brief as possible while still conveying your information clearly (this is not always easy).
- Please add captions to your tables as well, otherwise we will not know what we are looking at.

The Figure

- **Make sure that the resolution is high enough to not be pixelated at its final size.**
- Check that any text is readable at the final size (Using a smaller graph in Logger Pro will cause the text to be larger in relation to the graph when inserted into another program).
- For graphs, ensure that the axes are labeled (including units) and that there is a legend if you have multiple data sets on the same graphs.

Tables

- The first row of the table should be a header, where each item is labeled with what is contained in that row. If it is a physical measurement it should have the correct units.
- For tables include a short caption of what is contained in the table, or what was examined.
- The caption should start with a label so you can reference the figure from other places in your paper/report. For this course you should use "Table 1", "Table 2", etc. For an example of a good table caption please see Figure 8.

Table 1. Baseline characteristics of study participants

Variables	Intervention group (n=14)	Control group (n=15)
Women (no [%])	7 (50)	5 (33)
Median age (range)	22.0 (19 – 58)	21.0 (18 – 70)
First winter in icy conditions (no [%])	—	1 (7)
Previous falls on ice (no [%])	8 (57)	11 (73)
$\geq$ 1 fall this winter (no [%])	4 (29)	7 (50)
Injury from fall this winter (no [%])	1 (7)	—
Time been walking this route (no [%]):		
<6 months	3 (21)	2 (13)
6–12 months	9 (64)	9 (60)
>12 months	2 (14)	4 (26)

Figure 8: An example table from the paper Lianne Parkin, Sheila M Williams, and Patricia Priest, "Preventing Winter Falls: A Randomised Controlled Trial of a Novel Intervention" 122, no. 1298 (2009): 9.

How to make a graph in LoggerPro

1. Disconnect your sensors and open a new Logger Pro file (please reconnect the sensors for the next students when you are finished)
2. Create 4 new manual columns in Logger Pro `Data > New Manual Column` for you to enter the data that you collected. The new manual columns could be named: "resistor voltage", "resistor voltage" uncertainty", "resistor current" and "resistor current uncertainty"; etc.

3. Create a new page `Page > Add Page` and insert a table using `Insert > Table`, make sure that the table is large enough to show all of your new columns. You can now enter your collected data into the appropriate columns.

4. Double click on the top of each voltage column, go to the settings tab and set your voltage uncertainty column as the source of error bars in the bottom right of the screen as shown in Figure ??. Do the same with each current column.

5. Create another new page and insert a graph. Set the graph axes to be Voltage on the y-axis and Current on the x-axis for one of your components. Make sure that your error bars are visible on the screen and change the title of the graph to correspond with the component that your data is from.

6. Add a trend line if required

   (a) To perform a linear fit on each graph where you think the data may be linear in nature,

      i. Highlight the part of the graph that is linear.

      ii. Select 'linear fit'

      iii. Move the text box into a position that does not cover the data points. Show the uncertainties in the fit by right clicking on the box, selecting "**Linear fit options**" and checking the box marked "**Show Uncertainty**" as shown in Figure 10.

   (b) To add a polynomial trend line,

      i. Highlight the part of the graph that you wish to fit.

      ii. Select 'Analyze' then 'Curve Fit'.

      iii. Select the equation you wish to apply to your curve.

      iv. Select 'Automatic' and then 'Try Fit'. That will change the parameters of your fit values. Once the fit looks good please select 'OK'.

      v. Then right click on the information box on the graph and select 'Fit Options', and select 'Show Standard Error'.

7. Copy the graph in to the results section of this file below, one for each component tested (**a total of 2 graphs**). Remember to format the figures correctly and include a caption as described in the review below.

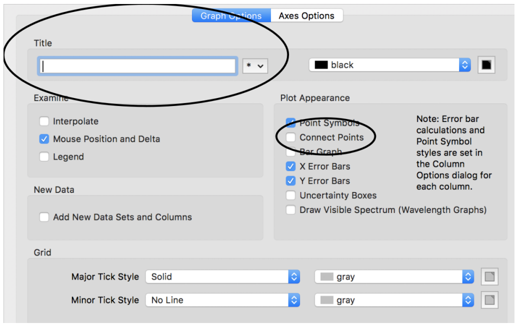


Figure 10: Graph options dialog, add a title, check the "Point Symbols" box and **uncheck** the "Connect Points" box.