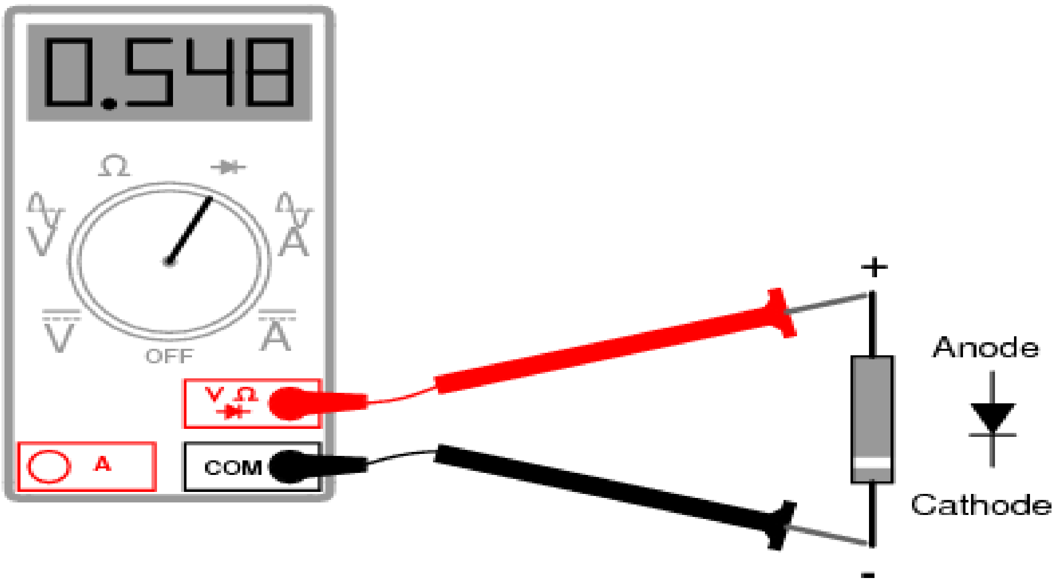
College of the Canyons: MakerSpace: The Multi-Meter….The Scientist's Friend!



This diagram shows an example multi-meter set up in a way to test a diode. Your multi meter is a 7-funtion device that uses the leads to test 6 of these functions. The 7th function is a port especially designed for testing transistors. It requires that you rotate the dial to the Hfe setting, which is at approximately the 5 o'clock position on the dial. Leads, dial setting and a few simple tests are what await you in this introduction to multi-meters. Please keep this lab handy as the multi-meter may or will be used in other labs and will certainly be used to detect the "output voltage" as a way of reading your soon to be created spectrophotometer! To put this another way, this device is actually a part of the final spectrophotometers you will be making as well as one of the basic pieces of technology you will work with in lab.

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For information on:
How to restock /secure items from MakerSpace. Location of "stock items" in lab. (box, component, multi-meter, etc.). Obtain electronic copies of this protocol @: http://www.canyons.edu/Offices/SchoolofAppliedTech/MakerSpace/Pages/default.aspx
MakerSpace: STCN 132, M-Th- 9:00 AM-6:00 PM F, Sa, 10:00 AM-2:00 PM
Prof. Jim Wolf, Biology Faculty (661) 362-3092 or jim.wolf@canyons.edu

Technical /Curricula Note: This lab should be printed and addressed partially in the first section of the class (sometime during the first few weeks of class, and definitely by the 4th or 5th week). Student groups formed in the spectrophotometer portion of the class (weeks 1-5) will want to print this lab up and bring it with them to the last of the meetings in the spectrophotometer series. Depending on group dynamics and decisions, the instructor may want to redirect the students into new working groups for the MakerSpace part of the course. It should also be mentioned that for a variety of reasons, the students' time in MakerSpace may vary and some students may go to MakerSpace with little to no faculty guidance. Others may want to work with the faculty on each lab. Add to this, the lack of clarity as to how well MakerSpace can accommodate a lab of this scale (8 groups of 3 students (24 students, could they even all fit), and it may change the very format of these and other **prototyping labs.**

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A. Objectives:

1. **Discover MakerSpace resources via a review** of a select group of MakerSpace items including: class meetings in MakerSpace, MakerSpace lab components, on-line resources, forms to be reviewed and papers to be signed.

2. **Introduce your team to a multi-meter**. Learn how to turn it on / off, attach leads and identify a select group of settings and related read-outs: such as: conductivity / resistance, battery testing and diodes. <u>*More functions will be covered in later labs FYI.*</u>

3. **Build a familiarity with electrical components and** introduce some parts of a spectrophotometer. List of parts, roles, schematic and visual descriptions. Selected parts for multi-meter tests include: power source (batteries), diode, resisters, switches, wires leads/connectors and alligator clips. More parts/ roles will be covered later FYI.

4. **Multi-meter tests**. Using probes and various alligator clips and wires, conduct simple tests on conductance, resistance, voltage and diodes.

5. **Resistor measurements**: **As time and resources (supplementary lab resources /online resources) permit** investigate resistance values, use of color codes and introduction to variable

resistors. Apply formulas for resistance calculations based on series and parallel circuits and verify that calculations and experimental values match.

6. Visit via **provided links** in order to review resources that cover concepts of circuit design and schematics, technical reference and various resources to permit more deeper examination of pending concepts (as time, interest, group dynamics permit).

7. Note lab structure / layout and recommend or comment on lab design format and consider **editing, updating** lab as needed.

B. Background Reading and How to Use This Handout:

This lab is available on line. A hard copy should be printed by each team member and completed as the various lab activities are conducted. Time permitting, this lab may require 2-3 visits to MakerSpace. ***Also***, ***as the individual students / team may want to revisit some of these activities a second or third time*** to ensure comfort with not only the provided theory, but the technique and technology. You may consider revisiting lab or with a group, with or without faculty help?

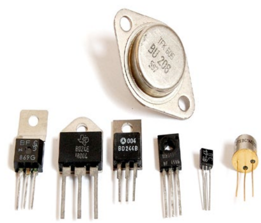
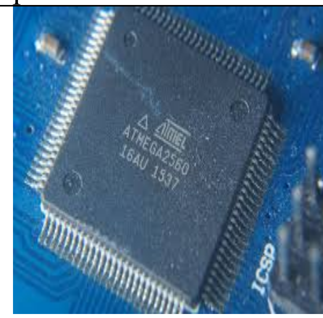
This lab is the first in a series of labs where you will be introduced to MakerSpace, work as a team, and need to be frank as to what parts of the lab do, or do-not make sense. You have spent the last part of this course in lab refining techniques and theory as they relate to the use of spectrophotometers and the creation and critique of a series of standard curves. You will now be asked to carry out the next series of labs in MakerSpace and possibly other locations. You will also be doing some labs that are new not only to you, but are also new to academia. The subject of building a working spectrophotometer covers MANY disciplines in science including: physics, engineering, biology, optics, electronics, engineering, 3-D printing, prototyping and countless other disciplines. So; again, let your instructor know what works, what does not, etc. You are not merely taking the lab, you are helping to refine it and design it in a way that will help make the class a better learning experience for later generations of students. You may need to read ahead, review a video, practice an activity, and despite our best efforts, you may fail! This is a reflection of the fact that the lab is both ambitious and the process of prototyping a working spectrophotometer has countless ideas, processes and techniques that could result in failure even if techniques and practices are meticulously followed. This is part of the immersive nature of this course. By trying and failing, you are setting the stage for doing some genuine science. Unlike a class where you fail a test, in an actual science setting, negative (or failing results) are not necessarily bad. You will simply need to repeat, reinvest and collaborate in a way that will hopefully get you where you want to go. So where do we start?

Given this involved prototyping lab series, these first activities is to be taken very seriously. The previous lab on volumetric technique should help you see the need for addressing technique very precisely when learning how to use a new piece if technology (i.e. micropipette). You will be introduced to a new piece of technology that you will see many times over the course of the coming labs. It is called a "multi-meter". You will not only be asked to use this device many times, you will need to find various ways to ensure you know not only the theory of the device, but also the application of this theory as you use this device. For instance, you will need to know how to measure an electrical current and then use this idea to check to see if the device you made has connections that will conduct electricity correctly. So, what are the things we want you to accomplish in this first lab of this ambitious lab series? First, we want you to get into working groups. These groups may be the same folks you were working with during the first part of this class, or it may be changed some, so that the shared skills of the group will help better ensure success in this part of the class. You will also need to go to the MakerSpace website to not only upload the next set of labs in the series, but to also make sure you address some introductory parts of the various labs. This includes some paperwork and reviewing some safety videos. Once you review the background information, get a copy of the lab activity and ensure everyone has viewed the videos and completed the paperwork, again; you will want to make sure you get to lab as a group and complete each activity as a team. This teamwork will still require that each member of your group complete a lab hard copy and keep these completed labs in your individual binders (this goes along with, and is in the same pattern that you established with the first part of the course). Every lab in this series will have a background part, and each section within the labs (lettered, see table of contents) will also have a brief bit of background. There is also a technical reference lab under development. This lab will serve as a reference lab where additional information on a range of subjects will be covered. Some ideas from the previous spectrophotometry labs may be in this lab, but most of the resources in this technical lab reference lab are from this prototyping lab series. Everything from where to order more light emitting diodes (LEDs) to technical literature on the LEDs optical properties as well as many of bits of technical literature that may help you with some aspect of this prototyping lab, especially if you decide to **retake the entire lab series** and want to work on or help to develop a more sophisticated prototype. This lab is tentatively called the "**Technical Literature Reference Lab**" or "**TLRL**" for short (nifty sounding name ehh?).

How to use this handout: The remainder of this lab series assumes that as a student, you have little to no background in solid state circuitry. This is not surprising, as most students have grown up in the era of the integrated circuit (or chips, computer chips, etc.). Within one computer chip, a billion components (mostly transistors) may be present. This has resulted in two trends in technology. First is the amazing amount of technology possible in a small device like a cell phone. A simple cell phone has more components and technology that the entire space program (that took humans to the moon)! Second is the concept of repair.

With very few exceptions, modern electronic devices are not repaired. The device is either entirely thrown away, or the chip or integrated circuit replaced. This has resulted in generations of students that have no familiarity with circuits, as there are very few devices currently made that use solid state circuit design. Solid state technology is the generation of electronics before chips and after tubes. See below images to clarify this progression. The transistor replaced most tubes and other components like resistors and capacitors were all made smaller, but some still existed as individual components on a readily observable circuit board. This prototyping lab will allow for students of science to create a solid-state spectrophotometer. By doing so, teams will learn valuable skills useful in many branches of science as well create some devices that will be used as part College of the Canyons Biology outreach program. These skills will be addressed over the breadth of the lab series and some skills have already been addressed in the spectrophotometer labs leading up to this prototyping lab series.

Image 1: Tubes, transistors and microchips allows for circuits to be built smaller and smaller. A modern cell phone built from tubes would easily be the size of a city bus!

Tubes: Average size about that of pill bottle.	**Transistors**: Average size, about size of pencil erasure	**Microchip**: billions of transistors and other parts on a postage stamp sized platform!
		

Ideas like volumetric theory and devices, standard curves, linear and log-based graphs as well as many non-scientific but equally important skills will further be developed. Working with groups, multitasking, delegating, paying attention to details, practicing a process as part of the technique idea inherent in any lab; and also giving back. These labs are as novel as they are difficult to develop. Prototyping is very demanding process and does not always work, even when trained professionals are used. Trying to create a series of labs where students can learn these skills is something cannot be completed unless we plan for total immersion in the process. It is not enough to talk about lab goals, create a lab activities or other assessment ideas. We need the process to be successful, but at the same time are training students on the process. So, enjoy this lab series, make every meeting, collaborate with fellow students, faculty and staff that are helping make this lab opportunity as real and useful as possible. Give back! Let us know what worked. What is broken? What was easy? You input is not only needed, it is required!

Lastly and additionally, these activities should be read in their entirety before doing the lab. If there are not read in lab, be sure to try to do this as homework. Once the readings are completed, the lab activities should be addressed in order initially (first time you attempt the labs). As you become more familiar with labs, devices, etc., you may want to revisit (and even repeat) a certain part of the lab as needed. **So, keep this lab a reference**.

C. MakerSpace Introduction: Working Groups and…

What to do? Start by putting contact information for all members of your working group. This may be handy for use later, and as your notebooks with the MakerSpace protocols will most likely stay in MakerSpace (when they are not with you or your group during the scope of this project), it may prove useful to have contact information available to all for a million unforeseen reasons!

Table 1: WRITE LEGIBLY: Working Group: MakerSpace Prototyping Exercise:
Lab Start Date_______________

Name	Email	Phone	Comments:

Find MakerSpace? You will likely be reading this while in one of the labs that is a run up to the prototyping labs or after printing up at home, so the first step is to simply find MakerSpace and when to meet?
MakerSpace Lab is located in STCN (student center) 132: Hours are M-Th 9-6 and F/Sa 10-2. It is right next door to the cafeteria / Subway FYI. Please check hours during a transition period: start of semester, spring break, etc. as hours tend to vary. Lastly, you can check out their accessibility @
www. http://www.canyons.edu/Offices/SchoolofAppliedTech/MakerSpace/Pages/Hours.aspx
or call 661-362-3601

Check out safety videos: Prior to coming into Makerspace for the first time, you will be asked to view 2 or 3 safety videos (more later as more skills / technologies are addressed). Please view ***Basic Shop and Safety Videos 1 and 2*** pull down menu @ following link:
http://www.canyons.edu/Offices/SchoolofAppliedTech/MakerSpace/Pages/default.aspx
Be sure to watch both videos and note link as you may want to revisit these videos or look at other content as directed, etc.

Paperwork: Wahoo! It would not a lab experience without some forms to complete. **Prior to attending your first MakerSpace lab you should complete two of the forms associated with working in MakerSpace. These forms are available on the pulldown menu, MakerSpace URL:**
http://www.canyons.edu/Offices/SchoolofAppliedTech/MakerSpace/Pages/default.aspx and look under forms. Please print a copy of both forms and complete all of the requested information on the:
a) MakerSpace agreement and
b) MakerSpace waiver
PLEASE NOTE: Both of these forms will require signatures / information from one's parent or legal guardian to be complete (if under 18).
All good lab experiences come with paperwork and a certain amount of redundancy, and this lab series is no exception. Please check off all of these items as you address them and then be sure these have all been checked prior to your first time visiting MakerSpace.

- **Working Groups Identified?**
- **MakerSpace Location Noted?**
- **Check-Out MakerSpace Website and View Both of Two Safety Videos**
- **Print-Up and Complete 2 forms / Bring With You to First Meeting!**

4 checks in 4 circles, and you are on your way to an amazing lab experience in MakerSpace!

Wahoo!

Equipment Check Out: Concurrent with this lab and the completion of the paperwork your group will be given a multi-meter and a box with a few select items in it. It is very important that you take a few minutes to review the contents of this box and to create labels that will help you identify your multi-meter and equipment box both later today and in **subsequent labs**. Please bring this lab copy and have it turned to the page with your groups' signatures. Also have all of your paperwork (signed). Concurrent with turning in all of your forms your group will be given a box. A label set will be made for both your box of supplies and your multi-meter. These items will be stored in MakerSpace, so be sure you not only review the contents of the box, but make sure to note where your items are stored in MakerSpace. The items you will check out is a multi-meter and a small plastic box (like when you go fishing!). The contents of the box will be checked off in the next section, and for now, affix labels (one set to your multi-meter and one set to your equipment), note contents, use rubber bands to seal box and attach multi-meter to box. Finally make sure **everyone in your group knows where your items are stored in MakerSpace**.

D. Equipment List and Item Check Off:

These items will be provided to you at the start of this lab/section. Please remember to affix labels to both your multi-meter and to the parts box. As you go through the part list, check off the items as you identify them. Many of the items will be seen in later labs, exercises, etc. As these labs unfold, additional information about how to describe them, features about the parts, etc. will be discussed, but for now, take a minute to ID what you can do and if appropriate make a drawing or make notes to help you recognize these parts as they are mentioned in later labs. CHECK off the items as you verify / ID them and let the staff know if any items are missing, not clear, not working, etc. On page ___ there is a partial list of some of the components required in the final device assembly, and other labs will also cover components, parts, images as needed.

D. Equipment List and Item Check Off: Reference images of page ___ or google, ask, etc.!)

Item Description	Number	Checked	Comments
Multi-meter	1		Ensure it turns on / put label on it.
Multi-meter leads	2		Red and black (pair)
Alligator clips and wires	2		Various colored wires with alligator clips at either end.
Light Emitting Diode (LED)	4		Clear, plastics with two leads, emits light under certain conditions.
resistors	12 total		3 sets of 4. Each set a different resistance: 330, 1,000 and 10,000 ohms
regular diode	1		Grey with black stripe, with two leads or wires attached.
batteries	3		1.5, 3 and 9 volt: Pg ___ for image.
Small piece of wire (insulated)	1		Insulation is plastic, metal core (copper), different colors FYI.
Small piece of solder	1		Solder is lead and tin. Looks like wire, no covering, flexible.
Variable resistor	1		3 prongs, small dial on side, usually blue /white
Label tape	1 strip		Wrapped around 1.5 volt battery.

Plastic parts box	1		Place label conspicuously, rubber band shut!
Magnets	2		Used for final prototype assembly.
Extra items????	Other items may be placed in box but	Not in time to get into	You copy of this lab!!

E. Multi-Meter: References, settings and a few basics:

Parts of many of these labs will be **repeated**. You may be asked to find and identify information related to circuit design on a specific subject no less than 10 times over the course of this lab series on prototyping and manufacturing a spectrophotometer. For instance, the first piece of technology you will be introduced to in this lab is also the device you will use every time you operate the spectrophotometer you will eventually make! **This repeating is not an oversight**. ***It is a central theme in all things technology***. You need to become very comfortable with the theory behind all of the activities we do in lab, but at the same time the lab practices and techniques are equally and even occasionally more important. For this and many other reasons the first piece of technology you will work with is the Multi-meter. These devices range from phenomenally expensive pieces of technology to relatively inexpensive units ($3.99 up to $199.00) like all multi-meters, your device can measure a range of scientific data (7 "types" in general). As you complete the labs and use the multi-meter and associated technology, you will be expected as a group to understand every operational aspect of the device as covered in this lab. ***It is not acceptable if you watch a colleague make measurements! Remember, science is not a spectator sport. You will want to complete every technique in lab yourself.*** You might even want to repeat many elements of this lab activity. As your comfort and knowledge grows, with each activity, you may be surprised by the role repeating plays in science! Not only will the repeating help obviously refine your technique, it may help you expand your theoretical frontiers. For instance, you will discover the device can be used to measure resistance (a value which gets a lot of discussion in the Technical Literature Reference Lab as well in many later labs), and with some practice this resistance setting can be used to measure current flow. Since current flow and resistance are somewhat the opposite of each other, it may seem confusing. This idea of using a device in this way is part of the theory and practice part of these labs. **You will appreciate how these theoretical opposites can be used when making measurements within lab. Theory and practice reinforce each other.**

Color codes, resistance calculations, tolerances and even the size of the device /component have some bearing on the theory and operation of the device. But there is also a simpler use of resistance in that we only have three resistors in our final spectrophotometer circuit. Resistors are among the easiest of devices to install correctly. They are hard to break, and if you spend some time with the multi-meter, you may discover that resistance can be used to measure the phenomena of conductance or circuit flow. These ideas; resistance and current flow, are essentially the opposite of each other, and there is certainly more one could cover. How much of the theory you decide to learn is up to you (to some extent) but appreciating the use of a resistor probe as a conductivity meter may help you to have confidence in the manner with which you assemble your spectrophotometric circuit / device. So, let's get to work and refine our technique while we work with the multi-meter and keep hacking away at the accompanying theory! Rinse, lather, repeat (more on this later).

E: Continues: A FEW BASICS:
LAB ACTIVITY: HAVE MULTI-METER AND BOX OF SUPPLIES HANDY AND AVAILABLE FOR USE AS NEEDED!

1. Leads, positive, negative, (+/--) red / black, ground? Accompanying your multi-meter are a set of leads: one red, one black. The leads that come standard are good for pushing into crevices or other cramped spaces associated with the minute gaps seen on most circuit board / devices. They can also be used to insert into the gaps seen on "breadboards" (discussed later). For now, you will want to make sure you appreciate the significance of these leads and what they tell you. Like any big idea in science, the roles of the leads also may lead to many different ideas, so for now you need to know **a few basics**, but like any subject, this too can "lead" to lots of investigations or problems if not addressed or used correctly (**get the pun**?).

2. Alligator Clips and Leads: These are essentially small pieces of wire (AKA leads) with a "jaw-shaped" clamps that are spring loaded and attached to either end of the wire. Squeezing the clamp allows for opening the jaws which then will grab tightly to whatever the user wishes attach them to (upon release). It is a slightly more permanent use of multi-meter in that the user assumes the connection is solid unless noted otherwise, and that the user does not hold the clips in place as is the case with the pointy leads. A pair of these are included with every kit (different colors), and more may be available for use in later labs as noted.

3. Leads? Plug them in? The sharp, pointed leads are designed to plug the multi meter into small crevices, openings, etc., (and alligator clips can then be attached to these leads as needed). The two ends of any one lead are different and the blunt end is also known as (AKA) as a "banana plug". For now, you will want to insert the leads into the correct holes located in the right, lower corner on the front of the device. The red probe / lead should have the banana plug end gently pushed into the middle hole on the front of the multi-meter, (the lower right corner of the device with the **VΩmA** (in red letters) notation on it). The hole below it is for the banana plug end of the black lead (COM, short for common lead, ground, negative or black lead (**see table P on page 15??).** *The upper most plug port (next to 10 A setting on dial) WILL not be used as it is used to measure VERY high amperage, and none of our designed labs reach this high a voltage.* For almost all uses of the multi-meter used in this lab (and entire course) these holes will be used as noted, and you can reference the **Technical Literature Reference Lab (TLRL)** for more information on the other settings, banana plug receptacles for the device or other uses for the devices that require using these other "plugs / settings."

4. On/Off: This may sound flippant, but the on-off switch should be addressed. Be sure to turn on the device only after you are clear as to what you intend to do. While it is not easy to change, the device does have a 9-volt battery inside. It will power the device for a very long, but obviously, only using the device when needed and thus only turning it on as needed will help extend the battery life. Depending on what setting the dial is at, the display may vary from 1 to 0.001 or some other variation. Any indication of a working display can be used to indicate the device has adequate power. If the battery is low, the display will become dim shortly after turning on (or possibly display a battery icon in some devices.)

5. Settings: The Dial and the Display: The display is a LCD (liquid crystal display) that has 4 digits and a few other elements that appear at various settings and /or conditions like low battery mentioned above. The digit display looks like "**1888**", and there is a decimal; and other elements that will become important later. With the device on, and the leads NOT connected, turn the dial slowly in any direction. You will see various elements of this display flash <u>into</u> and <u>out-of</u> appearance. To better understand the use of the multi-meter, the dial positions need to be looked at. Additionally, what the display says at each of the settings will also get some attention. ***<u>So, we will repeat the process of going around the dial two times (rinse, lather, repeat).</u>*** **The first cycle** will focus on the **dial position** and what **<u>values are inferred on the dial</u>**, how we will use some of the selected settings, etc. **The second time** around the dial will **<u>focus more on the display</u>** and focus even more specifically what the numbers mean and what parts of the display should warrant extra attention (numbers, decimal, etc.). The second time around will be a bit more interactive to help ensure that you are really paying attention to every element of this MakerSpace Multi-Meter Introductory Lab! Again, do every action yourself and so be sure to turn the dial, make the rotations, complete your copy of the lab protocol with respect to the readout, measurements, etc., as an individual, but also be collaborative with the members of your team. **Remember, science is not a spectator sport!**

AROUND THE DIAL: Rinse, Lather, Repeat. In the interest of getting students to look at this lab as a technique lab, you will need to practice, repeat, often many times, as is the classic set of directions seen on a bottle of shampoo. Why you should do this, as well as repeat it can be seen if you try the technique yourself the next time you wash your hair! It also works really well if your hair is really dirty, so wait for a few days to get really dirty hair! Squeeze some shampoo into your palm (note amount on instructions), apply to hair and bring shampoo / hair / water into a lather. Note the amount of lather, then rinse your hair completely. Repeat process (rinse, lather repeat). This second time around, the same amount of shampoo will result in a larger amount of lather, a richer texture to the lather and it will overall rinse quicker. This idea of rinse, lather, repeat, you will discover something about the theory of science that only results from a faithful execution of the technique part, especially the repeat part. Who would think something as simple a washing one's hair could result in a scientific moment. For instance, if you wash your hair a second time as after some time without a shower, you will discover something about chemistry!

Most soaps and detergent do not work as well if there are salts in the mix. People washing their hair in the ocean discover that salt water usually does not usually result in a good lather (soap suds). The salt ions effectively lessen or neutralize the lather effect. As you wash your hair a second time, you see this in the "shampoo effect". The first cleaning likely resulted in little lather as the salt in your hair (from days of sweat, etc.) lessens the lather. Subsequent cleaning results with the same amount of shampoo resulting in much more lather (shampoo effect). Like all chemistry / biology phenomena, the details of the phenomena are much more complex that this simple analogy explains, but it does show the main point. <u>Unless you repeated your hair care process, you would not discover this shampoo effect. Unless you repeat your "work around the dial" you may not discover all there is to know about using the device effectively…so go around the dial many times, or **rinse, lather, repeat**. Like all good analogies, this idea has been modified, borrowed, tested, etc. Some folks cite the consumption of alcohol as an extension of this effect, in that a small amount of alcohol after a night of drinking can make for a more intense inebriation (that feeling of being drunk), or that a small amount of alcohol can minimize a handover (the so-called "hair of the dog" effect). Both of these analogies as well as the consumption of alcohol are to be avoided in the context of these lab activities! So, repeat your technical lab activities as this is highly recommended, and extent to which you care for your hair and/or consume alcohol is a personnel choice that we will no longer speak about!</u>

Dial Exercise (On next page): Complete the dial locations by writing in the 20 locations: name each location and use pencil in with other dial information that is associate with 1 or more location (example hFe relates to just one dial slot, while resistance, DCV and DCA all have up to 5 settings!). In order, around the dial, staring with the 6 o'clock position. This is when the dial is essentially pointing straight downward, or it is pointing at the # 1 place / 200 ohm position, from here, clockwise, the values read: 2. 2000 ohm, 3. 20 K ohms, 4. 200 K ohms, Ω, 5. 2000 K Ω 6. 200 milli-volts, mv, 0.2 volts DC, 7. 2000 mv, 2 volts DC. 8. 20 volts DC. 9. 200 volts. DC 10. 250 volts. DC. 11. ACV 250. 12. 200 volts. ACV. 13. 1.5 volt, 9 volt
14. DCA 200 µl (micro) amps. 15. 2000 µl, 2 milli amps 16. 20 milli amps, 0.02 amps.
17. 200 milli amps, 0.2 amps. 18. 5 amps! 19. Hfe: testing transistors
20. Diode →|-- symbol for diode

While looking at the above units, etc. reflect on the first lab in the course series. Volumetric analysis and the all important units, powers of 10, etc….

Also, note the above units, series, etc. is essentially repeated below as you go around the dial. Be sure to be clear and precise with every notation, etc.

Diagram XX: Label the dial!
Take a minute to note your dial, and with a pencil, draw where these values would be noted on the dial of your device. Note these values are listed above and below for easy reference.

1 place / 200 ohm position, from here, clockwise, the values read: 2. 2000 ohm, 3. 20 K ohms, 4. 200 K ohms, Ω, 5. 2000 K Ω 6. 200 milli-volts, mv, 0.2 volts DC, 7. 2000 mv, 2 volts DC. 8. 20 volts DC. 9. 200 volts. DC 10. 250 volts. DC. 11. ACV 250. 12. 200 volts. ACV. 13. 1.5 volt, 9 volt 14. DCA 200 µl (micro) amps. 15. 2000 µl, 2 milli amps 16. 20 milli amps, 0.02 amps. 17. 200 milli amps, 0.2 amps. 18. 5 amps! 19. Hfe: testing transistors 20. Diode →|-- symbol for diode

F. Around the Dial: What are the 7 Functions?

F. Around the Dial (first time): The multi-meter has a large central dial that has 20 positions that "click" into position. To gain more familiarity with the device, we will go around the dial twice. The first time will be "around the clock". During this process we be largely focusing on why the locations are named what they are, why they are clustered, abbreviations, etc. **We then go around the dial one more time**. This time we will focus more on the readout (display). This changes as the switch position changes. So, by going through the dial twice, you will become more aware of a) what is the multi-meter set to read (the first time around the dial) and b) what is the readout saying (the second time around the dial!). Lastly, we will revisit the use of the multi-meter to take some simple measurements including resistance, conductivity, voltage, and inspecting diodes. Along the way, the lab will make reference to many supplemental ideas/links, etc., as well /and a few other examples, accompanying theory, etc. **but keep in mind this is a technique lab, so rinse, lather, repeat!.**

The dial: settings: around the clock! With the switch on, and the leads plugged in, be sure the lead tips **are not touching**. Now, we will use the multi-meter to introduce a number of terms and ideas that will be repeated numerous times during this prototyping lab. The order starts with the dial at the 6 o'clock position, pointing down. The tapered end of the dial has a small dot or depression in the plastic. Clock wise around the dial (from the 6 o'clock' position) are the following readings:

1. Resistance (positions 1-5). This is a basic value with many notations. It may be simply named "resistance", or the unit ohm may be applied. Ohm is the Greek letter **Ω,** which typically ranges many orders of magnitude (powers of 10, 1,10, up to million, etc. and even occasionally fractions 1/10, etc., but are rare in resistance measurements, so "micro-ohms" are not common). Since the metric system is also employed in many electronic measurements, you may want to refresh your memory about some basic metric values.

From 200 ohms (**Ω,**) at 6 o'clock clock wise through 5 positions, each is a power of 10 greater (log based) than position before it. So, the values read: 200 **Ω,** 2,000 **Ω,** 20,000 **Ω,** (also called 20 K**Ω,** as the K denotes 1000 in the metric system prefix kilo. Often the K is dropped (as it is on the dial) and 200K, 2000K are the last two positions (the last one could be denoted 2,000,000 **Ω,**, or 2,000 K**Ω,**, 2 million ohms or 2 Mega-Ohms! **Wow! That took a long time!**

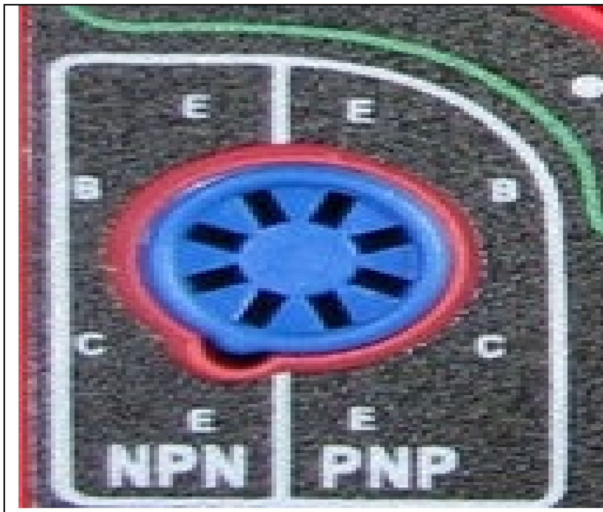
And it will take a little bit more time, as you should note a quick observation. With the device turned on and the leads touching (positive and negative), dial through the settings (all 5 resistance settings). You will notice if you do this slowly, *the readout changes very slightly.* Starting at 200 ohms, you may notice it is not exactly at zero. **We will get back to that later.** For now, notice the **decimal as it moves** with each switch of the dial! You can disconnect the leads and try this again. The decimal should be moving! This is because one display can allow you to read from a few ohms to millions of ohms. You can only do this correctly if you know what position the dial is in, and what the units mean. The good news is we only really need to use these settings to test 4 components or parts of our device. Three are simple resistors, and the 4th one is the slightly more complicated "variable" resistor. So, the multi-meter can be used to measure resistance in one of 5 settings by keeping an eye on the decimal (on the display). More on this later, but for now, focus on the dial settings. **Rinse, lather, repeat**.

So, let's keep going around the dial and remember, we are focusing on just what the terms means on the dial, the display decimal, and why the scale may change some will be addressed later.

2. DCV: Direct Current Voltage (DCV). These DCV settings start a little after 9 "o'clock" and end right before "midnight" (or pointing strait up /north) and range from 200 mV or 200 millivolts and go up to 250 volts. Direct current implies polarity, in that one pole will have a charge different than the other pole. See polarity table on page **21??** to help clarify this idea.
3. ACV Alternating Current Voltage. These setting at at "midnight" and just past it (250 or 200). Both voltage readings (200/250) WILL not be used much in this lab. So, if you want more information on these settings, see the **Technical Literature Reference Lab** (under development).
4. 1.5 Volts (4.0 milli-amps, mA) / 9V,25 mA: This setting is at 10:00 o'clock on the dial, and can be used to test commercially sold batteries from 1.5 volt size (AAA,AA,C,D) to 9 volt as common examples. Again, more on this later, but for now, mA stands for milli-amps or 1/1000 an ampere.
5. DCA/ 5A Direct Current Amperage / 5 amps: Coming around the dial from around 1:30 to around 4:00 are the amperage settings for a DC circuit. The highest DCA setting is at about 5 o'clock and is 5 amps. You may notice a red line around this setting, which suggests another probe position should be used when making measurements with this device. Recall that for all of the labs, the probes are to be inserted with the red in the middle and black in the lowest probe port. Just like DCV and ACV, the DCA settings are to be used only rarely. The 5A setting gives us a hint as to why. "5 A" is short hand for "5 amps". ***<u>This is a lethal amount of energy</u>***! So, by not using these settings we are also pointing out that this will allow you to use the device **SAFELY** as you avoid making measurements in the 5 amp range.

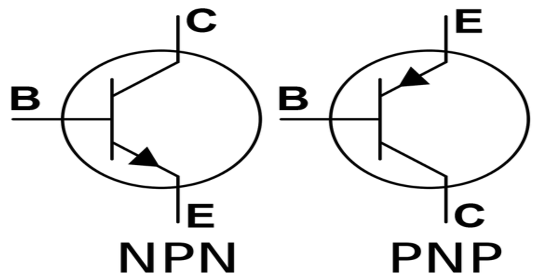
6. hFE: **Hybrid Parameter Forward Current Gain, Common Emitter**: Wow! That is the most complex name on the dial so far! This is the second to the last setting! Wahoo, this is setting number 19 if you are counting! It is right around 5:00 on the line and like ACV, DCV and DCA, it has it's uses, but we will largely be ignoring it in this class, except to point out what it is used for and a heathy dose of theory about the part that can be tested at this setting on the dial and the related port. The hFE setting allows one to use the only part of the device we have yet to address. Enough suspense? What does it do? When the operator puts the dial to hFE, the role of the small, button size disc with about 8 perforations on it comes into focus. More later, but for now, consider the below diagrams and keep this lab for future reference!

DIAGRAM __: Multi-meter with hFE settings / plug and related transistor information



Close up of plug port for transistor measurements from multi-meter. Our device will use 2 types of transistors: a NPN style (to right) and a phototransistor (sensitive to light).
Both transistors are among some of the most sophisticated pieces of equipment we will use in this device (both in theory and practice). The NPN uses three prongs, and thus care must be used in installing. As for more detail; ***rinse, lather, repeat!***

Schematic images of 2 types of transistors.



PNP and NPN style transistor schematic

Transistor image. Our device will use on transistor of this type, and another that actually looks like a light emitting diode (LED)! For now: **rinse, lather repeat!**

The plug port (above) allows for the multi-meter to not only test transistors, it is the transistor that helped create our solid state and microchip technology that is the bulk of the spectrophotometer we a creating. **So, settle in for a lecture on transistors, electronics and technology we now use every day.** Transistors come in a few “flavors” broadly given the initials NPN or PNP. We use a NPN style transistor in the circuit we will be eventually be creating. We will also use a phototransistor, which is a newer type transistor, being used in the light detection part of the spectrophotometer. In our device, a modified transistor called a phototransistor is used in the light detection part of the spectrophotometer. The phototransistor and LED’s all have changed greatly from the days when they were first invented. Light emitting diodes (LEDs) went from dim red lights that were two to three dollars each, to LEDs that come in every color in the rainbow, are super bright and literally 1000s of them form the basis of screens used in smart phones and other television and computer displays across the globe. In fact, they are so efficient, that they have been used in traffic lights and many light bulbs are now LED based technology which uses a fraction of the energy, and the bulbs will often last for decade.

It seems that every piece of technology associated with a spectrophotometer has become less expensive, miniaturized, etc. While this is a good, it has made using the device as a teaching tool difficult, as all of this technology has made it almost indecipherable and largely a throw away piece of technology using microchips. To better understand the science and the central role Beer’s law and spectrophotometers have played, a solid-state approach is being used. Solid state means that the devices will NOT use microchips, and thus it may be easier for students of science to better understand the electronics and processes that will be reviewed in this lab series to be largely conducted in MakerSpace. **In fact, this lab is so unique, it is being pitched to you as a lab you and your group may want to repeat!**

Just as the previous weeks' of repeatedly drawing and creating standard curves, so to could you consider repeating EVERY element of this lab series on prototyping (as the labs are largely the ones designed to be completed in MakerSpace). As you repeat the lab you too can peel away the layers of theory and technology that come with every science lab. Go from simply reading the lab and executing the lab for the first time, to having supreme lab confidence regarding the lab and eventually being critical of the process (and of course accompanying theory) as this approach is exactly what this lab/immersion course in meant to teach. Learn science by doing science and the theory will follow! So, as we look at new technology, we will return to transistors as these devices give us pause both in their identification, but also in their installation, and of course all of the related theory and practice. So back to the theory, then to the practice, lecture, theory and practice, lab, **rinse, lather repeat**!

Transistors were at the cradle of the first big electronics' revolution. Prior to transistors, most electronic devices like radios, televisions, etc. required tubes to operate. These tubes were large, made of glass and other metals and had their own set of issues regarding testing, disposal, etc. (diagram __, PG XX). In 1952, a few folks working primarily at Bell-Howell Laboratories created the first working solid state transistors. This allowed for the first wave of circuit miniaturization that would take the world by storm! Now radios were hand-held, and waves of solid state technology permeated the market. So, while transistors are phenomenally important to solid state construction (and allowed for the first wave of miniaturization), integrated circuits (IC) took this shrinking process even further. As a result of their small size, IC discussion will largely *not* be part of this course, except to point out they're a good subject of future study or more electronics, repeating this course, etc. Remember, the microchips (Integrated Circuits, IC) previously mentioned have billions of transistors on them, and numerous Noble prizes have been awarded to those who have investigated the role of transistors in science. One of the inventors of the transistor also did work on semi-conductor technology and microchips, resulting in one of the few times a Nobel prize has been awarded twice to one person (James Bardeen), and ushering in one of the clearest examples of academia going from pure research (transistor creation / discovery) to applied research (creation of very small /numerous transistors and even smaller transistors in micro-chips). **Concurrent with this revolution was the loss of many opportunities to discover science, as trying to figure out how a spectrophotometer works if it has semi-conductors (ICs, chips or microchips) inside it is next to impossible. Trying to figure out a spectrophotometer based on solid state technology is far more transparent and you will be soon embarking on the construction of a solid-state device. Remember… as Isaac Newton once said: If I have seen further, it is by standing on ye shoulders (sic) of Giants".**

7. Diodes: The last position is for diodes. The arrow pointing to the vertical line on the multi-meter dial denotes the device is set to check a diode. Diodes are devices that allow current to flow only in one direction and can do so under various conditions, such as at certain temperatures, or even possible emit light! This can be seen when the multi-meter is set on this diode setting, current will flow only one way if a diode is hooked up to the device. You might see this current as a number on the multi-meter display, or as a light as in the case of light emitting diodes or "LEDs". You can check out more about diodes later, (reference table XX, Pg. XX partial list of electrical components) or see the cover image for more information!

G. Around the Dial: What Does the Display or Readout Indicate?

One more time around the dial! On the below table are positions around the dial. They are listed in order from the 6 o'clock position (pointing down, 200 **Ω,** ohms, just like the last time around the dial!). We will proceed clockwise around the dial, or "to the right". This time, we want to take a look at the *digital display*, and see what it looks like as it relates to what position the dial is in! So, remove the probes, turn on the device and twist the dial to the 200 ohms, **Ω ,** setting. This will be the first line the below table, and ***as you go around the dial, record your observations as you complete the table.*** Once you go completely around the dial, note the table is recreated on page XX__. This table has more complete information and may be reviewed to help you better understand something about the display and dial that you did not see in this second time around the dial!

Table ___. Multi-meter: Around the Dial and Checking Out the Display!
Fill in the BLANK AND check your answers on page _____

#	Position Name /Symbol	Display	Comments
1	200 ohms, 0.2K ohms, Ω	1__ __.__	Positions 1-5 are
2		1 with NO decimal	all resistance. The
3	20 K ohms, 20,000 Ω		Scale changes, so
4		1__ __.__	keep an eye on the
5	2000 K ohms, 2,000,000 Ω	1 with NO decimal	decimal!
6	200 milli-volts, mv, 0.2 volts DC	00.1	6-10, volts, DC: direct current
7	2000 mv, 2 volts DC		No decimal
8		0.00	6-10, will settle to
9	200 volts. DC		a zero on display
10	250 volts. DC	000	
11			Hv (high voltage)
12	200 volts. ACV	00.0	AC, alternating current
13	1.5 volt, 9 volt	0.00	Battery tester
14	DCA 200 µl (micro) amps		direct current amps
15	2000 µl, 2 milli amps		14-17 measures amps.
16		0.00	**Very dangerous**
17	200 milli amps, 0.2 amps		70 milli amps can kill
18	**5 amps! Dangerous, adjust leads!**	0.00	5 amps req. training
19	Hfe: testing transistors		see lab for info…
20	Diode →|-- symbol for diode	1	one-way flow of?

H: Around the Dial: Resistance, Conductivity, Voltage and Diodes:

So…let's do some science. For this exercise, you will want to find the type of resistors that are bundled into groups of 4. Remove 1 from each of the piles (leaving 3 bundles of three resistors each, for later use). Take a good look at the resistors that have been provided with you in this set of supplies. Table 1 gives you another image of them, and most resistors are going to be about the size of a grain of rice, with bands painted on them. As mentioned previously, there is more to this color code than meets the eye, and if you want to investigate how this resistor color coded can be used to denote the resistance you can check out the **Technical Literature Reference Lab,** or investigate the link: https://www.allaboutcircuits.com/tools/resistor-color-code-calculator/ for more information on color codes, and how they help identify resistors values like resistance, measured in ohms, or tolerance, measures in percent. This color code is oddly difficult to see on very small resistors, and so we are going to use this an opportunity as a way of helping you **identify the resistor's resistance value with the multi-meter**. For now, the three resistors you have been provided look only slightly different. This is another example of theory and practice, as the color code should help you identify the resistance, but the small size of the resistors may make it hard to see.

You can read all about the color code and see what it is used for and later and we will mention some of these ideas, but as this lab is focused on lab activities, and getting things accomplished quickly, we will use a multi-meter to test the resistor values. As you probably see by now, this is VERY difficult to do in science (to go between theory and practice). Something as simple as using a multi-meter has a bunch of ideas that if not addressed can result in errors. Conversely, if we address all of the concerns, we will be doing only theory, and none of the practice! So, for the next few lab activities, the emphasis will be on getting you more comfortable with the devices, techniques, etc. and if something is not clear theoretically, or a device needs some clarification or practice for you to feel more competent to operate, please feel free to inquire about how to operate the device, if needed where to find the theory and consider even borrowing the device to practice on your own. For now, label each of these three resistors with a single piece of label tape each. Try to make the tape *quite small*, but big enough to record the following resistor values: 330 ohms **Ω,** 1000 ohms or 1K**Ω** and last is **10 KΩ** or 10,000 ohms. There is extra label tape in your boxes (wrapped around a battery). Cut into smaller pieces / strips to place a piece of tape around each of three resistors (one taken from each bundle). If you have a magnifying lens (or can borrow one), take a minute and see if you can identify the rings of color around the individual resistors. If you can see colors, you may be able to identify the resistance by noting the following patterns and associated values. Depending on which resistor you are holding, the colors will be:

- 10 K, brown, black, orange, or 1, 0, multiplier of 1000 for total of 10 K, (10,000)
- 1 K is brown black red or 1,0, multiplier of 100 for a total of 1 K (1,000)
- 330 ohms is orange, orange, brown 3,3, multiplier of 10 for a total of 330 ohms **(Ω).**
- **See a problem? Do you read, left to right? Back-wards? If there is a 4^{th} band that appears silver or gold, this is the 4^{th} band, so read accordingly. Start with band 1,2,3 then gold or silver. Not sure? Magnify to see better or better yet, try to hook up multi-meter and get a reading. Not sure how to do this? We will practice this some later FYI!**

So…back to theory and practice. We will use these three resistors later in concert with the multi-meter so as to determine the individual resistor's values. Before we do this, we want to continue through the dial settings, and go around a second time and see how the dial settings relate to the display or read out. If you have the time, you may also may to visit the website for more information on what the resistor color code is all about. Also…it will tell you not only about the bands, their use in determining resistance values, but about other bands for other values and also some science on how you can use resistors in novel ways to create a new resistance values with the resistors you have! More theory to come, but for now, back to practice. Place your three, taped resistors aside for now, but remember their location as we will need them soon.

A few quick demonstrations! For these demonstrations, be sure to have your multi-meter handy. These demos can be accomplished using the simple probe, or if you prefer, you can attach the leads with the alligator clips on them for almost any lab exercise (if they prove useful). In fact, your first demo shows how to use these leads!

XX?? Using a Multi-Meter to Check Connectivity / Conductivity (and Later Resistance Values).

Connectivity. To see if current is flowing, the idea of connectivity should be addressed. On a simple level, connectivity (or conductivity) can be viewed as having no resistance. If the leads or wires were never connected, there be total resistance of any flow of electricity. On the other end, if the wires were connected, the electricity (electrons as they flow) would flow, resulting in good connectivity or conduction. Theory sidebar! One common analogy likens electricity to water. The flow is called current or amperage and the pressure behind the flow is called the voltage. A static electricity discharge (like when you get shocked on dry, windy days) can span 1 centimeter of air, but only ***startles you***. It is really high voltage, so the pressure behind the electrons is really high, the amperage, (the total amount of electrons, is really low) so the discharge only startles. Why? High volts, low amps…OK. On the flip side, ***as little as a few milli-amps across the heart can kill***! A more robust lab / explanation on electrical connections is available on-line, so back to lab.

When you plug in the leads, how do you know it is plugged in? How sure are you that the connections are good? In general, the electrons flow from the negative (black or cathode) to the red lead (positive or anode). So, ensure the plugs are in as noted earlier (red banana plug in middle plug port), and the black banana plug should be plugged in the bottom plug (also called common or ground, negative or black anode). With these plugs in, twist dial to any of the resistance values. Attach and release the positive and negative leads as you watch the dial. The number should CHANGE from 1 to zero (or close to zero). Do not worry if it is not exactly zero, or if it waivers…it is the shift you are looking for! For now, try to attach the alligator clips / leads to the tips on the probes (for both, red and black) and then touch the opposite ends, and you should see the same change happening on the display. Get familiar with this idea of checking for *connectivity* as you will be doing LOTS of this (using probes, attaching alligator clips / wires, making connections, etc.), later, and we need to know if you appreciate how to make and test for connections / connectivity.

Conductivity Exercise:

Turn the multi-meter on. Connect probe tips together with a pair of alligator clips (which are connected themselves with a small piece of wire, these sets of two clips, with one connecting wire, come in different colors and usually there are 2-3 per kit, FYI). They come in many length and colors, and for this example any color will get the work done. Now try twisting the dial to one of the resistance settings. These range from 200 ohms (Ω) to 2 M ohms (2,000,000 MΩ), **or** from 6 o'clock on the dial, or in position "ONE" as you spin around the dial. This numbered approach (for identifying dial positions) will be revisited later and you already went through the idea of "around the clock" or **rinse, lather, repeat**.

1-5: Completed circuit, 5 readings on display

Now, with the leads attached, go from position 1-5, back and forth…As you do so, not the dial may change with each rotation, but it should come back to zero as this connection (between the probe tips with the alligator clips) creates a completed circuit and there is nothing stopping (impeding or resisting) the electricity from flowing from the black probe into the red probe through the alligator clip wire assembly. If this is NOT the case, double check the connections, make sure the probes are inserted in the device, etc. and if all else fails, check with the instructor (or get another multi-meter)!

1-5: Interrupted circuit, 5 readings on display, connections and resistance.
Now break the circuit with any interruption you see fit (disconnect 1 lead, both leads, pull out plugs, etc.) It is probably easiest to just remove the alligator clips FYI. As you do this, complete the following page of data samples. This exercise is much a matter of technique as it is an exercise in paying attention to detail and putting the right information in the right spot! The key is on the last pages of the lab manual (page XXX___), and be sure to consult with faculty if there are any problems associated with the process, data, equipment, etc.

Table 5: Connectivity and Resistance Measurement and Example Circuit Ideas:
Complete this table with the probes connected and not connected. **Key on page ____.**

Dial Setting: 1-5	Probes: connected /display is	Probe NOT connected, display is:
200 ohms		
2000 ohms 2 k**Ω**		
20,000 ohms 20 k**Ω**		
200,000 ohms 200 k**Ω**		
2,000,000 ohms, 2 mega **Ω**		

The readout is basically showing that with the **probes connected**, there is no resistance, or to put this another way, the electrons are flowing freely from the negative to the positive (black to red leads) and the **readout on device display is all ZEROS**. Once the **connection is broken**, the resistance is very high. The current cannot make the "leap" from the black to the red probe. So, the device simply reads **one** which the highest value the display can provide. While the numbers and data are simple, be ***sure to note the decimal point***. The numbers are only part of the process and something as simple as an overlooked decimal in reading and recording scientific data can result in the "**log of death**"!

Simply moving the decimal seems trivial, but if it is moved accidently "one to the left", as opposed to "one to the right", now suddenly, someone might get 100 times the medication, or conversely, get $1/100^{th}$ the amount to treat an illness, etc. For example, starting with 1.0, 2 to the left is 0.01 and going to the right 2 from 1.0 is 100.0. If the wrong direction is undertaken, the different is a factor of 10,00So…watch the display and note the decimal. So now let's use the resistance setting to measure some resistance. **For this activity, you will want to pull out the 3 resistors you earlier taped for easy identification**. Also, if you are so inclined, you can get the variable resistor (has three prongs, a blue dial and is a little larger than a pencil erasure). We may work with this later, but it helps to have all of these items in one place, and we can do as many of the simple resistance measurements on this device as time permits.

Resistance Measurement Exercises and a Brief Introduction to Variable Resistors:

Ohms, 2000KΩ to 200Ω, ohms, Ω. With the dial on the same group of settings from the previous exercise, move the dial to the appropriate resistance settings for the resistors you will check. For this exercise, you may want to reference other sources if you want to know what these resistors are (as in the links for the resistance color code) and for now, we will tell you shortly or you can check table XXX___. There are three types of resistors in this set up, and four are in the final spectrophotometer device over all! For now, get the 3 small, fixed resistors that you earlier put a piece of tape on. These are small, colored cylinders with bands of other colors (orange and red are among the most notable). One is 330 ohms, another 1000 ohms (or 1 K ohms) and another is 10 K ohms. So, how do we identify these resistor using the multi-meter? Use a range that will not be exceeded by the maximum resistance of your three you have been asked to examine. Since the highest resistor is 10 K, use the 20 K setting to be sure (on the dial). To think about this another way, the three resistors range from 330-10,000 ohms. If you were to set at 2000 ohms, you would not be able to measure the 10,000 ohm resistor! With the device set for 20 K, you need to attach one of the resistor to the probes (by wrapping the wire many times around the point tips), or you can use the alligator clips to make a more exotic "circuit". What-ever the attachment process you do, be sure to repeat this for each of the three resistors, and record the information in the grid below and make sure you address the next few pages to be sure you are complete:

Table ____ Resistance determination for three resistors used in device construction (330**Ω**, 1K**Ω** and 10 K**Ω)**

Dial Position (same for all)	Display	Resistor
20 K ohms **Ω**	00.3	330 ohms
20 K ohms **Ω**	01.0	1000 k ohms
20 K ohms **Ω**	10.0	10 K ohms

The display values may be slightly higher or lower, but when comparing between resistor samples, the difference is clear. BE SURE TO WRITE THE RESISTANCE DOWN on the tape you previously applied. ***<u>Be sure to REPEAT this process with all of the other 9 resistors you should still have left in your supply box. PLEASE write legibly and be diligent and complete this process with all of your "set value" resistors.</u>***

To better appreciate the role of the dial and how it relates to the display, please fill in the blanks on the below table. Start with the 10 K resistor and hook it up to the leads as done previously. With the device on, turn the dial to the 2000 K ohm and note the read out. It is 1, as resistance setting on multi-meter is far too low to read this resistors (2000 K verse 10K). Notice the device is able to provide reading only if the meter is set to a resistance that is close, and note below the resistance of the resistor being measured (so 200 ohms will not measure 330 ohms!). Complete the below table, and realize there is a completed table copy at the end of this lab for your reference:

Table ____ Displays of resistance measurements at all 5 resistance settings on multi-meter (200 -2,000,000 ohms

Dial Position	Display for 10 K resistor.	Display for 1 K resistor	Display for 330 **Ω** resistor
200 ohms, 0.2K ohms, Ω		1	1
2000 ohm, 2 K ohms, Ω	1		330
20 K ohms, 20,000 Ω	10.00	1.00	
200 K ohms, 200,000 Ω	10.0		00.3
2000 K ohms, 2,000,000 Ω		001	000

Confused? Relax, there are a lot of scale issues we could address, or investigate regarding the resistor color code and countless other factors to better assess resistance and other. For now, it is enough to know that you can set the leads, and get the values we discussed. If you want more theory, check the references or links. For now, we need to focus more on the how, and less of the why. If you want <u>one last test</u>, try connecting the all three resistors in "series" (end to end). The two unconnected ends can be hooked up the clips, and if done correctly, the device should read 11.30 at the 20K Ω setting! These three resistors are wired in series. There will be more opportunities to measure resistance in various configurations such as series, parallel, and IF TIME PERMITS: VARIABLE RESISTORS! Once you have completed some of these activities, take some time to check and label the resistance values for all of the set resistors in your kit. There should be a total of 9 you will turn in, and keep one each of the set resistors (330 Ω, 1,000 Ω and 10KΩ) for use in your later spectrophotometer assemblage. Feel free to practice some more, read ahead, and take your time getting this done, but this will be the last time set resistors are mentioned in this lab, so it is up to your team to complete all of the labeling, etc. for all 12 resistors in your original kit. Now we move on to more sophisticated parts.

A **variable resistor** has been included with your kit and will be part of the final device (once completely assembly). IF YOU HAVE TIME, consider working with the one provided. It is a three-pronged device, usually with a blue dial on it. The variable resistor is a 10 K ohm device. This means it has a maximum resistance of 10 K ohms and can be changed from a low of about 1000 ohm (1 K Ohms) to 10,000 ohms (10 K ohms). This is accomplished by turning the blue dial. This may be possible by hand, but a small groove on the device allows one to use a flat edge screw driver as well. Also, you will want to use alligator clips to test this device as trying to hold the probe tips in place while turning the dial can prove to be very difficult (even for experience technicians). The idea of using a variable resistor can be appreciated if one has ever used a dial or "dimmer-switch" to change the light intensity. This is most likely a variable resistor and is being used to change the current flow to a light (like the newer LED light sources currently available). So, if you have time, try the following exercises to get comfortable with the various tabs and setting possible with a variable resistor.

If the device is set for 20 K, and alligator clips are attached to pair of prongs on the ***<u>outer most edges</u>*** of the device, you will likely read 10 K. This full resistance is just like a "set" resistor. To change the device into a variable resistor, connect one of the probe leads to the middle prong and keep the other lead attached to an "outer prong" or to put this another way, connect the other lead to either end of the variable resistor. Record the resistance in the below table. For the purpose of this device, the prongs will be labeled 1,2,3, with 2 in the middle. As for red or black leads, since the resistor has no polarity, the prong color on the multi-meter does not matter. ***<u>More on polarity later</u>***. Next, place the lead that was on the edge, to the prong on the other edge. KEEP the MIDDLE lead/prong consistence through-out all measurements. As you make these measurements, complete the table. You will quickly see how the device works as you complete this table. Between each measurement, be sure to twist the dial some, so you get a different measurement set each time. So, get resistance measurements at all three settings, twist dial and get three more measurements and then repeat. Be sure to twist the dial a least one-half rotation (or more) between each measurement and feel free to twist the dial some before you start to get a "feel for the device". Most of these devices will have at least two full rotations possible and perhaps even four may be possible. **Remember, the technique will reveal the theory, so be sure to look at the answers /key, as they will help ensure you understand how the device works!**

Table XX__ Variable Resistor Measurements, 10 K Device, 20 K Multi-Meter Setting, 3 Dial Settings (One Each Trial). Please Record Resistance Values at All Possible Configuration.

Trial Number	Probes @ Prong #s 1 and 3	Probes @ Prong #s 2 and 3	Probes @ Prong #s 1 and 2	Total for Last Two Columns
1				
2				
3				

Note: **Key is on page ___,** but will likely not precisely match you actual data, as your readings will vary some. The key will be accompanied by some comments and ideas that will help you better understand how a variable resistor is used, how it is designed, and what you will be doing with the device later, (as time permits).

A big theoretical idea, but for now, as long as you get the right resistor and attach it to the right leads, it should all work out. If you want some more practice with connecting leads, etc. you can try the "connector sets" (AKA breadboards) that will be used later in the device construction. You can also read ahead to the next lab where we examine how to create simple circuits and along the way create examples of resistors wired in series and resistors wired in parallel. ***Take a minute to disconnect the device(s), turn off the meter and return the resistors to their box AND BE SURE TO RE-LABLE ALL SET RESISTORS WITH THE SET VALUES OF 330, 1,000 OR 10,000 OHMS! LAST REMINDER!!!!***

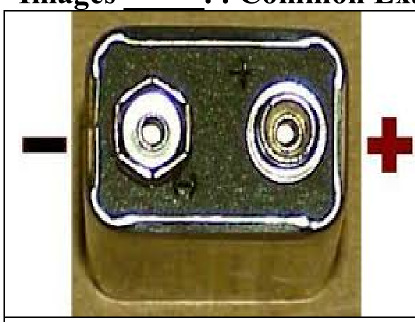
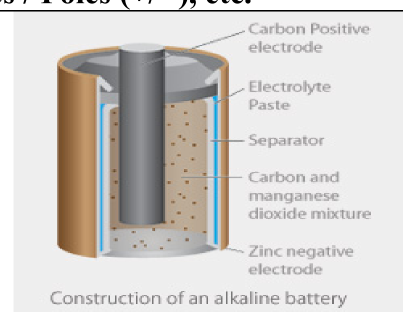
Voltage, batteries polarity. Some devices can be hooked up very simply by ensuring one lead is connected to one end, and repeated with the other lead / end. Other devices (and thus the associated use of the multi-meter) are not so simple. Later, we will address devices with 3 leads and polarity (transistors), but for now we will talk briefly about the idea of polarity, as this can be addressed by more simply considering two-lead devices. These terms related to polarity have very different meanings when applied to various examples in science. For electronic devices, this usually means that the wires or connection points need to be hooked up in such a way that the charges (polarity) is observed. Batteries have obvious examples of polarity with leads or "points of contact" that you may recognize as having a distinct positive or negative terminal. The multi-meters probes also have polarity. Black and red, negative and positive, cathode and anode all mean – and + respectively **(See Table P (POLARITY)).**

Table P (POLARITY): Notation and Abbreviation Inferring *Polarity* in Electronics.

Positive	**Negative**
plus	minus
++++++	-- -- -- -- --
red	black
anode	cathode
live	ground
++ **→|---** **→|--- alone is diode symbol**	**→|--- (arrow point towards negative) --**
Long lead (silver wire) on LED.	Short lead (silver wire) on LED
++++. vs. **--| |---**	**--| |--- vs.** -----
Beveled or flat edge on LED	Rounded edge on LED
Electrons travel towards	Electrons travel away

So, with some devices that have two leads, it is not enough to make sure they are hooked up right, the device itself must be oriented correctly with respect to the poles or polarity! For example, if a battery is inserted into a device, the device will not work if the battery leads (positive and negative parts) are not considered, or “hooked up correctly”. Despite the fact that leads are touching the battery, the fact the positive and negative parts of the battery are not touching the right leads (polarity) shows its effects when the device is not working. A number of devices have polarity, and of the most notable are **diodes**. If hooked up one way, the current (or flow of electrons) will stop (or substantially lessen). If turned around, the current will again flow. Some diodes do this at a certain voltage, others are sensitive to temperature changes. Still others give off light when the current is flowing the right way. Light emitting diodes (LEDs) are thus two devices in one! They control the direction current can flow, and also indicate this process when light is observed. Some capacitors, power supplies and other types of diodes all have some level of polarity (as do the previously mentioned transistors), but batteries are perhaps the best known of all of the electric devices that have polarity. Your kit has three batteries (see below diagrams). Please gather these batteries up, as well as a few sets of leads / alligator clips your multi-meter (with probes) and your colleagues to help examine these devices and what the multi-meter can tell you!

Images _____. : Common Example Batteries, Normal Voltages / Poles (+/--), etc.

		
9-volt battery with poles clearly noted. **DO NOT** hook up to light emitting diodes (**LEDs) without some training**!	**3-volt** Button batteries. Negative terminal is facing up, positive side is flat, often with writing (+ symbol). Negative sides are seen above.	**1.5-volt battery** (type AA, AAA, C and D are common) Positive tip can see as “carbon positive electrode” usually covered in metal

Voltage Exercise: Just like the resistance measurements you made, you need to pick the correct dial-setting to get good data. For this exercise these settings would be the DCV (Direct Current Volt) settings. DC is a type of current where the poles are set as being either permanently positively or permanently negative. AC stands for alternating current and is a slightly more exotic idea with the voltage alternating between a positive and negative settings, (usually about 60 times a second!) DCV will dominate our dialog as our device uses various DC sources, whether they are batteries or the result of a power converter that changes voltage, not only from AC to DC, but also “drops” or lowers the voltage to a “manageable” 3 -12 volts, as seen with our “power supply converters” used in the final circuit design. The “usual voltage” from a plug or outlet is about 110 AC and our device requires about 9-12 volts DC.

This idea of DC and AC actually goes back to the foundation of modern electronics and electrical supply. Two of the greatest inventors (of all time, and certainly in the fields of electricity and electronics; Edison and Tesla) could not agree if AC or DC was the superior way to deliver current over great distances (kilometers, etc.). They each have their own strengths and weaknesses. For now, it will be noted that Edison and Tesla we on opposites of the AC/DC wars, and you are encouraged to investigate this more if interested. For now, we will note the above and move on. All of measurements will be done in DCV. These settings range from 0.2 volts (200 millivolts) up to 250 DCV. The DVC settings pick-up right where the resistance setting end. Positions 6-10 or approximately "9 PM to midnight" on the ***dial***. Since our highest volt reading would be 9 volts, then measuring all three batteries voltage would be possible with the 20 DVC setting (position 8, about 10 o'clock). Use the previous diagrams and other resources (like the battery itself) to determine the voltage of the three batteries provided in your started kit. You should be able to (with a little practice) to get the 1.5, 3 and 9 volts batteries to all read as expected. If the values are switched (for example: read *minus* 9 volts), you may have simply switched the probe leads, as batteries' have polarity and thus, unlike resistors, the use of the probe / multi-meter requires some extra attention be given to proper use of the black and red leads. By convention (agreement among experts), the red is positive and the black lead is the negative. You can verify your understanding of these ideas by successfully getting correct measurements for all three batteries used in this introductory lab.

Second Battery Setting:$1.5^{\underline{v}}$(4.0 mA) $9^{\underline{v}}$(25 mA) If you have time, you can also check the batteries via the dial position at about 1:00 o'clock. This setting mentions 9 volts (25 mA) or 1.5 volts (4.0 mA). Both of these readings are designed for the most common batteries used commercially (1.5 and 9 volts). If the probes are hooked up correctly (+/--, positive / negative, etc, you will see the amperage displayed. The amperage is a measurement of how "*good*" the battery is. A brand new 9 volt has about 25 mA (milli-amps) of energy in it. A brand new AA, AAA, C, D, will have about 4 mA. Over time, the voltages for most batteries will stay relatively constant, but the amperage will slowly fade. Eventually this amperage will be so low that the battery will not "work" any more. The most obvious example of this is when the bulb on a flashlight goes dim. As amperage and voltage have yet to be completely addressed, for the purpose of this lab, it is enough to show you the setting and give you some ways to see if you are hooking up batteries correctly and getting readings that make sense. If you want some more insights into batteries, voltage and amperage, spend a few minutes looking up ***wattage***, which is the relationship of amps and volts as the relate to the power (or wattage) of the device and may give you a better understanding of why some batteries have the volts and amperage as described in this lab (i.e. 9 volts if roughly 25 mAmps, 1.5 volt is roughly 4 mAmps, 6 times 1.5 volts equals 9 volts/ 4 milli-amps times 6 is 24 milli amps ***or*** the milli-amps a 9 volt battery produces……. *Such are some of the awesome ideas your will discover as you take more physics or chemistry in your academic career*. **For now: rinse, lather repeat!**

Diodes:
In later labs we will see there are **three types of diodes** used in this device we will be making. a) regular diode, b) Zener Diodes and the previously mentioned LEDs or 3) light emitting diodes. Your multi-meter has a setting designed to check all types diodes, but you may need to spend some time learning how to hook them up correctly to the device, as all diodes have polarity (like the poles on a battery). Additionally, the diode settings are much harder to "see", and just like a battery, if installed incorrectly, your device may note work. The setting is just around 5 o'clock on the dial. The arrow and line symbol are used to denote the positive and negative parts (see table P). In fact, diodes are so important that the receive mentioned in this lab on the cover page, on a handful on images, as well as having over 4 ways to keep track of this polarity on the diode itself!

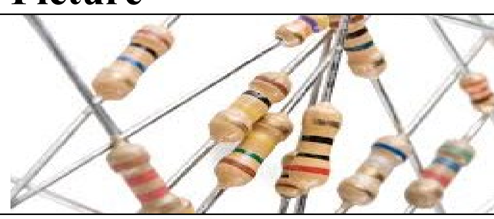
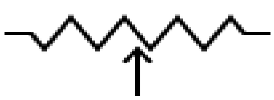
We need to develop this some, show how to make connections, etc. and use multi-meter to detect LED's If we use a power supply (even a battery) we will need to put resistors into the circuit. Most LED's require a "forward voltage" to work. This is the minimum voltage requires to get them to light up. The issue is a 3-volt power supply (2 regular batteries hooked up in series), as it too strong for red LEDs, and may not be strong enough for the other colors to be at their brightest. If too much power is passed through an LED, it can become very bright and start to warm up. Such intense light / heat can potentially damage an LED (perhaps permanently). So if a single power supply is to be used for multiple LEDs, it is important that one calculate the resistance requires to help ensure each LED is operating at its optimum. To this effect, we will build a simple circuit using the multi-meter as a way of lighting you LEDs. If you want to investigate more elaborate LED circuits and how to calculate the resistors required to get them to operate correctly, please check out the following link. It is really nifty and greatly clarifies things. https://learn.adafruit.com/lets-put-leds-in-things/from-scratch

Simple Diode Demonstrations: Have some fun with the 3 volt and a few red, blue, green and clear diodes. Along the way, you can familiarize yourself with the polarity of diodes, batteris and even the concepts of "forward voltage"

LED Demonstration, circuit symbols review and notation!

Have students ID each LED type (color) and label positive and negative leads as based on testing and review below table of LED related information.

Table One: Partial List of Electrical Components!

Part	Schematic Symbol	Picture	Comments
Resistor			**Bands can tell resistance if decoded**
Variable Resistor			**Tunable, like a dimmer switch**

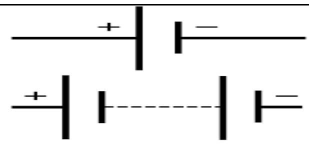
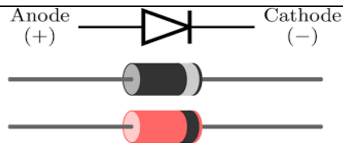
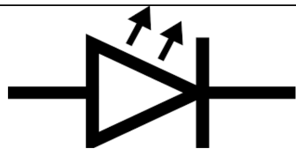
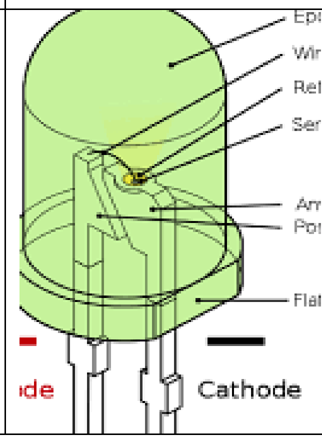
Power Source			**Power source can be variable in both volts and amps and will usually have poles.**
Diode			**Reg. Diode, plastic, Zener, glass**
Light Emitting Diode		 Note to right: flat side of diode allows for identification of cathode or neg. terminal in the all important LED!	

Table 2: Around the dial "KEY"

Multi-meter: Around the Dial and Checking Out the Display!

#	Position Name /Symbol	Display	Comments
1	200 ohms, 0.2K ohms, Ω	1__ __.__	Positions 1-5 are
2	2000 ohm, 2 K ohms, Ω	1 with NO decimal	all resistance. The
3	20 K ohms, 20,000 Ω	1__. ____	Scale changes, so
4	200 K ohms, 200,000 Ω	1__ __.__	keep an eye on the
5	2000 K ohms, 2,000,000 Ω	1 with NO decimal	decimal!
6	200 milli-volts, mv, 0.2 volts DC	00.1	6-10, volts, DC: direct current
7	2000 mv, 2 volts DC	000	No decimal
8	20 volts DC	0.00	6-10, will settle to
9	200 volts. DC	00.0	a zero on display

10	250 volts. DC	000	Hv (high voltage)
11	ACV 250	000	Hv (high voltage)
12	200 volts. ACV	00.0	AC, alternating current
13	1.5 volt, 9 volt	0.00	Battery tester
14	DCA 200 µl (micro) amps	00.0	direct current amps
15	2000 µl, 2 milli amps	000	14-17 measures amps.
16	20 milli amps, 0.02 amps	0.00	**Very dangerous**
17	200 milli amps, 0.2 amps	00.0	70 milli amps can kill
18	5 amps! Dangerous, adjust leads!	0.00	5 amps req. training
19	Hfe: testing transistors	000	see lab for info…
20	Diode →|-- symbol for diode	1	one-way flow….

Dial Setting: 1-5	Probes: connected /display is	Probe NOT connected, display is:
200 ohms	0.00	1__ __ . __
2000 ohms 2 k**Ω**	000	1__ __ __
20,000 ohms 20 k**Ω**	0.00	1__.__ __
200,000 ohms 200 k**Ω**	00.0	1 __ __.__
2,000,000 ohms, 2 mega **Ω**	000	1 __ __ __

Dial Position	Display for 10 K resistor.	Display for 1 K resistor	Display for 330 **Ω** resistor
200 ohms, 0.2K ohms, Ω	1	1	1
2000 ohm, 2 K ohms, Ω	1	1000	330
20 K ohms, 20,000 Ω	10.00	1.00	0.33
200 K ohms, 200,000 Ω	10.0	01.0	00.3
2000 K ohms, 2,000,000 Ω	010	001	000

Table ____ Displays of resistance measurements at all 5 resistance settings on multi-meter (200 - 2,000,000 ohms

Dial Position	Display for 10 K resistor.	Display for 1 K resistor	Display for 330 **Ω** resistor
200 ohms, 0.2K ohms, Ω		1	1
2000 ohm, 2 K ohms, Ω	1		330
20 K ohms, 20,000 Ω	10.00	1.00	
200 K ohms, 200,000 Ω	10.0		00.3
2000 K ohms, 2,000,000 Ω		001	000

Variable Resistor Data: Key and Device Design:

H1. **Technical Literature Reference Lab / "TLRL" Introduction**
H2. **Technical Literature Reference Lab: Table of Contents.**

LED / Light Source: Technical Literature:
Prototypes: Storage / Location
Vendor Information:
Mouser electronic:
Filament: PLA filament:
https://www.matterhackers.com/store/l/300mm-pla-filament-black-1-kg/sk/MSEWRUAW
MakerSpace: Policies and Procedures:

Post lab trick….calculating resistance in series? Resistance is parallel. Total resistance Tr is a series of resistors is simply the sum of the individual resistors. So, like the earlier example, if you hooked a 330 Ω and a 1000 Ω, the Tr would be 1,330 Ω. For resistors wired in parallel (side by side) the equation is slightly more involved. The Tr is based on the below equation.

The previous lab protocol can be reproduced for educational purposes only. It has been developed by Jim Wolf and numerous individuals who have contributed to this and other labs in the spectrophotometer series including but not limited to: Ahmed Miloud, Patrick Allen, Kishan Bhakta and staff and administrators from MakerSpace. Jim Wolf can be reached @ 661-362-3092 @ jim.wolf@canyons.edu

Last point…for some labs, we may want to look at OERs.. This stands for ***Open Educational Resources***. There OER are available from a range of websites and can be adopted in part or in their entirety. It may involve adopting some diagrams, perhaps a lab assignment? A homework assignment? Pre or post lab elements, etc. ?