5 Jan 2025

Physics 4L Laboratory 1 (2026) - Instruments and DC Circuits

Welcome to the first electrical laboratory exercise. Your state-of-the art equipment includes:

- A d*igital oscilloscope w/USB output for SCREENSHOTS and accompanying high-impedance probes.*
- *Two function generators; one with a synchronous pulse to serve as a trigger for the oscilloscope.*
- *Two bench-top digital multi-meters (use with care for current measurements).*
- *A multi-output power supply that can be run as constant voltage or constant current sources.*
- *Breadboard, power cables, signal cables, and hand tools.*

There is also a shared impedance meter by the parts supply bench to measure capacitance and inductance.

If you are stuck, or curious, about details of the equipment or the active components (transistors, diodes, op-amps, logic chips) that we use, then please read the manuals! These are online at the course website (https://neurophysics.ucsd.edu/physics4l.php). You will use this equipment again when you take Physics 120.

1-1. Common connections for the power supply

We wish to make a symmetric (dual) supply, i.e. one with a positive supply voltage (typically +15 V) and a negative supply voltage (typically -15 V) relative to ground. Connect two of the independent, floating supplies by ground the positive lead to make a negative supply and grounding the negative lead to make a positive supply.

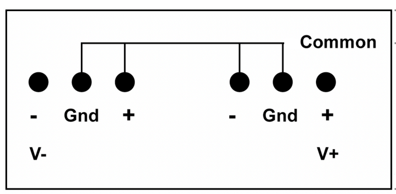

Figure 1.1

Q1: Why does this wiring-scheme work?

This is time to establish conventions that will help you keep your "Proto-Board" circuits intelligible. Try to build your circuit so that it looks like its circuit diagram:

- Bring power supply voltages to the breadboard, first to the banana jacks and from there to the bus strips. Place the positive supply voltage, **V_+**, *ground* or common, and negative supply voltage, **V_-**, on a horizontal breadboard *bus* strip and use this to feed vertical breadboard bus strips (Figure 1.3).
- Use color coding to help you follow your own wiring: use ***red*** for the positive supply, ***black*** for ground, ***green*** for the negative supply, and *yellow* for the digital supply.
- A focus is to get used to the breadboard (long columns are connected and serves as bus strips and short segments in each row are connected) and the way to connect instruments to the components.

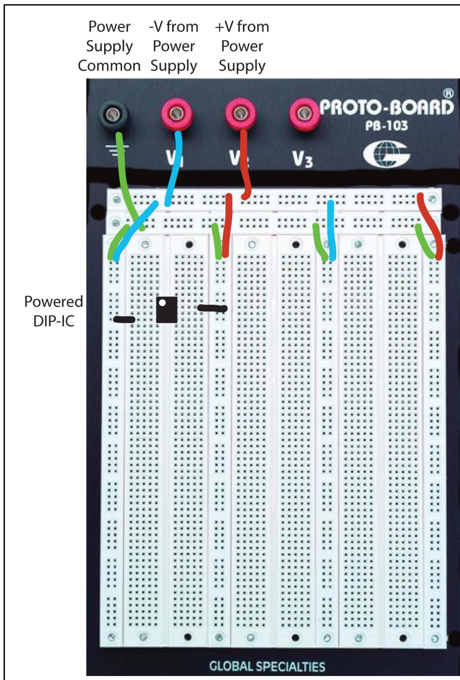

Figure 1.2. Protoboard set-up

5 Jan 2025

1-2. Quick review

Q2. What is the internal resistance of an ideal voltmeter ?

Q3 What is the internal resistance of an ideal ammeter ?

Q4 How do you interpret the precision, i.e., 1 % or 5 %, of a resistor?

1-3. A resistor - Ohm's Law

Choose a 1500 Ω resistor, and verify that the resistor obeys Ohm's law, by measuring **V** and **I** for different voltages (use the range -5V to +5 V with a 1V step) (Figure 1.3) and graph **I** (Y-axis) versus **V** (X-axis).

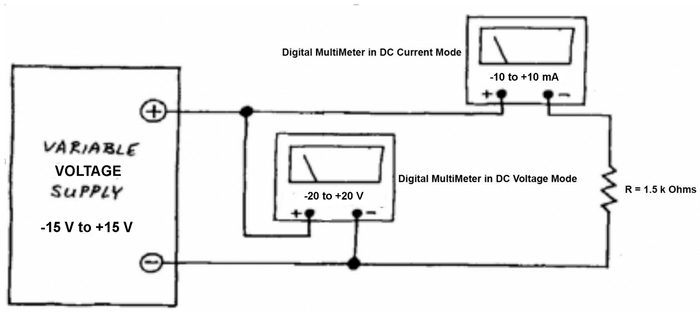

Figure 1.3: Circuit for measurement of resistor's **I** versus **V.** Use a DMM for both the Voltmeter ("infinite" input resistance) and the Ammeter ("zero" input resistance)**.** W*arning*: Current measurements use a separate input than voltage measurements on the DMM). Plus, the current input is fused. Use the low current input, the one marked "mA", and start at the highest setting on the dial, i.e., 500 mA , and work your way down to more sensitive settings. Never plug the Ammeter directly into the power supply - or pop goes the fuse.

Q5. Tabulate and graph your data. Remember to label your axes and the units.

Q6. Regress your data to get the slope, i.e., the value of "R". Is the value 1500 Ω? Why or why not?

Q7. Repeat this exercise with 3 additional 1500 Ω resistors. Are the values the same? Why or why not?

Q8. What are the two different configurations to measure the voltage and current, noting that the set-up in Figure 1.3 is one such way? Briefly (a few sentences) discuss their relative accuracy.

1-4. A light emitting diode

Now perform a similar measurement but using the power supply as a current source, i.e., **V** versus **I**, for a light emitting diode (LED); we use 5 mm (T-1-3/4) package. We only care about the diode part but the light emission makes it more fun. Use the 10 mA ammeter scales on your DMM. Do not exceed ~ 30 mA, the maximum current for most small LEDs!

3mm Round LEDs (Water Clear)		Forward voltage		Dominant wavelength		Luminous Intensity	
Part number	Emitting Color	(V) IF=20mA		IF=20mA		(mcd) IF=20mA	
		TYP	MAX	MIN	MAX	TYP	MAX
LED-WR3MMR	Red	1.8	2.3	620	640	2000	3000
LED-WR3MMY	Yellow	1.8	2.3	585	595	2000	3000
LED-WR3MMB	Blue	3.2	3.4	465	475	3000	5000
LED-WR3MMG	Green	3.2	3.4	520	530	8000	9000
LED-WR3MMW	White	3.2	3.4	/	/	8000	9000

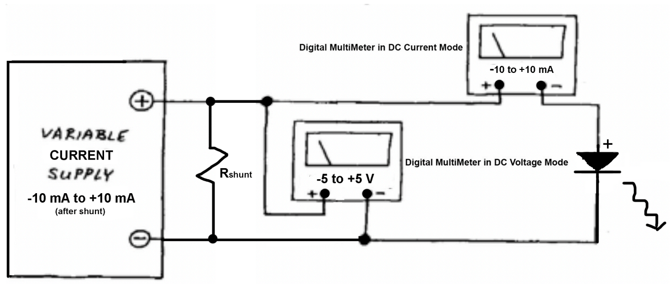

Figure 1.4: Circuit for measurement of a LED **I** versus **V.** Use a DMM for both the Voltmeter ("infinite" input resistance) and the Ammeter ("zero" input resistance). W*arning*: The current control on the power supply is crude, so we divide the output with a current divider, for which we chose R_{shunt} = 51Ω. Note that the shunt resistor has to handle the expected power dissapation, so we chose a 2 W resistor. Note that the longer led on the diode is "+".

Remember to measure for both + current and - current; for a diode the expected revers current can be less than 10 μA.

Q9. Tabulate and graph your data. What is different than the resistor? What are good parameters of the plot to note , i.e., slopes and breakpoints?

Q10. Roughly, what accounts for the nonlinear shape of the LED's V versus I curve?

Repeat this exercise with an additional LED of a different color.

Q11. Are the parameters of the plot the same?

Q12. What are the two different configurations to measure the voltage and current, noting that the set-up in Figure 1.2 is one such way? Briefly (a few sentences) discuss their relative accuracy.

1-5. Regression revisited

Every measurement has random errors and systematic errors. Let's learn a bit more about random errors.

Earlier you found the slope of the I-V relation for a resistor. But associated with the value of the slope is a variance, σ^2, which is to say that all the data points did not exactly fit on a straight line.

Q13. Go back and calculate the standard deviation, σ, for the slope.

This allows you to report the resistance as a mean ± a Standard Deviation, or R ± δR.

Repeat this analysis for all 4 resistors.

Q14. Keeping in mind the mean and the standard deviation of each resistors value, are all four of your resistors the same? Justify this.