EK 307 Lab: Light-Emitting Diodes

Your Name ____

Your Collaborators Name ____

Laboratory Goal: To explore the characteristics of the light emitting diode.

Learning Objectives:
- Voltage and current measurements
- Benchtop power supply
- Voltage vs. current relations in a nonlinear device

Deliverables:
- Show your LED test setup to a TA
- Show your V-I curves to your TA
- Submit the lab workbook and Screenshot of your spreadsheet data and plots to Blackboard

Background

Two terminal electronic devices can be characterized by their voltage versus current (V-I) relationship. Practically this means if we apply a voltage across the terminals there will be a current through the device we can measure. Conversely, if we inject a current into the device, we can measure the voltage across its terminals. For this lab we are assuming that electromagnetic effects are not present or are insignificant.

For many devices there are mathematical models that relate voltage to current. For resistors, it is Ohm's law, $I = V/R$, a simple linear relationship, where the slope is the reciprocal of resistance. For an ideal current source, the mathematical model is a numerical constant. For the ideal current source, the current will be constant for any applied terminal voltage.

The light emitting diode (LED) has a nonlinear voltage vs. current relation. Figure 1 is an example V-I curve for a nonlinear device. See the appendix for more detail on the model of an LED. In this lab you measure this relationship and plot it. To do this you will use the benchtop programmable power supply, a voltmeter, and an ammeter.

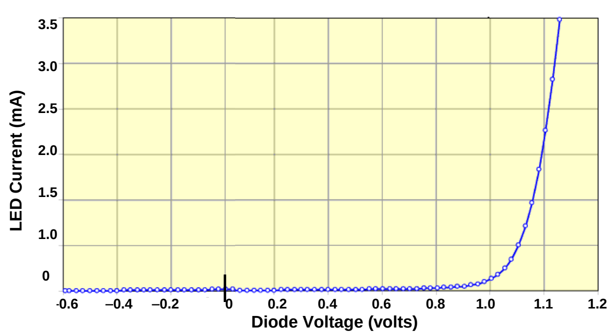


Figure 1: Example of a V-I curve for a nonlinear two terminal device. Your LED curves will have a similar shape but will numerically be different.

Develop V-I curves and test the power rating of LEDs

You will construct the test apparatus that is schematically represented in figure 2. It consists of the benchtop power supply, two meters and an LED. You will program the power supply to output different voltages. The power supply will hold the voltage constant as the current changes (up to a limit of 0.5 amps). An ammeter and voltmeter will be used to measure the current through and voltage across the LED. You will record voltage and current measurements in a spreadsheet and plot the results on the same axes for three individual LEDs.

1. Obtain three LEDs. They can be the same color or different colors. It is your choice. If possible, find the datasheet for your LEDs. You can do this by searching for the LED model number on the Internet. If you can not ascertain the exact LED, you can search for a 'generic' LED. If the color and package are the same as the LEDs you have, the specifications will be similar. **Do not reuse theses LEDs or return them to the parts counter. The experiments will damage them!**

2. Construct the circuit in figure 2. Use the benchtop multimeter to measure the current. Use your kit multimeter to measure voltage. There are test leads with the appropriate 'banana plugs' to connect to the instruments in bins on the bench. There are banana plug to alligator clip leads and loose clips to connect to the LED. Here is a video about using the bench power supply: https://youtu.be/p88eX4ib6Xw Here is a video about how to measure current: https://youtu.be/8Hzpk82fFPw **Measuring current my not be as intuitive as measuring voltage. To measure current with the ammeter in the lab you need to insert it into the circuit loop.**

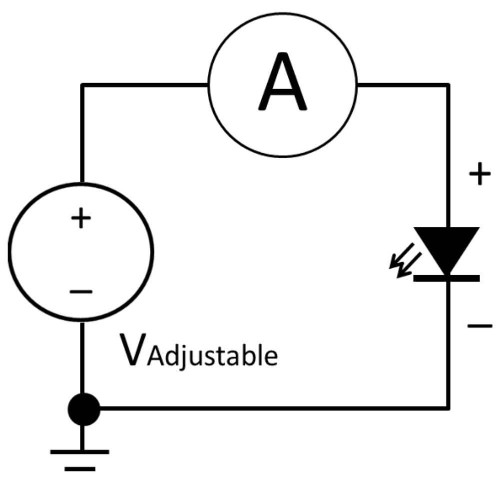


Figure 2: Measuring I-V characteristic of an LED

3. Be sure your power supply is set to zero volts before connecting your first LED to the apparatus.

4. Make a spreadsheet with a voltage column and a current column for each LED.

5. You will collect a series of data points where you increase the voltage one step at a time, then record the voltage and current in the spreadsheet. We suggest using 0.1 volt steps that range

from 1.5 to 4 volts. Note that the LED will get **hot** at the higher voltages. Do not touch it and make sure it is not touching anything valuable such as clothing or computer screens.

6. Note the voltage at which the LED turns on or starts to emit visible light.

7. Repeat this experiment for the other two LEDs you selected. Make new spreadsheet entries for each LED.

8. If the LEDs you selected are different colors, does the voltage that they being to emit visible light at differ?

9. Make a plot that shows the curves for the three LEDs on the same axes. The horizontal axis will be voltage, the vertical will be current. Figure 1 is an example of the layout. Be sure to label you axes and use a legend that indicates what each curve represents.

10. If you used three of the same color and model LEDs, comment on reasons why the results may be different. If you used different color LED's, why are the results different? You may want to consult the datasheets for the LEDs and look at the specifications to help you answer the question.

11. LEDs and diodes have a characteristic called the ‘forward voltage’. This is where the current starts to increase rapidly as the voltage increases. Can you identify the forward voltage region from your plots? How does it compare to the published value from the datasheets? Does the forward voltage correlate to when you started to see visible light emission?

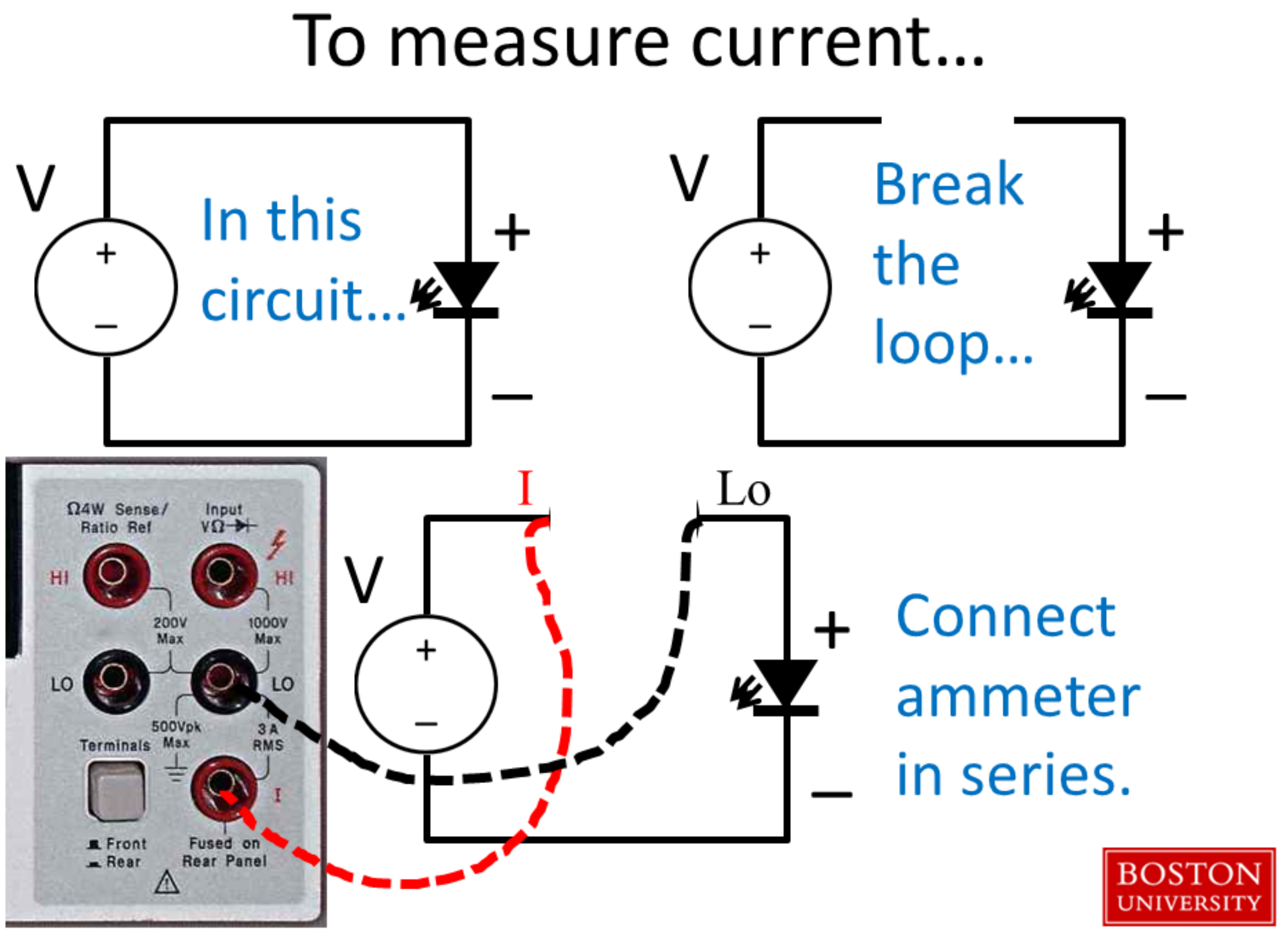
12. In your spreadsheet, add more columns, calculate the power consumed by each LED. Make a new figure that plots the voltage input vs. the power for each LED. Remember that power is voltage times current. Be sure to label axes and insert legends.

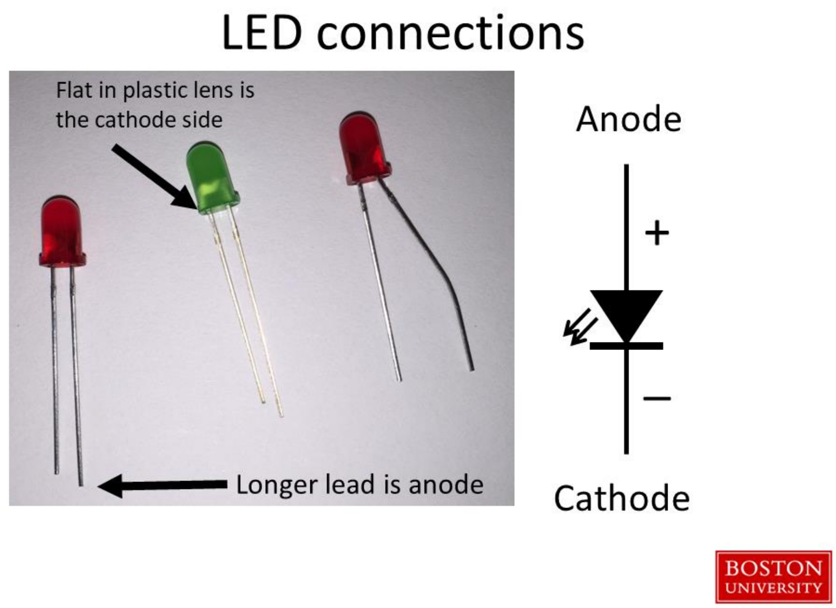
13. Consult the datasheets to determine if you exceeded the power rating of your LEDs. Comment below on your findings:

14. If you did exceed the power rating, the LEDs will be degraded. This will result in dimming, complete failure, a reduction of the slope of the V-I Curve, or erratic behavior. You can discard any damaged LEDs. There may be an E-waste bin in the lab to recycle them.

15. You are done! Be sure to upload this workbook and a screen shot of your spreadsheet data and plots to Blackboard.

Appendix: (You don’t need to include this section in your submission)



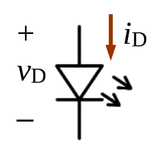


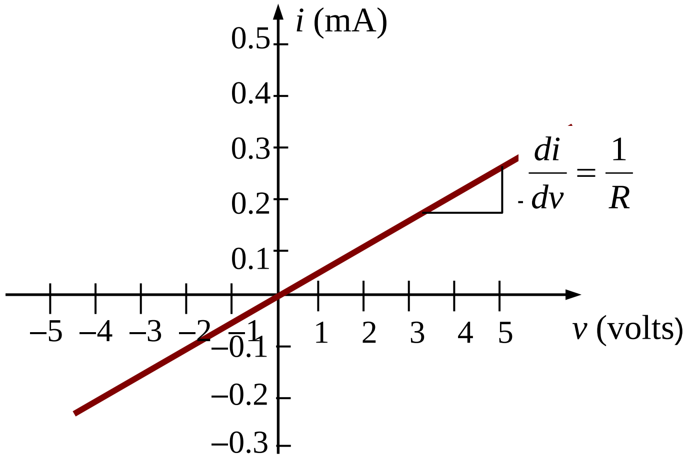
LEDs are polarized meaning they need to be connected in the proper orientation to emit light. The longer lead is the anode. The shorter lead is the cathode. If the leads are cut or bent the polarity can be determined by looking for the flat spot in the annulus of the plastic lens.

I-V curves

The current-voltage characteristic of a two-terminal circuit element, often called its “*i*-*v* curve”, describes the amount of current that flows through the element versus the voltage applied across it. The *i*-*v* curve is usually plotted with voltage on the horizontal axis and the current on the vertical axis.

A resistor has a very simple *i*-*v* curve defined by Ohm’s Law: $i = v/R$. This curve is actually a straight line because Ohm’s law is a linear equation. The plot below shows the i-v “curve” for a resistor of value R = 10 kΩ. Note that the line has slope $di/dv = 1/R$ = 0.1 mA/V.



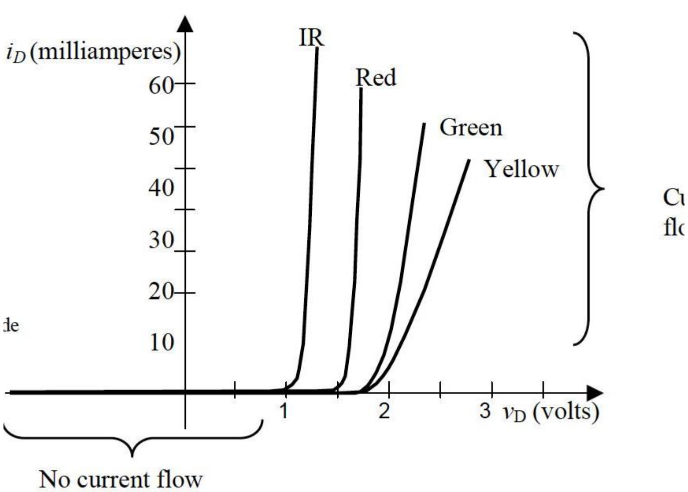


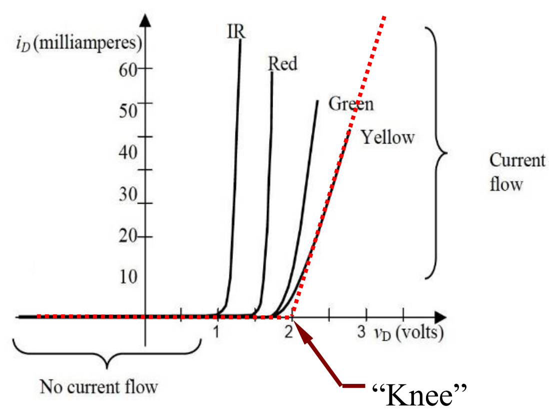
In contrast to a simple resistor, the light-emitting diode (LED) has a more complicated *i*-*v* equation:

$$i_D = I_S(e^{v_D/V_T} - 1)$$

Here i_D and v_D are the LED voltage and current, respectively, and I_S and V_T are constants. This formula is plotted below for LEDs of several different color types and values of I_S.

The *i*-*v* curve of an LED can be approximated using two straight lines: A horizontal line for voltages below the forward voltage, where no current flows; and a line having positive slope over the region where current does flow. The location where these two lines meet is called the "knee" of the *i*-*v* characteristic.





Straight lines that approximate actual *i*-*v* curve

As shown in the figure above, the current increases very rapidly for as the voltage is increased above the knee. If the applied voltage continues to increase, the current will continue to increase as well until the LED is no longer able to dissipate the inflow of power. At this point the LED sustains damage due to the excessive heat and burns out.