EK 307 Lab: Light-Emitting Diodes

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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.

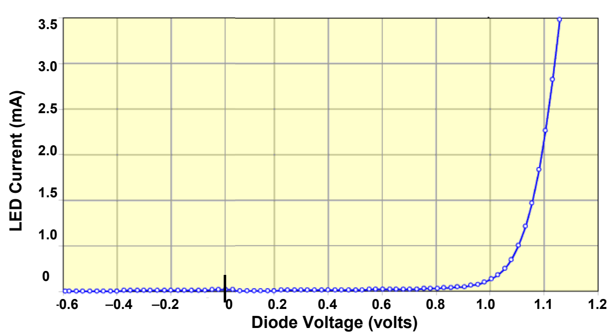


Figure 1: Example of a V-I curve for a nonlinear two terminal device. Your LED curves will have a similar shape but will numerically be different.

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.**

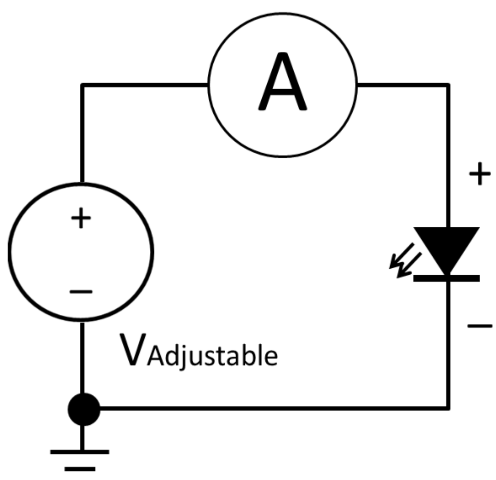


Figure 2: Measuring I-V characteristic of an LED

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.

2.5V

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?

Yes, likely do to different forward voltage

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.

Since I used 3 LEDs of different colours, the forward voltage (or in other words the minimum voltage they need in order to turn on) will be different. In this case we observe that the blue LED has a V_f of around 2.5V, while the red and green have V_f of 1.9V and 2V respectively. This is consistent with the data sheets which indicate typical forward voltages of around 1.8–2.0 V for red LEDs, about 2.0–2.2 V for green LEDs, and higher values (2.5–3.2 V or more) for blue LEDs. This also is coherent with the frequencies and therefore energies at these colors on the electromagnetic, where blue light has a higher frequency (shorter wavelenght) in comparison to green, and green is higher energy than red (which is at the lower end of the visible spectrum).

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?

As previously stated, The forward voltage region is identified on the I–V plots as the point where current rises steeply after remaining near zero at lower voltages. From the plots, this occurs at 1.9 V for the red LED, 2.0 V for the green LED, and 2.5 V for the blue LED. These values match well with the datasheet specifications (1.8–2.0 V red, 2.0–2.2 V green, 2.5–3.2 V blue). In each case, visible light emission begins around the same voltage where the current increase becomes rapid, consistent with the fact that the applied voltage must supply at least the photon energy corresponding to the LED’s emission wavelength.

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.

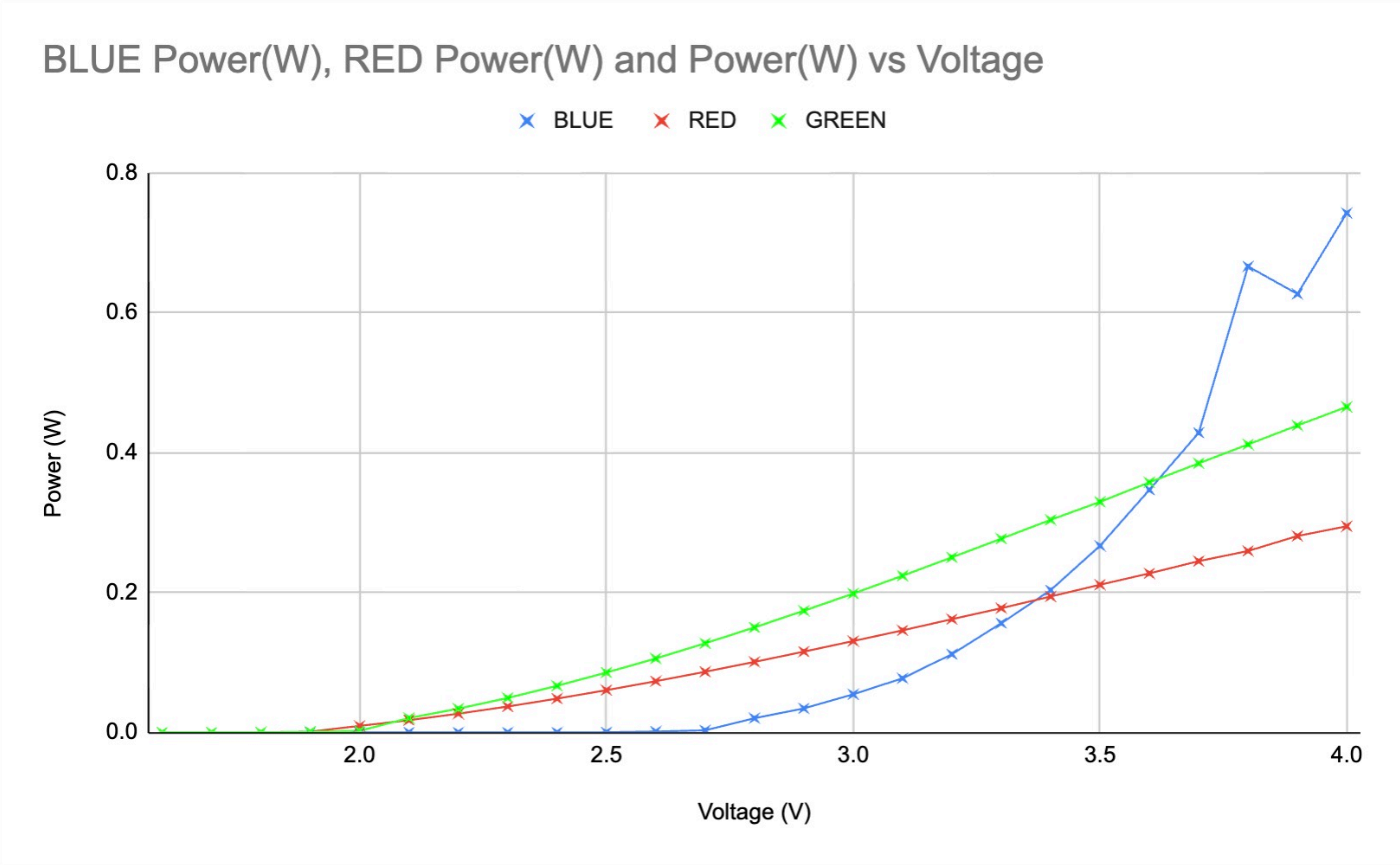
13. Consult the datasheets to determine if you exceeded the power rating of your LEDs. Comment below on your findings:

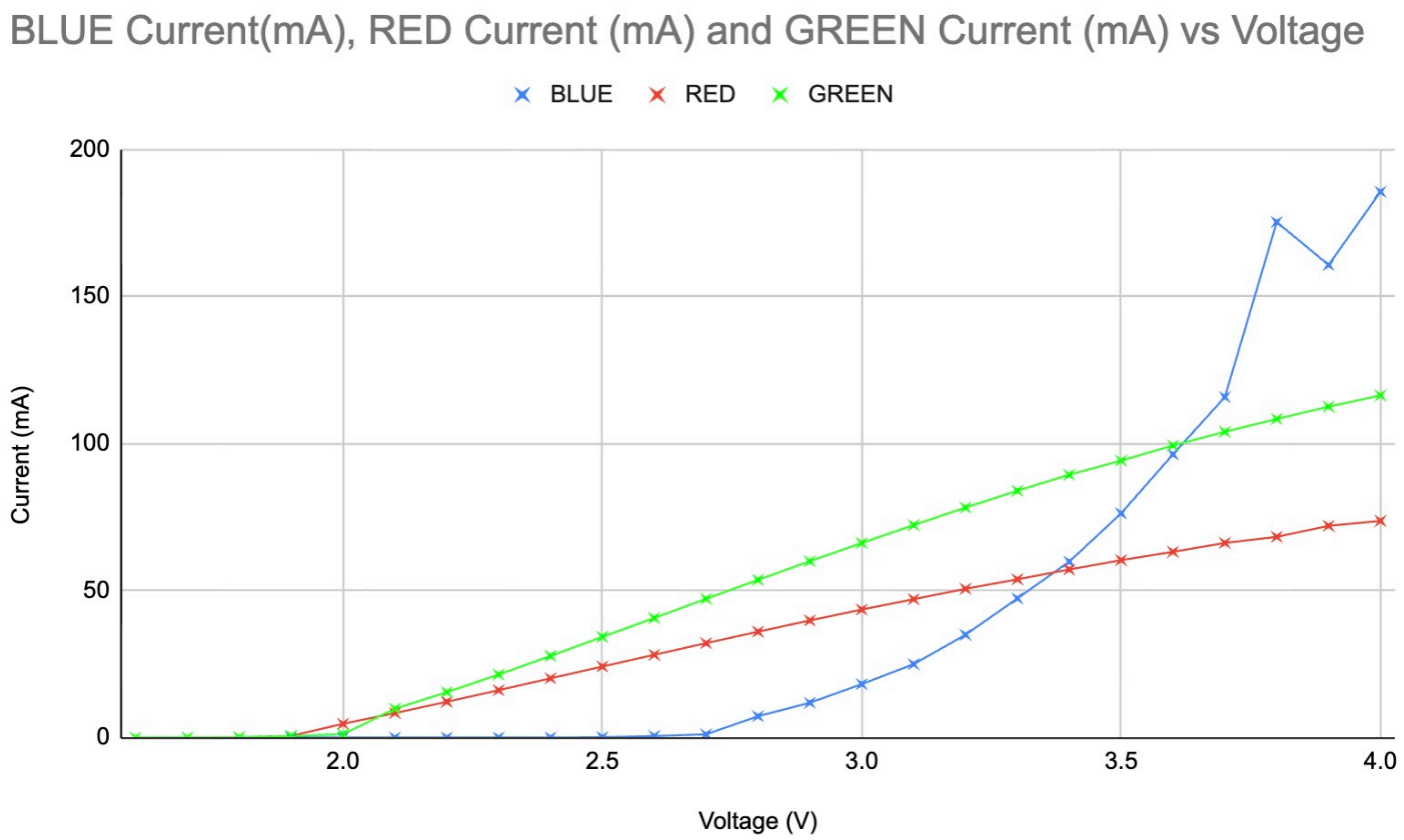
From the plots, the measured power dissipation in all three LEDs rises far above their datasheet maximum ratings of ~100 mW. The red LED reached ~294 mW, while the green and blue reached ~465 mW and ~742 mW respectively. These values are higher than the safe operating region and readon why they overheated and likely why the Blue LED stopped functioning properly at higher ranges and the V-I curve reduced in steepness

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.

Voltage (V)	BLUE Current (mA)	RED Current (mA)	GREEN Current (mA)	BLUE Power(W)	RED Power(W)	GREEN Power(W)
1.5	0	0.000146	0.000063	0	0.000000219	0.0000000945
1.6	0	0.001101	0.000744	0	0.0000017616	0.0000011904
1.7	0	0.010589	0.011487	0	0.0000180013	0.0000195279
1.8	0	0.12751	0.12619	0	0.000229518	0.000227142
1.9	0	0.57628	0.53279	0	0.001094932	0.001012301
2	0	4.672	1.1463	0	0.009344	0.0022926
2.1	0	8.3142	9.7866	0	0.01745982	0.02055186
2.2	0	12.164	15.429	0	0.0267608	0.0339438
2.3	0	16.097	21.41	0	0.0370231	0.049243
2.4	0.0084	20.131	27.74	0.00002016	0.0483144	0.066576
2.5	0.11474	24.147	34.229	0.00028685	0.0603675	0.0855725
2.6	0.508	28.138	40.633	0.0013208	0.0731588	0.1056458
2.7	1.098	32.094	47.163	0.0029646	0.0866538	0.1273401
2.8	7.255	35.987	53.591	0.020314	0.1007636	0.1500548
2.9	11.833	39.805	59.94	0.0343157	0.1154345	0.173826
3	18.158	43.519	66.133	0.054474	0.130557	0.198399
3.1	24.95	47.04	72.224	0.077345	0.145824	0.2238944
3.2	34.932	50.57	78.18	0.1117824	0.161824	0.250176
3.3	47.301	53.795	83.889	0.1560933	0.1775235	0.2768337
3.4	59.792	57.131	89.342	0.2032928	0.1942454	0.3037628
3.5	76.209	60.298	94.142	0.2667315	0.211043	0.329497
3.6	96.27	63.132	99.281	0.346572	0.2272752	0.3574116
3.7	115.743	66.153	103.935	0.4282491	0.2447661	0.3845595
3.8	175.252	68.233	108.302	0.6659576	0.2592854	0.4115476
3.9	160.661	71.975	112.479	0.6265779	0.2807025	0.4386681
4	185.552	73.65	116.307	0.742208	0.2946	0.465228


BLUE Power(W), RED Power(W) and Power(W) vs Voltage
BLUE
RED
GREEN
0.8
0.6
0.4
0.2
0.0
Power (W)
2.0
2.5
3.0
3.5
4.0
Voltage (V)



BLUE Current(mA), RED Current (mA) and GREEN Current (mA) vs Voltage
BLUE
RED
GREEN
200
150
100
50
0
Current (mA)
2.0
2.5
3.0
3.5
4.0
Voltage (V)