Your Name: ____

Your Lab Partners Name: ____

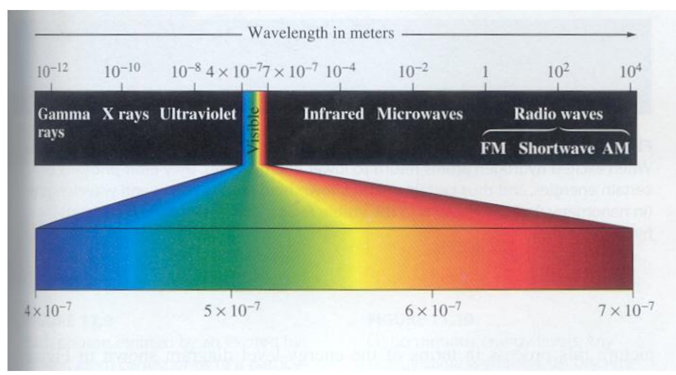
LAB: Exploring Light Emitting Diodes (LEDs)

Summary:

In this lab, we will be exploring the characteristics of Light Emitting Diodes (LEDs). In order to light up our LEDs, we will set up a simple circuit that allows us to control how much current we put into the LED. An important characteristic of individual LEDs is the *current-voltage curve* (abbreviated I-V curve). The I-V curve is a graph that plots the current (I) passing through the LED vs the voltage (V) across the LED. We will be working with different colored LEDs, and will explore the relationship between the colors of light emitted and the voltage, current, and power needed to light them up.

Background Information:

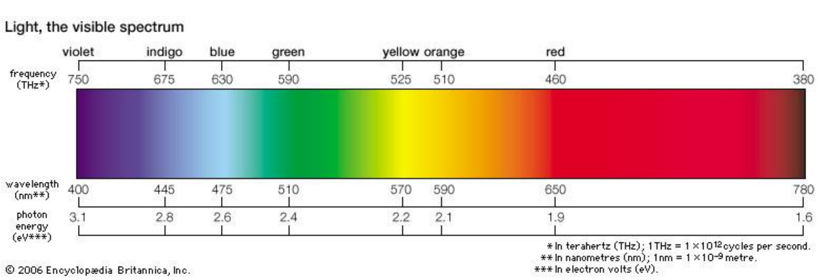
All visible light is a form of electro-magnetic (EM) radiation. The entire EM spectrum is shown on the right:



Different colors of light have different wavelengths and corresponding frequencies. In this lab, we will be using five LEDs in five different colors (the white LED does not appear on the table because it has multiple wavelengths). The colors and corresponding wavelengths are shown below:

Color of LEDs	Wavelength (nm) of LEDs
Blue	470
Green	569
Yellow	588
Red	623

* Remember, a nm (nanometer) is equivalent to 10^{-9} meters.



In addition, you will be working with two mystery LEDs. The colors and wavelengths of these mystery LEDs are not disclosed to you at this time.

The material that is used to make the diode determines the color of the LED. In class, we learned that GaN is used to make blue and white LEDs. Examples of materials used to produce different colored LEDs are Gallium

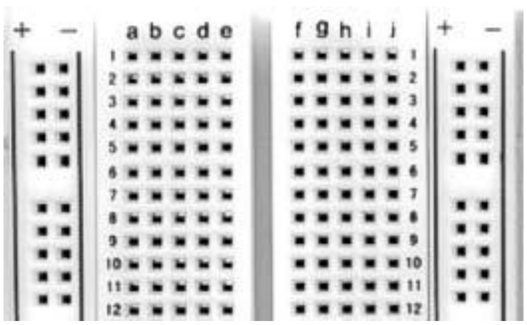
Arsenide (GaAs), which produces red LEDs, and Gallium Phosphide (GaP), which produces green LEDs.

The white LEDs that we are working with are actually blue LEDs. The blue LEDs shine blue light onto a phosphor that emits yellow light, and these colors combine to produce light that appears white. If you look at the white LED from above, you should be able to see the yellow phosphor. If you look at all the other LEDs, you will not see any yellow phosphor.

Equipment:

We will be using some lab electronics to power our LEDs and measure their current and voltage characteristics.

1. Breadboard:



The board that the LEDs and wires are connected to is called a *circuit board* or a *breadboard*. Many components can be directly plugged into the holes and wires can be used to form interconnections between them. The holes in the vertical columns under the + and - are connected (shorted) together. For the rest of the board, the holes are connected across horizontal rows. In the Figure to the left, the five holes in the top row (Row #1, Column a, b, c, d and e) are connected together. This means that if we apply a voltage to hole b1, the rest of the holes in the row (a1, c1, d1, e1) will have the same voltage.

2. Digital Multi-Meter (DMM):

DMMs can be used to measure voltage, current, or resistance. Voltage is measured in volts (V), current is measured in amps (A) and resistance is measured in ohms (Ω). DMM can be used for both AC (alternating current) and DC (direct current). DC is symbolized by a straight line and AC is symbolized by a wavy line. DC is used for measuring things like batteries and AC is used for measuring things like the voltage in a wall socket.

Volts

We will measure DC voltage (marked V⎓) and we will not make any measurements above 9 volts therefore, we will use the 20 V setting. Record voltage to the nearest hundredth of a volt (example: 5.01 V). When measuring voltage with a multi-meter: 1) make sure that the leads are plugged into the voltage (V) and common (com) connectors and 2) make sure that the knob is turned to DCV. To measure voltage touch the lead to any exposed wires on either side of the area in which you wish to measure the voltage drop (see diagram on next page).

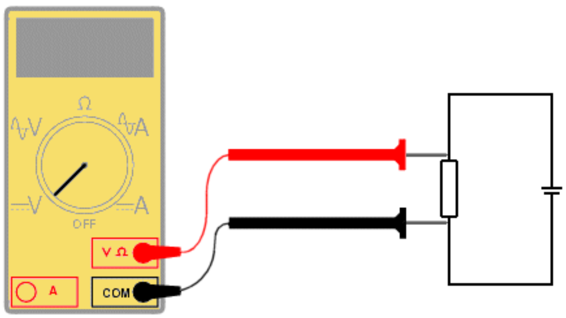
Current

We will measure DC current (marked A ⎓), and we will not make any measurements above 25 mA therefore, we will use the 200 mA setting. Record current to the nearest tenth of a milliamp (example 5.1 mA). When measuring current with a multi-meters 1) make sure the leads are plugged into the current (A) and common (com) connectors and 2) and make sure the knob is turned to DC. In order to measure the current you must insert the multi-meter into the circuit. This is done by breaking the circuit and hooking it up to either end of the multi meter (see below).

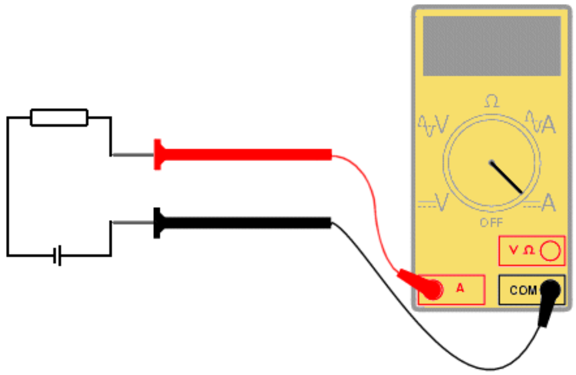
Resistance

The resistor that we are using should be around ~180 Ω therefore, we will use the 200 Ω setting. Record resistance to the nearest tenth of an ohm (example: 174.5 Ω). When measuring resistance with a multi-meter: 1) make sure that the leads are plugged into the resistance (Ω) and common (com) connectors and 2) make sure that the knob is turned to resistance. To measure resistance touch the lead to any exposed wires on either side of the area in which you wish to measure the resistance (see below).

Measuring Voltage/Resistance



Measuring Current

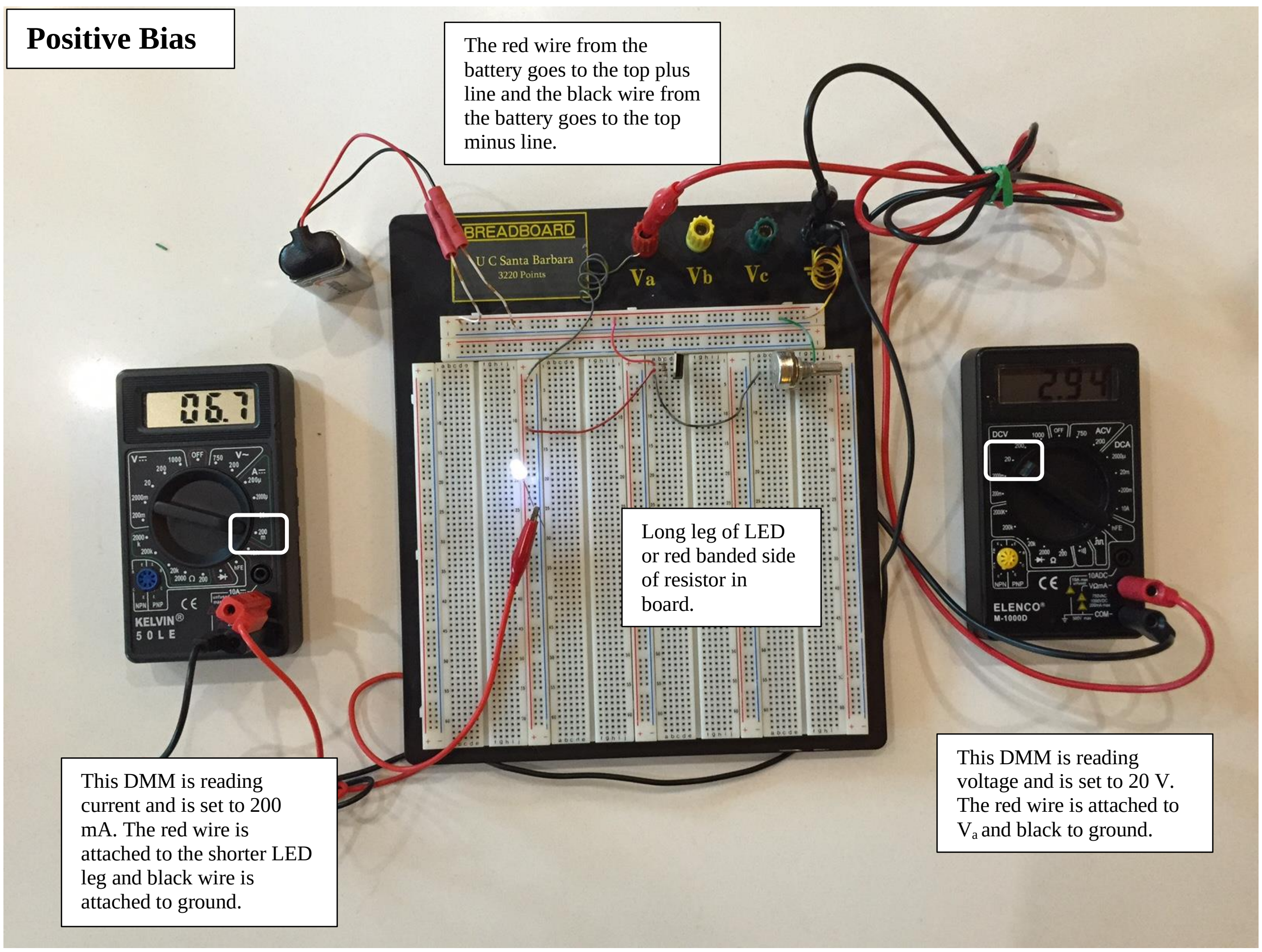


2. DC Power Supply:

We will supply DC voltage by using a 9 V battery, 10 KΩ potentiometer, and a LM317 voltage regulator.

LEDs and (resistors)
Positive Bias

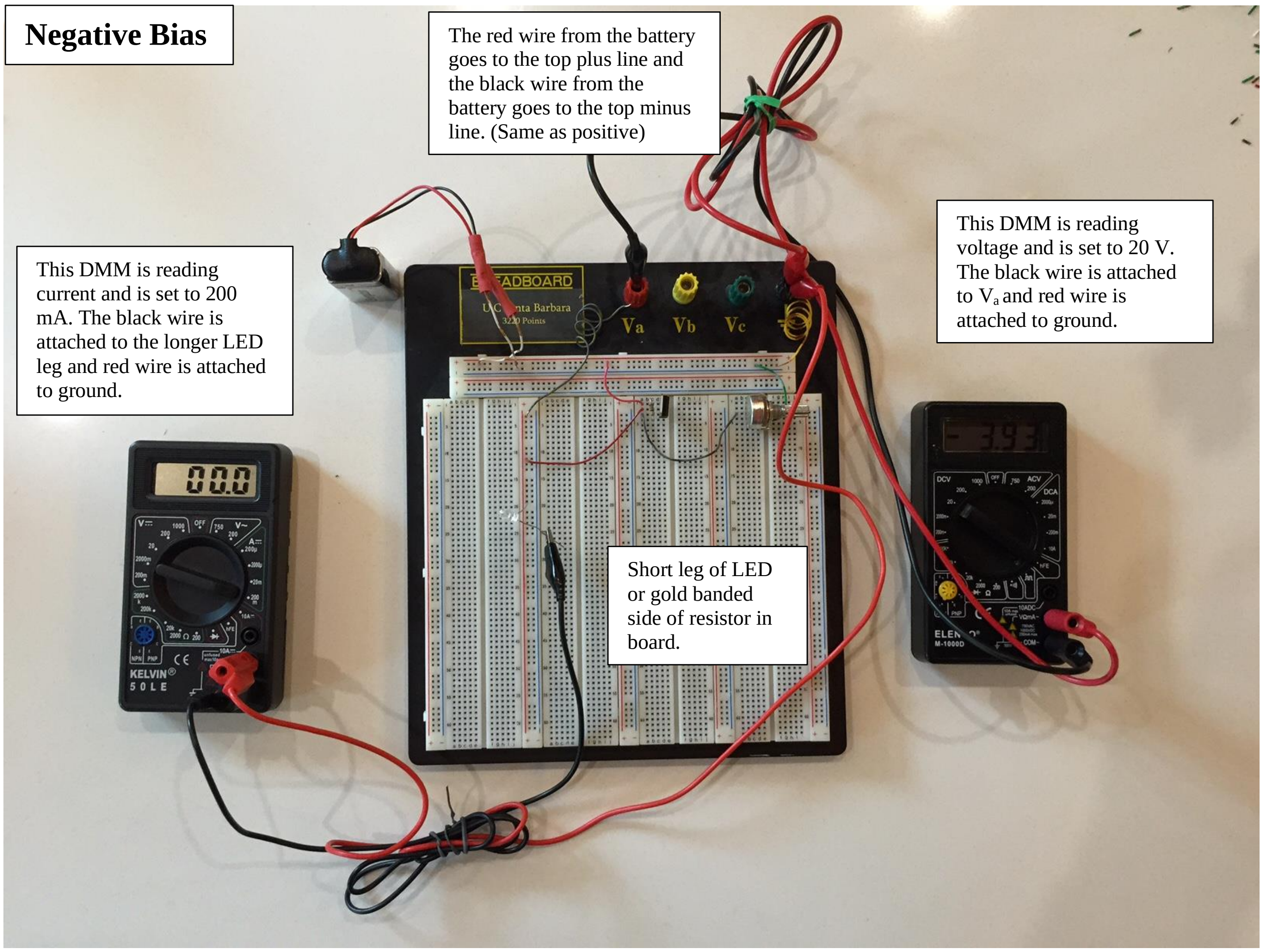
1. The wires from the DMM that are going to be used to measure voltage should be attached so that the black wire is attached to the plug on the top of the bread board labeled (⏚) and the red wire is attached to the plug on the top of the bread board labeled V_a.
2. Make Sure that the **long** leg of the LED (**red banded side** of the resistor) is in the bread board.
3. The wires from the DMM that are going to be used to measure current should be attached so that the black wire is attached to the plug on the top of the bread board labeled (⏚) and the red wire is attached to the short leg of the LED.



LEDs (and resistors)

Negative Bias

1. The wires from the DMM that are going to be used to measure voltage should be attached so that the red wire is attached to the plug on the top of the bread board labeled (⏚) and the black wire is attached to the plug on the top of the bread board labeled $V_{a.}$ (reverse from positive bias)
2. Make Sure that the **short** leg of the LED (**gold banded side** of the resistor) is in the bread board.
3. The wires from the DMM that are going to be used to measure current should be attached so that the red wire is attached to the plug on the top of the bread board labeled (⏚) and the black wire is attached to the long leg of the LED. (reverse from negative bias)



Procedure
Important Notes:

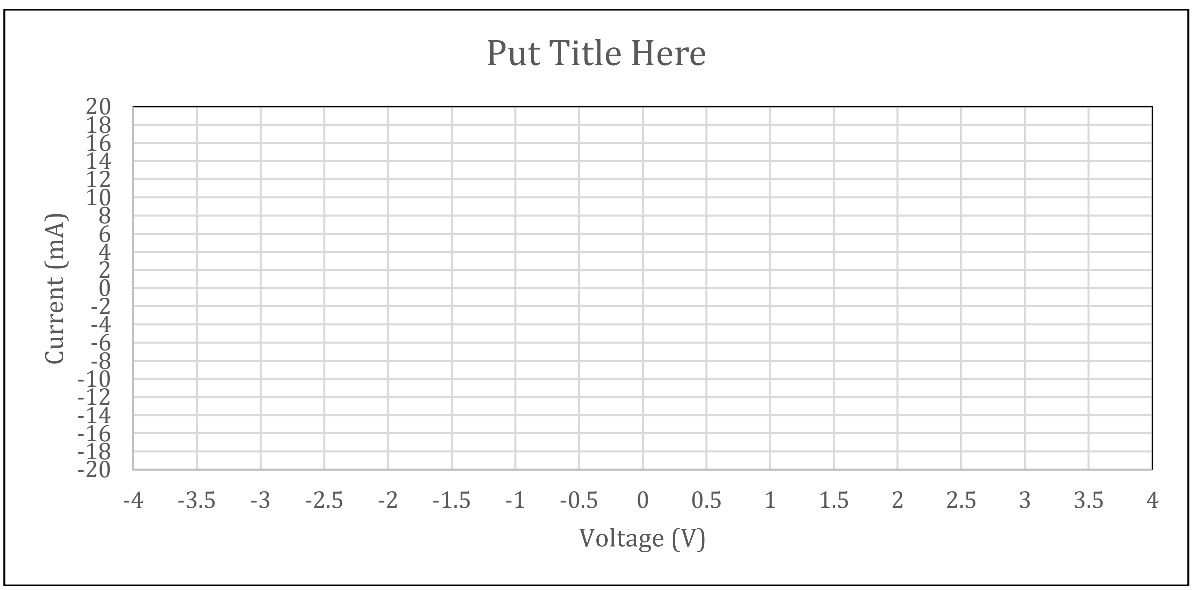
1. Read all of the information on pages 1-5.

2. Check your lab space and make sure you have 5 LEDs (white, blue, green, yellow, and red), 1 resister, the breadboard, 2 DMM, and 4 connectors.

3. The breadboard will be set up initially with a ~180 Ω resistor.

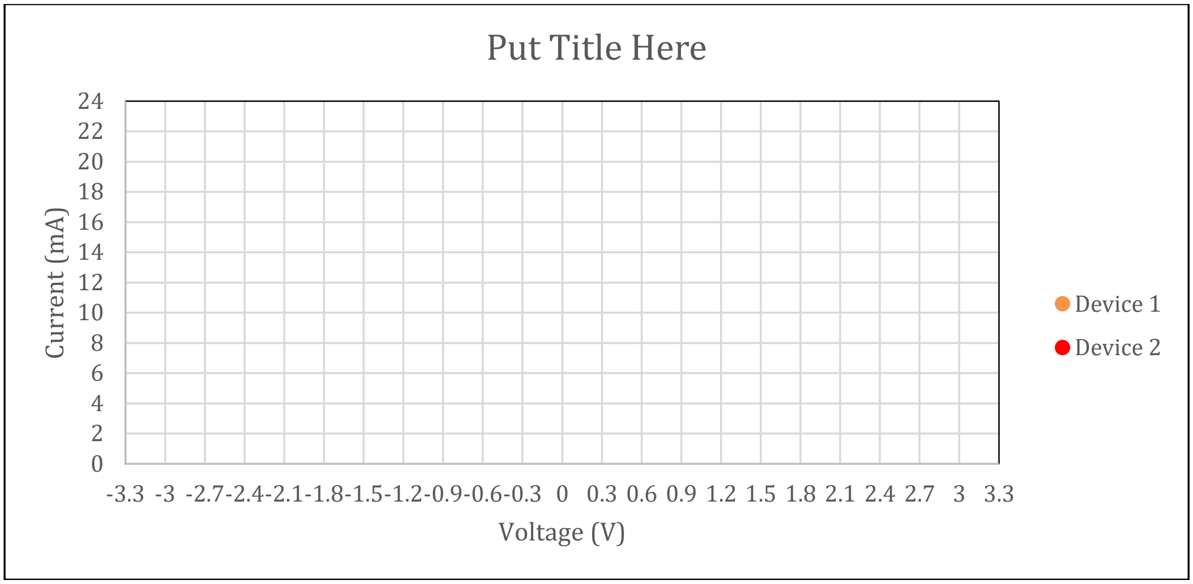
4. By applying voltages to the circuit, fill out the table for the resistor in the results section. You will need to measure the current in the circuit at -3 V, -1.5 V, and 0 V (all of these values can be ±0.5V) from the power supply. To get 0 V remove the battery from the board. To apply a negative voltage see page 5. Then switch the bread board to positively bias the resistor/LED see page 4. Then adjust the power supply voltage until you measure 5, 10, 15, and 20 mA current (all of these values can be ± 5 mA). Make sure to record the actual voltage and current on your chart. For data set you will need to calculate the power (mW) = current (mA) × voltage (V)

5. Once you have taken the measurements for the resistor use **Excel** to construct a current vs. voltage curve similar to the one seen below (points will be taken off if axis in wrong place or if titles are missing). The Y axis should go between -20 to 20 in steps of 2 and the X axis should go between -4 to 4 in steps of .5. Show Darby your graph before moving on.



6. Remove the resistor from the breadboard and insert the red LED in its place and take measurement for both positive and negative bias. Repeat the measurements that you did for the resistor, but in addition, there is another line where you should fill in which is the voltage and current needed when you first see the first bit of light. Known as the turn-on voltage ($V_{turn\text{-}on}$). You will have look carefully from above the LED to see that first glimpse of light**. <u>WARNING: Adjust the power supply slowly and carefully. Do not apply more than -3 V (3 V in the reverse direction) or 25 mA of current in the forward direction, or the LED will burn out.</u>**

7. Once you have taken the measurements for the red LED construct another current vs. voltage curve (do not put on the same plot as the resistor) similar to the one seen below (points will be taken off if axis in wrong place, titles are missing, or if there is no legend). The Y axis should go between 0 to 24 in steps of 2 and the X axis should go between -3.3 to 3.3 in steps of 0.3. Show Darby you graph before moving on.



8. Repeat the process for the other 4 know LEDs. The colors do not need to be done in order. As soon as you collect the data put it into the same plot as the red LED. This will allow you to see if the data makes sense. Make sure that you have a legend on the plot with appropriately colors to distinguish between the LEDs.

9. Have your LED plot approved by Darby and she will give you the two mystery LEDs. Fill in the table for Mystery LED #1 (the blue looking LED). Be very careful when recording the data for this LED. Make sure both you and your partner are paying attention. Continually ask yourself does this make sense. Do not take the voltage over 3 V or below -3 V.

10. Put the data points for mystery LED #1 on your LED plot.

11. Now try Mystery LED #2 (hazy LED). You do not need to fill a table out for this LED. You only need to identify the color—it will be one of the questions due with this report. What happens when you run this LED in forward and reverse biases?

12. Print out two full page color copies of your graph. On one graph, by hand draw on lines of best fit for all of the LEDs. Then determine the voltage (to the nearest tenth (0.1)) at 10 mA for each LED.

Results:

Things to remember:

1) Adjust the voltage very slowly or you will burn out your LEDs.
2) The numbers on the chart are what you should shoot for. You should be able to get **voltages** to be within **±0.5 V**. For the **current** you should be able to get **±5 mA**. Record the actual values read from the DMMs on the chart.
3) After you have made the measurement for each LED, graph your results before moving onto the next LED.
4) When you are not taking measurements remove the battery from the circuit.

Fill out the following tables for measurements on the resistor and the LEDs. The ideal values you are shooting for are typed in on the table. <u>Make sure to record the actual measured values</u> as well and use the measured values for your plots.

222 Ohm Resistor				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
		7		
		10		
		15		
		20		

Green LED				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
$V_{turn\text{-}on}$=				
		5		
		10		
		15		
		20		

*Make sure 10 mA reading is between 9.7-10.3 mA

Yellow LED				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
$V_{turn\text{-}on}$=				
		5		
		10		
		15		
		20		

Blue LED				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
$V_{turn\text{-}on}$=				
		5		
		10		
		15		
		20		

White LED				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
$V_{turn\text{-}on}$=				
		5		
		10		
		15		
		20		

Red LED				
Voltage (V)		Current (mA)		Power (mW)
-3				
-1.5				
0				
$V_{turn\text{-}on}$=				
		5		
		10		
		15		
		20		

Mystery LED #1 (blue looking mystery LED)		
Voltage (V)	Current (mA)	Power (mW)
-3		
-1.5		
0		
	10	
	15	
	20	

Apply a forward and a reserves bias to mystery LED #2 (cloudy LED). You will need to describe the properties of this LED for question 8.

Lab Report

1. Hand in the tables showing current, voltage and power consumed for each LED and the resistor. (You do not need to type these out you can just turn in this packet) (4 points)

2. Hand in a full page plot of the I-V curve for the resistor. (1 points)

3. Hand in 2 full page colored plots of the I-V curves for all the known LEDs and mystery LED #1. Make sure that one plot has hand drawn lines of best fit and the predicted voltages at 10 mA noted. (5 points)

4. Hand in a bar chart comparing power at 10 mA for each LED color. (2.5 points)

5. Hand in a bar chart comparing the ‘turn-on’ voltage for each LED color. (2.5 points)

Provide typed answers to the following questions. For this section answer each question individually and make sure to number them corresponding to the numbers on the questions. Remember you grade is based on the evidence that you provide to back up your statement.

6. Comment on your I-V curves, in particular comment on the difference between LEDs and the resistor and on the differences between the graphs for different LED colors. (5 points)

7. Comment on your chart comparing turn on voltages. What is the qualitative relationship between the LED color and the turn-on voltage? (5 points)

8. What area of the electromagnetic spectrum do think the mystery LED #1 is emitting at? You must generate an evidence based explanation for this. (5 points)

9. What color is mystery LED #2? (Hint: This may be a trick question of some sort) How do you think the LED is designed to give the color(s) you saw? What happens when you turn this LED around? (5 points)

10. In class we made the claim that white LEDs are just blue LEDs that stimulate phosphorus causing both light from the LEDs and phosphorus to combine to make white light. Based on your data do you believe this statement? Come up with an evidence based explanation of why or why note. (5 points)

You are encouraged to discuss things in groups while working on this lab 'report,' but all answers must be your own. Ask Darby any questions if you are stuck or need help with Excel.

Write a one-page letter to a "college student" that does not know about LEDs explaining the electric properties of LEDs, not how an LED works (a wire puts and electron into the conduction band of the n-type material), but how they electronically behave (LEDs turn on when …). This letter does not need to include all of you findings, but must incorporate some of your findings. The letter should be in paragraph form. You can include data (graphs, etc.) as part of your 1-page letter. Make sure that you back up all of your claims with data. (10 points)