Name:______________________________ **Date:** ____________________

Partner:______________________________ **This worksheet has two sides!**

Part I: Resistor

1. What is the color code for your resistor? (   ) (   ) (   ) (=   %)
2. Use the color code to look up the expected value of the resistance.
   The color code includes an uncertainty! R_{code} = (±   ) Ω
3. Use the multimeter in Ω mode to determine R at least 5 times: R_{meter} = (±   ) Ω
4. Use your plot of ΔV vs I to determine the resistance yet again: R_{plot} = (±   ) Ω
5. Discuss/explain with numbers: What do you think the "true" resistance is?

Part II: Light Bulb

1. The light bulb is not "ohmic", so in any real sense, it doesn't even have a resistance. Yet, when we use the multimeter in Ω mode, we still get a number. Do that at least 5 times, and write the average result and it's uncertainty here:

   R_{bulb} = (±   ) Ω
2. Use both *trendline* and *linest* to determine a best fit curve of the form:
   $\Delta V = a_0 + a_1 I + a_2 I^2 + a_3 I^3 + a_4 I^4 + a_5 I^5$. Compare the two closely, then write (some of) the coefficients here. Each has units as specified by the equation itself. For example, a_2 must be in V/Amp^2. So, include the units! Any scientific notation must occur OUTSIDE of the parentheses:

   a_0 = (±   ) ________

   a_1 = (±   ) ________

   a_2 = (±   ) ________

   a_3 = (±   ) ________

3. Explain why a parabolic (an order 2 polynomial) isn't sufficient to describe the light bulb. If you don't know why, the answer is to obviously just *try it* in Excel and see for yourself!

4. This question requires some (very minimal) calculus. Use your pentic equation above to determine the slope of your curve fit when $I = 0$.

   slope = ________ ± ________ Ω
5. Explain what you think the multimeter was doing when you used it to get a resistance for the light bulb.

Part III: LED

1. You were required to use a resistor in series with the LED. Use the multimeter to find just one measurement of its actual resistance:

R_{meter} = (__________ ± __________) Ω

2. Diodes, including LEDs, are so non-ohmic that the ohmmeter setting won’t tell you anything at all. However, some multimeters have a diode setting. Get a hand held multimeter, put it into diode mode (—▶|—), and try it both ways (i.e., swapping whether the red and black probes touch this leg or that leg of the diode). One of the two connections will cause the LED to light (a little), and it will also tell you a number. Write that number here. Don’t worry about uncertainty.

Expected Diode Value = V_D = (____________) V

Keep track of which leg of the diode is which! We will say V and I are positive when the diode is in the direction that can light.

3. What color was the LED when it was lit? color = ____________________

4. For diodes, it is customary to plot I_{diode} vs ΔV_{diode}, instead of the other way around. Your plot should have two fairly clear segments at (almost) right angles to each other. Without using trendline, linest, or a calculator, write the equation that you *see* when $\Delta V < V_D$. If you can’t see it in your mind, then make an actual plot of I vs ΔV vs for the cases where $\Delta V < 0.7\ V_D$. But if you do this, beware of getting caught up in meaningless sig figs… keep in mind that I expect you to be able to know the answer to this question without using any technology at all!

when $\Delta V < V_D$, $I(\Delta V)$ = ____________________

5. For the “other” portion of your plot, we notice that $I > 0$. Without using trendline, linest, or a calculator, write the equation that best describes *this* behavior. To see this result better, you could obviously be aided by making a plot of ΔV vs I for all the cases where $\Delta V \geq V_D$. I deliberately made this space small so you won’t be tempted to write irrelevant sig figs, or overly complicated formulas, etc. Like the previous question, the “ideal approximation” for this plot will be so simple that it will have *either* a slope or an intercept… but not both!

when $I > 0$, $\Delta V(I) \approx$ ____________

6. Use this last result to provide an English description of the meaning of V_D (that you measured in question 2, above).

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1. What is the color code for your resistor? (   ) (   ) (   ) (=   %)
2. Use the color code to look up the expected value of the resistance.
   The color code includes an uncertainty! R_{code} = (±   ) Ω
3. Use the multimeter in Ω mode to determine R at least 5 times: R_{meter} = (±   ) Ω
4. Use your plot of ΔV vs I to determine the resistance yet again: R_{plot} = (±   ) Ω
5. Discuss/explain with numbers: What do you think the "true" resistance is?

Part II: Light Bulb

1. The light bulb is not "ohmic", so in any real sense, it doesn't even have a resistance. Yet, when we use the multimeter in Ω mode, we still get a number. Do that at least 5 times, and write the average result and it's uncertainty here:

   R_{bulb} = (±   ) Ω

2. Use both *trendline* and *linest* to determine a best fit curve of the form: $\Delta V = a_0 + a_1 I + a_2 I^2 + a_3 I^3 + a_4 I^4 + a_5 I^5$. Compare the two closely, then write (some of) the coefficients here. Each has units as specified by the equation itself. For example, a_2 must be in V/Amp^2. So, include the units! Any scientific notation must occur OUTSIDE of the parentheses:

   a_0 = (±   ) __________

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3. Explain why a parabolic (an order 2 polynomial) isn't sufficient to describe the light bulb. If you don't know why, the answer is to obviously just *try it* in Excel and see for yourself!

4. This question requires some (very minimal) calculus. Use your pentic equation above to determine the slope of your curve fit when $I = 0$.

   slope = __________ ± __________ Ω

5. Explain what you think the multimeter was doing when you used it to get a resistance for the light bulb.

Part III: LED

1. You were required to use a resistor in series with the LED. Use the multimeter to find just one measurement of its actual resistance:

R_{meter} = (________ ± ___________) Ω

2. Diodes, including LEDs, are so non-ohmic that the ohmmeter setting won't tell you anything at all. However, some multimeters have a diode setting. Get a hand held multimeter, put it into diode mode (—▶|—), and try it both ways (i.e., swapping whether the red and black probes touch this leg or that leg of the diode). One of the two connections will cause the LED to light (a little), and it will also tell you a number. Write that number here. Don't worry about uncertainty.

Expected Diode Value = V_D = (___________) V

Keep track of which leg of the diode is which! We will say V and I are positive when the diode is in the direction that can light.

3. What color was the LED when it was lit? color = __________________

4. For diodes, it is customary to plot I_{diode} vs ΔV_{diode}, instead of the other way around. Your plot should have two fairly clear segments at (almost) right angles to each other. Without using trendline, linest, or a calculator, write the equation that you *see* when $\Delta V < V_D$. If you can't see it in your mind, then make an actual plot of I vs ΔV vs for the cases where $\Delta V < 0.7\ V_D$. But if you do this, beware of getting caught up in meaningless sig figs… keep in mind that I expect you to be able to know the answer to this question without using any technology at all!

when $\Delta V < V_D$, $I(\Delta V)$ = __________________

5. For the "other" portion of your plot, we notice that $I > 0$. Without using trendline, linest, or a calculator, write the equation that best describes *this* behavior. To see this result better, you could obviously be aided by making a plot of ΔV vs I for all the cases where $\Delta V \geq V_D$. I deliberately made this space small so you won't be tempted to write irrelevant sig figs, or overly complicated formulas, etc. Like the previous question, the "ideal approximation" for this plot will be so simple that it will have *either* a slope or an intercept… but not both!

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