PyLab 4 - Nonlinear Fitting Methods and Circuits

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Abstract:

The purpose of this lab was to take voltage and current values across a lightbulb with a tungsten filament and analyze the power laws between Voltage and Current. The lab showed that $I \propto V^{0.5882}$ for the tungsten bulb.

Introduction:

The purpose of this lab was to analyze the proportionality between the voltage and current across a tungsten light bulb. This was done using the curvefit() function in python along with a linear model function (y=mx+b) and an exponential model function ($y = mx^b$).

Equipment:

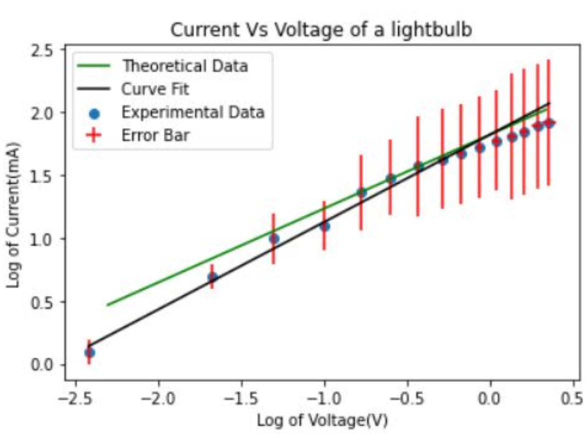
- Two Multimeters - used to measure current, and voltage
- Breadboard - used to add the loads to the circuit
- Wires - used to build the circuit
- Power Supply - used to supply power to the circuit

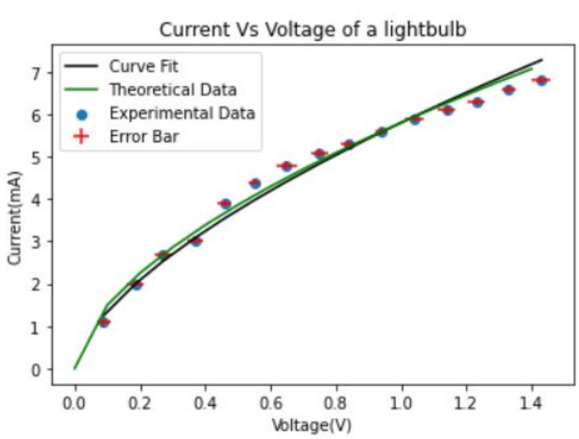
Procedure:

The first step was to set up the circuit. A series circuit was set up with the power supply, multimeter measuring current, and the lightbulb on the breadboard. The multimeter measuring voltage was connected parallel to the bulb. Starting at the lowest voltage setting on the power supply, it was slightly increased by increments of about 0.100V and the voltage/current readings from the multimeters were recorded. About 15 readings were taken alongside the error for each (±0.75% for current and ±0.25% for voltage). This data, which can be found in Appendix A, was then imported where they were plotted against each other using both the linear model function and the exponential model function (see introduction). Along with the imported data, error bars, a curvefit, and a theoretical plot were also created to analyze the accuracy of the data taken. The variance and reduced chi-squared values of the data were then calculated to check for accuracy.

Results:

Once the data was imported, the following plots were generated in Python. Both of these represent estimates of the actual relationship between V and I:





Both power law relations between V and I were calculated from the curvefit() function and were found to be ≅0.696 for the linear plot and ≅0.634 for the exponential plot. The desired value was 0.5882. This will be further discussed in the Discussion section.

Using the np.sqrt() function to calculate variance in my x and y values for the linear plot, I got 0.07 in the x parameter and 0.1 in the y. For the exponential plot, I got 0.1 in the x and 0.02 in the y.

The np.std() function was used to calculate the standard deviation for the y values in the linear and exponential plots. They were 0.5 and 1.7 respectively.

The reduced chi-squared values for each plot were then calculated using the following formula:

$$\chi^2 = \frac{1}{N-n}\sum_{i=1}^{N}\left(\frac{y_i - y(x_i)}{\sigma_i}\right)^2$$

Where: N = number of observation
n = number of parameters
y_i = current values
x_i = voltage values
σ_i = the error in the current values

For the linear plot, chi-squared was 0.59 and for the exponential plot, it was 0.23.

Discussion:

It turns out that the non-linear regression method gave a value closer to the expected exponent of 0.5882. This may be due to the fact that the non-linear method used the raw data exactly how it was imported, whereas the linear method tampered with the data using logarithms in order to force a linear regression. This causes the linear method to be more of an approximation. Looking at the plots above, it is clear that the non-linear regression method would give a more accurate value as the error bars are much smaller. This means the data is more accurate to the expected relationship.

Also, important an important result, of my data is that the values of my calculated exponents were not in range with the expected value for blackbody radiation. This could be due to some physical errors in the data collection process such as the resistance in the wires and the error in the power supply. Even considering these errors, however, my values were still close to what was expected. In terms of the expected tungsten value, I was not in range, yet I was still very close. This is could be due to the same errors mentioned earlier.

Both of my reduced chi-squared values were less than one, which means my model was an overfit. This may be due to the amount of reading taken as 15 readings is not very much.

Conclusion:

In conclusion, the proportionality between V and I was close to, but not exactly what was expected.

Appendix A:

Recorded Values

Voltage (V)	Current (mA)
0.089 ± 0.002	1.1 ± 0.1
0.187 ± 0.005	2.0 ± 0.1
0.271 ± 0.007	2.7 ± 0.2
0.368 ± 0.009	3.0 ± 0.2
0.46 ± 0.01	3.9 ± 0.3
0.55 ± 0.01	4.4 ± 0.3
0.65 ± 0.02	4.8 ± 0.4
0.75 ± 0.02	5.1 ± 0.4
0.84 ± 0.02	5.3 ± 0.4
0.94 ± 0.02	5.6 ± 0.4
1.04 ± 0.03	5.9 ± 0.4
1.14 ± 0.03	6.1 ± 0.5
1.23 ± 0.03	6.3 ± 0.5
1.33 ± 0.03	6.6 ± 0.5
1.43 ± 0.04	6.8 ± 0.5

References:

MULTIMETER (Digital), faraday.physics.utoronto.ca/specs/tegam130a.html.