Phys 265 - Lab 2 – Measurement of the index of refraction of glass

Download and edit `lab2lastname.py` *and* `refractionData.txt`*, which are posted on ELMS.*
Submit three items to your github account:

1. *Your completed version of lab2_lastname.py (re-named appropriately)*
2. *A screenshot of your desktop after running your code.*
3. *A two to three page summary of your final submission. See below for more information.*

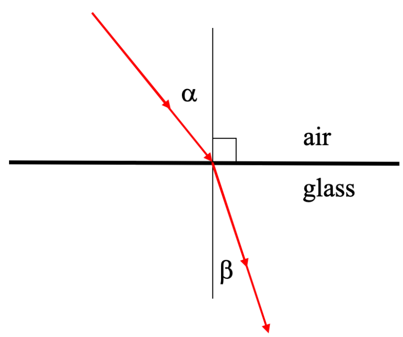
Introduction: You are a data scientist at a small industrial firm that has developed a new type of glass. To measure the index of refraction of the glass, the technical staff has collected refraction data using a laser of a certain wavelength. Your job is to analyze the data to extract the index of refraction of the glass, along with its experimental uncertainty.

After you have analyzed the data, you will write a short report describing how you arrived at your conclusions. Your report will be read by Carla, your supervisor. Carla has a BS degree in physics and an MBA (Master's in Business Administration). Because of her physics degree, Carla has some knowledge of optics, data analysis, and statistics, but it is not her area of expertise, and she has not done any data analysis in several years. This is why she has hired you as the data scientist.

Carla wants your results to eventually be included in a brochure that will market the new glass to customers. For this reason, she wants your plots and tables to be attractive and professional.

See below for more information about the data analysis report.

Background: A light ray traveling in air strikes a glass interface and refracts:



The angles α and β are related by Snell's law:

$$n_{air}\sin(\alpha) = n_{glass}\sin(\beta)$$

where α is the angle of incidence, β is the angle of refraction, and n_{air} and n_{glass} are the indices of refraction. Setting $n_{air} = 1$, then

$$\sin(\beta) = \sin(\alpha)/n_{glass}$$

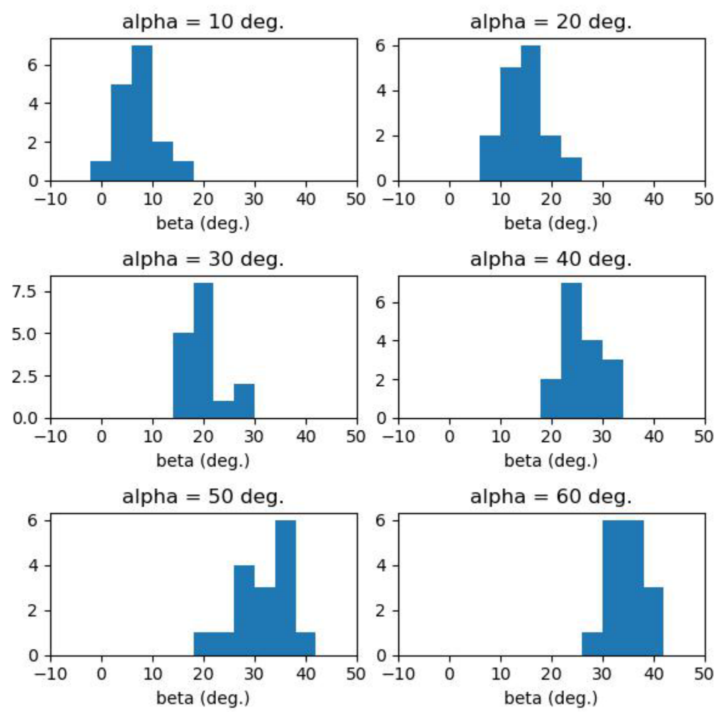
You will analyze refraction data and use Snell's law to determine the index of refraction of the glass and its uncertainty. To make the data points fall on a line, you will plot and fit the data as $\sin(\beta)$ vs $\sin(\alpha)$, rather than (α) vs. (β).

Dataset:

The angle of refraction was repeatedly measured (16 times each) at six different angles of incidence: α = 10°, 20°, 30°, 40°, 50°, and 60° degrees; a total of 96 measurements. These measurements are contained in `refractionData.txt;` see the header information in that file for more details. You should consider the angle α to have zero uncertainty, but the repeated measurements of β exhibit a random (statistical) uncertainty.

Part 1: Histogram the data

1. Open `refractionData.txt` and read the header information. Make sure you understand the meaning of the data contained in the file.
2. Use `np.loadtxt()` to read the data into a 2D `numpy` array. Recall that the parameter `skiprows` allows the header info to be ignored.
3. Make six histograms of the data, one for each angle of incidence. To make the plots, you can use the `axes[0], axes[1], ….., axes[5]` objects provided to you in `lab2lastname.py.`
4. Set the x-axis limits to be the same on all six histograms, and give them basic labeling so that they look like this:



Part 2: Print out a table of measurements

1. For each of the six datasets shown above, convert β to radians, and then compute the mean value of β and the standard deviation of the mean value of β, which we will call $\sigma(\beta)$. (Recall that the standard deviation of the mean is the uncertainty on the mean.)
2. Propagate the mean values of β and $\sigma(\beta)$ through the sine function, so you have six values of $\sin(\beta)$ and six uncertainties ($\sigma(\sin(\beta))$).
3. Print out to the terminal a table displaying the six values of:
   a. α

b. the sine of α
c. the mean value of β
d. the sine of the mean value of β
e. $\sigma(\sin(\beta))$.

4. Choose an appropriate number of significant figures to display in the table. Label the columns and otherwise make the table easily readable and understandable.

Part 3: Snell's law plot and fit

1. Use the `ax1` object given to you in `lab2lastname.py` to make a plot of $\sin(\beta)$ (on the y-axis) vs $\sin(\alpha)$ (on the x-axis). Show the uncertainties on the $\sin(\beta)$ datapoints using errorbars. Label the x and y axes.
2. According to Snell's Law, $\sin(\beta)$ is directly proportional to $\sin(\alpha)$. Define a function that accepts $\sin(\alpha)$ and n (the index of refraction) as inputs, and returns a value of $\sin(\beta)$.
3. Do a one-parameter χ^2 fit to your $\sin(\beta)$ vs $\sin(\alpha)$ plot, using the Snell's law function defined above.
4. Print out to the terminal the best fit value of the index of refraction, along with its uncertainty.
5. Draw the best fit line on your plot.
6. Compute and print to the terminal the χ^2 for the best fit line compared to the data, along with the number of degrees of freedom in the fit, and the p-value.

Part 4: Plot the chi squared as a function of the index of refraction

1. Compute the χ^2 of the data as a function of the index of refraction of the model function.
2. Use the `ax2` object given to you in `lab2lastname.py` to make a plot of the χ^2 as a function of n (the index of refraction).
3. Put vertical lines on the plot indicating where the minimum in the χ^2 occurs and where the (+) and (-) one sigma excursions of n occur.
4. Draw one horizontal line at the χ^2 minimum, and another horizontal line at the χ^2 minimum plus one. Do your horizontal lines intersect your vertical lines at the correct location?
5. Label the axes of your chi squared plot and give it a title.
6. Make the entire figure (both upper and lower plots) look nice.

Part 5: Improve the plots and table.

1. If necessary, go back and tweak your plots and your table of measurements to make them attractive and easy to understand.

Final submission: Submit your code along with a short report on your data analysis by uploading to your github account. Also upload a screen shot of your desktop after running your code.

Remember that Carla will want to know how you arrived at your conclusions, so you need to give her a few general reminders about how data analysis is done. Your report should include the two figures created in parts 1, 3, and 4 above, and the table of measurements created in part 2.

You do not need to include much python jargon in your report. Carla is not familiar with python is not interested in the python details.

Your report does not need to be very lengthy. It will be graded professionalism and organization. It needs to include all key information so that Carla can understand the data analysis. Remember that the figures and table will be included in a customer data sheet.