Data Analysis Lab

The purpose of this lab is to introduce you to the concepts and methods of data and error analysis in physics experiments that will be needed throughout Advanced Lab. This lab is a bit different from the others in that there is no in-lab component; you can work on this at home or wherever you like. Also, you don't need to write a formal report. Write up the solutions to the problems as you would a homework assignment. Data plots should be printed using appropriate computer software. **I highly recommend doing the Matlab assignment first, then using Matlab for the plotting when necessary in this assignment.** You will turn in the Matlab assignment, and this Data Analysis Lab, together. The analysis can be done either using a computer or by hand using a scientific calculator. You will not have a lab partner for this lab. You may consult with other students if you like, and you are encouraged to seek help from the instructor and/or TA if you need it, but the final work you turn in must be your own. For full credit present your data carefully and show all work. This assignment is due **FRIDAY, February 01, 2019 by NOON**.

Problems:

1. Take four coins, two each of two different kinds (*e.g.* two pennies and two nickels) and place them into a cup. Shake vigorously and throw them onto a horizontal surface such that each coin has an equal random chance of landing heads or tails up. Let H_p be the number of pennies that are heads up and H_n be the number of nickels that are heads up (I will use pennies and nickels but substitute whichever coins you may use). Define $Z = H_p \times H_n$.
a) List all possible values of Z for a single throw of your four coins
b) Find the probability of each value of Z. Note: you can calculate these using probability theory or simply tally them from the $2^4 = 16$ possible outcomes of a single throw. Remember that the probabilities must sum to 1.
c) What are the most probable and least probable values of Z?
d) Calculate the average (mean) value of Z for a very large number of throws.
e) Now make a total of twenty-five throws of the four coins and write down the value of Z for each throw. Make a plot with the possible values of Z on the horizontal axis, and the number of times each outcome occurred on the vertical axis. This type of plot is called a *histogram.*
f) Calculate the sample mean $\overline{Z_s}$, sample standard deviation σ_s, and standard deviation of the mean σ_{mean} for your data.
g) How do your results for (e) and (f) compare to your answers to (b)–(d)? Did your sample mean agree with the expected mean?

2. The period of a sine wave is measured to be $7.7 \pm 1.0\ \mu$s. What are the frequency and its estimated error? Express your answer in the form: $f = value \pm error$ and give the appro-

priate units.

3. In your laboratory you measure three independent quantities, X, Y, and Z, obtaining the following results with estimated errors: $X = 2.4 \pm 0.7$, $Y = 9.2 \pm 0.5$, and $Z = 8.0 \pm 0.3$.
a) If $Q = X \cdot (Y + Z)$, find the experimental value and estimated error of Q. Express your answer in the form: $Q = \textit{value} \pm \textit{error}$.
b) If you want to significantly reduce the error on Q, which is the most important quantity to remeasure more precisely?
c) If $R = X \cdot (Y - Z)$, find the experimental value and error of R. Express your answer in the form: $R = \textit{value} \pm \textit{error}$.
d) If you want to significantly reduce the error on R, which is the most important quantity to remeasure more precisely?

4. You use a digital thermometer to measure the temperature of an oven in your laboratory. The thermometer gives a reading to the nearest degree C and its calibration accuracy, according to the manufacturer, is $\pm 0.2\%$. You obtain a reading of 420° C. What is the estimated error?

5. A low power laser beam in air is incident at angle 30.00° from normal on the surface of a rectangular block of an unknown transparent material. You use a precision goniometer to measure the angle of the internally refracted light beam, relative to normal, and repeat the measurement a total of 10 times. You obtain the following results: 20.73, 21.21, 21.10, 19.99, 21.09, 20.96, 20.64, 20.56, 20.64, and 20.49 degrees.
a) Calculate the mean, sample standard deviation, and standard deviation of the mean, in degrees, for your angle data.
b) Use Snell's law to calculate the index of refraction of the material, with error. Express your answer in the form: $n = \textit{value} \pm \textit{error}$. Caution: you must think carefully about when to use degrees and when to convert to radians.

6. You use five different ammeters, labeled A–E, to measure the electric current in a transmission line. You obtain the following readings (all in Amperes): $I_A = 48 \pm 1$, $I_B = 47 \pm 2$, $I_C = 40 \pm 1$, $I_D = 50 \pm 2$, $I_E = 48 \pm 3$
a) Calculate the mean current and the standard deviation of the mean.
b) Which ammeter is the least precise? Explain.
c) Which ammeter is the least accurate? Explain.

7. You measure the temperature of a heated plate as a function of the distance from the coolest end, and obtain the following data:

x (cm)	0.0	2.0	5.0	9.0	14.0	20.0	30.0	40.0	60.0	80.0	100.0	120.0
T (C)	31	39	37	38	46	58	58	72	65	93	115	128

The statistical error on each point is 6° C. Assume the error in the distance is negligible. a) Plot these data with x on the horizontal axis and T on the vertical axis, with error bars. Fit the data to a straight line and report (b) the best fit slope m, (c) the best fit y-intercept b, (d) the error of the slope m, (e) the error of the y-intercept b, (f) the chi-squared, and (g) the reduced chi-squared. (h) Is this a good fit? Use the chi-squared test to justify your answer. (i) Include the best-fit line on your plot.