PHYS 251: Atomic Physics Lab
Due date (in lab): Sept. 4, 2024 (Wednesday section)
Sept. 5, 2024 (Thursday section)

Error Analysis Exercises

Problem #1: Statistical analysis
Ten different students use a 1 m ruler to measure the length of rope that is about 1.5 meters long and get the following values (in cm):
149.5 149.8 150.1 149.8 150.3 149.6 149.9 150.0 150.4 149.7

a) Calculate the average length of the rope.
b) Calculate/estimate the precision (i.e. error) of a single measurement.
c) Calculate the uncertainty on the average of the measurements of the rope length.

Problem #2: Error propagation
A student measures the lengths of the four sides of a rectangle and gets the following results (in cm):
300.5 ± 0.5 153.2 ± 0.3 299.9 ± 0.5 152.6 ± 0.3

a) Are the measurements consistent with each other? Explain.
b) Calculate the average lengths of the long and short sides of the rectangle and the associated errors on those averages.
c) Calculate the perimeter of the rectangle and the error on it.
d) Calculate the area of the rectangle and the error on it.
e) Calculate length of diagonal on rectangle and the error on it.
f) Calculate the angle in degrees that the diagonal makes with the long side of the rectangle and the error on it.

Problem #3: Unweighted vs weighted average with error bars
Five different students measure π (i.e. 3.1415926…) by various methods and get the following results:
3.15 ± 0.03 3.12 ± 0.01 3.16 ± 0.2 3.20 ± 0.05 3.14 ± 0.04

a) What is the average value of these measurements, and what is the error on this average.
b) A sixth student finds the following value for π with a much larger error bar: 2.7 ± 0.7
Calculate the average of the six measurements and the error on this average.
c) The sixth value is throwing off the average, even though it has a larger error bar. A more accurate way to calculate the average in this case is to use a weighted average that gives more weight to measurements with smaller error bars:

$$< x >_{weighted} = \frac{\sum(x_i/\sigma_i{}^2)}{\sum(1/\sigma_i{}^2)} \quad \text{with } \sigma_{weighted} = \sqrt{\frac{1}{\sum(1/\sigma_i{}^2)}}$$

Calculate the weighted average of the six measurements of π and the associated error on this weighted average, and then compare with the result from (b).