Data Analysis - 2021

Exercise sheet no 4: 26. October 2021
Systematic uncertainties and error propagation

Exercise 1: Systematic uncertainties (7 Points)

Look at the lab experiment Schussgeschwindigkeit ("air gun muzzle velocity"). (`http://www.physik.uzh.ch/%7Ematthias/espace-assistant/manuals/en/anleitung_sg_e.pdf`) of the first year. Restrict your attention to setup A.

(a) Think of possible systematic uncertainties and list at least three of them.

(b) Do you expect the individual uncertainties to have a small or large impact on the final result? Note for each listed uncertainty your answer.

(c) How would you estimate the uncertainties? Just give an idea.

(d) How would you minimize or avoid your listed systematic uncertainties?

Exercise 2: Common systematic uncertainty (3 Points)

You make three measurements of the electron charge. Each measurement has its own statistical uncertainty. In addition, there is a systematic uncertainty which is common to all three measurements. You can assume that the systematic uncertainty is independent of the central value of the results.

$$\text{Measurement 1} : \mathrm{m_e} = (1.39 \pm 0.20(\text{stat}) \pm 0.10(\text{syst})) \times 10^{-19}\,\mathrm{C}$$
$$\text{Measurement 2} : \mathrm{m_e} = (1.54 \pm 0.04(\text{stat}) \pm 0.10(\text{syst})) \times 10^{-19}\,\mathrm{C}$$
$$\text{Measurement 3} : \mathrm{m_e} = (1.47 \pm 0.10(\text{stat}) \pm 0.10(\text{syst})) \times 10^{-19}\,\mathrm{C}$$

Calculate the three correlation coefficients between the three pairs of measurements.

Exercise 3: Error propagation (4 Points)

You have been asked to determine the length, L, of the side of a cube. For simplicity, you assume that all sides have the same length. To do this you measured the volume, V, such that $V = 4\ \mathrm{cm}^3$.

- How big can the absolute uncertainty on your measurement of the volume, V be such that you obtain a measurement of the length, L, with a relative precision of 3%?
- How does the answer change depending on whether the uncertainty on the length is statistical or systematic in nature and why?

Exercise 4: Error propagation with correlated variables (6 Points)

The dataset in `sand.txt` on the course webpage reports the slope of a beach (2^{nd} column) as a function of the diameter of its sand granules (in mm) (1^{st} column). The third column

reports the uncertainty on the slope.
Assuming a simple linear relation between the two variables, the data was fitted with a straight line $y = m \cdot x + q$.
The best values for the parameters are:

- $m = 16.1 \pm 1\ \text{mm}^{-1}$,
- $q = -2.61 \pm 0.34$,

while the covariance matrix for the two is:

$$\begin{pmatrix} 1.068 & -0.302 \\ -0.302 & 0.118 \end{pmatrix}$$

(a) Plot the data with errorbars and the fitted line.

(b) Disregarding the correlation between the variables m and q, calculate the slope of a beach whose sand grains have the diameter of 1.5 mm. Report the number with the corresponding uncertainty.

(c) Repeat the task of point (b), this time taking into account the correlation between m and q. In which case is the uncertainty on the extrapolated value smaller? Argument your answer.

Deadline for submission: Friday, 5 November 2021 14:00
Form: Please submit your solutions to da@physik.uzh.ch. Solve questions 1-3 by hand (for calculations, only stating the result is not sufficient!) and attach a PDF version of your answer to the email. The answer to question 4 should be submitted as a single python script.