Lab exercise I – Density of a steel cube

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Objective: Study types of uncertainties, analyze uncertainty sources, determine ways to decrease uncertainties in experimental measurements, find the uncertainty in calculated values using the uncertainty propagation.

Report: Hand in a report with the answer to questions (Q marked in red).

Equipment:
Two instruments with different **systematic uncertainties** will be used to measure the side lengths of the cube: a sliding caliper, and a micrometer screw. The purpose is to study the effect of instrument precision on the uncertainty of the results.

Sliding calliper	Mitutoyo IP67	$\pm(0.02 + 1 \text{ digit})$ mm
Micrometer screw	Mitutoyo IP65	$\pm(0.002 + 1 \text{ digit})$ mm
Balance	OHAUS Pioneer PA2202C	± 0.02 g

Basic concepts:

The density, ρ, of a body is defined as the ratio between its mass, m, and its volume, V.

$$\rho = \frac{m}{V}$$

The cube in this lab has a regular shape. The distances between parallel, «mutual» surfaces are given by the symbols *a*, *b*, and *c*. We assume that the edges are perpendicular to each other. Volume is then given by:

$$V = abc$$

The uncertainty in any measured quantity, *x*, is generally composed of a random error, OXran, and a systematic error, OXsys. These are added quadratically (see also the eq. (20) in Theory compendium):

$$\delta x^2 = \delta x_{ran}^2 + \delta x_{sys}^2$$

Tasks:
Q1. Write the formulas for the uncertainties in ρ $(\delta\rho)$, and V (δV) using the expressions for uncertainty propagation from the Theory compendium, eq. (8)

Measurement procedures:

- Use sliding caliper to make six measurements of length of each side of the cube (see Figure A1). Present your data in a table 1.
- Use the micrometer screw to make the same six measurements of length of each side of the cube. Be careful not to use excessive force on the instrument. Use the outermost spindle axis for finer adjustments. You can stop tightening after a few dicks are heard. Do not touch any of the buttons. Present your data in a table 2.

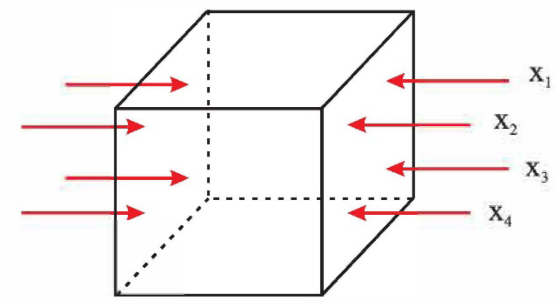

Figure A.1: Determination of one of the body's edges. The measurements are executed in a matrix pattern so that the actual length represents the average value of the edge.

- Weigh the cube. Write down the value in your report.

Data analysis:

Q2. Having the six measurements of each side of the cube, how to determine the final value for the lengths of *a*, *b*, *c* and the corresponding **random** uncertainties?

Q3. Determine the mean and the corresponding uncertainty in *a*, *b*, *c,* and do this for both the data sets.

Q4. Determine the total uncertainties in *a*, *b*, *c*. Present the data in your report according to the eq. (2) in Theory compendium.

Q5. Determine the uncertainty in the mass of the cube. What type of uncertainty is this? Present the data in your report according to the eq. (2) in Theory compendium.

Q6. Find two values for the volume of the cube with the corresponding uncertainties.

Q7. Find the relative uncertainties in percent for the Q3, Q4, Q6. Compare the values for the two sets of data obtained with the calliper and the micrometer. Comment in your report on this comparison.

Q8. Find the relative uncertainty for the mass of the cube.

Q9. Find the **weighted average** of the cube volume using eq. 16 – 19 from the theoretical compendium (chapter 4.2.2).

Q10. Find the cube density and the corresponding uncertainty. Present the final result in your report according to the eq. (2) in Theory compendium.

Q11. Collect at least two other results for the cube density from other groups. Compare your data. Is there a significant discrepancy between the results? (see chapter 2.3 in the Theory compendium – **Significant avvik**)

Q12. List possible sources for random and experimental uncertainties of the various measurements in your report. Suggest the ways to reduce them. If you found the significant discrepancy between your result and the result(s) of other groups, suggest what can be the reason for this.