Determination of the Density of Wood and Steel

Equipment

- block of wood
- metal sphere
- calipers
- meter stick

Goals of the experiment

- To find the best estimate of the density, ρ, of a wooden block and a metal sphere at room temperature.
- To determine the accuracy of the estimation.

Background

A fundamental property characterizing any material is its density. The average density, ρ, of a material of mass, M, which occupies the volume, V, is defined as:

$$\rho = \frac{M}{V} \tag{1.1}$$

The volume of the wooden block and the steel ball will be calculated based on repeated measurements of its dimension(s). Statistical methods will be used to estimate uncertainties of the measurements of each dimension (Type A uncertainty). The uncertainty of the single measurement of the mass of the block is a Type B uncertainty. The uncertainty of the single measurement of the mass of the metal sphere is also a Type B uncertainty. The combined standard uncertainty of the density will be determined using the law of propagation of uncertainty.

Discussion Exercises

- Find in the internet the Guide to the Expression of Uncertainty in Measurement (you can also see the link to it posted on *D2L* for your

course).

- Familiarize yourself with the following terms:
  - uncertainty and error;
  - type A and B of the uncertainty (be aware how type A and B uncertainty is estimated);
  - standard uncertainty and the symbol used for it;
  - combined standard uncertainty;
- In the laboratory report, briefly explain the difference between terms "precision" and "accuracy".

The experiment

Measurement of the volume

- Discuss with your group which method(s) to use to find the volume of the block and the sphere.
- Determine the volume of both objects using repeated measurements for the dimension(s). To incorporate into your measurement the likelihood that the object is not perfect, measure the dimension at different points on the object. *Hint*: In order for the standard deviation to truly represent the uncertainty, the readings must be taken with sufficient accuracy (there will be variations in your readings).
- In order to estimate the uncertainty in the dimension(s) use Type A uncertainty
- Calculate the volume and estimate its uncertainty. Explain how you arrived at that estimate.

Measurement of the mass

Measure the mass of each object on the balance supplied. Make the measurement as accurately as possible and estimate the uncertainty in a single measurement - for a digital balance the uncertainty is usually of the order of the last displayed digit (e.g. for a reading of M=254.4 g the uncertainty $u(M)$ is 0.1 g).

Data analysis

Calculate the density with uncertainty. Comment on any assumptions and estimates you made.

Discussion

Compare your value of the density of the block with the values of wood density provided in Table 1.1.

Compare the density of the ball with the acceptable value of the density of steel. In your report, reference the source of the acceptable value.

Wood	ρ_W $(\frac{g}{cm^3})$
Bamboo	0.3 - 0.4
Oak	0.6-0.9
White Pine	0.35-0.50

Table 1.1: Density of selected wood species.

Comparing values within uncertainties

For two values, $X_1 \pm u(X_1)$ and $X_2 \pm u(X_2)$, to agree within experimental uncertainties, the absolute difference between the values is smaller than the sum of their uncertainties, ie.

$$|X_1 - X_2| \leq (u(X_1) + u(X_2)) \tag{1.2}$$

Discussion questions

- Based on the information provided in Table 1.1 and logical reasoning, determine the material that the block is made of.
- Find examples of publishes values of density of steel and compare them with your results.
- What factors could have affected the values measured for the density of wood/steel?

The report

Your report should include the following:

- A title; your name, and those of your collaborators;
- Objective of the experiment (a summarizing statement about what you set out to observe);
- Short description of experimental methods;
- Data: all the measured values with their uncertainties.
- Analysis: Calculation of density of wood and steel and their uncertainties;

- Discussion:
  - a comparison of the calculated values of density with their expected values;
  - comments on possible sources of errors;
  - classification of errors as systematic and random;
  - answers to the three discussion questions.
- Your conclusion about the block material and whether the values of steel are equal within the experimental uncertainties; appropriate commentary on the agreement/disagreement.