Politechnika Wrocławska
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Laboratorium Podstaw Fizyki

Physics Laboratory - Report #1

Experiment: 100A

Density Determination of Solids

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INTRODUCTION

The density of a solid metal cylinder is found from the measurements made of its mass and volume. A double pan balance is used to find the mass and a caliper is used to measure the height and the two diameters of the cylinder in order to emphasize the relative differences in the uncertainties of the two measuring instruments. These uncertainties are shown to propagate through the calculation resulting in an uncertainty associated with the determination of density.

The density of a homogeneous material is defined as the mass per unit volume, or

$$\rho = \frac{mass}{volume} = \frac{m}{v}$$

The units associated with the density are $\boldsymbol{kg/m^3}$ **and** $\boldsymbol{g/cm^3}$

Whenever measurements are performed, two factors contribute to the total uncertainty associated with those measurements. First, an uncertainty exists which is associated with the instrument itself and its construction.

APPARATUS

- Digital weighing machine
- Caliper
- Micrometer screw
- Solid hollow metal cylinder

Calculation Table:

	d[m]	width[m]	H[m]	M[kg]	V (m^3)	d(kg/m^3)	d(g/cm^3)
1	0.0120	0.0186	0.0223	0.00965	0.00000354	2728.14	2.73
2	0.0119	0.0185	0.0223	0.00977	0.00000351	2780.24	2.78
3	0.0119	0.0185	0.0224	0.00965	0.00000353	2733.83	2.73
4	0.0119	0.0188	0.0223	0.00965	0.00000371	2601.03	2.60
5	0.0118	0.0187	0.0224	0.00966	0.00000370	2609.10	2.61
6	0.0119	0.0185	0.0225	0.00967	0.00000355	2727.32	2.73
7	0.0118	0.0185	0.0228	0.00965	0.00000364	2654.51	2.65
8	0.0119	0.0186	0.0228	0.00978	0.00000366	2671.46	2.67
9	0.0120	0.0186	0.0228	0.00978	0.00000362	2701.89	2.70
10	0.0117	0.0185	0.0228	0.00965	0.00000368	2622.99	2.62
11	0.0120	0.0185	0.0228	0.00967	0.00000355	2720.30	2.72
Average:	0.0119	0.0185	0.0226	0.00969	0.00000361	2685.25	2.69
Standard Deviation	$9{,}40\cdot10^{-5}$	$1{,}01\cdot10^{-4}$	$2{,}41\cdot10^{-4}$	$5{,}70\cdot10^{-5}$	$7{,}40\cdot10^{-8}$		
Resolution:	0.0001	0.0001	0.0001	0.00001			
type B	$5{,}80\cdot10^{-5}$	$5{,}80\cdot10^{-5}$	$5{,}80\cdot10^{-5}$	$5{,}80\cdot10^{-5}$			
A+B	0.00011	$1{,}20\cdot10^{-4}$	$2{,}41\cdot10^{-4}$	$5{,}70\cdot10^{-5}$	$7{,}40\cdot10^{-8}$		
$\mu_c(x)$						57.29	
$Exp.\mu_c(x)$						114.57	

Calculations:

<u>Density:</u>

The formula for calculating the density is:

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

And the formula for volume is:

$$V = \pi \cdot \frac{h}{4} \cdot (D^2 - d^2)$$

Where:

D is the width,

- d is the “d”,

From the data table.

Example for measurement “1”:

$$V = \pi \cdot \frac{0.0223}{4} \cdot (0.0186^2 - 0.012^2) = 3{,}54 \cdot 10^{-6}\ [m^3]$$

$$d = \frac{0.00965}{3{,}54 \cdot 10^{-6}} = 2728.14\ [kg/\ m^3]$$

Uncertainties:

The formula for uncertainty type A (standard deviation):

$$\boldsymbol{u_A(x)} \equiv s_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$$

Calculated using Excel formula “stdev()” for each variable.

The formula for uncertainty type B:

$$\boldsymbol{u_B(x)} = \sqrt{\frac{(\Delta_p x)^2}{3} + \frac{(\Delta_e x)^2}{3} + \frac{(\Delta_t x)^2}{3} + \cdots}$$

Where we only considered the calibration uncertainty (e.g. uncertainty of used instrument) $\Delta_p x$.

Summation of A and B are done by:

$$\boldsymbol{u(x)} = \sqrt{u_A^2(x) + u_B^2(x)}$$

Uncertainty of density:

$$\boldsymbol{u_c(y)} = \sqrt{\sum_{j=1}^{k}\left(\frac{\partial f}{\partial x_j}\right)^2 u^2(x_j)}$$

Translates to:

$$u_c(d) = \sqrt{(\frac{dd}{dm})^2 \cdot {u_m}^2 + (\frac{dd}{dV})^2 \cdot {u_V}^2}$$

$$= \sqrt{\frac{{u_m}^2}{V^2} + (\frac{-m\ \cdot u_V}{V^2})^2}$$

CONCLUSION

Discussion

The purpose of this exercise is to determine the uncertainty of the results. We can observe that for the measured parameters the uncertainty is quite big, it might be caused of the thing that density is measured indirectly for finding the value of mass and the volume. Because of this our uncertainty is a little high according to table. If we can use water for measure mass, we can measure elements correct mass.

Results and the Uncertainty

We found the density of the material to be 2685.25 ± 114.57 [kg/m^3]. Using the method outlined in the calculations sections.

Afterwards the uncertainty that we found for density is expended by "k=2" due to the formula:

$$U(x) = ku(x) \text{ or } U_c(x) = ku_c(x)$$