Uncertainty of Measurement and Report Writing

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Introduction:

The purpose of this lab was to introduce the concept of uncertainty in measuring instruments, by utilizing three different instruments to calculate density of an unknown material.

Theory:

The formula for density is as follows:

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

Therefore, to calculate the density of the unknown material, the mass and volume of the object is required. The mass of the object can be determined using the triple beam balance. The volume of the object can be calculated using the formula for volume:

$$V = l * w * h$$

The meter stick and caliper can be used to measure the respective dimensions, and volume can directly be calculated from said values. When using the beaker and graduated cylinder, the volume can be determined from the amount of water displaced when the object is fully submerged. A strip of tape can be used to mark the final water level.

Procedure:

The following apparatus were used in the experiment: a block of an unknown material, a triple beam balance, a graduated cylinder, a meter stick, a plastic vernier caliper, a beaker, and a strip of tape.

1. Using the triple balance beam, determine the mass of the object, including the uncertainty of the beam.
2. Measure the length, height, and height of the object using the meter stick, ensuring to account for uncertainty.
3. Plug the values determined into the formula for volume.
4. Following the formula for density, divide the mass by volume. Account for the uncertainty.
5. Record your density value.
6. Repeat steps 2-5 for the caliper.
7. Fill the beaker with 100 ml of water.
8. Submerge the object into the water. Mark the final volume with a piece of tape.
9. Pour the difference in volume into the graduated cylinder. Record the volume.
10. Calculate density using the volume and mass volume

Results and Calculation:

The following data was collected during the experiment:

	calipers		meter stick			volume:	
	(mm)	Uncert (mm)	(cm)	Uncert (mm)		(ml)	Uncert (ml)
length	32.0	0.025	2.9	0.5	initial:	200.0	25
width	32.0	0.025	2.9	0.5	final:	225.0	25
height	13.5	0.025	1.1	0.5	total:	25	35

After calculating the density using the obtained values, the following densities were determined:

	g/cm^3
Calipers	8.572 +- 4.0e-6
Meter Stick:	12.81 +- 0.63
Water volume:	4.0 +- 4.6
Average:	8 +- 1.5

Conclusion:

According to appendix A from the Uncertainty of Measurement and Report Writing report by Toronto Metropolitan University for PCS 211 (2022 edition), the material is likely to be iron or brass.

1. Results] Consider the validity of determining an average density from the three measurement methods. Calculate the average density (as well as propagating uncertainty) and justify why it is (or is not) beneficial to report the average for this situation.
    a. Determining the average density from three different methods produces a more ‘normal’ average value, by eliminating possible flukes in data. Three methods should have eliminated most flukes, therefore the average calculated is valid. However, if a value of higher accuracy was desired, using five or more methods would be appropriate. The average density calculated from the experimental results is 8 +- 1.5 g/cm^3. This number is beneficial to report as it eliminates

random errors and presents a value of reference should this experiment be repeated.

2. 2.) [Discussion] The uncertainty of the measurements were defined by the measurement instruments. Comment on other possible sources of uncertainty and provide an estimate of their magnitude. When should these sources of uncertainty be used instead of the measurement instrument uncertainty? Would considering these factors change the conclusion of the report?
    a. Other possible sources of uncertainty include the manufacturers of the measurement equipment and the people conducting the experiment.
    b. The magnitude of uncertainty from the manufacturers would be miniscule because of the usage of accurate and precise modern manufacturing machines. Therefore the magnitude of this uncertainty should be around 10^-6.
    c. Uncertainty related to the people performing the experiment can be the result of multiple factors, such as the skill of the experimenter to accurately measure data. Compared to the previous magnitude, the uncertainty magnitude is larger, possibly in the 10^-2~10^-1 range.

3. 3.) [Discussion] There is a fundamental difference between percent error and uncertainty. Explain in the report what that is and hence the need to calculate percent error.
    a. The difference between percent error and uncertainty is that percent error compares the experimental results to a predetermined value, resulting in a percentage range where the true value could be, whereas uncertainty provides a numerical range where the true value could be. Percent error could inform the experimenter

4. 4.) [Conclusion] What conclusion can one make based on the results agreeing or disagreeing with a theoretical or accepted value?
    a. Should the results agree with the accepted value multiple times, the experiment proves it was conducted correctly and accurate. Should the results disagree heavily with the accepted value, the experimenter should check their methods of data collection, instruments, or other possible sources of error in order to improve their next results. Should the results disagree slightly with the accepted value, the experiment should be repeated to ensure accuracy.

References:

Toronto Metropolitan University. (2022). PDF. Toronto; Toronto Metropolitan University.