Container Construction

Safety and Equipment

- No special safety precautions are necessary for this lab.
- Bags of grains (rice and beans)
- Construction paper
- Scotch tape
- Scissors
- Ruler
- Balance
- Beaker
- Graduated Cylinder

Introduction

The only quantities in nature that are exact are integers (1, 2, 3, ...). For example, the number of people in a room is an exact whole number (hopefully!). Any quantity that can take on an in-between value could have any real number value. Unfortunately, we can only write decimal numbers with a limited number of decimal places. That means that if we are concerned with the mass of an object, we can only record that mass with a limited ***resolution***. Scale of any given instrument is limited by the value of the smallest increment of that scale. *The uncertainty due to resolution is half of the smallest graduation of the instrument.*

Of course, there are other reasons that we may not know the exact value of a quantity. We may have a limited ability to measure the quantity. If we measure the height of a person with a measuring tape, for example, it may be difficult to make sure that we line up the ends of the measuring tape with the top and bottom of the person, that they stand up straight, that their hair isn't affecting the measurement, etc. Repeated measurements will involve these factors in different ways, leading to different results. That means that the process of measuring has limited ***accuracy***. There no such thing a perfectly accurate method of measurement. *One way of determining the uncertainty due to accuracy is to repeat a measurement many times and use the standard deviation of the measurement.*

Any difference between a written value and the actual real-world value is an ***error***. Generally, we don't know the error. But through experience we can put a limit on how big that error might be. This limit is called the ***measurement uncertainty*** in the value. Usually, the measurement uncertainty is determined based on the largest contributions. For example, when a person is using a stopwatch, the uncertainty may come from two sources. The stopwatch has an increment of 0.01 s, contributing an uncertainty of 0.005 s. But the person's reaction time could be 0.2 s. In this case, the reaction time overwhelms the stopwatch uncertainty. So, we estimate the uncertainty of "a person using a stopwatch" to be 0.2 s.

This lab will use measurements of the density of a granular material (beans or rice) to give a sense of where uncertainty can come from and how to use it. The definition of density is:

$$\text{Density} = \rho = \frac{m}{V} = \frac{\text{Mass}}{\text{Volume}}$$

To determine experimentally the density of an unknown material, we need to measure two values: the mass and volume of a sample of the material. Each measurement comes with some uncertainty. Those uncertainties will propagate in the calculation of the density. The final experimental value of the density should include both the calculated value and the propagated uncertainty. This is the standard form to express scientific quantities with uncertainty. For example, the densities in this experiment should be stated like, "the density of Material A determined using a beaker to measure volume was $\rho = (1020 \pm 25)\frac{g}{cm^3}$ ".

Objectives:

- *To construct a container for a given amount of grains.*

Part 1. Grains density

To determine the density of the grains, follow basic steps 1-7 below, once using a beaker, and again, using a graduate cylinder (for both types of grains):

1. Measure the mass of the *empty* container (beaker/graduated cylinder).
2. Fill your container to the desired level with the grains sample.
3. Measure the mass of the *container with the sample* in it.
4. Subtract the above values to calculate the mass of the grains alone.
5. Record the volume of the grains sample in the container.
6. Divide the mass by the volume to calculate the density of the grains.
7. Record ***the values*** into Table 1and Table 2 (identical tables for each type of grains).

To estimate the uncertainties of measurements and propagate them into calculations, follow steps 8-10 below, one for the beaker, and again, for the graduate cylinder:

8. Estimate the absolute uncertainty as a half the increment of the instrument.
9. Calculate the percent uncertainty as a ratio of absolute uncertainty to the measured value (expressed as %): $Percent\ uncertainty = \frac{Absolute\ Uncertainty}{Measured\ Value}$
10. Propagate the uncertainty following the rules of propagation:

- If calculation includes only addition or subtraction, then add the absolute uncertainties.
- If calculation includes multiplication or division, then add the percent uncertainties.

Description	Beaker			Graduate Cylinder		
	Value	Absolute Uncertainty	Percent Uncertainty	Value	Absolute Uncertainty	Percent Uncertainty
Mass of Container(g)						
Mass of Container+Sample (g)						
Mass of Sample (g)						
Volume of Sample (ml)						
Density of Sample (g/ml)						

Table 1/2. Measured and calculated values to determine the density of the …. (type of grains).

Part 2. Build a Container

The goal is to build a container that is just big enough to hold **all of** one of the granular materials in the plastic bag.

1. Compare the values of the density along with percent uncertainty for each type of grain and each method of volume measuring.
2. Discuss which one is the most reliable and should be used further in the construction. Include the conclusion statement into the abstract of the report.
3. Measure the total mass of the grains in the bag and calculate its volume.
4. Build a rectangular container. The volume should be the product of the length, width, and height. Note: 1 ml = 1 cm^3, so measure in centimeters.

$$\boldsymbol{V_{block} = L \times W \times H}$$

- ***Attention:*** *Build only* ***one container****, either for rice or for beans.*
- ***You do not get to practice filling your container!*** During this part of the lab, the bag must stay closed until your demonstration at the end of class.

5. When container is ready, bring the empty container and the bag of grains to the front of the room. With the instructor watching, fill your container.
6. Take a picture of the result for the lab report.
7. Assessment of the result will be as following:

- **Full credit:** Container is almost exactly full. No grains spill out over the sides.
- **10% Deduction:** Some grains spill over the sides, or the container is 1cm under-full.
- **20% Deduction:** Lots of grains spill, or the container is under-full more than 1cm
- **30% Deduction:** The container fails.

Requirements for Data Report 1 (also consult the rubric in Canvas):

Save your Excel files through your Canvas Group File Exchange

- The **abstract section** must contain the following explanations in paragraph form:
    - How the data was collected including the tools that were used for the measurements and their associated absolute uncertainties
    - How the data was analyzed including formulas used for computing values of density and uncertainties
    - Justification for the choice of the density: which grain/volumetric measuring device density was more precise? Which number did you look at to decide this?
    - How the overall volume of the grains was calculated and how dimensions of the container were calculated

- The **data section** must include
    - 2 Tables (labeled Table 1 for beans and Table 2 for rice and captioned—a sentence or two each explaining the contents of the tables)
    - 1 Photograph of the completed and filled container labeled as "Picture 1" or "Figure 1" and captioned