How Many? Lab

Random and Systematic Errors – Statistics Calculations

PHYS 104L

1 Goal

The goal of this week's lab is to check your understanding and skills regarding basic statistics calculations and the effects of random or systematic errors. You will use these techniques to attempt a determination of how many objects are in a container without being able to physically count them.

2 Introduction

In addition to the skills and ideas from the prior week's activities, you will need to know a couple of additional ideas as well. For one, we will expand a bit on calculating averages. If we have some number of objects, say 20 apples, and we wanted to know the average mass of an apple, we could do this two different ways. As we know from last week, we could measure the mass of each individual apple and then calculate the average as was defined last week. A second approach would be to just measure the mass of all the apples combined at once. If we took that total mass and divided by the number of apples, we would get the same value for the average mass.

Average Mass of an Object = Total Mass of Objects / Number of Objects

For our efforts in this lab, if we were able to determine the Total Mass of some number of objects and also determine a value for the Average Mass of those objects, we could calculate the number of objects by rearranging the above equation as

Number of Objects = Total Mass of Objects / Average Mass of an Object

We also know that since the mass values are measured quantities, they will have uncertainty in them. If the mass values have uncertainty in them, then the calculated Number of Objects will also have to have some uncertainty in it. If we know the uncertainty in the Total Mass (TM Unc) and the uncertainty in the Average Mass of an Object (AM Unc), we can calculate the uncertainty in the calculated values as follows

$$NumberUnc. = Number * \sqrt{\left(\frac{TMUnc}{TM}\right)^2 + \left(\frac{AMUnc}{AM}\right)^2}$$

If we add or subtract two numbers with uncertainties, the uncertainty in the result is

$$TotalUncertainty = \sqrt{{Unc_1}^2 + {Unc_2}^2}$$

3 Determining How Many

Procedure

1.) Your lab station should have the following equipment: triple beam balance, digital balance, two sets of two containers of objects. The containers for a given set are identical. One container will be filled with the objects and should not be opened during lab. The second container will have a small number of the same objects as in the other container. Record which sets of containers are at your lab station and what type of objects are in them. Your goal is to determine how many objects are in the full container. Start by using the larger digital mass balance to measure the mass of your full container with objects in it. Record this value as well as the uncertainty (Reading Error) for that measurement.

2.) Take the other container and empty the sample of objects out of it. Use the large digital mass balance to measure the mass of this empty container and the reading error in that measurement.

3.) Use the small digital mass balance to measure and record the mass of each of the individual objects in the sample.

4.) Repeat these measurements for the second set of containers.

Calculations

1.) Using the measurements for your first container set, calculate and record the Total Mass (TM) of the objects in the container by subtracting the mass of the empty container from that of the full container.

2.) Calculate and record the uncertainty in the TM using the formula given in this handout.

3.) Perform statistics calculations to determine the average, standard deviation, standard error and associated error for the data set of masses of individual objects in the sample.

4.) Calculate and record the Best Estimate for the number of objects in the full container.

5.) Calculate and record the Uncertainty in that Best Estimate using the equation in this handout.

6.) Record a properly rounded Result and Range for the number of objects in the full container.

7.) Calculate and record the Percent Uncertainty (Uncertainty/Value*100) for this result.

8.) Repeat steps 1-7 for the second set of containers.

Lab Questions

1.) How did the uncertainty in the average mass per object compare for the two sets? Explain why you think this was the case.

2.) How did the uncertainty in your two results compare? How did the percent uncertainty in your two results compare? Which result would you say is more precise? Explain.

3.) Do you believe your results are likely in agreement with the actual value or not? Explain your rationale. What could be an example of something that would cause your result not to agree? What kind of error would this be?

4.) If you had another two sets of containers, one set with thumbtacks and the other with raisins, which would you expect to have the higher percent uncertainty in the Result if you calculated the number of objects following the technique of this lab? In which case would expect the smaller percent uncertainty? Explain.

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Data Sheet / Report

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Which Container Sets

	Container Set Label	Item Description
First Set		
Second Set		

First Container Set Data Measurements:

Mass of Full Container _____ Uncertainty _____

Mass of Empty Container _____ Uncertainty _____

Mass of Individual Objects: Units _____

Second Container Set Data Measurements:

Mass of Full Container _____ Uncertainty _____

Mass of Empty Container _____ Uncertainty _____

Mass of Individual Objects: Units _____

First Container Set Calculations and Results:

Total Mass of Objects

_____

Uncertainty in TM

_____

Mass of a Single Object:

Average _____

Standard Deviation _____

Standard Error _____

Associated Error _____

Number of Objects Best Estimate

_____

Uncertainty in Number of Objects Best Estimate

_____

Result _____

Range _____

Second Container Set Calculations and Results:

Total Mass of Objects

_____

Uncertainty in TM

_____

Mass of a Single Object:

Average _____

Standard Deviation _____

Standard Error _____

Associated Error _____

Number of Objects Best Estimate

_____

Uncertainty in Number of Objects Best Estimate

_____

Result _____

Range _____