Lab1:
Measurement and Measurement Error

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1 Objectives

- To see how measurements and error analysis are a fundamental part of experimental science.
- To make some actual measurements and analyze the errors in them.
- To observe and understand the difference between accuracy and precision.
- To understand the nature of random and systematic errors.

2 Equipment

Ruler, metal rod, material to be weighed (liquid Nitrogen), and triple beam balance.

3 Procedure

3.1 Measure the length of a metal rod

Using the ruler, measure the length of a metal rod five times. **Don't forget to include the errors on your measurements.** When you are finished, average the values to get a better measure of the rods true length. Calculate the uncertainty of your final measurement (the ***"Error on the Mean"***).

$$\Delta\overline{x} = \frac{\Delta x}{\sqrt{N}}$$

Where Δx is the error on a single measurement and N is the number of measurements you made.

Another way to characterize the uncertainty on a measurement is the ***"Standard Deviation"***.

$$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

Where x_i is each measurement and the summation symbol, $\sum_{i=1}^{N}$, indicates that you sum over each of the N measurements *(hint: ask your TA for help if this doesn't make sense)*, N is the number of measurements made, and $\overline{x}$ is the mean value (average) of the measurement.

The standard deviation gives an indication of the "spread" of the data. It indicates the region about the mean where most (68%) of your measurements will occur. Calculate the standard deviation for your measurements and compare it to the error on the mean.

3.2 Measure your reaction time

Your reaction time is the time that passes between some external stimulus and your first action. We will use an old method to measure your reaction time. A falling ruler will suffice. This is what to do.

a)Have your partner hold the regular ruler vertically, holding it by the top and having the zero mark at the bottom.

b)Place your thumb and forefinger at the rulers bottom, surrounding the zero mark. Be prepared to pinch the ruler as it falls. **Rest your forearm on the lab table to steady your hand, and be sure you are not touching the ruler.**

c)Your partner will drop the ruler without warning.

d)Pinch and grab the falling ruler as fast as you can. Record the distance the ruler fell along with a reasonable error estimate for each measurement.

e)Compute your reaction time using Galileos formula: $t = \sqrt{\frac{2x}{g}}$. The meaning of the symbols will be explained in lab.

Make four measurements and record the corresponding reaction times. Record **your** reaction times in **your** lab notebook. Do not mix your times with your partners. This means you will make **four measurements per person**. Compute and record the individual times for each measurement. Be sure that both you and your lab partner have your reaction times measured. Each person only needs to record her own reaction time in her lab notebook. To find the error on your average reaction time, use the following formula.

$$\Delta\bar{t} = \frac{\Delta\overline{x}}{2\overline{x}}\ \bar{t}$$

Where $\Delta\bar{t}$ is the error on your average reaction time, $\Delta\overline{x}$ is the "Error on the Mean" for your measured distance, $\overline{x}$ is the average distance, and $\bar{t}$ is the average reaction time.

3.3 Measure the mass of a cold material

Go to the instructors table with your partner, where you will be given a cup containing some liquid Nitrogen. Using the balance on the instructors table, measure and record the mass of the cup 5 times, at 1 minute intervals. Be sure to include reasonable uncertainties. **Warning: The liquid Nitrogen is quite cold. If you stick your fingers in the mixture you will feel much pain.**

NOTE: On the following pages you will find an example lab write-up. ***ALL*** *of your work should be recorded in your lab notebook. The example here is to serve as a guide to structuring your your own write-up.*

Sample Lab Write-up – **All work should be recorded in your lab notebook.**

Lab 1:
Measurement and Measurement Error

Name: Section:

Partner:

Abstract:

*Concisely describe **what** you will be doing in this lab, **why** you are doing it, and **how** you will be doing it.*

Analysis

1. Rod Length

Rod 1	
Measurement 1	
Measurement 2	
Measurement 3	
Measurement 4	
Measurement 5	
Average Value	
Uncertainty	

Class Measurements

Rod 1	Measurement	Frequency
Average 1		
Average 2		
Average 3		
Average 4		
Average 5		
Average 6		
Average 7		
Average 8		
Average 9		
Average 10		
Total	n/a	

a)Explain the possible sources of error in these measurements? Are these errors random or systematic?

b)How well did your measurements agree with those of the rest of the class? If there was a disagreement, what kind of error was it? Random or systematic? What caused this error? The TA will help you draw a histogram of the classes measurements. What types of errors do you see?

2. Your Reaction Time

	Distance	Time
Measurement 1		
Measurement 2		
Measurement 3		
Measurement 4		
Average Value		
Uncertainty		

a)Describe the possible sources of error in this measurement and explain their relevance.

3. Mass of a Cold Material

	Mass
Measurement 1	
Measurement 2	
Measurement 3	
Measurement 4	
Measurement 5	
Average Value	
Uncertainty	

a)Describe the possible sources of error in this measurement and their relevance.

b)Do you see any pattern in the measured masses? What is it?

4.Which of your measurements (metal rods, reaction time, or mass) was the most uncertain? Why?

5.Which of your measurements (metal rods, reaction time, or mass) was the least uncertain? Why?

6.Which measurements (metal rods, reaction time, or mass) if any suffered from systematic error? Explain.

Calculations

This section can appear anywhere in your lab report. It can appear more than once. It needs to include ***example calculations for each quantity you compute*** *during your lab session.*

Conclusions

Succinctly describe what you learned today. State what you measured and give the result of your measurement.