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

Candle, ruler, special ruler, paper with closed curves, metal rod, material to be weighed (liquid Nitrogen), and triple beam balance.

3 Procedure

3.1 Measure the length of a metal rod

Using **only** the special ruler, measure the length of a metal rod 5 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. Next, use your metal ruler to measure your metal rod again. Measure 5 times as before and compute the average to refine your measured value. 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 $\sum_{i=1}^{N}$ 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 of your measurements will occur. Calculate the standard deviation for your measurements and compare it to the error on the mean.

3.2 Measure the height of the candle flame

Light your candle and let the flame burn steadily for a minute or so. Use the plastic ruler to measure the height of the flame. Make 6 measurements and try not to melt the ruler. Hold the ruler a small distance away from the flame. Record your measurements. Find the average value, the Error on the Mean, and the Standard Deviation of your measurement. Which of these values best characterizes the uncertainty on your measurement? Identify the technique you used to find the uncertainty of your final answer and record it along with your average value. **Remember to write only a sensible number of significant figures.**

3.3 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 4 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 **4 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.

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

Where $\Delta\overline{t}$ 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 $\overline{t}$ is the average reaction time.

3.4 Measure the diameter of a closed curve

Measure the diameter of the large closed curve. Measure this curve diameter across 6 *different* diameters of the curve. Record your measurements and the errors on those measurements. Compute the average diameter. Calculate the uncertainty on your average. Identify the technique you used to find the uncertainty of your final answer ("Error on the Mean" or "Standard Deviation"). Remember to write only a sensible number of significant figures.

3.5 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.**

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	Special Ruler	Plastic Ruler
Measurement 1		
Measurement 2		
Measurement 3		
Measurement 4		
Measurement 5		
Average Value		
Uncertainty		

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

b)How well did your measurements with the special ruler agree with those done with the plastic ruler? If there was a disagreement, what kind of error was it? Random or systematic? What caused this error?

2. Candle Flame Height

	Flame Height
Measurement 1	
Measurement 2	
Measurement 3	
Measurement 4	
Measurement 5	
Measurement 6	
Average Value	
Uncertainty	

a)Describe the possible sources of error in this measurement.
Are these errors random or systematic?

b)What might you do to get a better measurement of the flames height?

3. 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.

4. Closed Curve Diameter

	Curve Diameter
Measurement 1	
Measurement 2	
Measurement 3	
Measurement 4	
Measurement 5	
Measurement 6	
Average Value	
Uncertainty	

a)Describe the possible sources of error in this measurement.
Are these errors random or systematic?

b)What do the measurements tell you about the curves diameter?

5. 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?

6.Which of your measurements (metal rods, curve diameter, flame height, etc.) was the most uncertain? Why?

7.Which of your measurements (metal rods, curve diameter, flame height, etc.) was the least uncertain? Why?

8.Which measurements (metal rods, curve diameter, flame height, etc.), 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.