Lab 1 – Measurements & Uncertainty

Last Updated 04-14-2025

Name: ____________________

Lab Partners: ____________________

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Introduction

"Measure what is measurable,
and make measurable what is not so."
– Galileo Galilei

Every measurement you make in lab must have an estimated or calculated uncertainty associated with it that depends on several factors, including the precision of the instrument, the variability of the measured object and other complicating factors.

Throughout the entire quarter you will be taking measurements to help you learn scientific concepts. The goal of the first lab is to help you find the ideal ways for you to perform measurements, find the associated range of these measurements, and then implement these measurements properly when performing calculations.

Learning Goals:

- Take measurements and determine the appropriate associated uncertainty.
- Perform calculations based on measurements and propagate error accordingly.
- Decide if a measurement and theory are consistent using uncertainty.
- Write a lab conclusion that expresses findings from the experimental results.

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Steps marked with asterisks can be done after lab

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Experiment A: Measuring the Density of Styrofoam (45 Minutes)

In this experiment, you will measure the dimensions and mass of Styrofoam blocks and use your measurements to calculate various properties of the blocks along with their corresponding uncertainties.

A1. Choose three blocks and measure the length, width, and height of each block separately. Make these measurements at different locations along the blocks' dimensions since they're not uniform. Include all of your measurements in the table below, repeated for each block. Make sure to copy the values from every table into your lab notebook. If the standard deviation is less than the device uncertainty, use the measuring device precision.

Block	**Length (cm)**	**Width (cm)**	**Height (cm)**
Readings:			
Average:			
Uncertainty (Standard Deviation):			

A2. In your lab notebook, calculate the volumes of the blocks from the average values of length, width, and height. Be sure to propagate uncertainty properly (error propagation).

A3. Next, measure the mass of the bricks using the digital scale. Record your values in your lab notebook. If the value does not fluctuate, you may use the instrumental uncertainty of the scale.

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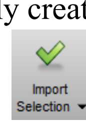
A4. Density is a measure of how compact matter is - it tells you how much stuff fits into a given volume and is found by dividing the mass of an object by its volume. In your lab notebook, calculate the density of each brick. Be sure to propagate your uncertainty. ****How would your uncertainty for density be different if the mass uncertainty were ignored? Which uncertainty dominates this calculation volume or mass?****

A5. Take the three values you found for volume and mass (along with their uncertainties) and input them into an Excel or Google Sheets workbook (you should have four columns: mass, deltamass, volume, deltavolume). Create a fifth column labeled "weights" which uses your deltavolume column with the equation $1/(\text{deltavolume})^2$. Save this file as an .xlsx file or a .csv file.

A6. Open up MATLAB. Go to Import Data and choose your newly created .xlsx or .csv file.

Make sure that you have selected the Import Selection button 

before moving on. (Import as column vectors). At this point, check in with your TA to see if the data imported into MATLAB properly.

A7. Go to the top bar and choose the Apps button. Click on the Curve Fitting button, . Choose volume as your X Data, mass as your Y Data, and weights as your Weights.

A8. We are fitting this data with a first order polynomial: f(x) = p1*x + p2. Under the Results window, you can find the results for p1 and p2 along with their upper and lower confidence bounds. Take a screenshot of the plot and parameter values. Make sure this plot is shared with the entire group.

A9. Now make a fit with a **custom function** in the drop down menu of functions: a linear fit with y-intercept set to 0 i.e. f(x) = p1*x. ***Explain why you'd want to make this choice of y-intercept. Are your confidence intervals smaller for p1 than in A8?***

A10. ***After you carry out your activity, consider the following questions to address:

- *What physical quantity does p1 correspond to?*
- *How close is p1 to the density values that you found for the three blocks? Was p1 within uncertainty values when compared to the three blocks individually?*
- *What value should p2 have? Is this p2 value from MATLAB consistent with what you feel it should be (within uncertainty)?****

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Experiment B: Measuring g (Rest of lab time)

In this experiment, you will be attempting to find a numerical value for the acceleration due to gravity on Earth's surface, g. You will also find the uncertainty in your value. There are four experiments available for you to choose from; you must choose three different experiments to perform.

The four experiments are:

- the ball-drop demo
  - Drop a metal ball from a specified height and use a trigger timer set to the "GATE" setting to measure g.
    - Steps:
      - Place metal ball in between metal flap and screwhead
      - Press "RESET" on the timer
      - Release ball such that it lands on floor pedal
      - Timer should stop once ball hits floor pedal
- the ball with built-in timer
  - Hold the baseball and its button and release both at the same time from a specified height, use the time measured on the display to measure g
    - Steps:
      - Ensure that the reading on the ball is 0.00
      - Hold the button while also holding the ball up with the same hand
      - Release ball and button at the same time, timer should stop when it reaches the ground.
- the cart on an incline
  - Let a cart roll down a ramp at a determined angle for a specified distance and a stopwatch to time it to measure g
  - Make sure that the cart is always at least 20 cm away from the motion sensor
- the pendulum
  - Let a pendulum of a determined length swing over a specified amount of periods with a stopwatch to measure the total time to measure g

B1. As a group choose the three demos to do and alert the TA as to your choice. Then, the TA will let you know which demo is free for you to perform.

B2. Perform your three demos and come up with a value for g and an uncertainty for each demo.

B3. From your three values of g and their respective uncertainties, come up with a single final value for g and an uncertainty.

B4. ***After you carry out your demos, consider the following questions to address:

- *Which demo gives you the value of g that you trust the most? Why?*

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- *If you only chose to do one of the three experiments, which would you choose?*
- *Which demo gives you the value of g that you trust the least? Why? Does it automatically have to be the experiment with the highest uncertainty?*
- *When coming up with a final value for g, how did you choose to weigh the results of each experiment?*
- *How did you determine the uncertainty for each experiment?*
- *How close is your final experimental result for g in B3 to the actual value of g (you can look for this online)? Was it within uncertainty? What does this imply about the precision and accuracy of your result?****