

Lab 01: Estimates and Measurements



A ruler is typically precise to 1/16th of an inch.

INTRODUCTION

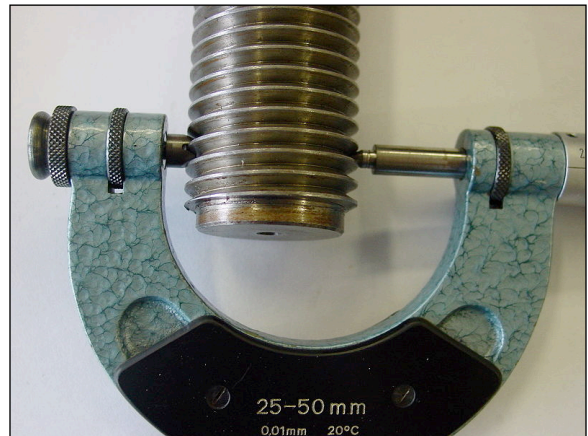
Making measurements is fundamental to science: geologists measure the age of rocks, astronomers measure the distances to the stars, biologists measure the rates of cell metabolism, physicists measure the masses of subatomic particles. Because measuring is so important, we need to have a good understanding of how measurements are made. This week we will practice making some simple measurements and drawing useful conclusions from our data.

Typically, we tend to think that precision and accuracy mean the same thing, and we probably use the words interchangeably. However, they do represent separate and distinct concepts, so we need to have a clear definition for each.

A carpenter building a house needs to be precise

to 1/8, or maybe 1/16 of an inch. So a tape measure or T-square marked in inches, subdivided down to an eighth or sixteenth of an inch is an adequate enough tool for him to use. But a machinist milling parts for a jet engine will need a more precise measuring tool—something that can measure much smaller increments, down to a thousandth or even a ten-thousandth of an inch. The carpenter's ruler simply isn't going to be useful to him. However, just because the carpenter's ruler is less precise than the machinist's micrometer does not automatically mean that the machinist is more accurate!

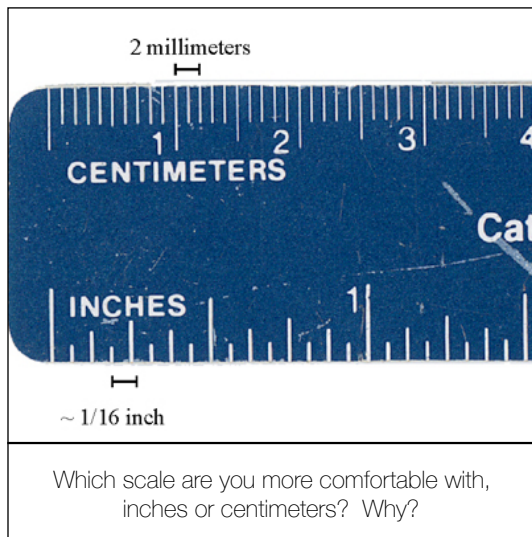
While precision is an inherent property of a measuring instrument, accuracy is related to the use of that tool. A machinist with a very precise micrometer can still make an inaccurate measurement—what if he has aligned the tool improperly, or read the dial incorrectly, or done something otherwise careless? The carpenter, using a less precise tool may be more accurate, if he is using his instrument properly and making his measurement carefully.



The micrometer is precise to 0.01mm, or about 1/10 the width of a human hair!

OBJECTIVES

- Become familiar with the process of making numerical estimates
- Understand the difference between precision and accuracy in measurement
- Learn to make reliable and repeatable measurements
- Practice recording data and information in a structured format
- Learn to identify trends in recorded data



Which scale are you more comfortable with, inches or centimeters? Why?

EQUIPMENT

- Rulers and meter sticks
- Triple beam balance
- Graduated cylinder
- Water

ACTIVITY 1: NUMERICAL ESTIMATES

Select four common items from among your workgroup (pencils, combs, keys, coins, etc.).

- Independently (without your lab partners), estimate the length (longest dimension) of each item in both inches and centimeters, and record in your lab notebook.
- Compare your estimates in centimeters with those of your partners. For each item, note the smallest estimate made by anyone, and the largest. Record this range of estimates in your notebook.
- Using a ruler or meter stick, measure each item (again, in inches and centimeters) and record.
- If you have not already, organize a neat and logical table of your estimates and measurements.

QUESTIONS

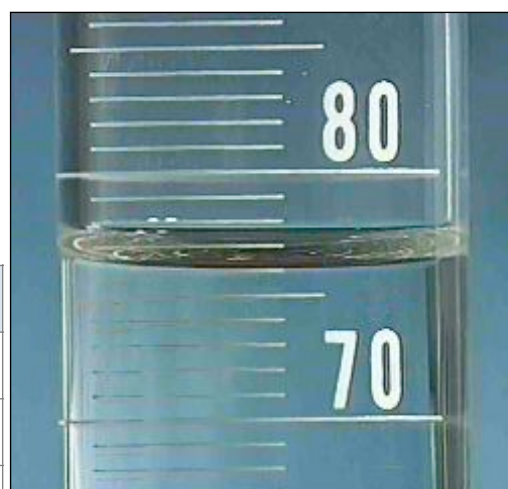
1. Find the one estimate that you made (in either inches or cm) that is closest to the actual measured length. Calculate the percent error using:

$$\%error = \left(\frac{\text{measurement} - \text{estimate}}{\text{measurement}} \right) \times 100$$

2. Did you over- or under-estimate? By how much (an error of about 5-10% would be pretty good). Look at your data and note if there is a pattern in your estimates: Do you tend to consistently over- or under-estimate, or is there randomness (some over-, some under-estimates)?
3. In general, were your estimates in one set of units consistently more accurate than your estimates in the other? If so, which set was more accurate? Why do you think that the units might make a difference in your estimates?
4. Using the meter stick, which set of units (inches or centimeters) is more precise? Why?
5. If two people measure the same object using the same tools, will their measurements have the same precision? The same accuracy? Explain briefly.
6. Compare the actual measurements (in centimeters) with your table of high and low estimates. Are the actual measurements within the range of estimates? Is your range of estimates bigger or smaller than $\pm 10\%$?

ACTIVITY 2: MASS, VOLUME, AND DENSITY

- Measure and record the mass of the empty graduated cylinder.
- Fill the cylinder with 20ml of water.
- Measure and record the mass of the cylinder + water. Subtract the mass of the dry cylinder to obtain the mass of the water. Make a neat table for your data.
- Repeat, increasing the volume of water in 20 ml increments until the cylinder is full.



The *meniscus* is that curve you see, because the water is literally climbing the wall of the cylinder. The cylinder is calibrated to be accurate when you measure with respect to the bottom, or dip, in the water line. This cylinder contains 76ml, not 78 ml.

VOLUME (ml)	MASS (g)	DENSITY (g/ml)
20		
40		
60		
80		
100		

Calculate the density for each trial, then notice: Is there a pattern of some sort? Are variations random? Is there some way to determine if you are actually seeing a mathematical trend of some kind?

QUESTIONS

7. Prepare a graph of mass as a function of volume. This means that **mass** belongs on the **y-axis** and **volume** belongs on the **x-axis**. Scale your axes appropriately and apply the scale consistently. When the data are plotted, use a ruler to draw the best-fit line for the data.
8. Find the slope of the line that you have drawn. What are the units on your slope?

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{m_2 - m_1}{V_2 - V_1}$$

9. Calculate the density of the water for each trial, using:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

10. Compare the values on the density table to the slope of the line. Related?
11. Why are the individual values for the density not all identical? Does the actual density of the water change when you change the amount of water in the cylinder? Explain.