

Lab #1

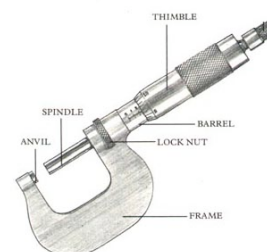
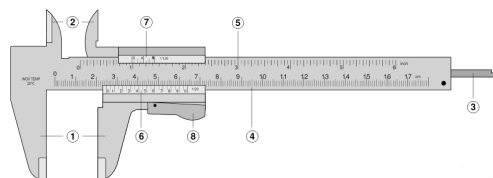
Measurements and Uncertainties

Objectives

To understand the precision of measurement devices, the uncertainties inherent to an experimental measurement, and how these uncertainties are carried through a final result when experimental data is used to calculate a physical quantity.

Material

- A stack of index cards
- Meter stick
- Plastic ruler
- Vernier caliper
- Micrometer screw
- Triple beam balance



Necessary readings

- Textbook: Section 1.7, *Significant Figures*
- Textbook: Appendix B.8, *Propagation of Uncertainty*
- <http://www.remi.poirier.com/Labs.html>
- <http://www.remi.poirier.com/Labs/uncertainties.html>

Experimental procedure

In this experiment you will use different measuring instruments to study the index cards provided to you. All measurements and relevant notes will be recorded in your logbook. The recorded data and information will be used in a subsequent lab.

1) Evaluation of Area

The area of the index card can be *calculated* from measurements of the *height* and *width* of a card. Use the meter stick and the plastic ruler to make those measurements and write them in your logbook in a table like the following one. Each column or row of a table should be headed with the proper dimension and unit, identified measured and calculated values. All values should have an uncertainty next to it, such as $x \pm \delta x$.

	Meter stick	Plastic ruler	
Height (cm)	$x \pm \delta x$	$x \pm \delta x$	<i>(measured)</i>
Width (cm)	$y \pm \delta y$	$y \pm \delta y$	<i>(measured)</i>
Area (cm ²)	$z \pm \delta z$	$z \pm \delta z$	<i>(calculated)</i>

It is often difficult with a meter stick to reach the precision of the scale ($\frac{1}{2}$ smallest division), due to the thickness of the stick and worn-out edges. Use your judgement to evaluate the uncertainty on quantities measured with the meter stick. It is much easier to

reach the precision of the scale with a clear plastic ruler. For that instrument an uncertainty of $\pm \frac{1}{2}$ smallest division is usually correct.

Using our simplest rules, the fractional uncertainty on the calculated area is the sum of the fractional uncertainties of the measured height and width. In the table however, convert this fractional uncertainty in absolute uncertainty. Use your logbook to make your calculations. It will be very useful in future labs to remember how it is done.

2) Evaluation of Thickness

The thickness of a single index card, is too small to be measured using the meter stick or even the plastic ruler since it is smaller than the precision of these instruments. So instead of doing a direct measurement of the thickness of a single card, it is possible to measure the thickness of several cards at once and divide by the number of cards. When an uncertain value is divided by an exact number, its uncertainty is also divided by the same number.

Use all your instruments on your stack of index cards, to evaluate the thickness with uncertainty of a single card in each case. The uncertainty of the vernier caliper and micrometer will be discussed in class.

	Thickness of “n” index cards (cm)	Thickness of a single card (cm)
Meter stick		
Plastic ruler		
Vernier caliper		
Micrometer screw		

(measured) (calculated)

In your logbook, you may use whatever units is more convenient to record your data (as long as you always note which one). In reports however, when one unit is chosen, such as meters, centimeters or millimeters, always keep the same unit throughout the length of the report.

Answer the following questions in your logbook: Which is most precise? Are the values for thickness in agreement with one another? Identify a possible source of error that may influence some of your measurements.

A graphical method can also be used to evaluate the thickness of an index card. This is the best method, since instead of using a single measurement to get the thickness, several measurements will be used. The more values are included in the graph, the more precise will be the evaluation of the thickness. For this specific case, make sure to have at least **10 measurements**. To further improve the precision, use the most precise instrument above to make each measurement. In your logbook draw a table such as the one below:

Describing title above the table, including which instrument was used.

number of cards	Thickness (units), \pm uncertainty

If you use the same instrument for each measurement, the uncertainty should be the same every time. Instead of rewriting it each and single time, write it in the column heading along with the proper units. This graph will be done and analysed in a subsequent lab. However without making the graph, **answer the following questions in your logbook:** If Thickness vs Number of cards was plotted, what kind of graph would it be: (linear, exponential, sinusoidal, ...)? How can the thickness of one index card be extracted from this graph?

The previous questions are essential because should you have to write a report on this experiment, you would have to discuss these in the introduction.

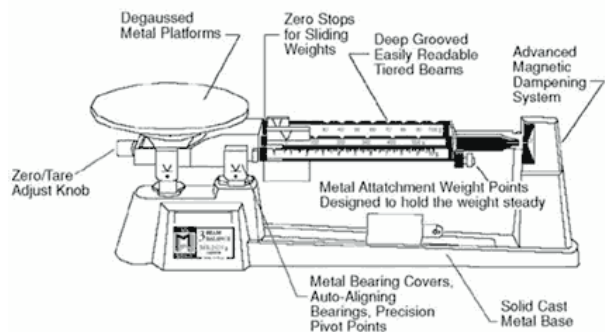
3) Evaluation of density

Density is a measure of mass per unit volume. You have gathered enough data so far to **calculate the volume** of an index card. Make this calculation in your logbook including propagation of uncertainties.

You must now use the triple-beam balance to measure the mass of an index card.

First, make sure the balance is calibrated (indicates zero, when nothing is on it) as discussed in class, then select a method to best evaluate the mass of a single index card.

The best method is the one leading to the most precise evaluation of the mass. In your logbook, describe your method and, as previously, draw the necessary table in order to record your data including units and uncertainties. Do not use a graphical method for this part.



Finally, **calculate in your logbook the density of the index cards**, express your result in kg/m^3 (with correct absolute uncertainties).