Measurement in the Physics Lab

INTRODUCTION:

If there's one thing all scientists do a lot of, it's measure. Science is a quantification process, and from this quantification comes insight into the nature of the universe. Every week you will be measuring in lab, and you will draw from these measurements a conclusion. But in order to measure you must first be proficient with the tools of the trade: the Vernier caliper, the micrometer, the meterstick, and the triple-beam balance.

THEORY:

The main thrust of this lab is instruction in the use of certain measuring instruments, but there is a bit of practical theory that goes with this instruction.

ERROR:

Error can be classified as either random or systematic.

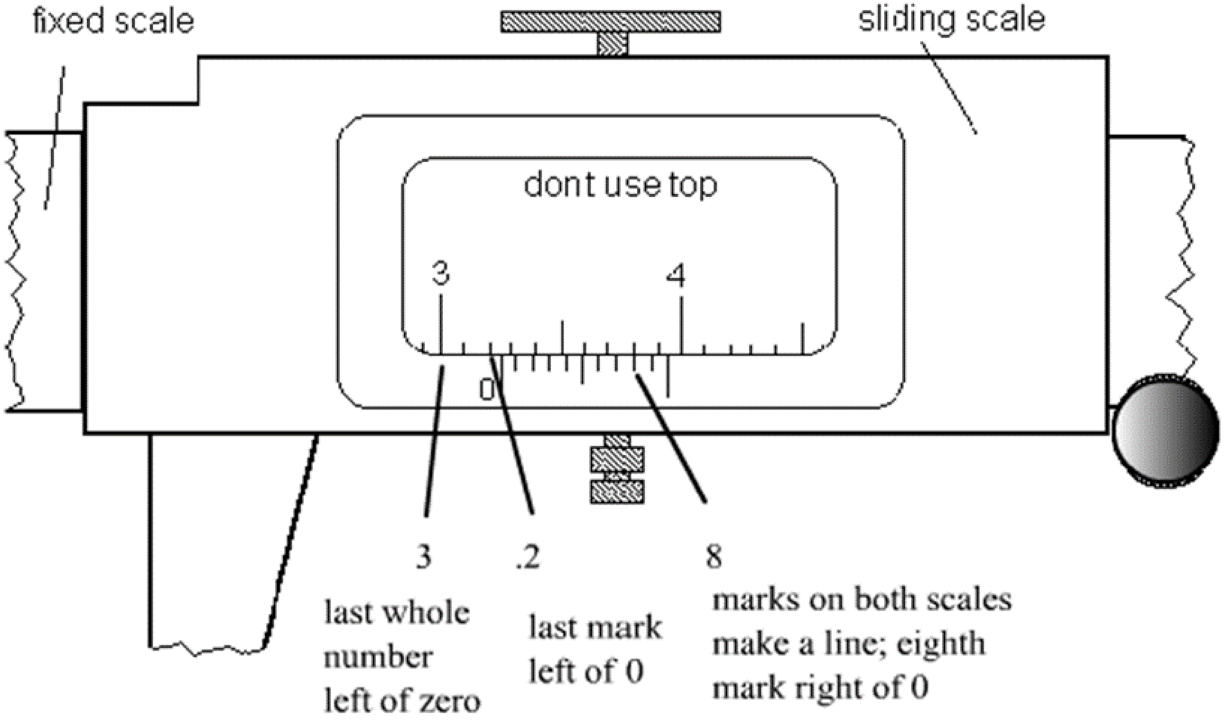
Random error: (sometimes erroneously called human error) comes from the perspective of individual measurements. For instance, suppose one partner measures something, and then the other partner measures the same thing. The judgment on where the needle points, or where the rounding occurs, causes small variations in the readings. (In some sense, the amount of random error in an experiment indicates the confidence level of your lab technique.) Importantly, these errors add to the true value as often as they detract. Therefore, averaging the data usually eliminates these errors. The more measurements that are made, the more averaging smoothes out these blips in the data set.

Systematic error: is the fault of the equipment. Suppose you use a steel measuring tape on a hot day. The steel expands when heated; consequently each mark is separated more than its stated value. Anything you measure with the tape in this condition will read shorter than it actually is, because the tape itself is longer than it should be. Systematic errors tend to give consistently higher or lower results which are not corrected by averaging. Elimination of these errors can only be accomplished by examining your equipment. One kind of systematic error which can be easily eliminated is zero error (not ‘‘no error’’!). When a caliper, micrometer, or other such device is closed, it should read ‘‘0’’, yet often the instrument doesn't close properly (usually because some student misadjusted it) and each reading will be too high or too low. Fixing this problem is merely a matter of noting the reading when the device is closed, and adding (if the instrument reads low) or subtracting (reads high) that value from each measurement.

MEASURING DEVICES:

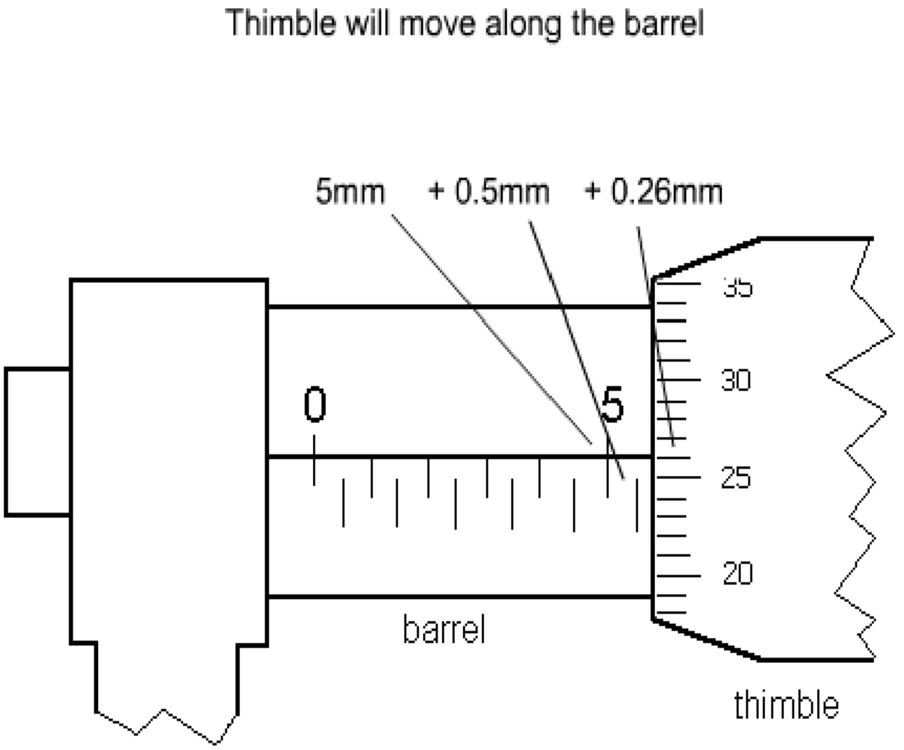
The meter stick and the triple beam balance are both self-explanatory; however, the Vernier caliper and the micrometer may be new to you, so some discussion is justified.

The Vernier Caliper: This device can measure both inside and outside dimensions down to **0.01cm** (don't use the top scale which measures in inches). Close the caliper gently on some test object to get an outer dimension reading, or expand the horns of the caliper into some cavity for an interior reading. See picture below:



The centimeter reading is taken by finding the first whole digit (as on a meter stick) on the fixed scale to the left of the zero mark on the sliding scale, 3 in the figure. The next number, the first decimal place, also comes from the fixed scale: it is the last small ‘‘hash’’ mark to the left of the zero, 0.2 in our case. It is the last number, the second decimal place, that is most difficult to establish. Find where a hash mark on the sliding scale makes a straight line with a similar mark on the fixed scale, 0.08 in the figure on the sliding scale. (This is the vernier quality of the caliper, and you will see other vernier style measuring devices in later labs.) Now add 3cm+ 0.2cm + 0.08cm for your reading. What is the uncertainty here?

The Micrometer: This instrument measures outer dimensions down to **0.01mm**, a factor of ten more precise than the caliper. Do not adjust the small knob at the end of the handle in any way! This is the calibration knob, and is pre-set by the lab technician. Close the micrometer gently around some test object. See picture below:



Each turn of the thimble opens the instrument 0.5mm; therefore two turns gives 1mm, four turns means 2mm, etc. These millimeter readings are notated by the hash marks which originate from the horizontal line on the barrel. The other marks which don’t touch that line indicate 0.5mm increments. In the figure the thimble has been turned eleven times, revealing the 5mm mark and the 0.5mm mark beyond it. The last number comes from the number on the thimble which lines up with the horizontal line on the barrel, in our case 0.26mm. This 0.26mm is added to 0.5mm so that the decimal side of the reading is 0.76mm. Add this to the 5mm above for the result. Of course, if the 0.5 mark had not been revealed, indicating only ten turns, then the reading would have been 5.26mm.

Always use the most precise measuring instrument available. Each time you use these instruments, check the zero reading, and note the uncertainty!

TASK:

1. To become familiar with several of the mechanical measuring devices used in physics
2. To determine the density of one cylinder and one block.

EQUIPMENT:

- Meter stick
- Metric Ruler
- Triple beam balance
- Vernier caliper
- Micrometer
- Metal Cylinder
- Wooden Block

PROCEDURE:

1. Note on your table the zero readings for the Vernier caliper and the micrometer
2. **Every report must include the measurements of all the members from the group.**
3. Measure the appropriate dimensions of the cylinder and the wooden block. **Each person must take 2 measurements of each dimension** for a total of 4 values per dimension (if you are in a group of three people your total number of measurements will be six). For instance measure the diameter at 4 (6) different places. This will give you 4 (6) values for your average.
4. **Be sure to include the units!**
5. **Use the Vernier caliper** to measure the height of the cylinder.
6. **Use the micrometer** to measure the diameter of the cylinder.
7. Mass the cylinder only once.
8. **Use the average** of the height and diameter values to calculate the volume of the cylinder.
9. Calculate the density of the cylinder in **grams/cm^3**.
10. Compare your calculated density to one of the theoretical values in the density table **provided in your lab website** by calculating the percent error.
11. **Express all your answers with the correct number of significant figures in your results section.**
12. **Use the ruler** to measure the height, width and depth of the wooden block. (Measure each dimension **twice per group member**, just as before)
13. Mass the wooden block only once. **Record the block number.**
14. Calculate the density of the block in **grams/cm^3**.
15. Compare your block's experimental density value with the density values **given in your lab website** by calculating the percent difference.
16. **Express all your answers with the correct number of significant figures in you results section.**