Measurement and Data Analysis
Laboratory Assignment, CHEM 1411
(revised 1/02/06)

1. Measuring Length

Using a meter stick, measure the length of the line segment between points A and B on the line. Measure this length in centimeters, cm, and in inches, in. Record the measured values on the data sheet.

For reference see: Physics Tutorial, Measuring Devices (meter stick and Vernier caliper); http://phoenix.phys.clemson.edu/tutorials/measure/

2. Measuring Volume

Part A. Graduated cylinder: Three graduated cylinders (cylinder A, cylinder B and cylinder C) containing different volumes of colored liquids are provided. Determine the volume markings represented on each cylinder. Record the volume of the liquid present in each cylinder on the data sheet.

The Meniscus When water is placed in a glass or plastic container the surface takes on a curved shape. This curve is known as a meniscus. Volumetric glassware is calibrated such that reading the bottom of the meniscus, when it is viewed at eye level, will give accurate results. Viewing the meniscus at any other angle will give inaccurate results. (see the following:)
http://acpcommunity.acp.edu/Facultystaff/genchem/GC1/lab/mvolume/volume.htm
Part B. Calculation: A metal cylinder (cylinder S, cylinder T, or cylinder X) will be provided. Determine the length of the metal cylinder and the diameter of the cylinder face, in cm. Record these determinations of the data sheet. Calculate the volume of the cylinder in cubic centimeters, cc, using the equation below.

\[
\text{Volume} = (\pi)(\text{height})(\text{radius})^2
\]

3. Measuring Mass

(see: [http://colossus.chem.umass.edu/genchem/chem110/110_Experiment_1.htm](http://colossus.chem.umass.edu/genchem/chem110/110_Experiment_1.htm))

**Mass: Electronic Balances:**

In determine mass you have three models of electronic balances available to you. These balances measure to 0.001g (1mg) and when you use them you should always record all three decimal places. The S.I. unit for mass is the kilogram (1 kg = 1000g). However it is not common to express mass in the laboratory in kilograms.

Be aware that these balances are somewhat delicate and very sensitive. Do not remove the plastic guard around each. While it may not always be practical to do so, it is good practice to stick with the same balance during any particular experiment. Pictured are the three models of analytical balances that we use in the General Chemistry. During the first lab, your TA will demonstrate the various idiosyncrasies of each!
When using the electronic balances, please observe the following:

1. Do not move the balance, this throws off the calibration and necessitates recalibration of the balance.
2. Weigh chemicals in containers that are dry on the outside. Never weigh directly on the pan.
3. Weigh everything at room temperature.
4. Zero the balance and keep the draft doors closed during weighing. Avoid leaning on the benches as this in fact interferes with the weighing!

**PLEASE LEAVE THE BALANCE CLEANER THAN YOU FOUND IT.** Brushes have been attached to each balance to facilitate this.

Determine the mass of the metal cylinder provided for exercise 2B above. Record the mass of the cylinder (nearest 0.001 g) on the data sheet.


Calculate the density of the metal for the cylinder provided in Part 2B above. The mass and the volume of the cylinder have been directly measured. The equation for the calculation of the density is:

\[
\text{Density} = \frac{\text{mass of cylinder}}{\text{volume of cylinder}}
\]

Record the calculated density value of the metal on the data sheet.

5. Data Analysis.

After measuring the density of the metal in Part 4 above, the question now becomes how to report the result. What error might be integrated into the obtained result? How accurate or how precise is the result?

For definition of accuracy and Precision, see:
[http://www.vanderbilt.edu/AnS/Chemistry/courses/chem104/experiment1/accuracy/accuracy.htm](http://www.vanderbilt.edu/AnS/Chemistry/courses/chem104/experiment1/accuracy/accuracy.htm) or [http://bell.mma.edu/~jbouch/Glossary/Precision.html](http://bell.mma.edu/~jbouch/Glossary/Precision.html)
If a series of measurements of the same variable or value is available, the determination of the standard deviation will provide an indication of how “tightly” the measured values are clustered about the mean of the measurements. For a discussion of standard deviation and Excel spreadsheet analysis see: [http://www.beyonddotechnology.com/tips016.shtml](http://www.beyonddotechnology.com/tips016.shtml). From this website the following statement is noted:

> Higher standard deviation is often interpreted as higher volatility. In comparison, lower standard deviation would likely be an indicator of stability. The most consistent values will usually be the set of numbers with the lowest standard deviation.

See also:  
- [http://www.mnstate.edu/wasson/ed602calcvarsdss.htm](http://www.mnstate.edu/wasson/ed602calcvarsdss.htm)  
- [http://phoenix.phys.clemson.edu/tutorials/excel/stats.html](http://phoenix.phys.clemson.edu/tutorials/excel/stats.html)  
- [http://www.gifted.uconn.edu/siegle/research/Normal/stdexcel.htm](http://www.gifted.uconn.edu/siegle/research/Normal/stdexcel.htm)  

Obtain from other students in the class calculated density values for the same designated metal cylinder (cylinder S, T or X, see Part 2B on page 2). Record these values in the table on the data sheet. Calculate the mean of the determined density values. Calculate the average deviation from the mean. Calculate the standard deviation of the determined density values.


**Mean**

The mean or average, $\bar{X}$, is calculated from:

$$\bar{X} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Where $N$ is the number of measurements and $x_i$ is each individual measurement. $\bar{X}$ is sometimes called the sample mean to differentiate it from the true or population mean, $\mu$. The formula for $\mu$ is the same as above, but $N$ must be at least 20 measurements.
Standard Deviation
The standard deviation, s, is a statistical measure of the precision for a series of repetitive measurements. The advantage of using s to quote uncertainty in a result is that it has the same units as the mean value. Under a normal distribution, ± one standard deviation encompasses 68% of the measurements and ± two standard deviations encompasses 96% of the measurements. It is calculated from:

\[ s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2} \]

Where N is the number of measurements, \( x_i \) is each individual measurement, and \( \bar{x} \) is the mean of all measurements. The quantity \( x_i - \bar{x} \) is called the "residual" or the "deviation from the mean" for each measurement. The quantity (N -1) is called the "degrees of freedom" for the measurement.

Properties of standard deviation
When using standard deviation keep in mind the following properties.

- Standard deviation is only used to measure spread or dispersion around the mean of a data set.
- Standard deviation is never negative.
- Standard deviation is sensitive to outliers. A single outlier can raise the standard deviation and in turn, distort the picture of spread.
- For data with approximately the same mean, the greater the spread, the greater the standard deviation.
- If all values of a data set are the same, the standard deviation is zero (because each value is equal to the mean).

See: http://www.statcan.ca/english/edu/power/ch12/variance.htm

When analysing normally distributed data, standard deviation can be used in conjunction with the mean in order to calculate data intervals.

If \( \bar{x} = \) mean, \( S = \) standard deviation and \( x = \) a value in the data set, then

- about 68% of the data lie in the interval: \( \bar{x} - S < x < \bar{x} + S \).
- about 95% of the data lie in the interval: \( \bar{x} - 2S < x < \bar{x} + 2S \).
- about 99% of the data lie in the interval: \( \bar{x} - 3S < x < \bar{x} + 3S \).
Relative Standard Deviation

The relative standard deviation (RSD) is useful for comparing the uncertainty between different measurements of varying absolute magnitude. The RSD is calculated from the standard deviation, s, and is commonly expressed as parts per thousand (ppt) or percentage (%):

\[
\text{RSD} = \left( \frac{s}{\overline{x}} \right) \times 1000 \text{ ppt} \quad \%\text{-RSD} = \left( \frac{s}{\overline{x}} \right) \times 100\%
\]

The %-RSD is also called the "coefficient of variance" or CV.

Reported Value (corrected for possible discarded values)

Reported value = mean ± (average deviation from mean)

Textbook Reading: Kotz (6th ed) pages 32 – 35