Errors, Accuracy, and Precision

In making physical measurements, one needs to keep in mind that measurements are not completely accurate. Each measurement will have some number of significant figures and should also have some indication as to how much we can "trust" it (i.e. error bars). Thus in order to reliably interpret experimental data, we need to have some idea as to the nature of the "errors" associated with the measurements. There are whole text books devoted to error analysis. We will not even attempt to be complete in our discussion of the topic, rather we will present some basic ideas to assist you in analyzing your data.

When dealing with error analysis, it is a good idea to know what we really mean by error. To begin with, let's talk about what error is not. Error is not a ***blunder*** such as forgetting to put the decimal point in right place, using the wrong units, transposing numbers, or any other silly mistake. Error is not your lab partner breaking your equipment. Error isn't even the difference between your own measurement and some generally accepted value. (That is a ***discrepancy***.) Accepted values also have errors associated with them; they are just better measurements than you will be able to make in a three-hour undergraduate physics lab. What we really mean by ***error*** has to do with uncertainty in measurements. Not everyone in lab will come up with the same measurements that you do and yet (with some obvious exceptions due to blunders) we may not give preference to one person's results over another's. Thus we need to classify types of errors.

Generally speaking, there are two types of errors: 1) ***systematic errors*** and 2) ***random errors***. Systematic errors are errors that are constant and always of the same sign and thus may not be reduced by averaging over a lot of data. Examples of systematic errors would be time measurements by a clock that runs too fast or slow, distance measurements by an inaccurately marked meter stick, current measurements by inaccurately calibrated ammeters, etc. Generally speaking, systematic errors are hard to identify with a single experiment. In cases where it is important, systematic errors may be isolated by performing experiments using different procedures and comparing results. If the procedures are truly different, the systematic errors should also be different and hopefully easily identified. An experiment that has very small systematic errors is said to have a high degree of ***accuracy***.

Random errors are a whole different bag. These errors are produced by any one of a number of unpredictable and unknown variations in the experiment. Examples might include fluctuations in room temperature, fluctuations in line voltage, mechanical vibrations, cosmic rays, etc. Experiments with very small random errors are said to have a high degree of ***precision***. Since random errors produce variations both above and below some average value, we may generally quantify their significance using statistical techniques.