Types of Errors

Random errors are caused by unpredictable variations in measurements. *They are characterized by a random distribution around the actual value*. Random errors are always present in every experiment. The effect a random error has on your results is inconsistent.

Systematic errors are the result of something not working as it should. There are two basic categories of systematic errors: an improperly calibrated instrument or a modeling error. An improperly calibrated instrument is such as a meter stick that starts at 1 cm instead of zero so that every measurement taken with that meter stick would be a cm too long. A modeling error is when our model of the lab does not match up to the "real world." Not accounting for friction or air resistance is a common modeling error. *All systematic errors should have the same affect on your measurement each time you make the measurement*.

Notice that "mathematical errors," mistakes in recording data and misreading of instruments are not considered errors (instead we will call these blunders). These blunders cannot be used to explain inaccurate or imprecise results because these so-called errors are avoidable. If you believe that you may have committed a blunder, then you should redo that part of the lab. While the presence of real errors will not affect your grade on a lab, uncorrected blunders will have a negative affect on your grade.

The Vocabulary

Data are numbers that come from direct measurement (do not involve any calculations).

Results are the answer received from doing calculations on the data.

Experimental value is a value found from measurement and/or calculations.

Actual Value is a value that can either be found in a reputable source (sometimes we will have to settle for direct measurement).

Experimental error is the difference between the experimental value and the actual value.

Percent error is the experimental error divided by the actual value multiplied by 100.

Precision is the spread of the data or how close each piece of data is to the rest of the data. The precision of a lab relates to the random error present in lab; the smaller the random error in a lab the greater the precision. The precision in a lab is directly related to the amount of *uncertainty* in the lab.

Accuracy is the how close the measured or derived value is to the actual value. The accuracy of a lab relates to the *systematic* error present in lab; the smaller the systematic error in a lab the greater the accuracy.

Uncertainty is an estimate of the range of *random* error associated with a measurement or a result. There are different ways to find the uncertainty: from a estimation of the range from repeated measurement and from the *standard deviation* of multiple measurements or results (given by the symbol σ).

Mean is the arithmetic average of a collection of data.

Standard deviation(σ) is the measurement of the range around the mean that would include roughly 68% of random data. The percent standard deviation (100%*σ/mean) gives you a good idea of the total random error.

Propagation of errors: When performing mathematical operations with quantities that have their own uncertainties, the result of these operations will have its own uncertainty found through the propagation of errors.

Significant figures: All results and measurements are only known to a certain digit. The last significant digit should be the digit you are uncertain about. Thus if the uncertainty is 1 mm in measuring length, then any measurement that is made is only significant to thousandth digit of a meter.

How to report results from a Lab

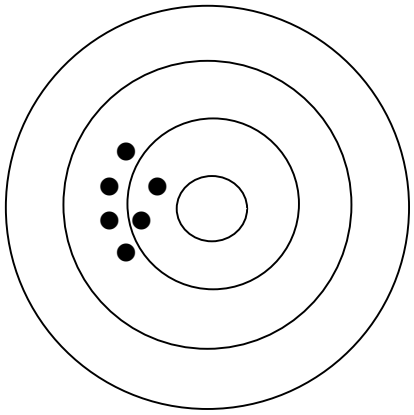
Any analysis of your results should always include a statement of both accuracy and precision.

The statement of accuracy should be the range of values represented by the experimental value ± the uncertainty. To be accurate the range of results should included the actual value.

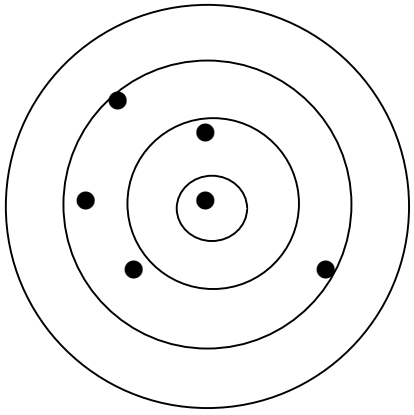
The statement of precision should involve analysis of the size of your uncertainty in comparison to your experimental value.

Precision versus Accuracy

A common illustrative example is arrows shot at a target. The accuracy is how close the arrows are to the center (the actual value) while the precision is how close the arrows are to each other.



high precision
low accuracy



low precision
high accuracy