Appendix B
A Note on Precision and Accuracy

The terms *precision* and *accuracy* are often used interchangeably but they have distinctly different meanings when used correctly. Precision refers to the repeatability of a measurement, accuracy to the correctness of the measurement.

Here's an example: Imagine weighing a coin on a laboratory balance. The display says 5.002 g. Is this measurement accurate? Is it precise? You remove the coin from the balance, check that the display returns to 0.000, and then weigh the coin again. This time the display says 5.005 g. Which measurement do you believe to be correct? Just to be sure, you repeat the process three more times, each time checking that the display returns to 0.000, and get readings of 5.000, 5.004, and 5.001 g. The mean and standard deviation of the measurements are 5.002 g and 0.002 g respectively.

Now you notice that the balance has a *Calibrate* button which you press (after removing the coin). After calibration you repeat the five measurements with results of 4.903, 4.906, 4.901, 4.905, and 4.902 g. This time the mean and standard deviation of the measurements are 4.903 and 0.002 g, respectively.

Notice that in both sets of measurements the standard deviation of the measurements was identical. However, before calibration the average of the measurements was too high by 0.099 g. The precision was the same (± 0.002) for each set of measurements but the accuracy depended critically on calibration. If the balance had not been properly maintained then we might expect some friction problems in the mechanism to lead to a greater standard deviation in the measurements, or a *lower precision*.

Beware, it is easy to be deceived by the number of digits on a display that a measurement is both precise and accurate when neither may be the case. Similarly, we need to be careful about specifying measurements with meaningless decimal places. If the standard deviation of the above measurements of the coin's weight was 0.02 g rather than 0.002 g, then it would be inappropriate to describe the weight of the coin with milligram precision because the uncertainty is at least 20 mg.

Note that if we wanted to digitally encode our measurements above we would need, at the very least, 13 bits ($2^{13} = 8192$) to store the measurements with adequate precision, since we want to measure 5,000 mg in increments of 1 mg.

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