Using Significant Figures

From Andrew Zimmerman Jones, (taken from http://physics.about.com Nov. 1, 2007)

Introducing Significant Figures

When making a measurement, a scientist can only reach a certain level of precision, limited either by the tools being used or the physical nature of the situation. The most obvious example is measuring distance. Consider what happens when measuring the distance an object moved using a tape measure (in metric units). The tape measure is likely broken down into smallest units of millimeters. Therefore, there's no way that you can measure with a precision greater than a millimeter. If the object moves 57.215493 millimeters, therefore, we can only tell for sure that it moved 57 millimeters (or 5.7 centimeters or 0.057 meters, depending on the preference in that situation).

In general, this level of rounding is fine. Getting the precise movement of a normal sized object down to a millimeter would be a pretty impressive achievement, actually. Imagine trying to measure the motion of a car to the millimeter, and you'll see that in general this isn't necessary. In the cases where such precision is necessary, you'll be using tools that are much more sophisticated than a tape measure. The number of meaningful numbers in a measurement is called the number of *significant figures* of the number. In our earlier example the 57 millimeter answer would provide us with 2 significant figures in our measurement.

Zeroes & Significant Figures

Consider the number 5,200. Unless told otherwise, it is generally the common practice to assume that only the two non-zero digits are significant. In other words, it is assumed that this number was rounded to the nearest hundred. However, if the number is written as 5,200.0, then it would have five significant figures. The decimal point and following zero is only added if the measurement is precise to that level.

Similarly, the number 2.30 would have three significant figures, because the zero at the end is an indication that the scientist doing the measurement did so at that level of precision. Some textbooks have also introduced the convention that a decimal point at the end of a whole number indicates significant figures as well. So 800. would have three significant figures while 800 has only one significant figure. Again, this is somewhat variable depending on the textbook. Following are some examples of different numbers of significant figures, to help solidify the concept:

One significant figure
4
900
0.00002

Two significant figures
3.7
0.0059
68,000
5.0

Three significant figures
9.64
0.00360
99,900

8.00
900. (in some textbooks)

Mathematics with Significant Figures

Scientific figures provide some different rules for mathematics than what you are introduced to in your mathematics class. The key in using significant figures is to be sure that you are maintaining the same level of precision throughout the calculation. In mathematics, you keep all of the numbers from your result, while in scientific work you frequently round based on the significant figures involved.

When adding or subtracting scientific data, it is only last digit (the digit the furthest to the right) which matters. For example, let's assume that we're adding three different distances:

5.324 + 6.8459834 + 3.1

The first term in the addition problem has four significant figures, the second has eight, and the third has only two. The precision, in this case, is determined by the shortest decimal point. So you will perform your calculation, but instead of 15.2699834 the result will be 15.3, because you will round to the tenths place (the first place after the decimal point), because while two of your measurements are more precise the third can't tell you anything more than the tenths place, so the result of this addition problem can only be that precise as well.

Note that your final answer in this case has three significant figures, while *none* of your starting numbers did. This can be very confusing to beginning students, and it's important to pay attention to that property of addition and subtraction.

When multiplying or dividing scientific data, on the other hand, the number of significant figures do matter. Multiplying significant figures will always result in a solution that has the same significant figures as the smallest significant figures you started with. So, on to the example:

5.638 x 3.1

The first factor has four significant figures and the second factor has two significant figures. Your solution will, therefore, end up with two significant figures. In this case, it will be 17 instead of 17.4778. You perform the calculation *then* round your solution to the correct number of significant figures. The extra precision in the multiplication won't hurt, you just don't want to give a false level of precision in your final solution.

The Limits of Significant Figures

Significant figures are a basic means that scientists use to provide a measure of precision to the numbers they are using. The rounding process involved still introduces a measure of error into the numbers, however, and in very high-level computations there are other statistical methods that get used. For virtually all of the physics that will be done in the high school and college level classrooms, however, correct use of significant figures will be sufficient to maintain the required level of precision.

Final Comments

Significant figures can be a significant stumbling block when first introduced to students, because it alters some of the basic mathematical rules that they have been taught for years. With significant figures, 4 x 12 = 50, for example. Similarly, the introduction of scientific notation to students who may not be fully comfortable with exponents or exponential rules can also create problems.

Keep in mind that these are tools which everyone who studies science had to learn at some point, and the rules are actually very basic. The trouble is almost entirely remembering which rule is applied at which time. When do I add exponents and when do I subtract them? When do I move the decimal point to the left and when to the right? If you keep practicing these tasks, you'll get better at them until they become second nature.

Finally, maintaining the proper units can be tricky. Remember that you can't directly add centimeters and meters, for example, but must first convert them into the same scale. This is a very common mistake for beginners but, like the rest, it is something that can very easily be overcome by slowing down, being careful, and thinking about what you're doing.