Appendix A: Scientific Calculations

This appendix is a guide to successfully completing scientific calculations. Any calculations necessary during the course of this lab must follow the methods described here. If after reading through this, you feel that you need more assistance, check out the info and exercises at http://www.bhc.edu/academics/science/harwoodr/Geol101. Select “Lab Materials” and select “Metric System and Scientific Notation.”

Conversions and Setting up Calculations: First, let’s go over some pointers on working with numbers in science. Nearly all scientific quantities are measured using the metric system, an invention of scientists to standardize measurements using multiples of 10. The English system, our measuring scheme here in America, uses a base of 12, and, after all, we have 10 fingers not 12! We Americans are stubborn, however, and usually use the English system in common non-scientific practice, so we will practice conversions. These conversions should not be treated lightly - one of NASA’s Mars probes crashed into the planet because someone forgot to convert!

Scientific calculations often involve many different quantities, such as length, mass, volume, temperature, and time. Each quantity will be measured in a unit, such as feet or meters for length, as shown in your textbook’s conversion chart. In order to perform calculations using multiple units of measure, YOU MUST KEEP TRACK OF THE UNITS AND SHOW ALL OF YOUR CALCULATIONS! You must also know the units of any conversion factor listed.

Here’s an example: Mt. Kilimanjaro is 19,340 feet tall. Convert this into (a) miles and (b) km. We know that there are 5280 feet in a mile, and 1.6 km in a mile.

(a). 19,340 feet * (1 mile / 5280 feet) = 3.663 miles
(b). 3.663 miles * (1.609 km / 1 mile) = 5.894 km

You may use any calculation technique as long as you follow two rules:

1. ALWAYS SHOW YOUR CALCULATIONS!
2. ALWAYS SHOW THE UNIT OF MEASURE ASSOCIATED WITH EACH NUMBER!

Scientific Notation: Numbers in science can be very big, or extremely tiny. The Earth is 4.5 billion years old -- that’s 4,500,000,000 -- a whole lot of zeros! We also work with tiny quantities, like 1 billionth of a second (0.000000001 sec) -- again, a lot of zeros. To make these numbers easier to work with, we use the measured numerals and represent the zeros as an exponent of 10. We do this simply by counting the number of places we must move the decimal to get a numeral to the 1/10th place. Here are some examples:

4,500,000,000 = 4.5 \times 10^9 - the 9 is figured by counting the number of decimal places you had to move the decimal to get 4.5

0.000000001 = 1.0 \times 10^{-9} - the 9 here is negative because you move the decimal to the left (always negative for numbers less than 1)

Use these rules for performing calculations in scientific notation:

When adding or subtracting, make the exponents equal (by moving the decimal place) and then add and subtract the numbers at that exponent level

1. When multiplying, multiply the numbers and add the exponents
2. When dividing, divide the numbers and subtract the exponents

**Significant Figures and Uncertainty:** In the examples above, the zeros are not as significant as the measured numerals 4.5 or 1.0. In scientific calculations, we want to focus on the measured, significant numbers, not just to be less cumbersome, but to limit the uncertainty of the calculation. If you measure a string and find that it is 17.87 cm long, your quantity has 4 significant figures, it is certain to the 1/100th decimal place. If you measure a longer string with an inferior ruler, you may get a measure of 112.4 cm - 4 significant figures, but only certain to the 1/10th decimal place. Simple enough, but you must limit the number of significant figures in a calculated answer according to these rules:

1. When adding or subtracting, your answer should be limited by the number of decimal places in the quantity with the greatest uncertainty. EX: 17.87 cm + 112.4 cm = 130.3 cm
2. When multiplying or dividing, your answer is limited to the number of significant figures in the quantity with the greatest uncertainty. 3.137 * 1.5 = 4.7
3. Zeros are tricky. If the zero is the rightmost numeral (or leftmost for quantities <1) and it's only function is to show the tens place, then it is NOT a significant figure. But these zeros ARE significant figures if they were measured to that level of certainty. You're probably scratching your head. Here are some examples.

\[
\begin{align*}
0.00306 &= 3.06 \times 10^{-3} & \rightarrow 3 \text{ significant figures} \\
1,102,000,000 &= 1.102 \times 10^9 & \rightarrow 4 \text{ significant figures} \\
2.30^\circ \text{C} \text{ (measured to the } 1/100 \text{ place)} & \rightarrow 3 \text{ significant figures}
\end{align*}
\]

If your calculator spits out a number like 2.30000000 as the solution to 8.05 / 3.5, then you do not count those zeros (the correct number would be 2.3 with 2 significant figures)

**Misc. Math:** In addition to the scientific math conventions already described, you need to be able to perform basic statistics, primarily using ratios and percentages. A ratio is a relative comparison of any two numbers. For example, a topographic map might have a scale represented as 1:24,000. This ratio means that 1 inch on the map equals 24,000 inches on the ground. There are many other uses of ratios in science, and they can be used to determine unknown quantities.

EX: The ratio of basalt rocks to granite in an area is 3 to 2. We count 60 granite rocks, how many basalt rocks do we have?
- Verbally, the question is. "3 is to 2 as X is to 60."
- Cross multiplying yields 3*60 = 2X.
- Canceling out the 2 by dividing on both sides yields 3*60/2 = X = 90 basalt rocks.

You also need to be able to calculate percentages. What percentage of the total rocks above is basalt?

\[
\begin{align*}
\text{Total rocks} &= \text{granite} + \text{basalt} = 150 \text{ rocks} \\
\% \text{ basalt} &= 90/150 \times 100 = 60\%
\end{align*}
\]

OK, that's it for math. I know most of you didn't take geology to immerse yourself in math. But math is part of all sciences, and we will use it off and on all semester.