**1. Student Guide Lab Math Basics**

*(Adapted from Denise Monti’s Phage Explorations Laboratory Mathematics Module)*

**SCIENTIFIC NOTATION**

Scientific notation is a method for expressing and working with very small and very large numbers. Numbers expressed in scientific notation comprise three parts: a coefficient, a base, and the exponent.

Consider the following:



This is the scientific notation for the number 625,000,000. To write a number in correct scientific three rules need to be applied:

1. The coefficient must be greater than or equal to 1 and less than 10.
2. The base must be 10.
3. The exponent must indicate the number of decimal places the decimal needs to be moved to convert the number to standard notation. A positive exponent indicates movement of the decimal point to the right; a negative exponent indicates movement of the decimal point to the left when converting to standard notation.

Listed below are some examples of numbers in scientific and standard notation.

| **Standard Notation** | **Scientific Notation** |
| --- | --- |
| 1,230,000 | 1.23 x 106 |
| 89,500,000,000,000,000,000,000 | 8.95 x 1022 |
| 0.0000000367 | 3.67 x 10-8 |
| 98,700,000,000,000 | 9.87 x 1013 |
| 0.0000000000000000782 | 7.82 x 10-17 |

In the following table, practice converting numbers from scientific notation to standard notation and vice versa.

| **Standard Notation** | **Scientific Notation** |
| --- | --- |
| 345,000 |  |
| 67,700,000,000,000 |  |
| 0.0000000559 |  |
| 0.0000078 |  |
|  | 1.35 x 105 |
|  | 6.90 x 10-4 |
|  | 7.32 x 108 |

**CALCULATING WITH SCIENTIFIC NOTATION**

Most calculations in the laboratory will be performed using a calculator, but it is important to understand how to perform basic mathematic functions using numbers expressed in scientific notation to double check your calculators (the “rule” of logic should always be applied).

**Multiplication**

When multiplying numbers expressed in scientific notation, multiply the coefficients and add the exponents. The base 10 will remain the same.

Multiply:

Solution:

**Division**

When dividing numbers expressed in scientific notation, divide the coefficients and subtract the exponents. The base 10 will remain the same.

Divide:

Solution:



Note: Be sure the final solution is expressed in correct scientific notation and meets the three principles outlined for scientific notation.

In the following table, practice multiplying and dividing numbers expressed in scientific notation.

| **Equation** | **Solution** |
| --- | --- |
| (1.03 x 105) \* (6.24 x 103) |  |
| (5.62 x 10-5) \* (1.25 x 10-2) |  |
| (4.31 x 103) \* (6.87 x 10-8) |  |
| (2.22 x 108) \* (5.52 x 106) |  |
| (1.03 x 1010) / (6.24 x 103) |  |
| (2.22 x 108) / (5.52 x 106) |  |
| (5.68 x 10-6) / (1.55 x 10-12) |  |

**ALTERNATE EXPRESSIONS OF EXPONENTS**

Exponents can be expressed several different ways and this can affect the written expression of a number in scientific notation. The following examples all express the number 1,250,000 in scientific notation.

**1,250,000 = 1.25 x 106  = 1.25E+6 = 1.25 x 10^6**

**METRIC SYSTEM**

The metric system is commonly used in the laboratory and in medicine to express units of measurement. In this course, we are most concerned with three units of measurement: length, weight, and volume. The table below indicates the standard metric unit for each measurement type.

| **Measurement** | **Unit** |
| --- | --- |
| Length | Meter (m) |
| Weight | Gram (g) |
| Volume of Liquid | Liter (L) |

The metric system uses common prefixes based on multiples of ten with each of the units to alter the size of the unit. The table below lists several of the most commonly used prefixes and their definitions. The best way to learn these is to **memorize** them so you can easily put them to practice in the laboratory.

| **Prefix** | **Abbreviation** | **Definition** |
| --- | --- | --- |
| Mega | (M) | 1.0 x 106 |
| Kilo | (k) | 1.0 x 103 |
| centi | (c) | 1.0 x 10-2 |
| **milli** | **(m)** | **1.0 x 10-3** |
| **micro\*** | **(µ)** | **1.0 x 10-6** |
| nano | (n) | 1.0 x 10-9 |
| pico | (p) | 1.0 x 10-12 |
| femto | (f) | 1.0 x 10-15 |

Relationships between units can be expressed in multiple ways:

1 kg = 1000 g (also, 1 g = 0.001 kg = 1.0 x 10-3 kg)

1 L = 1000 mL (also, 1 mL = 0.001 L = 1.0 x 10-3 L)

A very important relationship in molecular biology lab work is that 1 mL = 1000 µL

\*The value micro has alternate expressions that are sometimes used.

One micrometer (µm) can also be called 1 micron = 1 **µ**  = 1 x 10-6 meter.

One microliter (µL) can also be called1 lambda = 1**λ** = 1.0 x 10-6 liter

Practice selecting the correct prefix and measurement for each of the following scenarios.

Example: The distance from New York to London (kilometers, km)

| **Scenario** | **Unit of Measurement** | **Abbreviation** |
| --- | --- | --- |
| The length of your thumb |  |  |
| The volume of one drop of rain |  |  |
| The mass of a crayon |  |  |
| The volume of coffee in a mug |  |  |
| The width of a blade of grass |  |  |
| The mass of 3 grains of salt |  |  |

**CONVERTING NUMBERS USING THE METRIC SYSTEM**

To convert numbers from one unit to another using the metric system, first identify the definition of each prefix relative to the base unit of measurement (m, g, L). Then, use dimensional analysis (fancy name, simple technique) to convert from one unit of measurement to another.

Example: Convert 45 milligrams to grams.

Dimensional analysis:

$\frac{45 mg}{1} \left(\frac{1 g}{1.0 x 10^{3} mg}\right)= .045 g$

Example: Convert 25 mg/mL to µg/mL

$\frac{25 mg}{mL} \left(\frac{1 x 10^{3} µg}{1 mg}\right)= 2.50 x 10^{4} µg/mL$

Practice making conversions using dimensional analysis.

| **Problem** | **Solution** |
| --- | --- |
| 200mg = ? kg |  |
| 400nm = ? cm |  |
| 2mL = ? L |  |
| 2m = ? km |  |
| 480 µL = ? mL |  |
| 0.6 g = ? mg |  |
| 75 µg/µL = ? mg/mL |  |

**ANSWER KEY**

*(Adapted from Denise Monti’s Phage Explorations Laboratory Mathematics Module; SEA-PHAGES forums* [*https://seaphages.org/forums/topic/4387/*](https://seaphages.org/forums/topic/4387/) *07/21/17))*

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| 67,700,000,000,000 | **6.77 x 1013** |
| 0.0000000559 | **5.59 x 10-8** |
| 0.0000078 | **7.80 x 10-6** |
| **135,000** | 1.35 x 105 |
| **0.00069** | 6.90 x 10-4 |
| **732,000,000** | 7.32 x 108 |

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In the following table, practice multiplying and dividing numbers expressed in scientific notation.

| **Equation** | **Solution** |
| --- | --- |
| (1.03 x 105) \* (6.24 x 103) | **6.43 x 108** |
| (5.62 x 10-5) \* (1.25 x 10-2) | **7.03 x 10-7** |
| (4.31 x 103) \* (6.87 x 10-8) | **2.96 x 10-4** |
| (2.22 x 108) \* (5.52 x 106) | **1.23 x 1015** |
| (1.03 x 1010) / (6.24 x 103) | **1.65 x 106** |
| (2.22 x 108) / (5.52 x 106) | **4.02 x 101 (or 40.2)** |
| (5.68 x 10-6) / (1.55 x 10-12) | **3.66 x 106** |

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| **Scenario** | **Unit of Measurement** | **Abbreviation** |
| --- | --- | --- |
| The length of your thumb | **centimeters** | **cm** |
| The volume of one drop of rain | **microliters** | **µL** |
| The mass of a crayon | **grams** | **g** |
| The volume of coffee in a mug | **milliliters** | **mL** |
| The width of a blade of grass | **millimeters** | **mm** |
| The mass of 3 grains of salt | **milligrams** | **mg** |

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Practice making conversions using dimensional analysis.

| **Problem** | **Solution** |
| --- | --- |
| 200mg = ? kg |  **200 mg (**$\frac{1 g}{1000 mg}$**)(**$\frac{1.0 x 10^{-3} kg}{1 g}$**) = 2.0 x 10-4 kg** |
| 400nm = ? cm | **400 nm (**$\frac{1 m}{1.0 x 10^{9} nm}$**)(**$\frac{100 cm }{1 m}$**) = 4.0 x 10-5 cm** |
| 2mL = ? L |  **2 mL (**$\frac{1 L}{1000 mL}$**) = 2.0 x 10-3 L** |
| 2m = ? km | **2 m (**$\frac{1.0 x 10^{-3 km}}{1 m}$**) = 2.0 x 10-3 km** |
| 480 µL = ? mL | **480 µL (**$\frac{1 mL}{1000 µL}$**) = 0.48 mL** |
| 0.6 g = ? mg | **0.6 g (**$\frac{1000 mg}{1 g}$**) = 600 mg** |
| 75 µg/µL = ? mg/mL | **75**$\frac{ µg}{ µL}$ **(**$\frac{1000 µL}{1 mL}$**)(**$\frac{1 mg}{1000 µg}$**) = 75**$\frac{ mg}{ mL}$ |