The Metric System

Unit: Mathematics

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A

AP Physics 2 Learning Objectives: N/A

Knowledge/Understanding:

- Understand how units behave and combine algebraically.
- Know the 4 common prefixes and their numeric meanings.

Skills:

- Be able to describe quantities using metric units with & without prefixes.

Language Objectives:

- Understand and correctly use the terms "unit" and "prefix."
- Accurately describe and apply the concepts described in this section, using appropriate academic language.

Notes:

A unit is a specifically defined measurement. Units describe both the type of measurement, and a base amount.

For example, 1 cm and 1 inch are both lengths. They are used to measure the same dimension, but the specific amounts are different. (In fact, 1 inch is exactly 2.54 cm.)

Every measurement is a number multiplied by its unit. In algebra, the term "3*x*" means "3 times *x*". Similarly, the distance "75 m" means "75 *times* 1 meter".

<u>Both</u> the number <u>and</u> its units are necessary to describe any measurement. You ***always*** need to write the units. Saying that "12 is the same as 12 g" in physics is as ridiculous as saying "12 is the same as 12*x*" in math.

The metric system is a set of units of measurement that is based on natural quantities (on Earth) and powers of 10.

Use this space for summary and/or additional notes:

The metric system has 7 fundamental "base" units:

- meter (m): length
- kilogram (kg): mass (even though "kilo" is actually a prefix, mass is defined based on the kilogram, not the gram)
- second (s): time
- Kelvin (K): temperature
- mole (mol): amount of substance
- ampere (A): electric current
- candela (cd): intensity of light

Each of these base units is defined in some way that could be duplicated in a laboratory anywhere on Earth (except for the kilogram, which is defined by a physical object that is locked in a vault in the village of Sevres, France). All other metric units are combinations of one or more of these seven.

For example:

Velocity (speed) is a change in distance over a period of time, which would have units of distance/time (m/s).

Force is a mass subjected to an acceleration. Acceleration has units of distance/time^2 (m/s^2), and force has units of mass × acceleration. In the metric system this combination of units (kg·m/s^2) is called a newton (symbol "N"), which means: $1\text{ N} \equiv 1\text{ kg}\cdot\text{m/s}^2$

(The symbol "≡" means "is identical to," whereas the symbol "=" means "is equivalent to".)

Use this space for summary and/or additional notes:

The metric system uses prefixes to indicate multiplying a unit by a power of ten. There are prefixes for powers of ten from 10^{-18} to 10^{18}. The most commonly used prefixes are:

- mega (M) = 10^{6} = 1 000 000
- kilo (k) = 10^{3} = 1 000
- centi (c) = $10^{-2} = \frac{1}{100}$ = 0.01
- milli (m) = $10^{-3} = \frac{1}{1{,}000}$ = 0.001
- micro (μ) = $10^{-6} = \frac{1}{1\,000\,000}$ = 0.000 001

These prefixes can be used in combination with any metric unit, and they multiply just like units. "35 cm" means "35 times c times m" or "(35)($\frac{1}{100}$)(m)". If you multiply this out, you get 0.35 m.

Any metric prefix is allowed with any metric unit.

For example, standard atmospheric pressure is 101 325 Pa. This same number could be written as 101.325 kPa or 0.101 325 MPa.

There is a popular geek joke based on the ancient Greek heroine Helen of Troy. She was said to have been the most beautiful woman in the world, and she was an inspiration to the entire Trojan fleet. She was described as having "the face that launched a thousand ships." Therefore a milliHelen must be the amount of beauty required to launch one ship.

Use this space for summary and/or additional notes:

Conversions

If you need to convert from one prefix to another, the rule of thumb is that if the prefix gets larger, then the number needs to get smaller and vice-versa.

For example, suppose we need to convert 0.25 mg to μg.

The prefix "m" means 10^{-3} and "μ" means 10^{-6}. Therefore, you can replace the prefix "m" with the number 10^{-3}, and the prefix "μ" with the number 10^{-6}.

You can think of the rule in the following way:

$$0.25\text{ mg} = x\ \mu\text{g}$$

$$(0.25)\ (0.001)\text{ g} = (x)\ (0.000\,001)\text{ g}$$

$$\frac{(0.25)(0.001)}{0.000\,001} = 250\text{ g} = x$$

To do this in your head using "common sense," you can realize that when you jump from milli to micro, the prefix is getting *smaller* by 3 decimal places (going from 10^{-3} to 10^{-6}), which means the number that is attached to it needs to get *bigger* by 3 decimal places in order to keep the combined number-and-prefix the same. The answer must therefore be 250 μg.

Use this space for summary and/or additional notes:

The MKS vs. cgs Systems

Because physics heavily involves units that are derived from other units, it is important that you make sure all quantities are expressed in the appropriate units before applying formulas. (This is how we get around having to do factor-label unit-cancelling conversions—like you learned in chemistry—for every single physics problem.)

There are two measurement systems used in physics. In the MKS, or "meter-kilogram-second" system, units are derived from the S.I. units of meters, kilograms, seconds, moles, Kelvins, amperes, and candelas. In the cgs, or "centimeter-gram-second" system, units are derived from the units of centimeters, grams, seconds, moles, Kelvins, amperes, and candelas. The following table shows some examples:

Quantity	MKS Unit	S.I. Equivalent	cgs Unit	S.I. Equivalent
force	newton (N)	$\frac{\text{kg}\cdot\text{m}}{\text{s}^2}$	dyne (dyn)	$\frac{\text{g}\cdot\text{cm}}{\text{s}^2}$
energy	joule (J)	$\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$	erg	$\frac{\text{g}\cdot\text{cm}^2}{\text{s}^2}$
magnetic flux density	tesla (T)	$\frac{\text{N}}{\text{A}}, \frac{\text{kg}\cdot\text{m}}{\text{A}\cdot\text{s}^2}$	gauss (G)	$\frac{0.1\,\text{dyn}}{\text{A}}, \frac{0.1\,\text{g}\cdot\text{cm}}{\text{A}\cdot\text{s}^2}$

In this class, we will use exclusively MKS units. This means you only have to learn one set of derived units. However, you can see the importance, when you solve physics problems, of making sure all of the quantities are in MKS units before you plug them into a formula!

Homework Problems

1. 450 nm = _______________ m
2. $18.1\,\text{m}\ell$ = _______________ $\mu\ell$
3. 68 300 J = _______________ kJ
4. 6.56×10^4 kg = _______________ tonne

Use this space for summary and/or additional notes: