# The International System of Units

**Unit:** Math & Measurement

**MA Curriculum Frameworks (2016):** SP5

**Mastery Objective(s):** (Students will be able to…)

- Use and convert between metric prefixes attached to units.

**Success Criteria:**

- Conversions between prefixes move the decimal point the correct number of places.
- Conversions between prefixes move the decimal point in the correct direction.
- The results of conversions have the correct answers with the correct units, including the prefixes.

**Tier 2 Vocabulary:** prefix

**Language Objectives:**

- Set up and solve problems relating to the concepts described in this section.

## Notes:

*This section is intended to be a brief review. You learned to convert between metric prefixes in elementary or middle school.* ***You are expected to be able to fluently perform calculations that involve converting between metric prefixes.***

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 units. In algebra, the term "3x" means "3 times x". Similarly, the distance "75 m" means "75 times the distance 1 meter".

*The number and the units are* <u>*both*</u> *necessary to describe any measurement.* You *always* need to write the units. Saying that "12 is the same as 12 g" would be as ridiculous as saying "12 is the same as 12 × 3".

Use this space for summary and/or additional notes:

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

The metric system has 7 fundamental "base" units:

| **Unit** | **Quantity** | **Currently Based On** |
|---|---|---|
| meter (m) | length | the distance light travels in a specific time |
| kilogram (kg) | mass | the mass of the official prototype kilogram |
| second (s) | time | the time it takes for a particular type of radiation from a cesium-133 atom |
| Kelvin (K) | temperature | the temperature of the triple point of water |
| mole (mol) | amount of substance | the number of atoms in a specific mass of carbon-12 |
| ampere (A) | electric current | the amount of current that produces a specific force under specific conditions |
| candela (cd) | intensity of light | the amount of light per unit of area at a specific distance |

All other S.I. units are combinations of one or more of these seven base units.

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, which means:
$1\ \text{N} \equiv 1\ \text{kg·m/s}^2$

As of 2018, 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 in a safe in France).

Use this space for summary and/or additional notes:

In May 2019, all of the above S.I. units will be defined based on specifying exact values for certain fundamental constants:

- The Planck constant $h$ is exactly $6.626\,070\,15 \times 10^{-34}$ J·s
- The elementary charge $e$ is exactly $1.602\,176\,634 \times 10^{-19}$ C
- The Boltzmann constant $k$ is exactly $1.380\,649 \times 10^{-23}$ $J \cdot K^{-1}$
- The Avogadro constant $N_A$ is exactly $6.022\,140\,76 \times 10^{23}$ $mol^{-1}$
- The speed of light $c$ is exactly 299 792 458 $m \cdot s^{-1}$
- The ground state hyperfine splitting frequency of the caesium-133 atom $\Delta\nu(^{133}Cs)_{hfs}$ is exactly 9 192 631 770 Hz
- The luminous efficacy $K_{cd}$ of monochromatic radiation of frequency $540 \times 10^{12}$ Hz is exactly 683 $lm \cdot W^{-1}$

The S.I. base units are calculated from these seven definitions, after converting the derived units (joule, coulomb, hertz, lumen and watt) into the seven base units (second, meter, kilogram, ampere, kelvin, mole and candela).

Use this space for summary and/or additional notes:

## Rules for Writing S.I. Numbers and their Units

- The value of a quantity is written as a number followed by a space (representing a multiplication sign) and a unit symbol; *e.g.,* 2.21 kg, $7.3 \times 10^2$ m$^2$, or 22 K. This rule explicitly includes the percent sign (10 %, not 10%) and the symbol for degrees of temperature (37 °C, not 37°C). (However, note that angle measurements in degrees are written next to the number without a space.)
- Units do not have a period at the end, except at the end of a sentence.
- A prefix is part of the unit and is attached to the beginning of a unit symbol without a space. Compound prefixes are not allowed.
- Symbols for derived units formed by multiplication are joined with a center dot (·) or a non-breaking space; *e.g.,* N·m or N m.
- Symbols for derived units formed by division are joined with a solidus (fraction line), or given as a negative exponent. *E.g.,* "meter per second" can be written m/s, m s$^{-1}$, m·s$^{-1}$, or $\frac{\text{m}}{\text{s}}$.
- The first letter of symbols for units derived from the name of a person is written in upper case; otherwise, they are written in lower case. *E.g.,* the unit of pressure is named after Blaise Pascal, so its symbol is written "Pa" (note that "Pa" is a two-letter symbol), but the symbol for mole is written "mol". However, the symbol for liter is "L" rather than "l", because a lower case "l" can be confused with the number "1".
- A plural of a symbol must not be used; *e.g.,* 25 kg, not 25 kgs.
- Units and prefixes are case-sensitive. *E.g.,* the quantities 1 mW and 1 MW represent two different quantities (milliwatt and megawatt, respectively).
- The symbol for the decimal marker is either a point or comma on the line. In practice, the decimal point is used in most English-speaking countries and most of Asia, and the comma in most of Latin America and in continental European countries.
- Spaces should be used as a thousands separator (1 000 000) in contrast to commas (1,000,000) or periods (1.000.000), to reduce confusion resulting from the variation between these forms in different countries.
- Any line-break inside a number, inside a compound unit, or between number and unit should be avoided.

Use this space for summary and/or additional notes:

## Prefixes

The metric system uses prefixes to indicate multiplying a unit by a power of ten. There are prefixes for powers of ten from $10^{-24}$ to $10^{24}$ but in chemistry, only the following four are commonly used:

- kilo (k) = $10^{3}$ = 1000
- milli (m) = $10^{-3} = \frac{1}{1\,000}$ = 0.001
- centi (c) = $10^{-2} = \frac{1}{100}$ = 0.01
- micro (μ) = $10^{-6} = \frac{1}{1\,000\,000}$ = 0.000 001

Any metric prefix is allowed with any metric unit. For example, if a mole (mol) is $6.02 \times 10^{23}$ objects, then a millimole (mmol) would be

$(6.02 \times 10^{23}) \times \frac{1}{1\,000} = 6.02 \times 10^{20}$ objects.

An easier way to convert is to use the powers of ten that correspond with the prefixes to determine how many places to move the decimal point.

## Metric Prefixes

| Factor | | Prefix | Symbol |
|---|---|---|---|
| 1 000 000 000 000 000 000 000 000 | $10^{24}$ | yotta | Y |
| 1 000 000 000 000 000 000 000 | $10^{21}$ | zeta | Z |
| 1 000 000 000 000 000 000 | $10^{18}$ | exa | E |
| 1 000 000 000 000 000 | $10^{15}$ | peta | P |
| 1 000 000 000 000 | $10^{12}$ | tera | T |
| 1 000 000 000 | $10^{9}$ | giga | G |
| 1 000 000 | $10^{6}$ | mega | M |
| 1 000 | $10^{3}$ | kilo | k |
| 100 | $10^{2}$ | hecto | h |
| 10 | $10^{1}$ | deca | da |
| 1 | $10^{0}$ | — | — |
| 0.1 | $10^{-1}$ | deci | d |
| 0.01 | $10^{-2}$ | centi | c |
| 0.001 | $10^{-3}$ | milli | m |
| 0.000 001 | $10^{-6}$ | micro | μ |
| 0.000 000 001 | $10^{-9}$ | nano | n |
| 0.000 000 000 001 | $10^{-12}$ | pico | p |
| 0.000 000 000 000 001 | $10^{-15}$ | femto | f |
| 0.000 000 000 000 000 001 | $10^{-18}$ | atto | a |
| 0.000 000 000 000 000 000 001 | $10^{-21}$ | zepto | z |
| 0.000 000 000 000 000 000 000 001 | $10^{-24}$ | yocto | y |

Use this space for summary and/or additional notes:

Note that some of the prefixes skip by a factor of 10 and others skip by a factor of $10^3$. This means you can't just count the steps—you have to actually look at the exponents.

## Sample Problem:

15 Tm = _____ nm

- You need to move the decimal point 12 places to get to $10^0$, and 9 more places to get to $10^{-9}$, for a total of 21 places.
- Terameters are huge, and nanometers are much smaller. That means we're going to have a lot more nanometers than terameters, so we have to move the decimal point in the direction that makes the number larger (to the right).

Therefore, we need to move the decimal point 21 places to the right, which means we need to multiply by $10^{21}$.

You could simply write your answer as $15\times10^{21}\text{m}$, and it would be correct. (And you can enter it into your calculator that way and the right thing will happen.)

However, to be proper scientific notation, you need to make the part before the multiplication sign between 1 and 10, which means you need to make it 1.5. If the number before the × sign gets smaller, then the number after the × sign needs to get larger so the end result stays the same. Therefore, $15\times10^{21}\text{m}$ is the same as $1.5\times10^{22}\text{m}$, which is our final answer.

There is a popular joke based on the ancient Greek heroine Helen of Troy. She was said to have been the most beautiful woman in the world, and when she was kidnapped, the Trojan War was fought to bring her back to Sparta. Her beauty was described as "the face that launched a thousand ships." Therefore a milliHelen must be the amount of beauty needed to launch one ship.

Use this space for summary and/or additional notes:

## Homework Problems

Perform the following conversions.

1. 2.5 m = __________ cm

2. 18mL = __________ L

3. 68 kJ = __________ J

4. 6 500 mg = __________ kg

5. 101 kPa = __________ Pa

6. 325 ms = __________ s

Use this space for summary and/or additional notes: