# Metric Measurement

### Exponents and Scientific Notation

**Scientific notation** is used to represent large and small numbers, by moving the decimal and recording how far it moved. Exponents are indicated by superscripts. Scientific notation will move the decimal until the first digit of the number is in the ones place and uses $10^X$ where the value of 'X' shows how many places the decimal moved from its original placement.

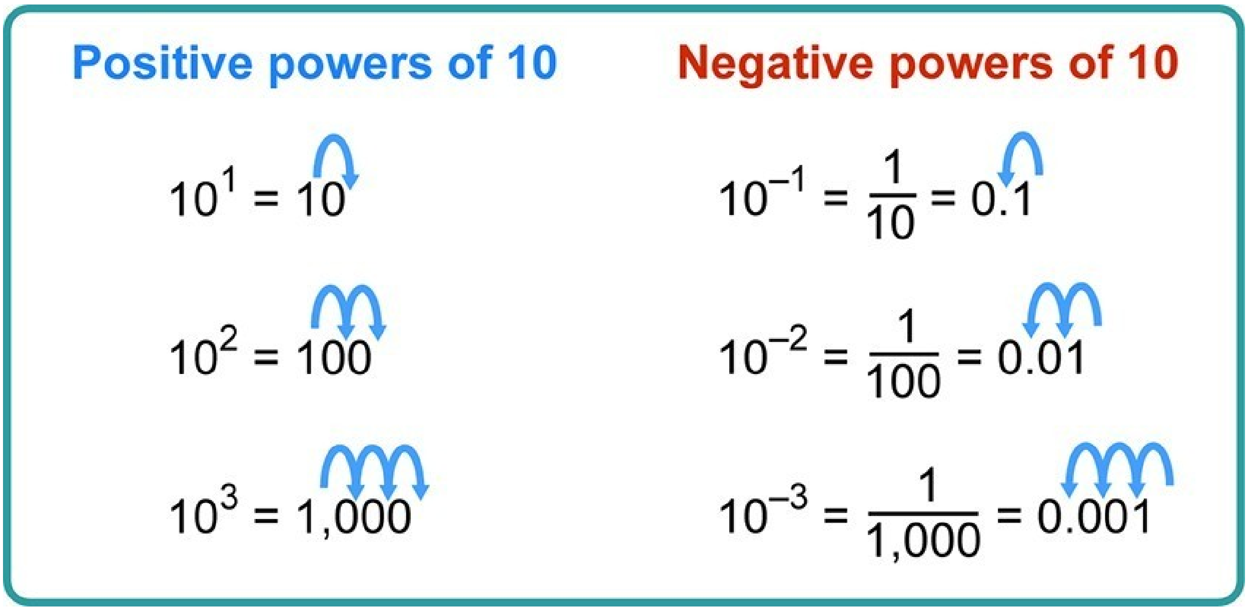
- A positive superscript means that the number is larger than one: the decimal moved to the left to represent the first digit in the ones place
    - 270 would be written

as 2.70×102

$2.70 \times 10^2$

- A negative superscript means that the number is smaller than one: the decimal moved to the right to represent the first digit in the ones place
    - 0.000356 would be written as $3.56 \times 10^{-4}$

Looking at exponents can immediately show the relative size of numbers: the larger the exponent, the larger the number. For example, any number times $10^3$ will be larger than any number times $10^2$, and $10^{-1}$ is larger than $10^{-2}$ as -1 is larger than -2.



## Powers of 10

| Power of 10 | Standard Form | Fractional Form | Place Value |
|---|---|---|---|
| $10^4$ | 10,000 | 10,000/1 | ten thousands |
| $10^3$ | 1,000 | 1,000/1 | thousands |
| $10^2$ | 100 | 100/1 | hundreds |
| $10^1$ | 10 | 10/1 | tens |
| $10^0$ | 1 | 1/1 | ones |
| $10^{-1}$ | 0.1 | 1/10 | tenths |
| $10^{-2}$ | 0.01 | 1/100 | hundredths |
| $10^{-3}$ | 0.001 | 1/1,000 | thousandths |
| $10^{-4}$ | 0.0001 | 1/10,000 | ten thousandths |

## Dimensional Analysis

Dimensional analysis is a way to convert between different units by multiplying equivalencies, sometimes called conversions. Conversions relate two different units together. This is done following the rules of algebra:

- Multiplying 1 by any number yields that number, e.g. 5 x 1 = 5
- Anything over itself is 1, e.g. 12/12 = 1
- If two numbers are equivalent, an equal sign is placed between them. E.g.) 3.4 = 3.4
- Identical units or numbers cancel top-to-bottom in fractions

For example, there are 12 inches in 1 foot. This is a conversion that relates two different units in an equivalent way: inches and feet. These two measurements are equivalent, so we can place an equal sign between them:
12 inches = 1 foot

… because these two are equivalent (equal sign between them), we can write them as a fraction.

1 foot/ 12 inches= 12inches/1 foot

Remember, anything over itself equals one, and these two values are equal so these fractions equal one. We can multiply one by any number without changing the number and cancel the units top-to-bottom. This is how we will change the unit without changing the measurement itself. If we had 30 inches, how many feet would that be? Start **with 30 inches and choose the correct fraction to cancel identical units top to bottom.**

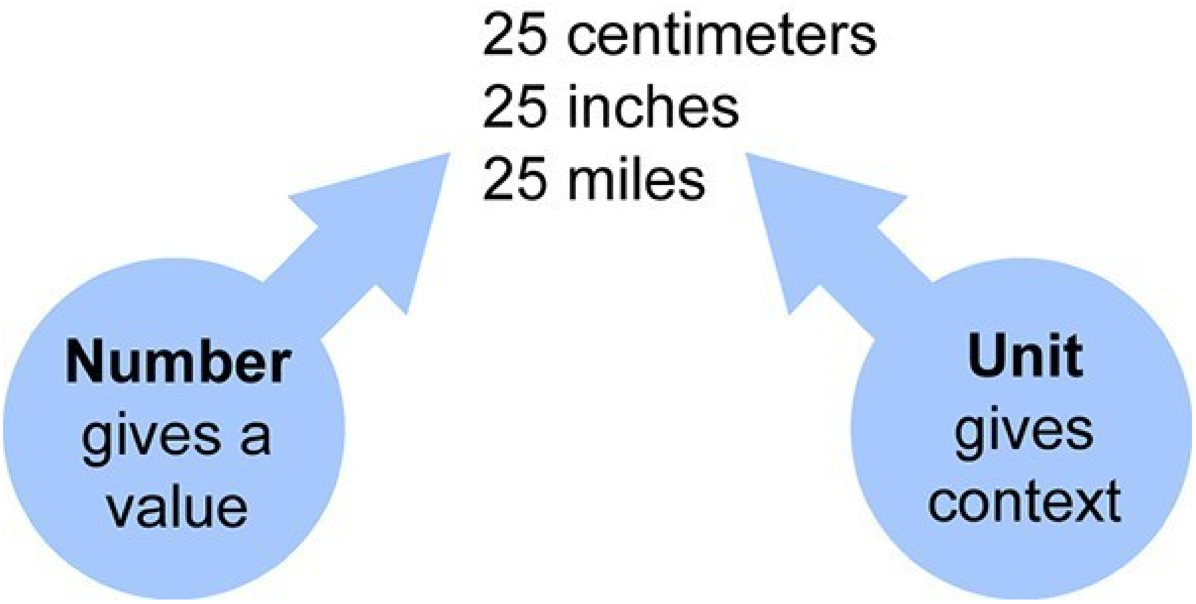
$$30\ inches\ x\ \frac{1\ foot}{12\ inches} = 2.5\ feet$$

**English Units and Metric Units**

In science, measurement is the basis of inquiry and understanding. Every measurement has two parts:

- A number
- A unit

A number without a unit is only half the story. Without both of these parts, it is unclear what was measured and what the number means. If you measure the length of a book, you would not report the answer as 11. You would specify centimeters, or maybe inches, to clarify how the length was measured. Similarly, you would not report length in pounds: appropriate units are essential in communicating these measurements.



Measurement can be **qualitative** or **quantitative**. We can weigh an object, or measure its height, or its volume: all of these measures are quantitative because they are objective, measured using a tool, and every individual with the same tool will produce the same result. We can subjectively use our senses (sight, smell, taste, touch) to determine if an object is pretty, delicious, or soft. This is not objective, but rather subjective because these qualities are not well defined and can differ from person to person; for example, a color-blind individual would not see the same color, and an identical injury to three people could have three different reported pain levels based on the individual's pain tolerance. Therefore, the most reliable measurements are objective and quantitative, eliminating bias and preference.

For an additional example related to healthcare, qualitative measurements are called symptoms and quantitative measurements are called signs. Both are important; but only signs can be objectively measured, like a fever. Symptoms like aches and pains cannot be accurately measured, but other factors such as respiration rate and blood pressure can give quantitative validity to symptoms.

For quantitative measurement, there are two major systems used to objectively measure:

**The Metric (SI) System**

Base units have no prefix:

- Length: meter (m)
- Mass: gram (g)
- Volume: liter (L)

Prefixes are used to show how far a measurement is from the base unit

- Based on powers of 10, for simple conversions
- Prefixes: Mega (M), Kilo (k), Hecto (h), Deca (da), Deci (d), Centi (c), Milli (m), Micro (mc) , Nano (n)

Used throughout most of the world.

**The English (Continental) System**

Units vary and never use prefixes:

- Length: inches, feet, yards, miles
- Weight: ounces, pounds, tons
- Volume: ounces, cups, pints, gallons

Used in a handful of countries, including the United States

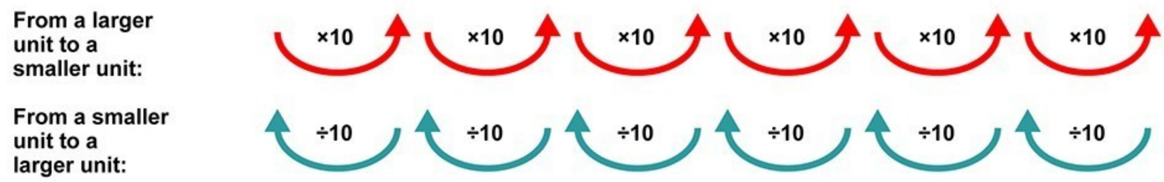
Meters and feet both measure length, liters and cups measure volume, and pounds and grams measure weight or mass

## Metric Units

Metric units are based on powers of 10, and we denote the different values of 10 using prefixes:

**Metric Units Mnemonic**

| Remember— | King | Henry | Died | By | Drinking | Chocolate | Milk |
|---|---|---|---|---|---|---|---|
| Prefix | Kilo- | Hecto- | Deca- | Base unit | Deci- | Centi- | Milli- |
| Length | Kilometer | Hectometer | Decameter | Meter | Decimeter | Centimeter | Millimeter |
| Mass | Kilogram | Hectogram | Decagram | Gram | Decigram | Centigram | Milligram |
| Volume | Kiloliter | Hectoliter | Decaliter | Liter | Deciliter | Centiliter | Milliliter |




This image shows the relationship between prefixes and the base unit, as well as to each other.

A simple mnemonic to remember the order of prefixes from largest to smallest is:

**K**ing **H**enry **D**ied **b**y **D**rinking **C**hocolate **M**ilk

**K**ilo **H**ecto **D**eca **b**ase **D**eci **C**enti **M**illi

There are three additional prefixes you will likely see: Mega, Micro, and Nano. Each of these are three steps (1000, or $10^3$) from the next prefix, with mega being large and micro and nano being small.

| | | | | |
|---|---|---|---|---|
| peta | P | $10^{15}$ | | 1 000 000 000 000 00 |
| tera | T | $10^{12}$ | | 1 000 000 000 000 |
| giga | G | $10^{9}$ | | 1 000 000 000 |
| mega | M | $10^{6}$ | | 1 000 000 |
| kilo | k | $10^{3}$ | | 1 000 |

| | | | | |
|---|---|---|---|---|
| hecto | h | $10^2$ | | 100 |
| deka | da | $10^1$ | | 10 |
| *base unit* | | $10^0$ | | 1 |
| deci | d | $10^{-1}$ | 1/10 | 0.1 |
| centi | c | $10^{-2}$ | 1/100 | 0.01 |
| milli | m | $10^{-3}$ | 1/1 000 | 0.001 |
| micro | µ | $10^{-6}$ | 1/1 000 000 | 0.000 001 |
| nano | n | $10^{-9}$ | 1/1 000 000 000 | 0.000 000 001 |
| Angstrom | Å | $10^{-10}$ | 1/10 000 000 000 | 0.000 000 000 1 |
| pico | p | $10^{-12}$ | 1/1 000 000 000 000 | 0.000 000 000 001 |

Knowing the prefixes from largest to smallest, we can easily recall any conversion within the metric system. We can use these prefixes with any SI base unit such as meters (m), Liters (L), or grams (g). From the table above, we see that there are $10^3$ of the base unit in a kx, where x is any of our SI units. For example, 1000 m in a km or 1000 g in a kg.

Starting with the largest unit, moving from left to right in the mnemonic will increase the number by moving the decimal to the right (bigger unit to smaller)

- 1 L = 1000 mL
- 1 kg = 1000 g
- 1 m = 100 cm

Starting with the smallest unit and moving from right to left in the mnemonic will decrease the number by moving the decimal to the left (small unit to bigger)

- 1 mL = 0.001 L
- 1 g = 0.001 kg

- 1 mm = 0.1 cm

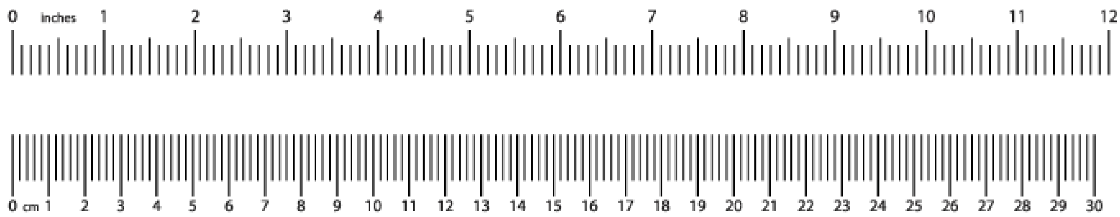
Each word in the mnemonic (prefix, including base unit) is one step. Count the number of steps between two prefixes to determine how many powers of 10 are between two prefixes.

The best way to understand these units is through practice, and remembering the following:

- Starting with a large unit (mega, kilo, etc) and converting to a smaller unit (e.g. base, deci, milli) will make the converted answer even larger
- Starting with a small unit (milli, centi, etg) and converting to a larger unit (e.g. base, kil) will made the converted value even smaller

Let's practice these skills: How many meters are in 30 millimeters?

First, let's look at the units provided: meters and millimeters. Meters is a base unit because it does not have a prefix, and the prefix **milli** in front of meter means **thousandth** or 1/1000 of a meter. This means 1 mm = 0.001 meters. This conversion makes sense, because on a ruler a millimeter is the smallest line, and on the ruler there are 300 mm; additionally, it would take about 3 rulers to make one meter! Looking at a single millimeter, this is an incredibly small fraction of a meter.




We will now set up the ladder to convert 30 mm to meters starting with the given. The given is always the number with a single unit, in this case it is 30 mm. Next, we will use the conversion equivalence to cancel the given unit, and end with the wanted unit on top. Finally, we will calculate the answer and include units.

$$\frac{30\,mm}{1} X \frac{0.001m}{1\,mm} = \frac{30}{1} X \frac{0.001\,m}{1} = 0.30\,m$$

Keep in mind that you can also write the conversion equivalence as 1 m = 1000 mm, because the proportions are the same: there are 1000 mm in one meter. Either way you write this, you will get the same answer. This extra choice might be intimidating at first, but through practice you might prefer to write conversion equivalences one way or another.

$$\frac{30\,mm}{1} X \frac{1\,m}{1,000\,mm} = \frac{30}{1} X \frac{1\,m}{1,000} = 0.30\,m$$

**Density**

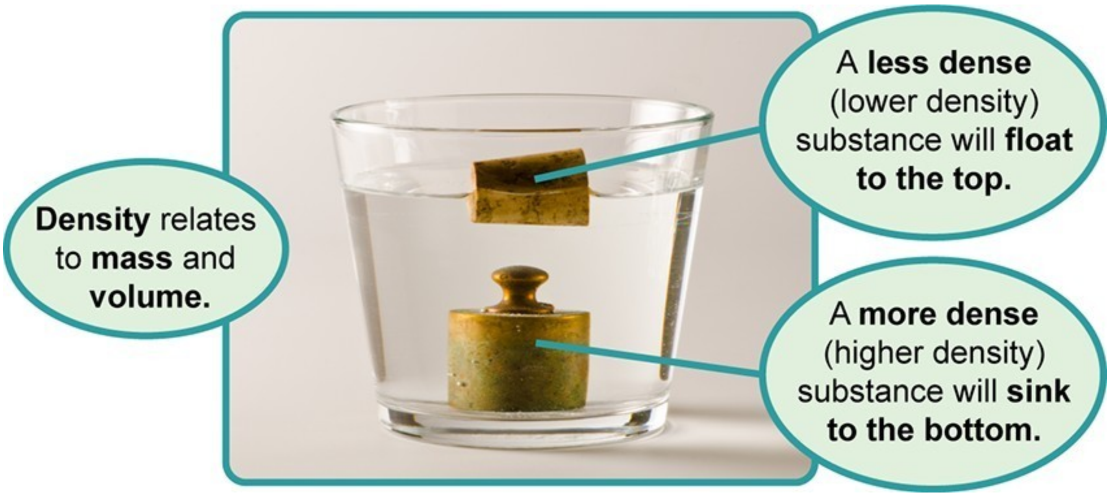
Some standard units relate two different units. For example, the speed of a car is reported as miles per hour (mph, or mi/hr), which relates miles and hours. The cost of produce is listed as price per pound ($/lb), which relates the cost to the weight

An important relationship is **density**, or the mass per volume.

A high density substance will have more mass in a smaller space; a less dense substance will have less mass in more space.

High density lipids (HDLs) are more compact, whereas low density lipids (LDLs) are less compact.

As you have likely experienced, a dense substance with higher density will sink whereas a less dense substance will float if they are combined.




The units for density are grams per milliliter (g/mL). In this case, the units tell the formula as well: the mass in grams should be divided by the volume in milliliters.

With this formula, density, mass, or volume can be calculated by knowing the other two values.

- Mass = volume x Density

Given an object with a volume of 15 mL and a density of 10 g/mL, we can multiply these values to find the mass of 150 g.

Mass= 15 mL x 10 g/mL

Mass= 150 g

- Volume = mass / Density

Given a mass of 100 g and a density of 5.0 g/mL, we can divide the 100 g mass by the 5.0 g/mL density to determine the volume would be 20 mL.