

What is a System of Measurement?

A system of measurement is a collection of units of measurement and rules relating them to each other.

- Must have **base units** defined for all major quantities that need to be measured (example: a *foot*).
- Must specify **equivalency** relationship for all **additional units** used to measure the same quantity (example: length can also be measured in *inches* or *miles*, defined as 1 foot = 12 inches, 1 mile = 5280 feet).

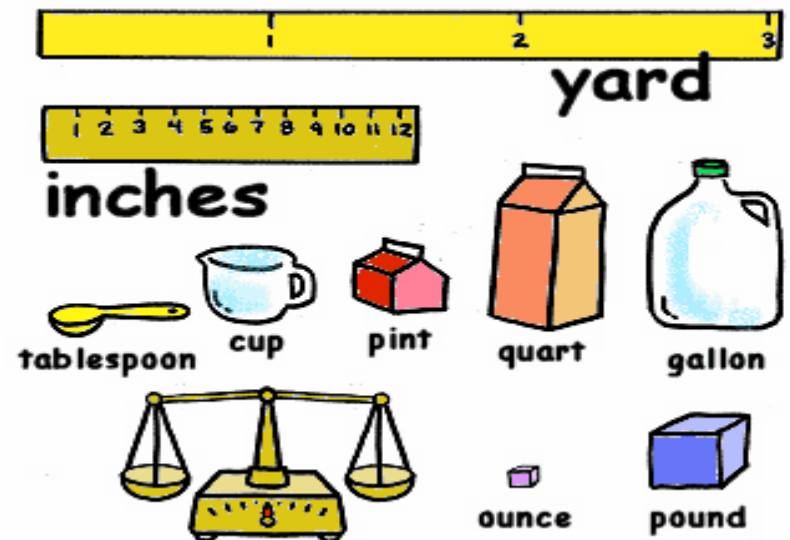
Systems of measurement have historically been **important, regulated and defined** for the purposes of science and commerce.

English Units Based Systems

- **Imperial** System of Measurement (British Empire, 1824):
 - Distance/Length: Inch, foot, yard, mile
 - Volume: fluid ounce, pint, quart, gallon
 - Area: Acre
 - Weight/Mass (three different systems!): grain, ounce, pound, stone, ton



- **US Customary** System of Measurement:
 - Mostly *same unit names*
 - **Units are not identical!**
(1 US gal=0.83 imp gal)
 - Different units for liquid and dry measures (liquid/dry ounce)



The Metric System

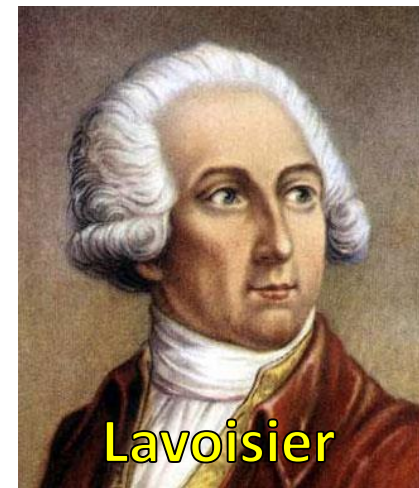
The metric system is an **internationally agreed decimal** (based on power of 10) system of measurement. It was originally introduced by France in 1799.

Modern "**Metric system**" term is a synonym for "**SI**" or the "**International System of Units**" (1960)—the **official system of measurement** in almost every country in the world.



Origin of the Metric System

- Idea of standardized system of measurement based on the **decimal** was first proposed as early as ~1670.
- The first practical implementation was carried out by French Revolutionaries towards the end of the 18th century.
- In 1790 a **committee** (including mathematicians **Laplace** and **Legendre**, and chemist **Lavoisier**) was appointed to **develop a unified, natural, universal system of measurement**.



It was called the "**metric**" system (French for *measure*).

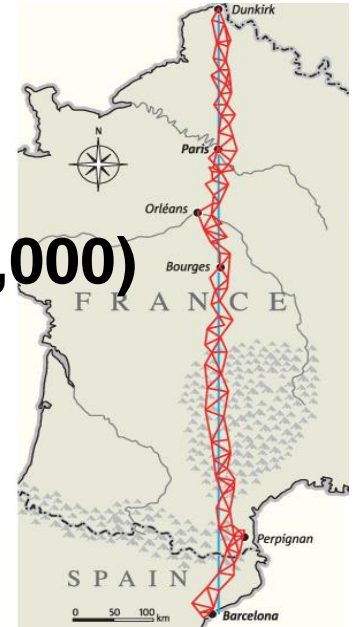
Metric System Basics

- The metric system was built around three base units that corresponded to a **certain kind of measurement**:
 - Length = **meter**
 - Volume = **liter**
 - Weight (Mass) = **gram**
- The **base units** were derived from the **natural world**: the *dimensions of the Earth* and *properties of water*.
- Decimal multiplicative prefixes were added to base units to make up the **full range** of metric system:
 - **milli** + **meter** = millimeter
 - **nano** + **liter** = nanoliter
 - **kilo** + **gram** = kilogram
 - **micro** + **meter** = micrometer
- Historically, prototypes (“originals”) of base units were kept in the ***Archives Nationales* in France** with **copies manufactured and distributed** among other countries - members of The Metre Convention of 1875 (and subsequent conventions).

Original Definitions

1. **Meter** (length) - **one ten millionth ($1/10,000,000$) of the quarter of the Earth's meridian***.

*determined based on the 1792-1798 survey of the length of the Earth's meridian between Dunkirk (51°N) and Barcelona (41°N) through Paris.



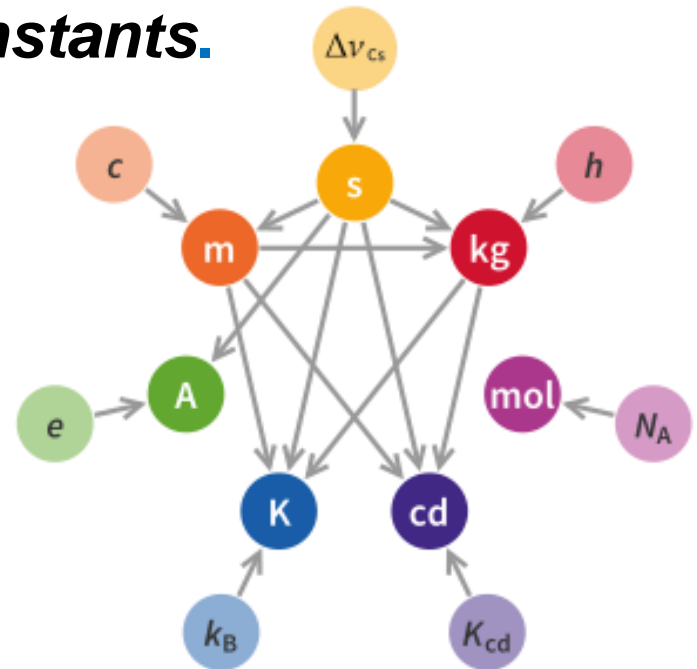
2. **Gram** (mass) - **the mass of one cubic centimeter of water at the melting point of water.**
3. **Second** (time) - **$1/86,400$ of a mean solar day; the fraction $1/31,556,925.9747$ of the tropical year 1900.**
4. **Degree Centigrade** (temperature) - **obtained by assigning 0°C to the freezing point of water and 100°C to the boiling point of water.**

Fundamental SI Units

As Metric System evolved into the **SI system**, **seven** mutually independent fundamental units have been selected:

1. **Meter** (length)
2. **Kilogram** (mass)
3. **Second** (time)
4. **Kelvin** (temperature)
5. **Ampere** (electric current)
6. **Candela** (luminous intensity)
7. **Mole** (amount of elementary entities like atoms or molecules)

On May 20, 2019, all seven have been **redefined** based on *fundamental physical constants*.



Prefixes in Metric System

Prefix	Symbol	Factor	
tera	T	10000000000000	10^{12}
giga	G	1000000000	10^9
mega	M	1000000	10^6
kilo	k	1000	10^3
hecto	h	100	10^2
deca	da	10	10^1
(none)	(none)	1	10^0
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}

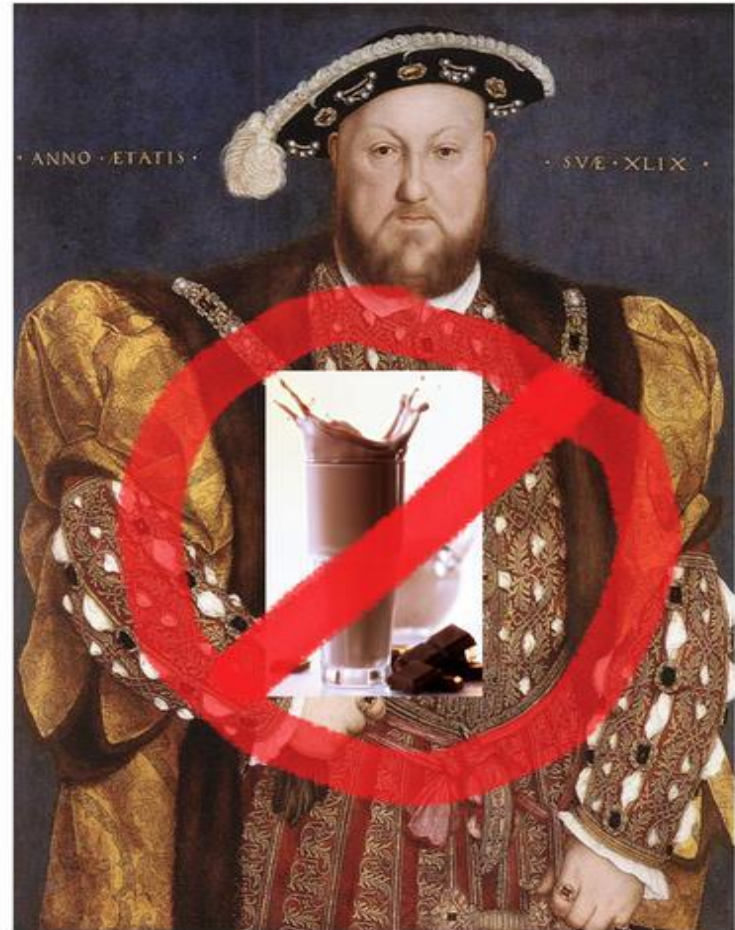
What is the order of the metric system?

- King Henry Died by Drinking Chocolate Milk

larger

- King: **Kilo**
- Henry: **Hecto**
- Died: **Deca**
- By: **Base** (m, L, g)
- Drinking: **Deci**
- Chocolate: **Centi**
- Milk: **Milli**

smaller

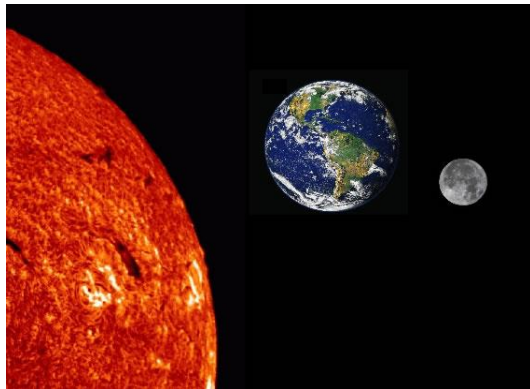


Metric Examples

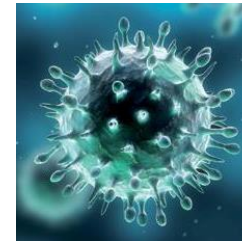
Any US paper currency note (\$1, \$5, \$10, \$20) has a mass of 1 g; the mass of a nickel is 5 g; the mass of a penny is 2.5 grams.



A typical doorknob is ~1 m high.



The mass of the Earth is 6×10^{24} kg; the mass of the Moon is 7.3×10^{22} kg; the mass of the Sun is 1.99×10^{30} kg.



Diameter of Influenza virus is ~20 nm.

Typical airport runway length is 3.35 km; Boeing 767 jet is 64 m long.



The diameter of a CD or a DVD is 12 cm; the diameter of the center hole is 15 mm.