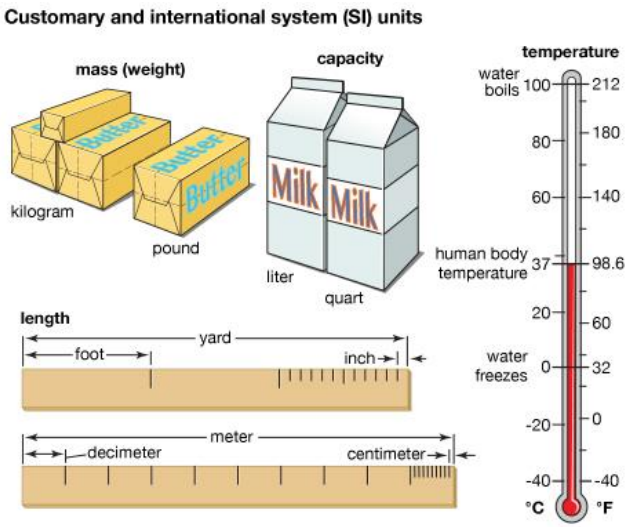
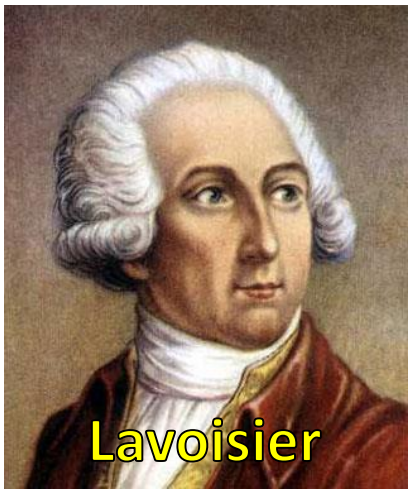
The Metric System



The International System of Units

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**
  - **Kilo + gram = Kilogram**
- Historically, **prototypes** ("originals") of base units were kept in the ***Archives Nationales*** **in France** with **copies manufactured and distributed** among other 17 countries - members of The Metre Convention of 1875.

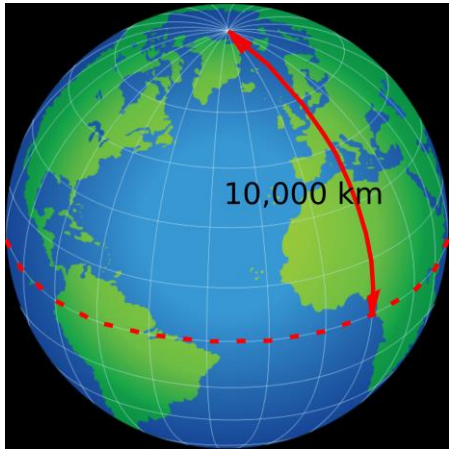
Fundamental Units

By design, the **base units** used in the Metric System must be **realizable**, ideally with reference to natural phenomena.

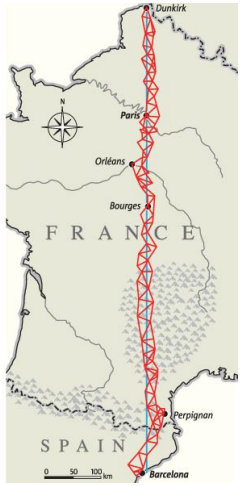
As Metric System evolved into the **SI system**, **seven mutually independent fundamental units** have been selected:

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)

The Meter, m
(Metric, SI)

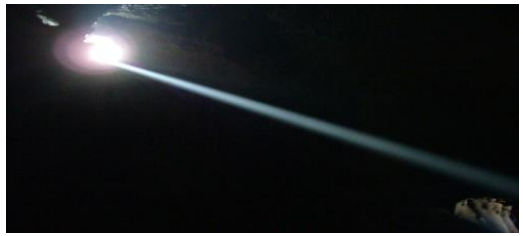


- **Original definition (1791): <u>one ten millionth (1/10,000,000) of the quarter of the Earth's meridian</u>** (distance between the North Pole and the Equator through Paris was determined based on a Pierre Méchain and Jean-Baptiste Delambre 1792-1798 survey of the length of the Earth's meridian between Dunkirk (51°N) and Barcelona (41°N) through Paris).

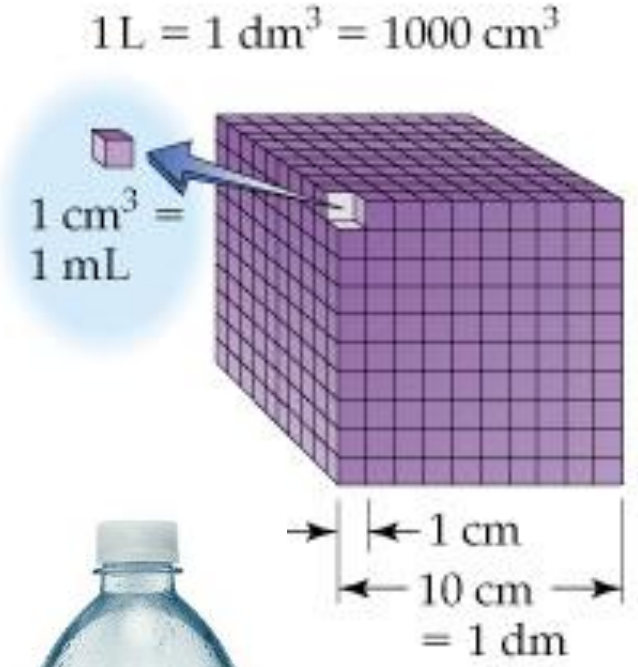


- **1799: platinum bar**, known as the ***<u>mètre des Archives</u>***. The International Metre Commission in Paris (1870-72, 1875): new **"metric prototypes"** made of **90% platinum and 10% iridium**.

- **1983: One meter is the distance traveled by a ray of light through a vacuum in 1/299,792,458 second.** The definition in terms of the speed of light means that the meter can be realized using any light source of known frequency, rather than defining a "preferred" source.



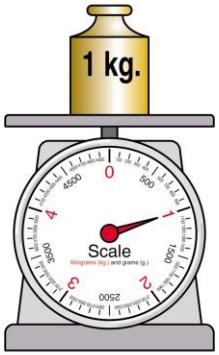
The Liter, L
(Metric, non-SI)



- **Unit of volume, one of three original base units** in metric system circa 1799.
- Volume = Length x Width x Height
- **The liter is equal to 1 cubic decimeter** (10×10×10 centimeters) or 1/1,000 cubic meter.
- One liter of liquid water has a mass of *almost exactly* one kilogram.
- Most commonly used for **fluids** and **solids that can be poured** (which are measured by the capacity or size of their container).

The Gram and the Kilogram, g and kg (Metric, SI)

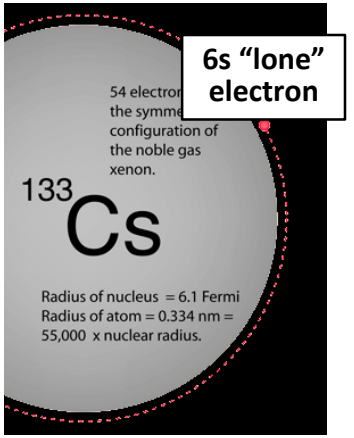
- **Mass**: the amount of matter in an object.
- **The gram, 1795**: the mass of one cubic centimeter of water at the melting point of water.
- The **original prototype kilogram** manufactured in 1799 had a mass equal to the mass of 1.000025 liters of water at 4°C.
- **1875: The International Prototype Kilogram, a cylinder of platinum/platinum-iridium alloy.**
- Kilogram is the only SI unit that is **still directly defined by an artifact**.
- **2005:** International Committee for Weights and Measures recommended that the kilogram be redefined in terms of a fundamental constant of nature.



1 kilogram = 1000 grams

The Second, s
(Metric, SI)

- Earliest documented scientific use of **second as a unit of time**: ~1000 by Persian scholar al-Biruni.
- **Carl Friedrich Gauss, 1832**: proposed to use second as **a base unit**.
- **Original definition: 1/86,400 of a mean solar day** (the Earth's rotation is slowing down, so in this definition a second was not a constant…)
- International Astronomical Union, 1952-1956 redefinition: the fraction 1/31,556,925.9747 of the tropical year 1900.
- **Current definition** (developed by General Conference on Weights and Measures in 1967 and refined in 1997): definition using atomic clocks as **the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom at rest at a temperature of 0 K**.

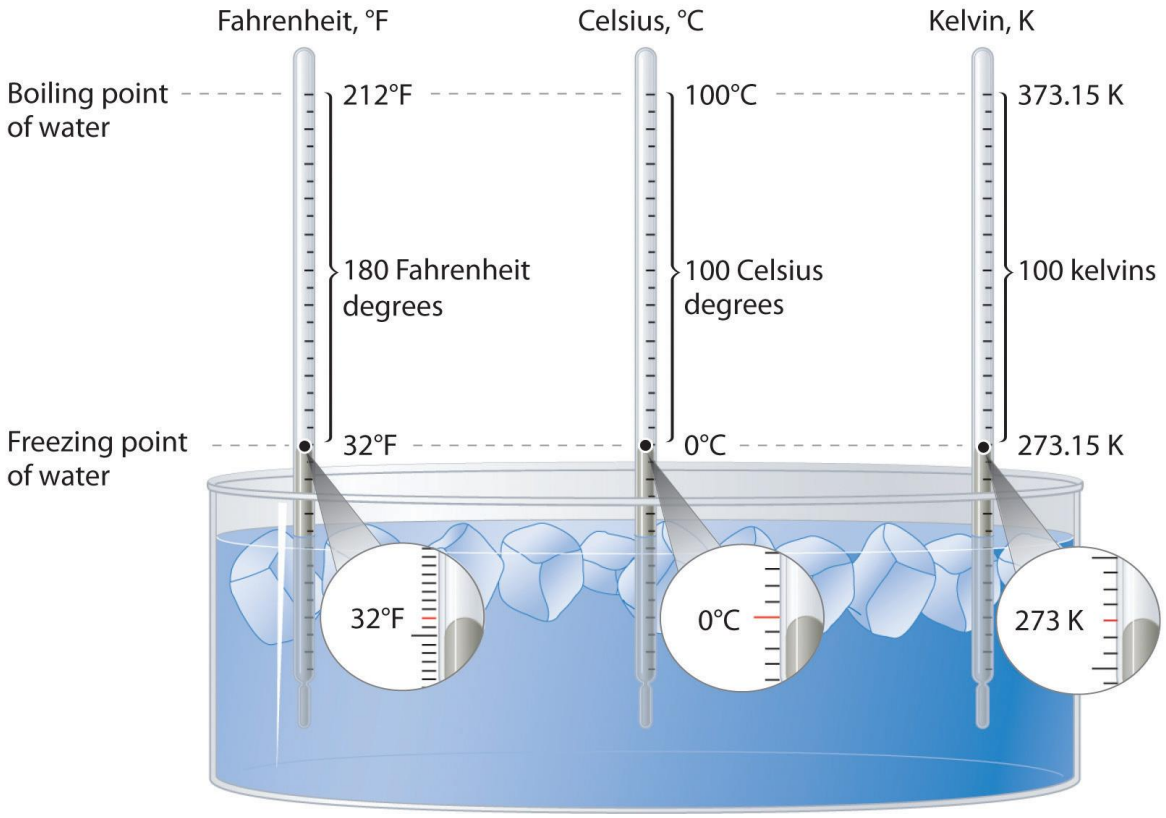


- SI prefixes starting from millisecond are commonly used to measure time less than a second (submultiples); non-SI units *minutes, hours, days, Julian years, Julian centuries,* and *Julian millennia* are used to measure multiples of second.

The Kelvin, K
(SI)

- **Unit of thermodynamic temperature** (*absolute temperature*)**.**

- **Original (1743):** the **centigrade scale** (renamed "Celsius" in 1948) is obtained by assigning **0°C to the freezing point of water** and **100°C to the boiling point of water** both at a pressure of one standard atmosphere with *mercury* being the working material.



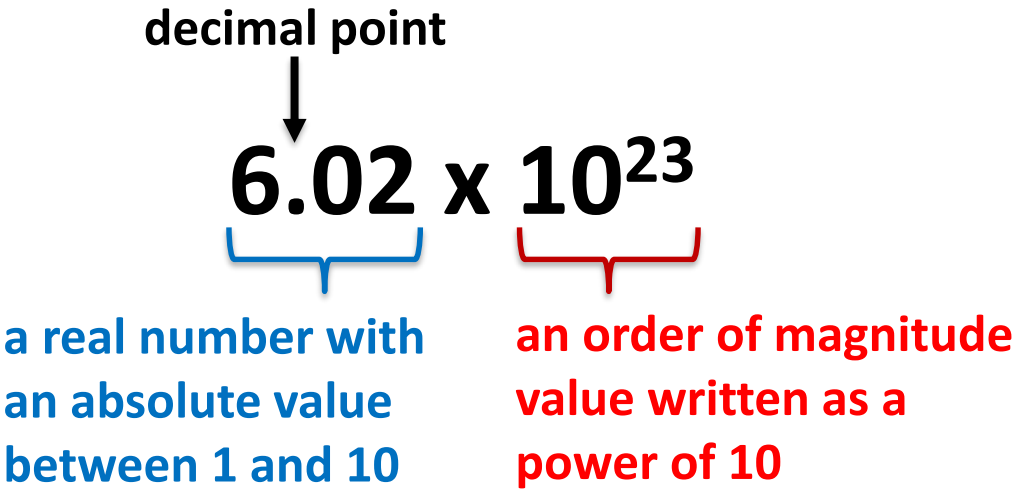
- **Current (1967): 1/273.16 of the thermodynamic temperature of the triple point of water** (triple point of water = 273.16 K = 0.01°C by definition)**.**

Prefixes in Metric System

Prefix	Symbol	Factor	
tera	T	1000000000000	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}

Scientific Notation

- **Scientific notation** (also referred to as *"standard form"* or *"standard index form"*) is a way of writing numbers that are too big or too small to be conveniently written in decimal form.



- **When using SI system**, order of magnitude is restricted to follow standard SI prefixes; the resulting number representation is called *"engineering notation"*.

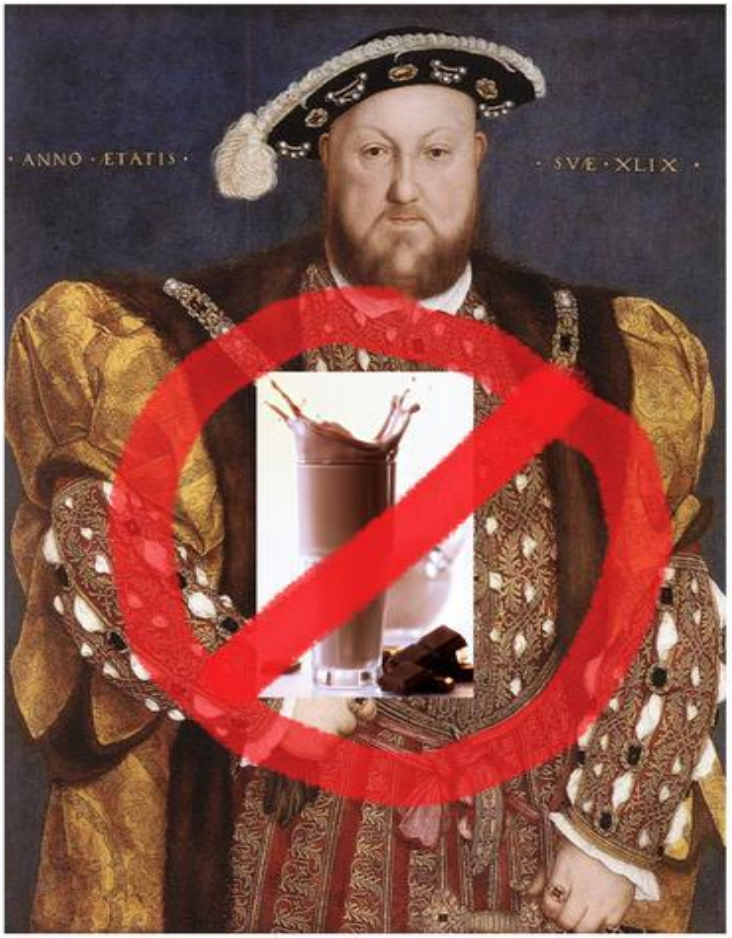
What is the order of the metric system?

- **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**

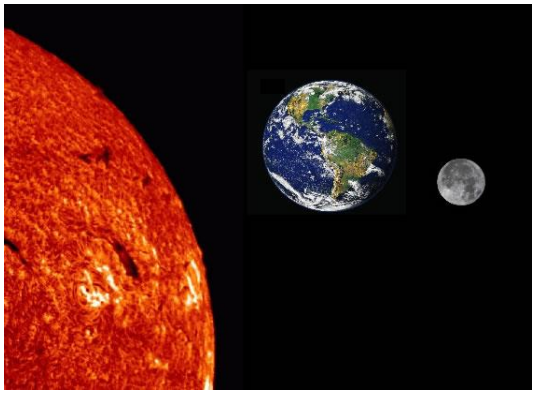
smaller



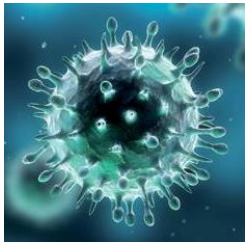
Examples

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.

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

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

Imperial-Metric Equivalences

- **Units of Weight**
  - 1 oz = 28.35 g
  - 1 lb = 454 g
  - 2.2 lb = 1 kg

- **Units of Capacity**
  - 1.06 qt = 1 L
  - 1 gal = 3.79 L

- **Units of Length**
  - 1 in = 2.54 cm
  - 3.28 ft = 1 m
  - 1.09 yd = 1 m
  - 1 mi = 1.61 km