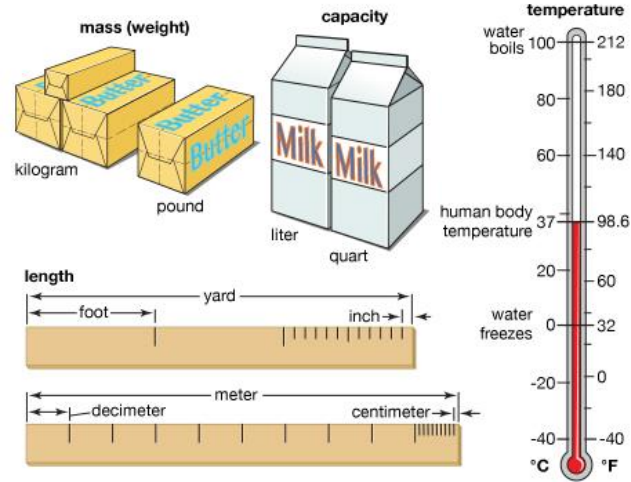


The Metric System



Customary and international system (SI) units



kilometer centimeter
10⁺³ micrometer
femto nano centi
mega atto 10⁻⁶ nanometer
10⁺⁶ kilo meter



The International System of Units

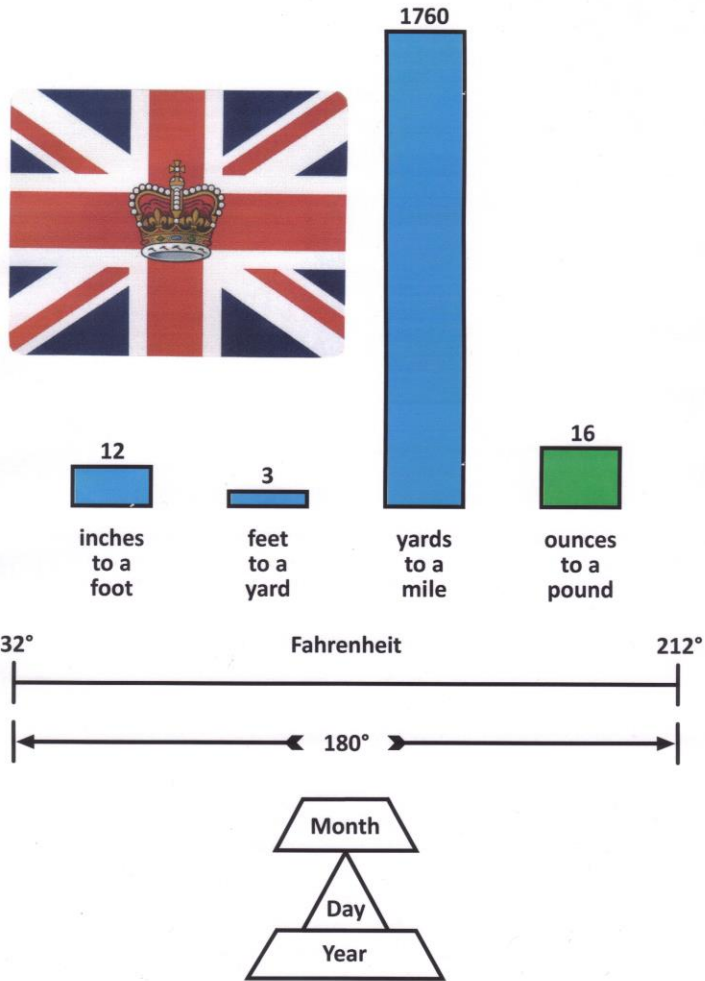
What is a System of Measurement?

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

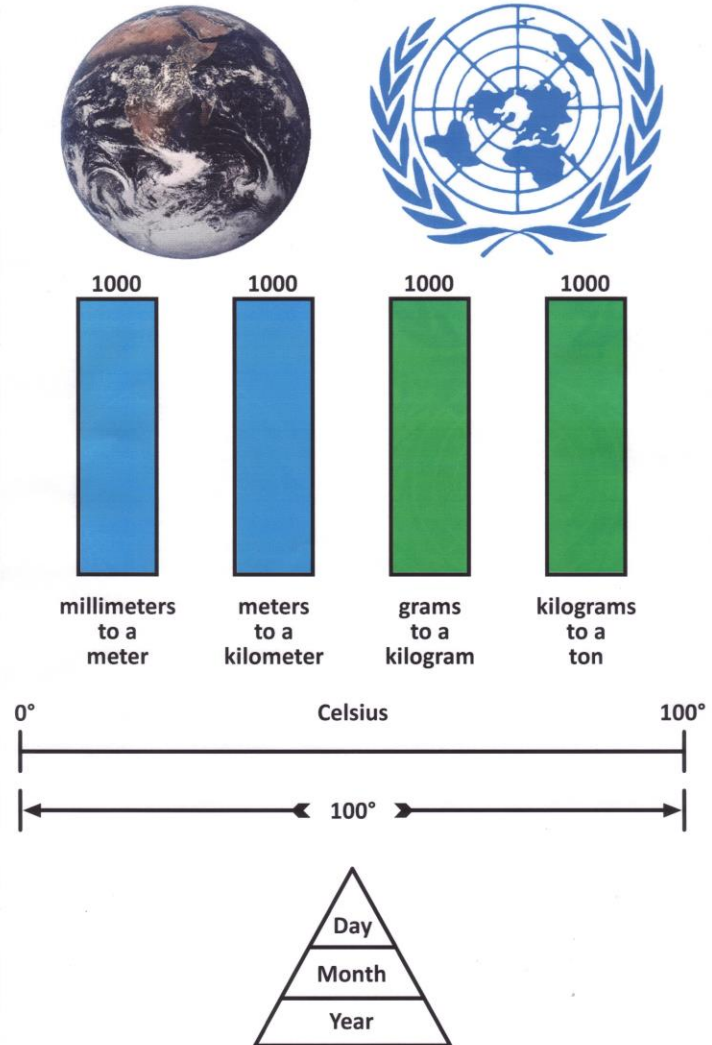
- Must have **base units** defined for all major quantities that need to be measured (example: a *foot*).
- Must specify **equivalency** relationship for all **additional units** used to measure the same quantity (example: length can also be measured in *inches* or *miles*, defined as 1 foot = 12 inches,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

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

US Customary/Imperial



Metric



The Metric System

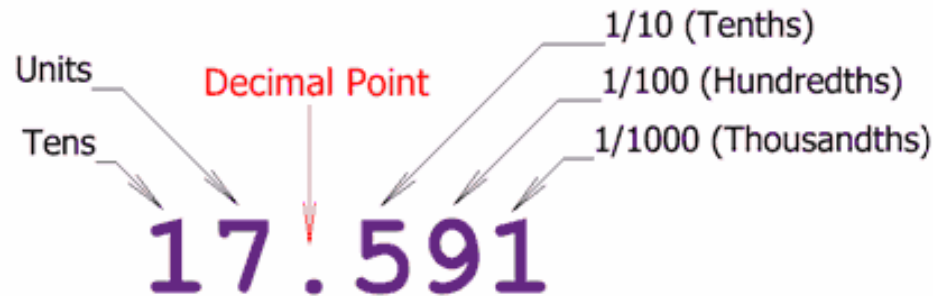
is an **internationally agreed decimal** (based on power of 10) system of measurement originally introduced by France in 1799 as a **unified, natural, universal system**.



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

Decimal System

- The decimal numeral system (also called “base ten”) has **ten as its base** and is **most widely used by modern civilizations**.
- **Decimal notation** is the **writing of numbers in a base-10 numeral system**:



- A forerunner of modern European decimal notation was introduced by Simon Stevin in the 16th century.

Example: 73.248 = 73①2①4②8③

- In the **Metric System**, multiples and sub-multiples of all units follow a decimal pattern.

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 applied to base units to make up the full range of metric system:
 - milli x meter = 1/1000 x meter = millimeter
 - kilo x gram = 1000 x gram = kilogram
 - micro x liter = 1/1000,000 x liter = microliter
 - kilo x meter = 1000 x meter = kilometer



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)	(base unit)	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?

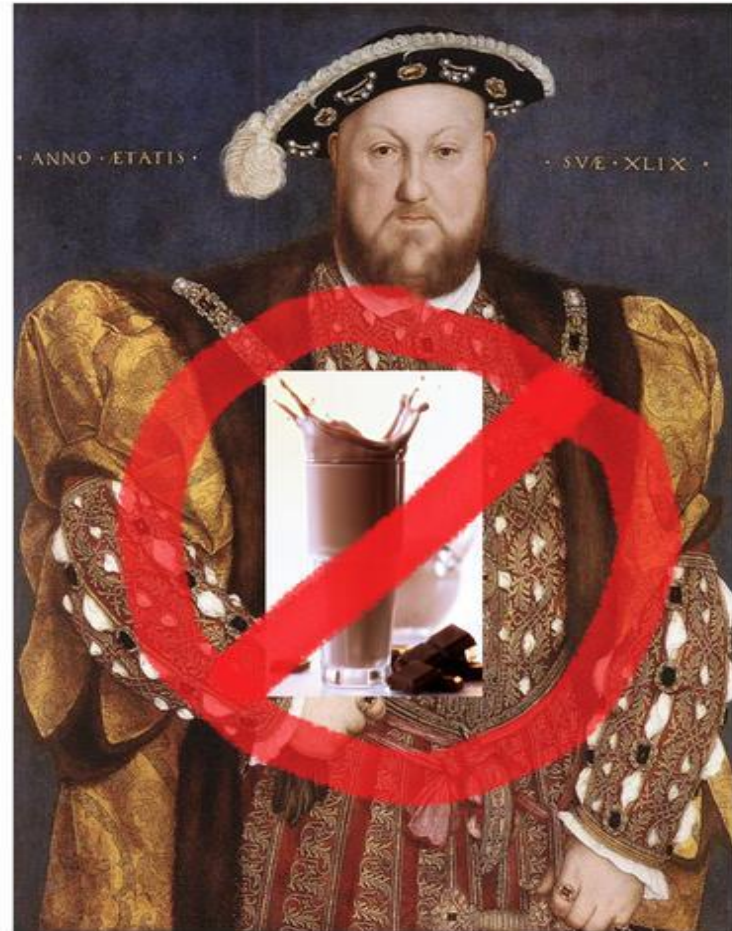
- King Henry Died by Drinking Chocolate Milk

larger



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

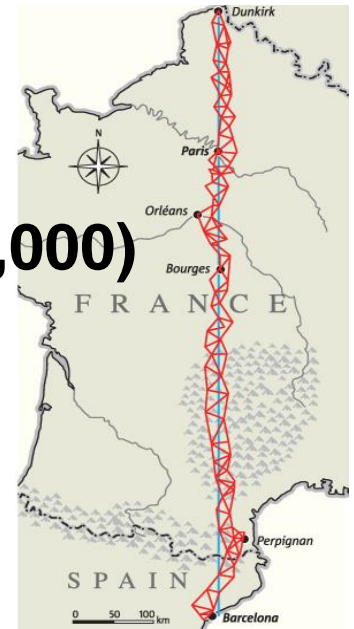
smaller



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.



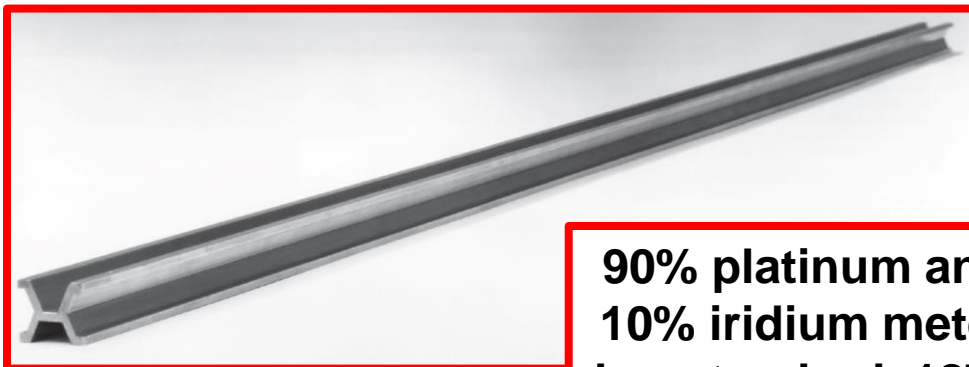
2. **Gram** (mass) - **the mass of one cubic centimeter of water at the melting point of water.**
3. **Second** (time) - **$1/86,400$ of a mean solar day (*redefined later as the fraction $1/31,556,925.9747$ of the tropical year 1900*).**
4. **Degree Centigrade** (temperature) - **obtained by assigning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

Prototypes

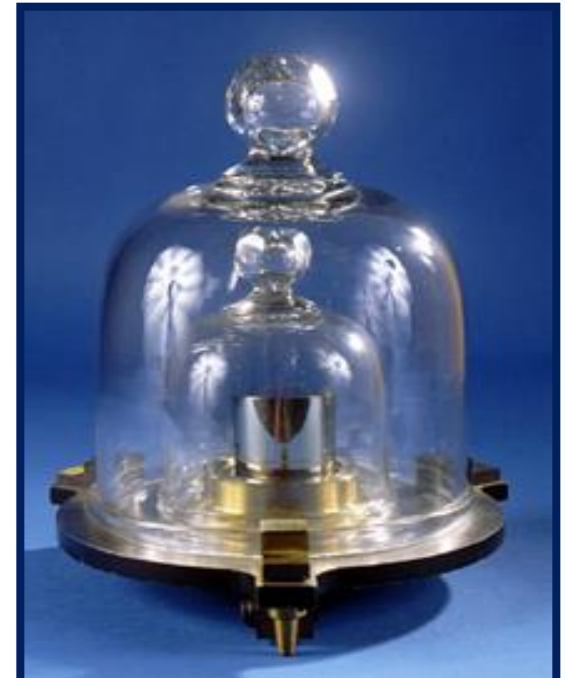
Historically, **prototypes** (“originals”) of base units were kept in the ***Archives Nationales*** in France with **copies manufactured and distributed** among other countries - members of The Metre Convention of 1875 (and subsequent conventions).



1799 platinum bar
known as ***le mètre***
des Archives



**90% platinum and
10% iridium meter
bar standard, 1875**



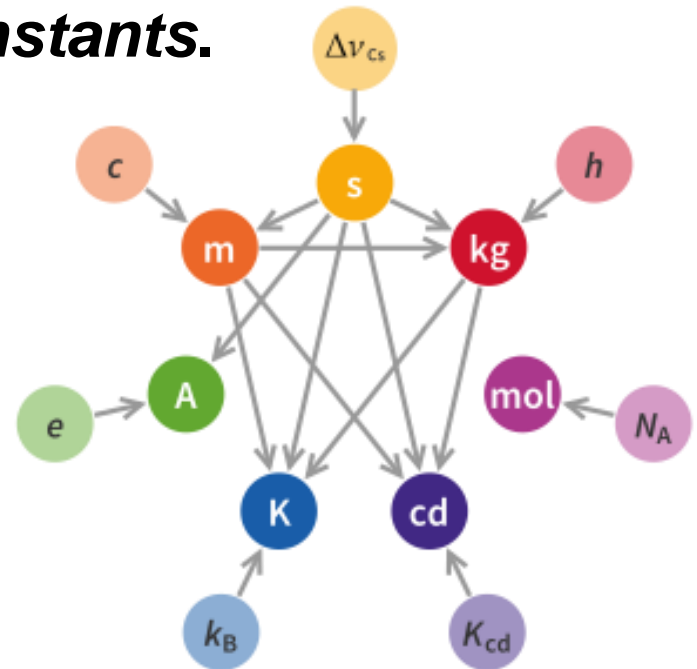
**IPK, International
Prototype Kilogram**

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** (count of elementary entities like atoms or molecules)

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



Metric Examples

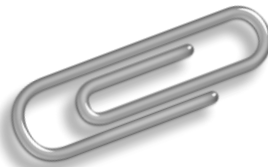
Any US paper currency note (\$1, \$5, \$10, \$20) has a mass of 1 g; the mass of a nickel is 5 g; the mass of a penny is 2.5 grams.



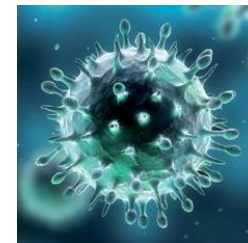
A typical doorknob is ~1 m high.



The mass of a gold bar is *precisely* 1 kg.



A paperclip is *about* 1 g.



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.