Measurement

- the **assignment of numbers** to objects or events
- a type of **quantitative observation** made with a **measuring instrument**
- includes both a **number** and a **unit**
- **units** of measurement are essentially **arbitrary: people make them up** and then **agree to use them**

Measuring is an important part of everyday life!

What can we measure?

How can we measure?

Why do we measure?

How well can we measure?

WHAT can we measure?	**And HOW?**
• Length	✓ Ruler
• Distance on land	✓ Measuring Chain/Tape
• Depth of water	✓ Sonar (echo sounder)
• Mass	✓ Weighing scale
• Temperature	✓ Thermometer
• Time	✓ Clock, timer
• Light	✓ Photometer
• Electric current	✓ Ammeter
• Color	✓ Spectrometer

AND SO ON...

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*).

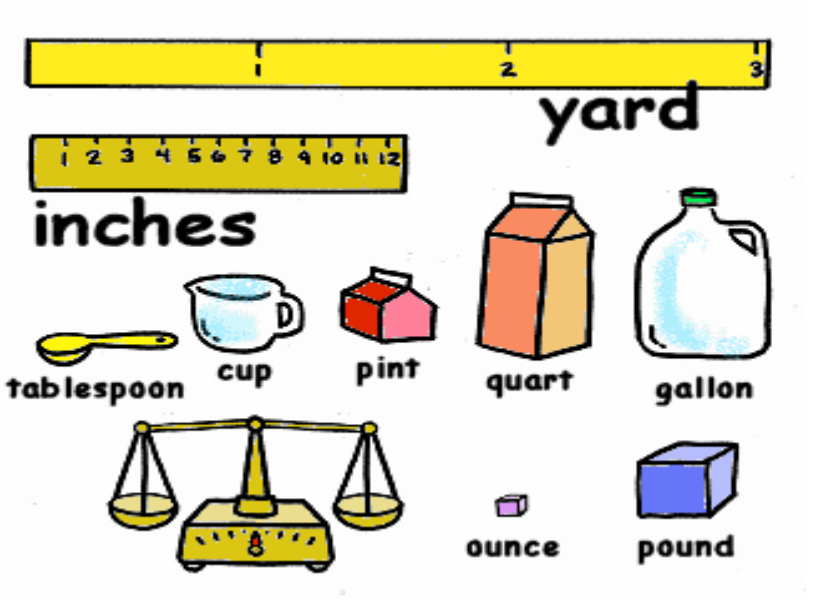
- Must specify **equivalency** relationship **for all additional units** used to measure the same quantity (example: length can also be measured in *inches* or *miles*, defined as 1 foot = 12 inches, 1 mile = 5280 feet).

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)



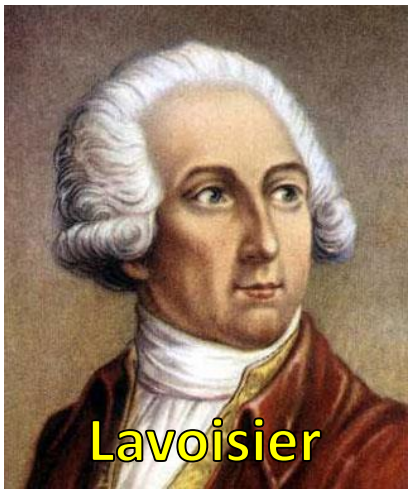
The Metric System

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.**

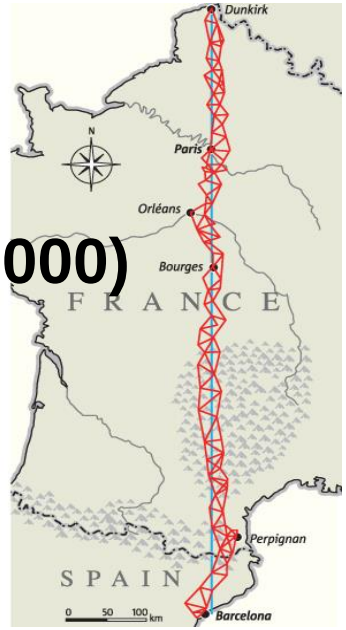


It was called the "metric" system (French for *measure*).

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**
  - **kilo + gram = kilogram**
  - **nano + liter = nanoliter**
  - **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.**

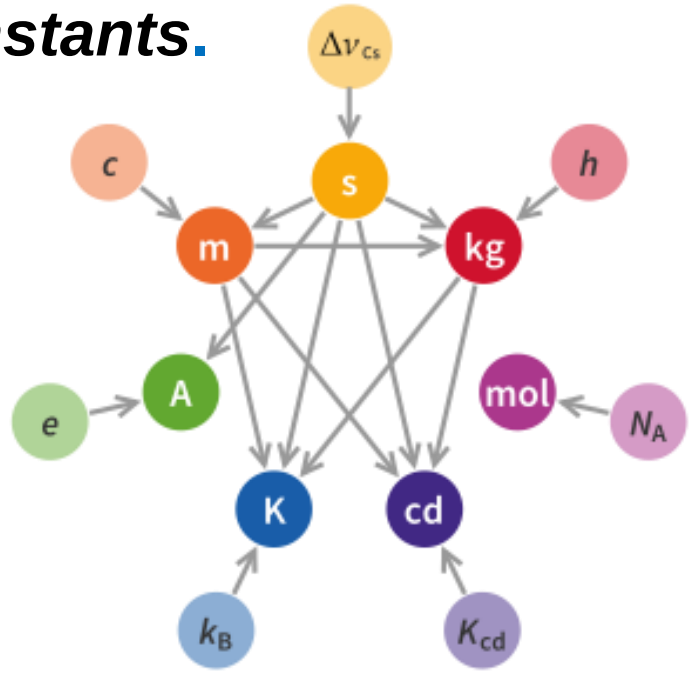
4. **Degree Centigrade** (temperature) - obtained by assigning **0°C to the freezing point of water** and **100°C to the boiling point of water.**

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	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}

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