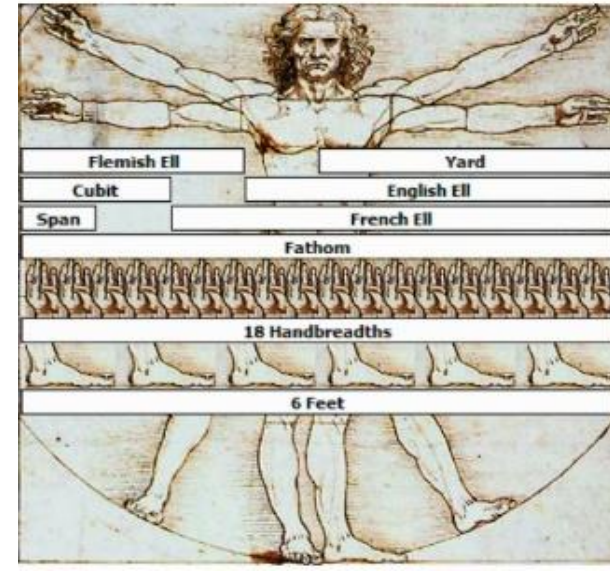


Measurement



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?

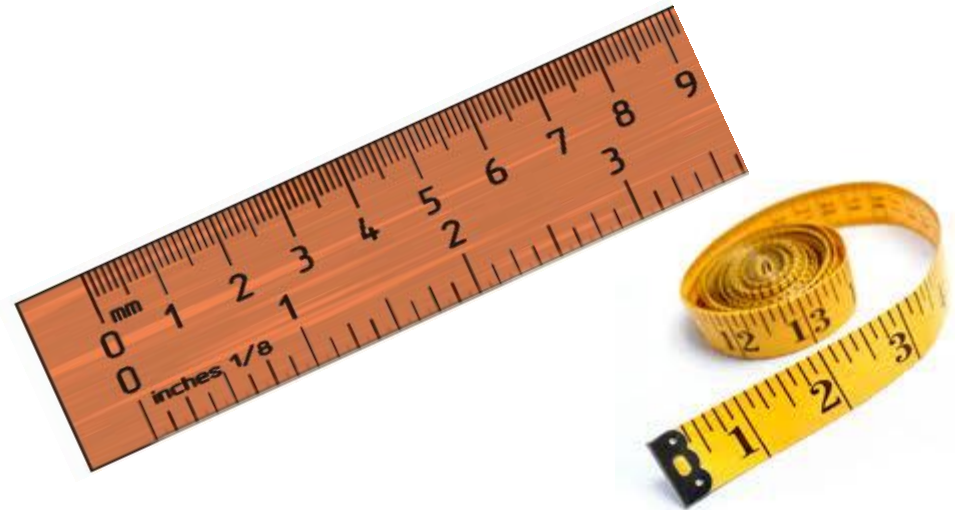
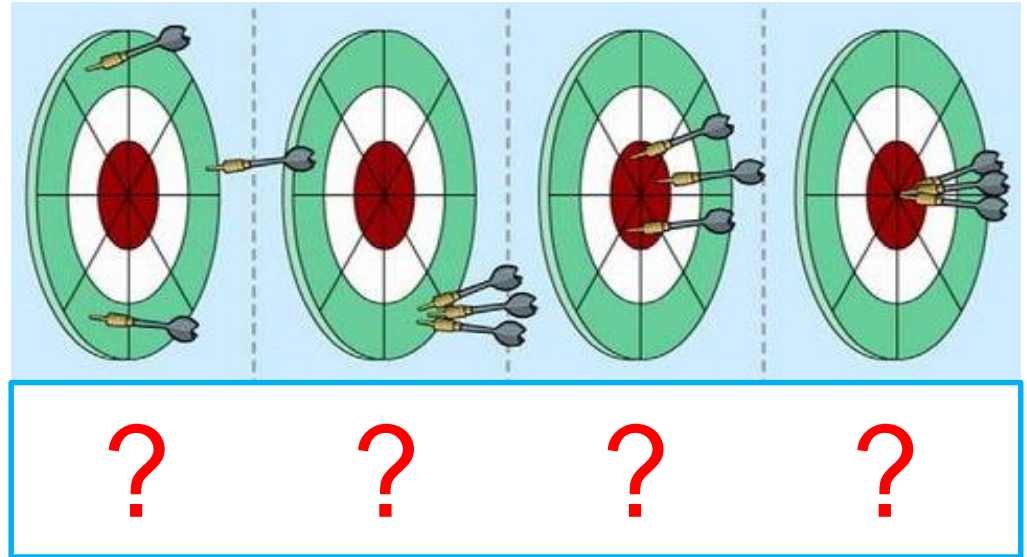
Why do we measure?

How can we measure?

How good can we measure?

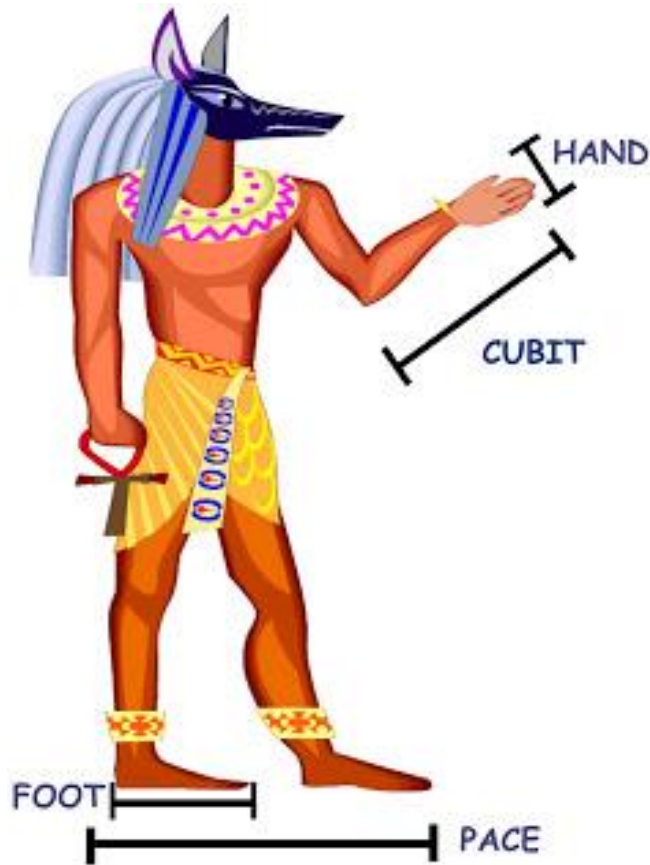
How good is the measurement?

- **Accuracy** is how close a measured value is to the *actual (true) value*.
- **Precision** is how close the measured values are to *each other* (repeatability and reproducibility).
- **Bias** is a built-in (systematic) error which makes *all measurements wrong by a certain amount*.



History of Measurement

- Objects were initially measured for *convenience*, to *aid commerce* and *prevent fraud*.



- The **Egyptians** among other civilizations **were the first to begin recording measurements** around 3200 BC.
- **Early** measurements were based on **body parts** or **common objects**.



1 Carob Seed = 1 Carat

Problems with Early Measurement Systems

1. People have different sized body parts, as well as there is a variety among common objects like grains...



Grain, India



Barleycorn



Wheat

2. ...so measurements are not accurate, especially when dealing with fractions and multiples...

SOLUTION: Standard Measurement Systems!

Standard Measurement Systems

- **Standard Measurement Systems** define units based on some **standard**, same for all, **to measure against**.
- Early standard systems often used body parts of the king or ruler as the standard. When the king died, a new measurement system would have to be created...
- **17th-18th century:** apparent **necessity for mutual standardization** of weights and measures **between nations** who traded and exchanged scientific ideas.
- At that time, every country had their own “standard” system of weights and measures. *England had three different systems just within its own borders!*

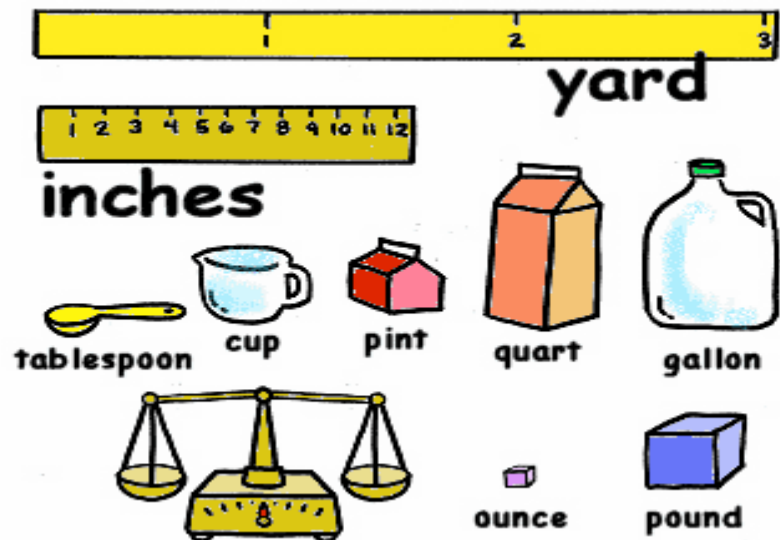
English Units Based Systems

- **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, 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)



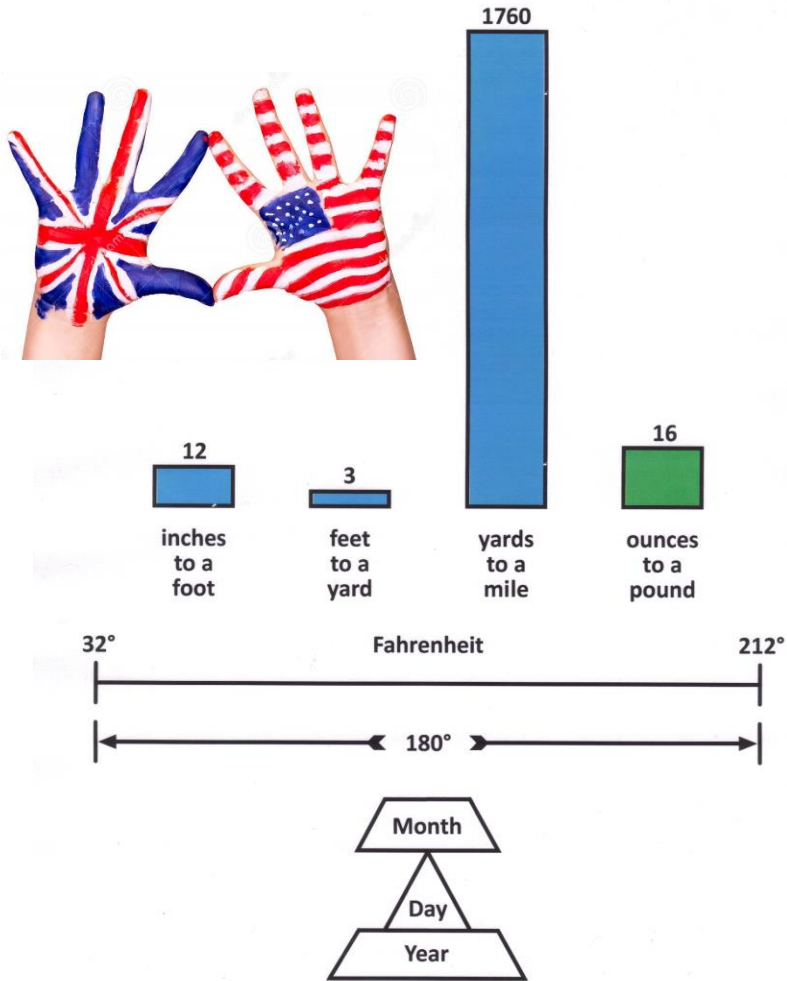
The Metric System

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

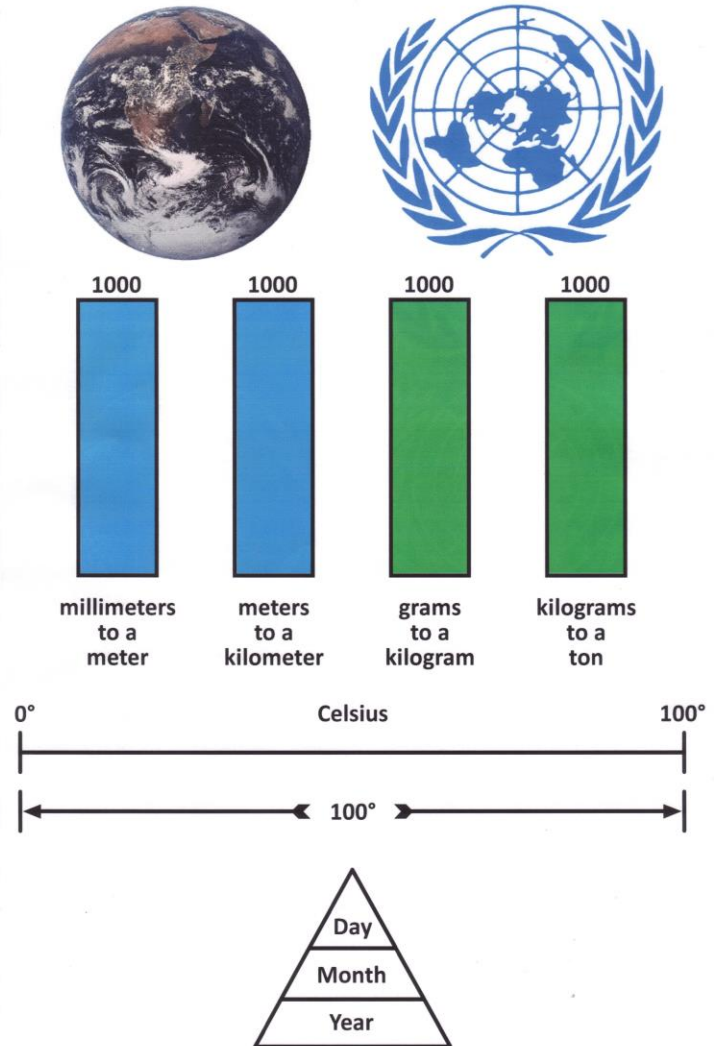
Modern "**Metric system**" term is a synonym for "**SI**" or the "**International System of Units**" (1960)—the **official system of measurement** in almost every country in the world.



US Customary/Imperial



Metric



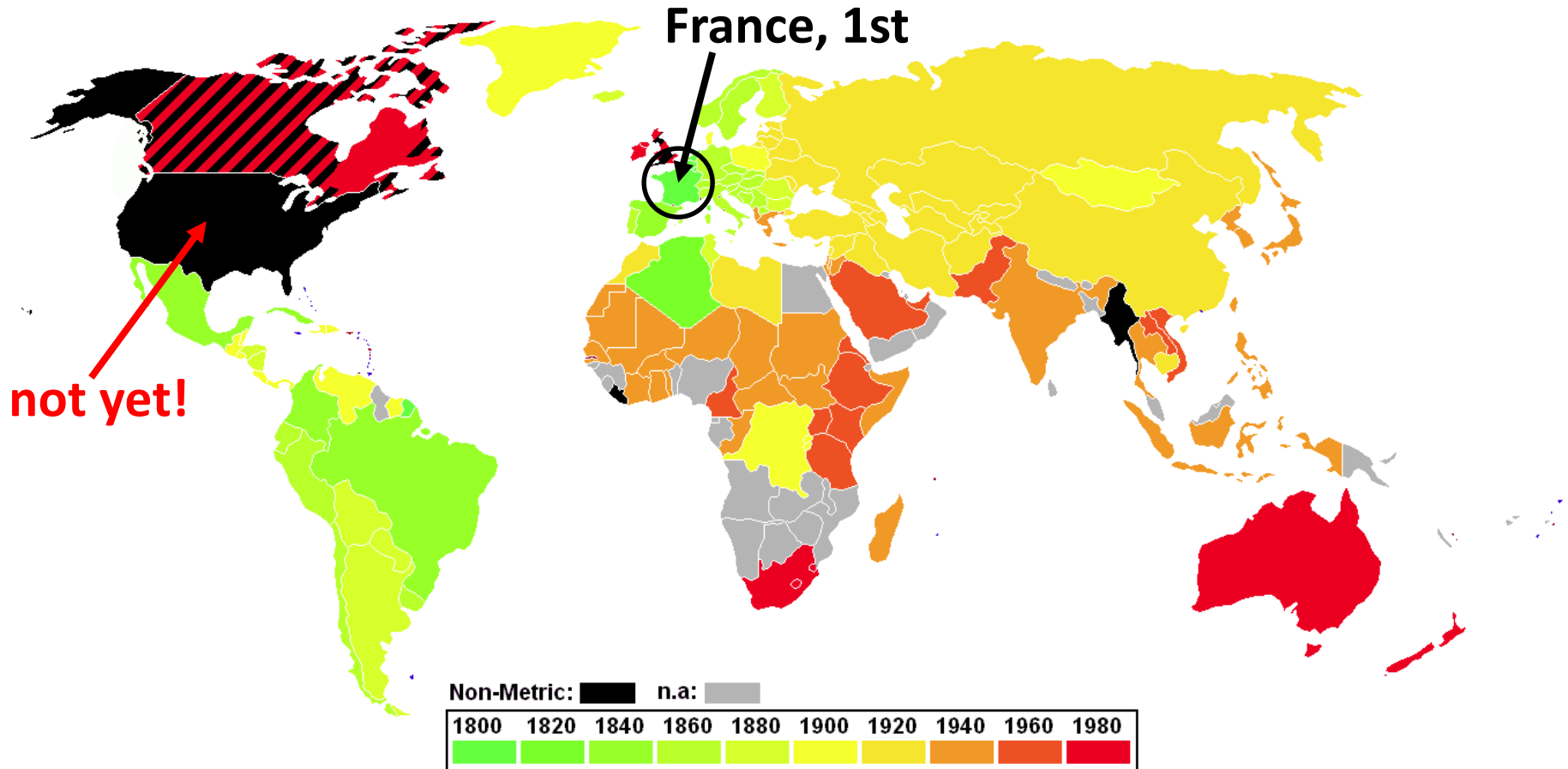
Equivalencies

US Customary/Imperial

Metric

Length	1 foot = 12 inches	1 centimeter = 10 millimeters
	1 yard = 3 feet	1 meter = 100 centimeters
	1 mile = 1760 yards	1 kilometer = 1000 meters
Area	1 sq. foot = 144 sq. inches	1 sq. centimeter = 100 sq. millimeters
	1 sq. yard = 9 sq. feet	1 sq. meter = 10000 sq. centimeters
	1 acre = 4840 sq. yards	1 sq. kilometer = 100 hectares
Mass	1 ounce = 437.5 grains	1 gram = 1000 milligrams
	1 pound = 16 ounces	1 kilogram = 1000 grams
	1 stone = 14 pounds	1 tonne = 1000 kilograms
Volume	1 cu foot = 1728 cu inches	1 cu decimeter = 1000 cu centimeters
	1 cu yard = 27 cu feet	1 cu meter = 1000 cu decimeters
	1 pint = 20 fluid ounces	1 liter = 1 cu decimeter
	1 gallon = 8 pints	1 hectoliter = 100 liters

Metrication of the World



Currently **USA is the only country** (and perhaps also Myanmar and Liberia) **that does not use Metric System...**

Metric System in the USA

- The metric system has been **officially sanctioned for use in the United States since 1866**, but it remains the only country that has not fully adopted the metric system as its official system of measurement.
- Metric System was only **partially** adopted, **mostly in Science** (but not Manufacturing!)..

How good is “partially”?

Gimli Glider

July 23, 1983: Air Canada Flight 143 (Boeing 767-233 jet), **ran out of fuel** at an altitude of 41,000 feet (12 km), **about halfway through its flight** from Montreal to Edmonton.

The crew were able to **glide the aircraft safely to an emergency landing** at Gimli Industrial Park Airport. None of the 61 passengers were seriously hurt.

Investigation: **fuel loading was miscalculated** due to a misunderstanding of the recently adopted metric system which replaced the imperial system.

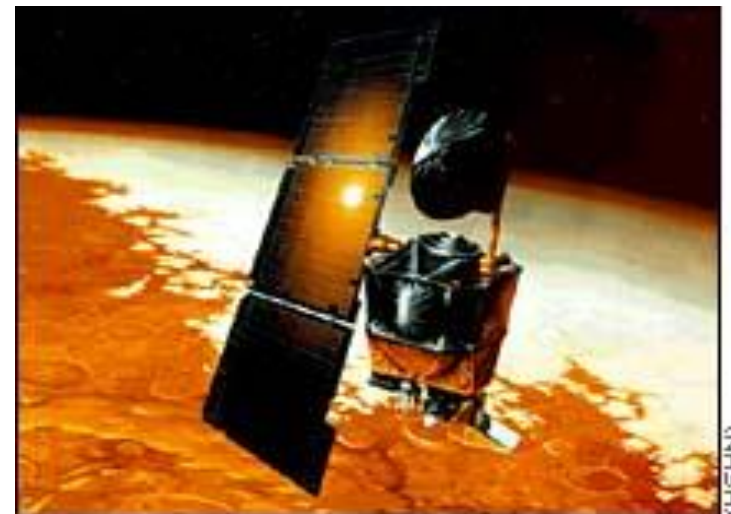


Loss of NASA orbiter

NASA's Mars Climate Orbiter
lost on September 23, 1999.
Cost: \$125 million.

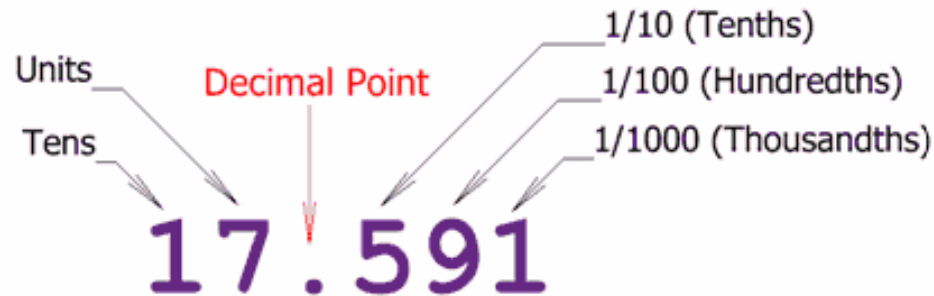
The spacecraft insertion trajectory came too close to the planet; the Orbiter disintegrated upon entering the upper Martian atmosphere.

For a key spacecraft operation, Lockheed Martin engineering team used **Imperial units** of measurement while the NASA's team used more conventional **Metric system**...



Review: 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 = 73①2②4③8④

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