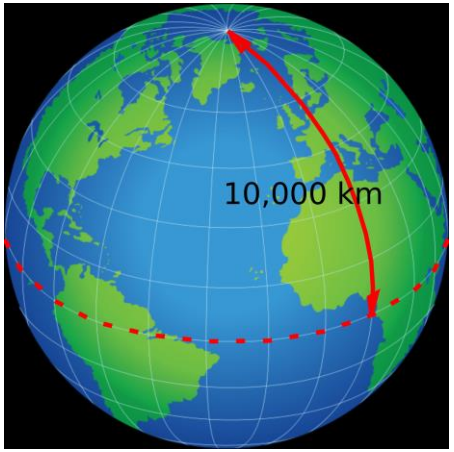
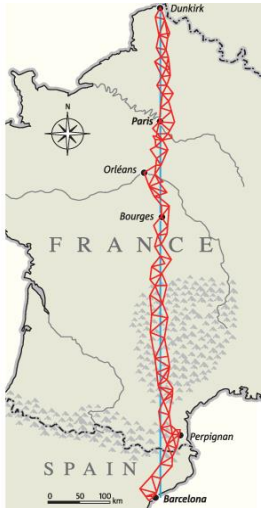
The Metric System

PART 2

The Meter, m
(Metric, SI)



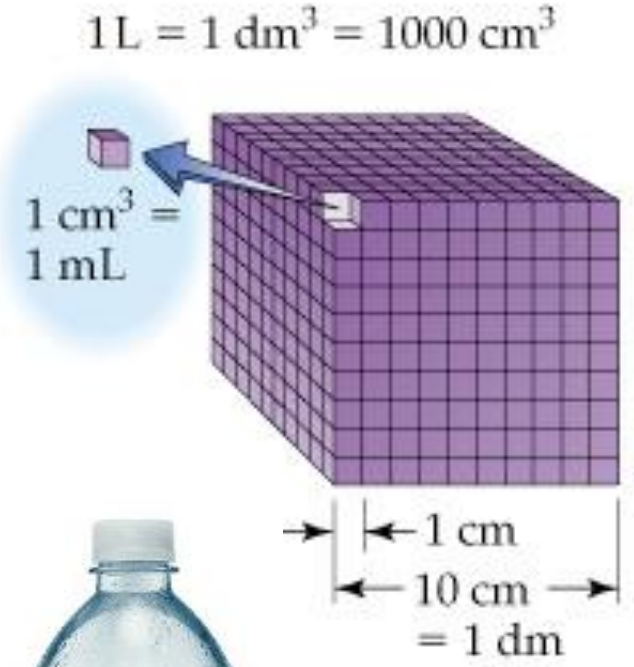
- **Original definition (1791): <u>one ten millionth (1/10,000,000) of the quarter of the Earth's meridian</u>** (distance between the North Pole and the Equator through Paris was determined based on a Pierre Méchain and Jean-Baptiste Delambre 1792-1798 survey of the length of the Earth's meridian between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

- **Improved (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*.

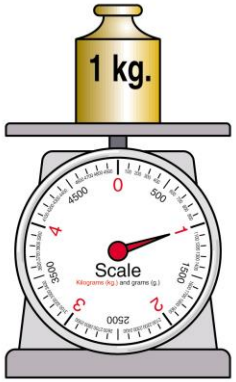
The Liter, L
(Metric, non-SI)



- **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.**
- **2005:** International Committee for Weights and Measures recommended that the kilogram be redefined in terms of a fundamental constant of nature.

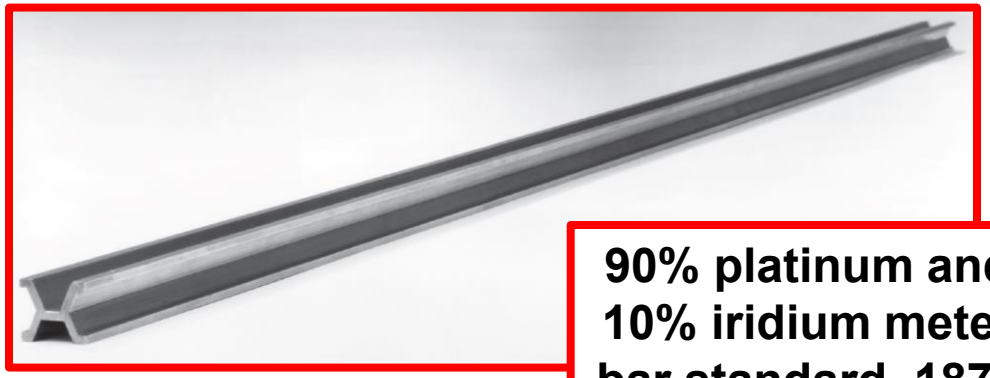


1 kilogram = 1000 grams

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***

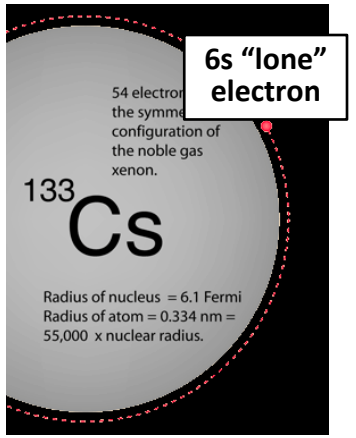


90% platinum and 10% iridium meter bar standard, 1875

IPK, International Prototype Kilogram

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 obviously not very good…)
- International Astronomical Union, 1952-1956 redefinition: the fraction 1/31,556,925.9747 of the tropical year 1900.
- **Improved 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**.

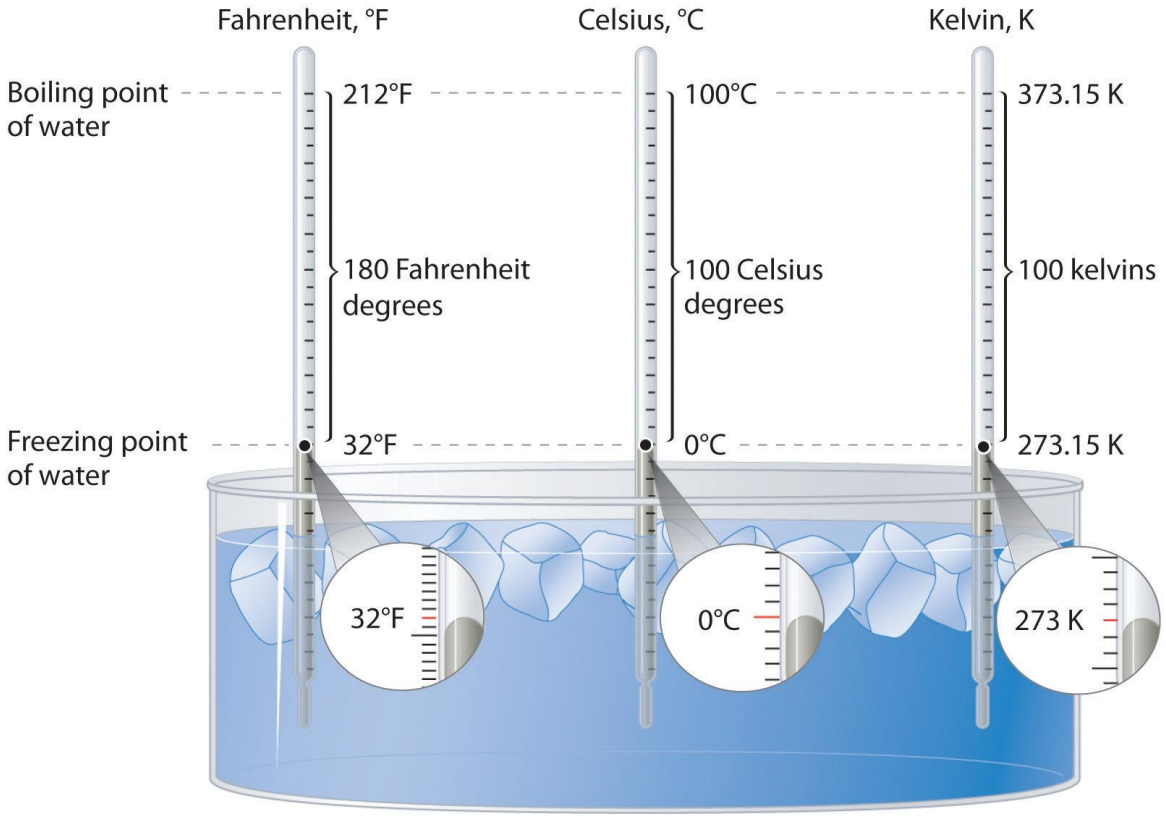


- SI prefixes starting from millisecond are commonly used to measure time less than a second (submultiples); non-SI units *minutes, hours, days, Julian years, Julian centuries,* and *Julian millennia* are used to measure multiples of second.

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.



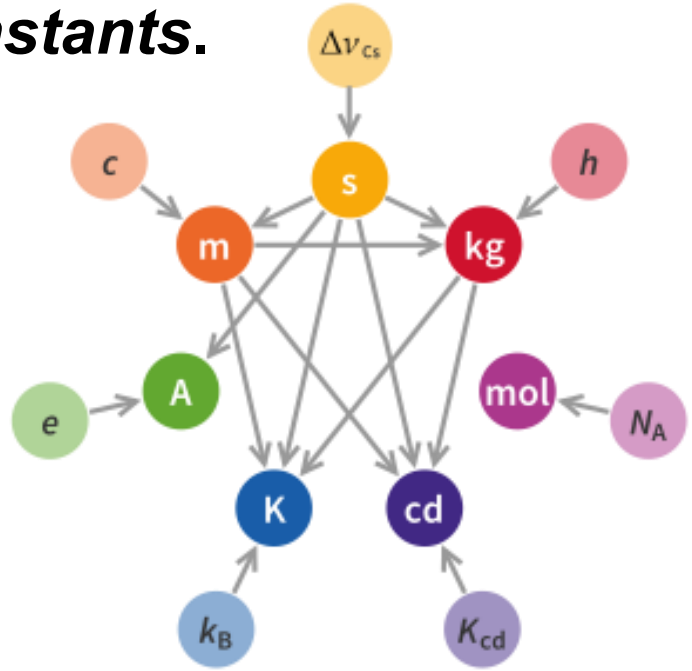
- **Improved (1967):** **1/273.16 of the thermodynamic temperature of the triple point of water** (triple point of water = 273.16 K = 0.01°C by definition).

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*.



Fundamental Physical Constants

The units in the revised SI are based completely on seven unchanging quantities or "universal constants", including:

- **the *speed of light in vacuum*,** c=299,792,458 meters per second, which is the "speed limit" in the Universe
- **the *elementary charge*,** e=1.602176634 × 10^{-19} coulombs, which is the amount of electric charge in an electron
- **the *Planck* constant,** h=6.626 070 15 × 10^{-34} Joule seconds, which in quantum mechanics defines the minimum size ("quantum") of the packets of energy exchanged by matter
- **the *Boltzmann* constant,** k=1.380649 × 10^{-23} joules per kelvin, which relates an object's energy to its temperature
- **To learn about Δv_{Cs} , K_{cd} , and N_A, visit the NIST webpage at https://www.nist.gov/si-redefinition/meet-constants**

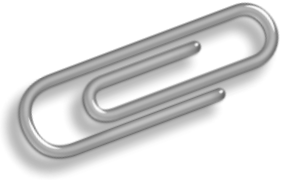
The values of the constants are the same everywhere in the Universe, so they can be regarded as "invariants of nature".

Metric Examples

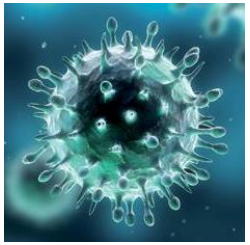
Any US paper currency note ($1, $5, $10, $20) has a mass of 1 g; the mass of a nickel is 5 g; the mass of a penny is 2.5 grams.

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.