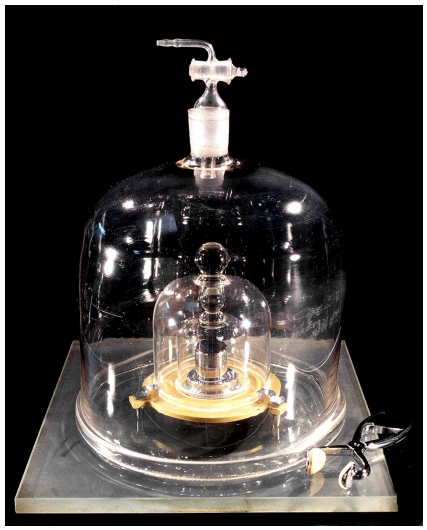
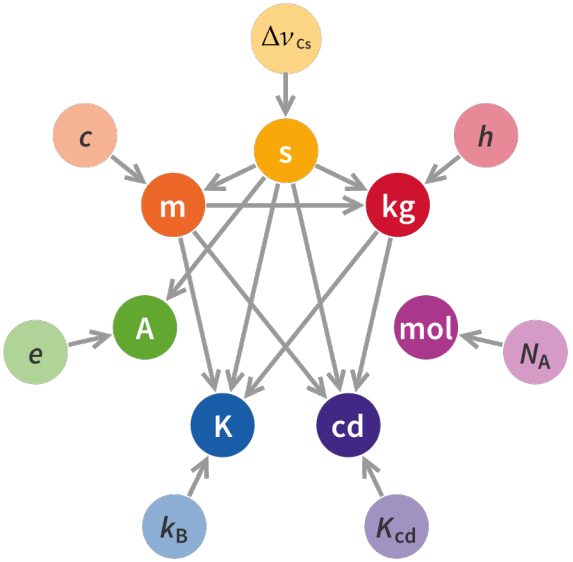
# Système international d'unités

The Metric System: Base units and their origins and definitions.



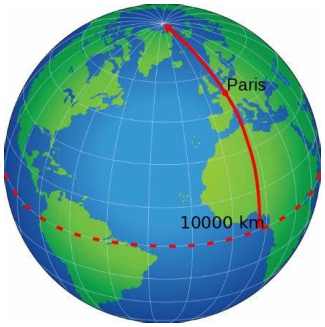


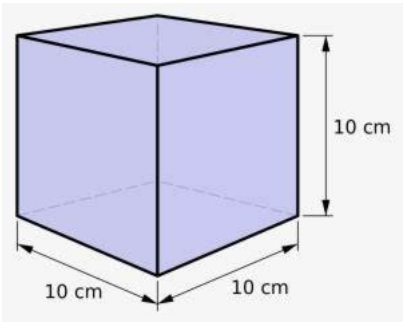

$h$

# Brief History


- Before SI, units were all over the place
  - Varied from nation to nation, region by region. It even varied from town to town and down to transaction to transaction
- The need for easy scientific collaboration called for a uniform system of units.
- First efforts were unsuccessful over the dispute of which latitude to use for lengths of pendulums.
- France would take its own initiative to create standard units.

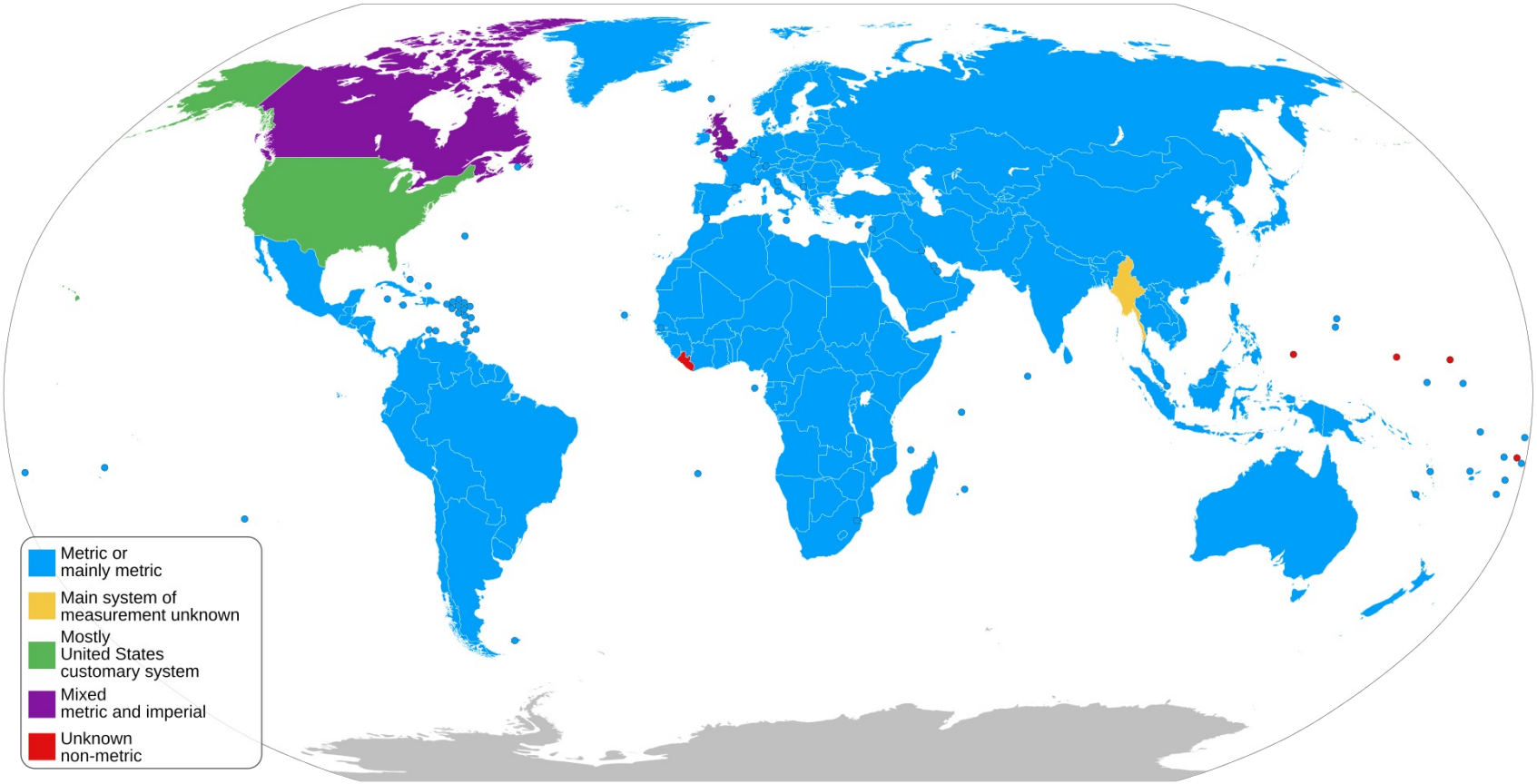
# Brief History (cont.)



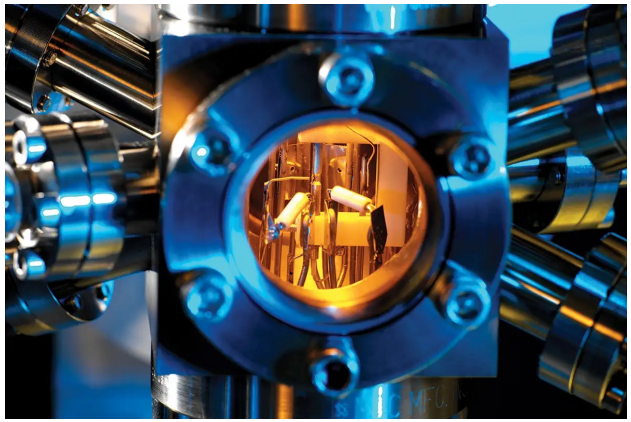

- 1790: The Académie des sciences tasked prominent French scientists to create a new uniform system of units
- Metre: equal to one ten-millionth of the distance from the North Pole to the Equator (Earth quadrant), measured along the Paris meridian
- Kilogramme: equal to mass of a cube of water with sides equal to one hundredth of a metre * 1000
  - Note: the gramme was initially proposed, but was deemed too small to be practical

# Modern Users



# Base Units: Second

- Pre-2019 definition: The second is 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
- Current definition: The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency, $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom, to be 9,192,631,770 when expressed in the unit Hz, which is equal to $s^{-1}$.
  - Effectively: $1s = \frac{9192631770}{\Delta\nu_{Cs}}$



# Base Units: Meter

- Pre-2019 definition: The metre is the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second
- Current definition: The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299,792,458 when expressed in the unit $ms^{-1}$, where the second is defined in terms of the caesium frequency $\Delta v_{Cs}$
  - Effectively: $1m = \frac{9192631770}{299792458}\frac{c}{\Delta v_{Cs}}$

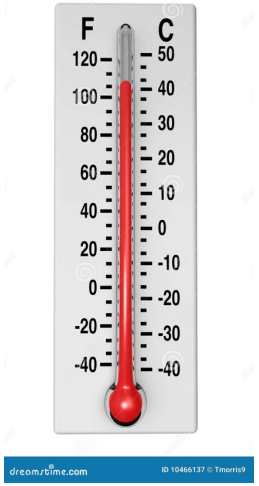
# Base Unit: Kilogram

- Pre-2019 definition: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram
- Current definition: The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be $6.62607015 * 10^{-34}$ when expressed in the unit J·s, which is equal to $\frac{kg\ m^2}{s}$, where the metre and the second are defined in terms of c and $\Delta v_{Cs}$.
  - Effectively: $1kg = \frac{(299792458)^2}{(6.62607015*10^{-34})(9192631770)} \frac{h\ \Delta v_{Cs}}{c^2}$

Notes: $Js = \frac{J}{Hz}$, $E = hf$, drift of the prototype

# Base Unit: Kelvin

- Pre-2019 definition: The kelvin, unit of thermodynamic temperature, is $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water.
- Current definition: The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be $1.380649 * 10^{-23}$ when expressed in the unit $JK^{-1}$, which is equal to $\frac{kg\ m^2}{s^2 K}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta v_{Cs}$.
  - Effectively: $1K = \frac{1.380649*10^{-23}}{(6.62607015*10^{-34})(9192631770)} \frac{h\ \Delta v_{Cs}}{k}$

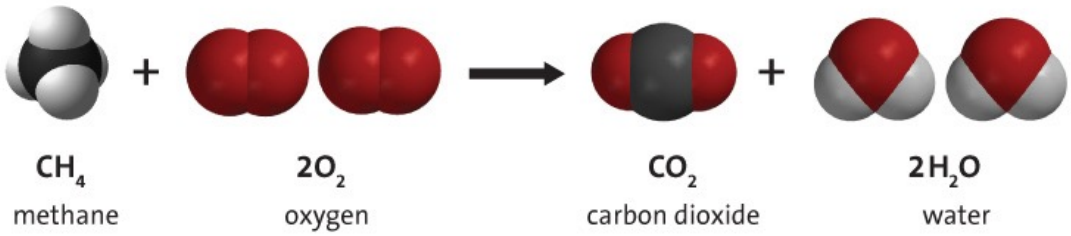


# Base Units: Ampere

- Pre-2019 Definition:  The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10−7 newton per metre of length.
- Current definition: The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be $1.602176634 * 10^{-19}$ when expressed in the unit C, which is equal to A·s, where the second is defined in terms of $\Delta v_{Cs}$.
- Effectively: $1\mathrm{A} = \frac{e\Delta v_{Cs}}{(1.602176634*10^{-19})(9192631770)}$

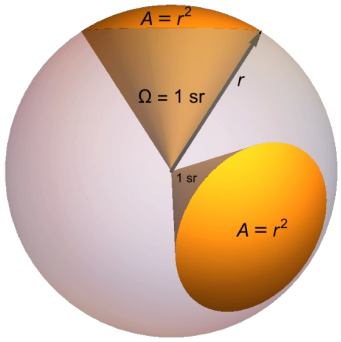
# Base Units: Mole

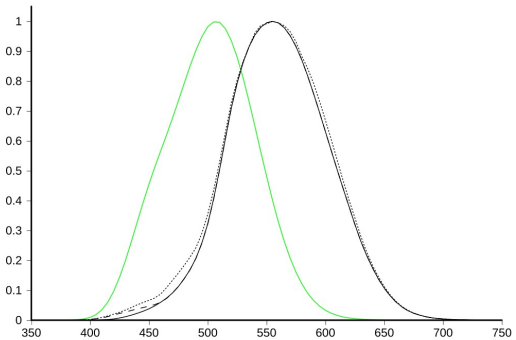
- Pre-2019 definition - The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.
- Current definition: The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.02214076 * 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, $N_A$, when expressed in the unit $mol^{-1}$ and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.



# Base Units: Candela

- Pre -2019: The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 * 10^{12}$ Hz and that has a radiant intensity in that direction of $\frac{1}{683}$ watt per steradian.
- Current definition: The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency $540 * 10^{12}$ Hz, $K_{cd}$, to be 683 when expressed in the unit $\frac{lm}{W}$, which is equal to $\frac{cd\ sr}{W}$, or $\frac{cd\ sr\ s^3}{kg\ m}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta v_{Cs}$.
- Effectively: $1cd = \frac{1}{683(6.62607015*10^{-34})(9192631770)^2} K_{cd}\ h\ (\Delta v_{Cs})^2$



# What about the US?

- Metric Conversion Act of 1975
  - Sets SI as the preferred system of measurements in all activities, but not compulsory.
- Executive Order 12770 by President George H.W. Bush, 7/25/91
  - Orders all executive departments to use SI as the preferred system of measurement for commerce and trade.


# Conversion

- 1 inch = 25.4mm
- 1 lb = 453.59237g
- Note that these are exact conversions.