A (bit of) history of the SI units

a Gatsby tea talk (v2)

20/11/2018

What’s the SI?

- International system of units
- Most widely used system of measurement
- Is coherent
- Built on seven base units: kilogram, metre, second, ampere, kelvin, mole and candela
- Definitions are now entirely based on invariant constants of nature

Second (s)

- People started using it around the 16th-17th centuries

- Gauss proposed in 1832 starting using the second as the base unit of time

- As a fraction of a solar day: the CGS and MKS system used the same definition of second: 1/86400 mean solar day (adopted internationally in the 1940s)

Second (s)

- As a fraction of a year: It was known by the time that earth's orbit around the sun was much more stable than earth's rotation. They adopted units of the sidereal year as the new time scale (ephemeris time)

- Later changed to units of tropical year. The second was thus defined as 1/31,556,925.9747 of the tropical year for January 0 1900 at 12 ephemeris time (in 1960)

- However, the tropical year was not measured but was calculated from a formula based on observations in previous centuries.

- None of the current mechanical or Quartz clocks were precise enough to measure the ephemeris second

Second (s)

- Discovery of atomic clocks lead to the current definition of the second (since 1967): 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 caesium-133 (at 0K)

- This length corresponds to the length of the previous ephemeris time

Metre (m)

- In 1793 it was defined as 1/10,000,000 the distance from the equator to the north pole.

- The French led an expedition from 1792 to 1799 to measure that distance, and then fashioned a prototype bar that became the standard in 1799 (not very accurate though)

- The bar was changed in 1889 and a new bar was created

Metre (m)

- In 1983, it was changed to no longer depend on a physical artefact.

- Defined as the length of the path travelled by light in vacuum during 1/299792458 second.

Kilogram (kg)

- Original definitions: (1793) mass of 1cm^3 of pure water then (1889) changed into the mass of a precisely fashioned metal cylinder kept in a secure vault under very strict conditions (and yet its mass still changed over years)

- In 2018, the value of the Planck constant was fixed to be exactly $6.62607015 \times 10^{-34}$ $kg \cdot m^2 \cdot s^{-1}$ thereby defining the kilogram in terms of the second and the metre (which is defined in terms of the second)

Kelvin (K)

- In 1743 the centigrade scale is obtained by assigning 0°C to the freezing point of water and 100°C to the boiling point (at 1atm)

- Kelvin (introduced in late 19th century) defined in 1954 as 1/273.16 of the thermodynamic temperature of the triple point of water (0.01°C) (which implies that 0K = -273.15°C)

- In 2018, the Kelvin is defined by fixing the value of the Boltzmann constant to 1.380649×10^{-23} $\mathrm{kg}\cdot\mathrm{m}^2\cdot\mathrm{s}^{-2}\cdot\mathrm{K}^{-1}$ thereby defining the Kelvin in terms of the kilogram, metre and the second

Mole (mol)

- Since 1967, it was defined as the number of atoms in 0.012kg of carbon-12.

- In 2018, the value of the Avogadro constant is fixed to $6.02214076 \times 10^{23}$ mol^{-1}

Ampere (A)

- Previous definition (since 1946) was the constant current, which if maintained in two straight conductors of infinite length and negligible cross-section held at 1 m apart, would produce a force of $2\times10^{-7}\,\mathrm{kg}\cdot\mathrm{m}^{-2}$

- In 2018, the value of the elementary charge is fixed to $1.602176634\times10^{-19}\ \mathrm{A}\cdot\mathrm{s}$ which defines the ampere in terms of the second.

Candela (cd)

- Since 1979, defined as the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540\times10^{12}\ s^{-1}$ and that has a radiant intensity in that direction of $1/683\ kg\cdot m^2\cdot s^{-3}\ sr^{-1}$ (Watts per steradian)

"You, in this country [the USA], are subjected to the British insularity in weights and measures; you use the foot, inch and yard. I am obliged to use that system, but must apologise to you for doing so, because it is so inconvenient, and I hope Americans will do everything in their power to introduce the French metrical system. ... I look upon our English system as a wickedly, brain-destroying system of bondage under which we suffer. The reason why we continue to use it, is the imaginary difficulty of making a change, and nothing else;"

– *William Thomson Kelvin*
In *Journal of the Franklin Institute (1884)*