Perspective

New Measurement System

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New Measurement system: New definitions of fundamental units Kilogram, ampere, Kelvin and mol became effective from 20^{th} May 2019. Measurement is something essential for research, science, economy and business (commercial purpose). As it is important in a global network system so that man must agree how and what is measured. The basis for that is since 1960 the international unit systems in short SI (French: Système international d'unitès). It is the most widely spread unit system for physical dimensions with the seven fundamental units ampere, candela, Kelvin, kilogram, meter, mol and second.

The international society to be precise the states of meter convention has decided in its general conference for measure and weights (CGPM - Conference Gènèrale des poids et Mesures) on the 16^{th} November 2018 in Versailles as fundamental revision of SI. Inadequacies, with the definition of ampere, Kelvin, kilogram and mol made necessary this great and important change.

Background: It should with that be able to measure directly give one agreement as to how one for example the mass of 1 kilogram exactly determine. Previously it was in vogue on an artifact, an old kilogram in Paris, this platinum-irridium cylinder preserved in a safe of international office for measure and weight (BIPM – Bureau International des Poids et Measures) in Sèvres in Paris is the Kilogram as per definition. All other measure-standards of metrological institutes worldwide are with it made similar. Ridiculous indeed that the measure of old kilogram changes. Just so its copies are published – identically manufactured cylinders of old kilograms as it the physical technical Federal institute in Braunschweig (PTB) possesses. As a portion amounts to the difference one half µg/year. Similarly it goes with other units. That leads to that the official values of natural constants, which are founded on the old units change regularly. The committee on data for science and technology recommended a yearlong global measure marathon 2017 for final values for seven natural constants. Exactly these, so the decision of CGPM, illustrate them 20 May 2019 the foundation for all seven SI fundamental units.

As a consequence the progress illustrate in measurement system directly with the accuracy of units. Through that the domain (area) such as quantum technologies can gain. There is real time application everywhere in the context of digitally controlled production process, medical diagnosis, or the climate research where it matters, highest to the occurrences in measurement.

Constant of Cesium-frequency $\Delta\nu$
How long lasts a second.

Seconds(s): Time belongs as meter and kilogram to the physical dimension which all plays a big role day to day. Every child knows or can calculate that a day lasts for 24 hours and correspondingly 86400s. Originally, the fundamental unit(s) was derived from astronomical measurements. But that is naturally very much incorrect. The definition of time unit second was determined already since 1967 on a defined natural constant; the frequency of hyper fine structure passage (going over) in cesium basic condition (133cs) of 9192631770Hz.

While this frequency to be more precisely said is a frequency difference between two atomic nuclear energy levels, it is with Δν earmarked: Δ (big delta) stands in physics for a difference, ν (nu) stands for the frequency. The chosen frequency corresponds to a radiation in microwave area. With that the atomic watches get converted to a correctness of 10-16. Fully practical this correctness as for example has influences on the correctness of navigation system. It exhibits already today that other ions and atoms change over (transition) exist in optical-spectral area which allow the watches by relative uncertainty as little as 10-16. These would improve application possibility in communication technology, satellite techniques and in the applied geodesy. Weaker transition for that is chosen, to that it gives at present an international competition. The natural constant Δv, previously defined on the cesium, is therefore before long, newly determined.

Boltzmann Constant k
At the null point a frosty affair

Kelvin (K): When we customarily measure temperature, then it is grad Celsius (°C). This scale was established through Swedish astronomer Anders Celsius. As fixed point he used the temperatures of freezing point and boiling point of water at the normal pressure, therefore, consequently at 1013,25 hPa atmospheric pressure. In between there are 100 same size (dimension) sections.

With the expansion of old MKS unit system in 1954 also came Kelvin (K) as fundamental unit to that. It is the 273.16. Part of the thermodynamic temperature of tripel point of water. The tripel point of water lies at 0.01°C. The problem: The tripel point is certainly also as much as a temperature constant, varies however with isotope synthesis of water. With that a temperature of 0°C converted to 273.15K. And OK corresponds to absolute null point of temperature. The numerical value of a temperature difference in K and °C is however the same. In new SI unit system goes on K the Boltzmann Constant K back but also on h and Δv. In practice the metrologists have the Boltzmann Constant with highly sensitive gas thermometers destined so called primary thermometers. They will be used in future for high precision determination of temperature or other gas properties.

The elementary charge e
Constantly full under current

Ampere (A): It would in 1954 at that time valid unit system MKS as the fourth fundamental unit for the current l introduced. With that it stands in Ohm's law with current U (in volt V) and resistance R in Ohm (Ω) in relation I = U/R. The ampere named after the French mathematician and physicist André-Marie Ampere was defined since 1948 as the energy of temporary constant electrical current which in vacuum between two parallel endlessly long straight conductors with negligible small circular cross-section and gap of 1 meter between these conductors would cause a power of 2x10-7N per meter conductor length.

It was difficult to realize that in experiment one could better preset soon the volt and ohm on two according to 1960 invented effects: The Josephson effect and the Klitzing effect. Since 1990 the metrologists worldwide defined ampere on the basis of two natural constants which with these effects play role, move with that but outside of in 1960 valid SI. The SI reform on 20th May 2019 defines now ampere on the basis of one own natural constant of elementary charge.

$$e = 1,602176634 10^{-19} C \ (C = As).$$

In between individual electrons and with that their electric charge in special semiconductor arrangement is measurable.

Perfectly beautifully luminous
Photometric radiation equivalent K_{cd}

Candela (cd): In our working days it was before a few years almost unknown the fundamental candela till the classical incandescent lamps through other illuminants were removed. There emerged in then advisors immediately the light intensity unit cd. Gängiger is with illuminants in between the current for lighting intensity lumen (lm). Both these are connected together. The light intensity is on the solid angle covered up current for light. As fundamental unit candela came up with the ampere and Kelvin in 1954 to previous MKS fundamental unit. In 1979 it was newly defined as the light intensity in a definite direction of source of radiation which monochromatic radiation of frequency 540×10^{12} Hz emits and thereby light intensity in this direction amount to 1/683 W through steradiant: The mentioned frequency corresponds in air 555 nm and with that green light, for that the human eye has the highest sensitivity of seeing best in the eye.

Beyond 20th May Candela becomes definite through the photometric radiation equivalent Kcd of monochromatic radiation of frequency of 540×10^{12} Hz. This radiation intensity becomes as natural constant defined as K_{cd} = 683 lm/W. To that play as role as with Kelvin h and Δv. The photometric radiation equivalent is a mass for that, how much current of light of a definite radiation performance for the human eye is useful. The more the sensitivity of eyes the higher the radiation equivalent. That the sensitivity of human eyes at 540×10^{12} Hz is the radiation equivalent for all other wavelengths and for wavelengths; combination is smaller.

The Planck operation quantum h
The mother of all measurements

Kilogram (kg): Previously a metallic body of platinum-iridium alloy (90% Pt, 10% Ir) was valid as mother of all weights. In 1878 the scientists prepared out of that a one Kg cylinder with 39mm diameter and height of 39 mm. Since then it remained latent in controlled atmosphere under a type of three-fold cheese-cover in treasury of international office for mass and weight (BIPM) near Paris. It's mass defined earlier the unit of Kg. With cyclic wise weights of the cylinder it put out that the old kilo without knowledgeable cause loses a weight 50µg in 40 years. Base in sufficient, the definition of kilogram stands on reliable support.

The Planck's operation quantum was discovered h. The numerical value of this constant is $6.62607015 \times 10^{-34}$ J (Js = kg $m^2 s^{-1}$) fixed together with the definition for the second (s) and the meter (m) equally per natural constants. It gives the definition for the kilogram as function of Planck's operation quantum h. on this basis it gives two experiments with which metrological institution in future will prepare the standard mass for 1 kg. The so-called watt weighing machine as also the number of atoms in highly pure silicon sphere.

The Avogadro Constant N_A
The number of molecules

Mol (mol): Since the beginning of chemistry the scientists require a reliable size, in order to be able to state the number or the weight of atoms and molecules. Physicists and chemists orient themselves with that at "atomic weight" of carbon isotope ^{12}C or at its relative atom mass 1967 was as the definition as determined. The Mol is the fundamental unit of quantity of matter of a system, that out of just so consists of many details like atoms contained in 0.012 kg of carbonuclide ^{12}C is equal to 129 mol.

Already in 1811 the physicist from Italy Amedeo Avogadro discovered that equal volumes of different ideal gases containing the same number of molecules, named after him the Avogadro Constant (N_A) gives up the particle number N per quantity of matter n. With that n can be an atom, molecule ion, electron or one other particulate.

After the 20th May 2019, the definition of Mols is based on the determination of Avogadro's constant. A Mol consists then exactly of $6{,}02214076.10^{23}$ particles. These are more than 602 trilliard particles per Mol. For determination in future silicon spheres out of ^{28}Si with a purity of 99,999% are utilized. Similarly as with kilogram, the spheres have rather varying diameter. With such monocrystals the number of atoms can be specially counted exactly.

Other Unit
Velocity of Light c

Meter (m): The unit of length (m) was originally on an artifact as it is called in metrologies-technical, Chinese defined the so-called old meter. As the old kilogram for the mass definition it goes back to the French Revolution. In 1791 the constitution giving gathering decided in Paris the introduction of one universal unit of length. The new length mass should be tenth milliards portion of earth's meridian quadrant (the stretch from pole to equator). Since 1799 it gave two specimens of the old meter.

In 1875, it brought to the international meter convention an agreement in which the signing states amongst other decided the changeover of old meter and the old kilogram as standard unit of measure.

Already in 1960 the meter prototype was replaced through a natural constant which the 1650 763,73times of the wavelength of atoms of nuclides defined ^{86}Crypton with the change of condition 5d5 to the condition 2ρ10 sent out in vacuum expanding radiation. With that exactness of 10^{-8} is achieved. With this the meter was ahead of other fundamental units previously but in comparison to the unit of time second(s). Since 1967 likewise on natural constant rested caused by previously inaccurate. However the fixing of meter follows since 1983 as that stretch which light in vacuum in 1/299 792 458 s traverses.

Fundamental natural constant is with that is c, which the velocity of light in vacuum (c = 299 792 458 $m.s^{-1}$). To that cesium frequency Δν. The meter definition remains unchanged, from 20th May; both the natural constants are however formerly written.

Source: Fokus: Das Neue Einheitensystem,
VDI nachrichten 17 May 2019 Nr 20; FOKUS