2012-02-02

The New SI — Draft definitions of the SI Base Units

The above issue has been intensively discussed internationally, not least in our informal network. Before the CGPM 2011 the Swedish delegation discussed the Draft Resolutions of the SI Base units. The Swedish delegation submitted the following comments to the CGPM through CIPM.

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2011-09-13

On the draft redefinitions for four of the SI base units

The creation of a system of units can be performed in many different ways. Which way to choose is a matter of convention. The way used by ISO, IEC, and CCU is the following:

1) A system of quantities is created, i.e. a limited number of quantities that are considered to be independently of each other, are selected as base quantities, and non-contradictory equations that define the derived quantities are chosen.

2) For each base quantity a base unit is defined. It should be noted that base units need not to be defined independent of each other, whereas the base quantities are considered to be independent of each other. This distinction between base quantities and base units has caused much confusion in the past. For example, in the SI the definition of the metre depends on the second, whereas length is considered to be independent of time in the ISQ.

3) Recommendations for the realization of all base units and some important derived units are adopted by convention. For the SI such recommendations are adopted by BIPM.

The most common system of quantities today is the International System of Quantities, ISQ, on which the most common system of units today, the SI, is based.

In the invitation to the CGPM, 2011 there is the draft Resolution A concerning the possible future redefinitions of four of the SI base units, i.e. the kilogram (for mass), the ampere (for electric current), the kelvin (for thermodynamic temperature), and the mole (for amount of substance).

<u>Kilogram (symbol kg)</u>
It is proposed that the present definition of the kilogram as the mass of the International Prototype of the kilogram, kept at BIPM, which is evidently not stable, be replaced with a new definition fixing the value of the Planck constant, h, expressed in the coherent derived SI unit joule second, J · s. This is of course possible, but rather implicit and abstract. Such a definition is difficult to understand for high school students who are learning the SI, because they don’t know, what the Planck constant stands for. Maybe even their teachers don’t know that. Therefore we strongly prefer the alternative proposal to define the SI base unit of mass as the mass of a fixed number of ^{12}C atoms, unbound, at rest, and in their ground state. This is by far more explicit and understandable for most people. Thereby the mass of ^{12}C is fixed when expressed in the SI base unit for mass. An additional advantage with the latter definition is that relative atomic masses of all nuclides in the Periodic System are referred to the mass of ^{12}C, thus making them into number-ratios, the simplest way of expressing them.

Ampere (symbol A)
It is proposed that the present definition of the ampere, by which the value of the magnetic constant, μ_0, is fixed expressed in the coherent derived SI unit henry per metre, H/m, be replaced with a new definition, by which the value of the elementary charge, *e*, is fixed expressed in the coherent derived SI unit coulomb, C. This might be confusing, because people could conclude that the electric charge is the base quantity and not the electric current. An even more serious problem with the proposed definition is, however, that you lose fixed values expressed in the coherent derived SI units for four fundamental constants, i.e. except for the magnetic constant, the electric constant, ε_0, the impedance of vacuum, Z_0, and the admittance of vacuum Y_0, but you only gain a fixed value expressed in a coherent derived SI unit for one fundamental constant, i.e. the elementary charge. Since the value of the speed of electromagnetic waves (light) in vacuum, c_0, is fixed expressed in a coherent derived SI unit metre per seconf, m/s, by the definition of the SI base unit for length, metre, m, it follows that $\varepsilon_0 = 1/(\mu_0\, c_0^2)$, $Z_0 = \mu_0\, c_0$, and $Y_0 = 1/(\mu_0\, c_0)$ also have fixed values expressed in coherent derived SI units. I strongly prefer the definition by which the magnetic constant is fixed expressed in an SI unit.

Kelvin (symbol K)
It is proposed that the present definition of the kelvin, by which the value of the thermodynamic temperature of the triple point of water is fixed expressed in the SI base unit kelvin, be replaced with a definition by which the value of the Bolzmann constant is fixed expressed in the coherent derived SI unit joule per kelvin, J/K. This is an improvement, because the triple point of water is really not a fundamental constant, but the Bolzmann constant is. The triple point of water depends on the isotopic composition of the water. We are in favour of the proposed new definition.

Mole (symbol mol)
It is proposed that the present definition of the mole, by which the value of the mass of 1 mol of carbon 12, ^{12}C, atoms, unbound, at rest, and in their ground state, is fixed expressed in the SI base unit kilogram, kg, be replaced with a definition by which the value of the Avogadro constant is fixed expressed in the coherent derived SI unit per mole, mol^{-1}. This proposal has raised much discussion in the chemical society in the world and quite understandably so. We are in favour of the proposed new definition.

Wording of the definitions
Two principal options have been discussed, i.e. the explicit unit definition and the explicit (fundamental) constant definition. The options could be illustrated by the following examples:

Explicit unit definition
Metre, symbol m
The metre is the SI base unit for length; it is equal to the length of the path travelled by light in vacuum during (1/299 792 458) s
Note: This definition implies that the value of the speed of light in vacuum is c_0 := 299 792 458 m/s.

Explicit constant definition
Metre, symbol m
The speed of light in vacuum is c_0 := 299 792 458 m/s; thus the SI base unit for length, the metre, is equal to the length of the path travelled by light in vacuum during (1/299 792 458) s

It is true that the fundamental constants are more fundamental concepts than the SI base units, which are invented by mankind. However, in this context it is the SI base units that are essential, not the fundamental constants. The fundamental constants are in this context only used as tools. We also see a problem with the definition of the SI base unit for luminous intensity, the candela, symbol cd. What fundamental constant is fixed by the definition of the candela? We prefer the explicit unit definitions.

Order of the base quantities in the ISQ and the base units in the SI
The present order of the base quantities in the ISQ and the corresponding base units in the SI are the following:

length	unit metre, m
mass	unit kilogram , kg
time	unit second, s
electric current	unit ampere, A
thermodynamic temperature	unit kelvin, K
amount of substance	unit mole, mol
luminous intensity	unit candela, cd

The ISQ, in which the order of the base quantities is given, is handled by ISO/TC 12 and IEC/TC 25. There is no proposal in ISO or IEC to change the historical order of the base quantities in the ISQ. As stated before the base quantities are considered to be independent of each other, and is thus no ground to change the order in the ISQ. The SI should follow the same order for the corresponding base units. It is true, as also was stated before, but only as step 2) in the creation of a unit system, that the definitions of the base units may depend on each other. Thus, for example, the definition of the SI base unit metre depends on the definition of the SI base unit second. This is, however, no ground to violate the order in the ISQ, which is the step 1) in the creation of system of units. We strongly prefer to keep the present order of the base units on the SI in accordance with the ISQ.

Why fix the values for the Planck constant and the elementary charge?
It has been argued that fixing the values of the Planck constant and the elementary charge is desirable, because then the values of the Josephson constant, $K_J = 2e/h$ and of the von Klitzing constant $R_K = h/e^2$, are also fixed expressed in SI units and can replace the conventional values of the Josephson constant K_{J-90}, and the von Klitzing constant, R_{K-90},. These constants are used to realize the SI coherent derived units volt, V, and ohm, Ω. This is, however, only the third and last step in the creation of a system of units and shall not destroy the structure of the previous two steps, especially step 2). That is why I am not in favour of this proposal as I have said above.

There have been two major schools in the CCU; the system theoreticians, e.g. Ulrich Stille, DE, Jan de Boer, NL, Henning Højgaard-Jensen, DK, Erik Rudberg, SE, and later Max McGlashan, GB (for the mole), who constructed the present SI built on the the MKSA-system proposed by Giovanni Giorgi, IT, in 1901, and developed in IEC by Giorgi and John Wennerberg , SE, and the metrologists, today led by the Chairman of CCU, Ian Mills, GB.

Conclusion
There is not yet a world wide consensus on the new definitions of the SI base units It is therefore very premature to make any recommendations on how to redefine the SI base units.

We strongly propose that the CGPM 2011 decides to invite the CIPM to further study the different options to redefine the base units in the SI and report to the CGPM 2011.

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From the IUPAC Commission on Isotopic Abundances and Atomic Weights the attached comments were sent to the CIPM before the 2011 CGPM.

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Neither the Swedish comments nor the comments from IUPAC were submitted to the CGPM. Instead the planned meeting of the CCU 2012 was cancelled and the next meeting of the CGPM was decided to take place one year earlier then usual, i.e. 2014 instead of 2015. In my opinion this is a classical example of how to block every opposition.

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