Le nouveau système d'unités

Le 20 mai 2019, un nouveau système international d'unités va être mis en place. Il fait une large place à la Mécanique quantique en s'appuyant sur des expériences qui en sont issues. La figure 1 présente une image qui permet de comprendre les associations qui ont été réalisées.

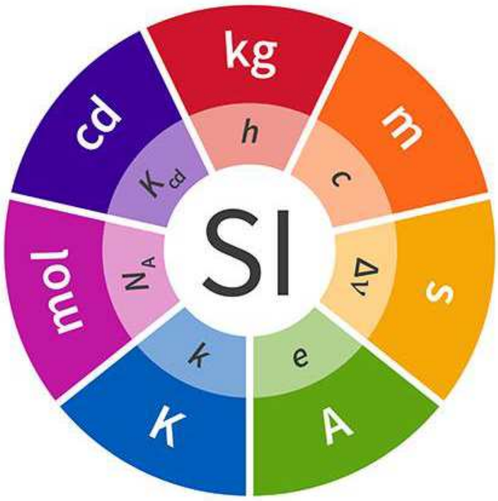

FIGURE 1 – Le nouveau système international d'unités - SI

La Conférence Générale du Bureau International des Poids et Mesures qui s'est déroulée à Versailles en novembre 2018 a fixé des valeurs pour des constantes fondamentales de la Physique. Elle a ensuite fixé 4 nouvelles définitions des unités de base du Système International d'Unités.

1 Grandeurs fixées

Les constantes fondamentales fixées sont données dans la liste suivante :

— the unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{\mathrm{Cs}}$ is $9\,192\,631\,770\,\mathrm{Hz}$,
— the speed of light in vacuum c is $299\,792\,458\,\mathrm{m}\cdot\mathrm{s}^{-1}$,
— the PLANCK constant h is $6,626\,070\,15\times10^{-34}\,\mathrm{J}\cdot\mathrm{s}$,
— the elementary charge e is $1,602\,176\,634\times10^{-19}\,\mathrm{C}$,
— the BOLTZMANN constant k is $1,380\,649\times10^{-23}\,\mathrm{J}\cdot\mathrm{K}^{-1}$,
— the AVOGADRO constant N_A is $6,022\,140\,76\times10^{23}\,\mathrm{mol}^{-1}$,
— the luminous efficacy of monochromatic radiation of frequency $540\times10^{12}\,\mathrm{Hz}$, K_{cd} is $683\,\mathrm{lm/W}$,

where the hertz, joule, coulomb, lumen, and watt, with unit symbols Hz, J, C, lm, and W, respectively, are related to the units second, metre, kilogram, ampere, kelvin, mole, and candela, with unit symbols s, m, kg, A, K, mol, and cd, respectively, according to $\mathrm{Hz}=\mathrm{s}^{-1}$, $\mathrm{J}=\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}$, $\mathrm{C}=\mathrm{A}\cdot\mathrm{s}$, $\mathrm{lm}=\mathrm{cd}\cdot\mathrm{sr}^{-1}$ (candela par unité d'angle solide) and $\mathrm{W}=\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-3}$.

2 Évolution du statut des références précédentes du Système International

It follows from the new definition of the SI described above, and from the recommended values of the 2017 special adjustment of the Committee on Data for Science and Technology (CODATA) on which the values of the defining constants are based, that effective from 20 May 2019 :

— the mass of the international prototype of the kilogram $m(K)$ is equal to $1\,\mathrm{kg}$ within a relative standard uncertainty equal to that of the recommended value of h at the time this Resolution was adopted, namely $1,0 \times 10^{-8}$ and that in the future its value will be determined experimentally,

— the vacuum magnetic permeability μ_0 is equal to $4\pi \times 10^{-7}\,\mathrm{H \cdot m^{-1}}$ within a relative standard uncertainty equal to that of the recommended value of the fine-structure constant a at the time this Resolution was adopted, namely $2,3 \times 10^{-10}$ and that in the future its value will be determined experimentally,

— the thermodynamic temperature of the triple point of water TTPW is equal to $273,16\,\mathrm{K}$ within a relative standard uncertainty closely equal to that of the recommended value of k at the time this Resolution was adopted, namely $3,7 \times 10^{-7}$, and that in the future its value will be determined experimentally,

— the molar mass of carbon 12, $M(^{12}\mathsf{C})$, is equal to $0.012\,\mathrm{kg \cdot mol^{-1}}$ within a relative standard uncertainty equal to that of the recommended value of $N_A h$ at the time this Resolution was adopted, namely$4,5 \times 10^{-10}$, and that in the future its value will be determined experimentally.

3 Les nouvelles définitions

Starting from the new definition of the SI described above in terms of fixed numerical values of the defining constants, definitions of each of the seven base units are deduced by taking, as appropriate, one or more of these defining constants to give the following set of definitions, effective from 20 May 2019 :

— The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{\mathsf{Cs}}$, 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 $\mathrm{s^{-1}}$.

— 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 $\mathrm{m \cdot s^{-1}}$, where the second is defined in terms of $\Delta\nu_{\mathsf{Cs}}$.

— 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 $6,626\,070\,15 \times 10^{-34}$ when expressed in the unit $\mathrm{J \cdot s}$, which is equal to $\mathrm{kg \cdot m^2 \cdot s^{-1}}$, where the metre and the second are defined in terms of c and $\Delta\nu_{\mathsf{Cs}}$.

— 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 $1,602\,176\,634 \times 10^{-19}$ when expressed in the unit C, which is equal to $\mathrm{A \cdot s}$, where the second is defined in terms of $\Delta\nu_{\mathsf{Cs}}$.

— 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 $1,380\,649 \times 10^{-23}$ when expressed in the unit $\mathrm{J \cdot K^{-1}}$, which is equal to $\mathrm{kg \cdot m^2 \cdot s^{-2} \cdot K^{-1}}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{\mathsf{Cs}}$.

— The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6\,022\,140\,76 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit $\mathrm{mol^{-1}}$ 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.

— 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 $540 \times 10^{12}\,\mathrm{Hz}$, K_{cd}, to be 683 when expressed in the unit $\mathrm{lm \cdot W^{-1}}$, which is equal to $\mathrm{cd \cdot sr \cdot W^{-1}}$, or $\mathrm{cd \cdot sr \cdot kg^{-1} \cdot m^{-2} \cdot s^3}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{\mathsf{Cs}}$.