The new SI and fundamental constants

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The International System of Units (SI) is expected to undergo a revolutionary change on May 20, 2019. In October 2017, the International Committee on Weights and Measures met at the International Bureau of Weights and Measures near Paris and recommended a new definition of the SI such that a particular set of constants would have certain values when expressed in the new SI units. In particular, the new SI would be defined by the statement:

The International System of Units, the SI, is the system of units in which

- **the unperturbed ground state hyperfine splitting frequency of the caesium 133 atom ν_{Cs} is 9 192 631 770 Hz,**
- **the speed of light in vacuum c is 299 792 458 m/s,**
- **the Planck constant h is $6.626\,070\,15 \times 10^{-34}$ J/Hz,**
- **the elementary charge e is $1.602\,176\,634 \times 10^{-19}$ C,**
- **the Boltzmann constant k is $1.380\,649 \times 10^{-23}$ J/K,**
- **the Avogadro constant N_A is $6.022\,140\,76 \times 10^{23}$ mol^{-1},**
- **the luminous efficacy K_{cd} of monochromatic radiation of frequency 540×10^{12} hertz is 683 lm/W.**

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The CODATA 2017 values of h, e, k, and N_A for the revision of the SI

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Committee on Data for Science and Technology (CODATA) Task Group on Fundamental Constants

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. . . The redefinition is still on track. **The next event**, which is hopefully only proforma, is a vote at the General Conference on Weights and Measures i**n November** in Versailles, France, in which the 50 something countries agree to endorse the changes.

After that, **the changes are expected to become official on May 20, 2019**. We are going to do the 2018 LSA for the constants using the new SI unit definitions, which as you know will change the constants significantly. We expect to get the new set of constants out at about the same time as the redefinition becomes official.

Best regards,
Peter (e-mail, 9/18/2018)

A couple of comments: Quantities with a mass, such as the Bohr radius, the Rydberg energy, and the Bohr magneton (with $k \equiv 1/4\pi\epsilon_0$),

$$a_\infty = \frac{\hbar^2}{m_e k e^2}, \qquad E_R = \frac{m_e k^2 e^4}{2\hbar^2}, \qquad \mu_B = \frac{e\hbar}{2m_e},$$

will still come with experimental errors. The fine-structure constant,

$$\alpha = \frac{ke^2}{\hbar c},$$

will come with an error too, because now ϵ_0 and μ_0 will now float, subject to the constraint $\epsilon_0\mu_0 = 1/c^2$.

1. Physical Constants

Table 1.1. Reviewed 2015 by P.J. Mohr and D.B. Newell (NIST). Mainly from the "CODATA Recommended Values of the Fundamental Physical Constants: 2014" by P.J. Mohr, D.B. Newell, and B.N. Taylor in arXiv:1507.07956 (2015) and RMP (to be submitted). The last set of constants (beginning with the Fermi coupling constant) comes from the Particle Data Group and is the only set updated for this 2018 edition. The figures in parentheses after the values give the 1-standard-deviation uncertainties in the last digits; the corresponding fractional uncertainties in parts per 10^9 (ppb) are given in the last column. This set of constants (aside from the last group) is recommended for international use by CODATA (the Committee on Data for Science and Technology). The full 2014 CODATA set of constants may be found at `http://physics.nist.gov/constants`. See also P.J. Mohr and D.B. Newell, "Resource Letter FC-1: The Physics of Fundamental Constants," Am. J. Phys. **78**, 338 (2010).

Quantity	Symbol, equation	Value	Uncertainty (ppb)
speed of light in vacuum	c	$299\ 792\ 458$ m s^{-1}	exact*
Planck constant	h	$6.626\ 070\ 040(81)\times10^{-34}$ J s	12
Planck constant, reduced	$\hbar \equiv h/2\pi$	$1.054\ 571\ 800(13)\times10^{-34}$ J s	12
		$= 6.582\ 119\ 514(40)\times10^{-22}$ MeV s	6.1
electron charge magnitude	e	$1.602\ 176\ 6208(98)\times10^{-19}$ C $= 4.803\ 204\ 673(30)\times10^{-10}$ esu	6.1, 6.1
conversion constant	$\hbar c$	$197.326\ 9788(12)$ MeV fm	6.1
conversion constant	$(\hbar c)^2$	$0.389\ 379\ 3656(48)$ GeV^2 mbarn	12
electron mass	m_e	$0.510\ 998\ 9461(31)$ MeV$/c^2 = 9.109\ 383\ 56(11)\times10^{-31}$ kg	6.2, 12
proton mass	m_p	$938.272\ 0813(58)$ MeV$/c^2 = 1.672\ 621\ 898(21)\times10^{-27}$ kg	6.2, 12
		$= 1.007\ 276\ 466\ 879(91)$ u $= 1836.152\ 673\ 89(17)\ m_e$	0.090, 0.095
deuteron mass	m_d	$1875.612\ 928(12)$ MeV$/c^2$	6.2
unified atomic mass unit (u)	(mass ^{12}C atom)$/12 = (1$ g$)/(N_A$ mol$)$	$931.494\ 0954(57)$ MeV$/c^2 = 1.660\ 539\ 040(20)\times10^{-27}$ kg	6.2, 12
permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	$8.854\ 187\ 817\ldots\times10^{-12}$ F m^{-1}	exact
permeability of free space	μ_0	$4\pi\times10^{-7}$ N A$^{-2} = 12.566\ 370\ 614\ldots\times10^{-7}$ N A^{-2}	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	$7.297\ 352\ 5664(17)\times10^{-3} = 1/137.035\ 999\ 139(31)^\dagger$	0.23, 0.23
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	$2.817\ 940\ 3227(19)\times10^{-15}$ m	0.68
(e^- Compton wavelength)$/2\pi$	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	$3.861\ 592\ 6764(18)\times10^{-13}$ m	0.45
Bohr radius ($m_{\text{nucleus}} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	$0.529\ 177\ 210\ 67(12)\times10^{-10}$ m	0.23
wavelength of 1 eV$/c$ particle	$hc/(1$ eV$)$	$1.239\ 841\ 9739(76)\times10^{-6}$ m	6.1
Rydberg energy	$hcR_\infty = m_e e^4/2(4\pi\epsilon_0)^2\hbar^2 = m_e c^2\alpha^2/2$	$13.605\ 693\ 009(84)$ eV	6.1
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	$0.665\ 245\ 871\ 58(91)$ barn	1.4
Bohr magneton	$\mu_B = e\hbar/2m_e$	$5.788\ 381\ 8012(26)\times10^{-11}$ MeV T^{-1}	0.45
nuclear magneton	$\mu_N = e\hbar/2m_p$	$3.152\ 451\ 2550(15)\times10^{-14}$ MeV T^{-1}	0.46
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	$1.758\ 820\ 024(11)\times10^{11}$ rad s^{-1} T^{-1}	6.2
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	$9.578\ 833\ 226(59)\times10^{7}$ rad s^{-1} T^{-1}	6.2
gravitational constant‡	G_N	$6.674\ 08(31)\times10^{-11}$ m^3 kg^{-1} s^{-2}	4.7×10^4
		$= 6.708\ 61(31)\times10^{-39}\ \hbar c$ (GeV$/c^2)^{-2}$	4.7×10^4
standard gravitational accel.	g_N	$9.806\ 65$ m s^{-2}	exact
Avogadro constant	N_A	$6.022\ 140\ 857(74)\times10^{23}$ mol^{-1}	12
Boltzmann constant	k	$1.380\ 648\ 52(79)\times10^{-23}$ J K^{-1}	570
		$= 8.617\ 3303(50)\times10^{-5}$ eV K^{-1}	570
molar volume, ideal gas at STP	$N_A k(273.15$ K$)/(101\ 325$ Pa$)$	$22.413\ 962(13)\times10^{-3}$ m^3 mol^{-1}	570
Wien displacement law constant	$b = \lambda_{\max}T$	$2.897\ 7729(17)\times10^{-3}$ m K	570
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4/60\hbar^3 c^2$	$5.670\ 367(13)\times10^{-8}$ W m^{-2} K^{-4}	2300
Fermi coupling constant**	$G_F/(\hbar c)^3$	$1.166\ 378\ 7(6)\times10^{-5}$ GeV^{-2}	510
weak-mixing angle	$\sin^2\hat\theta(M_Z)$ ($\overline{\text{MS}}$)	$0.231\ 22(4)^{\dagger\dagger}$	1.7×10^5
$W^\pm$ boson mass	m_W	$80.379(12)$ GeV$/c^2$	1.5×10^5
Z^0 boson mass	m_Z	$91.1876(21)$ GeV$/c^2$	2.3×10^4
strong coupling constant	$\alpha_s(m_Z)$	$0.1181(11)$	9.3×10^6

$\pi = 3.141\ 592\ 653\ 589\ 793\ 238$ $\quad$ $e = 2.718\ 281\ 828\ 459\ 045\ 235$ $\quad$ $\gamma = 0.577\ 215\ 664\ 901\ 532\ 861$

1 in $\equiv 0.0254$ m	1 G $\equiv 10^{-4}$ T	1 eV $= 1.602\ 176\ 6208(98)\times10^{-19}$ J	kT at 300 K $= [38.681\ 740(22)]^{-1}$ eV
1 Å $\equiv 0.1$ nm	1 dyne $\equiv 10^{-5}$ N	1 eV$/c^2 = 1.782\ 661\ 907(11)\times10^{-36}$ kg	0 °C $\equiv 273.15$ K
1 barn $\equiv 10^{-28}$ m^2	1 erg $\equiv 10^{-7}$ J	$2.997\ 924\ 58\times10^9$ esu $= 1$ C	1 atmosphere $\equiv 760$ Torr $\equiv 101\ 325$ Pa

* The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

† At $Q^2 = 0$. At $Q^2 \approx m_W^2$ the value is $\sim 1/128$.

‡ Absolute lab measurements of G_N have been made only on scales of about 1 cm to 1 m.

** See the discussion in Sec. 10, "Electroweak model and constraints on new physics."

†† The corresponding $\sin^2\theta$ for the effective angle is 0.23155(4).

What does it mean for the Review?

We get values of masses and magnetic moments of the electron, muon, proton, and neutron, straight from the latest CODATA publication, so could expect some small changes.

Otherwise, I don't see how this will affect any of the particle properties. Perhaps it is of concern in a review or two.

Of course, it represents a big change in how we think about what the constants **are**, just as the definition of c as a fixed number did 35 years ago.