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 group of constants (beginning with the Fermi coupling constant) comes from the Particle Data Group. 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 ... $\times10^{-12}$ F m^{-1}	exact
permeability of free space	μ_0	$4\pi \times 10^{-7}$ N A^{-2} = 12.566 370 614 ... $\times10^{-7}$ 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)†	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)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	3.861 592 6764(18)$\times10^{-13}$ m	0.45
Bohr radius ($m_{\rm nucleus} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	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	$\omega^e_{\rm cycl}/B = e/m_e$	1.758 820 024(11)$\times10^{11}$ rad s^{-1} T^{-1}	6.2
proton cyclotron freq./field	$\omega^p_{\rm cycl}/B = e/m_p$	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	$b = \lambda_{\rm max}T$	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}	500
weak-mixing angle	$\sin^2\widehat{\theta}(M_Z)$ ($\overline{\rm MS}$)	0.231 29(5)††	2.2×10^5
$W^\pm$ boson mass	m_W	80.385(15) GeV/c^2	1.9×10^5
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)	1.0×10^7

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

1 in $\equiv$ 0.0254 m	1 G $\equiv 10^{-4}$ T	1 eV = 1.602 176 6208(98) $\times 10^{-19}$ 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) $\times 10^{-36}$ kg	0 °C $\equiv$ 273.15 K
1 barn $\equiv 10^{-28}$ m^2	1 erg $\equiv 10^{-7}$ J	2.997 924 58 $\times 10^9$ 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(5).