1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2013 by P.J. Mohr (NIST). Mainly from the "CODATA Recommended Values of the Fundamental Physical Constants: 2010" by P.J. Mohr, B.N. Taylor, and D.B. Newell in Rev. Mod. Phys. **84**, 1527 (2012). 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 2010 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	6.626 069 57(29)$\times10^{-34}$ J s	44
Planck constant, reduced	$\hbar \equiv h/2\pi$	1.054 571 726(47)$\times10^{-34}$ J s	44
		= 6.582 119 28(15)$\times10^{-22}$ MeV s	22
electron charge magnitude	e	1.602 176 565(35)$\times10^{-19}$ C = 4.803 204 50(11)$\times10^{-10}$ esu	22, 22
conversion constant	$\hbar c$	197.326 9718(44) MeV fm	22
conversion constant	$(\hbar c)^2$	0.389 379 338(17) GeV^2 mbarn	44
electron mass	m_e	0.510 998 928(11) MeV/c^2 = 9.109 382 91(40)$\times10^{-31}$ kg	22, 44
proton mass	m_p	938.272 046(21) MeV/c^2 = 1.672 621 777(74)$\times10^{-27}$ kg	22, 44
		= 1.007 276 466 812(90) u = 1836.152 672 45(75) m_e	0.089, 0.41
deuteron mass	m_d	1875.612 859(41) MeV/c^2	22
unified atomic mass unit (u)	(mass ^{12}C atom)/12 = (1 g)/(N_A mol)	931.494 061(21) MeV/c^2 = 1.660 538 921(73)$\times10^{-27}$ kg	22, 44
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	$4\pi\times10^{-7}$ 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 5698(24)$\times10^{-3}$ = 1/137.035 999 074(44)†	0.32, 0.32
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 3267(27)$\times10^{-15}$ m	0.97
(e^- Compton wavelength)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	3.861 592 6800(25)$\times10^{-13}$ m	0.65
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 92(17)$\times10^{-10}$ m	0.32
wavelength of 1 eV/c particle	$hc/(1\text{ eV})$	1.239 841 930(27)$\times10^{-6}$ m	22
Rydberg energy	$hcR_\infty = m_e e^4/2(4\pi\epsilon_0)^2\hbar^2 = m_e c^2\alpha^2/2$	13.605 692 53(30) eV	22
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 245 8734(13) barn	1.9
Bohr magneton	$\mu_B = e\hbar/2m_e$	5.788 381 8066(38)$\times10^{-11}$ MeV T^{-1}	0.65
nuclear magneton	$\mu_N = e\hbar/2m_p$	3.152 451 2605(22)$\times10^{-14}$ MeV T^{-1}	0.71
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	1.758 820 088(39)$\times10^{11}$ rad s^{-1} T^{-1}	22
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	9.578 833 58(21)$\times10^{7}$ rad s^{-1} T^{-1}	22
gravitational constant‡	G_N	6.673 84(80)$\times10^{-11}$ m^3 kg^{-1} s^{-2}	1.2×10^5
		= 6.708 37(80)$\times10^{-39}$ $\hbar c$ $(GeV/c^2)^{-2}$	1.2×10^5
standard gravitational accel.	g_N	9.806 65 m s^{-2}	exact
Avogadro constant	N_A	6.022 141 29(27)$\times10^{23}$ mol^{-1}	44
Boltzmann constant	k	1.380 6488(13)$\times10^{-23}$ J K^{-1}	910
		= 8.617 3324(78)$\times10^{-5}$ eV K^{-1}	910
molar volume, ideal gas at STP	$N_A k$(273.15 K)/(101 325 Pa)	22.413 968(20)$\times10^{-3}$ m^3 mol^{-1}	910
Wien displacement law constant	$b = \lambda_{\text{max}}T$	2.897 7721(26)$\times10^{-3}$ m K	910
Stefan-Boltzmann constant	$\sigma = \pi^2k^4/60\hbar^3c^2$	5.670 373(21)$\times10^{-8}$ W m^{-2} K^{-4}	3600
Fermi coupling constant**	$G_F/(\hbar c)^3$	1.166 378 7(6)$\times10^{-5}$ GeV^{-2}	500
weak-mixing angle	$\sin^2\widehat{\theta}(M_Z)$ ($\overline{\text{MS}}$)	0.231 26(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	$\alpha_s(m_Z)$	0.1185(6)	5.1×10^6

π = 3.141 592 653 589 793 238 e = 2.718 281 828 459 045 235 γ = 0.577 215 664 901 532 861

1 in ≡ 0.0254 m	1 G ≡ 10^{-4} T	1 eV = 1.602 176 565(35) × 10^{-19} J	kT at 300 K = $[38.681\ 731(35)]^{-1}$ eV
1 Å ≡ 0.1 nm	1 dyne ≡ 10^{-5} N	1 eV/c^2 = 1.782 661 845(39) × 10^{-36} kg	0 °C ≡ 273.15 K
1 barn ≡ 10^{-28} m^2	1 erg ≡ 10^{-7} J	2.997 924 58 × 10^9 esu = 1 C	1 atmosphere ≡ 760 Torr ≡ 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 ∼ 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).