1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2004 by P.J. Mohr and B.N. Taylor (NIST). Based mainly on the "CODATA Recommended Values of the Fundamental Physical Constants: 2002" by P.J. Mohr and B.N. Taylor, to be published in 2004. 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 2002 CODATA set of constants may be found at `http://physics.nist.gov/constants`

Quantity	Symbol, equation	Value	Uncertainty (ppb)
speed of light in vacuum	c	299 792 458 m s^{-1}	exact*
Planck constant	h	6.626 0693(11)$\times 10^{-34}$ J s	170
Planck constant, reduced	$\hbar \equiv h/2\pi$	1.054 571 68(18)$\times 10^{-34}$ J s	170
		= 6.582 119 15(56)$\times 10^{-22}$ MeV s	85
electron charge magnitude	e	1.602 176 53(14)$\times 10^{-19}$ C = 4.803 204 41(41)$\times 10^{-10}$ esu	85, 85
conversion constant	$\hbar c$	197.326 968(17) MeV fm	85
conversion constant	$(\hbar c)^2$	0.389 379 323(67) GeV^2 mbarn	170
electron mass	m_e	0.510 998 918(44) MeV/c^2 = 9.109 3826(16)$\times 10^{-31}$ kg	86, 170
proton mass	m_p	938.272 029(80) MeV/c^2 = 1.672 621 71(29)$\times 10^{-27}$ kg	86, 170
		= 1.007 276 466 88(13) u = 1836.152 672 61(85) m_e	0.13, 0.46
deuteron mass	m_d	1875.612 82(16) MeV/c^2	86
unified atomic mass unit (u)	(mass ^{12}C atom)/12 = (1 g)/(N_A mol)	931.494 043(80) MeV/c^2 = 1.660 538 86(28)$\times 10^{-27}$ kg	86, 170
permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	8.854 187 817 ... $\times 10^{-12}$ F m^{-1}	exact
permeability of free space	μ_0	$4\pi \times 10^{-7}$ N A^{-2} = 12.566 370 614 ... $\times 10^{-7}$ N A^{-2}	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	7.297 352 568(24)$\times 10^{-3}$ = 1/137.035 999 11(46)†	3.3, 3.3
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 325(28)$\times 10^{-15}$ m	10
(e^- Compton wavelength)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e \alpha^{-1}$	3.861 592 678(26)$\times 10^{-13}$ m	6.7
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 2108(18)$\times 10^{-10}$ m	3.3
wavelength of 1 eV/c particle	$hc/(1\ \text{eV})$	1.239 841 91(11)$\times 10^{-6}$ m	85
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 6923(12) eV	85
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 245 873(13) barn	20
Bohr magneton	$\mu_B = e\hbar/2m_e$	5.788 381 804(39)$\times 10^{-11}$ MeV T^{-1}	6.7
nuclear magneton	$\mu_N = e\hbar/2m_p$	3.152 451 259(21)$\times 10^{-14}$ MeV T^{-1}	6.7
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	1.758 820 12(15)$\times 10^{11}$ rad s^{-1} T^{-1}	86
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	9.578 833 76(82)$\times 10^{7}$ rad s^{-1} T^{-1}	86
gravitational constant‡	G_N	6.6742(10)$\times 10^{-11}$ m^3 kg^{-1} s^{-2}	1.5×10^5
		= 6.7087(10)$\times 10^{-39}$ $\hbar c$ (GeV/c^2)$^{-2}$	1.5×10^5
standard gravitational accel.	g_n	9.806 65 m s^{-2}	exact
Avogadro constant	N_A	6.022 1415(10)$\times 10^{23}$ mol^{-1}	170
Boltzmann constant	k	1.380 6505(24)$\times 10^{-23}$ J K^{-1}	1800
		= 8.617 343(15)$\times 10^{-5}$ eV K^{-1}	1800
molar volume, ideal gas at STP	$N_A k$(273.15 K)/(101 325 Pa)	22.413 996(39)$\times 10^{-3}$ m^3 mol^{-1}	1700
Wien displacement law constant	$b = \lambda_{\max} T$	2.897 7685(51)$\times 10^{-3}$ m K	1700
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4/60\hbar^3 c^2$	5.670 400(40)$\times 10^{-8}$ W m^{-2} K^{-4}	7000
Fermi coupling constant**	$G_F/(\hbar c)^3$	1.166 37(1)$\times 10^{-5}$ GeV^{-2}	9000
weak-mixing angle	$\sin^2\hat{\theta}(M_Z)$ ($\overline{\text{MS}}$)	0.23120(15)††	6.5×10^5
$W^\pm$ boson mass	m_W	80.425(38) GeV/c^2	4.8×10^5
Z^0 boson mass	m_Z	91.1876(21) GeV/c^2	2.3×10^4
strong coupling constant	$\alpha_s(m_Z)$	0.1187(20)	1.7×10^7

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 $\equiv$ 0.0254 m	1 G $\equiv 10^{-4}$ T	1 eV = 1.602 176 53(14) $\times 10^{-19}$ J	kT at 300 K = [38.681 684(68)]$^{-1}$ eV
1 Å $\equiv$ 0.1 nm	1 dyne $\equiv 10^{-5}$ N	1 eV/c^2 = 1.782 661 81(15) $\times 10^{-36}$ 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 0.23149(15).