1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2002 by P.J. Mohr and B.N. Taylor (NIST). Based mainly on the "CODATA Recommended Values of the Fundamental Physical Constants: 1998" by P.J. Mohr and B.N. Taylor, J. Phys. Chem. Ref. Data **28**, 1713 (1999) and Rev. Mod. Phys. **72**, 351 (2000). 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 1998 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	6.626 068 76(52)$\times 10^{-34}$ J s	78
Planck constant, reduced	$\hbar \equiv h/2\pi$	1.054 571 596(82)$\times 10^{-34}$ J s	78
		= 6.582 118 89(26)$\times 10^{-22}$ MeV s	39
electron charge magnitude	e	1.602 176 462(63)$\times 10^{-19}$ C = 4.803 204 20(19)$\times 10^{-10}$ esu	39, 39
conversion constant	$\hbar c$	197.326 960 2(77) MeV fm	39
conversion constant	$(\hbar c)^2$	0.389 379 292(30) GeV^2 mbarn	78
electron mass	m_e	0.510 998 902(21) MeV/c^2 = 9.109 381 88(72)$\times 10^{-31}$ kg	40, 79
proton mass	m_p	938.271 998(38) MeV/c^2 = 1.672 621 58(13)$\times 10^{-27}$ kg	40, 79
		= 1.007 276 466 88(13) u = 1836.152 667 5(39) m_e	0.13, 2.1
deuteron mass	m_d	1875.612 762(75) MeV/c^2	40
unified atomic mass unit (u)	(mass ^{12}C atom)/12 = (1 g)/(N_A mol)	931.494 013(37) MeV/c^2 = 1.660 538 73(13)$\times 10^{-27}$ kg	40, 79
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	$\alpha = e^2/4\pi\epsilon_0\hbar c$	7.297 352 533(27)$\times 10^{-3}$ = 1/137.035 999 76(50)†	3.7, 3.7
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 285(31)$\times 10^{-15}$ m	11
(e^- Compton wavelength)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e \alpha^{-1}$	3.861 592 642(28)$\times 10^{-13}$ m	7.3
Bohr radius ($m_{\text{nucleus}} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	0.529 177 208 3(19)$\times 10^{-10}$ m	3.7
wavelength of 1 eV/c particle	$hc/(1\text{ eV})$	1.239 841 857(49)$\times 10^{-6}$ m	39
Rydberg energy	$hcR_\infty = m_e e^4/2(4\pi\epsilon_0)^2\hbar^2 = m_e c^2\alpha^2/2$	13.605 691 72(53) eV	39
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 245 854(15) barn	22
Bohr magneton	$\mu_B = e\hbar/2m_e$	5.788 381 749(43)$\times 10^{-11}$ MeV T^{-1}	7.3
nuclear magneton	$\mu_N = e\hbar/2m_p$	3.152 451 238(24)$\times 10^{-14}$ MeV T^{-1}	7.6
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	1.758 820 174(71)$\times 10^{11}$ rad s^{-1} T^{-1}	40
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	9.578 834 08(38)$\times 10^{7}$ rad s^{-1} T^{-1}	40
gravitational constant‡	G_N	6.673(10)$\times 10^{-11}$ m^3 kg^{-1} s^{-2}	1.5×10^6
		= 6.707(10)$\times 10^{-39}$ $\hbar c$ (GeV/c^2)$^{-2}$	1.5×10^6
standard gravitational accel.	g_n	9.806 65 m s^{-2}	exact
Avogadro constant	N_A	6.022 141 99(47)$\times 10^{23}$ mol^{-1}	79
Boltzmann constant	k	1.380 650 3(24)$\times 10^{-23}$ J K^{-1}	1700
		= 8.617 342(15)$\times 10^{-5}$ eV K^{-1}	1700
molar volume, ideal gas at STP	$N_A k(273.15\text{ K})/(101\ 325\text{ Pa})$	22.413 996(39)$\times 10^{-3}$ m^3 mol^{-1}	1700
Wien displacement law constant	$b = \lambda_{\max} T$	2.897 768 6(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 39(1)$\times 10^{-5}$ GeV^{-2}	9000
weak-mixing angle	$\sin^2\widehat{\theta}(M_Z)$ ($\overline{\text{MS}}$)	0.23113(15)††	6.5×10^5
$W^\pm$ boson mass	m_W	80.423(39) 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	$\alpha_s(m_Z)$	0.1172(20)	1.7×10^7

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

1 in ≡ 0.0254 m	1 G ≡ 10^{-4} T	1 eV = 1.602 176 462(63) $\times 10^{-19}$ J	kT at 300 K = [38.681 686(67)]$^{-1}$ eV
1 Å ≡ 0.1 nm	1 dyne ≡ 10^{-5} N	1 eV/c^2 = 1.782 661 731(70) $\times 10^{-36}$ kg	0 °C ≡ 273.15 K
1 barn ≡ 10^{-28} m^2	1 erg ≡ 10^{-7} J	2.997 924 58 $\times 10^9$ 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 $\sim 1/128$.

‡ 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 0.23143(15).