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	$\epsilon_0 = 1/\mu_0 c^2$	$8.854\,187\,817\ldots\times 10^{-12}$ F m^{-1}	exact
permeability of free space	μ_0	$4\pi\times 10^{-7}$ N A^{-2} $= 12.566\,370\,614\ldots\times 10^{-7}$ N A^{-2}	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	$7.297\,352\,533(27)\times 10^{-3} = 1/137.035\,999\,76(50)^{\dagger}$	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	$\lambdabar_e = \hbar/m_e c = r_e\alpha^{-1}$	$3.861\,592\,642(28)\times 10^{-13}$ 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
		$= 6.707(10)\times 10^{-39}\ \hbar c\ (\text{GeV}/c^2)^{-2}$	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	$\sigma = \pi^2k^4/60\hbar^3c^2$	$5.670\,400(40)\times 10^{-8}$ 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	$\sin^2\widehat{\theta}(M_Z)\ (\overline{\text{MS}})$	$0.23113(15)^{\dagger\dagger}$	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

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

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).