1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2010 by P.J. Mohr (NIST). Mainly from the "CODATA Recommended Values of the Fundamental Physical Constants: 2006" by P.J. Mohr, B.N. Taylor, and D.B. Newell in Rev. Mod. Phys. **80** (2008) 633. 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 2006 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** (2010) 338.

Quantity	Symbol, equation	Value	Uncertainty (ppb)
speed of light in vacuum	c	299 792 458 m s^{-1}	exact*
Planck constant	h	$6.626\ 068\ 96(33)\times10^{-34}$ J s	50
Planck constant, reduced	$\hbar \equiv h/2\pi$	$1.054\ 571\ 628(53)\times10^{-34}$ J s	50
		$= 6.582\ 118\ 99(16)\times10^{-22}$ MeV s	25
electron charge magnitude	e	$1.602\ 176\ 487(40)\times10^{-19}$ C $= 4.803\ 204\ 27(12)\times10^{-10}$ esu	25, 25
conversion constant	$\hbar c$	197.326 9631(49) MeV fm	25
conversion constant	$(\hbar c)^2$	0.389 379 304(19) GeV^2 mbarn	50
electron mass	m_e	$0.510\ 998\ 910(13)\ \text{MeV}/c^2 = 9.109\ 382\ 15(45)\times10^{-31}$ kg	25, 50
proton mass	m_p	$938.272\ 013(23)\ \text{MeV}/c^2 = 1.672\ 621\ 637(83)\times10^{-27}$ kg	25, 50
		$= 1.007\ 276\ 466\ 77(10)\ \text{u} = 1836.152\ 672\ 47(80)\ m_e$	0.10, 0.43
deuteron mass	m_d	$1875.612\ 793(47)\ \text{MeV}/c^2$	25
unified atomic mass unit (u)	(mass ^{12}C atom)/12 = (1 g)/(N_A mol)	$931.494\ 028(23)\ \text{MeV}/c^2 = 1.660\ 538\ 782(83)\times10^{-27}$ kg	25, 50
permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	$8.854\ 187\ 817\ldots\times10^{-12}\ \text{F m}^{-1}$	exact
permeability of free space	μ_0	$4\pi\times10^{-7}\ \text{N A}^{-2} = 12.566\ 370\ 614\ldots\times10^{-7}\ \text{N A}^{-2}$	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	$7.297\ 352\ 5376(50)\times10^{-3} = 1/137.035\ 999\ 679(94)^{\dagger}$	0.68, 0.68
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	$2.817\ 940\ 2894(58)\times10^{-15}$ m	2.1
(e^- Compton wavelength)/2π	$\lambda\!\!\!^{-}_e = \hbar/m_e c = r_e\alpha^{-1}$	$3.861\ 592\ 6459(53)\times10^{-13}$ m	1.4
Bohr radius ($m_{\text{nucleus}} = \infty$)	$a_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2 = r_e\alpha^{-2}$	$0.529\ 177\ 208\ 59(36)\times10^{-10}$ m	0.68
wavelength of 1 eV/c particle	$hc/(1\ \text{eV})$	$1.239\ 841\ 875(31)\times10^{-6}$ m	25
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 93(34) eV	25
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 245 8558(27) barn	4.1
Bohr magneton	$\mu_B = e\hbar/2m_e$	$5.788\ 381\ 7555(79)\times10^{-11}\ \text{MeV T}^{-1}$	1.4
nuclear magneton	$\mu_N = e\hbar/2m_p$	$3.152\ 451\ 2326(45)\times10^{-14}\ \text{MeV T}^{-1}$	1.4
electron cyclotron freq./field	$\omega^e_{\text{cycl}}/B = e/m_e$	$1.758\ 820\ 150(44)\times10^{11}\ \text{rad s}^{-1}\ \text{T}^{-1}$	25
proton cyclotron freq./field	$\omega^p_{\text{cycl}}/B = e/m_p$	$9.578\ 833\ 92(24)\times10^{7}\ \text{rad s}^{-1}\ \text{T}^{-1}$	25
gravitational constant‡	G_N	$6.674\ 28(67)\times10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	1.0×10^5
		$= 6.708\ 81(67)\times10^{-39}\ \hbar c\ (\text{GeV}/c^2)^{-2}$	1.0×10^5
standard gravitational accel.	g_N	$9.806\ 65\ \text{m s}^{-2}$	exact
Avogadro constant	N_A	$6.022\ 141\ 79(30)\times10^{23}\ \text{mol}^{-1}$	50
Boltzmann constant	k	$1.380\ 6504(24)\times10^{-23}\ \text{J K}^{-1}$	1700
		$= 8.617\ 343(15)\times10^{-5}\ \text{eV K}^{-1}$	1700
molar volume, ideal gas at STP	$N_A k$(273.15 K)/(101 325 Pa)	$22.413\ 996(39)\times10^{-3}\ \text{m}^3\ \text{mol}^{-1}$	1700
Wien displacement law constant	$b = \lambda_{\max}T$	$2.897\ 7685(51)\times10^{-3}$ m K	1700
Stefan-Boltzmann constant	$\sigma = \pi^2k^4/60\hbar^3c^2$	$5.670\ 400(40)\times10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	7000
Fermi coupling constant**	$G_F/(\hbar c)^3$	$1.166\ 37(1)\times10^{-5}\ \text{GeV}^{-2}$	9000
weak-mixing angle	$\sin^2\widehat{\theta}(M_Z)$ ($\overline{\text{MS}}$)	$0.231\ 16(13)^{\dagger\dagger}$	5.6×10^5
$W^\pm$ boson mass	m_W	80.399(23) GeV/c^2	2.9×10^5
Z^0 boson mass	m_Z	91.1876(21) GeV/c^2	2.3×10^4
strong coupling constant	$\alpha_s(m_Z)$	0.1184(7)	5.9×10^6

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

1 in ≡ 0.0254 m	$1\ \text{G} \equiv 10^{-4}$ T	$1\ \text{eV} = 1.602\ 176\ 487(40)\times10^{-19}$ J	kT at 300 K $= [38.681\ 685(68)]^{-1}$ eV
1 Å ≡ 0.1 nm	$1\ \text{dyne} \equiv 10^{-5}$ N	$1\ \text{eV}/c^2 = 1.782\ 661\ 758(44)\times10^{-36}$ kg	0 °C ≡ 273.15 K
$1\ \text{barn} \equiv 10^{-28}\ \text{m}^2$	$1\ \text{erg} \equiv 10^{-7}$ J	$2.997\ 924\ 58\times10^9$ 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 0.23146(12).