

1. PHYSICAL CONSTANTS

Table 1.1. Reviewed 2007 by P.J. Mohr and B.N. Taylor (NIST). Based mainly on the “CODATA Recommended Values of the Fundamental Physical Constants: 2006” by P.J. Mohr, B.N. Taylor, and D.B. Newell (to be published in Rev. Mod. Phys. and J. Phys. Chem. Ref. Data). 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 10⁹ (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>.

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) × 10 ⁻³⁴ J s	50
Planck constant, reduced	$\hbar \equiv h/2\pi$	1.054 571 628(53) × 10 ⁻³⁴ J s = 6.582 118 99(16) × 10 ⁻²² MeV s	50 25
electron charge magnitude	e	1.602 176 487(40) × 10 ⁻¹⁹ C = 4.803 204 27(12) × 10 ⁻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) MeV/c ² = 9.109 382 15(45) × 10 ⁻³¹ kg	25, 50
proton mass	m_p	938.272 013(23) MeV/c ² = 1.672 621 637(83) × 10 ⁻²⁷ kg = 1.007 276 466 77(10) u = 1836.152 672 47(80) m_e	25, 50 0.10, 0.43
deuteron mass	m_d	1875.612 793(47) MeV/c ²	25
unified atomic mass unit (u)	(mass ¹² C atom)/12 = (1 g)/(N _A mol)	931.494 028(23) MeV/c ² = 1.660 538 782(83) × 10 ⁻²⁷ kg	25, 50
permittivity of free space	$\epsilon_0 = 1/\mu_0 c^2$	8.854 187 817 ... × 10 ⁻¹² F m ⁻¹	exact
permeability of free space	μ_0	4π × 10 ⁻⁷ N A ⁻² = 12.566 370 614 ... × 10 ⁻⁷ N A ⁻²	exact
fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	7.297 352 5376(50) × 10 ⁻³ = 1/137.035 999 679(94) [†]	0.68, 0.68
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 2894(58) × 10 ⁻¹⁵ m	2.1
(e ⁻ Compton wavelength)/2π	$\lambda_e = \hbar/m_e c = r_e \alpha^{-1}$	3.861 592 6459(53) × 10 ⁻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) × 10 ⁻¹⁰ m	0.68
wavelength of 1 eV/c particle	$\hbar c/(1 \text{ eV})$	1.239 841 875(31) × 10 ⁻⁶ m	25
Rydberg energy	$\hbar c R_\infty = m_e e^4 / 2(4\pi\epsilon_0)^2 \hbar^2 = m_e c^2 \alpha^2 / 2$	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) × 10 ⁻¹¹ MeV T ⁻¹	1.4
nuclear magneton	$\mu_N = e\hbar/2m_p$	3.152 451 2326(45) × 10 ⁻¹⁴ MeV T ⁻¹	1.4
electron cyclotron freq./field	$\omega_{\text{cycl}}^e / B = e/m_e$	1.758 820 150(44) × 10 ¹¹ rad s ⁻¹ T ⁻¹	25
proton cyclotron freq./field	$\omega_{\text{cycl}}^p / B = e/m_p$	9.578 833 92(24) × 10 ⁷ rad s ⁻¹ T ⁻¹	25
gravitational constant [‡]	G_N	6.674 28(67) × 10 ⁻¹¹ m ³ kg ⁻¹ s ⁻² = 6.708 81(67) × 10 ⁻³⁹ $\hbar c$ (GeV/c ²) ⁻²	1.0 × 10 ⁵ 1.0 × 10 ⁵
standard gravitational accel.	g_N	9.806 65 m s ⁻²	exact
Avogadro constant	N_A	6.022 141 79(30) × 10 ²³ mol ⁻¹	50
Boltzmann constant	k	1.380 6504(24) × 10 ⁻²³ J K ⁻¹ = 8.617 343(15) × 10 ⁻⁵ eV K ⁻¹	1700 1700
molar volume, ideal gas at STP	$N_A k(273.15 \text{ K}) / (101 325 \text{ Pa})$	22.413 996(39) × 10 ⁻³ m ³ mol ⁻¹	1700
Wien displacement law constant	$b = \lambda_{\text{max}} T$	2.897 7685(51) × 10 ⁻³ m K	1700
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4 / 60 \hbar^3 c^2$	5.670 400(40) × 10 ⁻⁸ W m ⁻² K ⁻⁴	7000
Fermi coupling constant**	$G_F / (\hbar c)^3$	1.166 37(1) × 10 ⁻⁵ GeV ⁻²	9000
weak-mixing angle	$\sin^2 \hat{\theta}(M_Z)$ ($\overline{\text{MS}}$)	0.231 19(14) ^{††}	6.5 × 10 ⁵
W [±] boson mass	m_W	80.398(25) GeV/c ²	3.6 × 10 ⁵
Z ⁰ boson mass	m_Z	91.1876(21) GeV/c ²	2.3 × 10 ⁴
strong coupling constant	$\alpha_s(m_Z)$	0.1176(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 = 1.602 176 487(40) × 10 ⁻¹⁹ J	kT at 300 K = [38.681 685(68)] ⁻¹ eV
1 Å ≡ 0.1 nm 1 dyne ≡ 10 ⁻⁵ N		1 eV/c ² = 1.782 661 758(44) × 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 $\sim 1/128$.

‡ 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(13).