Appendix 1

Table of fundamental physical constants

[From Particle Data Group; *Phys. Lett.* **B592** (2004) 1–1109; *J. Phys.* **G33** (2006) 1–1232; P.J. Mohr & B.N. Taylor, CODATA Recommended Values of the Fundamental Constants: 2002, *Rev. Mod. Phys.* **77** (2005) 1–107; B.N. Taylor & E.R. Cohen, *J. Res. Nat. Inst. Standards and Technology* **95** (1990) 497–523; R.C. Weast & M.J. Astle (eds.), *Handbook of Chemistry and Physics*, CRC Press, Boca Raton, Florida (1973).]

Speed of light*	c	$299\,792\,458\,\mathrm{m/s}$
Planck's constant	h	$6.626\,069\,3 \cdot 10^{-34}\,\mathrm{J\,s}$ $\pm 0.000\,001\,1 \cdot 10^{-34}\,\mathrm{J\,s}$
Planck's constant, reduced	$\hbar = \dfrac{h}{2\pi}$	$1.054\,571\,68 \cdot 10^{-34}\,\mathrm{J\,s}$ $\pm 0.000\,000\,18 \cdot 10^{-34}\,\mathrm{J\,s}$ $= 6.582\,119\,15 \cdot 10^{-22}\,\mathrm{MeV\,s}$ $\pm 0.000\,000\,56 \cdot 10^{-22}\,\mathrm{MeV\,s}$
Electron charge†	e	$1.602\,176\,53 \cdot 10^{-19}\,\mathrm{C}$ $\pm 0.000\,000\,14 \cdot 10^{-19}\,\mathrm{C}$ $= 4.803\,204\,41 \cdot 10^{-10}\,\mathrm{esu}$ $\pm 0.000\,000\,41 \cdot 10^{-10}\,\mathrm{esu}$
Gravitational constant	G	$6.674\,2 \cdot 10^{-11}\,\mathrm{m^3/(kg\,s^2)}$ $\pm 0.001\,0 \cdot 10^{-11}\,\mathrm{m^3/(kg\,s^2)}$

* The value of the velocity of light forms the basis for the definition of the length unit, the metre. 1 m is now defined to be the distance travelled by light in 1/299 792 458 s. The quoted value for the speed of light is therefore exact and without error.

† esu = electrostatic charge unit.

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Avogadro number	N_A	$6.022\,141\,5 \cdot 10^{23}\,\mathrm{mol}^{-1}$ $\pm 0.000\,001\,0 \cdot 10^{23}\,\mathrm{mol}^{-1}$
Boltzmann constant	k	$1.380\,650\,5 \cdot 10^{-23}\,\mathrm{J/K}$ $\pm 0.000\,002\,4 \cdot 10^{-23}\,\mathrm{J/K}$
Molar gas constant	$R(= kN_A)$	$8.314\,473\,\mathrm{J/(K\,mol)}$ $\pm 0.000\,014\,\mathrm{J/(K\,mol)}$
Molar volume, ideal gas at STP‡	V_{mol}	$22.413\,996 \cdot 10^{-3}\,\mathrm{m^3/mol}$ $\pm 0.000\,039 \cdot 10^{-3}\,\mathrm{m^3/mol}$
Permittivity of free space§	$\varepsilon_0 = 1/\mu_0 c^2$	$8.854\,187\,817\,\ldots \cdot 10^{-12}\,\mathrm{F/m}$
Permeability of free space	μ_0	$4\pi \cdot 10^{-7}\,\mathrm{N/A^2}$ $= 12.566\,370\,614\,\ldots \cdot 10^{-7}\,\mathrm{N/A^2}$
Stefan–Boltzmann constant	$\sigma = \dfrac{\pi^2 k^4}{60\,\hbar^3 c^2}$	$5.670\,400 \cdot 10^{-8}\,\mathrm{W/\left(m^2\,K^4\right)}$ $\pm 0.000\,040 \cdot 10^{-8}\,\mathrm{W/\left(m^2\,K^4\right)}$
Electron mass	m_e	$0.510\,998\,918\,\mathrm{MeV}/c^2$ $\pm 0.000\,000\,044\,\mathrm{MeV}/c^2$ $= 9.109\,382\,6 \cdot 10^{-31}\,\mathrm{kg}$ $\pm 0.000\,001\,6 \cdot 10^{-31}\,\mathrm{kg}$
Proton mass	m_p	$938.272\,029\,\mathrm{MeV}/c^2$ $\pm 0.000\,080\,\mathrm{MeV}/c^2$ $= 1.672\,621\,71 \cdot 10^{-27}\,\mathrm{kg}$ $\pm 0.000\,000\,29 \cdot 10^{-27}\,\mathrm{kg}$
Unified atomic mass unit (u)	$(1\,\mathrm{g}/N_A)$	$931.494\,043\,\mathrm{MeV}/c^2$ $\pm 0.000\,080\,\mathrm{MeV}/c^2$ $= 1.660\,538\,86 \cdot 10^{-27}\,\mathrm{kg}$ $\pm 0.000\,000\,28 \cdot 10^{-27}\,\mathrm{kg}$
Charge-to-mass ratio of the electron	e/m_e	$1.758\,820\,11 \cdot 10^{11}\,\mathrm{C/kg}$ $\pm 0.000\,000\,20 \cdot 10^{11}\,\mathrm{C/kg}$

‡ Standard temperature and pressure ($0\,°\mathrm{C} \mathrel{\widehat{=}} 273.15\,\mathrm{K}$ and $1\,\mathrm{atm} = 101\,325\,\mathrm{Pa}$).

§ Because of the fact that the velocity of light c is without error by definition, and because μ_0 is defined to be $\mu_0 = 4\pi \cdot 10^{-7}\,\mathrm{N/A^2}$, ε_0 is also exact.

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Fine-structure constant[¶] α	$\alpha^{-1} = \left(\frac{e^2}{4\pi\varepsilon_0\hbar c}\right)^{-1}$	137.035 999 11 ±0.000 000 46
Classical electron radius	$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$	$2.817\,940\,325 \cdot 10^{-15}$ m $\pm 0.000\,000\,028 \cdot 10^{-15}$ m
Electron Compton wavelength	$\frac{\lambda_e}{2\pi} = \frac{\hbar}{m_e c} = \frac{r_e}{\alpha}$	$3.861\,592\,678 \cdot 10^{-13}$ m $\pm 0.000\,000\,026 \cdot 10^{-13}$ m
Bohr radius	$r_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_e e^2} = \frac{r_e}{\alpha^2}$	$0.529\,177\,210\,8 \cdot 10^{-10}$ m $\pm 0.000\,000\,001\,8 \cdot 10^{-10}$ m
Rydberg energy	$E_{\mathrm{Ry}} = m_e c^2 \alpha^2/2$	13.605 692 3 eV ±0.000 001 2 eV
Bohr magneton	$\mu_{\mathrm{B}} = e\hbar/2m_e$	$5.788\,381\,804 \cdot 10^{-11}$ MeV/T $\pm 0.000\,000\,039 \cdot 10^{-11}$ MeV/T
Gravitational acceleration, sea level[‖]	g	$9.806\,65$ m/s^2
Mass of Earth	$M_♁$	$5.792\,3 \cdot 10^{24}$ kg $\pm 0.000\,9 \cdot 10^{24}$ kg
Solar mass	$M_\odot$	$1.988\,44 \cdot 10^{30}$ kg $\pm 0.000\,30 \cdot 10^{30}$ kg

[¶] At a four-momentum transfer squared $q^2 = -m_e^2$. At $q^2 = -m_W^2$ the value is approximately 1/128, where $m_W = 80.40\,\mathrm{GeV}/c^2$ is the mass of the W boson.

[‖] Exact by definition. Actually g varies for different locations on Earth. At the equator $g \approx 9.75\,\mathrm{m/s^2}$, at the poles $g \approx 9.85\,\mathrm{m/s^2}$.

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