B Constants

B.1 UNIVERSAL CONSTANTS

Table B.1 contains fundamental constants that by definition[1] have exact values. Using these constants, basic SI units, such as meter, second, kilogram, mol and ampere can be defined, as described in Appendix E.1.

Table B.2 contains selected derived or measured constants expressed in the SI units. Some of them (e.g. the universal gas constant) are directly derived from the defined constants given in Table B.1, whereas the others are obtained from measurements.

Table B.3 contains constants that are useful in solar energy applications.

B.2 STANDARD CONDITIONS

Standard conditions for temperature and pressure are necessary to allow comparison between different sets of data. Unfortunately there are no universally accepted standards so far. The most used standards are those of the International Union of Pure and Applied Chemistry (IUPAC) and the National Institute of Standards and Technology (NIST).

In chemistry, IUPAC proposed the following definition of **standard temperature and pressure** (STP), valid from 1982:

- temperature of 273.15 K,
- absolute pressure 10^5 Pa (1 bar).

NIST proposed the **normal temperature and pressure** (NTP) standard as follows:

- temperature of 293.15 K,
- absolute pressure 101.325 kPa (1 atm).

The international **standard metric condition** for natural gas and similar fluids are:

- temperature of 288.15 K,
- absolute pressure 101.325 kPa (1 atm).

The volumetric flow rate of such fluids is then expressed either in **standard cubic meter per second**, sm^3/s, or in **normal cubic meter per second**, nm^3/s. It is a good engineering practice to specify the reference conditions of temperature and pressure in any technical publication.

[1] According to 2019 redefinition of the SI base units.

Table B.1
Defining Constants of the International System of Units (SI)

Constant	Symbol	Value	Unit
Speed of light in vacuum	c	299 792 458	$\mathrm{m{\cdot}s^{-1}}$
Planck constant	h	$6.626\,070\,15\times10^{-34}$	J·s
Elementary charge	e	$1.602\,176\,634\times10^{-19}$	C
Boltzmann constant	k_B	$1.380\,649\times10^{-23}$	$\mathrm{J{\cdot}K^{-1}}$
Avogadro constant	N_A	$6.022\,140\,76\times10^{23}$	$\mathrm{mol^{-1}}$
Luminous efficacy	K_{cd}	638	$\mathrm{lm{\cdot}W^{-1}}$
Hyperfine transition frequency of ^{133}Cs	$\Delta\nu_{Cs}$	9 192 631 770	Hz

Source: CODATA Recommended Values of the Fundamental Constants of Physics and Chemistry, retrieved from physics.nist.gov/constants on 2020-02-22.

Note: All values are exact.

Table B.2
Other Derived or Measured Universal Constants

Constant	Symbol	Value	Unit
Universal gas constant	R	8.314 462 618 153 24[a]	$\mathrm{J{\cdot}K^{-1}{\cdot}mol^{-1}}$
Stefan-Boltzmann constant	σ	$5.670\,374\,419...\times10^{-8}$	$\mathrm{W{\cdot}m^{-2}{\cdot}K^{-4}}$
Electron rest mass	m_e	$9.109\,383\,7015(28)\times10^{-31}$	kg
Proton rest mass	m_p	$1.672\,621\,923\,69(51)\times10^{-27}$	kg
Neutron rest mass	m_n	$1.674\,927\,498\,04(95)\times10^{-27}$	kg
Atomic mass unit, or dalton	u	$1.660\,539\,066\,60(50)\times10^{-27}$	kg
Vacuum magnetic permeability	μ_0	$1.256\,637\,062\,12(19)\times10^{-6}$	$\mathrm{N\,A^{-2}}$
Vacuum electric permittivity	ε_0	$8.854\,187\,8128(13)\times10^{-12}$	$\mathrm{F\,m^{-1}}$
Newtonian constant of gravitation	G_N	$6.674\,30(15)\times10^{-11}$	$\mathrm{m^3{\cdot}kg^{-1}{\cdot}s^{-2}}$
Standard acceleration of gravity	g	9.806 65[a]	$\mathrm{m{\cdot}s^{-2}}$

Source: CODATA Recommended Values of the Fundamental Constants of Physics and Chemistry, retrieved from physics.nist.gov/constants on 2020-02-22.

[a] Exact value

Table B.3
Useful Constants in Solar Energy Applications

Constant	Symbol	Value	Unit
Earth mean equatorial radius	$R_\oplus$	$6.378\ 1366(1)\times10^6$	m
Mass of Earth	$M_\oplus$	$5.972\ 3(9)\times10^{24}$	kg
Mean radius of Earth's orbit		149.6×10^6	km
Aphelion of Earth's orbit		152.1×10^6	km
Perihelion of Earth's orbit		147.1×10^6	km
Orbital period of Earth		365.256 365 004	day
Solar radius[a]	$R_\odot$	695 700	km
Sun mean equatorial radius		696 342(65)[b]	km
Mass of Sun	$M_\odot$	1.9884×10^{30}	kg
Average solar constant above atmosphere	G_{SC}	1.361[c]	kW/m^2
Temperature of the Sun's surface	$T_\odot$	5 778	K
Solar luminosity[d]	$\mathtt{L_{sol}}$, $L_\odot$	3.828×10^{26}	W

[a] Solar radius is a unit of distance defined as the radius of the layer in the Sun's photosphere where the optical depth equals 2/3.
[b] As measured from space during the 2003 and 2006 Mercury transit [28].
[c] Based on satellite measurements [56].
[d] Solar luminosity is a unit of radiant flux, defined by the International Astronomical Union. It corresponds to the total power output of the Sun.