SI units

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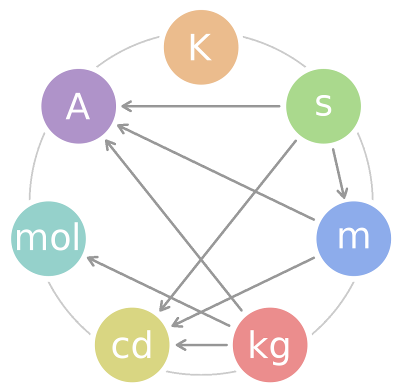
SI base unit

The International System of Units (**SI**) defines seven units of measure as a basic set from which all other SI units are derived. These **SI base units** and their physical quantities are:[1]

- metre for length
- kilogram for mass
- second for time
- ampere for electric current
- kelvin for temperature
- candela for luminous intensity
- mole for the amount of substance.



The seven SI base units and the interdependency of their definitions

The SI base quantities form a set of mutually independent dimensions as required by dimensional analysis commonly employed in science and technology. However, in a given realization of these units they may well be interdependent, i.e. defined in terms of each other.[1]

The names of all SI units are written in lowercase characters (e.g., the *metre* has the symbol m), except that the symbols of units named after persons are written with an initial capital letter (e.g., the *ampere* has the uppercase symbol A).

Many other units, such as the litre, are formally not part of the SI, but are accepted for use with SI.

SI base units

Name	Symbol	Measure	Definition	Historical Origin / Justification
metre	**m**	length	"The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second." *17th CGPM (1983, Resolution 1, CR, 97)*	$^{1}/_{10,000,000}$ of the distance from the Earth's equator to the North Pole measured on the circumference through Paris.
kilogram	**kg**	mass	"The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram." *3rd CGPM (1901, CR, 70)*	The mass of one litre of water. A litre is one thousandth of a cubic metre.
second	**s**	time	"The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom." *13th CGPM (1967/68, Resolution 1; CR, 103)* "This definition refers to a caesium atom at rest at a temperature of 0 K." *(Added by CIPM in 1997)*	The day is divided in 24 hours, each hour divided in 60 minutes, each minute divided in 60 seconds. A second is $^{1}/_{(24 \times 60 \times 60)}$ of the day
ampere	**A**	electric current	"The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length." *9th CGPM (1948)*	The original "International Ampere" was defined electrochemically as the current required to deposit 1.118 milligrams of silver per second from a solution of silver nitrate. Compared to the SI ampere, the difference is 0.015%.

kelvin	**K**	thermodynamic temperature	"The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water." *13th CGPM (1967/68, Resolution 4; CR, 104)* "This definition refers to water having the isotopic composition defined exactly by the following amount of substance ratios: 0.000 155 76 mole of ^{2}H per mole of ^{1}H, 0.000 379 9 mole of ^{17}O per mole of ^{16}O, and 0.002 005 2 mole of ^{18}O per mole of ^{16}O." *(Added by CIPM in 2005)*	The Celsius scale: the Kelvin scale uses the degree Celsius for its unit increment, but is a thermodynamic scale (0 K is absolute zero).
mole	**mol**	amount of substance	"1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is “mol.” 2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles." *14th CGPM (1971, Resolution 3; CR, 78)* "In this definition, it is understood that unbound atoms of carbon 12, at rest and in their ground state, are referred to." *(Added by CIPM in 1980)*	Atomic weight or molecular weight divided by the molar mass constant, 1 g/mol.
candela	**cd**	luminous intensity	"The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian." *16th CGPM (1979, Resolution 3; CR, 100)*	The candlepower, which is based on the light emitted from a burning candle of standard properties.

Future redefinitions

There have been several modifications to the definitions of the base units, and additions of base units, since the Metre Convention in 1875. Since the redefinition of the metre in 1960, the kilogram is the only unit which is directly defined in terms of a physical artifact rather than a property of nature. However, the mole, the ampere and the candela are also linked through their definitions to the mass of this platinum–iridium cylinder stored in a vault near Paris. It has long been an objective of metrology to find a way to define the kilogram in terms of a fundamental constant, in the same way that the metre is now defined in terms of the speed of light.

The 21st General Conference on Weights and Measures (CGPM, 1999) placed these efforts on an official footing, and recommended "that national laboratories continue their efforts to refine experiments that link the unit of mass to fundamental or atomic constants with a view to a future redefinition of the kilogram." Two main possibilities have attracted attention: the Planck constant and the Avogadro constant.

In 2005, the International Committee for Weights and Measures (CIPM) approved the preparation of new definitions for the kilogram, the ampere, and the kelvin and it noted the possibility of a new definition for the mole based on the Avogadro constant.[2] The 23rd CGPM (2007) decided to postpone any legal change until the next General Conference in 2011.[3]

In a note to the CIPM in October 2009,[4] Ian Mills, the President of the CIPM *Consultative Committee - Units (CCU)* cataloged the uncertainties of the fundamental constants of physics according to the current definitions and their values under the proposed new definition. He urged the CIPM to accept the proposed changes in the definition of the *kilogram*, *ampere*, *kelvin* and *mole* so that they are referenced to the values of the fundamental constants, namely Planck's constant (h), the electron charge (e), Boltzmann's constant (k), and Avogadro's constant (N_A).[5]

References

[1] International Bureau of Weights and Measures (2006), *The International System of Units (SI)* (http://www.bipm.org/utils/common/pdf/si_brochure_8_en.pdf) (8th ed.), ISBN 92-822-2213-6,

[2] 94th Meeting of the International Committee for Weights and Measures (2005). Recommendation 1: Preparative steps towards new definitions of the kilogram, the ampere, the kelvin and the mole in terms of fundamental constants (http://www.bipm.org/utils/en/pdf/CIPM2005-EN.pdf)

[3] 23rd General Conference on Weights and Measures (2007). Resolution 12: On the possible redefinition of certain base units of the International System of Units (SI) (http://www.bipm.org/utils/en/pdf/Resol23CGPM-EN.pdf).

[4] Ian Mills, President of the CCU (2009-10). "Thoughts about the timing of the change from the Current SI to the New SI" (http://www.bipm.org/cc/CIPM/Allowed/98/CIPM2009_49_TIMING_THE_NEW_SI.pdf). CIPM. . Retrieved 2010-02-23.

[5] Ian Mills (29 September 2010). "Draft Chapter 2 for SI Brochure, following redefinitions of the base units" (http://www.bipm.org/utils/en/pdf/si_brochure_draft_ch2.pdf). CCU. . Retrieved 2011-01-01.

External links

- BIPM (http://www.bipm.org/en/si/base_units/)
- National Physical Laboratory (http://www.npl.co.uk/mass/faqs/kilogram.html)
- NIST -SI (http://physics.nist.gov/cuu/Units/index.html)

SI derived unit

The International System of Units (SI) specifies a set of seven base units from which all other units of measurement are formed. These other units are called **SI derived units** and are also considered part of the standard. SI units was after the French *Le Système International d'Unités* which opted for a universal, unified and self-consistent system of measurement units based on the MKS (metre-kilogram-second) system.

The names of SI units are always written in lowercase. The unit symbols of units named after persons, however, are always spelled with an initial capital letter (e.g., the symbol of hertz is Hz; but metre becomes m).

Derived units with special names

Base units can be combined to derive units of measurement for other quantities. In addition to the two dimensionless derived units radian (rad) and steradian (sr), 20 other derived units have special names.

Named units derived from SI base units

Name	Symbol	Quantity	Expression in terms of other units	Expression in terms of SI base units
hertz	**Hz**	frequency	1/s	s^{-1}
radian	**rad**	angle	$m \cdot m^{-1}$	dimensionless
steradian	**sr**	solid angle	$m^2 \cdot m^{-2}$	dimensionless
newton	**N**	force, weight	$kg \cdot m/s^2$	$kg \cdot m \cdot s^{-2}$
pascal	**Pa**	pressure, stress	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
joule	**J**	energy, work, heat	N·m = C·V = W·s	$m^2 \cdot kg \cdot s^{-2}$
watt	**W**	power, radiant flux	J/s = V·A	$m^2 \cdot kg \cdot s^{-3}$
coulomb	**C**	electric charge or quantity of electricity	s·A	s·A

volt	**V**	voltage, electrical potential difference, electromotive force	W/A = J/C	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
farad	**F**	electric capacitance	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
ohm	**Ω**	electric resistance, impedance, reactance	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
siemens	**S**	electrical conductance	1/Ω = A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
weber	**Wb**	magnetic flux	J/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
tesla	**T**	magnetic field strength, magnetic flux density	$V \cdot s/m^2 = Wb/m^2 = N/(A \cdot m)$	$kg \cdot s^{-2} \cdot A^{-1}$
henry	**H**	inductance	V·s/A = Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
celsius	**°C**	celsius temperature	K − 273.15	K − 273.15
lumen	**lm**	luminous flux	$lx \cdot m^2$	cd·sr
lux	**lx**	illuminance	lm/m^2	$m^{-2} \cdot cd \cdot sr$
becquerel	**Bq**	radioactivity (decays per unit time)	1/s	s^{-1}
gray	**Gy**	absorbed dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
sievert	**Sv**	equivalent dose (of ionizing radiation)	J/kg	$m^2 \cdot s^{-2}$
katal	**kat**	catalytic activity	mol/s	$s^{-1} \cdot mol$

Other common units, such as the litre, are not SI units, but are accepted for use with SI (cf. non-SI units accepted for use with SI).

Supplementary units

Until 1995, the SI classified the radian and the steradian as *supplementary units*, but this designation was abandoned and the units were grouped as derived units.

Other quantities and units

Compound units derived from SI units

Name	Symbol	Quantity	Expression in terms of SI base units
square metre	$\mathbf{m^2}$	area	m^2
cubic metre	$\mathbf{m^3}$	volume	m^3
metre per second	**m/s**	speed, velocity	$m \cdot s^{-1}$
cubic metre per second	$\mathbf{m^3/s}$	volumetric flow	$m^3 \cdot s^{-1}$
metre per second squared	$\mathbf{m/s^2}$	acceleration	$m \cdot s^{-2}$
metre per second cubed	$\mathbf{m/s^3}$	jerk, jolt	$m \cdot s^{-3}$
metre per quartic second	$\mathbf{m/s^4}$	snap, jounce	$m \cdot s^{-4}$
radian per second	**rad/s**	angular velocity	s^{-1}

newton second	**N·s**	momentum, impulse	$m \cdot kg \cdot s^{-1}$
newton metre second	**N·m·s**	angular momentum	$m^2 \cdot kg \cdot s^{-1}$
newton metre	**N·m = J/rad**	torque, moment of force	$m^2 \cdot kg \cdot s^{-2}$
newton per second	**N/s**	yank	$m \cdot kg \cdot s^{-3}$
reciprocal metre	$\mathbf{m^{-1}}$	wavenumber	m^{-1}
kilogram per square metre	$\mathbf{kg/m^2}$	area density	$m^{-2} \cdot kg$
kilogram per cubic metre	$\mathbf{kg/m^3}$	density, mass density	$m^{-3} \cdot kg$
cubic metre per kilogram	$\mathbf{m^3/kg}$	specific volume	$m^3 \cdot kg^{-1}$
mole per cubic metre	$\mathbf{mol/m^3}$	amount of substance concentration	$m^{-3} \cdot mol$
cubic metre per mole	$\mathbf{m^3/mol}$	molar volume	$m^3 \cdot mol^{-1}$
joule second	**J·s**	action	$m^2 \cdot kg \cdot s^{-1}$
joule per kelvin	**J/K**	heat capacity, entropy	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$
joule per kelvin mole	**J/(K·mol)**	molar heat capacity, molar entropy	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
joule per kilogram kelvin	**J/(K·kg)**	specific heat capacity, specific entropy	$m^2 \cdot s^{-2} \cdot K^{-1}$
joule per mole	**J/mol**	molar energy	$m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1}$
joule per kilogram	**J/kg**	specific energy	$m^2 \cdot s^{-2}$
joule per cubic metre	$\mathbf{J/m^3}$	energy density	$m^{-1} \cdot kg \cdot s^{-2}$
newton per metre	$\mathbf{N/m = J/m^2}$	surface tension	$kg \cdot s^{-2}$
watt per square metre	$\mathbf{W/m^2}$	heat flux density, irradiance	$kg \cdot s^{-3}$
watt per metre kelvin	**W/(m·K)**	thermal conductivity	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
square metre per second	$\mathbf{m^2/s}$	kinematic viscosity, diffusion coefficient	$m^2 \cdot s^{-1}$
pascal second	$\mathbf{Pa \cdot s = N \cdot s/m^2}$	dynamic viscosity	$m^{-1} \cdot kg \cdot s^{-1}$
coulomb per square metre	$\mathbf{C/m^2}$	electric displacement field	$m^{-2} \cdot s \cdot A$
coulomb per cubic metre	$\mathbf{C/m^3}$	electric charge density	$m^{-3} \cdot s \cdot A$
ampere per square metre	$\mathbf{A/m^2}$	electric current density	$A \cdot m^{-2}$
siemens per metre	**S/m**	conductivity	$m^{-3} \cdot kg^{-1} \cdot s^3 \cdot A^2$
siemens square metre per mole	$\mathbf{S \cdot m^2/mol}$	molar conductivity	$kg^{-1} \cdot s^3 \cdot mol^{-1} \cdot A^2$
farad per metre	**F/m**	permittivity	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
henry per metre	**H/m**	permeability	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
volt per metre	**V/m**	electric field strength	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
ampere per metre	**A/m**	magnetic field strength	$A \cdot m^{-1}$
candela per square metre	$\mathbf{cd/m^2}$	luminance	$cd \cdot m^{-2}$

coulomb per kilogram	**C/kg**	exposure (X and gamma rays)	$kg^{-1}\cdot s\cdot A$
gray per second	**Gy/s**	absorbed dose rate	$m^2\cdot s^{-3}$
ohm metre	**Ω·m**	resistivity	$m^3\cdot kg\cdot s^{-3}\cdot A^{-2}$

References

- I. Mills, Tomislav Cvitas, Klaus Homann, Nikola Kallay, IUPAC: *Quantities, Units and Symbols in Physical Chemistry*, 2nd edition (June 1993), Blackwell Science Inc (p. 72)

Non-SI units mentioned in the SI

This is a list of units that are not defined as part of the International System of Units (SI), but are otherwise **mentioned in the SI**[1] [2] , because either the SI accepts their use as being multiples or submultiples of SI-units, or they have important contemporary application, or are otherwise commonly encountered.

Units officially accepted for use with the SI

Name	Symbol	Quantity	Equivalent SI unit
Widely used units expected to be used indefinitely			
minute	**min**	time (SI unit multiple)	1 min = 60 s
hour	**h**	time (SI unit multiple)	1 h = 60 min = 3600 s
day	**d**	time (SI unit multiple)	1 d = 24 h = 1440 min = 86400 s
degree of arc	**°**	angle (dimensionless unit)	1° = (π/180) rad
minute of arc	**′**	angle (dimensionless unit)	1′ = (1/60)° = (π/10800) rad
second of arc	**″**	angle (dimensionless unit)	1″ = (1/60)′ = (1/3600)° = (π/648000) rad
hectare	**ha**	area (decimal unit multiple)	1 ha = 100 a = 10000 m^2 = 1 hm^2
litre	**l** or **L**	volume (decimal unit multiple)	1 l = 1 dm^3 = 0.001 m^3
tonne	**t**	mass (decimal unit multiple)	1 t = 10^3 kg = 1 Mg
Logarithmic units			
neper	**Np**	dimensionless ratio of field quantities	$L_F = \ln(F/F_0)$ Np
		dimensionless ratio of power quantities	$L_P = {}^1\!/_2 \ln(P/P_0)$ Np
bel, **decibel**	**B**, **dB**	dimensionless ratio of field quantities	$L_F = 2 \log_{10}(F/F_0)$ B
		dimensionless ratio of power quantities	$L_P = \log_{10}(P/P_0)$ B
Units with experimentally determined values			
electron-volt	**eV**	energy	1 eV = 1.60217653(14) × 10^{-19} J
atomic mass unit **dalton**	**u** **Da**	mass	1 u = 1 Da = 1.66053886(28) × 10^{-27} kg
astronomical unit	**ua**[3] [4] [5]	length	1 au = 1.49597870691(6) × 10^{11} m
Natural units (n.u.)			

n.u. of speed	$\mathbf{c_0}$	speed	299792458 m/s (exact)[6]
n.u. of action	**ħ**	action	$1.05457168(18) \times 10^{-34}$ J·s
n.u. of mass	$\mathbf{m_e}$	mass of the electron	$9.1093826(16) \times 10^{-31}$ kg
n.u. of time	$\hbar/(m_e c_0^2)$	time	$1.2880886677(86) \times 10^{-21}$ s
Atomic units (a.u.)			
a.u. elementary charge	**e**	elementary charge	$1.60217653(14) \times 10^{-19}$ C
a.u. of length (bohr)	$\mathbf{a_0}$	Bohr radius	$0.5291772108(18) \times 10^{-10}$ m
a.u. of energy (hartree)	$\mathbf{E_h}$	Hartree energy	$4.35974417(75) \times 10^{-18}$ J
a.u. of time	$\mathbf{\hbar/E_h}$	time	$2.418884326505(16) \times 10^{-17}$ s

Common units not officially sanctioned

Name	Symbol	Quantity	Equivalent SI unit
Ångström, angstrom	**Å**	length	1 Å = 0.1 nm = 10^{-10} m
nautical mile	**nm**	length	1 nautical mile = 1852 m
knot	**kt**	speed	1 knot = 1 nautical mile per hour = (1852/3600) m/s
are	**a**	area	1 a = 1 dam^2 = 100 m^2
barn	**b**	area	1 b = 10^{-28} m^2
bar	**bar**	pressure	1 bar = 10^5 Pa
millibar	**mbar**	pressure	1 mbar = 1 hPa = 100 Pa (was used in atmospheric meteorology, the preferred unit is now the hectopascal)
atmosphere	**atm**	pressure	1 atm = 1013.25 mbar = 1013.25 hPa = 1.01325×10^5 Pa (commonly used in atmospheric meteorology, in oceanology and for pressures within liquids, or in the industry for pressures within containers of liquified gas)

References

[1] "Non-SI units accepted for use with the SI, and units based on fundamental constants" (http://www.bipm.org/en/si/si_brochure/chapter4/4-1.html) (PDF). *SI brochure (8th edition)*. BIPM. . Retrieved 2010-08-28.

[2] Taylor, Barry N. (ed.) (2001). "The International System of Units (SI)" (http://physics.nist.gov/Pubs/SP330/sp330.pdf). *Special Publication 330*. Gaithersburg, Maryland: National Institute of Standards and Technology (NIST). .

[3] International Bureau of Weights and Measures (2006), *The International System of Units (SI)* (http://www.bipm.org/utils/common/pdf/si_brochure_8_en.pdf) (8th ed.), p. 126, ISBN 92-822-2213-6,

[4] ISO 80000

[5] *The IAU Style Manual (1989): The Preparation of Astronomical Papers and Reports* (http://www.iau.org/static/publications/stylemanual1989.pdf), p. 23,

[6] In this case it is not the speed of light, but the length of the meter that is obtained by experiment

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