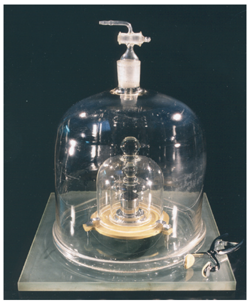
Collage carte SI

The International System of Units, the SI, is the internationally agreed basis for expressing measurements at all levels of precision and in all areas of science, technology, and human endeavour.



The international prototype of the kilogram, K, the only remaining artefact used to define a base unit of the SI.

Base units of the SI

There are two classes of units in the SI, base units and derived units. The seven **base units** of the SI, listed in the table on the right alongside their corresponding **base quantities**, provide the reference used to define all the measurement units of the International System.

Derived units

Derived units are defined as products of powers of the base units and are used to measure **derived quantities.**

Some examples of derived quantities and units

Derived quantity, symbol	Derived unit, symbol
area, A	square metre, m^2
volume, V	cubic metre, m^3
speed, velocity, v	metre per second, m/s
acceleration, a	metre per second squared, m/s^2
mass density, ρ	kilogram per cubic metre, kg/m^3
current density, j	ampere per square metre, A/m^2
magnetic field strength, H	ampere per metre, A/m
concentration, c	mole per cubic metre, mol/m^3
luminance, L_v	candela per square metre, cd/m^2
refractive index, n	(the number) one

The seven base units of the SI

Quantity

Base unit, symbol: definition of unit

length

metre, m: 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.

mass

kilogram, kg: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

time, duration

second, s: 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.

electric current

ampere, A: 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.

thermodynamic temperature

kelvin, K: The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

amount of substance

mole, mol: 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. 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.

luminous intensity

candela, cd: 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.

Dimensionless quantities, also called **quantities of dimension one**, are usually defined as the ratio of two quantities of the same kind (for example, refractive index, in the table on the left, is the ratio of two speeds). Thus the unit of a dimensionless quantity is the ratio of two identical SI units, and is therefore always equal to one. However in expressing the values of dimensionless quantities the unit one, 1, is not written.

Some derived units are given a **special name**, this being simply a compact form for the expression of combinations of base units that are used frequently. There are 22 special names for units approved for use in the SI.

Derived units with special names in the SI

Derived quantity	Name of derived unit	Symbol for unit	Expression in terms of other units
plane angle	radian	rad	m/m = 1
solid angle	steradian	sr	$m^2/m^2 = 1$
frequency	hertz	Hz	s^{-1}
force	newton	N	$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	$N/m^2 = m^{-1}\ kg\ s^{-2}$
energy, work, amount of heat	joule	J	$N\ m = m^2\ kg\ s^{-2}$
power, radiant flux	watt	W	$J/s = m^2\ kg\ s^{-3}$
electric charge	coulomb	C	s A
electric potential difference	volt	V	$W/A = m^2\ kg\ s^{-3} A^{-1}$
capacitance	farad	F	$C/V = m^{-2}\ kg^{-1}\ s^4\ A^2$
electric resistance	ohm	Ω	$V/A = m^2\ kg\ s^{-3}\ A^{-2}$
electric conductance	siemens	S	$A/V = m^{-2}\ kg^{-1}\ s^3\ A^2$
magnetic flux	weber	Wb	$V\ s = m^2\ kg\ s^{-2} A^{-1}$
magnetic flux density	tesla	T	$Wb/m^2 = kg\ s^{-2}\ A^{-1}$
inductance	henry	H	$Wb/A = m^2\ kg\ s^{-2}\ A^{-2}$
Celsius temperature	degree Celsius	°C	K
luminous flux	lumen	lm	cd sr = cd
illuminance	lux	lx	$lm/m^2 = m^{-2}$ cd
activity referred to a radionuclide	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	$J/kg = m^2\ s^{-2}$
dose equivalent	sievert	Sv	$J/kg = m^2\ s^{-2}$
catalytic activity	katal	kat	s^{-1} mol

Although the hertz and the becquerel are both equal to the reciprocal second, the hertz is only used for cyclic phenomena, and the becquerel for stochastic processes in radioactive decay.

The unit of Celsius temperature is the degree Celsius, °C, which is equal in magnitude to the kelvin, K. The quantity Celsius temperature, t, is related to thermodynamic temperature, T, by the equation:

$$t/^\circ\mathrm{C} = T/\mathrm{K} - 273.15.$$

Decimal multiples and sub-multiples of SI units

A set of multiple and sub-multiple **prefixes** have been adopted for use with the SI units. They may be used with any of the base units and with any of the derived units with special names.

The SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	µ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

When the prefixes are used, the prefix name and the unit name are combined to form a single word, and similarly the prefix symbol and the unit symbol are written without any space to form a single symbol, which may itself be raised to any power.
For example, we may write: kilometre, km; microvolt, µV; $50\ \mathrm{V/cm} = 50\ \mathrm{V}\ (10^{-2}\,\mathrm{m})^{-1} = 5000\ \mathrm{V/m}$.

The kilogram, kg, is an exception, because although it is a base unit the name already includes the prefix kilo, for historical reasons. Multiples and sub-multiples of the kilogram are written by combining prefixes with the gram: thus we write milligram, mg, not microkilogram, µkg.

Collage carte BIPM

Units outside the SI

The SI is the only system of units that is universally recognized, so that it has a distinct advantage in establishing a dialogue over the whole world. Nonetheless, for historical reasons some non-SI units are still widely used to meet the needs of special interest groups, or because there is no convenient SI alternative. It will always remain the prerogative of a scientist to use the units that he or she considers to be best suited to the purpose. However when non-SI units are used, the conversion factor to the SI should be quoted (with a few exceptions of very familiar non-SI units).

Some of the most important and familiar non-SI units approved for use with the SI are the minute, symbol min, the hour, symbol h, and the day, symbol d, as units of time.

Using the SI to express the values of quantities

The **value of a quantity** is written as the product of a number and a unit. One space is always left between the number and the unit. The numerical value depends on the choice of unit, so that the same value of a quantity may have different numerical values when expressed in different units. For example, the value of the speed of a bicycle might be $\upsilon = 5.0\ \mathrm{m/s} = 18\ \mathrm{km/h}$.

Quantity symbols are printed in an italic (slanting) type. Either capital or lower case letters may be used.

Unit symbols are printed in a roman (upright) type, regardless of the type used in the surrounding text. They are mathematical entities and not abbreviations; they are never followed by a stop (except at the end of a sentence) nor by an s for the plural. They are written in lower case letters, except that the first letter is a capital when the unit is named for an individual (for example, ampere, A; kelvin, K; hertz, Hz; coulomb, C; but metre, m; second, s). The use of the correct form for unit symbols is mandatory.

For each quantity, there is only one SI unit. However the same SI unit may be used to express the values of several different quantities. For example, the J/K is the SI unit of both heat capacity and entropy. It is therefore important not to use the unit alone to specify the quantity.

The decimal marker may be either a point (i.e. a stop) or a comma, as is customary in the language of the surrounding text.

When a number has many digits, it is customary to group the digits into threes about the decimal point for easy reading, using a (thin) space; neither a point nor a comma should be used.

Because units symbols are mathematical entities, they may be treated by the ordinary rules of algebra. For example, the equation $T = 293\ \mathrm{K}$ may equally be written $T/\mathrm{K} = 293$. This procedure is described as the use of quantity calculus, or the algebra of quantities. It is often useful to use the ratio of a quantity to its unit for heading the columns of a table, or labelling the axes of a graph, so that the entries in the table or the labels of the tick marks on the axes are all simply numbers.

For further information
see the website
of the Bureau International
des Poids et Mesures,
BIPM, at

www.bipm.org

This text is a short summary of the 8th edition of the SI Brochure, prepared by the Comité Consultatif des Unités (CCU) of the Comité International des Poids et Mesures (CIPM), and is published by the BIPM.

Ernst Göbel, President of the CIPM
Ian Mills, President of the CCU
Andrew Wallard, Director of the BIPM

March 2006

Bureau International des Poids et Mesures (BIPM)

Organisation Intergouvernementale
de la Convention du Mètre

Pavillon de Breteuil
F-92312 Sèvres France

BIPM

The International System of Units SI

Bureau International des Poids et Mesures

BIPM

www.bipm.org