The `SIunits` package*
Consistent application of SI units

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Abstract

This article describes the `SIunits` package that provides support for the Système International d'Unités (SI).

The Système International d'Unités (SI), the modern form of the metric system, is the most widely used system of units and measures around the world. But despite this there is widespread misuse of the system with incorrect names and symbols used as a matter a course - even by well educated and trained people who should know better. For example how often do we see: mHz, Mhz or mhz written when referring to computer clock rates? The correct form is actually MHz. Note that the capitalisation does matter.

Hence, a clear system for the use of units is needed, satisfying the next principles:

1. the system should consist of measuring units based on unvariable quantities in nature;
2. all units other than the base units should be derived from these base units; and
3. multiples and submultiples of the units should be decimal.

The name Système International d'Unités (International System of Units) with the international abbreviation SI was adopted by the Conférence Générale des Poids et Mesures (CGPM) in 1960. It is a coherent system based on seven base units (CGPM 1960 and 1971).

The `SIunits` package can be used to standardise the use of units in your writings. Most macros are easily adaptable to personal preferences. However, you are welcome (and strongly invited[1]) to suggest any improvements.

*This file has version number v1.36, last revised 2007/12/02

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[1]There is an enormous LaTeX Knowledge Base out there.

What's new?

New in version 1.36

1. Real minus sign in text mode

New in version 1.35

1. Improved `\elecronvolt` appearance[2]
2. Added `\dalton`, `\atomicmassunit` units (both formally non-SI)
3. Minor improvements to the documentation

New in version 1.34

1. Maintainer is now Joseph Wright (`joseph.wright@morningstar2.co.uk`)
2. Bug fix for negative signs in textstyle mode[3]
3. License changed to LPPL 1.3 or later

[2] All changes for this version suggested by Philip Ratcliffe
[3] Thanks to Stefan Pinnow

Contents

1 Introduction

1.1 Historical notes

In 1948 the 9th General Conference on Weights and Measures (CGPM[4]), by its Resolution 6, instructed the International Committee for Weights and Measures (CIPM[4]):

> 'to study the establishment of a complete set of rules for units of measurement';
>
> 'to find out for this purpose, by official inquiry, the opinion prevailing in scientific, technical, and educational circles in all countries'; and
>
> 'to make recommendations on the establishment of a *practical system of units of measurement* suitable for adoption by all signatories to the Meter Convention.'

The same General Conference also laid down, by its Resolution 7, general principles for unit symbols and also gave a list of units with special names.

The 10th CGPM (1954), by its Resolution 6, and the 14th CGPM (1971), by its Resolution 3, adopted as base units of this 'practical system of units,' the units of the following seven quantities: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity.

The 11th CGPM (1960), by its Resolution 12, adopted the name *Système International d'Unités (International System of Units)*, with the international abbreviation *SI*, for this practical system of units of measurement, and laid down rules for the prefixes, the derived and supplementary units, and other matters, thus establishing a comprehensive specification for units of measurement.

1.2 The classes of SI units

The General Conference decided to base the International System on a choice of seven well-defined units which by convention are regarded as dimensionally independent: the metre, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. These units are called *base units*.

The second class of SI units contain *derived units*, i. e., units that can be formed by combining base units according to the algebraic relations linking the corresponding quantities. The names and symbols of some units thus formed in terms of base units can be replaced by special names and symbols which can themselves be used to form expressions and symbols of other derived units (see section 2.2, p. 10).

The 11th CGPM (1960) admitted a third class of SI units, called *supplementary units* and containing the SI units of plane and solid angle.

The 20th CGPM (1995) decided to eliminate the class of supplementary units as a separate class in the SI. Thus the SI now consists of only two classes of units: base units and derived units, with the radian and the steradian, which are the two supplementary units, subsumed into the class of derived SI units.

[4]See section 1.4 for acronyms

1.3 The SI prefixes

The General Conference has adopted a series of prefixes to be used in forming the decimal multiples and submultiples of SI units. Following CIPM Recommendation 1 (1969), the set of prefixes is designated by the name *SI prefixes*.

The multiples and submultiples of SI units, which are formed by using the SI prefixes, should be designated by their complete name, *multiples and submultiples of SI units*, in order to make a distinction between them and the coherent set of SI units proper.

1.4 Acronyms

The SI was established in 1960 by the CGPM. The CGPM is an intergovernmental treaty organisation created by a diplomatic treaty called the Meter Convention (*Convention du Mètre*, often called the Treaty of the Meter in the United States). The Meter Convention was signed in Paris in 1875 by representatives of seventeen nations, including the United States. There are now forty-eight Member States, including all the major industrialised countries. The Convention, modified slightly in 1921, remains the basis of all international agreement on units of measurement.

The Meter Convention also created the International Bureau of Weights and Measures (BIPM, Bureau International des Poids et Mesures) and the International Committee for Weights and Measures (CIPM, Comité International des Poids et Mesures). The BIPM, which is located in Sèvres, a suburb of Paris, France, and which has the task of ensuring worldwide unification of physical measurements, operates under the exclusive supervision of the CIPM, which itself comes under the authority of the CGPM.

CGPM General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*). The CGPM is the primary intergovernmental treaty organisation responsible for the SI, representing nearly 50 countries. It has the responsibility of ensuring that the SI is widely disseminated and modifying it as necessary so that it reflects the latest advances in science and technology.

CIPM International Committee for Weights and Measures (*Comité International des Poids et Mesures*). The CIPM comes under the authority of the CGPM. It suggests modifications to the SI to the CGPM for formal adoption. The CIPM may also on its own authority pass clarifying resolutions and recommendations regarding the SI.

BIPM International Bureau of Weights and Measures (*Bureau International des Poids et Mesures*). The BIPM, located outside Paris, has the task of ensuring worldwide unification of physical measurements. It is the "international" metrology institute, and operates under the exclusive supervision of the CIPM.

1.5 Some useful definitions

quantity in the general sense A quantity in the general sense is a property ascribed to phenomena, bodies, or substances that can be quantified for, or assigned to, a particular phenomenon, body, or substance. Examples are mass and electric charge.

quantity in the particular sense A quantity in the particular sense is a quantifiable or assignable property ascribed to a particular phenomenon, body, or substance. Examples are the mass of the moon and the electric charge of the proton.

physical quantity A physical quantity is a quantity that can be used in the mathematical equations of science and technology.

unit A unit is a particular physical quantity, defined and adopted by convention, with which other particular quantities of the same kind are compared to express their value.

The **value of a physical quantity** is the quantitative expression of a particular physical quantity as the product of a number and a unit, the number being its numerical value. Thus, the numerical value of a particular physical quantity depends on the unit in which it is expressed.

More formally, the value of quantity A can be written as $A = \{A\}[A]$, where $\{A\}$ is the numerical value of A when A is expressed in the unit $[A]$. The numerical value can therefore be written as $\{A\} = A/[A]$, which is a convenient form for use in figures and tables. Thus to eliminate the possibility of misunderstanding, an axis of a graph or the heading of a column of a table can be labelled '$t/°\mathrm{C}$' instead of '$t(°\mathrm{C})$' or 'Temperature (°C)'. Similarly, another example: '$E/(\mathrm{V/m})$' instead of '$E(\mathrm{V/m})$' or 'Electric field strength (V/m)'.

For example: the value of the height h_W of the Washington Monument is $h_W = 169\ \mathrm{m} = 555\ \mathrm{ft}$[5]. Here h_W is the physical quantity, its value expressed in the unit metre, unit symbol m, is 169 m, and its numerical value when expressed in metres is 169.

2 SI units

2.1 SI base units

2.1.1 Definitions

The SI is founded on seven SI base units for seven base quantities assumed to be mutually independent. The primary definitions of the SI base units are in French. Their current definitions, along with an English translation, are given below:

metre; *mètre*

Le mètre est la longueur du trajet parcouru dans le vide par la lumière pendant une durée de 1/299 792 458 *de seconde.*
(17th CGPM (1983), Resolution 1).

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.

[5] foot (ft) is not part of the SI units

kilogram; *kilogramme*

Le kilogramme est l'unité de masse; il est égal à la masse du prototype international du kilogramme.
(1st CGPM (1889) and 3rd CGPM (1901)).

The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
Note: This international prototype is made of platinum-iridium and is kept at the International Bureau of Weights and Measures, Sèvres, France.

second; *seconde*

La seconde est la durée de 9 192 631 770 *périodes de la radiation correspondant à la transition entre les deux niveaux hyperfins de l'état fondamental de l'atome de cesium 133.*
(13th CGPM (1967), Resolution 1).

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 cesium-133 atom.

Note: This definition refers to a caesium atom at rest at a temperature of 0 K.

ampere; *ampère*

L'ampère est l'intensité d'un courant constant qui, maintenu dans deux conducteurs parallèles, rectilignes, de longueur infinie, de section circulaire négligeable, et placés à une distance de 1 mètre l'un de l'autre dans le vide, produirait entre ces conducteurs une force égale à 2×10^{-7} *newton par mètre de longueur.*
(9th CGPM (1948), Resolutions 2 and 7).

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.

kelvin; *kelvin*

Le kelvin, unité de température thermodynamique, est la fraction 1/273.16 *de la température thermodynamique du point triple de l'eau.*
(13th CGPM (1967), Resolution 4).

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

Note: The 13th CGPM (1967, Resolution 3) also decided that the unit kelvin and its symbol K should be used to express both thermodynamic temperature and an interval or a difference of temperature, instead of 'degree Kelvin' with symbol °K.

In addition to the thermodynamic temperature (symbol T) there is also the Celsius (symbol t) defined by the equation $t = T - T_0$ where $T_0 = 273.15$ K. Celsius temperature is expressed in degree Celsius; *degré Celsius* (symbol °C).

The unit 'degree Celsius' is equal to the unit 'kelvin'; in this case, 'degree Celsius' is a special name used in place of 'kelvin'. A temperature interval or difference of Celsius temperature can, however, be expressed in kelvins as well as in degrees Celsius.

mole; *mole*

1. La mole est la quantité de matière d'un système contenant autant d'entités élémentaires qu'il y a d'atomes dans $0,012$ *kilogramme de carbone* 12.

2. Lorsqu'on emploie la mole, les entités élémentaires doivent être spécifiées et peuvent être des atomes, des molécules, des ions, des électrons, d'autres particules ou des groupements spécifiés de telles particules.
(14th CGPM (1971), Resolution 3).

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.

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 particle.

Note: In this definition, it is understood that the carbon 12 atoms are unbound, at rest and in their ground state.

candela; *candela*

La candela est l'intensité lumineuse, dans une direction donnée, d'une source qui émet une radiation monochromatique de fréquence 540×10^{12} *hertz et dont l'intensité énergétique dans cette direction est* $1/683$ *watt par stéradian.*
(16th CGPM (1979), Resolution 3).

The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of a frequency 540×10^{12} hertz and has a radiant intensity in that direction of $1/683$ watt per steradian.

Table 1: — SI base units —

Quantity	**Name**	**Symbol**
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 2: — Examples of SI derived units —

Derived quantity	**Name**	**Symbol**
area	square metre	m^2
volume	cubic metre	m^3
speed, velocity	metre per second	m/s
acceleration	metre per second squared	m/s^2
wave number	reciprocal metre	m^{-1}
mass density	kilogram per cubic metre	kg/m^3
specific volume	cubic metre per kilogram	m^3/kg
current density	ampere per square metre	A/m^2
magnetic field strength	ampere per metre	A/m
amount-of-substance concentration	mole per cubic metre	mol/m^3
luminance	candela per square metre	cd/m^2
mass fraction	kilogram per kilogram	kg/kg^a

[a] the symbol 1 for quantities of dimension 1 such as mass fraction is generally omitted.

2.1.2 Symbols

The base units of the International System are collected in table 1 with their names and their symbols (10th CGPM (1954), Resolution 6; 11th CGPM (1960), Resolution 12; 13th CGPM (1967), Resolution 3; 14th CGPM (1971), Resolution 3).

2.2 SI derived units

Derived units are units which may be expressed in terms of base units by means of the mathematical symbols of multiplication and division. Certain derived units have been given special names and symbols, and these special names and symbols may themselves be used in combination with those for base and other derived units to express the units of other quantities.

2.2.1 Units expressed in terms of base units

Table 2 lists some examples of derived units expressed directly in terms of base units. The derived units are obtained by multiplication and division of base units.

2.2.2 SI derived units with special names and symbols

For ease of understanding and convenience, 21 SI derived units have been given special names and symbols, as shown in table 3. They may themselves be used to express other derived units.

2.2.3 Use of SI derived units with special names and symbols

Examples of SI derived units that can be expressed with the aid of SI derived units having special names and symbols (including the radian and steradian) are given in table 3. The advantages of using the special names and symbols of SI derived units are apparent in table 4. Consider, for example, the quantity molar entropy: the unit J/mol K is obviously more easily understood than its SI base-unit equivalent, $\mathrm{m^2\ kg\ s^{-2}\ K^{-1}mol^{-1}}$. Nevertheless, it should always be recognised that the special names and symbols exist for convenience. Tables 3 & 4 also show that the values of several different quantities are expressed in the same SI unit. For example, the joule per kelvin (J/K) is the SI unit for heat capacity as well as for entropy. Thus the name of the unit is not sufficient to define the quantity measured. A derived unit can often be expressed in several different ways through the use of base units and derived units with special names. In practice, with certain quantities, preference is given to using certain units with special names, or combinations of units, to facilitate the distinction between quantities whose values have identical expressions in terms of SI base units. For example, the SI unit of frequency is specified as the hertz (Hz) rather than the reciprocal second ($\mathrm{s^{-1}}$), and the SI unit of moment of force is specified as the newton metre (N m) rather than the joule (J).

2.3 Dimension of a quantity

Any SI derived quantity Q can be expressed in terms of the SI base quantities length (l), mass (m), time (t), electric current (I), thermodynamic temperature (T), amount of substance (n), and luminous intensity (I_v) by an equation of the form

$$Q = l^\alpha m^\beta t^\gamma I^\delta T^\varepsilon n^\zeta I_\mathrm{v}^\eta \sum_{k=1}^{K} a_k,$$

where the exponents α, β, γ, ... are numbers and the factors a_k are also numbers. The dimension of Q is defined to be

$$\dim Q = \mathsf{L}^\alpha \mathsf{M}^\beta \mathsf{T}^\gamma \mathsf{I}^\delta \Theta^\varepsilon \mathsf{N}^\zeta \mathsf{J}^\eta,$$

where L, M, T, I, Θ, N and J are the dimensions of the SI base quantities length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity, respectively. The exponents α, β, γ, ... are called "dimensional exponents". The SI derived unit of Q is $\mathrm{m^\alpha\ kg^\beta\ s^\gamma\ A^\delta\ K^\varepsilon\ mol^\zeta\ cd^\eta}$, which is obtained by replacing the dimensions of the SI base quantities in the dimension of Q with the symbols for the corresponding base units.

> *For example:* Consider a nonrelativistic particle of mass m in uniform motion which travels a distance l in a time t. Its velocity is $v = l/t$ and its kinetic energy is $E_\mathrm{k} = mv^2/2 = l^2mt^{-2}/2$. The dimension of E_k is $\dim E_\mathrm{k} = \mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}$ and the dimensional exponents are 2, 1, and −2.

Table 3: — SI derived units with special names and symbols —

Name	**Expression in SI base units**	**Symbol**	**Expression in SI derived units**
radian[a]	$\mathrm{m\ m^{-1}} = 1^b$	rad	$\mathrm{m\ m^{-1}}$
steradian[a]	$\mathrm{m^2\ m^{-2}} = 1^b$	sr[c]	$\mathrm{m^2\ m^{-2}}$
hertz	$\mathrm{s^{-1}}$	Hz	$\mathrm{s^{-1}}$
newton	$\mathrm{m\ kg\ s^{-2}}$	N	$\mathrm{m\ kg\ s^{-2}}$
pascal	$\mathrm{m^{-1}\ kg\ s^{-2}}$	Pa	$\mathrm{N\ m^{-2}}$
joule	$\mathrm{m^2\ kg\ s^{-2}}$	J	N m
watt	$\mathrm{m^2\ kg\ s^{-3}}$	W	$\mathrm{J\ s^{-1}}$
coulomb	A s	C	A s
volt	$\mathrm{m^2\ kg\ s^{-3}\ A^{-1}}$	V	$\mathrm{W\ A^{-1}}$
farad	$\mathrm{m^{-2}\ kg^{-1}\ s^4\ A^2}$	F	$\mathrm{C\ V^{-1}}$
ohm	$\mathrm{m^2\ kg\ s^{-3}\ A^{-2}}$	Ω	$\mathrm{V\ A^{-1}}$
siemens	$\mathrm{m^{-2}\ kg^{-1}\ s^3\ A^2}$	S	$\mathrm{A\ V^{-1}}$
weber	$\mathrm{m^2\ kg\ s^{-2}\ A^{-1}}$	Wb	$\mathrm{m^2\ kg\ s^{-2}\ A^{-1}}$
tesla	$\mathrm{kg\ s^{-2}\ A^{-1}}$	T	$\mathrm{Wb\ m^{-2}}$
henry	$\mathrm{m^2\ kg\ s^{-2}\ A^{-2}}$	H	$\mathrm{Wb\ A^{-1}}$
celsius	K	°C	K
lumen	$\mathrm{cd\ m^2\ m^{-2}}$[c]	lm	cd sr
lux	$\mathrm{cd\ m^2\ m^{-4}}$	lx	$\mathrm{lm\ m^{-2}}$
becquerel	$\mathrm{s^{-1}}$	Bq	$\mathrm{s^{-1}}$
gray	$\mathrm{m^2\ s^{-2}}$	Gy	$\mathrm{J\ kg^{-1}}$
sievert[d]	$\mathrm{m^2\ s^{-2}}$	Sv	$\mathrm{J\ kg^{-1}}$
katal[e]	$\mathrm{s^{-1}\ mol}$	kat	$\mathrm{s^{-1}\ mol}$

[a] The radian and steradian may be used advantageously in expressions for derived units to distinguish between quantities of a different nature but of the same dimension; some examples are given in table 4.

[b] In practice, the symbols rad and sr are used where appropriate, but the derived unit '1' is generally omitted.

[c] In photometry, the unit name steradian and the unit symbol sr are usually retained in expressions for derived units.

[d] Other quantities expressed in sieverts are ambient dose equivalent, directional dose equivalent, personal dose equivalent, and organ equivalent dose.

[e] The 21st Conférence Générale des Poids et Mesures decides to adopt the special name katal, symbol kat, for the SI unit mole per second to express catalytic activity, especially in the fields of medicine and biochemistry, ... (21th CGPM (1999), Resolution 12).

Table 4: — Examples of SI derived units expressed with the aid of SI derived units having special names and symbols —

Derived quantity	**Name**	**Symbol**
angular velocity	radian per second	rad/s
angular acceleration	radian per second squared	rad/s^2
dynamic viscosity	pascal second	Pa s
moment of force	newton metre	N m
surface tension	newton per metre	N/m
heat flux density, irradiance	watt per square metre	W/m^2
radiant intensity	watt per steradian	W/sr
radiance	watt per square metre steradian	W/m^2 sr
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram kelvin	J/kg K
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per metre kelvin	W/m K
energy density	joule per cubic metre	J/m^3
electric field strength	volt per metre	V/m
electric charge density	coulomb per cubic metre	C/m^3
electric flux density	coulomb per square metre	C/m^2
permittivity	farad per metre	F/m
permeability	henry per metre	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity	joule per mole kelvin	J/mol K
exposure (x and γ rays)	coulomb per kilogram	C/kg
absorbed dose rate	gray per second	Gy/s
catalytic (activity) concentration	katal per cubic metre	kat/m^3

The SI derived unit of E_k is then $m^2\ kg\ s^{-2}$, which is given the special name "joule" and special symbol J.

2.3.1 Units for dimensionless quantities, quantities of dimension one

A derived quantity of dimension one, which is sometimes called a "dimensionless quantity", is one for which all of the dimensional exponents are zero: $\dim Q = 1$. It therefore follows that the derived unit for such a quantity is also the number one, symbol 1, which is sometimes called a "dimensionless derived unit". Thus the SI unit of all quantities having the dimensional product one is the number one. Examples of such quantities are refractive index, relative permeability, and friction factor. All of these quantities are described as being dimensionless, or of dimension one, and have the coherent SI unit 1. Their values are simply expressed as numbers and, in general, the unit 1 is not explicitly shown.

For example: The mass fraction w_B of a substance B in a mixture is given by $w_B = m_B/m$, where w_B is the mass of B and m is the mass of the mixture. The dimension of w_B is $\dim w_B = \mathsf{M}^1\mathsf{M}^{-1} = 1$; all of the dimensional exponents of w_B are zero, and its derived unit is $kg^1\ kg^{-1} = 1$ also.

In a few cases, however, a special name is given to this unit, mainly to avoid confusion between some compound derived units. This is the case for the radian, steradian and neper.

2.4 Rules and style conventions for writing and using SI unit symbols

The general principles concerning writing the unit symbols were adopted by the 9th CPGM (1948), by its Resolution 7:

1. Roman (upright) type, in general lower case[6], is used for the unit symbols. If, however, the name of the unit is derived from a proper name, the first letter of the symbol is in upper case.
2. Unit symbols are unaltered in the plural.
3. Unit symbols are not followed by a period[7].

To ensure uniformity in the use of the SI unit symbols, ISO International Standards give certain recommendations. Following these recommendations:

a) The product of two or more units are indicated by means of either a half-high (that is, centred) dot or a space[8]. The half-high dot is preferred, because it is less likely to lead to confusion,

for example:

$N \cdot m$ or N m.

[6]The recommended symbol for the litre ('liter') in the United States is L.

[7]Unless at the end of a sentence.

[8]ISO suggests that if a space is used to indicate units formed by multiplication, the space may be omitted if it does not cause confusion. This possibility is reflected in the common practice of using the symbol kWh rather than $kW \cdot h$ or kW h for the kilowatt hour.

b) A solidus (oblique stroke,/), a horizontal line, or negative exponents may be used to express a derived unit formed from two others by division,

for example:

m/s, $\frac{\text{m}}{\text{s}}$, or m s^{-1}

c) The solidus must not be repeated on the same line unless ambiguity is avoided by parentheses. In complicated cases negative exponents or parentheses should be used,

for example:

m/s^2 or m s^{-2} *but not:* m/s/s

m kg/(s^3 A) or m kg s^{-3} A^{-1} *but not:* m kg/s^3/A

2.4.1 Space between numerical value and unit symbol

In the expression for the value of a quantity, the unit symbol is placed after the numerical value and a space is left between the numerical value and the unit symbol. The only exceptions to this rule are for the unit symbols for degree, minute, and second for plane angle: °, ′, and ″, respectively (see Table 8), in which case no space is left between the numerical value and the unit symbol.

for example:

$\alpha = 30°22'8''$ Note: α is a quantity symbol for plane angle.

This rule means that the symbol °C for the degree Celsius is preceded by a space when one expresses the values of Celsius temperatures.

for example:

$t = 30.2$ °C *but not* $t = 30.2$°C

3 SI Prefixes

3.1 Decimal multiples and submultiples of SI units

The 11th CGPM (1960), by its Resolution 12, adopted a first series of prefixes and symbols of prefixes to form the names and symbols of the decimal multiples and submultiples of SI units. Prefixes for 10^{-15} and 10^{-18} were added by the 12th CGPM (1964), by its Resolution 8, those for 10^{15} and 10^{18} by the CGPM (1975), by its Resolution 10, and those for 10^{21}, 10^{24}, 10^{-21}, and 10^{-24} were proposed by the CIPM for approval by the 19th CGPM (1991), and adopted. The prefixes are as shown in tabel 5.

3.2 Rules for using SI prefixes

In accord with the general principles adopted by the ISO[9], the CIPM recommends that the following rules for using the SI prefixes be observed:

[9]ISO 31, in 'Units of measurement,' ISO Standards Handbook 2, 2nd Edition, ISO, Geneva, 1982, pp. 17–238

Table 5: — SI prefixes —

Name	Symbol	Factor	Name	Symbol	Factor
yocto	y	$10^{-24} = (10^3)^{-8}$	yotta	Y	$10^{24} = (10^3)^{8}$
zepto	z	$10^{-21} = (10^3)^{-7}$	zetta	Z	$10^{21} = (10^3)^{7}$
atto	a	$10^{-18} = (10^3)^{-6}$	exa	E	$10^{18} = (10^3)^{6}$
femto	f	$10^{-15} = (10^3)^{-5}$	peta	P	$10^{15} = (10^3)^{5}$
pico	p	$10^{-12} = (10^3)^{-4}$	tera	T	$10^{12} = (10^3)^{4}$
nano	n	$10^{-9} = (10^3)^{-3}$	giga	G	$10^{9} = (10^3)^{3}$
micro	μ	$10^{-6} = (10^3)^{-2}$	mega	M	$10^{6} = (10^3)^{2}$
milli	m	$10^{-3} = (10^3)^{-1}$	kilo	k	$10^{3} = (10^3)^{1}$
centi	c	10^{-2}	hecto	h	10^{2}
deci	d	10^{-1}	deca[a]	da	10^{1}

[a] In the USA, the spelling 'deka' is extensively used.

1. Prefix symbols are printed in roman (upright) type without spacing between the prefix symbol and the unit symbol.

2. The grouping formed by the prefix symbol attached to the unit symbol constitutes a new inseparable symbol (of a multiple of the unit concerned) which can be raised to a positive or negative power and which can be combined with other unit symbols to form compound unit symbols,

   for example:

   $1\ \mathrm{cm}^3 = (10^{-2}\ \mathrm{m})^3 = 10^{-6}\ \mathrm{m}^3$

   $1\ \mathrm{cm}^{-1} = (10^{-2}\ \mathrm{m})^{-1} = 10^{2}\ \mathrm{m}^{-1}$

   $1\ \mathrm{V/cm} = (1\ \mathrm{V})/(10^{-2}\ \mathrm{m}) = 10^{2}\ \mathrm{V/m}$

3. Compound prefixes, i. e., prefixes formed by juxtaposition of two or more SI prefixes are not to be used,

   for example:

   1 pg (one picogram), *but not* 1 mng (one millinanogram)

4. A prefixes should never be used alone,

   for example:

   $10^6/\mathrm{m}^3$, *but not* M/m^3

3.2.1 The kilogram

It is important to note that the kilogram is the only SI unit with a prefix as part of its name and symbol. Because multiple prefixes may not be used, in the case of the kilogram the prefix names are used with the unit name 'gram' and the prefix symbols are used with the unit symbol g, *for example:*
10^{-6} kg = 1 mg (one milligram), *but not* 10^{-6} kg = 1 μkg (one microkilogram).

Table 6: — Prefixes for binary multiples —

Factor	Name	Symbol	Origin		Derivation	
2^{10}	kibi	Ki	kilobinary:	$(2^{10})^1$	kilo:	$(10^3)^1$
2^{20}	mebi	Mi	megabinary:	$(2^{10})^2$	mega:	$(10^3)^2$
2^{30}	gibi	Gi	gigabinary:	$(2^{10})^3$	giga:	$(10^3)^3$
2^{40}	tebi	Ti	terabinary:	$(2^{10})^4$	tera:	$(10^3)^4$
2^{50}	pebi	Pi	petabinary:	$(2^{10})^5$	peta:	$(10^3)^5$
2^{60}	exbi	Ei	exabinary:	$(2^{10})^6$	exa:	$(10^3)^6$

Table 7: — Examples and comparisons with SI prefixes —

one kibibit	1 Kibit	=	2^{10} bit	=	1 024 bit
one kilobit	1 kbit	=	10^3 bit	=	1 000 bit
one mebibyte	1 MiB	=	2^{20} B	=	1 048 576 B
one megabyte	1 MB	=	10^6 B	=	1 000 000 B
one gibibyte	1 GiB	=	2^{30} B	=	1 073 741 824 B
one gigabyte	1 GB	=	10^9 B	=	1 000 000 000 B

3.2.2 The ‘degree Celsius’

Except for the kilogram, any SI prefix may be used with any SI unit, including the ‘degree Celsius’ and its symbol °C, *for example:*
10^{-3} °C = 1 m°C (one millidegree Celsius), *or* 10^6 °C = 1 M°C.

4 Prefixes for binary multiples

In December 1998 the International Electrotechnical Commission (IEC), the leading international organization for worldwide standardization in electrotechnology, approved as an IEC International Standard names and symbols for prefixes for binary multiples for use in the fields of data processing and data transmission. The prefixes are as shown in table 6. It is suggested that in English, the first syllable of the name of the binary-multiple prefix should be pronounced in the same way as the first syllable of the name of the corresponding SI prefix, and that the second syllable should be pronounced as “bee”.

Note

It is important to recognize that the new prefixes for binary multiples are *not* part of the International System of Units (SI), the modern metric system. However, for ease of understanding and recall, they were derived from the SI prefixes for positive powers of ten. As can be seen from the above table, the name of each new prefix is derived from the name of the corresponding SI prefix by retaining the first two letters of the name of the SI prefix and adding the letters “bi”, which recalls the word “binary”. Similarly, the symbol of each new prefix is derived from the symbol of the corresponding SI prefix by adding the letter “i”, which again recalls the word “binary”. (For consistency with the other prefixes for binary multiples, the symbol Ki is used for 2^{10} rather than ki.)

4.1 Official publication

These prefixes for binary multiples, which were developed by IEC Technical Committee (TC) 25, Quantities and units, and their letter symbols, with the strong support of the International Committee for Weights and Measures (CIPM) and the Institute of Electrical and Electronics Engineers (IEEE), were adopted by the IEC as *Amendment 2 to IEC International Standard IEC 60027-2: Letter symbols to be used in electrical technology - Part 2: Telecommunications and electronics*. The full content of *Amendment 2*, which has a publication date of 1999-01, is reflected in the tables above and the suggestion regarding pronunciation.

4.2 The `binary.sty` style for binary prefixes and (non-SI) units

The `binary.sty` style for binary prefixes and (non-SI) units can be loaded by using the option binary, as in `\usepackage[binary]{SIunits}`. This unit should always be used in conjunction with the `SIunits` package.

5 Units outside the SI

Units that are outside the SI may be divided into three categories:

1. those units that are accepted for use with the SI;
2. those units that are temporarily accepted for use with the SI; and
3. those units that are not accepted for use with the SI and thus must strictly be avoided.

5.1 Units accepted for use with the SI

The CIPM (1969) recognised that users of SI will also wish to employ with it certain units not part of it, but which are important and are widely used. These units are given in table 8. The combination of units of this table with SI units to form compound units should be restricted to special cases in order not to lose the advantage of the coherence of SI units.

It is likewise necessary to recognise, outside the International System, some other units that are useful in specialised fields, because their values expressed in SI units must be obtained by experiment, and are therefore not known exactly (table 9).

5.2 Units temporarily accepted for use with the SI

Because of existing practice in certain fields or countries, in 1978 the CIPM considered that it was permissible for the units given in table 10 to continue to be used with the SI until the CIPM considers that their use is no longer necessary. However, these units must not be introduced where they are not presently used.

6 Last notes about correct usage of the SI

The following points underline some of the important aspects about using SI units and their symbols, and also mention some of the common errors that are made.

Table 8: — Units accepted for use with the SI —

Name	Symbol	Value in SI units
minute (time)	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s
degree[a]	°	$1° = (\pi/180)$ rad
minute (plane angle)	′	$1′ = (1/60)° = (\pi/10\,800)$ rad
second (plane angle)	″	$1″ = (1/60)′ = (\pi/648\,000)$ rad
litre	l, L[b]	$1\ \mathrm{l} = 1\ \mathrm{L} = 1\ \mathrm{dm}^3 = 10^{-3}\ \mathrm{m}^3$
tonne[c]	t	$1\ \mathrm{t} = 10^3$ kg
neper[d e]	Np	1 Np = 1
bel[f e]	B	$1\ \mathrm{B} = (1/2)\ln 10$ (Np)[g]

[a]ISO 31 recommends that the degree be subdivided decimally rather than using the minute and second.

[b]The alternative symbol for the litre, L, was adopted by the CGPM in order to avoid the risk of confusion between the letter l and the number 1. Thus, although both l and L are internationally accepted symbols for the litre, to avoid this risk the symbol to be used in the United States is L.

[c]In some English-speaking countries this unit is called 'metric ton'.

[d]The neper is used to express values of such logarithmic quantities as field level, power level, sound pressure level, and logarithmic decrement. Natural logarithms are used to obtain the numerical values of quantities expressed in nepers. The neper is coherent with the SI, but not yet adopted by the CGPM as an SI unit. For further information see International Standard ISO 31.

[e]The bel is used to express values of such logarithmic quantities as field level, power level, sound pressure level, and attenuation. Logarithms to base ten are used to obtain the numerical values of quantities expressed in bels. The submultiple decibel, dB, is commonly used. For further information see International Standard ISO 31.

[f]In using these units it is particularly important that the quantity be specified. The unit must not be used to imply the quantity.

[g]Np is enclosed in parentheses because, although the neper is coherent with the SI, it has not yet been adopted by the CGPM.

Table 9: — Units accepted for use with the SI whose values in SI units are obtained experimentally —

Name	Symbol	Definition
electronvolt	eV	[a]
unified atomic mass unit	u	[b]

[a]The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum; $1\ \mathrm{eV} = 1.602\,177\,33 \times 10^{-19}$ J with a combined standard uncertainty of $0.000\,000\,49 \times 10^{-19}$ J.

[b]The unified atomic mass unit is equal to 1/12 of the mass of an atom of the nuclide ^{12}C; $1\ \mathrm{u} = 1.660\,540\,2 \times 10^{-27}$ kg with a combined standard uncertainty of $0.000\,001\,0 \times 10^{-27}$ kg.

Table 10: — Units in use temporarily with the SI —

Name	**Symbol**	**Value in SI units**
nautical mile[a]		1 nautical mile = 1 852 m
knot		1 nautical mile per hour = (1 852/3 600) m/s
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
are[b]	a	1 a = 1 dam^2 = 10^2 m^2
hectare[b]	ha	1 ha = 1 hm^2 = 10^4 m^2
barn[c]	b	1 b = 100 fm^2 = 10^{-28} m^2
bar[d]	bar	1 bar = 0.1 MPa = 10^5 Pa
gal[e]	Gal	1 Gal = 1 cm/s^2 = 10^{-2} m/s^2
curie[f]	Ci	1 Ci = 3.7×10^{10} Bq
roentgen[g]	R	1 R = 2.58×10^{-4} C/s
rad[h]	rad	1 rad = 1 cGy = 10^{-2} Gy
rem[i]	rem	1 rem = 1 cSv = 10^{-2} Sv

[a] The nautical mile is a special unit employed for marine and aerial navigation to express distances. The conventional value given above was adopted by the First International Extraordinary Hydrographic Conference, Monaco, 1929, under the name "International nautical mile".

[b] This unit and its symbol were adopted by the CIPM in 1879 (BIPM Proc. Verb. Com. Int. Poids et Mesures, 1879, p. 41) and are used to express agrarian areas.

[c] The barn is a special unit employed in nuclear physics to express effective cross sections.

[d] This unit and its symbol are included in Resolution 7 of the 9th CGPM (1948).

[e] The gal is a special unit employed in geodesy and geophysics to express the acceleration due to gravity.

[f] The curie is a special unit employed in nuclear physics to express activity of radionuclides (12th CGPM (1964), Resolution 7).

[g] The roentgen is a special unit employed to express exposure of x or γ radiations.

[h] The rad is a special unit employed to express absorbed dose of ionising radiations. When there is risk of confusion with the symbol for radian, rd may be used as the symbol for rad.

[i] The rem is a special unit used in radioprotection to express dose equivalent.

The SI differs from some of the older systems in that it has *definite* rules governing the way the units and symbols are used.

- The unit of measure is the *'metre'*, not *'meter'*. The latter is a device used for measuring things. (Unless you live in the USA - in which case you will just have to live with the ambiguity.)
- Using a comma to separate groups of three digits is not recommended - a (thin) space is preferable, since many countries use the comma as the decimal point marker. Both the USA and UK use the 'dot on the line' (full stop). So the following would be correct: 1 234 555.678 990.
- The term **billion** should be avoided since in most countries outside the USA (including the UK) it means a million-million (prefix tera), whereas in the USA it means a thousand million (prefix giga). Likewise the term **trillion** means million-million-million (prefix exa) in most countries outside the USA.
- The 'litre' ('liter' in the US) is one of those units which is approved by the CGPM for use with the metric system. The official unit of volume in the SI is the cubic metre. However, since this is not convenient for much day-to-day use the CGPM has approved the use of the 'other unit', the litre. The litre represents a cubic decimetre and you may use either the symbol 'l' or 'L'[10] (small or capital 'ell') to represent it. They do not approve using any prefixes other than milli or micro with it. It was originally defined as the volume occupied by 1 kg of water. Subsequently it was found that this was not precisely 1 cubic decimetre, so the term litre was withdrawn. Later it was re-introduced officially as 1 cubic decimetre exactly. So, $1\,\mathrm{l} = 1\,\mathrm{dm}^3 = 1\,\mathrm{L}$.

7 How to use the package

7.1 Loading

Most features are controlled by package options that can be selected when the package is loaded (e. g `\usepackage[`⟨*options*⟩`]{SIunits}`) or at 'runtime' as an optional argument(list) to the `\SIunits` command (e. g. `\SIunits[`⟨*options*⟩`]`).

```
\documentclass[]{article}

\usepackage[options]{SIunits}

\begin{document}
...
\SIunits[options]
...
\end{document}
```

[10] Recommended symbol for the 'liter' in the USA

7.2 The package options

The options can be grouped in the following categories:

1. unit spacing;
2. quantity-unit spacing;
3. conflicts;
4. textstyle;
5. miscellaneous.

7.2.1 Unit spacing options

cdot This mode provides the use of `\cdot` as spacing in units.

thickspace This mode provides the use of `\;` (thick math space) as spacing in units.

mediumspace This mode provides the use of `\:` (medium math space) as spacing in units.

thinspace This mode provides the use of `\,` (thin math space) as spacing in units.

7.2.2 Quantity-unit spacing options

thickqspace This mode provides the use of `\;` (thick math space) as spacing between numerical quantities and units.

mediumqspace This mode provides the use of `\:` (medium math space) as spacing between numerical quantities and units.

thinqspace This mode provides the use of `\,` (thin math space) as spacing between numerical quantities and units.

7.2.3 Options to prevent conflicts

Conflicts with the `amssymb` package

In the `amssymb` package the command `\square` is defined. This will cause error messages when the `amssymb` package is used in combination with the `SIunits` package. To prevent errors one can choose two different options:

amssymb This option redefines the `amssymb` command `\square` to get the desired `SIunits` definition of the command.
Note: When using this option, the `amssymb` command `\square` can **not** be used.

squaren This option defines a new command `\squaren` that can be used instead of the `SIunits` command `\square`.
Note: When using this option, the `amssymb` definition for `\square` is used.

Conflicts with the `pstricks` package

In the `pstricks` package the command `\gray` is defined. This will cause error messages when the `pstricks` package is used in combination with the `SIunits` package. To prevent errors one can choose two different options:

pstricks This option redefines the `pstricks` command `\gray` to get the desired `SIunits` definition of the command.
Note: When using this option, the `pstricks` command `\gray` can **not** be used.

Gray This option defines a new command `\Gray` that can be used instead of the `SIunits` command `\gray`.
Note: When using this option, the `pstricks` definition for `\gray` is used.

Conflicts with the `babel` package in combination with the italian language

In the `babel` package, when using the italian language, the command `\unit` is defined. This will prevent `SIunits` from functioning. To prevent this, choose the option:

italian This option defines a new command `\unita` (italian for unit) that can be used instead of the `SIunits` command `\unit`.
Note: When using this option, the `babel` definition for `\unit` is used.

7.2.4 textstyle

textstyle When using the option textstyle units are printed in the typeface of the enclosing text, automatically.

7.2.5 miscellaneous

binary This option loads the file `binary.sty`, which defines prefixes for binary multiples.

noams This option redefines the `\micro` command; use it when you don't have the AMS font, eurm10.

derivedinbase This mode provides the ready-to-use expressions of SI derived units in SI base units, e. g. `\pascalbase` to get 'm^{-1} kg s^{-2}'.

derived This mode provides the ready-to-use expressions of SI derived units in SI derived units, e. g. `\derpascal` to get 'N m^{-2}'.

See table 11 for examples of the spacing options.

Command Reference

7.3 How to compose units in your text.

The purpose of the `SIunits` package is: to give an author an intuitive system for writing units. Just type (in LaTeX-kind commands) what you would say: `\kilogram` or `\kelvin` to get 'kg' or 'K'.

Table 11: — Spacing options —

Option	Example
cdot	$\mathrm{N \cdot m}$
thickspace	$\mathrm{N\ m}$
mediumspace	$\mathrm{N\ m}$
thinspace	$\mathrm{N\,m}$
thickqspace	$10\ \mathrm{N\ m}$
mediumqspace	$10\ \mathrm{N\ m}$
thinqspace	$10\,\mathrm{N\ m}$

To use the prefixes with SI units simply place them before the unit, e. g. `\milli\ampere`, `\deca\metre` (or `\deka\meter`) or `\mega\ohm` to get: 'mA', 'dam' or 'MΩ'. Decimal values of the prefixes can be made by adding `d` behind the prefix command. See command reference on page 25.

7.3.1 Division or multiplication of SI units

The next step is the formation of units based on division and/or multiplication of SI units.

Division How to get the unit of speed?

1. Write down the unit in words: `metre per second`
2. Replace the spaces with backlashes to get the command: `\metre\per\second`
3. The result is: 'm/s'.

Simple! Ready!

Multiplication Now an example of multiplication of units, the unit of torque (newton metre):

1. Write down the unit in words: `newton metre`
2. To get an separation character between the two units use the command `\usk` (unitskip): `\newton\usk\metre`
3. The result is: 'N m'. The spacing between the units depends on the spacing options (see: page 22).

Mixed case The mixed case should be simple now; the unit of thermal conductivity (watt per metre kelvin):

1. Use your just-learned-knowledge:`\watt\per\metre\usk\kelvin`
2. The result is: 'W/m K'.

Now, you can do it all in one step! Intuitive & simple.

SI base units

`\metre`	m	`\second`	s	`\mole`	mol
`\meter`	m	`\ampere`	A	`\candela`	cd
`\kilogram`	kg	`\kelvin`	K		

SI derived units

`\hertz`	Hz	`\farad`	F	`\degreecelsius`	°C
`\newton`	N	`\ohm`	Ω	`\lumen`	lm
`\pascal`	Pa	`\siemens`	S	`\lux`	lx
`\joule`	J	`\weber`	Wb	`\becquerel`	Bq
`\watt`	W	`\tesla`	T	`\gray`	Gy
`\coulomb`	C	`\henry`	H	`\sievert`	Sv
`\volt`	V	`\celsius`	°C		

Units outside of SI

`\angstrom`	Å	`\dday`	d	`\minute`	min
`\arcminute`	′	`\degree`	°	`\neper`	Np
`\arcsecond`	″	`\electronvolt`	eV	`\rad`	rad
`\are`	a	`\gal`	Gal	`\rem`	rem
`\atomicmass`	u	`\gram`	g	`\roentgen`	R
`\barn`	b	`\hectare`	ha	`\rperminute`	r/min
`\bbar`	bar	`\hour`	h	`\tonne`	t
`\bel`	B	`\liter`	L	`\ton`	t
`\curie`	Ci	`\litre`	l		

SI Prefixes

`\yocto`	y	`\milli`	m	`\mega`	M
`\zepto`	z	`\centi`	c	`\giga`	G
`\atto`	a	`\deci`	d	`\tera`	T
`\femto`	f	`\deca`	da	`\peta`	P
`\pico`	p	`\deka`	da	`\exa`	E
`\nano`	n	`\hecto`	h	`\zetta`	Z
`\micro`	μ	`\kilo`	k	`\yotta`	Y

Decimal values of SI Prefixes

`\yoctod`	10^{-24}	`\millid`	10^{-3}	`\megad`	10^{6}
`\zeptod`	10^{-21}	`\centid`	10^{-2}	`\gigad`	10^{9}
`\attod`	10^{-18}	`\decid`	10^{-1}	`\terad`	10^{12}
`\femtod`	10^{-15}	`\decad`	10^{1}	`\petad`	10^{15}
`\picod`	10^{-12}	`\dekad`	10^{1}	`\exad`	10^{18}
`\nanod`	10^{-9}	`\hectod`	10^{2}	`\zettad`	10^{21}
`\microd`	10^{-6}	`\kilod`	10^{3}	`\yottad`	10^{24}

7.3.2 Raising SI units to a power

The `SIunits` package provides a set of functions to get units raised to a particular power.

Squaring and cubing How to get the units of area (square metre) and volume (cubic metre)?

1. Write down the unit in words: `square metre` and `cubic metre`
2. Replace the spaces with backlashes to get the commands: `\square\metre` and `\cubic\metre`
3. The result is: ' m^2' and 'm^3'.

I can hear you say: "We only use the word 'square' before the unit metre, normally we place the word 'squared' behind the unit name.". OK, lets try: `\second\squared` and `\second\cubed` gives: 's^2' and 's^3'. Thus, no problem.

The reciprocal, reciprocal squaring and - cubing How to get negative powers?

1. Use `\rpsquare` or `\rpsquared`, and `\rpcubic` and `\rpcubed`
2. *For example:* `\rpsquare\metre` and `\second\rpcubed`
3. The result is: ' m^{-2}' and 's^{-3}'.

Normally, we leave out the exponent 1, but sometimes we want to use the exponent -1. How to form the unit of frequency (reciprocal second = Hz)

1. Write down the unit in words: `reciprocal second`,
2. Replace the spaces with backlashes to get the commands: `\reciprocal\second`,
3. The result is: 's^{-1}'.

The power function The `\power` macro has been added to be able to form the wildest types of power raising: `\power{10}{35}` gives: 10^{35}.

7.4 Quantities and units

Use the command `\unit` to get consistent spacing between numerical quantities and units. Usage:
`\unit{120}{\kilo\meter\per\hour}` gives: 120 km/h.

7.4.1 Ready-to-use units

`\amperemetresecond`	A m s
`\amperepermetre`	A/m
`\amperepermetrenp`	A m^{-1}
`\amperepersquaremetre`	A/m^2
`\amperepersquaremetrenp`	A m^{-2}

\candelapersquaremetre	$\mathrm{cd/m^2}$
\candelapersquaremetrenp	$\mathrm{cd\ m^{-2}}$
\coulombpercubicmetre	$\mathrm{C/m^3}$
\coulombpercubicmetrenp	$\mathrm{C\ m^{-3}}$
\coulombperkilogram	C/kg
\coulombperkilogramnp	$\mathrm{C\ kg^{-1}}$
\coulombpermol	C/mol
\coulombpermolnp	$\mathrm{C\ mol^{-1}}$
\coulombpersquaremetre	$\mathrm{C/m^2}$
\coulombpersquaremetrenp	$\mathrm{C\ m^{-2}}$
\cubicmetre	$\mathrm{m^3}$
\faradpermetre	F/m
\faradpermetrenp	$\mathrm{F\ m^{-1}}$
\graypersecond	Gy/s
\graypersecondnp	$\mathrm{Gy\ s^{-1}}$
\henrypermetre	H/m
\henrypermetrenp	$\mathrm{H\ m^{-1}}$
\jouleperkelvin	J/K
\jouleperkelvinnp	$\mathrm{J\ K^{-1}}$
\jouleperkilogram	J/kg
\jouleperkilogramnp	$\mathrm{J\ kg^{-1}}$
\joulepermole	J/mol
\joulepermolenp	$\mathrm{J\ mol^{-1}}$
\joulepermolekelvin	J/mol K
\joulepermolekelvinnp	$\mathrm{J\ mol^{-1}\ K^{-1}}$
\joulepersquaremetre	$\mathrm{J/m^2}$
\joulepersquaremetrenp	$\mathrm{J\ m^{-2}}$
\joulepertesla	J/T
\jouleperteslanp	$\mathrm{J\ T^{-1}}$
\kilogrammetrepersecond	kg m/s
\kilogrammetrepersecondnp	$\mathrm{kg\ m\ s^{-1}}$
\kilogrammetrepersquaresecond	$\mathrm{kg\ m/s^2}$
\kilogrammetrepersquaresecondnp	$\mathrm{kg\ m\ s^{-2}}$
\kilogrampercubicmetre	$\mathrm{kg/m^3}$
\kilogrampercubicmetrenp	$\mathrm{kg\ m^{-3}}$
\kilogramperkilomole	kg/kmol
\kilogramperkilomolenp	$\mathrm{kg\ kmol^{-1}}$
\kilogrampermetre	kg/m
\kilogrampermetrenp	$\mathrm{kg\ m^{-1}}$
\kilogrampersecond	kg/s
\kilogrampersecondnp	$\mathrm{kg\ s^{-1}}$
\kilogrampersquaremetre	$\mathrm{kg/m^2}$
\kilogrampersquaremetrenp	$\mathrm{kg\ m^{-2}}$
\kilogrampersquaremetresecond	$\mathrm{kg/m^2\ s}$
\kilogrampersquaremetresecondnp	$\mathrm{kg\ m^{-2}\ s^{-1}}$
\kilogramsquaremetre	$\mathrm{kg\ m^2}$
\kilogramsquaremetrenp	$\mathrm{kg\ m^2}$
\kilogramsquaremetrepersecond	$\mathrm{kg\ m^2/s}$
\kilogramsquaremetrepersecondnp	$\mathrm{kg\ m^2\ s^{-1}}$

\kilowatthour	kWh
\metrepersquaresecond	$\mathrm{m/s^2}$
\metrepersquaresecondnp	$\mathrm{m\ s^{-2}}$
\molepercubicmetre	$\mathrm{mol/m^3}$
\molepercubicmetrenp	$\mathrm{mol\ m^{-3}}$
\newtonpercubicmetre	$\mathrm{N/m^3}$
\newtonpercubicmetrenp	$\mathrm{N\ m^{-3}}$
\newtonperkilogram	N/kg
\newtonperkilogramnp	$\mathrm{N\ kg^{-1}}$
\newtonpersquaremetre	$\mathrm{N/m^2}$
\newtonpersquaremetrenp	$\mathrm{N\ m^{-2}}$
\ohmmetre	Ω m
\pascalsecond	Pa s
\persquaremetresecond	$\mathrm{1/m^2\ s}$
\persquaremetresecondnp	$\mathrm{m^{-2}\ s^{-1}}$
\radianpersecond	rad/s
\radianpersecondnp	$\mathrm{rad\ s^{-1}}$
\radianpersquaresecond	$\mathrm{rad/s^2}$
\radianpersquaresecondnp	$\mathrm{rad\ s^{-2}}$
\squaremetre	$\mathrm{m^2}$
\squaremetrepercubicmetre	$\mathrm{m^2/m^3}$
\squaremetrepercubicmetrenp	$\mathrm{m^2\ m^{-3}}$
\squaremetrepernewtonsecond	$\mathrm{m^2/N\ s}$
\squaremetrepernewtonsecondnp	$\mathrm{m^2\ N^{-1}\ s^{-1}}$
\squaremetrepersecond	$\mathrm{m^2/s}$
\squaremetrepersecondnp	$\mathrm{m^2\ s^{-1}}$
\squaremetrepersquaresecond	$\mathrm{m^2/s^2}$
\squaremetrepersquaresecondnp	$\mathrm{m^2\ s^{-2}}$
\voltpermetre	V/m
\voltpermetrenp	$\mathrm{V\ m^{-1}}$
\wattpercubicmetre	$\mathrm{W/m^3}$
\wattpercubicmetrenp	$\mathrm{W\ m^{-3}}$
\wattperkilogram	W/kg
\wattperkilogramnp	$\mathrm{W\ kg^{-1}}$
\wattpersquaremetre	$\mathrm{W/m^2}$
\wattpersquaremetrenp	$\mathrm{W\ m^{-2}}$
\wattpersquaremetresteradian	$\mathrm{W/m^2\ sr}$
\wattpersquaremetresteradiannp	$\mathrm{W\ m^{-2}\ sr^{-1}}$

8 How the package works

8.1 Compatibility

The package has been tested using:

1. MiKTEX 1.10*b*, including LaTeX 2ε standard classes (LaTeX 2ε [1997/12/01] patch level 1) and TEX 3.14159, both under Microsoft Windows 95 and MS Windows NT 4.0.

2. MiKTEX 1.11, including LaTeX 2ε standard classes (LaTeX 2ε [1998/06/01])

and TEX 3.14159, both under Microsoft Windows 95 and MS Windows NT 4.0.

3. MiKTEX 2 UP 1, including LATEX 2_ε standard classes (LATEX 2_ε [2000/11/28]) and TEX 3.14159, under Microsoft Windows 2000 professional.

8.2 Known problems and limitations

1. When you don't have the AMS font `eurm10` use the option `noams`.
2. The amssymb package defines the `\square` command. Two possible solutions to avoid conflicts:
   - Use option `amssymb`: `\usepackage[amssymb]{SIunits}`. When using this option the amssymb command `\square` is redefined to the SIunits command.
   - Use option `squaren`: `\usepackage[squaren]{SIunits}`. When using this option the amssymb command `\square` is not redefined. Use the newly defined SIunits command `\squaren` instead of `\square` to get the desired behaviour.

   Note: Load `SIunits` package after `amssymb` package.
3. The pstricks package defines the `\gray` command. Two possible solutions to avoid conflicts:
   - Use option `pstricks`: `\usepackage[pstricks]{SIunits}`. When using this option the pstricks command `\gray` is redefined to the SIunits command.
   - Use option `Gray`: `\usepackage[Gray]{SIunits}`. When using this option the pstricks command `\gray` is not redefined. Use the newly defined SIunits command `\Gray` instead of `\gray` to get the desired behaviour.

   Note: Load `SIunits` package after `pstricks` package.

No further known problems or limitations. That doesn't mean this package is bug free, but it indicates the lack of testing that's been done on the package.

8.3 Sending a bug report

Reports of new bugs in the package are most welcome. However, I do **not** consider this to be a 'supported' package. This means that there is no guarantee I (or anyone else) will put any effort into fixing the bug (of course I will try to find some time). But, on the other hand, someone may try debugging, so filing a bug report is always a good thing to do! (If nothing else, your discoveries may end up in future releases of this document.) Before filing a bug report, please take the following actions:

1. Ensure your problem is not due to your input file;
2. Ensure your problem is not due to your own package(s) or class(es);

3. Ensure your problem is not covered in the section "Known problems and limitations" above;

4. Try to locate the problem by writing a minimal LaTeX 2_ε input file which reproduces the problem. Include the command
`\setcounter{errorcontextlines}{999}`
in your input;

5. Run your file through LaTeX 2_ε;

6. Send a description of your problem, the input file and the log file via e-mail to: `SIunits@webschool.nl`.

9 In conclusion

9.1 Acknowledgements

I want to thank Werenfried Spit (`w.spit@WITBO.NL`) answering my question to `TEX-NL@NIC.SURFNET.NL` about the "power functie", as well as Hans Hagen (`pragma@WXS.NL`) for the kind reaction to that question.

v0.01: Typos Jürgen von Haegen (`vonHagen@engr.psu.edu`)

v0.02 Beta 1: `\addunit` macro added Hint: Hans Bessem (`j.m.bessem@wbmt.tudelft.nl`)

v0.02 Beta 4: Typos Rafael Rodriguez Pappalardo (`rafapa@cica.es`)

v0.02 Beta 5: Tips/non-SI units Timothy C. Burt (`tcburt@comp.uark.edu`)

v0.02 Beta 7: `\angstrom` definition changed Hint: Lutz Schwalowsky (`schalow@mineralogie.uni-hamburg.de`); Solution: Piet van Oostrum (`piet@cs.uu.nl`)

v0.04: `\ohm` definition corrected Jürgen von Haegen (`vonHagen@engr.psu.edu`)

v0.06: Conflict with `amssymb` solved thanks to Timothy C. Burt (`tcburt@comp.uark.edu`)

9.2 References

1. National Institute of Standards and Technology Special Publication 330, *The International System of Units (SI), 1991 Edition*, by Barry N. Taylor, 62 p.: `http://physics.nist.gov/Document/sp330.pdf`

2. National Institute of Standards and Technology Special Publication 811, *Guide for the Use of the International System of Units (SI), 1995 Edition*, by Barry N. Taylor, 84 p.: `http://physics.nist.gov/Document/sp811.pdf`

3. National Institute of Standards and Technology, *Diagram of SI unit relationships:* `http://physics.nist.gov/cuu/Units/SIdiagram2.html`

4. International Bureau of Weights and Measures (*Bureau International des Poids et Mesures*), *SI brochure:* `http://www.bipm.fr/pdf/si-brochure.pdf` and *Supplement 2000:* `http://www.bipm.fr/pdf/si-supplement2000.pdf`

5. National Physical Laboratory, *The International System of Units:* `http://www.npl.co.uk/npl/reference/si_units.html`

6. National Institute of Standards and Technology, *The NIST reference on Constants, Units and Uncertainty:* `http://physics.nist.gov/cuu/Units/introduction.html`

7. David Barlett, *The Metric System: a concise reference guide:* `http://subnet.virtual-pc.com/ba424872/`