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260.1™

IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)

IEEE Standards Coordinating Committee 14

Sponsored by the
Standards Coordinating Committee on Quantities, Units, and Letter Symbols
(SCC14)

IEEE

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Abstract: Letter symbols for units of measurement are covered in this standard. It does not include abbreviations for technical terms, nor does it cover symbols for physical quantities.
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Introduction

This introduction is not part of IEEE Std 260.1-2004, IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units.)

This standard supersedes ANSI/IEEE Std 260.1-1993 in accordance with IEEE's policy of periodic standards review and update. Since the 1993 standard was approved, significant changes have occurred in the International System of Units (SI). Corresponding updates have been issued for some of the documents referred to by this standard. Significant, newly revised references are IEEE/ASTM SI 10-2002 (superseding ANSI/IEEE Std 268-1992 and ASTM E 380) and the seventh edition of Le Système international d'unités (The International System of Units, 1998, BIPM).

Since IEEE Std 260.1-1993 was issued, the IEEE has adopted Policy 9.19, Metric Policy, which calls upon all IEEE organizational units to support the use of the SI. The IEEE-SA Standards Board Implementation Plan for this policy, approved in 1995, states in part:

> Stage III—After January 1, 2000: Proposed new standards and revised standards submitted for approval shall use metric units exclusively in the normative portions of the standard. Inch-pound data may be included, if necessary, in footnotes or annexes that are informative only.

Standards Coordinating Committee 14 (SCC14) shall work with the committees responsible for generating IEEE standards to help them carry out this implementation plan. Policy 9.19 recognizes the need for some exceptions and contains the following statement: "Necessary exceptions to this policy, such as where a conflicting world industry practice exists, must be evaluated on an individual basis and approved by the responsible major board of the Institute for a specific period of time." SCC14, as part of the coordination process, shall review requests for individual exceptions and shall report its recommendations to the IEEE-SA Standards Board.

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Contents

IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)

1. Overview

1.1 Organization

This standard is divided into six clauses. Clause 1 provides the organization and scope of this standard. Clause 2 gives the reference to the IEEE/ASTM standard on metric practice. Clause 3 provides a list of abbreviations used throughout this standard. Clause 4 establishes the general principles of letter symbol standardization and includes a list of SI prefixes and their symbols. Clause 5 provides a list of units and their symbols. Clause 6 makes provisions for adaptation of this standard in cases where only a character set limited in capability is available.

This standard also contains two annexes. Annex A provides information about the identification of reference levels when using logarithmic scaling units. Annex B provides a bibliography.

1.2 Scope

This standard covers letter symbols[1] for units of measurement. It does not include abbreviations for technical terms, nor does it cover symbols for physical quantities.[2]

The symbols given in this standard are intended for all applications, including use in text and equations; in graphs and diagrams; and on panels, labels, and nameplates. Provision is made for modifications to be used when only character sets of limited capability are available.

[1]"Letter symbol" as a technical term does not have the same meaning as either "name" or "abbreviation." An abbreviation is a letter or a combination of letters that by convention represents a word or a name in a particular language. For example, the symbol for electromotive force is *E*, whereas the abbreviation is emf in English, fem in French, and EMK in German. The unit names ampere and second have sometimes been abbreviated amp and sec, respectively, but this usage is now deprecated. The standard unit symbols for ampere and second are A and s, respectively.

[2]As used in this standard, the term *physical quantity* means a measurable attribute of phenomena or matter. Examples are length, mass, and time.

2. References

This standard shall be used in conjunction with the latest version of the following publication:

IEEE/ASTM SI 10-2002, American National Standard for Use of the International System of Units (SI): The Modern Metric System.[3]

3. Abbreviations

ANSI American National Standards Institute

CGPM Conférence Générale des Poids et Mesures (General Conference on Weights and Measures)

cgs centimeter-gram-second

CIPM Comité International des Poids et Mesures (International Committee for Weights and Measures)

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineers

ISO International Organization for Standardization

SI Système International d'Unités (International System of Units)

4. General principles of letter symbol standardization

4.1 Letter symbols

Letter symbols include symbols for physical quantities (quantity symbols) and symbols for the units in which these quantities are measured (unit symbols).

A quantity symbol is, in general, a single letter[4] (for example, I for electric current) specified as to general form of type and modified when appropriate by one or more subscripts or superscripts. In a given work, the same letter symbol should appear throughout for the same physical quantity, regardless of the units employed or of special values assigned.

A unit symbol[5] is a letter or group of letters (for example, mm for millimeter), or in a few cases a special sign, that may be used in place of the name of a unit. It may include numbers to indicate exponents (for example, m^2 for square meter) and multiplication or division operators (for example, m/s for meter per second).

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[4] Symbols composed of two letters are sometimes used for numerical transport parameters, such as *Re* for Reynolds number.

[5] Unit symbols have sometimes been treated in the same manner as general abbreviations, but the recommendations of the International Committee for Weights and Measures (CIPM), and of many other international and national bodies concerned with standardization, emphasize the symbolic character of these designations and rigidly prescribe the manner in which they shall be treated. This concept of the unit symbol is therefore adopted in this standard.

4.2 Alphabets and typography

Letter symbols are mainly restricted to the English and Greek alphabets. Those Greek letters that are easily confused with English letters shall be avoided. The type families that are used for text in modern book and journal publishing all include sloping (italic) type faces and related upright (roman) type faces. The former are used for quantity symbols; the latter, for unit symbols. The distinctions are discussed more fully in the following paragraphs. (In the context of this standard, upright is used simply in contrast with sloping and carries no connotation regarding serifs, line widths, or the like.) In situations where upright and sloping are not both available, care shall be taken to avoid confusion between quantities and units.

Unconventional typefaces should generally not be used for letter symbols. Script and Old English faces, for example, are not appropriate for unit symbols. Such special faces have seen limited use for quantity symbols, but good modern practice avoids them.

Symbols for physical quantities, mathematical variables, indexes, and general functions[6] are printed in sloping type. For example:

— A area
— e elementary electric charge
— x, y, z Cartesian coordinates
— i, j, k, n indexes
— $f(x)$ function of x

Symbols for units of measurement, mathematical constants, specific mathematical functions, operators, and numerals are printed in upright type. For example:

— cm centimeter
— e base of natural logarithms
— $\sin x$ sine of x
— $\mathrm{J}_2(z), \mathrm{J}_n(z)$ Bessel functions
— $\mathrm{d}x$ differential of x
— $E = \frac{1}{2}mv^2$ formula for kinetic energy

Subscripts and superscripts are governed by the above principles. Those that are letter symbols for quantities or for indexes are printed in sloping type, while all others are printed in upright type. For example:

— C_p heat capacity at constant pressure p
— a_{ij}, a_{45} matrix elements
— I_i, I_o input current, output current
— x_{av} average value of x

For indicating the vector character of a quantity, boldface sloping type is used. For example:

— $\boldsymbol{F}$ force
— $\boldsymbol{H}$ magnetic field strength

Ordinary sloping type is used to represent the magnitude of a vector quantity. It is also commonly used for a vector quantity when there is no need to draw attention to the vector character of the quantity.

When tensor quantities of second or higher order are to be represented by a single letter, sans serif type should be used (for example, $\boldsymbol{\mathsf{A}}, \boldsymbol{\mathsf{B}}$).

[6] The term *general functions* is here used to contrast with specific mathematical functions, for which upright type is to be used.

4.3 Remarks concerning quantity symbols

Quantity symbols may be used in mathematical expressions in any way consistent with good mathematical usage. The product of two quantities, a and b, is indicated by writing ab. The quotient may be indicated by writing

$$\frac{a}{b} \quad a/b \quad \text{or} \quad ab^{-1}$$

If more than one slash (/) is used in any algebraic term, parentheses shall be inserted to remove any ambiguity. Thus, one may write $(a/b)/c$, or $a/(b/c)$, but not $a/b/c$.

Subscripts and superscripts are widely used with quantity symbols. Several subscripts or superscripts, sometimes separated by commas, may be attached to a single letter. But, so far as logical clarity permits, subscripts and superscripts should not be attached to other subscripts and superscripts. A symbol that has been modified by a superscript should be enclosed in parentheses before an exponent is attached.

Conflicts that occur because different quantities are assigned identical symbols in the same or different standard symbol lists should be resolved in one of the following ways:

a) By use of a reserve symbol (alternative symbol) if one is listed.

b) By use of a subscript or superscript selected by the author for one or more of the conflicting requirements.

c) By use of uppercase letters as variants for lowercase letters and vice versa, but only if no ambiguity results.

4.4 Remarks concerning unit symbols

An upright (roman) type font shall be used for unit symbols, even when the surrounding text is in a sloping font. In general, unit symbols are lowercase letters, except for a very few that use special signs (such as ° for degree). If, however, the symbol is for a unit whose name is derived from a proper name (e.g., James Watt), uppercase upright type is used for the first letter (W, for the example given).[7] As a further exception to the general rule, the symbol L is used for liter to avoid confusion between the lowercase letter l and the numeral 1. Some additional exceptions arise in the special cases where symbols are joined, as in eV, the symbol for electronvolt, and in mmHg, the symbol for conventional millimeter of mercury, a unit of pressure. The distinction between uppercase and lowercase letters shall be followed, even if the symbol appears in applications where the other lettering is uppercased. The form of unit symbols is the same for both singular and plural, and they are not followed by a period except at the end of a sentence.

In the complete expression for a quantity, a space should be left between the numerical value and the unit symbol. For example, write 35 mm, not 35mm, and 2.371 m, not 2.371m. When the quantity is used in an adjectival sense, a hyphen is often used in lieu of a space between the number and the unit name or between the number and the symbol.

— *Example:* A 3-meter pole. The length is 3 meters.

— *Example:* A 35-mm film. The width is 35 mm.

EXCEPTION: No space is left between the numerical value and the symbols for degree, minute, and second of plane angle.

[7] Prefixes are considered separately (see 4.5).

When a compound unit is formed by multiplication of two or more other units, its symbol consists of the symbols for the separate units joined by a raised dot (preferred) or separated by a thin, non-breaking space (for example, N·m or N m for newton meter). The dot may be omitted in the case of familiar compounds such as watthour (symbol Wh) if confusion is unlikely. Hyphens should not be used in symbols for compound units. Positive and negative exponents may be used with the symbols for units.

When a compound unit is formed by division of one unit by another, its symbol is constructed in one of the following forms:

$$\mathrm{m/s} \quad \text{or} \quad \mathrm{m \cdot s^{-1}} \quad \text{or} \quad \frac{\mathrm{m}}{\mathrm{s}}$$

NOTE—$\mathrm{m{\cdot}s^{-1}}$ or $\mathrm{m\ s^{-1}}$ may be used for meter per second but $\mathrm{ms^{-1}}$ symbolizes 1/ms or $10^3\ \mathrm{s^{-1}}$ as described in 4.5. The raised dot or space is therefore extremely important.[8]

In simple cases use of the slash is preferred, but in no case should more than one slash, or a slash followed by a product, be used in the same expression unless parentheses are inserted to avoid ambiguity. For example, write:

— J/(mol·K) or $\mathrm{J{\cdot}mol^{-1}{\cdot}K^{-1}}$ or (J/mol)/K

— but not J/mol/K or J/mol·K

In complicated cases, negative powers should be used.[9]

Letter symbols and mathematical notation should not be mixed with unit names in the same expression. For example, write joules per kilogram or J/kg. Do not write joules/kilogram or joules/kg, or J/kilogram.

4.5 The International System of Units (SI)

In this standard, some units are identified as SI units. These units belong to the International System of Units (Le Système International d'Unités), which is the name given in 1960 by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) to the coherent system of units built upon the base units in Table 1.

Table 1—SI base units

Unit	Physical quantity
meter	length
kilogram	mass
second	time
ampere	electric current
kelvin	thermodynamic temperature
mole	amount of substance
candela	luminous intensity

[8]Notes in text, tables, and figures are given for information only, and do not contain requirements needed to implement the standard.
[9] The notation for products and quotients of unit symbols is intentionally made more explicit than that given in 4.3 for quantity symbols because some unit symbols are composed of more than one letter.

The spellings *meter* and *liter* are recommended.[10] The variant spellings *metre* and *litre* are also used.[11]

The prefixes in Table 2 are used to indicate decimal multiples or submultiples of SI units.

Table 2—SI prefixes

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

Compound prefixes, formed by the juxtaposition of two or more SI prefixes, shall not be used. For example, use

— nm, not mµm

— pF, not µµF

For historical reasons, although the SI unit of mass is the kilogram (kg), the SI prefixes are attached to the gram (g). Thus, use milligram (mg), not microkilogram (µkg).

[10]These spellings are in accordance with guidance given by the U.S. Department of Commerce, which, under the Metric Conversion Act of 1975, is given the responsibility of interpreting SI for the United States.

[11] The spelling of some unit names varies from language to language. One of the principal advantages of unit symbols is that they are language invariant.

If values are required outside the range covered by the prefixes, they should be expressed using powers of ten applied to the unit in question. Thus, 10^{-34} J.

An exponent attached to a symbol containing a prefix indicates that the multiple or submultiple of the unit (the unit with its prefix) is raised to the power expressed by the exponent. For example, where := indicates "is defined as,":

— cm^3 := $(10^{-2}\ m)^3$ = $10^{-6}\ m^3$
— ns^{-1} := $(10^{-9}\ s)^{-1}$ = $10^9\ s^{-1}$
— mm^2/s := $(10^{-3}\ m)^2/s$ = $10^{-6}\ m^2/s$

For further information concerning metric practice and SI, refer to IEEE/ASTM SI 10-2002.

4.6 Usage

The use of unit symbols in place of full names of the units is frequently desirable where space is restricted. Their use presupposes that the reader will find them intelligible. When an unfamiliar unit symbol is first used in text, it should be followed by its name in parentheses or the name should be given with the symbol in parentheses; the symbol may be used alone thereafter. Explanatory notes or keys should be included where appropriate on drawings and in tabular matter.

Attachment of letters to a unit symbol as a means of giving information about the quantity under consideration is incorrect. Thus MWe for "megawatts electrical (power)," Vac for "volts ac," and kJt for "kilojoules thermal (energy)" shall not be used. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig," so often used to distinguish between absolute and gage pressure. If the context leaves any doubt as to which is meant, the word pressure shall be qualified appropriately. For example:

— "...at a gage pressure of 13 kPa" or
— "...at an absolute pressure of 13 kPa"

When space limitations make it necessary to juxtapose information about the quantity being measured with the unit name or unit symbol, such information shall be separated from the unit symbol by a space, by a comma followed with a space, or by the equivalent. Thus, the following examples are appropriate for use on nameplates, gage scale plates, table headings, graph labels, etc.:

— rating—115 V ac
— kPa, gage
— kPa (abs.)

On the other hand, letters may be attached to a unit symbol where needed to properly identify the unit involved. In such symbols as inHg, mmHg, and ftH_2O, the suffixes are needed to identify the units, which are units of pressure, not of length. Similarly, it is proper to write Btu_{IT}, cal_{th}, gal_{US}, etc. to distinguish from the related but different units Btu_{60}, cal_{15}, gal_{Imp}, etc. However, such subscripts are neither needed nor permitted with SI units.

5. Unit symbols

Symbols for units are listed in Table 3 alphabetically by the name of the unit. The list is intended to be reasonably complete but could not possibly include all units in current use.

Obsolescent units, such as apothecaries' weights, and units used almost exclusively in narrow fields of commerce, such as the bushel and hundredweight, have been omitted. Many compound symbols and many illustrations of the use of the SI prefixes are included. Other combined forms may easily be constructed using multiplication, division, and exponentiation according to the principles set forth in 4.4.

The distinction between uppercase and lowercase letters shown in the list is part of the standardization of the symbol, following international rules. Changing the letter case changes the symbol and violates this standard. There are situations in which the standard symbols cannot be used, for example, when the printing equipment has no provision for Greek letters or for lowercase letters. These situations are discussed in Clause 6.

Table 3—Units of the SI and units used with the SI

Unit	Symbol	Notes[a]
ampere	A	SI unit of electric current. Also, SI unit of magnetomotive force.
ampere-hour	Ah	Also A·h.
ampere per meter	A/m	SI unit of magnetic field strength.
ångström	Å	Å := 10^{-10} m Deprecated (see IEEE/ASTM SI 10-2002).
astronomical unit	ua	ua = 1.495 979 × 10^{11} m
atmosphere, standard	atm	atm := 101 325 Pa Deprecated (see IEEE/ASTM SI 10-2002).
atmosphere, technical	at	at := kgf/cm^2 Deprecated (see IEEE/ASTM SI 10-2002).
atomic mass unit (unified)	u	See unified atomic mass unit.
atto	a	SI prefix for 10^{-18}.
attoampere	aA	
bar	bar	bar := 100 kPa Deprecated (see IEEE/ASTM SI 10-2002).
barn	b	b := 10^{-28} m^2 Deprecated (see IEEE/ASTM SI 10-2002).
barrel	bbl	bbl := 42 gal US = 158.99 L This is the standard barrel used for petroleum and petroleum products. Different standard barrels are used for other commodities.
baud	Bd	In telecommunications, a unit of signaling speed equal to one element per second.
becquerel	Bq	SI unit of activity of a radionuclide.
bel	B	See Annex A for guidance concerning notation.
billion electronvolts	GeV	The name gigaelectronvolt is preferred for this unit.
bit	b	In information theory, the bit is a unit of information content equal to the information content of a message, the *a priori* probability of which is one-half. In computer science, the name bit is used as a short form of *binary digit*.
bit per second	b/s	

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
British thermal unit (International Table)	Btu_{IT}	Btu_{IT} = 1055.056 J
British thermal unit (thermochemical)	Btu_{th}	Btu_{th} = 1054.350 J
byte	B	A byte is a string of bits, usually eight bits long, operated on as a unit. A byte is capable of holding one character in the local character set.
calorie (International Table)	cal_{IT}	cal_{IT} := 4.1868 J Deprecated (see IEEE/ASTM SI 10-2002).
calorie (nutrition)	kcal	kcal := 4184 J
calorie (thermochemical)	cal_{th}	cal_{th} := 4.184 J Deprecated (see IEEE/ASTM SI 10-2002).
candela	cd	SI unit of luminous intensity.
candela per square inch	cd/in^2	Use of the SI unit, cd/m^2, is preferred.
candela per square meter	cd/m^2	SI unit of luminance.
candle	cd	The unit of luminous intensity has been given the name candela; use of the name candle for this unit is deprecated.
centi	c	SI prefix for 10^{-2}.
centimeter	cm	
centipoise	cP	cP := mPa·s The name centipoise is deprecated (see IEEE/ASTM SI 10-2002).
centistokes	cSt	cSt := mm^2/s The name centistokes is deprecated (see IEEE/ASTM SI 10-2002).
circular mil	cmil	cmil := $(\pi/4)\cdot10^{-6}$ in^2
coulomb	C	SI unit of electric charge.
cubic centimeter	cm^3	
cubic foot	ft^3	
cubic foot per minute	ft^3/min	
cubic foot per second	ft^3/s	
cubic inch	in^3	
cubic meter	m^3	
cubic meter per second	m^3/s	
cubic yard	yd^3	
curie	Ci	Ci := 3.7×10^{10} Bq A unit of activity of a radionuclide. Use of the SI unit, the becquerel, is preferred.
cycle per second	Hz	See hertz.
day	d	d := 24 h = 86 400 s

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
deci	d	SI prefix for 10^{-1}.
decibel	dB	See Annex A for guidance concerning notation.
degree (plane angle)	°	
degree Celsius	°C	SI unit of Celsius temperature. The degree Celsius is a special name for the kelvin, used in expressing Celsius temperatures or temperature intervals.
degree Fahrenheit	°F	Note that the symbols for °C, °F, and °R are composed of two elements, written with no space between the ° and the letter that follows. The two elements that make the complete symbol are not to be separated.
degree Kelvin		Now called the kelvin.
degree Rankine	°R	
deka	da	SI prefix for 10.
dyne	dyn	dyn := 10^{-5} N Deprecated (see IEEE/ASTM SI 10-2002).
electronvolt	eV	eV = 1.602 176 × 10^{-19} J, approximately Experimentally determined unit of energy accepted for use with SI.
erg	erg	erg := 10^{-7} J Deprecated (see IEEE/ASTM SI 10-2002).
exa	E	SI prefix for 10^{18}.
exbi	Ei	Prefix for 2^{60}.
farad	F	SI unit of capacitance.
femto	f	SI prefix for 10^{-15}.
femtometer	fm	
foot	ft	ft := 0.3048 m
foot of water	ftH_2O	ftH_2O = 2989.1 Pa (ISO)[b]
foot per minute	ft/min	
foot per second	ft/s	
foot per second squared	ft/s^2	
foot pound-force	ft·lbf	
footcandle	fc	fc := lm/ft^2 The name lumen per square foot is also used for this unit. Use of the SI unit of illuminance, the lux (lumen per square meter), is preferred.
footlambert	fL	fL := (1/π) cd/ft^2 A unit of luminance. One lumen per square foot leaves a surface whose luminance is one footlambert in all directions within a hemisphere. Use of the SI unit, the candela per square meter, is preferred.
gal	Gal	Gal := cm/s^2 Deprecated (see IEEE/ASTM SI 10-2002).

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
gallon	gal	gal (Imp) = 4.5461 L
		gal (US) := 231 in^3 = 3.7854 L
gauss	G	The gauss is the electromagnetic cgs unit of magnetic flux density. Deprecated (see IEEE/ASTM SI 10-2002).
gibi	Gi	Prefix for 2^{30} = 1 073 741 824.
gibibyte	GiB	GiB := 2^{30} B = 1 073 741 824 B
giga	G	SI prefix for 10^9.
gigabit	Gb	Gb := 10^9 b
gigabyte	GB	GB := 10^9 B
gigaelectronvolt	GeV	
gigahertz	GHz	
gilbert	Gb, Gi	The gilbert is the electromagnetic cgs unit of magnetomotive force. Deprecated (see IEEE/ASTM SI 10-2002).
grain	gr	gr := lb/7000
gram	g	
gram per cubic centimeter	g/cm^3	
gray	Gy	SI unit of absorbed dose in the field of radiation dosimetry.
hectare	ha	ha := hm^2
hecto	h	SI prefix for 10^2
henry	H	SI unit of inductance.
hertz	Hz	SI unit of frequency.
horsepower	hp	Use of the SI unit of power, the watt, is preferred.
hour	h	h := 60 min = 3600 s
inch	in	in := 2.54 cm
inch of mercury	inHg	inHg = 3386.4 Pa (ISO)[b]
inch of water	inH_2O	inH_2O = 249.09 Pa (ISO)[b]
inch per second	in/s	
joule	J	J := N·m = W·s SI unit of energy, work, and quantity of heat.
joule per kelvin	J/K	SI unit of heat capacity and of entropy.
katal	kat	kat := mol/s SI unit of catalytic activity.
kelvin	K	SI unit of thermodynamic temperature. In 1967, the CGPM gave the name kelvin to the SI unit of temperature, which had formerly been called degree Kelvin, and assigned it the symbol K (without the symbol °).

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
kibi	Ki	Prefix for 2^{10} = 1024.
kibibyte	KiB	KiB := 2^{10} B = 1024 B
kilo	k	SI prefix for 10^3. The symbol K shall not be used for kilo. The prefix kilo shall not be used to mean 2^{10} (that is, 1024).
kilobit per second	kb/s	
kilobyte	kB	kB := 1000 bytes
kilogauss	kG	Deprecated (see IEEE/ASTM SI 10-2002).
kilogram	kg	SI unit of mass.
kilogram-force	kgf	1kgf := 9.806 65 N Deprecated (see IEEE/ASTM SI 10-2002).
kilohertz	kHz	
kilohm	kΩ	
kilometer	km	
kilometer per hour	km/h	
kilopound-force	klbf	
kilovar	kvar	
kilovolt	kV	
kilovoltampere	kVA	
kilowatt	kW	
kilowatthour	kWh	kWh := 3.6 MJ
knot	kn	kn := nmi/h
lambert	L	L := (1/π) cd/cm^2 A cgs unit of luminance. Deprecated (see IEEE/ ASTM SI 10-2002).
liter	L	L := 10^{-3} m^3 In 1979, the CGPM approved L and l as alternative symbols for the liter. Because of frequent confusion with the numeral 1, the letter symbol l is not recommended for US use (see Federal Register notice of July 28, 1998, vol. 63, no. 144, p. 40334). The script ℓ shall not be used as a symbol for liter.
liter per second	L/s	
lumen	lm	SI unit of luminous flux.
lumen per square foot	lm/ft^2	A unit of illuminance and also a unit of luminous exitance. Use of the SI unit, lumen per square meter, is preferred.
lumen per square meter	lm/m^2	SI unit of luminous exitance.
lumen per watt	lm/W	SI unit of luminous efficacy.

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
lumen second	lm·s	SI unit of quantity of light.
lux	lx	lx := lm/m^2 SI unit of illuminance.
maxwell	Mx	The maxwell is the electromagnetic cgs unit of magnetic flux. Deprecated (see IEEE/ASTM SI 10-2002).
mebi	Mi	Prefix for 2^{20} = 1 048 576.
mebibyte	MiB	MiB = 2^{20} B = 1 048 576 B
mega	M	SI prefix for 10^6. The prefix mega shall not be used to mean 2^{20} (that is, 1 048 576).
megabit	Mb	Mb = 10^6 b = 1 000 000 b
megabit per second	Mb/s	
megabyte	MB	MB := 1 000 000 bytes
megaelectronvolt	MeV	
megahertz	MHz	
megohm	MΩ	
meter	m	SI unit of length.
meter cubed	m^3	SI unit of volume.
meter per second	m/s	SI unit of speed.
meter per second squared	m/s^2	SI unit of acceleration.
meter squared	m^2	SI unit of area.
metric ton	t	t := 1000 kg
mho	mho	The name mho was formerly given to the reciprocal ohm. Deprecated; see siemens (S).
micro	µ	SI prefix for 10^{-6}.
microampere	µA	
microfarad	µF	
microgram	µg	
microhenry	µH	
microinch	µin	
microliter	µL	See note for liter.
micrometer	µm	
micron	µm	The name micron is deprecated. Use micrometer.
micropascal	µPa	The normal threshold of hearing at 1 kHz is approximately 20 µPa.
microsecond	µs	
microwatt	µW	
mil	mil	mil := 0.001 in

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
mile (statute)	mi	mi := 5280 ft = 1609 m
mile per hour	mi/h	Although use of mph as an abbreviation is common, it should not be used as a symbol.
milli	m	SI prefix for 10^{-3}.
milliampere	mA	
millibar	mbar	mbar := hPa
milligram	mg	
millihenry	mH	
milliliter	mL	See note for liter.
millimeter	mm	
millimeter of mercury	mmHg	mmHg = 133.322 Pa Deprecated (see IEEE/ASTM SI 10-2002).
millimicron	nm	Use of the name millimicron for the nanometer is deprecated.
millipascal second	mPa·s	Replaces the centipoise.
millisecond	ms	
millivolt	mV	
milliwatt	mW	
minute (plane angle)	'	
minute (time)	min	1 min := 60 s Time may also be designated by means of superscripts as in the following example: $9^{h}\ 46^{m}\ 30^{s}$.
mole	mol	SI unit of amount of substance.
month	mo	Not uniquely defined.
nano	n	SI prefix for 10^{-9}.
nanoampere	nA	
nanofarad	nF	
nanometer	nm	
nanosecond	ns	
nautical mile	nmi	nmi := 1852 m
neper	Np	See Annex A for guidance concerning notation.
newton	N	SI unit of force.
newton meter	N·m	SI unit of torque (moment of force) or of work or energy. When referring to energy, the joule is normally used: J := N·m.
newton per square meter	N/m^2	SI unit of pressure or stress; see pascal.
octet	o	An octet is a string of eight bits, operated on as a unit.

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
oersted	Oe	The oersted is the electromagnetic cgs unit of magnetic field strength. Deprecated (see IEEE/ASTM SI 10-2002).
ohm	Ω	SI unit of electric resistance.
ounce (avoirdupois)	oz	oz := 1/16 lb = 28.350 g
pascal	Pa	Pa := N/m^2 SI unit of pressure or stress.
pascal second	Pa·s	SI unit of dynamic viscosity.
pebi	Pi	Prefix for 2^{50} = 1 125 899 906 842 624.
peta	P	SI prefix for 10^{15}.
phot	ph	ph := lm/cm^2 The cgs unit of illuminance. Deprecated (see IEEE/ASTM SI 10-2002).
pico	p	SI prefix for 10^{-12}.
picofarad	pF	
picowatt	pW	
pint	pt	pt (Imp) = 0.568 26 L
		pt (US dry) = 0.550 61 L
		pt (US liquid) = 0.473 18 L
poise	P	Deprecated (see IEEE/ASTM SI 10-2002).
pound (avoirdupois)	lb	lb := 0.453 592 37 kg
pound per cubic foot	lb/ft^3	
pound-force	lbf	lbf = 4.4482 N
pound-force foot	lbf·ft	
pound-force per square foot	lbf/ft^2	
pound-force per square inch	lbf/in^2	Although use of the abbreviation psi is common, it should not be used as a symbol.
poundal	pdl	pdl := $lb·ft/s^2$ = 0.1383 N
quart	qt	qt (Imp) = 1.1365 L
		qt (US dry) = 1.1012 L
		qt (US liquid) = 0.946 35 L
rad	rad	rad := 0.01 Gy A unit of absorbed dose in the field of radiation dosimetry. Use of the SI unit, the gray, is preferred.
radian	rad	SI unit of plane angle.
rem	rem	rem := 0.01 Sv A unit of dose equivalent in the field of radiation dosimetry. Use of the SI unit, the sievert, is preferred.
revolution per minute	r/min	Although use of rpm as an abbreviation is common, it should not be used as a symbol.

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
revolution per second	r/s	
roentgen	R	A unit of exposure in the field of radiation dosimetry.
second (plane angle)	"	
second (time)	s	SI unit of time.
siemens	S	$S := \Omega^{-1}$ SI unit of conductance.
sievert	Sv	SI unit of dose equivalent in the field of radiation dosimetry.
slug	slug	slug := lbf·s^2/ft = 14.594 kg.
square foot	ft^2	
square inch	in^2	
square meter	m^2	
square meter per second	m^2/s	SI unit of kinematic viscosity.
square millimeter per second	mm^2/s	Replaces the centistokes.
square yard	yd^2	
steradian	sr	SI unit of solid angle.
stilb	sb	sb := cd/cm^2 A cgs unit of luminance. Deprecated (see IEEE/ASTM SI 10-2002).
stokes	St	Deprecated (see IEEE/ASTM SI 10-2002).
tebi	Ti	Prefix for 2^{40} = 1 099 511 627 776.
tera	T	SI prefix for 10^{12}.
terabyte	TB	TB := 10^{12} B
tesla	T	T := Wb/m^2 SI unit of magnetic flux density (magnetic induction).
therm	thm	thm = 1.000×10^5 Btu
ton (short)	ton	ton := 2000 lb
ton, metric	t	t := 1000 kg Use of the name tonne for this unit is deprecated in the US (see IEEE/ASTM SI 10-2002).
unified atomic mass unit	u	u = $1.660\ 539 \times 10^{-27}$ kg The (unified) atomic mass unit is defined as one-twelfth of the mass of an atom of the carbon-12 nuclide. Use of the old atomic mass unit (amu), defined by reference to oxygen, is deprecated (see IEEE/ASTM SI 10-2002).
var	var	IEC name and symbol for the SI unit of reactive power.
volt	V	SI unit of voltage.
volt per meter	V/m	SI unit of electric field strength.

Table 3—Units of the SI and units used with the SI *(continued)*

Unit	Symbol	Notes[a]
voltampere	VA	IEC name and symbol for the SI unit of apparent power.
watt	W	SI unit of power.
watt per meter kelvin	W/(m·K)	SI unit of thermal conductivity.
watt per steradian	W/sr	SI unit of radiant intensity.
watt per steradian square meter	$W/(sr \cdot m^2)$	SI unit of radiance.
watthour	Wh	Wh := 3.6 kJ
weber	Wb	Wb := V·s SI unit of magnetic flux.
yard	yd	yd := 0.914 4 m
year	a	Not uniquely defined.
yocto	y	SI prefix for 10^{-24}.
yotta	Y	SI prefix for 10^{24}.
zepto	z	SI prefix for 10^{-21}.
zetta	Z	SI prefix for 10^{21}.

[a]The notes give exact definitions (indicated by the symbol :=) for many of the units and give conversion factors in other cases. The conversion factors indicated with the equals sign are accurate to the number of figures shown. For more accurate conversion factors and other general information about units, see IEEE/ASTM SI 10-2002.
[b]The term (ISO) means that the definition is from ISO 31 [B4] (see Annex B).

6. Unit symbols to be used with limited character sets

Historically the originator of written information had full control of its appearance when distributed to the readers. Now that information is often transmitted electronically, this control of the final appearance of information is in jeopardy. This loss of control is commonly seen in the use of three common forms of communication formats: electronic mail, HTML-formatted web pages, and the transmission of computer files.

The problem in electronic transmission of information is that there are no universally accepted standards in use. The problem is exacerbated by the use of multiple types of platforms (at the transmission end, the receiving end, and in the transmission path), encoding protocols, type families, operating systems, and computer programs. The originator must now take care to ensure that when information is transmitted, received, and decoded it is faithfully reproduced, at least as far as technical details are concerned.

Various technical details relating to the transmission of quantities and units are discussed below. These should be followed whenever the originator suspects that the communication path is limited by the following constraints.

6.1 Limitations arising from the use of ASCII 0000-0127

Perhaps the most common digitally encoded character set used around the world in electronic communications is the American Standard Code for Information Interchange (ASCII). Since the uppercase and lowercase Latin letters are all represented, the only SI symbols not available are the uppercase omega (Ω), used for the ohm, and the lowercase mu (μ), used for the prefix micro. The normal arithmetic and algebraic symbols +, –,), (, =, <, >, /, period (.), and comma (,) are available; note that the hyphen is used as the minus sign as is commonly done in typewriting. The use of superscripts and subscripts is not possible. The following substitutions are to be used when communications are limited to basic ASCII codes (character values of 0000 through 0127):

a) For μ, substitute u.

—*Example:* μA for microampere becomes uA.

b) For Ω , substitute Ohm.

—*Example:* The symbol Ω for ohm becomes Ohm.

c) For °C, substitute C.

—*Example:* A temperature of 12 degrees Celsius becomes 12 C.

d) For units of plane angle, substitute as follows:

—	degree	°	use	deg
—	minute	'	use	min
—	second	"	use	sec

NOTE—Depending on the recipient's type face (often called "font"), the straight minute and second symbols may be replaced by the curly apostrophe (or single quote) and double quote but this should not result in any ambiguity.

e) For superscripted numerals in units, use numerals on the line. Use either a caret or omit any space between the principal unit symbol and its exponent, whether positive or negative. The use of the caret is more explicit and less likely to be misunderstood than merely placing the exponent on the line without an intervening space. The latter, however, is the form specified by ISO 2955 [B15].[12]

—*Example:* The symbol for square millimeter becomes either mm^2 or mm2. The symbol for watt per square meter becomes W/m^2, W/m2, W m^-2, or W m-2.

f) For superscripted numerals used to indicate the exponent of a numerical quantity or variable, use the carat before the numeral.

—*Example:* A square that is 8 cm by 8 cm has an area of (8 cm)^2 or 64 cm^2.

g) For subscripts, use an underscore (_) or a parenthetical expression starting with the word "sub" followed by a space.

—*Example:* V_{ab} may be written as V_ab or V(sub ab). Note that sloping type is not available.

h) For a raised dot within products of units, use a space or a full stop (a period; i.e., a dot on the line). The former is preferred, but the latter is the form specified by ISO 2955 [B15].

— *Example:* The joule (1 J = 1 W·s) is equivalent to 1 W s or 1 W.s.

i) For a raised dot (·) or multiplicative cross (×) between numerical quantities, use a lowercase x. Spaces surrounding the x improve clarity.

— *Example:* The product 4·5 may be represented by 4 x 5.

[12]The numbers in brackets correspond to those of the bibliography in Annex B.

j) For the symbol π use pi.

— *Example:* There are 2pi radians in a complete circle.

NOTE—Since pi is not a unit symbol there is no space between it and the numeral.

k) For ± (plus or minus) use +/– and for its inverse use –/+.

l) For ≈ (approximately) use ~ (tilde).

6.2 Limitations arising from the use of HTML-coded web pages and electronic mail

Hypertext Markup Language (HTML)-coded pages are normally read with "browsers," which vary in their capabilities and style. Even with an imposed limitation to the use of one specified browser in a given communications link, individual operators might set various preferences that can significantly alter the display of information. Similarly, programs that read electronic mail ("e-mail") vary and can cause similar problems. These preferences include the type font, type face, type size (all are sometimes collectively called "font" in colloquial parlance), spacing (proportional or fixed pitch), and encoding protocols (e.g., ASCII, Unicode, ISO-8859-1, etc.). The result can be confusion of symbols and the spacing between numeral and unit or within units.

Authors who use HTML have a wider array of tags and codes at their disposal but this usually leads to cross-platform problems. The ASCII code for the non-breaking space (0160) is not implemented identically on all platforms, for example. On some, the space may be extraordinarily wide. Some browsers differ in their ability to decode HTML tags. Scaling problems often occur when trying to represent individual symbols with in-line embedded graphic images. These may appear smaller or larger than the surrounding HTML encoded text.

It would be prudent to standardize explicitly the platforms, operating systems, programs, preferences, etc. in a given communications link but transmission beyond a select group of receivers becomes virtually impossible to control. To maintain absolute control of the formatting of information would require distribution of hard copies. The next best technique, and one that will allow electronic transmission is the use of graphic representations of the pages. The sender of graphic images is cautioned that some programs may distort aspect ratios, which would create problems for scale drawings but should satisfactorily convey typography. Proprietary programs that combine graphic and embedded font information are available and maintain aspect ratios, even across platform or operating system boundaries.

In light of the above considerations the following guidance is specified:

a) The transmitter of information should either ensure that the path and receiving end will enable accurate rendering of the transmitted information or should explicitly state the necessary information for the receiver to do so—e.g., type font, program to be used for reading the information, including version, operating system and platform on which it is run.

b) When the above is not readily possible the transmitter should revert to the limitations of basic ASCII as discussed in 6.1. This basic character set is usually included in most encoding protocols as a baseline and the fewest differences exist with this set of characters across platform, operating system, and program lines.

c) When the possibility exists that a line break may be imposed on transmitted information by the path or the receiver, the space between the numeral and the unit in a quantity should still be used but spaces between symbols in a compound unit should be avoided. If necessary, spell out the unit name rather than using a compounded unit symbol.

— *Example:* For 12 N·m use 12 N m only if spacing between the N and the m are assured; otherwise use 12 newton meters.

6.3 Examples of symbols for limited character sets

Table 4 shows many examples of how the foregoing principles may be applied.

The column labeled Form I applies to data systems that have the capability to use both uppercase and lowercase letters; digits; and at least the graphic characters apostrophe (') quotation mark ("), hyphen (-), period (.), and slash (/). However, they do not have the capability to use the Greek letters mu (μ) and omega (Ω).

The column labeled Form II applies to data systems that are further limited in that they have only one case (either uppercase or lowercase), and they lack the apostrophe and quotation mark.

Table 4 Examples of symbols for limited character sets

	Form I	Form II	
	(Both cases)	(Lowercase only)	(Uppercase only)
ampere	A	a	A
ampere per meter	A/m	a/m	A/M
ångström	A	a	A
barrel	bbl	bbl	BBL
becquerel	Bq	bq	BQ
British thermal unit	Btu	btu	BTU
candela per square meter	cd/m2	cd/m2	CD/M2
centimeter	cm	cm	CM
coulomb	C	c	C
cubic meter per second	m3/s	m3/s	M3/S
decibel	dB	db	DB
degree (angle)	deg	deg	DEG
degree Celsius	c	c	C
degree Fahrenheit	F	f	F
farad	F	f	F
foot per second	ft/s	ft/s	FT/S
henry	H	h	H
hertz	Hz	hz	HZ
hour	h	h	H
joule per kelvin	J/K	j/k	J/K
kilogram	kg	kg	KG
kilometer	km	km	KM
kilowatthour	kWh	kwh	KWH
liter	L	l	L
lumen per watt	lm/W	lm/w	LM/W
megahertz	MHz	mhz	MHZ
megohm	MOhm	mohm	MOHM
meter	m	m	M
metric ton	t	t	T

Table 4 Examples of symbols for limited character sets *(continued)*

	Form I	Form II	
	(Both cases)	**(Lowercase only)**	**(Uppercase only)**
microfarad	uF	uf	UF
microsecond	us	us	US
mile per hour	mi/h	mi/h	MI/H
milliliter	mL	ml	ML
millipascal second	mPa s	mpa s	MPA S
newton meter	Nm	nm	NM
picowatt	pW	pw	PW
pound-force foot	lbf ft	lbf ft	LBF FT
tesla	T	t	T
volt per meter	V/m	v/m	V/M
watt per steradian square meter	W(sr m2)	w(sr m2)	W(SR M2)
weber	Wb	wb	WB
yard	yd	yd	YD

6.4 Limitations arising from importing and exporting documents between computer programs

Despite the claim by many program vendors that their programs can "translate" into or from various formats, experience indicates that problems are frequently encountered. These problems occur even when using the same program but on different platforms. For example, Ω and μ often are not transferred properly from one program or platform to another. The transmitter of information is advised to proceed with caution and to take every step available to ensure accurate transmission. The use of proprietary programs such as mentioned above or such as TEX or LATEX may provide a solution to this problem, but the users must be on their guard. In general, unformatted text files adhering to the guidance of 6.1 are the safest editable documents to import or export.

Annex A

(normative)

Notation for expressing the reference of a level

The level representing a physical quantity x with a reference quantity x_{ref} may be indicated by

— $L_x(\mathrm{re}\ x_{ref})$ or by $L_{x/xref}$

Examples, where the last example is for both a reference value and a weighting scale denoted as A:

a) The statement that the level of an electric current is 10 Np below 1 A can be written as

— $L_I(\mathrm{re}\ 1\ \mathrm{A}) = -10\ \mathrm{Np}$

b) The statement that a certain power level is 7 dB above 1 mW can be written as

— $L_P(\mathrm{re}\ 1\ \mathrm{mW}) = 7\ \mathrm{dB}$

c) The statement that a certain electric field strength is 50 Np above 1 µV/m can be written as

— $L_E(\mathrm{re}\ 1 \mu\mathrm{V/m}) = 50\ \mathrm{Np}$

d) The statement that a certain sound pressure level is 15 dB above the level corresponding to a reference pressure of 20 µPa can be written as

— $L_p(\mathrm{re}\ 20\ \mu\mathrm{Pa}) = 15\ \mathrm{dB}$

or as

— $L_{p/(20\ \mu\mathrm{Pa})} = 15\ \mathrm{dB}$

e) The statement that a certain sound pressure level is 60 dB above the level correspoinding to a reference pressure of 20 µPa with the measurements weighted in accordance with the A scale:

— $L_{\mathrm{A}}(\mathrm{re}\ 20\ \mu\mathrm{Pa}\ ) = 60\ \mathrm{dB}$

In presenting data, particularly in tabular form or in graphical symbols, a condensed notation is often needed for identifying the reference value. Then the following condensed form, illustrated by application to the above examples, may be used:

— –10 Np (1 A)

— 7 dB (1 mW)

— 50 Np (1 µV/m)

— 15 dB (20 µPa)

— 60 dB (A)

A “1” in the expression of a reference quantity is sometimes omitted. This is not recommended in cases where confusion could occur. When a constant reference quantity is used repeatedly in a given context and explained in the text, it may be omitted.

Annex B

(informative)

Bibliography

[B1] ANSI X3.50-1986 (Reaff 1992), American National Standard for Information Systems-Representations for U.S. Customary, SI, and Other Units to Be Used in Systems with Limited Character Sets.[13]

[B2] BIPM. 1998. Le Système internationale d'unités (The International System of Units), 7th edition, referred to herein as "the SI brochure."

[B3] IEEE Std 1541™-2002, IEEE Standard for Prefixes for Binary Multiples.[14, 15]

[B4] ISO 31-0: 1992, Quantities and units—Part 0: General principles.[16]

[B5] ISO 31-1: 1992, Quantities and units—Part 1: Space and time.

[B6] ISO 31-2: 1992, Quantities and units—Part 2: Periodic and related phenomena.

[B7] ISO 31-3: 1992, Quantities and units—Part 3: Mechanics.

[B8] ISO 31-4: 1992, Quantities and units—Part 4: Heat.

[B9] ISO 31-5: 1979, Quantities and units—Part 5: Electricity and magnetism.

[B10] ISO 31-6: 1992, Quantities and units—Part 6: Light and related electromagnetic radiations.

[B11] ISO 31-7: 1992, Quantities and units—Part 7: Acoustics.

[B12] ISO 31-8: 1980, Quantities and units—Part 8: Physical chemistry and molecular physics.

[B13] ISO 1000: 1981, SI units and recommendations for the use of their multiples and of certain other units.

[B14] ISO 1683: 1983, Reference quantities for units expressed as levels in decibels.

[B15] ISO 2955: 1983, Information processing-Representation of SI and other units in systems with limited character sets.

[B16] NIST Special Publication 330 (2001), The International System of Units (SI).[17]

[13] ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42 Street, 13th Floor, New York, NY 10036, USA.

[14] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

[15] The IEEE standards or products referred to in this annex are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

[16] ISO publications are available from ISO, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[17] NIST publications are available from the Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA.