INTERNATIONAL STANDARD

ISO 80000-1

First edition
2009-11-15

Quantities and units

Part 1:
General

Grandeurs et unités

Partie 1: Généralités

Reference number
ISO 80000-1:2009(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of ISO 80000-1 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 80000-1 was prepared by Technical Committee ISO/TC 12, *Quantities and units* in co-operation with IEC/TC 25, *Quantities and units*.

This first edition of ISO 80000-1 cancels and replaces ISO 31-0:1992 and ISO 1000:1992. It also incorporates the Amendments ISO 31-0:1992/Amd.1:1998, ISO 31-0:1992/Amd.2:2005 and ISO 1000:1992/Amd.1:1998. The major technical changes from the previous standard are the following:

- the structure has been changed to emphasize that quantities come first and units then follow;
- definitions in accordance with ISO/IEC Guide 99:2007 have been added;
- Annexes A and B have become normative;
- a new normative Annex C has been added.

ISO 80000 consists of the following parts, under the general title *Quantities and units*:

- *Part 1: General*
- *Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*
- *Part 3: Space and time*
- *Part 4: Mechanics*
- *Part 5: Thermodynamics*
- *Part 7: Light*
- *Part 8: Acoustics*
- *Part 9: Physical chemistry and molecular physics*
- *Part 10: Atomic and nuclear physics*
- *Part 11: Characteristic numbers*
- *Part 12: Solid state physics*

IEC 80000 consists of the following parts, under the general title *Quantities and units*:

— *Part 6: Electromagnetism*

— *Part 13: Information science and technology*

— *Part 14: Telebiometrics related to human physiology*

Introduction

0.1 Quantities

Systems of quantities and systems of units can be treated in many consistent, but different, ways. Which treatment to use is only a matter of convention. The presentation given in this International Standard is the one that is the basis for the International System of Units, the SI (from the French: *Système international d'unités*), adopted by the General Conference on Weights and Measures, the CGPM (from the French: *Conférence générale des poids et mesures*).

The quantities and relations among the quantities used here are those almost universally accepted for use throughout the physical sciences. They are presented in the majority of scientific textbooks today and are familiar to all scientists and technologists.

NOTE For electric and magnetic units in the CGS-ESU, CGS-EMU[1)] and Gaussian systems, there is a difference in the systems of quantities by which they are defined. In the CGS-ESU system, the electric constant ε_0 (the permittivity of vacuum) is defined to be equal to 1, i.e. of dimension one; in the CGS-EMU system, the magnetic constant μ_0 (permeability of vacuum) is defined to be equal to 1, i.e. of dimension one, in contrast to those quantities in the ISQ where they are not of dimension one. The Gaussian system is related to the CGS-ESU and CGS-EMU systems and there are similar complications. In mechanics, Newton's law of motion in its general form is written $\boldsymbol{F} = c \cdot m\boldsymbol{a}$. In the old technical system, MKS[2)], $c = 1/g_n$, where g_n is the standard acceleration of free fall; in the ISQ, $c = 1$.

The quantities and the relations among them are essentially infinite in number and are continually evolving as new fields of science and technology are developed. Thus, it is not possible to list all these quantities and relations in this International Standard; instead, a selection of the more commonly used quantities and the relations among them is presented.

It is inevitable that some readers working in particular specialized fields may find that the quantities they are interested in using may not be listed in this International Standard or in another International Standard. However, provided that they can relate their quantities to more familiar examples that are listed, this will not prevent them from defining units for their quantities.

Most of the units used to express values of quantities of interest were developed and used long before the concept of a system of quantities was developed. Nonetheless, the relations among the quantities, which are simply the equations of the physical sciences, are important, because in any system of units the relations among the units play an important role and are developed from the relations among the corresponding quantities.

The system of quantities, including the relations among them the quantities used as the basis of the units of the SI, is named the *International System of Quantities*, denoted "ISQ", in all languages. This name was not used in ISO 31, from which the present harmonized series has evolved. However, ISQ does appear in ISO/IEC Guide 99:2007 and in the SI Brochure[8], Edition 8:2006. In both cases, this was to ensure consistency with the new *Quantities and units* series that was under preparation at the time they were published; it had already been announced that the new term would be used. It should be realized, however, that ISQ is simply a convenient notation to assign to the essentially infinite and continually evolving and expanding system of quantities and equations on which all of modern science and technology rests. ISQ is a shorthand notation for the "system of quantities on which the SI is based", which was the phrase used for this system in ISO 31.

1) CGS = centimetre-gram-second; ESU = electrostatic units; EMU = electromagnetic units.

2) MKS = metre-kilogram-second.

0.2 Units

A system of units is developed by first defining a set of base units for a small set of corresponding base quantities and then defining derived units as products of powers of the base units corresponding to the relations defining the derived quantities in terms of the base quantities. In this International Standard and in the SI, there are seven base quantities and seven base units. The base quantities are length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity. The corresponding base units are the metre, kilogram, second, ampere, kelvin, mole, and candela, respectively. The definitions of these base units, and their practical realization, are at the heart of the SI and are the responsibility of the advisory committees of the International Committee for Weights and Measures, the CIPM (from the French: *Comité international des poids et mesures*). The current definitions of the base units, and advice for their practical realization, are presented in the SI Brochure [8], published by and obtainable from the International Bureau of Weights and Measures, the BIPM (from the French: *Bureau international des poids et mesures*). Note that in contrast to the base units, each of which has a specific definition, the base quantities are simply chosen by convention and no attempt is made to define them otherwise then operationally.

0.3 Realizing the values of units

To realize the value of a unit is to use the definition of the unit to make measurements that compare the value of some quantity of the same kind as the unit with the value of the unit. This is the essential step in making measurements of the value of any quantity in science. Realizing the values of the base units is of particular importance. Realizing the values of derived units follows in principle from realizing the base units.

There may be many different ways for the practical realization of the value of a unit, and new methods may be developed as science advances. Any method consistent with the laws of physics could be used to realize any SI unit. Nonetheless, it is often helpful to review experimental methods for realizing the units, and the CIPM recommends such methods, which are presented as part of the SI Brochure.

0.4 Arrangement of the tables

In parts 3 to 14 of this International Standard, the quantities and relations among them, which are a subset of the ISQ, are given on the left-hand pages, and the units of the SI (and some other units) are given on the right-hand pages. Some additional quantities and units are also given on the left-hand and right-hand pages, respectively. The item numbers of quantities are written pp-nn.s (pp, part number; nn, running number in the part, respectively; s, sub-number). The item numbers of units are written pp-nn.l (pp, part number; nn, running number in the part, respectively; l, sub-letter).

Quantities and units

Part 1: General

1 Scope

ISO 80000-1 gives general information and definitions concerning quantities, systems of quantities, units, quantity and unit symbols, and coherent unit systems, especially the International System of Quantities, ISQ, and the International System of Units, SI.

The principles laid down in ISO 80000-1 are intended for general use within the various fields of science and technology, and as an introduction to other parts of this International Standard.

Ordinal quantities and nominal properties are outside the scope of ISO 80000-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The content in this clause is essentially the same as in ISO/IEC Guide 99:2007. Some notes and examples are modified.

3.1
quantity
property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by means of a number and a reference

NOTE 1 The generic concept ‘quantity’ can be divided into several levels of specific concepts, as shown in the following table. The left hand side of the table shows specific concepts under ‘quantity’. These are generic concepts for the individual quantities in the right hand column.

length, l	radius, r	radius of circle A, r_A or r(A)
	wavelength, λ	wavelength of the sodium D radiation, λ_D or λ(Na; D)
energy, E	kinetic energy, T	kinetic energy of particle i in a given system, T_i
	heat, Q	heat of vaporization of sample i of water, Q_i
electric charge, Q		electric charge of the proton, e
electric resistance, R		electric resistance of resistor i in a given circuit, R_i
amount-of-substance concentration of entity B, c_B		amount-of-substance concentration of ethanol in wine sample i, $c_i(C_2H_5OH)$
number concentration of entity B, C_B		number concentration of erythrocytes in blood sample i, C(Erys; B_i)
Rockwell C hardness (150 kg load), HRC(150 kg)		Rockwell C hardness of steel sample i, HRC_i(150 kg)

NOTE 2 A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such. For magnitude of a quantity, see 3.19.

NOTE 3 Symbols for quantities are given in the ISO 80000 and IEC 80000 series, *Quantities and units*. The symbols for quantities are written in italics. A given symbol can indicate different quantities.

NOTE 4 A quantity as defined here is a scalar. However, a vector or a tensor, the components of which are quantities, is also considered to be a quantity.

NOTE 5 The concept ’quantity’ may be generically divided into, e.g. ‘physical quantity’, ‘chemical quantity’, and ‘biological quantity’, or ‘base quantity’ and ‘derived quantity’.

NOTE 6 Adapted from ISO/IEC Guide 99:2007, definition 1.1, in which there is an additional note.

3.2
kind of quantity
aspect common to mutually comparable quantities

NOTE 1 Kind of quantity is often shortened to “kind”, e.g. in quantities of the same kind.

NOTE 2 The division of the concept ‘quantity’ into several kinds is to some extent arbitrary.

EXAMPLE 1 The quantities diameter, circumference, and wavelength are generally considered to be quantities of the same kind, namely, of the kind of quantity called length.

EXAMPLE 2 The quantities heat, kinetic energy, and potential energy are generally considered to be quantities of the same kind, namely, of the kind of quantity called energy.

NOTE 3 Quantities of the same kind within a given system of quantities have the same quantity dimension. However, quantities of the same dimension are not necessarily of the same kind.

EXAMPLE The quantities moment of force and energy are, by convention, not regarded as being of the same kind, although they have the same dimension. Similarly for heat capacity and entropy, as well as for number of entities, relative permeability, and mass fraction.

NOTE 4 In English, the terms for quantities in the left half of the table in 3.1, Note 1, are often used for the corresponding ‘kinds of quantity’. In French, the term “nature” is only used in expressions such as “grandeurs de même nature” (in English, “quantities of the same kind”).

NOTE 5 Adapted from ISO/IEC Guide 99:2007, definition 1.2, in which “kind” appears as an admitted term. Note 1 has been added.

3.3
system of quantities
set of quantities together with a set of non-contradictory equations relating those quantities

NOTE 1 Ordinal quantities (see 3.26), such as Rockwell C hardness, and nominal properties (see 3.30), such as colour of light, are usually not considered to be part of a system of quantities because they are related to other quantities through empirical relations only.

NOTE 2 Adapted from ISO/IEC Guide 99:2007, definition 1.3, in which Note 1 is different.

3.4
base quantity
quantity in a conventionally chosen subset of a given system of quantities, where no quantity in the subset can be expressed in terms of the other quantities within that subset

NOTE 1 The subset mentioned in the definition is termed the “set of base quantities”.

EXAMPLE The set of base quantities in the International System of Quantities (ISQ) is given in 3.6.

NOTE 2 Base quantities are referred to as being mutually independent since a base quantity cannot be expressed as a product of powers of the other base quantities.

NOTE 3 ‘Number of entities’ can be regarded as a base quantity in any system of quantities.

NOTE 4 Adapted from ISO/IEC Guide 99:2007, definition 1.4, in which the definition is slightly different.

3.5
derived quantity
quantity, in a system of quantities, defined in terms of the base quantities of that system

EXAMPLE In a system of quantities having the base quantities length and mass, mass density is a derived quantity defined as the quotient of mass and volume (length to the power three).

NOTE Adapted from ISO/IEC Guide 99:2007, definition 1.5, in which the example is slightly different.

3.6
International System of Quantities
ISQ
system of quantities based on the seven base quantities: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity

NOTE 1 This system of quantities is published in the ISO 80000 and IEC 80000 series *Quantities and units*, Parts 3 to 14.

NOTE 2 The International System of Units (SI) (see item 3.16) is based on the ISQ.

NOTE 3 Adapted from ISO/IEC Guide 99:2007, definition 1.6, in which Note 1 is different.

3.7
quantity dimension
dimension of a quantity
dimension
expression of the dependence of a quantity on the base quantities of a system of quantities as a product of powers of factors corresponding to the base quantities, omitting any numerical factor

EXAMPLE 1 In the ISQ, the quantity dimension of force is denoted by dim $F = \mathrm{LMT}^{-2}$.

EXAMPLE 2 In the same system of quantities, dim $\rho_B = ML^{-3}$ is the quantity dimension of mass concentration of component B, and ML^{-3} is also the quantity dimension of mass density, ρ.

EXAMPLE 3 The period, T, of a particle pendulum of length l at a place with the local acceleration of free fall g is

$$T = 2\,\pi\sqrt{\frac{l}{g}} \quad \text{or} \quad T = C(g)\sqrt{l} \quad \text{where} \quad C(g) = \frac{2\pi}{\sqrt{g}}$$

Hence $\dim C(g) = \mathrm{T} \cdot \mathrm{L}^{-1/2}$.

NOTE 1 A power of a factor is the factor raised to an exponent. Each factor is the dimension of a base quantity.

NOTE 2 The conventional symbolic representation of the dimension of a base quantity is a single upper case letter in roman (upright) type. The conventional symbolic representation of the dimension of a derived quantity is the product of powers of the dimensions of the base quantities according to the definition of the derived quantity. The dimension of a quantity Q is denoted by dim Q.

NOTE 3 In deriving the dimension of a quantity, no account is taken of its scalar, vector, or tensor character.

NOTE 4 In a given system of quantities,

— quantities of the same kind have the same quantity dimension,

— quantities of different quantity dimensions are always of different kinds, and

— quantities having the same quantity dimension are not necessarily of the same kind.

NOTE 5 Symbols representing the dimensions of the base quantities in the ISQ are:

Base quantity	Symbol for dimension
length	L
mass	M
time	T
electric current	I
thermodynamic temperature	Θ
amount of substance	N
luminous intensity	J

Thus, the dimension of a quantity Q is denoted by dim $Q = \mathrm{L}^{\alpha}\mathrm{M}^{\beta}\mathrm{T}^{\gamma}\mathrm{I}^{\delta}\Theta^{\varepsilon}\mathrm{N}^{\zeta}\mathrm{J}^{\eta}$ where the exponents, named dimensional exponents, are positive, negative, or zero. Factors with exponent zero and the exponent 1 are usually omitted. When all exponents are zero, see 3.8.

NOTE 6 Adapted from ISO/IEC Guide 99:2007, definition 1.7, in which Note 5 and Examples 2 and 3 are different and in which “dimension of a quantity” and “dimension” are given as admitted terms.

3.8
quantity of dimension one
dimensionless quantity
quantity for which all the exponents of the factors corresponding to the base quantities in its quantity dimension are zero

NOTE 1 The term “dimensionless quantity” is commonly used and is kept here for historical reasons. It stems from the fact that all exponents are zero in the symbolic representation of the dimension for such quantities. The term “quantity of dimension one” reflects the convention in which the symbolic representation of the dimension for such quantities is the symbol 1, see Clause 5. This dimension is not a number, but the neutral element for multiplication of dimensions.

NOTE 2 The measurement units and values of quantities of dimension one are numbers, but such quantities convey more information than a number.

NOTE 3 Some quantities of dimension one are defined as the ratios of two quantities of the same kind. The coherent derived unit is the number one, symbol 1.

EXAMPLE Plane angle, solid angle, refractive index, relative permeability, mass fraction, friction factor, Mach number.

NOTE 4 Numbers of entities are quantities of dimension one.

EXAMPLE Number of turns in a coil, number of molecules in a given sample, degeneracy of the energy levels of a quantum system.

NOTE 5 Adapted from ISO/IEC Guide 99:2007, definition 1.8, in which Notes 1 and 3 are different and in which "dimensionless quantity" is given as an admitted term.

3.9
unit of measurement
measurement unit
unit
real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the second quantity to the first one as a number

NOTE 1 Measurement units are designated by conventionally assigned names and symbols.

NOTE 2 Measurement units of quantities of the same quantity dimension may be designated by the same name and symbol even when the quantities are not of the same kind. For example, joule per kelvin and J/K are respectively the name and symbol of both a measurement unit of heat capacity and a measurement unit of entropy, which are generally not considered to be quantities of the same kind. However, in some cases special measurement unit names are restricted to be used with quantities of specific kind only. For example, the measurement unit 'second to the power minus one' (1/s) is called hertz (Hz) when used for frequencies and becquerel (Bq) when used for activities of radionuclides. As another example, the joule (J) is used as a unit of energy, but never as a unit of moment of force, i.e. the newton metre (N · m).

NOTE 3 Measurement units of quantities of dimension one are numbers. In some cases, these measurement units are given special names, e.g. radian, steradian, and decibel, or are expressed by quotients such as millimole per mole equal to 10^{-3} and microgram per kilogram equal to 10^{-9}.

NOTE 4 For a given quantity, the short term "unit" is often combined with the quantity name, such as "mass unit" or "unit of mass".

NOTE 5 Adapted from ISO/IEC Guide 99:2007, definition 1.9, in which the definition and Note 2 are slightly different and in which "measurement unit" and "unit" are given as admitted terms.

3.10
base unit
measurement unit that is adopted by convention for a base quantity

NOTE 1 In each coherent system of units, there is only one base unit for each base quantity.

EXAMPLE In the SI, the metre is the base unit of length. In the CGS systems, the centimetre is the base unit of length.

NOTE 2 A base unit may also serve for a derived quantity of the same quantity dimension.

EXAMPLE The derived quantity rainfall, when defined as areic volume (volume per area), has the metre as a coherent derived unit in the SI.

NOTE 3 For number of entities, the number one, symbol 1, can be regarded as a base unit in any system of units. Compare Note 3 in 3.4.

NOTE 4 Adapted from ISO/IEC Guide 99:2007, definition 1.10, in which the example in Note 2 is slightly different. The last sentence in Note 3 has been added.

3.11
derived unit
measurement unit for a derived quantity

EXAMPLE The metre per second, symbol m/s, and the centimetre per second, symbol cm/s, are derived units of speed in the SI. The kilometre per hour, symbol km/h, is a measurement unit of speed outside the SI but accepted for use with the SI. The knot, equal to one nautical mile per hour, is a measurement unit of speed outside the SI.

[ISO/IEC Guide 99:2007, 1.11]

3.12
coherent derived unit
derived unit that, for a given system of quantities and for a chosen set of base units, is a product of powers of base units with no other proportionality factor than one

NOTE 1 A power of a base unit is the base unit raised to an exponent.

NOTE 2 Coherence can be determined only with respect to a particular system of quantities and a given set of base units.

EXAMPLE If the metre, the second, and the mole are base units, the metre per second is the coherent derived unit of velocity when velocity is defined by the quantity equation $v = \mathrm{d}\boldsymbol{r}/\mathrm{d}t$ and the mole per cubic metre is the coherent derived unit of amount-of-substance concentration when amount-of-substance concentration is defined by the quantity equation $c = n/V$. The kilometre per hour and the knot, given as examples of derived units in 3.11, are not coherent derived units in such a system of quantities.

NOTE 3 A derived unit can be coherent with respect to one system of quantities but not to another.

EXAMPLE The centimetre per second is the coherent derived unit of speed in a CGS system of units but is not a coherent derived unit in the SI.

NOTE 4 The coherent derived unit for every derived quantity of dimension one in a given system of units is the number one, symbol 1. The name and symbol of the measurement unit one are generally not indicated.

[ISO/IEC Guide 99:2007, 1.12]

3.13
system of units
set of base units and derived units, together with their multiples and submultiples, defined in accordance with given rules, for a given system of quantities

[ISO/IEC Guide 99:2007, 1.13]

3.14
coherent system of units
system of units, based on a given system of quantities, in which the measurement unit for each derived quantity is a coherent derived unit

EXAMPLE Set of coherent SI units and relations between them.

NOTE 1 A system of units can be coherent only with respect to a system of quantities and the adopted base units.

NOTE 2 For a coherent system of units, numerical value equations have the same form, including numerical factors, as the corresponding quantity equations. See examples of numerical value equations in 3.25.

NOTE 3 Adapted from ISO/IEC Guide 99:2007, definition 1.14, in which Note 2 is different.

3.15
off-system measurement unit
off-system unit
measurement unit that does not belong to a given system of units

EXAMPLE 1 The electronvolt ($\approx$ 1,602 18 × 10^{-19} J) is an off-system measurement unit of energy with respect to the SI.

EXAMPLE 2 Day, hour, minute are off-system measurement units of time with respect to the SI.

NOTE Adapted from ISO/IEC Guide 99:2007, definition 1.15, in which Example 1 is different and in which “off-system unit” is given as an admitted term.

3.16
International System of Units
SI
system of units, based on the International System of Quantities, their names and symbols, including a series of prefixes and their names and symbols, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)

NOTE 1 The SI is founded on the seven base quantities of the ISQ and the names and symbols of the corresponding base units, see 6.5.2.

NOTE 2 The base units and the coherent derived units of the SI form a coherent set, designated the “set of coherent SI units”.

NOTE 3 For a full description and explanation of the International System of Units, see edition 8 of the SI brochure published by the Bureau International des Poids et Mesures (BIPM) and available on the BIPM website.

NOTE 4 In quantity calculus, the quantity ‘number of entities’ is often considered to be a base quantity, with the base unit one, symbol 1.

NOTE 5 For the SI prefixes for multiples of units and submultiples of units, see 6.5.4.

NOTE 6 Adapted from ISO/IEC Guide 99:2007, definition 1.16, in which Notes 1 and 5 are different.

3.17
multiple of a unit
measurement unit obtained by multiplying a given measurement unit by an integer greater than one

EXAMPLE 1 The kilometre is a decimal multiple of the metre.

EXAMPLE 2 The hour is a non-decimal multiple of the second.

NOTE 1 SI prefixes for decimal multiples of SI base units and SI derived units are given in 6.5.4.

NOTE 2 SI prefixes refer strictly to powers of 10, and should not be used for powers of 2. For example, 1 kbit should not be used to represent 1024 bits (2^{10} bits), which is a kibibit (1 Kibit).

Prefixes for binary multiples are:

Factor	Value	Prefix	
		Name	Symbol
$(2^{10})^8$	1 208 925 819 614 629 174 706 176	yobi	Yi
$(2^{10})^7$	1 180 591 620 717 411 303 424	zebi	Zi
$(2^{10})^6$	1 152 921 504 606 846 976	exbi	Ei
$(2^{10})^5$	1 125 899 906 842 624	pebi	Pi
$(2^{10})^4$	1 099 511 627 776	tebi	Ti
$(2^{10})^3$	1 073 741 824	gibi	Gi
$(2^{10})^2$	1 048 576	mebi	Mi
$(2^{10})^1$	1 024	kibi	Ki

Source: IEC 80000-13:2008.

NOTE 3 Adapted from ISO/IEC Guide 99:2007, definition 1.17, in which Notes 1 and 2 are different.

3.18
submultiple of a unit
measurement unit obtained by dividing a given measurement unit by an integer greater than one

EXAMPLE 1 The millimetre is a decimal submultiple of the metre.

EXAMPLE 2 For plane angle, the second is a non-decimal submultiple of the minute.

NOTE SI prefixes for decimal submultiples of SI base units and SI derived units are given in 6.5.4.

[ISO/IEC Guide 99:2007, 1.18]

3.19
quantity value
value of a quantity
value
number and reference together expressing magnitude of a quantity

EXAMPLE 1	Length of a given rod:	5,34 m or 534 cm
EXAMPLE 2	Mass of a given body:	0,152 kg or 152 g
EXAMPLE 3	Curvature of a given arc:	112 m^{-1}
EXAMPLE 4	Celsius temperature of a given sample:	–5 °C
EXAMPLE 5	Electric impedance of a given circuit element at a given frequency, where j is the imaginary unit:	(7 + 3j) Ω
EXAMPLE 6	Refractive index of a given sample of glass:	1,32
EXAMPLE 7	Rockwell C hardness of a given sample (150 kg load):	43,5 HRC(150 kg)
EXAMPLE 8	Mass fraction of cadmium in a given sample of copper:	3 μg/kg or 3×10^{-9}
EXAMPLE 9	Molality of Pb^{2+} in a given sample of water:	1,76 μmol/kg
EXAMPLE 10	Amount-of-substance concentration of lutropin in a given sample of plasma (WHO international standard 80/552):	5,0 IU/l (WHO International Units per litre)

NOTE 1 According to the type of reference, a quantity value is either

— a product of a number and a measurement unit (see Examples 1, 2, 3, 4, 5, 8 and 9); the measurement unit one is generally not indicated for quantities of dimension one (see Examples 6 and 8), or

— a number and a reference to a measurement procedure (see Example 7), or

— a number and a reference material (see Example 10).

NOTE 2 The number can be complex (see Example 5).

NOTE 3 A quantity value can be presented in more than one way (see Examples 1, 2 and 8).

NOTE 4 In the case of vector or tensor quantities, each component has a quantity value.

EXAMPLE Force acting on a given particle, e.g. in Cartesian components $(F_x; F_y; F_z)$ = (–31,5; 43,2; 17,0) N, where (–31,5; 43,2; 17,0) is a numerical-value vector and N (newton) is the unit, or $(F_x; F_y; F_z)$ = (–31,5 N; 43,2 N; 17,0 N) where each component is a quantity.

NOTE 5 Adapted from ISO/IEC Guide 99:2007, definition 1.19, in which Example 10 and Note 4 are different and in which “value of a quantity” and “value” are given as admitted terms.

3.20
numerical quantity value
numerical value of a quantity
numerical value
number in the expression of a quantity value, other than any number serving as the reference

NOTE 1 For quantities of dimension one, the reference is a measurement unit which is a number and this is not considered as a part of the numerical quantity value.

EXAMPLE In an amount-of-substance fraction equal to 3 mmol/mol, the numerical quantity value is 3 and the unit is mmol/mol. The unit mmol/mol is numerically equal to 0,001, but this number 0,001 is not part of the numerical quantity value, which remains 3.

NOTE 2 For quantities that have a measurement unit (i.e. those other than ordinal quantities), the numerical value $\{Q\}$ of a quantity Q is frequently denoted $\{Q\} = Q/[Q]$, where $[Q]$ denotes the measurement unit.

EXAMPLE For a quantity value of $m = 5{,}721$ kg, the numerical quantity value is $\{m\} = (5{,}721 \text{ kg})/\text{kg} = 5{,}721$. The same quantity value can be expressed as 5 721 g in which case the numerical quantity value $\{m\} = (5\,721 \text{ g})/\text{g} = 5\,721$. See 3.19.

NOTE 3 Adapted from ISO/IEC Guide 99:2007, definition 1.20, in which Note 2 is different and in which “numerical value of a quantity” and “numerical value” are given as an admitted terms.

3.21
quantity calculus
set of mathematical rules and operations applied to quantities other than ordinal quantities

NOTE In quantity calculus, quantity equations are preferred to numerical value equations because quantity equations are independent of the choice of measurement units, whereas numerical value equations are not (see also 4.2 and 6.3).

[ISO/IEC Guide 99:2007, 1.21]

3.22
quantity equation
mathematical relation between quantities in a given system of quantities, independent of measurement units

EXAMPLE 1 $Q_1 = \zeta Q_2 Q_3$ where Q_1, Q_2 and Q_3 denote different quantities, and where ζ is a numerical factor.

EXAMPLE 2 $T = (1/2)\, mv^2$, where T is the kinetic energy and v is the speed of a specified particle of mass m.

EXAMPLE 3 $n = It / F$ where n is the amount of substance of a univalent component, I is the electric current and t is the duration of the electrolysis, and F is the Faraday constant.

[ISO/IEC Guide 99:2007, 1.22]

3.23
unit equation
mathematical relation between base units, coherent derived units or other measurement units

EXAMPLE 1 For the quantities in Example 1 of item 3.22, $[Q_1] = [Q_2]\,[Q_3]$ where $[Q_1]$, $[Q_2]$ and $[Q_3]$ denote the measurement units of Q_1, Q_2 and Q_3, respectively, provided that these measurement units are in a **coherent** system of units.

EXAMPLE 2 $\text{J} := \text{kg m}^2/\text{s}^2$, where J, kg, m, and s are the symbols for the joule, kilogram, metre, and second, respectively. (The symbol := denotes “is by definition equal to” as given in ISO 80000-2:2009, item 2-7.3.)

EXAMPLE 3 1 km/h = (1/3,6) m/s.

NOTE Adapted from ISO/IEC Guide 99:2007, definition 1.23, in which the Example 2 is different.

3.24
conversion factor between units
ratio of two measurement units for quantities of the same kind

EXAMPLE km/m = 1 000 and thus 1 km = 1 000 m.

NOTE The measurement units may belong to different systems of units.

EXAMPLE 1 h/s = 3 600 and thus 1 h = 3 600 s.

EXAMPLE 2 (km/h)/(m/s) = (1/3,6) and thus 1 km/h = (1/3,6) m/s

[ISO/IEC Guide 99:2007, 1.24]

3.25
numerical value equation
numerical quantity value equation
mathematical relation between numerical quantity values, based on a given quantity equation and specified measurement units

EXAMPLE 1 For the quantities in the first example in item 3.22, $\{Q_1\} = \zeta \{Q_2\} \{Q_3\}$ where $\{Q_1\}$, $\{Q_2\}$ and $\{Q_3\}$ denote the numerical values of Q_1, Q_2 and Q_3, respectively, provided that they are expressed in base units or coherent derived units or both.

EXAMPLE 2 In the quantity equation for kinetic energy of a particle, $T = (1/2)\, mv^2$, if $m = 2$ kg and $v = 3$ m/s, then $\{T\} = (1/2) \times 2 \times 3^2$ is a numerical value equation giving the numerical value 9 of T in joules.

NOTE Adapted from ISO/IEC Guide 99:2007, definition 1.25, in which "numerical quantity value equation" is given as an admitted term.

3.26
ordinal quantity
quantity, defined by a conventional measurement procedure, for which a total ordering relation can be established, according to magnitude, with other quantities of the same kind, but for which no algebraic operations among those quantities exist

EXAMPLE 1 Rockwell C hardness.

EXAMPLE 2 Octane number for petroleum fuel.

EXAMPLE 3 Earthquake strength on the Richter scale.

EXAMPLE 4 Subjective level of abdominal pain on a scale from zero to five.

NOTE 1 Ordinal quantities can enter into empirical relations only and have neither measurement units nor quantity dimensions. Differences and ratios of ordinal quantities have no physical meaning.

NOTE 2 Ordinal quantities are arranged according to ordinal quantity-value scales (see 3.28).

[ISO/IEC Guide 99:2007, definition 1.26]

3.27
quantity-value scale
measurement scale
ordered set of quantity values of quantities of a given kind of quantity used in ranking, according to magnitude, quantities of that kind

EXAMPLE 1 Celsius temperature scale.

EXAMPLE 2 Time scale.

EXAMPLE 3 Rockwell C hardness scale.

NOTE Adapted from ISO/IEC Guide 99:2007, 1.27, in which "measurement scale" is given as an admitted term.

3.28
ordinal quantity-value scale
ordinal value scale
quantity-value scale for ordinal quantities

EXAMPLE 1 Rockwell C hardness scale

EXAMPLE 2 Scale of octane numbers for petroleum fuel

NOTE 1 An ordinal quantity-value scale may be established by measurements according to a measurement procedure.

NOTE 2 Adapted from ISO/IEC Guide 99:2007, 1.28, in which "ordinal value scale" is given as an admitted term.

3.29
conventional reference scale
quantity-value scale defined by formal agreement

[ISO/IEC Guide 99:2007, definition 1.29]

3.30
nominal property
property of a phenomenon, body, or substance, where the property has no magnitude

EXAMPLE 1 Sex of a human being.

EXAMPLE 2 Colour of a paint sample.

EXAMPLE 3 Colour of a spot test in chemistry.

EXAMPLE 4 ISO two-letter country code.

EXAMPLE 5 Sequence of amino acids in a polypeptide.

NOTE 1 A nominal property has a value, which can be expressed in words, by alpha-numerical codes, or by other means.

NOTE 2 "Nominal property value" is not to be confused with "nominal quantity value", which is not used in this International Standard.

NOTE 3 Adapted from ISO/IEC Guide 99:2007, 1.30, in which Note 2 is different.

4 Quantities

4.1 The concept of quantity

In this International Standard, *quantities* used for the quantitative description of a phenomenon, substance or body are treated.

Ordinal quantities, arranged according to quantity-value scales (such as the Beaufort scale, the Richter scale and colour-intensity scales) or expressed as the result of conventional tests (e.g. hardness and corrosion resistance) are not treated here. Neither *nominal properties*, such as the sex of a human being or the ISO two-letter country codes, nor currencies are treated here.

4.2 Kind of quantity — Quantity calculus

Quantities may be grouped together into categories of quantities that are mutually comparable. Diameters, distances, heights, wavelengths and so on would constitute such a category, generally called *length*. Mutually comparable quantities are called *quantities of the same kind*.

Mathematic operations can be performed on quantities other than ordinal quantities, as explained below.

Two or more quantities cannot be added or subtracted unless they belong to the same category of mutually comparable quantities. Hence, quantities on each side of an equal sign in an equation must also be of the same kind.

Quantities are multiplied and divided by one another according to the rules of algebra, resulting in new quantities.

Performing the mathematical operations addition, subtraction, multiplication and division of quantities is called *quantity calculus*. In quantity calculus, the algebraic expressions should be quantities or numbers.

4.3 System of quantities — Base quantities and derived quantities

Quantities are related through equations that express laws of nature or define new quantities. Each equation between quantities is called a *quantity equation*.

It is convenient to consider some quantities of different kinds as mutually independent. Such quantities are called *base quantities*. Other quantities, called *derived quantities,* are defined or expressed in terms of *base quantities* by means of equations.

It is a matter of choice how many and which quantities are considered to be base quantities. It is also a matter of choice which equations are used to define the derived quantities. Each set of non-contradictory equations between quantities is called a *system of quantities*.

4.4 Universal constants and empirical constants

Some quantities are considered to be constant under all circumstances. Such quantities are called *universal constants* or *fundamental physical constants*.

EXAMPLE 1 The Planck constant, $h = 6{,}626\ 068\ 96(33) \times 10^{-34}$ J · s [CODATA 2006].

EXAMPLE 2 The Faraday constant, $F = 96\ 485{,}339\ 9(24)$ C/mol [CODATA 2006].

Other quantities may be constant under some circumstances, but depend on others. Their values are generally obtained by measurement. They are called *empirical constants*.

EXAMPLE 3

The result of measuring at a certain station the length l and the periodic time T, for each of several particle pendulums, can be expressed by one quantity equation

$$T = C\sqrt{l}$$

where C is an empirical constant that depends on the location.

Theory shows that

$$C = \frac{2\pi}{\sqrt{g}}$$

where g is the local acceleration of free fall, which is another empirical constant.

4.5 Constant multipliers in quantity equations

Equations between quantities sometimes contain constant multipliers. These multipliers depend on the definitions chosen for the quantities occurring in the equations, i.e. on the system of quantities chosen. Such multipliers may be purely numerical and are then called *numerical factors*.

EXAMPLE 1

In the CGS system, length, mass, and time are the three base quantities. In that system, the kinetic energy of a particle in classical mechanics is

$$T = \frac{1}{2} m v^2$$

where T is kinetic energy, m is mass and v is speed. The same relation is also true in the ISQ.

A multiplier may include one or more universal constants.

EXAMPLE 2

In the ISQ, the Coulomb law for electric charges is

$$F = \frac{1}{4\pi\, \varepsilon_0} \frac{q_1\, q_2}{r^2}$$

where F is force, q_1 and q_2 are two electric charges, r is distance and ε_0 is a universal constant, i.e. the electric constant.

A multiplier may also include one or more *conventional quantity values*.

EXAMPLE 3

In the now obsolete MKS system, length, mass, and time are the three base quantities. In that system, the Newton law of motion is

$$F = \frac{1}{g_n} m\, a$$

where F is force, m is mass, a is acceleration, and g_n is a conventional quantity value, i.e. the standard acceleration of free fall adopted by the CGPM 1901. (In this system, force and mass have the same dimension.)

Constant multipliers other than numerical factors are often called *coefficients*.

4.6 International System of Quantities, ISQ

The special choice of base quantities and quantity equations, including multipliers, given in ISO 80000 and IEC 80000 defines the *International System of Quantities*, denoted “ISQ” in all languages. Derived quantities can be defined in terms of the base units by quantity equations. There are seven base quantities in the ISQ: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity.

5 Dimensions

In the system of quantities under consideration, any quantity Q can be expressed in terms of the base quantities by means of an equation. The expression may consist of a sum of terms. Each of these terms can be expressed as a product of powers of base quantities A, B, C, … from a chosen set, sometimes multiplied by a numerical factor ξ, i.e. $\xi A^{\alpha} B^{\beta} C^{\gamma} \ldots$, where the set of exponents α, β, γ, … is the same for each term.

The *dimension* (see 3.7) of the quantity Q is then expressed by the *dimensional product*

$$\dim Q = \mathrm{A}^{\alpha} \mathrm{B}^{\beta} \mathrm{C}^{\gamma} \ldots$$

where A, B, C, … denote the dimensions of the base quantities A, B, C, …, respectively, and α, β, γ, … are called the *dimensional exponents*.

A quantity whose dimensional exponents are all equal to zero has the dimensional product denoted $\mathrm{A}^0\mathrm{B}^0\mathrm{C}^0 \ldots = 1$, where the symbol 1 denotes the corresponding dimension. Such a quantity is called a *quantity of dimension one* and is expressed by a number.

NOTE For historical reasons, a quantity of dimension one is often called *dimensionless*. See Note 1 in 3.8.

In the ISQ, with the seven base quantities length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity, the dimensions of the base quantities are denoted L, M, T, I, Θ, N and J, respectively. Hence, in the ISQ, the dimension of a quantity Q in general becomes

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

EXAMPLE

Quantity	**Dimension**
speed	LT^{-1}
frequency	T^{-1}
force	LMT^{-2}
energy	$\mathrm{L}^2\mathrm{MT}^{-2}$
entropy	$\mathrm{L}^2\mathrm{MT}^{-2}\Theta^{-1}$
electric tension	$\mathrm{L}^2\mathrm{MT}^{-3}\mathrm{I}^{2}$
magnetic flux	$\mathrm{L}^2\mathrm{MT}^{-2}\mathrm{I}^{-1}$
illuminance	$\mathrm{L}^{-2}\mathrm{J}$
molar entropy	$\mathrm{L}^2\mathrm{MT}^{-2}\Theta^{-1}\mathrm{N}^{-1}$
efficiency	1

6 Units

6.1 Units and numerical values

If a particular example of a quantity of a given kind is chosen as a reference quantity called the *unit* (see 3.9), then any other quantity of the same kind can be expressed in terms of this unit, as a product of this unit and a number. That number is called the *numerical value* of the quantity expressed in this unit.

EXAMPLE 1 The wavelength of one of the sodium spectral lines is

$$\lambda \approx 5{,}896 \times 10^{-7}\ \mathrm{m}$$

Here, λ is the symbol for the quantity wavelength, m is the symbol for the unit of length, the metre, and $5{,}896 \times 10^{-7}$ is the numerical value of the wavelength expressed in metres.

In formal treatments of quantities and units, this relation may be expressed in the form

$$Q = \{Q\} \cdot [Q]$$

where Q is the symbol for the quantity, $[Q]$ is the symbol for the unit and $\{Q\}$ is the symbol for the numerical value of the quantity Q expressed in the unit $[Q]$. For vectors and tensors, the components are quantities that can be expressed as described above. Vectors and tensors can also be expressed as a numerical value vector or tensor, respectively, multiplied by a unit.

If a quantity is expressed in another unit that is k times the first unit, the new numerical value becomes $1/k$ times the first numerical value because the quantity, which is the product of the numerical value and the unit, is independent of the unit.

EXAMPLE 2

Changing the unit for the wavelength in the previous example from the metre to the nanometre, which is 10^{-9} times the metre, leads to a numerical value which is 10^9 the numerical value of the quantity expressed in metres.

Thus,

$$\lambda \approx 5{,}896 \times 10^{-7}\ \mathrm{m} = 5{,}896 \times 10^{-7} \times 10^{9}\ \mathrm{nm} = 589{,}6\ \mathrm{nm}$$

It is essential to distinguish between the quantity itself and the numerical value of the quantity expressed in a particular unit. The numerical value of a quantity expressed in a particular unit could be indicated by placing braces (curly brackets) around the quantity symbol and using the unit as a subscript, e.g. $\{\lambda\}_{\mathrm{nm}}$. It is, however, preferable to indicate the numerical value explicitly as the ratio of the quantity to the unit.

EXAMPLE 3 $\lambda/\mathrm{nm} \approx 589{,}6$

This notation is particularly recommended for use in graphs and headings of columns in tables.

6.2 Mathematical operations

The product and the quotient of two quantities, Q_1 and Q_2, satisfy the relations

$$Q_1 Q_2 = \{Q_1\}\{Q_2\} \cdot [Q_1][Q_2]$$

$$\frac{Q_1}{Q_2} = \frac{\{Q_1\}}{\{Q_2\}} \cdot \frac{[Q_1]}{[Q_2]}$$

Thus, the product $\{Q_1\}\{Q_2\}$ is the numerical value $\{Q_1 Q_2\}$ of the quantity $Q_1 Q_2$, and the product $[Q_1][Q_2]$ is the unit $[Q_1 Q_2]$ of the quantity $Q_1 Q_2$. Similarly, the quotient $\{Q_1\}/\{Q_2\}$ is the numerical value $\{Q_1/Q_2\}$ of the quantity Q_1/Q_2, and the quotient $[Q_1]/[Q_2]$ is the unit $[Q_1/Q_2]$ of the quantity Q_1/Q_2. Units such as $[Q_1][Q_2]$ and $[Q_1]/[Q_2]$ are called *compound units*.

EXAMPLE 1 The speed, v, of a particle in uniform motion is given by

$v = l/t$

where l is the distance travelled in the duration t.

Thus, if the particle travels a distance $l = 6$ m in the duration $t = 2$ s, the speed, v, is equal to

$$v = l/t = (6\ \mathrm{m})/(2\ \mathrm{s}) = 3\ \mathrm{m/s}$$

NOTE A quantity defined as A/B is called ‘quotient of A by B’ or ‘A per B’, but not ‘A per unit B’.

Equations between numerical values, such as $\{Q_1 Q_2\} = \{Q_1\}\{Q_2\}$, are called *numerical value equations*. Equations between units, such as $[Q_1 Q_2] = [Q_1][Q_2]$, are called *unit equations*.

The arguments of exponential functions, logarithmic functions, trigonometric functions, etc., are numbers, numerical values, or combinations of dimension one of quantities (see Clause 5).

EXAMPLE 2 $\exp(E/kT)$; $\ln(p/\mathrm{kPa})$; $\sin(\pi/3)$; $\cos(\omega t + \alpha)$

The ratio of two quantities of the same kind and any function of that ratio, such as the logarithm of that ratio, are different quantities although they describe the same physical situation.

EXAMPLE 3 p/p_0 and $\ln(p/p_0)$ are different quantities. Note that in mathematics for numbers, $\ln(p/p_0) = \ln p - \ln p_0$, but $\ln p$ and $\ln p_0$ have no meaning in quantity calculus where p denotes pressure.

6.3 Quantity equations and numerical value equations

The three types of equation introduced above, i.e. quantity equations, numerical value equations, and unit equations, are used in science and technology. Quantity equations and numerical value equations are generally used; unit equations are used less frequently. Numerical value equations (and of course unit equations) depend on the choice of units, whereas quantity equations have the advantage of being independent of this choice. Therefore, the use of quantity equations is normally preferred and is strongly recommended.

EXAMPLE

A simple quantity equation is

$$v = l/t$$

as given in 6.2.

Using, for example, kilometre per hour (symbol km/h), metre (symbol m) and second (symbol s) as the units for speed, distance, and duration, respectively, the following numerical value equation is derived:

$$\{v\}_{\text{km/h}} = 3{,}6\ \{l\}_{\text{m}}/\{t\}_{\text{s}}$$

where $\{v\}_{\text{km/h}} = v/(\text{km/h})$.

The number 3,6 that occurs in this numerical value equation results from the particular units chosen; with other choices, it would generally be different.

Since numerical factors in numerical value equations depend on the units chosen, it is recommended not to omit the subscripts in such equations. If subscripts are not used, the units shall be clearly stated in the same context.

6.4 Coherent systems of units

Units might be chosen arbitrarily, but making an independent choice of the unit for each quantity would lead to the appearance of additional numerical factors in the numerical value equations.

It is possible, however, and in practice more convenient, to choose a *system of units* in such a way that the numerical value equations have exactly the same form, including the numerical factors, as the corresponding equations in a chosen system of quantities. To establish such a system of units, first one and only one unit for each base quantity is defined. The units of the base quantities are called *base units*. Then, the units of all derived quantities are expressed in terms of the base units in accordance with the equations in the system of quantities. The units of the derived quantities are called *derived units*. A system of units defined in this way is called *coherent* with respect to the system of quantities, including the equations in question.

In a coherent system of units, the expression of each unit corresponds to the dimension of the quantity in question, i.e. the expression of the unit is obtained by replacing the symbols for base dimensions in the quantity dimension by those for the base units, respectively. In particular, a quantity of dimension one acquires the unit one, symbol 1. In such a coherent system of units, no numerical factor other than 1 ever occurs in the expressions for the derived units in terms of the base units.

6.5 The International System of Units, SI

6.5.1 General

The *International System of Units*, denoted *SI* in all languages, was adopted by the 11th International Conference on Weights and Measures, *CGPM* [1960] (*Conférence générale des poids et mesures*). The SI is a coherent system of units with respect to the ISQ.

The SI comprises

— base units, and

— derived units

that together form the coherent system of SI units.

6.5.2 SI base units

The seven SI base units are listed in Table 1.

Table 1 — SI base units for the ISQ base quantities

ISQ base quantity	SI base unit	
	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

6.5.3 SI derived units

The expressions for the coherent SI derived units in terms of the SI base units can be obtained from the dimensional products of the corresponding ISQ derived quantities by using the following formal substitutions:

L → m		Θ → K
M → kg		N → mol
T → s		J → cd
I → A		1 → 1

These substitutions are reversible. Hence, the dimension of a derived quantity in the ISQ can be obtained from its coherent derived unit in the SI in terms of the base units.

EXAMPLE 1

Quantity	**Symbol for SI derived unit expressed in terms of the SI base units**	**Quantity**	**Symbol for SI derived unit expressed in terms of the SI base units**
speed	m/s	electric potential	$kg \cdot m^2/(s^3 \cdot A)$
frequency	s^{-1}	magnetic flux	$kg \cdot m^2/(s^2 \cdot A)$
force	$kg \cdot m/s^2$	photon irradiance	s^{-1}/m^2
energy	$kg \cdot m^2/s^2$	molar entropy	$kg \cdot m^2/(s^2 \cdot K \cdot mol)$
entropy	$kg \cdot m^2/(s^2 \cdot K)$	efficiency	1

Units are special cases of quantities and can thus be used in quantity equations, whereas dimensions cannot. Neither dimensions nor units include any numerical factors other than one. Each unit has a magnitude, whereas dimensions do not. Dimensions refer to a system of quantities, whereas units refer to a specific system of units coherent with the system of quantities.

For some of the SI derived units, special names and symbols exist; those approved by the CGPM are listed in Tables 2 and 3.

It is often advantageous to use special names and symbols in compound units.

EXAMPLE 2

Using the derived unit joule, 1 J = 1 $m^2 \cdot kg/s^2$, the symbol for the unit for molar entropy may be written J/(K · mol).

Using the derived unit volt, 1 V = 1 $m^2 \cdot kg/(s^3 \cdot A)$, the symbol for the unit for magnetic flux may be written V · s.

Table 2 — SI derived units with special names and symbols

ISQ derived quantity	SI derived unit		
	Special name	Special symbol	Expressed in SI base units and SI derived units
plane angle	radian	rad	rad = m/m = 1
solid angle	steradian	sr	sr = m^2/m^2 = 1
frequency	hertz	Hz	Hz = s^{-1}
force	newton	N	N = $kg \cdot m/s^2$
pressure, stress	pascal	Pa	Pa = N/m^2
energy	joule	J	J = N · m
power	watt	W	W = J/s
electric charge	coulomb	C	C = A · s
electric potential difference	volt	V	V = W/A
capacitance	farad	F	F = C/V
electric resistance	ohm	Ω	Ω = V/A
electric conductance	siemens	S	S = Ω^{-1}
magnetic flux	weber	Wb	Wb = V · s
magnetic flux density	tesla	T	T = Wb/m^2
inductance	henry	H	H = Wb/A
Celsius temperature	degree Celsius	°C	°C = K
luminous flux	lumen	lm	lm = cd · sr
illuminance	lux	lx	lx = lm/m^2

Table 3 — SI derived units with special names and symbols admitted for reasons of safeguarding human health

ISQ derived quantity	SI derived unit		
	Special name	Special symbol	Expressed in SI base units and SI derived units
activity (of a radionuclide)	becquerel	Bq	$\mathrm{Bq} = \mathrm{s}^{-1}$
absorbed dose	gray	Gy	Gy = J/kg
dose equivalent	sievert	Sv	Sv = J/kg
catalytic activity	katal	kat	kat = mol/s

It should be noted that an SI derived unit in some cases can be equal to an SI base unit. For example, rainfall is given as areic volume (volume per area), which is a derived quantity and hence expressed in a derived unit. The coherent SI derived unit is cubic metre divided by square metre equal to metre, which is also an SI base unit, symbol $\mathrm{m}^3/\mathrm{m}^2 = \mathrm{m}$.

The unit one, symbol 1, is generally an SI derived unit, for example, the derived SI unit for friction factor is newton per newton equal to one, symbol N/N = 1. Consider, however, the unit one for the quantity counting number, e.g. number of protons in an atom. Here, the quantity counting number is considered as a base quantity because it cannot be expressed in terms of any other base quantities. Hence, in this case, the unit one, symbol 1, is often considered as a base unit, although the CGPM has not yet adopted it as an SI base unit.

6.5.4 SI prefixes

In order to avoid large or small numerical values, decimal multiples and submultiples of the coherent SI units are formed with the SI prefixes listed in Table 4. These *SI multiple units* and *SI submultiple units* are not coherent with respect to the ISQ.

Table 4 — SI prefixes

Factor	Prefix	
	Name	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^{1}	deca	da

Factor	Prefix	
	Name	Symbol
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

The symbol of a prefix is considered to be combined with the single unit symbol to which it is directly attached, forming with it a new symbol for a decimal multiple or submultiple that can be raised to a positive or negative power and that can be combined with other unit symbols to form symbols for compound units.

EXAMPLE 1

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

$1\ \mu\mathrm{s}^{-1} = (10^{-6}\ \mathrm{s})^{-1} = 10^6\ \mathrm{s}^{-1}$

$1\ \Omega/\mathrm{km} = 1\ \Omega/(10^3\ \mathrm{m}) = 10^{-3}\ \Omega/\mathrm{m}$

Compound prefixes shall not be used.

EXAMPLE 2 Write nm (nanometre) for 10^{-9} m, not mμm.

NOTE 1 For historical reasons, the name of the SI base unit of mass, the kilogram, contains the SI prefix “kilo”. The names of the decimal multiples and submultiples of the kilogram are formed by adding the prefixes to the submultiple gram (symbol g), e.g. milligram, symbol mg instead of microkilogram (μkg).

It has been proposed to adopt a new name for the SI base unit of mass, without a prefix. At the same time, the submultiple gram would be given the same status as an additional unit used with the SI as the litre, symbol l, equal to the submultiple cubic decimetre, symbol dm^3, and the tonne, symbol t, equal to the multiple megagram, symbol Mg. If this is accepted, gram and kilogram can continue to be used, as the litre and centilitre are used today.

The SI prefixes denote exact powers of 10. They shall not be used to denote binary multiples. Prefixes for binary multiples are given in 3.17. Additional information on the origin and derivation of these multiples is given in IEC 80000-13:2008, Clause 4.

EXAMPLE 3

1 kbit = 1 000 bit

1 Kibit = 1 024 bit

NOTE 2 The SI prefixes are also used together with the ISO currency codes, e.g.

1 kEUR = 1 000 EUR (European euro)

1 kGBP = 1 000 GBP (British pound)

1 MUSD = 1 000 000 USD (US dollar)

1 GSEK = 1 000 000 000 SEK (Swedish crown)

6.5.5 The unit one

The coherent SI unit for any quantity of dimension one is the unit one, symbol 1. It is generally not written out explicitly when such a quantity is expressed numerically.

EXAMPLE 1 Number of turns in a winding $N = 25 \times 1 = 25$

In the case of certain such quantities, however, the unit one has special names and symbols that could be used or not, depending on the context.

EXAMPLE 2

plane angle, $\alpha = 0{,}52\ \mathrm{rad} = 0{,}52$

solid angle, $\Omega = 2{,}3\ \mathrm{sr} = 2{,}3$

level of a power quantity, $L_F = 12\ \mathrm{Np} = 12$ (see Table 5)

Such special names and symbols may be used in expressions for derived units to facilitate distinction between quantities of different kinds, but having the same dimension.

EXAMPLE 3

angular velocity, $\omega = 17$ rad/s

photon flux, $\Phi = 37 \times 10^{6}$ s^{-1}

attenuation coefficient, $\alpha = 0{,}83$ Np/m

curvature, $k = 0{,}34$ m^{-1}

Special names and symbols for the unit one may be combined with SI prefixes, but the unit one itself, or its symbol 1, may not. Instead, the numerical value may be expressed by using powers of 10.

NOTE It has been proposed to adopt a special name and symbol for the unit one and its symbol 1 for general use, which could be combined with prefixes.

In some cases, per cent, symbol %, where 1 % := 0,01, is used as a submultiple of the coherent unit one.

EXAMPLE 4 reflection factor, $r = 83\ \% = 0{,}83$

Also, per mil (or per mille), symbol ‰, where 1 ‰ := 0,001, is used as a submultiple of the coherent unit one.

Since the units “per cent” and “per mil” are numbers, it is meaningless to speak about, for example, percentage by mass or percentage by volume. Additional information, such as % (m/m) or % (V/V) shall therefore not be attached to the unit symbol %. See also 7.2. The preferred way of expressing, for example, a mass fraction is “the mass fraction of B is $w_B = 0{,}78$” or “the mass fraction of B is $w_B = 78\ \%$”. Furthermore, the term “percentage” shall not be used in a quantity name, because it is misleading. If a mass fraction is 0,78 = 78 %, is the percentage then 78 or 78 % = 0,78? Instead, the unambiguous term “fraction” shall be used. Mass and volume fractions can also be expressed in units such as µg/g = 10^{-6} or ml/m^3 = 10^{-9}.

Abbreviations such as ppm, pphm, ppb and ppt are language-dependent and ambiguous and shall not be used. Instead, the use of powers of 10 is recommended.

6.5.6 Other units

There are certain non-SI units that are recognized by the International Committee for Weights and Measures, *CIPM* (*Comité International des Poids et Mesures*), as having to be retained for use together with the SI. These units are given in Tables 5 and 6.

Table 5 — Units used with the SI

Quantity	Unit		
	Name	**Symbol**	**Definition**
time	minute	min	1 min := 60 s
	hour	h	1 h := 60 min
	day	d	1 d := 24 h
plane angle	degree	°	1° := (π/180) rad
	minute	′	1′ := (1/60)°
	second	″	1″ := (1/60)′
volume	litre	l, L [a]	1 l := 1 dm^3
mass	tonne	t	1 t := 1 000 kg
level	neper [b]	Np [b]	1 Np := ln e = 1
	bel	B	1 B := (1/2) ln 10 Np ≈ 1,151 293

[a] The CGPM has approved the two symbols l and L for the litre due to the risk of confusion between l and 1 in some fonts. Only the original symbol l is used by ISO and IEC because it is not derived from a proper name of a person.

[b] The unit neper, symbol Np, is coherent with the SI, but not yet adopted by the CGPM as an SI unit. Levels are defined in the ISQ using natural logarithms.

Table 6 — Units used with the SI, whose values in SI units are obtained experimentally

Quantity	Unit		
	Name	Symbol	Definition
energy	electronvolt	eV	kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum 1 eV = 1,602 176 487(40) × 10^{-19} J [CODATA 2006]
mass	dalton[a]	Da[a]	1/12 of the mass of an atom of the nuclide ^{12}C at rest and in its ground state 1 Da = 1,660 538 782(83) × 10^{-27} kg [CODATA 2006]
length	astronomical unit	ua	conventional value approximately equal to the mean value of the distance between the Sun and the Earth 1 ua = 1,495 978 706 91(6) × 10^{11} m

a The dalton was earlier called *unified atomic mass unit*, symbol u.

There are also certain non-SI units that are recognized by the CIPM to be used temporarily together with the SI. They are given, where appropriate, in the Remarks column on the unit pages (right-hand pages) in the other parts of ISO 80000 and IEC 80000.

Some units for special purposes are adopted by ISO, IEC or OIML, such as the var, symbol var, (1 var := 1 V · A) for reactive power.

Many other units exist, e.g. atomic units, CGS units, Imperial units and US customary units. Except for the atomic units, the use of all such units is deprecated.

To express values of physical quantities, Arabic numerals followed by the international symbol for the unit shall be used.

7 Printing rules

7.1 Symbols for quantities

7.1.1 General

Symbols for quantities are generally single letters from the Latin or Greek alphabet, sometimes with subscripts or other modifying signs. Symbols for characteristic numbers, such as the Mach number, symbol Ma, are, however, written with two letters from the Latin alphabet, the initial of which is always capital. It is recommended that such two-letter symbols be separated from other symbols if they occur as factors in a product.

The quantity symbols are always written in italic (sloping) type, irrespective of the type used in the rest of the text.

The quantity symbol is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

Notations for vector and tensor quantities are given in ISO 80000-2.

Symbols for quantities are given in ISO 80000 (parts 3 to 5 and 7 to 12) and IEC 80000 (parts 6, 13 and 14).

No recommendation is made or implied about the font of italic type in which symbols for quantities are to be printed.

7.1.2 Subscripts

When, in a given context, different quantities have the same letter symbol or when, for one quantity, different applications or different values are of interest, a distinction can be made by use of subscripts.

The following principles for the printing of subscripts apply.

— A subscript that represents a physical quantity or a mathematical variable, such as a running number, is printed in italic (sloping) type.

— Other subscripts, such as those representing words or fixed numbers, are printed in roman (upright) type.

EXAMPLE

Italic subscripts		Roman subscripts	
C_p	(p: pressure)	C_g	(g: gas)
c_i	(i: running number)	c_3	(3: third)
$\Sigma_n a_n \omega_n$	(n: running number)	g_n	(n: normal)
F_x	(x: x-component)	μ_r	(r: relative)
g_{ik}	(i, k: running numbers)	S_m	(m: molar)
I_λ	(λ: wavelength)	$T_{1/2}$	(1/2: half)

NOTE For a list of common subscripts, see IEC 60027-1.

7.1.3 Combination of symbols for quantities

When symbols for quantities are combined in a product of two or more quantities, this combination is indicated in one of the following ways:

$$ab,\ a\ b,\ a \cdot b,\ a \times b$$

NOTE 1 In some fields, e.g. vector algebra, distinction is made between $\boldsymbol{a} \cdot \boldsymbol{b}$ and $\boldsymbol{a} \times \boldsymbol{b}$.

Division of one quantity by another is indicated in one of the following ways:

$$\frac{a}{b},\ a/b,\ a\ b^{-1},\ a \cdot b^{-1}$$

Do not write ab^{-1} without a space between a and b^{-1}, as ab^{-1} could be misinterpreted as $(ab)^{-1}$.

NOTE 2 The solidus "/" can easily be confused with the italic upper-case "I" or the italic lower-case "l", in particular when sans serif fonts are used. The horizontal bar is often preferable to denote division.

These procedures can be extended to cases where the numerator or denominator or both are themselves products or quotients. In such a combination, a solidus (/) shall not be followed by a multiplication sign or a division sign on the same line unless parentheses are inserted to avoid any ambiguity.

EXAMPLE 1

$$\frac{ab}{c} = ab/c = ab\ c^{-1}$$

$$\frac{a/b}{c} = \frac{a}{bc} = (a/b)/c = a/(bc), \text{ not } a/b/c$$

$$\frac{a/b}{c/d} = \frac{ad}{bc}$$

$$\frac{a}{bc} = a/(b \cdot c), \text{ (not } a/b \cdot c\text{)}$$

The solidus can be used in cases where the numerator and the denominator involve addition and subtraction, provided parentheses are employed when required to avoid ambiguity. Multiplication and division have priority over addition and subtraction in compound expressions. Exponentiation (powering) has priority over multiplication and division and over monadic operations, for example $-a^2$ is equal to $-(a^2)$, not $(-a)^2$.

EXAMPLE 2

$(a + b)\ (c + d)$, parentheses are required

$a + b \cdot c + d = a + (b \cdot c) + d$, parentheses are not required

$(a + b)/(c + d)$, parentheses are required

$a + b / c + d = a + (b / c) + d$, parentheses are not required

There shall be spaces on both sides of most signs for dyadic operators such as +, −, ±, × and · (but not for the solidus), and relations, such as =, <, ⩽, but not after monadic operators + and −.

Parentheses may also be used to remove ambiguities that arise from the use of certain other mathematical operations.

EXAMPLE 3

$\ln x + y = (\ln x) + y$, not $\ln(x + y)$

Note that in this example, the ambiguity could also be removed by altering the order of operations.

Other mathematical signs and symbols recommended for use in sciences and technology are given in ISO 80000-2.

Symbols, but never words or abbreviations, for quantities shall be used in expressions and equations.

EXAMPLE 4 Write velocity is equal to distance per duration or $v = l/t$, but not velocity = distance/duration or $v = l$ per t.

7.1.4 Expressions for quantities

The symbol of the unit shall be placed after the numerical value in the expression for a quantity, leaving a space between the numerical value and the unit symbol. It should be noted that this rule also applies to the units per cent, % and per mil, ‰. It should also be noted that, in accordance with this rule, the symbol °C for the degree Celsius shall be preceded by a space when expressing a Celsius temperature.

The only exceptions to this rule are for the units degree, minute and second for plane angle, in which case there shall be no space between the numerical value and the unit symbol.

If the quantity to be expressed is a sum or a difference of quantities, then either parentheses shall be used to combine the numerical values, placing the common unit symbol after the complete numerical value, or the expression shall be written as the sum or difference of expressions for the quantities.

EXAMPLE 1

l = 12 m − 7 m = (12 − 7) m = 5 m, not 12 − 7 m

t = 23,6 °C, not t = 23,6° C

U = 230 × (1 + 5 %) V = 230 × 1,05 V ≈ 242 V, not U = 230 V + 5 %

Descriptive terms or names of quantities shall not be arranged in the form of an equation. Names of quantities or multiletter abbreviated terms, for example, presented in italics or with subscripts, shall not be used in the place of symbols.

EXAMPLE 2 Write $\rho = \frac{m}{V}$ and not $density = \frac{mass}{volume}$

7.2 Names and symbols for units

7.2.1 General

Symbols for units are always written in roman (upright) type, irrespective of the type used in the rest of the text. The unit symbol shall remain unaltered in the plural and is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

Most symbols for units consist of one or more letters from the Latin or Greek alphabet. These letters are lower case, except that the initial letter is a capital in the symbol for a unit derived from a proper name of a person. An exception is made for unit symbols containing signs in exponent position, e.g. °C.

EXAMPLE 1

V	volt
s	second
Sh	shannon
mol	mole
Ω	ohm
µm	micrometre

The rule for writing unit symbols with a capital initial is not applicable for unit names, which differ from language to language. See also 7.2.5.

When an international symbol for a unit exists, then this, and no other, shall be used.

Any attachment to a unit symbol as a means of giving information about the special nature of the quantity or context of measurement under consideration is not permitted.

EXAMPLE 2

$U_{\mathrm{max}} = 500\ \mathrm{V}$, not $U = 500\ \mathrm{V}_{\mathrm{max}}$

$P_{\mathrm{mech}} = 750\ \mathrm{W}$, not $P = 750\ \mathrm{W}_{\mathrm{mech}}$

$w_{\mathrm{B}} = 0{,}76 = 76\ \%$, neither $0{,}76\ (m/m)$ nor $76\ \%\ (m/m)$

Expressions for units shall contain nothing else than unit symbols and mathematical symbols.

EXAMPLE 3 Write “the water content is 170 $\mathrm{kg/m^3}$”, not “170 kg $\mathrm{H_2O/m^3}$”.

No recommendation is made or implied about the font of roman type in which symbols for units are to be printed.

7.2.2 Combination of symbols for units

A compound unit formed by multiplication of two or more units shall be indicated in one of the following ways:

N · m, N m

NOTE The latter form may also be written without a space, i.e. Nm, provided that special care is taken when the symbol for one of the units is the same as the symbol for a prefix. This is the case for m, metre and milli, and for T, tesla and tera.

EXAMPLE mN means millinewton, not metre newton.

A compound unit formed by dividing one unit by another shall be indicated in one of the following ways:

$$\frac{\mathrm{m}}{\mathrm{s}}, \qquad \mathrm{m/s}, \qquad \mathrm{m \cdot s^{-1}}, \qquad \mathrm{m\ s^{-1}}$$

Exponentiation has priority over multiplication and division. A solidus (/) shall not be followed by a multiplication sign or a division sign on the same line unless parentheses are inserted to avoid any ambiguity. In complicated cases, negative powers or a horizontal bar may be used.

7.2.3 Prefixes

Symbols for prefixes shall be printed in roman (upright) type, irrespective of the type used in the rest of the text, without a space between the symbol for the prefix and the symbol for the unit to which it is attached.

No recommendation is made or implied about the font of roman type in which symbols for prefixes are to be printed.

7.2.4 English names of compound units

In the English language, the name of the product of two units is the concatenation of the two names, separated by a space.

EXAMPLE 1 newton metre

The name of the power a of a unit is the name of that unit followed by “to the power n”. However, the powers two and three may be expressed by “squared” and “cubed”, respectively.

EXAMPLE 2 second to the power minus one, metre per second squared

The name of the quotient of two units is formed by inserting the word “per” between the two names. A compound name shall never contain more then one “per” (without parentheses).

EXAMPLE 3 metre per second, joule per kilogram kelvin, not joule per kilogram per kelvin

7.2.5 Spelling of names of quantities and of units in the English and French languages

Names of quantities and names of units are spelled with a lower case initial in English and French, except in the beginning of a sentence when a capital initial is used. However, in quantity names containing a person’s name, the person’s name is spelled with a capital initial.

EXAMPLE 1 Celsius temperature Alfvén number

For SI units, it is only the unit name *degree Celsius*, symbol °C, that contains a capital letter.

EXAMPLE 2 newton tesla

7.3 Numbers

7.3.1 General

Numbers shall be printed in roman (upright) type, irrespective of the type used in the rest of the text.

No recommendation is made or implied about the font of roman type in which symbols for numbers are to be printed.

To facilitate the reading of numbers with many digits, these may be separated into groups of three, counting from the decimal sign towards the left *and* the right. No group shall contain more than three digits. Where such separation into groups of three is used, the groups shall be separated by a small space and not by a point or a comma or by any other means.

EXAMPLE 1 1 234,567 8 rather than 1 234,5678 0,567 8 rather than 0,5678

In the case where there is no decimal part (and thus no decimal sign), the counting shall be from the right-most digit towards the left.

EXAMPLE 2 In the number "1 234", the right-most digit is that underlined.

The separation into groups of three should not be used for ordinal numbers used as reference numbers, e.g. ISO 80000-1.

The year shall always be written without a space, e.g. 1935.

A plus or minus sign before a number (or a quantity), used to indicate "same sign" or "change of sign", is a monadic operator and shall not be separated from the number by a space (see Example 3). However, for operations, signs and symbols, there shall be a space on both sides of the sign or symbol, as shown in the examples given in Example 4. See also 7.1.3. For signs denoting a relation, such as =, < and >, there shall also be a space on both sides.

EXAMPLE 3 A Celsius temperature from −7 °C to +5 °C.

EXAMPLE 4 $5 + 2$ $5 - 3$ $n \pm 1{,}6$ $D < 2$ mm > 5 mm

7.3.2 Decimal sign

The decimal sign is either a comma or a point on the line. The same decimal sign should be used consistently within a document.

If the magnitude (absolute value) of the number is less than 1, the decimal sign shall be preceded by a zero.

EXAMPLE 0,567 8

NOTE 1 In accordance with the ISO/IEC Directives, Part 2, 2004, *Rules for the structure and drafting of International Standards*, the decimal sign is a comma on the line in International Standards.

NOTE 2 The General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*) at its meeting in 2003 passed unanimously the following resolution:

"The decimal marker shall be either a point on the line or a comma on the line."

In practice, the choice between these alternatives depends on customary use in the language concerned.

It is customary to use the decimal point in most documents written in the English language, and the decimal comma in documents written in the French language (and a number of other European languages), except in some technical areas where the decimal comma is always used.

7.3.3 Multiplication and division

The sign for multiplication of numbers is a cross (×) or a half-high dot (·). There shall be a space on both sides of the cross or the dot (see also 7.1.3). The multiplication cross (×) or half-high dot (·) shall be used to indicate the multiplication of numbers and numerical values (as shown in Examples 1 and 2), and in vector products and Cartesian products. The half-high dot (·) shall be used to indicate a scalar product of vectors and comparable cases. It may also be used to indicate a product of scalars and in compound units and is preferred for the multiplication of letter symbols.

EXAMPLE 1 $l = 2{,}5 \times 10^3$ m

EXAMPLE 2 $A = 80$ mm × 25 mm

ISO 80000-2:2009, Item 2-9.5, gives an overview of multiplication symbols for numbers. ISO 80000-2 also contains examples of vector products, scalar products and Cartesian products of sets.

In some cases, the multiplication sign may be omitted, e.g. $4c - 5d$, $6ab$, $7(a + b)$, 3 ln 2.

If the point is used as the decimal sign, the cross and not the half-high dot should be used as the multiplication sign between numbers expressed with digits[3]. If the comma is used as the decimal sign, both the cross and the half-high dot may be used as the multiplication sign between numbers expressed with digits[3].

EXAMPLE 3 $4\,711.32 \times 0.351\,2$ $4\,711{,}32 \cdot 0{,}351\,2$ $4\,711{,}32 \times 0{,}351\,2$

Division of one number by another is indicated in one of the following ways:

$$\frac{a}{b} \qquad a/b \qquad a\,b^{-1} \qquad a \cdot b^{-1}$$

Negative exponents should be avoided when the numbers are expressed with digits[3], except when the base is 10.

EXAMPLE 4 10^{-3} is acceptable 3^{-3} should be avoided

These provisions can be extended to cases where the numerator, denominator or both are themselves products or quotients. In such a combination, a solidus (/) shall not be followed by a multiplication sign or a division sign on the same line unless parentheses are inserted to avoid any ambiguity.

7.3.4 Error and uncertainty

When a number is given without any further information, it is generally interpreted so that the last digit is rounded with a rounding range equal to 1 in the last digit (see Annex B). Thus, for example, the number 401 008 is generally assumed to represent a value between 401 007,5 and 401 008,5. In this case, the maximum magnitude of the *error* in the number 401 008 is 0,5. However, in some applications rounding is replaced by truncation (i.e. by simply cutting off the last digits), e.g. 401 008,91 becomes 401 008. In this case, the number 401 008 represents a value between 401 008,0 and 401 009,0 and the error is between 0 and 1. Similarly, the number 40,100 8 is generally assumed to represent a value between 40,100 75 and 40,100 85 or sometimes a value between 40,100 80 and 40,100 90.

Digits of a number are called *significant digits* if the corresponding number is considered to lie within the error limits of the last digit(s).

Consider the number 401 000. Here, 401 contains three significant digits, but it is not known if the right-most three zeros are significant or are just used to indicate the order of magnitude. It is recommended to indicate that distinction in the following way:

401×10^3	three significant digits
$401{,}0 \times 10^3$	four significant digits
$401{,}00 \times 10^3$	five significant digits
$401{,}000 \times 10^3$	six significant digits

All digits after a decimal sign are considered to be significant.

3) “Numbers expressed as digits” refers to numbers such as “12”, as opposed to “twelve”.

Numerical values of quantities are often given with an associated *standard uncertainty*. Provided that the assumed distribution for the corresponding quantity is normal, a numerical value and the associated uncertainty may be expressed as exemplified by:

$l = a(b)$ m

where

l is a length expressed in the unit metre, m;

a is the numerical value;

b denotes a standard uncertainty (see ISO/IEC Guide 99) expressed in terms of the least significant digit(s) in a.

EXAMPLE In the expression

$l =$ 23,478 2(32) m

l is the length expressed in the unit metre, m;

23,478 2 is the numerical value;

32 represents a standard uncertainty equal to 0,003 2.

NOTE Uncertainties are often expressed in the following manner: (23,478 2 ± 0,003 2) m. This is, however, wrong from a mathematical point of view. 23,478 2 ± 0,003 2 means 23,481 4 or 23,475 0, but not all values between these two values. According to ISO/IEC Guide 98-3:2008, 7.2.2 note, "The ± format should be avoided whenever possible because it has traditionally been used to indicate an interval corresponding to a high level of confidence and thus may be confused with expanded uncertainty".

Note that in the context of engineering tolerances, 23,478 2 ± 0,003 2 expresses the limits of a zone (i.e. upper limit equal to 23,481 4 and lower limit equal to 23,475 0) having an extent of 0,006 4 (2 × 0,003 2) symmetrically dispersed around 23,478 2 thus encompassing all values between and including those limits.

7.4 Chemical elements and nuclides

Symbols for chemical elements shall be printed in roman (upright) type, irrespective of the type used in the rest of the text. The symbols consist of one or two letters from the Latin alphabet. The initial letter is a capital and a following letter, if any, is lower case. The symbol shall not be followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

EXAMPLE 1 H He C Ca

A complete list of symbols for chemical elements is given in ISO 80000-9.

Attached subscripts and superscripts specifying a nuclide or molecule shall have the following meanings and positions.

The nucleon number (mass number) of a nuclide is shown in the left superscript position, e.g.

$^{14}\mathrm{N}$

The number of atoms of a nuclide in a molecule is shown in the right subscript position, e.g.

$^{14}\mathrm{N}_2$

NOTE If the number of atoms is equal to 1, it is not indicated, e.g. $\mathrm{H_2O}$.

The proton number (atomic number) of a nuclide is shown in the left subscript position, e.g.

$_{64}\mathrm{Gd}$

A state of ionization or an excited state is shown in the right superscript position.

EXAMPLE 2

State of ionization: Na^{+}, PO_4^{3-} or $(\mathrm{PO}_4)^{3-}$

Nuclear excited state: $^{110}\mathrm{Ag}^{\mathrm{m}}$

7.5 Greek alphabet

Table 7 — Greek letters

Name	Roman type		Italic type	
alpha	Α	α	*Α*	*α*
beta	Β	β	*Β*	*β*
gamma	Γ	γ	*Γ*	*γ*
delta	Δ	δ	*Δ*	*δ*
epsilon	Ε	ε, ϵ	*Ε*	*ε*, *ϵ*
zeta	Ζ	ζ	*Ζ*	*ζ*
eta	Η	η	*Η*	*η*
theta	Θ	ϑ, θ	*Θ*	*ϑ*, *θ*
iota	Ι	ι	*Ι*	*ι*
kappa	Κ	ϰ, κ	*Κ*	*ϰ*, *κ*
lambda	Λ	λ	*Λ*	*λ*
mu	Μ	μ	*Μ*	*μ*
nu	Ν	ν	*Ν*	*ν*
xi	Ξ	ξ	*Ξ*	*ξ*
omicron	Ο	ο	*Ο*	*ο*
pi	Π	π, ϖ	*Π*	*π*, *ϖ*
rho	Ρ	ρ, ϱ	*Ρ*	*ρ*, *ϱ*
sigma	Σ	σ	*Σ*	*σ*
tau	Τ	τ	*Τ*	*τ*
ypsilon	Υ	υ	*Υ*	*υ*
phi	Φ	φ, ϕ	*Φ*	*φ*, *ϕ*
chi	Χ	χ	*Χ*	*χ*
psi	Ψ	ψ	*Ψ*	*ψ*
omega	Ω	ω	*Ω*	*ω*

Annex A
(normative)

Terms in names for physical quantities

A.1 General

If no special name for a quantity exists, a name is commonly formed in combination with terms like coefficient, factor, parameter, ratio, constant, etc. Similarly, terms like specific, density, molar, concentration, etc., are added to names of physical quantities to indicate other related or derived quantities. Just as in the choice of an appropriate symbol, the naming of a physical quantity may also need some guidance.

It is not the intention of this annex to impose strict rules to eliminate the relatively frequent deviations which have been incorporated in the various scientific languages. However, the principles presented should be followed when naming new quantities. Furthermore, when reviewing existing terms, deviations from these principles should be critically examined.

Since quantities are themselves always independent of the unit in which they are expressed, a quantity name shall not reflect the name of any corresponding unit. However, there are a few exceptions to this general rule, such as voltage. The name "electric tension" corresponds to voltage in many languages other than English. It is recommended to use the name "electric tension" wherever possible. Also see the term "molar" in A.6.5, Note.

NOTE 1 Most of the examples in this annex are drawn from existing practice and are not intended to constitute new recommendations.

NOTE 2 Names of terms are greatly language-dependent and these recommendations apply mainly to English.

A.2 Coefficients, factors

A.2.1 If, under certain conditions, a quantity A is proportional to another quantity B, this can be expressed by the multiplicative relation $A = k \cdot B$. The quantity k that occurs as a multiplier in this equation is often called a *coefficient* or a *factor*.

A.2.2 The term "coefficient" should be used when the two quantities A and B have different dimensions.

EXAMPLE 1

Hall coefficient: A_H	$E_H = A_H(\boldsymbol{B} \times \boldsymbol{J})$
linear expansion coefficient: α_l	$\mathrm{d}l/l = \alpha_l \, \mathrm{d}T$
diffusion coefficient: D	$\boldsymbol{J} = -D \, \mathbf{grad} \, n$

NOTE Sometimes, the term "modulus" is used instead of the term "coefficient".

EXAMPLE 2

modulus of elasticity: E	$\sigma = E\varepsilon$

A.2.3 The term “factor” should be used when the two quantities A and B have the same dimension.

EXAMPLE

coupling factor: k $L_{mn} = k(L_m L_n)^{1/2}$

quality factor: Q $|X| = QR$

friction factor: μ $F = \mu F_\mathrm{n}$

A.3 Parameters, numbers, ratios

A.3.1 Combinations of quantities which occur as such in equations are often considered to constitute new quantities. Such quantities are sometimes called *parameters*.

EXAMPLE

Grüneisen parameter: γ $\gamma = \alpha_V/(k\, c_V \rho)$

A.3.2 Some combinations of dimension one of quantities, such as those occurring in the description of transport phenomena, are called *characteristic numbers* and carry the term “number” in their names.

EXAMPLE

Reynolds number: Re $Re = \rho v l/\eta$

Prandtl number: Pr $Pr = \eta c_p/\lambda$

A.3.3 Quotients of dimension one of two quantities are often called *ratios*.

EXAMPLE 1

heat capacity ratio: γ $\gamma = C_p/C_V$

thermal diffusion ratio: k_T $k_T = D_T/D$

mobility ratio: b $b = \mu_-/\mu_+$

Sometimes, the term “fraction” is used for ratios smaller than one.

EXAMPLE 2

amount-of-substance fraction of B: x_B $x_\mathrm{B} = n_\mathrm{B}/n$

packing fraction: f $f = \Delta_\mathrm{r}/A$

The term “index” is sometimes used instead of ratio. Extension of this usage is not recommended.

EXAMPLE 3

refractive index: n $n = c_0/c$

A.4 Levels

The logarithm of the ratio of a quantity, Q, and a reference value of that quantity, Q_0, is called a *level*.

EXAMPLE

level of a power quantity: L_P $L_P = \ln(P/P_0)$

