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Quantities and units

Part 1:
General

Grandeurs et unités

Partie 1: Généralités

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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 (≈ 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.