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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 12, *Quantities and units*, in collaboration with IEC/TC 25, *Quantities and units*.

This second edition cancels the first edition (ISO 80000-1:2009), which has been technically revised. It also incorporates the Technical Corrigendum ISO 80000-1:2009/Cor.1:2011.

The main changes are as follows:

— More focus on concepts and terminology based on a system of quantities, particularly following the recent major revision of the International System of Units (SI) and the proposed revisions of the International vocabulary of metrology (VIM).

— At the same time, subclauses of previous editions of this document which essentially reproduced content from other sources – particularly metrological vocabulary, descriptions of SI units and compilations of fundamental constants – have been substantially removed from the present edition, in accordance with a resolution taken by ISO/TC 12 in 2020.

A list of all parts in the ISO 80000 and IEC 80000 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Systems of quantities – as defined in ISO/IEC Guide 99 – can be treated in many consistent, but different, ways. Which treatment to use is partly a matter of convention.

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.

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 the ISO/IEC 80000 series; 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 document 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.

The system of quantities presented in this document is named the International System of Quantities (ISQ), in all languages. This name was not used in ISO 31 series, from which the present harmonized series has evolved. However, the ISQ does appear in ISO/IEC Guide 99 and is the system of quantities underlying the International System of Units, denoted “SI”, in all languages according to the SI Brochure.

Quantities and units —

Part 1:
General

1 Scope

This document 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).

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

The ISO/IEC 80000 series does not, as yet, cover ordinal quantities and nominal properties.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

BIPM *The International System of Units (SI)*, 9th edition (2019), https://www.bipm.org/en/publications/si-brochure

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 99 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Quantities

4.1 The concept of quantity

In this document, it is accepted that things (including physical bodies and phenomena, substances, events, etc.) are characterized by properties, according to which things can be compared, in terms of having the same property or not, such as the shape of rigid bodies or the blood group of human beings. Some properties make things comparable also by order, so that for example winds can be compared by their strength and earthquakes can be compared by their magnitude. Finally, some properties make things comparable not only in terms of equivalence and order, but also in more complex ways, and in particular by ratio, as is the case for most physical quantities, according to which the mass or the electric charge of a body might be twice the mass or the electric charge of another body, and so on.

Not all properties, and more specifically quantities, can be compared with each other. For example, while the diameter of a cylindrical rod can be compared to the height of a block, the diameter of a rod cannot be compared to the mass of a block.

Quantities that are comparable are said to be of the same kind[4] and are instances of the same general quantity. Hence, diameters and heights are quantities of the same kind, being instances of the general quantity length.

It is customary to use the same term, "quantity", to refer to both general quantities, such as length, mass, etc., and their instances, such as given lengths, given masses, etc. Accordingly, we are used to saying both that length is a quantity and that a given length is a quantity, by maintaining the specification – "general quantity, Q" or "individual quantity, Q_a" – implicit and exploiting the linguistic context to remove the ambiguity.

When specific terms are used for quantities, Annex A shall be followed.

4.2 System of quantities — Base quantities and derived quantities

A set of quantities and their relations are called a system of quantities. General quantities are related through equations that express laws of nature or define new general 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.

4.3 Universal constants and empirical constants

Some individual quantities are considered to be constant under all circumstances. Such quantities are called universal constants or fundamental physical constants[5].

EXAMPLE 1 The Planck constant, h.

EXAMPLE 2 The Faraday constant, F.

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 location the length l and the periodic time T, for each of several 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.

4.4 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 a system of quantities where length, mass, and time are three base quantities, 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. This equation contains the numerical factor $\frac{1}{2}$.

A multiplier may include one or more universal (or empirical) constants.

EXAMPLE 2

The Coulomb law for electric charges in a system of quantities with three base quantities is

$$F = \frac{q_1 q_2}{r^2}$$

where F is scalar force, q_1 and q_2 are two point-like electric charges, r is distance.

For a rationalised system of quantities with four base quantities, where a base quantity of an electrical nature is added, the expression becomes

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

where ε_0 is, since the 2019 redefinition of SI base units, an empirical constant, i.e., the electric constant (it was formerly a universal constant).

A multiplier may also include one or more conventional quantity values, such as ε_0 in the last example.

Constant multipliers other than numerical factors are often called coefficients (see A.2.2).

4.5 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 (ISQ). Derived quantities can be defined in terms of the base units by quantity equations, see 6.4. 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, the relation between any general quantity Q and the base quantities can be expressed by means of an equation. The equation may include a sum of terms, each of which 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., $\xi \cdot A^\alpha B^\beta C^\gamma \cdots$, where the set of exponents α, β, γ, ... is the same for each term.

The dimension 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.

Quantities that are of the same kind (e.g., length) have the same dimension, even if they are originally expressed in different units (such as yards and metres). If quantities have different dimensions (such as length vs. mass), they are of different kinds[4][6] and cannot be compared[7].

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. There is no agreement on how to refer to such quantities. They have been called dimensionless quantities (although this term should now be avoided), quantities with dimension one, quantities with dimension number, or quantities with the unit one. Such quantities are dimensionally simply numbers. To avoid confusion, it is helpful to use explicit units with these quantities where possible, e.g., m/m, nmol/mol, rad, as specified in the SI Brochure. It is especially important to have a clear description of any such quantity when expressing a measurement result.

NOTE 1 These quantities include those defined as a quotient of two quantities of the same dimension and those defined as numbers of entities.

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 by 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	$\mathrm{L}^2\mathrm{MT}^{-3}\mathrm{I}^{-1}$
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 General

In this clause units are dealt with in relation to systems of quantities. Further guidance about units, given in the SI Brochure, shall be followed.

6.2 Units and numerical values

If a particular instance of a quantity of a given kind is chosen as a reference quantity called the unit, 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 $5{,}896 \cdot 10^{-7}$ is the numerical value of the wavelength expressed in metres.

In formal treatments, this relation between quantities and units may be expressed[6] in the form

$$Q_\mathrm{a} = \{Q_\mathrm{a}\}\ [Q]$$

where Q_a is the symbol for an individual quantity, $[Q]$ is the symbol for the unit and $\{Q_\mathrm{a}\}$ is the symbol for the numerical value of the quantity Q_a 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, expressed as 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.

6.3 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 $\{Q_1Q_2\}$ of the quantity Q_1Q_2, and the product $[Q_1]\ [Q_2]$ is the unit $[Q_1Q_2]$ of the quantity Q_1Q_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

$$v = \frac{l}{t}$$

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

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

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 $\{Q_1Q_2\} = \{Q_1\}\ \{Q_2\}$, are called numerical value equations. Equations between units, such as $[Q_1Q_2] = [Q_1]\ [Q_2]$, are called unit equations.

The arguments of exponential functions, logarithmic functions, trigonometric functions, etc., are numbers, numerical values, or combinations of quantities with a dimensional product equal to one (see Clause 5).

EXAMPLE 2

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

6.4 Quantity equations and numerical value equations

The three types of equations introduced in 4.2 and 6.3, 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

$$v = \frac{l}{t}$$

as given in 6.3, example 1.

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:

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

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

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.

6.5 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 quantity 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 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.

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 shall be 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 80000-3 to ISO 80000-5 and ISO 80000-7 to ISO 80000-12 and IEC 80000-6 and IEC 80000-13.

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), n is the running number, and i and k are the running ordinal number	S_m	(m: molar)
I_λ	(λ: wavelength)	$T_{1/2}$	(1/2: half)

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:

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

Writing ab^{-1} with a space between a and b^{-1}, as $a\ b^{-1}$, avoids misinterpretation 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

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

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

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

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

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 unary 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

Binary operators, for example +, −, (but not /), shall be preceded and followed by thin spaces. This rule does not apply in case of unary operators, as in −17,3 (see further in 7.2).

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 mathematical expressions and equations (see 7.1.4).

EXAMPLE 4

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

7.1.4 Expressions for quantities

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

$l = 12\ \text{m} - 7\ \text{m} = (12 - 7)\ \text{m} = 5\ \text{m}$, not $12 - 7\ \text{m}$

$U = 230 \cdot (1 + 5\ \%)\ \text{V} = 230 \cdot 1{,}05\ \text{V} \approx 242\ \text{V}$, not $U = 230\ \text{V} + 5\ \%$

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

EXAMPLE 2

Write $\rho = \dfrac{m}{V}$ and not $density = \dfrac{mass}{volume}$ or $z_{density} = \dfrac{x_{mass}}{y_{volume}}$.

7.1.5 Expressions for dimensions

The symbol of any base quantity of the ISQ is a single upright uppercase character, as listed in Clause 5. The dimension of a derived quantity Q of the ISQ is expressed as

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

where A, B, C, ... are symbols of dimensions of base quantities. The symbol of a dimension with exponent 0 is usually omitted. The dimension of a quantity such that the exponents of all its dimensions are 0 is written 1.

7.2 Numbers

7.2.1 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 23$\underline{4}$”, 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 unary 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

7.2.2 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 the ISO/IEC Directives, Part 2, 2021, *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 (Fr: 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.

7.2.3 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 multiplication cross (×) or half-high dot (·) shall be used both to denote multiplication of numbers and as a part of the number in exponential notation. 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 80000-2:2019, Item 2-10.5, 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[1]. 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[1].

EXAMPLE 3

4 711.32 × 0.351 2   4 711,32 × 0,351 2   4 711,32 · 0,351 2

1) "Numbers expressed as digits" refers to numbers such as "12", as opposed to "twelve".

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

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

Negative exponents should be avoided when the numbers are expressed with digits[1)], 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 on the same line unless parentheses are inserted to avoid any ambiguity.

7.2.4 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. Rules for rounding, as given in Annex B, shall be followed. 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.

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 for length measurement, by:

$$l = a(b)\ \mathrm{m}$$

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.

7.3 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

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.

$_{64}\mathrm{Gd}$

The state of ionization and the state of electrical excitation are shown in the right superscript position. The state of nuclear excitation is shown with the symbol * in the left superscript position and for a metastable nuclide is indicated by adding the letter m (in roman type) to the mass number of the nuclide.

EXAMPLE 2

State of ionization:	Na^+, PO_4^{3-} or $(\mathrm{PO}_4)^{3-}$
State of electrical excitation:	He^*, NO^*

State of nuclear excitation: ^{127*}Xe or, when metastable, $^{133\text{m}}$Xe.

7.4 Greek alphabet

Table 1 — 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)

Specific terms used for 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. Also see the term "molar" in A.5.5, 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 strongly 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: R_H	$E = \rho J + R_H (B \times J)$
linear expansion coefficient: α_l	$dl / l = \alpha_l \, dT$
diffusion coefficient: D	$\boldsymbol{J} = -D \, \textbf{grad} \, n$

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 $\quad L_{mn} = k\sqrt{L_m \cdot L_n}$

quality factor: Q $\quad |X| = QR$

friction factor: μ $\quad F = \mu \cdot F_n$.

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

thermodynamic Grüneisen parameter: γ $\quad \gamma = \alpha K_T / (C_V \rho)$

A.3.2 Some combinations of quantities of unit one, such as those occurring in the description of transport phenomena, are called characteristic numbers [ISO 80000-11] and carry the term "number" in their names.

EXAMPLE

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

Prandtl number: Pr $\quad Pr = \nu / a$

A.3.3 Quotients of two quantities of the same kind are often called ratios:

EXAMPLE 1

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

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

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

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

EXAMPLE 2

amount-of-substance fraction of B: x_B $\quad x_B = n_B / n$

packing fraction: f $\quad f = \Delta_r / A$

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

EXAMPLE 3

refractive index: n $\quad n = c_0 / c$

A.4 Constants

A.4.1 A quantity that is considered to have the same value under all circumstances is called a universal constant or a fundamental physical constant, see CODATA[5].

A.4.2 A quantity that has the same value under all circumstances for a particular substance is called a constant of matter. Provided no special name exists, the name of such a quantity includes the term "constant".

EXAMPLE decay constant for a particular nuclide: λ

A.4.3 Other quantities that keep the same value under particular circumstances or that result from mathematical calculations are also sometimes given names including the term "constant". Extension of this usage is not recommended.

EXAMPLE

equilibrium constant for a chemical reaction (which varies with temperature): K_p

Madelung constant for a particular lattice: α

A.5 Terms with general application

A.5.1 The adjective "specific" is often added to the name of a quantity to indicate the quotient of that quantity and mass.

EXAMPLE

specific heat capacity: c	$c = C / m$
specific volume: v	$v = V / m$
specific entropy: s	$s = S / m$
specific activity: a	$a = A / m$

NOTE 1 The adjective "mass" is sometimes used instead of the adjective "specific".

NOTE 2 In some fields, such as acoustics, the adjective "specific" can refer to other quantities than mass.

A.5.2 The noun "density" is added to the name of a quantity to indicate the quotient of that quantity and the volume. See also A.5.3 and A.5.4.

EXAMPLE

mass density: ρ	$\rho = m / V$
electric charge density: ρ	$\rho = Q / V$
energy density: e	$e = E / V$

A.5.3 The term "surface … density" is added to the name of a quantity to indicate the quotient of that quantity and the area. Also, the noun "area" is occasionally used.

EXAMPLE 1

surface mass density: ρ_A	$\rho_A = m / A$
surface electric charge density: ρ_A	$\rho_A = Q / A$

The noun "density" is added to the name of a quantity expressing a flux or a current to indicate the quotient of such a quantity and the surface area. See also A.5.2.

EXAMPLE 2

density of heat flow rate: q $\quad q = \Phi / A$

electric current density: J $\quad J = I / A$

magnetic flux density: B $\quad B = \Phi / A$

A.5.4 The term “linear … density” or the adjective “linear” is added to the name of a quantity to indicate the quotient of that quantity and the length. Also, the noun “line” is occasionally used.

EXAMPLE 1

linear mass density: ρ_l $\quad \rho_l = m / l$

The term “linear” is also added to the name of a quantity solely to distinguish between similar quantities.

EXAMPLE 2

mean linear range: R $\quad R = \sum R_i / n$

mean mass range: R_ρ $\quad R_\rho = R\rho$

linear expansion coefficient: α_l $\quad \alpha_l = l^{-1}\mathrm{d}l/\mathrm{d}T$

cubic expansion coefficient: α_V $\quad \alpha_V = V^{-1}\mathrm{d}V/\mathrm{d}T$

linear attenuation coefficient: μ $\quad \mu = -J^{-1}\mathrm{d}J/\mathrm{d}x$

mass attenuation coefficient: μ_m $\quad \mu_m = \mu / \rho$

A.5.5 The adjective “molar” is added to the name of a quantity to indicate the quotient of that quantity and the amount of substance.

EXAMPLE

molar volume: V_m $\quad V_\mathrm{m} = V / n$

molar internal energy: U_m $\quad U_\mathrm{m} = U / n$

molar mass: M $\quad M = m / n$

NOTE The word “molar” violates the principle that the name of the quantity should not be mixed with the name of the unit (mole in this case). See A.1.

A.5.6 The term “concentration” is added to the name of a quantity, especially for a substance in a mixture, to indicate the quotient of that quantity and the total volume.

EXAMPLE

amount-of-substance concentration of B: c_B $\quad c_\mathrm{B} = n_\mathrm{B} / V$

molecular concentration of B: C_B $\quad C_\mathrm{B} = N_\mathrm{B} / V$

mass concentration of B: ρ_B $\quad \rho_\mathrm{B} = m_\mathrm{B} / V$

The term “spectral concentration” is used in English to denote a spectral distribution function.

