INTERNATIONAL STANDARD

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AMENDMENT 1
1998-12-15

Quantities and units —

Part 1: Space and time
Part 2: Periodic and related phenomena
Part 3: Mechanics
Part 4: Heat
Part 5: Electricity and magnetism
Part 6: Light and related electromagnetic radiations
Part 7: Acoustics
Part 8: Physical chemistry and molecular physics
Part 9: Atomic and nuclear physics
Part 10: Nuclear reactions and ionizing radiations
Part 12: Characteristic numbers
Part 13: Solid state physics

AMENDMENT 1

Grandeurs et unités —

Partie 1: Espace et temps
Partie 2: Phénomènes périodiques et connexes
Partie 3: Mécanique
Partie 4: Chaleur
Partie 5: Électricité et magnétisme
Partie 6: Lumière et rayonnements électromagnétiques connexes
Partie 7: Acoustique
Partie 8: Chimie physique et physique moléculaire
Partie 9: Physique atomique et nucléaire
Partie 10: Réactions nucléaires et rayonnements ionisants
Partie 12: Nombres caractéristiques
Partie 13: Physique de l'état solide

AMENDEMENT 1

Reference number
ISO 31 (parts 1 to 10, 12 and 13):1992/Amd.1:1998(E)

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.

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.

Amendment 1 to parts 1 to 10, 12 and 13 of International Standard ISO 31:1992 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors.*

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ISO 31-10:1992/Amd.1:1998(E)
ISO 31-12:1992/Amd.1:1998(E)
ISO 31-13:1992/Amd.1:1998(E)

Quantities and units —

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AMENDMENT 1

Page v

Replace subclause 0.3.2 with the following text:

0.3.2 Remark on units for quantities of dimension one

The coherent unit for any quantity of dimension one is the number one, symbol 1. When the value of such a quantity is expressed, the unit symbol 1 is generally not written out explicitly.

EXAMPLE

Refractive index $n = 1{,}53 \times 1 - 1{,}53$

Prefixes shall not be used to form multiples or submultiples of this unit. Instead of prefixes, powers of 10 may be used.

EXAMPLE

Reynolds number $Re = 1{,}32 \times 10^3$

Considering that plane angle is generally expressed as the ratio of two lengths and solid angle as the ratio of two areas, in 1995 the CGPM has specified that, in the International System of Units, the radian, rad, and the steradian, sr, are "dimensionless" derived units. This implies that the quantities plane angle and solid angle are considered as derived quantities of dimension one. The units radian and steradian may be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different nature but having the same dimension.

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Price based on 1 page

INTERNATIONAL STANDARD

ISO 31-1

Second edition
1992-09-01

Quantities and units —

Part 1:
Space and time

Grandeurs et unités —
Partie 1: Espace et temps

Reference number
ISO 31-1:1992(E)

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.

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.

International Standard ISO 31-1 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors.*

This second edition cancels and replaces the first edition (ISO 31-1:1978). The major technical changes from the first edition are the following:

— the decision by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM) in 1980 concerning the status of supplementary units has been incorporated;

— units in use temporarily have been transferred to the "Conversion factors and remarks" column.

The scope of Technical Committee ISO/TC 12 is standardization of units and symbols for quantities and units (and mathematical symbols) used within the different fields of science and technology, giving, where necessary, definitions of these quantities and units. Standard conversion factors for converting between the various units also come under the scope of the TC. In fulfilment of this responsibility, ISO/TC 12 has prepared ISO 31.

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ISO 31 consists of the following parts, under the general title *Quantities and units*:

— *Part 0: General principles*

— *Part 1: Space and time*

— *Part 2: Periodic and related phenomena*

— *Part 3: Mechanics*

— *Part 4: Heat*

— *Part 5: Electricity and magnetism*

— *Part 6: Light and related electromagnetic radiations*

— *Part 7: Acoustics*

— *Part 8: Physical chemistry and molecular physics*

— *Part 9: Atomic and nuclear physics*

— *Part 10: Nuclear reactions and ionizing radiations*

— *Part 11: Mathematical signs and symbols for use in the physical sciences and technology*

— *Part 12: Characteristic numbers*

— *Part 13: Solid state physics*

Annexes A and B of this part of ISO 31 are for information only.

Introduction

0.1 Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on the left-hand pages and the units on the corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of an item has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

0.2 Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one name and only one symbol for the quantity are given; where two or more names or two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When two types of italic (sloping) letter exist (for example as with ϑ, θ; φ, ϕ; g, g) only one of these is given. This does not mean that the other is not equally acceptable. In general it is recommended that such variants should not be given different meanings. A symbol within parentheses implies that it is a "reserve symbol", to be used when, in a particular context, the main symbol is in use with a different meaning.

0.3 Tables of units

0.3.1 General

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see ISO 31-0.

The units are arranged in the following way:

a) The names of the SI units are given in large print (larger than text size). The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM).

The SI units and their decimal multiples and sub-multiples are recommended, although the decimal multiples and sub-multiples are not explicitly mentioned.

b) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

These units are separated by a broken line from the SI units for the quantities concerned.

c) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size) in the "Conversion factors and remarks" column.

d) The names of non-SI units which should not be combined with SI units are given only in annexes in some parts of ISO 31. These annexes are informative and not integral parts of the standard. They are arranged in three groups:

1) special names of units in the CGS system;

2) names of units based on the foot, pound and second and some other related units;

3) names of other units.

0.3.2 Remark on units for quantities of dimension one

The coherent unit for any quantity of dimension one is the number one (1). When the value of such a quantity is expressed, the unit 1 is generally not written out explicitly. Prefixes shall not be used to form multiples or sub-multiples of this unit. Instead of prefixes, powers of 10 may be used.

EXAMPLES

Refractive index $n = 1{,}53 \times 1 = 1{,}53$

Reynolds number $Re = 1{,}32 \times 10^3$

Considering that plane angle is generally expressed as the ratio between two lengths, and solid angle as the ratio between an area and the square of a length, the CIPM specified in 1980 that, in the International System of Units, the radian and steradian are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as dimensionless derived quantities. The units radian and steradian may be used in expressions for derived units to facilitate distinction between quantities of different nature but having the same dimension.

0.4 Numerical statements

All numbers in the "Definition" column are exact.

When numbers in the "Conversion factors and remarks" column are exact, the word "exactly" is added in parentheses after the number.

Quantities and units —

Part 1:
Space and time

1 Scope

This part of ISO 31 gives names and symbols for quantities and units of space and time. Where appropriate, conversion factors are also given.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 31. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 31 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8601:1988, *Data elements and interchange formats — Information interchange — Representation of dates and times.*

3 Names and symbols

The names and symbols for quantities and units of space and time are given on the following pages.

SPACE AND TIME				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
1-1	angle, (plane angle)	$\alpha, \beta, \gamma, \vartheta, \varphi$	The angle between two half-lines terminating at the same point is defined as the ratio of the length of the included arc of the circle (with its centre at that point) to the radius of that circle	Other symbols are also used.
1-2	solid angle	Ω	The solid angle of a cone is defined as the ratio of the area cut out on a spherical surface (with its centre at the apex of that cone) to the square of the radius of the sphere	
1-3.1	length	l, L		Length is one of the base quantities on which the SI is based.
1-3.2	breadth	b		
1-3.3	height	h		
1-3.4	thickness	d, δ		
1-3.5	radius	r, R		
1-3.6	diameter	d, D		
1-3.7	length of path	s		
1-3.8 (—)	distance	d, r		
1-3.9 (—)	cartesian coordinates	x, y, z		
1-3.10 (—)	radius of curvature	ϱ		

Units				SPACE AND TIME
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
1-1.a	radian	rad	1 rad = 1 m/m = 1	See the introduction, subclause 0.3.2. The radian is the angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.
1-1.b	degree	°	$1° = \frac{\pi}{180}$ rad	1° = 0,017 453 3 rad There shall be no space between a numerical value and any of these superscript-type unit symbols. The degree should preferably be sub-divided decimally. The unit symbol shall then be placed after the number. EXAMPLE Write 17,25° rather than 17°15′.
1-1.c	minute	′	1′ = (1/60)°	
1-1.d	second	″	1″ = (1/60)′	
1-2.a	steradian	sr	1 sr = 1 m^2/m^2 = 1	See the introduction, subclause 0.3.2. The steradian is the solid angle of a cone which, having its vertex in the centre of a sphere, cuts off on the surface of the sphere an area equal to that of a square with sides of length equal to the radius of the sphere.
1-3.a	metre	m	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second	ångström (Å), 1 Å = 10^{-10} m (exactly) nautical mile, 1 nautical mile = 1 852 m (exactly) This definition was adopted by the First International Extraordinary Hydrographic Conference, in 1929.

SPACE AND TIME (*continued*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
1-4 (—)	curvature	$\varkappa$	$\varkappa = 1/\varrho$	
1-5 (*1-4.1*)	area	A, (S)	$A = \iint \mathrm{d}x\,\mathrm{d}y$ where x and y are cartesian coordinates	For an element of area, $\mathrm{d}\sigma$ is sometimes used.
1-6 (*1-5.1*)	volume	V	$V = \iiint \mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z$ where x, y and z are cartesian coordinates	For an element of volume, $\mathrm{d}\tau$ is sometimes used.
1-7 (*1-6.1*)	time, time interval, duration	t		Time is one of the base quantities on which the SI is based.
1-8 (*1-7.1*)	angular velocity	ω	$\omega = \dfrac{\mathrm{d}\varphi}{\mathrm{d}t}$	
1-9 (*1-8.1*)	angular acceleration	α	$\alpha = \dfrac{\mathrm{d}\omega}{\mathrm{d}t}$	This equation applies to rotation about a fixed axis. It may also be applied generally, provided that both ω and α are regarded as vectors.

Units				SPACE AND TIME (*continued*)
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
1-4.a	reciprocal metre, metre to the power minus one	m^{-1}		
1-5.a	square metre	m^2		The unit are, symbol a, (and its multiple hectare, symbol ha) are used to express agrarian areas, 1 a = 100 m^2 (exactly).
1-6.a	cubic metre	m^3		
1-6.b	litre	l, L	1 l = 1 dm^3	1 l = 10^{-3} m^3 (exactly) In 1964 the 12th CGPM redefined the litre as 1 l = 1 dm^3. According to the older definition the litre was equal to 1,000 028 dm^3. The two symbols for the litre are on an equal footing. The CGPM will later consider the possibility of retaining only one of the symbols.
1-7.a	second	s	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom	
1-7.b	minute	min	1 min = 60 s	For representations of time of day, see ISO 8601.
1-7.c	hour	h	1 h = 60 min = 3 600 s	
1-7.d	day	d	1 d = 24 h = 86 400 s	
1-8.a	radian per second	rad/s		For other units, see 1-1.b...d.
1-9.a	radian per second squared	rad/s^2		For other units, see 1-1.b...d.

SPACE AND TIME (*concluded*)				Quantities
Item No.	**Quantity**	**Symbol**	**Definition**	**Remarks**
1-10 (*1-9.1*)	velocity	v, c, u, v, w	$v = \frac{ds}{dt}$	v is the general notation. c is used for speed or velocity of propagation of waves. When vector notation is not used, the notation u, v, w for the components of a velocity c is recommended. In the English language the magnitude of velocity is usually called speed. In the French language the term "celérité" is used for speed or velocity of propagation of waves.
1-11.1 (*1-10.1*)	acceleration	a	$a = \frac{dv}{dt}$	This equation applies to rectilinear motion. It also applies generally if a and v are vectors.
1-11.2 (*1-10.2*)	acceleration of free fall, acceleration due to gravity	g		Standard acceleration of free fall: g_n = 9,806 65 m/s^2 (exactly) (3rd CGPM, 1901)

Units				SPACE AND TIME (*concluded*)
Item No.	**Name of unit**	**International symbol for unit**	**Definition**	**Conversion factors and remarks**
1-10.a	metre per second	m/s		
1-10.b	kilometre per hour	km/h		1 km/h = $\frac{1}{3,6}$ m/s (exactly) = 0,277 778 m/s knot (kn), 1 kn = 1 nautical mile per hour = 0,514 444 m/s
1-11.a	metre per second squared	m/s^2		

Annex A
(informative)

Units based on the foot, pound and second and some other units

The use of these units is deprecated.

Quantity item No.	Quantity	Unit Item No.	Name of unit with symbol	Conversion factors and remarks
1-3.1	length	1-3.A.a	inch: in	1 in = 25,4 mm (exactly) The "mil" or "thou" is sometimes used to denote the "milli-inch".
		1-3.A.b	foot: ft	1 ft = 12 in (exactly) = 0,304 8 m (exactly) The U.S. Survey foot, used by the U.S. Coast and Geodetic Survey, is defined as 1 U.S. Survey foot = $\frac{1\,200}{3\,937}$ m = 1,000 002 × 0,304 8 m = 0,304 800 6 m
		1-3.A.c	yard: yd	1 yd = 3 ft (exactly) = 36 in (exactly) = 0,914 4 m (exactly) This definition was adopted legally by the United States in 1959 (Announcement U.S. Dept. of Commerce, National Bureau of Standards, F.R. Doc. 59-5442 d.d. June 30, 1959) and by the United Kingdom in 1963 (Weights and Measures Act, 1963). An exception is made for the U.S. Survey foot — see the remark to 1-3.A.b.
		1-3.A.d	mile	1 mile = 5 280 ft (exactly) = 1 609,344 m (exactly) The mile of 5 280 ft is also known as the statute mile. 1 U.S. Survey mile = 1 609,347 m
1-5	area	1-5.A.a	square inch: in^2	1 in^2 = 645,16 mm^2 (exactly) The "circular mil" is sometimes used to designate an area of $\frac{\pi}{4} \times 10^{-6}$ in^2 = 506,707 5 μm^2
		1-5.A.b	square foot: ft^2	1 ft^2 = 0,092 903 04 m^2 (exactly)
		1-5.A.c	square yard: yd^2	1 yd^2 = 0,836 127 36 m^2 (exactly) The abbreviations sq in, sq ft and sq yd are commonly used.
		1-5.A.d	square mile: $mile^2$	1 $mile^2$ = 2,589 988 km^2 1 U.S. Survey $mile^2$ = 2,589 998 km^2 1 $mile^2$ = 640 acres (exactly)
		1-5.A.e	acre	1 acre = 4 046,856 m^2 1 U.S. Survey acre = 4 046,873 m^2 1 acre = 4 840 yd^2 (exactly)

Units based on the foot, pound and second and some other units (*continued*)				
Quantity item No.	**Quantity**	**Unit item No.**	**Name of unit with symbol**	**Conversion factors and remarks**
1-6	volume	1-6.A.a	cubic inch: in^3	1 in^3 = 16,387 064 cm^3 (exactly)
		1-6.A.b	cubic foot: ft^3	1 ft^3 = 28,316 85 dm^3 (exactly)
		1-6.A.c	cubic yard: yd^3	1 yd^3 = 0,764 554 9 m^3 The abbreviations cu in, cu ft and cu yd are commonly used.
		1-6.A.d	gallon (UK): gal (UK)	1 gal (UK) = 277,420 in^3 = 4,546 092 dm^3 (exactly) = 1,200 95 gal (US)
		1-6.A.e	pint (UK): pt (UK)	8 pt (UK) = 1 gal (UK) 1 pt (UK) = 0,568 261 25 dm^3 (exactly) = 1,200 95 liq pt (US)
		1-6.A.f	fluid ounce (UK): fl oz (UK)	160 fl oz (UK) = 1 gal (UK) 1 fl oz (UK) = 28,413 06 cm^3 = 0,960 760 fl oz (US)
		1-6.A.g	bushel (UK)	1 bushel (UK) = 8 gal (UK) = 36,368 72 dm^3 (exactly) = 1,032 06 bu (US)
		1-6.A.h	gallon (US): gal (US)	1 gal (US) = 231 in^3 = 3,785 412 dm^3 = 0,832 674 gal (UK)
		1-6.A.i	liquid pint (US): liq pt (US)	8 liq pt (US) = 1 gal (US) 1 liq pt (US) = 0,473 176 5 dm^3 = 0,832 674 pt (UK)
		1-6.A.j	fluid ounce (US): fl oz (US)	128 fl oz (US) = 1 gal (US) 1 fl oz (US) = 29,573 53 cm^3 = 1,040 84 fl oz (UK)
		1-6.A.k	barrel (US) for petroleum, etc.	1 barrel (US) (petroleum) = 9 702 in^3 = 158,987 3 dm^3 = 34,972 3 gal (UK) = 42 gal (US)
		1-6.A.l	bushel (US): bu (US)	1 bu (US) = 2 150,42 in^3 = 35,239 07 dm^3 = 0,968 939 bushel (UK)
		1-6.A.m	dry pint (US): dry pt (US)	64 dry pt (US) = 1 bu (US) 1 dry pt (US) = 0,550 610 5 dm^3 = 0,968 939 pt (UK)
		1-6.A.n	dry barrel (US): bbl (US)	1 bbl (US) (dry) = 7 056 in^3 = 115,627 1 dm^3

Units based on the foot, pound and second and some other units (*concluded*)				
Quantity item No.	**Quantity**	**Unit item No.**	**Name of unit with symbol**	**Conversion factors and remarks**
1-10	velocity	1-10.A.a	foot per second: ft/s	1 ft/s = 0,304 8 m/s (exactly)
		1-10.A.b	mile per hour: mile/h	1 mile/h = 0,447 04 m/s (exactly)
1-11.1	acceleration	1-11.A.a	foot per second squared: ft/s^2	1 ft/s^2 = 0,304 8 m/s^2 (exactly)

Annex B
(informative)

Other non-SI units given for information, especially regarding the conversion factor

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Conversion factors and remarks
1-1	angle, (plane angle)	1-1.B.a	gon (or grade): gon	1 gon = $\frac{\pi}{200}$ rad = 0,015 707 96 rad
1-3.1	length	1-3.B.a	light year: (l.y.)[1]	1 light year is the distance travelled in 1 year by electromagnetic waves in free space. 1 l.y. = 9,460 730 × 10^{15} m
		1-3.B.b	astronomical unit: (AU)[2]	1 AU = 1,495 978 7 × 10^{11} m (adopted value in System of Astronomic Constants, 1976)
		1-3.B.c	parsec: pc	1 parsec is the distance at which 1 astronomical unit subtends an angle of 1 second of arc. 1 pc = 206 264,8 AU = 30,856 78 × 10^{15} m
1-7	time	1-7.B.a	year, tropical year: a, a_{trop}	The tropical year is the time which elapses between two successive passages of the sun through the mean vernal equinox. This time interval is related to the corresponding difference of mean longitude of the sun, which depends on time in a not exactly linear form; i.e. a_{trop} is not constant but decreases at a rate of nearly 0,53 s per century. The tropical year is approximately equal to 365,242 20 d = 31 556 926 s.
1-11.2	acceleration of free fall	1-11.B.a	gal: Gal	1 Gal = 0,01 m/s^2 (exactly) The milligal is commonly used in geodesy.

1) "l.y." is an abbreviation for the name light year.

2) "AU" is an abbreviation for the name astronomical unit.

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Descriptors: system of units, international system of units, units of measurement, quantities, time, length, angles (geometry), area, volume, symbols, definitions, conversion of units, conversion factor.

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