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Quantities and units —

Part 7: Acoustics

*Grandeurs et unités —
Partie 7: Acoustique*



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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.

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 31-7 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors*.

This second edition cancels and replaces the first edition (ISO 31-7:1978). 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;
- the special remark on logarithmic quantities and units has been elaborated;
- the annex on CGS units has been deleted.

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*

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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.

0.5 Special remarks

0.5.1 General

The explanations in the "Definition" column for quantities assume that systems will normally be linear.

When it is necessary to use subscripts to avoid confusion between similar symbols in different fields, the subscript "a" is recommended for use in acoustics.

0.5.2 Remark on logarithmic quantities and units

The expression for the time dependence of a damped harmonic oscillation can be written either in real notation or as the real part of a complex notation

$$F(t) = Ae^{-\delta t} \cos \omega t = \operatorname{Re}(Ae^{(-\delta + j\omega)t})$$

This simple relation involving δ and ω can be obtained only when e (base of natural logarithms) is used as the base of the exponential function. The coherent SI unit for the damping coefficient δ and the angular frequency ω is second to the power minus one, 1/s. Using the special names neper, Np, and radian, rad, for the units of δt and ωt respectively, the units for δ and ω become neper per second, Np/s, and radian per second, rad/s, respectively. Neper and radian are special names for the "dimensionless" unit one, 1. The neper is used as a unit for logarithmic quantities; the radian is used as a unit for plane angles and for the phase of circular functions.

Corresponding variation in space is treated in the same manner

$$F(x) = Ae^{-\alpha x} \cos \beta x = \operatorname{Re}(Ae^{-\gamma x}), \quad \gamma = \alpha + j\beta$$

where the unit for α is neper per metre, Np/m, and the unit for β is radian per metre, rad/m.

In ISO 31, the level of a field quantity is therefore defined as the natural logarithm of a ratio of two amplitudes, $L_F = \ln(F/F_0)$, and is hence a quantity of dimension one. The unit neper (= the number 1) is the level of a field quantity when $F/F_0 = e$.

Since power is often proportional to the square of an amplitude, a factor 1/2 is introduced in the definition of the level of a power quantity $L_P = (1/2) \ln(P/P_0)$ in order to make the level of the power quantity under these circumstances equal to the level of the field quantity.

In practice the non-coherent unit degree, ...°, ($1^\circ = \pi/180$ rad) is often used for angles and the non-coherent unit bel, B, [$1 \text{ B} = (1/2) \ln 10 \text{ Np} \approx 1,151\,293 \text{ Np}$] based on common logarithms (base 10) for logarithmic quantities. Instead of the bel, its sub-multiple the decibel, dB, is commonly used.

Quantities and units —

Part 7: Acoustics

1 Scope

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 31. At the time of publication, the editions indicated were 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 editions of the standards indicated below. Members of IEC and ISO

maintain registers of currently valid International Standards.

ISO 16:1975, *Acoustics — Standard tuning frequency (Standard musical pitch)*.

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

ISO 131:1979, *Acoustics — Expression of physical and subjective magnitudes of sound or noise in air*.

3 Names and symbols

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

ACOUSTICS				Quantities
Item No.	Quantity	Symbol	Definition	Remarks
7-1	period, periodic time	T	Time of one cycle	
7-2	frequency	f, ν	$f = 1/T$	For the standard tuning frequency (standard musical pitch), see ISO 16.
7-3	frequency interval		For two tones, the binary logarithm of the ratio of the higher frequency to the lower frequency	
7-4	angular frequency, pulsatance	ω	$\omega = 2\pi f$	
7-5	wavelength	λ	Distance in the direction of propagation of a periodic wave between two successive points where at a given time the phase is the same	
7-6 (—)	repetency, wavenumber	σ	$\sigma = 1/\lambda$	The vector quantities σ and k corresponding to repetency and angular repetency are called wave vector and propagation vector respectively.
7-7 (7-6.1)	angular repetency, angular wavenumber	k	$k = 2\pi\sigma$	
7-8 (7-7.1)	volumic mass, mass density, density	ρ	Mass divided by volume	

Units				ACOUSTICS
Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
7-1.a	second	s		
7-2.a	hertz	Hz	1 Hz = 1 s ⁻¹	1 Hz is the frequency of a periodic phenomenon of which the period is 1 s.
7-3.a	octave		The frequency interval between f_1 and f_2 is one octave if $f_2/f_1 = 2$	The numerical value of the frequency interval in octaves is given by $\lg(f_2/f_1)$, ($f_2 \geq f_1$).
7-4.a	radian per second	rad/s		
7-4.b	reciprocal second, second to the power minus one	s ⁻¹		
7-5.a	metre	m		
7-6.a	reciprocal metre, metre to the power minus one	m ⁻¹		
7-7.a	radian per metre	rad/m		
7-7.b	reciprocal metre, metre to the power minus one	m ⁻¹		
7-8.a	kilogram per cubic metre	kg/m ³		

ACOUSTICS (<i>continued</i>)				Quantities
Item No.	Quantity	Symbol	Definition	Remarks
7-9.1 (7-8.1)	static pressure	p_s	Pressure that would exist in the absence of sound waves	When any of the quantities 7-9.2 to 7-13 inclusive is periodic, its symbol is often used without modification for its root-mean-square (r.m.s.) value.
7-9.2 (7-8.2)	(instantaneous) sound pressure	$p, (p_a)$	Difference between the instantaneous total pressure and the static pressure	
7-10 (7-9.1)	(instantaneous) sound particle displacement	$\xi, (x)$	Instantaneous displacement of a particle in a medium from what would be its position in the absence of sound waves	
7-11 (7-10.1)	(instantaneous) sound particle velocity	u, v	$u = \frac{\partial \xi}{\partial t}$	
7-12 (7-11.1)	(instantaneous) sound particle acceleration	a	$a = \frac{\partial u}{\partial t}$	
7-13 (7-12.1)	(instantaneous) volume flow rate	$q, U, (q_v)$	Instantaneous rate of volume flow due to a sound wave	
7-14.1 (7-13.1)	velocity of sound, (phase velocity)	$c, (c_a)$	$c = \frac{\omega}{k} = \lambda f$	
7-14.2 (—)	group velocity	c_g	$c_g = \frac{d\omega}{dk}$	
7-15 (7-14.1)	sound energy density, volumic sound energy	$w, (w_a), (e)$	Mean sound energy in a given volume divided by that volume	If the energy density varies with time, the mean must be taken over an interval during which the sound may be considered statistically stationary.
7-16 (7-15.1)	sound power	P, P_a	Power emitted, transferred or received as sound waves	
7-17 (7-16.1)	sound intensity	I, J	For unidirectional sound power, sound power through a surface normal to the direction of propagation divided by the area of the surface	

Units		ACOUSTICS (continued)		
Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
7-9.a	pascal	Pa		bar (bar), 1 bar = 100 kPa (exactly)
7-10.a	metre	m		
7-11.a	metre per second	m/s		
7-12.a	metre per second squared	m/s ²		
7-13.a	cubic metre per second	m ³ /s		
7-14.a	metre per second	m/s		
7-15.a	joule per cubic metre	J/m ³		
7-16.a	watt	W		
7-17.a	watt per square metre	W/m ²		

ACOUSTICS (continued)				Quantities
Item No.	Quantity	Symbol	Definition	Remarks
7-18	acoustic impedance	Z_a	At a surface, the complex representation of sound pressure divided by the complex representation of volume flow rate	In definitions 7-18 to 7-20.2, the quantities in the numerators and denominators are assumed to be sinusoidal.
7-19	mechanical impedance	Z_m	At a surface (or at a point), the complex representation of total force divided by the complex representation of average particle velocity at that surface (or of particle velocity at that point) in the direction of the force	$Z_a = \frac{Z_s}{A}$ $Z_m = AZ_s$ where A is the area of the surface considered.
7-20.1 (7-17.2)	surface density of mechanical impedance	Z_s	At a surface, the complex representation of sound pressure divided by the complex representation of particle velocity	For a non-dissipative medium $Z_c = c\rho$.
7-20.2 (7-17.1)	characteristic impedance of a medium	Z_c	At a point in a medium and for a plane progressive wave, the complex representation of sound pressure divided by the complex representation of particle velocity	
7-21 (7-20.1)	sound pressure level	L_p	$L_p = \ln(p/p_0) = \ln 10 \cdot \lg(p/p_0)$ where p is the root-mean-square value of the sound pressure and the reference pressure p_0 is equal to 20 μPa	The subscript p is often omitted, especially when other subscripts are needed. See also ISO 31-2:1992, item No. 2-9.
7-22 (7-21.1)	sound power level	L_w	$L_w = \frac{1}{2} \ln(P/P_0) = \frac{1}{2} \ln 10 \cdot \lg(P/P_0)$ where P is the root-mean-square value of the sound power and the reference power P_0 is equal to 1 pW	See also ISO 31-2:1992, item No. 2-10.
7-23 (7-22.1)	damping coefficient	δ	If a quantity is a function of time t given by $F(t) = Ae^{-\delta t} \cos[\omega(t - t_0)]$ then δ is the damping coefficient	

Units		ACOUSTICS (continued)		
Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
7-18.a	pascal second per cubic metre	$\text{Pa} \cdot \text{s}/\text{m}^3$		
7-19.a	newton second per metre	$\text{N} \cdot \text{s}/\text{m}$		
7-20.a	pascal second per metre	$\text{Pa} \cdot \text{s}/\text{m}$		
7-21.a	bel	B	1 B is the sound pressure level when $2 \lg(p/p_0) = 1$	See the introduction, subclause 0.5.2. Instead of the bel, B, the sub-multiple decibel, dB, is commonly used. Generally $L_p = 2 \lg(p/p_0)$ B = $20 \lg(p/p_0)$ dB.
7-22.a	bel	B	1 B is the sound power level when $\lg(P/P_0) = 1$	See the introduction, subclause 0.5.2. Instead of the bel, B, the sub-multiple decibel, dB, is commonly used. Generally $L_w = \lg(P/P_0)$ B = $10 \lg(P/P_0)$ dB.
7-23.a	reciprocal second, second to the power minus one	s^{-1}		
7-23.b	neper per second	Np/s		

ACOUSTICS (continued)				Quantities
Item No.	Quantity	Symbol	Definition	Remarks
7-24 (7-23.1)	time constant, relaxation time	τ	$\tau = 1/\delta$ where δ is the damping coefficient	
7-25 (7-24.1)	logarithmic decrement	Λ	Product of damping coefficient and period. $\Lambda = \delta T$	
7-26.1 (7-25.1)	attenuation coefficient	α	If a quantity is a function of distance x given by $F(x) = Ae^{-\alpha x} \cos[\beta(x - x_0)]$ then α is the attenuation coefficient and β is the phase coefficient	The quantity $1/\alpha$ is called the attenuation length. $m = 2\alpha$ is called the power attenuation coefficient. When there is risk of confusion with 7-27.4, $m/2$ is used instead of α for the attenuation coefficient.
7-26.2 (7-25.2)	phase coefficient	β		The quantity $\beta(x - x_0)$ is called the phase.
7-26.3 (7-25.3)	propagation coefficient	γ	$\gamma = \alpha + j\beta$	$k' = -j\gamma$ is the complex angular wave-number.
7-27.1 (7-26.1)	dissipation factor, dissipance	δ, ψ	Ratio of the dissipated sound power to the incident sound power	
7-27.2 (7-26.2)	reflection factor, reflectance	$r, (\rho)$	Ratio of the reflected sound power to the incident sound power	
7-27.3 (7-26.3)	transmission factor, transmittance	τ	Ratio of the transmitted sound power to the incident sound power	$\delta + r + \tau = 1$
7-27.4 (7-26.4)	absorption factor, absorbance	$\alpha, (\alpha_a)$	Ratio of the dissipated and transmitted sound power to the incident sound power	$\alpha = \delta + \tau$
7-28 (7-27.1)	sound reduction index	R	$R = \frac{1}{2} \ln(1/\tau) =$ $\frac{1}{2} \ln 10 \cdot \lg(1/\tau)$ where τ is the transmission factor	

Units		ACOUSTICS (<i>continued</i>)		
Item No.	Name of unit	International symbol for unit	Definition	Conversion factors and remarks
7-24.a	second	s		
7-25.a	neper	Np		See the introduction, subclause 0.5.2.
7-26.a	reciprocal metre, metre to the power minus one	m ⁻¹		α and β are often given in Np/m and rad/m respectively.
7-27.a	one	1		See the introduction, subclause 0.3.2.
7-28.a	bel	B	1 B is the sound reduction index when $\lg(1/\tau) = 1$	See the introduction, subclause 0.5.2. Instead of the bel, B, the sub-multiple decibel, dB, is commonly used. Generally $R = \lg(1/\tau) \text{ B} = 10 \lg(1/\tau) \text{ dB}$.

ACOUSTICS (concluded)				Quantities
Item No.	Quantity	Symbol	Definition	Remarks
7-29 (7-28.1)	equivalent absorption area of a surface or object	A	In a diffuse sound field, that area of a surface having an absorption factor equal to 1, which, if diffraction effects are neglected, would, in the same diffuse sound field, absorb the same power	
7-30 (7-29.1)	reverberation time	T	Time required for the average sound energy density in an enclosure to decrease to 10^{-6} of its initial value (i.e. by 60 dB) after the source has stopped	
7-31 (7-30.1)	loudness level	L_N	$L_N = \ln(p_{\text{eff}}/p_0)_{1 \text{ kHz}} = \ln 10 \cdot \lg(p_{\text{eff}}/p_0)_{1 \text{ kHz}}$ where p_{eff} is the root-mean-square value of the sound pressure of a pure tone of 1 kHz, which is judged by a normal observer under standardized listening conditions as being as loud as the sound under investigation, and where $p_0 = 20 \mu\text{Pa}$	See also ISO 31-2. These are not purely physical quantities, but entail subjective evaluation.
7-32 (7-31.1)	loudness	N	A normal observer's auditory estimate of the ratio between the strength of the sound considered and that of a reference sound having a loudness level of 40 phons	