SLOVENSKI STANDARD
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Veličine in enote - 7. del: Svetloba

Quantities and units - Part 7: Light

Grandeurs et unités - Partie 7: Lumière

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INTERNATIONAL STANDARD

ISO 80000-7

First edition
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Quantities and units —

Part 7: **Light**

Grandeurs et unités —

Partie 7: Lumière

Reference number
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Contents

Page

Foreword

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

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

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

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

ISO 80000-7 was prepared by Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors* in cooperation with IEC/TC 25, *Quantities and units, and their letter symbols.*

This first edition of ISO 80000-7 cancels and replaces the third edition of ISO 31-6:1992. It also incorporates the Amendment ISO 31-6:1992/Amd.1:1998. The major technical changes from the previous standard are the following:

— the presentation of *numerical statements* has been changed;

— 0.5.3 *Photopic quantities*, 0.5.4 *Scotopic quantities* and 0.5.5 *Values* have been added;

— the *normative references* have been changed;

— new items have been added and denoted by dash (see 0.1);

— the order and the definitions of luminous terms have been changed to bring the presentation more in line with the International Electrotechnical Vocabulary.

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 Arrangements of the tables

The tables of quantities and units in this International Standard 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 on the right-hand pages 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 parenthesis 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 names in English and in French of the most important quantities within the field of this International Standard are given together with their symbols and, in most cases, their definitions. These names and symbols are recommendations. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed on the left hand pages of the table; they are not intended to be complete.

The scalar, vector or tensor character of quantities is pointed out, especially when this is needed for the definitions.

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 letters exist (for example as with ϑ and θ; φ and ϕ; *a* and a; *g* and g) only one of these is given. This does not mean that the other is not equally acceptable. It is recommended that such variants should not be given different meanings. A symbol within parenthesis 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.

In this English edition, the quantity names in French are printed in an italic font, and are preceded by *fr*. The gender of the French name is indicated by (m) for masculine and (f) for feminine, immediately after the noun in the French name.

0.3 Tables of units

0.3.1 General

The names of units for the corresponding quantities are given together with the international symbols and the definitions. These unit names are language-dependent, but the symbols are international and the same in all languages. For further information, see the SI Brochure (8th edition 2006) from BIPM and ISO 80000-1[1)].

The units are arranged in the following way.

a) The coherent SI units are given first. The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM). The use of coherent SI units,

1) To be published.

and their decimal multiples and submultiples formed with the SI prefixes are recommended, although the decimal multiples and submultiples are not explicitly mentioned.

b) Some non-SI units are then given, being those accepted by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM), or by the International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), or by ISO and IEC, for use with the SI.

   Such units are separated from the SI units in the item by use of a broken line between the SI units and the other units.

c) Non-SI units currently accepted by the CIPM for use with the SI are given in small print (smaller than the text size) in the "Conversion factors and remarks" column.

d) Non-SI units that are not recommended are given only in annexes in some parts of this International Standard. These annexes are informative, in the first place for the conversion factors, and are not integral parts of the standard. These deprecated units are arranged in two groups:

   1) units in the CGS system with special names;

   2) units based on the foot, pound, second, and some other related units.

e) Other non-SI units given for information, especially regarding the conversion factors, are given in another informative annex.

0.3.2 Remark on units for quantities of dimension one, or dimensionless quantities

The coherent unit for any quantity of dimension one, also called a dimensionless quantity, 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 1 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 are recommended.

EXAMPLE 2 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 specified that, in the SI, the radian, symbol rad, and steradian, symbol 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 are thus equal to one; they may either be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different kind but having the same dimension.

0.4 Numerical statements in this International Standard

The sign $=$ is used to denote "is exactly equal to", the sign $\approx$ is used to denote "is approximately equal to", and the sign $:=$ is used to denote "is by definition equal to".

Numerical values of physical quantities that have been experimentally determined always have an associated measurement uncertainty. This uncertainty should always be specified. In this International Standard, the magnitude of the uncertainty is represented as in the following example.

EXAMPLE $l = 2{,}347\,82(32)$ m

In this example, $l = a(b)$ m, the numerical value of the uncertainty b indicated in parentheses is assumed to apply to the last (and least significant) digits of the numerical value a of the length l. This notation is used when b represents the standard uncertainty (estimated standard deviation) in the last digits of a. The numerical example given above may be interpreted to mean that the best estimate of the numerical value of the length l (when l is expressed in the unit metre) is 2,347 82 and that the unknown value of l is believed to lie between $(2{,}347\,82 - 0{,}000\,32)$ m and $(2{,}347\,82 + 0{,}000\,32)$ m with a probability determined by the standard uncertainty 0,000 32 m and the normal probability distribution of the values of l.

0.5 Special remarks

0.5.1 Quantities

ISO 80000-7 contains a selection of quantities pertaining to light and other electromagnetic radiation. “Radiant” quantities relating to radiation in general may be useful for the whole range of electromagnetic radiations, whereas “luminous” quantities pertain only to visible light.

In several cases, the same symbol is used for a trio of corresponding radiant, luminous and photon quantities with the understanding that subscripts e for energetics, v for visible and p for photon will be added whenever confusion between these quantities might otherwise occur.

For ionizing radiations, however, see ISO 80000-10.

Systematically, different fonts are used to distinguish between italic “vee” v for speed and Greek “nu” ν for frequency.

Several of the quantities in ISO 80000-7 can be defined for monochromatic light, i.e. light of a single frequency ν only. They are denoted by their reference quantity as an argument like $q(\nu)$. An example is speed $c(\nu)$ of light in a medium or the refractive index in a medium $n(\nu) = c_0/c(\nu)$. Some of those quantities are fractions $\mathrm{d}q$ of a quantity q corresponding to the light with wavelength in the interval $[\lambda,\ \lambda + \mathrm{d}\lambda]$ divided by the range $\mathrm{d}\lambda$ of that interval. These quantities are called spectral quantities and are denoted by subscript λ.They are additive so that the integral $q = \int_0^\infty q_\nu(\nu)\,\mathrm{d}\nu$ yields the overall quantity, e.g. radiance L (item 7-15).

Instead of frequency ν, other reference quantities of light may be used: angular frequency $\omega = 2\pi\nu$, wavelength $\lambda = c_0/n\nu$, wavelength in vacuum $\lambda_0 = c_0/\nu$, wavenumber in medium $\sigma = 1/\lambda$, wavenumber in vacuum $\tilde{\nu} = \nu/c_0 = \sigma/n = 1/\lambda_0$, etc. As an example, the refractive index may be given as $n(\lambda_0 = 555\ \text{nm}) \approx 1{,}333$. Also, spectral radiance $L_\lambda(\lambda)$ (item 7-15, Remark) has the meaning of spectral “density” corresponding to the integrated quantity – radiance L (item 7-15).

Spectral quantities corresponding to different reference quantities are related, e.g.

$$\mathrm{d}q = q_\nu(\nu)\,\mathrm{d}\nu = q_\omega(\omega)\,\mathrm{d}\omega = q_{\tilde{\nu}}(\tilde{\nu})\,\mathrm{d}\tilde{\nu} = q_\lambda(\lambda)\,\mathrm{d}\lambda = q_\sigma(\sigma)\,\mathrm{d}\sigma$$

thus

$$q_\nu(\nu) = 2\pi q_\omega(\omega) = q_{\tilde{\nu}}(\tilde{\nu})/c_0 = q_\lambda(\lambda)\,c_0/n = q_\sigma(\sigma)\,n/c_0$$

For historical reasons, the wavelength λ is still mostly used as a reference quantity being the most accurately measured quantity in the past. From the theoretical point of view, the frequency ν is more suitable reference quantity, keeping its value when a light beam passes through media with different refractive index n.

0.5.2 Units

In photometry and radiometry, the unit steradian is retained for convenience.

0.5.3 Photopic quantities

In the great majority of instances, photopic vision (provided by the cones and used for vision in daylight) is dealt with. Standard values of the spectral luminous efficiency function $V(\lambda)$ for photopic vision were originally adopted by the CIE in 1924. These values were adopted by the CIPM [see BIPM Monograph: *Principles Governing Photometry* (1983)].

0.5.4 Scotopic quantities

For scotopic vision (provided by the rods and used for vision at night), corresponding quantities from item 7-28 to item 7-48 are defined in the same manner as the photopic ones, using symbols with a prime.

For item 7-28, spectral luminous efficiency, the remarks would read:

> Standard values of luminous efficiency function $V'(\lambda)$ for scotopic vision were originally adopted by CIE in 1951. They were later adopted by the CIPM [see BIPM Monograph: *Principles Governing Photometry* (1983)].

For item 7-29, maximum spectral luminous efficacy (for scotopic vision), the definition would read:

> "for scotopic vision, $K'_{\mathrm{m}} = \dfrac{683}{V'(555{,}016\ \mathrm{nm})}\ \mathrm{lm/W} \approx 1\ 700\ \mathrm{lm/W}$."

0.5.5 Values

The fundamental physical constants given in ISO 80000-7 series are quoted in the consistent values of the fundamental physical constants published in "2006 CODATA recommended values". See also CODATA website redirecting to: http://physics.nist.gov/cuu/Constants/index.html.

Quantities and units —

Part 7:
Light

1 Scope

ISO 80000-7 gives names, symbols and definitions for quantities and units used for light and other electromagnetic radiation. Where appropriate, conversion factors are also given.

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 80000-3:2006, *Quantities and units — Part 3: Space and time*

ISO 80000-4:2006, *Quantities and units — Part 4: Mechanics*

ISO 80000-5:2007, *Quantities and units — Part 5: Thermodynamics*

IEC 80000-6:2008, *Quantities and units — Part 6: Electromagnetism*

ISO 80000-9:—[2], *Quantities and units — Part 9: Physical chemistry and molecular physics*

ISO 80000-10:—[3], *Quantities and units — Part 10: Atomic and nuclear physics*

3 Names, symbols, and definitions

The names, symbols, and definitions for quantities and units used in optics are given in the tables on the following pages.

2) To be published. (Revision of ISO 31-8:1992)

3) To be published. (Revision of ISO 31-9:1992 and ISO 31-10:1992)

LIGHT				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-1 (*6-2*)	frequency *fr fréquence* (f)	ν, f	$\nu = 1/T$ where T is the period (ISO 80000-3:2006, item 3-12)	See ISO 80000-3:2006, item 3-15.1, but in spectroscopy, ν is mostly used. Light passing through different media keeps its frequency, but not its wavelength or wavenumber.
7-2.1 (—)	wavenumber in vacuum *fr nombre* (m) *d'onde dans le vide*	$\tilde{\nu}$	$\tilde{\nu} = \nu/c_0$ where ν is the frequency (item 7-1) and c_0 is the speed (ISO 80000-3:2006, item 3-8.2) of light in vacuum (item 7-4.1)	See also ISO 80000-3:2006, item 3-18. $\nu = 1/\lambda_0$ where λ_0 is the wavelength in vacuum (item 7-3.1).
7-2.2 (*6.4*)	wavenumber *fr nombre* (m) *d'onde*	σ	$\sigma = \nu/c$ where ν is the frequency (item 7-1) and c is the speed of light in medium (item 7-4.2)	See also ISO 80000-3:2006, item 3-18. $\sigma = \tilde{\nu}/n$ in a medium with refractive index n (item 7-5). $\sigma = 1/\lambda$ where λ is the wavelength in medium (item 7-3.2). Light passing through different media keeps its frequency, but not its wavelength or wavenumber.
7-3.1	wavelength in vacuum *fr longueur* (f) *d'onde dans le vide*	λ_0	for a monochromatic wave, $\lambda_0 = c_0/\nu$ where ν is the frequency (item 7-1) of that wave and c_0 is the speed of light in vacuum (item 7-4.1)	In a medium with refractive index n (item 7-5), $\lambda_0 = n\,\lambda$
7-3.2 (*6-3*)	wavelength *fr longueur* (f) *d'onde*	λ	for a monochromatic wave, propagating in a medium, $\lambda = c/\nu$ where ν is the frequency (item 7-1) of that wave and c is the phase speed (ISO 80000-3:2006, item 3-8.2) of electromagnetic radiation of a specified frequency	See ISO 80000-3:2006, item 3-17. For a monochromatic wave, wavelength is the distance between two successive points in a direction perpendicular to the wavefront where at a given instant the phase differs by 2π. $\lambda = 1/\sigma$ where σ is the wavenumber in medium (item 7-2.2). In a medium with refractive index n (item 7-5), $\lambda = \lambda_0/n$ In an anisotropic medium, the direction of light propagation must be defined.

UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-1.a	hertz	Hz	1 Hz := 1 s^{-1}	
7-2.a	metre to power minus one	m^{-1}		The unit for wavenumber commonly used in spectroscopy is centimetre to power minus one, cm^{-1}, rather than metre to power minus one, m^{-1}.
7-3.a	metre	m		ångström (Å); 1 Å := 10^{-10} m

(continued)