BRITISH STANDARD

BS ISO 80000-7:2008

Quantities and units

Part 7: Light

ICS 01.060

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British Standards

National foreword

This British Standard is the UK implementation of ISO 80000-7:2008. It supersedes BS ISO 31-6:1992 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee SS/7, General metrology, quantities, units and symbols.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

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

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

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

Attention is drawn to the possibility that some of the elements of 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*

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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*

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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.

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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.

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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 $n(\lambda_0 = 555\ \mathrm{nm}) \approx 1{,}333$. 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)].

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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.

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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)

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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.

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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

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LIGHT				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-4.1 (*6-6*)	speed of light in vacuum, speed of electro-magnetic waves in vacuum *fr vitesse* (f) *de la lumière dans le vide, vitesse* (f) *des ondes électro-magnétiques dans le vide*	c_0	speed of electromagnetic waves in vacuum $c_0 :=$ 299 792 458 m · s^{-1}	The speed of light in vacuum is a fundamental constant used for definition of metre. See ISO 80000-3:2006, item 3-1.a and IEC 80000-6:2008, item 6-35.2. In relativity, the terms subluminal, luminal and superluminal speed are sometimes used for speed less than, equal to, or greater than the speed of light in vacuum.
7-4.2	speed of light *fr vitesse* (f) *de la lumière*	c	in a medium, the phase speed (ISO 80000-3:2006, item 3-8.2) of electromagnetic radiation in a given direction and of a specified frequency	
7-5 (*6-44*)	refractive index *fr indice* (m) *de réfraction*	n	$n = c_0/c$ where c_0 is the speed of light in vacuum (item 7-4.1) and c is the phase speed (ISO 80000-3:2006, item 3-8.2) in a given direction of electromagnetic radiation of a specified frequency in a medium	In a medium, c depends upon the frequency ν of light used; thus $n = n(\nu)$. For a medium with absorption, complex refractive index $\underline{\boldsymbol{k}} = \underline{n}\boldsymbol{k}_0$ may be defined where $\boldsymbol{k}_0$ is the wave vector in vacuum and $\underline{\boldsymbol{k}}$ is the complex wave vector in a medium. Then, $\underline{n} = n + \mathrm{i}k = n + \mathrm{i}\alpha/4\pi\tilde{\nu}$ where α is the linear absorption coefficient (item 7-25.2) and i is the imaginary unit. For an anisotropic medium, n is a tensor.
7-6 (*6-7*)	radiant energy *fr énergie* (f) *rayonnante*	$Q, W,$ (U, Q_e)	energy (ISO 80000-5:2007, item 5-20.1) emitted, transferred or received as radiation	Visible radiant energy is called luminous energy (item 7-34). Photonic energy may be expressed by photon numbers (item 7-49).

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-4.a	metre per second	$m \cdot s^{-1}$		
7-5.a	one	1		See the Introduction, 0.3.2.
7-6.a	joule	J	$1\ J := 1\ kg \cdot m^2 \cdot s^{-2}$	

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-7 (*6-8*)	radiant energy density *fr énergie* (f) *rayonnante volumique*	w, ρ	$w = \frac{\mathrm{d}Q}{\mathrm{d}V}$ where dQ is the radiant energy (item 7-6) in an elementary three-dimensional domain, divided by the volume dV (ISO 80000-3:2006, item 3-4) of that domain	The radiant energy density within a blackbody is given by $w = \frac{4\sigma}{c_0} T^4$ where σ is the Stefan-Boltzmann constant (item 7-56), c_0 is the speed of light in vacuum (item 7-4.1) and T is the thermodynamic temperature (ISO 80000-5:2007, item 5-1). See the Introduction, 0.5.1.
7-8 (*6-9*)	spectral radiant energy density in terms of wavelength *fr énergie* (f) *rayonnante spectrique volumique en longueur d'onde*	w_λ, ρ_λ	$w_\lambda(\lambda) = \frac{\mathrm{d}w}{\mathrm{d}\lambda}$ where dw is the infinitesimal part of radiant energy density w (item 7-7) corresponding to light with wavelength λ (item 7-3.2) in the infinitesimal interval [λ, $\lambda + \mathrm{d}\lambda$], divided by the range dλ of that interval	The spectral radiant energy density within a blackbody is given by $w_\lambda = 8\pi h c_0 \cdot f(\lambda, T)$ where h is the Planck constant (ISO 80000-10:—, item 10-5.1), c_0 is the speed of light in vacuum (item 7-4.1), and T is the thermodynamic temperature (ISO 80000-5:2007, item 5-1). For $f(\lambda, T)$, see items 7-57 and 7-58.
7-9 (*6-9*)	spectral radiant energy density in terms of wavenumber *fr énergie* (f) *rayonnante spectrique volumique en longueur d'onde*	$\rho_{\tilde{\nu}}$, $w_{\tilde{\nu}}$	$w_{\tilde{\nu}}(\tilde{\nu}) = \frac{\mathrm{d}w}{\mathrm{d}\tilde{\nu}}$ where d$\tilde{\nu}$ is the infinitesimal part of radiant energy density w (item 7-7) corresponding to light with wavenumber $\tilde{\nu}$ (item 7-3.2) in the infinitesimal interval [$\tilde{\nu}$, $\tilde{\nu} + \mathrm{d}\tilde{\nu}$] divided by the range $d\tilde{\nu}$ of that interval	In spectroscopy, symbol $\rho_{\tilde{\nu}}$ is used.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-7.a	joule per cubic metre	$J \cdot m^{-3}$		
7-8.a	joule per metre to the power four	$J \cdot m^{-4}$		
7-9.a	joule per metre squared	$J \cdot m^{-2}$		

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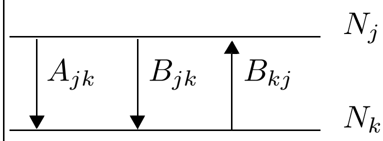
LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-10 (—)	Einstein transition probability for spontaneous emission $j \rightarrow k$ *fr probabilité* (f) *de transition d'Einstein pour l'émission spontanée* $j \rightarrow k$	A_{jk}	$-\mathrm{d}N_j/\mathrm{d}t = A_{jk}N_j$ where $-\mathrm{d}N_j$ is the number of molecules spontaneously leaving the state j for the state k during a time interval of duration $\mathrm{d}t$, N_j is the number of molecules in the state j and $E_j > E_k$	The emitted or absorbed wave has the wavenumber $\tilde{\nu}_{jk} = (E_j - E_k)/hc_0$. The relation between Einstein coefficients is $A_{jk} = 8\pi hc_0\tilde{\nu}^3 B_{\tilde{\nu},\,jk}$ $B_{kj} = B_{jk}$
7-11 (—)	Einstein transition probability for induced emission $j \rightarrow k$, Einstein transition probability for stimulated emission $j \rightarrow k$ *fr probabilité* (f) *de transition d'Einstein pour l'émission induite* $j \rightarrow k$, *probabilité* (f) *de transition d'Einstein pour l'émission stimulée* $j \rightarrow k$	B_{jk}, $B_{\tilde{\nu},\,jk}$	$-\mathrm{d}N_j/\mathrm{d}t = \rho_{\tilde{\nu}}(\tilde{\nu}_{jk})\,B_{jk}N_j$ where $-\mathrm{d}N_j$ is the number of molecules leaving the state j for the state k by induced emission due to radiation of spectral energy density $\rho_{\tilde{\nu}}(\tilde{\nu})$ (item 7-9) in a time interval of duration $\mathrm{d}t$, N_j is the number of molecules in the state j and $E_j > E_k$	The coefficients $B_{\tilde{\nu},\,kj}$ are defined here using spectral energy density $\rho_{\tilde{\nu}}(\tilde{\nu})$ in terms of wavenumber $\tilde{\nu}$. They may also be defined in terms of frequency ν using $\rho_\nu(\nu)$ in which case $B_{\nu,\,kj} = c_0\,B_{\tilde{\nu},\,kj}$ has SI unit metre per kilogram. 
7-12 (—)	Einstein transition probability for induced absorption $j \rightarrow k$ *fr probabilité* (f) *de transition d'Einstein pour l'absorption induite* $j \rightarrow k$	B_{kj}, $B_{\tilde{\nu},\,kj}$	$-\mathrm{d}N_k/\mathrm{d}t = \rho_{\tilde{\nu}}(\tilde{\nu}_{jk})\,B_{kj}N_k$ where $-\mathrm{d}N_k$ is the number of molecules leaving the state k for the state j by induced absorption due to radiation of spectral energy density $\rho_{\tilde{\nu}}(\tilde{\nu})$ (item 7-9) in a time interval of duration $\mathrm{d}t$, N_k is the number of molecules in the state k and $E_j > E_k$	

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-10.a	second to the power minus one	s^{-1}		
7-11.a	second kilogram to the power minus one	$s \cdot kg^{-1}$		For the coefficients $B_{\nu,\,jk}$ using spectral energy density $\rho_\nu(\nu)$ in terms of frequency ν, the SI unit is $m \cdot kg^{-1}$.
7-12.a	second kilogram to the power minus one	$s \cdot kg^{-1}$		For the coefficients $B_{\nu,\,kj}$ using spectral energy density $\rho_\nu(\nu)$ in terms of frequency ν, the SI unit is $m \cdot kg^{-1}$.

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-13 (*6-10*)	radiant flux, radiant power *fr flux* (m) *énergétique*, *puissance* (f) *rayonnante*	Φ, P, (Φ_e)	$\Phi = \frac{dQ}{dt}$ where dQ is the radiant energy (item 7-6) emitted, transferred or received during a time interval of the duration dt (ISO 80000-3:2006, item 3-7)	Spectral radiant flux is the spectral concentration of radiant flux, $\Phi_\lambda(\lambda) = \frac{d\Phi}{d\lambda}$, $\Phi = \int_0^\infty \Phi_\lambda(\lambda)\, d\,\lambda$. Corresponding definitions apply for spectral concentration (spectral density) of similar radiometric quantities such as $I_\lambda(\lambda) = \frac{dI}{d\lambda}$ for items 7-14 and 7-13. They are denoted also simply I_λ and Φ_λ, respectively and called spectral quantities. Then, $I = \int_0^\infty I_\lambda(\lambda)\, d\,\lambda = \int_0^\infty I_\lambda\, d\,\lambda$ etc. Visible radiant flux is called luminous flux (item 7-32). Photonic flux may be expressed by photon numbers (see item 7-50).
7-14 (*6-13*)	radiant intensity *fr intensité* (f) *énergétique*	I, (I_e)	in a given direction from a source, $I = \frac{d\Phi}{d\Omega}$ where dΦ is the radiant flux (item 7-13) leaving the source in an elementary cone containing the given direction with the solid angle dΩ (ISO 80000-3:2006, item 3-6)	$I = \int_0^\infty I_\lambda(\lambda)\, d\,\lambda$ where $I_\lambda(\lambda)$ is spectral radiant intensity. See the Introduction, 0.5.1, and the Remarks in item 7-13. Visible radiant intensity is called luminous intensity (item 7-35). Photonic intensity may be expressed by photon numbers (see item 7-51).

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-13.a	watt	W		$1\ \text{W} = 1\ \text{J} \cdot \text{s}^{-1}$ This unit is identical to the unit for mechanical power (ISO 80000-4:2006, item 4-26.a).
7-14.a	watt per steradian	$\text{W} \cdot \text{sr}^{-1}$		For the steradian, see the Introduction, 0.3.2.

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-15 (*6-14*)	radiance *fr luminance* (f) *énergétique, radiance* (f)	L, (L_e)	at a point on a surface of a source and in a given direction, $L = \frac{dI}{dA} \frac{1}{\cos \alpha}$ where dI is the radiant intensity (item 7-14) emitted from an element of the surface with area dA (ISO 80000-3:2006, item 3-3) and angle α is the angle between the normal to the surface and the given direction	$L = \int_0^\infty L_\lambda(\lambda)\, d\lambda$ where $L_\lambda(\lambda)$ is spectral radiance. See the Introduction, 0.5.1, and the Remarks in item 7-13. $L_{e\lambda}(\lambda) = \frac{c(\lambda)}{4\pi} w_\lambda(\lambda) = hc_0^2 \cdot f(\lambda, T)$ where $c(\lambda)$ is the phase speed (ISO 80000-3:2006, item 3-8.2) of electromagnetic radiation of a wavelength λ (item 7-3.2) in a given medium, for $w_\lambda(\lambda)$, see item 7-8, and for $f(\lambda, T)$, see items 7-57 and 7-58, c_0 is the speed of light in vacuum (item 7-4.1) and h is the Planck constant (ISO 80000-10:—, item 10-6.1). For blackbody radiation, $L = \frac{\sigma}{\pi} T^4$ where T is the thermodynamic temperature (ISO 80000-5:2007, item 5-1) and σ is the Stefan-Boltzmann constant (item 7-56). Visible radiance is called luminance (item 7-37). Photonic radiance may be expressed by photon numbers (see item 7-52).

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-15.a	watt per steradian metre squared	$W \cdot sr^{-1} \cdot m^{-2}$		

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-16 (*6-16*)	spherical irradiance, radiant fluence rate *fr éclairement* (m) *sphérique énergétique, débit* (m) *de fluence énergétique*	E_0, ($E_{e,0}$)	at a point in space, $E_0 = \int L \, d\Omega$ where $d\Omega$ is the solid angle (ISO 80000-3:2006, item 3-6) of each elementary beam passing through the given point and L its radiance (item 7-15) at that point in the direction of the beam	Spherical irradiance is equal to the total radiant flux incident on a small sphere divided by the area of the diametrical cross-section of the sphere. In an isotropic homogenous radiation field where c is the speed of light, E_0/c is the radiant energy density (item 7-7), and the irradiance (item 7-19) of a surface is $E_0/4$. See the Introduction, 0.5.1, and the Remarks in item 7-13. Visible spherical irradiance is called spherical illuminance (item 7-38).
7-17 (*6-11*)	radiant spherical exposure, radiant fluence *fr exposition* (f) *sphérique énergétique, fluence* (f) *énergétique*	H_0, ($H_{e,0}$)	$H_0 = \int_0^{\Delta t} E_0 \, dt$ where E_0 is the spherical irradiance (item 7-16) acting during time interval with duration Δt (ISO 80000-3:2006, item 3-7)	Visible radiant spherical exposure is called luminous spherical exposure (item 7-39).
7-18 (*6-15*)	radiant exitance *fr exitance* (f) *énergétique*	M, (M_e)	at a point on a surface, $M = \frac{d\Phi}{dA}$ where $d\Phi$ is the radiant flux (item 7-13) leaving the element of the surface with area dA (ISO 80000-3:2006, item 3-3)	Formerly called radiant emittance. $M = \int_0^{\infty} M_\lambda(\lambda) \, d\lambda$ See the Introduction, 0.5.1, and the Remarks in item 7-13. For blackbody radiation, $M = \sigma T^4$ where T is thermodynamic temperature (ISO 80000-5:2007, item 5-1) and σ is the Stefan-Boltzmann constant (item 7-56). For $M_\lambda(\lambda) = c_1 f(\lambda, T)$, see items 7-57 and 7-58. Visible radiant exitance is called luminous exitance (item 7-40). Photonic exitance may be expressed by photon numbers (see item 7-53).

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-16.a	watt per metre squared	$W \cdot m^{-2}$		
7-17.a	joule per metre squared	$J \cdot m^{-2}$		
7-18.a	watt per metre squared	$W \cdot m^{-2}$		

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-19 (*6-16*)	irradiance *fr éclairement* (m) *énergétique*	E, (E_e)	at a point on a surface, $E = \frac{\mathrm{d}\Phi}{\mathrm{d}A}$ where dΦ is the radiant flux (item 7-13) incident on an element of the surface with area dA (ISO 80000-3:2006, item 3-6)	$E = \int_0^\infty E_\lambda(\lambda)\,\mathrm{d}\lambda$ where $E_\lambda(\lambda)$ is spectral irradiance. See the Introduction, 0.5.1, and the Remarks in item 7-13. Visible irradiance is called illuminance (item 7-36). Photonic irradiance may be expressed by photon numbers (see item 7-54).
7-20 (*6-17*)	radiant exposure *fr exposition* (f) *énergétique*	H, (H_e)	$H = \int_0^{\Delta t} E\,\mathrm{d}t$ where E is the irradiance (item 7-19) acting during the time interval with duration Δt (ISO 80000-3:2006, item 3-7)	Visible radiant exposure is called luminous exposure (item 7-41). Photonic radiant exposure may be expressed by photon numbers (see item 7-55).
7-21.1 (*6-21.1*)	emissivity, emittance *fr émissivité* (f)	ε	$\varepsilon = M/M_b$ where M is the radiant exitance (item 7-18) of a thermal radiator and M_b is the radiant exitance of a blackbody at the same temperature (ISO 80000-5:2007, item 5-1)	
7-21.2 (*6-21.2*)	spectral emissivity, emissivity at a specified wavelength *fr émissivité* (f) *spectrale*	$\varepsilon(\lambda)$	$\varepsilon(\lambda) = M_\lambda(\lambda)/M_{b,\lambda}(\lambda)$ where $M_\lambda(\lambda)$ is the spectral radiant exitance (item 7-18) of a thermal radiator and $M_{b,\lambda}(\lambda)$ is the spectral radiant exitance of a blackbody at the same temperature	The spectral emissivity is a function of wavelength (item 7-3.2); this is usually indicated by the symbol $\varepsilon(\lambda)$. For $M_\lambda(\lambda)$, see item 7-18 and Remarks in item 7-13.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-19.a	watt per metre squared	$W \cdot m^{-2}$		
7-20.a	joule per metre squared	$J \cdot m^{-2}$		
7-21.a	one	1		See the Introduction, 0.3.2.

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-22.1 (*6-40.1*)	absorptance *fr facteur* (m) *d'absorption, absorptance* (f)	α, a	$\alpha = \Phi_\mathrm{a}/\Phi_\mathrm{m}$ where Φ_a is the absorbed radiant flux (item 7-13) or the absorbed luminous flux (item 7-32) and Φ_m is the radiant flux (item 7-13) or luminous flux (item 7-32) of the incident radiation	$\alpha = I_\mathrm{a}/I_\mathrm{m}$, $\rho = I_\mathrm{r}/I_\mathrm{m}$, $\rho = I_\mathrm{t}/I_\mathrm{m}$. These quantities are also defined spectrally, in which case, “spectral” is added before these quantity names (e.g. spectral reflectance), and the symbols are expressed as $\alpha(\lambda)$, $\rho(\lambda)$ and $\tau(\lambda)$, respectively. The quantities α, ρ, τ are averages of the spectral quantities weighted by the spectral distribution of the used light. Due to the energy conservation, $\alpha + \rho + \tau = 1$ except when polarized radiation is observed. See also items 7-47.1, 7-47.2 and 7-47.3
7-22.2 (*6-40.2*)	reflectance *fr facteur* (m) *de réflexion, réflectance* (f)	ρ	$\rho = \Phi_\mathrm{r}/\Phi_\mathrm{m}$ where Φ_r is the reflected radiant flux (item 7-13) or the reflected luminous flux (item 7-32) and Φ_m is the radiant flux (item 7-13) or luminous flux (item 7-32) of the incident radiation	
7-22.3 (*6-40.3*)	transmittance *fr facteur* (m) *de transmission, transmittance* (f)	τ, T	$\rho = \Phi_\mathrm{t}/\Phi_\mathrm{m}$ where Φ_t is the transmitted radiant flux (item 7-13) or luminous flux (item 7-32) and Φ_m is the radiant flux (item 7-13) or luminous flux (item 7-32) of the incident radiation	
7-23.1 (*6-41*)	transmittance density, optical density, decadic absorbance *fr densité* (f) *optique, absorbance* (f)	A_{10}, D	$A_{10}(\lambda) = -\mathrm{lg}\,(\tau(\lambda))$ where τ is the transmittance (item 7-22.3) at given wavelength λ (item 7-3.2)	In spectroscopy, the name “absorbance A_{10}” is generally used.
7-23.2 (—)	napierian absorbance *fr absorbance* (f) *népérienne*	A_e, B	$A_\mathrm{e}(\lambda) = -\mathrm{ln}\,(\tau(\lambda))$ where τ is the transmittance (item 7-22.3) at given wavelength λ (item 7-3.2)	$A_\mathrm{e}(\lambda) = l\alpha_\lambda(\lambda)$ where α is the linear absorption coefficient (item 7-25.2) and l is the length (ISO 80000-3:2006, item 3-1.1) traversed.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-22.a	one	1		See the Introduction, 0.3.2.
7-23.a	one	1		See the Introduction, 0.3.2.

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-24.1 (*6-40.4*)	radiance factor *fr facteur* (m) *de luminance énergétique*	β, (β_e)	$\beta = L_n / L_d$ where L_n is the radiance (item 7-15) of a surface element in a given direction and L_d is the radiance (item 7-15) of the perfect reflecting or transmitting diffuser identically irradiated and viewed	Reflectance factor is equivalent to radiance factor or luminance factor (item 7-48) when the cone angle is infinitely small, and is equivalent to reflectance when the cone angle is 2π sr. These quantities are also defined spectrally and called spectral radiance factor $\beta(\lambda)$ and spectral reflectance factor $R(\lambda)$. The ideal isotropic (Lambertian) diffuser with reflectance or transmittance equal to 1 is called a perfect diffuser.
7-24.2 (—)	reflectance factor *fr facteur* (m) *de réflectance*	R	$R = \Phi_n / \Phi_d$ where Φ_n is the radiant flux (item 7-13) or luminous flux (item 7-32) reflected in the directions delimited by a given cone and Φ_d is the flux reflected in the same directions by an identically irradiated diffuser of reflectance (item 7-22.2) equal to 1	
7-25.1 (*6-42.1*)	linear attenuation coefficient, linear extinction coefficient *fr coefficient* (m) *d'atténuation linéique*	μ, μ_l	$\mu(\lambda) = \dfrac{1}{\Phi_\lambda(\lambda)} \dfrac{d\Phi_\lambda(\lambda)}{dl}$ where $\dfrac{d\Phi}{\Phi}$ is the relative decrease in the spectral radiant flux (item 7-13) Φ of a collimated beam of electro-magnetic radiation corresponding to the wavelength λ (item 7-3.2) during traversal of an infinitesimal layer of a medium and dl is the length (ISO 80000-3:2006, item 3-1.1) traversed	Spectral attenuation coefficient is the corresponding spectral quantity. Similarly, luminous and photon quantities can be defined.
7-25.2 (*6-42.2*)	linear absorption coefficient *fr coefficient* (m) *d'absorption linéique*	α, a	$\alpha(\lambda) = \dfrac{1}{\Phi_\lambda(\lambda)} \dfrac{d\Phi_\lambda(\lambda)}{dl}$ where $\dfrac{d\Phi}{\Phi}$ is the relative decrease, caused by absorption, in the spectral radiant flux (item 7-13) Φ of a collimated beam of electro-magnetic radiation corresp-onding to the wavelength λ (item 7-3.2) during traversal of an infinitesimal layer of a medium and dl is the length (ISO 80000-3:2006, item 3-1.1) traversed	$\alpha = -\ln(T)/l = A_e/l$ Linear absorption coefficient is that part of the linear attenuation coefficient that is due to absorption. Scattering might also contribute. See Remarks in item 7-25.1.

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-24.a	one	1		See the Introduction, 0.3.2.
7-25.a	metre to the power minus one	m^{-1}		

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-26.1 (—)	mass attenuation coefficient *fr coefficient* (m) *d'atténuation massique*	μ_m	$\mu_m = \mu/\rho$ where μ is the linear attenuation coefficient (item 7-25.1) and ρ is the mass density (ISO 80000-4:2006, item 4-2) of the medium	See Remarks in item 7-25.1.
7-26.2 (—)	mass absorption coefficient *fr coefficient* (m) *d'absorption massique*	a_m	$a_m = a/\rho$ where a is the linear absorption coefficient (item 7-25.2) and ρ is the mass density (ISO 80000-4:2006, item 4-2) of the medium	See Remarks in item 7-25.1.
7-27 (*6-43*)	molar absorption coefficient *fr coefficient* (m) *d'absorption molaire*	$\varkappa$	$\varkappa = aV_\mathrm{m}$ where a is the linear absorption coefficient (item 7-25.2) and V_m is the molar volume (ISO 80000-9:—, item 9-6)	See Remarks in item 7-25.1. $\varkappa = ac$ where c is the amount-of-substance concentration (ISO 80000-9:—, item 9-13).
7-28 (*6-37.2*)	spectral luminous efficiency *fr efficacité* (f) *lumineuse relative spectrale*	$V(\lambda)$	ratio of the spectral radiant flux $\Phi_\lambda(\lambda_\mathrm{m})$ (item 7-13) at wavelength λ_m (item 7-3.2) to spectral radiant flux $\Phi_\lambda(\lambda)$ (item 7-13) at wavelength λ (item 7-3.2) such that both radiations produce equal luminous sensations under specified photometric conditions and λ_m is chosen so that the maximum value of this ratio is equal to 1	Standard values of 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 Reference [3]). $V(\lambda)$ is used for quantities describing photopic vision. For scotopic vision, see 0.5.4.
7-29 (*6-36.3*)	maximum spectral luminous efficacy *fr efficacité* (f) *lumineuse spectrale maximale*	K_m	$K_\mathrm{m} = \frac{683}{V(555{,}016\ \mathrm{nm})}\ \mathrm{lm/W}$ $\approx 683\ \mathrm{lm/W}$ where $V(\lambda)$ is the spectral luminous efficiency (item 7-28)	The value 683 lm/W is defined for monochromatic radiation at frequency 540×10^{12} Hz (555,016 nm in standard air) in the SI definition of the candela. K_m is the maximum value of $K(\lambda)$. For scotopic vision, see 0.5.4.

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-26.a	metre squared per kilogram	$m^2 \cdot kg^{-1}$		
7-27.a	metre squared per mole	$m^2 \cdot mol^{-1}$		
7-28.a	one	1		See the Introduction, 0.3.2.
7-29.a	lumen per watt	$lm \cdot W^{-1}$		

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-30 (*6-37.1*)	luminous efficiency *fr efficacité* (f) *lumineuse relative*	V	$V = \frac{\int_0^\infty V(\lambda)\Phi_\lambda(\lambda)\,\mathrm{d}\lambda}{\int_0^\infty \Phi_\lambda(\lambda)\,\mathrm{d}\lambda}$ where $\Phi_\lambda(\lambda)$ is the spectral radiant flux (item 7-13), $V(\lambda)$ is the spectral luminous efficiency (item 7-28) and λ is the wavelength (item 7-3.2)	$V = K/K_\mathrm{m}$ where K is the luminous efficacy of radiation (item 7-33.1) and K_m is the maximum spectral luminous efficacy (item 7-29). For scotopic vision, see 0.5.4.
7-31 (*6-36.2*)	spectral luminous efficacy *fr efficacité* (f) *lumineuse spectrale*	$K(\lambda)$	$K(\lambda) = K_\mathrm{m}\,V(\lambda)$ where K_m is the maximum spectral luminous efficacy (item 7-29), $V(\lambda)$ is the spectral luminous efficiency (item 7-28) and λ is the wavelength (item 7-3.2)	For scotopic vision, see 0.5.4.
7-32 (*6-30*)	luminous flux *fr flux* (m) *lumineux*	Φ_v, (Φ)	$\Phi_\mathrm{v} = K_\mathrm{m}\int_0^\infty \Phi_\lambda(\lambda)\,V(\lambda)\,\mathrm{d}\lambda$ where K_m is the maximum spectral luminous efficacy (item 7-29), $\Phi_\lambda(\lambda)$ is the spectral radiant flux (item 7-13, Remarks 7-13), $V(\lambda)$ is the spectral luminous efficiency (item 7-28) and λ is the wavelength (item 7-3.2)	Luminous flux evaluates the radiation by its visual response using the standard spectral luminous efficiency. See the Introduction, 0.5.1. For the analogous radiant quantity, see item 7-13. For the analogous photon quantity, see item 7-50. For scotopic vision, see 0.5.4.

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-30.a	one	1		See the Introduction, 0.3.2.
7-31.a	lumen per watt	$\mathrm{lm \cdot W^{-1}}$		
7-32.a	lumen	lm	$1\ \mathrm{lm} := 1\ \mathrm{cd \cdot sr}$	

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-33.1 (*6-36.1*)	luminous efficacy of radiation *fr efficacité* (f) *lumineuse d'un rayonnement*	K	$K = \frac{\Phi_\mathrm{v}}{\Phi}$ where Φ_v is the luminous flux (item 7-32) and Φ is the corresponding radiant flux (item 7-13)	$K = \frac{\int_0^\infty K(\lambda)\,\Phi_\lambda(\lambda)\,\mathrm{d}\lambda}{\int_0^\infty \Phi_\lambda(\lambda)\,\mathrm{d}\lambda}$ For $K(\lambda)$, see item 7-31.
7-33.2 (—)	luminous efficacy of a source *fr efficacité* (f) *lumineuse d'une source*	η_v, (η)	$\eta_\mathrm{v} = \frac{\Phi_\mathrm{v}}{P}$ where Φ_v is the luminous flux (item 7-32) and P is the corresponding electric active power (IEC 80000-6:2008, item 6-56) consumed by the source	
7-34 (*6-31*)	luminous energy, quantity of light *fr quantité* (f) *de lumière*	Q_v, (Q)	$Q = \int_0^{\Delta t} \Phi_\mathrm{v}\,\mathrm{d}t$ where Φ_v is the luminous flux (item 7-32) occurring during the time interval with duration Δt (ISO 80000-3:2006, item 3-7)	$Q_\mathrm{v} = \int_0^\infty Q_\lambda(\lambda) K(\lambda)\,\mathrm{d}\lambda$ For $K(\lambda)$, see item 7-31, for $Q_\lambda(\lambda)$, see item 7-6. See the Introduction, 0.5.1. For scotopic vision, see 0.5.4. For the analogous radiant quantity, see item 7-6. For the analogous photon quantity, see item 7-49.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-33.a	lumen per watt	$\mathrm{lm \cdot W^{-1}}$		
7-34.a	lumen second	$\mathrm{lm \cdot s}$		
7-34.b	lumen hour	$\mathrm{lm \cdot h}$		$1\ \mathrm{lm \cdot h} = 3\,600\ \mathrm{lm \cdot s}$

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-35 (*6-29*)	luminous intensity *fr intensité* (f) *lumineuse*	I_v, (I)	Luminous intensity is one of the base quantities in the International System of Quantities, ISQ, on which the International System of Units, SI, is based.	Luminous intensity is measured by a photometer. In a given direction from a source, $I_\mathrm{v} = \frac{\mathrm{d}\Phi_\mathrm{v}}{\mathrm{d}\Omega}$ where $\mathrm{d}\Phi_\mathrm{v}$ is the luminous flux (item 7-32) leaving the source in an elementary cone containing the given direction with the solid angle $\mathrm{d}\Omega$. $I_\mathrm{v} = \int_0^\infty I_\lambda(\lambda)K(\lambda)\,\mathrm{d}\lambda$ See item 7-31 for $K(\lambda)$. See the Introduction, 0.5.1. For scotopic vision, see 0.5.4. For the analogous radiant quantity, see item 7-14. For the analogous photon quantity, see item 7-51.
7-36 (*6-34*)	illuminance *fr éclairement* (m) *lumineux*, *éclairement* (m)	E_v, (E)	at a point on a surface, $E_\mathrm{v} = \frac{\mathrm{d}\Phi}{\mathrm{d}A}$ where $\mathrm{d}\Phi$ is the luminous flux (item 7-32) incident on an element of the surface with area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-3)	$E_\mathrm{v} = \int_0^\infty E_\lambda(\lambda)K(\lambda)\,\mathrm{d}\lambda$ See item 7-31 for $K(\lambda)$. See the Introduction, 0.5.1. For scotopic vision, see 0.5.4. For the analogous radiant quantity, see item 7-19. For the analogous photon quantity, see item 7-54.
7-37 (*6-32*)	luminance *fr luminance* (f)	L_v, (L)	at a point on a surface and in a given direction, $L_\mathrm{v} = \frac{\mathrm{d}I_\mathrm{v}}{\mathrm{d}A}$ where $\mathrm{d}I_\mathrm{v}$ is the luminous intensity (item 7-35) of an element of the surface with the area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-3) of the orthogonal projection of this element on a plane perpendicular to the given direction	$L_\mathrm{v} = \int_0^\infty L_{\mathrm{v},\lambda}(\lambda)K(\lambda)\,\mathrm{d}\lambda$ See item 7-31 for $K(\lambda)$. See the Introduction, 0.5.1. For scotopic vision, see 0.5.4. For the analogous radiant quantity, see item 7-15. For the analogous photon quantity, see item 7-52.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-35.a	candela	cd	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 $\times$ 10^{12} Hz and that has a radiant intensity in that direction of 1/683 W/sr	
7-36.a	lux	lx	$1 \text{ lx} := 1 \text{ lm} \cdot \text{m}^{-2}$	
7-37.a	candela per square metre	$\text{cd} \cdot \text{m}^{-2}$		

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-38 (—)	spherical illuminance, luminous fluence rate *fr éclairement* (m) *sphérique lumineux,* *débit* (m) *de fluence lumineuse*	$E_{\mathrm{v},0}$	at a point in space, quantity defined by $E_{\mathrm{v},0} = \int_{4\pi\,\mathrm{sr}} L_\mathrm{v}\, \mathrm{d}\Omega$ where $\mathrm{d}\Omega$ is the solid angle (ISO 80000-3:2006, item 3-6) of each elementary beam passing through the given point and L_v its luminance (item 7-37) at that point in the direction of the beam	Spherical illuminance is equal to quotient of the total luminous flux Φ_v (item 7-32) incident on a small sphere by the cross section area of that sphere. See the Introduction, 0.5.1, and the Remarks in item 7-13. For the analogous radiant quantity, see item 7-16.
7-39 (—)	luminous spherical exposure, luminous fluence *fr exposition* (f) *sphérique lumineuse,* *fluence* (f) *lumineuse*	$H_{\mathrm{v},0}$	time integral of the spherical illuminance $E_{\mathrm{v},0}$ (item 7-38) over the given duration Δt (ISO 80000-3:2006, item 3-7), thus $H_{\mathrm{v},0} = \int_0^{\Delta t} E_{\mathrm{v},0}(t)\, \mathrm{d}t$	For the analogous radiant quantity, see item 7-17.
7-40 (*6-33*)	luminous exitance *fr exitance* (f) *lumineuse*	M_v, (M)	at a point on a surface, the luminous flux $\mathrm{d}\Phi_\mathrm{v}$ (item 7-32) leaving an element of the surface, divided by the area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-6) of that element, thus $M_\mathrm{v} = \frac{\mathrm{d}\Phi_\mathrm{v}}{\mathrm{d}A}$	$M_\mathrm{v} = \int_0^\infty M_\lambda(\lambda) K(\lambda)\, \mathrm{d}\lambda$ See item 7-31 for $K(\lambda)$. See the Introduction, 0.5.1. For the analogous radiant quantity, see item 7-18. For the analogous photon quantity, see item 7-53.
7-41 (*6-35*)	luminous exposure *fr exposition* (f) *lumineuse,* *lumination* (f)	H_v, (H)	time integral of illuminance E_v (item 7-36) during the duration Δt (ISO 80000-3:2006, item 3-7), thus $H_\mathrm{v} = \int_0^{\Delta t} E_\mathrm{v}(t)\, \mathrm{d}t$	Formerly called quantity of illumination or light exposure. Luminous exposure is equal to the quotient of luminous energy $\mathrm{d}Q_\mathrm{v}$ (item 7-34) incident on an element of the surface over given duration, by the area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-6) of that element, i.e. $H_\mathrm{v} = \mathrm{d}Q_\mathrm{v}/\mathrm{d}A$ For the analogous radiant quantity, see item 7-20. For the analogous photon quantity, see item 7-55. For scotopic vision, see 0.5.4.

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-38.a	lux	lx		
7-39.a	lux second	lx·s		
7-39.b	lux hour	lx·h		1 lx · h = 3 600 lx · s
7-40.a	lumen per square metre	$lm \cdot m^{-2}$		
7-41.a	lux second	lx·s		
7-41.b	lux hour	lx·h		1 lx · h = 3 600 lx · s

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-42 (—)	colour stimulus function, relative colour stimulus function *fr courbe* (f) *d'un stimulus de couleur*, *courbe* (f) *relative d'un stimulus de couleur*	$\varphi_\lambda(\lambda)$	$\varphi_\lambda(\lambda) = X_\lambda(\lambda)/R$ where $X_\lambda(\lambda)$ is the spectral distribution of a radiometric quantity $X(\lambda)$, such as radiance (item 7-15) or radiant flux (item 7-13), as a function of wavelength (item 7-3.2), and R is a fixed reference value	
7-43 (—)	tristimulus values *fr composantes* (f) *trichromatiques*	X, Y, Z; X_{10}, Y_{10}, Z_{10}	amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered. For a given colour stimulus described by the colour stimulus function $\varphi_\lambda(\lambda)$ of a radiometric quantity, $X = k \int_0^\infty \varphi_\lambda(\lambda)\bar{x}(\lambda)\,\mathrm{d}\lambda$ $Y = k \int_0^\infty \varphi_\lambda(\lambda)\bar{y}(\lambda)\,\mathrm{d}\lambda$ $Z = k \int_0^\infty \varphi_\lambda(\lambda)\bar{z}(\lambda)\,\mathrm{d}\lambda$ where $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are the CIE colour matching functions (item 7-44), and analogous expressions are for X_{10}, Y_{10}, Z_{10}.	X, Y, Z are in the 1931 CIE colorimetric system. X_{10}, Y_{10}, Z_{10} are in the 1964 CIE colorimetric system. For sources, k may be chosen as $k = K_\mathrm{m}$ where K_m is maximum luminous spectral efficacy (item 7-29). For object colours, $\varphi_\lambda(\lambda)$ is given by one of the three products $\varphi_\lambda(\lambda) = S_\lambda(\lambda) \cdot \begin{cases} \rho(\lambda) \\ \tau(\lambda) \\ \beta(\lambda) \end{cases}$ where $S_\lambda(\lambda)$ is the relative spectral distribution of a quantity characterizing the source illuminating the object, $\rho(\lambda)$ is luminous reflectance (item 7-47.2), $\tau(\lambda)$ is luminous transmittance (item 7-47.3), $\beta(\lambda)$ is luminous factor (item 7-48), and k is chosen to be $k = 100/\int_0^\infty S_\lambda(\lambda)\bar{y}(\lambda)\,\mathrm{d}\lambda$

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-42.a	one	1		
7-43.a	See Remarks		$[X] = [Y] = [Z] = [k] \cdot \mathrm{m}$	For more information, see e.g. Reference [3].

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-44 (*6-38*)	CIE colour-matching functions *fr fonctions* (f) *colorimétrique CIE*	$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$; $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$	tristimulus values of monochromatic stimuli of equal radiant power	Values of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are defined in the 1931 CIE colorimetric system (2° observer) — applicable to fields of observation of angular opening from 1° to 4°. The “CIE 1931 colour space” was created by the International Commission on Illumination (CIE) in 1931. Values of $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ are defined in the 1964 CIE colorimetric system (10° observer) — applicable to fields of observation with angles greater than 4°.
7-45 (*6-39*)	chromaticity coordinates *fr coordonnées* (f) *trichromatiques*	x, y, z; x_{10}, y_{10}, z_{10}	ratio of each of a set of three tristimulus values to their sum, thus $x = X/(X + Y + Z)$, $y = Y/(X + Y + Z)$, $z = Z/(X + Y + Z)$ and similar expressions apply to x_{10}, y_{10}, z_{10}	Values of x, y, z are in the 1931 CIE colorimetric system (2° observer). Values of x_{10}, y_{10}, z_{10} are in the 1964 CIE colorimetric system (10° observer). Since $x + y + z = 1$, two variables x, y are sufficient to express chromaticity.
7-46 (—)	colour temperature *fr température* (f) *de couleur*	T_c	temperature of a blackbody whose radiation has the same chromaticity coordinates (item 7-45)	

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-44.a	one	1		See the Introduction, 0.3.2.
7-45.a	one	1		See the Introduction, 0.3.2.
7-46.a	kelvin	K		

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-47.1 (—)	luminous absorptance *fr facteur* (m) *d'absorption lumineuse, absorptance* (f) *lumineuse*	α_v	ratio of the absorbed luminous flux $\varPhi_\mathrm{v,a}$ (item 7-32) to the luminous flux $\varPhi_\mathrm{v,m}$ (item 7-32) of the incident radiation, thus $\alpha_\mathrm{v} = \varPhi_\mathrm{v,a}/\varPhi_\mathrm{v,m}$	From the spectral reflectance $\rho(\lambda)$ (item 7-22.2), luminous reflectance is given by $\rho_\mathrm{v} = \dfrac{\int_0^\infty \rho(\lambda)\varPhi_\lambda(\lambda)V(\lambda)\,\mathrm{d}\lambda}{\int_0^\infty \varPhi_\lambda(\lambda)V(\lambda)\,\mathrm{d}\lambda}$ where $\varPhi_\lambda(\lambda)$ is the spectral radiant flux (or relative spectral distribution) of the source, and $V(\lambda)$ is the spectral luminous efficiency (item 7-28). Similar expressions for luminous absorptance and transmittance apply. See also items 7-22.1, 7-22.2 and 7-22.3.
7-47.2 (—)	luminous reflectance *fr facteur* (m) *de réflexion lumineuse, réflectance* (f) *lumineuse*	ρ_v	ratio of the reflected luminous flux $\varPhi_\mathrm{v,r}$ (item 7-32) to the luminous flux $\varPhi_\mathrm{v,m}$ (item 7-32) of the incident radiation, thus $\rho_\mathrm{v} = \varPhi_\mathrm{v,r}/\varPhi_\mathrm{v,m}$	
7-47.3 (—)	luminous transmittance *fr facteur* (m) *de transmission lumineuse, transmittance* (f) *lumineuse*	τ_v	ratio of the transmitted luminous flux $\varPhi_\mathrm{v,t}$ (item 7-32) to the luminous flux $\varPhi_\mathrm{v,m}$ (item 7-32) of the incident radiation, thus $\tau_\mathrm{v} = \varPhi_\mathrm{v,t}/\varPhi_\mathrm{v,m}$	
7-48 (—)	luminance factor *fr facteur* (m) *de luminance*	β, (β_v)	ratio of the luminance $L_\mathrm{v,n}$ (item 7-37) of the surface element in the given direction to the luminance $L_\mathrm{v,d}$ of a perfect reflecting or transmitting diffuser identically illuminated, thus $\beta = L_\mathrm{v,n}/L_\mathrm{v,d}$	This quantity is also defined spectrally and called the spectral luminance factor. Luminance factor can be calculated from spectral radiance factor $\beta(\lambda)$ (item 7-24.1) using similar equation as given in the Remarks for item 7-47. For the analogous radiant quantity, see item 7-24.1.
7-49 (*6-22*)	photon number *fr nombre* (m) *de photons*	N_p, (Q_p)	for monochromatic radiation of frequency ν (item 7-1), $N_\mathrm{p} = Q/h\nu$ where Q is radiant energy (item 7-6), and h is the Planck constant (ISO 80000-10:—, item 10-5.1)	At low energies, the number of photons is considered to be an average. Symbol ν is Greek letter nu.

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-47.a	one	1		See the Introduction, 0.3.2.
7-48.a	one	1		See the Introduction, 0.3.2.
7-49.a	one	1		See the Introduction, 0.3.2.

(continued)

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-50 (*6-23*)	photon flux *fr flux* (m) *photonique*	Φ_p, Φ	quotient of the number dN_p of photons (item 7-49) emitted, transmitted, or received in a time interval, by its duration dt (ISO 80000-3:2006, item 3-7), thus $\Phi_\mathrm{p} = \mathrm{d}N_\mathrm{p}/\mathrm{d}t$	The photon flux Φ_p is related to the spectral radiant power $\Phi_\lambda(\lambda)$ by $\Phi_\mathrm{p} = \int \Phi_\lambda(\lambda) \frac{\lambda}{hc_0}\,\mathrm{d}\lambda$ where h is the Planck constant (ISO 80000-10:—, item 10-6.1), and c_0 is the speed of light in vacuum (item 7-4.1). For the analogous radiant quantity, see item 7-13. For the analogous visible quantity, see item 7-32.
7-51 (*6-24*)	photon intensity *fr intensité* (f) *photonique*	I_p, I	in a given direction from a source, the photon flux dΦ_p (item 7-50) leaving the source, or an element of the source, in an elementary cone containing the given direction, divided by the solid angle dΩ (ISO 80000-3:2006, item 3-6) of that cone, thus $I_\mathrm{p} = \mathrm{d}\Phi_\mathrm{p}/\mathrm{d}\Omega$	For the analogous radiant quantity, see item 7-14. For the analogous visible quantity, see item 7-35.
7-52 (*6-25*)	photon luminance, photon radiance *fr luminance* (f) *photonique*	L_p, L	at a point on a surface and in a given direction, the photon intensity dI_p (item 7-51) of an element of the surface, divided by the area dA (ISO 80000-3:2006, item 3-3) of the orthogonal projection of this element on a plane perpendicular to the given direction, thus $L_\mathrm{p} = \mathrm{d}I_\mathrm{p}/\mathrm{d}A$	For the analogous radiant quantity, see item 7-15. For the analogous visible quantity, see item 7-37.
7-53 (*6-26*)	photon exitance *fr exitance* (f) *photonique*	M_p, M	at a point on a surface, the photon flux dΦ_p (item 7-50) leaving an element of the surface, divided by the area dA (ISO 80000-3:2006, item 3-3) of that element, thus $M_\mathrm{p} = \mathrm{d}\Phi_\mathrm{p}/\mathrm{d}A$	For the analogous radiant quantity, see item 7-18. For the analogous visible quantity, see item 7-40.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-50.a	second to the power minus one	s^{-1}		
7-51.a	second to the power minus one per steradian	$s^{-1} \cdot sr^{-1}$		
7-52.a	second to the power minus one per steradian metre squared	$s^{-1} \cdot sr^{-1} \cdot m^{-2}$		
7-53.a	second to the power minus one per metre squared	$s^{-1} \cdot m^{-2}$		

(continued)

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LIGHT **QUANTITIES**

Item No.	Name	Symbol	Definition	Remarks
7-54 (*6-27*)	photon irradiance *fr éclairement* (m) *photonique*	E_p, E	at a point on a surface, the photon flux $\mathrm{d}\Phi_\mathrm{p}$ (item 7-50) incident on an element of the surface, divided by the area $\mathrm{d}A$ (ISO 80000-3:2006, item 3-3) of that element, thus $E_\mathrm{p} = \mathrm{d}\Phi_\mathrm{p}/\mathrm{d}A$	For the analogous radiant quantity, see item 7-19. For the analogous visible quantity, see item 7-36.
7-55 (*6-28*)	photon exposure *fr exposition* (f) *photonique*	H_p, H	time integral of photon irradiance E_p (item 7-54) during the duration Δt (ISO 80000-3:2006, item 3-7), thus $H_\mathrm{p} = \int_0^{\Delta t} E_\mathrm{p}\,\mathrm{d}t$	For the analogous radiant quantity, see item 7-20. For the analogous visible quantity, see item 7-41.
7-56 (*6-18*)	Stefan-Boltzmann constant *fr constante* (f) *de Stefan-Boltzmann*	σ	constant σ in the expression for the radiant exitance (item 7-18) of a blackbody at thermodynamic temperature T (ISO 80000-5:2007, item 5-1), thus $M = \sigma T^4$	$\sigma =$ 5,670 400(40) $\times$ 10^{-8} W · m^{-2} · K^{-4} See CODATA 2006[4]. Further, $\sigma = \dfrac{2\pi^5 k^4}{15 h^3 c_0^2}$ where k is the Boltzmann constant (ISO 80000-9:—, item 9-37), h is the Planck constant (ISO 80000-10:—, item 10-6.1) and c_0 is the speed of light in vacuum (item 7-4.1).
7-57 (*6-19*)	first radiation constant *fr première constante* (f) *de rayonnement*	c_1	constants c_1 and c_2 in the expression for the spectral radiant exitance (item 7-18) of a blackbody at the thermodynamic temperature T (ISO 80000-5:2007, item 5-1), thus $M_\lambda(\lambda) = c_1 f(\lambda, T) = c_1 \dfrac{\lambda^{-5}}{\exp(c_2 \lambda^{-1} T^{-1}) - 1}$	$c_1 =$ 3,741 771 18(19) $\times$ 10^{-16} W · m^2 $c_2 =$ 1,468 775 2(25) $\times$ 10^{-2} m · K See CODATA 2006[4]. Further, $c_1 = 2\pi h c_0^2$, and $c_2 = h c_0/k$ where k is the Boltzmann constant (ISO 80000-9:—, item 9-37), h is the Planck constant (ISO 80000-10:—, item 10-6.1) and c_0 is the speed of light in vacuum (item 7-4.1). The name “first radiation constant” has also been used for the factors $8\pi h c_0$ and $h c_0^2$ in the corresponding expressions for w_λ and $L_\lambda(\lambda)$ (see Remarks in items 7-13 and 7-15)
7-58 (*6-20*)	second radiation constant *fr seconde constante* (f) de *rayonnement*	c_2		

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UNITS				**LIGHT**
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-54.a	second to the power minus one per metre squared	$s^{-1} \cdot m^{-2}$		
7-55.a	metre to the power minus two	m^{-2}		
7-56.a	watt per metre squared kelvin to the power four	$W \cdot m^{-2} \cdot K^{-4}$		
7-57.a	watt metre squared	$W \cdot m^{2}$		
7-58.a	metre kelvin	$m \cdot K$		

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LIGHT				**QUANTITIES**
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
7-59.1 (*6-45.1*)	object distance *fr distance* (f) *de l'objet*	p	for a centred optical system, distance (ISO 80000-3:2006, item 3-1.9) from a given object to the closest surface of the centred optical system	Distances are taken positive in the direction of the light flow and negative in the opposite distance. Then, for a thin lens, $f' = -f$ and $\frac{1}{p'} - \frac{1}{p} = \frac{1}{f}$ When $f' = -f$, the absolute value $\|f\|$ is often called focal distance.
7-59.2 (*6-45.2*)	image distance *fr distance* (f) *de l'image*	p'	for a centred optical system, distance (ISO 80000-3:2006, item 3-1.9) from an image of the given object to the closest surface of the centred optical system	
7-59.3 (—)	object focal distance *fr distance* (f) *focale de l'objet*	f	for a centred optical system, distance (ISO 80000-3:2006, item 3-1.9) from the focal point at the object side to the closest surface of the centred optical system	
7-59.4 (—)	image focal distance *fr distance* (f) *focale de l'image*	f'	for a centred optical system, distance (ISO 80000-3:2006, item 3-1.9) from the focal point at the image side to the closest surface of the centred optical system	
7-60 (*6-46*)	lens power *fr vergence* (f)	φ	algebraic quantity characterizing the focusing properties of an optical system, thus $\varphi = 1/f$ where f is the object focal distance (item 7-59.3)	
7-61 (—)	degree of linear polarization *fr degré* (m) *de polarisation rectiligne*	P	$P = (I_0 - I_1)/(I_0 + I_1)$ where I_0 is the radiant intensity (item 7-14) or the luminous intensity (item 7-35) observed through an ideal polarizer when the polarizer is set so that the intensity transmitted is maximal, and I_1 is the intensity when the polarizer is set perpendicular to that direction.	The degree of circular polarization can be observed behind a $\lambda/4$ plate.

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UNITS				LIGHT
Item No.	**Name**	**Symbol**	**Definition**	**Conversion factors and remarks**
7-59.a	metre	m		
7-60.a	metre to the power minus one	m^{-1}		In optics, diopter D is often used: $1\ D := 1\ m^{-1}$.
7-61.a	one	1		See the Introduction, 0.3.2.

(concluded)

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