INTERNATIONAL STANDARD

ISO 80000-7

Second edition
2019-08

Quantities and units —

Part 7:
Light and radiation

Grandeurs et unités —

Partie 7: Lumière et rayonnements

Reference number
ISO 80000-7:2019(E)

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Published in Switzerland

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Foreword

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

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

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

This second edition cancels and replaces the first edition (ISO 80000-7:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the table giving the quantities and units has been simplified;

— some definitions and the remarks have been stated physically more precisely.

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

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

Introduction — Special remarks

0.1 Quantities

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

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 among these quantities might otherwise occur.

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

Several of the quantities in ISO 80000-7 can be defined for monochromatic radiation, i.e. radiation of a single frequency ν only. They are denoted by their reference quantity as an argument like $q(\nu)$. An example is speed of light in a medium $c(\nu)$, or the refractive index in a medium $n(\nu) = c_0/c(\nu)$ Some of those quantities are derivatives

$$q'(\lambda)=\frac{\mathrm{d}q(\lambda)}{\mathrm{d}\lambda}=\lim_{\Delta\lambda\to 0}\frac{q(\lambda+\Delta\lambda)-q(\lambda)}{\Delta\lambda}$$

of a quantity which are also frequently described as fractions $\Delta q(\lambda)$ of a quantity q corresponding to the radiation with wavelength in the interval $[\lambda,\lambda+\Delta\lambda]$ divided by the range $\Delta\lambda$ of that interval to point to the physical measurement process behind. Such fractions must be additive so that the integral yields the overall quantity, e.g. radiance (item 7-6.1) and spectral radiance (item 7-6.2). These derivatives of quantities are called spectral quantities and are denoted by subscript λ.

On the other hand, some multidimensional quantities like radiant intensity $I_\mathrm{e}(\vartheta,\varphi)$, irradiance $E_\mathrm{e}(x,y)$, radiance $L_\mathrm{e}(x,y,\vartheta,\varphi)$, etc., are quantities that are strictly defined as values of a derivative at a certain point, a certain direction or at a certain point and direction in space. Hence, the most fundamental definition according to ISO 80000-2 would be e.g. in case of the most complex term "radiance" (item 7-6.1):

"at a given point (x_1,y_1) of a real or imaginary surface, in a given direction (ϑ_1,φ_1),

$$L_\mathrm{e}(x,y,\vartheta,\varphi)=\frac{\partial^2\Phi_\mathrm{e}(x,y,\vartheta,\varphi)}{\partial A(x,y)\cdot\cos\varepsilon\cdot\partial\Omega(\vartheta,\varphi)}=\left(\frac{\partial^2\Phi_\mathrm{e}}{\partial A\cdot\cos\varepsilon\cdot\partial\Omega}\right)_{\substack{x=x_1\\ y=y_1\\ \vartheta=\vartheta_1\\ \varphi=\varphi_1}}$$

where $\Phi_\mathrm{e}(x,y,\vartheta,\varphi)$ represents the radiant flux transmitted through an area $A(x,y)$ at a given point (x_1,y_1) and propagating in a given direction (ϑ_1,φ_1), and ε is the angle between the normal $\overline{A(x_1,y_1)}$ to that area at the given point and the given direction (ϑ_1,φ_1)".

To ease the use of the table in Clause 3, the simplified definitions (like item 7-6.1 in case of radiance) are used which assume that fractions of quantities are always isotropic and uniform and continuous. In this case, the given definitions are equivalent to the fundamental approach given above.

Instead of frequency ν, other reference quantities of light may be used: angular frequency $\omega=2\pi\nu$, wavelength in a medium $\lambda=c_0/(n\nu)$, 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 $n(\lambda = 555\text{ nm}) \approx 1{,}333$.

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

$$dq = q_\nu(\nu) d\nu = q_\omega(\omega) d\omega = q_{\tilde{\nu}}(\tilde{\nu}) d\tilde{\nu} = q_\lambda(\lambda) d\lambda = q_\sigma(\sigma) d\sigma$$

thus

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

From the theoretical point of view, the frequency ν is the more fundamental reference quantity, keeping its value when a light beam passes through media with different refractive index, n. For historical reasons, the wavelength, λ, is still mostly used as a reference quantity as it had been the most accurately measured quantity in the past. In this respect, spectral quantities, as the spectral radiance (item 7-6.2), $L_{e,\lambda}(\lambda)$, have the meaning of spectral "densities" corresponding to the respective integrated quantities – i.e. in the case of radiance, $L_e(\lambda)$ (item 7-6.1),

$$L_{e,\lambda} = \frac{\partial L_e}{\partial \lambda}$$

0.2 Units

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

0.3 Photopic quantities

In the great majority of instances, photopic vision (provided by the cones in the human visual system 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 International Commission on Illumination (CIE) in 1924. These values were adopted by the International Committee for Weights and Measures (CIPM) (see BIPM Monograph in Reference [11]).

0.4 Scotopic quantities

For scotopic vision (provided by the rods and used for vision at night), corresponding quantities are defined in the same manner as the photopic ones (items 7-10 to 7-18), using symbols with a prime.

For the term "spectral luminous efficiency" (item 7-10.2), 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[11]."

For the term "maximum luminous efficacy" (item 7-11.3), the definition would read:

> "<for scotopic vision> maximum value of the spectral luminous efficacy for scotopic vision"

In the Remark it would read:

"The value is calculated by

$$K'_{\mathrm{m}} = \frac{683\ \mathrm{lm\ W^{-1}}}{V'(\lambda_{\mathrm{cd}})} \approx 1\,700\ \mathrm{lm\ W^{-1}}$$

where $V'(\lambda)$ is the spectral luminous efficiency in terms of wavelength λ for scotopic vision and λ_{cd} is the wavelength in air corresponding to the frequency $540 \cdot 10^{12}$ Hz given in the definition of the SI unit candela."

0.5 Mesopic quantities

For mesopic vision (provided by the rods and cones and used for vision intermediate between photopic and scotopic vision), corresponding quantities are defined in the same manner as the photopic ones (items 7-10 to 7-18), using symbols with the subscript "mes".

For the term "spectral luminous efficiency" (item 7-10.2), the remarks would read:

"Standard values of spectral luminous efficiency functions $V_{\mathrm{mes}}(\lambda)$ for mesopic vision depend on the used adaptation level *m* and were originally recommended by CIE in 2010[12]. They are adopted by the CIPM[11]."

For the term "maximum luminous efficacy" (item 7-11.3), the definition would read:

"<for mesopic vision> adaptation level *m* dependent maximum value of the spectral luminous efficacy for mesopic vision"

In the Remark it would read:

"The value is calculated by

$$K_{\mathrm{m,mes};m} = \frac{683\ \mathrm{lm\ W^{-1}}}{V_{\mathrm{mes};m}(\lambda_{\mathrm{cd}})}$$

where $V_{\mathrm{mes};m}(\lambda)$ is the spectral luminous efficiency for mesopic vision at an adaptation level *m* and λ_{cd} is the wavelength in air corresponding to the frequency $540 \cdot 10^{12}$ Hz given in the definition of the SI unit candela."

Quantities and units —

Part 7:
Light and radiation

1 Scope

This document gives names, symbols, definitions and units for quantities used for light and optical radiation in the wavelength range of approximately 1 nm to 1 mm. Where appropriate, conversion factors are also given.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

Names, symbols, definitions and units for quantities used in light and optical radiation in the wavelength range of approximately 1 nm to 1 mm are given in Table 1.

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

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

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

In the field of light, the CIE maintains the Electronic international lighting vocabulary, available at http://eilv.cie.co.at/.

Table 1 — Quantities and units used in light and optical radiation in the wavelength range of approximately 1 nm to 1 mm

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-1.1	speed of light in a medium	c	phase speed of an electromagnetic wave at a given point in a medium	m s^{-1}	See also ISO 80000-3. The value of the speed of light in a medium can depend on the frequency, polarization, and direction. For the definition of the speed of electromagnetic waves in vacuum, c_0, see ISO 80000-1.
7-1.2	refractive index	n	quotient of speed of light in vacuum (ISO 80000-1) and speed of light in a medium (item 7-1.1)	1	The value of the refractive index can depend on the frequency, polarization, and direction. The refractive index is expressed by $n = c_0/c$, where c_0 is the speed of light in vacuum and c is the speed of light in the medium. For a medium with absorption, the complex refractive index $\underline{n}$ is defined by $\underline{n} = n + \mathrm{i}k$ where k is spectral absorption index (IEC 60050-845) and i is imaginary unit. The refractivity is expressed by n −1, where n is refractive index.
7-2.1	radiant energy <electromagnetism>	Q_e, W, U (Q)	energy (ISO 80000-5) emitted, transferred or received in form of electromagnetic waves	J kg m^2 s^{-2}	Radiant energy can be expressed by the time integral of radiant flux (item 7-4.1), Φ_e, over a given duration (ISO 80000-3), Δt $Q_e = \int_{\Delta t} \Phi_e \mathrm{d}t$ Radiant energy is expressed either as a function of wavelength (ISO 80000-3), λ, as a function of frequency (ISO 80000-3), ν, or as a function of wavenumber, σ. (See also 0.1.) The corresponding photometric quantity is “luminous energy” (item 7-12). The corresponding quantity for photons is “photon energy” (item 7-19.2).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-2.2	spectral radiant energy	$Q_{e,\lambda}$, W_λ, U_λ (Q_λ)	spectral density of radiant energy, expressed by $Q_{e,\lambda}=\frac{dQ_e}{d\lambda}$ where Q_e is radiant energy (item 7-2.1) in terms of wavelength λ (ISO 80000-3)	J/nm kg m s^{-2}	The integral of (total) radiant energy is determined by the wavelength interval (λ_1, λ_2) under consideration: $Q_e=\int_{\lambda_1}^{\lambda_2} Q_{e,\lambda} d\lambda$
7-3.1	radiant energy density	w (ρ_e)	volumetric density of radiant energy, expressed by $w=\frac{dQ_e}{dV}$ where Q_e is radiant energy (item 7-2.1) in an elementary three-dimensional domain and V is the volume (ISO 80000-3) of that domain	J/m^3 kg m^{-1} s^{-2}	Radiant energy density within a Planckian radiator is given by $w=\frac{4\sigma}{c_0}T^4$ where σ is the Stefan-Boltzmann constant (ISO 80000-1), c_0 is speed of light in vacuum (ISO 80000-1) and T is thermodynamic temperature (ISO 80000-5).
7-3.2	spectral radiant energy density in terms of wavelength	w_λ	change of radiant energy density with wavelength, expressed by $w_\lambda=\frac{dw}{d\lambda}$ where w is radiant energy density (item 7-3.1) as a function of wavelength λ (ISO 80000-3)	J/(m^3 nm) kg m^{-2} s^{-2}	Spectral radiant energy density within a Planckian radiator is given by $w_\lambda = 8\pi hc_0 \cdot f(\lambda, T)$, where h is the Planck constant (ISO 80000-1), c_0 is speed of light in vacuum (ISO 80000-1), T is thermodynamic temperature (ISO 80000-5) and $f(\lambda,T)=\frac{\lambda^{-5}}{\exp\left(c_2\lambda^{-1}T^{-1}\right)-1}$ For the radiation constant c_2 in $f(\lambda, T)$, see ISO 80000-1.
7-3.3	spectral radiant energy density in terms of wavenumber	$w_{\tilde{\nu}}$, $\rho_{\tilde{\nu}}$	change of radiant energy density with wavenumber, expressed by $w_{\tilde{\nu}}=\frac{dw}{d\tilde{\nu}}$ where w is radiant energy density (item 7-3.1) as a function of wavenumber $\tilde{\nu}$ (ISO 80000-3)	J/m^2 kg s^{-2}	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-4.1	radiant flux, radiant power	Φ_e, P_e (Φ, P)	change in radiant energy with time, expressed by $\Phi_e = \frac{dQ_e}{dt}$ where Q_e is the radiant energy (item 7-2.1) emitted, transferred or received and t is time (ISO 80000-3)	W kg m^2 s^{-3}	The corresponding photometric quantity is "luminous flux" (item 7-13). The corresponding quantity for photons is "photon flux" (item 7-20).
7-4.2	spectral radiant flux, spectral radiant power	$\Phi_{e,\lambda}$, $P_{e,\lambda}$ (Φ_λ, P_λ)	spectral density of radiant flux, expressed by $\Phi_{e,\lambda} = \frac{d\Phi_e}{d\lambda}$ where Φ_e is radiant flux (item 7-4.1) in terms of wavelength λ (ISO 80000-3)	W/nm kg m s^{-3}	The integral of (total) radiant flux is determined by the wavelength interval (λ_1, λ_2) under consideration: $\Phi_e = \int_{\lambda_1}^{\lambda_2} \Phi_{e,\lambda} d\lambda$
7-5.1	radiant intensity	I_e (I)	density of radiant flux with respect to solid angle in a specified direction, expressed by $I_e = \frac{d\Phi_e}{d\Omega}$ where Φ_e is the radiant flux (item 7-4.1) emitted in a specified direction, and Ω is the solid angle (ISO 80000-3) containing that direction	W/sr kg m^2 s^{-3} sr^{-1}	The definition holds strictly only for a point source. The distribution of the radiant intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the radiant flux (item 7-4.1) within a certain solid angle (ISO 80000-3), Ω, of a source: $\Phi_e = \iint_\Omega I_e(\vartheta, \varphi) \sin\vartheta d\varphi d\vartheta$ The corresponding photometric quantity is "luminous intensity" (item 7-14). The corresponding quantity for photons is "photon intensity" (item 7-21).
7-5.2	spectral radiant intensity	$I_{e,\lambda}$ (I_λ)	spectral density of radiant intensity, expressed by $I_{e,\lambda} = \frac{dI_e}{d\lambda}$ where I_e is radiant intensity (item 7-5.1) in terms of wavelength λ (ISO 80000-3)	W/(sr nm) kg m s^{-3} sr^{-1}	The integral of (total) radiant intensity is determined by the wavelength interval (λ_1, λ_2) under consideration: $I_e = \int_{\lambda_1}^{\lambda_2} I_{e,\lambda} d\lambda$

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-6.1	radiance	L_e (L)	density of radiant intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface, expressed by $L_e = \frac{dI_e}{dA} \frac{1}{\cos\alpha}$ where I_e is radiant intensity (item 7-5.1), A is area (ISO 80000-3), and α is the angle between the normal to the surface at the specified point and the specified direction	W/(sr m^2) kg s^{-3} sr^{-1}	See also 0.1. For Planckian radiation, $L_e = \frac{\sigma}{\pi} T^4$ where T is thermodynamic temperature (ISO 80000-5) and σ is the Stefan-Boltzmann constant (ISO 80000-1). The corresponding photometric quantity is "luminance" (item 7-15). The corresponding quantity for photons is "photon radiance" (item 7-22).
7-6.2	spectral radiance	$L_{e,\lambda}$ (L_λ)	density of radiance with respect to wavelength, expressed by $L_{e,\lambda} = \frac{dL_e}{d\lambda}$ where L_e is radiance (item 7-6.1) in terms of wavelength λ (ISO 80000-3)	W/(sr m^2 nm) kg m^{-1} s^{-3} sr^{-1}	For Planckian radiation, $L_{e,\lambda}(\lambda) = \frac{c(\lambda)}{4\pi} \omega_\lambda(\lambda) = hc_0^2 \cdot f(\lambda, T)$ where $c(\lambda)$ is phase speed (ISO 80000-3) of electromagnetic radiation of a wavelength (ISO 80000-3) λ in a given medium, $\omega_\lambda(\lambda)$ is spectral radiant energy density in terms of wavelength, c_0 is speed of light in vacuum (ISO 80000-1), h is the Planck constant (ISO 80000-1), and $f(\lambda, T) = \frac{\lambda^{-5}}{\exp(c_2 \lambda^{-1} T^{-1}) - 1}$ where the radiation constant $c_2 = hc/k$. The integral of (total) radiance is determined by the wavelength interval (λ_1, λ_2) under consideration: $L_e = \int_{\lambda_1}^{\lambda_2} L_{e,\lambda} d\lambda$

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-7.1	irradiance	E_e (E)	density of incident radiant flux with respect to area at a point on a real or imaginary surface, expressed by $E_e = \frac{d\Phi_e}{dA}$ where Φ_e is radiant flux (item 7-4.1) and A is the area (ISO 80000-3) on which the radiant flux is incident	W/m^2 kg s^{-3}	The corresponding photometric quantity is "illuminance" (item 7-16). The corresponding quantity for photons is "photon irradiance" (item 7-23). The quantity "spherical irradiance" is defined by the mean value of irradiance on the outer curved surface of a very small (real or imaginary) sphere at a point in space. It can be expressed by $E_{e,0} = \int_{4\pi} L_e d\Omega$ where Ω is solid angle (ISO 80000-3) and L_e is radiance (item 7-6.1). (See CIE DIS 017/E:2016, term 17-21-054.) It can be expressed by the quotient of the radiant flux (item 7-4.1) of all the radiation incident on the outer surface of an infinitely small sphere centred at the specified point and the area (ISO 80000-3) of the diametrical cross-section of that sphere. Spherical irradiance is also called "fluence rate" or "radiant fluence rate". The corresponding photometric quantity to spherical irradiance is called "spherical illuminance".
7-7.2	spectral irradiance	$E_{e,\lambda}$ (E_λ)	density of irradiance with respect to wavelength, expressed by $E_{e,\lambda} = \frac{dE_e}{d\lambda}$ where E_e is irradiance (item 7-7.1) in terms of wavelength λ (ISO 80000-3)	W/(m^2 nm) kg m^{-1} s^{-3}	The integral of (total) irradiance is determined by the wavelength interval (λ_1, λ_2) under consideration: $E_e = \int_{\lambda_1}^{\lambda_2} E_{e,\lambda} d\lambda$

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-8.1	radiant exitance DEPRECATED: radiant emittance	M_e (M)	density of exiting radiant flux with respect to area at a point on a real or imaginary surface, expressed by $M_e = \frac{d\Phi_e}{dA}$ where Φ_e is radiant flux (item 7-4.1) and A is the area (ISO 80000-3) from which the radiant flux leaves	W/m² kg s^{-3}	For Planckian radiation, $M_e = \sigma T^4$ where T is thermodynamic temperature (ISO 80000-5) and σ is the Stefan-Boltzmann constant (ISO 80000-1). The corresponding photometric quantity is "luminous exitance" (item 7-17). The corresponding quantity for photons is "photon exitance" (item 7-24).
7-8.2	spectral radiant exitance	$M_{e,\lambda}$ (M_λ)	density of radiant exitance with respect to wavelength, expressed by $M_{e,\lambda} = \frac{dM_e}{d\lambda}$ where M_e is radiant exitance (item 7-8.1) in terms of wavelength λ (ISO 80000-3)	W/(m² nm) kg m^{-1} s^{-3}	The integral of (total) radiant exitance is determined by the wavelength interval (λ_1, λ_2) under consideration: $M_e = \int_{\lambda_1}^{\lambda_2} M_{e,\lambda} d\lambda$
7-9.1	radiant exposure	H_e (H)	density of incident radiant energy with respect to area at a point on a real or imaginary surface, expressed by $H_e = \frac{dQ_e}{dA}$ where Q_e is radiant energy (item 7-2.1) and A is the area on which the radiant energy is incident (ISO 80000-3)	J/m² kg s^{-2}	The corresponding photometric quantity is "luminous exposure" (item 7-18). The corresponding quantity for photons is "photon exposure" (item 7-25).
7-9.2	spectral radiant exposure	$H_{e,\lambda}$ (H_λ)	density of radiant exposure with respect to wavelength, expressed by $H_{e,\lambda} = \frac{dH_e}{d\lambda}$ where H_e is radiant exposure (item 7-9.1) in terms of wavelength λ (ISO 80000-3)	J/(m² nm) kg m^{-1} s^{-2}	The integral of (total) radiant exposure is determined by the wavelength interval (λ_1, λ_2) under consideration: $H_e = \int_{\lambda_1}^{\lambda_2} H_{e,\lambda} d\lambda$

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-10.1	luminous efficiency <specified photometric condition>	V	quotient of radiant flux (item 7-4.1) weighted by the spectral luminous efficiency (item 7-10.2) and the corresponding radiant flux for a specified photometric condition	1	Luminous efficiency for photopic vision is expressed by $$V = \frac{\int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) d\lambda}{\int_0^\infty \Phi_{e,\lambda}(\lambda) d\lambda} = \frac{K}{K_m}$$ where $\Phi_{e,\lambda}$ is spectral radiant flux (item 7-4.2), $V(\lambda)$ is spectral luminous efficiency, λ is wavelength, K is luminous efficacy of radiation (item 7-11.1), and K_m is maximum luminous efficacy (item 7-11.3). For scotopic and mesopic vision see 0.4 and 0.5. Symbols for different photometric conditions: V, <for photopic vision>; V', <for scotopic vision>; $V_{mes;m}$, <for mesopic vision>; V_{10}, <for the CIE 10° photopic photometric observer>; V_M, <for the CIE 1988 modified 2° spectral luminous efficiency function for photopic vision>.
7-10.2	spectral luminous efficiency <specified photometric condition>	$V(\lambda)$	quotient of the radiant flux (item 7-4.1) at wavelength λ_m and that at wavelength λ, such that both produce equally intense luminous sensations for a specified photometric condition and λ_m is chosen so that the maximum value of this quotient is equal to 1	1	The spectral luminous efficiency of the human eye depends on a number of factors, particularly the state of visual adaptation and the size and position of the source in the visual field. The photometric condition should be specified (e.g. photopic, scotopic, mesopic). If it is not specified, photopic vision is assumed and the symbol $V(\lambda)$ is used. For scotopic and mesopic vision see 0.4 and 0.5. Symbols for different photometric conditions: $V(\lambda)$, <for photopic vision>; $V'(\lambda)$, <for scotopic vision>; $V_{mes;m}(\lambda)$, <for mesopic vision>; $V_{10}(\lambda)$, <for the CIE 10° photopic photometric observer>; $V_M(\lambda)$, <for the CIE 1988 modified 2° spectral luminous efficiency function for photopic vision>.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-11.1	luminous efficacy of radiation <specified photometric condition>	K	quotient of luminous flux (item 7-13) and the corresponding radiant flux (item 7-4.1) for a specified photometric condition	lm/W cd sr kg^{-1} m^{-2} s^3	Luminous efficacy of radiation for photopic vision is expressed by $K = \frac{\Phi_v}{\Phi_e}$ where Φ_v is luminous flux (item 7-13) and Φ_e is radiant flux (item 7-4.1). For scotopic and mesopic vision see 0.4 and 0.5. Symbols for different photometric conditions: K, <for photopic vision>; K', <for scotopic vision>; $K_{mes;m}$, <for mesopic vision>; K_{10}, <for the CIE 10° photopic photometric observer>; K_M, <for the CIE 1988 modified 2° spectral luminous efficiency function for photopic vision>.
7-11.2	spectral luminous efficacy <specified photometric condition>	$K(\lambda)$	product of spectral luminous efficiency (item 7-10.2) and maximum luminous efficacy (item 7-11.3) for a specified photometric condition	lm/W cd sr kg^{-1} m^{-2} s^3	Spectral luminous efficacy for photopic vision is expressed by $K(\lambda) = K_m V(\lambda)$ where K_m is maximum luminous efficacy (item 7-11.3), $V(\lambda)$ is spectral luminous efficiency (item 7-10.2) and λ is wavelength. For scotopic and mesopic vision see 0.4 and 0.5. Symbols for different photometric conditions: $K(\lambda)$, <for photopic vision>; $K'(\lambda)$, <for scotopic vision>; $K_{mes;m}(\lambda)$, <for mesopic vision>; $K_{10}(\lambda)$, <for the CIE 10° photopic photometric observer>; $K_M(\lambda)$, <for the CIE 1988 modified 2° spectral luminous efficiency function for photopic vision>.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-11.3	maximum luminous efficacy <specified photometric condition>	K_m	maximum value of spectral luminous efficacy for a specified photometric condition	lm/W cd sr kg^{-1} m^{-2} s^3	See also 0.4 and 0.5. The value of maximum luminous efficacy for photopic vision is calculated by $K_m = \frac{683}{V(\lambda_{cd})}$ cd sr W^{-1} ≈ 683 lm W^{-1} where $V(\lambda)$ is the spectral luminous efficiency for photopic vision and λ_{cd} is the wavelength in air corresponding to the frequency $540 \cdot 10^{12}$ Hz specified in the definition of the SI unit candela. Symbols for different photometric conditions: K_m, <for photopic vision>; K'_m, <for scotopic vision>; $K_{m,mes;m}$, <for mesopic vision>; $K_{m,10}$, <for the CIE 10° photopic photometric observer>; $K_{m,M}$, <for the CIE 1988 modified 2° spectral luminous efficiency function for photopic vision>.
7-11.4	luminous efficacy of a source	η_v (η)	quotient of the luminous flux emitted and the power consumed by the source, expressed by $\eta_v = \frac{\Phi_v}{P}$ where Φ_v is luminous flux (item 7-13) and P is the power (ISO 80000-4) consumed by the source	lm/W cd sr kg^{-1} m^{-2} s^3	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-12	luminous energy DEPRECATED: quantity of light	Q_v (Q)	energy of electromagnetic waves weighted by the spectral luminous efficiency (item 7-10.2) multiplied by maximum luminous efficacy (item 7-11.3) of a specified photometric condition	lm s cd sr s	Luminous energy for photopic vision is expressed by $Q_v = K_m \int_0^\infty Q_{e,\lambda}(\lambda)V(\lambda)d\lambda$ where $Q_{e,\lambda}(\lambda)$ is the spectral radiant energy (item 7-2.2) at wavelength λ (ISO 80000-3), $V(\lambda)$ is spectral luminous efficiency (item 7-10.2), and K_m is maximum luminous efficacy (7-11.3). Luminous energy can be emitted, transferred or received. Luminous energy can be expressed by the time integral of the luminous flux (item 7-13), Φ_v, over a given duration (ISO 80000-3), Δt $Q_v = \int_{\Delta t} \Phi_v dt$ The corresponding radiometric quantity is "radiant energy" (item 7-2.1). The corresponding quantity for photons is "photon energy" (item 7-19.2).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-13	luminous flux	Φ_v (Φ)	change in luminous energy with time, expressed by $\Phi_v = \frac{dQ_v}{dt}$ where Q_v is the luminous energy (item 7-12) emitted, transferred or received and t is time (ISO 80000-3)	lm cd sr	Luminous flux is a quantity derived from the radiant flux (item 7-4.1), Φ_e, by evaluating the radiation according to its action upon the CIE standard photometric observer. (See CIE S 017/E:2011, term 17-738.) Luminous flux can be derived from the spectral radiant flux distribution by $\Phi_v = K_m \int_0^\infty \Phi_{e,\lambda}(\lambda) V(\lambda) d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $\Phi_{e,\lambda}(\lambda)$ is spectral radiant flux (item 7-4.2), $V(\lambda)$ is spectral luminous efficiency (item 7-10.2) and λ is wavelength (ISO 80000-3). The corresponding radiometric quantity is "radiant flux" (item 7-4.1). The corresponding quantity for photons is "photon flux" (item 7-20).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-14	luminous intensity	I_v (I)	density of luminous flux with respect to solid angle in a specified direction, expressed by $I_v = \frac{d\Phi_v}{d\Omega}$ where Φ_v is the luminous flux (item 7-13) emitted in a specified direction, and Ω is the solid angle (ISO 80000-3) containing that direction	cd	The definition holds strictly only for a point source. The distribution of the luminous intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ, φ), is used to determine the luminous flux (item 7-13) within a certain solid angle (ISO 80000-3) Ω of a source: $\Phi_v = \iint_{\Omega} I_v(\vartheta, \varphi) \sin\vartheta \, d\varphi \, d\vartheta$ Luminous intensity can be derived from the spectral radiant intensity distribution by $I_v = K_m \int_0^{\infty} I_{e,\lambda}(\lambda) V(\lambda) \, d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $I_{e,\lambda}(\lambda)$ is the spectral radiant intensity (item 7-5.2) at wavelength λ (ISO 80000-3), and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). The corresponding radiometric quantity is “radiant intensity” (item 7-5.1). The corresponding quantity for photons is “photon intensity” (item 7-21).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-15	luminance	L_v (L)	density of luminous intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface, expressed by $L_v = \frac{dI_v}{dA} \frac{1}{\cos\alpha}$ where I_v is luminous intensity (item 7-14), A is area (ISO 80000-3) and α is the angle between the normal to the surface at the specified point and the specified direction	cd m^{-2}	Luminance can be derived from the spectral radiance distribution by $L_v = K_m \int_0^\infty L_{e,\lambda}(\lambda) V(\lambda) d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $L_{e,\lambda}(\lambda)$ is the spectral radiance (item 7-6.2) at wavelength λ (ISO 80000-3), and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). See also 0.1. Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. The corresponding radiometric quantity is "radiance" (item 7-6.1). The corresponding quantity for photons is "photon radiance" (item 7-22).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-16	illuminance	E_v (E)	density of incident luminous flux with respect to area at a point on a real or imaginary surface, expressed by $E_v = \frac{d\Phi_v}{dA}$ where Φ_v is luminous flux (item 7-13) and A is the area (ISO 80000-3) on which the luminous flux is incident	lx cd sr m^{-2}	Illuminance can be derived from the spectral irradiance distribution by $E_v = K_m \int_0^\infty E_{e,\lambda}(\lambda) V(\lambda) d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $E_{e,\lambda}(\lambda)$ is the spectral irradiance (item 7-7.2) at wavelength λ (ISO 80000-3), and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. The corresponding radiometric quantity is “irradiance” (item 7-7.1). The corresponding quantity for photons is “photon irradiance” (item 7-23). The quantity “spherical illuminance” is defined by the mean value of illuminance on the outer curved surface of a very small (real or imaginary) sphere at a point in space. It can be expressed by $E_{v,0} = \int_{4\pi} L_v d\Omega$ where Ω is solid angle (ISO 80000-3) and L_v is luminance (item 7-15). It can be expressed by the quotient of the luminous flux (item 7-13) of all the light incident on the outer surface of an infinitely small sphere centred at the given point, and the area (ISO 80000-3) of the diametrical cross-section of that sphere.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-17	luminous exitance	M_v (M)	density of exiting luminous flux with respect to area at a point on a real or imaginary surface, expressed by $M_v = \frac{d\Phi_v}{dA}$ where Φ_v is luminous flux (item 7-13) and A is the area (ISO 80000-3) from which the luminous flux leaves	lm/m^2 cd sr m^{-2}	Luminous exitance can be derived from the spectral radiant exitance distribution by $M_v = K_m \int_0^\infty M_{e,\lambda}(\lambda) V(\lambda) d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $M_{e,\lambda}(\lambda)$ is the spectral radiant exitance (item 7-8.2) at wavelength λ (ISO 80000-3), and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. The corresponding radiometric quantity is “radiant exitance” (item 7-8.1). The corresponding quantity for photons is “photon exitance” (item 7-24).
7-18	luminous exposure DEPRECATED: quantity of illumination DEPRECATED: light exposure	H_v (H)	density of incident luminous energy with respect to area at a point on a real or imaginary surface, expressed by $H_v = \frac{dQ_v}{dA}$ where Q_v is luminous energy (item 7-12) and A is the area on which the luminous energy is incident (ISO 80000-3)	lx s cd sr m^{-2} s	Luminous exposure can be derived from the spectral radiant exposure distribution by $H_v = K_m \int_0^\infty H_{e,\lambda}(\lambda) V(\lambda) d\lambda$ where K_m is maximum luminous efficacy (item 7-11.3), $H_{e,\lambda}(\lambda)$ is the spectral radiant exposure (item 7-9.2) at wavelength λ (ISO 80000-3), and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. The corresponding radiometric quantity is “radiant exposure” (item 7-9.1). The corresponding quantity for photons is “photon exposure” (item 7-25).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-19.1	photon number, number of photons	N_p	quotient of radiant energy and photon energy, expressed by $N_p = \frac{Q_e}{h\nu}$ where Q_e is radiant energy (item 7-2.1), h is the Planck constant (ISO 80000-1), and ν is the frequency (ISO 80000-3) of the corresponding electromagnetic wave	1	Photon number can also be expressed by the time integral of the photon flux (item 7-20), Φ_p, over a given duration, Δt, $N_p = \int_{\Delta t} \Phi_p \mathrm{d}t$
7-19.2	photon energy	Q_p (Q)	product of the Planck constant and frequency, expressed by $Q_p = h\nu$ where h is the Planck constant (ISO 80000-1) and ν is the frequency (ISO 80000-3) of the corresponding electromagnetic wave	J kg m^2 s^{-2}	Photon energy can be emitted, transferred or received. For monochromatic radiation, photon energy may be expressed by photon number (item 7-19.1). The corresponding radiometric quantity is “radiant energy” (item 7-2.1). The corresponding photometric quantity is “luminous energy” (item 7-12).
7-20	photon flux	Φ_p (Φ)	rate of photon number per time interval, expressed by $\Phi_p = \frac{\mathrm{d}N_p}{\mathrm{d}t}$ where N_p is photon number (e.g. given by item 7-19.1), transmitted or received, and t is time (ISO 80000-3)	s^{-1}	Photon flux Φ_p is related to radiant flux (item 7-4.1), Φ_e, of monochromatic radiation, by $\Phi_p = \frac{\Phi_e}{h\nu}$ where h is the Planck constant (ISO 80000-1), and ν is the frequency (ISO 80000-3) of the corresponding electromagnetic wave. The corresponding radiometric quantity is “radiant flux” (item 7-4.1). The corresponding photometric quantity is “luminous flux” (item 7-13).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-21	photon intensity	I_p (I)	density of photon flux with respect to solid angle in a specified direction, expressed by $$I_p = \frac{d\Phi_p}{d\Omega}$$ where Φ_p is the photon flux (item 7-20) emitted in the given direction, and Ω is the solid angle (ISO 80000-3) containing that direction	$s^{-1}\ sr^{-1}$	The distribution of the photon intensities as a function of the direction of emission, e.g. given by the polar angles (ϑ,φ), is used to determine the photon flux (item 7-20) within a certain solid angle (ISO 80000-3) Ω of a source: $$\Phi_p = \iint_\Omega I_p(\vartheta,\varphi)\sin\vartheta d\varphi d\vartheta$$ The corresponding radiometric quantity is “radiant intensity” (item 7-5.1). The corresponding photometric quantity is “luminous intensity” (item 7-14).
7-22	photon radiance	L_p (L)	density of photon intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface, expressed by $$L_p = \frac{dI_p}{dA}\frac{1}{\cos\alpha}$$ where I_p is photon intensity (item 7-21), A is area (ISO 80000-3) and α the angle between the normal to the surface at the specified point and the specified direction	$m^{-2}\ s^{-1}\ sr^{-1}$	The corresponding radiometric quantity is “radiance” (item 7-6.1). The corresponding photometric quantity is “luminance” (item 7-15).
7-23	photon irradiance	E_p (E)	density of incident photon flux with respect to area at a point on a real or imaginary surface, expressed by $$E_p = \frac{d\Phi_p}{dA}$$ where Φ_p is photon flux (item 7-20) and A is the area (ISO 80000-3) on which the photon flux is incident	$m^{-2}\ s^{-1}$	The corresponding radiometric quantity is “irradiance” (item 7-7.1). The corresponding photometric quantity is “illuminance” (item 7-16).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-24	photon exitance	M_p (M)	density of exiting photon flux with respect to area at a point on a real or imaginary surface, expressed by $M_p = \frac{d\Phi_p}{dA}$ where Φ_p is photon flux (item 7-20) and A is the area (ISO 80000-3) from which the photon flux leaves	$m^{-2}\ s^{-1}$	The corresponding radiometric quantity is "radiant exitance" (item 7-8.1). The corresponding photometric quantity is "luminous exitance" (item 7-17).
7-25	photon exposure	H_p (H)	density of incident photon number with respect to area at a point on a real or imaginary surface, expressed by $H_p = \frac{dN_p}{dA}$ where N_p is photon number (item 7-19.1) and A is the area (ISO 80000-3) on which the photons are incident	m^{-2}	The corresponding radiometric quantity is "radiant exposure" (item 7-9.1). The corresponding photometric quantity is "luminous exposure" (item 7-18).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-26.1	tristimulus values for the CIE 1931 standard colorimetric observer	X, Y, Z	amounts of the three reference colour stimuli in the CIE 1931 standard colorimetric system, required to match the colour of the stimulus considered	see Remark	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 for the CIE 1931 standard colorimetric observer (2° observer) (item 7-27.1). For sources, k may be chosen as $k = K_m$ where K_m is the maximum luminous efficacy (item 7-11.3) so that $Y = L_v$ (item 7-15) and the unit of X, Y, Z is [cd m^{-2}].

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-26.1 *(cont.)*					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 the spectral reflectance, $\tau(\lambda)$ is the spectral transmittance, $\beta(\lambda)$ is the spectral radiance factor, and k is chosen to be $k=100/\int_0^\infty S_\lambda(\lambda)\bar{y}(\lambda)\mathrm{d}\lambda$ Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. In this case, the unit of X, Y, Z is [1].
7-26.2	tristimulus values for the CIE 1964 standard colorimetric observer	X_{10}, Y_{10}, Z_{10}	amounts of the three reference colour stimuli in the CIE 1964 standard colorimetric system, required to match the colour of the stimulus considered	see Remark	For a given colour stimulus described by the colour stimulus function $\varphi_\lambda(\lambda)$ of a radiometric quantity, $X_{10}=k\int_0^\infty\varphi_\lambda(\lambda)\bar{x}_{10}(\lambda)\mathrm{d}\lambda$ $Y_{10}=k\int_0^\infty\varphi_\lambda(\lambda)\bar{y}_{10}(\lambda)\mathrm{d}\lambda$ $Z_{10}=k\int_0^\infty\varphi_\lambda(\lambda)\bar{z}_{10}(\lambda)\mathrm{d}\lambda$ where $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ are the CIE colour-matching functions for the CIE 1964 standard colorimetric observer (10° observer) (item 7-27.2).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-26.2 *(cont.)*					For sources, k may be chosen as $k = K_{10}$ where K_{10} is the maximum luminous efficacy (item 7-11.3) of the CIE 1964 standard colorimetric observer so that $Y_{10} = L_{10}$ and the unit of X, Y, Z is [cd m^{-2}]. 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 the spectral reflectance, $\tau(\lambda)$ is the spectral transmittance, $\beta(\lambda)$ is the spectral radiance factor, and k is chosen to be $k=100/\int_0^\infty S_\lambda(\lambda)\bar{y}(\lambda)\mathrm{d}\lambda$ Integral limits can be confined depending on the spectral sensitivity of the detectors used as a sensor. In this case, the unit of X, Y, Z is [1].
7-27.1	CIE colour-matching functions for the CIE 1931 standard colorimetric observer	$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$	functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ in the CIE 1931 standard colorimetric system	1	Values of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ are defined in the CIE 1931 standard colorimetric system (2° observer) — applicable to fields of observation of angular opening from 1° to 4°.
7-27.2	CIE colour-matching functions for the CIE 1964 standard colorimetric observer	$\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$	functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ in the CIE 1964 standard colorimetric system	1	Values of $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$ and $\bar{z}_{10}(\lambda)$ are defined in the CIE 1964 standard colorimetric system (10° observer) — applicable to fields of observation with angles greater than 4°.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-28.1	chromaticity coordinates in the CIE 1931 standard colorimetric system	x, y, z	coordinates expressing the quotients of each of a set of three tristimulus values for the CIE 1931 standard colorimetric observer (item 7-26.1) and their sum, expressed by $x = X/(X+Y+Z)$, $y = Y/(X+Y+Z)$, $z = Z/(X+Y+Z)$	1	Since $x + y + z = 1$, two variables are sufficient to express chromaticity.
7-28.2	chromaticity coordinates in the CIE 1964 standard colorimetric system	x_{10}, y_{10}, z_{10}	coordinates expressing the quotients of each of a set of three tristimulus values for the CIE 1964 standard colorimetric observer (item 7-26.2) and their sum, expressed by $x_{10} = X_{10}/(X_{10}+Y_{10}+Z_{10})$, $y_{10} = Y_{10}/(X_{10}+Y_{10}+Z_{10})$, $z_{10} = Z_{10}/(X_{10}+Y_{10}+Z_{10})$	1	Since $x_{10} + y_{10} + z_{10} = 1$, two variables are sufficient to express chromaticity.
7-29.1	colour temperature	T_c	temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus	K	
7-29.2	correlated colour temperature	T_{cp}	temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a modified 1976 CIE Uniform Chromaticity Scale (UCS) diagram where $u', \frac{2}{3}v'$ are the coordinates of the Planckian locus and the test stimulus	K	

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-30.1	emissivity	ε, ε_T	quotient of the radiant exitance of a radiator and the radiant exitance of a Planckian radiator at the same temperature, expressed by $\varepsilon = \frac{M}{M_b}$ where M is the radiant exitance (item 7-8.1) of a thermal radiator and M_b is the radiant exitance of a Planckian radiator at the same temperature (ISO 80000-5)	1	
7-30.2	emissivity at a specified wavelength	$\varepsilon(\lambda)$	quotient of the radiant exitance of a radiator at a specified wavelength and the radiant exitance of a Planckian radiator at the same temperature and at the same wavelength, expressed by $\varepsilon(\lambda) = M(\lambda) / M_b(\lambda)$ where $M(\lambda)$ is the radiant exitance (item 7-8.1) of a thermal radiator at a specified wavelength and $M_b(\lambda)$ is the radiant exitance of a Planckian radiator at the same temperature at a specified wavelength (ISO 80000-3)	1	
7-31.1	absorptance	α a	quotient of absorbed radiant flux and incident radiant flux, expressed by $\alpha = \frac{\Phi_a}{\Phi_m}$ where Φ_a is absorbed radiant flux (item 7-4.1) and Φ_m is incident radiant flux	1	This quantity is also defined spectrally in terms of wavelength, in which case "spectral" is added before the quantity name. Due to energy conservation, $\alpha + \rho + \tau = 1$ except when polarized radiation is observed, where ρ is reflectance (item 7-31.3) and τ is transmittance (item 7-31.5).

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-31.2	luminous absorptance	α_v	quotient of absorbed luminous flux and incident luminous flux, expressed by $\alpha_v = \frac{\Phi_{v,a}}{\Phi_{v,m}}$ where $\Phi_{v,a}$ is absorbed luminous flux (item 7-13) and $\Phi_{v,m}$ is incident luminous flux	1	From spectral absorptance, $\alpha(\lambda)$, luminous absorptance can be calculated by $\alpha_v = \frac{\int_0^\infty \alpha(\lambda)\Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}{\int_0^\infty \Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}$ where $\Phi_{e,\lambda}(\lambda)$ is spectral radiant flux (or relative spectral distribution) of the source, and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). See also item 7-31.1.
7-31.3	reflectance	ρ	quotient of reflected radiant flux and incident radiant flux, expressed by $\rho = \frac{\Phi_r}{\Phi_m}$ where Φ_r is reflected radiant flux (item 7-4.1) and Φ_m is incident radiant flux	1	This quantity is also defined spectrally in terms of wavelength, in which case, "spectral" is added before the quantity name. Due to energy conservation, $\alpha + \rho + \tau = 1$ except when polarized radiation is observed, where α is absorptance (item 7-31.1) and τ is transmittance (item 7-31.5).
7-31.4	luminous reflectance	ρ_v	quotient of reflected luminous flux and incident luminous flux, is expressed by $\rho_v = \frac{\Phi_{v,r}}{\Phi_{v,m}}$ where $\Phi_{v,r}$ is reflected luminous flux (item 7-13) and $\Phi_{v,m}$ is incident luminous flux	1	From spectral reflectance, $\rho(\lambda)$, luminous reflectance can be calculated by $\rho_v = \frac{\int_0^\infty \rho(\lambda)\Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}{\int_0^\infty \Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}$ where $\Phi_{e,\lambda}(\lambda)$ is spectral radiant flux (or relative spectral distribution) of the source, and $V(\lambda)$ is spectral luminous efficiency (item 7-10.2). See also item 7-31.3.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-31.5	transmittance	τ T	quotient of transmitted radiant flux and incident radiant flux, expressed by $\tau = \frac{\Phi_t}{\Phi_m}$ where Φ_t is transmitted radiant flux (item 7-4.1) and Φ_m is incident radiant flux	1	This quantity is also defined spectrally in terms of wavelength, in which case, "spectral" is added before the quantity name. Due to energy conservation, $\alpha + \rho + \tau = 1$ except when polarized radiation is observed, where α is absorptance (item 7-31.1) and ρ is reflectance (item 7-31.3).
7-31.6	luminous transmittance	τ_v	quotient of transmitted luminous flux and incident luminous flux, expressed by $\tau_v = \frac{\Phi_{v,t}}{\Phi_{v,m}}$ where $\Phi_{v,t}$ is transmitted luminous flux (item 7-13) and $\Phi_{v,m}$ is luminous flux of the incident radiation	1	From the spectral transmittance $\tau(\lambda)$, luminous transmittance can be calculated by $\tau_v = \frac{\int_0^\infty \tau(\lambda)\Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}{\int_0^\infty \Phi_{e,\lambda}(\lambda)V(\lambda)d\lambda}$ where $\Phi_{e,\lambda}(\lambda)$ is the spectral radiant flux (or relative spectral distribution) of the source, and $V(\lambda)$ is the spectral luminous efficiency (item 7-10.2). See also item 7-31.5.
7-32.1	transmittance optical density, optical density, transmittance density, decadic absorbance	D, A_{10} D_τ	logarithm to base 10 of the reciprocal of the transmittance, τ (item 7-31.5)	1	If defined in terms of wavelength, the optical density can be expressed by $A_{10}(\lambda) = -\lg[\tau(\lambda)]$ where $\tau(\lambda)$ is the transmittance (item 7-31.5) in terms of wavelength. In spectroscopy, the name "absorbance A_{10}" is generally used.
7-32.2	Napierian absorbance	A_n, B	natural (Napierian) logarithm of the reciprocal of the transmittance, τ (item 7-31.5)	1	If defined in terms of wavelength, the Napierian absorbance can be expressed by $A_n(\lambda) = B(\lambda) = -\ln[\tau(\lambda)]$ It can also be expressed as $A_n(\lambda) = l\alpha(\lambda)$ where α is linear absorption coefficient (item 7-35.2) and l is length (ISO 80000-3) traversed.

Table 1 *(continued)*

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition		
7-33.1	radiance factor	β_e (β)	quotient of the radiance of a surface element in a specified direction and the radiance of the perfect reflecting diffuser or perfect transmitting diffuser identically irradiated and viewed, expressed by $\beta_e = \frac{L_{e,n}}{L_{e,d}}$ where $L_{e,n}$ is the radiance (item 7-6.1) of a surface element in a given direction and $L_{e,d}$ is the radiance of the perfect reflecting or transmitting diffuser identically irradiated and viewed	1	The definition holds for a surface element of a non-self-radiating medium, in a given direction and under specified conditions of irradiation. Radiance factor is equivalent to reflectance factor (item 7-34) or luminance factor (item 7-33.2) when the cone angle is infinitely small, and is equivalent to reflectance (item 7-31.3) 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 (item 7-31.3) or transmittance (item 7-31.5) equal to 1 is called "perfect diffuser".
7-33.2	luminance factor	β_v (β)	quotient of the luminance of a surface element in a specified direction and the luminance of the perfect reflecting diffuser or perfect transmitting diffuser identically illuminated and viewed, expressed by $\beta_v = \frac{L_{v,n}}{L_{v,d}}$ where $L_{v,n}$ is the luminance (item 7-15) of a surface element in a given direction and $L_{v,d}$ is the luminance of the perfect reflecting or transmitting diffuser identically illuminated and viewed	1	The definition holds for a surface element of a non-luminous medium, in a given direction and under specified conditions of irradiation. This quantity is also defined spectrally and is called "spectral luminance factor". For the analogous radiant quantity "radiance factor", see item 7-33.1.