



COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

**RADIOMETRIC AND PHOTOMETRIC
CHARACTERISTICS OF MATERIALS
AND THEIR MEASUREMENT**

CIE 38 - 1977

Dieser Bericht wurde vom Technischen Komitee TC-2.3 "Lichttechnische Stoffkennzahlen" der CIE ausgearbeitet. Er entspricht der Mehrheit der Meinungen des Komitees, in dem die meisten Mitgliedsländer der CIE vertreten sind und wird zum zukünftigen Studium empfohlen. Er ist keine offiziell anerkannte CIE-Empfehlung, die von den Nationalen Komitees der Mitgliedsländer anerkannt wurde. Es muß darauf hingewiesen werden, daß alle Empfehlungen dieses Berichts nur als Anleitung dienen und nicht verbindlich sind.

This report has been prepared by the CIE Technical Committee TC-2.3 "Photometric characteristics of materials".

It represents the opinion of the majority of the Committee members who represent most member countries of the CIE.

This report is recommended for future study and it is not an officially agreed CIE recommendation, approved by the National Committee of the Chamber countries. It should be noted that recommendations in this report are advisory and not mandatory.

Ce rapport a été préparé par le Comité Technique CIE TC-2.3 "Caractéristiques photométriques des matériaux"

Il a été approuvé par la majorité du comité, dans lequel sont représentés la plupart des Pays membres de la CIE, et il est recommandé pour une future étude.

Ce n'est pas une Recommandation officielle de la CIE approuvée par les Comités Nationaux des Pays membres. Il faut noter que toutes les recommandations de ce rapport sont conseillées et non obligatoires.

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SUMMARY

**Radiometric and Photometric Characteristics of Materials
and their Measurement**

If a material is irradiated, some portion of the incident optical radiation is reflected, another portion absorbed, and a third portion transmitted. This action of a material can be described by the physical, radiant, luminous or spectral characteristics of the material. Fluorescent materials can be described in the same manner but behave as sources for the portion of the radiation which is re-emitted as fluorescence. The terms reflected, transmitted, fluorescent, and total radiance or luminance can be used to describe fluorescent materials. The adjective spectral is used to distinguish spectral properties from radiant or luminous properties.

The report is a survey of the processes which occur if a material is irradiated, and of the characteristics of the material which are important in determining its behavior in general and in a few special cases. The report also clarifies the definitions of characteristics and processes.

RESUME

**Caractéristiques radiométriques et photométriques des
matériaux et leur mesure**

Quand un rayonnement tombe sur un matériau, une fraction en est réfléchi, une autre absorbée et une dernière transmise. Cette propriété des matériaux est décrite par des caractéristiques physiques, radiométriques, photométriques et spectrales des matériaux. Les propriétés des matériaux luminescents sont décrites comme celles des matériaux non luminescents, quoique lesdits matériaux soient des sources primaires de lumière pour ce qui concerne la fraction luminescente de leur rayonnement. Pour les caractéristiques des matériaux luminescents, les fractions déterminées par la réflexion (transmission) ou la luminescence peuvent être qualifiées "de réflexion" ("de transmission") ou "de luminescence".

Le présent rapport donne un aperçu des processus qui se déroulent quand un rayonnement ou de la lumière tombe sur des matériaux, un aperçu des caractéristiques généralement utilisées, ainsi que de quelques caractéristiques particulières; de plus, il uniformise les définitions.

ZUSAMMENFASSUNG

**Strahlungsphysikalische und lichttechnische Stoffkennzahlen
und deren Messung**

Fällt Strahlung auf einen Werkstoff, so wird ein Teil reflektiert, ein Teil absorbiert und ein Teil transmittiert. Diese Wirkung der Werkstoffe kann durch physikalische, strahlungsphysikalische, lichttechnische und spektrale Stoffkennzahlen gekennzeichnet werden. Die Eigenschaften von lumineszierenden Werkstoffen werden im allgemeinen ebenso beschrieben, obwohl diese Stoffe für den von der

Lumineszenz herrührenden Teil ihrer Strahlung Selbststrahler (Selbstleuchter) sind. Bei den lumineszierende Werkstoffe kennzeichnenden Stoffkennzahlen können die durch Reflexion (Transmission) bzw. Lumineszenz bestimmten Anteile durch Vorsilben "Reflexions"- ("Transmissions-") bzw. "Lumineszenz"- gekennzeichnet werden. Das Wort "spektral" weist auf den spektralen Charakter der entsprechenden Stoffkennzahlen hin.

Dieser Bericht gibt einen Überblick über die Vorgänge beim Auftreffen von Strahlung oder Licht auf Werkstoffe, über die allgemein verwendeten und einige spezielle Stoffkennzahlen und vereinheitlicht die Begriffsbestimmungen.

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1. Scope of the Report

If a material is irradiated by optical radiation, some portion of the incident radiation is reflected, another portion absorbed, and often a third portion transmitted. This action of a material can be described by various characteristics of properties (spectral, general, physical, or photometric) of that material.

The properties of fluorescent materials are generally described in the same manner as those of nonfluorescent materials, although the former behave as primary sources for that portion of the radiation which is generated by fluorescence. In the case of radiance (luminance) for fluorescent materials, the adjectives reflected, (transmitted), fluorescent and total can be used (see 6.2.7).

This report, in conjunction with the International Lighting Vocabulary², is a survey of the processes which occur if a material is irradiated, and of the characteristics of the material which are important in determining its behavior in general and in a few special cases. The report also clarifies the definitions of the characteristics and processes. As this report cannot alter the CIE vocabulary, an asterisk "*" at the corresponding definitions indicates deviation from the vocabulary.

As some quantities are valid only for spectral and some for both spectral and integral values, the word spectral will be used when the quantities are valid only for spectral values. In the report, the following abbreviations are used for logarithms:

lg = logarithm to the base ten

ln = natural logarithm

Certain correlations among various characteristics are described.

For the most important characteristics, practical methods of measurement are given to insure that measurements in different laboratories yield similar values.

A classification based on photometric principles is devised such that materials may be classified by ranges of values of their photometric properties.

2. Spectral, General, Radiometric, and Photometric Characteristics

The processes and characteristics described in this report apply to optical radiation, particularly light.

For the distinction among various kinds of characteristics the nature of the weighting function, that is, the relative spectral sensitivity distribution $s(\lambda)_{rel}$ of the receiver, is decisive^{3,7}).

Optical quantities are often functions of wavelength λ (or frequency ν , wave number σ , etc.). When considered for monochromatic radiation, they are designated by writing the name of the quantity preceded by the adjective "spectral", and by writing its symbol followed by λ (or ν , or σ , etc.) in parentheses, e.g., spectral emissivity, $\epsilon(\lambda)$.

If the spectral concentration (i.e., the amount per unit interval of wavelength) of a quantity X is considered, it may also be designated as an abbreviation by the name of the quantity preceded by the adjective "spectral," and by the symbol with the subscript λ (or ν , or σ , etc.), e.g., spectral radiant flux Φ_λ . It must be remembered that X and X_λ are quantities having different dimensions, because

$$x_{\lambda} = \frac{dX}{d\lambda} \quad (1)$$

If the wavelength dependence of a spectral quantity is known, the corresponding photometric, radiant, or general quantity may be calculated for any spectral-power distribution.

For characteristics which refer to visible radiation, photometric quantities are used. The weighting function in this case is the spectral luminous-efficiency distribution for photopic vision $V(\lambda)$.

For "radiant" characteristics, the weighting function is independent of wavelength; $s(\lambda)_{\text{rel}} = 1$.

For "general" characteristics, the weighting function must be specified. Examples of such weighting functions are the CIE spectral tristimulus values¹ $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$, the erythemal effectiveness distribution⁵, and the spectral efficiency of CO_2 assimilation in plants⁸²).

If S_{λ} is the relative spectral-power distribution of the radiant quantity describing the radiation incident on a material, $s(\lambda)_{\text{rel}}$ is the weighting function, and $\alpha(\lambda)$ is the corresponding spectral characteristic, then the general characteristic α is calculated by

$$\alpha = \frac{\int_0^{\infty} S_{\lambda} \alpha(\lambda) s(\lambda)_{\text{rel}} d\lambda}{\int_0^{\infty} S_{\lambda} s(\lambda)_{\text{rel}} d\lambda} \quad (2)$$

Photometric characteristics are a special case of general characteristics, for which the weighting function $s(\lambda)_{rel} \equiv V(\lambda)$:

$$\alpha = \frac{\int_{360 \text{ nm}}^{830 \text{ nm}} S_{\lambda} \alpha(\lambda) V(\lambda) d\lambda}{\int_{360 \text{ nm}}^{830 \text{ nm}} S_{\lambda} V(\lambda) d\lambda} \quad (3)$$

Radiant characteristics are a special case of general characteristics for which the weighting function $s(\lambda)_{rel} = 1$:

$$\alpha = \frac{\int_0^{\infty} S_{\lambda} \alpha(\lambda) d\lambda}{\int_0^{\infty} S_{\lambda} d\lambda} \quad (4)$$

If there is a risk of ambiguity, then a photometric characteristic should be preceded by the adjective "luminous" and its symbol should have the subscript "v" (e.g. luminous reflectance ρ_v), whereas a radiant characteristic may be preceded by the adjective "radiant", and its symbol given the subscript "e" (e.g., radiant reflectance ρ_e).

For radiant characteristics which are to be determined within a certain wavelength range, this range should be specified by a prefix to the term and a subscript to the symbol, e.g., the radiant reflectance within the ultraviolet range:

UV-A-radiant reflectance ρ_{eUV-A} .

For each spectral characteristic there exists a corresponding luminous or radiant characteristic as well as several general characteristics. Definitions which are given for one type of characteristic are similarly valid for the other types of characteristics.

3. Parameters Affecting the Characteristics

The characteristics are not specific properties of a material since they also depend on other parameters. They are, in fact, "characteristics of nonprimary sources".

In general the characteristics depend on the following facts:

- a) The spectral composition of the radiation
The spectral distribution of the radiation shall be specified, for example, by naming the illuminant such as Standard Illuminant A or D65, by its distribution temperature^{*}) or, for monochromatic radiation, by specifying the wavelength and bandwidth (half-width). For the measurement of fluorescent materials, the sample must be irradiated with the illuminant for which the characteristic is to be determined.
- b) The state of polarization of the radiation
If a characteristic is not determined with unpolarized radiation, the state of polarization and the azimuth of the plane of polarization must be specified. The reflected or transmitted radiation is usually partly polarized even if the incident radiation is unpolarized.

-
- ^{*}) The distribution temperature should characterize the spectral distribution of the radiation for the total wavelength range involved; if necessary one must state wavelengths λ_1 and λ_2 which limit the range for which the distribution temperature characterizes the spectral distribution.

c) The angle of incidence

If the characteristic is to be determined for any geometry other than normal incidence by a collimated beam, the geometrical distribution of the incident radiation must be specified; e.g., for a collimated, non-normal beam the angle of incidence ε_1 , measured from the normal to the surface (Figure 1) must be given; or for hemispherical irradiation the subscript "dif" should be given, e.g., ρ_{dif} for reflectance for hemispherical irradiation.

d) The angle of viewing

If a characteristic is determined for a particular angle of viewing, this angle must be given (Figure 1) by the angle ε_2 (or θ) between the optical axis of the viewing beam and the normal to the azimuth surface, and the azimuth φ , that is, the angle between the plane of incidence and the plane of viewing. If ε_1 and ε_2 are coplanar ($\varphi = 0^\circ$ or 180°) they may be given as a subscript; for example, the luminance factor β is defined for $\varepsilon_1 = 45^\circ$ and $\varepsilon_2 = 0^\circ$: $\beta_{45/0}$.

If the surface of the material has a structure with directional features, the angular orientation of these features with respect to the plane of incidence or the plane of viewing must be specified.

e) The angular extent of the incident radiation and the viewing beam

The value of a characteristic generally depends on the angular extents of the incident radiation and the viewing beam. The characteristic approaches a constant value if the angular extents approach zero.

The cone angles of the incident and viewing beams (Figure 2) must both be specified if they cannot be kept small enough.

f) The thickness of the sample

If necessary, the thickness of the sample must be given. For materials with protective coatings, the type and thickness of the coating must be given.

g) The temperature

Characteristics are normally given for 25°C, if no other temperature is specified.

h) The state of the surface

Characteristics are normally given for a clean, dry sample, if not specified otherwise.

i) The weighting function

See Section 2.

If other parameters affect the characteristic (for example, illuminance or irradiance, UV-irradiation, or IR-irradiation), they must be specified.

4. Refraction

4.1. Refraction (45-05-085)*)

Change in the direction of propagation of radiation determined by change in the velocity of propagation in passing through an optically non-homogeneous medium, or in passing from one medium to another.

) Where a definition is taken from the International Lighting Vocabulary²⁾, the index number of this term in the Vocabulary is appended. Deviations from the Vocabulary are indicated by an asterisk "".

4.2. Refractive index (of a medium, for monochromatic radiation of wavelength λ) (45-20-225)*

Ratio of the velocity c of the electromagnetic waves in vacuum to the phase velocity v of the waves of the monochromatic radiation in the medium.

symbol: n

$$\text{spectral refractive index } n(\lambda) = \frac{c}{v} \quad (5)$$

Note. This index is equal to the ratio of the sines of the angles of incidence (ε_1) and refraction (ε_2) when a ray crosses the surface separating vacuum and medium.

$$n(\lambda) = \sin \varepsilon_1 / \sin \varepsilon_2 \quad (6)$$

4.3. Complex refractive index

For absorbing, isotropic materials the law of refraction is valid only in its complex form. The spectral complex refractive index $n^*(\lambda)$ is given by:

$$n^*(\lambda) = n(\lambda) - i\kappa(\lambda) \quad (7)$$

where $\kappa(\lambda)$ is the spectral absorption index (see Section 8.2.7.).

5. Diffusion (Scattering)

5.1. Media

5.1.1. Diffuser (45-20-185)

Device used to alter the spatial distribution of a radiant (luminous) flux and depending essentially on the phenomenon of diffusion.

Note 1. In the International Lighting Vocabulary²⁾ this term in German is given as "streuender Körper" (scattering body).

Note 2. A distinction is made between selective diffusers and nonselective diffusers accordingly as their diffusing properties depend on the wavelength of the incident radiation or not.

Note 3. If all the radiation reflected or transmitted by the diffuser is diffused, so that radiation directed according to the laws of geometrical optics is not present, the diffuser is said to be completely diffusing, independently of whether the reflected or transmitted radiation is uniformly distributed in space or not.

5.1.2. Isotropic diffuser (45-20-190)*

Diffuser producing isotropic diffusion (radiance (luminance) which is the same in all directions).

5.1.3. Perfect reflecting (transmitting) diffuser (45-20-195)

Ideal isotropic diffuser with a reflectance (transmittance) equal to 1.

5.2. Processes

5.2.1. Diffusion (45-05-075)* (scattering)

Change of the spatial distribution of a beam of radiation when it is deviated in many directions by a surface or by a medium, without change of wavelength.

Note. The deviated light has a continuous spatial distribution.

5.2.2. Isotropic diffusion (45-20-180)* (isotropic scattering)

Ideal diffusion in which the spatial distribution of diffused radiation is such that the radiance (luminance) is the same in all directions.

5.2.3. Indicatrix of diffusion (45-20-215)* (scattering indicatrix)

Representation in space, in the form of a surface expressed in polar coordinates, of the angular distribution of (relative)

radiant (luminous) intensity or of (relative) radiance (luminance) of an element of surface of a medium which diffuses by reflection or by transmission.

In the case of a narrow beam of radiation it is convenient to represent the indicatrix of diffusion in Cartesian coordinates. If the angular distribution has rotational symmetry, a meridian section of the surface is sufficient.

Note. The term indicatrix is often used to denote, instead of the surface, the curve obtained in a similar manner in a plane normal to the element concerned.

5.3. Characterizing Quantities

5.3.1. Diffusion factor (of a diffusing surface by reflection or by transmission) (45-20-205)*

Ratio of the mean of the values of luminance L measured at 20° and 70° (0.35 and 1.22 rad) to the luminance measured at 5° (0.09 rad) from the normal, when the surface considered is illuminated normally.

symbol: σ

$$\sigma = \frac{L(20) + L(70)}{2L(5)} \quad (8)$$

Note 1. The diffusion factor is intended to give an indication of the spatial distribution of the diffused flux. It is equal to 1 for every isotropic diffuser, whatever the value of the diffuse reflectance (transmittance).

Note 2. This way of defining the diffusion factor can be applied only to materials for which the indicatrix of diffusion does not differ appreciably from that of ordinary opal glasses.

5.3.2. Half-value angle (for a diffusing surface by reflection or by transmission) (45-20-210)*

Angle of observation at which the luminance L_{γ} has half the value of the luminance L_0 of the diffused light at the angle of 0° , with perpendicular incidence of the light.

symbol: γ

$$L_{\gamma} = \frac{1}{2} L_0 \quad (9)$$

Note. For indicating the shape of the indicatrix of diffusion it is recommended that the diffusion factor σ be used for strongly diffusing materials, and the half-value angle γ for poorly diffusing materials.

5.3.3. Linear spectral scattering coefficient (of a diffusing medium, for a collimated beam of radiation)

Quotient of the relative decrease due to scattering of the spectral concentration of a nearly collimated, normally incident beam during traversal of an infinitesimal layer of the medium, divided by the thickness of that layer.

symbol: $s(\lambda)$

$$s(\lambda) = \frac{1}{L_{e\lambda}} \cdot \frac{dL_{e\lambda}}{d l} \quad (10)$$

Note. The linear spectral scattering coefficient is the part of the linear spectral attenuation coefficient (see section 8.2.9.) that is due to scattering.

6. Reflection

6.1. Processes

6.1.1. Reflection (45-05-060)*

Return of radiation by a medium without change of wavelength.

Note 1. The reflected radiation can be regular, diffuse or mixed.

Note 2. One portion of the flux falling on a medium is reflected at the surface of the medium (surface reflection); another portion can be backscattered from the interior of the medium (volume reflection).

6.1.2. Regular reflection; specular reflection (45-20-010)

Reflection without diffusion in accordance with the laws of optical reflection as in a mirror.

6.1.3. Diffuse reflection (45-20-015)

Diffusion by reflection in which, on the macroscopic scale, there is no regular reflection.

6.1.4. Isotropic diffuse reflection (45-20-025)*

Diffuse reflection in which the spatial distribution of the reflected radiation is such that the radiance (luminance) is the same in all directions of the hemisphere of incidence.

6.1.5. Mixed reflection (45-20-020)*

Partly regular and partly diffuse reflection.

Note. The irradiance (illuminance) received from a point source, after regular (diffuse) reflection, varies inversely as the square of the distance from the image of the source (from the diffuser).

6.1.6. Retro-reflection; reflex reflection (45-20-030)

Reflection in which radiation is returned in directions close to the direction from which it came, this property being maintained over wide variations of the direction of the incident radiation.

6.1.7. Gloss (45-20-035)*

Property of a surface which, due to regular reflection or a pointed indicatrix of reflection, is responsible for the degree to which reflected highlights or the images of objects may be seen as behind the surface (this definition is under review).

6.2. Characterizing quantities

6.2.1. Reflectance (45-20-040)*

Ratio of the reflected radiant (luminous) flux to the incident flux.

symbol: ρ

$$\text{spectral reflectance } \rho(\lambda) = \Phi_{e\lambda\rho} / \Phi_{e\lambda} \quad (11)$$

where $\Phi_{e\lambda\rho}$ is reflected spectral radiant flux and $\Phi_{e\lambda}$ is incident spectral radiant flux.

Note 1. Where mixed reflection (6.1.5.) occurs, the (total) reflectance may be divided into two parts, regular reflectance (ρ_r) and diffuse reflectance (ρ_d), corresponding respectively to the two modes of reflection referred to in definitions 6.1.2. and 6.1.3.

$$\rho = \rho_r + \rho_d \quad (12)$$

6.2.2. Regular reflectance

Ratio of the radiant (luminous) flux, that after reflection is proportional to the inverse square of the distance from the image of the source, to the incident flux.

symbol: ρ_r

6.2.3. Diffuse reflectance

Ratio of the radiant (luminous) flux that has undergone diffuse reflection to the incident flux.

symbol: ρ_d

6.2.4. Reflectivity (45-20-050)

Reflectance of a layer of material of such a thickness that there is no change of reflectance with increase in thickness.

symbol: ρ_∞

6.2.5. Reflection (optical) density (45-20-055)

Logarithm to base ten of the reciprocal of the reflectance.

symbol: D spectral reflection (optical) density:

$$D(\lambda) = \lg \frac{1}{\bar{\rho}(\lambda)} \quad (13)$$

6.2.6. Spectral Fresnel reflectance

If a transparent, absorbing body (refractive index n , absorption index κ) has smooth surfaces and no disturbing surface layers the Fresnel reflectances $\bar{\rho}_p(\lambda)$ and $\bar{\rho}_s(\lambda)$ may be calculated for the components of the flux which are polarized parallel or normal to the plane of incidence, respectively.⁷³⁾

For a nonabsorbing material ($\kappa = 0$) and an angle of incidence ε_1 the two components may be calculated as follows: (in these equations the symbol λ , indicating wavelength dependence, is omitted)

$$\bar{\rho}_s = \left[\frac{\cos \varepsilon_1 - (n^2 - \sin^2 \varepsilon_1)^{1/2}}{\cos \varepsilon_1 + (n^2 - \sin^2 \varepsilon_1)^{1/2}} \right]^2 = \frac{\sin^2 (\varepsilon_1 - \varepsilon_2)}{\sin^2 (\varepsilon_1 + \varepsilon_2)} \quad (14)$$

$$\bar{\rho}_p = \left[\frac{n^2 \cos \varepsilon_1 - (n^2 - \sin^2 \varepsilon_1)^{1/2}}{n^2 \cos \varepsilon_1 + (n^2 - \sin^2 \varepsilon_1)^{1/2}} \right]^2 = \frac{\tan^2 (\varepsilon_1 - \varepsilon_2)}{\tan^2 (\varepsilon_1 + \varepsilon_2)} \quad (15)$$

For unpolarized radiation the total Fresnel reflectance is given by:

$$\bar{\rho}_t = \frac{1}{2} (\bar{\rho}_s + \bar{\rho}_p) \quad (16)$$

With incident angle $\varepsilon_1 = 0$ (index "0") equations 14 and 15 are identical.

$$\bar{\rho}_0 = \bar{\rho}_{t,0} = \bar{\rho}_{s,0} = \bar{\rho}_{p,0} = \left(\frac{n-1}{n+1} \right)^2 \quad (17)$$

For unpolarized radiation which irradiates the surface hemispherically with constant spectral radiance from vacuum, an equation for the Fresnel reflectance for diffuse light $\bar{\rho}_{\text{dif}}$ is

given in the literature⁷²).

6.2.7. Radiance (luminance) factor (at a representative element on the surface of a non-self-radiating medium, in a given direction, under specified conditions of irradiation (illumination) (45-20-200)*

Ratio of the radiance (luminance) of the medium to that of a perfect reflecting or transmitting diffuser identically irradiated (illuminated).

symbol: β spectral radiance factor $\beta(\lambda) = L_{e\lambda}/L_{e\lambda w}$ (18)

where $L_{e\lambda}$ is the spectral radiance of the medium and $L_{e\lambda w}$ is the spectral radiance of a perfect reflecting diffuser.

Note 1. In German, this quantity ("Leuchtdichtefaktor") was formerly called "Remissionsgrad".

Note 2. In German, the term "Leuchtdichtefaktor" is still often found in the literature for the radiance (luminance) coefficient (see 6.2.8.).

Note 3. In German, in place of the luminance factor β (or reflectance ρ or transmittance τ) it is usual in colorimetry to use the quantity "Hellbezugswert" $A = 100 \beta$ (100τ , or 100ρ).

Note 4. In case of fluorescent media the radiance (luminance) factor is the sum of two portions, the reflected radiance (luminance) factor β_S and the fluorescent radiance (luminance) factor β_L ^{84,86}).

$$\beta_T = \beta_S + \beta_L \quad (19)$$

6.2.7.1. Reflected radiance (luminance) factor (at a representative element of the surface of a medium, in a given direction, under specified conditions of irradiation (illumination))

Ratio of the radiance (luminance) due to reflection of the medium to that of a perfect reflecting diffuser identically irradiated (illuminated).

symbol: β_S

6.2.7.2. Luminescence radiance (luminance) factor (at a representative element of the surface of a medium, in a given direction, under specified conditions of irradiation (illumination))

Ratio of the medium to the radiance (luminance) of a perfect reflecting diffuser identically irradiated (illuminated).

symbol: β_L

Note: The spectral luminescence radiance (luminance) factor is a material constant that depends also on the spectral distribution of the irradiation.

6.2.8. Radiance (luminance) coefficient (at a representative element of the surface of a non-self-radiating medium, in a given direction, under specified conditions of irradiation (illumination))

Quotient of the radiance (luminance) of the medium by the irradiance (illumination) on the medium.

symbol: q spectral radiance coefficient

$$q(\lambda) = L_{e\lambda} / E_{e\lambda} \quad (20)$$

where $L_{e\lambda}$ is the spectral radiance of the medium and $E_{e\lambda}$ is the spectral irradiance on the body. The radiance (luminance)

coefficient should be applied only in reference to scattered radiation.

Note. In German the quantity "Leuchtdichtekoeffizient" is sometimes still called "Leuchtdichtefaktor" (see 6.2.7.).

6.2.9. Coefficient of luminous intensity (45-60-425)*

Quotient of the luminous intensity reflected in the direction considered by the illuminance (normal incidence) at the retro-reflector for given angles of incidence, observation, and rotation. (The angle of observation α is the angle between the straight lines that connect the midpoints of the illuminating source and detector with the midpoint of the sample.)

(The angle of rotation is that angle by which the sample is rotated about its normal from an arbitrarily specified position).

$$\text{symbol: } R \qquad R = I_E / E_{\perp} \qquad (21)$$

where I_E is the luminous intensity at the angle ε_2 and $E_{\perp}$ is the illuminance at the retro-reflector for normal incidence.

Note 1. In the photometry of the retro-reflectors, this coefficient is designated by the abbreviation C.I.L. It is usually expressed in millicandelas per lux ($\text{mcd} \cdot \text{lx}^{-1}$).

Note 2. The plane of the incident light (the plane that contains the surface normal and the direction of incidence) and the plane of reflected light (the plane containing the surface normal as well as the midpoints of the sample and detector) should be perpendicular to each other.

Note 3. For measurements on retro-reflectors or reflex materials care must be taken that the cone angle of the viewing beam is sufficiently small.^{6,46)}

6.2.10. Coefficient of retroreflection

Quotient of the luminous intensity of a reflex material in the direction considered by the product of the illuminance at normal incidence and the area of reflex material for given angle of incidence, observation and rotation.

symbol: R'

$$R' = \frac{I_{\varepsilon}}{E_{\perp} A} \quad (22)$$

where

I_{ε} is the luminous intensity at the angle ε_2

$E_{\perp}$ is the illuminance at the reflex material for normal incidence

A is the area of the reflex material evaluated

Note 1. The direction of incidence and of observation lies in the same plane, which contains the surface normal of the reflex material.

Note 2. The coefficient of retroreflection is expressed in $\text{cd m}^{-2} \text{lx}^{-1}$.

Note 3. The luminance coefficient q is obtained from the coefficient of retroreflection R' when multiplied by a factor $(\cos \varepsilon_1 \cdot \cos \varepsilon_2)^{-1}$. Since ε_2 is generally only slightly different from ε_1 it is sufficient to use $\cos^{-2} \varepsilon_1$ as multiplication factor.

$$q = R' (\cos \varepsilon_1 \cdot \cos \varepsilon_2)^{-1} \approx R' (\cos^2 \varepsilon_1)^{-1} \quad (23)$$

Note 4. For measurements on (reflex) materials, care must be taken that the cone angle of the viewing beam is sufficiently small.^{6,46}

6.2.11. Reflectance factor (at a representative element of a surface, for the part of the reflected radiation contained in a given cone with apex at the representative element of the surface, and for incident radiation of given spectral composition and geometrical distribution)
(45-20-201)*

Ratio of the radiant (luminous) flux reflected in the directions delimited by the cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated (illuminated).

symbol: R

Note 1. For specularly reflecting surfaces that are irradiated (illuminated) by a source of small solid angle, the reflectance factor may be much larger than 1 if the cone includes the mirror image of the source. In this case the value of reflectance factor obtained with an instrument will depend on the measuring geometry (specifically sample size, source-sample distance, and sample-receptor distance) unless the sample size is sufficiently small to permit all of the specularly reflected flux to be incident on the receiver.

Note 2. If the solid angle of the cone approaches 2π sr the reflectance factor approaches the reflectance. In this case a regular component (if present) must be included. This can be excluded if the regular component is sufficiently defined and a suitable trap is used; then the reflectance factor approaches the diffuse reflectance.

Note 3. If the solid angle of the cone approaches zero sr the reflectance factor approaches the radiance (luminance) factor, provided there is no regular reflection in the direction of observation.

Note 4. The term "directional reflectance" is used currently in USA in this sense.

Note 5. It is recommended that the reflectometer value (6.2.12) be used rather than the reflectance factor.

6.2.12. Reflectometer value (45-20-202)

Value measured by means of a particular reflectometer.

symbol: R'

Note: The reflectometer employed should be specified. The measured reflectometer value depends on the geometric characteristics of the reflectometer, on the illuminant, on the spectral sensitivity of the receptor (even when equipped with filters) and on the reference standard used. If necessary, these conditions should be specified.

7. Transmission

7.1. Media

7.1.1. Transparent medium (45-20-155)*

Medium in which the light transmission is mainly regular and which has a high regular transmittance. Objects are seen distinctly through such a medium if its geometrical form is suitable.

7.1.2. Translucent medium (45-20-160)*

Medium which transmits light entirely, or almost entirely, by diffuse transmission. In general objects are not seen distinctly through such a medium.

7.1.3. Opaque medium (45-20-165)*

Medium which transmits no light or practically none.

7.2. Processes

7.2.1. Transmission (45-05-065)

Passage of radiation through a medium without change of wavelength.

7.2.2. Regular transmission, direct transmission (45-20-065)

Transmission without diffusion.

7.2.3. Diffuse Transmission (45-20-070)

Transmission in which diffusion occurs independently, on the macroscopic scale, of the laws of refraction.

7.2.4. Isotropic diffuse transmission (45-20-080)*

Diffuse transmission in which the spatial distribution of the transmitted radiation is such that the radiance (luminance) is the same in all directions of the hemisphere in which the radiation is transmitted.

7.2.5. Mixed transmission (45-20-075)

Partly regular and partly diffuse transmission.

Note. The irradiance (illuminance) received from a point source, after regular (diffuse) transmission varies inversely as the square of the distance to the source or its image (to the diffuser).

7.3. Characterizing quantities7.3.1. Transmittance (45-20-085)*

Ratio of the transmitted radiant (luminous) flux to the incident flux.

symbol: τ Spectral transmittance $\tau(\lambda) = \frac{\Phi_{e\lambda\tau}}{\Phi_{e\lambda}}$ (24)

where $\Phi_{e\lambda\tau}$ is the transmitted spectral radiant flux and $\Phi_{e\lambda}$ is the incident spectral radiant flux.

Note. Where mixed transmission (7.2.5.) occurs, the (total) transmittance may be divided into two parts, regular transmittance (τ_r) and diffuse transmittance (τ_d), corresponding respectively to the two modes of transmission referred to in definitions 7.2.2. and 7.2.3.

$$\tau = \tau_r + \tau_d \quad (25)$$

7.3.2. Regular transmittance

Ratio of the radiant (luminous) flux, that after passing through the medium has undergone regular transmission, to the incident radiant (luminous) flux.

symbol: τ_r