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Part 2:
CIE standard illuminants

Colorimétrie —

Partie 2: Illuminants CIE normalisés

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

CIE Central Bureau
Babenbergerstraße 9/9A
A-1010 Vienna, Austria
Phone: +43 1 714 3187
Fax: +41 22 749 09 47
Email: ciecb@cie.co.at
Website: www.cie.co.at

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 the International Commission on Illumination (CIE) in cooperation with ISO/TC 274.

This first edition of ISO/CIE 11664-2 cancels and replaces ISO 11664-2:2007/CIE S 014-2:2006, of which it constitutes a minor revision, incorporating minor editorial updates.

A list of all parts in the ISO/CIE 11664 series can be found on the ISO website and CIE website.

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

Introduction

The illuminants defined in this document are as follows:

a) CIE standard illuminant A

CIE standard illuminant A is intended to represent typical tungsten-filament lighting. Its relative spectral power distribution is that of a Planckian radiator at a temperature of approximately 2 856 K. CIE standard illuminant A should be used in all applications of colorimetry involving the use of incandescent lighting, unless there are specific reasons for using a different illuminant. CIE standard illuminant A is used in photometry as primary reference spectrum for the calibration of photometric devices.

b) CIE standard illuminant D65

CIE standard illuminant D65 is intended to represent average daylight having a correlated colour temperature of approximately 6 500 K. CIE standard illuminant D65 should be used in all colorimetric calculations requiring representative outdoor daylight, unless there are specific reasons for using a different spectral power distribution. Variations in the relative spectral power distribution of daylight are known to occur, particularly in the ultraviolet spectral region, as a function of season, time of day, and geographic location. However, CIE standard illuminant D65 is used pending the availability of additional information on these variations.

c) CIE standard illuminant D50

CIE standard illuminant D50 is intended to represent daylight with a correlated colour temperature of approximately 5 000 K. CIE standard illuminant D50 should be used in colorimetric calculations where the use of such a correlated colour temperature is intended.

Values for the relative spectral power distribution of CIE standard illuminants A, D65 and D50 are given in this document at 1 nm intervals from 300 nm to 830 nm.

The term "illuminant" refers to a defined spectral power distribution, not necessarily realizable or provided by an artificial source. Illuminants are used in colorimetry to compute the tristimulus values of reflected or transmitted object colours under specified conditions of illumination. The CIE has also defined other illuminants, such as illuminant C and other D illuminants. These illuminants are described in Publication CIE 015, but they do not have the status of CIE standard illuminants. It is recommended that one of the three CIE standard illuminants defined in this document be used wherever possible. This will greatly facilitate the comparison of published results.

In most practical applications of colorimetry, it is sufficient to use the values of CIE standard illuminants A, D65 and D50 at less frequent wavelength intervals or in a narrower spectral region than defined in this document. Data and guidelines that facilitate such practice are provided in Publication CIE 015, together with other recommended procedures for practical colorimetry.

The term "source" refers to a physical emitter of light, such as a lamp or the sky. In certain cases, the CIE recommends laboratory sources that approximate the spectral power distributions of CIE illuminants. In all cases, however, the definition of a CIE recommended source is secondary to the definition of the corresponding CIE illuminant, because of the possibility that, from time to time, new developments will lead to improved sources that represent a particular illuminant more accurately or are more suitable for laboratory use.

For laboratory realizations of CIE standard illuminant A, a CIE standard source, the CIE standard source A, is described in this document. At present, there are no CIE recommended sources representing CIE standard illuminants D65 and D50.

Colorimetry — Part 2: CIE standard illuminants

1 Scope

This document specifies three CIE standard illuminants for use in colorimetry: CIE standard illuminant A for the representation of typical tungsten-filament lighting, CIE standard illuminant D65 for the representation of average daylight having a correlated colour temperature of approximately 6 500 K, and CIE standard illuminant D50 for the representation of daylight with a correlated colour temperature of approximately 5 000 K. Values of the relative spectral power distribution of the three illuminants are included in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

CIE S 017, *ILV: International Lighting Vocabulary*

ISO 23603/CIE S 012 *Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour*

BIPM *The International System of Units (SI), 9th edition, published on May 20, 2019*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017 and the following apply.

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/

3.1
chromaticity coordinates, pl
coordinates expressing the ratios of each of a set of three tristimulus values to their sum

Note 1 to entry: As the sum of the three chromaticity coordinates equals 1, two of them are sufficient to define a chromaticity.

Note 2 to entry: In the CIE 1931 and 1964 standard colorimetric systems, the chromaticity coordinates are represented by the symbols x, y, z and x_{10}, y_{10}, z_{10}.

Note 3 to entry: The chromaticity coordinates are a quantity of unit one.

[SOURCE: CIE S 017:–[1], entry 17-23-053]

3.2
chromaticity diagram
plane diagram in which points specified by chromaticity coordinates represent the chromaticities of colour stimuli

Note 1 to entry: In the CIE standard colorimetric systems y is normally plotted as ordinate and x as abscissa, to obtain an x, y chromaticity diagram.

[SOURCE: CIE S 017:–[1], entry 17-23-054]

3.3
CIE standard illuminant
illuminant standardized by the CIE for the purpose of harmonization

[SOURCE: CIE S 017:– [1], entry 17-23-021, modified – notes to entry omitted]

3.4
CIE standard source
artificial source specified by the CIE whose radiation approximates a CIE standard illuminant

[SOURCE: CIE S 017:– [1], entry 17-23-022, modified – notes to entry omitted]

3.5

CIE 1976 uniform chromaticity scale diagram
CIE 1976 UCS diagram

uniform chromaticity scale diagram produced by plotting in rectangular coordinates v' against u', quantities defined by the equations

$$u' = 4\,X / (X + 15\,Y + 3\,Z) = 4\,x / (-2\,x + 12\,y + 3)$$

$$v' = 9\,Y / (X + 15\,Y + 3\,Z) = 9\,y / (-2\,x + 12\,y + 3)$$

where X, Y, Z are the tristimulus values in the CIE 1931 or 1964 standard colorimetric systems, and x, y are the corresponding chromaticity coordinates of the colour stimulus considered

Note 1 to entry: The CIE 1976 uniform-chromaticity-scale diagram is a modification of, and supersedes, the CIE 1960 UCS diagram in which v was plotted against u in rectangular coordinates. The relationships between the two pairs of coordinates are: $u' = u$; $v' = 1{,}5\,v$.

[SOURCE: CIE S 017:–[1], entry 17-23-073]

3.6
colour temperature
T_{c}
temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus

Note 1 to entry: The colour temperature is expressed in kelvin (K).

[SOURCE: CIE S 017:–[1], entry 17-23-067]

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1 Under preparation. Stage at the time of publication: CIE DIS 017:2016

3.7
correlated colour temperature
CCT
T_{cp}
temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a modified 1976 UCS diagram where u', $2/3v'$ are the coordinates of the Planckian locus and the test stimulus

Note 1 to entry: The concept of correlated colour temperature should not be used if the chromaticity of the test source differs more than $\Delta C = \left[\left(u'_t - u'_p\right)^2 + \frac{4}{9}\left(v'_t - v'_p\right)^2\right]^{1/2} = 5 \times 10^{-2}$ from the Planckian radiator, where u'_t, v'_t refer to the test source, u'_p, v'_p to the Planckian radiator.

Note 2 to entry: Correlated colour temperature can be calculated by a simple minimum search computer program that searches for that Planckian temperature that provides the smallest chromaticity difference between the test chromaticity and the Planckian locus, or e.g. by a method recommended by Robertson, A.R. "Computation of correlated color temperature and distribution temperature", J. Opt. Soc. Am. 58, 1528-1535, 1968.
(Note that the values in some of the tables in this reference are not up-to-date).

Note 3 to entry: The correlated colour temperature is expressed in kelvin (K).

[SOURCE: IEC 60050-845:–[2], Term 17-23-068]

3.8
daylight illuminant
D illuminant
illuminant having the same or nearly the same relative spectral power distribution of the radiant flux as a phase of daylight

[SOURCE: CIE S 017:–[3], entry 17-23-020]

3.9
illuminant
radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception

[SOURCE: CIE S 017:–[3], entry 17-23-018, Note 1 to entry omitted.]

3.10
Planckian radiator
blackbody
ideal thermal radiator that absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization

Note 1 to entry: A Planckian radiator has, for any wavelength and any direction, the maximum spectral distribution of radiance for a thermal radiator in thermal equilibrium at a given temperature.

[SOURCE: CIE S 017:–[3], entry 17-24-004]

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2 Under preparation. Stage at the time of publication: IEC CDV 60050-845:2018.

3 Under preparation. Stage at the time of publication: CIE DIS 017:2016

3.11
Planckian locus
locus of points in a chromaticity diagram that represents chromaticities of the radiation of Planckian radiators at different temperatures

[SOURCE: CIE S 017:–[4], entry 17-23-059]

3.12
tristimulus values, <of a colour stimulus> pl
amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered

Note 1 to entry: In the CIE standard colorimetric systems, the tristimulus values are represented, for example, by the symbols R, G, B; X, Y, Z; R_{10}, G_{10}, B_{10};or X_{10}, Y_{10}, Z_{10}.

[SOURCE: CIE S 017:–[4], entry 17-23-038]

4 CIE standard illuminant A

4.1 Definition

When CIE standard illuminant A is referred, the relative power distribution values provided in Table A.1 shall be used. If required, other intermediate values may be derived by linear interpolation from the published values. The relative spectral power distribution of CIE standard illuminant A, $S_{\mathrm{A}}(\lambda)$, is defined by the equation

$$S_{\mathrm{A}}(\lambda) = 100\left(\frac{560}{\lambda}\right)^{5} \times \frac{\exp\dfrac{1{,}435\times10^{7}}{2\,848\times560}-1}{\exp\dfrac{1{,}435\times10^{7}}{2\,848\,\lambda}-1} \tag{1}$$

where λ is the wavelength in nanometres and the numerical values in the two exponential terms are definitive constants originating from the first definition of Illuminant A in 1931. This spectral power distribution is normalized to the value 100 (exactly) at the wavelength 560 nm (exactly).

CIE standard illuminant A is defined over the 300 nm to 830 nm spectral region.

Note 1 Table A.1 provides the relative spectral power distribution of CIE standard illuminant A between 300 nm and 830 nm to six significant digits, at 1 nm intervals. For all practical purposes it suffices to use these tabulated values instead of the values calculated from Equation (1).

Note 2 Despite the fact that Equation (1) is based on Planck's equation for vacuum, the wavelengths are to be taken as being in standard air (dry air at 15 ºC and 101 325 Pa, containing 0,03 % by volume of carbon dioxide). This makes CIE standard illuminant A compatible with other CIE colorimetric and photometric data.

4.2 Theoretical basis

Equation (1) is equivalent to and can be derived from the expression

$$S(\lambda) = 100\, M_{\mathrm{e},\lambda}(\lambda,T) \,/\, M_{\mathrm{e},\lambda}(560, T), \tag{2}$$

where

[4] Under preparation. Stage at the time of publication: CIE DIS 017:2016

$$M_{e,\lambda}(\lambda,T) = c_1\,\lambda^{-5}\,[\exp(c_2 / \lambda\, T) - 1]^{-1}, \qquad (3)$$

λ is the wavelength (in nm),

and the ratio c_2 / T is given by

$$c_2 / T = 1{,}435 \times 10^7 / 2\,848 \text{ nm}. \qquad (4)$$

Since the numerical value of c_1 cancels out of Equation (2), this definition of CIE standard illuminant A involves no assumptions about the numerical values of c_1, c_2, and T other than the ratio defined in Equation (4).

4.3 Supplementary notes

CIE standard illuminant A was originally defined in 1931 (CIE, 1931) as the relative spectral power distribution of a Planckian radiator of temperature

$$T_{\text{CIE 1931}} = 2\,848 \text{ K}, \qquad (5)$$

the value of the second radiation constant c_2 then being taken as

$$c_{2,\text{ CIE 1931}} = 14\,350\ \mu\text{m}\cdot\text{K}. \qquad (6)$$

The form of definition as given in Equation (1) was carefully chosen to ensure that CIE standard illuminant A was defined as a relative spectral power distribution and not as a function of temperature. As explained in 4.2 above, the definition of the relative spectral power distribution has not changed since 1931 and Equation (1) simply expresses it in a general form.

What has changed is the temperature assigned to this distribution. The value of c_2 given in Equation (6) and used by the CIE in 1931 is different from the respective values that were assigned to this constant in the International Temperature Scales (ITS) or International Practical Temperature Scales (IPTS) of 1927 ($c_{2,\text{ITS-27}}$ = 14 320 µm·K), 1948 ($c_{2,\text{IPTS-48}}$ = 14 380 µm·K), 1968 and 1990 ($c_{2,\text{IPTS-68}} = c_{2,\text{ITS-90}}$ = 14 388 µm·K). The revised International System of Units (SI) (BIPM, The International System of Units (SI), 9th edition) has fixed the value of the Planck constant, which changes the value of c_2 to 1,438 776 877 5.. × 10^{-2} m·K. Although this has had no effect on the relative spectral power distribution of CIE standard illuminant A, the correlated colour temperatures of sources recommended for laboratory realizations have been different over the years, depending on the values of c_2 used.

As may be seen from Equation (4), the colour temperatures associated with CIE standard illuminant A on the various international temperature scales referred to above were $T_{\text{ITS-27}}$ = 2 842 K, $T_{\text{IPTS-48}}$ = 2 854 K, and $T_{\text{IPTS-68}} = T_{\text{ITS-90}}$ = 2 856 K, respectively (see also 7.1). The assigned temperature for CIE standard illuminant A is 2855,496 K, thus proximately 2855,5 K.

5 CIE standard illuminant D65

5.1 Definition

When CIE standard illuminant D65 is referred, the relative spectral power distribution values provided in Table A.1 shall be used. The values are presented at 1 nm intervals over the wavelength range from 300 nm to 830 nm; the wavelength values given apply in standard air. If required, other intermediate values may be derived by linear interpolation from the published values. 5

5 Information on the procedure used to derive D65 values is given in CIE 15.

