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Colorimetry —

Part 2: CIE standard illuminants

Colorimétrie —

Partie 2: Illuminants CIE normalisés

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Foreword

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

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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This document was prepared by the International Commission on Illumination (CIE) in cooperation with Technical Committee ISO/TC 274, *Light and lighting*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces ISO 11664-2:2007/CIE S 014-2:2006, which has been technically revised.

The main changes are as follows:

— CIE illuminant D50 has been included as CIE standard illuminant because of its extensive use in the fields of graphic, arts and photography.

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

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

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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 2 855,5 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

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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.

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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, other daylight illuminants, and illuminants for LED and other electric light sources. These illuminants are described in 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 specified in this document. Data and guidelines that facilitate such practice are provided in 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 sun. 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.

CIE standard source A, the practical realization of CIE standard illuminant A, is described in this document. At present, there are no CIE-recommended sources representing CIE standard illuminants D65 and D50.

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Colorimetry —

Part 2: CIE standard illuminants

1 Scope

This document defines 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.

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CIE S 017, *ILV: International Lighting Vocabulary*

3 Terms and definitions

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

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

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

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

CIE maintains a terminology database for use in standardization at the following address:

— CIE e-ILV: available at http://cie.co.at/e-ilv

3.1
illuminant
radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception

[SOURCE: CIE S 017:2020, Entry 17-23-018, modified — Notes to entry omitted.]

3.2
CIE standard illuminant
illuminant standardized by the CIE for the purpose of harmonization

[SOURCE: CIE S 017:2020, Entry 17-23-021, modified — Notes to entry omitted.]

3.3
CIE standard source
artificial source specified by the CIE whose radiation approximates a CIE standard illuminant

[SOURCE: CIE S 017:2020, Entry 17-23-022, modified — Notes to entry omitted.]

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3.4
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 017:2020, Entry 17-23-020, modified — Notes to entry omitted.]

3.5
standard air
dry air at 15 °C and 101 325 Pa, containing 0,045 % by volume of carbon dioxide

[SOURCE: CIE 018:2019, Clause 3]

4 CIE standard illuminant A

4.1 Definition

The relative spectral power distribution of CIE standard illuminant A, $S_A(\lambda)$, is defined by Formula (1) over the wavelength range 300 nm to 830 nm.

$$S_A(\lambda) = 100 \left(\frac{560}{\lambda} \right)^5 \times \frac{\exp \frac{1{,}435 \times 10^7}{2\,848 \times 560} - 1}{\exp \frac{1{,}435 \times 10^7}{2\,848\ \lambda} - 1} \tag{1}$$

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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 (see also Annex C). This spectral power distribution is normalized to the value 100 (exactly) at the wavelength 560 nm (exactly).

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NOTE Table A.1 in Annex A provides the relative spectral power distribution of CIE standard illuminant A to six significant digits, at 1-nm intervals. For practical purposes it suffices to use these tabulated values instead of the values calculated from Formula (1).

Despite the fact that Formula (1) is based on Planck's equation for vacuum, the wavelengths are to be taken as being in standard air (see 3.5). This makes CIE standard illuminant A compatible with other CIE colorimetric and photometric data.

4.2 Theoretical basis

Formula (1) is equivalent to and can be derived from Formula (2):

$$S_\lambda(\lambda) = 100 \frac{M_{e,\lambda}(\lambda, T)}{M_{e,\lambda}(560, T)} \tag{2}$$

where

$$M_{e,\lambda}(\lambda, T) = c_1\, \lambda^{-5} \left[\exp\left(\frac{c_2}{\lambda T} \right) - 1 \right]^{-1};$$

λ is the wavelength (in nm);

the quotient c_2/T is given by 14 350 µm·K/2 848 K = (1,435 × 10^7/2 848) nm.

Since the numerical value of c_1 cancels out Formula (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 quotient c_2/T.

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The constant c_2 is calculated from $h \cdot c/k$ and its value is 14 387,768 55 ... µm·K, using the values of the Planck constant, h, the speed of light in vacuum, c, and the Boltzmann constant, k, as specified in *The International System of Units*[1]. Using this value for c_2, the assigned temperature for CIE standard illuminant A is 2 855,496 ... K, thus approximately 2 855,5 K.

NOTE More information regarding the historical changes to the temperature used to define CIE standard illuminant A can be found in Annex C.

5 CIE standard illuminant D65

5.1 Definition

CIE standard illuminant D65 shall be as defined in Annex B by the relative spectral power distribution values provided in Column 2 of Table B.1. 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 shall be derived by linear interpolation from the published values.

5.2 Experimental basis

The relative spectral power distribution of CIE standard illuminant D65 is based on experimental measurements of daylight in the wavelength range 330 nm to 700 nm, with extrapolations to 300 nm and 830 nm, as reported by Judd et al.[2] The extrapolated values are believed to be sufficiently accurate for conventional colorimetric purposes, but are not recommended for non-colorimetric use.

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5.3 Correlated colour temperature

CIE standard illuminant D65 has a nominal correlated colour temperature of 6 500 K.

NOTE Using the value of c_2 = 14 388 µm·K specified in the *International Temperature Scale* of 1990,[3] the definition of correlated colour temperature (CIE S 017, 17–23–068) and the relative spectral power distribution data of Table B.1, the correlated colour temperature of CIE standard illuminant D65 is found to be 6 502,712 K. Using the value of c_2 = 14 387,768 775 ... µm·K, as shown in 4.2, the definition of correlated colour temperature (CIE S 017, 17–23–068) and the relative spectral power distribution data of Table B.1, the correlated colour temperature of CIE standard illuminant D65 is found to be 6 502,608 K. The difference from the nominal correlated colour temperature of 6 500 K of CIE standard illuminant D65 is judged to be insignificantly small.

6 CIE standard illuminant D50

6.1 Definition

CIE standard illuminant D50 shall be as defined in Annex B by the relative spectral power distribution values provided in Column 3 of Table B.1. 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 shall be derived by linear interpolation from the published values.

6.2 Correlated colour temperature

CIE standard illuminant D50 has a nominal correlated colour temperature of 5 000 K.

NOTE Using the value of c_2 = 14 388 µm·K specified in the *International Temperature Scale* of 1990,[3] the definition of correlated colour temperature (CIE S 017, 17–23–068) and the relative spectral power distribution data of Table B.1, the correlated colour temperature of CIE standard illuminant D50 is found to be 5 001,319 K. Using the value of c_2 = 14 387,768 775 ... µm·K, as shown in 4.2, the definition of correlated colour temperature (CIE S 017, 17–23–068) and the relative spectral power distribution data of Table B.1, the correlated colour temperature of CIE standard illuminant D50 is found to be 5 001,239 K. The difference from the nominal correlated colour temperature of 5 000 K of CIE standard illuminant D50 is judged to be insignificantly small.

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The actual correlated colour temperature of CIE standard illuminant D50 is slightly different from 5 000 K; however, this is judged to be visually insignificant.

7 Sources for realizing CIE standard illuminants

7.1 Source for CIE standard illuminant A

CIE standard illuminant A can be realized by CIE standard source A, defined as a gas-filled, tungsten-filament lamp operating at an assigned temperature T = (2 848 K/14 350 μm·K) · c_2, where c_2 is expressed in μm·K. A lamp with a fused-quartz envelope or window is recommended if the spectral power distribution of the ultraviolet radiation of CIE standard illuminant A is to be realized more accurately.

The assigned temperature, T, is currently approximated to 2 855,5 K as shown in 4.2.

7.2 Sources for CIE standard illuminants D65 and D50

At present, there are no CIE-recommended standard sources for realizing CIE standard illuminants D65 and D50. The quality of sources intended for laboratory realization of CIE standard illuminant D65 or D50 can be assessed by a method described in ISO 23603/CIE S 012.[4]

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Annex A
(informative)

Table of relative spectral power distribution of CIE standard illuminant A

CIE standard illuminant A is defined by Formula (1) in 4.1. Table A.1 is provided for practical use only.

Table A.1 — Relative spectral power distribution of CIE standard illuminant A (wavelengths in standard air)

λ/nm	$S_A(\lambda)$
300	0,930 483
301	0,967 643
302	1,005 97
303	1,045 49
304	1,086 23
305	1,128 21
306	1,171 47
307	1,216 02
308	1,261 88
309	1,309 10
310	1,357 69
311	1,407 68
312	1,459 10
313	1,511 98
314	1,566 33
315	1,622 19
316	1,679 59
317	1,738 55
318	1,799 10
319	1,861 27
320	1,925 08
321	1,990 57
322	2,057 76
323	2,126 67
324	2,197 34
325	2,269 80
326	2,344 06
327	2,420 17
328	2,498 14
329	2,578 01
330	2,659 81
331	2,743 55
332	2,829 28

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Table A.1 *(continued)*

λ/nm	$S_A(\lambda)$
333	2,917 01
334	3,006 78
335	3,098 61
336	3,192 53
337	3,288 57
338	3,386 76
339	3,487 12
340	3,589 68
341	3,694 47
342	3,801 52
343	3,910 85
344	4,022 50
345	4,136 48
346	4,252 82
347	4,371 56
348	4,492 72
349	4,616 31
350	4,742 38
351	4,870 95
352	5,002 04
353	5,135 68
354	5,271 89
355	5,410 70
356	5,552 13
357	5,696 22
358	5,842 98
359	5,992 44
360	6,144 62
361	6,299 55
362	6,457 24
363	6,617 74
364	6,781 05
365	6,947 20
366	7,116 21
367	7,288 11
368	7,462 92
369	7,640 66
370	7,821 35
371	8,005 01
372	8,191 67
373	8,381 34
374	8,574 04
375	8,769 80
376	8,968 64

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Table A.1 *(continued)*

λ/nm	$S_A(\lambda)$
377	9,170 56
378	9,375 61
379	9,583 78
380	9,795 10
381	10,009 6
382	10,227 3
383	10,448 1
384	10,672 2
385	10,899 6
386	11,130 2
387	11,364 0
388	11,601 2
389	11,841 6
390	12,085 3
391	12,332 4
392	12,582 8
393	12,836 6
394	13,093 8
395	13,354 3
396	13,618 2
397	13,885 5
398	14,156 3
399	14,430 4
400	14,708 0
401	14,989 1
402	15,273 6
403	15,561 6
404	15,853 0
405	16,148 0
406	16,446 4
407	16,748 4
408	17,053 8
409	17,362 8
410	17,675 3
411	17,991 3
412	18,310 8
413	18,633 9
414	18,960 5
415	19,290 7
416	19,624 4
417	19,961 7
418	20,302 6
419	20,647 0
420	20,995 0

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