CIE S 005/E

Standard

CIE Standard Illuminants for Colorimetry

Illuminants colorimétriques normalisés CIE
CIE Normlichtarten für Farbmessung

CIE Central Bureau, Vienna
Kegelgasse 27, A-1030 Vienna, Austria

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Descriptor: Standardisation of colour measurement
Standard colorimetric system

Foreword

This CIE Standard has been prepared by CIE Technical Committee 2-33, "Rationalisation of CIE Standard Illuminants A and D65"*), and was approved by the CIE Board of Administration and the National Committees of the CIE.

The numerical values of the relative spectral distributions of standard illuminants A and D65 defined by this Standard are the same, within an accuracy of six significant digits, as those defined in earlier versions of these illuminants.

Standards produced by the CIE are concise documentation of data, defining aspects of light and lighting for which international harmony requires a unique definition. As such, CIE Standards are a primary source of internationally accepted and agreed data that can be taken, essentially unaltered, into universal standard systems.

CIE Standard Illuminants for Colorimetry

Contents

*) Chairman of this TC was K. D. Mielenz (US), members were: J. J. Hsia (US), J. R. Moore (GB), A. R. Robertson (CA), H. Terstiege (DE), J. F. Verrill (GB).

FINAL
DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 10526

CIE S 005

CIE

Voting begins on:
1998-09-03

Voting terminates on:
1998-11-03

CIE standard illuminants for colorimetry

Illuminants colorimétriques normalisés CIE

Reference number
ISO/FDIS 10526:1998(E)
CIE S 005-1998

Foreword

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

International Standard ISO 10526 was prepared as Standard CIE S 005 by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodies casting a vote, and is published as a joint ISO/CIE edition.

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.

International Standard ISO 10526 was prepared by Technical Committee 2-33 (Rationalisation of CIE Standard Illuminants A and D65) of the CIE.

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1. Scope

This International Standard specifies two illuminants for use in colorimetry. The illuminants, which are defined in clauses 4 and 5 of this International Standard, are as follows:

a) CIE standard illuminant A
This is intended to represent typical, domestic, 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.

b) CIE standard illuminant D65
This is intended to represent average daylight and has a correlated colour temperature of approximately 6 500 K. CIE standard illuminant D65 should be used in all colorimetric calculations requiring representative daylight, unless there are specific reasons for using a different illuminant. 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 should be used pending the availability of additional information on these variations.

Values for the relative spectral power distribution of CIE standard illuminants A and D65 are given in Table 1 of this International Standard. Values are given 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 a 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 illuminant C and other illuminants D. These illuminants are described in Publication CIE 15.2-1986 [1], but they do not have the status of primary CIE standards accorded to the CIE standard illuminants A and D65 described in this International Standard. It is recommended that one of the two CIE standard illuminants defined in this International Standard be used wherever possible. This will greatly facilitate the comparison of published results.

It is noted that in the fields of graphic arts and photography extensive use is also made of CIE illuminant D50, for example ISO 3644 [2] and ISO 13655 [3].

In most practical applications of colorimetry, it is sufficient to use the values of CIE standard illuminants A and D65 at less frequent wavelength intervals or in a narrower spectral region than defined in this Standard. Data and guidelines that facilitate such practice are provided in Publication CIE 15.2 [1], 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.

Subclause 6.1 of this International Standard describes CIE source A, which is recommended for laboratory realizations of CIE standard illuminant A. At present, there is no CIE recommended source representing CIE standard illuminant D65.

2. Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying most recent editions of the standards

indicated below. Members of CIE, the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) maintain registers of currently valid international standards.

CIE 15.2-1986: *Colorimetry*

CIE 17.4-1987: *International Lighting Vocabulary* - equivalent to IEC 50(845)

CIE 51-1981: *A method for assessing the quality of daylight simulators for colorimetry*

ISO/CIE 10527-1991: *CIE standard colorimetric observers*

3. Definitions

For the purposes of this International Standard, the following definitions apply. These definitions are taken from Publication CIE 17.4-1987 [4], where other relevant terms will also be found.

3.1 chromaticity co-ordinates

Ratio of each of a set of three tristimulus values to their sum.

NOTE1 As the sum of the three chromaticity co-ordinates equals 1, two of them are sufficient to define a chromaticity.

NOTE2 In the CIE standard colorimetric systems, the chromaticity co-ordinates are represented by the symbols x, y, z and x_{10}, y_{10}, z_{10}.

3.2 chromaticity diagram

A plane diagram in which points specified by chromaticity co-ordinates represent the chromaticities of colour stimuli.

3.3 CIE standard illuminants

The illuminants A and D65 defined by the CIE in terms of relative spectral power distributions.

3.4 CIE standard sources

Artificial sources, specified by the CIE, whose relative spectral power distributions are approximately the same as those of CIE standard illuminants*.

3.5 CIE 1976 uniform-chromaticity-scale diagram; CIE 1976 UCS diagram

The uniform-chromaticity-scale diagram produced by plotting in rectangular co-ordinates v' against u', quantities defined by the equations

$$u' = 4X/(X + 15Y + 3Z) = 4x/(-2x + 12y + 3)$$
$$v' = 9Y/(X + 15Y + 3Z) = 9y/(-2x + 12y + 3)$$

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

3.6 colour temperature *Tc*

The temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus.

* This definition is a revision of the definition given in CIE 17.4-1987.

3.7 correlated colour temperature T_{cp}

The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

NOTE The recommended method of calculating the correlated colour temperature of a stimulus is to determine, on a chromaticity diagram, the temperature corresponding to the point on the Planckian locus that is intersected by the agreed isotemperature line containing the point representing the stimulus (see Publication CIE 15.2 [1]).

3.8 daylight illuminant

Illuminant having the same, or nearly the same, relative spectral power distribution as a phase of daylight.

3.9 illuminant

Radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception.

3.10 Planckian radiator; black-body

Ideal thermal radiator that absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization. This radiator has, for any wavelength and any direction, the maximum spectral concentration of radiance for a thermal radiator in thermal equilibrium at a given temperature.

3.11 Planckian locus

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

3.12 primary light source

Surface or object emitting light produced by a transformation of energy.

3.13 secondary light source

Surface or object which is not self-emitting but receives light and re-directs it, at least in part, by reflection or transmission.

3.14 tristimulus values (of a colour stimulus)

Amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered.

NOTE In the CIE standard colorimetric systems, the tristimulus values are represented by the symbols X, Y, Z and X_{10}, Y_{10}, Z_{10}.

4. CIE standard illuminant A

4.1 Definition

The relative spectral power distribution $S^A(\lambda)$ of CIE standard illuminant A is defined by the equation

$$S^A(\lambda) = 100\left(\frac{0{,}56}{\lambda}\right)^5 \times \frac{\exp\frac{1\,435\,000}{159\,488} - 1}{\exp\frac{14\,350}{2\,848\,\lambda} - 1} \qquad (1)$$

where

λ is the vacuum wavelength in micrometres and the numerical constants in the two exponential terms are integers.

This spectral power distribution is normalized to the value 100 (exactly) at the vacuum wavelength 0,56 µm (exactly)*.

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

NOTE Table 1 provides the relative spectral power distribution of CIE standard illuminant A between 300 nm and 830 nm at one nm intervals. For all practical purposes it suffices to use these tabulated values instead of the values calculated from equation 1.

4.2 Theoretical basis

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

$$S(\lambda) = 100\, M_{e,\lambda}(\lambda,T) / M_{e,\lambda}(0{,}56\ T), \qquad (2)$$

where

$$M_{e,\lambda}(\lambda,T) = c_1\, \lambda^{-5}\, [\exp(c_2/\lambda T) - 1]^{-1}, \quad [\text{Units of } W\cdot m^{-2}\cdot\mu m^{-1}], \qquad (3)$$

is the spectral radiant exitance of a Planckian radiator of temperature T, c_1 and c_2 are the first and second radiation constants and the ratio c_2/T is given by

$$c_2/T = 14\,350 / 2\,848\ \mu m. \qquad (4)$$

Since the numerical value of c_1 is of no importance in calculating the relative spectral power distribution of an illuminant, the 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 [5] as the relative spectral power distribution of a Planckian radiator of temperature

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

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

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

This form of definition as given in Equ. 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, $c_{2,ITS-27} = 14\,320\ \mu m\cdot K$, $c_{2,IPTS-48} = 14\,380\ \mu m\cdot K$, and $c_{2,IPTS-68} = c_{2,ITS-90} = 14\,388\ \mu m\cdot K$, that were assigned to this constant in the International Temperature Scales of 1927, 1948, 1968 and 1990. 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.

* The value of 2 848 x 0,56 is 1 594,88; to avoid decimal figures, both nominator and denominator in the exponential term in the nominator of equation 1 were multiplied by 100.

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_{27} = 2 842 K, T_{48} = 2 854 K, and T_{68} = T_{90} = 2 856 K, respectively (see 6.1).

It is implicit in the 1931 definition of CIE standard illuminant A that the term λ in equation 1 denotes a vacuum wavelength. The use of air, instead of vacuum, wavelengths will cause the following, insignificantly small, errors of the relative spectral distribution of CIE standard illuminant A: - 0,2 % at 300 nm, -0,1 % at 400 nm, - 0,03 % at 500 nm, + 0,02 % at 600 nm, + 0,05 % at 700 nm and + 0,08 % at 800 nm.

5. CIE standard illuminant D65

5.1 Definition

The relative spectral power distribution $S^{D65}(\lambda)$ of CIE standard illuminant D65 is defined by the values given in table 1 which are presented at 1 nm intervals over the wavelength range from 300 nm to 830 nm. If required, other intermediate values may 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, MacAdam, and Wyszecki [6]. The extrapolated values are believed to be sufficiently accurate for conventional colorimetric purposes, but are not recommended for non-colorimetric use.

5.3 Correlated colour temperature

CIE standard illuminant D65 has a nominal correlated colour temperature of 6 500 K. The exact value depends on the convention used to assign a correlated colour temperature to a stimulus whose chromaticity, as in this case, does not fall precisely on the Planckian locus.

NOTE: Using the value of c_2 = 14 388 µm·K specified in the International Temperature Scale of 1990 and the recommended convention that lines of constant correlated colour temperature are normal to the Planckian locus in a chromaticity diagram in which $2v'/3$ is plotted against u', where u', v' are the co-ordinates used in the CIE 1976 uniform-chromaticity-scale diagram, the correlated colour temperature of CIE standard illuminant D65 was found to be within 4 K of 6 500 K. This difference from the nominal temperature of the CIE standard illuminant was judged to be insignificantly small.

6. CIE sources for producing CIE standard illuminants

6.1 CIE source A

CIE standard illuminant A can be realized by CIE source A, defined as a gas-filled, tungsten-filament lamp operating at a correlated colour temperature

$$T = \frac{2848\,c_2}{14350}\ \mathrm{K} \qquad (7)$$

on a radiation temperature scale specified by a given value of the second radiation constant c_2. 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.

* Information on the procedure used to derive D65 values is given in Publication CIE 15.2 [1].

The value of c_2 specified in the International Temperature Scale of 1990 (ITS-90) is $c_{2,ITS-90}$ = 14 388 µm·K, and thus the correlated colour temperature of CIE source A on this scale is given by

$$T_{90} = \frac{14388}{14350} \times 2848K = 2856K \text{ (approximately)} \qquad (8)$$

Sources calibrated on earlier temperature scales may have to be recalibrated in order to conform with the ITS-90.

This description of CIE source A is supplementary to, and not part of, the definition of CIE standard illuminant A.

6.2 Source for CIE standard illuminant D65

At present, there is no CIE recommended source for realizing CIE standard illuminant D65. The quality of sources intended for laboratory realization of CIE standard illuminant D65 can be assessed by a method described in Publication CIE 51 [7]*.

7. Bibliography

[1] Commission Internationale de l'Éclairage, *Publication CIE* **15.2**-*1986.* Colorimetry.

[2] ISO 3644:1976, Cinematography - Spindles for 8 mm Type R motion-picture cameras and projectors - Dimensions.

[3] ISO 13655:1996, Graphic technology - Spectral measurement and colorimetric computation for graphic arts images.

[4] Commission Internationale de l'Éclairage / International Electrotechnical Commission, *Publication CIE* **17.4**-*1987.* International Lighting Vocabulary.

[5] Commission Internationale de l'Éclairage, *Proceedings of the 8th Session of the CIE*, Cambridge, 1931.

[6] Judd DB, MacAdam DL and Wyszecki G, (in collaboration with Budde HW, Condit HR, Henderson ST and Simonds JL). Spectral Distribution of Typical Daylight as a Function of Correlated Colour Temperature. *J. Opt. Soc. Am.* **54**, (1964) pp.1031-1040.

[7] Commission Internationale de l'Éclairage, *Publication CIE* **51**-*1981.* A method for assessing the quality of daylight simulators for colorimetry.

* CIE is studying recent developments in daylight simulators with a view to recommending a practical artificial source for CIE standard illuminant D65 in the near future. Readers of this standard should consult CIE Publication Lists for possible amendments and new recommendations.

Table 1
Relative spectral power distributions of CIE standard illuminants A and D65

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
300	0,930 483	0,0341 000	350	4,742 38	44,911 7
301	0,967 643	0,360 140	351	4,870 95	45,084 4
302	1,005 97	0,686 180	352	5,002 04	45,257 0
303	1,045 49	1,012 22	353	5,135 68	45,429 7
304	1,086 23	1,338 26	354	5,271 89	45,602 3
305	1,128 21	1,664 30	355	5,410 70	45,775 0
306	1,171 47	1,990 34	356	5,552 13	45,947 7
307	1,216 02	2,316 38	357	5,696 22	46,120 3
308	1,261 88	2,642 42	358	5,842 98	46,293 0
309	1,309 10	2,968 46	359	5,992 44	46,465 6
310	1,357 69	3,294 50	360	6,144 62	46,638 3
311	1,407 68	4,988 65	361	6,299 55	47,183 4
312	1,459 10	6,682 80	362	6,457 24	47,728 5
313	1,511 98	8,376 95	363	6,617 74	48,273 5
314	1,566 33	10,071 1	364	6,781 05	48,818 6
315	1,622 19	11,765 2	365	6,947 20	49,363 7
316	1,679 59	13,459 4	366	7,116 21	49,908 8
317	1,738 55	15,153 5	367	7,288 11	50,453 9
318	1,799 10	16,847 7	368	7,462 92	50,998 9
319	1,861 27	18,541 8	369	7,640 66	51,544 0
320	1,925 08	20,236 0	370	7,821 35	52,089 1
321	1,990 57	21,917 7	371	8,005 01	51,877 7
322	2,057 76	23,599 5	372	8,191 67	51,666 4
323	2,126 67	25,281 2	373	8,381 34	51,455 0
324	2,197 34	26,963 0	374	8,574 04	51,243 7
325	2,269 80	28,644 7	375	8,769 80	51,032 3
326	2,344 06	30,326 5	376	8,968 64	50,820 9
327	2,420 17	32,008 2	377	9,170 56	50,609 6
328	2,498 14	33,690 0	378	9,375 61	50,398 2
329	2,578 01	35,371 7	379	9,583 78	50,186 9
330	2,659 81	37,053 5	380	9,795 10	49,975 5
331	2,743 55	37,343 0	381	10,009 6	50,442 8
332	2,829 28	37,632 6	382	10,227 3	50,910 0
333	2,917 01	37,922 1	383	10,448 1	51,377 3
334	3,006 78	38,211 6	384	10,672 2	51,844 6
335	3,098 61	38,501 1	385	10,899 6	52,311 8
336	3,192 53	38,790 7	386	11,130 2	52,779 1
337	3,288 57	39,080 2	387	11,364 0	53,246 4
338	3,386 76	39,369 7	388	11,601 2	53,713 7
339	3,487 12	39,659 3	389	11,841 6	54,180 9
340	3,589 68	39,948 8	390	12,085 3	54,648 2
341	3,694 47	40,445 1	391	12,332 4	57,458 9
342	3,801 52	40,941 4	392	12,582 8	60,269 5
343	3,910 85	41,437 7	393	12,836 6	63,080 2
344	4,022 50	41,934 0	394	13,093 8	65,890 9
345	4,136 48	42,430 2	395	13,354 3	68,701 5
346	4,252 82	42,926 5	396	13,618 2	71,512 2
347	4,371 56	43,422 8	397	13,885 5	74,322 9
348	4,492 72	43,919 1	398	14,156 3	77,133 6
349	4,616 31	44,415 4	399	14,430 4	79,944 2

Table 1 *(continued)*

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
400	14,708 0	82,754 9	450	33,085 9	117,008
401	14,989 1	83,628 0	451	33,543 2	117,088
402	15,273 6	84,501 1	452	34,004 0	117,169
403	15,561 6	85,374 2	453	34,468 2	117,249
404	15,853 0	86,247 3	454	34,935 8	117,330
405	16,148 0	87,120 4	455	35,406 8	117,410
406	16,446 4	87,993 6	456	35,881 1	117,490
407	16,748 4	88,866 7	457	36,358 8	117,571
408	17,053 8	89,739 8	458	36,839 9	117,651
409	17,362 8	90,612 9	459	37,324 3	117,732
410	17,675 3	91,486 0	460	37,812 1	117,812
411	17,991 3	91,680 6	461	38,303 1	117,517
412	18,310 8	91,875 2	462	38,797 5	117,222
413	18,633 9	92,069 7	463	39,295 1	116,927
414	18,960 5	92,264 3	464	39,796 0	116,632
415	19,290 7	92,458 9	465	40,300 2	116,336
416	19,624 4	92,653 5	466	40,807 6	116,041
417	19,961 7	92,848 1	467	41,318 2	115,746
418	20,302 6	93,042 6	468	41,832 0	115,451
419	20,647 0	93,237 2	469	42,349 1	115,156
420	20,995 0	93,431 8	470	42,869 3	114,861
421	21,346 5	92,756 8	471	43,392 6	114,967
422	21,701 6	92,081 9	472	43,919 2	115,073
423	22,060 3	91,406 9	473	44,448 8	115,180
424	22,422 5	90,732 0	474	44,981 6	115,286
425	22,788 3	90,057 0	475	45,517 4	115,392
426	23,157 7	89,382 1	476	46,056 3	115,498
427	23,530 7	88,707 1	477	46,598 3	115,604
428	23,907 2	88,032 2	478	47,143 3	115,711
429	24,287 3	87,357 2	479	47,691 3	115,817
430	24,670 9	86,682 3	480	48,242 3	115,923
431	25,058 1	88,500 6	481	48,796 3	115,212
432	25,448 9	90,318 8	482	49,353 3	114,501
433	25,843 2	92,137 1	483	49,913 2	113,789
434	26,241 1	93,955 4	484	50,476 0	113,078
435	26,642 5	95,773 6	485	51,041 8	112,367
436	27,047 5	97,591 9	486	51,610 4	111,656
437	27,456 0	99,410 2	487	52,181 8	110,945
438	27,868 1	101,228	488	52,756 1	110,233
439	28,283 6	103,047	489	53,333 2	109,522
440	28,702 7	104,865	490	53,913 2	108,811
441	29,125 3	106,079	491	54,495 8	108,865
442	29,551 5	107,294	492	55,081 3	108,920
443	29,981 1	108,508	493	55,669 4	108,974
444	30,414 2	109,722	494	56,260 3	109,028
445	30,850 8	110,936	495	56,853 9	109,082
446	31,290 9	112,151	496	57,450 1	109,137
447	31,734 5	113,365	497	58,048 9	109,191
448	32,181 5	114,579	498	58,650 4	109,245
449	32,632 0	115,794	499	59,254 5	109,300

Table 1 *(continued)*

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
500	59,861 1	109,354	550	92,912 0	104,046
501	60,470 3	109,199	551	93,615 7	103,641
502	61,082 0	109,044	552	94,320 6	103,237
503	61,696 2	108,888	553	95,026 7	102,832
504	62,312 8	108,733	554	95,733 9	102,428
505	62,932 0	108,578	555	96,442 3	102,023
506	63,553 5	108,423	556	97,151 8	101,618
507	64,177 5	108,268	557	97,862 3	101,214
508	64,803 8	108,112	558	98,573 9	100,809
509	65,432 5	107,957	559	99,286 4	100,405
510	66,063 5	107,802	560	100,000	100,000
511	66,696 8	107,501	561	100,715	99,633 4
512	67,332 4	107,200	562	101,430	99,266 8
513	67,970 2	106,898	563	102,146	98,900 3
514	68,610 2	106,597	564	102,864	98,533 7
515	69,252 5	106,296	565	103,582	98,167 1
516	69,896 9	105,995	566	104,301	97,800 5
517	70,543 5	105,694	567	105,020	97,433 9
518	71,192 2	105,392	568	105,741	97,067 4
519	71,843 0	105,091	569	106,462	96,700 8
520	72,495 9	104,790	570	107,184	96,334 2
521	73,150 8	105,080	571	107,906	96,279 6
522	73,807 7	105,370	572	108,630	96,225 0
523	74,466 6	105,660	573	109,354	96,170 3
524	75,127 5	105,950	574	110,078	96,115 7
525	75,790 3	106,239	575	110,803	96,061 1
526	76,455 1	106,529	576	111,529	96,006 5
527	77,121 7	106,819	577	112,255	95,951 9
528	77,790 2	107,109	578	112,982	95,897 2
529	78,460 5	107,399	579	113,709	95,842 6
530	79,132 6	107,689	580	114,436	95,788 0
531	79,806 5	107,361	581	115,164	95,077 8
532	80,482 1	107,032	582	115,893	94,367 5
533	81,159 5	106,704	583	116,622	93,657 3
534	81,838 6	106,375	584	117,351	92,947 0
535	82,519 3	106,047	585	118,080	92,236 8
536	83,201 7	105,719	586	118,810	91,526 6
537	83,885 6	105,390	587	119,540	90,816 3
538	84,571 2	105,062	588	120,270	90,106 1
539	85,258 4	104,733	589	121,001	89,395 8
540	85,947 0	104,405	590	121,731	88,685 6
541	86,637 2	104,369	591	122,462	88,817 7
542	87,328 8	104,333	592	123,193	88,949 7
543	88,021 9	104,297	593	123,924	89,081 8
544	88,716 5	104,261	594	124,655	89,213 8
545	89,412 4	104,225	595	125,386	89,345 9
546	90,109 7	104,190	596	126,118	89,478 0
547	90,808 3	104,154	597	126,849	89,610 0
548	91,508 2	104,118	598	127,58	89,742 1
549	92,209 5	104,082	599	128,312	89,874 1

Table 1 *(continued)*

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
600	129,043	90,006 2	650	165,028	80,026 8
601	129,774	89,965 5	651	165,726	80,045 6
602	130,505	89,924 8	652	166,424	80,064 4
603	131,236	89,884 1	653	167,121	80,083 1
604	131,966	89,843 4	654	167,816	80,101 9
605	132,697	89,802 6	655	168,510	80,120 7
606	133,427	89,761 9	656	169,203	80,139 5
607	134,157	89,721 2	657	169,895	80,158 3
608	134,887	89,680 5	658	170,586	80,177 0
609	135,617	89,639 8	659	171,275	80,195 8
610	136,346	89,599 1	660	171,963	80,214 6
611	137,075	89,409 1	661	172,650	80,420 9
612	137,804	89,219 0	662	173,335	80,627 2
613	138,532	89,029 0	663	174,019	80,833 6
614	139,260	88,838 9	664	174,702	81,039 9
615	139,988	88,648 9	665	175,383	81,246 2
616	140,715	88,458 9	666	176,063	81,452 5
617	141,441	88,268 8	667	176,741	81,658 8
618	142,167	88,078 8	668	177,419	81,865 2
619	142,893	87,888 7	669	178,094	82,071 5
620	143,618	87,698 7	670	178,769	82,277 8
621	144,343	87,257 7	671	179,441	81,878 4
622	145,067	86,816 7	672	180,113	81,479 1
623	145,790	86,375 7	673	180,783	81,079 7
624	146,513	85,934 7	674	181,451	80,680 4
625	147,235	85,493 6	675	182,118	80,281 0
626	147,957	85,052 6	676	182,783	79,881 6
627	148,678	84,611 6	677	183,447	79,482 3
628	149,398	84,170 6	678	184,109	79,082 9
629	150,117	83,729 6	679	184,770	78,683 6
630	150,836	83,288 6	680	185,429	78,284 2
631	151,554	83,329 7	681	186,087	77,427 9
632	152,271	83,370 7	682	186,743	76,571 6
633	152,988	83,411 8	683	187,397	75,715 3
634	153,704	83,452 8	684	188,050	74,859 0
635	154,418	83,493 9	685	188,701	74,002 7
636	155,132	83,535 0	686	189,350	73,146 5
637	155,845	83,576 0	687	189,998	72,290 2
638	156,558	83,617 1	688	190,644	71,433 9
639	157,269	83,658 1	689	191,288	70,577 6
640	157,979	83,699 2	690	191,931	69,721 3
641	158,689	83,332 0	691	192,572	69,910 1
642	159,397	82,964 7	692	193,211	70,098 9
643	160,104	82,597 5	693	193,849	70,287 6
644	160,811	82,230 2	694	194,484	70,476 4
645	161,516	81,863 0	695	195,118	70,665 2
646	162,221	81,495 8	696	195,750	70,854 0
647	162,924	81,128 5	697	196,381	71,042 8
648	163,626	80,761 3	698	197,009	71,231 5
649	164,327	80,394 0	699	197,636	71,420 3

Table 1 *(continued)*

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
700	198,261	71,609 1	750	227,000	63,592 7
701	198,884	71,883 1	751	227,522	61,875 2
702	199,506	72,157 1	752	228,041	60,157 8
703	200,125	72,431 1	753	228,558	58,440 3
704	200,743	72,705 1	754	229,073	56,722 9
705	201,359	72,979 0	755	229,585	55,005 4
706	201,972	73,253 0	756	230,096	53,288 0
707	202,584	73,527 0	757	230,604	51,570 5
708	203,195	73,801 0	758	231,110	49,853 1
709	203,803	74,075 0	759	231,614	48,135 6
710	204,409	74,349 0	760	232,115	46,418 2
711	205,013	73,074 5	761	232,615	48,456 9
712	205,616	71,800 0	762	233,112	50,495 6
713	206,216	70,525 5	763	233,606	52,534 4
714	206,815	69,251 0	764	234,099	54,573 1
715	207,411	67,976 5	765	234,589	56,611 8
716	208,006	66,702 0	766	235,078	58,650 5
717	208,599	65,427 5	767	235,564	60,689 2
718	209,189	64,153 0	768	236,047	62,728 0
719	209,778	62,878 5	769	236,529	64,766 7
720	210,365	61,604 0	770	237,008	66,805 4
721	210,949	62,432 2	771	237,485	66,463 1
722	211,532	63,260 3	772	237,959	66,120 9
723	212,112	64,088 5	773	238,432	65,778 6
724	212,691	64,916 6	774	238,902	65,436 4
725	213,268	65,744 8	775	239,370	65,094 1
726	213,842	66,573 0	776	239,836	64,751 8
727	214,415	67,401 1	777	240,299	64,409 6
728	214,985	68,229 3	778	240,760	64,067 3
729	215,553	69,057 4	779	241,219	63,725 1
730	216,120	69,885 6	780	241,675	63,382 8
731	216,684	70,405 7	781	242,130	63,474 9
732	217,246	70,925 9	782	242,582	63,567 0
733	217,806	71,446 0	783	243,031	63,659 2
734	218,364	71,966 2	784	243,479	63,751 3
735	218,920	72,486 3	785	243,924	63,843 4
736	219,473	73,006 4	786	244,367	63,935 5
737	220,025	73,526 6	787	244,808	64,027 6
738	220,574	74,046 7	788	245,246	64,119 8
739	221,122	74,566 9	789	245,682	64,211 9
740	221,667	75,087 0	790	246,116	64,304 0
741	222,210	73,937 6	791	246,548	63,818 8
742	222,751	72,788 1	792	246,977	63,333 6
743	223,290	71,638 7	793	247,404	62,848 4
744	223,826	70,489 3	794	247,829	62,363 2
745	224,361	69,339 8	795	248,251	61,877 9
746	224,893	68,190 4	796	248,671	61,392 7
747	225,423	67,041 0	797	249,089	60,907 5
748	225,951	65,891 6	798	249,505	60,422 3
749	226,477	64,742 1	799	249,918	59,937 1

Table 1 *(continued)*

λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$	λ / nm	$S^A(\lambda)$	$S^{D65}(\lambda)$
800	250,329	59,451 9	816	256,595	55,248 0
801	250,738	58,702 6	817	256,968	55,796 1
802	251,144	57,953 3	818	257,338	56,344 3
803	251,548	57,204 0	819	257,706	56,892 4
804	251,950	56,454 7	820	258,071	57,440 6
805	252,350	55,705 4	821	258,434	57,727 8
806	252,747	54,956 2	822	258,795	58,015 0
807	253,142	54,206 9	823	259,154	58,302 2
808	253,535	53,457 6	824	259,511	58,589 4
809	253,925	52,708 3	825	259,865	58,876 5
810	254,314	51,959 0	826	260,217	59,163 7
811	254,700	52,507 2	827	260,567	59,450 9
812	255,083	53,055 3	828	260,914	59,738 1
813	255,465	53,603 5	829	261,259	60,025 3
814	255,844	54,151 6	830	261,602	60,312 5
815	256,221	54,699 8			

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