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CIE standard colorimetric observers

Observateurs de référence colorimétrique CIE

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Contents

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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 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.

The objectives of the CIE are

a) to provide an international forum for the discussion of all matters relating to science, technology and art in the fields of light and lighting and for the interchange of information between countries in these fields;

b) to develop basic standards and procedures of metrology in the fields of light and lighting;

c) to provide guidance on the application of principles and procedures in the development of International Standards and national standards in the fields of light and lighting;

d) to prepare and publish standards, reports and other publications concerned with all matters relating to science, technology and art in the fields of light and lighting;

e) to maintain liaison and technical interaction with other international organizations concerned with matters relating to science, technology, standardization and art in the fields of light and lighting.

Within these objectives, light and lighting embrace fundamental subjects such as vision, photometry and colorimetry, involving natural and man-made radiations in the ultraviolet, visible and infrared regions of the spectrum, and also applications covering all uses of light, indoors and out, including environmental and aesthetic effects, and also means for the production and control of light and radiation.

The technical activities of the CIE are covered by seven divisions, each being responsible for a major subject area of interest to the CIE. Technical Committees consisting of small groups of experts are established in each division to work on separate subjects. The text of this International Standard was prepared by Division 1: *Vision and Colour.* The ratification of a CIE Standard requires the approval of the division members, the Council and national member bodies of the CIE.

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

International Standard ISO/CIE 10527 was prepared as Standard CIE S002 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.

International Standard ISO/CIE 10527 was prepared by Technical Committee CIE/TC 1.3, *Colorimetry*.

Annex A of this International Standard is for information only.

Introduction

Colours with different spectral compositions can look alike. An important function of colorimetry is to determine whether a pair of such metameric colours will look alike. The use of visual colorimeters for this purpose is handicapped by variations in the colour matches made amongst observers classified as having normal colour vision. Visual colorimetry also tends to be time-consuming. For these reasons, it has long been the practice in colorimetry to make use of sets of colour-matching functions to calculate tristimulus values for colours: equality of tristimulus values for a pair of colours indicates that the colour appearances of the two colours match, when they are viewed in the same conditions by an observer for whom the colour-matching functions apply. The use of standard sets of colour-matching functions makes the comparison of tristimulus values obtained at different times and locations possible.

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CIE standard colorimetric observers

1 Scope

This International Standard specifies colour-matching functions for use in colorimetry. Two sets of colour-matching functions are specified.

a) Colour-matching functions for the CIE 1931 standard colorimetric observer

This set of colour-matching functions is representative of the colour-matching properties of observers with normal colour vision for visual field sizes of angular subtense from about 1° to about 4°, for vision at photopic levels of adaptation.

b) Colour-matching functions for the CIE 1964 supplementary standard colorimetric observer

This set of colour-matching functions is representative of the colour-matching properties of observers with normal colour vision for visual field sizes of angular subtense greater than about 4°, for vision at sufficiently high photopic levels and with spectral power distributions such that no participation of the rod receptors of the retina is to be expected.

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 International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

CIE Publication 15.2 : 1986, *Colorimetry*.

CIE Publication 17.4 : 1987, *International lighting vocabulary* (IEC/CIE joint publication).

3 Definitions

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

3.1 colour stimulus function, $\varphi_\lambda(\lambda)$: Description of a colour stimulus by the spectral concentration of a radiometric quantity (such as radiance or radiant power) as a function of wavelength.

3.2 relative colour stimulus function, $\varphi(\lambda)$: Relative spectral power distribution of the colour stimulus function.

3.3 metametric colour stimuli; metamers: Spectrally different colour stimuli that have the same tristimulus values.

3.4 monochromatic stimulus: spectral stimulus: A stimulus consisting of a monochromatic radiation.

3.5 equi-energy spectrum: Spectrum of a radiation whose spectral concentration of a radiometric quantity as a function of wavelength is constant throughout the visible region.

3.6 additive mixture of colour stimuli: Method of stimulation that combines on the retina the actions of various stimuli in such a manner that they cannot be perceived individually.

3.7 colour matching: Action of making a colour stimulus appear the same in colour as a given colour stimulus.

3.8 trichromatic system: System for specifying colour stimuli in terms of tristimulus values based on matching colours by additive mixture of three suitably chosen reference colour stimuli.

3.9 reference colour stimuli, [R], [G], [B]; [X], [Y], [Z]; $[X_{10}]$, $[Y_{10}]$, $[Z_{10}]$; etc.: The set of three colour stimuli on which a trichromatic system is based.

3.10 tristimulus values, R, G, B; X, Y, Z; X_{10}, Y_{10}, Z_{10}; etc.: Amounts of three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered.

3.11 colour-matching functions, $\bar{r}(\lambda)$, $\bar{g}(\lambda)$, $\bar{b}(\lambda)$; $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$; $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$; etc.: The tristimulus values of monochromatic stimuli of equal radiant power.

3.12 CIE 1931 standard colorimetric system (X, Y, Z): A system for determining the tristimulus values of any spectral power distribution using the set of reference colour stimuli [X], [Y], [Z], and the three CIE colour-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ adopted by the CIE in 1931.

3.13 CIE 1964 supplementary standard colorimetric system (X_{10}, Y_{10}, Z_{10}): A system for determining the tristimulus values of any spectral power distribution using the set of reference colour stimuli [X_{10}], [Y_{10}], [Z_{10}], and the three CIE colour-matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ adopted by the CIE in 1964.

3.14 CIE colour-matching functions: The functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ in the CIE 1931 standard colorimetric system and $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ in the CIE 1964 supplementary standard colorimetric system.

3.15 CIE 1931 standard colorimetric observer: An ideal observer whose colour-matching properties correspond to the CIE colour-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$.

3.16 CIE 1964 supplementary standard colorimetric observer: An ideal observer whose colour-matching properties correspond to the CIE colour-matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$.

3.17 chromaticity coordinates, r, g, b; x, y, z; x_{10}, y_{10}, z_{10}; etc.: Ratio of each of a set of three tristimulus values to their sum.

3.18 spectral chromaticity coordinates, $r(\lambda)$, $g(\lambda)$, $b(\lambda)$; $x(\lambda)$, $y(\lambda)$, $z(\lambda)$; $x_{10}(\lambda)$, $y_{10}(\lambda)$, $z_{10}(\lambda)$; etc.: Chromaticity coordinates of monochromatic stimuli.

3.19 spectral luminous efficiency, $V(\lambda)$: Ratio of the radiant flux at wavelength λ_m to that at wavelength λ, such that both radiations produce an equal visual response under specified photometric conditions and λ_m is chosen so that the maximum value of this ratio is equal to 1.

3.20 perfect reflecting diffuser: Ideal isotropic diffuser with a reflectance equal to unity.

4 Specifications

4.1 Colour-matching functions

The colour-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ of the CIE 1931 standard colorimetric observer are defined by the values given in table 1, and those $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$, of the CIE 1964 supplementary standard colorimetric observer are defined by the values given in table 2. The values are given at 1 nm wavelength intervals from 360 nm to 830 nm. If values are required at closer wavelength intervals than 1 nm, they should be derived by linear interpolation.

4.2 Spectral chromaticity coordinates

Tables 1 and 2 also give values for the spectral chromaticity coordinates, $x(\lambda)$, $y(\lambda)$, $z(\lambda)$; $x_{10}(\lambda)$, $y_{10}(\lambda)$, $z_{10}(\lambda)$; these have been derived from the appropriate colour-matching functions by forming the ratios:

$$x(\lambda) = \bar{x}(\lambda)/[\bar{x}(\lambda) + \bar{y}(\lambda) + \bar{z}(\lambda)]$$

$$y(\lambda) = \bar{y}(\lambda)/[\bar{x}(\lambda) + \bar{y}(\lambda) + \bar{z}(\lambda)]$$

$$z(\lambda) = \bar{z}(\lambda)/[\bar{x}(\lambda) + \bar{y}(\lambda) + \bar{z}(\lambda)]$$

$$x_{10}(\lambda) = \bar{x}_{10}(\lambda)/[\bar{x}_{10}(\lambda) + \bar{y}_{10}(\lambda) + \bar{z}_{10}(\lambda)]$$

$$y_{10}(\lambda) = \bar{y}_{10}(\lambda)/[\bar{x}_{10}(\lambda) + \bar{y}_{10}(\lambda) + \bar{z}_{10}(\lambda)]$$

$$z_{10}(\lambda) = \bar{z}_{10}(\lambda)/[\bar{x}_{10}(\lambda) + \bar{y}_{10}(\lambda) + \bar{z}_{10}(\lambda)]$$

NOTE — All wavelengths are for a vacuum.

5 Derivation of the colour-matching functions for the CIE 1931 standard colorimetric observer

5.1 Experimental basis

The CIE 1931 colour-matching functions, $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$, were derived from experimental work carried out by Wright[6] and by Guild[7] in which a total of 17 observers matched the monochromatic stimuli of the spectrum, over the range of about 400 nm to 700 nm, with additive mixtures of red, green and blue lights, using observing fields of 2° angular subtense.

5.2 Transformation procedures

The experimental results were converted into those that would have been obtained if the matching had been carried out using, as reference colour stimuli, monochromatic radiations of wavelengths 700 nm for the red [R], 546,1 nm for the green [G] and 435,8 nm for the blue [B], measured in units such that equal quantities of [R], [G] and [B] were required to match the equi-energy spectrum.

The results for the 17 observers were averaged and then slightly adjusted so that by adding together suitable proportions of the [R], [G], [B] colour-matching functions $\bar{r}(\lambda)$, $\bar{g}(\lambda)$, $\bar{b}(\lambda)$, it was possible to obtain a function identical to that of the CIE spectral luminous efficiency, $V(\lambda)$; the proportions used were in the ratios of 1,000 0 to 4,590 7 to 0,060 1, and these were then the relative luminances of unit quantities of [R], [G] and [B]. The CIE 1931 colour-matching functions were then determined by the following equations:

$$\bar{x}(\lambda) = [0{,}49\bar{r}(\lambda) + 0{,}31\bar{g}(\lambda) + 0{,}20\bar{b}(\lambda)]n$$

$$\bar{y}(\lambda) = [0{,}176\,97\bar{r}(\lambda) + 0{,}812\,40\bar{g}(\lambda) + 0{,}010\,63\bar{b}(\lambda)]n$$

$$\bar{z}(\lambda) = [0{,}00\bar{r}(\lambda) + 0{,}01\bar{g}(\lambda) + 0{,}99\bar{b}(\lambda)]n$$

where n is a normalising constant given by

$$n = V(\lambda)/[0{,}176\,97\bar{r}(\lambda) + 0{,}812\,40\bar{g}(\lambda) + 0{,}010\,63\bar{b}(\lambda)].$$

n is a constant, not a function of wavelength, because the coefficients 0,176 97, 0,812 40, and 0,010 63 are in the same ratios to one another as the ratio of 1,000 0 to 4,590 7 to 0,060 1; n is equal to:

$$(1{,}000\,0 + 4{,}590\,7 + 0{,}060\,1)/(0{,}176\,97 + 0{,}812\,40 + 0{,}010\,63) = 5{,}650\,8$$

The values of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ given in table 1 from 360 nm to 400 nm and from 700 nm to 830 nm are extrapolations.

5.3 Transformation properties

The transformation given in the above equations was chosen to achieve the following objectives. First, the $\bar{y}(\lambda)$ function is identical to the $V(\lambda)$ function. Second, the values of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are all positive for all wavelengths of the spectrum (unlike $\bar{r}(\lambda)$, $\bar{g}(\lambda)$, $\bar{b}(\lambda)$, one of which is negative at most wavelengths because of the need to desaturate spectral stimuli when matching them with red, green, and blue reference stimuli). Third, the values of $\bar{z}(\lambda)$ are zero for wavelengths longer than 650 nm. Fourth, the values of $\bar{x}(\lambda)$ are nearly zero at wavelengths around 505 nm. Fifth, the values of $\bar{x}(\lambda)$ and $\bar{y}(\lambda)$ are small at the short-wavelength end of the spectrum. Sixth, the equi-energy spectrum is specified by equal amounts of X, Y and Z.

Because the $\bar{y}(\lambda)$ function is identical to the $V(\lambda)$ function, the Y tristimulus value is proportional to luminance.

5.4 Comparison with earlier data

The values of $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ given in table 1 for the spectral range of 380 nm to 780 nm at 5 nm intervals, when rounded to four decimal places, agree closely with those originally published in 1931. There are only three minor differences: at λ = 775 nm the new value of $\bar{x}(\lambda)$ is 0,000 1 instead of 0,000 0; at λ = 555 nm, $\bar{y}(\lambda)$ = 1,000 0 instead of 1,000 2 and at λ = 740 nm, $\bar{y}(\lambda)$ = 0,000 2 instead of 0,000 3. These changes are considered insignificant in most colorimetric computations.

When the relative luminances of unit quantities of [R], [G] and [B] are deduced from the data of table 1, the values obtained are 1,000 0 to 4,588 8 to 0,060 3 instead of 1,000 0 to 4,590 7 to 0,060 1, the relative radiances being 71,893 8 to 1,374 7 to 1,000 0 instead of 72,096 2 to 1,379 1 to 1,000 0. These changes are also considered insignificant in practice.

6 Derivation of the colour-matching functions for the CIE 1964 supplementary standard colorimetric observer

6.1 Experimental basis

The CIE 1964 colour-matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$, were derived from experimental work carried out by Stiles and Burch[8] and by Speranskaya[9] in which a total of 67 observers matched monochromatic stimuli of the spectrum from approximately 390 nm to 830 nm with additive mixtures of red, green, and blue lights, using observing fields of 10° angular subtense (but ignoring the central 4° or so).

6.2 Transformation procedures

The experimental results were converted into those that would have been obtained if the matching had been carried out using, as reference colour stimuli, monochromatic radiations of wavenumbers 15 500 cm^{-1} for the red [R_{10}], 19 000 cm^{-1} for the green [G_{10}], and 22 500 cm^{-1} for the blue [B_{10}], corresponding approximately to wavelengths 645,2 nm, 526,3 nm and 444,4 nm respectively. The units used for the quantities of [R_{10}], [G_{10}] and [B_{10}] were such that equal amounts were required to match the equi-energy spectrum. A weighted average of the results for the 67 observers was used to provide a set of colour-matching functions $\bar{r}_{10}(\nu)$, $\bar{g}_{10}(\nu)$, $\bar{b}_{10}(\nu)$. The CIE 1964 colour-matching functions were then derived by the following equations:

$$\bar{x}_{10}(\nu) = 0{,}341\,080\,\bar{r}_{10}(\nu) + 0{,}189\,145\,\bar{g}_{10}(\nu) + 0{,}387\,529\,\bar{b}_{10}(\nu)$$

$$\bar{y}_{10}(\nu) = 0{,}139\,058\,\bar{r}_{10}(\nu) + 0{,}837\,460\,\bar{g}_{10}(\nu) + 0{,}073\,316\,\bar{b}_{10}(\nu)$$

$$\bar{z}_{10}(\nu) = 0{,}000\,000\,\bar{r}_{10}(\nu) + 0{,}039\,553\,\bar{g}_{10}(\nu) + 2{,}026\,200\,\bar{b}_{10}(\nu)$$

In table 2, the CIE 1964 colour-matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ are given on a wavelength basis and were obtained by interpolation from the frequency-based functions given above. The values in the range of 360 nm to 390 nm are extrapolations.

6.3 Transformation properties

The transformation given in the equations in 6.2 was chosen to achieve a colorimetric system (X_{10}, Y_{10}, Z_{10}) having a coordinate system broadly similar to that of the CIE 1931 (X, Y, Z) system. However, in the 1964 system, the data were not constrained to fit the CIE $V(\lambda)$ spectral luminous efficiency function, and the Y_{10} tristimulus value is not proportional to luminance.

6.4 Comparison with earlier data

The values given in table 2 are the same as those given in CIE Publication No. 15 (1971).

7 Practical application of colour-matching functions for CIE standard colorimetric observers

7.1 Obtaining tristimulus values

The data given in tables 1 and 2 provide the tristimulus values and chromaticity coordinates of all monochromatic stimuli directly or by interpolation. For stimuli consisting of radiation of various wavelengths, the tristimulus values X, Y, Z and X_{10}, Y_{10}, Z_{10} are calculated by integration over the spectral range 360 nm to 830 nm using the following equations:

$$X = k \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}(\lambda)\,\mathrm{d}\lambda \qquad X_{10} = k_{10} \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}_{10}(\lambda)\,\mathrm{d}\lambda$$

$$Y = k \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}(\lambda)\,\mathrm{d}\lambda \qquad Y_{10} = k_{10} \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}_{10}(\lambda)\,\mathrm{d}\lambda$$

$$Z = k \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}(\lambda)\,\mathrm{d}\lambda \qquad Z_{10} = k_{10} \int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}_{10}(\lambda)\,\mathrm{d}\lambda$$

where

$\varphi_\lambda(\lambda)$ is the colour stimulus function of the stimulus considered;

$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$, $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ are the appropriate CIE colour-matching functions;

k and k_{10} are constants.

Tristimulus values are usually evaluated on a relative basis, and the constants, k and k_{10} are then chosen according to agreed conventions; however, it is essential that, for stimuli that will be considered together, the same value for k (or for k_{10}) be adopted, so that all the tristimulus values involved are assessed on the same basis. For reflecting object-colours, k and k_{10} shall be chosen so that Y and Y_{10} are equal to 100 for the perfect reflecting diffuser, and, for transmitting object-colours, so that Y and Y_{10} are equal to 100 for the perfect transmitter. In the case of primary light sources, if it is required that Y be equal to the absolute value of the photometric quantity, k shall be equal to K_m, the maximum spectral luminous efficacy (which is equal to 683 lm/W) and $\varphi_\lambda(\lambda)$ shall then be the spectral concentration of the radiometric quantity corresponding to the photometric quantity required.

7.2 The basis for integration

The integration step in the equations in 7.1 implies additivity of colour matches: that is, if two colour stimuli [C_1] and [C_2] have tristimulus values X_1, Y_1, Z_1 and X_2, Y_2, Z_2, respectively, then the additive mixture of [C_1] and [C_2] will have tristimulus values $X_1 + X_2$, $Y_1 + Y_2$, $Z_1 + Z_2$. Experimental investigations have shown that, although additivity of this type sometimes fails to occur, the principle of additivity is sufficiently valid for predicting colour matches in most cases of importance in practical colorimetry.

7.3 Rod activity

The tristimulus values in the CIE 1964 supplementary standard colorimetric system are relevant only to those observing conditions where the luminances are sufficiently high and the spectral power distributions are such that no significant participation of the rod receptors of the retina is to be expected.

7.4 The use of restricted data

For most practical applications of colorimetry, it is sufficient to use values of colour-matching functions at less frequent intervals of wavelength than every 1 nm, covering a more restricted range of wavelengths than from 360 nm to 830 nm, and using fewer decimal places than are given in tables 1 and 2. Data and guidelines that facilitate such practice are given in CIE Publication No. 15.2, together with various other recommended procedures for practical colorimetry.

7.5 Standard of reflectance

The perfect reflecting diffuser is the CIE reference standard for the colorimetry of reflecting samples.

Table 1 — Colour-matching functions and chromaticity coordinates of CIE 1931 standard colorimetric observer

Wave-length λ nm	CIE colour-matching functions			Chromaticity coordinates		
	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
360	0.000 129 900 0	0.000 003 917 000	0.000 606 100 0	0.175 56	0.005 29	0.819 15
61	0.000 145 847 0	0.000 004 393 581	0.000 680 879 2	0.175 48	0.005 29	0.819 23
62	0.000 163 802 1	0.000 004 929 604	0.000 765 145 6	0.175 40	0.005 28	0.819 32
63	0.000 184 003 7	0.000 005 532 136	0.000 860 012 4	0.175 32	0.005 27	0.819 41
64	0.000 206 690 2	0.000 006 208 245	0.000 966 592 8	0.175 24	0.005 26	0.819 50
365	0.000 232 100 0	0.000 006 965 000	0.001 086 000	0.175 16	0.005 26	0.819 58
66	0.000 260 728 0	0.000 007 813 219	0.001 220 586	0.175 09	0.005 25	0.819 66
67	0.000 293 075 0	0.000 008 767 336	0.001 372 729	0.175 01	0.005 24	0.819 75
68	0.000 329 388 0	0.000 009 839 844	0.001 543 579	0.174 94	0.005 23	0.819 83
69	0.000 369 914 0	0.000 011 043 23	0.001 734 286	0.174 88	0.005 22	0.819 90
370	0.000 414 900 0	0.000 012 390 00	0.001 946 000	0.174 82	0.005 22	0.819 96
71	0.000 464 158 7	0.000 013 886 41	0.002 177 777	0.174 77	0.005 23	0.820 00
72	0.000 518 986 0	0.000 015 557 28	0.002 435 809	0.174 72	0.005 24	0.820 04
73	0.000 581 854 0	0.000 017 442 96	0.002 731 953	0.174 66	0.005 24	0.820 10
74	0.000 655 234 7	0.000 019 583 75	0.003 078 064	0.174 59	0.005 22	0.820 19
375	0.000 741 600 0	0.000 022 020 00	0.003 486 000	0.174 51	0.005 18	0.820 31
76	0.000 845 029 6	0.000 024 839 65	0.003 975 227	0.174 41	0.005 13	0.820 46
77	0.000 964 526 8	0.000 028 041 26	0.004 540 880	0.174 31	0.005 07	0.820 62
78	0.001 094 949	0.000 031 531 04	0.005 158 320	0.174 22	0.005 02	0.820 76
79	0.001 231 154	0.000 035 215 21	0.005 802 907	0.174 16	0.004 98	0.820 86
380	0.001 368 000	0.000 039 000 00	0.006 450 001	0.174 11	0.004 96	0.820 93
81	0.001 502 050	0.000 042 826 40	0.007 083 216	0.174 09	0.004 96	0.820 95
82	0.001 642 328	0.000 046 914 60	0.007 745 488	0.174 07	0.004 97	0.820 96
83	0.001 802 382	0.000 051 589 60	0.008 501 152	0.174 06	0.004 98	0.820 96
84	0.001 995 757	0.000 057 176 40	0.009 414 544	0.174 04	0.004 98	0.820 98
385	0.002 236 000	0.000 064 000 00	0.010 549 99	0.174 01	0.004 98	0.821 01
86	0.002 535 385	0.000 072 344 21	0.011 965 80	0.173 97	0.004 97	0.821 06
87	0.002 892 603	0.000 082 212 24	0.013 655 87	0.173 93	0.004 94	0.821 13
88	0.003 300 829	0.000 093 508 16	0.015 588 05	0.173 89	0.004 93	0.821 18
89	0.003 753 236	0.000 106 136 1	0.017 730 15	0.173 84	0.004 92	0.821 24
390	0.004 243 000	0.000 120 000 0	0.020 050 01	0.173 80	0.004 92	0.821 28
91	0.004 762 389	0.000 134 984 0	0.022 511 36	0.173 76	0.004 92	0.821 32
92	0.005 330 048	0.000 151 492 0	0.025 202 88	0.173 70	0.004 94	0.821 36
93	0.005 978 712	0.000 170 208 0	0.028 279 72	0.173 66	0.004 94	0.821 40
94	0.006 741 117	0.000 191 816 0	0.031 897 04	0.173 61	0.004 94	0.821 45
395	0.007 650 000	0.000 217 000 0	0.036 210 00	0.173 56	0.004 92	0.821 52
96	0.008 751 373	0.000 246 906 7	0.041 437 71	0.173 51	0.004 90	0.821 59
97	0.010 028 88	0.000 281 240 0	0.047 503 72	0.173 47	0.004 86	0.821 67
98	0.011 421 70	0.000 318 520 0	0.054 119 88	0.173 42	0.004 84	0.821 74
99	0.012 869 01	0.000 357 266 7	0.060 998 03	0.173 38	0.004 81	0.821 81
400	0.014 310 00	0.000 396 000 0	0.067 850 01	0.173 34	0.004 80	0.821 86
01	0.015 704 43	0.000 433 714 7	0.074 486 32	0.173 29	0.004 79	0.821 92
02	0.017 147 44	0.000 473 024 0	0.081 361 56	0.173 24	0.004 78	0.821 98
03	0.018 781 22	0.000 517 876 0	0.089 153 64	0.173 17	0.004 78	0.822 05
04	0.020 748 01	0.000 572 218 7	0.098 540 48	0.173 10	0.004 77	0.822 13
405	0.023 190 00	0.000 640 000 0	0.110 200 0	0.173 02	0.004 78	0.822 20
06	0.026 207 36	0.000 724 560 0	0.124 613 3	0.172 93	0.004 78	0.822 29
07	0.029 782 48	0.000 825 500 0	0.141 701 7	0.172 84	0.004 79	0.822 37
08	0.033 880 92	0.000 941 160 0	0.161 303 5	0.172 75	0.004 80	0.822 45
09	0.038 468 24	0.001 069 880	0.183 256 8	0.172 66	0.004 80	0.822 54

Table 1 — (*continued*)

Wavelength λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
410	0.043 510 00	0.001 210 000	0.207 400 0	0.172 58	0.004 80	0.822 62
11	0.048 995 60	0.001 362 091	0.233 692 1	0.172 49	0.004 80	0.822 71
12	0.055 022 60	0.001 530 752	0.262 611 4	0.172 39	0.004 80	0.822 81
13	0.061 718 80	0.001 720 368	0.294 774 6	0.172 30	0.004 80	0.822 90
14	0.069 212 00	0.001 935 323	0.330 798 5	0.172 19	0.004 82	0.822 99
415	0.077 630 00	0.002 180 000	0.371 300 0	0.172 09	0.004 83	0.823 08
16	0.086 958 11	0.002 454 800	0.416 209 1	0.171 98	0.004 86	0.823 16
17	0.097 176 72	0.002 764 000	0.465 464 2	0.171 87	0.004 89	0.823 24
18	0.108 406 3	0.003 117 800	0.519 694 8	0.171 74	0.004 94	0.823 32
19	0.120 767 2	0.003 526 400	0.579 530 3	0.171 59	0.005 01	0.823 40
420	0.134 380 0	0.004 000 000	0.645 600 0	0.171 41	0.005 10	0.823 49
21	0.149 358 2	0.004 546 240	0.718 483 8	0.171 21	0.005 21	0.823 58
22	0.165 395 7	0.005 159 320	0.796 713 3	0.170 99	0.005 33	0.823 68
23	0.181 983 1	0.005 829 280	0.877 845 9	0.170 77	0.005 47	0.823 76
24	0.198 611 0	0.006 546 160	0.959 439 0	0.170 54	0.005 62	0.823 84
425	0.214 770 0	0.007 300 000	1.039 050 1	0.170 30	0.005 79	0.823 91
26	0.230 186 8	0.008 086 507	1.115 367 3	0.170 05	0.005 97	0.823 98
27	0.244 879 7	0.008 908 720	1.188 497 1	0.169 78	0.006 18	0.824 04
28	0.258 777 3	0.009 767 680	1.258 123 3	0.169 50	0.006 40	0.824 10
29	0.271 807 9	0.010 664 43	1.323 929 6	0.169 20	0.006 64	0.824 16
430	0.283 900 0	0.011 600 00	1.385 600 0	0.168 88	0.006 90	0.824 22
31	0.294 943 8	0.012 573 17	1.442 635 2	0.168 53	0.007 18	0.824 29
32	0.304 896 5	0.013 582 72	1.494 803 5	0.168 15	0.007 49	0.824 36
33	0.313 787 3	0.014 629 68	1.542 190 3	0.167 75	0.007 82	0.824 43
34	0.321 645 4	0.015 715 09	1.584 880 7	0.167 33	0.008 17	0.824 50
435	0.328 500 0	0.016 840 00	1.622 960 0	0.166 90	0.008 55	0.824 55
36	0.334 351 3	0.018 007 36	1.656 404 8	0.166 45	0.008 96	0.824 59
37	0.339 210 1	0.019 214 48	1.685 295 9	0.165 98	0.009 40	0.824 62
38	0.343 121 3	0.020 453 92	1.709 874 5	0.165 48	0.009 87	0.824 65
39	0.346 129 6	0.021 718 24	1.730 382 1	0.164 96	0.010 35	0.824 69
440	0.348 280 0	0.023 000 00	1.747 060 0	0.164 41	0.010 86	0.824 73
41	0.349 599 9	0.024 294 61	1.760 044 6	0.163 83	0.011 38	0.824 79
42	0.350 147 4	0.025 610 24	1.769 623 3	0.163 21	0.011 94	0.824 85
43	0.350 013 0	0.026 958 57	1.776 263 7	0.162 55	0.012 52	0.824 93
44	0.349 287 0	0.028 351 25	1.780 433 4	0.161 85	0.013 14	0.825 01
445	0.348 060 0	0.029 800 00	1.782 600 0	0.161 11	0.013 79	0.825 10
46	0.346 373 3	0.031 310 83	1.782 968 2	0.160 31	0.014 49	0.825 20
47	0.344 262 4	0.032 883 68	1.781 699 8	0.159 47	0.015 23	0.825 30
48	0.341 808 8	0.034 521 12	1.779 198 2	0.158 57	0.016 02	0.825 41
49	0.339 094 1	0.036 225 71	1.775 867 1	0.157 63	0.016 84	0.825 53
450	0.336 200 0	0.038 000 00	1.772 110 0	0.156 64	0.017 71	0.825 65
51	0.333 197 7	0.039 846 67	1.768 258 9	0.155 60	0.018 61	0.825 79
52	0.330 041 1	0.041 768 00	1.764 039 0	0.154 52	0.019 56	0.825 92
53	0.326 635 7	0.043 766 00	1.758 943 8	0.153 40	0.020 55	0.826 05
54	0.322 886 8	0.045 842 67	1.752 466 3	0.152 22	0.021 61	0.826 17
455	0.318 700 0	0.048 000 00	1.744 100 0	0.150 99	0.022 74	0.826 27
56	0.314 025 1	0.050 243 68	1.733 559 5	0.149 69	0.023 95	0.826 36
57	0.308 884 0	0.052 573 04	1.720 858 1	0.148 34	0.025 25	0.826 41
58	0.303 290 4	0.054 980 56	1.705 936 9	0.146 93	0.026 63	0.826 44
59	0.297 257 9	0.057 458 72	1.688 737 2	0.145 47	0.028 12	0.826 41

Table 1 — *(continued)*

Wave-length λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	
460	0.290 800 0	0.060 000 00	1.669 200 0	0.143 96	0.029 70	0.826 34
61	0.283 970 1	0.062 601 97	1.647 528 7	0.142 41	0.031 39	0.826 20
62	0.276 721 4	0.065 277 52	1.623 412 7	0.140 80	0.033 21	0.825 99
63	0.268 917 8	0.068 042 08	1.596 022 3	0.139 12	0.035 20	0.825 68
64	0.260 422 7	0.070 911 09	1.564 528 0	0.137 37	0.037 40	0.825 23
465	0.251 100 0	0.073 900 00	1.528 100 0	0.135 50	0.039 88	0.824 62
66	0.240 847 5	0.077 016 00	1.486 111 4	0.133 51	0.042 69	0.823 80
67	0.229 851 2	0.080 266 40	1.439 521 5	0.131 37	0.045 88	0.822 75
68	0.218 407 2	0.083 666 80	1.389 879 9	0.129 09	0.049 45	0.821 46
69	0.206 811 5	0.087 232 80	1.338 736 2	0.126 66	0.053 43	0.819 91
470	0.195 360 0	0.090 980 00	1.287 640 0	0.124 12	0.057 80	0.818 08
71	0.184 213 6	0.094 917 55	1.237 422 3	0.121 47	0.062 59	0.815 94
72	0.173 327 3	0.099 045 84	1.187 824 3	0.118 70	0.067 83	0.813 47
73	0.162 688 1	0.103 367 4	1.138 761 1	0.115 81	0.073 58	0.810 61
74	0.152 283 3	0.107 884 6	1.090 148 0	0.112 78	0.079 89	0.807 33
475	0.142 100 0	0.112 600 0	1.041 900 0	0.109 60	0.086 84	0.803 56
76	0.132 178 6	0.117 532 0	0.994 197 6	0.106 26	0.094 49	0.799 25
77	0.122 569 6	0.122 674 4	0.947 347 3	0.102 78	0.102 86	0.794 36
78	0.113 275 2	0.127 992 8	0.901 453 1	0.099 13	0.112 01	0.788 86
79	0.104 297 9	0.133 452 8	0.856 619 3	0.095 31	0.121 94	0.782 75
480	0.095 640 00	0.139 020 0	0.812 950 1	0.091 29	0.132 70	0.776 01
81	0.087 299 55	0.144 676 4	0.770 517 3	0.087 08	0.144 32	0.768 60
82	0.079 308 04	0.150 469 3	0.729 444 8	0.082 68	0.156 87	0.760 45
83	0.071 717 76	0.156 461 9	0.689 913 6	0.078 12	0.170 42	0.751 46
84	0.064 580 99	0.162 717 7	0.652 104 9	0.073 44	0.185 03	0.741 53
485	0.057 950 01	0.169 300 0	0.616 200 0	0.068 71	0.200 72	0.730 57
86	0.051 862 11	0.176 243 1	0.582 328 6	0.063 99	0.217 47	0.718 54
87	0.046 281 52	0.183 558 1	0.550 416 2	0.059 32	0.235 25	0.705 43
88	0.041 150 88	0.191 273 5	0.520 337 6	0.054 67	0.254 09	0.691 24
89	0.036 412 83	0.199 418 0	0.491 967 3	0.050 03	0.274 00	0.675 97
490	0.032 010 00	0.208 020 0	0.465 180 0	0.045 39	0.294 98	0.659 63
91	0.027 917 20	0.217 119 9	0.439 924 6	0.040 76	0.316 98	0.642 26
92	0.024 144 40	0.226 734 5	0.416 183 6	0.036 20	0.339 90	0.623 90
93	0.020 687 00	0.236 857 1	0.393 882 2	0.031 76	0.363 60	0.604 64
94	0.017 540 40	0.247 481 2	0.372 945 9	0.027 49	0.387 92	0.584 59
495	0.014 700 00	0.258 600 0	0.353 300 0	0.023 46	0.412 70	0.563 84
96	0.012 161 79	0.270 184 9	0.334 857 8	0.019 70	0.437 76	0.542 54
97	0.009 919 960	0.282 293 9	0.317 552 1	0.016 27	0.462 95	0.520 78
98	0.007 967 240	0.295 050 5	0.301 337 5	0.013 18	0.488 21	0.498 61
99	0.006 296 346	0.308 578 0	0.286 168 6	0.010 48	0.513 40	0.476 12
500	0.004 900 000	0.323 000 0	0.272 000 0	0.008 17	0.538 42	0.453 41
01	0.003 777 173	0.338 402 1	0.258 817 1	0.006 28	0.563 07	0.430 65
02	0.002 945 320	0.354 685 8	0.246 483 8	0.004 87	0.587 12	0.408 01
03	0.002 424 880	0.371 698 6	0.234 771 8	0.003 98	0.610 45	0.385 57
04	0.002 236 293	0.389 287 5	0.223 453 3	0.003 64	0.633 01	0.363 35
505	0.002 400 000	0.407 300 0	0.212 300 0	0.003 86	0.654 82	0.341 32
06	0.002 925 520	0.425 629 9	0.201 169 2	0.004 64	0.675 90	0.319 46
07	0.003 836 560	0.444 309 6	0.190 119 6	0.006 01	0.696 12	0.297 87
08	0.005 174 840	0.463 394 4	0.179 225 4	0.007 99	0.715 34	0.276 67
09	0.006 982 080	0.482 939 5	0.168 560 8	0.010 60	0.733 41	0.255 99

Table 1 — (*continued*)

Wavelength λ nm	CIE colour-matching functions			Chromaticity coordinates		
	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	$x(\lambda)$	$y(\lambda)$	$z(\lambda)$
510	0.009 300 000	0.503 000 0	0.158 200 0	0.013 87	0.750 19	0.235 94
11	0.012 149 49	0.523 569 3	0.148 138 3	0.017 77	0.765 61	0.216 62
12	0.015 535 88	0.544 512 0	0.138 375 8	0.022 24	0.779 63	0.198 13
13	0.019 477 52	0.565 690 0	0.128 994 2	0.027 27	0.792 11	0.180 62
14	0.023 992 77	0.586 965 3	0.120 075 1	0.032 82	0.802 93	0.164 25
515	0.029 100 00	0.608 200 0	0.111 700 0	0.038 85	0.812 02	0.149 13
16	0.034 814 85	0.629 345 6	0.103 904 8	0.045 33	0.819 39	0.135 28
17	0.041 120 16	0.650 306 8	0.096 667 48	0.052 18	0.825 16	0.122 66
18	0.047 985 04	0.670 875 2	0.089 982 72	0.059 32	0.829 43	0.111 25
19	0.055 378 61	0.690 842 4	0.083 845 31	0.066 72	0.832 27	0.101 01
520	0.063 270 00	0.710 000 0	0.078 249 99	0.074 30	0.833 80	0.091 90
21	0.071 635 01	0.728 185 2	0.073 208 99	0.082 05	0.834 09	0.083 86
22	0.080 462 24	0.745 463 6	0.068 678 16	0.089 94	0.833 29	0.076 77
23	0.089 739 96	0.761 969 4	0.064 567 84	0.097 94	0.831 59	0.070 47
24	0.099 456 45	0.777 836 8	0.060 788 35	0.106 02	0.829 18	0.064 80
525	0.109 600 0	0.793 200 0	0.057 250 01	0.114 16	0.826 21	0.059 63
26	0.120 167 4	0.808 110 4	0.053 904 35	0.122 35	0.822 77	0.054 88
27	0.131 114 5	0.822 496 2	0.050 746 64	0.130 55	0.818 93	0.050 52
28	0.142 367 9	0.836 306 8	0.047 752 76	0.138 70	0.814 78	0.046 52
29	0.153 854 2	0.849 491 6	0.044 898 59	0.146 77	0.810 40	0.042 83
530	0.165 500 0	0.862 000 0	0.042 160 00	0.154 72	0.805 86	0.039 42
31	0.177 257 1	0.873 810 8	0.039 507 28	0.162 53	0.801 24	0.036 23
32	0.189 140 0	0.884 962 4	0.036 935 64	0.170 24	0.796 52	0.033 24
33	0.201 169 4	0.895 493 6	0.034 458 36	0.177 85	0.791 69	0.030 46
34	0.213 365 8	0.905 443 2	0.032 088 72	0.185 39	0.786 73	0.027 88
535	0.225 749 9	0.914 850 1	0.029 840 00	0.192 88	0.781 63	0.025 49
36	0.238 320 9	0.923 734 8	0.027 711 81	0.200 31	0.776 40	0.023 29
37	0.251 066 8	0.932 092 4	0.025 694 44	0.207 69	0.771 05	0.021 26
38	0.263 992 2	0.939 922 6	0.023 787 16	0.215 03	0.765 59	0.019 38
39	0.277 101 7	0.947 225 2	0.021 989 25	0.222 34	0.760 02	0.017 64
540	0.290 400 0	0.954 000 0	0.020 300 00	0.229 62	0.754 33	0.016 05
41	0.303 891 2	0.960 256 1	0.018 718 05	0.236 89	0.748 52	0.014 59
42	0.317 572 6	0.966 007 4	0.017 240 36	0.244 13	0.742 62	0.013 25
43	0.331 438 4	0.971 260 6	0.015 863 64	0.251 36	0.736 61	0.012 03
44	0.345 482 8	0.976 022 5	0.014 584 61	0.258 58	0.730 51	0.010 91
545	0.359 700 0	0.980 300 0	0.013 400 00	0.265 78	0.724 32	0.009 90
46	0.374 083 9	0.984 092 4	0.012 307 23	0.272 96	0.718 06	0.008 98
47	0.388 639 6	0.987 418 2	0.011 301 88	0.280 13	0.711 72	0.008 15
48	0.403 378 4	0.990 312 8	0.010 377 92	0.287 29	0.705 32	0.007 39
49	0.418 311 5	0.992 811 6	0.009 529 306	0.294 45	0.698 84	0.006 71
550	0.433 449 9	0.994 950 1	0.008 749 999	0.301 60	0.692 31	0.006 09
51	0.448 795 3	0.996 710 8	0.008 035 200	0.308 76	0.685 71	0.005 53
52	0.464 336 0	0.998 098 3	0.007 381 600	0.315 92	0.679 06	0.005 02
53	0.480 064 0	0.999 112 0	0.006 785 400	0.323 06	0.672 37	0.004 57
54	0.495 971 3	0.999 748 2	0.006 242 800	0.330 21	0.665 63	0.004 16
555	0.512 050 1	1.000 000 0	0.005 749 999	0.337 36	0.658 85	0.003 79
56	0.528 295 9	0.999 856 7	0.005 303 600	0.344 51	0.652 03	0.003 46
57	0.544 691 6	0.999 304 6	0.004 899 800	0.351 67	0.645 17	0.003 16
58	0.561 209 4	0.998 325 5	0.004 534 200	0.358 81	0.638 29	0.002 90
59	0.577 821 5	0.996 898 7	0.004 202 400	0.365 96	0.631 38	0.002 66

Table 1 — (*continued*)

Wavelength λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
560	0.594 500 0	0.995 000 0	0.003 900 000	0.373 10	0.624 45	0.002 45
61	0.611 220 9	0.992 600 5	0.003 623 200	0.380 24	0.617 50	0.002 26
62	0.627 975 8	0.989 742 6	0.003 370 600	0.387 38	0.610 54	0.002 08
63	0.644 760 2	0.986 444 4	0.003 141 400	0.394 51	0.603 57	0.001 92
64	0.661 569 7	0.982 724 1	0.002 934 800	0.401 63	0.596 59	0.001 78
565	0.678 400 0	0.978 600 0	0.002 749 999	0.408 73	0.589 61	0.001 66
66	0.695 239 2	0.974 083 7	0.002 585 200	0.415 83	0.582 62	0.001 55
67	0.712 058 6	0.969 171 2	0.002 438 600	0.422 92	0.575 63	0.001 45
68	0.728 828 4	0.963 856 8	0.002 309 400	0.429 99	0.568 65	0.001 36
69	0.745 518 8	0.958 134 9	0.002 196 800	0.437 04	0.561 67	0.001 29
570	0.762 100 0	0.952 000 0	0.002 100 000	0.444 06	0.554 72	0.001 22
71	0.778 543 2	0.945 450 4	0.002 017 733	0.451 06	0.547 77	0.001 17
72	0.794 825 6	0.938 499 2	0.001 948 200	0.458 04	0.540 84	0.001 12
73	0.810 926 4	0.931 162 8	0.001 889 800	0.464 99	0.533 93	0.001 08
74	0.826 824 8	0.923 457 6	0.001 840 933	0.471 90	0.527 05	0.001 05
575	0.842 500 0	0.915 400 0	0.001 800 000	0.478 78	0.520 20	0.001 02
76	0.857 932 5	0.907 006 4	0.001 766 267	0.485 61	0.513 39	0.001 00
77	0.873 081 6	0.898 277 2	0.001 737 800	0.492 41	0.506 61	0.000 98
78	0.887 894 4	0.889 204 8	0.001 711 200	0.499 15	0.499 89	0.000 96
79	0.902 318 1	0.879 781 6	0.001 683 067	0.505 85	0.493 21	0.000 94
580	0.916 300 0	0.870 000 0	0.001 650 001	0.512 49	0.486 59	0.000 92
81	0.929 799 5	0.859 861 3	0.001 610 133	0.519 07	0.480 03	0.000 90
82	0.942 798 4	0.849 392 0	0.001 564 400	0.525 60	0.473 53	0.000 87
83	0.955 277 6	0.838 622 0	0.001 513 600	0.532 07	0.467 09	0.000 84
84	0.967 217 9	0.827 581 3	0.001 458 533	0.538 46	0.460 73	0.000 81
585	0.978 600 0	0.816 300 0	0.001 400 000	0.544 79	0.454 43	0.000 78
86	0.989 385 6	0.804 794 7	0.001 336 667	0.551 03	0.448 23	0.000 74
87	0.999 548 8	0.793 082 0	0.001 270 000	0.557 19	0.442 10	0.000 71
88	1.009 089 2	0.781 192 0	0.001 205 000	0.563 27	0.436 06	0.000 67
89	1.018 006 4	0.769 154 7	0.001 146 667	0.569 26	0.430 10	0.000 64
590	1.026 300 0	0.757 000 0	0.001 100 000	0.575 15	0.424 23	0.000 62
91	1.033 982 7	0.744 754 1	0.001 068 800	0.580 94	0.418 46	0.000 60
92	1.040 986 0	0.732 422 4	0.001 049 400	0.586 65	0.412 76	0.000 59
93	1.047 188 0	0.720 003 6	0.001 035 600	0.592 22	0.407 19	0.000 59
94	1.052 466 7	0.707 496 5	0.001 021 200	0.597 66	0.401 76	0.000 58
595	1.056 700 0	0.694 900 0	0.001 000 000	0.602 93	0.396 50	0.000 57
96	1.059 794 4	0.682 219 2	0.000 968 640 0	0.608 03	0.391 41	0.000 56
97	1.061 799 2	0.669 471 6	0.000 929 920 0	0.612 98	0.386 48	0.000 54
98	1.062 806 8	0.656 674 4	0.000 886 880 0	0.617 78	0.381 71	0.000 51
99	1.062 909 6	0.643 844 8	0.000 842 560 0	0.622 46	0.377 05	0.000 49
600	1.062 200 0	0.631 000 0	0.000 800 000 0	0.627 04	0.372 49	0.000 47
01	1.060 735 2	0.618 155 5	0.000 760 960 0	0.631 52	0.368 03	0.000 45
02	1.058 443 6	0.605 314 4	0.000 723 680 0	0.635 90	0.363 67	0.000 43
03	1.055 224 4	0.592 475 6	0.000 685 920 0	0.640 16	0.359 43	0.000 41
04	1.050 976 8	0.579 637 9	0.000 645 440 0	0.644 27	0.355 33	0.000 40
605	1.045 600 0	0.566 800 0	0.000 600 000 0	0.648 23	0.351 40	0.000 37
06	1.039 036 9	0.553 961 1	0.000 547 866 7	0.652 03	0.347 63	0.000 34
07	1.031 360 8	0.541 137 2	0.000 491 600 0	0.655 67	0.344 02	0.000 31
08	1.022 666 2	0.528 352 8	0.000 435 400 0	0.659 17	0.340 55	0.000 28
09	1.013 047 7	0.515 632 3	0.000 383 466 7	0.662 53	0.337 22	0.000 25

Table 1 — (continued)

Wave-length λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
610	1.002 600 0	0.503 000 0	0.000 340 000 0	0.665 76	0.334 01	0.000 23
11	0.991 367 5	0.490 468 8	0.000 307 253 3	0.668 87	0.330 92	0.000 21
12	0.979 331 4	0.478 030 4	0.000 283 160 0	0.671 86	0.327 95	0.000 19
13	0.966 491 6	0.465 677 6	0.000 265 440 0	0.674 72	0.325 09	0.000 19
14	0.952 847 9	0.453 403 2	0.000 251 813 3	0.677 46	0.322 36	0.000 18
615	0.938 400 0	0.441 200 0	0.000 240 000 0	0.680 08	0.319 75	0.000 17
16	0.923 194 0	0.429 080 0	0.000 229 546 7	0.682 58	0.317 25	0.000 17
17	0.907 244 0	0.417 036 0	0.000 220 640 0	0.684 97	0.314 86	0.000 17
18	0.890 502 0	0.405 032 0	0.000 211 960 0	0.687 25	0.312 59	0.000 16
19	0.872 920 0	0.393 032 0	0.000 202 186 7	0.689 43	0.310 41	0.000 16
620	0.854 449 9	0.381 000 0	0.000 190 000 0	0.691 51	0.308 34	0.000 15
21	0.835 084 0	0.368 918 4	0.000 174 213 3	0.693 49	0.306 37	0.000 14
22	0.814 946 0	0.356 827 2	0.000 155 640 0	0.695 39	0.304 48	0.000 13
23	0.794 186 0	0.344 776 8	0.000 135 960 0	0.697 21	0.302 67	0.000 12
24	0.772 954 0	0.332 817 6	0.000 116 853 3	0.698 94	0.300 95	0.000 11
625	0.751 400 0	0.321 000 0	0.000 100 000 0	0.700 61	0.299 30	0.000 09
26	0.729 583 6	0.309 338 1	0.000 086 133 33	0.702 19	0.297 73	0.000 08
27	0.707 588 8	0.297 850 4	0.000 074 600 00	0.703 71	0.296 22	0.000 07
28	0.685 602 2	0.286 593 6	0.000 065 000 00	0.705 16	0.294 77	0.000 07
29	0.663 810 4	0.275 624 5	0.000 056 933 33	0.706 56	0.293 38	0.000 06
630	0.642 400 0	0.265 000 0	0.000 049 999 99	0.707 92	0.292 03	0.000 05
31	0.621 514 9	0.254 763 2	0.000 044 160 00	0.709 23	0.290 72	0.000 05
32	0.601 113 8	0.244 889 6	0.000 039 480 00	0.710 50	0.289 45	0.000 05
33	0.581 105 2	0.235 334 4	0.000 035 720 00	0.711 73	0.288 23	0.000 04
34	0.561 397 7	0.226 052 8	0.000 032 640 00	0.712 90	0.287 06	0.000 04
635	0.541 900 0	0.217 000 0	0.000 030 000 00	0.714 03	0.285 93	0.000 04
36	0.522 599 5	0.208 161 6	0.000 027 653 33	0.715 12	0.284 84	0.000 04
37	0.503 546 4	0.199 548 8	0.000 025 560 00	0.716 16	0.283 80	0.000 04
38	0.484 743 6	0.191 155 2	0.000 023 640 00	0.717 16	0.282 81	0.000 03
39	0.466 193 9	0.182 974 4	0.000 021 813 33	0.718 12	0.281 85	0.000 03
640	0.447 900 0	0.175 000 0	0.000 020 000 00	0.719 03	0.280 94	0.000 03
41	0.429 861 3	0.167 223 5	0.000 018 133 33	0.719 91	0.280 06	0.000 03
42	0.412 098 0	0.159 646 4	0.000 016 200 00	0.720 75	0.279 22	0.000 03
43	0.394 644 0	0.152 277 6	0.000 014 200 00	0.721 55	0.278 42	0.000 03
44	0.377 533 3	0.145 125 9	0.000 012 133 33	0.722 32	0.277 66	0.000 02
645	0.360 800 0	0.138 200 0	0.000 010 000 00	0.723 03	0.276 95	0.000 02
46	0.344 456 3	0.131 500 3	0.000 007 733 333	0.723 70	0.276 28	0.000 02
47	0.328 516 8	0.125 024 8	0.000 005 400 000	0.724 33	0.275 66	0.000 01
48	0.313 019 2	0.118 779 2	0.000 003 200 000	0.724 91	0.275 08	0.000 01
49	0.298 001 1	0.112 769 1	0.000 001 333 333	0.725 47	0.274 53	0.000 00
650	0.283 500 0	0.107 000 0	0.000 000 000 000	0.725 99	0.274 01	0.000 00
51	0.269 544 8	0.101 476 2		0.726 49	0.273 51	
52	0.256 118 4	0.096 188 64		0.726 98	0.273 02	
53	0.243 189 6	0.091 122 96		0.727 43	0.272 57	
54	0.230 727 2	0.086 264 85		0.727 86	0.272 14	

Table 1 — (continued)

Wave-length λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
655	0.218 700 0	0.081 600 00	0.000 000 0	0.728 27	0.271 73	0.000 00
56	0.207 097 1	0.077 120 64		0.728 66	0.271 34	
57	0.195 923 2	0.072 825 52		0.729 02	0.270 98	
58	0.185 170 8	0.068 710 08		0.729 36	0.270 64	
59	0.174 832 3	0.064 769 76		0.729 68	0.270 32	
660	0.164 900 0	0.061 000 00		0.729 97	0.270 03	
61	0.155 366 7	0.057 396 21		0.730 23	0.269 77	
62	0.146 230 0	0.053 955 04		0.730 47	0.269 53	
63	0.137 490 0	0.050 673 76		0.730 69	0.269 31	
64	0.129 146 7	0.047 549 65		0.730 90	0.269 10	
665	0.121 200 0	0.044 580 00		0.731 09	0.268 91	
66	0.113 639 7	0.041 758 72		0.731 28	0.268 72	
67	0.106 465 0	0.039 084 96		0.731 47	0.268 53	
68	0.099 690 44	0.036 563 84		0.731 65	0.268 35	
69	0.093 330 61	0.034 200 48		0.731 83	0.268 17	
670	0.087 400 00	0.032 000 00		0.731 99	0.268 01	
71	0.081 900 96	0.029 962 61		0.732 15	0.267 85	
72	0.076 804 28	0.028 076 64		0.732 30	0.267 70	
73	0.072 077 12	0.026 329 36		0.732 44	0.267 56	
74	0.067 686 64	0.024 708 05		0.732 58	0.267 42	
675	0.063 600 00	0.023 200 00		0.732 72	0.267 28	
76	0.059 806 85	0.021 800 77		0.732 86	0.267 14	
77	0.056 282 16	0.020 501 12		0.733 00	0.267 00	
78	0.052 971 04	0.019 281 08		0.733 14	0.266 86	
79	0.049 818 61	0.018 120 69		0.733 28	0.266 72	
680	0.046 770 00	0.017 000 00		0.733 42	0.266 58	
81	0.043 784 05	0.015 903 79		0.733 55	0.266 45	
82	0.040 875 36	0.014 837 18		0.733 68	0.266 32	
83	0.038 072 64	0.013 810 68		0.733 81	0.266 19	
84	0.035 404 61	0.012 834 78		0.733 94	0.266 06	
685	0.032 900 00	0.011 920 00		0.734 05	0.265 95	
86	0.030 564 19	0.011 068 31		0.734 14	0.265 86	
87	0.028 380 56	0.010 273 39		0.734 22	0.265 78	
88	0.026 344 84	0.009 533 311		0.734 29	0.265 71	
89	0.024 452 75	0.008 846 157		0.734 34	0.265 66	
690	0.022 700 00	0.008 210 000		0.734 39	0.265 61	
91	0.021 084 29	0.007 623 781		0.734 44	0.265 56	
92	0.019 599 88	0.007 085 424		0.734 48	0.265 52	
93	0.018 237 32	0.006 591 476		0.734 52	0.265 48	
94	0.016 987 17	0.006 138 485		0.734 56	0.265 44	
695	0.015 840 00	0.005 723 000		0.734 59	0.265 41	
96	0.014 790 64	0.005 343 059		0.734 62	0.265 38	
97	0.013 831 32	0.004 995 796		0.734 65	0.265 35	
98	0.012 948 68	0.004 676 404		0.734 67	0.265 33	
99	0.012 129 20	0.004 380 075		0.734 69	0.265 31	
700	0.011 359 16	0.004 102 000		0.734 69	0.265 31	
01	0.010 629 35	0.003 838 453		0.734 69	0.265 31	
02	0.009 938 846	0.003 589 099		0.734 69	0.265 31	
03	0.009 288 422	0.003 354 219		0.734 69	0.265 31	
04	0.008 678 854	0.003 134 093		0.734 69	0.265 31	

Table 1 — *(continued)*

Wavelength λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
705	0.008 110 916	0.002 929 000	0.000 000 0	0.734 69	0.265 31	0.000 00
06	0.007 582 388	0.002 738 139		0.734 69	0.265 31	
07	0.007 088 746	0.002 559 876		0.734 69	0.265 31	
08	0.006 627 313	0.002 393 244		0.734 69	0.265 31	
09	0.006 195 408	0.002 237 275		0.734 69	0.265 31	
710	0.005 790 346	0.002 091 000		0.734 69	0.265 31	
11	0.005 409 826	0.001 953 587		0.734 69	0.265 31	
12	0.005 052 583	0.001 824 580		0.734 69	0.265 31	
13	0.004 717 512	0.001 703 580		0.734 69	0.265 31	
14	0.004 403 507	0.001 590 187		0.734 69	0.265 31	
715	0.004 109 457	0.001 484 000		0.734 69	0.265 31	
16	0.003 833 913	0.001 384 496		0.734 69	0.265 31	
17	0.003 575 748	0.001 291 268		0.734 69	0.265 31	
18	0.003 334 342	0.001 204 092		0.734 69	0.265 31	
19	0.003 109 075	0.001 122 744		0.734 69	0.265 31	
720	0.002 899 327	0.001 047 000		0.734 69	0.265 31	
21	0.002 704 348	0.000 976 589 6		0.734 69	0.265 31	
22	0.002 523 020	0.000 911 108 8		0.734 69	0.265 31	
23	0.002 354 168	0.000 850 133 2		0.734 69	0.265 31	
24	0.002 196 616	0.000 793 238 4		0.734 69	0.265 31	
725	0.002 049 190	0.000 740 000 0		0.734 69	0.265 31	
26	0.001 910 960	0.000 690 082 7		0.734 69	0.265 31	
27	0.001 781 438	0.000 643 310 0		0.734 69	0.265 31	
28	0.001 660 110	0.000 599 496 0		0.734 69	0.265 31	
29	0.001 546 459	0.000 558 454 7		0.734 69	0.265 31	
730	0.001 439 971	0.000 520 000 0		0.734 69	0.265 31	
31	0.001 340 042	0.000 483 913 6		0.734 69	0.265 31	
32	0.001 246 275	0.000 450 052 8		0.734 69	0.265 31	
33	0.001 158 471	0.000 418 345 2		0.734 69	0.265 31	
34	0.001 076 430	0.000 388 718 4		0.734 69	0.265 31	
735	0.000 999 949 3	0.000 361 100 0		0.734 69	0.265 31	
36	0.000 928 735 8	0.000 335 383 5		0.734 69	0.265 31	
37	0.000 862 433 2	0.000 311 440 4		0.734 69	0.265 31	
38	0.000 800 750 3	0.000 289 165 6		0.734 69	0.265 31	
39	0.000 743 396 0	0.000 268 453 9		0.734 69	0.265 31	
740	0.000 690 078 6	0.000 249 200 0		0.734 69	0.265 31	
41	0.000 640 515 6	0.000 231 301 9		0.734 69	0.265 31	
42	0.000 594 502 1	0.000 214 685 6		0.734 69	0.265 31	
43	0.000 551 864 6	0.000 199 288 4		0.734 69	0.265 31	
44	0.000 512 429 0	0.000 185 047 5		0.734 69	0.265 31	
745	0.000 476 021 3	0.000 171 900 0		0.734 69	0.265 31	
46	0.000 442 453 6	0.000 159 778 1		0.734 69	0.265 31	
47	0.000 411 511 7	0.000 148 604 4		0.734 69	0.265 31	
48	0.000 382 981 4	0.000 138 301 6		0.734 69	0.265 31	
49	0.000 356 649 1	0.000 128 792 5		0.734 69	0.265 31	
750	0.000 332 301 1	0.000 120 000 0		0.734 69	0.265 31	
51	0.000 309 758 6	0.000 111 859 5		0.734 69	0.265 31	
52	0.000 288 887 1	0.000 104 322 4		0.734 69	0.265 31	
53	0.000 269 539 4	0.000 097 335 60		0.734 69	0.265 31	
54	0.000 251 568 2	0.000 090 845 87		0.734 69	0.265 31	

Table 1 — (*continued*)

Wavelength λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
755	0.000 234 826 1	0.000 084 800 00	0.000 000 0	0.734 69	0.265 31	0.000 00
56	0.000 219 171 0	0.000 079 146 67		0.734 69	0.265 31	
57	0.000 204 525 8	0.000 073 858 00		0.734 69	0.265 31	
58	0.000 190 840 5	0.000 068 916 00		0.734 69	0.265 31	
59	0.000 178 065 4	0.000 064 302 67		0.734 69	0.265 31	
760	0.000 166 150 5	0.000 060 000 00		0.734 69	0.265 31	
61	0.000 155 023 6	0.000 055 981 87		0.734 69	0.265 31	
62	0.000 144 621 9	0.000 052 225 60		0.734 69	0.265 31	
63	0.000 134 909 8	0.000 048 718 40		0.734 69	0.265 31	
64	0.000 125 852 0	0.000 045 447 47		0.734 69	0.265 31	
765	0.000 117 413 0	0.000 042 400 00		0.734 69	0.265 31	
66	0.000 109 551 5	0.000 039 561 04		0.734 69	0.265 31	
67	0.000 102 224 5	0.000 036 915 12		0.734 69	0.265 31	
68	0.000 095 394 45	0.000 034 448 68		0.734 69	0.265 31	
69	0.000 089 023 90	0.000 032 148 16		0.734 69	0.265 31	
770	0.000 083 075 27	0.000 030 000 00		0.734 69	0.265 31	
71	0.000 077 512 69	0.000 027 991 25		0.734 69	0.265 31	
72	0.000 072 313 04	0.000 026 113 56		0.734 69	0.265 31	
73	0.000 067 457 78	0.000 024 360 24		0.734 69	0.265 31	
74	0.000 062 928 44	0.000 022 724 61		0.734 69	0.265 31	
775	0.000 058 706 52	0.000 021 200 00		0.734 69	0.265 31	
76	0.000 054 770 28	0.000 019 778 55		0.734 69	0.265 31	
77	0.000 051 099 18	0.000 018 452 85		0.734 69	0.265 31	
78	0.000 047 676 54	0.000 017 216 87		0.734 69	0.265 31	
79	0.000 044 485 67	0.000 016 064 59		0.734 69	0.265 31	
780	0.000 041 509 94	0.000 014 990 00		0.734 69	0.265 31	
81	0.000 038 733 24	0.000 013 987 28		0.734 69	0.265 31	
82	0.000 036 142 03	0.000 013 051 55		0.734 69	0.265 31	
83	0.000 033 723 52	0.000 012 178 18		0.734 69	0.265 31	
84	0.000 031 464 87	0.000 011 362 54		0.734 69	0.265 31	
785	0.000 029 353 26	0.000 010 600 00		0.734 69	0.265 31	
86	0.000 027 375 73	0.000 009 885 877		0.734 69	0.265 31	
87	0.000 025 524 33	0.000 009 217 304		0.734 69	0.265 31	
88	0.000 023 793 76	0.000 008 592 362		0.734 69	0.265 31	
89	0.000 022 178 70	0.000 008 009 133		0.734 69	0.265 31	
790	0.000 020 673 83	0.000 007 465 700		0.734 69	0.265 31	
91	0.000 019 272 26	0.000 006 959 567		0.734 69	0.265 31	
92	0.000 017 966 40	0.000 006 487 995		0.734 69	0.265 31	
93	0.000 016 749 91	0.000 006 048 699		0.734 69	0.265 31	
94	0.000 015 616 48	0.000 005 639 396		0.734 69	0.265 31	
795	0.000 014 559 77	0.000 005 257 800		0.734 69	0.265 31	
96	0.000 013 573 87	0.000 004 901 771		0.734 69	0.265 31	
97	0.000 012 654 36	0.000 004 569 720		0.734 69	0.265 31	
98	0.000 011 797 23	0.000 004 260 194		0.734 69	0.265 31	
99	0.000 010 998 44	0.000 003 971 739		0.734 69	0.265 31	
800	0.000 010 253 98	0.000 003 702 900		0.734 69	0.265 31	
01	0.000 009 559 646	0.000 003 452 163		0.734 69	0.265 31	
02	0.000 008 912 044	0.000 003 218 302		0.734 69	0.265 31	
03	0.000 008 308 358	0.000 003 000 300		0.734 69	0.265 31	
04	0.000 007 745 769	0.000 002 797 139		0.734 69	0.265 31	

Table 1 — (*concluded*)

Wavelength λ nm	CIE colour-matching functions $\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$	Chromaticity coordinates $x(\lambda)$	$y(\lambda)$	$z(\lambda)$
805	0.000 007 221 456	0.000 002 607 800	0.000 000 0	0.734 69	0.265 31	0.000 00
06	0.000 006 732 475	0.000 002 431 220		0.734 69	0.265 31	
07	0.000 006 276 423	0.000 002 266 531		0.734 69	0.265 31	
08	0.000 005 851 304	0.000 002 113 013		0.734 69	0.265 31	
09	0.000 005 455 118	0.000 001 969 943		0.734 69	0.265 31	
810	0.000 005 085 868	0.000 001 836 600		0.734 69	0.265 31	
11	0.000 004 741 466	0.000 001 712 230		0.734 69	0.265 31	
12	0.000 004 420 236	0.000 001 596 228		0.734 69	0.265 31	
13	0.000 004 120 783	0.000 001 488 090		0.734 69	0.265 31	
14	0.000 003 841 716	0.000 001 387 314		0.734 69	0.265 31	
815	0.000 003 581 652	0.000 001 293 400		0.734 69	0.265 31	
16	0.000 003 339 127	0.000 001 205 820		0.734 69	0.265 31	
17	0.000 003 112 949	0.000 001 124 143		0.734 69	0.265 31	
18	0.000 002 902 121	0.000 001 048 009		0.734 69	0.265 31	
19	0.000 002 705 645	0.000 000 977 057 8		0.734 69	0.265 31	
820	0.000 002 522 525	0.000 000 910 930 0		0.734 69	0.265 31	
21	0.000 002 351 726	0.000 000 849 251 3		0.734 69	0.265 31	
22	0.000 002 192 415	0.000 000 791 721 2		0.734 69	0.265 31	
23	0.000 002 043 902	0.000 000 738 090 4		0.734 69	0.265 31	
24	0.000 001 905 497	0.000 000 688 109 8		0.734 69	0.265 31	
825	0.000 001 776 509	0.000 000 641 530 0		0.734 69	0.265 31	
26	0.000 001 656 215	0.000 000 598 089 5		0.734 69	0.265 31	
27	0.000 001 544 022	0.000 000 557 574 6		0.734 69	0.265 31	
28	0.000 001 439 440	0.000 000 519 808 0		0.734 69	0.265 31	
29	0.000 001 341 977	0.000 000 484 612 3		0.734 69	0.265 31	
830	0.000 001 251 141	0.000 000 451 810 0		0.734 69	0.265 31	

$\Sigma\bar{x}(\lambda)$ = 106.865 469 489 595
$\Sigma\bar{y}(\lambda)$ = 106.856 917 101 172
$\Sigma\bar{z}(\lambda)$ = 106.892 251 278 636

Table 2 — Colour-matching functions and chromaticity coordinates of CIE 1964 supplementary standard colorimetric observer

Wave-length, λ nm	CIE colour-matching functions			Chromaticity coordinates		
	$\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$	$x_{10}(\lambda)$	$y_{10}(\lambda)$	$z_{10}(\lambda)$
360	0.000 000 122 200	0.000 000 013 398	0.000 000 535 027	0.182 22	0.019 98	0.797 80
361	0.000 000 185 138	0.000 000 020 294	0.000 000 810 720	0.182 20	0.019 97	0.797 83
362	0.000 000 278 83	0.000 000 030 56	0.000 001 221 20	0.182 17	0.019 97	0.797 86
363	0.000 000 417 47	0.000 000 045 74	0.000 001 828 70	0.182 15	0.019 96	0.797 89
364	0.000 000 621 33	0.000 000 068 05	0.000 002 722 20	0.182 12	0.019 95	0.797 93
365	0.000 000 919 27	0.000 000 100 65	0.000 004 028 30	0.182 10	0.019 94	0.797 96
366	0.000 001 351 98	0.000 000 147 98	0.000 005 925 70	0.182 07	0.019 93	0.798 00
367	0.000 001 976 54	0.000 000 216 27	0.000 008 665 10	0.182 04	0.019 92	0.798 04
368	0.000 002 872 5	0.000 000 314 2	0.000 012 596 0	0.182 00	0.019 91	0.798 09
369	0.000 004 149 5	0.000 000 453 7	0.000 018 201 0	0.181 96	0.019 90	0.798 14
370	0.000 005 958 6	0.000 000 651 1	0.000 026 143 7	0.181 92	0.019 88	0.798 20
371	0.000 008 505 6	0.000 000 928 8	0.000 037 330 0	0.181 88	0.019 86	0.798 26
372	0.000 012 068 6	0.000 001 317 5	0.000 052 987 0	0.181 83	0.019 85	0.798 32
373	0.000 017 022 6	0.000 001 857 2	0.000 074 764 0	0.181 78	0.019 83	0.798 39
374	0.000 023 868	0.000 002 602	0.000 104 870	0.181 73	0.019 81	0.798 46
375	0.000 033 266	0.000 003 625	0.000 146 220	0.181 67	0.019 80	0.798 53
376	0.000 046 087	0.000 005 019	0.000 202 660	0.181 61	0.019 78	0.798 61
377	0.000 063 472	0.000 006 907	0.000 279 230	0.181 55	0.019 76	0.798 69
378	0.000 086 892	0.000 009 449	0.000 382 450	0.181 48	0.019 74	0.798 78
379	0.000 118 246	0.000 012 848	0.000 520 720	0.181 41	0.019 71	0.798 88
380	0.000 159 952	0.000 017 364	0.000 704 776	0.181 33	0.019 69	0.798 98
381	0.000 215 080	0.000 023 327	0.000 948 230	0.181 25	0.019 66	0.799 09
382	0.000 287 49	0.000 031 15	0.001 268 20	0.181 17	0.019 63	0.799 20
383	0.000 381 99	0.000 041 35	0.001 686 10	0.181 09	0.019 60	0.799 31
384	0.000 504 55	0.000 054 56	0.002 228 50	0.181 00	0.019 57	0.799 43
385	0.000 662 44	0.000 071 56	0.002 927 80	0.180 91	0.019 54	0.799 55
386	0.000 864 50	0.000 093 30	0.003 823 70	0.180 80	0.019 51	0.799 69
387	0.001 121 50	0.000 120 87	0.004 964 20	0.180 70	0.019 47	0.799 83
388	0.001 446 16	0.000 155 64	0.006 406 70	0.180 58	0.019 43	0.799 99
389	0.001 853 59	0.000 199 20	0.008 219 30	0.180 45	0.019 39	0.800 16
390	0.002 361 6	0.000 253 4	0.010 482 2	0.180 31	0.019 35	0.800 34
391	0.002 990 6	0.000 320 2	0.013 289 0	0.180 16	0.019 29	0.800 55
392	0.003 764 5	0.000 402 4	0.016 747 0	0.180 00	0.019 24	0.800 76
393	0.004 710 2	0.000 502 3	0.020 980 0	0.179 83	0.019 18	0.800 99
394	0.005 858 1	0.000 623 2	0.026 127 0	0.179 65	0.019 11	0.801 24
395	0.007 242 3	0.000 768 5	0.032 344 0	0.179 47	0.019 04	0.801 49
396	0.008 899 6	0.000 941 7	0.039 802 0	0.179 27	0.018 97	0.801 76
397	0.010 870 9	0.001 147 8	0.048 691 0	0.179 06	0.018 91	0.802 03
398	0.013 198 9	0.001 390 3	0.059 210 0	0.178 85	0.018 84	0.802 31
399	0.015 929 2	0.001 674 0	0.071 576 0	0.178 62	0.018 77	0.802 61
400	0.019 109 7	0.002 004 4	0.086 010 9	0.178 39	0.018 71	0.802 90
401	0.022 788	0.002 386	0.102 740	0.178 15	0.018 65	0.803 20
402	0.027 011	0.002 822	0.122 000	0.177 90	0.018 59	0.803 51
403	0.031 829	0.003 319	0.144 020	0.177 65	0.018 52	0.803 83
404	0.037 278	0.003 880	0.168 990	0.177 39	0.018 46	0.804 15
405	0.043 400	0.004 509	0.197 120	0.177 12	0.018 40	0.804 48
406	0.050 223	0.005 209	0.228 570	0.176 84	0.018 34	0.804 82
407	0.057 764	0.005 985	0.263 470	0.176 53	0.018 29	0.805 18
408	0.066 038	0.006 833	0.301 900	0.176 21	0.018 23	0.805 56
409	0.075 033	0.007 757	0.343 870	0.175 86	0.018 18	0.805 96
410	0.084 736	0.008 756	0.389 366	0.175 49	0.018 13	0.806 38

Table 2 — (*continued*)

Wave-length, λ nm	CIE colour-matching functions			Chromaticity coordinates		
	$\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$	$x_{10}(\lambda)$	$y_{10}(\lambda)$	$z_{10}(\lambda)$
411	0.095 041	0.009 816	0.437 970	0.175 09	0.018 08	0.806 83
412	0.105 836	0.010 918	0.489 220	0.174 65	0.018 02	0.807 33
413	0.117 066	0.012 058	0.542 900	0.174 20	0.017 94	0.807 86
414	0.128 682	0 013 237	0.598 810	0.173 72	0.017 87	0.808 41
415	0.140 638	0.014 456	0.656 760	0.173 23	0.017 81	0.808 96
416	0.152 893	0.015 717	0.716 580	0.172 72	0.017 76	0.809 52
417	0.165 416	0.017 025	0.778 120	0.172 21	0.017 72	0.810 07
418	0.178 191	0.018 399	0.841 310	0.171 68	0.017 73	0.810 59
419	0.191 214	0.019 848	0.906 110	0.171 16	0.017 77	0.811 07
420	0.204 492	0.021 391	0.972 542	0.170 63	0.017 85	0.811 52
421	0.217 650	0.022 992	1.038 90	0.170 10	0.017 97	0.811 93
422	0.230 267	0.024 598	1.103 10	0.169 57	0.018 11	0.812 32
423	0.242 311	0.026 213	1.165 10	0.169 02	0.018 28	0.812 70
424	0.253 793	0.027 841	1.224 90	0.168 46	0.018 48	0.813 06
425	0.264 737	0.029 497	1.282 50	0.167 90	0.018 71	0.813 39
426	0.275 195	0.031 195	1.338 20	0.167 33	0.018 97	0.813 70
427	0.285 301	0.032 927	1.392 60	0.166 76	0.019 25	0.813 99
428	0.295 143	0.034 738	1.446 10	0.166 19	0.019 56	0.814 25
429	0.304 869	0.036 654	1.499 40	0.165 61	0.019 91	0.814 48
430	0.314 679	0.038 676	1.553 48	0.165 03	0.020 28	0.814 69
431	0.324 355	0.040 792	1.607 20	0.164 45	0.020 68	0.814 87
432	0.333 570	0.042 946	1.658 90	0.163 88	0.021 10	0.815 02
433	0.342 243	0.045 114	1.708 20	0.163 32	0.021 53	0.815 15
434	0.350 312	0.047 333	1.754 80	0.162 75	0.021 99	0.815 26
435	0.357 719	0.049 602	1.798 50	0.162 17	0.022 49	0.815 34
436	0.364 482	0.051 934	1.839 20	0.161 59	0.023 02	0.815 39
437	0.370 493	0.054 337	1.876 60	0.160 98	0.023 61	0.815 41
438	0.375 727	0.056 822	1.910 50	0.160 36	0.024 25	0.815 39
439	0.380 158	0.059 399	1.940 80	0.159 71	0.024 95	0.815 34
440	0.383 734	0.062 077	1.967 28	0.159 02	0.025 73	0.815 25
441	0.386 327	0.064 737	1.989 10	0.158 32	0.026 53	0.815 15
442	0.387 858	0.067 285	2.005 70	0.157 61	0.027 34	0.815 05
443	0.388 396	0.069 764	2.017 40	0.156 89	0.028 18	0.814 93
444	0.387 978	0.072 218	2.024 40	0.156 15	0.029 07	0.814 78
445	0.386 726	0.074 704	2.027 30	0.155 39	0.030 02	0.814 59
446	0.384 696	0.077 272	2.026 40	0.154 60	0.031 05	0.814 35
447	0.382 006	0.079 979	2.022 30	0.153 77	0.032 19	0.814 04
448	0.378 709	0.082 874	2.015 30	0.152 90	0.033 46	0.813 64
449	0.374 915	0.086 000	2.006 00	0.151 98	0.034 86	0.813 16
450	0.370 702	0.089 456	1.994 80	0.151 00	0.036 44	0.812 56
451	0.366 089	0.092 947	1.981 40	0.150 01	0.038 09	0.811 90
452	0.361 045	0.096 275	1.965 30	0.149 03	0.039 74	0.811 23
453	0.355 518	0.099 535	1.946 40	0.148 04	0.041 45	0.810 51
454	0.349 486	0.102 829	1.924 80	0.147 02	0.043 26	0.809 72
455	0.342 957	0.106 256	1.900 70	0.145 94	0.045 22	0.808 84
456	0.335 893	0.109 901	1.874 10	0.144 79	0.047 37	0.807 84
457	0.328 284	0.113 835	1.845 10	0.143 53	0.049 77	0.806 70
458	0.320 150	0.118 167	1.813 90	0.142 15	0.052 47	0.805 38
459	0.311 475	0.122 932	1.780 60	0.140 62	0.055 50	0.803 88
460	0.302 273	0.128 201	1.745 37	0.138 92	0.058 92	0.802 16

Table 2 — (*continued*)

Wavelength, λ nm	CIE colour-matching functions $\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$	Chromaticity coordinates $x_{10}(\lambda)$	$y_{10}(\lambda)$	$z_{10}(\lambda)$
461	0.292 858	0.133 457	1.709 10	0.137 14	0.062 50	0.800 36
462	0.283 502	0.138 323	1.672 30	0.135 38	0.066 05	0.798 57
463	0.274 044	0.143 042	1.634 70	0.133 56	0.069 72	0.796 72
464	0.264 263	0.147 787	1.595 60	0.131 63	0.073 61	0.794 76
465	0.254 085	0.152 761	1.554 90	0.129 52	0.077 87	0.792 61
466	0.243 392	0.158 102	1.512 20	0.127 18	0.082 62	0.790 20
467	0.232 187	0.163 941	1.467 30	0.124 60	0.087 98	0.787 42
468	0.220 488	0.170 362	1.419 90	0.121 77	0.094 08	0.784 15
469	0.208 198	0.177 425	1.370 00	0.118 59	0.101 06	0.780 35
470	0.195 618	0.185 190	1.317 56	0.115 18	0.109 04	0.775 78
471	0.183 034	0.193 025	1.262 40	0.111 71	0.117 81	0.770 48
472	0.170 222	0.200 313	1.205 00	0.108 04	0.127 14	0.764 82
473	0.157 348	0.207 156	1.146 60	0.104 13	0.137 09	0.758 78
474	0.144 650	0.213 644	1.088 00	0.100 01	0.147 72	0.752 27
475	0.132 349	0.219 940	1.030 20	0.095 73	0.159 09	0.745 18
476	0.120 584	0.226 170	0.973 830	0.091 31	0.171 27	0.737 42
477	0.109 456	0.232 467	0.919 430	0.086 78	0.184 30	0.728 92
478	0.099 042	0.239 025	0.867 460	0.082 16	0.198 27	0.719 57
479	0.089 388	0.245 997	0.818 280	0.077 48	0.213 23	0.709 29
480	0.080 507	0.253 589	0.772 125	0.072 78	0.229 24	0.697 98
481	0.072 034	0.261 876	0.728 290	0.067 82	0.246 54	0.685 64
482	0.063 710	0.270 643	0.686 040	0.062 44	0.265 23	0.672 33
483	0.055 694	0.279 645	0.645 530	0.056 78	0.285 10	0.658 12
484	0.048 117	0.288 694	0.606 850	0.050 99	0.305 93	0.643 08
485	0.041 072	0.297 665	0.570 060	0.045 19	0.327 54	0.627 27
486	0.034 642	0.306 469	0.535 220	0.039 53	0.349 72	0.610 75
487	0.028 896	0.315 035	0.502 340	0.034 15	0.372 26	0.593 59
488	0.023 876	0.323 335	0.471 400	0.029 17	0.394 98	0.575 85
489	0.019 628	0.331 366	0.442 390	0.024 74	0.417 66	0.557 60
490	0.016 172	0.339 133	0.415 254	0.020 99	0.440 11	0.538 90
491	0.013 300	0.347 860	0.390 024	0.017 71	0.463 08	0.519 21
492	0.010 759	0.358 326	0.366 399	0.014 63	0.487 20	0.498 17
493	0.008 542	0.370 001	0.344 015	0.011 82	0.512 07	0.476 11
494	0.006 661	0.382 464	0.322 689	0.009 36	0.537 31	0.453 33
495	0.005 132	0.395 379	0.302 356	0.007 30	0.562 52	0.430 18
496	0.003 982	0.408 482	0.283 036	0.005 73	0.587 32	0.406 95
497	0.003 239	0.421 588	0.264 816	0.004 70	0.611 31	0.383 99
498	0.002 934	0.434 619	0.247 848	0.004 28	0.634 11	0.361 61
499	0.003 114	0.447 601	0.232 318	0.004 56	0.655 31	0.340 13
500	0.003 816	0.460 777	0.218 502	0.005 59	0.674 54	0.319 87
501	0.005 095	0.474 340	0.205 851	0.007 43	0.692 18	0.300 39
502	0.006 936	0.488 200	0.193 596	0.010 07	0.708 84	0.281 09
503	0.009 299	0.502 340	0.181 736	0.013 41	0.724 49	0.262 10
504	0.012 147	0.516 740	0.170 281	0.017 37	0.739 08	0.243 55
505	0.015 444	0.531 360	0.159 249	0.021 87	0.752 58	0.225 55
506	0.019 156	0.546 190	0.148 673	0.026 83	0.764 95	0.208 22
507	0.023 250	0.561 180	0.138 609	0.032 16	0.776 14	0.191 70
508	0.027 690	0.576 290	0.129 096	0.037 77	0.786 13	0.176 10
509	0.032 444	0.591 500	0.120 215	0.043 60	0.794 86	0.161 54
510	0.037 465	0.606 741	0.112 044	0.049 54	0.802 30	0.148 16

Table 2 — (*continued*)

Wave-length, λ nm	CIE colour-matching functions $\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$	Chromaticity coordinates $x_{10}(\lambda)$	$y_{10}(\lambda)$	$z_{10}(\lambda)$
511	0.042 956	0.622 150	0.104 710	0.055 80	0.808 18	0.136 02
512	0.049 114	0.637 830	0.098 196	0.062 55	0.812 38	0.125 07
513	0.055 920	0.653 710	0.092 361	0.069 73	0.815 11	0.115 16
514	0.063 349	0.669 680	0.087 088	0.077 24	0.816 57	0.106 19
515	0.071 358	0.685 660	0.082 248	0.085 02	0.816 98	0.098 00
516	0.079 901	0.701 550	0.077 744	0.093 00	0.816 52	0.090 48
517	0.088 909	0.717 230	0.073 456	0.101 08	0.815 41	0.083 51
518	0.098 293	0.732 570	0.069 268	0.109 20	0.813 85	0.076 95
519	0.107 949	0.747 460	0.065 060	0.117 28	0.812 04	0.070 68
520	0.117 749	0.761 757	0.060 709	0.125 24	0.810 19	0.064 57
521	0.127 839	0.775 340	0.056 457	0.133 22	0.807 95	0.058 83
522	0.138 450	0.788 220	0.052 609	0.141 38	0.804 90	0.053 72
523	0.149 516	0.800 460	0.049 122	0.149 65	0.801 18	0.049 17
524	0.161 041	0.812 140	0.045 954	0.158 02	0.796 89	0.045 09
525	0.172 953	0.823 330	0.043 050	0.166 41	0.792 17	0.041 42
526	0.185 209	0.834 120	0.040 368	0.174 78	0.787 13	0.038 09
527	0.197 755	0.844 600	0.037 839	0.183 07	0.781 90	0.035 03
528	0.210 538	0.854 870	0.035 384	0.191 26	0.776 60	0.032 14
529	0.223 460	0.865 040	0.032 949	0.199 26	0.771 36	0.029 38
530	0.236 491	0.875 211	0.030 451	0.207 06	0.766 28	0.026 66
531	0.249 633	0.885 370	0.028 029	0.214 64	0.761 26	0.024 10
532	0.262 972	0.895 370	0.025 862	0.222 07	0.756 09	0.021 84
533	0.276 515	0.905 150	0.023 920	0.229 36	0.750 80	0.019 84
534	0.290 269	0.914 650	0.022 174	0.236 55	0.745 38	0.018 07
535	0.304 213	0.923 810	0.020 584	0.243 64	0.739 87	0.016 49
536	0.318 361	0.932 550	0.019 127	0.250 67	0.734 27	0.015 06
537	0.332 705	0.940 810	0.017 740	0.257 66	0.728 60	0.013 74
538	0.347 232	0.948 520	0.016 403	0.264 63	0.722 87	0.012 50
539	0.361 926	0.955 600	0.015 064	0.271 60	0.717 10	0.011 30
540	0.376 772	0.961 988	0.013 676	0.278 59	0.711 30	0.010 11
541	0.391 683	0.967 540	0.012 308	0.285 58	0.705 45	0.008 97
542	0.406 594	0.972 230	0.011 056	0.292 54	0.699 51	0.007 95
543	0.421 539	0.976 170	0.009 915	0.299 47	0.693 49	0.007 04
544	0.436 517	0.979 460	0.008 872	0.306 36	0.687 41	0.006 23
545	0.451 584	0.982 200	0.007 918	0.313 23	0.681 28	0.005 49
546	0.466 782	0.984 520	0.007 030	0.320 08	0.675 10	0.004 82
547	0.482 147	0.986 520	0.006 223	0.326 90	0.668 88	0.004 22
548	0.497 738	0.988 320	0.005 453	0.333 71	0.662 63	0.003 66
549	0.513 606	0.990 020	0.004 714	0.340 51	0.656 36	0.003 13
550	0.529 826	0.991 761	0.003 988	0.347 30	0.650 09	0.002 61
551	0.546 440	0.993 530	0.003 289	0.354 08	0.643 79	0.002 13
552	0.563 426	0.995 230	0.002 646	0.360 87	0.637 44	0.001 69
553	0.580 726	0.996 770	0.002 063	0.367 65	0.631 04	0.001 31
554	0.598 290	0.998 090	0.001 533	0.374 42	0.624 62	0.000 96
555	0.616 053	0.999 110	0.001 091	0.381 16	0.618 16	0.000 68
556	0.633 948	0.999 770	0.000 711	0.387 87	0.611 69	0.000 44
557	0.651 901	1.000 000	0.000 407	0.394 54	0.605 21	0.000 25
558	0.669 824	0.999 710	0.000 184	0.401 16	0.598 73	0.000 11
559	0.687 632	0.998 850	0.000 047	0.407 72	0.592 25	0.000 03
560	0.705 224	0.997 340	0.000 000	0.414 21	0.585 79	0.000 00

Table 2 — (*continued*)

Wave-length, λ nm	CIE colour-matching functions			Chromaticity coordinates		
	$\bar{x}_{10}(\lambda)$	$\bar{y}_{10}(\lambda)$	$\bar{z}_{10}(\lambda)$	$x_{10}(\lambda)$	$y_{10}(\lambda)$	$z_{10}(\lambda)$
561	0.722 773	0.995 260	0.000 000	0.420 70	0.579 30	0.000 00
562	0.740 483	0.992 740		0.427 23	0.572 77	
563	0.758 273	0.989 750		0.433 79	0.566 21	
564	0.776 083	0.986 300		0.440 36	0.559 64	
565	0.793 832	0.982 380		0.446 92	0.553 08	
566	0.811 436	0.977 980		0.453 46	0.546 54	
567	0.828 822	0.973 110		0.459 96	0.540 04	
568	0.845 879	0.967 740		0.466 40	0.533 60	
569	0.862 525	0.961 890		0.472 77	0.527 23	
570	0.878 655	0.955 552		0.479 04	0.520 96	
571	0.894 208	0.948 601		0.485 24	0.514 76	
572	0.909 206	0.940 981		0.491 41	0.508 59	
573	0.923 672	0.932 798		0.497 54	0.502 46	
574	0.937 638	0.924 158		0.503 62	0.496 38	
575	0.951 162	0.915 175		0.509 64	0.490 36	
576	0.964 283	0.905 954		0.515 59	0.484 41	
577	0.977 068	0.896 608		0.521 47	0.478 53	
578	0.989 590	0.887 249		0.527 26	0.472 74	
579	1.001 91	0.877 986		0.532 96	0.467 04	
580	1.014 16	0.868 934		0.538 56	0.461 44	
581	1.026 50	0.860 164		0.544 08	0.455 92	
582	1.038 80	0.851 519		0.549 54	0.450 46	
583	1.051 00	0.842 963		0.554 92	0.445 08	
584	1.062 90	0.834 393		0.560 22	0.439 78	
585	1.074 30	0.825 623		0.565 44	0.434 56	
586	1.085 20	0.816 764		0.570 57	0.429 43	
587	1.095 20	0.807 544		0.575 59	0.424 41	
588	1.104 20	0.797 947		0.580 50	0.419 50	
589	1.112 00	0.787 893		0.585 30	0.414 70	
590	1.118 52	0.777 405		0.589 96	0.410 04	
591	1.123 80	0.766 490		0.594 51	0.405 49	
592	1.128 00	0.755 309		0.598 95	0.401 05	
593	1.131 10	0.743 845		0.603 27	0.396 73	
594	1.133 20	0.732 190		0.607 49	0.392 51	
595	1.134 30	0.720 353		0.611 60	0.388 40	
596	1.134 30	0.708 281		0.615 60	0.384 40	
597	1.133 30	0.696 055		0.619 51	0.380 49	
598	1.131 20	0.683 621		0.623 31	0.376 69	
599	1.128 10	0.671 048		0.627 02	0.372 98	
600	1.123 99	0.658 341		0.630 63	0.369 37	
601	1.118 90	0.645 545		0.634 14	0.365 86	
602	1.112 90	0.632 718		0.637 54	0.362 46	
603	1.105 90	0.619 815		0.640 84	0.359 16	
604	1.098 00	0.606 887		0.644 03	0.355 97	
605	1.089 10	0.593 878		0.647 13	0.352 87	
606	1.079 20	0.580 781		0.650 13	0.349 87	
607	1.068 40	0.567 653		0.653 04	0.346 96	
608	1.056 70	0.554 490		0.655 85	0.344 15	
609	1.044 00	0.541 228		0.658 58	0.341 42	
610	1.030 48	0.527 963		0.661 22	0.338 78	