

CIE standard colorimetric observers

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National foreword

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO/CIE title page, pages ii to iv, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Contents

	Page
National foreword	Inside front cover
Foreword	iii
Text of ISO/CIE 10527	1

INTERNATIONAL STANDARD

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CIE standard colorimetric observers

Observateurs de référence colorimétrique CIE



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Contents

	Page
Foreword	iii
Introduction	1
1 Scope	1
2 Normative references	1
3 Definitions	1
4 Specifications	3
4.1 Colour-matching functions	3
4.2 Spectral chromaticity coordinates	3
5 Derivation of the colour-matching functions for the CIE 1931 standard colorimetric observer	3
5.1 Experimental basis	3
5.2 Transformation procedures	3
5.3 Transformation properties	4
5.4 Comparison with earlier data	4
6 Derivation of the colour-matching functions for the CIE 1964 supplementary standard colorimetric observer	4
6.1 Experimental basis	4
6.2 Transformation procedures	5
6.3 Transformation properties	5
6.4 Comparison with earlier data	5
7 Practical applications of colour-matching functions for CIE standard colorimetric observers	5
7.1 Obtaining tristimulus values	5
7.2 The basis for integration	6
7.3 Rod activity	6
7.4 The use of restricted data	6
7.5 Standard of reflectance	6
Annex A (informative) Bibliography	Inside back cover
Table 1 — Colour-matching functions and chromaticity coordinates of CIE 1931 standard colorimetric observer	7
Table 2 — Colour-matching functions and chromaticity coordinates of CIE 1964 supplementary standard colorimetric observer	16

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.

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]; [X₁₀], [Y₁₀], [Z₁₀]; 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 [X₁₀], [Y₁₀], [Z₁₀], 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

Table 1 and Table 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.