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Part 3: CIE tristimulus values

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by the International Commission on Illumination (CIE) in cooperation with Technical Committee ISO/TC 274, *Light and lighting*.

This first edition of ISO/CIE 11664-3 cancels and replaces ISO 11664-3:2012 | CIE S 014-3:2011, of which it constitutes a minor revision, incorporating minor editorial updates.

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

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

Introduction

Colour stimuli with different spectral distributions can look alike. An important function of colorimetry is to determine which stimuli look alike to a given observer with a given set of colour-matching functions. This is done by calculating a set of three tristimulus values for each stimulus. Equality of tristimulus values indicates equality of colour appearance under equal irradiation and viewing conditions. This document is based on long-standing CIE recommendations (see CIE 15[1]) for the calculation of tristimulus values.

Colorimetry —

Part 3:
CIE tristimulus values

1 Scope

This document specifies methods of calculating the tristimulus values of colour stimuli for which the spectral distributions are provided. These colour stimuli can be produced by self-luminous light sources or by reflecting or transmitting objects.

This document requires that the colour stimulus function be tabulated at measurement intervals of 5 nm or less in a wavelength range of at least 380 nm to 780 nm. Extrapolation methods are suggested for cases where the measured wavelength range is less than 380 nm to 780 nm.

The standard method is defined as summation at 1 nm intervals over the wavelength range from 360 nm to 830 nm. Alternative abridged methods are defined for larger intervals (up to 5 nm) and shorter ranges (down to 380 nm to 780 nm). The alternative methods are to be used only when appropriate and when the user has reviewed the impact on the final results.

This document can be used in conjunction with the CIE 1931 standard colorimetric observer or the CIE 1964 standard colorimetric observer.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/CIE 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 23539, *Photometry — The CIE system of physical photometry*

CIE S 017, *ILV: International Lighting Vocabulary*

3 Terms and definitions

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

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

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

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

4 Symbols and abbreviations

k, k_{10}	normalizing constants
K_m	maximum spectral luminous efficacy of radiation in the CIE standard system of physical photometry
$K_{m,10}$	maximum spectral luminous efficacy of radiation when the $V_{10}(\lambda)$ function is used for photometry
$R(\lambda)$	spectral reflectance factor
$S(\lambda)$	relative spectral distribution of an illuminant
$V(\lambda)$	spectral luminous efficiency function in the CIE standard system of physical photometry
$V_{10}(\lambda)$	spectral luminous efficiency function when the $\bar{y}_{10}(\lambda)$ function is used for photometry
$W_x(\lambda)$, $W_y(\lambda)$, $W_z(\lambda)$	pre-calculated weighting functions for tristimulus integration using the CIE 1931 standard colorimetric observer
$W_{x,10}(\lambda)$, $W_{y,10}(\lambda)$, $W_{z,10}(\lambda)$	pre-calculated weighting functions for tristimulus integration using the CIE 1964 standard colorimetric observer
x, y, z	chromaticity coordinates calculated using the CIE 1931 standard colorimetric observer
x_{10}, y_{10}, z_{10}	chromaticity coordinates calculated using the CIE 1964 standard colorimetric observer
$\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$	colour-matching functions of the CIE 1931 standard colorimetric observer (also known as the CIE 2° standard colorimetric observer)
$\bar{x}_{10}(\lambda), \bar{y}_{10}(\lambda), \bar{z}_{10}(\lambda)$	colour-matching functions of the CIE 1964 standard colorimetric observer (also known as the CIE 10° standard colorimetric observer)
X, Y, Z	tristimulus values calculated using the CIE 1931 standard colorimetric observer
X_{10}, Y_{10}, Z_{10}	tristimulus values calculated using the CIE 1964 standard colorimetric observer
$\beta(\lambda)$	spectral radiance factor
$\Delta\lambda$	wavelength interval
$\varphi_\lambda(\lambda)$	colour stimulus function (description of a colour stimulus by the spectral concentration of a radiometric quantity, such as radiance or radiant power, as a function of wavelength)
$\varphi(\lambda)$	relative colour stimulus function (relative spectral distribution of the colour stimulus function)
λ	wavelength
$\rho(\lambda)$	spectral reflectance
$\tau(\lambda)$	spectral transmittance

5 Standard method

5.1 General

This document may be used in conjunction with the CIE 1931 standard colorimetric observer or the CIE 1964 standard colorimetric observer. If the angle subtended at the eye by the colour stimulus (or fields to be matched in colour) is between about 1° and 4° the CIE 1931 standard colorimetric observer shall be used. If this angular subtense is greater than 4° the CIE 1964 standard colorimetric observer shall be used. The same colorimetric observer shall be used for all stimuli to be compared with each other.

5.2 Calculation of tristimulus values

In the CIE 1931 standard colorimetric system, tristimulus values *X*, *Y* and *Z* are defined as integrals over the spectral range 360 nm to 830 nm according to Formulae (1) to (3):

$$X = k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}(\lambda)\,\mathrm{d}\lambda \tag{1}$$

$$Y = k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}(\lambda)\,\mathrm{d}\lambda \tag{2}$$

$$Z = k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}(\lambda)\,\mathrm{d}\lambda \tag{3}$$

where

$\varphi_{\lambda}(\lambda)$ is the colour stimulus function to be evaluated;

$\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ are the colour-matching functions of the CIE 1931 standard colorimetric observer;

k is a normalizing constant defined in 5.3 and 5.4.

The standard method for evaluating these integrals is numerical summation from 360 nm to 830 nm at wavelength intervals, $\Delta\lambda$, equal to 1 nm according to Formulae (4) to (6):

$$X = k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}(\lambda)\,\Delta\lambda \tag{4}$$

$$Y = k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}(\lambda)\,\Delta\lambda \tag{5}$$

$$Z = k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}(\lambda)\,\Delta\lambda \tag{6}$$

using colour-matching functions $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ defined with seven significant figures in ISO/CIE 11664-1 and a colour stimulus function, $\varphi_{\lambda}(\lambda)$, measured using a symmetrical triangular or trapezoidal bandpass with a half width equal to 1 nm.

Tristimulus values are often evaluated on a relative basis. In such cases the relative colour stimulus function, $\varphi(\lambda)$, may be used instead of the colour stimulus function, $\varphi_{\lambda}(\lambda)$. It is essential that, for stimuli that will be considered together, all the spectral distributions involved be assessed on the same relative basis. The tristimulus values obtained are then relative in the sense that all the values involved may