INTERNATIONAL STANDARD

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CIE S 014-3/E

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Colorimetry —

Part 3:
CIE tristimulus values

Colorimétrie —

Partie 3: Composantes trichromatiques CIE

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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.

ISO 11664-3 was prepared as Standard CIE S 014-3/E by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodies casting a vote, and is published as a joint ISO/CIE edition.

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

ISO 11664-3 was prepared by CIE Technical Committee 1-57 of Division: *Vision and colour*.

ISO 11664 consists of the following parts, under the general title *Colorimetry*:

— *Part 1: CIE standard colorimetric observers*

— *Part 2: CIE standard illuminants*

— *Part 3: CIE tristimulus values*

— *Part 4: CIE 1976 L*a*b* Colour space*

— *Part 5: CIE 1976 L*u*v* Colour space and u', v' uniform chromaticity scale diagram*

CIE S 014-3/E:2011

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
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Standard

Colorimetry - Part 3: CIE Tristimulus Values

Colorimétrie - Partie 3: Composantes trichromatiques CIE

Farbmessung - Teil 3: CIE-Farbwerte

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Foreword

Standards produced by the Commission Internationale de l'Eclairage are concise documents on aspects of light and lighting that require a unique definition. They are a primary source of internationally accepted and agreed data which can be taken, essentially unaltered, into universal standard systems.

This CIE Standard has been prepared by Technical Committee TC 1-57* of Division 1 "Vision and Colour" of the Commission Internationale de l'Eclairage and approved by the National Committees of the CIE.

The following ISO and IEC committees and working groups co-operated in the preparation of this standard:

IEC TC100/TA2 (Audio, video and multimedia systems)

ISO TC6 (Paper, board and pulps)

ISO TC35/SC9/WG22 (Paints and varnishes)

ISO TC38/SC1/WG7 (Textiles)

ISO TC42 (Photography)

ISO TC130 (Graphic technology)

ISO/IEC/JTC1/SC28 (Office systems)

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CONTENTS

Colorimetry - Part 3: CIE Tristimulus Values

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 Standard is based on long-standing CIE recommendations (CIE, 2004) for the calculation of tristimulus values.

1 Scope

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

The Standard 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.

The Standard may be used in conjunction with the CIE 1931 standard colorimetric observer or the CIE 1964 standard colorimetric observer.

2 Normative References

The following referenced documents are indispensable for the application 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.

CIE DS 017.2/E:2009. *ILV: International Lighting Vocabulary*.

ISO 11664-1:2007(E)/CIE S 014-1/E:2006. Joint ISO/CIE Standard: *Colorimetry Part 1. CIE Standard Colorimetric Observers.*

ISO 11664-2:2007(E)/CIE S 014-2/E:2006. Joint ISO/CIE Standard: *Colorimetry Part 2. CIE Standard Illuminants.*

ISO 23539:2005(E)/CIE S 010/E:2004. Joint ISO/CIE Standard: *Photometry - The CIE System of Physical Photometry.*

3 Definitions, Symbols and Abbreviations

For the purposes of this International Standard, the terms and definitions given in CIE DS 017.2/E:2009 (International Lighting Vocabulary), and the following symbols and abbreviations apply.

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

4 Standard Method

The Standard 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.

4.1 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 the equations:

$$\begin{aligned} X &= k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}(\lambda)\,\mathrm{d}\lambda \\ Y &= k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}(\lambda)\,\mathrm{d}\lambda \\ Z &= k\int_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}(\lambda)\,\mathrm{d}\lambda \end{aligned} \tag{1}$$

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; and k is a normalizing constant defined below. 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 the equations:

$$\begin{aligned} X &= k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{x}(\lambda)\,\Delta\lambda \\ Y &= k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{y}(\lambda)\,\Delta\lambda \\ Z &= k\sum_{\lambda} \varphi_{\lambda}(\lambda)\,\bar{z}(\lambda)\,\Delta\lambda \end{aligned} \tag{2}$$

using colour-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ defined with 7 significant figures in ISO 11664-1:2007(E)/CIE S 014-1/E:2006 and a colour stimulus function, $\varphi_{\lambda}(\lambda)$, measured using a symmetrical triangular or trapezoidal bandpass with a halfwidth 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 be multiplied by the same single arbitrary constant, k. In certain cases, however, k shall be chosen according to agreed conventions; these conventions are explained in 4.2 and 4.3.

NOTE The wavelength range of 360 nm to 830 nm is in accordance with established CIE practice (ISO 11664-1:2007(E)/CIE S 014-1/E:2006 and CIE, 2004). Clause 5 of this Standard specifies abridged methods that may be used when data are not available over the full range of 360 nm to 830 nm at 1 nm intervals.