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Photometry — The CIE system of physical photometry

Photométrie — Le système CIE de photométrie physique

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11

Email: copyright@iso.org
Website: www.iso.org

CIE Central Bureau
Babenbergerstraße 9/9A • A-1010 Vienna

Phone: +43 1 714 3187
Fax: +41 22 749 09 47
Email: ciecb@cie.co.at
Website: www.cie.co.at

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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 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).

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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 23539 cancels and replaces ISO 23539:2005/CIE S 010:2004, which has been technically revised.

The main changes are as follows:

— The scope of the document has changed to incorporate the spectral luminous efficiency functions published by the CIE for a) mesopic vision and b) 10° photopic vision, on the basis of CIE 018:2019.

— The International System of Units (SI) and its reformulation of the definition of the candela – effective on 20 May 2019 – has been incorporated (Resolution 1, 26th CGPM, 2018).

— A list of normative references has been added.

— Specific requirements have been added regarding the use of units, tabulated values and interpolation of intermediate values.

— The background of the CIE system of physical photometry, specifically the evolution of the photometric base unit, has been updated in Annex C.

— The CIE 2015 cone-fundamental-based spectral luminous efficiency functions for a) 2° field size and b) 10° field size have been added in Annex E based on CIE 170-2:2015.

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

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Introduction

The purpose of photometry is to measure light as perceived by human eyes. The brightness of a luminous surface depends not only on the amount of radiation it emits, transmits or reflects, but also on its spectral composition and on the visual response function of the observer viewing it. Because human visual response varies at different light levels and from person to person, precise photometry requires the definition of representative standard observers. The CIE system of physical photometry specifies procedures for the quantitative evaluation of optical radiation in terms of internationally agreed spectral luminous efficiency functions for human vision. $V(\lambda)$ represents photopic vision, $V'(\lambda)$ represents scotopic vision and $V_{\mathrm{mes};m}(\lambda)$ represents mesopic vision, the latter being intermediate between photopic and scotopic vision. Furthermore, $V_{10}(\lambda)$ represents 10° photopic vision. These luminous efficiency functions adopted from CIE 018:2019[1] and BIPM-2019/05,[2] together with the SI base unit, the candela, constitute a system that enables the calculation of values of photometric quantities for optical radiation as well as light-emitting, light-transmitting or light-reflecting surfaces, to be precisely determined based on the International System of Units (SI), regardless of the spectral composition of the radiation emitted, transmitted or reflected.

The CIE system of physical photometry has some limitations in respect to the brightness of coloured surfaces: two light sources of different colour but with the same measured luminance value will not necessarily be perceived as equally bright. CIE has therefore published a more complex model (CIE 200:2011)[3] for specific situations. For eye-mediated non-image-forming effects of light induced partially or completely by the intrinsically photosensitive retinal ganglion cells (ipRGCs), CIE S 026/E:2018[4] is used.

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Photometry — The CIE system of physical photometry

1 Scope

This document specifies the characteristics of the system of physical photometry established by the CIE and accepted as the basis for the measurement of light. It defines the photometric quantities, units and standards that make up the CIE system of physical photometry and that have been officially accepted by the Comité International des Poids et Mesures (CIPM). This comprises:

— the definition of photometric quantities, symbols and units;

— the definition of CIE spectral luminous efficiency functions for photopic vision, scotopic vision, mesopic vision and 10° photopic vision;

— the definition of CIE photometric observers that conforms to these functions;

— the definition of maximum luminous efficacy for photopic vision, mesopic vision, scotopic vision and 10° photopic vision.

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.

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 and the following apply.

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

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

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

CIE maintains a terminology database for use in standardization at the following address:

— CIE e-ILV: available at https://cie.co.at/e-ilv

3.1
CIE photometric observer
CIE observer
ideal observer having a relative spectral responsivity that conforms to a CIE-defined spectral luminous efficiency function for human vision and that complies with the summation law implied in the definition of luminous flux

Note 1 to entry: CIE has defined spectral luminous efficiency functions for photopic vision, $V(\lambda)$, and scotopic vision, $V'(\lambda)$, which are CIE standard photometric observer(s). Furthermore, CIE has defined CIE photometric observers for mesopic vision, $V_{\mathrm{mes};m}(\lambda)$, and 10° photopic vision, $V_{10}(\lambda)$, as well as published definitions of cone-fundamental-based spectral luminous efficiency functions[5].

Note 2 to entry: CIE photometric observers are distinct from CIE standard photometric observers, which only include spectral luminous efficiency functions for photopic vision, $V(\lambda)$, and scotopic vision, $V'(\lambda)$.

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Note 3 to entry: Other spectral luminous efficiency functions defined in this document are also intended to define CIE photometric observers.

Note 4 to entry: Other spectral luminous efficiency functions will possibly be included as CIE photometric observers. However, only the functions tabled in Clause 8 relate the given spectral radiometric quantity to the International System of Units (SI).

3.2
10° photopic vision
10° vision
photopic vision based on the CIE 10° photopic photometric observer

Note 1 to entry: 10° photopic vision corresponds to vision by the normal eye in situations where the visual target has an angular subtense larger than 4° or is seen off-axis.

4 Photometric quantities and units

4.1 Photometric quantities

The most commonly used photometric quantities are:

— luminous flux;

— luminous intensity;

— luminance;

— illuminance.

These quantities are defined in CIE S 017 and their definitions, adopted by the Consultative Committee for Photometry and Radiometry (CCPR) of the International Committee for Weights and Measures (CIPM), are referred to in this clause. After the redefinition of the SI units in 2019,[6] the definition of the unit of candela is tied to the definitions of the SI units kilogram, second and metre. It is important to note that the 2019 reformulation of the definition of the candela does not make a numerical difference in the calculations of the photometric quantities.

To avoid confusion, photometric quantities are distinguished symbolically from their radiometric equivalents by the subscript “v”, whereas radiometric quantities receive the subscript “e”. The same subscripts are also applicable to photometric and radiometric quantities other than those listed (e.g. luminous exposure, radiant exposure). For photometric quantities using spectral luminous efficiency functions other than that for 2° photopic vision, $V(\lambda)$, the quantity names and symbols described in Clause 6 are used.

For many practical purposes the simplest physical quantity used in optical radiometry is the radiant flux or radiant power, Φ_e, measured in watts (W), which is emitted by a source of radiation, transmitted by a medium of propagation or received at a surface. The corresponding photometric quantity is the luminous flux, Φ_v, measured in lumen (lm), derived from radiant flux, Φ_e, by evaluating the radiation according to its action upon a CIE standard photometric observer or CIE photometric observer. In this document the relation between radiometric quantities and photometric quantities is shown by example using the relation between the radiant flux and the (photopic) luminous flux using the CIE standard photometric observer for photopic vision, as well as other CIE photometric observers. The general relation between a given luminous flux, $\Phi_{v,X}$, for a specific photometric condition, X, and the spectral radiant flux $\Phi_{e,\lambda}(\lambda)$ is given in 7.3, with specific observers shown in 7.5 to 7.8.

The most commonly used photometric quantities given in this subclause, as well as others such as luminous exitance and luminous exposure, are defined in CIE S 017. All photometric quantities can be formulated in terms of luminous flux and appropriate geometric factors. The defining relationships for other photopic, scotopic and mesopic photometric quantities are formed from the formulae in 7.5 to 7.8 by replacing the symbols for radiant flux and luminous flux with the appropriate radiometric and photometric symbols.

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