INTERNATIONAL STANDARD

ISO 12646

Third edition
2015-07-15

Graphic technology — Displays for colour proofing — Characteristics

Technologie graphique — Affichages pour la réalisation d'épreuves en couleur — Caractéristiques

Reference number
ISO 12646:2015(E)

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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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 130, *Graphic technology.*

This third edition cancels and replaces the second edition (ISO 12646:2008), which has been technically revised to improve the compatibility with the requirements of soft proofing defined in ISO 14861.

Introduction

The ability to match colour images displayed on colour displays to the images produced when the same digital file is rendered by proofing and printing systems (commonly referred to as "soft" proofing) is increasingly expected in graphic arts. Obtaining such a match is not simple and to be fully accurate requires careful control of many aspects of the process. The primary purpose of this International Standard is to make recommendations with respect to the soft proof displays requirements. If these are met, it is then possible for a soft proofing system such as defined in ISO 14861 to accurately colour match to the hard copy proof. Hence, this International Standard is intended for display manufacturers in order to qualify their display for use in graphic arts proofing systems.

The appearance of a colour image on a colour display is influenced by many physical factors other than controlled ambient viewing conditions. Among the most important of these are uniformity, size and resolution (in order to permit rendition of the proof at close to its normal size and with the finest detail visible on the hard copy at normal viewing distances), variation of electro-optical properties with viewing direction, freedom from flicker and glare (specular reflections with distinct images), the opto-electronic calibration of the display, and the settings of its display driver software. In this regard, to be acceptable in a proofing system that provides a reasonable level of image quality, the display needs to also exhibit these properties at an acceptable quality.

Note that even for displays of the highest quality, the appearance of the displayed image will be limited by the accuracy of the colour transformation used for converting the digital file from its encoded colour space to that required for display purposes.

This International Standard specifies requirements for displays to be used in soft proofing systems defined by ISO 14861. ISO 14861 primarily focuses on applications where the displayed image will be compared to a hard copy in an adjacent viewing cabinet or where the viewing cabinet intentionally contains the display. Furthermore, in order to address the different needs for the soft proofing use cases, two different conformance levels (class A and class B) will be defined in this International Standard.

However, in some practical situations, the image on the screen is evaluated in the absence of a hard copy. This International Standard might be used as reference, but this is not required. Users of this International Standard will also benefit from CIE Publication 122 which provides an overview of the relationship between digital and colorimetric data. Those unfamiliar with the evaluation of displays will also find it helpful to read IEC 61223-2-5 which contains much useful detailed information about evaluation and testing of image display devices.

Graphic technology — Displays for colour proofing — Characteristics

1 Scope

This International Standard specifies requirements for two conformance levels for the characteristics of displays to be used for soft proofing of colour images. Included are requirements for uniformity and variations of electro-optical properties with viewing direction for different driving signals.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system or values represented by a material measure of a reference material and the corresponding values realized by standards

[SOURCE: ISO International Vocabulary of Basic and General Terms in Metrology]

Note 1 to entry: However, in typical graphic arts, use cases calibration is understood as an active process where a display or a printer is adjusted such that it produces the defined aim values.

3.2
colorimeter
instrument for measuring colour values such as the tristimulus values of a colour stimulus

[SOURCE: ISO 12637-2:2008, 2.18]

3.3
design viewing direction
DVD
direction for which specific electro-optical characteristics of the display have been optimized

Note 1 to entry: Examples of important electro-optical characteristics are maximum luminance and maximum contrast in definite direction.

3.4
gamma
γ
best-fit parameter which relates the display normalized output luminance to a normalized input digital value presented to the display system including its hardware and software components as given in Formula (1):

$$L = \left(S\right)^{\gamma} + O$$

where

L is the normalized output luminance;

S is the normalized input digital value;

O is the offset.

3.5
ON-state
condition in which the display is switched on

Note 1 to entry: This definition is important for light-valve-like displays which might emit a significant light intensity even when displaying the darkest image (R = G = B = 0) in the ON-state.

3.6
spectrophotometer
instrument for measuring the reflectance or transmittance of light (or other radiation) by an object at one or more wavelengths in the spectrum

[SOURCE: ISO 105-A08:2001, 2.24]

3.7
viewing cone
VC
conical space originating at the display surface that includes all viewing directions with a specified angle of inclination, θ (3.8)

3.8
viewing angle
θ
angle between the normal to the display and the *design viewing direction* (3.3)

4 Requirements

4.1 General

All display tests should be performed for a display calibrated to a luminance of 160 cd/m^2 and a chromaticity corresponding to a D50 (x = 0,3 457 and y = 0,3 585) illuminant with a 2° observer at a gamma of 2,2. The display shall display a ”white” image consisting of the maximum value in each channel, red, green, and blue (255 for 8-bit). It shall be reported if other calibration aims were used.

NOTE 1 This calibration condition is typical of the conditions used in the graphic arts industry and ensures that the results of different tested displays can be compared because uniformity can be dependent to some extent on the chosen gamma, luminance, and white point settings.

If a display to be tested will be used solely in a specific soft proofing system where no display calibration is used, but only the state of the display is characterized, the calibration can be omitted. The luminance, the white point chromaticity (as expressed in CIExy units), and tone reproduction curve (as expressed by a single gamma value or as a set of tabulated values) shall be reported.

The display shall be tested in a stable condition. In order to establish the individual stabilization time, each display to be tested shall be operated in the calibration mode for 12 h in a room with controlled temperature conditions. The room temperature shall not change more than ±0,5 °C and shall be in the range of 18 °C to 28 °C.

The stabilization time (warm up time) is achieved when the luminance change is less than 2 % (compared to the average of the measurements of the last 9 h of the 12 h period) and the white point is within ±0,005 for CIE Δx, Δy of the calibrated conditions. If the display will not achieve stable conditions, it shall not be used.

The warm up behaviour of a display shall be reported with a graph of luminance and CIE Δx, Δy in measured values and in percentage compared to the average of the last 9 h of the 12 h period.

NOTE 2 When using viewing condition P2, according to ISO 3664, a luminance of 160 cd/m^2 correlates with an illuminance of 500 lux illuminating a perfect reflecting diffusor.

4.2 Uniformity of luminance and chromaticity

4.2.1 General

The uniformity of a soft proofing system is vital and shall be checked for solid colours and for tonality (gradation) changes of the screen. If the informative requirements of 4.2.2. or 4.2.3 are not met, this shall be reported. Therefore, the following method is normatively required in ISO 14861. However, since there are soft proofing solutions that are able to perform a spatial resolved uniformity correction, this International Standard makes the uniformity assessment informative.

It shall be reported and if hardware based, look up table display corrections are turned on (if present).

4.2.2 Evaluation of tone uniformity

The CIELAB values of a uniform 5 × 5 grid are calculated using the measurement of the centre patch at maximum driving as the reference white illuminant. Note that this method may result in some CIEL* values being greater than 100. 24 readings are compared with the centre colour for three different driving levels, namely white, at the maximum driving level (R = G = B = 255 for 8-bit displays), grey at about half maximum driving level (R = G = B = 127 for 8-bit displays), and dark grey at about one fourth of maximum driving level (R = G = B = 63 for 8-bit displays) by means of the DE00 colour difference formulae. For the white and the grey driving levels, the DE00 colour differences should be equal or less than four.

4.2.3 Tonality evaluation (uniformity)

Utilizing luminance (cd/m^2) measurements of grey at half maximum driving level (R = G = B = 127 for 8-bit displays) and white at max driving level (R = G = B = 255 for 8-bit displays) the grey/white ratio should be calculated for the 25 regions. For the non-central regions, new ratios, T_i, with i = {1,..,24} should be computed by dividing the individual grey/white ratios, R_i, with i = {1,...,24} by the grey/white ratio of the centre, R_c, subtracting one and calculate the absolute value of the number. This measure of the deviation from uniform tonality should be less than 10 %, i.e. max (T_i), i = {1,..,24} should be less than 0,10.

$$T_{\mathrm{i}} = abs\left(R_{\mathrm{i}} / R_{\mathrm{c}} - 1\right), \left(\mathrm{i} = 1, ..., 24\right) \quad (1)$$

The uniformity of tonality, determined as max (T_i), with i = {1,..,24}, should be less than 0,1.

4.3 Viewing cone characteristics

The instrumentation setup and measurement geometry for viewing cone measurements shall be as defined in 5.4.2.

Based on the viewing cone which is visible for an observer viewing a display centred with one eye at a given viewing distance (default: 500 mm), the maximal viewing angles theta_max (θ_{max}) shall be calculated for the horizontal, diagonal and vertical directions. In addition, theta_max for the four 45° angles (starting at 45° being 90° apart from each other) shall be calculated. The maximum inclination (theta_max) depends on screen size, screen aspect ratio (ratio of display width and height), and viewing distance and will be calculated as follows:

$$\theta_{\mathrm{max},horizontal} = \arctan\left(W2 / VD\right) * 180^{\circ} / \pi \quad (2)$$

$$\theta_{\mathrm{max},vertical} = \arctan\left(H2 / VD\right) * 180^{\circ} / \pi \quad (3)$$

$$\theta_{\max,diagonal} = \arctan\left(D2 / VD\right) * 180^\circ / \pi \quad (4)$$

$$\theta_{\max,45} = \arctan\left(D45\_2 / VC\right) * 180^\circ / \pi \quad (5)$$

where

$W2$	is the half of the display width in mm;
$H2$	is the half of the display height in mm;
$D2$	is half of the display diagonal in mm;
VD	is the viewing distance in mm;
$D45\_2$	is half of the 45° diagonal calculated by D45_2 = H2/sin(45°*$_{\pi}$/180°).

EXAMPLE For a 15 inch laptop display with an aspect ratio of 1,6 (display height = 202 mm, display width = 323 mm, diagonal = 15"*25,4 = 381 mm), seen from 500 mm viewing distance $\theta_{\max, horizontal}$ is 17,9°, $\theta_{\max, vertical}$ is 11,4°, $\theta_{\max, diagonal}$ is 20,9°, and $\theta_{\max, 45}$ is 15,9°.

All viewing angles theta up to theta_max are assessed in steps of 10° (or smaller). Theta_max is rounded according to the assessed step width. It shall be reported if the intended viewing distance exceeds 500 mm.

NOTE 1 It is important to note that the viewing distance a user might choose might be different (often between 500 mm and 800 mm). The tolerances have been defined with a default viewing distance of 500 mm in mind. This viewing distance represents the lower range which is typical for desktop application soft proofing.

A display suitable for graphic arts soft proofing should exhibit low colour deviations for all driving levels over the visible viewing cone. A stable colour over the visible viewing cone is assessed by calculating DE00 for all viewing angles up to theta_max for each azimuth angle. The colour deviation shall be less DE00 of 10 for white at maximum driving level (R = G = B = 255 for 8-bit displays) and grey at about half maximum driving level (R = G = B = 127 for 8-bit displays) and should be less DE00 of 10 for dark grey at about one fourth of maximum driving level (R = G = B = 63) and for a driving level which results in a luminance level equal to 1 % of the calibrated luminance (default 1,6 cd/m^2).

NOTE 2 The state of technology does not allow displays to be produced with little or no colour deviation over the viewing cone. A maximum deviation of DE00 of 10 is a reasonable tolerance for this deviation. Also the gradation across the viewing cone can vary for some types of displays. This can be observed visually by "washed out" looking mid-tones. The practice shows that those displays still can be used with good success for graphic arts work. Although for demanding users, displays with a more stable gradation are needed. This situation was the reasoning for introducing two classes for this single criterion. When technology evolves tighter, tolerances can be used.

The viewing angle dependent gradation difference (Delta Gamma) as defined in 5.3 shall be equal or less than "ΔGamma" of 10 % for grey at about half of maximum driving level (R = G = B = 127 for 8-bit displays). Displays not passing the "ΔGamma" criteria, but all other normative criteria of this International Standard are categorized as class B displays. Displays passing all criteria are categorized as class A displays.

4.4 Reflective characteristics

The reflective properties of the display surface in the power off shall be judged visually in a darkroom using a point source. The reflection of the point source off the screen should appear hazy and should smoothly decrease as one turns away from the direction of specular reflection.

5 Test methods

5.1 General

For each patch displayed (sequentially at the image centre), the measured spectral radiance and/or CIEXYZ values shall be recorded. CIELAB values are calculated, if needed. (refer to ISO 13655 for calculation) The white point used shall be reported.

The display is calibrated and profiled to the target values defined for a specific application.

NOTE The measurement device should be calibrated if possible, for example, by the manufacturer. If this is not possible, the inter-instrument agreement between two devices or comparison to a visual in-house reference like a proof print can help to estimate that the measuring device is functioning correctly.

5.2 Preparation and display set-up

Prior to calibration and any measurement, the display shall be switched on and allowed to warm as defined in 4.1. All measurements shall be carried out on the calibrated and characterized display according to 4.1. The information (e.g. calibration process, software used, ICC profiles) necessary to describe and repeat the measurements shall be reported with the data.

If not otherwise required, all measurements shall be carried out at the design viewing direction and in contact with the faceplate. If no design viewing direction is stated by the vendor, the normal to the display surface shall be used instead.

5.3 Viewing angle dependent tonality evaluation (“ΔGamma”)

To ensure a stable image appearance, it is vital that the gradation varies as little as possible over the viewing angle and area of the display. The Delta Gamma (tone reproduction) is assessed by first calculating a normalized, “relative” luminance value for grey for the centre of the display and for each viewing direction or point to compare against. The relative luminance Y_rel is calculated as the ratio between the luminance at grey of about half maximum driving level (R = G = B = 127 for 8-bit displays) to the luminance of white at maximum driving level (R = G = B = 255 for 8-bit displays). To assess if the gradation is stable, a so-called “ΔGamma” value is calculated using Formula (5).

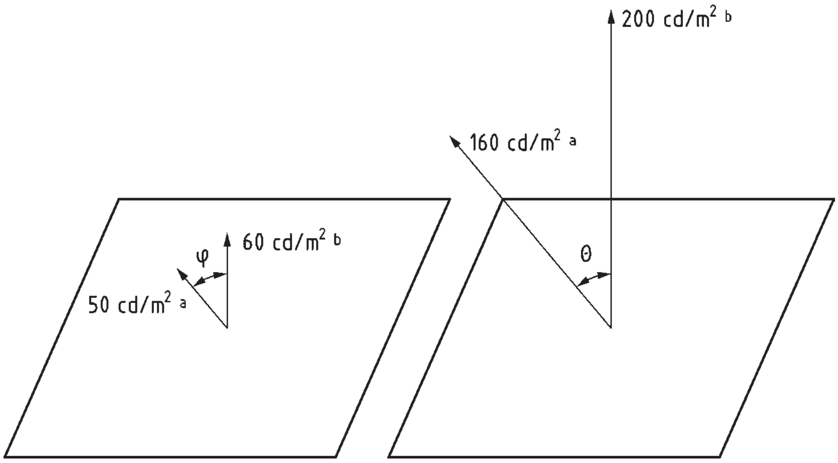
$$\text{"}\Delta\text{Gamma"} \sim [Y_{\text{rel}}(\textit{testcolours}, \theta, \phi)] / [Y_{\text{rel}}(\textit{reference colours} \ @ \ \textit{DVD})] - 1 \tag{6}$$

with

$$Y_{\text{rel}} = Y_{\text{grey}} / Y_{\text{white}}$$

An example is presented in Figure 1.

NOTE A stable gradation could be expressed as a gamma change (see given example). Here, the gradation is assessed by calculating the percentage how a normalized grey luminance differs from the normalized grey luminance of the reference angle (at design viewing direction). To make it easy to communicate this value to the practitioner, this can be called “ΔGamma”, including quotation marks, to make clear that this is not a real gamma difference, but only related to a gamma difference.



Key

a $$Y_{\text{rel}}(Testcolours, \varphi, \theta) = \frac{50}{160} = 0,312 \sim \gamma = 1,68$$

b $$Y_{\text{rel}}(reference\ colours@DVD) = \frac{60}{200} = 0,3 \sim \gamma = 1,74$$

NOTE $$\frac{0,312}{0,3} - 1 = 0,0417 \rightarrow \text{"}\Delta\text{Gamma"} = 4,2\%$$

Figure 1 — Example calculation of "Delta Gamma"

5.4 Measurement conditions

5.4.1 Photometric and colorimetric measurements

The following requirements pertain to measurements either at the faceplate (contact measurement) or telespectroradiometrically. The measurement at the faceplate of the display shall be carried out using either a spectroradiometer or a colorimeter. The measurement at some distance from the faceplate of the display shall be carried out in a dark room with the configuration shown in Figure 2. For both cases, the optical axis of the instrument shall be in line with the design viewing direction.

Spectroradiometers and spectrophotometers shall comply with the following requirements:

a) the wavelength range shall include the interval from 400 nm to 720 nm;

b) the angular angle of the sensing cone, i.e. the angle region over which the efflux is sensed by the receiver, shall not be more than a half angle of 5° and should not be more than a half angle of 2,5° (see Figure 2);

c) for telespectroradiometric measurements, the distance, *d*, shall be chosen such that the number of pixels sampled during measurement is at least 150. For measurement at the face plate, the area measured for each sample shall have a diameter of no less than 4 mm and shall contain at least 150 pixels.

d) the chromaticity accuracy when measuring an incandescent source shall be CIExy = ±0,002 at luminance levels between 0,5 cd/m^2 and at least 800 cd/m^2.

e) the 2*k* uncertainty of the wavelength where *k* is the coverage factor defined in ISO 15790 should be less than 0,5 nm and shall be less than 1 nm as described in the wavelength standard (incandescent reference source with colour temperature of 2 856K ± 50K with certified values of spectral radiance or irradiance tabulated at 5 nm intervals for an average half-power bandwidth of between 4 nm and 5 nm);

f) the reference for spectral data shall be based on computed data at 5 nm intervals where the spectral response function is triangular with a 5 nm bandwidth at the half-power point.

g) the resolution of the measuring device shall be smaller or equal to 10 nm (FWHM) and should be smaller or equal to 5 nm (FWHM). If the measurements are taken at sampling intervals smaller than 5 nm, the procedure for widening the bandwidth specified in ISO 13655 shall be used for deriving and reporting data at 5 nm intervals;

h) at a luminance greater than 80 cd/m^2 and at a spectral distribution corresponding to that of the white state of the display, the repeatability of the spectroradiometer shall be less than 0,001 for CIE $u'v'$and 0,5 % of the luminance level being measured;

i) for flat panel displays only, the polarization error of the instrument is limited as follows: the luminance, measured at five azimuthal positions of the instrument, spaced 30° apart, shall be within 5 % of the average of the five measurements, and CIExy chromaticity shall be within 0,002 of the five measurements.

Tristimulus colorimeters shall comply with the following requirements:

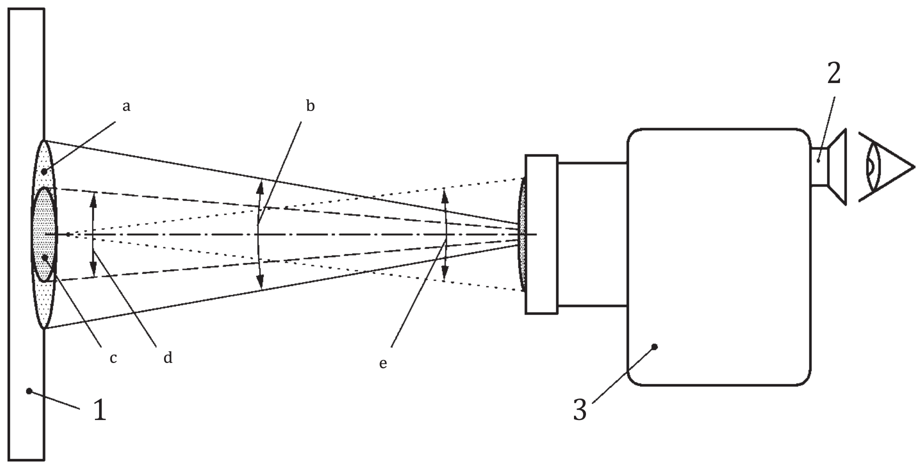
a) the angular angle of the sensing cone, i.e. the angle region over which the efflux is sensed by the receiver, shall not be more than a half angle of 5° and should not be more than a half angle of 2,5° (see Figure 2);

b) for measurement at some distance, the distance, *d*, shall be chosen such that the number of pixels sampled during measurement is at least 150. For measurement at the face plate, the area measured for each sample shall have a diameter of no less than 4 mm and shall contain at least 150 pixels.

c) the repeatability (stability) shall be less than 0,001 for CIExy and 0,5 % for the luminance using a stable light source having a luminance higher than 80 cd/m^2.

d) the chromaticity accuracy when measuring an incandescent source shall be CIExy = ±0,002 at luminance levels between 0,5 cd/m^2 and at least 800 cd/m^2.

NOTE CIE standard source A is chosen for traceability measurements because of its practicality and ease of realization.



Key

1 DUT, object of measurement

2 viewport

3 LMD, receiver

a Field of view.

b Angular field of view.

c Measurement field.

d Measurement field angle.

e Aperture angle.

NOTE Refer to CIE Publication No. 69 for more details. In case of LCD-DUT, the angular aperture shall be <5° (±2,5°) per IEC 61747.

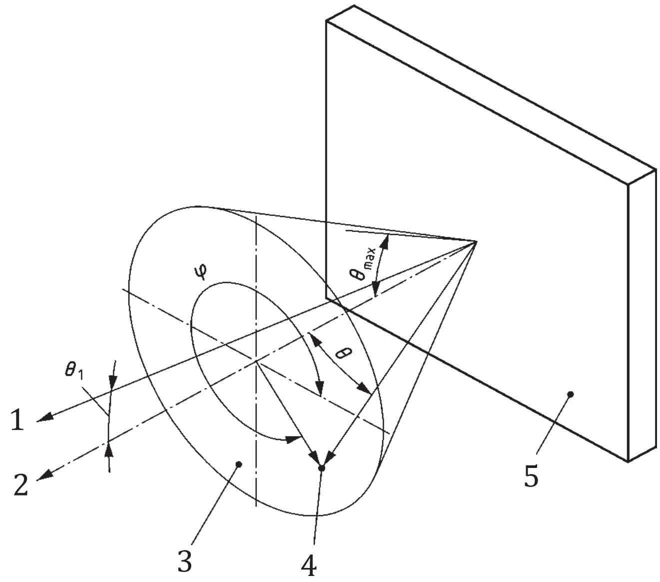
Figure 2 — Set-up for non-contact measurements (adapted from IEC 61747)

5.4.2 Measurements as a function of viewing direction

5.4.2.1 Angle definitions

For the purpose of these measurements, the following definitions apply. The azimuth angle, φ, is measured anti-clockwise from the three o'clock position (see Figure 3). The viewing angle, θ, is measured from the surface normal, n.

NOTE For more information on coordinates and viewing, see ISO 9241-302:2008.



Key

1	design viewing direction
2	surface normal (*n*)
3	viewing cone
4	point defining the measurement direction with respect to θ and φ
5	flat panel displays
θ	angle of inclination of measurement direction with respect to the surface normal
θ_1	angle of inclination of the normal with respect to the Design Viewing Direction
θ_{max}	maximum angle of inclination with respect to the surface normal
φ	angle of azimuth of measurement direction

Figure 3 — Spherical coordinate system

5.4.2.2 Viewing cone

Measurements of the directional luminance and colorimetric distribution shall be carried out in a darkroom at the centre of the display using conoscopical measurements or other instrumentation capable of measuring the colorimetric properties for different angles of azimuth and inclination (see IEC 61223-2-5).

The measurement shall be carried out at a defined position within the so-called viewing cone (see Figure 3, key 4). The viewing cone is limited by the maximum angle of inclination, θ_{max}, a single "one-eyed" observer can see.

NOTE 1 The viewing cone described corresponds to the viewing direction range class II of ISO 9241-302:2008.

NOTE 2 If two persons are to view the display simultaneously, the resulting viewing angles might be addressed and evaluated separately. This is not part of this International Standard.

NOTE 3 The viewing directions under which the periphery of the monitor (i.e. edge and corner locations), as seen by the observer, are obtained from the viewing direction to the centre of the monitor by the viewing distance and by the dimensions of the monitor screen area as explained in detail, for example, in ISO 13406-2 (see ISO 13406-2, Clause 7).

With that geometry defined, four or eight viewing directions can be calculated according to the vantage point situation.

The actual measurements for evaluation of the variation of luminance, contrast, and chromaticity with viewing direction are then carried out at the centre location of the screen area. The variation of optical properties with viewing direction at this location is assumed to be identical to the variation at all other locations. This assumption is justified by metrological verification and on the fact that these variations are dominated by crystal optics. So if the dark state of the display screen (no voltage, only cell gap and cell thickness variations obvious) and medium states of gray (with electrical addressing and driving) are uniform across the screen area (this is evaluated from one viewing direction, usually from the normal direction), then also the variations with viewing direction at all other locations are the same (i.e. beyond the limits of metrological detection).

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Price based on 12 pages