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ISO 5631-2

Second edition
2014-07-15

Paper and board — Determination of colour by diffuse reflectance —

Part 2: Outdoor daylight conditions (D65/10°)

Papier et carton — Détermination de la couleur par réflectance diffuse —

Partie 2: Conditions de lumière du jour extérieure (D65/10°)

Reference number
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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).

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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 6, *Paper, board and pulps*.

This second edition cancels and replaces the first edition (ISO 5631-2:2008), of which it constitutes a minor revision.

ISO 5631 consists of the following parts, under the general title *Paper and board — Determination of colour by diffuse reflectance*:

— *Part 1: Indoor daylight conditions (C/2°)*

— *Part 2: Outdoor daylight conditions (D65/10°)*

— *Part 3: Indoor illumination conditions (D50/2°)*

Introduction

The colour of an object can be uniquely characterized by means of a triplet of colour coordinates such as the CIE X,Y,Z tristimulus values or the CIELAB 1976 L^*, a^*, b^* coordinates, for a specified CIE illuminant and CIE standard observer.

Apart from the optical properties of the sample, the values of such coordinates depend upon the conditions of measurement, particularly the spectral and geometric characteristics of the instrument used. This part of ISO 5631 should therefore be read in conjunction with ISO 2469.

This part of ISO 5631 describes the measurement and description of colour in terms of the CIE standard illuminant D65 and the CIE 1964 (10°) standard observer. The analogous measurement and description of colour in terms of the CIE illuminant C and the CIE 1931 (2°) standard observer are described in ISO 5631-1.

ISO 5631-3 describes the measurement and description of colour in terms of the CIE standard illuminant D50 and the CIE 1931 (2°) standard observer. This method is especially applicable to comparison of papers in graphic arts situations where the customer wishes to make measurements under these illuminant/observer conditions required by ISO 13655. The choice of illuminant conditions is important when determining the colour coordinates of white papers containing a fluorescent whitening agent. In ISO 5631-1, the UV content of the illumination is lower than those specified in this part of ISO 5631, approximating UV levels encountered in indoor rather than outdoor viewing conditions.

Paper and board — Determination of colour by diffuse reflectance —

Part 2: Outdoor daylight conditions (D65/10°)

1 Scope

This part of ISO 5631 specifies a method for measuring the colour of paper and board by the diffuse reflectance method with the elimination of specular gloss.

It can be used to determine the colour of papers or boards that contain fluorescent whitening agents, provided the UV content of the illumination on the test piece has been previously adjusted to give the calibrated colourimetric value corresponding to CIE standard illuminant D65, using a fluorescent reference standard with an assigned CIE whiteness (D65/10°) value provided by an authorized laboratory, as described in ISO 11475.

This part of ISO 5631 is not applicable to coloured papers or boards that incorporate fluorescent dyes or pigments.

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 2469, *Paper, board and pulps — Measurement of diffuse radiance factor (diffuse reflectance factor)*

ISO 11475:2004, *Paper and board — Determination of CIE whiteness, D65/10° (outdoor daylight)*

ASTM E 308-06, *Standard Practice for Computing the Colors of Objects by Using the CIE System*

CIE Publication 15:2004, *Colorimetry*, 3rd ed

3 Terms and definitions

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

3.1
radiance factor
β
ratio of the radiance of a surface element of a body in the direction delimited by a given cone, with its apex at the surface element, to that of the perfect reflecting diffuser under the same conditions of illumination

Note 1 to entry: For fluorescent (luminescent) materials, the total radiance factor, β, is the sum of two portions, the reflected radiance factor, β_R, and the luminescent radiance factor, β_L, so that $\beta_T = \beta_R + \beta_L$.

Note 2 to entry: For non-fluorescent materials, the reflected radiance factor, β_R, is numerically equal to the reflectance factor, R.

3.2
intrinsic radiance factor
β_∞
radiance factor of a layer or pad of material thick enough to be opaque, such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured radiance factor

Note 1 to entry: The ratio is often expressed as a percentage.

3.3
reflectance factor
R
ratio of the radiation reflected by a surface element of a body in the direction delimited by a given cone, with its apex at the surface element to that of the perfect reflecting diffuser under the same conditions of illumination

Note 1 to entry: The ratio is often expressed as a percentage.

Note 2 to entry: The reflectance factor is influenced by the backing if the body is translucent.

3.4
intrinsic reflectance factor
R_∞
reflectance factor of a layer or pad of material thick enough to be opaque, such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured reflectance factor

Note 1 to entry: The reflectance factor of a non-opaque sheet is dependent on the background and is not a material property.

3.5
tristimulus values
X_{10}, Y_{10}, Z_{10}
amount of the three reference colour stimuli, in a given chromatic system, required to match the stimulus considered

Note 1 to entry: In this part of ISO 5631, the CIE standard illuminant D65 and the CIE 1964 (10°) standard observer are used to define the trichromatic system.

Note 2 to entry: The subscript 10 is applied to conform to the CIE convention that tristimulus values have the subscript 10 when the CIE 1964 (10°) standard observer is used.

3.6
CIELAB colour space
three-dimensional, approximately uniform colour space, produced by plotting, in rectangular coordinates L^*, a^*, b^*, quantities defined by the formulae given in Clause 9

Note 1 to entry: The quantity, L^*, is a measure of the lightness of the test piece, where $L^* = 0$ corresponds to black and $L^* = 100$ is defined by the perfect reflecting diffuser. Visually, the quantities a^* and b^* represent respectively the red-green and yellow-blue axes in colour space, such that

— $+a^*$ is a measure of the degree of redness of the test piece,

— $-a^*$ is a measure of the degree of greenness of the test piece,

— $+b^*$ is a measure of the degree of yellowness of the test piece, and

— $-b^*$ is a measure of the degree of blueness of the test piece.

If both a^* and b^* are equal to zero, the test piece is grey.

4 Principle

The light reflected from a sample under specified conditions is analysed either by a tristimulus-filter colourimeter or by an abridged spectrophotometer, and the colour coordinates are then calculated for D65/10° conditions.

5 Apparatus

5.1 Reflectometer, having the geometric, spectral, and photometric characteristics described in ISO 2469, and calibrated in accordance with the provisions of ISO 2469.

If materials containing fluorescent whitening agents are to be measured, the reflectometer shall be equipped with a radiation source having an adequate UV-content control, adjusted to a UV condition corresponding to the D65 standard illuminant by the use of a reference standard, as described in ISO 11475.

5.1.2 Filter reflectometer, a set of filters that, in conjunction with the optical characteristics of the basic instrument, give overall responses equivalent to the CIE tristimulus values X_{10}, Y_{10}, and Z_{10} of the CIE 1964 standard colourimetric system of the test piece evaluated for the CIE standard illuminant D65. In the case of a filter reflectometer, the radiation falling upon the test piece shall have a UV content corresponding to that of the CIE standard illuminant D65.

5.1.3 Abridged spectrophotometer, the instrument shall have a function that permits calculation of the CIE tristimulus values X_{10}, Y_{10}, and Z_{10}, of the CIE 1964 standard colourimetric system of the test piece evaluated for the CIE standard illuminant D65, using the weighting functions given in Annex A.

In the case of an abridged spectrophotometer, the instrument shall have an adjustable filter with a cut-off wavelength of 395 nm or some other equivalent system, and this filter shall be adjusted or the system shall be calibrated with the help of the fluorescent reference standard (5.2.2), so that the UV content of the illumination falling upon the sample corresponds to that of the CIE standard illuminant D65.

5.2 Reference standards, for calibration of the instrument and the working standards, used frequently enough to ensure satisfactory calibration and UV adjustment.

5.2.1 Non-fluorescent reference standard, for photometric calibration, issued by an authorized laboratory in accordance with the provisions of ISO 2469.

5.2.2 Fluorescent reference standard, for use in adjusting the UV content of the radiation incident upon the sample, having a CIE whiteness (D65/10°) value assigned by an authorized laboratory, as prescribed in ISO 11475:2004, Annex B.

5.3 Working standards, calibrated frequently enough to ensure that satisfactory calibration is maintained.

5.3.1 Two plates of flat opal glass, made of ceramic or other suitable material, cleaned, and calibrated as described in ISO 2469.

NOTE In some instruments, the function of the primary working standard can be taken over by a built-in internal standard.

5.3.2 Stable plastic or other tablet, incorporating a fluorescent whitening agent.

5.4 Black cavity, having a reflectance factor that does not differ from its nominal value by more than 0,2 %, at all wavelengths. The black cavity should be stored upside down in a dust-free environment or with a protective cover.

NOTE 1 The condition of the black cavity can be checked by reference to the instrument maker.

NOTE 2 The nominal value is given by the manufacturer.

6 Sampling and conditioning

If the tests are being made to evaluate a lot of paper or board, the sample should be selected in accordance with ISO 186. If the tests are made on another type of sample, make sure that the test pieces taken are representative of the sample received.

Conditioning according to ISO 187 is recommended but not required, though preconditioning with elevated temperatures should not be applied since it might change the optical properties.

7 Preparation of test pieces

Avoiding watermarks, dirt, and obvious defects, cut rectangular test pieces approximately 75 mm × 150 mm. Assemble at least 10 test pieces in a pad with their top sides uppermost; the number should be such that doubling the number of test pieces does not alter the radiance factor. Protect the pad by placing an additional sheet of paper or board on both the top and bottom of the pad. Avoid contamination and unnecessary exposure to light or heat.

Mark the top test piece in one corner to identify the sample and its top side, or to distinguish between the two sides.

If the top side can be distinguished from the wire side, it shall be uppermost; if not, as can be the case for papers manufactured on twin-wire machines, ensure that the same side of the sheet is uppermost.

8 Procedure

8.1 Ensure that calibration has been performed as described in ISO 11475 according to the instrument maker's instructions.

8.2 Remove the protective sheets from the top and the bottom of the test piece pad. Without touching the test area, use the procedure appropriate to the instrument to obtain the three CIE tristimulus values of the first test piece (or CIELAB values if the instrument is designed to report directly in this colour space). Read and record the tristimulus values to the nearest 0,01 unit.

8.3 Move the uppermost test piece to the bottom of the pad and determine the values for subsequent test pieces until at least 10 test pieces have been evaluated. If required, repeat the procedure for the other side of the test pieces.

9 Calculation

9.1 CIE tristimulus values

If the instrument has a bandpass of 5 nm or narrower, calculate the CIE tristimulus values in accordance with CIE Publication 15:2004, 3rd ed. In all other cases, calculate the tristimulus values using the appropriate weighting functions given in ASTM E 308-06. If the instrument does not provide the CIE tristimulus values directly, obtain them by calculation using the tables provided in Annex A.

9.2 CIELAB coordinates

Calculate the CIELAB coordinates from the tristimulus values X_{10}, Y_{10}, Z_{10} by means of the following formulae:

$$L^* = 116\left(Y_{10}/Y_{10.n}\right)^{1/3} - 16 \tag{1}$$

$$a^* = 500\left[\left(X_{10}/X_{10.n}\right)^{1/3} - \left(Y_{10}/Y_{10.n}\right)^{1/3}\right] \tag{2}$$

$$b^* = 200\left[\left(Y_{10}/Y_{10.n}\right)^{1/3} - \left(Z_{10}/Z_{10.n}\right)^{1/3}\right] \tag{3}$$

where $X_{10.n}$, $Y_{10.n}$, and $Z_{10.n}$ are the tristimulus values of the perfect reflecting diffuser under D65/10° conditions. These are given as the "white point" values in Annex A.

Alternative formulae shall, however, be used if any of the ratios $X_{10}/X_{10.n}$, $Y_{10}/Y_{10.n}$, and $Z_{10}/Z_{10.n} \leq (24/116)^3$ are satisfied as follows:

a) If $(X_{10}/X_{10.n}) \leq (24/116)^3$, replace the term $(X_{10}/X_{10.n})^{1/3}$ in Formula (2) by the expression $(841/108)\,(X_{10}/X_{10.n}) + 16/116$.

b) If $(Y_{10}/Y_{10.n}) \leq (24/116)^3$, replace the term $(Y_{10}/Y_{10.n})^{1/3}$ in Formulae (1), (2), and (3) by the expression $(841/108)\,(Y_{10}/Y_{10.n}) + 16/116$.

c) If $(Z_{10}/Z_{10.n}) \leq (24/116)^3$, replace the term $(Z_{10}/Z_{10.n})^{1/3}$ in Formula (3) by the expression $(841/108)\,(Z_{10}/Z_{10.n}) + 16/116$.

NOTE 1 The term $(24/116)^3$ is approximately equal to 0,008 856.

NOTE 2 The term (841/108) is approximately equal to 7,787.

NOTE 3 Formula (1) transforms to $L^* = 903{,}3(Y_{10}/Y_{10.n})$ when $(Y_{10}/Y_{10.n}) \leq (24/116)^3$.

9.3 Dispersion of the results

Since the three-dimensional statistical calculations are extremely complicated, the following simple procedure for assessing the dispersion is recommended.

Calculate the mean values $< L^* >$, $< a^* >$, and $< b^* >$ of the L^*, a^*, and b^* values.

Calculate, for each test piece, the deviation $\Delta E_{ab}{}^*$ from the mean according to Formula (4):

$$\Delta E_{ab}{}^* = \sqrt{\left[\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2\right]} \tag{4}$$

where ΔL^*, Δa^*, and Δb^* are the differences between the L^*, a^*, and b^* values of the test piece and the corresponding mean values $< L^* >$, $< a^* >$, $< b^* >$.

Calculate the mean $< \Delta E_{ab}{}^* >$ value. This is known as the Mean Colour Difference from the Mean (MCDM) value and defines the dispersion in terms of a sphere of radius $< \Delta E_{ab}{}^* >$ about the mean point in CIELAB space.

NOTE This calculation uses the expression for the colour difference between two samples which can be calculated in these coordinates as:

$$\Delta E_{ab}{}^* = \sqrt{\left[\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2\right]} \tag{5}$$

where ΔL^*, Δa^*, and Δb^* are the differences between the L^*, a^*, and b^* values of the two samples.

The calculation of colour differences is not, however, covered in this part of ISO 5631.

10 Expression of results

Report the L^*, a^*, and b^* values to three significant figures and the dispersion as the MCDM value to two significant figures.

NOTE Information about the nature of the variations can be obtained by calculating the mean ΔL^*, Δa^*, and Δb^* as defined in Formula (4), but this is not covered by this part of ISO 5631.

11 Precision

Information relating to the precision of the method is not yet available. It should be noted, however, that, when white or near-white samples containing a fluorescent whitening agent are measured, the reproducibility between instruments will be reduced, since the adjustment of the UV content to match that of the CIE standard illuminant D65 is limited to a single-point adjustment based on the CIE whiteness (D65/10°) value of a fluorescent reference standard.

12 Test report

The test report shall include the following information:

a) a reference to this part of ISO 5631;

b) the date and place of testing;

c) the precise identification of the sample and the side or sides tested;

d) whether the test pieces were conditioned and, if so, the conditioning atmosphere used;

e) the average colour coordinates and the mean colour difference from the mean (see 9.3) for the required side(s) of the sample;

f) the type of instrument used;

g) any departure from this part of ISO 5631 which could have affected the results.

Annex A
(normative)

Calculation of tristimulus values

The desired tristimulus values are obtained by summing the products of the spectral radiance factors and the weighting factors, *W*, (see Tables A.1 and A.2) given as Tables 6.19 and 6.20 in ASTM E 308-06[1)] for the CIE 1964 (10°) standard observer and the CIE standard illuminant D65.

ASTM E 308-06 presents two sets of tables. The tables given in this annex are the tables which should normally be used. They have been prepared to apply a correction for spectral bandpass dependence built into the calculation of the tristimulus values, using data for which the bandpass is approximately equal to the measurement interval.

The figure labelled “check sum” at the bottom of each column of the tables given in this annex is the algebraic sum of the entries. It provides, as a convenience, a check value to ensure that the tables have been copied correctly, should copying be required. These check sums are not identical to the “white point” data located below them, in most cases because of round-off. These “white point” data shall be used as $X_{10.n}$, $Y_{10.n}$, $Z_{10.n}$ when converting tristimulus values, calculated by using these tables, to CIELAB coordinates.

The instructions given below, taken from ASTM E 308-06, 7.3.2.2, should be applied when the values are not available at the top or at the bottom of the range.

When data for $\beta(\lambda)$ are not available for the full wavelength range from 360 nm to 780 nm, add the weights at the wavelengths for which data are not available to the weights at the shortest or longest wavelength for which spectral data are available; for example:

a) add the weights for all wavelengths (360 nm, ...,) for which measured data are not available to the next higher weight for which such data are available;

b) add the weights for all wavelengths (..., 780 nm) for which measured data are not available to the next lower weight for which such data are available.

In the absence of fluorescence, the spectral radiance factor can be replaced by, or referred to as, the spectral reflectance factor, $R(\lambda)$.

Table A.1 — Weighting factors, *W*, for instruments measuring at 10 nm intervals

Wavelength nm	$W_{10.X}$	$W_{10.Y}$	$W_{10.Z}$
360	0,000	0,000	0,000
370	0,000	0,000	−0,001
380	0,001	0,000	0,004
390	0,005	0,000	0,020
400	0,097	0,010	0,436
410	0,616	0,064	2,808
420	1,660	0,171	7,868
430	2,377	0,283	11,703

1) Reprinted, with permission, from E 308-06, *Standard Practice for Computing the Colors of Objects by Using the CIE System*, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, USA. A copy of the complete standard may be obtained from ASTM (http://www.astm.org).

Table A.1 *(continued)*

Wavelength nm	$W_{10,X}$	$W_{10,Y}$	$W_{10,Z}$
440	3,512	0,549	17,958
450	3,789	0,888	20,358
460	3,103	1,277	17,861
470	1,937	1,817	13,085
480	0,747	2,545	7,510
490	0,110	3,164	3,743
500	0,007	4,309	2,003
510	0,314	5,631	1,004
520	1,027	6,896	0,529
530	2,174	8,136	0,271
540	3,380	8,684	0,116
550	4,735	8,903	0,030
560	6,081	8,614	−0,003
570	7,310	7,950	0,001
580	8,393	7,164	0,000
590	8,603	5,945	0,000
600	8,771	5,110	0,000
610	7,996	4,067	0,000
620	6,476	2,990	0,000
630	4,635	2,020	0,000
640	3,074	1,275	0,000
650	1,814	0,724	0,000
660	1,031	0,407	0,000
670	0,557	0,218	0,000
680	0,261	0,102	0,000
690	0,114	0,044	0,000
700	0,057	0,022	0,000
710	0,028	0,011	0,000
720	0,011	0,004	0,000
730	0,006	0,002	0,000
740	0,003	0,001	0,000
750	0,001	0,000	0,000
760	0,000	0,000	0,000
770	0,000	0,000	0,000
780	0,000	0,000	0,000
Check sum	**94,813**	**99,997**	**107,304**
White point	**94,811**	**100,000**	**107,304**

Table A.2 — Weighting factors, *W*, for instruments measuring at 20 nm intervals

Wavelength nm	$W_{10.X}$	$W_{10.Y}$	$W_{10.Z}$
360	0,000	0,000	0,000
380	0,003	−0,001	0,025
400	0,056	0,013	0,199
420	2,951	0,280	13,768
440	7,227	1,042	36,808
460	6,578	2,534	37,827
480	1,278	4,872	14,226
500	−0,259	8,438	3,254
520	1,951	14,030	1,025
540	6,751	17,715	0,184
560	12,223	17,407	−0,013
580	16,779	14,210	0,004
600	17,793	10,121	−0,001
620	13,135	5,971	0,000
640	5,859	2,399	0,000
660	1,901	0,741	0,000
680	0,469	0,184	0,000
700	0,088	0,034	0,000
720	0,023	0,009	0,000
740	0,005	0,002	0,000
760	0,001	0,000	0,000
780	0,000	0,000	0,000
Check sum	**94,812**	**100,001**	**107,306**
White point	**94,811**	**100,000**	**107,304**

Bibliography

[1] ISO 186, *Paper and board — Sampling to determine average quality*

[2] ISO 187, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

[3] ISO 2470-2, *Paper, board and pulps — Measurement of diffuse blue reflectance factor — Part 2: Outdoor daylight conditions (D65 brightness)*

[4] ISO 5631-1, *Paper and board — Determination of colour by diffuse reflectance — Part 1: Indoor daylight conditions (C/2°)*

[5] ISO 5631-3, *Paper and board — Determination of colour by diffuse reflectance — Part 3: Indoor illumination conditions (D50/2°)*

[6] ISO/CIE 10526:1999, *CIE standard illuminants for colorimetry*

[7] ISO/CIE 10527:1991, *CIE standard colorimetric observers*

[8] ISO 13655:2009, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

[9] Publication C.I.E. S017: 2011, *ILV: International lighting vocabulary*, CIE Central Bureau, Kegelgasse 27, A-1030 Vienna, Austria

[10] Erb W., & Krystek K. *Truncation error in colorimetric computations*, Col. Res. Appl. 8, **Vol. 1**, 1983

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