INTERNATIONAL

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Standard Terminology of Appearance[1]

This standard is issued under the fixed designation E 284; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Appearance, including the appearance of objects, materials, and light sources, is of importance in many arts, industries, and scientific disciplines. Appearance terms are used in a wide range of ASTM standards as well as other documents of concern in standardization, testing, and specification. The purpose of this terminology standard is to define terms relating to the description of appearance.

Definitions are of two distinctly different kinds. A *descriptive* definition reports existing usage, whereas a *prescriptive* definition is an invitation to use a term in a specific way. By agreement of ASTM Committee E12 on Color and Appearance, the definitions in this terminology standard are taken to be *prescriptive* in nature. Committee E12 thereby assumes a position of leadership in usage.

Terms and definitions in several terminology standards and vocabularies other than ASTM (see References), as well as other ASTM terminology standards, have been considered for inclusion in this terminology standard. An effort has been made to achieve greater accuracy, brevity, clarity, precision, and internal consistency, and to draw distinctions that are useful in the practical measurement and specification of appearance.

Suggestions for additions or revisions to this terminology standard are welcome.

1. Scope*

1.1 This terminology standard defines terms used in the description of appearance, including but not limited to color, gloss, opacity, scattering, texture, and visibility of both materials (ordinary, fluorescent, retroreflective) and light sources (including visual display units).

1.2 It is the policy of ASTM Committee E12 on Color and Appearance that this terminology standard include important terms and definitions explicit to the scope, whether or not the terms are currently used in an ASTM standard. Terms that are in common use and appear in common-language dictionaries (see Refs **(1–4)**[2]) are generally not included, except when the dictionaries show multiple definitions and it seems desirable to indicate the definitions recommended for E12 standards.

1.3 The usage of terms describing appearance varies considerably. In some cases, different usage of a term in different fields has been noted.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 242 Terminology of Ceramic Whitewares and Related Products
C 286 Terminology Relating to Porcelain Enamel and Ceramic-Metal Systems
C 460 Terminology for Asbestos-Cement
D 16 Terminology for Paint, Related Coatings, Materials, and Applications
D 123 Terminology Relating to Textiles
D 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)
D 883 Terminology Relating to Plastics
D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics
D 1129 Terminology Relating to Water
D 1245 Practice for Examination of Water-Formed Deposits by Chemical Microscopy

[1] This terminology is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.01 on Terminology.
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[2] The boldface numbers in parentheses refer to a list of references at the end of text.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

D 1535 Practice for Specifying Color by the Munsell System
D 1695 Terminology of Cellulose and Cellulose Derivatives
D 1889 Test Method for Turbidity of Water
D 2805 Test Method for Hiding Power of Paints by Reflectometry
E 131 Terminology Relating to Molecular Spectroscopy
E 135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials
E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials
E 313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
E 349 Terminology Relating to Space Simulation
E 456 Terminology Relating to Quality and Statistics
E 491 Practice for Solar Simulation for Thermal Balance Testing of Spacecraft
E 808 Practice for Describing Retroreflection
E 809 Practice for Measuring Photometric Characteristics of Retroreflectors
E 903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
E 1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation
E 1767 Practice for Specifying the Geometries of Observation and Measurement to Characterize the Appearance of Materials
E 2175 Practice for Specifying the Geometry of Multiangle Spectrophotometers
E 2214 Practice for Specifying and Verifying the Performance of Color-Measuring Instruments
F 923 Guide to Properties of High Visibility Materials Used to Improve Individual Safety

2.2 *Other Documents*

ANSI PH2.36 Terms, Symbols, and Notation for Optical Transmission and Reflection Measurement (Optical Density)[4]
CIE Publication No. 51 A Method for Assessing the Quality of Daylight Simulators for Colorimetry[5]
ISO 13655 Spectral Measurement and Colorimetric Computation for Graphic Arts Images[6]
ISO 3664:2000 Viewing Conditions – Graphic Technology and Photography[6]
TAPPI T 452 Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm)[7]

3. Significance and Use

3.1 This terminology standard contains definitions of appearance terms applicable to the work of many ASTM technical committees. Its use by committees other than Committee E12 on Color and Appearance, and its citation in the standards of such committees, is encouraged.

3.2 In this terminology standard, definitions of terms used in other ASTM standards are indicated by placing the designation of that standard in parentheses at the end of the definition. Definitions used by other organizations (see Refs **(5–7)**) are indicated similarly by placing in parentheses at the end of the definition the acronym of the organization, occasionally with the date of its terminology standard quoted. In either case, a superscript letter may be used to indicate the degree of correspondence between the definition given herein and that in the citation. Superscript *A* indicates that the two are identical; *B* that the given definition is a modification of that cited, with little difference in essential meaning; and *C* that the two differ substantially.

3.3 A further parenthetical inclusion at the end of the definition gives the revision, if after 1981, in which the definition was added to this terminology standard or last revised.

3.4 Where appropriate, symbols or acronyms are listed for terms in this terminology standard. Since usage varies, these listings should be considered as recommendations, not as mandatory. If a different symbol or acronym is used in another ASTM standard, this should be indicated in that standard.

3.5 In the 1990 edition of this terminology standard, a great many terms were relocated to conform to the recommendation of the *Form and Style for ASTM Standards*, (Blue Book) that listings be in spoken word order. In general, there are no cross-references between the old and new listings, except where a special function is served. An example of such a special function is to list all terms relating to a given basic quantity, for example, all terms defining various sorts of angles.

3.6 This terminology standard adopts the following usage of certain word endings. The ending "ion" denotes a process, as in *reflection*; "ance" denotes a property of a specimen, as in *reflectance*; and "ity" denotes a property of the kind of material of which the specimen is composed, as in *reflectivity*. Exceptions exist, as in the common use of *illumination* and *radiation* to refer to quantities as well as processes.

4. Terminology

4.1 *Definitions:*

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from U.S. National Committee of the CIE (International Commission on Illumination), C/o Thomas M. Lemons, TLA-Lighting Consultants, Inc., 7 Pond St., Salem, MA 01970, http://www.cie-usnc.org.

[6] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[7] Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, http://www.tappi.org.

AATCC blue wool lightfastness standards, *n*—standard dyed-wool samples of seven grades, each step in the series representing a doubling of lightfastness.

Discussion—Available from the American Association of Textile Chemists and Colorists.

abridged spectrophotometry, *n*—the measurement of reflectance factor or transmittance factor in a number of wavelength bands rather than as continuous functions of wavelength.

Discussion—The wavelength bands may be isolated by the use of an array of sensors with a dispersing system or by the use of narrow-band filters.

absorbance, *A*, *n*—logarithm to the base 10 of the reciprocal of the internal transmittance T_I. $A = \log_{10} (1/T_I) = -\log_{10} T_I$. (1990) **(E 131)** [B]

absorptance α, *n*—the ratio of the absorbed radiant or luminous flux to the incident flux. **[CIE]** [A]

absorption, *n*—the transformation of radiant energy to a different form of energy by interaction with matter. **[CIE]** [A]

absorption coefficient, α, *n*—measure of the absorption of radiant energy from an incident beam (P_o) as it traverses an absorbing medium according to Bouguer's law, $P = P_o e^{-\alpha b}$, where *b* is the sample optical pathlength. (1988) **(E 131)**

absorption tinting strength, *n*—relative change in the absorption properties of a standard white material when a specified amount of an absorbing colorant, black or chromatic, is added to it. (1988a)

Discussion—See the Discussion to **masstone**.

absorptivity, *a*, *n*—the absorbance divided by the product of the concentration, *c*, of the substance and the sample optical pathlength, *b*, $a = A/bc$. The units of *b* and *c* shall be specified. (1988) **(E 131)** [B]

accuracy, *n*—the closeness of agreement between a test result and an accepted reference value. (1993)

Discussion—The qualitative term accuracy, when applied to a set of observed values, will be a combination of a random precision component and a systematic error or bias component. Since in routine use random components and bias components cannot be completely separated, the reported "accuracy" must be interpreted as a combination of these two elements. See **bias, precision**.

achromatic, *adj*—(*1*) *for primary light sources*, the computed chromaticity of the equal-energy spectrum. (1995)

(*2*) *for surface colors*, the color of a whitish light, serving as the illuminant, to which adaptation has taken place in the visual system of the observer. (1995)

(*3*) perceived as having no hue, that is, as white, gray, or black. **[CIE]** [B]

Adams color difference, *n*—color difference calculated by using the Adams-Nickerson opponent-color equations, based on applying the Munsell Value function to CIE 1931 tristimulus values *X, Y, Z.* (1988)

additive color mixture, *n*—superposition or other nondestructive combination of lights of different perceived colors. (1995)

additive color stimulus mixture, *n*— method of simulation that combines on the retina the actions of various color stimuli in such a manner that they cannot be perceived individually. (1995a) **[CIE]** [A]

additive primaries, *n*— same as **primary color stimuli**.

ambient field, *n*—when an object or light source is viewed, the complete area beyond the surround from which light might reach the observer's eyes and influence the object's appearance. See **surround**.

American Public Health Association (APHA) color, *n*—see **platinum cobalt color scale**.

angle, *n*—see **aperture angle, aperture solid angle, azimuthal angle, entrance angle, observation angle, rotation angle, specular angle**.

angle of illumination, *n*—angle between the specimen normal and the illuminator axis. (1991b)

angle of incidence, *n*—the angle between a ray impinging on a surface at a point and the perpendicular to the surface at that point. In *the description of a beam*, the angle of incidence of the ray at the center of the beam.

angle of reflection, *n*—the angle between a ray reflected from a surface at a point and the perpendicular to the surface at that point.

angle of view, *n*—angle between the normal to the surface of the specimen and the axis of the receiver. (1988a)

angle, rotation, *n*— see **rotation angle**.

angular subtense, *n*— *visual*, the angle subtended (by an object) at the first nodal point of the eye.

annular, *adj*—descriptor for directional illuminating (or viewing) geometry in which the illuminator provides radiation (or the receiver possesses responsivity) that is distributed continuously and uniformly throughout the 360° of azimuth of the measurement. (See also *circumferential* .) (1989) **(E 1164)** [A]

anormal, *adj*—of angles, measured with reference to the normal to the surface. (2008)

anormal angle, *n*—the angle subtended at a point on the specimen by a given ray and the normal. (2009)

Discussion—Use the inward normal with transmitted rays; use the outward normal for other rays. In uniplanar instruments, the "point" is the point of incidence and the anormal angle is understood to have a sign. The anormal angle of an illumination axis is positive or zero. The anormal angle of a detection axis is negative if the illumination and detection axes are on opposite sides of the line of the normal and positive or zero otherwise. **(E 1767)** [C], **(E 2175)** [C]

aperture angle, 2κ, *n*—angle subtended at a point on a specimen by the maximum dimension of the illuminator or receiver, within which the flux in a directional beam is contained. (1990)

Discussion—In optics, the symbol κ is used for the half angle; hence the recommended symbol here is 2κ.

aperture mode, *n*—color seen through an aperture which prevents its association with a specific object or source.

aperture solid angle, ω, *n*—solid angle subtended at a point on the specimen, defined by the sum of rays from the illuminator or the sum of directions in which the receiver is sensitive to incoming radiation. (1990)

aperture stop, *n*—the physical diameter that limits the size of the cone of radiation that an optical system will accept from an axial point on the object. (1988) **[OSA]**[A]

appearance, *n*—(*1) of an object*, the collected visual aspects of an object or a scene. (2006b)

(2) perceived, the visual perception of an object, including size, shape, color, texture, gloss, transparency, opacity, etc., separately or integrated. (2006b)

area reflector, *n*—reflector subtending a relatively large solid angle at the observer's eye, so that the observer can clearly distinguish its size and shape. (1988)

artificial daylight, *n*—an artificial light that has a spectral power distribution approximating that of a phase of natural daylight. (1995)

aspecular, *adj*—of angles, measured with reference to the specular direction. (2008)

aspecular angle, *n*—the angle subtended at the point of incidence by a given ray and the specular direction. (2009)

Discussion—In instruments, the "given ray" is understood to be a detection direction. In uniplanar instruments, the aspecular angle is to be understood to have a sign: negative when the specular direction lies properly between the detection direction and the illuminator axis and positive otherwise.

(E 1767)[C]**, (E 2175)**[C]

attributes of color—(*1) for the object mode of appearance*, hue, lightness, and saturation. In the Munsell system, Munsell Hue, Munsell Value, and Munsell Chroma.

(*2*) *for the illuminant or aperture mode*, hue, brightness, and saturation.

azimuthal angle, η, *n*—angle between the plane containing the axis of the illuminator (or the path of illumination) and the specimen normal and the plane containing the axis of the receiver (or the path of reception) and the specimen normal. The origin and direction of measure of the angle should be specified when required. (1990)

azimuthal viewing, *n*—deprecated term; do not use. Replace *azimuthal* by *annular* or *circumferential*. (1995a)

banding, *n*—a non-uniformity of color appearance on a scale much larger than colorant particles, characterized by a band or several nearly parallel indistinct stripes differing slightly in color from the remaining area.

bandpass, *adj*—having to do with a passband. (2006)

bandwidth, *n*—the width of a passband at its half-peak transmittance. (2006)

barré, *n*—a defect characterized by bars or streaks, fillingwise in woven fabrics or coursewise in weft-knit fabrics, caused by uneven tension in knitting, or defective yarn, improper needle action, or other similar factors.

basic color terms, *n*—a group of eleven color names found in anthropological surveys to be in wide use in fully developed languages: white, black, red, green, yellow, blue, brown, gray, orange, purple, pink. (1990)

beam, *n*—*in optics* , a concentrated unidirectional flow of radiant energy. (1988)

Beer's law, *n*—the absorbance of a homogeneous sample containing an absorbing substance is directly proportional to the concentration of the absorbing substance. See also **absorptivity**. (1988) **(E 131)** [A]

bias, *n*—a systematic difference between the sample mean of the measurements or test results and an accepted reference value. (1993)

Discussion—Bias is the systematic component of accuracy. There may be one or more systematic error components contributing to the bias. In *appearance measurement*, the accepted reference value is usually assigned to a standard specimen; see **physical standard**.

*biconical***,** *adj*— see the preferred but not equivalent term, **bidirectional,** as in bidirectional optical measuring system. (1991b)

*bidirectional***,** *adj*— see **bidirectional optical measuring system**. (1991)

bidirectional optical measuring system, *n*—an optical system for measuring the reflecting or transmitting properties of specimens, wherein the illuminator and receiver each subtend small angles at the specimen surface. (1988a)

bidirectional scattering distribution function (BSDF), *n*—for a uniformly-illuminated surface, the distribution with respect to the scatter direction of the average surface radiance divided by the surface irradiance when that surface is illuminated in a specified direction. (2006a)

Discussion—BSDF is a differential function dependent on the wavelength, incident direction, scatter direction, and polarization states of the incident and scattered fluxes. The BSDF is equivalent to the fraction of the incident flux scattered per unit projected solid angle. The BSDF of a lambertian surface is independent of scatter direction. The BSDF of a specularly reflecting surface has a sharp peak in the specular direction. Each measurement of BSDF obtains an average of the local BSDF at points within the measurement aperture. If a surface scatters non-uniformly from one position to another then a series of measurements over the sample surface must be averaged to obtain a suitable statistical uncertainty.

bispectral fluorescence radiance factor, $b_{F_\lambda}(\mu)$**,** *n*—the ratio of the spectral radiance at wavelength λ due to fluorescence from a point on the specimen when irradiated at wavelength μ to the total radiance of the perfectly reflecting diffuser similarly irradiated and viewed (see NPL Report MOM 12).

bispectral radiance factor, $b_\lambda(\mu)$**,** *n*—the ratio of the spectral radiance (radiance per unit waveband) at wavelength λ from a point on a specimen when irradiated at wavelength μ to the total (integrated spectral) radiance of the perfectly reflecting diffuser similarly irradiated and viewed.

$$b_\lambda(\mu) = L_\lambda(\mu)/L(\mu)_d \tag{1}$$

bispectral reflection radiance factor, $b_{R\lambda}(\mu)$, *n*—the ratio of the spectral radiance at wavelength λ due to reflection from a point on the specimen when irradiated at wavelength μ to the total radiance of the perfectly reflecting diffuser similarly irradiated and viewed.

bispectrometer, *n*—an optical instrument equipped with a source of irradiation, two monochromators, and a detection system, such that a specimen can be measured at independently-controlled irradiation and viewing wavelengths. The bispectrometer is designed to allow for calibration to provide quantitative determination of the bispectral radiation-transfer properties of the specimen. **(8)**

Discussion—Typically, a reference detection system monitors the radiation incident on the specimen. This reference detection system serves to compensate for both temporal and spectral variations in the flux incident upon the specimen, by normalization of readings from the instrument's emission detection system.

blackbody, *n*— see the preferred term, **full radiator**.

bleached specimen, *n*—specimen whose absorptance has been decreased by chemical or radiant means. (1987) **[TAPPI]**[A]

bleeding, *n*—the unintentional transfer of coloring matter from one medium to or through another.

bloom, *n*—the scattering of light in directions near the specular angle of reflection by a deposit on or exudation from a specimen.

blur, *n*—unsharpness (of an image). (2006)

Discussion—Blur may result from effects of motion, defocus, diffraction, or other factors.

blur, *vt*—to make (an image) less sharp. (2006)

body color, *n*—color produced by absorption and scattering of light by colorants within a colored material. (1988)

Bouguer's law, *n*—the absorbance of a homogeneous sample is directly proportional to the thickness of the sample in the optical path. (Also known as **Lambert's [thickness] law**.) (1988) **(E 131)**[A]

brightness, *n*—(*1*) aspect of visual perception whereby an area appears to emit more or less light. (1995) **[CIE]**[B] **(F 923)**[B]

(*2*) *of an object color*, combination of lightness and saturation.

(*3*) *in the textile industry*, perceived as saturated, vivid, deep, or clean.

Discussion—This usage may conflict with Definition 2 in the case of dark colors.

(*4*) *of paper*, reflectance of an infinitely thick specimen (reflectivity) measured for blue light with a centroid wavelength of 457 nm under specified spectral and geometric conditions of measurement. (1987) **[TAPPI T 452]**[B]

(*5*) *dyer's*, the color quality, combining lightness and saturation, that would be decreased by adding black, gray, or a complementary color to a chromatic dye.

bronzy color (or bronzing), *n*—a metallic coloration observed when viewing the light reflected at angles near the angle of specular reflection, the color usually being quite different from that observed for other directions.

calibrate, *v*—to find and eliminate systematic errors of an instrument scale or method of measurement by use of material standards and techniques traceable to an authorized national or international measurement system. (1994a)

Discussion—*As defined here*, calibration is normally carried out by an instrument manufacturer. See **standardize, verify**.

candela, *cd*, *n*—the SI unit of luminous intensity; the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of (1/683) watt per steradian.

Discussion—The lone frequency of 540×10^{12} Hz mentioned in the definition has a wavelength of 555.016 nm in standard air, which for almost all purposes can be taken to be 555 nm without affecting the accuracy of a real measurement. For sources at other frequencies (wavelengths), scale their spectral radiant intensities by the spectral luminous efficiency function, V(λ).

[CIE][A]

centroid wavelength, *n*—wavelength marking the center, in terms of area under a curve, of a function of wavelength weighted by multiplication with a specified response function. (1988)

Discussion—In the case of (TAPPI) **brightness** (of paper) the response function is obtained by the use of a special blue tristimulus-colorimeter filter.

characterize, *v*—to specify the parameters or performance of an instrument or method of measurement. (1994)

Discussion—For example, in appearance measurement, the parameters might include the geometric and spectral nature of the illuminator and the receiver, and the performance might be specified by measures of reliability, precision, and bias.

chatoyance, *n*—appearance characterized by a changeable luster or color, sometimes including a spatially-undulating narrow white band or stripe.

chemical luminescence, *n*—luminescence resulting from a chemical reaction. (See also **luminescence**.)

chroma, *n*—(*1*) attribute of color used to indicate the degree of departure of the color from a neutral color of the same lightness. See also **Munsell chroma**. (1989b)

(*2*) C^*, (in the CIE 1976 L^*, a^*, b^* or L^*, u^*, v^* system) the quantity $C^*_{ab} = (a^{*2} + b^{*\,2})^{1/2}$ or $C^*_{uv} = (u^{*2} + v^{*\,2})^{1/2}$. (1989b).

(*3*) attribute of a visual perception, produced by an object color, that permits a judgment to be made of the amount of pure chromatic color present, irrespective of the amount of achromatic color. (1995)

DISCUSSION—See also **saturation**, Definition (2).

chromatic, *adj*—perceived as having a hue; not white, gray, or black.

chromatic adaptation, *n*—changes in the visual system's sensitivities due to changes in the spectral quality of illuminating and viewing conditions. (1988)

chromaticity, *n*—the color quality of a color stimulus definable by its chromaticity coordinates, or by its dominant (or complementary) wavelength and its purity taken together. **[CIE]** [A]

chromaticity coordinates, *n*—the ratio of each of the tristimulus values of any viewed light to the sum of the three. (1995)

DISCUSSION—Chromaticity coordinates in the CIE 1931 system of color specification are designated by x, y, z and in the CIE 1964 supplementary system x_{10}, y_{10}, z_{10}.)

chromaticity diagram, *n*—a plane diagram in which points specified by chromaticity coordinates represent the chromaticities of lights (color stimuli). (1995) **[CIE]** [B]

chromaticness, *n*—(*1*) attribute of visual perception combining the hue and saturation. (1995)

(*2*) attribute of a visual perception according to which the color of an area appears to be more or less chromatic. (1995)

DISCUSSION—The term *colorfulness* is sometimes used as a synonym for Definition (2).

[CIE, 1970] [B] **[CIE, 1987]** [B]

CIE, *n*—the abbreviation for the French title of the International Commission on Illumination, Commission Internationale de l'Éclairage.

CIE color-rendering index, *R*, *n*—measure of the degree to which the computed chromaticity of a CIE test color sample illuminated by a test illuminant conforms to that of the same sample illuminated by a reference illuminant. (1995)

DISCUSSION—For eight CIE test-color samples, the results are CIE special color-rendering indices, R_i, $i = 1–8$. The average of these is the CIE general color-rendering index R_a.

[CIE] [C]

CIE primaries, *n*—the primary color stimuli used in the CIE system of colorimetry.

CIE spectral tristimulus values, *n*— tristimulus values or color-matching functions of the spectral components of an equal-energy spectrum in the CIE (*XYZ*) system. (1990)

DISCUSSION—The color matching functions are assigned the symbols $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ in the CIE 1931 colorimetric system and $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ in the CIE 1964 supplementary colorimetric system. **[CIE]** [B]

CIE 1931 (x, y) chromaticity diagram , *n*—chromaticity diagram for the CIE 1931 standard observer, in which the CIE 1931 chromaticity coordinates are plotted, with x as abscissa and y as ordinate. (1993)

CIE 1964 (x_{10}, y_{10}) chromaticity diagram, *n*—chromaticity diagram for the CIE 1964 supplementary standard observer, in which the CIE 1964 chromaticity coordinates are plotted, with x_{10} as abscissa and y_{10} as ordinate. (1993)

CIE 1976 (u', v') or (u'_{10}, v'_{10}) chromaticity diagram, *n*—chromaticity diagram in which the CIE 1976 L^* u^* v^* (CIELUV) chromaticity coordinates are plotted, with u' (or u'_{10}) as abscissa and v' (or v'_{10}) as ordinate. (1993)

DISCUSSION—These chromaticity diagrams should be used when diagrams more nearly equally visually spaced than the (x, y) or (x_{10}, y_{10}) diagrams are desired.

CIE 1931 standard colorimetric system, *n*—a system for determining the tristimulus values of any spectral power distribution using the set of reference color stimuli *X, Y, Z* and the three CIE color-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ adopted by the CIE in 1931. (1987) **[CIE]** [A]

CIE standard illuminant *A*, *n*—colorimetric illuminant, representing the full radiator at 2855.6 K, defined by the CIE in terms of a relative spectral power distribution. **[CIE]** [B]

CIE standard illuminant *B*, *n*—colorimetric illuminant, representing direct sunlight with a correlated color temperature of 4874 K, defined by the CIE in terms of a relative spectral power distribution. Declared obsolete by the CIE in 1983. (1988)

CIE standard illuminant *C*, *n*—colorimetric illuminant, representing daylight with a correlated color temperature of 6774 K, defined by the CIE in terms of a relative spectral power distribution. **[CIE]** [B]

CIE standard illuminant D_{65}, *n*—colorimetric illuminant, representing daylight with a correlated color temperature of 6504 K, defined by the CIE in terms of a relative spectral power distribution. (1987) **[CIE]** [B]

CIE 1931 standard observer, *n*—ideal colorimetric observer with color matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ corresponding to a field of view subtending a 2° angle on the retina; commonly called the "2° standard observer." (1988) **[CIE]** [B]

CIE standard source *A*, *n*—a gas-filled tungsten-filament lamp operated at a correlated color temperature of 2855.6 K.

[CIE][B]

CIE standard source *B*, *n*—standard source A combined with a specified liquid filter, to provide radiant flux with a correlated color temperature of 4874 K. Declared obsolete by the CIE in 1983. (1988)

CIE standard source *C*, *n*—standard source A combined with a specified liquid filter, to provide radiant flux with a correlated color temperature of 6774 K. (1988) **[CIE]**[B]

CIE 1964 supplementary standard colorimetric system, *n*—a system for determining the tristimulus values of any spectral power distribution using the set of reference color stimuli X_{10}, Y_{10} , Z_{10}, and the three CIE color-matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ adopted by the CIE in 1964. (1989) **[CIE]**[A]

CIE 1964 supplementary standard observer, *n*—ideal colorimetric observer with color matching functions $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$ corresponding to a field of view subtending a 10° angle on the retina; commonly called the "10° standard observer." (1988) **[CIE]**[B]

CIE 1976 uniform-chromaticity-scale diagram, *n*—the uniform-chromaticity-scale diagram produced by plotting in rectangular coordinates v' against u', quantities defined as follows:

$$u' = 4X/(X + 15Y + 3Z) = 4x/(-2x + 12y + 3) \quad (2)$$
$$v' = 9Y/(X + 15Y + 3Z) = 9y/(-2x + 12y + 3)$$

for the CIE 1931 standard colorimetric system, or v'_{10} against u'_{10} for the CIE 1964 supplementary standard colorimetric system, in which case in the above formulae X_{10}, Y_{10}, Z_{10} are used instead of *X, Y, Z* and x_{10}, y_{10} instead of *x, y*. (1987) **[CIE]**[A]

CIELAB color difference, *n*—color difference calculated by using the CIE 1976 L^* a^* b^* opponent-color scales, based on applying a cube-root transformation to CIE 1931 tristimulus values *X, Y, Z* or CIE 1964 tristimulus values X_{10}, Y_{10}, Z_{10}. (1988)

CIELUV color difference, *n*—color difference calculated by using the CIE 1976 L^* u^* v^* opponent-color scales, based on a linear transformation of CIE chromaticity coordinates *x, y*, or x_{10}, y_{10} and a cube-root transformation of *Y* or Y_{10} to L^*, applied to CIE 1931 tristimulus values *X, Y, Z* or CIE 1964 tristimulus values X_{10}, Y_{10}, Z_{10}. (1988)

circumferential, *adj*—descriptor for directional illuminating (or viewing) geometry in which the illuminator provides radiation (or the receiver possesses responsivity) in many beams (or directions), normally distributed at uniform intervals throughout the 360° of azimuth of the measurement. The number and angular distribution of the beams (or directions) should be specified. (See also *annular*.) (1990) **(E 1164)**[A]

clarity, *n*—the characteristic of a transparent body whereby distinct high-contrast images or high-contrast objects (separated by some distance from the body) are observable through the body.

cmc (*l:c*) color difference, *n*—color difference calculated by use of the formula developed by the Colour Measurement Committee of the Society of Dyers and Colourists of Great Britain. (1990)

Discussion—Based on the lightness, hue, chroma version of CIELAB, it incorporates chroma and hue-angle correction terms for improved visual spacing and variable weighting factors for lightness (*l*) and chroma (*c*) relative to hue for improved correlation depending on type of judgment (acceptability, perceptibility) and application (textiles, others).

coefficient of line retroreflection, R_M, *n—of a reflecting stripe*, the ratio of the coefficient of luminous intensity (R_I) of a retroreflecting stripe to its length (*l*), expressed in candelas per lux per metre ($cd \cdot lx^{-1} \cdot m^{-1}$). $R_M = (R_I/l)$. (1988) **(E 808)**[A]

coefficient of luminous intensity R_I, *n—of a retroreflector* , ratio of the luminous intensity (*I*) of the retroreflector in the direction of observation to the illuminance ($E_\perp$) at the retroreflector on a plane perpendicular to the direction of the incident light, expressed in candelas per lux ($cd \cdot lx^{-1}$). $R_I = (I/E_\perp)$. (1988) **(E 808)**[A]

coefficient of retroreflected luminance, R_L, *n*— ratio of the luminance, *L*, of a projected surface to the normal illuminance, $E_\perp$, at the surface on a plane normal to the incident light, expressed in candelas per square metre per lux ($cd \cdot m^{-2} \cdot lx^{-1}$). $R_L = (L/E_\perp)$. (1988) **(E 808)**[B]

coefficient of retroreflection, R_A, *n—of a plane reflecting surface*, the ratio of the coefficient of luminous intensity (R_I) of a plane retroreflecting surface to its area (*A*), expressed in candelas per lux per square metre ($cd \cdot lx^{-1} \cdot m^{-2}$). $R_A = (R_I/A)$. (1988) **(E 808)**[A]

collector, *n*—optical components, such as the cornea and lens of the eye, which guide radiant flux from a specimen being observed or measured to a sensor.

Discussion—A collector and a sensor comprise a receiver.

color, *n*—(*1*) *of an object*, aspect of object appearance distinct from form, shape, size, position, or gloss that depends upon the spectral composition of the incident light, the spectral reflectance or transmittance of the object, and the spectral response of the observer, as well as the illuminating and viewing geometry. (1987)

(*2*) *perceived*, attribute of visual perception that can be described by color names such as white, gray, black, yellow, brown, vivid red, deep reddish purple, or by combinations of such names.

Discussion—Perceived color depends greatly on the spectral power distribution of the color stimulus, but also on the size, shape, structure, and surround of the stimulus area, the state of adaptation of the observer's visual system, and the observer's experience with similar observations. **[TAPPI]**[A]

(*3*) *colorimetric* , characteristics of a color stimulus denoted by a colorimetric specification with three values, such as tristimulus values.

Discussion—Tristimulus values are sometimes derived on a relative rather than an absolute basis. In this case they may need to be supplemented by the value of a suitable absolute photometric quantity. The appearance of colors depends not only on their absolute tristimulus values, but also on the conditions under which they are viewed, including the nature of the surround; however, colors having the same absolute tristimulus values appear the same in identical viewing conditions. Spectrally different color stimuli can have the same absolute tristimulus values.

[TAPPI][A]**[CIE]** [B]

color angle, *n*—*in measurement of gonioapparent phenomena*, half the angle between the illumination and detection axes of the measurement geometry. (2008)

Discussion—The color of an interference pigment is determined by the angle of incidence of the light relative to the normal of the interference pigment flake. Flakes in a coating have an angular distribution, and the interference effect will be exhibited in a given measurement geometry only by the flakes that are oriented so that they behave as specular reflectors. Since the refractive index of the specimen is often unknown, color angle is defined here as if the flakes were in air. Color angle provides a relative indication of the angle between the flake normal and the illuminator axis.

colorant, *n*—dye, pigment, or other agent used to impart a color to a material. (1988)

color atlas, *n*—a collection of color samples arranged according to a color order system. (1990)

color constancy, *n*—the general tendency of the colors of an object to remain constant when the color of the illumination is changed.

color difference, *n*—(*1*) *perceived*, the magnitude and character of the difference between two colors described by such terms as redder, bluer, lighter, darker, grayer, or cleaner.

(*2*) *computed*, the magnitude and direction of the difference between two psychophysical color stimuli and their components computed from tristimulus values, or chromaticity coordinates and luminance factor, by means of a specified set of color-difference equations.

color-difference units, *n*—units of size of the color differences calculated according to various equations. Such color differences *cannot* be accurately converted between different equations by the use of average factors. (1988)

*colorfulness***,** *n*— see **chromaticness** (2). (1991a)

color grading, *n*—the act of identifying a specimen by a color grade or color score, which is specific to the color and the material graded.

*colorimeter***,** *n*— see **tristimulus colorimeter, visual colorimeter**.

colorimetric purity, p_c, *n*—the fraction of spectrally pure light in an additive mixture with reference achromatic (white) light to produce a color that matches that of the color stimulus considered. (As a reference achromatic light, the CIE recommends an equal energy source for self-luminous bodies and illuminant D_{65} (daylight) for nonself-luminous bodies.) **[CIE]**[B]

colorimetric spectrometer, *n*—spectrometer that is capable of producing spectral reflectance or transmittance data and colorimetric data (such as tristimulus values and derived coordinates) derived from the spectral data. See **spectrocolorimeter** .

Discussion—Colorimetric spectrometers differ from UV-VIS analytical spectrometers by demanding more stability on the radiometric scale but allowing more tolerance on the wavelength scale. **(E 2214)** [C]

colorimetry, *n*—the science of color measurement.

color match, *n*—(*1*) condition existing when colors match within a specified or agreed tolerance. Sometimes called *commercial color match*. (1988a)

Discussion—Compliance with tolerances can be determined instrumentally or visually. If the test for compliance is visual, physical color tolerance standards may be used for reference.

(*2*) condition existing when colors are indistinguishable; a normal observer is usually implied. Sometimes called an *exact color match*. (1988a).

color matching, *n*—procedure for providing, by selection, formulation, adjustment, or other means, a trial color that is indistinguishable from, or within specified tolerances of, a specified standard color under specified conditions. (1988a)

color-matching functions, *n*—the amounts, in any trichromatic system, of the three reference color stimuli needed to match by an additive mixture monochromatic components of an equal energy spectrum.

Discussion—Symbols for these functions are lower case letters, each with a bar above and followed by the Greek letter λ in parentheses; the lower case letters corresponding to the capital letter symbols for the reference color stimuli of the system; for example, $\bar{r}(\lambda)$, $\bar{g}(\lambda)$, $\bar{b}(\lambda)$ in an *RGB* system, $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$, in the CIE 1931 *XYZ* colorimetric system, and $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$, in the CIE 1964 supplementary system which is based on the 10° field of view.

color measurement, *n*—process of deriving, by visual or instrumental means, a set of three numbers that describe the attributes of a color, in the form of a color notation or a colorimetric specification. (1988)

*color mixture***,** *n*— see **additive color mixture, additive color stimulus mixture,** or **subtractive color mixture**.

color notation, *n*—the symbols used in a systematic way to designate colors.

color order system, *n*—a rational method or plan of ordering and specifying all producible object or display colors, or all within a limited domain, by means of a set of physical standards selected and displayed so as to represent adequately the whole set of such colors under consideration. (1990)

color perception, *n*—subjective impression of color, as modified by the conditions of observation and by mental interpretation of the stimulus object. (1987) **[TAPPI]**[A]

color preference, *n*—preference, within a specific application, for one color over other related colors. (1988)

Discussion—Examples include preferred blue for sky or green for grass in photographic color reproduction, and preferred white for bond paper.

color rendering, *n*—effect of a light source on the color appearances of objects compared to their color appearances under a reference light source. (See also **CIE color rendering index**.) (1988)

color scale, *n*— see **Gardner color scale, petroleum color scale, platinum-cobalt color scale, Saybolt color**.

color solid, *n*— see **color space**. (1987)

color space, *n*—a geometric space, usually of three dimensions, in which colors are arranged systematically.

color specification, *n*—notation or set of three color-scale values used to designate a color in a specified color system. Practical color specifications may include color tolerances as well as target color designation. (1988)

color staining, *n*—the discoloration of a material by transfer of colorant from another material. **(D 123)** [C]

color stimulus, *n*—a radiant flux capable of producing a color perception. (1995)

color stimulus function, $\phi(\lambda)$, *n*—description of a color stimulus by the spectral concentration of a radiometric quantity, such as radiance or radiant power, as a function of wavelength.

Discussion—Compare with spectral power distribution. Unlike a spectral power distribution, a color stimulus function is specific to flux that is seen by the eye.

[CIE][A]

color temperature, *n*— *of a source*, the temperature, usually expressed in kelvins, of a full radiator that would emit light of the same chromaticity as the source. (See also **correlated color temperature, distribution temperature**.) **[CIE]**[B]

color tolerance, *n*—the permissible color difference between sample and specified color.

color tolerance set, *n*—a group of colored standards, usually seven painted chips, arranged on a single card, one exhibiting a desired color, and two each exhibiting the limits of the permissible range of color variation in each of the color attributes.

Discussion—An example is one desired color, two limits on Munsell value, two limits on Munsell hue, and two limits on Munsell chroma.

complementary color percepts, *n*—(*1*) pairs of color percepts, one of which is induced by the other through simultaneous contrast; (*2*) pairs of color percepts, one of which is the negative after-image of the other.

complementary colors, *n*—color stimuli that produce a specified achromatic stimulus when they are suitably mixed in an additive manner.

complementary color stimuli, *n*—pairs of color stimuli that, by additive mixture produce an achromatic stimulus.

complementary wavelength, *n*—the wavelength of a spectrally pure light that when added to the light reflected or transmitted by the specimen will produce a combination that color matches a reference achromatic (white) light.

conspicuity, *n*—the characteristics of an object that determine the likelihood that it will come to the attention of an observer. (1990)

contrast, *n*—(*1*) *objective*, the degree of dissimilarity of a measured quantity such as luminance of two areas, expressed as a number computed by a specified formula.

Discussion—The following formulas for the luminance contrast between areas having luminance L_1, and L_2(where L_2 is the larger) have been adopted by the CIE:

$$C_a = \frac{L_2 - L_1}{L_1}, C_b = \frac{L_2 - L_1}{(L_2 + L_1)/2}, C_c = L_2/L_1 \qquad (3)$$

The following formulas are also in use:

$$C_d = L_2 - L_1 , C_e = \frac{L_2 - L_1}{L_2}, C_M = \frac{L_2 - L_1}{L_2 + L_1} \qquad (4)$$

If the illumination of the areas of interest is uniform and constant, the luminances are proportional to the reflectances (or transmittances) and these quantities may be used in place of luminances in these formulas. The simple ratio, $C_c = L_2/L_1$, is usually used in ASTM standards.

(*2*) *subjective*, the degree of dissimilarity in appearance of two parts of a field of view seen simultaneously or successively. **[CIE]**[B]

contrast gloss, *n*— see **luster**.

contrast ratio, *n*—*in paint and coatings*, the ratio of the reflectance of a film on a black substrate to that of an identical film on a white substrate. See **opacity**. (2007)

Discussion—Opacity is the property of a film whereby it has the ability to hide. This property is commonly assessed by the test of contrast ratio.

The reflectances of the black and the white and the weighting of reflectance at different wavelengths vary from application to application. **(D 2805)[A], (D 16)[C]**

correlated color temperature, *n—of a source*, the temperature, usually expressed in kelvins, of a full radiator that would emit light of the chromaticity most closely resembling that of the light from the source.

DISCUSSION—Correlated color temperature extends the concept of *color temperature* to any source emitting light having a chromaticity nearly, though not exactly, the same as the chromaticity of the light emitted by a full radiator at some temperature.

crazing, *n*—a network of apparent fine cracks on or beneath the surface of materials such as in transparent plastics, glazed ceramics, glass, or clear coatings.

daylight illuminant, *n*—illuminant having the same, or nearly the same, relative spectral power distribution as a phase of daylight. (1987) **[CIE][A]**

densitometer, *n*—instrument designed for measuring optical density of a photographic negative or positive or a printed image. (1987) **[TAPPI][A]**

densitometry, *n*—technique for measurement of optical density by use of a densitometer. (1988)

density, *n*—see **reflectance density, reflection density, transmission density,** or **transmittance density**.

detector, *n*—device to convert radiant energy into a neural signal (such as the eye) or an electrical signal (such as a phototube, photomultiplier tube, photocell, photodiode, or the like). (1988)

diagonal elements, *n— in bispectral photometry*, elements of a bispectral matrix for which irradiation and viewing wavelengths are equal.

diagonal fluorescence, *n— in bispectral photometry*, the contribution of fluorescence to diagonal values of a bispectral radiance factor matrix, due to the finite range of actual irradiation and viewing wavelengths when nominal irradiation and viewing wavelengths are equal ($\mu = \lambda$).

dielectric, *adj*—pertaining to the appearance of those materials for which the first surface reflectance is characteristic of the illuminant; compare **metal-like**. (1995)

diffuse, *adj—in optical propagation*, transmission or reflection of flux with diffusion.

diffuse reflectance, ρ_d, *n*—the ratio of the reflected flux to the incident flux, where the reflection is at all angles within the hemisphere bounded by the plane of measurement except in the direction of the specular reflection angle. (1992)

DISCUSSION—The size of the specular reflection angle depends on the instrument and the measurement conditions used. For its precise definition the make and model of the instrument or the aperture angle or aperture solid angle of the specularly reflected beam should be specified.

diffuse reflectance factor, R_d, *n*—the ratio of the flux reflected at all angles within the hemisphere bounded by the plane of measurement except in the direction of the specular reflection angle, to the flux reflected from the perfect reflecting diffuser under the same geometric and spectral conditions of measurement. (1992)

DISCUSSION—The size of the specular reflection angle depends on the instrument and the measurement conditions used. For its precise definition the make and model of the instrument or the aperture angle or aperture solid angle of the specularly reflected beam should be specified.

diffuse reflection, *n*—reflection in which flux is scattered in many directions by diffusion at or below the surface. See **diffusion** .

diffuse transmission, *n*—transmission in which diffusion occurs, independently, on a macroscopic scale, of the laws of refraction. **[CIE][A]**

diffuse transmittance, T_d, *n*—the ratio of the flux transmitted by a specimen to the incident flux, the transmitted flux being measured at all forward angles except the regular transmission angle. (1992)

DISCUSSION—The size of the regular transmission angle depends on the instrument and the measurement conditions used. For its precise definition the make and model of the instrument or the aperture angle or aperture solid angle of the regularly transmitted beam should be specified.

diffuser, *n*—device used to alter the spatial distribution of flux by diffusion. **[CIE][B]**

diffusion, *n*—change of the angular distribution of a beam of radiant flux by a transmitting material or a reflecting surface such that flux incident in one direction is continuously distributed in many directions, the process not conforming (on a macroscopic scale) to the laws of Fresnel (regular) reflection and refraction and there being no change in frequency (wavelength) of the monochromatic components of the flux.

DIN color system, *n*—color order system developed for the Deutsche Industrie Normung (German Standardization Institute) to provide equality of visual spacing of colors in specified series, based on the attributes hue, saturation, and relative darkness degree. (1988)

directional, *adj*—(1) so designed that performance depends on direction or is restricted in direction; more effective in some directions than others. (1988a)

(2) referring to a beam, beam in which the flux measured is confined to directions that differ moderately from the centroid direction or axis of the beam. (E 179) (1991b)

DISCUSSION—Moderately may be defined by specifying an appropriate aperture angle.

directionality, *n— (1) perceived*, the degree to which the appearance of a surface changes as the surface is rotated in its own plane,