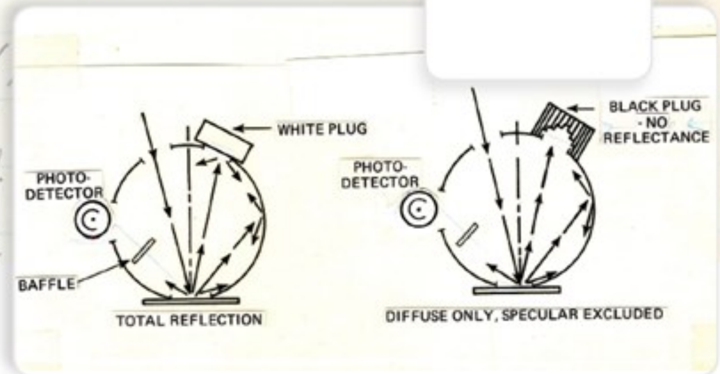
Applications Note

AN 1092



Yxy Color Scale

Dominant wavelength and excitation purity may be determined using Y, x, and y.

Abstract

The XYZ CIE Tristimulus Values do not correspond very well to the visual attributes of a color. The Y value is the only one that is easy to understand because it correlates with lightness. In an attempt to develop a more understandable color scale, the CIE developed the CIE Chromaticity Coordinates x, y, and z, which are calculated from the CIE Tristimulus Values (XYZ). Most often, the values of Yxy are reported as CIE Chromaticity Coordinates. This is because Y provides a lightness function. The sum of x, y, and z is 1.0, so z can be determined easily if needed .

The world's true measure of color

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Background

In 1931, experiments were performed to determine how a standard human observer perceives color. The experiments were done by projecting lights onto a screen and having an observer match one light using a combination of red, green, and blue lights. The observer changed the amounts of red, green, and blue light projected onto the screen so that the light spot created matched the single light. In a few cases, one of the three matching lights had to be projected on the light to be matched in order to achieve a match, which was, in essence, subtracting light from the matching lights. These experiments were done with the observer having a very small (two degree) field of view. The curves generated from this data were

mathematically manipulated so that all the curves were positive and the y was equal to the luminosity function (the way humans perceive brightness). The resulting curves, x, y, and z, are referred to as the CIE 2 degree Standard Observer functions.

In 1964, similar experiments were performed using a larger (ten degree) field of view. At that time, more was known about the anatomy and function of parts of the eye and it was determined that the ten degree field of view would be a better indicator of how color is actually perceived by humans than the two degree field of view. Thus, the CIE 10 degree Standard Observer functions were created.

The CIE Tristimulus Values (XYZ) are calculated from these CIE Standard Observer functions, taking into account the type of illumination and reflectance of the sample. At each wavelength x, y, and z are multiplied by the spectral energy emitted by the light source. Then that value is multiplied by the reflectance of the sample at each wavelength. The values for all the wavelengths are then summed. The XYZ values are calculated based on the luminosity of a perfect reflecting diffuser which has a reflectance of 100 at each wavelength. The sums are divided by the sum of the spectral energy times y at each wavelength because Y for the perfect white must equal 100 by definition. CIE Publication 15.2 (1986) contains information on the XYZ color scale and CIE Standard Observer functions.

The XYZ color scale may be used to quantify the color of an object. The reflectance curves of different colored objects are different so their XYZ values will also be different. However, the XYZ values do not fit into a color solid, so it is difficult to determine the actual color of an object based solely on its XYZ values. The XYZ values are most often used as a starting point for the calculation of other color values which fit into various color solids and, therefore, yield values from which the actual color of an object may be more easily determined based on the numbers alone. The colors of standard tiles are usually determined and listed in XYZ values.

The Y value is also the luminous reflectance for the sample since y is equal to the luminosity function. Y is sometimes used to quantify the brightness of an object.

Conditions for Measurement

Instrumental: Any HunterLab color measurement instrument

Illuminant: Any

Standard Observer Function: 2 or 10 degree

Transmittance and/or Reflectance: Either (The word transmittance may be substituted for reflectance in any of the text above and formulas below.)

Formulas

$$X = 100 \frac{\int E_\lambda R_\lambda \bar{x}_\lambda d\lambda}{\int E_\lambda \bar{y}_\lambda d\lambda}$$

$$Y = 100 \frac{\int E_\lambda R_\lambda \bar{y}_\lambda d\lambda}{\int E_\lambda \bar{y}_\lambda d\lambda}$$

$$Z = 100 \frac{\int E_\lambda R_\lambda \bar{z}_\lambda d\lambda}{\int E_\lambda \bar{y}_\lambda d\lambda}$$

where

$\bar{x}_\lambda$, $\bar{y}_\lambda$, and $\bar{z}_\lambda$ = components of the Standard Observer function

E_λ = illuminant function

R_λ = reflectance (or transmittance) of the object at a given wavelength

λ = wavelength of measurement.

For a worked-out example of these calculations, see pages 366-367 of *The Measurement of Appearance*, Second edition by Richard S. Hunter and Richard W. Harold.

Typical Applications

This color scale may be used for measurement of the color of any object whose color can be measured.

About HunterLab

HunterLab is the technology leader in color measurement solutions, providing instruments, software, knowledge and service to a wide variety of industries.
With over 5 decades of experience in more than 65 countries, HunterLab applies our leading edge technology to your products helping you measure and communicate color simply and effectively.

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