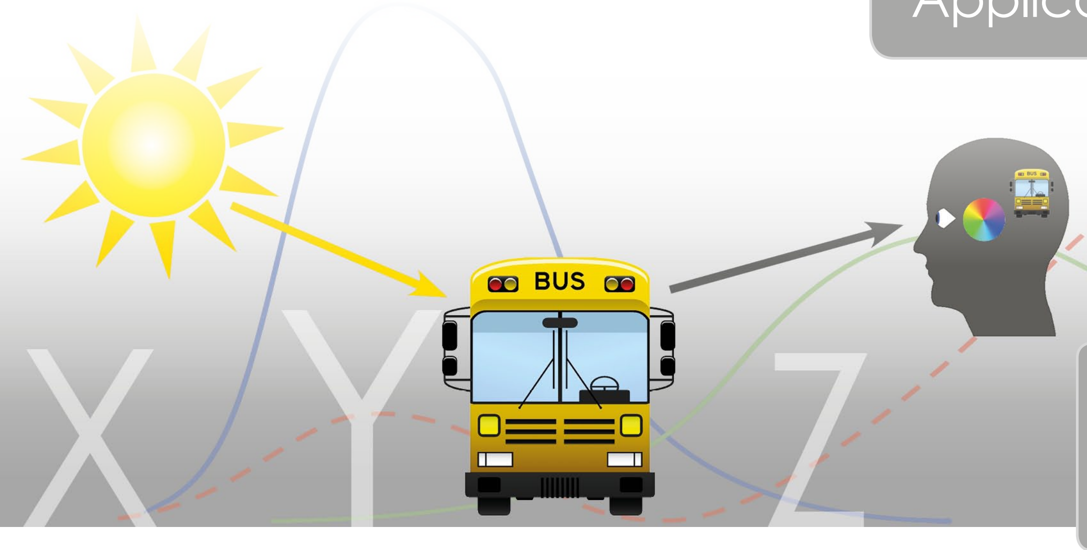
Application Note

AN 1002.00



CIE Standard Observers and calculation of CIE X, Y, Z color values

"Three components are necessary for the human perception of color - a white light source, an object to look at and a human observer. Each component must be represented as numbers to quantify human color perception."

ABSTRACT

Humans perceive color and appearance subjectively and differently, even with a trained eye. In a model for human color perception, the observer is represented as the human eye that receives light reflected or transmitted from an object and processed in the brain to become a color perception.

This application note is a review of the calculation of CIE X, Y, Z color values while "standardizing" the human observer as a numerical representation of what the "average person" sees.

The world's true measure of color

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DEFINING THE STANDARD OBSERVER

In the 1920s two researchers from the UK, David Wright and John Guild, performed color matching experiments using human volunteers to develop and quantify the color ability of a standard, or average, human observer. In 1931 the CIE published the 2° Standard Observer based on their research. This Standard Observer is called 2° because, during the color matching experiment, subjects looked through a hole that allowed them a 2° field of view. At the time it was believed that all the color-sensing cones of the eye were located within a 2° arc of the fovea, located directly back from the retina of the eye. The experiments were performed by projecting colors from across the visible spectrum onto a screen. Multiple people matched each spectral color light using a combination of red, green, and blue lights. The curves generated from this data resulted in bar x, bar y and bar z functions, referred to as the 1932 CIE 2° degree Standard Observer.

By the 1960s, it was realized that cones in the human visual system covered a larger field of view than previously believed.The visual matching experiments were repeated by W. S. Stiles, J. M. Burch and N. I. Speranskaya using this wider field of view and in 1964, the CIE 10° Standard Observer was published. The 10° Standard Observer is recommended as best representing the spectral response of human observers. As shown in Figure 2, the 1931 2° Standard Observer is similar to the 1964 10° Standard Observer and was not discontinued with the 1964 release due to its incorporation in many industry product specifications. Today, the 1964 10° Standard Observer is recommended by the CIE as appropriate for most industrial color applications but the 1931 2° remains available as a measurement choice. The relative sizes of the two fields of view are shown in Figure 1.

The 1931 2° and 1964 10° Standard Observer functions are used in the calculation of color values to reflect the human response to the visible spectrum.

Figure 1. The 2° and 10° Degree Fields of View defining the CIE Standard Observer.

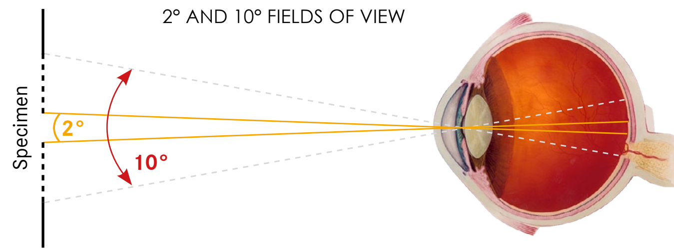


Figure 2. CIE 2° versus 10° Degree Standard Observer.

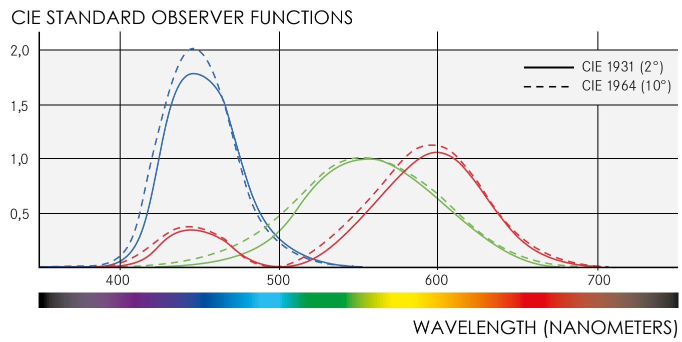
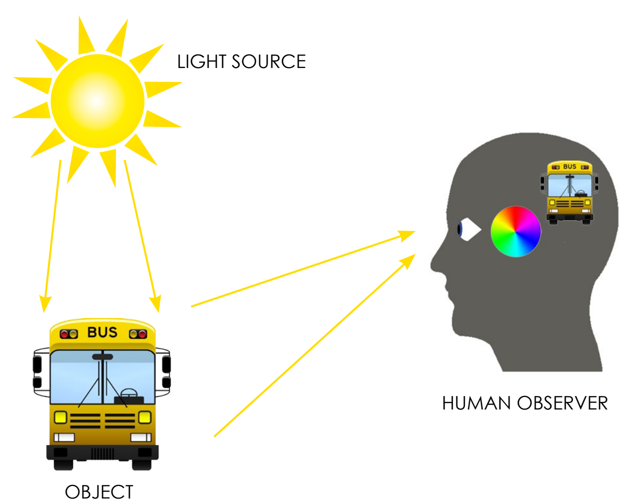


Figure 3. Visual Observing Situation Model.



DEFINING COLOR VALUES

The CIE X, Y, Z tristimulus values are calculated from the CIE Standard Observer functions, a selected CIE illuminant and the reflectance or transmission of the sample. At each wavelength, bar x, bar y and bar z functions are multiplied by the CIE illuminant. Then that value is multiplied by the reflectance or transmission of the sample at each wavelength. The values for all the wavelengths are then summed and integrated to display CIE X, Y, Z color values.

CIE X, Y, Z tristimulus values are calculated as follows:

X = ∫(R or T) * illuminant factor *bar x of standard observer

Y = ∫(R or T) * illuminant factor * bar y of standard observer

Z = ∫(R or T) * illuminant factor * bar z of standard observer

where R = Reflectance or T=Transmittance for the spectral range of the instrument

Note that X, Y, and Z include factors for the CIE standard observer in their formulas. All other tristimulus color scales, such as Hunter L, a, b or CIE L*a*b*, are calculated from the CIE X, Y, Z color scale.

CONCLUSION

This note was provided as background information to relate human color vision to instrumental color measurements. Using instruments to measure color perception creates an objective and precise method to quantify a perceived by humans.

REFERENCES

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ABOUT HUNTERLAB

HunterLab, the first name in color measurement, provides ruggedly dependable, consistently accurate, and cost effective color measurement solutions. With over 6 decades of experience in more than 65 countries, HunterLab applies leading edge technology to measure and communicate color simply and effectively. The company offers both diffuse/8° and a complete line of true 45°/0° optical geometry instruments in portable, bench-top and production in-line configurations. HunterLab, the world's true measure of color.

Hunter Associates Laboratory Inc.,
11491 Sunset Hills Road, Reston, VA 20190-5280 USA
helpdesk@hunterlab.com
www.hunterlab.com

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