

# Applications Note

$\Delta = 2t + \frac{\lambda}{2}$  (must equal a whole number of  $\lambda$  for a bright fringe or

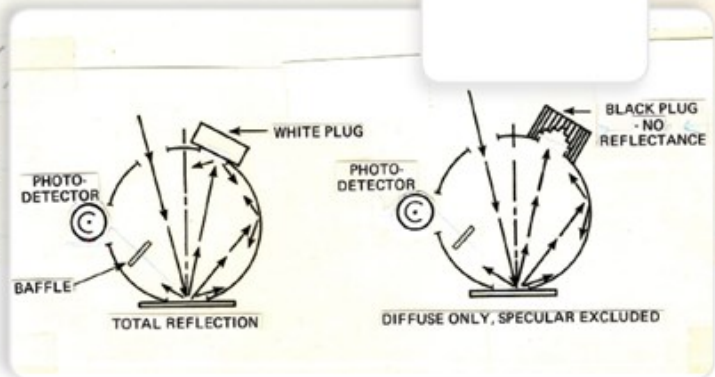
$$n\lambda = 2t + \frac{\lambda}{2}$$

$$t = \frac{n\lambda - \frac{\lambda}{2}}{2} = \frac{\lambda}{2} \left( n - \frac{1}{2} \right)$$

substituting

$$D^2 = 2\lambda \left[ \frac{\lambda}{2} \left( n - \frac{1}{2} \right) \right]$$

AN 1103



## CIE L\*a\*b\* Color Scale

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

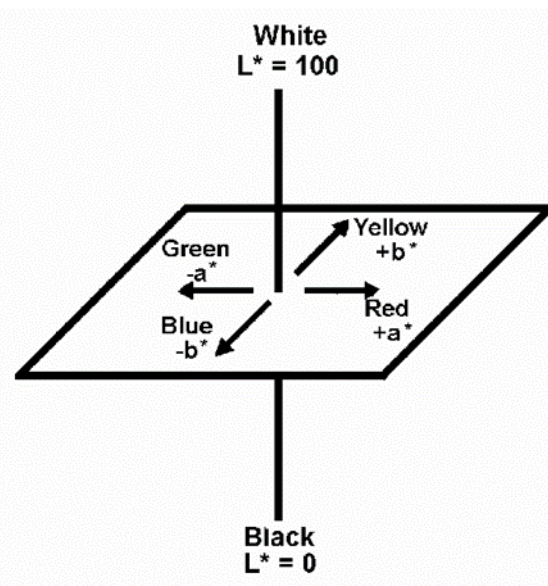
### Abstract

The CIELAB color space, also referred to as  $L^*a^*b^*$ , is a color space defined by the International Commission on Illumination (abbreviated CIE) in 1976. It expresses color as three values:  $L^*$  for perceptual lightness and  $a^*$  and  $b^*$  for the four unique colors of human vision: red, green, blue and yellow.

## Background

In 1976, the CIE recommended the CIE L\*a\*b\*, or CIELAB, color scale for use. CIE Publication 15.2 (1986), Section 4.2, contains details on this color scale. It was intended to provide a standard, approximately uniform color scale which could be used by everyone so that color values could be easily compared.

The CIELAB color scale is an approximately uniform color scale. In a uniform color scale, the differences between points plotted in the color space correspond to visual differences between the colors plotted. The CIELAB color space is organized in a cube form. The L\* axis runs from top to bottom. The maximum for L\* is 100, which represents a perfect reflecting diffuser. The minimum for L\* is zero, which represents black. The a\* and b\* axes have no specific numerical limits. Positive a\* is red. Negative a\* is green. Positive b\* is yellow. Negative b\* is blue. Below is a diagram representing the CIELAB color space.



There are delta values associated with this color scale.  $DL^*$ ,  $Da^*$ , and  $Db^*$  indicate how much a standard and sample differ from one another in L\*, a\*, and b\*. These delta values are often used for quality control or formula adjustment. Tolerances may be set for the delta values. Delta values that are out of the tolerances indicate that there is too much difference between the standard and the sample. The type of correction needed may be determined by which delta value is out of tolerance. For example, if  $Da^*$  is out of tolerance, the redness/greenness needs to be adjusted. Whether the sample is redder or greener than the standard is indicated by the sign of the delta value. For example, if  $Da^*$  is positive, the sample is redder than the standard.

The total color difference,  $DE^*$ , may also be calculated. The  $DE^*$  is a single value which takes into account the differences between the L\*, a\*, and b\* of the sample and standard. It does not indicate which parameter(s) (L\*, a\*, and/or b\*) are out of tolerances if  $DE^*$  is out of tolerance. It may also be misleading in some cases where  $DL^*$ ,  $Da^*$ , or  $Db^*$  is out of tolerance, but  $DE^*$  is still within tolerance.

In addition, there are two other delta values that are related to this scale, DC\* and DH\*. The DC\* is the difference in chroma between the sample and standard as described in a polar coordinate system. The DH\* is the difference in hue angle between the sample and standard as described in a polar coordinate system.

The CIELAB color scale may be used on any object whose color may be measured. It is used extensively in many industries. As was intended, it provides a standard scale for comparison of color values.

### Conditions for Measurement

**Instrumental:** Any HunterLab color measurement instrument

**Illuminant:** Any

**Standard Observer Function:** 2 or 10 degree

**Transmittance and/or Reflectance:** Either.

### Formulas

If  $X/X_n$ ,  $Y/Y_n$ , and  $Z/Z_n$  are all greater than 0.008856, then

$$L^* = 116 \sqrt[3]{Y/Y_n} - 16$$

$$a^* = 500 \left( \sqrt[3]{X/X_n} - \sqrt[3]{Y/Y_n} \right)$$

$$b^* = 200 \left( \sqrt[3]{Y/Y_n} - \sqrt[3]{Z/Z_n} \right)$$

If any of  $X/X_n$ ,  $Y/Y_n$ , or  $Z/Z_n$  is equal to or less than 0.008856, then

$$L^* = 903.3 \left( Y/Y_n \right)$$

$$a^* = 500 \left[ f \left( X/X_n \right) - f \left( Y/Y_n \right) \right]$$

$$b^* = 200 \left[ f \left( Y/Y_n \right) - f \left( Z/Z_n \right) \right]$$

where

X, Y, and Z are the CIE Tristimulus Values

$X_n$ ,  $Y_n$ , and  $Z_n$  are the tristimulus values for the illuminant

$Y_n$  is 100.00

$X_n$  and  $Z_n$  are listed in the tables below.

**CIE 2-degree Standard Observer**

<b>Illuminant</b>	<b>X<sub>n</sub></b>	<b>Z<sub>n</sub></b>
A	109.83	35.55
C	98.04	118.11
D65	95.02	108.82
F2	98.09	67.53
TL 4	101.40	65.90
UL 3000	107.99	33.91
D50	96.38	82.45
D60	95.23	100.86
D75	94.96	122.53

**CIE 10-degree Standard Observer**

<b>Illuminant</b>	<b>X<sub>n</sub></b>	<b>Z<sub>n</sub></b>
A	111.16	35.19
C	97.30	116.14
D65	94.83	107.38
F2	102.13	69.37
TL 4	103.82	66.90
UL 3000	111.12	35.21
D50	96.72	81.45
D60	95.21	99.60
D75	94.45	120.70

$$f(X/X_n) = \sqrt[3]{X/X_n} \quad \text{when } X/X_n > 0.008856$$

$$f(X/X_n) = 7.87 \left( \frac{X}{X_n} \right) + \frac{16}{116} \quad \text{when } X/X_n < 0.008856$$

$$f(Y/Y_n) = \sqrt[3]{Y/Y_n} \quad \text{when } Y/Y_n > 0.008856$$

$$f(Y/Y_n) = 7.87 \left( \frac{Y}{Y_n} \right) + \frac{16}{116} \quad \text{when } Y/Y_n < 0.008856$$

$$f(Z/Z_n) = \sqrt[3]{Z/Z_n} \quad \text{when } Z/Z_n > 0.008856$$

$$f(Z/Z_n) = 7.87 \left( \frac{Z}{Z_n} \right) + \frac{16}{116} \quad \text{when } Z/Z_n < 0.008856$$

$$\Delta L^* = L^*_{\text{sample}} - L^*_{\text{standard}} \quad \begin{array}{l} + \Delta L^* \text{ means sample is lighter than standard} \\ - \Delta L^* \text{ means sample is darker than standard} \end{array}$$

$$\Delta a^* = a^*_{\text{sample}} - a^*_{\text{standard}} \quad \begin{array}{l} + \Delta a^* \text{ means sample is redder than standard} \\ - \Delta a^* \text{ means sample is greener than standard} \end{array}$$

$$\Delta b^* = b^*_{\text{sample}} - b^*_{\text{standard}} \quad \begin{array}{l} + \Delta b^* \text{ means sample is yellower than standard} \\ - \Delta b^* \text{ means sample is bluer than standard} \end{array}$$

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

$$\Delta C^* = C^*_{\text{sample}} - C^*_{\text{standard}}$$

where

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (\text{this is called metric chroma})$$

$$\Delta H^* = \sqrt{\Delta E^{*2} - \Delta L^{*2} - \Delta C^{*2}}$$

## 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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