CIE L*C*h Color Scale

Background
The CIE L*C*h or CIELCh color scale is an approximately uniform scale with a polar color space. The CIELCh scale values are calculated from the CIELAB scale values. They are described in Section 4.2 of CIE Publication 15.2 (1986). The L*, lightness, value is the same in each scale. The C* value, chroma, and the h value, hue angle, are calculated from the a* and b* of the CIELAB scale. The CIELCh color space is diagrammed below.

The basic delta values for this scale are $\Delta L^*$, $\Delta C^*$, and $\Delta H^*$. They are the differences between the sample and standard in L*, C*, and h*. The total color difference, $\Delta E^*$ is the same as the $\Delta E^*$ in the CIELAB scale.

Another total color difference value often used with this color scale is $\Delta E_{cmc}$. $\Delta E_{cmc}$ and associated values will be discussed in a separate Applications Note. Please refer to it for further information.

Conditions for Measurement
Instrumental: Any HunterLab color measurement instrument
Illuminant: Any

Standard Observer Function: 2 or 10 degree

Transmission and/or Reflectance: Either.

Formulas

If X/Xn, Y/Yn, and Z/Zn are all greater than 0.008856, then use the following equation for L*:

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

If any of X/Xn, Y/Yn, or Z/Zn is equal to or less than 0.008856, then use this equation for L*:

\[
L^* = 903.3 \left( \frac{Y}{Y_n} \right)
\]

where

X, Y, and Z are the CIE Tristimulus Values.

Xn, Yn, and Zn are the tristimulus values for the illuminant.

Yn is 100.00.

Xn and Zn are listed in the tables below.

### CIE 2 Degree Standard Observer

<table>
<thead>
<tr>
<th>Illuminant</th>
<th>Xn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>109.83</td>
<td>35.55</td>
</tr>
<tr>
<td>C</td>
<td>98.04</td>
<td>118.11</td>
</tr>
<tr>
<td>D65</td>
<td>95.02</td>
<td>108.82</td>
</tr>
<tr>
<td>F2</td>
<td>98.09</td>
<td>67.53</td>
</tr>
<tr>
<td>TL 4</td>
<td>101.40</td>
<td>65.90</td>
</tr>
<tr>
<td>UL 3000</td>
<td>107.99</td>
<td>33.91</td>
</tr>
<tr>
<td>D50</td>
<td>96.38</td>
<td>82.45</td>
</tr>
<tr>
<td>D60</td>
<td>95.23</td>
<td>100.86</td>
</tr>
<tr>
<td>D75</td>
<td>94.96</td>
<td>122.53</td>
</tr>
</tbody>
</table>

### CIE 10 Degree Standard Observer

<table>
<thead>
<tr>
<th>Illuminant</th>
<th>Xn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>111.16</td>
<td>35.19</td>
</tr>
<tr>
<td>C</td>
<td>97.30</td>
<td>116.14</td>
</tr>
<tr>
<td>D65</td>
<td>94.83</td>
<td>107.38</td>
</tr>
<tr>
<td>F2</td>
<td>102.13</td>
<td>69.37</td>
</tr>
<tr>
<td>TL 4</td>
<td>103.82</td>
<td>66.90</td>
</tr>
<tr>
<td>UL 3000</td>
<td>111.12</td>
<td>35.21</td>
</tr>
<tr>
<td>D50</td>
<td>96.72</td>
<td>81.45</td>
</tr>
<tr>
<td>D60</td>
<td>95.21</td>
<td>99.60</td>
</tr>
<tr>
<td>D75</td>
<td>94.45</td>
<td>120.70</td>
</tr>
</tbody>
</table>

\[
C^* = \sqrt{a^*} + b^*^2
\]
\[ h = \arctan \frac{b^*}{a^*} \]

where

If \( X/X_n, Y/Y_n, \) and \( Z/Z_n \) are all greater than 0.008856, then use:

\[
a^* = 500 \left( \frac{X}{X_n} - \frac{1}{3} \frac{Y}{Y_n} \right)
\]

\[
b^* = 200 \left( \frac{Y}{Y_n} - \frac{1}{3} \frac{Z}{Z_n} \right)
\]

If any of \( X/X_n, Y/Y_n, \) or \( Z/Z_n \) is equal to or less than 0.008856, then use:

\[
a^* = 500 \left[ f \left( \frac{X}{X_n} \right) - f \left( \frac{Y}{Y_n} \right) \right]
\]

\[
b^* = 200 \left[ f \left( \frac{Y}{Y_n} \right) - f \left( \frac{Z}{Z_n} \right) \right]
\]

where

\[ f \left( \frac{X}{X_n} \right) = \frac{1}{3} \frac{X}{X_n} \quad \text{when } X/X_n > 0.008856 \]

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

\[ f \left( \frac{Y}{Y_n} \right) = \frac{1}{3} \frac{Y}{Y_n} \quad \text{when } Y/Y_n > 0.008856 \]

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

\[ f \left( \frac{Z}{Z_n} \right) = \frac{1}{3} \frac{Z}{Z_n} \quad \text{when } Z/Z_n > 0.008856 \]

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

\[
\Delta L^* = L^*_{\text{sample}} - L^*_{\text{standard}}
\]

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

\[
\Delta H^* = \sqrt{\Delta E^* - \Delta L^* - \Delta C^*} \quad \text{if } h^o_{\text{SMP}} > h^o_{\text{STD}}, \text{ then } \Delta H^* \text{ is regarded as positive.}
\]

\[
\text{if } h^o_{\text{SMP}} < h^o_{\text{STD}}, \text{ then } \Delta H^* \text{ is regarded as negative.}
\]
Typical Applications

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

For Additional Information Contact:

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