Errata V10 and Updates


4th Printing

How to tell which printing?
You can tell by looking at the copyright page. On the bottom, you’ll see numbers: 10 9 … 4. The last number lists the printing.

Thanks to all my readers for pointing out errors,
Roy Berns
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July 13, 2006
Errata

Page 60
Left column, second plot. The axes should be script \( \mathcal{X}, \mathcal{Y}, \) and \( \mathcal{Z} \) as they are defining the three-space axes.

Page 69
The CIELAB L* equation is shown for very dark colors. For colors with \( Y/Y_n > 0.008856 \), the equation should be:

\[
L^* = 116(Y/Y_n)^{1/3} - 16
\]

This was correct in the first two printings and changed incorrectly in the third printing, and not corrected in the fourth printing. In the Update section, I have written a new sidebar that can be printed, cut out, and pasted in.

Page 70
Right column, yellowness index equation. The correct equation should be:

\[
Y_I = 100 \frac{1.2769X - 1.0592Z}{Y}
\]

Page 103
Right column. The equations have errors. The correct equations should be:

Bidirectional geometries:

\[
\begin{align*}
E_{\text{reference white}} &= -2.79\Delta L^* + 1.50\Delta a^* + 2.96\Delta b^* \\
E_{\text{reference black}} &= -0.32\Delta L^* - 0.48\Delta a^* - 0.42\Delta b^* \\
E_{\text{wavelength}} &= 0.08\Delta L^* - 0.82\Delta a^* + 0.67\Delta b^*
\end{align*}
\]

Integrating sphere, specular component included geometries

\[
\begin{align*}
E_{\text{reference white}} &= -2.58\Delta L^* + 1.79\Delta a^* + 3.04\Delta b^* \\
E_{\text{reference black}} &= -0.36\Delta L^* - 0.62\Delta a^* - 0.54\Delta b^* \\
E_{\text{wavelength}} &= 0.05\Delta L^* - 0.95\Delta a^* + 0.77\Delta b^*
\end{align*}
\]
Page 202
Right column, matrix inversion. The correct equation should be:

\[
R = \frac{Y_{g,\text{max}}Z_{b,\text{max}} - Y_{b,\text{max}}Z_{g,\text{max}}}{\Delta} X + \frac{X_{b,\text{max}}Z_{g,\text{max}} - X_{g,\text{max}}Z_{b,\text{max}}}{\Delta} Y \\
\quad + \frac{X_{g,\text{max}}Y_{b,\text{max}} - X_{b,\text{max}}Y_{g,\text{max}}}{\Delta} Z
\]

\[
G = \frac{Y_{b,\text{max}}Z_{r,\text{max}} - Y_{r,\text{max}}Z_{b,\text{max}}}{\Delta} X + \frac{X_{r,\text{max}}Z_{b,\text{max}} - X_{b,\text{max}}Z_{r,\text{max}}}{\Delta} Y \\
\quad + \frac{X_{b,\text{max}}Y_{r,\text{max}} - X_{r,\text{max}}Y_{b,\text{max}}}{\Delta} Z
\]

\[
B = \frac{Y_{r,\text{max}}Z_{g,\text{max}} - Y_{g,\text{max}}Z_{r,\text{max}}}{\Delta} X + \frac{X_{g,\text{max}}Z_{r,\text{max}} - X_{r,\text{max}}Z_{g,\text{max}}}{\Delta} Y \\
\quad + \frac{X_{r,\text{max}}Y_{g,\text{max}} - X_{g,\text{max}}Y_{r,\text{max}}}{\Delta} Z
\]

Page 208
Right column, (K/S) of the unknown should be capital K and S and the substrate should be subtracted. The correct equation should be:

\[
\begin{bmatrix}
  c_1 \\ c_2 \\ c_3
\end{bmatrix} = \begin{bmatrix}
  \frac{k}{s}_{\lambda=1,1} & \frac{k}{s}_{\lambda=1,2} & \frac{k}{s}_{\lambda=1,3} \\
  \frac{k}{s}_{\lambda=2,1} & \frac{k}{s}_{\lambda=2,2} & \frac{k}{s}_{\lambda=2,3} \\
  \frac{k}{s}_{\lambda=3,1} & \frac{k}{s}_{\lambda=3,2} & \frac{k}{s}_{\lambda=3,3}
\end{bmatrix}^{-1} \begin{bmatrix}
  \frac{K}{S}_{\lambda=1,\text{unknown}} & -\frac{k}{s}_{\lambda=1,t} \\
  \frac{K}{S}_{\lambda=2,\text{unknown}} & -\frac{k}{s}_{\lambda=2,t} \\
  \frac{K}{S}_{\lambda=3,\text{unknown}} & -\frac{k}{s}_{\lambda=3,t}
\end{bmatrix}.
\]

Page 214
Left column, Eq. (F-9) should be:

\[
\begin{pmatrix}
  X_c \\ Y_c \\ Z_c
\end{pmatrix} = \begin{pmatrix}
  0.98699 & -0.14705 & 0.15996 \\
  0.43231 & 0.51836 & 0.04929 \\
  -0.00853 & 0.04004 & 0.96849
\end{pmatrix} \begin{pmatrix}
  R_Y \\ G_Y \\ B_Y
\end{pmatrix}.
\]

Page 217
Right column, Eq. (G-6) should be:

\[
\begin{bmatrix}
  R_{\text{display}} \\ G_{\text{display}} \\ B_{\text{display}}
\end{bmatrix} = \begin{bmatrix}
  X_{r,\text{max}} & X_{g,\text{max}} & X_{b,\text{max}} \\
  Y_{r,\text{max}} & Y_{g,\text{max}} & Y_{b,\text{max}} \\
  Z_{r,\text{max}} & Z_{g,\text{max}} & Z_{b,\text{max}}
\end{bmatrix}^{-1} \begin{bmatrix}
  X_{\text{display}} \\ Y_{\text{display}} \\ Z_{\text{display}}
\end{bmatrix}.
\]

Page 241
Left column, P.L Vora and H. J. Trussell pages are incorrect. They should be 1499-1508.
Here are the equations for the CIE 1976 $L^*a^*b^*$ (CIELAB) space. Its calculation depends on the ratio of either $X/X_n$, or $Y/Y_n$ or $Z/Z_n$ [notated $f(x)$] where $X_n$, $Y_n$, and $Z_n$ are the tristimulus values of the reference white (see page 59).

\[
L^* = 116 f(Y/Y_n) - 16
\]
\[
a^* = 500 \left[ f(X/X_n) - f(Y/Y_n) \right]
\]
\[
b^* = 200 \left[ f(Y/Y_n) - f(Z/Z_n) \right]
\]
\[
f(x) = \begin{cases} 
  x^{1/3} & x > 0.008856 \\
  7.787x + 16/116 & x \leq 0.008856 
\end{cases}
\]
\[
C_{ab}^* = \sqrt{a^{*2} + b^{*2}}
\]
\[
h_{ab} = \tan^{-1}(b^*/a^*) = \arctan(b^*/a^*)
\]

The reverse equations are

\[
X = X_n f^{-1}\left( \frac{L^*+16}{116} + \frac{a^*}{500} \right)
\]
\[
Y = Y_n f^{-1}\left( \frac{L^*+16}{116} \right)
\]
\[
Z = Z_n f^{-1}\left( \frac{L^*+16}{116} - \frac{b^*}{200} \right)
\]
\[
f^{-1}(x) = \begin{cases} 
  x^3 & x > 0.206893 \\
  \frac{1}{7.787}\left( x - \frac{16}{116} \right) & x \leq 0.206893 
\end{cases}
\]

When colors are defined by $L^*$, $C_{ab}^*$, and $h_{ab}$, first transform back to $a^*$ and $b^*$.

\[
a^* = C_{ab}^* \cos(h_{ab})
\]
\[
b^* = C_{ab}^* \sin(h_{ab})
\]
Page 72
Left column, side bar. The following equation clarifies the geometric meaning of $\Delta H^*_{ab}$ compared to what is written in the book:

$$\Delta H^*_{ab} = 2(C_{ab,\text{standard}}^* C_{ab,\text{batch}}^*)^{1/2} \sin \left( \frac{h_{ab,\text{batch}} - h_{ab,\text{standard}}}{2} \right)$$

Page 121
Recent CIE Color-Difference Activities
Since the book’s publication in 2000, the CIE technical committee 1-47 has developed a new color-difference equation, CIEDE2000 or $\Delta E_{00}$. Its derivation is described in Luo, Cui, Rigg, The development of the CIE 2000 colour-difference formula: CIEDE2000, Color Research Application, 26:340-350 (2001) and CIE Publication 142-2001 Improvement to Industrial Color-Difference Evaluation. The specific mathematics are shown below:

$$\Delta E_{00} = \left[ \frac{\Delta L'}{k_L S_L} \right]^2 + \left[ \frac{\Delta C_{ab}^*}{k_C S_C} \right]^2 + \left[ \frac{\Delta H_{ab}^*}{k_H S_H} \right]^2 + R_T \left[ \frac{\Delta C_{ab}^* \Delta H_{ab}^*}{k_C S_C k_H S_H} \right]^{1/2}$$

$L' = L^*$
$a' = a^* (1 + G)$
$b' = b^*$

$$G = 0.5 \left( 1 - \sqrt{\frac{C_{ab}^{*7}}{C_{ab}^{*7} + 25^7}} \right)$$

$$S_L = 1 + \frac{0.015(L' - 50)^2}{\sqrt{20 + (L' - 50)^2}}$$

$$S_C = 1 + 0.045C'$$

$$S_H = 1 + 0.015C'T$$

$$T = 1 - 0.17 \cos(\bar{H} - 30) + 0.24 \cos(2\bar{H}) + 0.32 \cos(3\bar{H} + 6) - 0.20 \cos(4\bar{H} - 63)$$

$$R_T = - \sin(2\Delta\Theta) R_c$$

$$\Delta\Theta = 30 \exp \left( - \frac{h' - 275}{25} \right)^2$$

$$R_c = 2 \left( \frac{C^{*7}}{C^{*7} + 25^7} \right)^{1/2}$$
The Bradford chromatic-adaptation transformation, shown in Eqs. (F-7) – (F-9), has been replaced with CIECAT02, that is, the CIE chromatic-adaptation transformation (CAT), 2002. See N. Maroney, et al., The CIECAM02 Color Appearance Model, Proceedings IS&T/SID Tenth Color Imaging Conference, 23-27 (2002). The math is the following:

\[
\begin{pmatrix}
R \\
G \\
B
\end{pmatrix} = \mathbf{M}_{\text{CAT02}} \begin{pmatrix}
X \\
Y \\
Z
\end{pmatrix}
\]

(F-7)

\[
\mathbf{M}_{\text{CAT02}} = \begin{pmatrix}
0.7328 & 0.4296 & -0.1624 \\
-0.7036 & 1.6975 & 0.0061 \\
0.0030 & 0.0136 & 0.9834
\end{pmatrix}
\]

This leads to the following set of pseudo-cone fundamentals:

The von Kries adaptation transform is the following:

\[
R_c = \frac{R_{D65}}{R_n} R
\]

\[
G_c = \frac{G_{D65}}{G_n} G.
\]

\[
B_c = \frac{B_{D65}}{B_n} B
\]

(F-8)

This is advantageous over the Bradford transform because it is readily invertible. The inverse matrix to (F-7) is the following:

\[
\begin{pmatrix}
X_c \\
Y_c \\
Z_c
\end{pmatrix} = \begin{pmatrix}
1.096124 & -0.278869 & 0.182745 \\
0.454369 & 0.473533 & 0.072098 \\
-0.009628 & -0.005698 & 1.015326
\end{pmatrix} \begin{pmatrix}
R_c \\
G_c \\
B_c
\end{pmatrix}
\]

(F-9)
The corresponding color calculation and color inconstancy index were recalculated for the vinyl.

Here are the results:

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<th>A, 10°</th>
<th>D65, 10°</th>
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