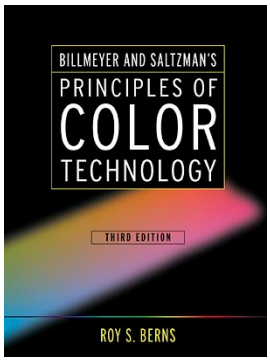
Errata V7

R. S. Berns, *Billmeyer and Saltzman's Principles of Color Technology*, 3rd edition, John Wiley, New York, 2000



These are the errors I have found and that have been sent to me by understanding readers. If you find any others, please let me know! A downloadable PDF of this document (in color, of course) can be found at either: www.wiley.com/color or www.cis.rit.edu/people/faculty/berns/.

Thanks in advance,
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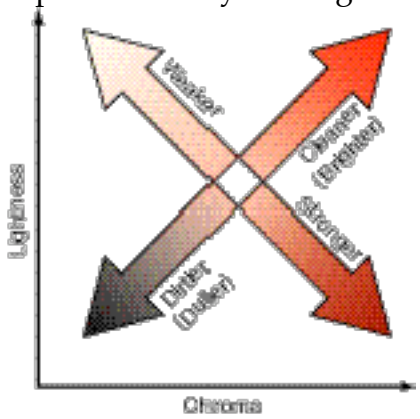
November 25, 2003

Page 6
Figure legends on the bottom of the page are reversed.

Page 24
The left-hand figure did not print correctly. The figure should have looked like:



Page 52
Right column, about 2/3 down, "fancv" should be "fancy."

Page 54
Top-right figure caption, five lines down, “of the same X, Y, and Z primaries,” should read “similar, X, Y, and Z primaries.”

Page 59
The table of tristimulus values has both CIE and ASTM values. Here are the ASTM values from E-308:

Illuminant	Observer	X	Y	Z
A	2°	109.850	100.000	35.585
	10°	111.144	100.000	35.200
C	2°	98.074	100.000	118.232
	10°	97.285	100.000	116.145
D65	2°	95.047	100.000	108.883
	10°	94.811	100.000	107.304
D50	2°	96.422	100.000	82.521
	10°	96.720	100.000	81.427
F2	2°	99.186	100.000	67.393
	10°	103.279	100.000	69.027

Here are the CIE data:

Illuminant	Observer	X	Y	Z
A	2°	109.850	100.000	35.585
	10°	111.144	100.000	35.200
C	2°	98.07	100.00	118.23
	10°	97.28	100.00	116.14
D65	2°	95.047	100.000	108.883
	10°	94.811	100.000	107.304
D50	2°	96.42	100.00	82.49
	10°	96.72	100.00	81.41

Page 65
Left column, 4th line from the bottom, "lightess" should be "lightness."

The equation for calculating u' from chromaticities is wrong. It should be:

$$u' = \frac{4x}{-2x + 12y + 3}$$

Also, the reverse equations can be simplified:

$$x = \frac{9u'}{6u' - 16v' + 12}$$

$$y = \frac{4v'}{6u' - 16v' + 12}$$

Page 66
The Priest 1920 square-root function, shown in the left-hand box is wrong. It should be:

$$V = 10Y^{1/2} \quad (0 \le Y \le 1)$$

Page 67
The Hunter Lab equations are incorrect. The correct equation is:

$$a = \frac{175\left(0.0102X_n\right)^{1/2}\left(X/X_n - Y/Y_n\right)}{\left(Y/Y_n\right)^{1/2}}$$

$$b = \frac{70\left(0.00847Z_n\right)^{1/2}\left(Y/Y_n - Z/Z_n\right)}{\left(Y/Y_n\right)^{1/2}}$$

Page 68
In the right-hand column figure title, "Roberston" should be "Robertson."

Page 69
The CIELAB L* equation for Y/Y_n less than 0.01 (actually, less than 0.008856) should be:

$$L^* = 903.3(Y/Y_n) \text{ for } Y/Y_n \le 0.008856$$

"where (fY/Y_n)=…" should be "where $f(Y/Y_n)$ =…"

Page 72
The equation for ΔC^*_{ab} is missing square terms for the standard. The correct equation is:

$$\Delta C^*_{ab} = C^*_{ab} - C^*_{ab} = \left[a^{*2}_{batch} + b^{*2}_{batch}\right]^{1/2} - \left[a^{*2}_{standard} + b^{*2}_{standard}\right]^{1/2}$$

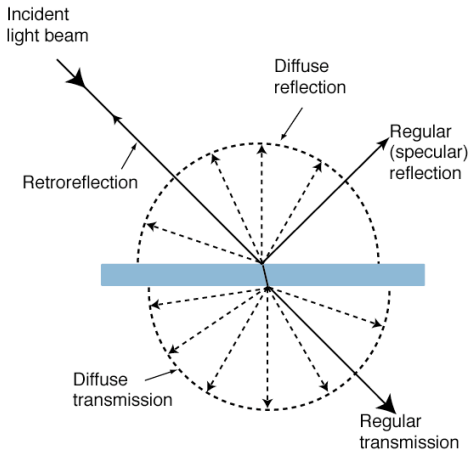
The Sève equation has the batch and standard reversed. The correct equation is the following:

$$\Delta H^*_{ab} = \frac{a^*_{standard}b^*_{batch} - a^*_{batch}b^*_{standard}}{\left[0.5\left(C^*_{ab,standard}C^*_{ab,batch} + a^*_{standard}a^*_{batch} + b^*_{standard}b^*_{batch}\right)\right]^{1/2}}$$

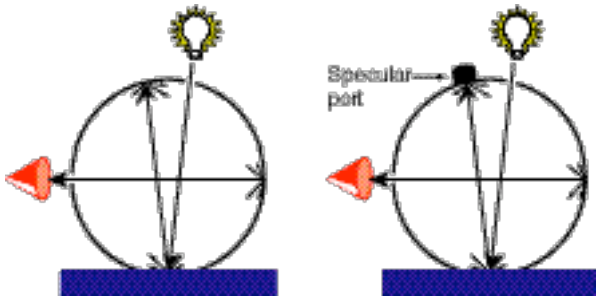
The following equation clarifies the geometric meaning of ΔH^*_{ab}:

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

Page 83
The upper right-hand figure has the regular reflection drawn incorrectly, at a greater angle than the opposite angle of incidence. The correct figure is:



Page 85
Strictly speaking, the left-hand figure is correct because light is reversible through an optical system (Helmholtz principle). However, the figure is confusing. The following figure is more intuitive:



Page 85
Top right-hand figure heading has a typo. Second to last line in heading, "measurerment" should be "measurement."

Page 93
Left side bar refers to seven channels. “Seven” should be replaced with “six.” (My original filter database had seven filters; the filter peaking at 700 nm was omitted.)

Page 98
Right-hand column, first paragraph, 9th line: “…be no less that…” replaced with “…be no less than…”

Page 99
The equation for standard error should show the standard deviation and standard errors as lower case.

Page 103
The equation for estimating wavelength error from ΔL*, Δa*, and Δb* bidirectional measurements has a typo. The constant in front of ΔL* should be positive 0.08. That is:

$$E_{\substack{\text{reference}\\ \text{white}}} = -2.79\Delta L^* + 1.50\Delta a^* + 2.96\Delta b^*$$

$$E_{\substack{\text{reference}\\ \text{black}}} = -0.32\Delta L^* - 0.48\Delta a^* - 0.42\Delta b^*$$

$$E_{\text{wavelength}} = 0.08\Delta L^* - 0.82\Delta a^* + 0.67\Delta b^*$$

Page 107
8th line from the bottom on the left column, add "are" between "there" and "many." This results in: "… a *threshold* has been measured and there are many techniques used…"

Page 116
Right column, 3rd line down, "dimensions" is printed strangely.
Page 117
The two figures plotting the relationship between ΔC^*_{ab} or ΔH^*_{ab} and C^*_{ab}: the equations should be $S_C = 1.0 + 0.04C^*_{ab}$ and $S_H = 1.2 + 0.01C^*_{ab}$.

Page 121
The equation for CIE94 is missing a left parenthesis. The correct equation is:

$$\Delta E^*_{94} = \left[\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^*_{ab}}{k_H S_H}\right)^2\right]^{1/2}$$

$$S_L = 1$$

$$S_C = 1 + 0.045C^*_{ab}$$

$$S_H = 1 + 0.015C^*_{ab}$$

$$k_L = k_C = k_H = 1 \text{ for reference conditions}$$

$$C^*_{ab} = C^*_{ab,\text{standard}} \text{ or } \sqrt{C^*_{ab,1}C^*_{ab,2}}$$

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 ΔE_{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 142-2001Improvement to Industrial Color-Difference Evaluation. The specific mathematics are shown below:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H'_{ab}}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'_{ab}}{k_C S_C}\right)\left(\frac{\Delta H'_{ab}}{k_H S_H}\right)\right]^{1/2}$$

$$L' = L^*$$

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

$$b' = b^*$$

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

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

$$S_C = 1 + 0.045\bar{C}'$$

$$S_H = 1 + 0.015\bar{C}'T$$

$$\begin{aligned} T = 1 &- 0.17\cos(\bar{h}' - 30) \\ &+ 0.24\cos(2\bar{h}') \\ &+ 0.32\cos(3\bar{h}' + 6) \\ &- 0.20\cos(4\bar{h}' - 63) \end{aligned}$$

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

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

$$R_c = 2\left(\frac{\bar{C}'^7}{\bar{C}'^7 + 25^7}\right)^{1/2}$$

Page 125
Bottom figure: the y-axis legend should read "cumulative percentage of observations."

Page 130
Right column, 14th line from the bottom, "uisng" should be "using."

Page 157
Right column, 3rd line down: "Bouger" should be "Bouguer."

Page 159
Right column, sidebar: the first-surface correction from measured to internal transmittance has several typos. The correct equation is the following:

$$T_{\lambda,i} = \frac{-(1 - K_1)^2 + \left[(1 - K_1)^4 + 4K_1^2 T_{\lambda,m}^2\right]^{1/2}}{2K_1^2 T_{\lambda,m}}$$

Page 166
Right column, 5th line from the bottom: "c_y is 0.0185" should be "c_y is 0.185…"

Page 166 - 167
In the numerical example, I messed the handling of white. That is on page 166, white is subtracted from the unit k/s determination. On page 167, I didn't carry this through. Letting cw = 1 for the simultaneous equation calculation is wrong. The correct assumption is that $c_w = (1 - c_y - c_m)$. This leads to the following equations:

$$\left(\frac{K}{S}\right)_{\lambda,B} = (1 - c_y - c_m)\left(\frac{k}{s}\right)_{\lambda,w} + c_y\left(\frac{k}{s}\right)_{\lambda,y} + c_m\left(\frac{k}{s}\right)_{\lambda,m}$$

$$= \left(\frac{k}{s}\right)_{\lambda,w} - c_y\left(\frac{k}{s}\right)_{\lambda,w} - c_m\left(\frac{k}{s}\right)_{\lambda,w} + c_y\left(\frac{k}{s}\right)_{\lambda,y} + c_m\left(\frac{k}{s}\right)_{\lambda,m}$$

$$= \left(\frac{k}{s}\right)_{\lambda,w} + c_y\left[\left(\frac{k}{s}\right)_{\lambda,y} - \left(\frac{k}{s}\right)_{\lambda,w}\right] + c_m\left[\left(\frac{k}{s}\right)_{\lambda,m} - \left(\frac{k}{s}\right)_{\lambda,w}\right]$$

$$\left(\frac{K}{S}\right)_{\lambda,B} - \left(\frac{k}{s}\right)_{\lambda,w} = c_y\left[\left(\frac{k}{s}\right)_{\lambda,y} - \left(\frac{k}{s}\right)_{\lambda,w}\right] + c_m\left[\left(\frac{k}{s}\right)_{\lambda,m} - \left(\frac{k}{s}\right)_{\lambda,w}\right]$$

This leads to the following mixing equations:

Wavelength	Mixing equation
420 nm	$2.078 - 0.035 = c_y(7.538 - 0.035) + c_m(3.410 - 0.035)$
560 nm	$2.149 - 0.007 = c_y(0.018 - 0.007) + c_m(18.323 - 0.007)$

We leave it to the reader to confirm that $c_y = 0.2197$ and $c_m = 0.1168$. Recalling that we defined $c_w = (1 - c_y - c_m)$, the final percentages simply the concentrations multiplied by 100. Thus the recipe for the brown sample is 21.97% yellow, 11.68% magenta, and 66.35% white.

Page 169
Right column, 3rd line from the bottom: the b* equation is incorrect. The correct equation is:

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

Page 172
Left column, 21st line down: "the fact that fact they" should be "the fact that they"

Page 183
Right column, sidebar: the third colorant should have a concentration of 0.4:

$$c_1 = 0.2g \quad c_2 = 0.3g \quad c_3 = 0.4g \quad c_4 = 0.5g$$

Page 184
Left column, flowchart, bottom right-hand box: “Calulate” should be “Calculate.”

Page 208
In equation E-1, the conversion equation from reflectance to K/S is missing a square. The correct equation is:

$$\left(\frac{K}{S}\right)_{\lambda,\mathrm{mix}} = \left(\frac{k}{s}\right)_{\lambda,t} + c_1\left(\frac{k}{s}\right)_{\lambda,1} + c_2\left(\frac{k}{s}\right)_{\lambda,2} + c_3\left(\frac{k}{s}\right)_{\lambda,3}, \tag{E-1}$$

where

$$\left(\frac{K}{S}\right)_{\lambda} = \frac{\left(1-R_{\lambda,i}\right)^2}{2R_{\lambda,i}}.$$

Equation (E-4) has lower-case (k/s) for the unknown. These should be caps:

$$\begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} = \begin{bmatrix} \left(\frac{k}{s}\right)_{\lambda=1,1} & \left(\frac{k}{s}\right)_{\lambda=1,2} & \left(\frac{k}{s}\right)_{\lambda=1,3} \\ \left(\frac{k}{s}\right)_{\lambda=2,1} & \left(\frac{k}{s}\right)_{\lambda=2,2} & \left(\frac{k}{s}\right)_{\lambda=2,3} \\ \left(\frac{k}{s}\right)_{\lambda=3,1} & \left(\frac{k}{s}\right)_{\lambda=3,2} & \left(\frac{k}{s}\right)_{\lambda=3,3} \end{bmatrix}^{-1} \begin{bmatrix} \left(\frac{K}{S}\right)_{\lambda=1,\mathrm{unknown}} - \left(\frac{k}{s}\right)_{\lambda=1,t} \\ \left(\frac{K}{S}\right)_{\lambda=2,\mathrm{unknown}} - \left(\frac{k}{s}\right)_{\lambda=2,t} \\ \left(\frac{K}{S}\right)_{\lambda=3,\mathrm{unknown}} - \left(\frac{k}{s}\right)_{\lambda=3,t} \end{bmatrix}$$

Page 214
Right column, 2nd line, replace "illuminant" with "observer." That is, "… are defined for D65 and the selected observer."

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

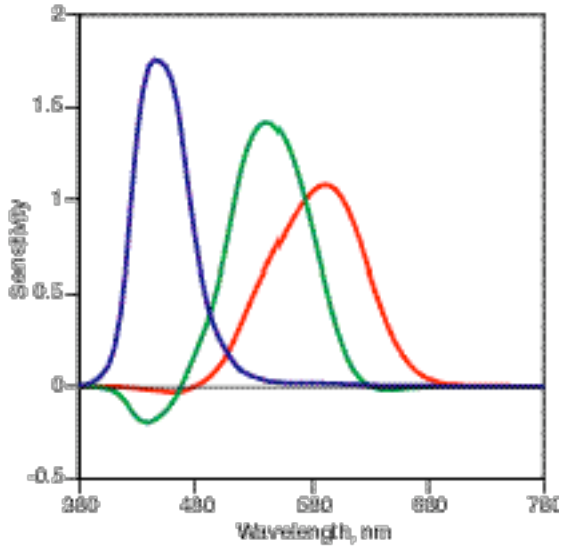
$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} = \begin{bmatrix} 0.98699 & -0.14705 & 0.15996 \\ 0.43231 & 0.51836 & 0.04929 \\ -0.00853 & 0.04004 & 0.96849 \end{bmatrix} \begin{bmatrix} R_cY \\ G_cY \\ B_cY \end{bmatrix}. \tag{F-9}$$

Pages 213 – 214
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:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \mathbf{M}_{CAT02} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \text{(F-7)}$$

$$\mathbf{M}_{CAT02} = \begin{bmatrix} 0.7328 & 0.4296 & -0.1624 \\ -0.7036 & 1.6975 & 0.0061 \\ 0.0030 & 0.0136 & 0.9834 \end{bmatrix}.$$

This leads to the following set of pseudocone fundamentals:



The von Kries adaptation transform is the following:

$$R_c = \frac{R_{D65}}{R_n} R$$

$$G_c = \frac{G_{D65}}{G_n} G. \qquad \text{(F-8)}$$

$$B_c = \frac{B_{D65}}{B_n^p} B$$

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

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} = \begin{bmatrix} 1.096124 & -0.278869 & 0.182745 \\ 0.454369 & 0.473533 & 0.072098 \\ -0.009628 & -0.005698 & 1.015326 \end{bmatrix} \begin{bmatrix} R_c \\ G_c \\ B_c \end{bmatrix}. \qquad \text{(F-9)}$$

Pages 218, 220, and 221

The ColorChecker sample between Red and Magenta should be Yellow, not Yellow green.

Page 218
Right-hand column: insert “is” between “as it” and “for the IBM” on line 1.

Page 219
Equation (G-10) has a typo. For the B channel, "3.27" should be "8.27":

$$R_{camera} = 3.81x10^{-4} d_r - 1.86x10^{-2}$$

$$G_{camera} = 3.82x10^{-4} d_g - 1.89x10^{-2}$$

$$B_{camera} = 8.27x10^{-4} d_b - 1.89x10^{-2}$$

Page 222
The sRGB equation, (G-16), needs to have each matrix element multiplied by 100. The error occurred because I forgot that in Eq. (G-13), the tristimulus values are divided by 100 in order to apply the Bradford chromatic adaptation transform. Normally, following this transformation, the corresponding-color tristimulus values are multiplied by 100 so that Y=100 for the white point. However, the sRGB matrix assumes tristimulus values scaled such that Y=1. The correct matrix is:

$$\begin{bmatrix} R_{display} \\ G_{display} \\ B_{display} \end{bmatrix} = \begin{bmatrix} 3.2410 & -1.5374 & -0.4986 \\ -0.9692 & 1.8760 & 0.0416 \\ 0.0556 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} \hat{X}_c \\ \hat{Y}_c \\ \hat{Z}_c \end{bmatrix}$$

Page 226
"R. Ashok" should be "A. Roy." (For obvious reasons, I thought his first name was Roy ☺)