see similar files: http://farbe.li.tu-berlin.de/CES2/CES2.HTM
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

TUB registration: 20220401-CES2/CES2L0NA.TXT /.PS
application for measurement of display output

TUB material: code=rha4ta

CIELAB 1976 $L^*a^*b^*$ color space definition and reversal

$L^* = 116\,(Y/Y_n)^{1/3} - 16$
$a^* = 500\,[\,(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\,]$
$b^* = 200\,[\,(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\,]$

$X = X_n\,[\,(L^* + 16)/116 + a^*/500\,]^3$
$Y = Y_n\,[\,(L^* + 16)/116\,]^3$
$Z = Z_n\,[\,(L^* + 16)/116 - b^*/200\,]^3$

CES20−1N

Q-function changes; transition from light- to color metrics

scaling function of **light metrics:**
$\boldsymbol{Q\,[k(x-u)]} = Q[k(\log L - \log L_u)]$
$\log L \to \log P$ **for color metrics:**
$Q[k(\log P - \log L_u)]$
$= Q[k(\log L - \log L_u + \log P - \log L)]$
with saturation $p = \log P - \log L$
for color metrics: $\boldsymbol{Q\,[k(x-u+p)]}$

CES20−2N

CIELAB 1976 $L^*a^*b^*$ color space and CIELAB$_u$ 2022 $L^{*u}\,a^{*u}\,b^{*u}$ color space

$L^* = 116\,(Y/Y_n)^{1/3} - 16$ $\quad [Y/Y_n]^{1/3} > 24/116$
$a^* = 500\,[\,(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\,]$ $\quad Y > 0{,}885$
$b^* = 200\,[\,(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\,]$

$L^{*u} = 116\,c_u\,(Y/Y_u)^{1/3} - 16 = L^* - 0{,}49$ $\quad Y_u = 18$
$a^{*u} = 500\,c_u\,[\,(X/X_u)^{1/3} - (Y/Y_u)^{1/3}\,] = a^*$
$b^{*u} = 200\,c_u\,[\,(Y/Y_u)^{1/3} - (Z/Z_u)^{1/3}\,] = b^*$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES21−1N

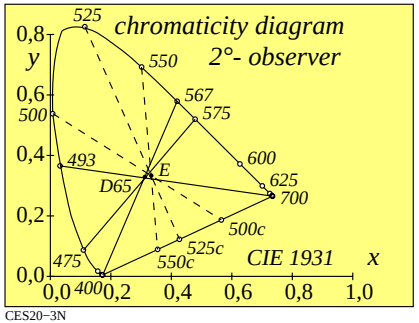
CIELAB 1976 $L^*a^*b^*$ color space and CIELAB$_v$ 2022 $L^{*v}\,a^{*v}\,b^{*v}$ color space

$L^* = 116\,(Y/Y_n)^{1/3} - 16$ $\quad [Y/Y_n]^{1/3} > 24/116$
$a^* = 500\,[\,(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\,]$ $\quad Y > 0{,}885$
$b^* = 200\,[\,(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\,]$

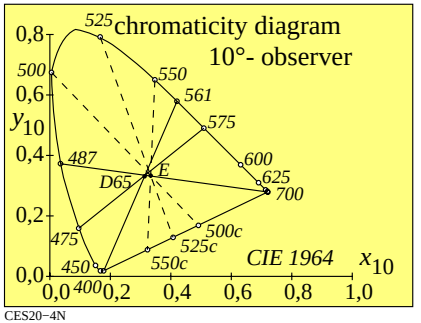
$L^{*v} = 116\,c_v\,(Y/Y_v)^{1/3} - 16 = L^*$ $\quad Y_v = 18{,}41$
$a^{*v} = 500\,c_v\,[\,(X/X_v)^{1/3} - (Y/Y_v)^{1/3}\,] = a^*$
$b^{*v} = 200\,c_v\,[\,(Y/Y_v)^{1/3} - (Z/Z_v)^{1/3}\,] = b^*$

$c_v = [Y_v/Y_n]^{1/3} = 0{,}1841^{1/3} = 0{,}5689$, similar for X, Z
$v_L = 116c_v = 66$, $v_a = 500c_v = 284{,}56$, $v_b = 200c_v = 113{,}78$

CES21−2N



CES20−3N



CES20−4N

CIELAB$_u$ 2022 $L^{*u}\,a^{*u}\,b^{*u}$ color space

definition and reversal $(X_u/X_n = Y_u/Y_n = Z_u/Z_n = 0{,}18)$

$L^{*u} = 116\,c_u\,(Y/Y_u)^{1/3} - 16 = L^*_{CIELAB} - 0{,}49$
$a^{*u} = 500\,c_u\,[(X/X_u)^{1/3} - (Y/Y_u)^{1/3}] = a^*_{CIELAB}$
$b^{*u} = 200\,c_u\,[(Y/Y_u)^{1/3} - (Z/Z_u)^{1/3}] = b^*_{CIELAB}$

$X = X_u[\,(L^{*u} + 16)/(116c_u) + a^{*u}/(500c_u)]^3$
$Y = Y_u[\,(L^{*u} + 16)/(116c_u)]^3$ $\quad Y_u = 18$
$Z = Z_u[\,(L^{*u} + 16)/(116c_u) - b^{*u}/(200c_u)]^3$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES21−3N

CIELAB$_v$ 2022 $L^{*v}\,a^{*v}\,b^{*v}$ color space

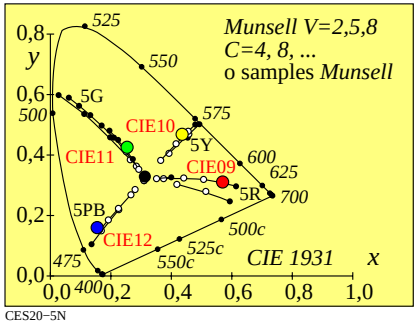
definition and reversal $(X_v/X_n = Y_v/Y_n = Z_v/Z_n = 0{,}1841)$

$L^{*v} = 116\,c_v\,(Y/Y_v)^{1/3} - 16 = L^*_{CIELAB}$
$a^{*v} = 500\,c_v\,[(X/X_v)^{1/3} - (Y/Y_v)^{1/3}] = a^*_{CIELAB}$
$b^{*v} = 200\,c_v\,[(Y/Y_v)^{1/3} - (Z/Z_v)^{1/3}] = b^*_{CIELAB}$

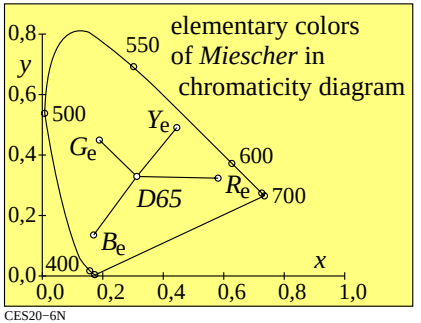
$X = X_v[\,(L^{*v} + 16)/(116c_v) + a^{*v}/(500c_v)]^3$
$Y = Y_v[\,(L^{*v} + 16)/(116c_v)]^3$ $\quad Y_v = 18{,}41$
$Z = Z_v[\,(L^{*v} + 16)/(116c_v) - b^{*v}/(200c_v)]^3$

$c_v = [Y_v/Y_n]^{1/3} = 0{,}1841^{1/3} = 0{,}5689$, similar for X, Z
$v_L = 116c_v = 66$, $v_a = 500c_v = 284{,}56$, $v_b = 200c_v = 113{,}78$

CES21−4N



CES20−5N



CES20−6N

CIELAB$_u$ 2022 $L^{*u}\,a^{*u}\,b^{*u}$ color space

definition and reversal $(X_u/X_n = Y_u/Y_n = Z_u/Z_n = 0{,}18)$

$L^{*u} = u_L\,(Y/Y_u)^{1/3} - 16 = L^*_{CIELAB} - 0{,}49$
$a^{*u} = u_a\,[(X/X_u)^{1/3} - (Y/Y_u)^{1/3}] = a^*_{CIELAB}$
$b^{*u} = u_b\,[(Y/Y_u)^{1/3} - (Z/Z_u)^{1/3}] = b^*_{CIELAB}$

$X = X_u[\,(L^{*u} + 16)/u_L + a^{*u}/u_a]^3$
$Y = Y_u[\,(L^{*u} + 16)/u_L]^3$ $\quad Y_u = 18$
$Z = Z_u[\,(L^{*u} + 16)/u_L - b^{*u}/u_b]^3$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES21−5N

CIELAB$_v$ 2022 $L^{*v}\,a^{*v}\,b^{*v}$ color space

definition and reversal $(X_v/X_n = Y_v/Y_n = Z_v/Z_n = 0{,}1841)$

$L^{*v} = v_L\,(Y/Y_v)^{1/3} - 16 = L^*_{CIELAB}$
$a^{*v} = v_a\,[(X/X_v)^{1/3} - (Y/Y_v)^{1/3}] = a^*_{CIELAB}$
$b^{*v} = v_b\,[(Y/Y_v)^{1/3} - (Z/Z_v)^{1/3}] = b^*_{CIELAB}$

$X = X_v[\,(L^{*v} + 16)/v_L + a^{*v}/v_a]^3$
$Y = Y_v[\,(L^{*v} + 16)/v_L]^3$ $\quad Y_v = 18{,}41$
$Z = Z_v[\,(L^{*v} + 16)/v_L - b^{*v}/v_b]^3$

$c_v = [Y_v/Y_n]^{1/3} = 0{,}1841^{1/3} = 0{,}5689$, similar for X, Z
$v_L = 116c_v = 66$, $v_a = 500c_v = 284{,}56$, $v_b = 200c_v = 113{,}78$

CES21−6N

CIELAB 1976 $L^*a^*b^*$ color space

definition and derivation $(X_u/X_n = Y_u/Y_n = Z_u/Z_n = 0{,}18)$

$L^* = 116\,(Y/Y_n)^{1/3} - 16$ $\quad [Y/Y_n]^{1/3} > 24/116$
$a^* = 500\,[\,(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\,]$ $\quad Y > 0{,}885$
$b^* = 200\,[\,(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\,]$

$dL^*/dY = 116\,[(Y/Y_n)^{-2/3}/(3Y_n)]$ $\quad Y_n = 100$
$da^*/dY = 500\,[(X/X_n)^{-2/3}/(3X_n) - (Y/Y_n)^{-2/3}/(3Y_n)]$
$db^*/dY = 200\,[(Y/Y_n)^{-2/3}/(3X_n) - (Z/Z_n)^{-2/3}/(3Z_n)]$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES20−7N

CIELAB$_u$ 2022 $L^{*u}\,a^{*u}\,b^{*u}$ color space

definition and derivation $(X_u/X_n = Y_u/Y_n = Z_u/Z_n = 0{,}18)$

$L^{*u} = 65{,}51\,(Y/Y_u)^{1/3} - 16 = L^*_{CIELAB} - 0{,}49$
$a^{*u} = 282{,}35\,[(X/X_u)^{1/3} - (Y/Y_u)^{1/3}] = a^*_{CIELAB}$
$b^{*u} = 112{,}94\,[(Y/Y_u)^{1/3} - (Z/Z_u)^{1/3}] = b^*_{CIELAB}$

$dL^{*u}/dY = 65{,}51\,[(Y/Y_u)^{-2/3}/(3Y_u)]$ $\quad Y_u = 18$
$da^{*u}/dY = 284{,}56\,[(X/X_u)^{-2/3}/(3X_u) - (Y/Y_u)^{-2/3}/(3Y_u)]$
$db^{*u}/dY = 113{,}78\,[(Y/Y_u)^{-2/3}/(3X_u) - (Z/Z_u)^{-2/3}/(3Z_u)]$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES20−8N

CIELAB$_u$ 2022 $L^{*u}\,a^{*u}\,b^{*u}$ color space

definition and reversal $(X_u/X_n = Y_u/Y_n = Z_u/Z_n = 0{,}18)$

$L^{*u} = 65{,}51\,(Y/Y_u)^{1/3} - 16 = L^*_{CIELAB} - 0{,}49$
$a^{*u} = 282{,}35\,[(X/X_u)^{1/3} - (Y/Y_u)^{1/3}] = a^*_{CIELAB}$
$b^{*u} = 112{,}94\,[(Y/Y_u)^{1/3} - (Z/Z_u)^{1/3}] = b^*_{CIELAB}$

$X = X_u[\,(L^{*u} + 16)/65{,}51 + a^{*u}/282{,}35]^3$
$Y = Y_u[\,(L^{*u} + 16)/65{,}51]^3$ $\quad Y_u = 18$
$Z = Z_u[\,(L^{*u} + 16)/65{,}51 - b^{*u}/112{,}94]^3$

$c_u = [Y_u/Y_n]^{1/3} = 0{,}18^{1/3} = 0{,}5647$, similar for X, Z
$u_L = 116c_u = 65{,}51$, $u_a = 500c_u = 282{,}35$, $u_b = 200c_u = 112{,}94$

CES21−7N

CIELAB$_v$ 2022 $L^{*v}\,a^{*v}\,b^{*v}$ color space

definition and reversal $(X_v/X_n = Y_v/Y_n = Z_v/Z_n = 0{,}1841)$

$L^{*v} = 66\,(Y/Y_v)^{1/3} - 16 = L^*_{CIELAB}$
$a^{*v} = 284{,}56\,[(X/X_v)^{1/3} - (Y/Y_v)^{1/3}] = a^*_{CIELAB}$
$b^{*v} = 113{,}78\,[(Y/Y_v)^{1/3} - (Z/Z_v)^{1/3}] = b^*_{CIELAB}$

$X = X_v[\,(L^{*v} + 16)/66 + a^{*v}/284{,}56]^3$
$Y = Y_v[\,(L^{*v} + 16)/66]^3$ $\quad Y_v = 18{,}41$
$Z = Z_v[\,(L^{*v} + 16)/66 - b^{*v}/113{,}78]^3$

$c_v = [Y_v/Y_n]^{1/3} = 0{,}1841^{1/3} = 0{,}5689$, similar for X, Z
$v_L = 116c_v = 66$, $v_a = 500c_v = 284{,}56$, $v_b = 200c_v = 113{,}78$

CES21−8N