

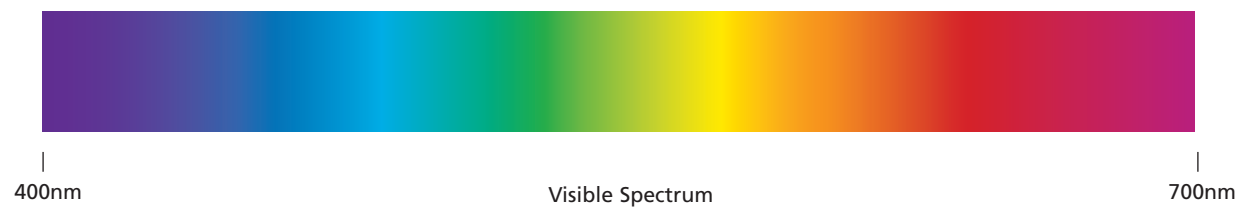


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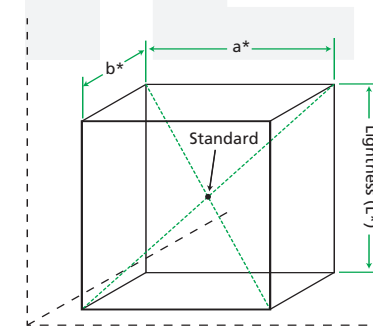
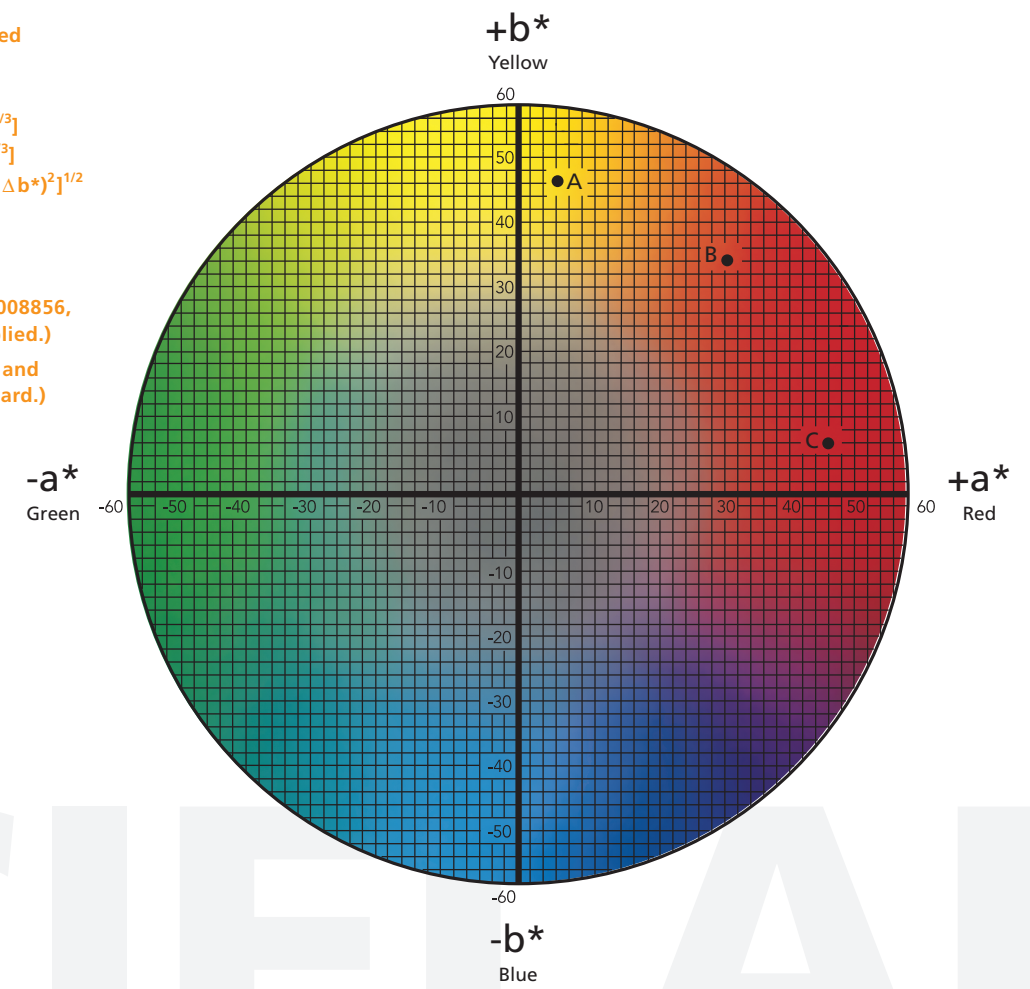
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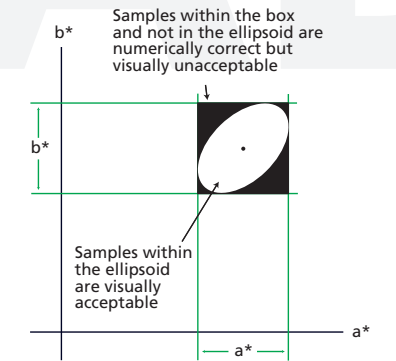
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CIELAB Tolerancing

CIELAB tolerancing uses rectangular coordinates based on the following formulas:
 $L^* = 116(Y/Y_n)^{1/3} - 16$
 $a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$
 $b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$
 $\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$
 $\Delta L^* = L^*_t - L^*_s$
 $\Delta a^* = a^*_t - a^*_s$
 $\Delta b^* = b^*_t - b^*_s$
 (If $X/X_n, Y/Y_n$ or Z/Z_n is $\leq .008856$, modified formulas are applied.)
 (Subscript T indicates trial and subscript S indicates standard.)



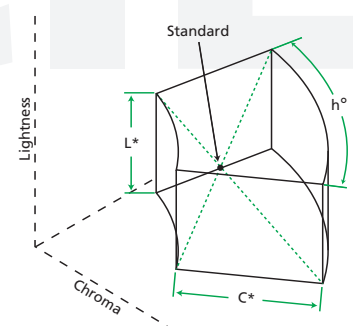
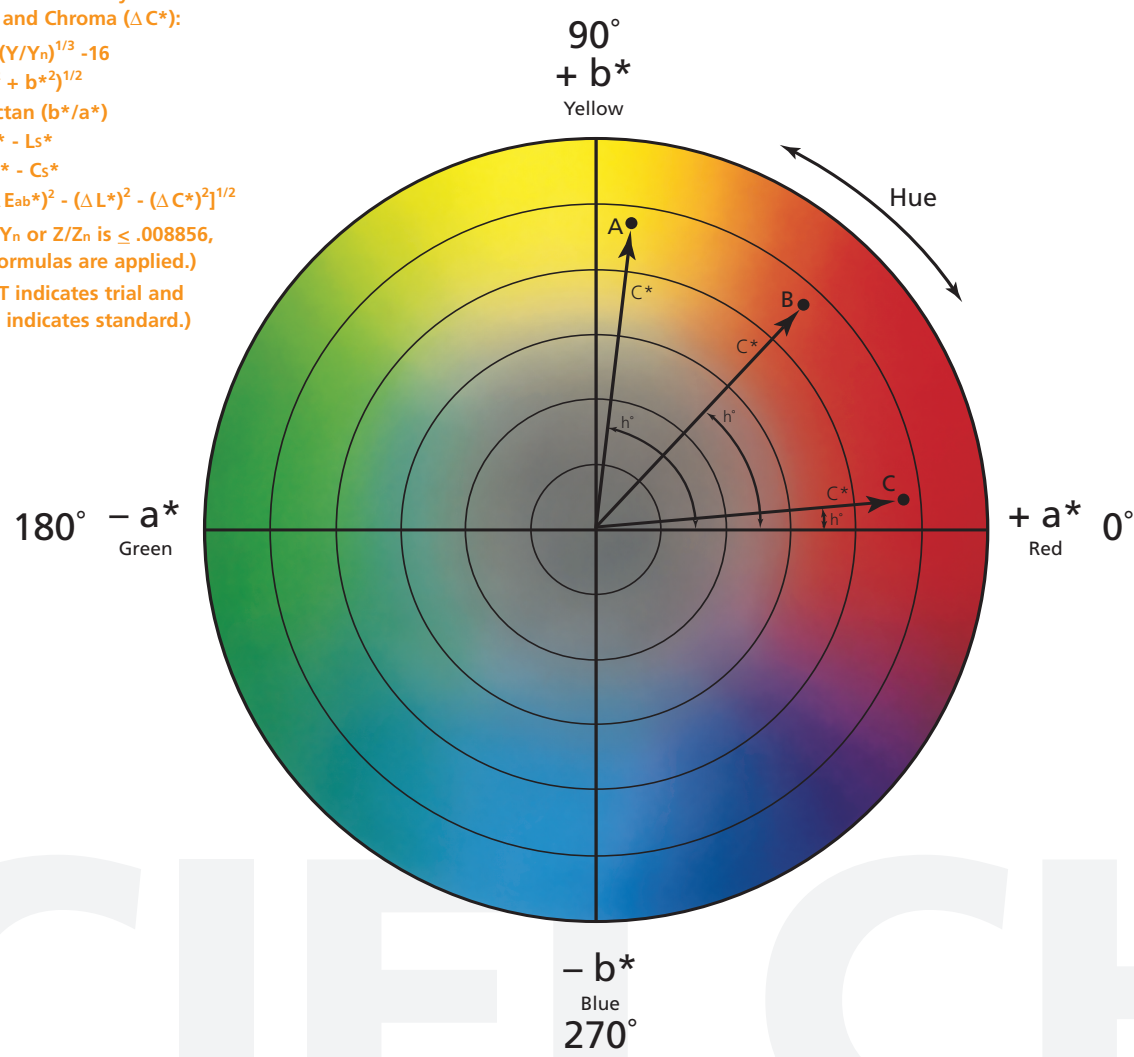
CIELAB tolerance box



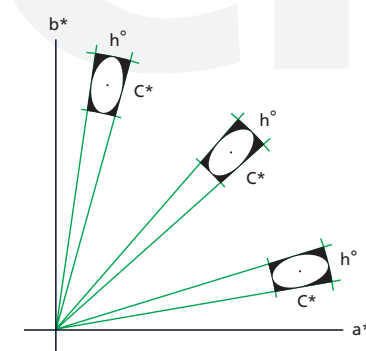
Numerically correct vs. visually acceptable

CIELCH Tolerancing

CIELCH tolerancing uses polar coordinates to give direct numerical color differences as they relate to Hue (ΔH^*) and Chroma (ΔC^*):
 $L^* = 116(Y/Y_n)^{1/3} - 16$
 $C^* = (a^{*2} + b^{*2})^{1/2}$
 $h^{\circ} = \arctan(b^*/a^*)$
 $\Delta L^* = L^*_t - L^*_s$
 $\Delta C^* = C^*_t - C^*_s$
 $\Delta H^* = [(\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*)^2]^{1/2}$
 (If $X/X_n, Y/Y_n$ or Z/Z_n is $\leq .008856$, modified formulas are applied.)
 (Subscript T indicates trial and subscript S indicates standard.)



CIELCH tolerance wedge



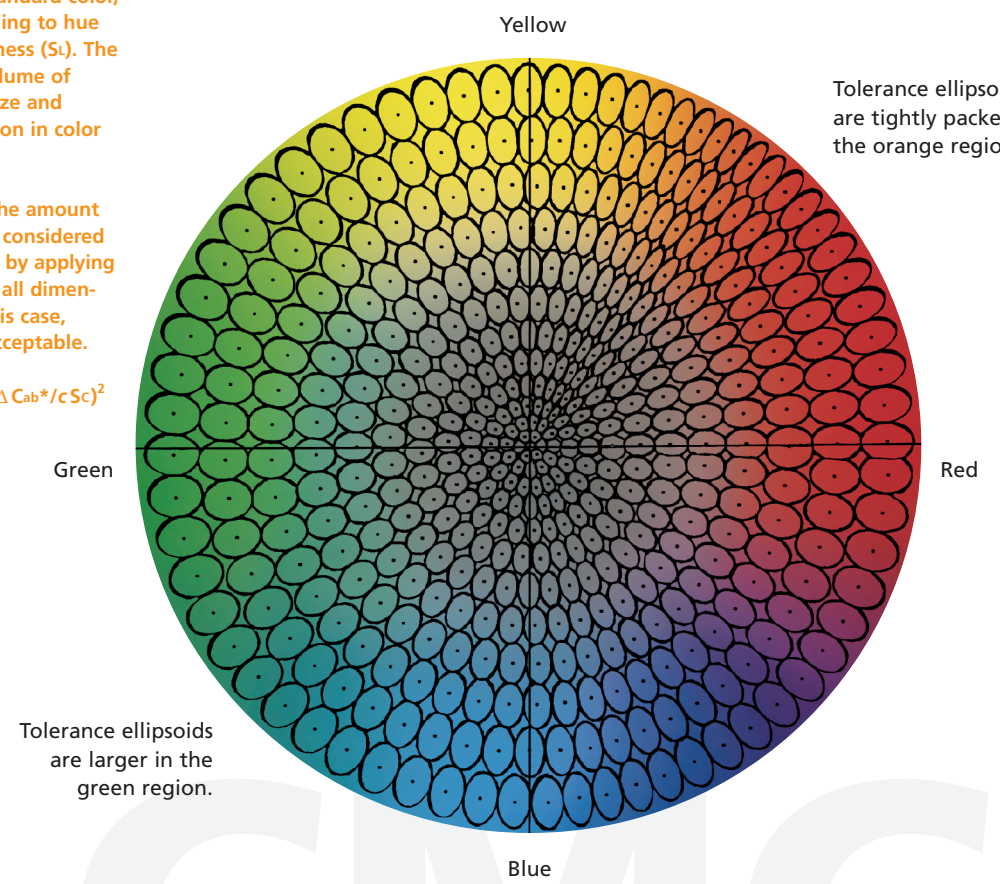
CIELCH tolerance vs. visually acceptable

CMC Tolerancing

CMC tolerancing is a modification of CIELCH which provides better agreement between visual assessment and instrumentally measured color difference. The CMC ΔE calculation defines an ellipsoid, around the standard color, with semi-axes corresponding to hue (S_H), chroma (S_C) and lightness (S_L). The ellipsoid represents the volume of acceptance and varies in size and shape depending on position in color space.

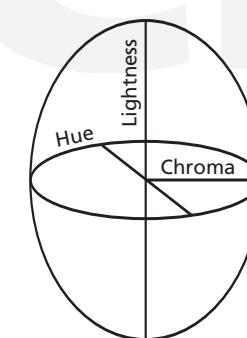
In commercial situations, the amount of color differences that is considered acceptable is accounted for by applying a commercial factor (cf) to all dimensions of the ellipsoid. In this case, $\Delta E_{CMC} \leq cf$ is considered acceptable.

$$\Delta E_{CMC} = [(\Delta L^*/S_L)^2 + (\Delta C^*/S_C)^2 + (\Delta H^*/S_H)^2]^{1/2}$$

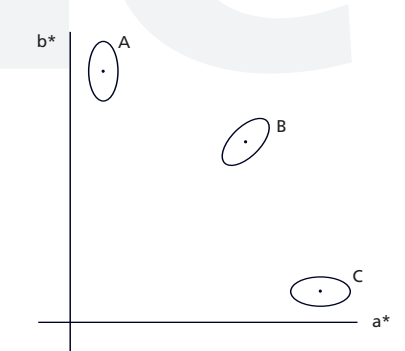


Tolerance ellipsoids are tightly packed in the orange region.

Tolerance ellipsoids are larger in the green region.



Tolerance ellipsoid



ΔE_{CMC} tolerance vs. visually acceptable