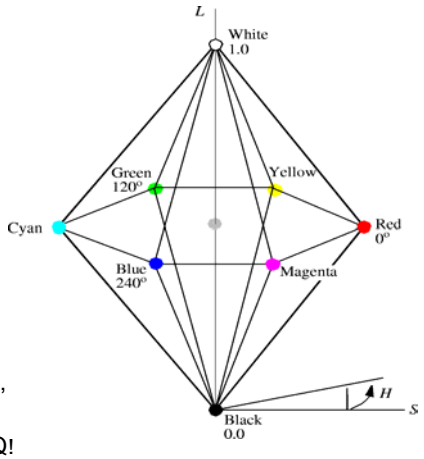
The HLS color Model

- Hue, lightness, saturation
- Double-hexcone subset



- Maximally saturated hues are at S = 1,
- Less attractive for sliders or dials
- Neither V nor L correspond to Y in YIQ!
- Conceptually easier for some people to view white as a point

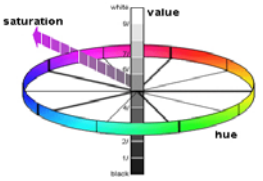
Problems with Standard Color Systems

- They are perceptually non-uniform
  - move through color space from color C_1 to a new color C_1' through a distance ΔC
    $C_1' = C_1 + \Delta C$
  - move through the same distance ΔC, starting from a different color C_2
    $C_2' = C_2 + \Delta C$
  - the change in color in both cases is mathematically equal,
    but is not perceived as equal!
- Interpolation, e.g., by moving a slider almost always causes a perceptual change in the other two parameters, which is not reflected by changes in those sliders; thus, changing hue frequently will affect saturation and value (even in Photoshop)!
- Ideally want a perceptually uniform space:
  - two colors that are equally distant are perceived as equally distant, and changing one parameter does not perceptually alter the other two
- Historically, the first perceptually-uniform color space was the Munsell system

The Munsell System

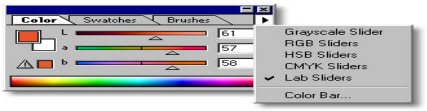
- Created from perceptual data, not as a transformation of or approximation to CIE
- Uniform perceptually-based 3D space
  - accounts for the fact that a bright yellow is much lighter than a bright blue, and that many more levels of saturation of blue can be distinguished than of yellow
- Magnitude of change in one parameter always maps to the same effect on perception

- Hues arranged on a circle
  - a 20 degree rotation through this circle always causes the same perceptual change, no matter where on the circle you start from
  - does not cause changes in saturation or value
- Saturation as distance from center of circle
  - moving away from the center a certain distance always causes the same perceptual change
  - does not cause changes in hue or value
- Value as height in space
  - moving vertically always causes the same perceptual change
  - does not cause changes in hue or saturation



CIE Lab

- CIE Lab was introduced in 1976
  - popular for use in measuring reflective and transmissive objects
- Three components:
  - L^* is luminosity
  - a^* is red/green axis
  - b^* is yellow/blue axis



- Mathematically described space and a perceptually uniform color space
- Given white = (X_n, Y_n, Z_n)

$$L^* = 116\ (Y / Y_n)^{1/3} - 16 \text{ , when } Y / Y_n > 0.008856$$
$$L^* = 903.292\ (Y / Y_n) \text{ when } Y / Y_n \leq 0.008856$$
$$a^* = 500\ (f(X / X_n) - f(Z / Z_n))$$
$$b^* = 200\ (f(X / X_n) - f(Z / Z_n))$$

$$\text{where } f(t) = t^{1/3} \text{ when } Y / Y_n > 0.008856$$
$$\text{else } f(t) = 7.787\ t + 16 / 116$$

- These transformations cause regions of colors perceived as identical to be of the same size

Color Model Pros and Cons

- RGB
  + Cartesian coordinate system
  + linear
  + hardware-based (easy to transform to video)
  + tristimulus-based
  - hard to use to pick and name colors
  - doesn't cover gamut of perceivable colors
  - non-uniform: equal geometric distance => unequal perceptual distance

- CIE
  + covers gamut of perceived colors
  + based on human perception (matching experiments)
  + linear
  + contains all other spaces
  - non-uniform (but variations such as CIE Lab are closer to Munsell, which is uniform)
  - xy-plot of chromaticity horseshoe diagram doesn't show luminance

Color Model Pros and Cons

- (CIE cont.) Example: Photoshop Lab color model is based on CIE Lab space
  + based on psychological colors (y-b, r-g, w-b)
  - terrible interface in Photoshop
    - no visualization of the color space
    - very difficult to determine what values mean if you are unfamiliar with the space
    - picks colors which are out of the print gamut
  - primarily used as an internal space to convert between RGB and CMYK

- HSV
  + easy to convert to RGB
  + easy to specify colors
  - nonlinear
  - doesn't cover gamut of perceivable colors
  - nonuniform