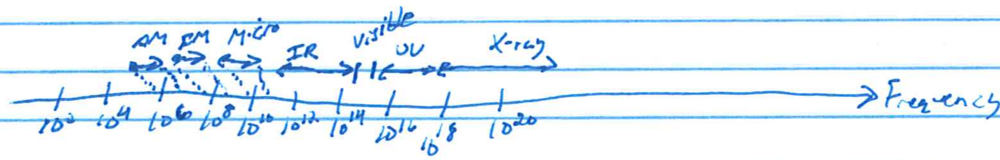
Lecture 09 - Color Models (Chapter 19)

I. Introduction - so far we have been limited to RGB selection of colors. However, this has issues. (1) it is not great for non electronic medium, (2) it isn't natural to specify

A. Properties of light

i. Light is radient energy often described as a wave

ii. The frequency of the wave describes its "color"



"red" $\approx 3.8 \times 10^{14}$ hz "violet" $\approx 7.9 \times 10^{14}$ hz

iii. Wavelength is distance traveled between oscillations of a wave. It more conveniently describes color, but is material dependent.

In a vacuum - "red" is about 380 nm "violet" is 780 nm

iv. For an object, materials absorb some frequences and reflect others. What we percieve as an objects color is the combination of frequencies in the reflection. "hue" is the dominent frequency of the percieved color.

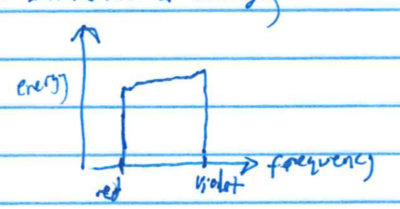
B. Psychological Characteristics of color - other sensations

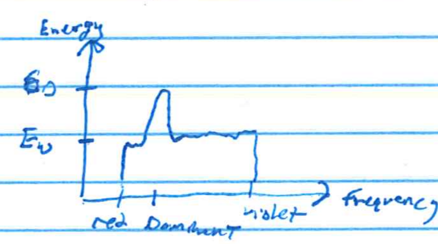
i. Brightness - total light energy or luminance of the light

ii. Purity or Saturation - proximity to a pure hue. Eg. Pastel colors have low purity/saturation and appear nearly "white"

iii. Chromaticity collectively refers to purity and hue.

iv. In terms of energy





E_D - energy of dominant frequency

E_W - energy of white light component (other frequencies)

White light

Hue ⇒ Dominant Frequency

Brightness ⇒ area under the curve

Purity ⇒ $E_D - E_W$

C. Color models - method for explaining properties or behavior of color. No model is perfect.

i. Mix primary colors. Color Gamut is expressiveness of color model

ii. Two primary colors that combine to white light are complementary colors.

iii. No set of primary colors can express all colors - 3 sufficient for most purposes

iv. Artists add black or white to pigments (pure colors). Shades are created by adding black, while tints are from white. Tones are added white and black.

D. Standard Color Primaries and the Chromaticity Diagram

i. 3 standard primaries were defined in 1931 by CIE (Commission Internationale de l'Eclairage). They are entirely imaginary and defined mathematically.

ii. XYZ color model - derived by amounts of imaginary colors mixed together just like RGB color model.

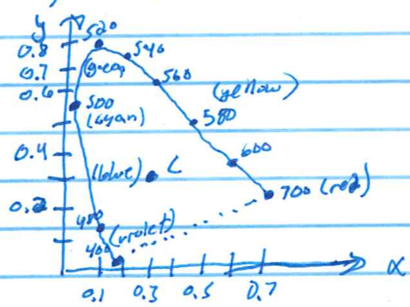
iii. Normalized XYZ values - easier to express

$$x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z} \quad \text{where } x+y+z = 1$$

So we only need x, y to define a color. Usually with a luminance (brightness factor) Y

$$X = \frac{x}{y}Y \quad Z = \frac{z}{y}Y \quad \text{where } z = 1-x-y$$

iv. CIE Chromaticity Diagram - plot of x, y values from normalized XYZ model



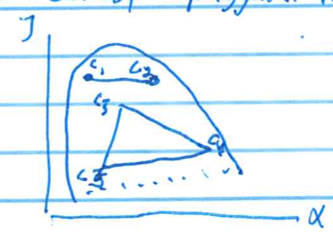
--- purple line (not part of spectrum)

C white light position (illuminant C)

- complementary colors are on opposite sides of C and collinear. *show example*

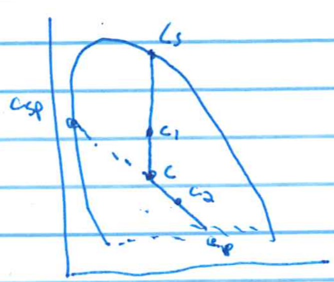
Useful for comparing color gamut.

v. Color Gamut - polygonal region of chromaticity diagram



compare gamuts of 2 color system vs 3 color system.

vi. Dominant wave length - draw straight line from C to chromaticity curve if point ends on purple line look at complement of Cp (can't on purple line)



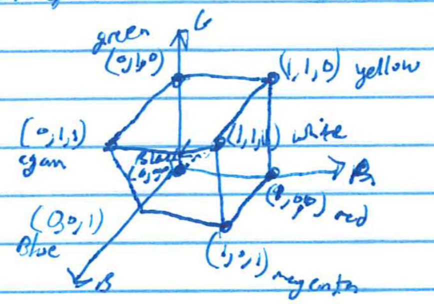
vii. Purity - distance of color from C / distance of spectral color to C

purity of 100% is a spectral color.

II. The RGB color model – for emitting devices (emitting – additive process)

A. One theory of vision states we perceive a combination of 3 colors – red, green, blue
This is basis for electronics being in RGB.

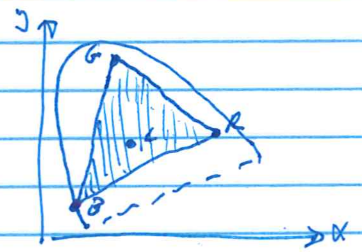
B. Can represent as unit cube on R, G, B axis



– Color is weighted sum of color components. (vectors)

.... – greys

C. Color gamut

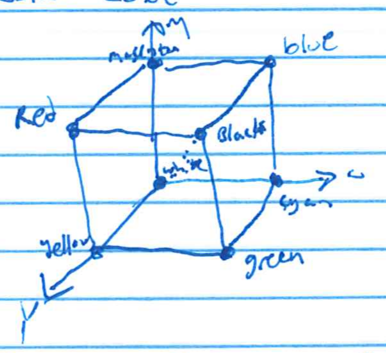


R is ~(0.67, 0.33) in x,y
G is ~(0.21, 0.71) in x,y
B is ~(0.14, 0.08) in x,y

III. CMY + CMYK – for output devices w/ physical pigments (viewing – subtracting process), e.g. Printer

A. Cyan, Magenta, Yellow K is black component for purity

B. Color cube



.... greys

C. Conversion between RGB and CMY(K)

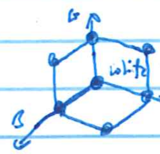
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

To CMYK: set K = max(R, G, B) and subtract out of C, M, Y
other way: K is min(C, M, Y) and subtract out of R, G, B

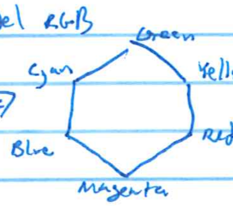
IV. HSV color ~~value~~ model – Intuitive for artists.

A. Hue, Saturation, Value

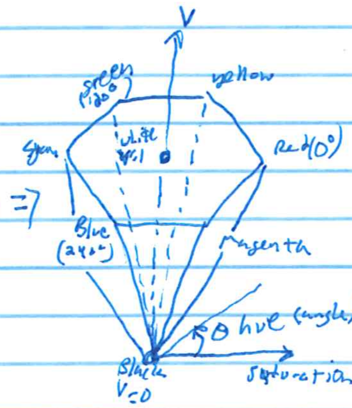
i. In relation to color model RGB



Forms Hexagon. ⇒



in 3D a hexagonal cone ⇒



So

ii. Hue – H – angle about cone

iii. Saturation – S distance from center. Designates purity. Allows adding tints to colors

iv. Value – V – 0 is apex of cone black, 1 is top white. Allows adding shades to colors

So adding shade is modifying V, adding tint is modifying S.

V. Other models –

A. HLS – Hue Lightness Saturation. Similar to HSV but double cone instead.

B. YIQ – For sending color as a signal. Y is from XYZ, I – In-phase (Orange/Cyan), Q – Quadrature (Green/Magenta)