Color

Light and color

- Spectra
- Radiometry, photometry, colorimetry

Trichromatic color matching

- Grassman's laws
- Color coordinates
- Human color vision

Computer representations of color

- RGB
- HSV, HSB, HSL
- CMYK

Spectrum

The electromagnetic spectrum

Three example spectra

Measuring Light and Color

Radiometry

- **The amount of *power* per wavelength interval [Watts].**

Photometry

- **The relative brightness of a light source (color or black/white) when compared to a standard candle [Candela].**
- **Uniform perceptual brightness scale [Brills].**

Colorimetry

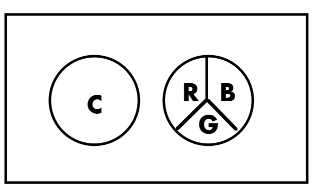
- **The color coordinates of a color source as determined by color matching [CIE XYZ].**

Color Matching

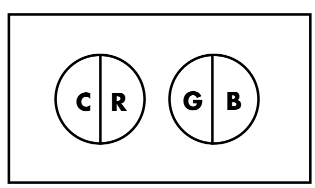
Adjust brightness of 3 primaries to "match" color

C - color to be matched

RGB - laser sources (R=700 nm, G=546 nm, B=435 nm)



C = R + G + B



C + R = G + B

Therefore: *humans have trichromatic color vision*

Human Color Vision

- **There are 3 light sensitive pigments in your cones (L,M,N), each with a different *spectral response curve***

$$R = \int r(\lambda)S(\lambda)d\lambda$$

$$G = \int g(\lambda)S(\lambda)d\lambda$$

$$B = \int b(\lambda)S(\lambda)d\lambda$$

- **Biological basis of color blindness - genetic disease**
  - **deuternopia - no r**
  - **protanopis - no g**
  - **tritanopis - no b**

Grassman's Laws

Color matching is linear!

1. Scaling the color and the primaries by the same factor preserves the match

2. To match a color formed by adding two colors, add the primaries for each color

Therefore: 3x3 linear transformation between color spaces, e.g. RGB and LMN and monitor

Spectral Matching Functions

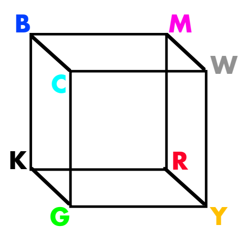
Spectral matching curves

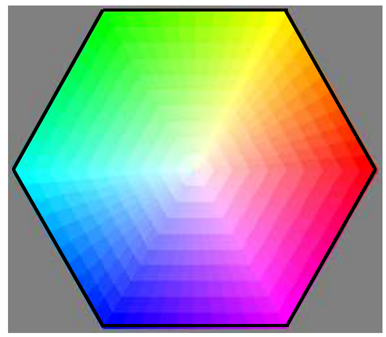
Match each pure color in the visible spectrum (rainbow), and record the color coordinates as a function of wavelength

CIE Diagrams

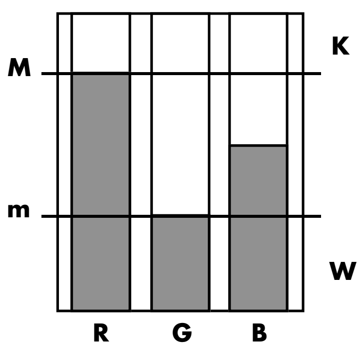
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 2.77 & 1.75 & 1.13 \\ 1.00 & 4.59 & 0.06 \\ 0.00 & 0.57 & 5.59 \end{bmatrix} \begin{bmatrix} R_\lambda \\ G_\lambda \\ B_\lambda \end{bmatrix}$$

Color Spaces





HSV and HSL



M=max(R,G,B), m=min(R,G,B)

r=(M-R)/(M-m)

g=(M-G)/(M-m)

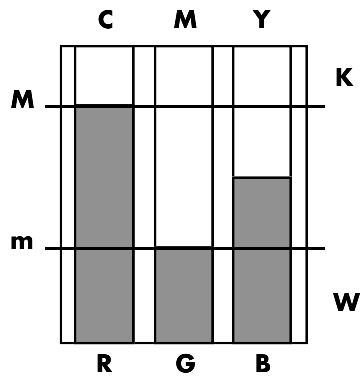
b=(M-B)/(M-m)

if(M==R) H=(6+b-g)/6

....

HSL	HSV
L=(M+m)/2	V=M
S=(M-m)/(M+m)	S=(M-m)/M

CMYK



$R = (1\text{-}C)\ (1\text{-}K)\ W$

$G = (1\text{-}M)\ (1\text{-}K)\ W$

$B = (1\text{-}Y)\ (1\text{-}K)\ W$

$K = G(1-\max(R,G,B))$

$C = 1 - R/(1\text{-}K)$

$M = 1 - G/(1\text{-}K)$

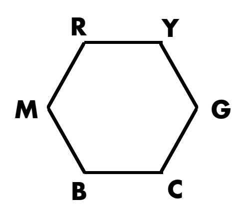
$Y = 1 - B/(1\text{-}K)$

Color Wheels

Additive

Primaries: R, G, B

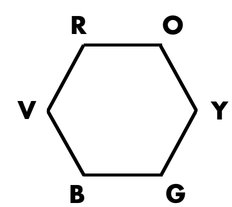
Secondaries: C, M, Y



Subtractive

Primaries: R, Y, B

Secondaries: G, V, O



Pigment mixing??