COLOR THEORY
Is color a constant characteristic?
The Electromagnetic Spectrum

Light wave

\[ \lambda = \text{wave length} \]
\[ E = \text{amplitude of electric field} \]
\[ M = \text{amplitude of magnetic field} \]
The Electromagnetic Spectrum

Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray

About the size of:
Buildings
Grains of Sugar
Protozoans
Bacteria
Molecules
Atoms
Atomic Nuclei

Wavelength in meters
Color Characteristics

- **Brightness**
  - The total light energy

- **Hue**
  - Dominant frequency

- **Saturation/Purity**
  - Closeness to pure spectral color
Color Characteristics

\[ E_D \]

\[ E_W \]

Energy

Frequency

\[ f_D \]

Red

Violet
Color Characteristics
Color Models

- Primary Colors
- Intuitive Color Concepts
Human cones
Chromaticity Diagram

CIE 1931

Graph showing the spectral distribution of X, Y, and Z color sensitivity functions.
Chromaticity Diagram

$I(\lambda)$
Chromaticity Diagram

\[ X = k \int_{\text{visible} \lambda} f_X(\lambda)I(\lambda) \, d\lambda \]

\[ Y = k \int_{\text{visible} \lambda} f_Y(\lambda)I(\lambda) \, d\lambda \]

\[ Z = k \int_{\text{visible} \lambda} f_Z(\lambda)I(\lambda) \, d\lambda \]

\[ k=683 \text{ lumen/watt} \]
Chromaticity Diagram

\[ x = \frac{X}{X + Y + Z} \]

\[ y = \frac{Y}{X + Y + Z} \]

\[ z = \frac{Z}{X + Y + Z} \]

\[ x + y + z = 1 \]
Chromaticity Diagram

- White color
- Complementary colors
- Color gamut
- Dominant wavelength
- Purity $= \frac{d_1}{d_1 + d_2}$
- Ideal colors
Chromaticity Diagram

Ideal Green

Ideal Blue  Ideal Red
Additive Colors

- Given 3 colors:

\[ S_1 = (x_1, y_1), \quad S_2 = (x_2, y_2), \quad S_3 = (x_3, y_3) \]

Their additive color \( S = (x, y) \) is defined by:

\[
\begin{pmatrix}
1 & 1 & 1 \\
1/y_1 & 1/y_2 & 1/y_3 \\
x_1/y_1 & x_2/y_2 & x_3/y_3
\end{pmatrix}
\begin{pmatrix}
Y_1 \\
Y_2 \\
Y_3
\end{pmatrix}
= 
\begin{pmatrix}
Y \\
Y/y \\
x/y \cdot Y
\end{pmatrix}
\]
RGB Color Model

- Red, Green and Blue are primaries
- Diagonal represents grey colors
The CIE RGB color space

- Monochromatic R, G, B are used as primaries
- R (700 nm), G (546.1 nm), B (435.8 nm)
The CIE RGB color space
RGB - Devise Dependent

sRGB

Adobe RGB
YIQ Color Model

- Used by the NTSC color TV system

\[
Y = 0.299R + 0.587G + 0.114B \\
I = R - Y \\
Q = B - Y
\]

- Other models:
  - YUV (used by the PAL color TV system)
  - YCrCb
CMY(K) Color Model

- $(C, M, Y) = (1 - R, 1 - G, 1 - B)$
- Used mainly in printers where light is absorbed by dyes
Color Subtraction

white light

\[ W - R - G = B \]

Yellow=0
Magenta=1
Cyan=1

white paper
HSV Color Model

- **Hue** – primary wavelength
- **Saturation** – purity
- **Value** - brightness

![Diagram of HSV color model](image)
HLS Color Model

- Hue – primary wavelength
- Saturation – purity
- Lightness – gray level