Color Mixing

Color Systems and Additive and Subtractive Colors
Describing Color
Color Attributes

- Hue (color) corresponds to **wavelength**
- Brightness corresponds to **amplitude**
- Saturation or Purity corresponds to **Monochromaticity** of colored light

Blue hue at various levels of saturation

Blue hue at various levels of brightness
Systems for Quantifying Color

- Three Systems (of many)
  - Munsell Color System
  - CIE Chromaticity Diagram
  - L.A.B. Color System
- Numerical quantification of color
- Allows for precise matching of colors in printing and dye industries
The Munsell Color Tree

- Arranges colors according to hue, brightness, and saturation
Munsell Color System

A page from the Munsell Book of Color
The CIE Chromaticity Diagram

- Hues on perimeter
- Saturation levels decrease internally

- A (tungsten at 2856 K)
- B (direct sunlight, ≈ 6770 K)
- C (overcast sunlight, ≈ 5800 K)
- D65 (daylight, ≈ 6504 K)
- Point E marks equal energy.
Chromaticity vs. Gamut

- We can't see everything
- We can't create everything!

There is a limited gamut of colors in a monitor. Each monitor is slightly different.
L.A.B. Color System

- L = lightness
- a = red-green
- b = blue-yellow
Two Types of Color Mixing

- **Subtractive Color Mixing**
  - More familiar type
  - Mixing of paints, dyes, inks

- **Additive Color Mixing**
  - Mixing of colored lights
Colored Pigments as Microfilters

- Colored pigments + binder = paint
- Pigment particles act as tiny colored filters
Colored Pigments as Microfilters

White prime

Light green finish (2 coats)

Missing: original wallpaper

Glue size on plaster
Analysis of wallpapers in Colonial Williamsburg
CSI: real or fake?

Rice starch was a common binder in earlier wallpapers. It shows a nice pattern under polarized light.
CSI: real or fake?

Old papers were not made of “paper pulp” from trees (<1900)
CSI: real or fake?

Modern papers do have pulp from pine trees (conifers)
Pigments as Colored Filters

Primary Subtractive Colors

white light

yellow

blue

red
Subtractive Color Mixing

- Mixing of paints

Primary colors:

- Y
- B
- R

Complementary colors formed by mixing 2 primary colors:

- G
- O
- V
Complementary Colors

- *The Zouave, 1888*
  Vincent van Gogh
  (Dutch 1853-1890)

Use of complementary colors by Impressionist painters.
Complementary colors
Dullness of black and white

Paul Cezanne, "Still Life, Drapery, Pitcher, and Fruit Bowl"
1893-1894
Monet early work
What happens if you mix...

3 subtractive primary colors???
\[ R + B + Y = \quad \text{Dark Brown or Black} \]

- A primary with its complementary?
  \[ R + G = \quad ??? \]
  \[ B + O = \quad ??? \]
  \[ Y + V = \quad ??? \]

Making “blacks”.

- white light
- blue
- red
- yellow
Confused yet?
Key Concepts — Subtractive

- Mixing of pigments, inks, dyes, paints
- Each pigment **selectively absorbs** (subtracts out) certain colors (wavelengths) of light
- Mixing of pigments decreases amount of light transmitted
  - Can lead to “muddy colors”
Printer’s Subtractive Colors

- CYMK
  - Cyan (blue)
  - Yellow (yellow)
  - Magenta (red)
  - Black (K)
Additive Color Mixing

- Characterized by mixing of colored lights
- Additive primary colors are...

- Red (R)
- Green (G)
- Blue (B)
Additive Color Mixing

Primary green covers middle wavelengths

R + G = Yellow
B + G = Cyan
R + G + B = White
Primary red covers the long wavelengths
R + B = Magenta

Additive color mixing with red, green and blue additive primary colors.
Complementary Additive Colors

- Formed by the mixing of 2 primary colors

\[ R + B = M \]

\[ B + G = C \]

\[ R + G = Y \]
Key Concepts — **Additive**

- Each light adds certain wavelengths of light to the mix (color)

Mixing of lights **increases the total amount** of light transmitted

Mixed lights are **brighter**
What Happens if You Mix...

- 3 additive primary colors?
  \[ R + B + G = \text{White Light} \]

- 2 additive complementary colors?
  \[ C + Y = ??? \]
  \[ Y + M = ??? \]
  \[ C + M = ??? \]

http://www.huevaluechroma.com/042.php
Color Mixing

- cyan
- yellow
- magenta
- green
- red

\[(B+G) + (B+R) = B\]
\[(B+G) + (G+R) = G\]
\[(R+G) + (B+R) = R\]
Mixing of Primary Colors

Additive (light) color combinations:
- Green
- Red
- Blue

Subtractive (paint) color combinations:
- Cyan
- Magenta
- Yellow

Additive and subtractive color combinations:
- White light
- Black
Illuminated Colored Objects

White Light

Blue
In Red Light
In Blue Light
In Green Light
In Yellow Light
Maxwell Disks

- James Clerk Maxwell (1831-1879)
- Rapidly spinning disks with two colored halves

Vision persistence blends the colors
Pointillist Movement

- George Seurat (1859-1891)

*Sunday Afternoon on the Island of La Grande Jatte* (1886)
Chicago Art Institute
Pointillism

- George Seurat
- Neoimpressionist painter
- *La Poudreuse* (Madeleine Knobloch)
  1889
Close-up of Seurat Painting

- Tiny dots of color
- Blended by the eye of the observer
- Additive color mixing
\[ M = R + B \]
\[ C = B + G \]
\[ W = R + G + B \]
\[ Y = R + G \]
Colors in your TV and Computer

Examine screen with magnifier

RGB phosphors

Additive color mixing of lights
Four-Color Process Printing

- CYMK
  - Cyan (blue)
  - Yellow (yellow)
  - Magenta (red)
  - Black
The Moire Effect

- Overlapping of two or more images of closely spaced lines

http://www.mathematik.com/Moire/