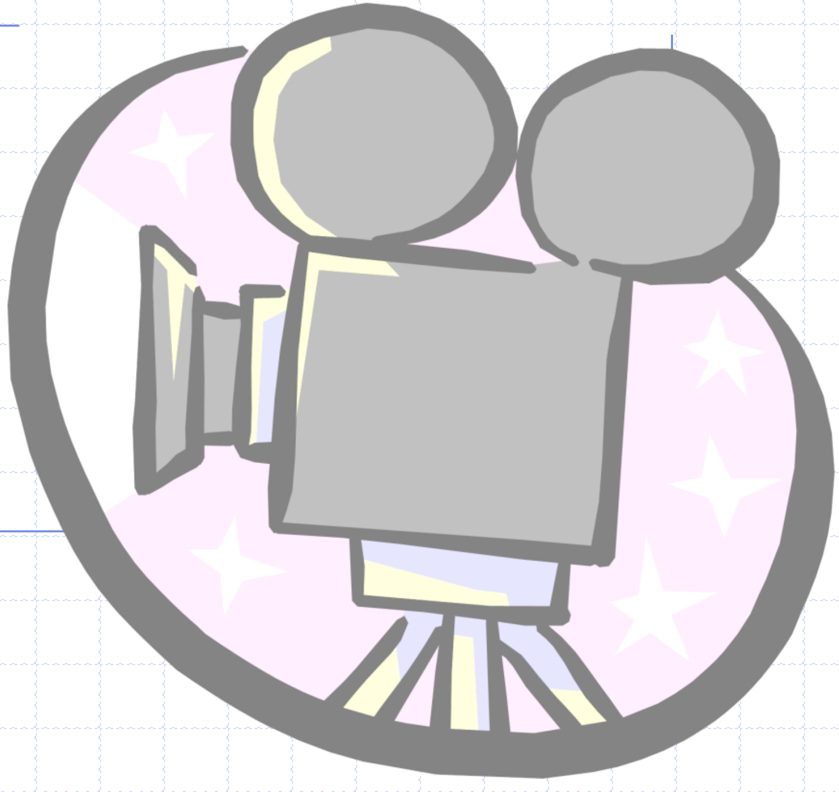
# Color Models & Visualization



# Pl. Read the COLOR ; not the word……….

YELLOW BLUE ORANGE

BLACK RED GREEN

PURPLE YELLOW RED

ORANGE GREEN BLACK

BLUE RED PURPLE

GREEN BLUE ORANGE

# Left- Right conflict..

Your right brain tries to say the color

But....

Your left brain insists on reading the word....

# Preview

- **Motive**

  - Color is a powerful descriptor/feature that often simplifies object identification and extraction from a scene.

  - Human can discern thousands of color shades and intensities, compared to about only two dozen shades of gray.

# Color Fundamentals

The experiment of Sir Isaac Newton, in 1666.

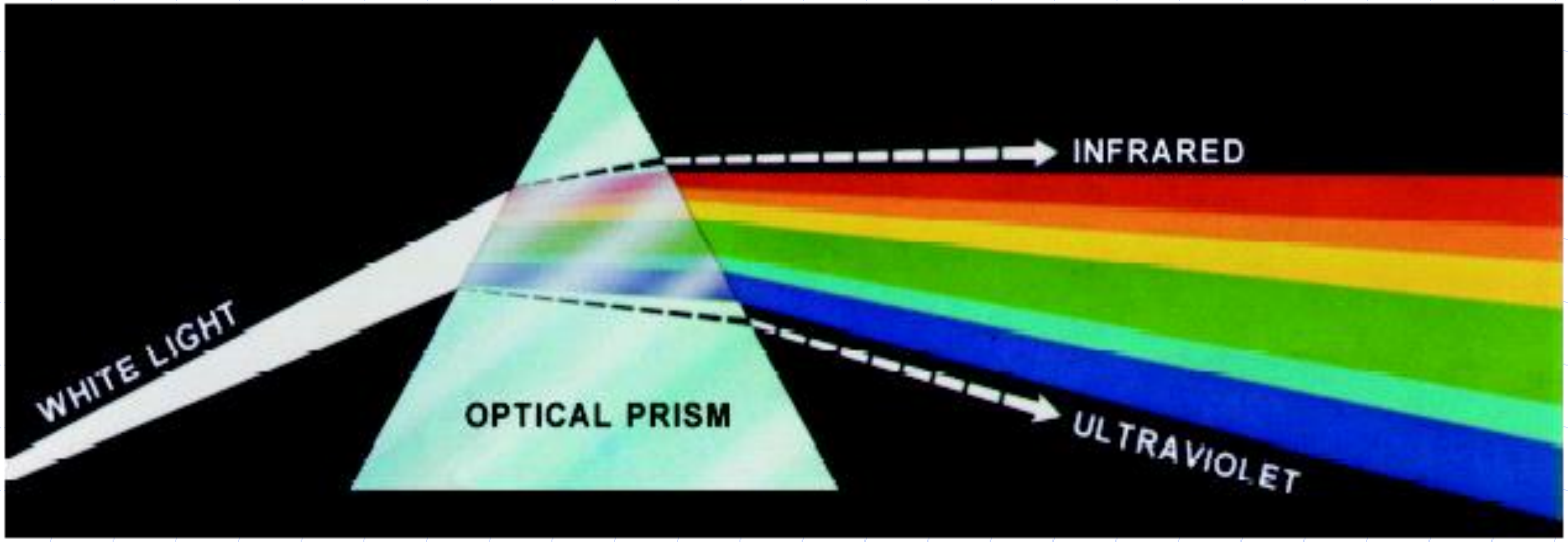
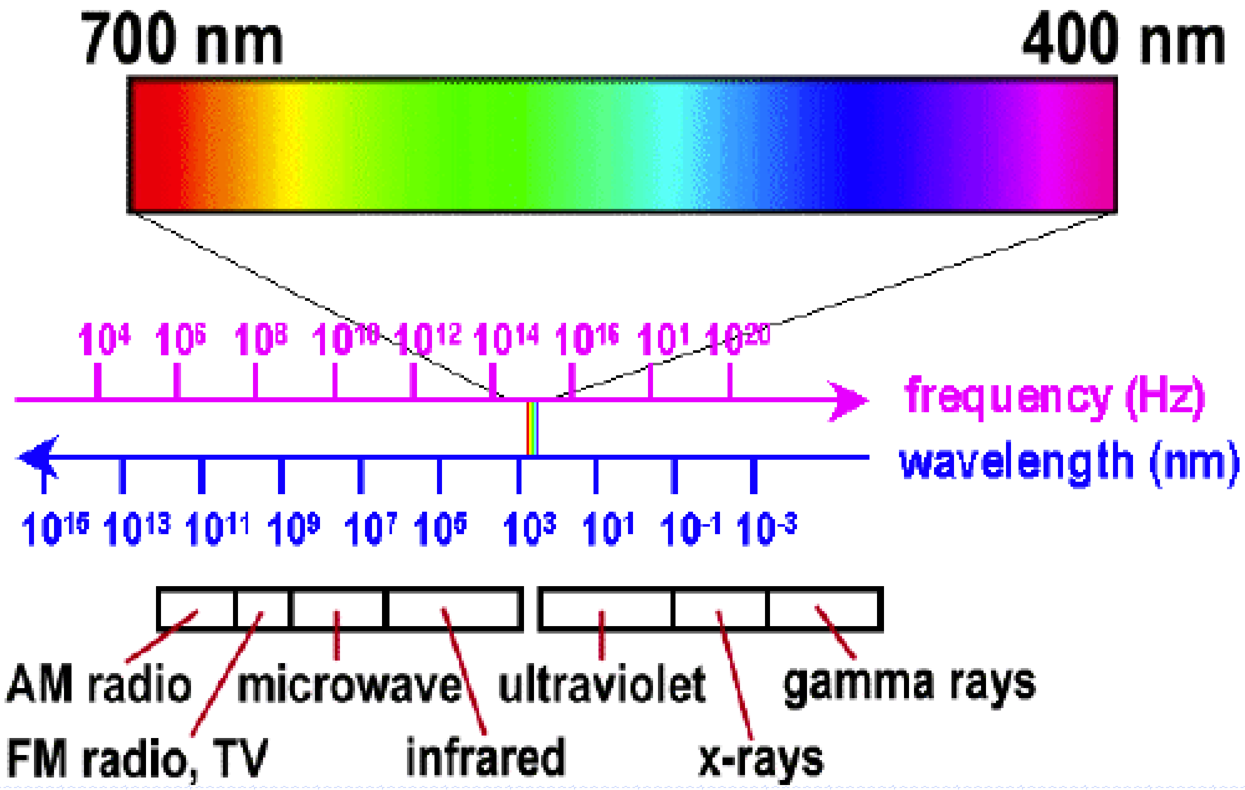



**FIGURE 6.1** Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

# Visible Light



# Color Fundamentals (con't)

- Standard wavelength values for the primary colors

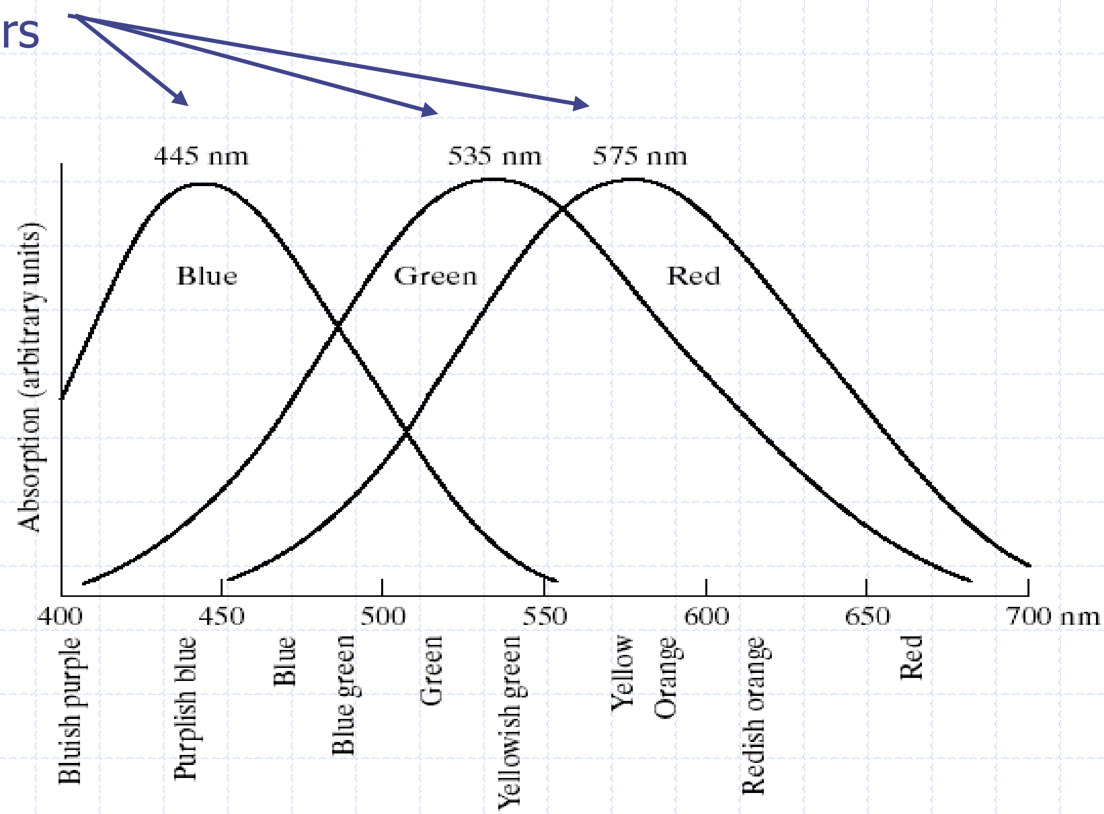
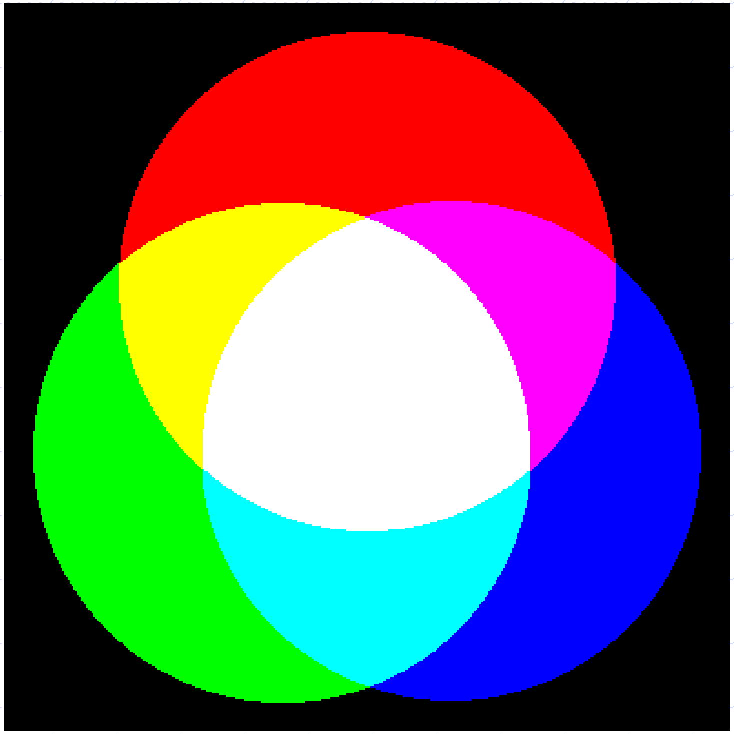



**FIGURE 6.3** Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

# *Color Fundamentals (con’t)*

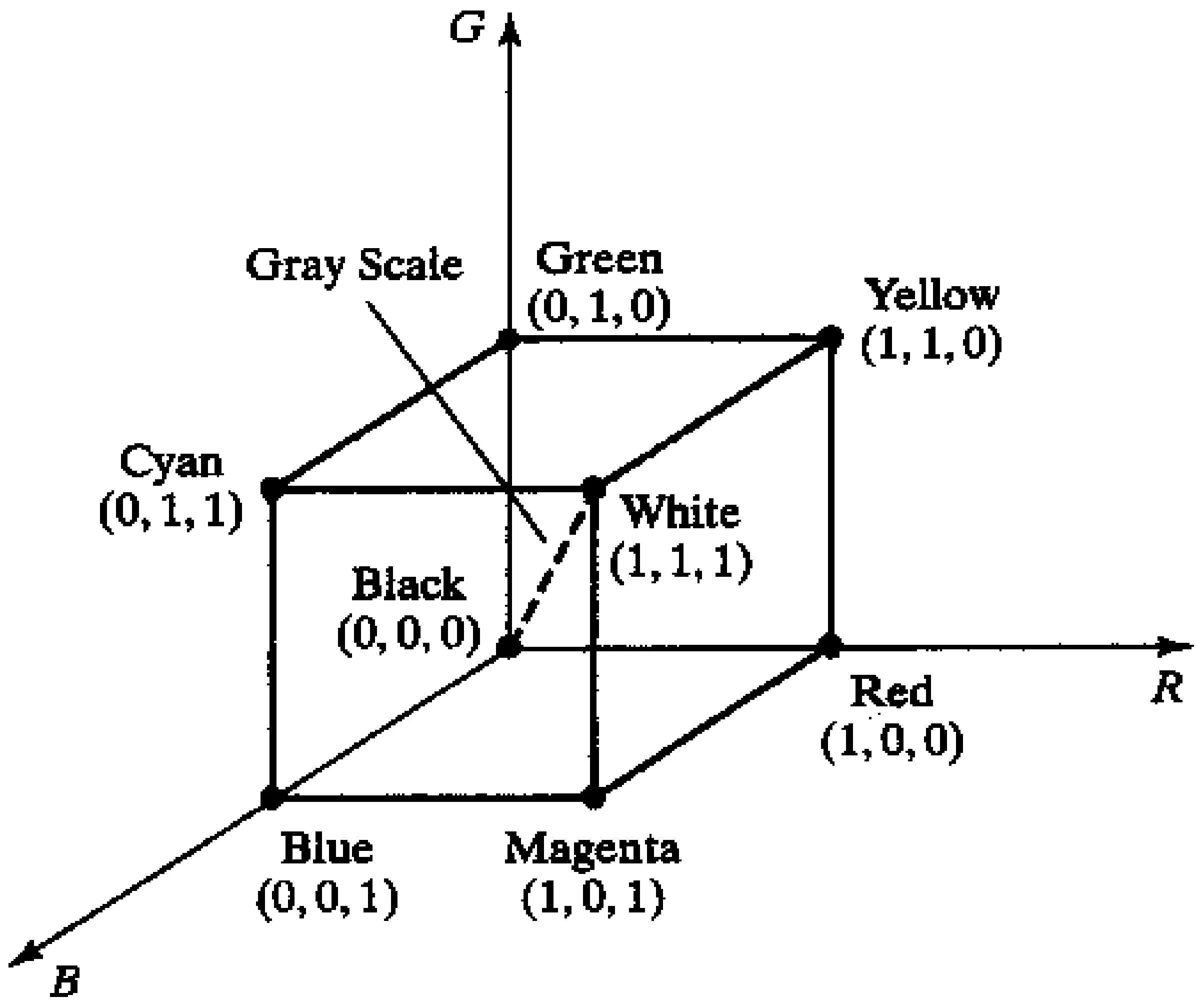
- **Basic quantities to describe the quality of light source:**
  - Radiance: Total amount of energy that flows from the light source (in W)
  - Luminance: A measure of the amount of energy an observer perceives from the light source (in lm)
  - Brightness: A subjective descriptor that embodies the achromatic notion of intensity and is practically impossible to measure

# RGB Color model



Active displays, such as computer monitors and television sets, emit combinations of red, green and blue light. This is an **additive** color model

# The RGB Color Spaces



# The RGB Color Models (con't)

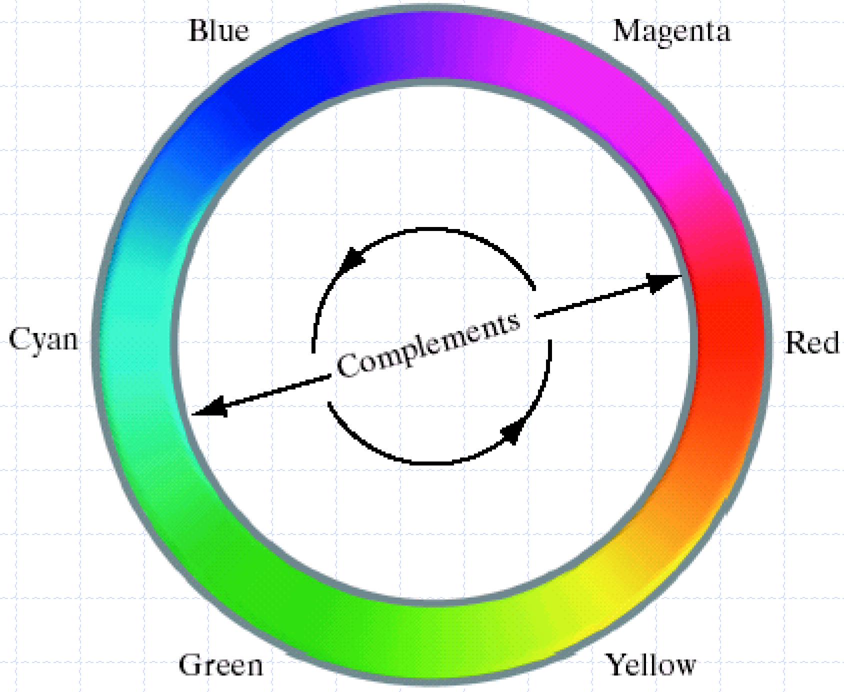
**FIGURE 6.8** RGB 24-bit color cube.

$$\left(2^8\right)^3 = 16{,}777{,}216 \text{ Colors}$$

# Color Image Processing

## Color Transformation: Color Correction

The proportion of any color can be increased by decreasing the amount of the opposite (or complementary) color in the image or by raising the proportion of the two immediately adjacent colors or decreasing the percentage of the two colors adjacent to the complement.

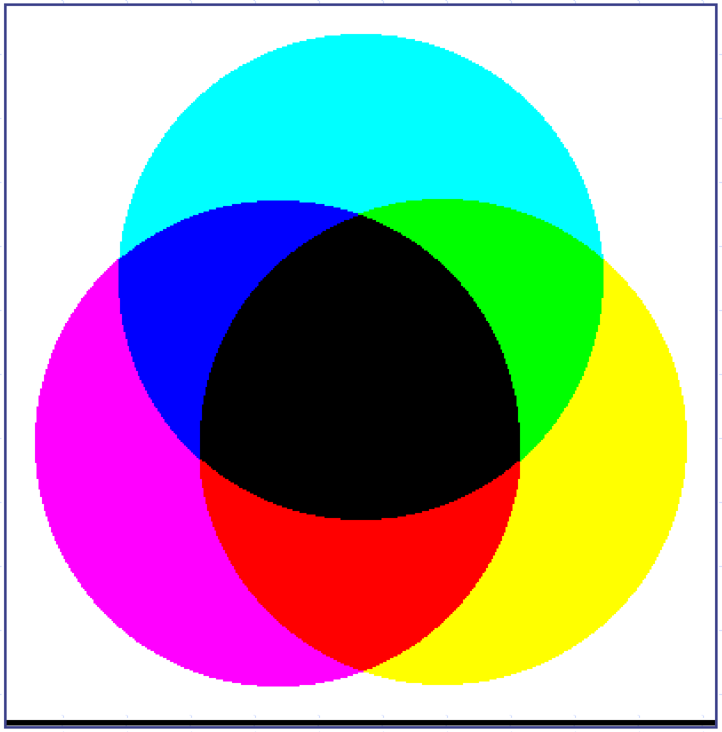



**Magenta ↓**

Removing Red and Blue

Adding Green

# CMY Color model

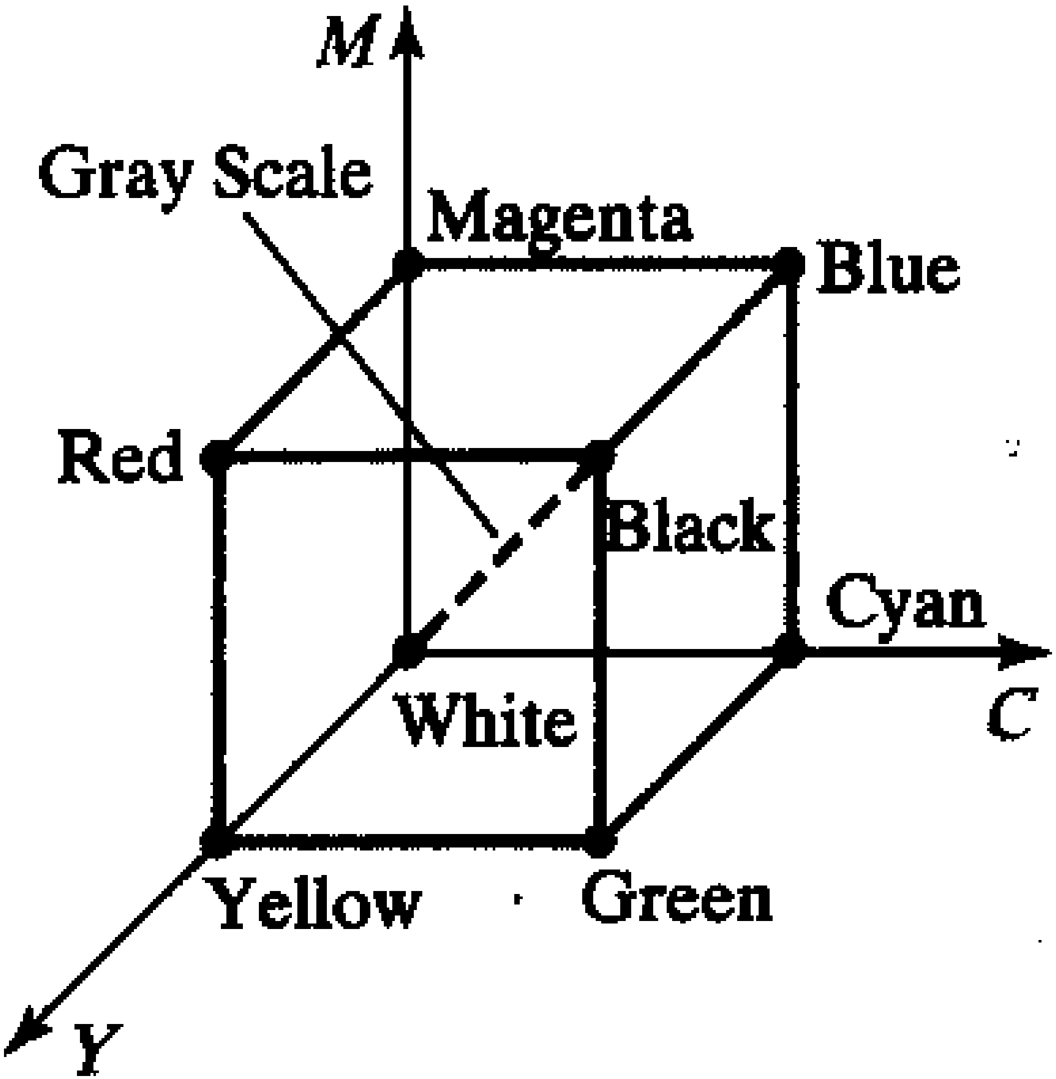


Passive displays, such as color inkjet printers, **absorb** light instead of emitting it. Combinations of **cyan**, **magenta** and **yellow** inks are used. This is a **subtractive** color model.

# CMY

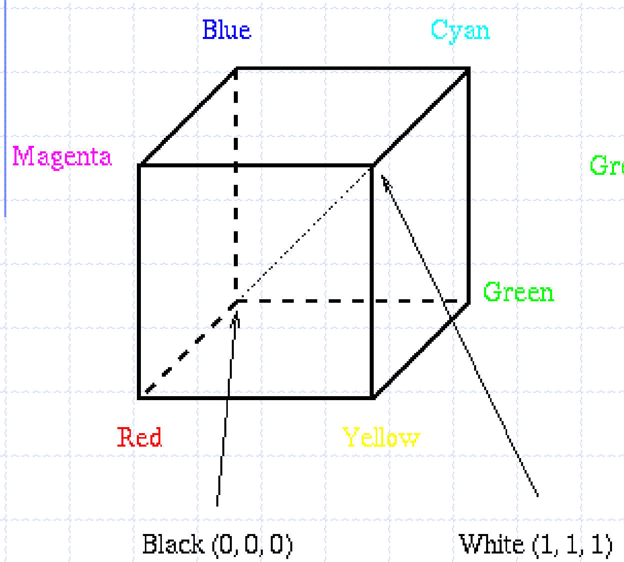
- CMY cartridges for colour printers.

# The CMY and CMYK Color Spaces

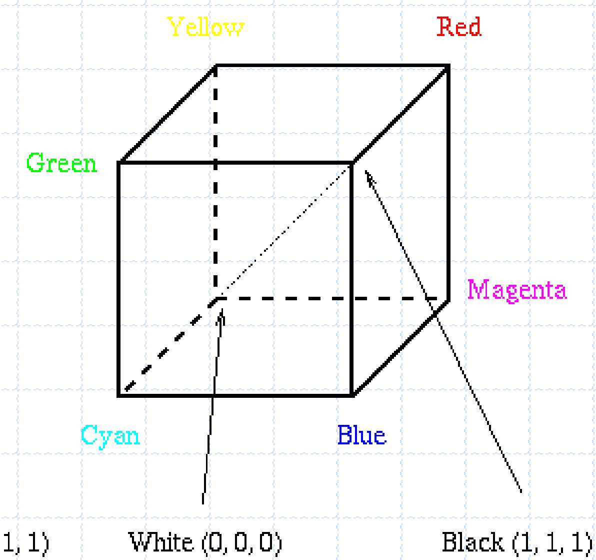


# RGB and CMY

- Converting between RGB and CMY




The RGB Cube




The CMY Cube

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

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

# The CMY and CMYK Color Models

- Cyan, Magenta and Yellow are the secondary colors of light
- Most devices that deposit colored pigments on paper, such as color printers and copiers, require CMY data input.

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

The conversion from RGB to CMY is given by the formula

$$\begin{bmatrix} c \\ m \\ y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

**Example:** The red colour is written in RGB as (1,0,0). In CMY it is written as

$$\begin{bmatrix} c \\ m \\ y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} r \\ g \\ b \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$$

that is, magenta and yellow.

**Example :** The magenta is written in CMY as (0,1,0). In RGB it is written as

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

giving,

$$\begin{bmatrix} r \\ g \\ b \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$$

that is, red and blue.

# CMYK model

- For printing and graphics art industry, CMY is not enough; a fourth primary, K which stands for black, is added.
- Conversions between RGB and CMYK are possible, although they require some extra processing.

# YIQ Color Coordinate System

- YIQ is defined by the National Television System Committee (NTSC)
- Y describes the luminance
- I and Q describes the chrominance
- A more compact representation of the color.

# *Color Fundamentals (con't)*

- **The characteristics generally used to distinguish one color from another are Brightness, Hue, and Saturation.**
  - Hue: Represents dominant color as perceived by an observer
  - Saturation: Relative purity or the amount of white light mixed with a hue
- **Hue and saturation taken together are called *Chromaticity*, and therefore, a color may be characterized by its Brightness and Chromaticity.**

# YUV/YCbCr Coordinate

- YUV is the color coordinate used in color TV in PAL system, somewhat different from YIQ

*(//Phase Alternating Line (PAL) is a colour encoding system for **analogue television**. It was one of three major analogue colour television standards, the others being NTSC and SECAM//)*

- YCbCr is the digital equivalent of YUV, used for digital TV, with 8 bit for each component, in range of 0-255

YCbCr Color Space is used in MPEG video compression standards

- Y is luminance
- Cb is blue chromaticity
- Cr is red chromaticity

$$Y = 0.257*R + 0.504*G + 0.098*B + 16$$

$$Cr = 0.439*R - 0.368*G - 0.071*B + 128$$

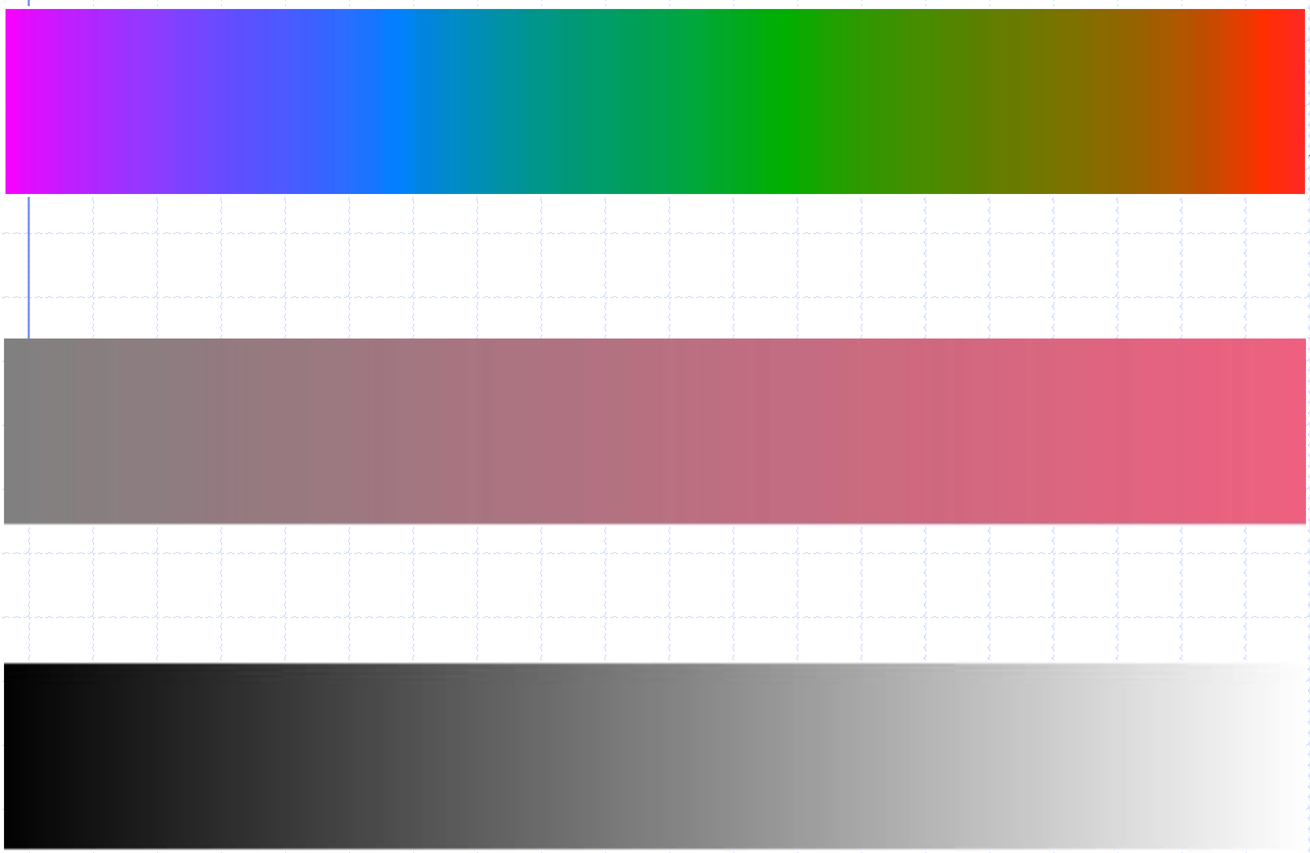
$$Cb = - 0.148*R - 0.291*G + 0.439*B + 128$$

- **More bits of bandwidth are used to represent Y than to represent I and Q, because our eye is more sensitive to changes in luminance**

- YIQ color space (Matlab conversion function: rgb2ntsc):

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

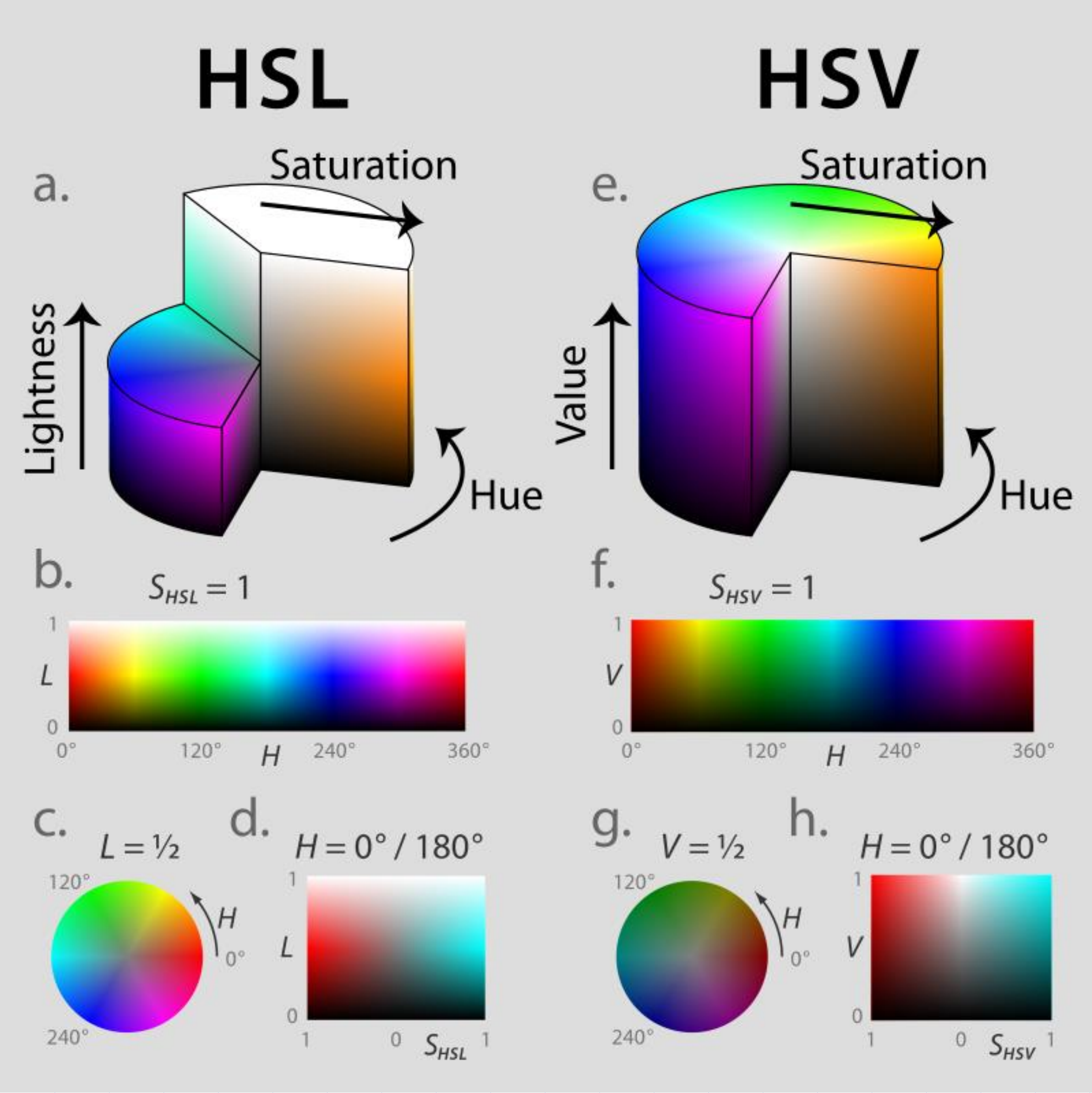
# HSI Color Model



H
*dominant wavelength*

S
*purity*
*% white*

I
*Intensity*

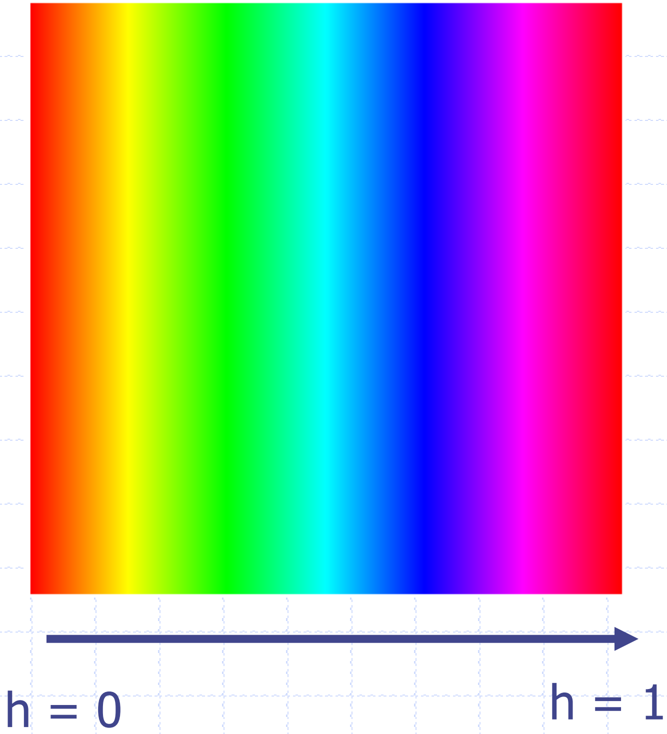



Designers use the HSV color model **when selecting colors for paint or ink** because HSV better represents how people relate to colors than the RGB color model does. The HSV color wheel also contributes to high-quality graphics.

# Hue

The HSV spectrum of bright pure colours ( s = 1, v = 1 ).

Notice the cyclicality of the hue. The red corresponds both to h=0 and h=1.



# Saturation

- Bright colours (v=1) with decreasing values of saturation.

s = 1

s = 0.75

s = 0.5



s = 0.25

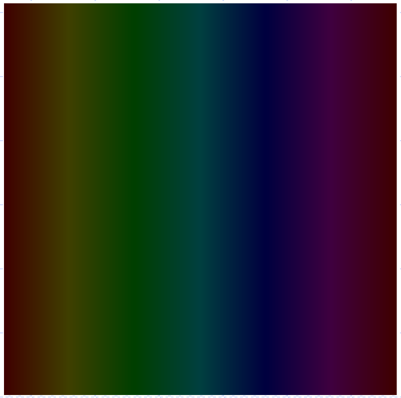
# Value

Pure colours (s=1) with decreasing values of “value” (brightness).

v = 1

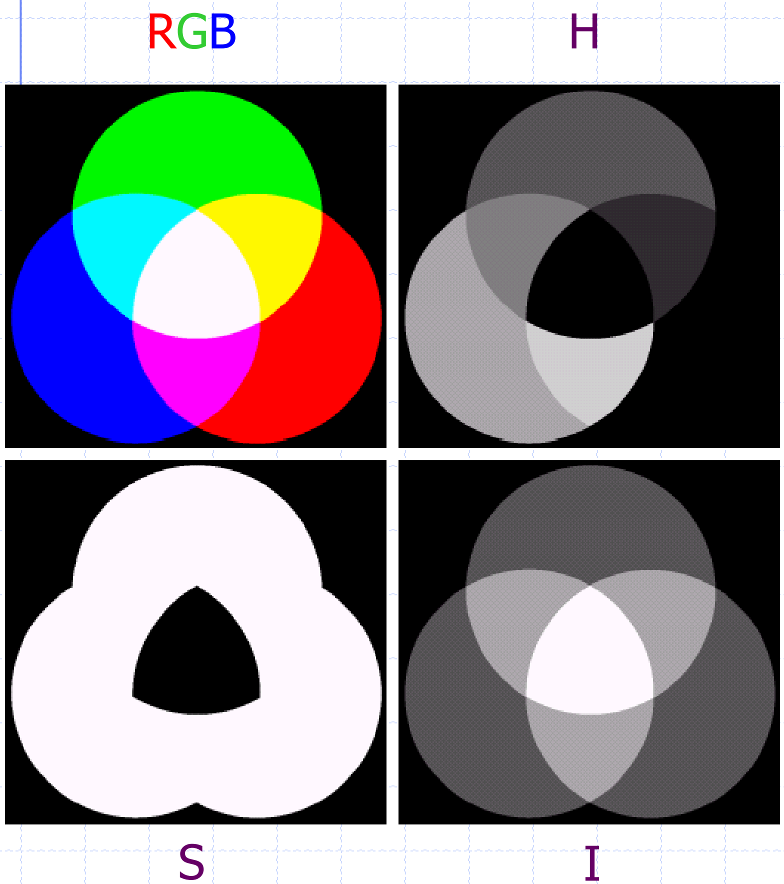
v = 0.75

v = 0.5



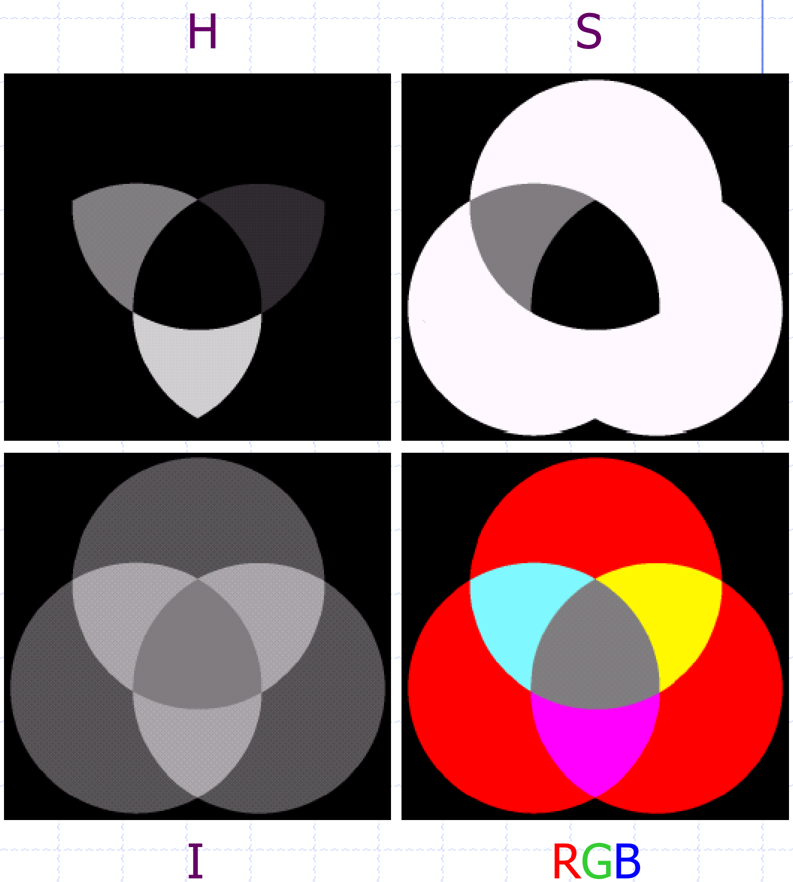
v = 0.25

# The HSI Color Models




a b
c d

**FIGURE 6.16** (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

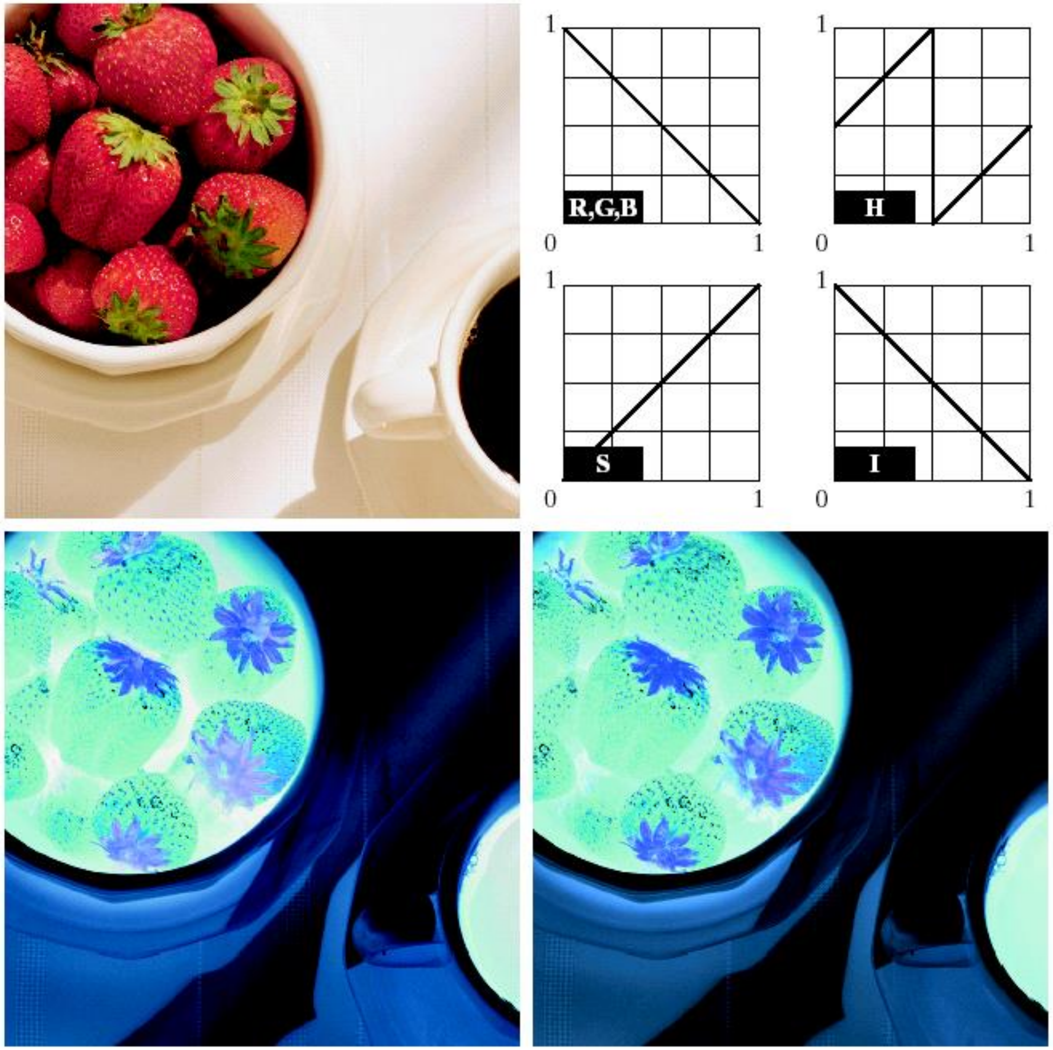



a b
c d

**FIGURE 6.17** (a)–(c) Modified HSI component images. (d) Resulting RGB image. (See Fig. 6.16 for the original HSI images.)

# Color Image Processing

## Color Transformation: Color Complement




a b
c d

**FIGURE 6.33** Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

# Color Image Processing

## Color Transformation: Tonal Correction

Middle-key Image

Flat

Corrected

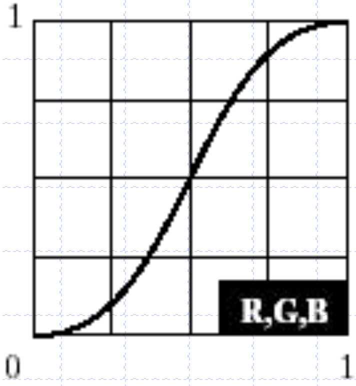
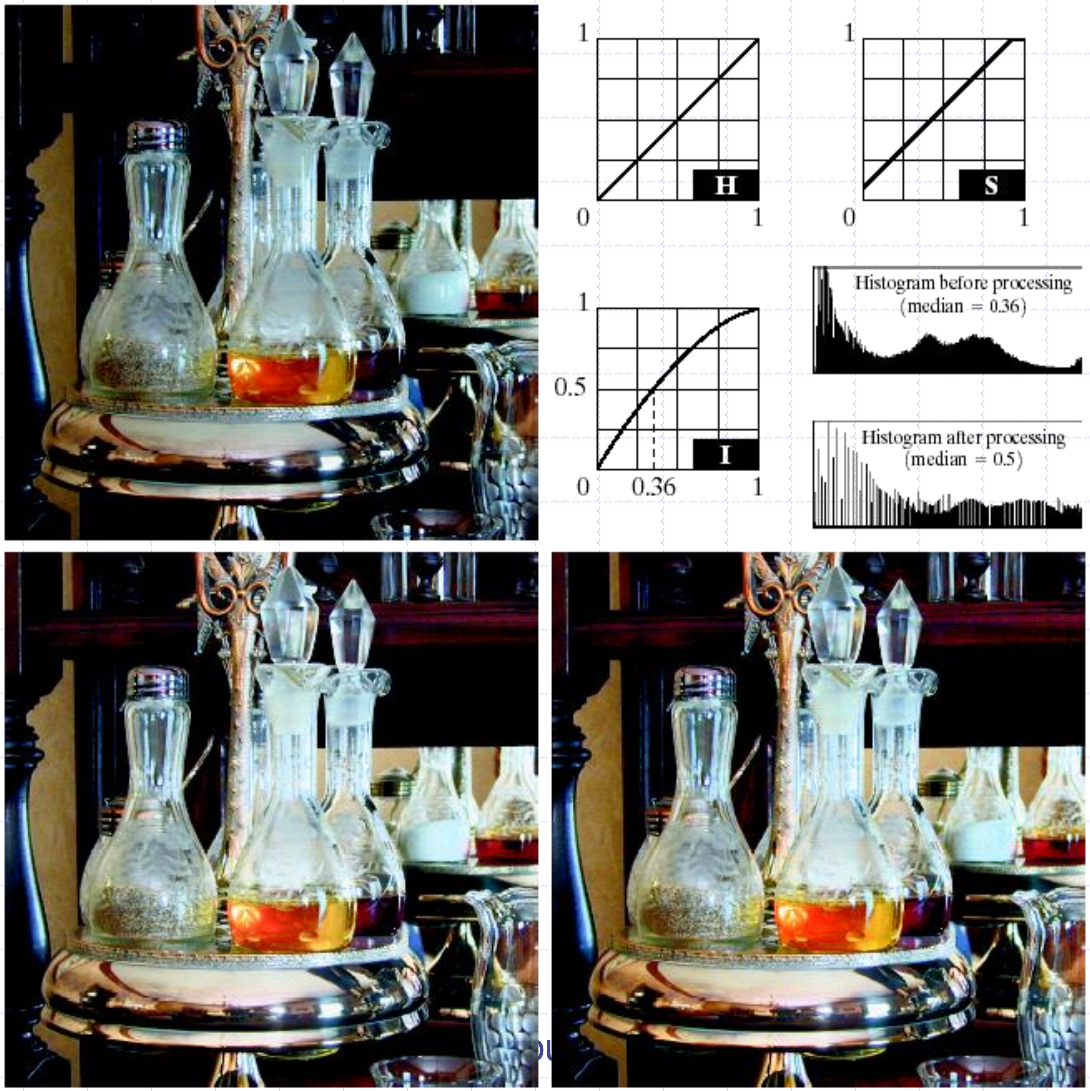



**FIGURE 6.35** Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not alter the image hues.

# Color Image Processing

## Color Transformation: Histogram Processing




a b
c d

**FIGURE 6.37** Histogram equalization (followed by saturation adjustment) in the HSI color space.

Histogram Equalizing the Intensity

Saturation Adjustment

# Color Image Processing
## Color Image Smoothing

a b
c d

**FIGURE 6.38**
(a) RGB image.
(b) Red component image.
(c) Green component.
(d) Blue component.

Red

Green

Blue

# Color Image Processing

## Color Image Smoothing

Hue | Saturation | Intensity

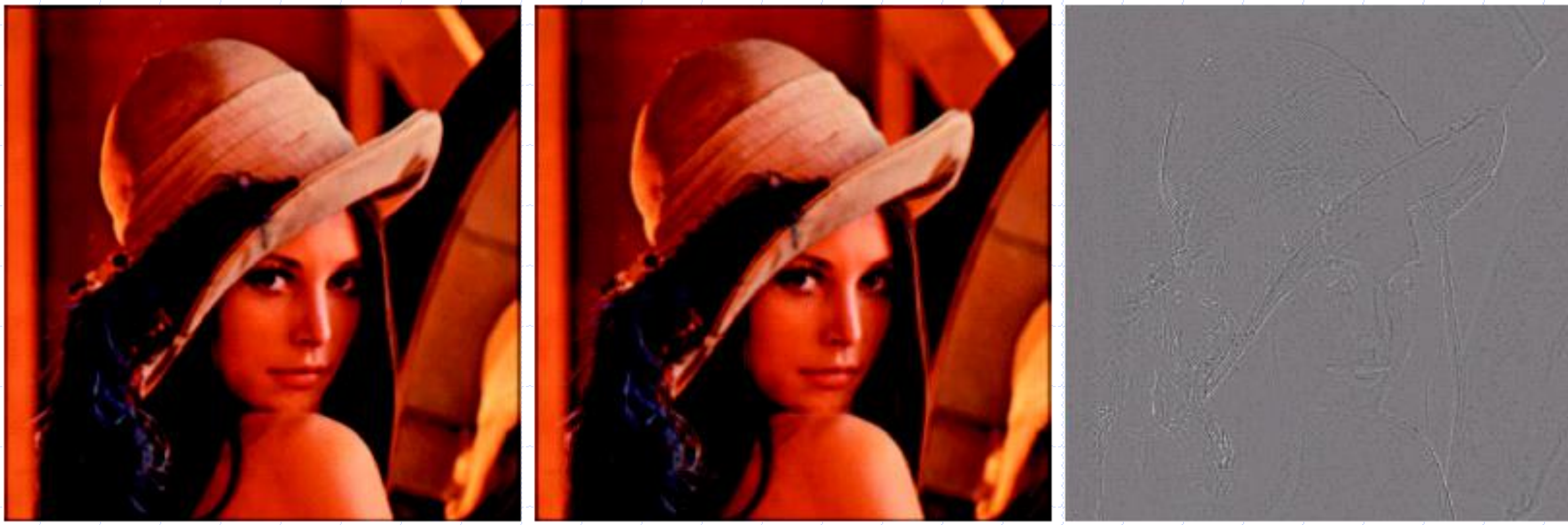
a b c

**FIGURE 6.39** HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

# Color Image Processing

## Color Image Smoothing

Averaging R,G and B Averaging Intensity Difference



a b c

**FIGURE 6.40** Image smoothing with a 5 × 5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

# Color Image Processing

## Color Image Sharpening

Sharpening R,G and B    Sharpening Intensity    Difference

a b c

**FIGURE 6.41** Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the intensity component and converting to RGB. (c) Difference between the two results.

# Color Image Processing

## Color Segmentation: Color Edge Detection

a b
c d

**FIGURE 6.46** (a) RGB image. (b) Gradient computed in RGB color vector space. (c) Gradients computed on a per-image basis and then added. (d) Difference between (b) and (c).

# Color Image Processing

## Color Segmentation: Color Edge Detection

a b c

**FIGURE 6.47** Component gradient images of the color image in Fig. 6.46. (a) Red component, (b) green component, and (c) blue component. These three images were added and scaled to produce the image in Fig. 6.46(c).

# Color Image Processing
## Noise in Color Images

a b
c d

**FIGURE 6.48**
(a)–(c) Red, green, and blue component images corrupted by additive Gaussian noise of mean 0 and variance 800. (d) Resulting RGB image. [Compare (d) with Fig. 6.46(a).]

# Color Image Processing
## Noise in Color Images

a b c

**FIGURE 6.49** HSI components of the noisy color image in Fig. 6.48(d). (a) Hue. (b) Saturation. (c) Intensity.

# Color Image Processing

## Noise in Color Images

a b
c d

**FIGURE 6.50** (a) RGB image with green plane corrupted by salt-and-pepper noise. (b) Hue component of HSI image. (c) Saturation component. (d) Intensity component.