Color Spectrum

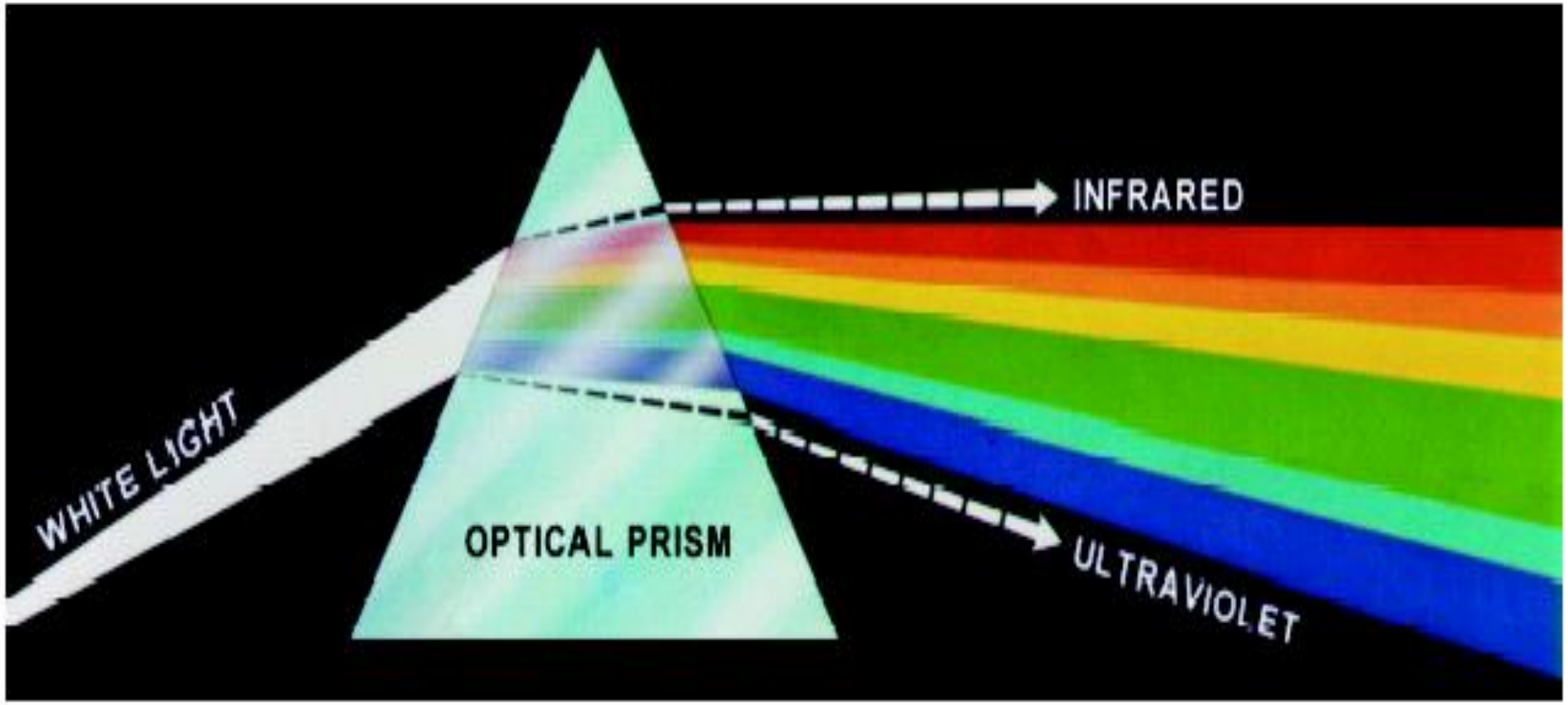


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Electromagnetic Spectrum

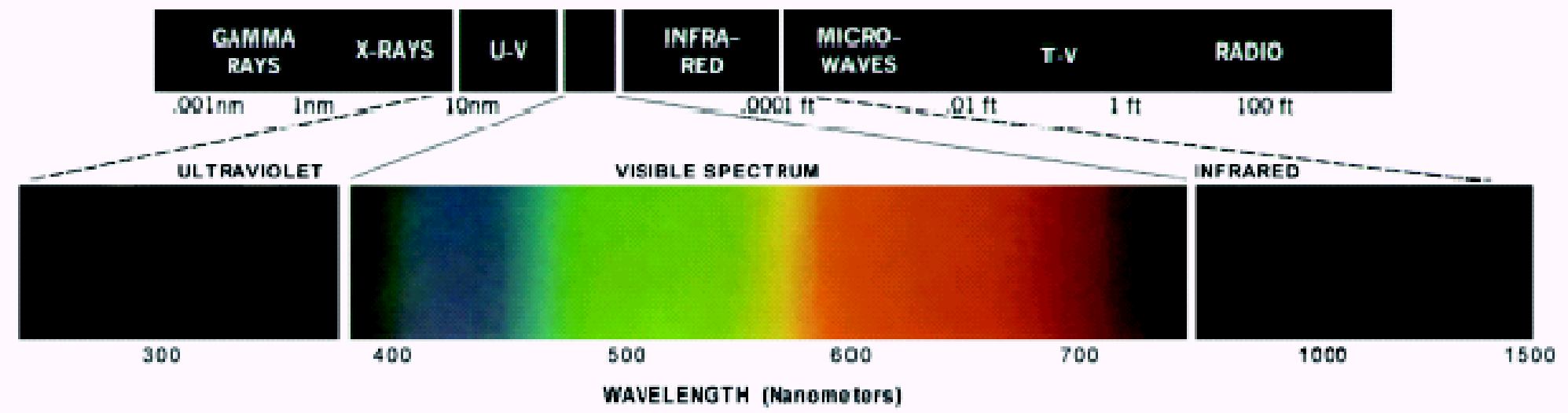
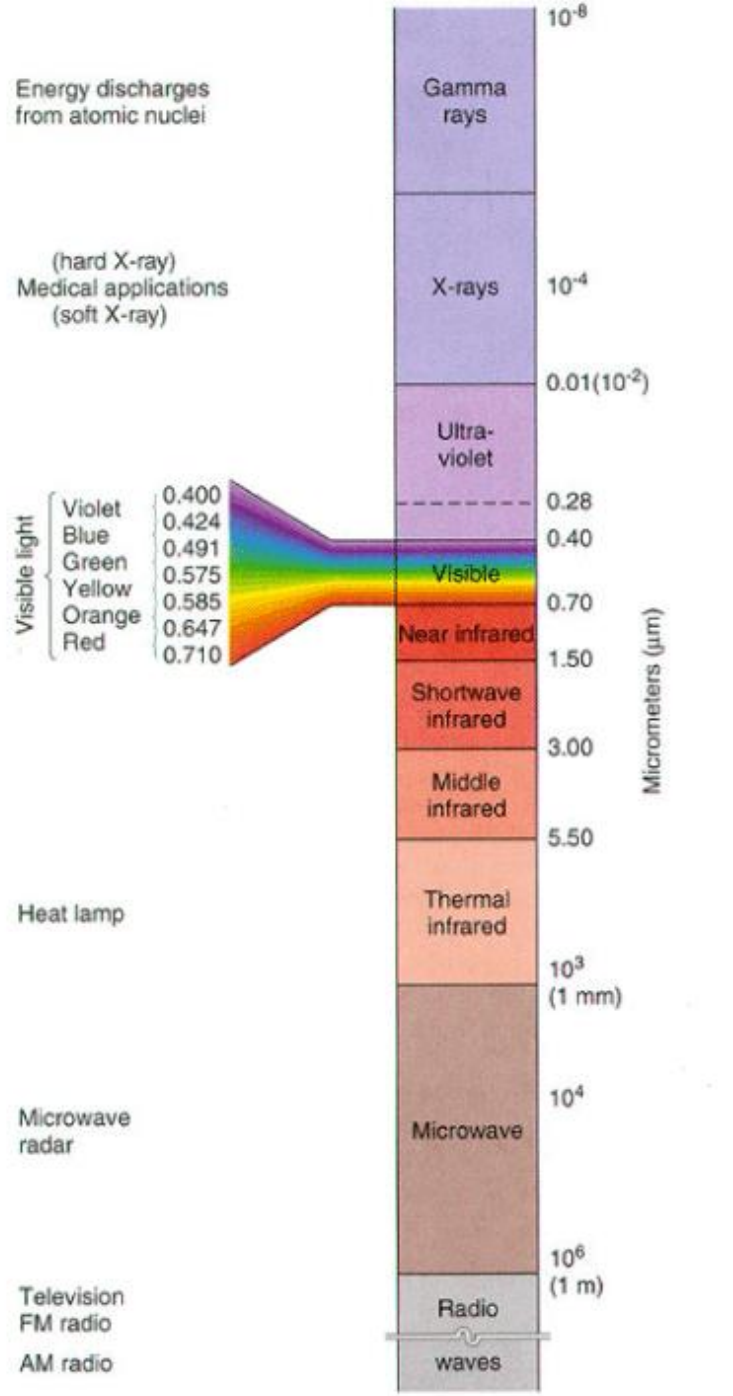


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Physical Background

- Visible light: a narrow band of electromagnetic radiation → **380nm (blue) - 780nm (red)**

- Wavelength: Each physically distinct colour corresponds to at least one wavelength in this band.



source: Christopherson (2000) *Geosystems*

Color Fundamentals

- The colors that humans and some animals perceive in an object are determined by the nature of light reflected from the object

Achromatic vs Chromatic Light

- Achromatic (void of color) Light: Its only contribute is its 'Intensity' or amount

- Chromatic Light: spans the electromagnetic spectrum from approximately 400 to 700nm

Human Perception

- Detailed experimental evidences has established that the 6 to 7 million cones in the human eye can be divided into three principal sensing categories, corresponding roughly to red, green and blue

- Approximately 65% of all cones are sensitive to Red Light, 33% are sensitive to Green Light and about 2% are sensitive to Blue Light (most sensitive)

Human Perception

- Due to these absorption characteristic of Human Eye colors are seen as variable combinations of the so-called 'Primary Colors' Red, Green and Blue

- The primary colors can be added to produce secondary colors of Light

  - Magenta (Red+Blue)
  - Cyan (Green+Blue)
  - Yellow (Red+Green)

Absorption of Light by red, green and blue cones in Human Eye

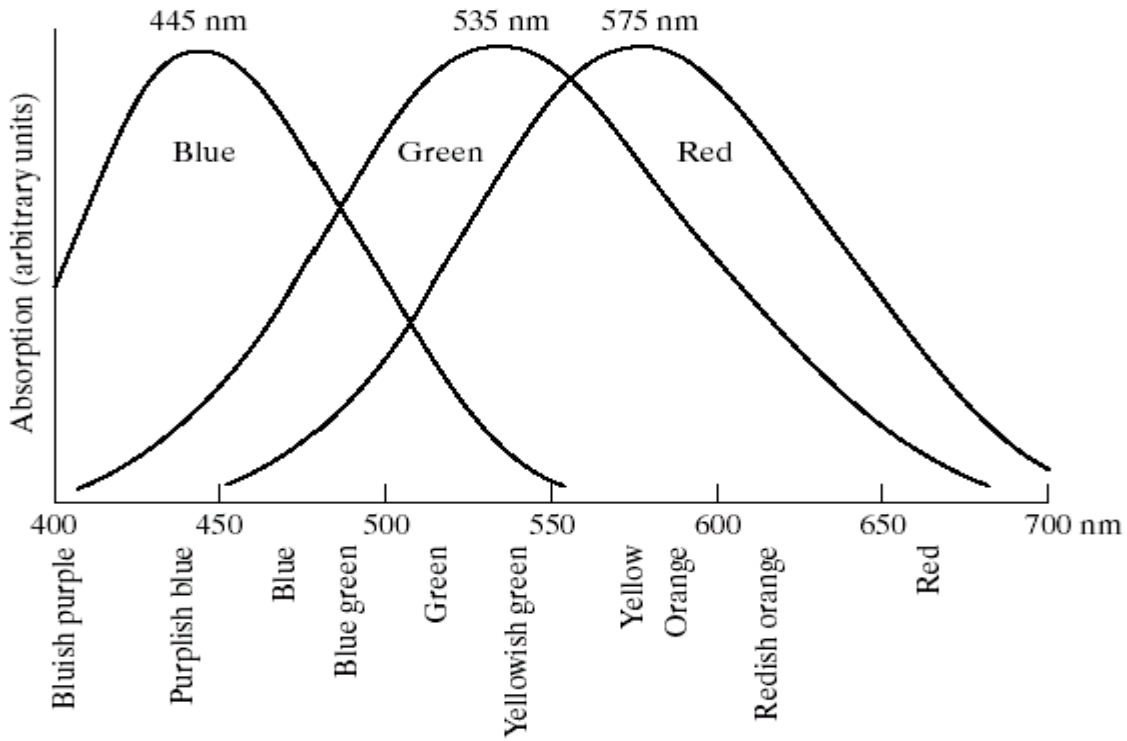
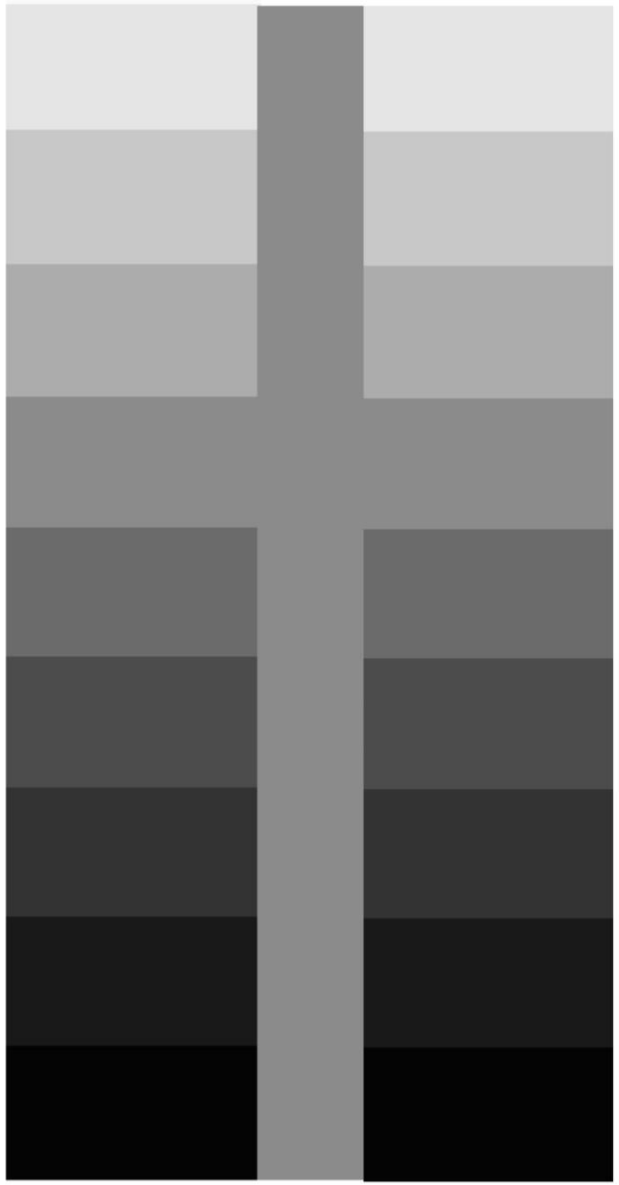


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

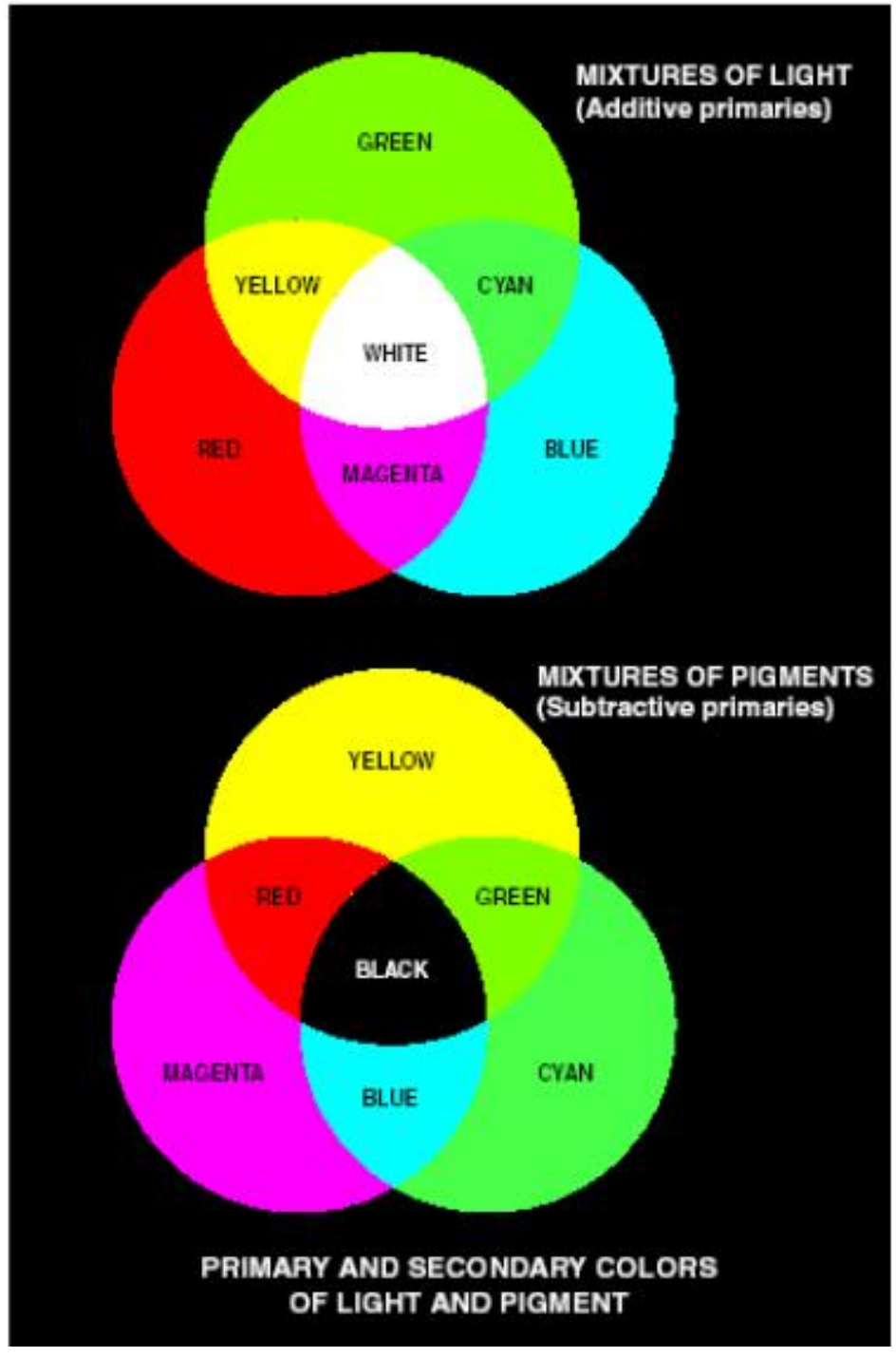
- Mixing the three primaries or a secondary with its opposite primary colors in the right intensities produces white light

Brightness



Primary Color of Light vs Primary Color of Pigments

- Red, Green and Blue Colors are Primary Colors of Light
- In Primary Color of Pigments a primary color is defined as the one that subtracts or absorbs a primary color of Light and reflects or transmits the other two
- Therefore the Primary Colors of Pigments are Magenta, Cyan and Yellow and secondary colors are Red, Green and Blue
- A proper combination of three pigment primaries or a secondary with its opposite primary produces Black
- Color Television Reception is an example of the additive nature of Light Colors


MIXTURES OF LIGHT
(Additive primaries)
GREEN
YELLOW
CYAN
WHITE
RED
MAGENTA
BLUE
MIXTURES OF PIGMENTS
(Subtractive primaries)
YELLOW
RED
GREEN
BLACK
MAGENTA
BLUE
CYAN
PRIMARY AND SECONDARY COLORS
OF LIGHT AND PIGMENT

Color Models

- The purpose of a color model (also called Color Space or Color System) is to facilitate the specification of colors in some standard way

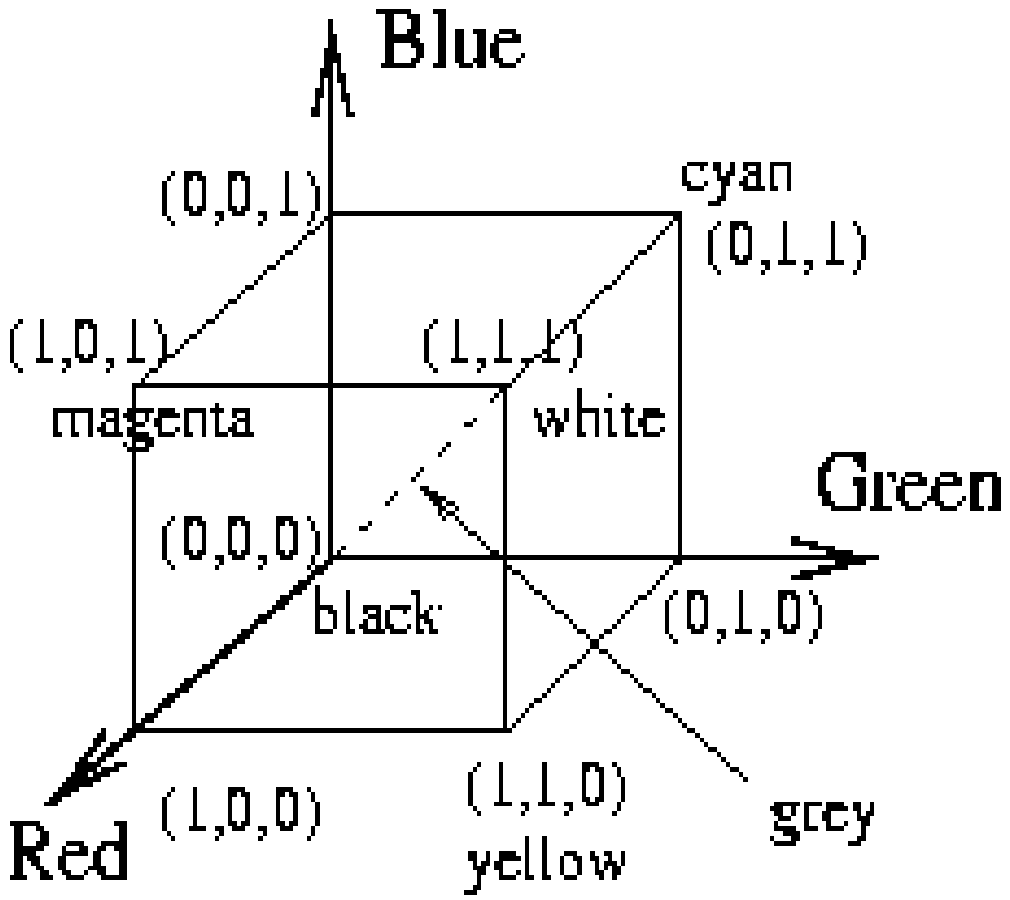
- A color model is a specification of a coordinate system and a subspace within that system where each color is represented by a single point

- **Color Models**

  RGB (Red, Green, Blue)
  CMY (Cyan, Magenta, Yellow)
  HSI (Hue, Saturation, Intensity)
  YIQ (Luminance, In phase, Quadrature)
  YUV (Y' stands for the luma component (the brightness) and U and V are the chrominance (color) components)

RGB Model

- Each color is represented in its primary color components Red, Green and Blue
- This model is based on Cartesian Coordinate System



RGB Model

- In this model, the primary colors are red, green, and blue. It is an additive model, in which colors are produced by adding components, with white having all colors present and black being the absence of any color.

- This is the model used for active displays such as television and computer screens.

- The RGB model is usually represented by a unit cube with one corner located at the origin of a three-dimensional color coordinate system, the axes being labeled R, G, B, and having a range of values [0, 1]. The origin (0, 0, 0) is considered black and the diagonally opposite corner (1, 1, 1) is called white. The line joining black to white represents a gray scale and has equal components of R, G, B.

RGB Color Cube

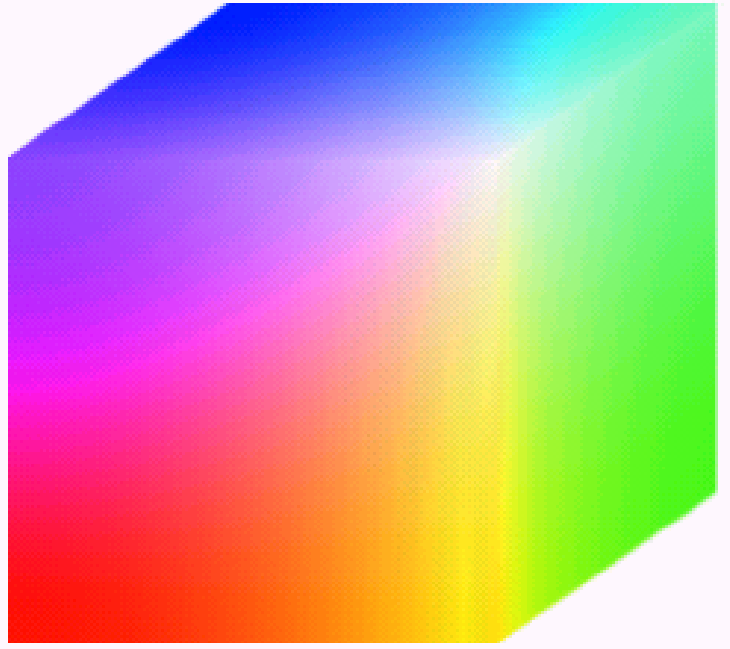


FIGURE 6.8 RGB 24-bit color cube.

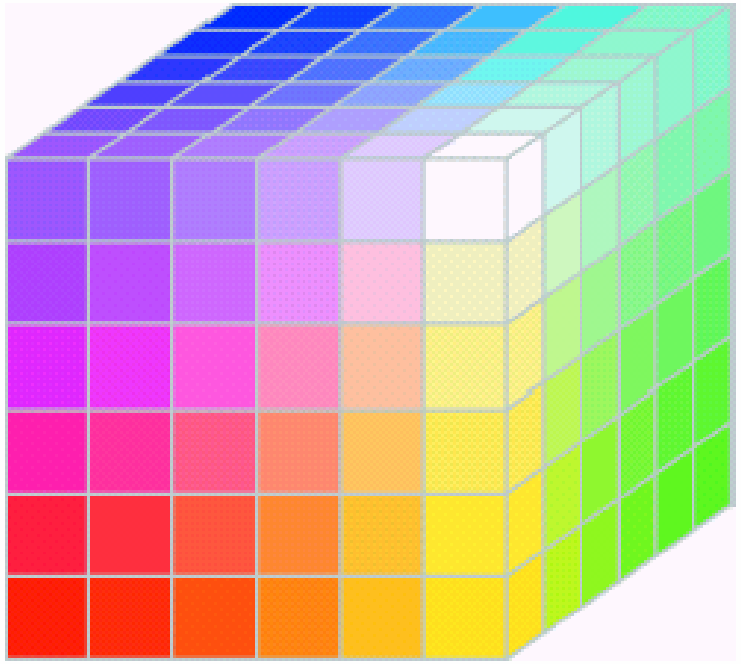


FIGURE 6.11 The RGB safe-color cube.

- The total number of colors in a 24 Bit image is $(2^8)^3$ =16,777,216 (> 16 million)

CMY and CMYK Color Model

- Cyan, magenta, and yellow are the secondary colors with respect to the primary colors of red, green, and blue. However, in this subtractive model, they are the primary colors and red, green, and blue, are the secondaries. In this model, colors are formed by subtraction, where adding different pigments causes various colors not to be reflected and thus not to be seen. Here, white is the absence of colors, and black is the sum of all of them. This is generally the model used for printing.

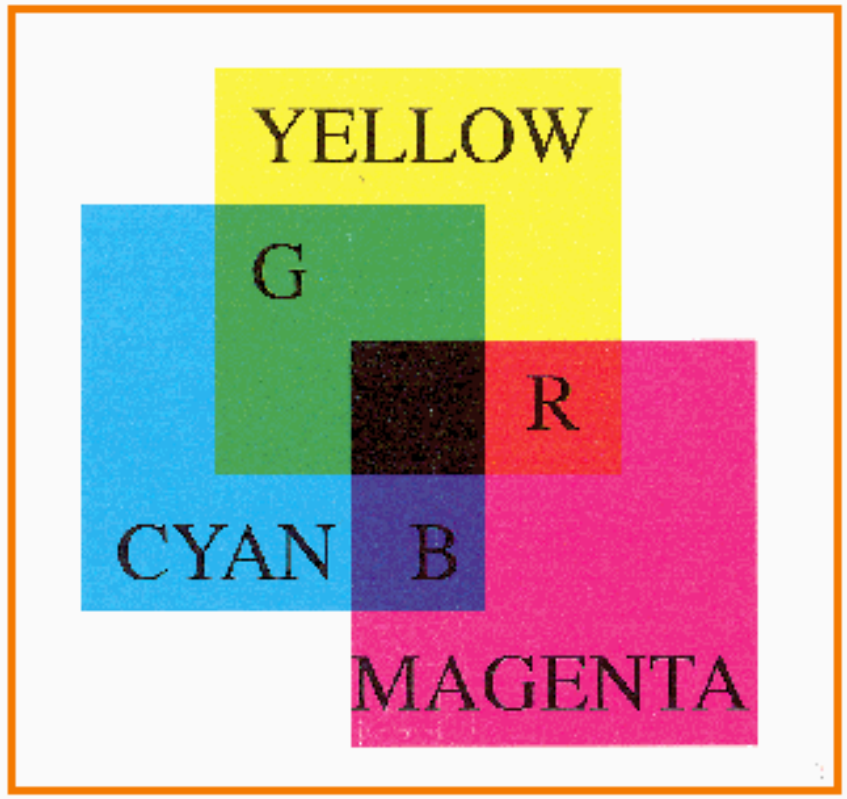
- Most devices that deposit color pigments on paper (such as Color Printers and Copiers) requires CMY data input or perform RGB to CMY conversion internally

$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1.00 \\ 1.00 \\ 1.00 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

CMY and CMYK Color Model

- CMY is a Subtractive Color Model
- Equal amounts of Pigment primaries (Cyan, Magenta and Yellow) should produce Black
- In practice combining these colors for printing produces a "Muddy-Black" color
- So in order to produce "True-Black" a fourth color "Black" is added giving rise to CMYK model

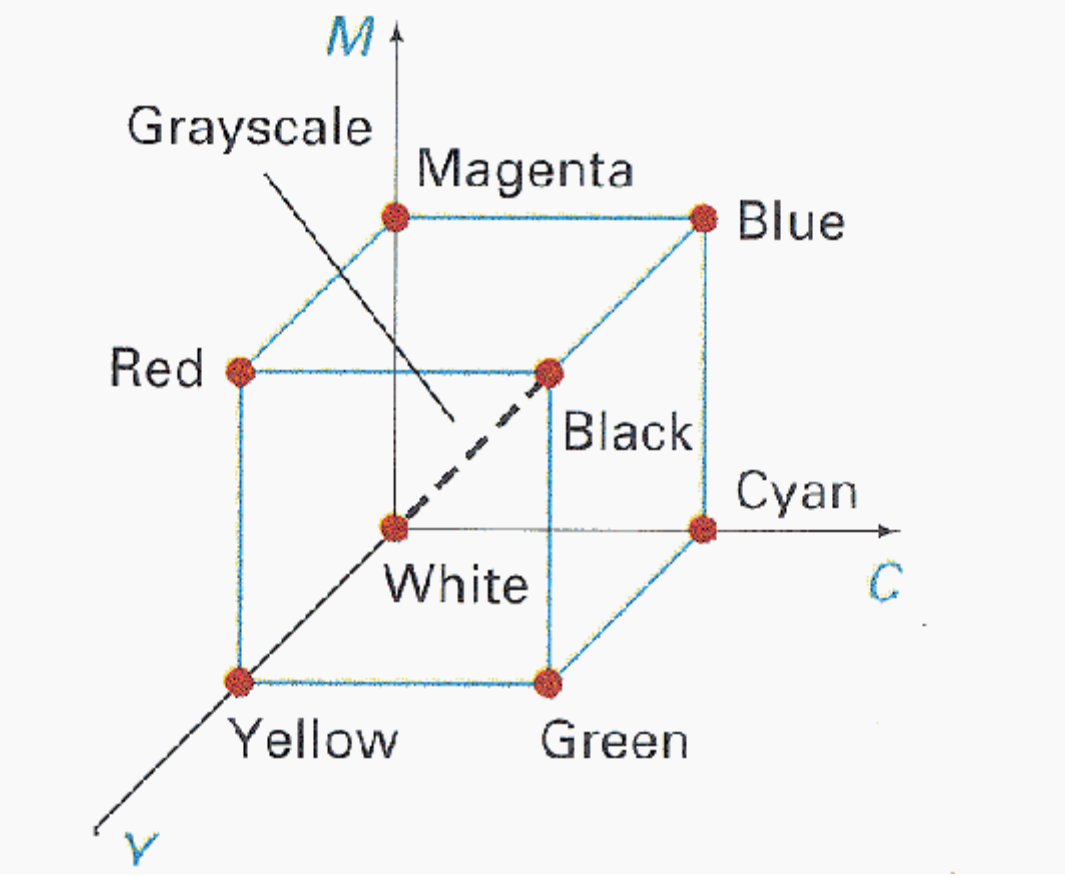
CMY Color Model



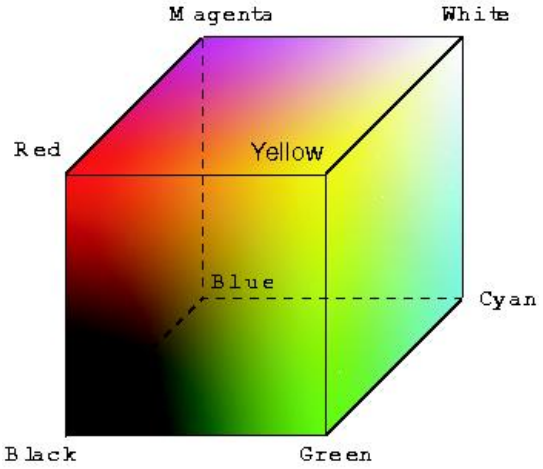
Colors are subtractive

C	M	Y	Color
0.0	0.0	0.0	White
1.0	0.0	0.0	Cyan
0.0	1.0	0.0	Magenta
0.0	0.0	1.0	Yellow
1.0	1.0	0.0	Blue
1.0	0.0	1.0	Green
0.0	1.0	1.0	Red
1.0	1.0	1.0	Black
0.5	0.0	0.0	
1.0	0.5	0.5	
1.0	0.5	0.0	

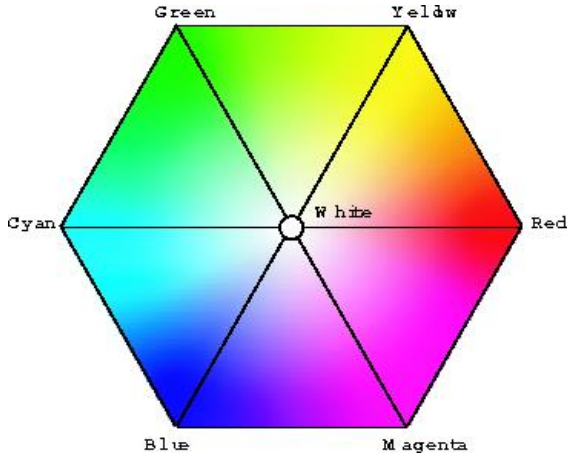
CMY Color Model



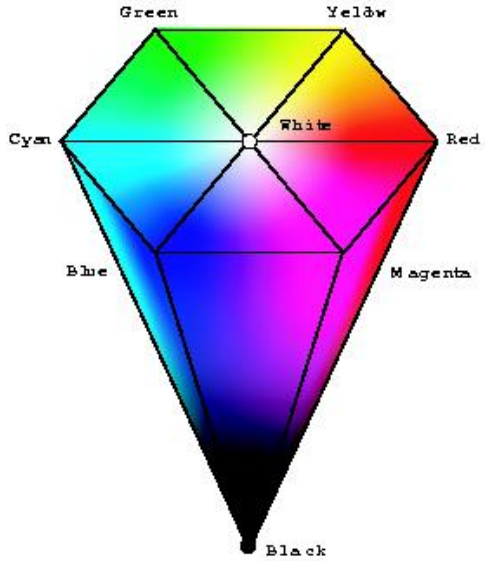
HSV Color Model



RGB cube



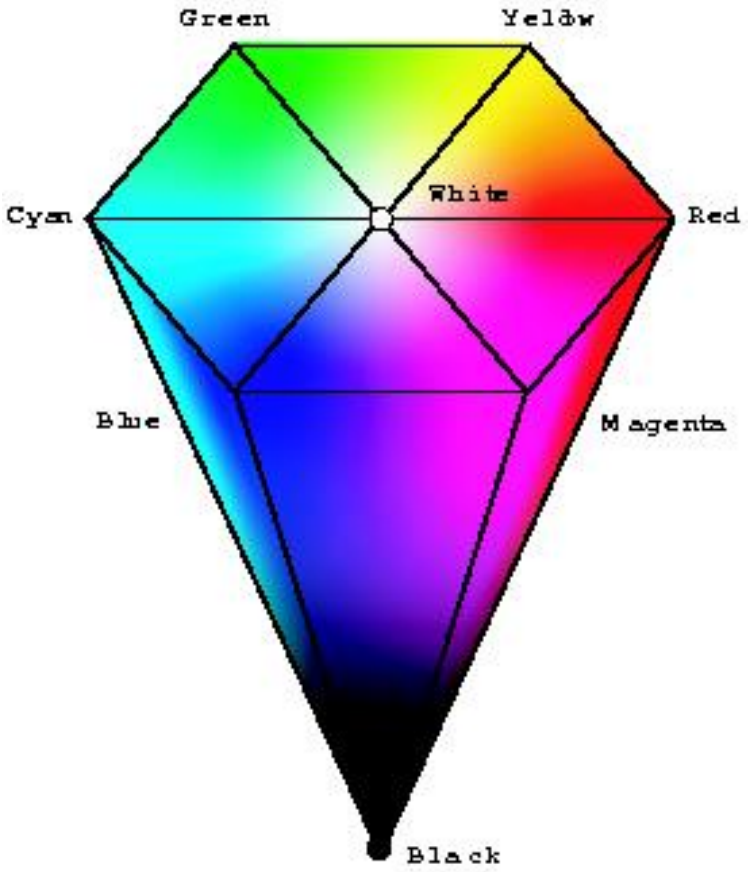
HSV top view

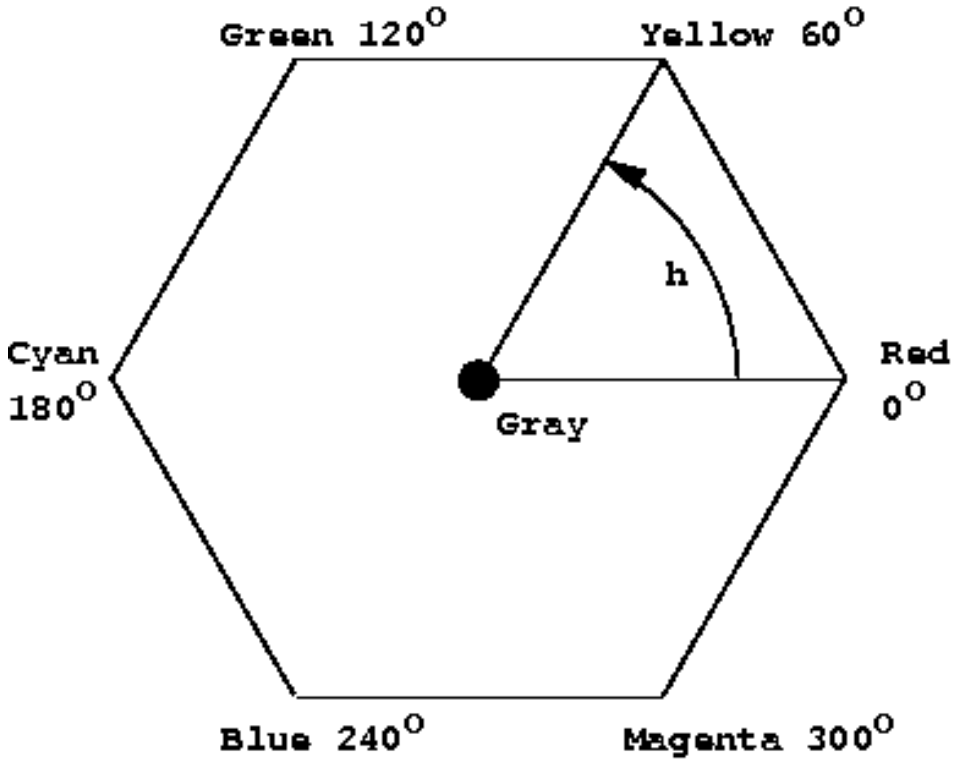


HSV cone

HSV is a projection of the RGB space

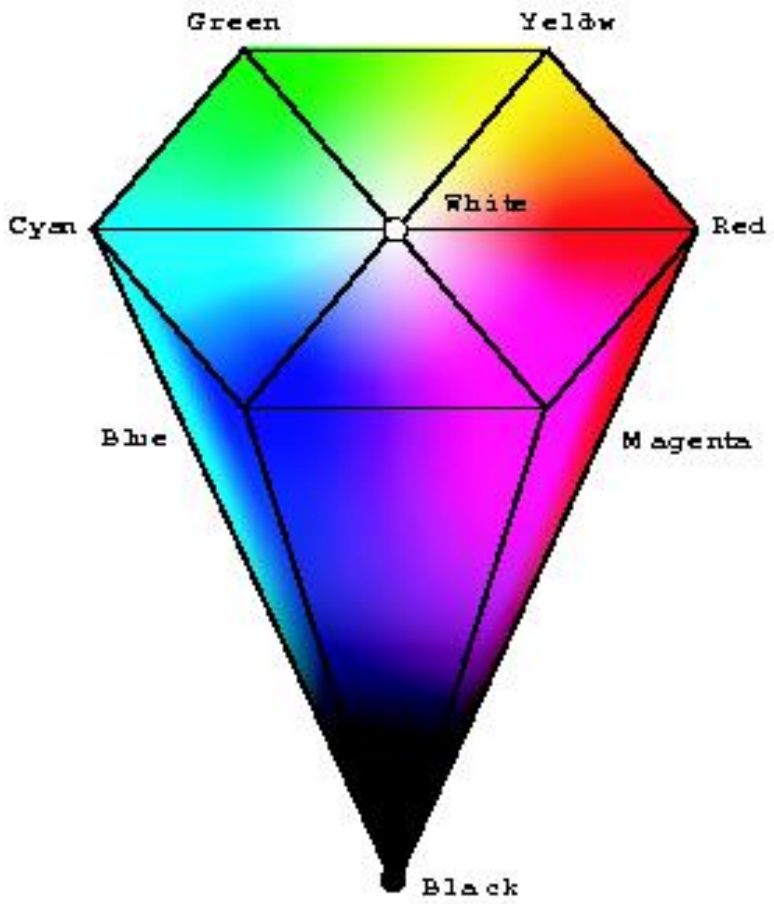
HSV Color Model

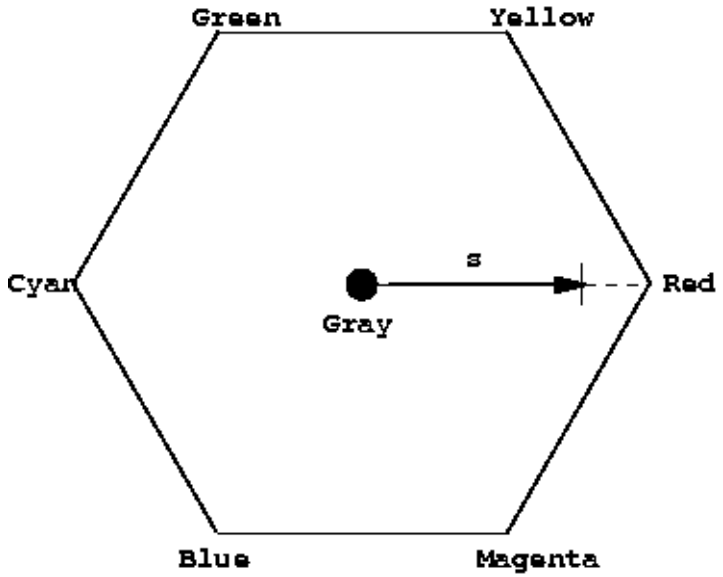




, an angular measure (0 … 360)

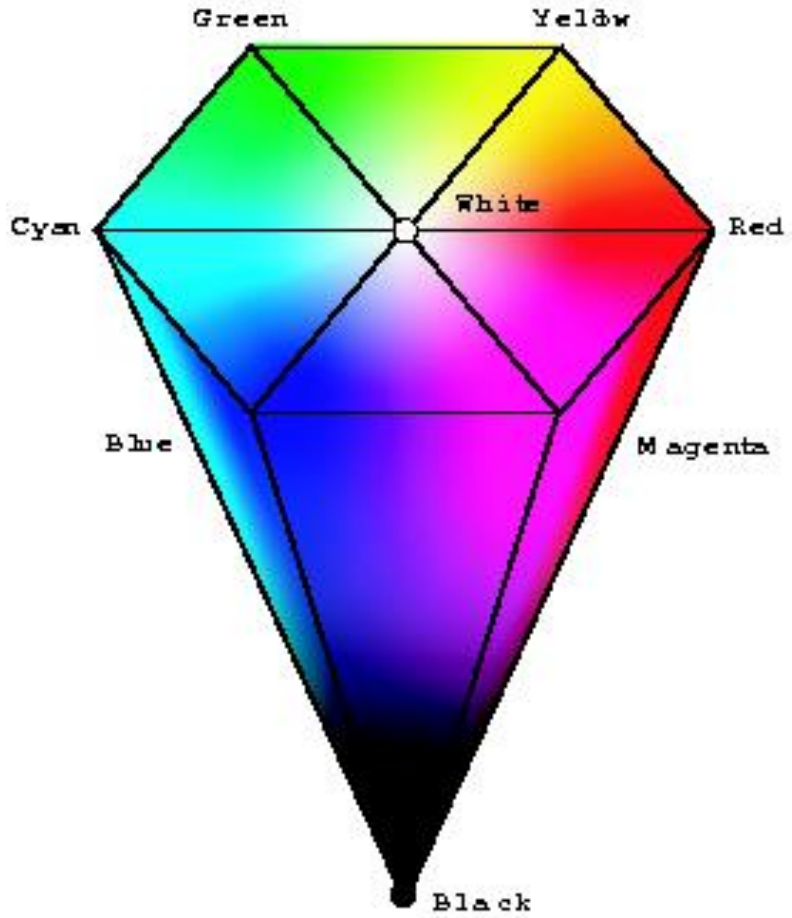
HSV Color Model

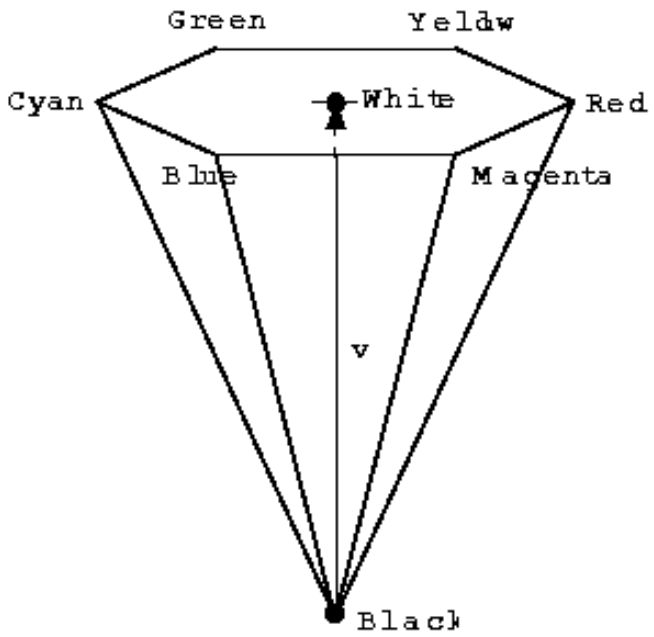




Saturation, a fractional measure (0.0 … 1.0)

HSV Color Model





Value, a fractional measure (0.0 … 1.0)