Color models and Application

Properties of Light

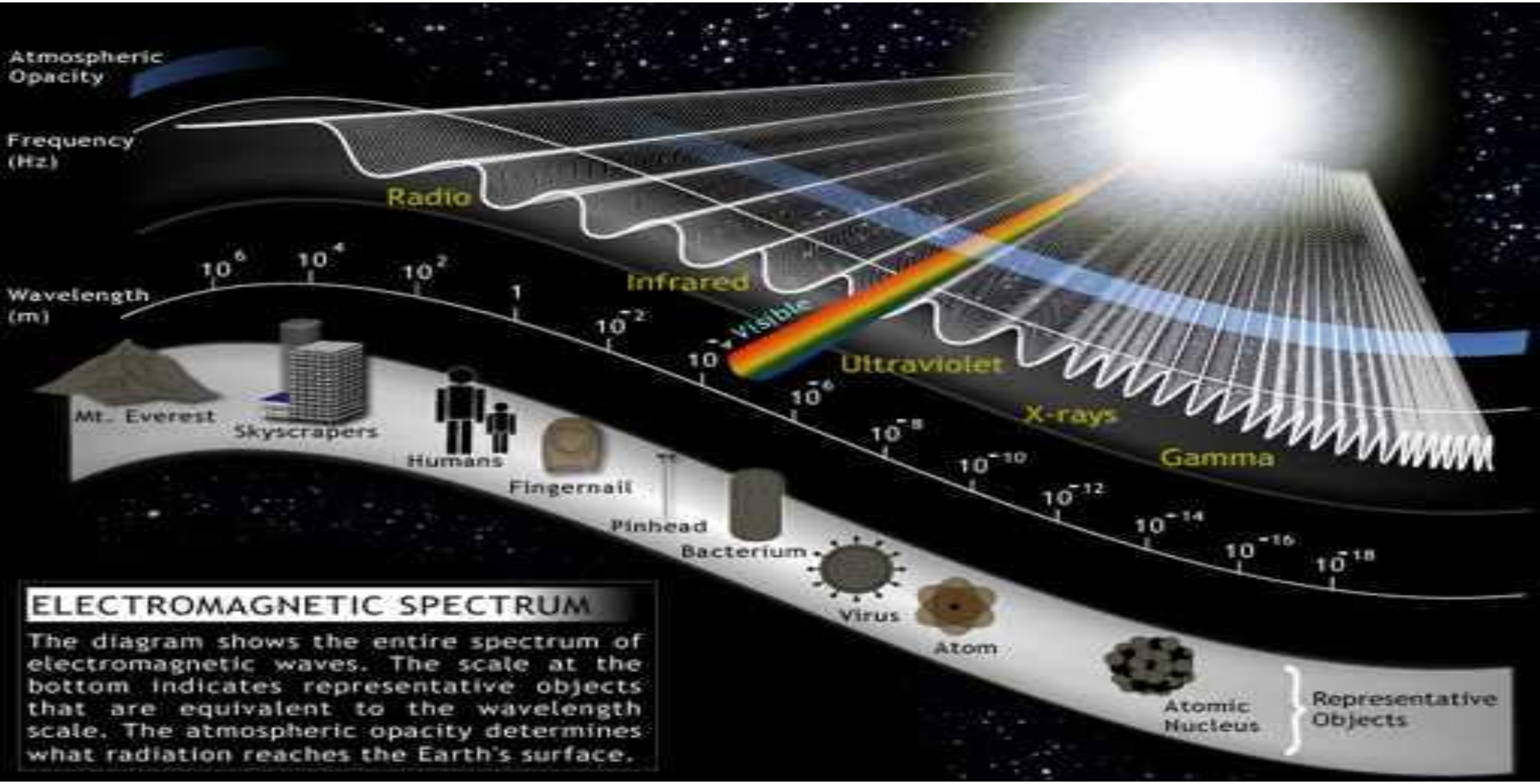
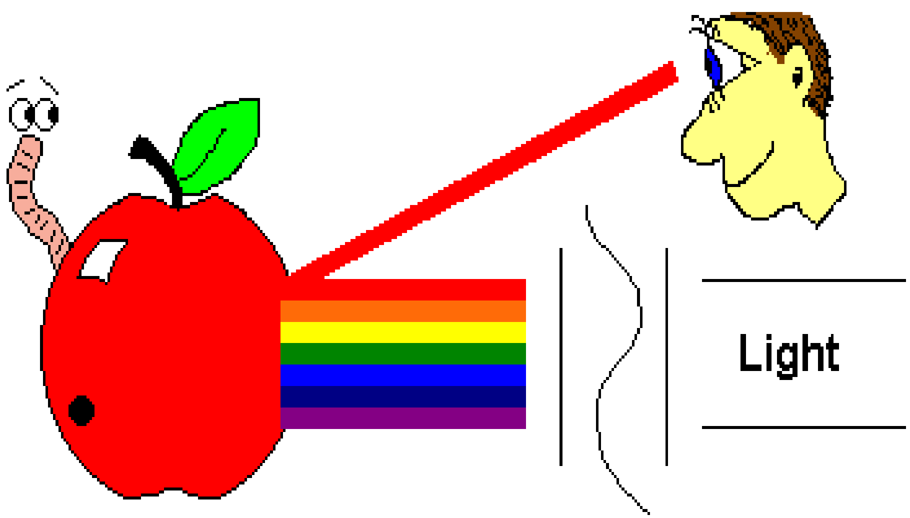


FIGURE-1

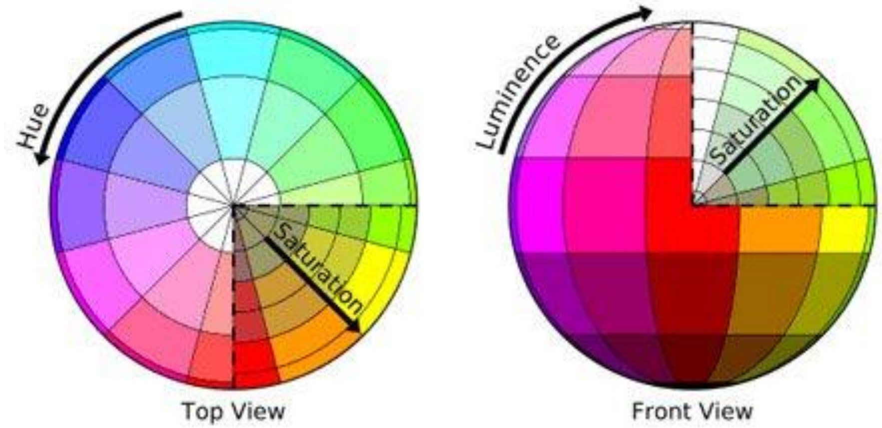
Each frequency value within the visible region of the electromagnetic spectrum corresponds to a distinct **spectral color.**

Properties of Light

- When white light is incident on an opaque object , some frequencies are reflected and some are absorbed.
- The combination of frequencies present in the reflected in the reflected light determines the color of the object that we see.(**Dominant frequency** or **Hue**)



Characteristics of Color



1. Dominant Frequency (Hue)
   The color we see (red, green, purple).

2. Brightness
   The total light energy, how bright is the color (How bright are the lights illuminating the object?)

3. Purity (Saturation)
   Purity describes how close a light appears to be to a pure spectral color, such as pink is less saturated than red.

Chromaticity refers to the two properties (purity & hue) together.

Color Model

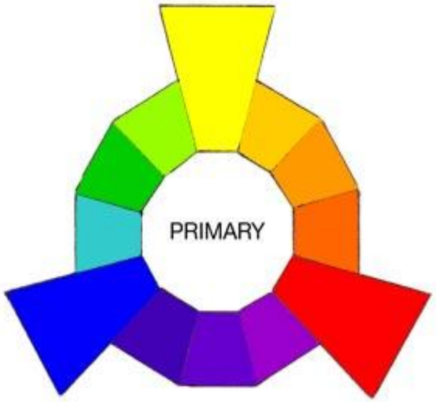
- A color model is an abstract mathematical model describing the way colors can be represented as tuples of numbers, typically as three or four values or color components. *[Wikipedia]*

- Any method for explaining the properties or behavior of color within some particular context is called a Color Model.*[Hearn, Baker ,computer graphics with OpenGL]*

Color Model

Primary Colors

Sets of colors that can be combined to make a useful range of colors



Color Gamut

Set of all colors that we can produce from the primary colors.

Complementary Colors

Pairs of colors which, when combined in the right proportions, produce white.

Example, in the RGB model: red & cyan , green & magenta , blue & yellow.

- No finite set of real primary colors can be combined to produce all possible visible colors.
- However, given a set of three primary colors, we can characterize any fourth color using color-mixing processes.

Color Model

Shades , Tints & Tones

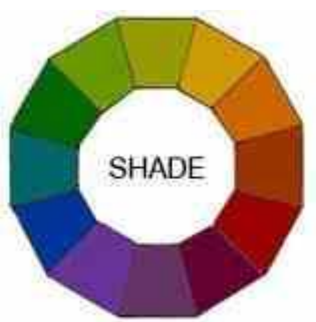
- A shade is produced by “dimming ” a hue.[Adding black].

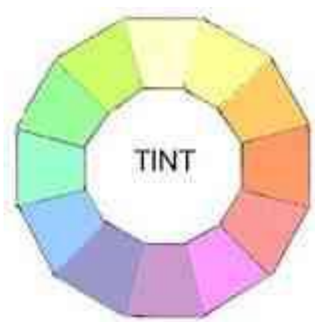
  Dark Blue = pure blue + black

- A tint is produced by "lightening" a hue. [Adding white].

  Pastel red = pure red + white

- Tone refers to the effects of reducing the "colorfulness" of a hue. [adding gray] or [adding black & white].





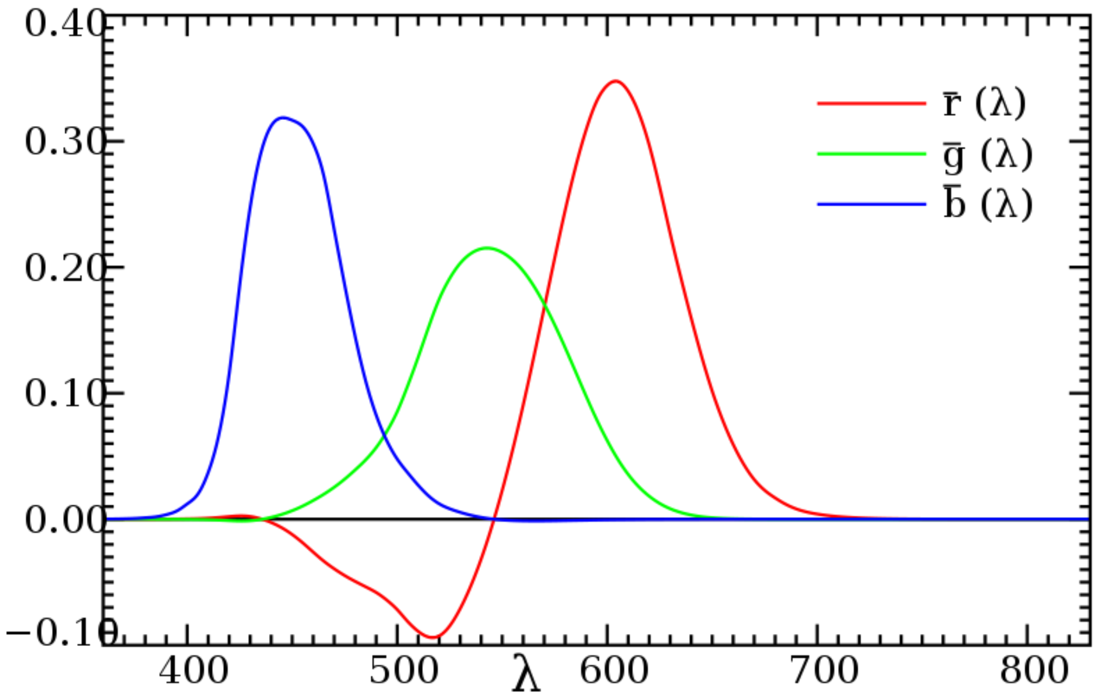
Thus, shading takes a hue toward black, tinting takes a hue towards white, and tones cover the range between.

CIE Chromaticity Diagram

- Used to describe colors as accurately as possible.
- Uses the fact that colors can be described by combinations of three basic colors, called <u>Primary colors</u>.
- Primary colors
  - Colors used in a color model to produce all the other colors in that model.
  - Cannot be made from the other (two) colors defining the model.

CIE Chromaticity Diagram

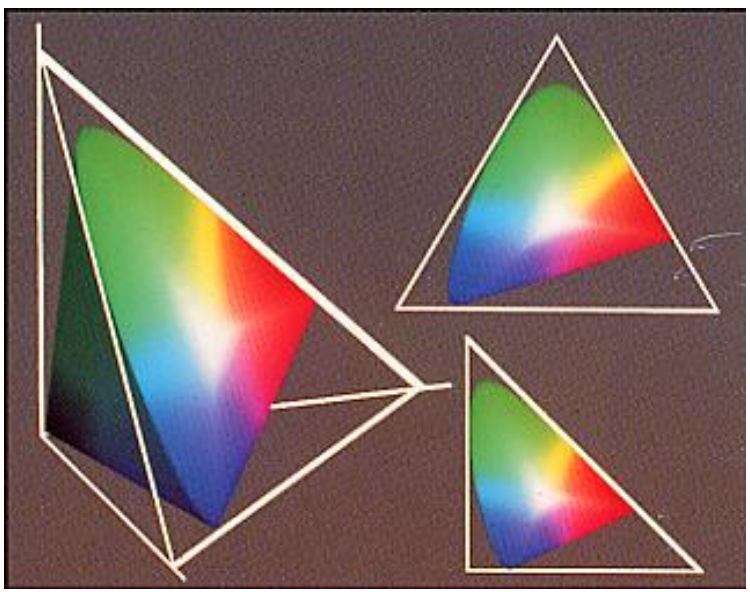
- CIE's three primary colors are imaginary.
- They cannot be seen, but they can be used to define other visible colors.

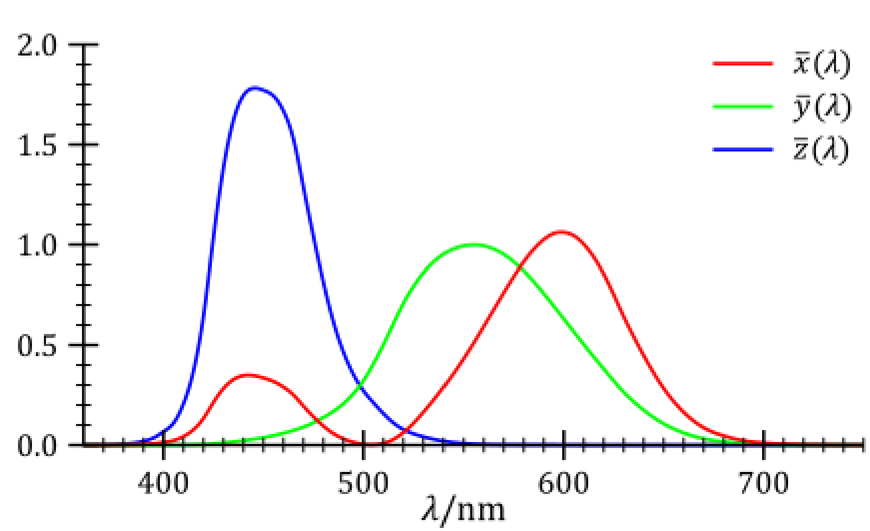


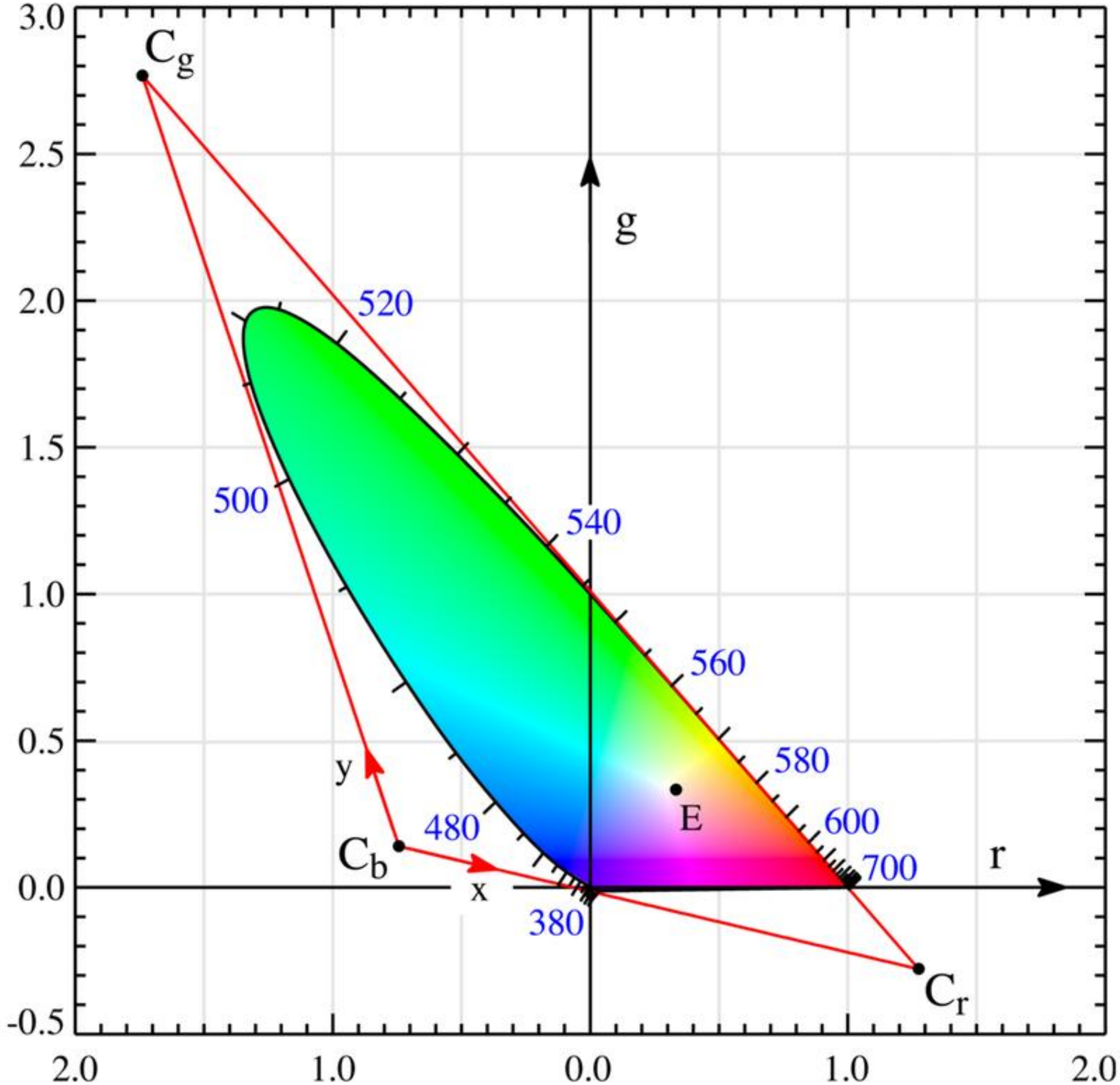
- Any color $S = AX + BY + CZ$
- $S = AX + BY + CZ$ can be normalized to
  - x = A/(A+B+C)
  - y = B/(A+B+C)
  - z = C/(A+B+C)

  ➔ **s** = $xX + yY + zZ$, where $x + y + z = 1$

  ➔ **s** lies in the plane $x + y + z = 1$ in 3D







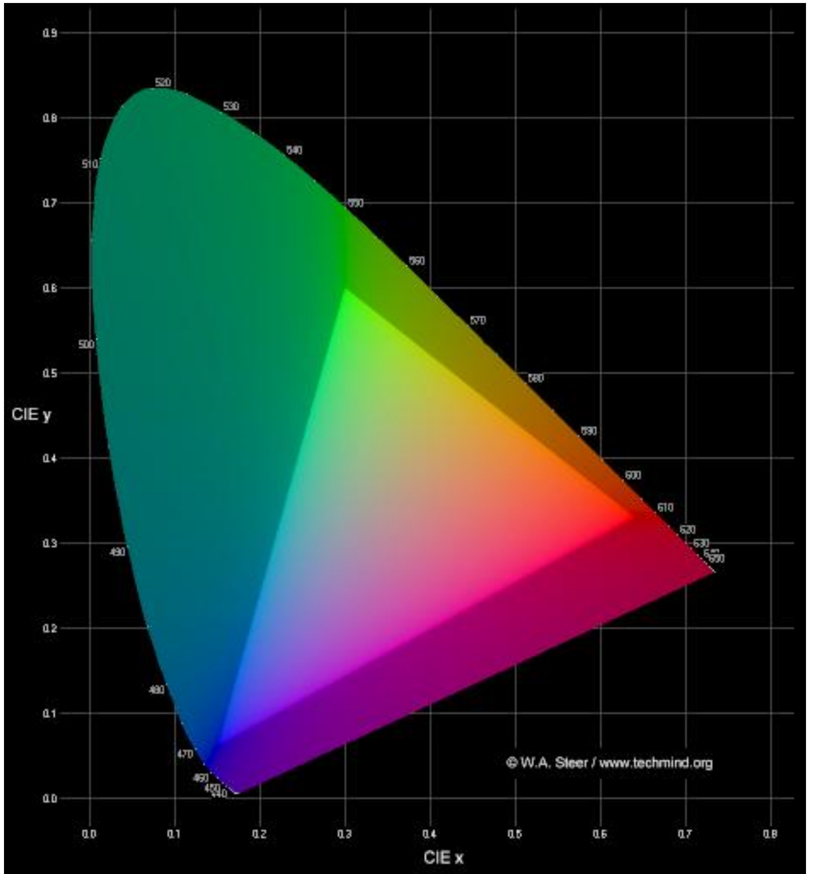
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2.0
1.0
0.0
1.0
2.0
C_g
C_b
C_r
g
r
x
y
E
520
500
540
560
580
600
700
480
380

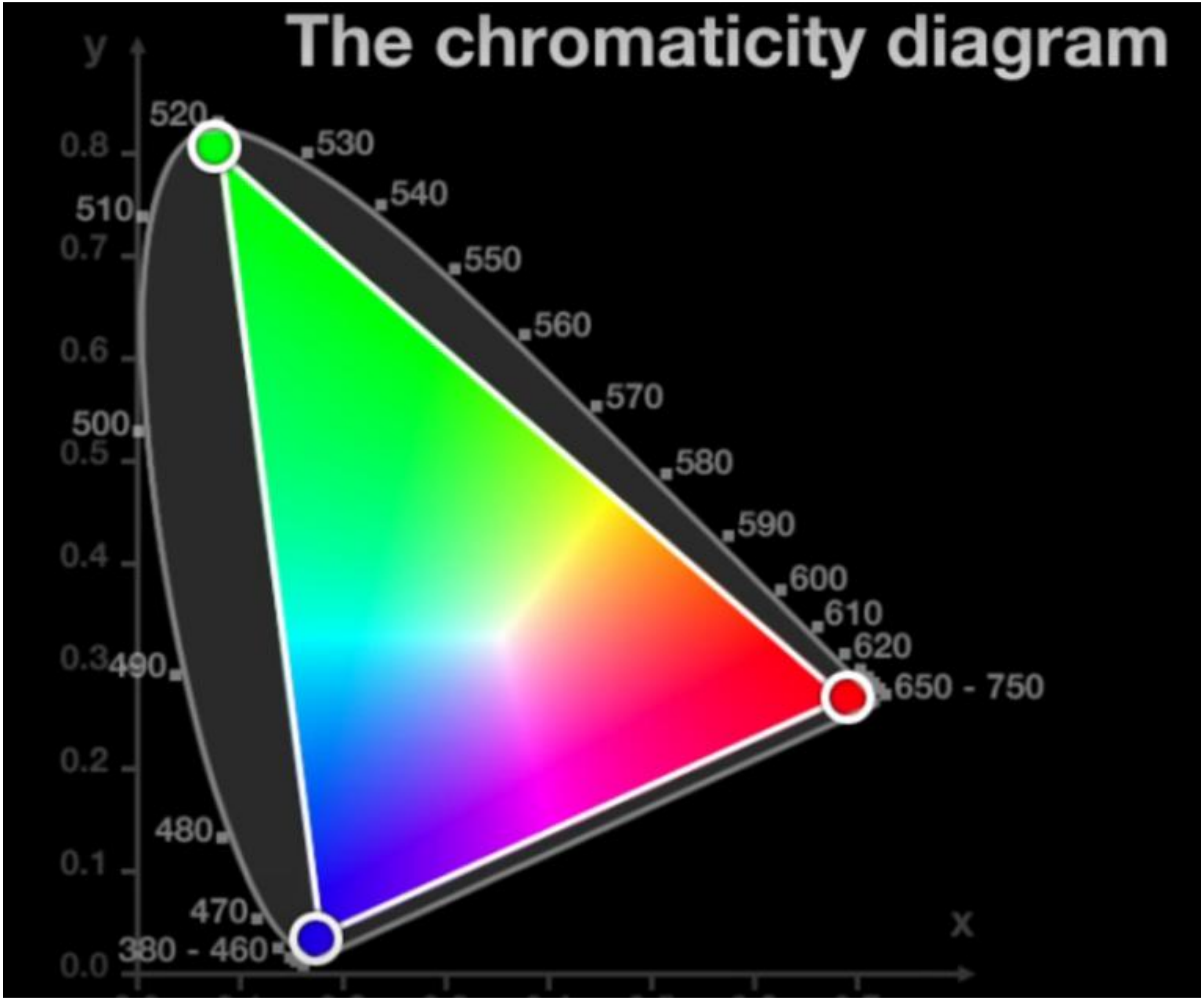
Uses of CIE chromaticity diagram

- Any colors on the line *l* between two colors *a* and *b*
  - Is a combination of *a* and *b*
  - Is a legitimate color
- Complementary colors
  - Any two colors on a line passing through white and added up to be white are complementary
  - red⇔cyan   green⇔magenta   blue⇔yellow

Uses of CIE chromaticity diagram

- Any color within a triangle can be generated by the three vertices of the triangle





The chromaticity diagram
y
x
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
520
530
540
550
560
570
580
590
600
610
620
650 - 750
510
500
490
480
470
380 - 460

RGB color model

RGB Color Model

- RGB is an additive color model For computer displays **uses light** to display color , Colors result from **transmitted light**
- **Red** + **Green** + **Blue** = **White**

CMYK Color Model

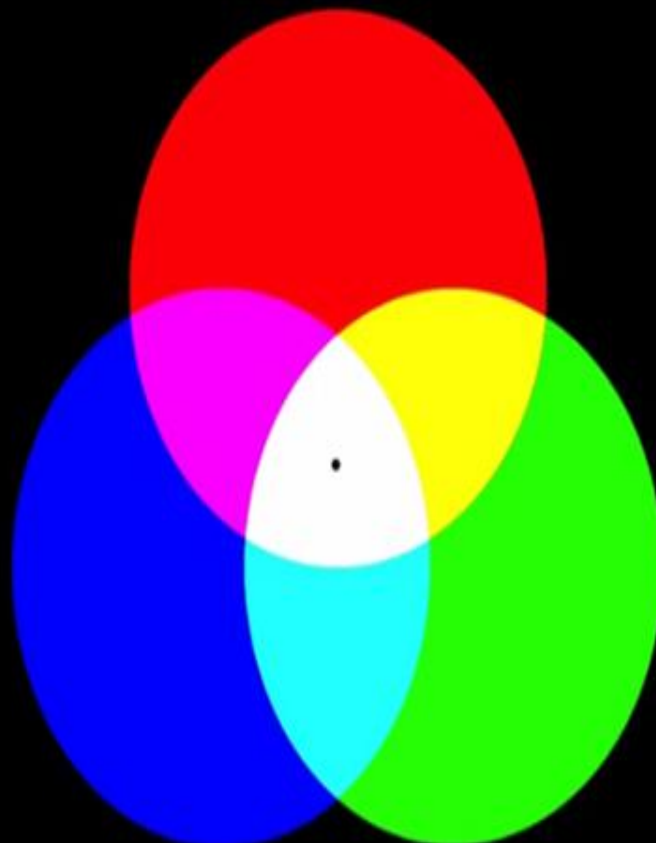
CMYK (subtractive color model) is the standard color model used in offset printing for full-color documents. Because such printing uses inks of these four basic colors, it is often called **four-color printing**.

- Where two colors of RGB overlaps, we see a new color formed by mixing of the two additive primaries. These new colors are:

- A greenish blue called **cyan**.
- A blushed red called **magenta**.
- A bright **yellow**.
- The key color , **Black**.

Rgb- red

And similarly for Blue and green



Actually, what happens is you exhaust the neurons from the cones to the brain in the proportion to which the cones are stimulated. Then, when you stare at the white screen afterwards, your cones are receiving the full spectrum of colours making white but the nerves that carry the message to the brain fire less if they are exhausted and more if they are not. Thus you see the colours that have not exhausted the neurons and those are the complementary colours to the ones that exhausted the neurons. After a while everything balances out and the exhaustion/recovery becomes equalized and the neurons carry the white in full to the brain

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CMYK Color Model

We can express this effect pseudo-algebraically. Writing R, G and B for **red, green** and **blue**, C, M and Y for **cyan,** magenta and **yellow,** and **W** for **white**, and using (**+**) to mean additive mixing of light, and (**–**) to mean subtraction of light, we have:

- C (cyan) = G + B = W - R
- M (magenta) = R + B = W - G
- Y (yellow) = R + G = W – B

In each equation, the colour on the left is called the **complementary** colour of the one at the extreme right; for example, magenta is the complementary colour of **green.**

Subtractive Colour—Mixing Pigments & Dyes

YELLOW

The yellow pigment

absorbs blue light.

Allows red and green

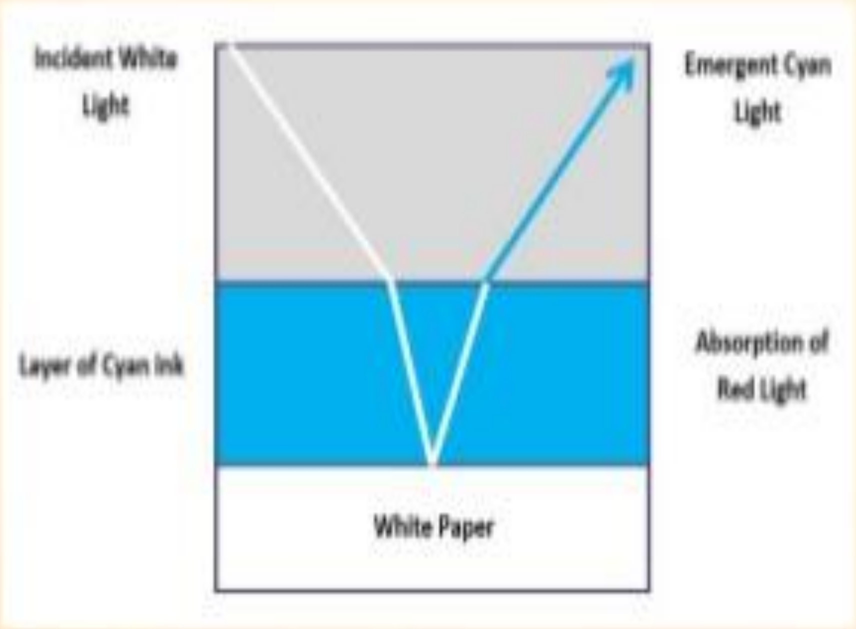
light to pass through or

reflect from its surface.

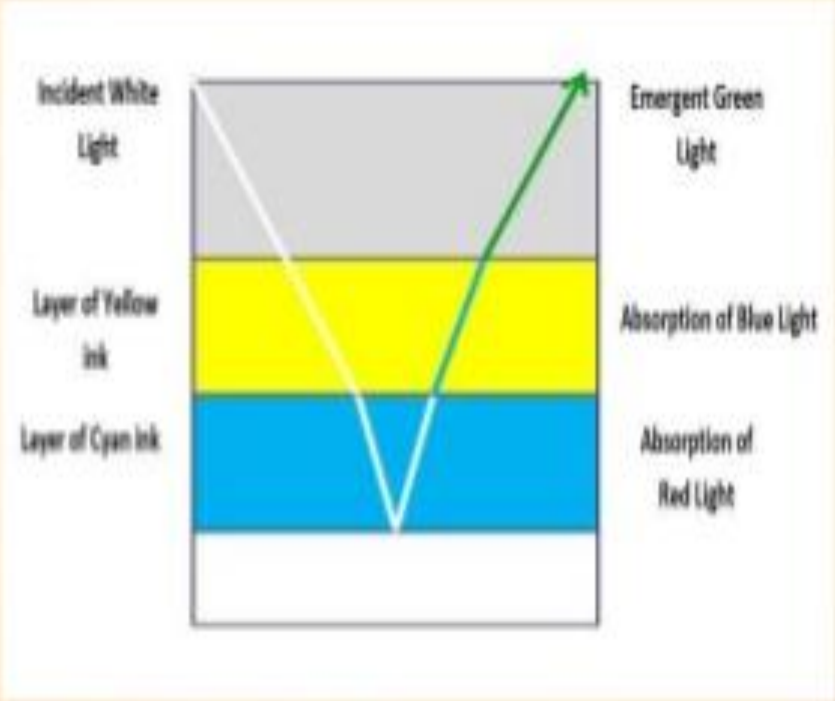
We perceive the red and green light, and see yellow.

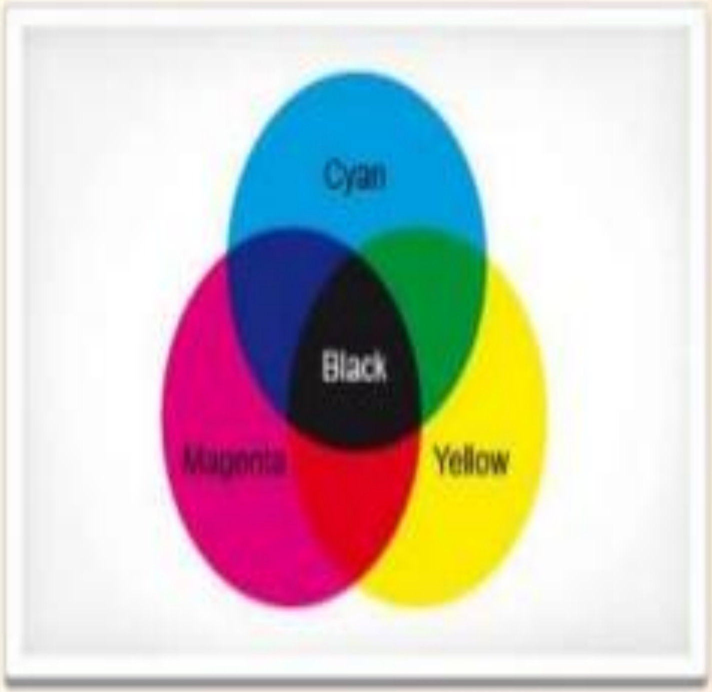
The process of reflection

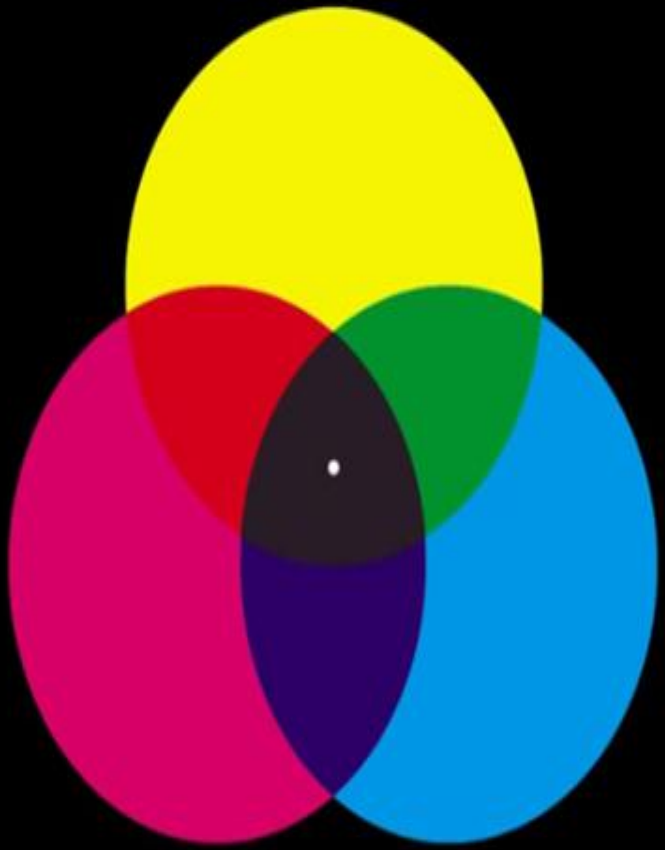
when we talk of 'cyan ink', we mean ink that, when it is applied to **white paper** and illuminated by white light will **absorb** the **red** component, allowing the **green** and **blue**, which combine to produce the **cyan** colour, to be reflected back.



• If we apply a layer of such an ink to white paper, and then add a layer of yellow, the yellow ink will absorb incident blue light, so the combination of the cyan and yellow inks produces a green colour.



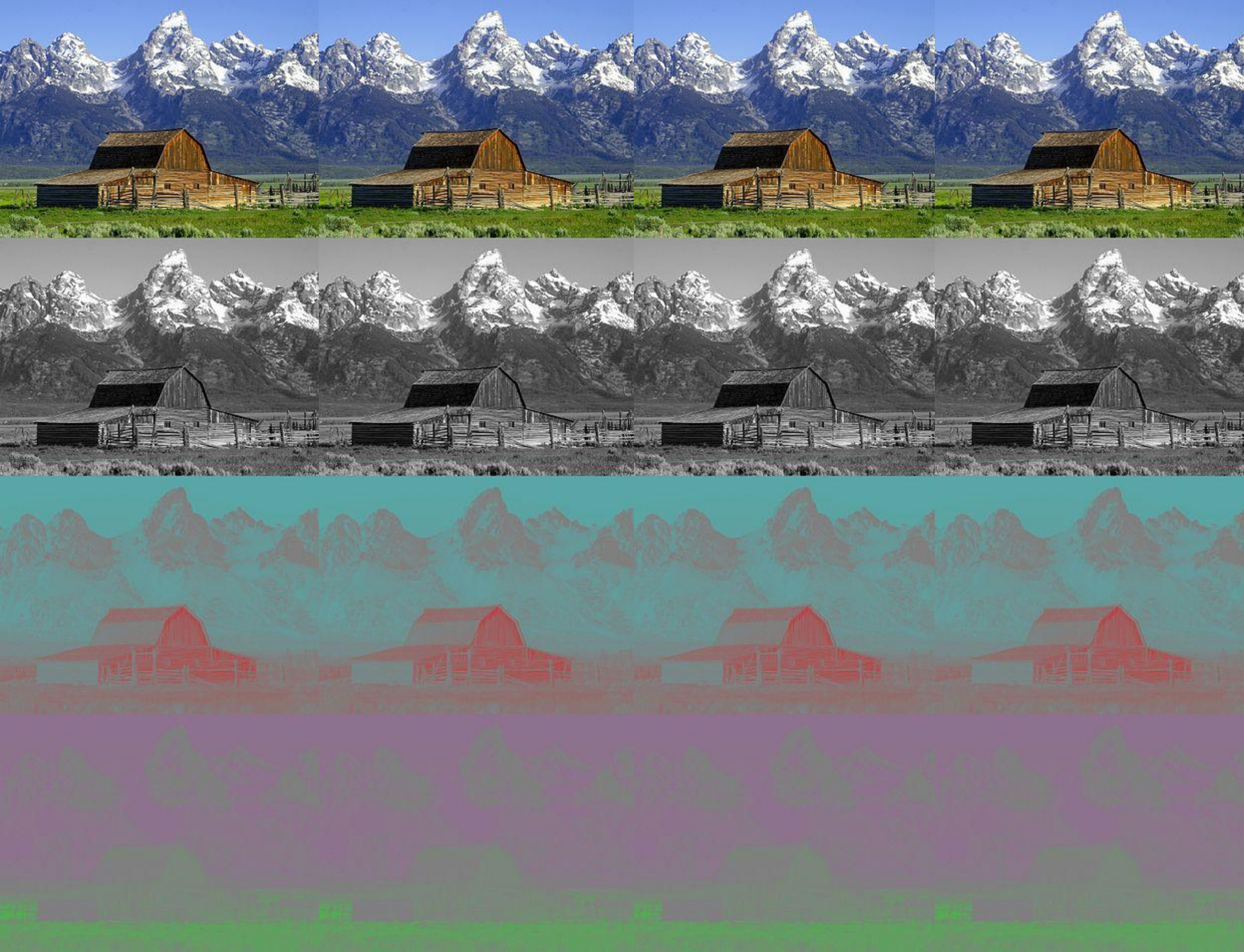




YIQ Color Model

- YIQ
  - *Y*: luminance
  - *I*, *Q*: chromaticity
  - Only *Y* shown in black-and-white TV
- RGB → YIQ

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



YIQ Color Model

- Human's visual properties
  - More sensitive to changes in luminance than in hue or saturation

    ➔ more bits should be used to represent *Y* than *I* and *Q*
  - Limited color sensation to objects covering extremely small part of our field of view

    ➔ One, rather than two color dimensions would be adequate

    ➔ *I* or *Q* can have a lower bandwidth than the others

YIQ Color Model

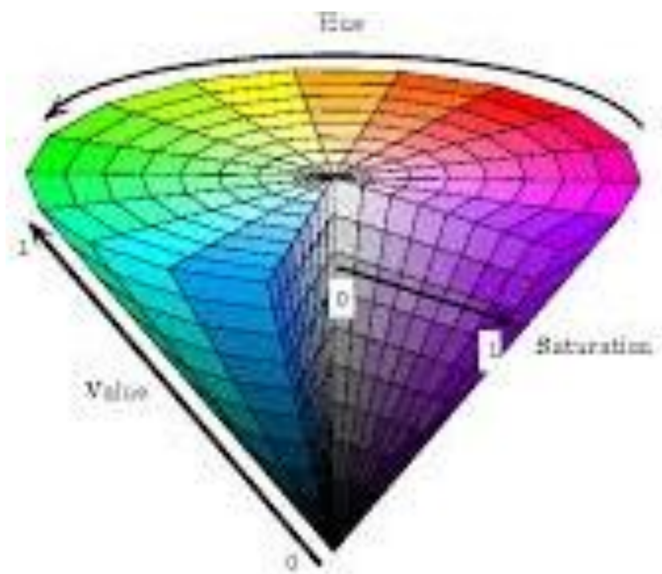
- NTSC encoding of YIQ into broadcast signal
  - Uses human's visual system properties to maximize information transmitted in a fixed bandwidth
  - Y: 4MHz
  - I: 1.5MHz
  - Q: 0.6MHz

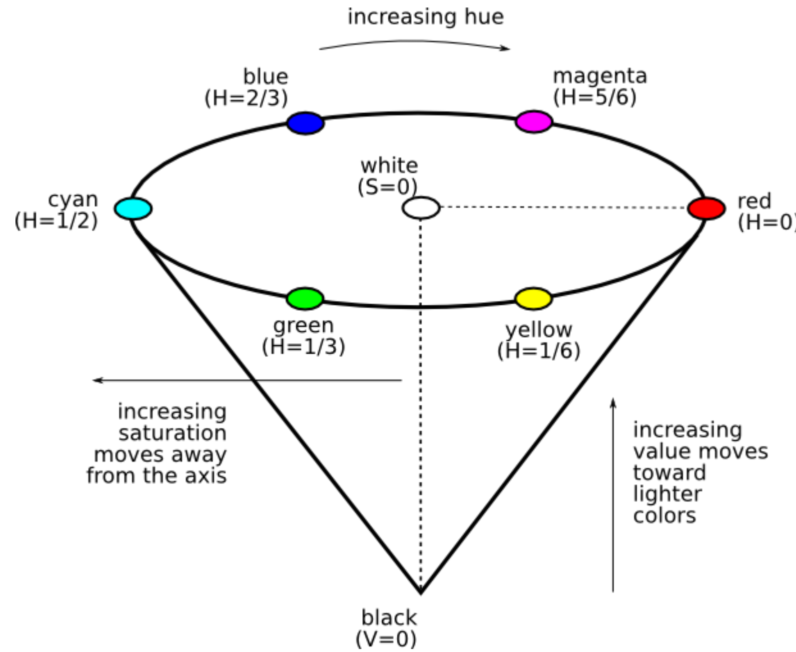
YIQ Color Model

- Used in U.S. commercial color-TV broadcasting
  - Recoding of RGB for transmission efficiency
  - Backward compatible with black-and-white TV
  - Transmitted using NTSC (National Television System Committee) standard

HSV Model

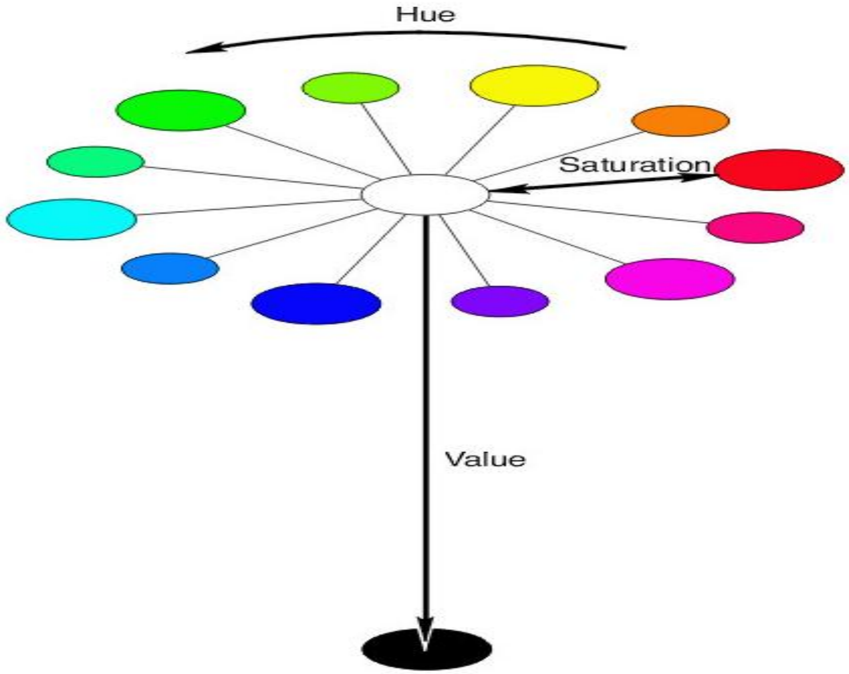
Every color is represented by three components Hue (H), Saturation (S) and Value (V)

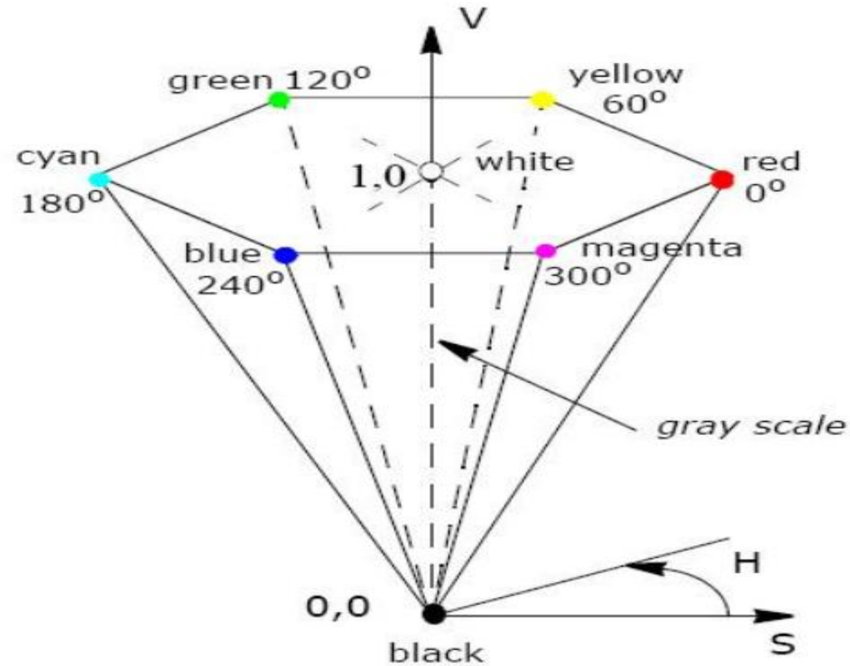




HSV Model

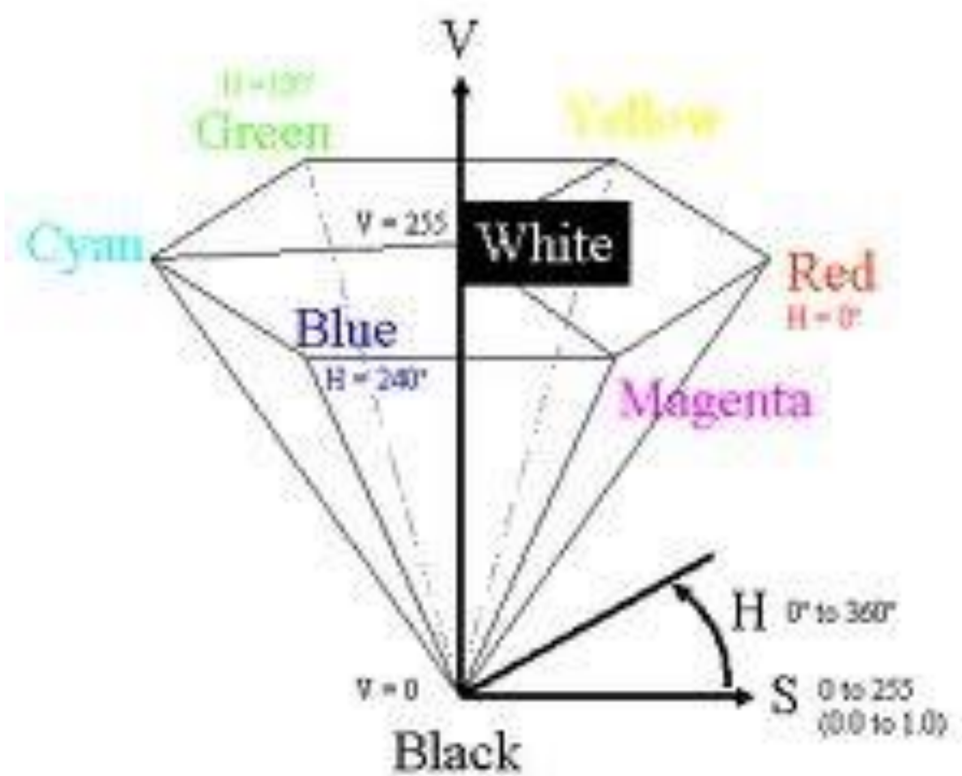
The **Hue (H)** of a color refers to which pure color it resembles. All tints, tones and shades of red have the same hue. (simply the color we see)





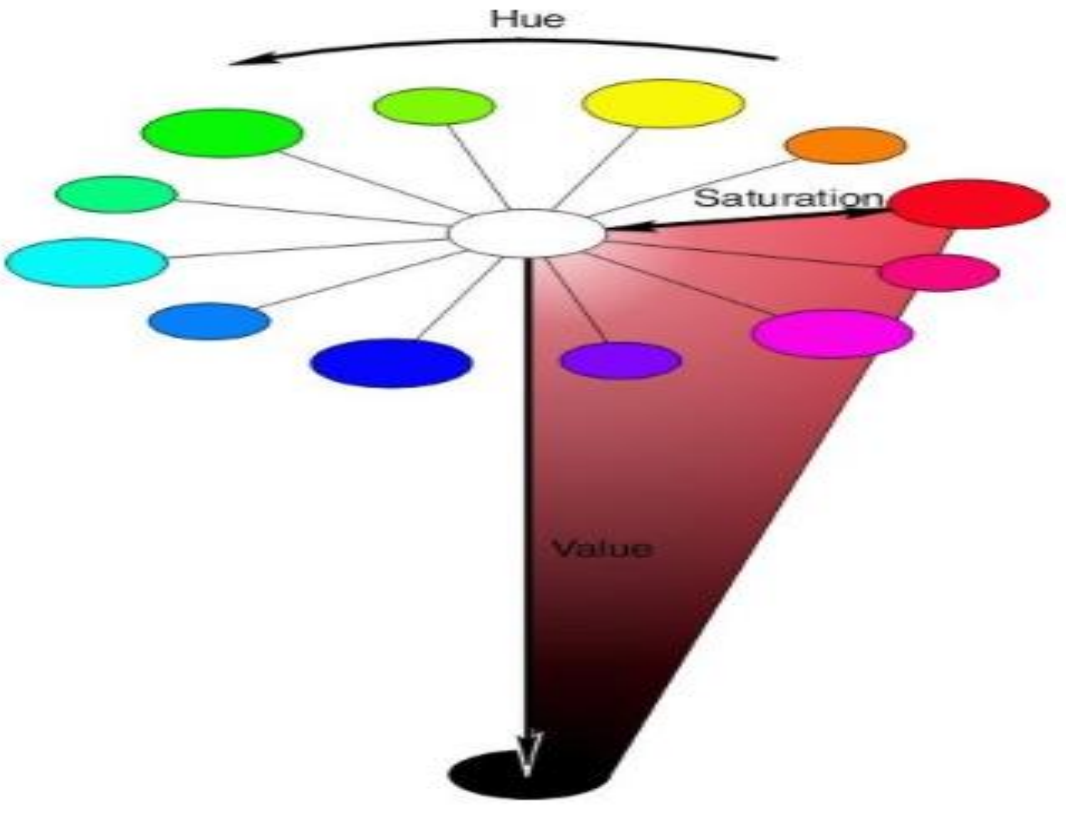
HSV Model

The **Value (V)** of a color, also called its lightness, describes how dark the color is. A value of 0 is black, with increasing lightness moving away from black.



HSV Model

The **Saturation (S)** of a color describes how white the color is. Or the amount of white added to the color. A pure red is fully saturated (S=1) means no white added



Applications

- Use in Marketing
- Specific Color meaning
- Attracting Attention
- Individual differences

Thank you!