# Color in Computer Graphics

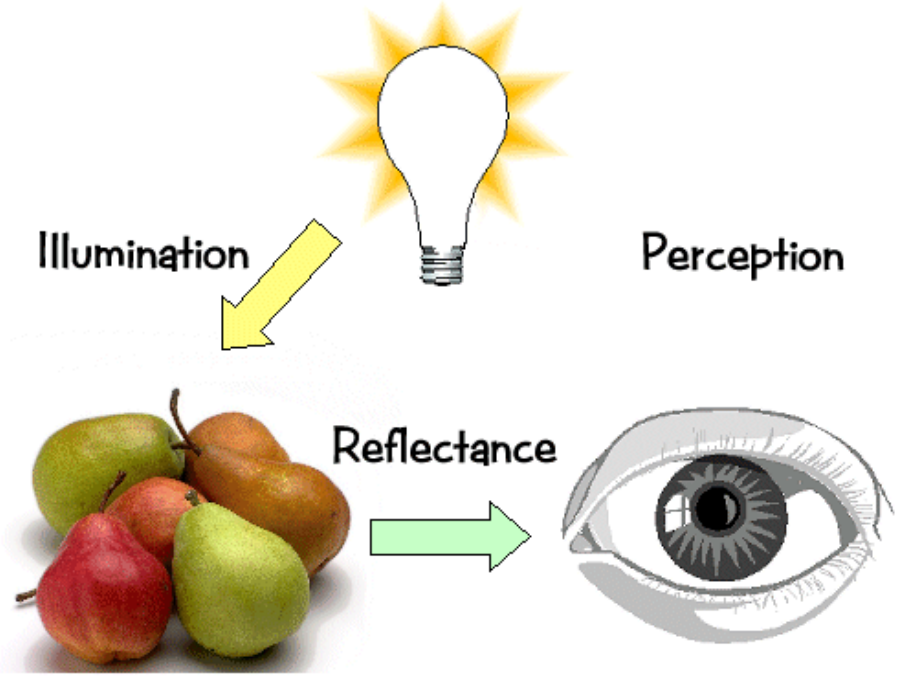
# Outline

- **Color Perception**
- Color Spaces

- Ref
  - http://cs.anu.edu.au/escience/lecture/cg/Color/
  - http://dba.med.sc.edu/price/irf/Adobe_tg/models/main.html

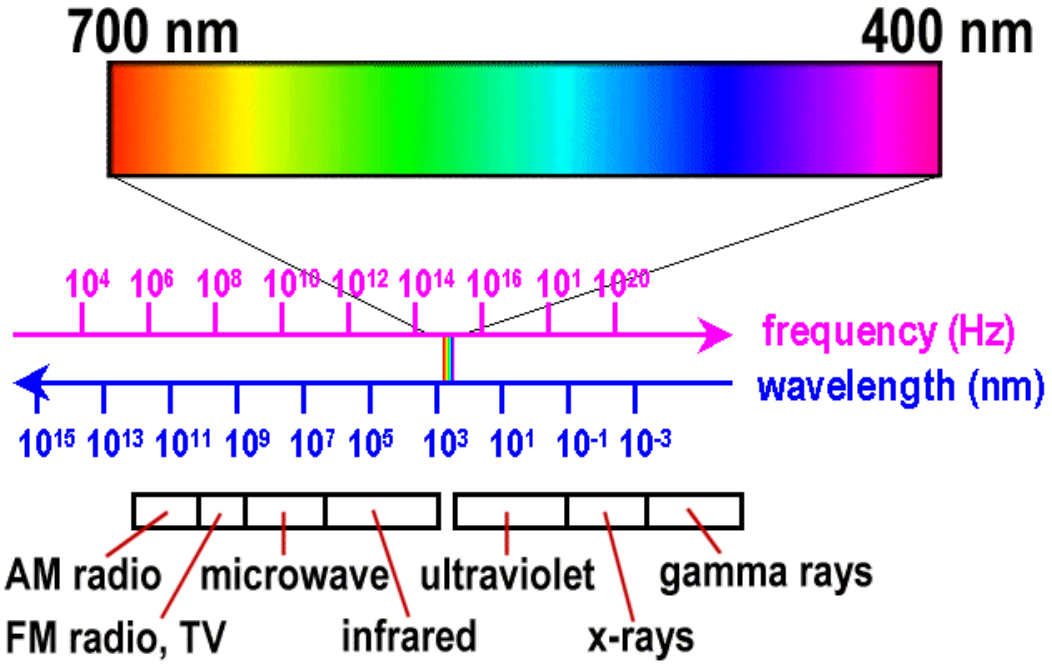
# Elements of Colour

- How do we perceive colour ?



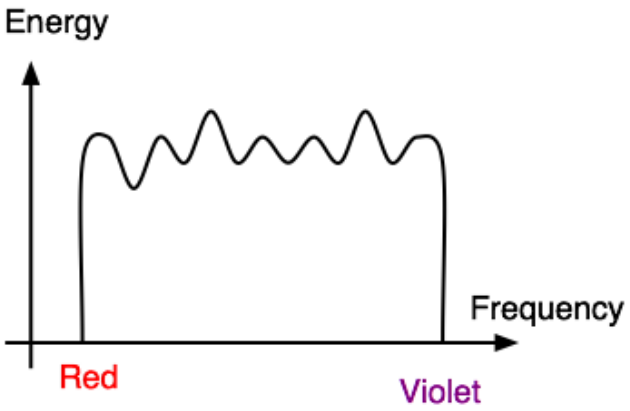
# Visible Spectrum

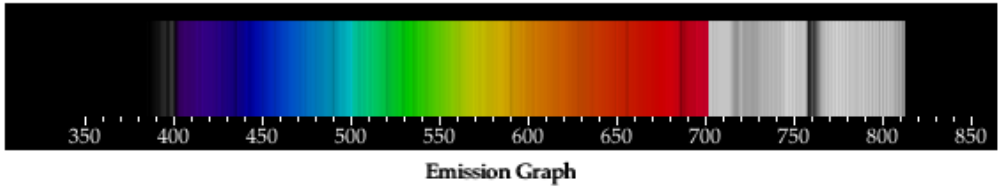
- Visible light is a very small part of electromagnetic energy



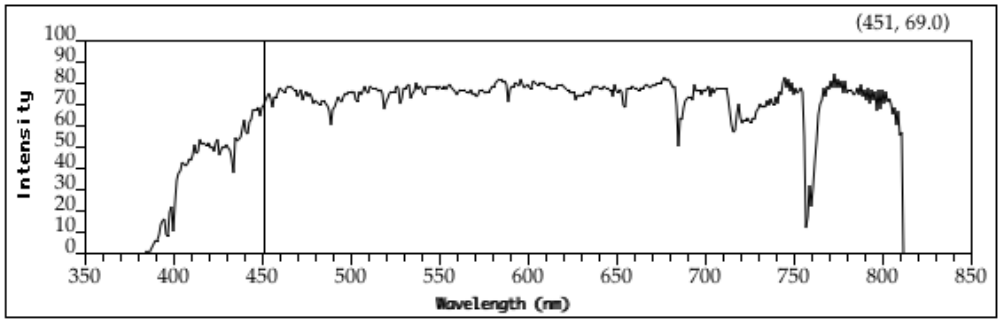
# The span of the white light

- Sun or light bulb emit all frequencies within the visible range to produce what we perceive as the "white light"




Emission Graph




Electromagnetic Spectrum

**Sun Spectroscopy**

# The span of the white light (cont)

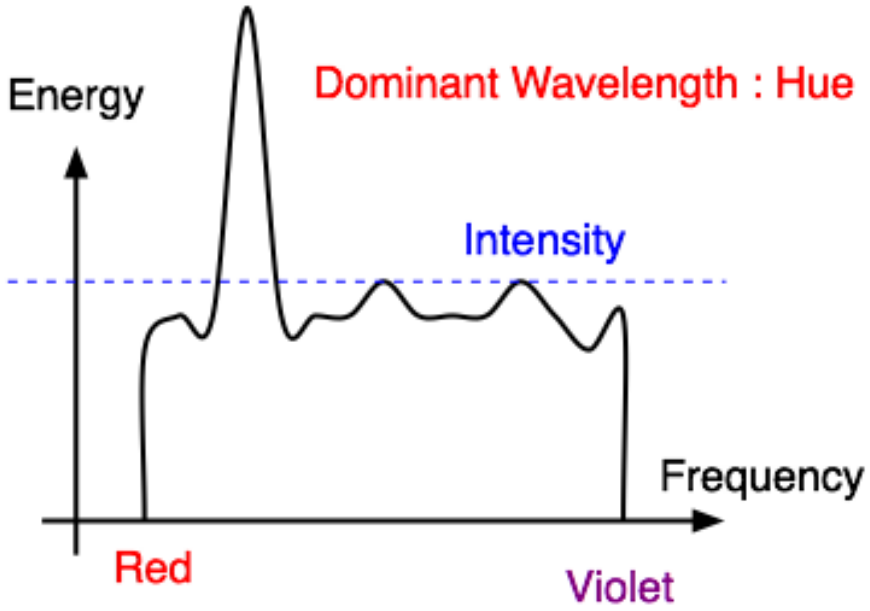
- When white light is incident upon an object, some frequencies are reflected and some are absorbed by the object.
- It is the combination of frequencies present in the reflected light that determines what we perceive as the color of the object

# Light characteristics

- When we view a source of light, our eyes respond respond to :
  - Hue (color)
  - Brightness
  - Purity or Saturation
- Chromaticity :
  - Hue
  - Purity or Saturation

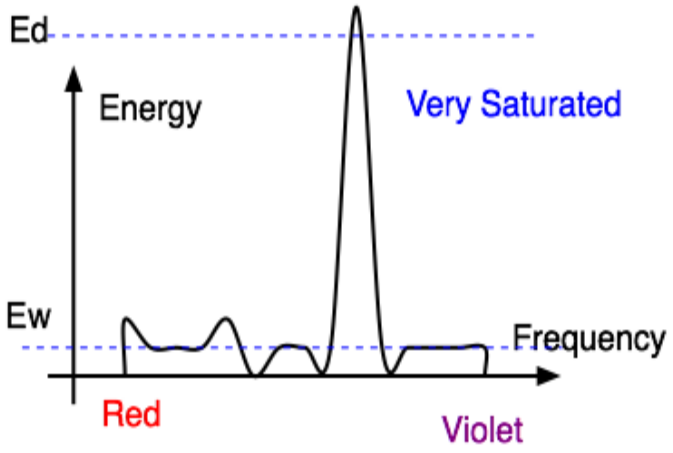
# Hue

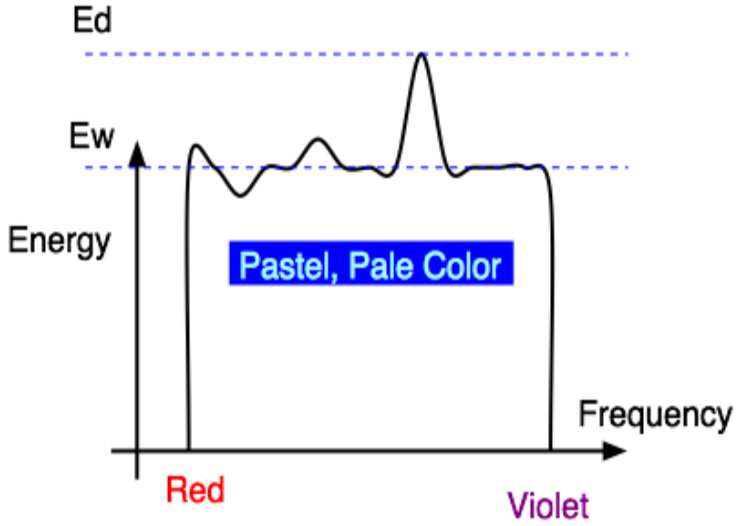
- The **Hue** (or simply, the "color") is the dominant *wavelength (or dominant frequency)*



# Purity or Saturation of Light

- Purity of 100% when Ew = 0
- Purity of 0% when Ed = Ew



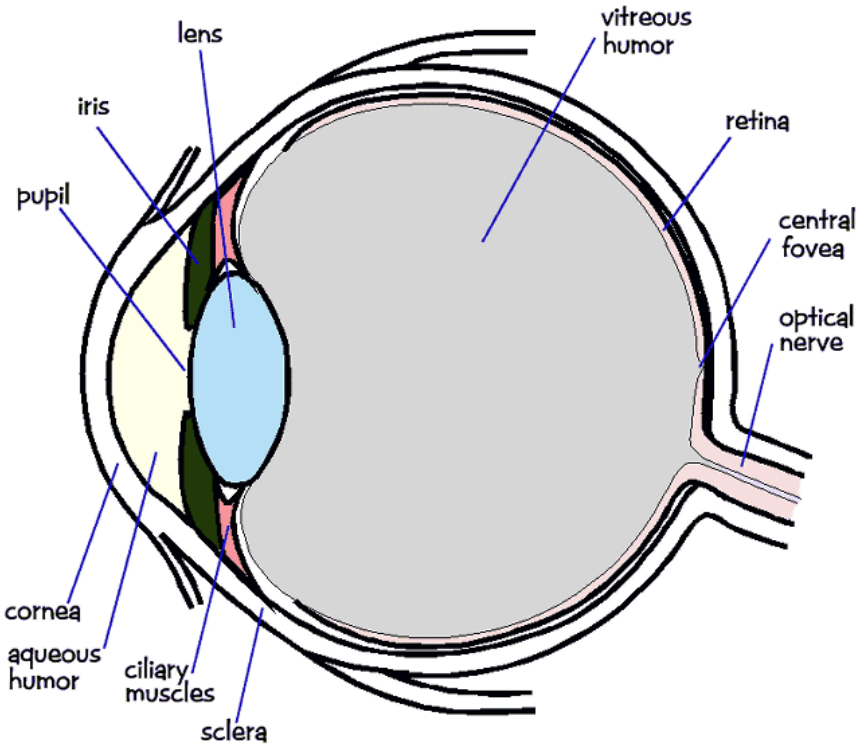



# Intensity, Brightness

- The integration of the energy for all the visible wavelengths is proportional to the intensity of the colour
- **Intensity** : Radiant Energy emitted per unit of time, per unit solid angle, and per unit projected area of the source (related to the luminance of the source)
- **Brightness** : perceived intensity of light

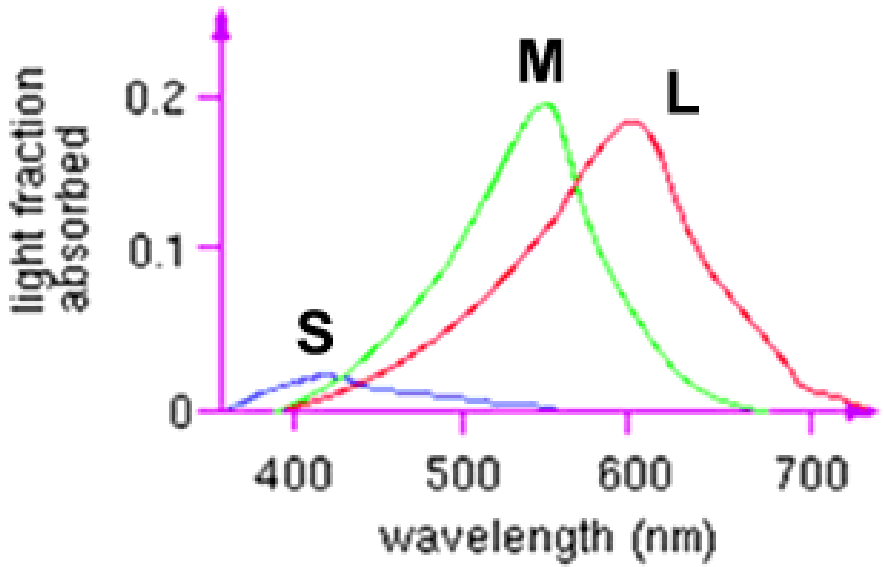
# The Eye

- The photosensitive part of the eye is called the **retina**.
- The retina is largely composed of two types of cells
  - ***Rods:*** light sensitive
  - ***Cones:*** responsible for color perception.



# Cons

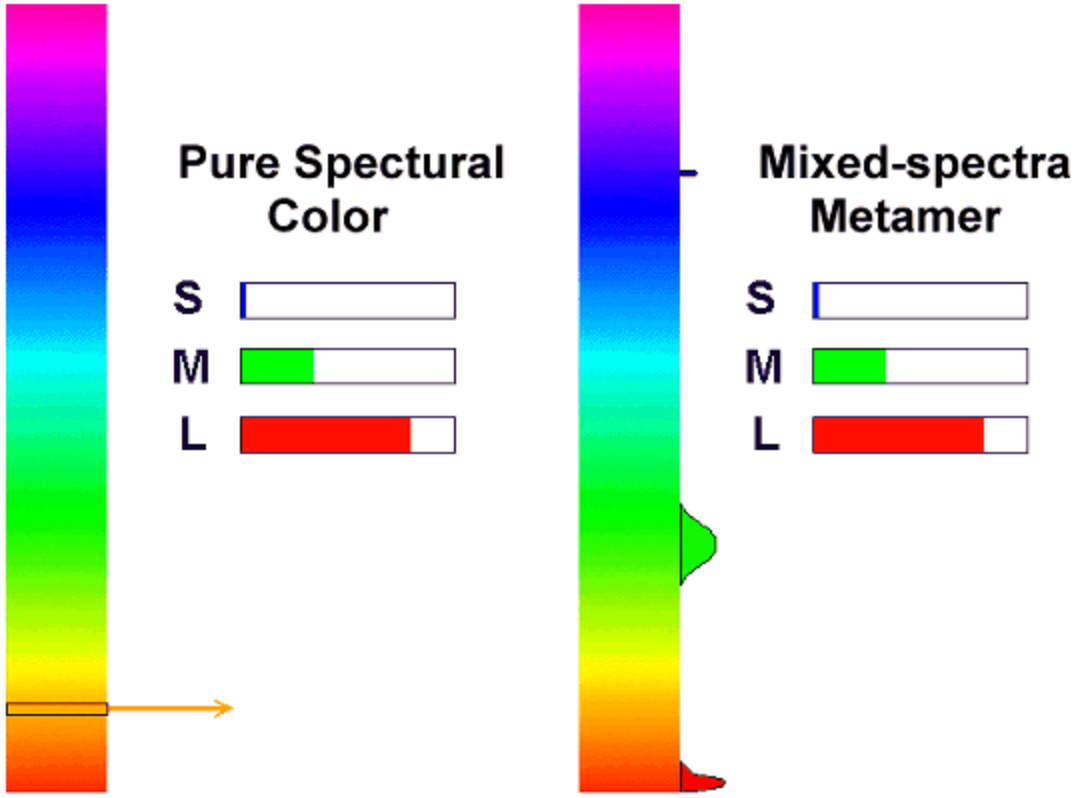
- Three types of cones
  - S ~ blue
  - M ~ green
  - L ~ red



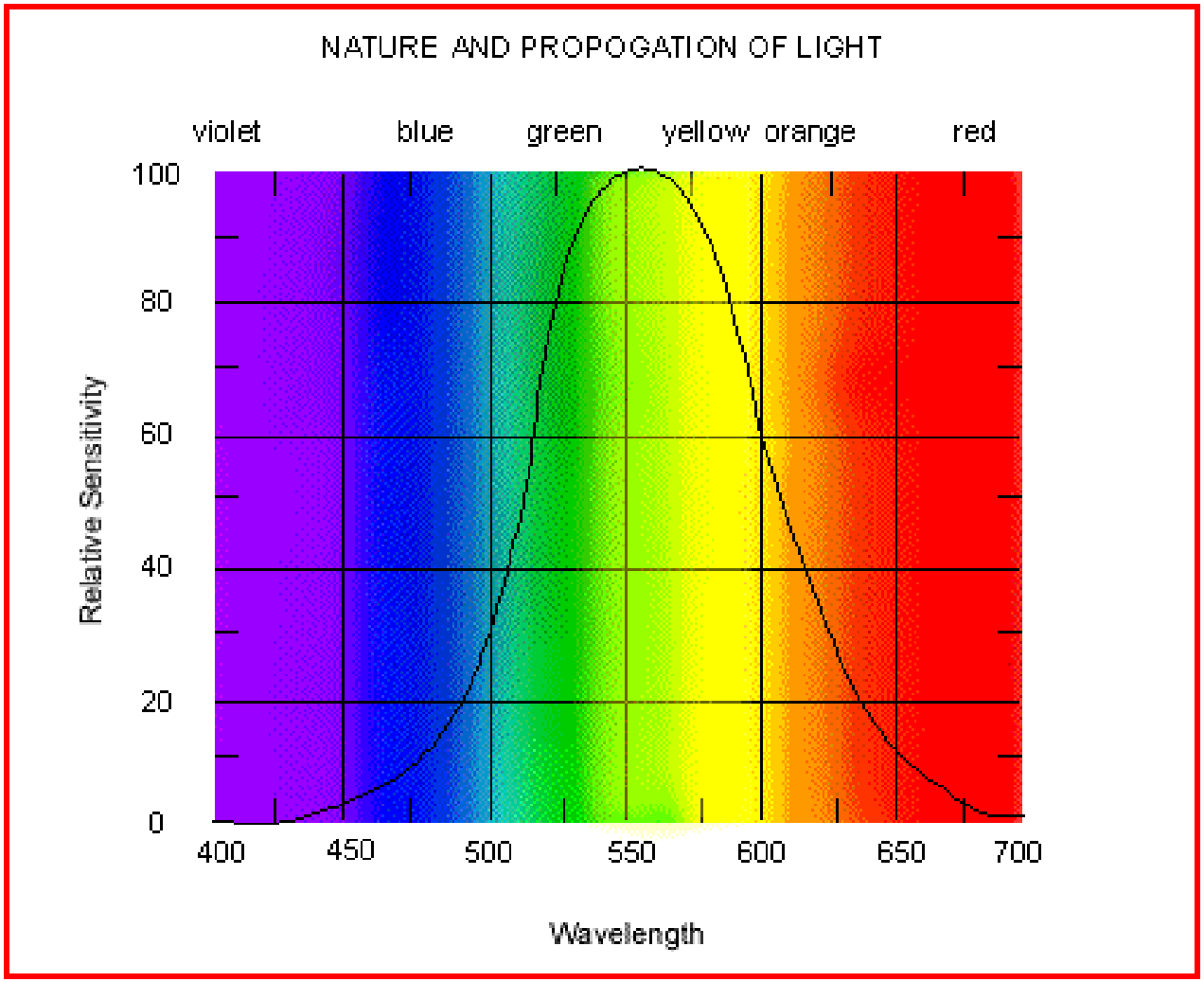
# Color Perception

- Different spectra can result in a perceptually identical sensations called **metamers**
- Color perception results from the simultaneous stimulation of 3 cone types (**trichromat**)
- Our perception of color is also affected by surround effects and adaptation

# Color Perception (cont)



# Color Perception (cont)

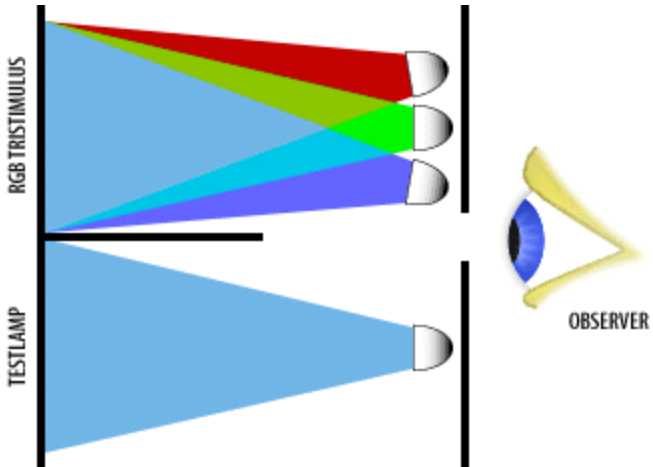


# Outline

- Color Perception
- **Color Spaces**

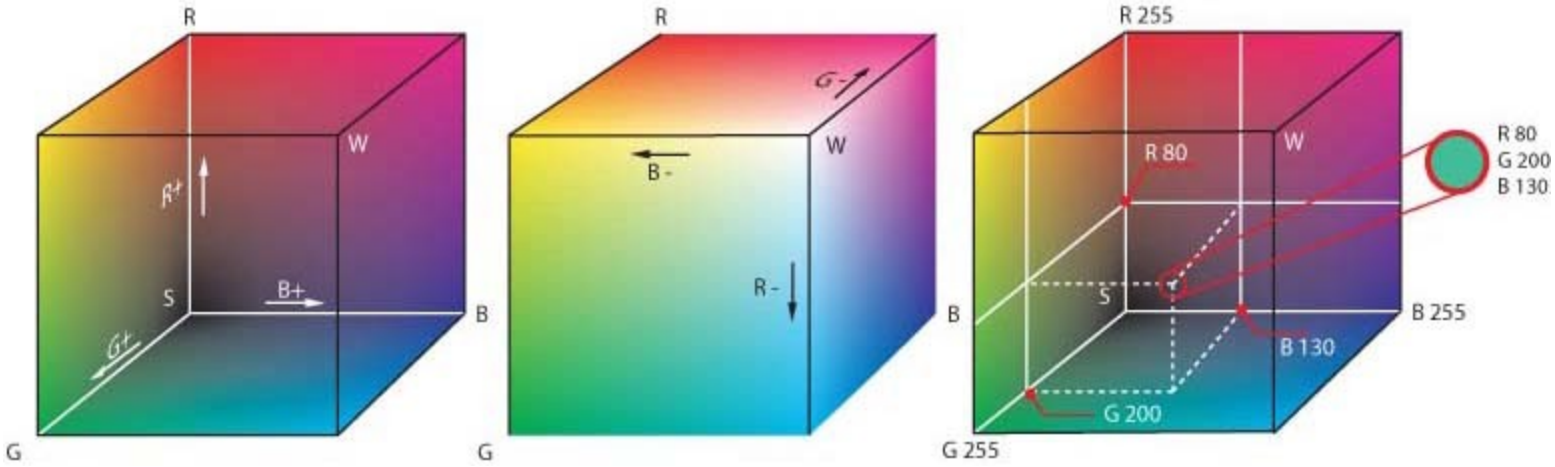
# Colour Matching

- Experiments: observers match color of a given wavelength by mixing three other pure wavelengths, such as R=700nm, G=546nm, and B=436nm.
- Note that the phosphors of color TVs and other CRTs do not emit pure red, green, or blue light of a single wavelength, as it is the case for this experiment.

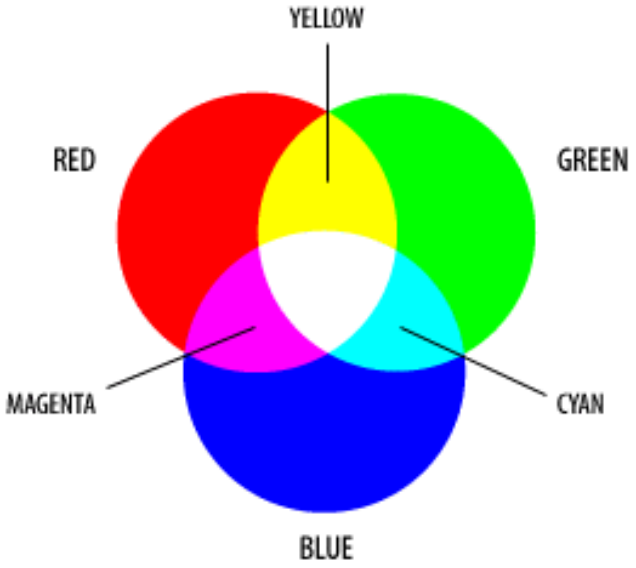


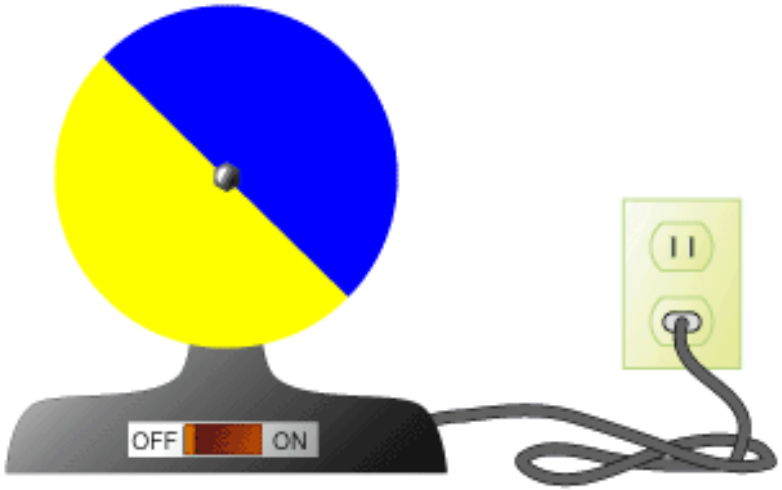
# RGB Color Space

- The **additive color** model used for computer graphics is represented by the RGB color cube, where R, G, and B represent the colors produced by red, green and blue phosphorus



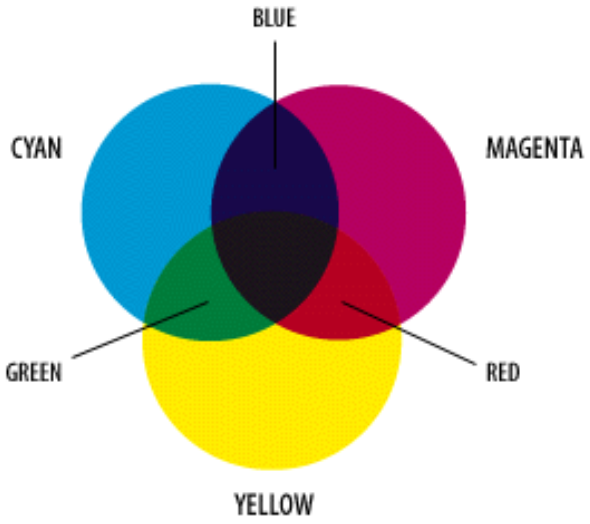
# RGB Color Space (cont)

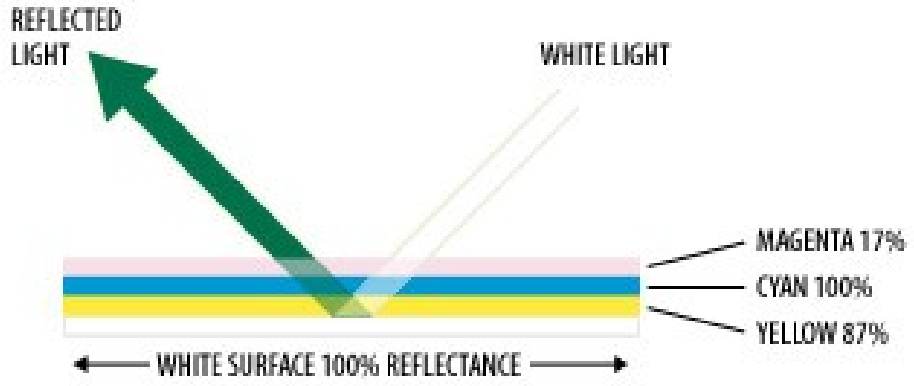


# CMY Color Space

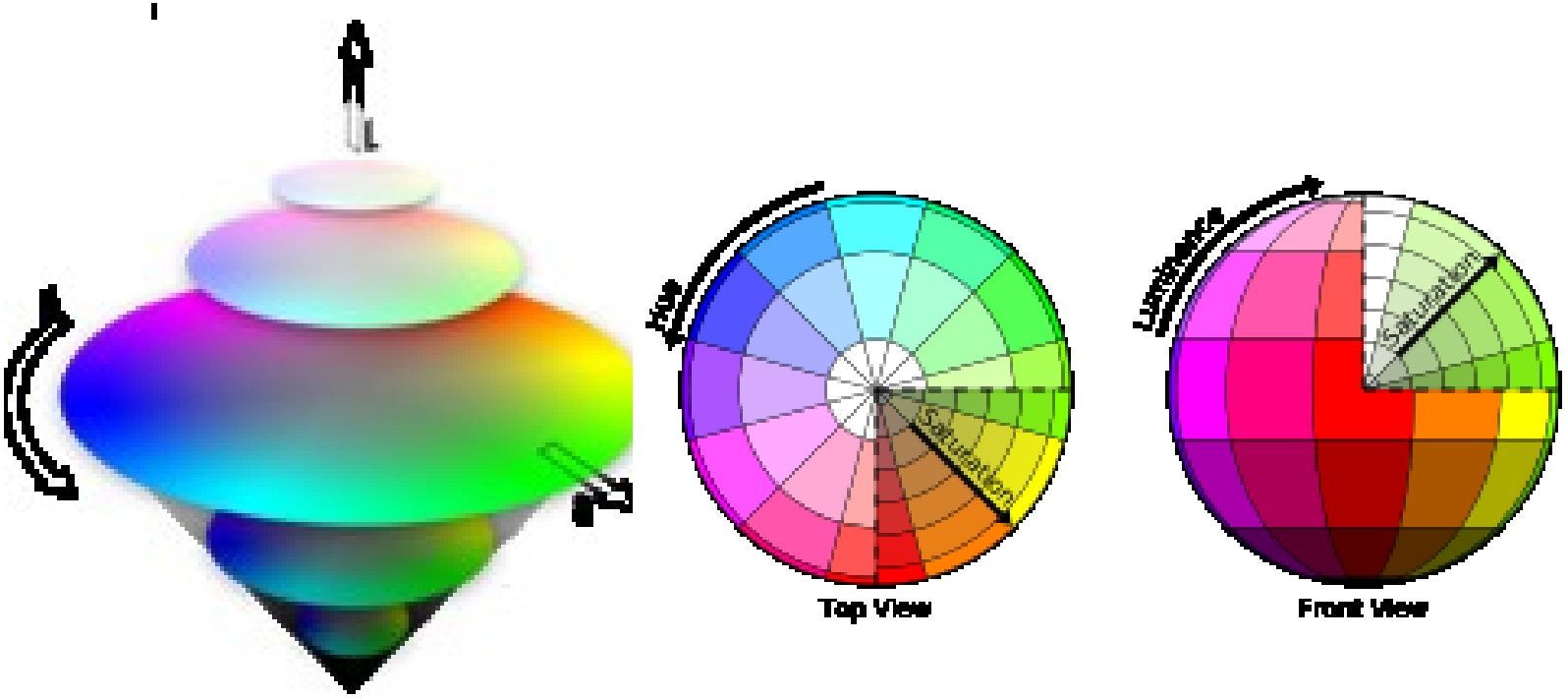
- The **subtractive color** model is represented by the CMY (cyan, magenta, and yellow) color



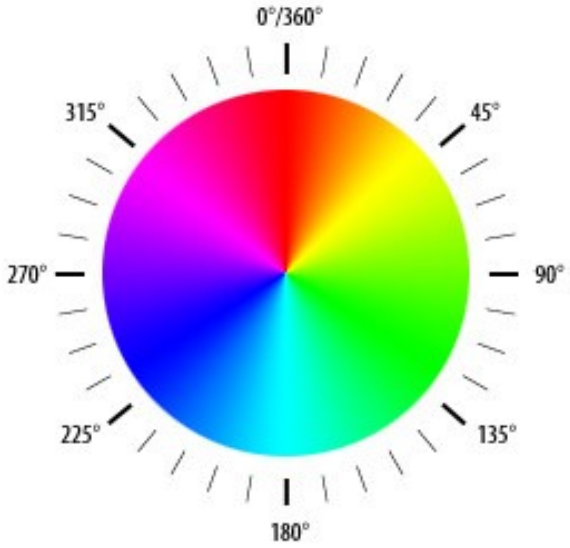
# HSB / HLS Color Space

- HSB/HLS are two variations of a very basic color model for defining colors in desktop graphics programs that closely matches the way we perceive



# HSB / HLS Color Space (cont)

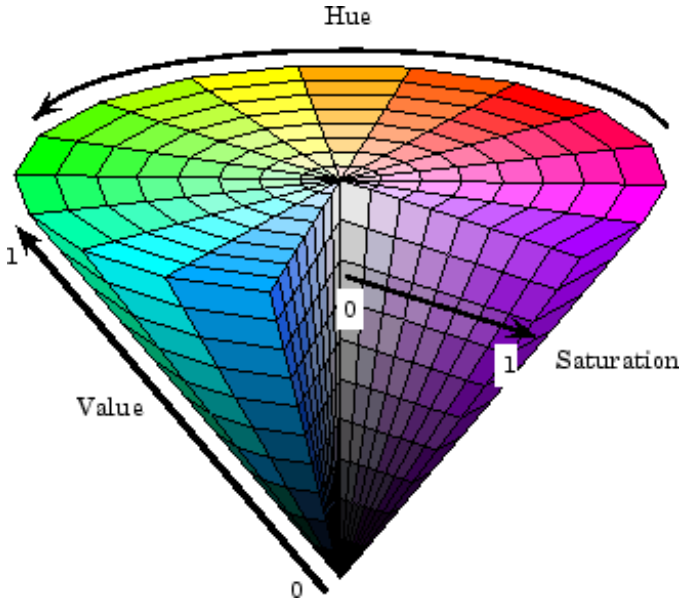
- Hue

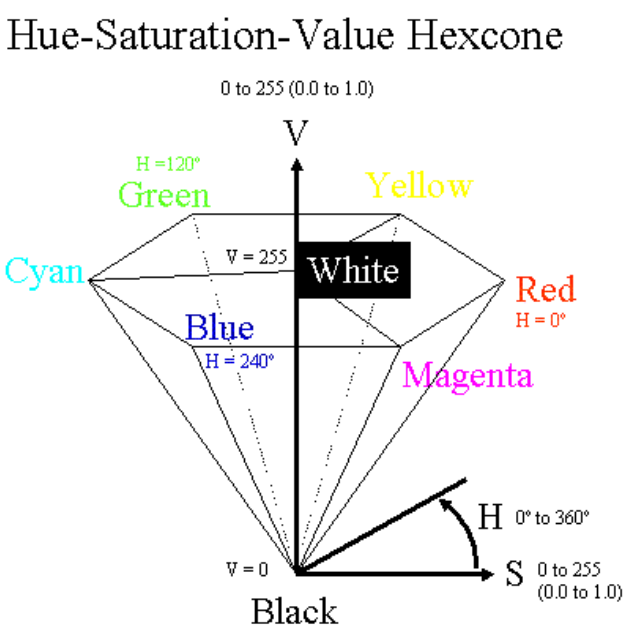



- Saturation

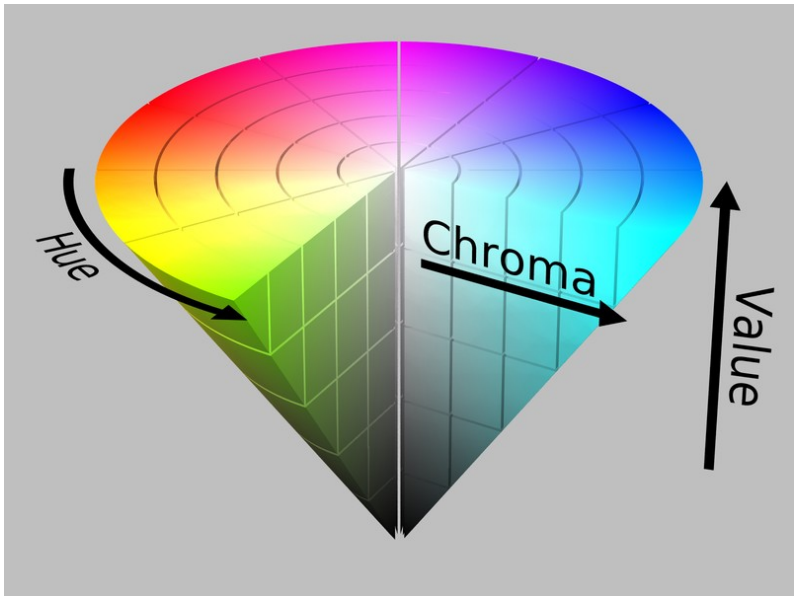

- Lightness

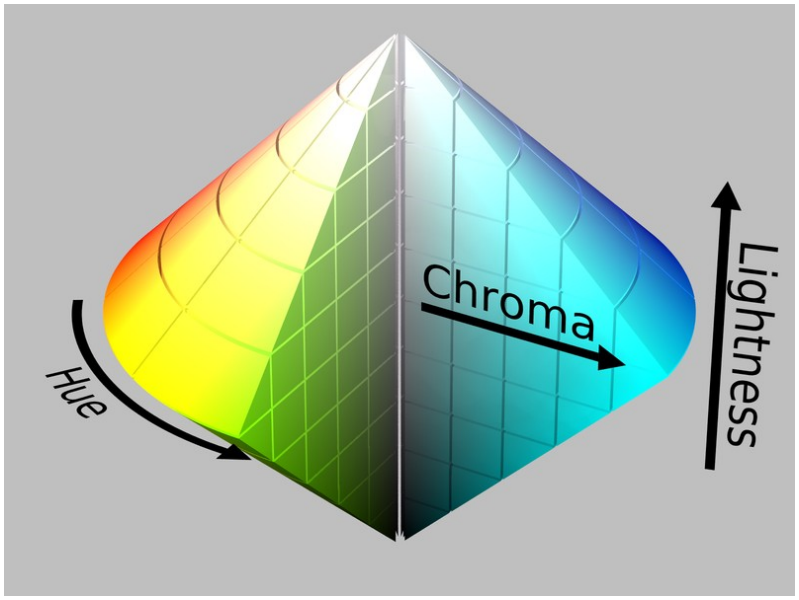
# HSV Color Space



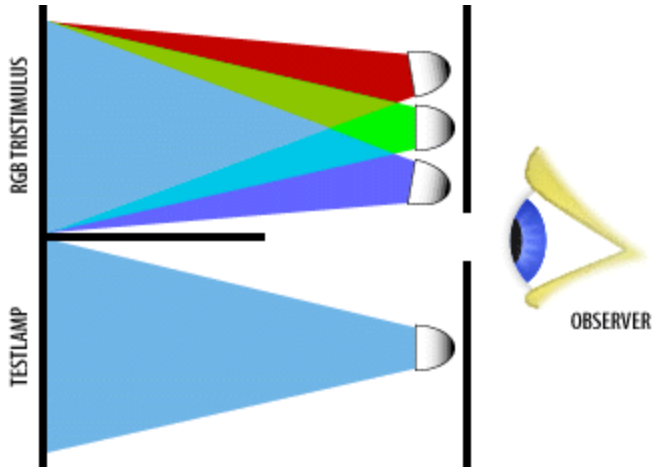
# HSV vs HSL

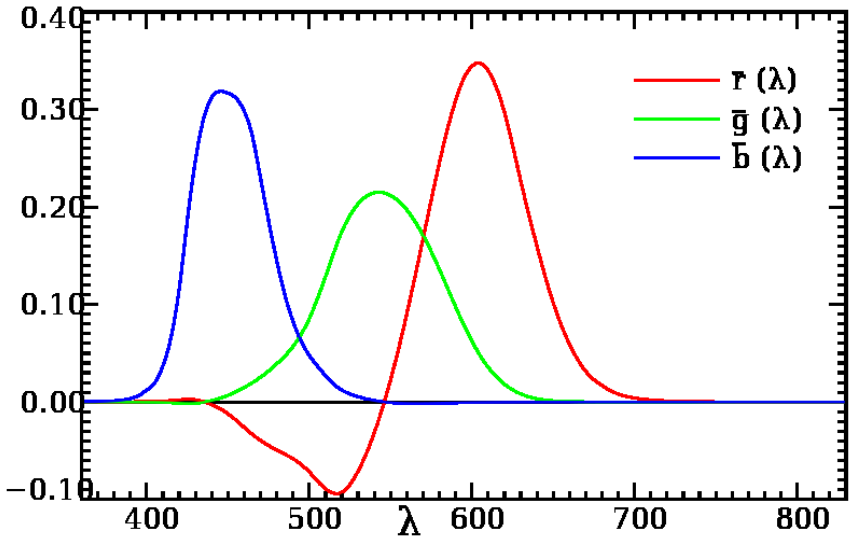


# CIE Color Space

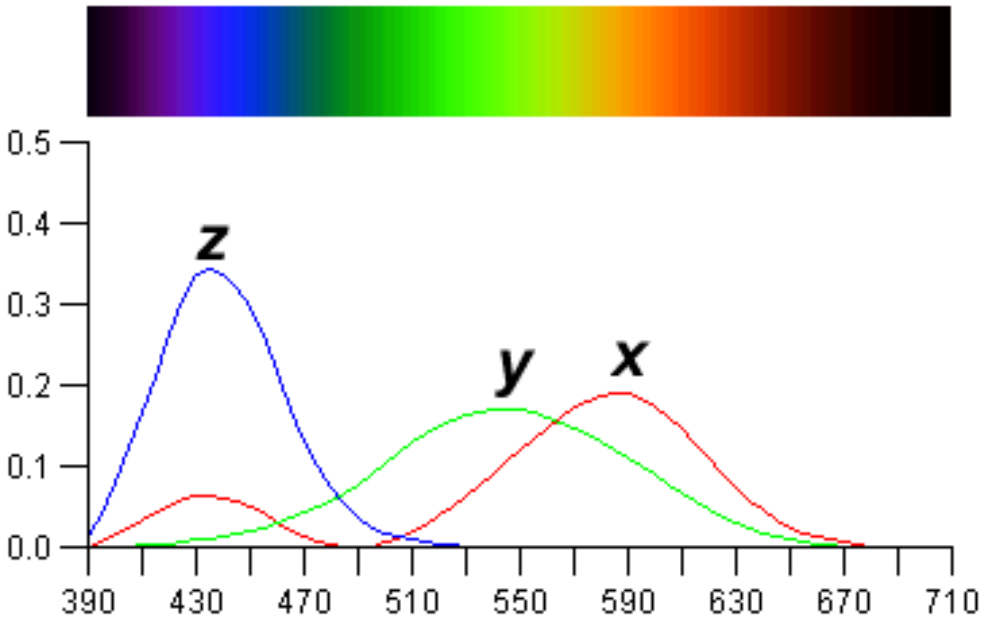
- Sometimes the red light needs to be added to the target before a match can be achieved. This is shown on the graph by having its intensity, R, take on a negative value.



# CIE Color Space (cont)

- CIE ("Commission Internationale d'Eclairage") defined three new hypothetical light sources, x, y, and z, which yield positive matching curves:



# CIE vs RGB

- the 1931 CIE Chromaticity Diagram represents the whole gamut of human color perception