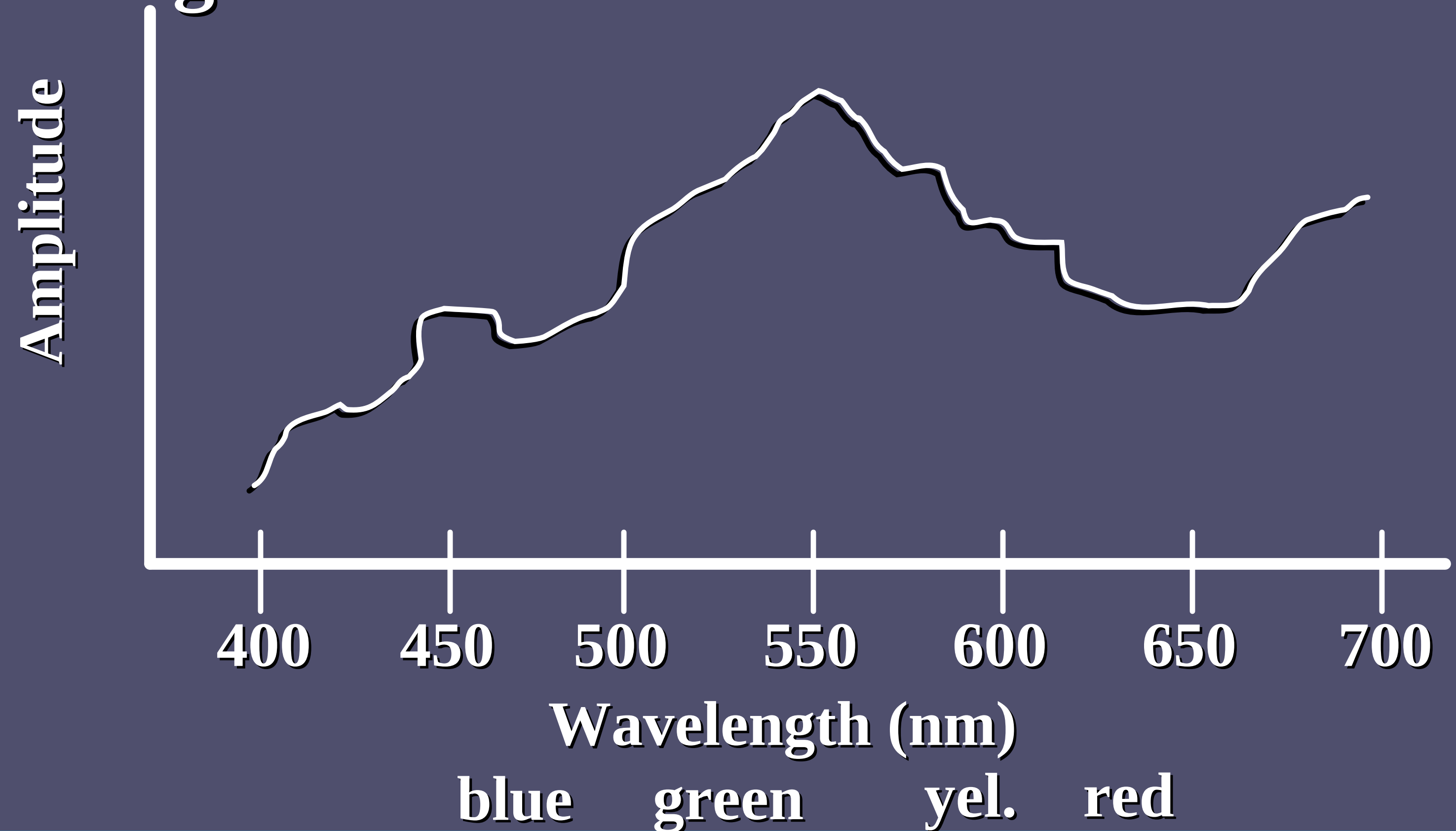
Light and Color

Frequency Spectrum

Spectrum describes frequency distribution of a light source



Definitions

Hue: quality that distinguishes one color family from another (i.e. red, yellow, green, blue, etc.)

Chroma: degree of color's departure from greyscale

Value/Lightness: quality distinguishing light from dark colors

More definitions

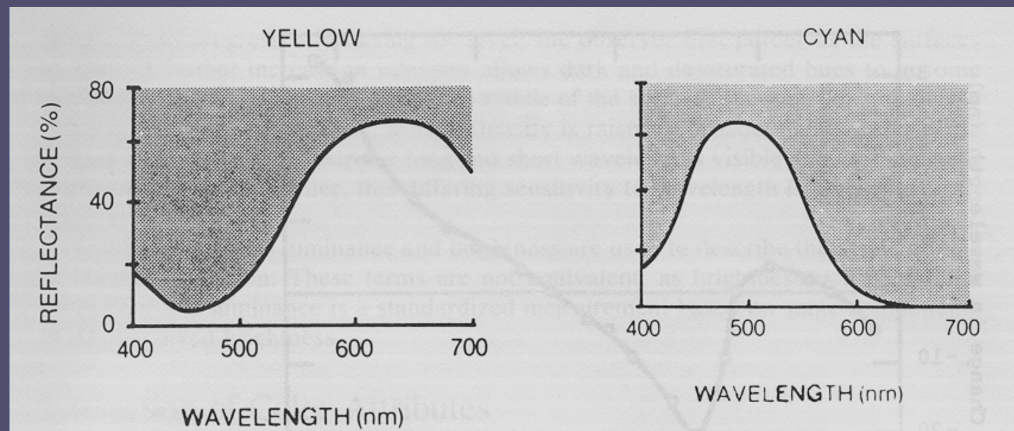
- Achromatic light: literally light without chroma, or greyscale light
  - fairly uniform frequency distribution
- Monochromatic light: light which has all intensity near a single frequency

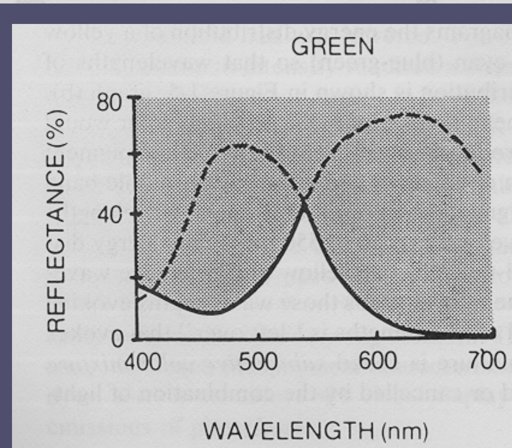
Color Mixture - Subtractive

Applies when mixing pigments and dyes

- Each substance absorbs certain frequencies
- Combining substances absorbs the union of these frequencies
- Resulting reflected light is intersection of colors reflected by each

Subtractive Mixture Example





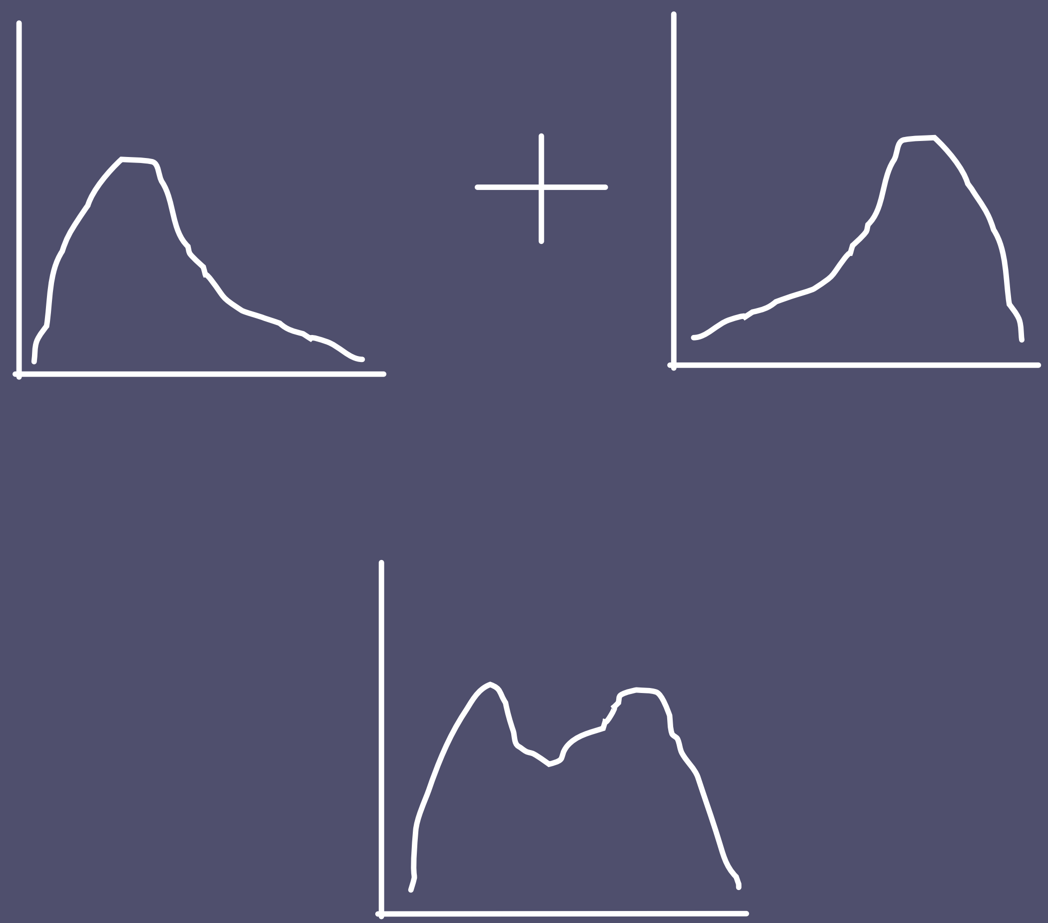
from Gerald Murch, "Color Displays and Color Science", in **Color and the Computer***, H. John Durrett, ed., page 10.*

Color Mixture - Additive

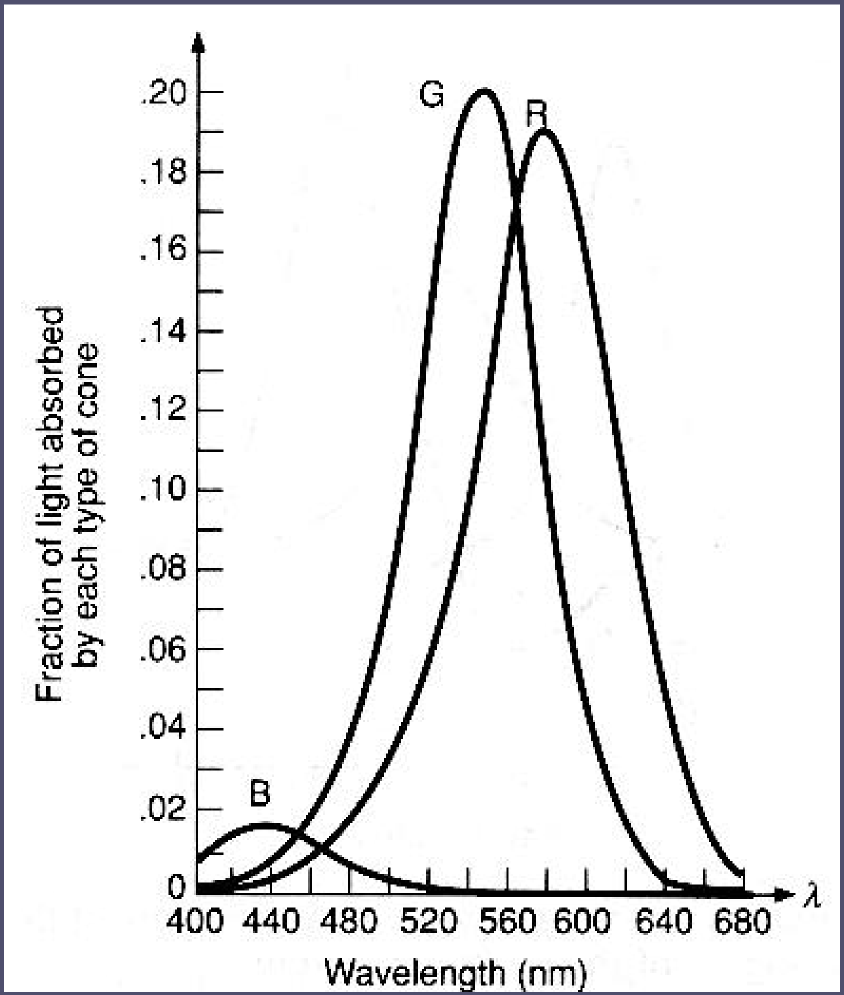
Applies to mixing of luminescent colors, such as color CRT and LCD displays, etc.

- Color refers to actual frequency spectrum of light
- Combining lights adds their frequency spectra

Additive Color Example



3 Types of retinal cones



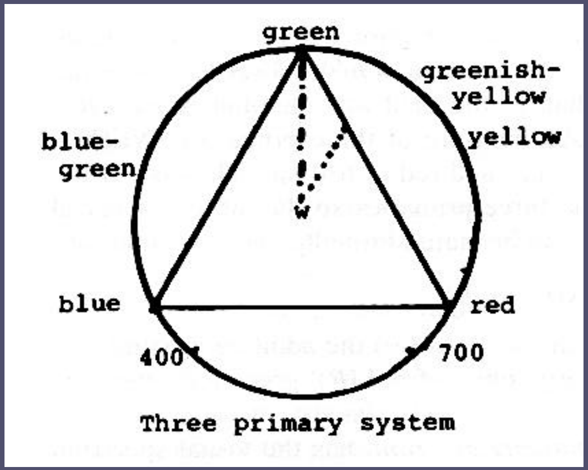
***From Foley, vanDam, Feiner, and Hughes,* Computer Graphics: Principles and Practice, 2nd edition, page 577**

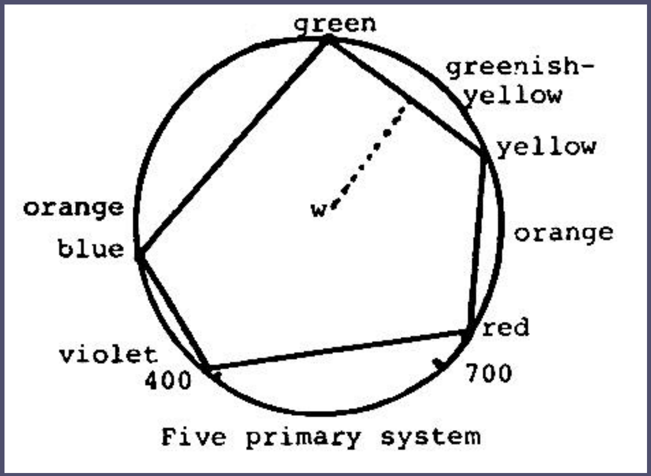
Efficient Color Computations in Computer Graphics

- Represent frequency spectrum as discrete set of samples
  - Typically 3 samples: red, green, and blue
  - Monitors also use samples corresponding to different phosphors
  - Eye also has 3 samples (types of cones)
- Does *not* imply that three samples for initial and intermediate produce accurate computations

Color Space Gamut

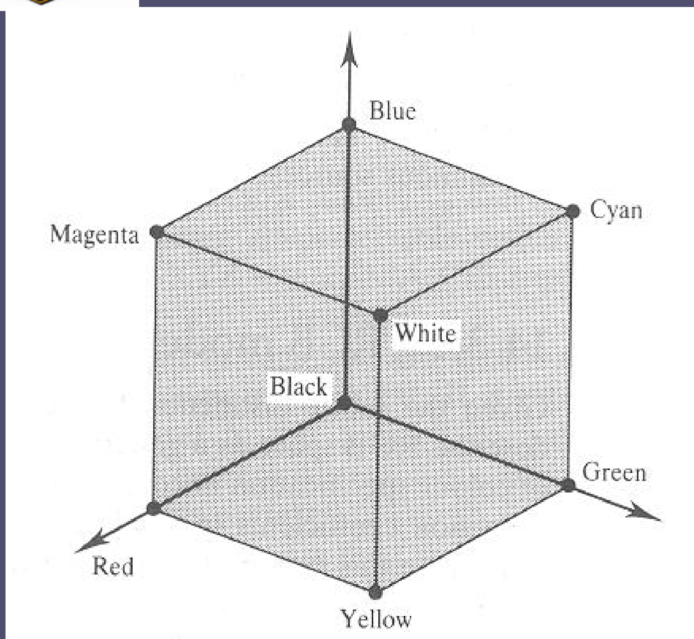
- Color gamut: subspace of visible colors
- No system of mixing colors from fixed number of primaries can represent all visible colors





from Gerald Murch, "Color Displays and Color Science", in Color and the Computer, *H. John Durrett, ed., page 13.*

Color Spaces - RGB cube



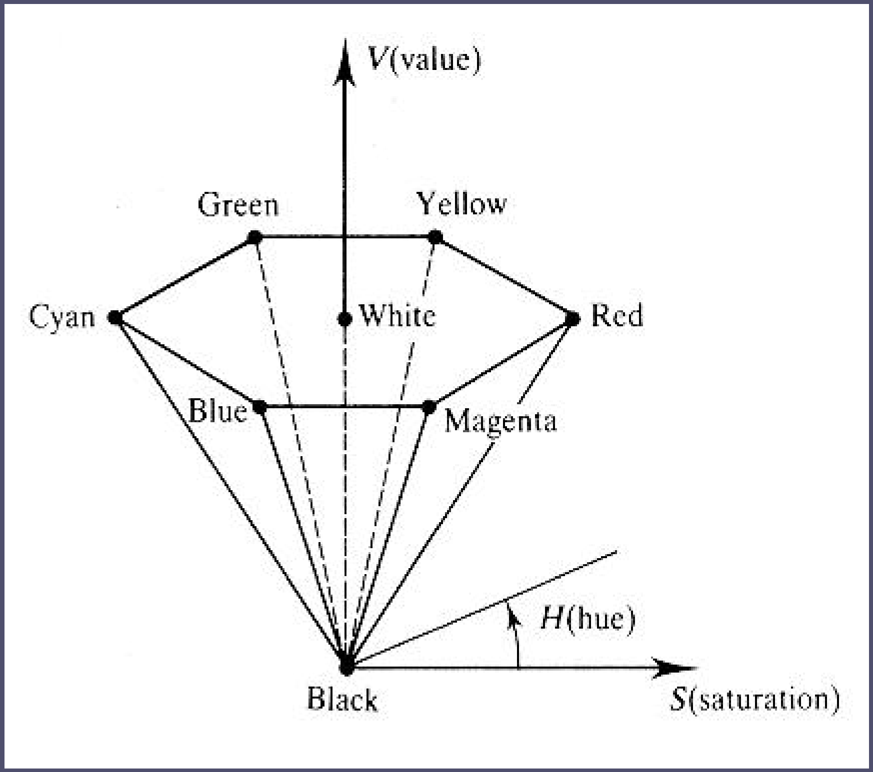
From Alan Watt, 3D Computer Graphics*, 2nd edition, p. 416*

from Foley, vanDam, Feiner, and Hughes, Computer Graphics: Principles and Practice*, plate II.4*

Shortcomings:

- **perceptually non-linear**
- **non-intuitive for human specification**

Color Spaces - HSV hexacone



From Alan Watt, 3D Computer Graphics*, 2nd edition, p. 419*

- **Still not perceptually linear**
- **Axes correspond to more intuitive perceptual qualities**
  - **Selection similar to artist color mixing**
  - **choose hue of base pigment, add white, add black**
- **Derived from projections of RGB cube**

HLS double hexacone

Similar to HSV hexacone

Pulls white to make the apex of upper cone

- Gives white and black similar geometric representation

L (lightness) is similar to V, but the primaries occur at L=0.5 (for HSV, V=1 for primaries)

CIE Color Space

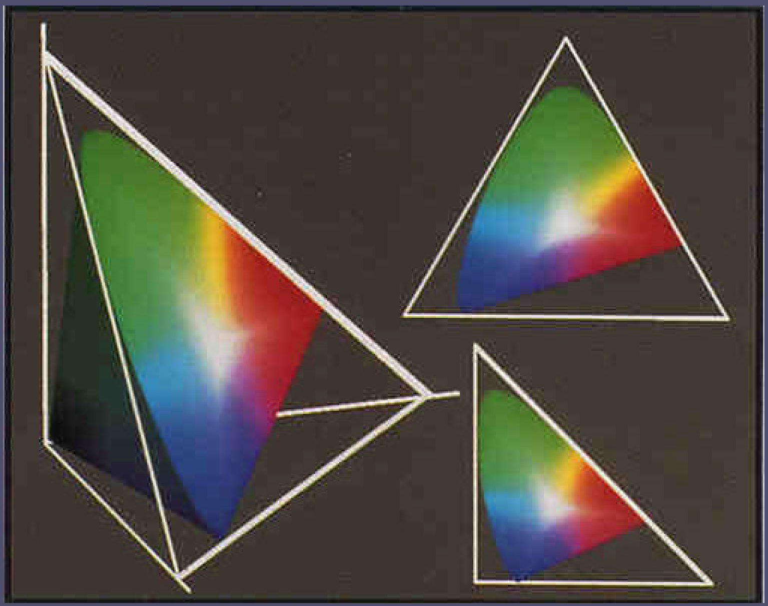
Employs 3 artificial primaries: X, Y, Z

- Mathematical abstractions, not physically realizable
- Allow supersaturation

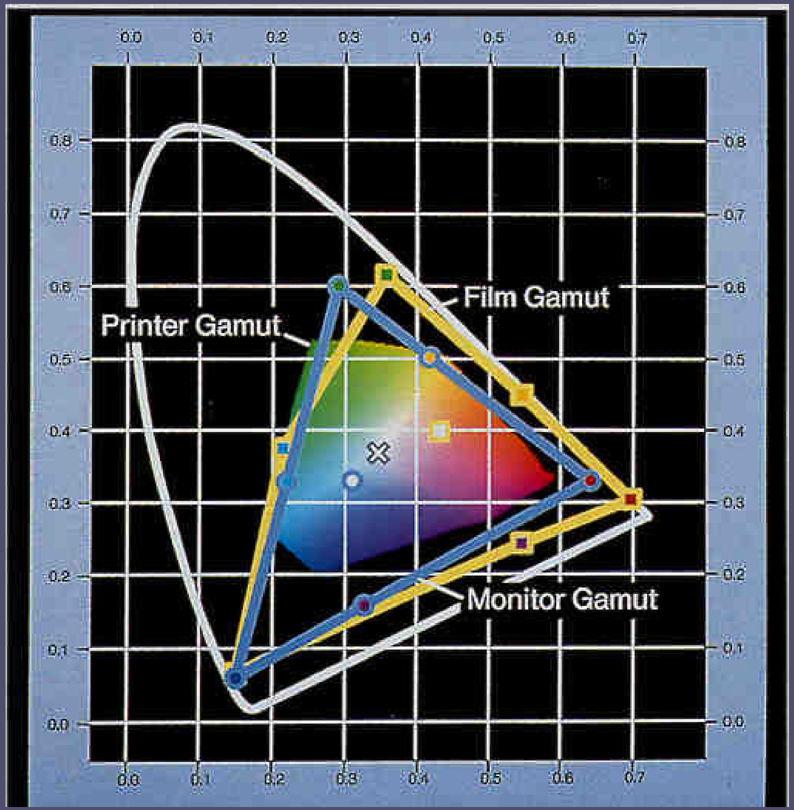
Larger than visible spectrum

Standard for representing colors and converting between spaces

CIE Space and Device Gamuts



Chromaticity Diagram



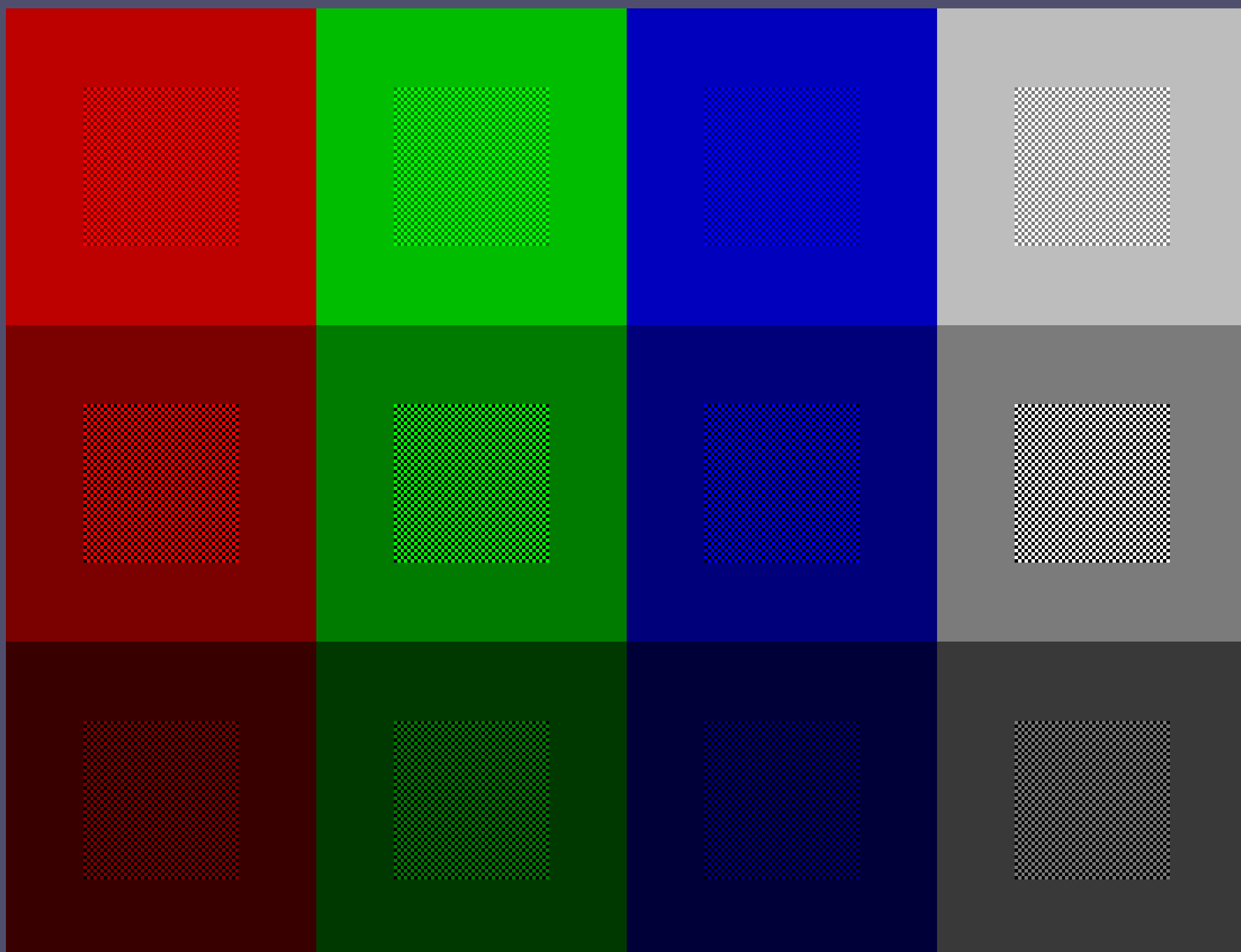
from Foley, vanDam, Feiner, and Hughes, Computer Graphics: Principles and Practice, *plates II.1 and II.2*

Gamma Correction

Exponential function converts from device-independent RGB space to device-dependent RGB

- Gamma is exponent
- Every monitor is different
- Monitor color intensities are non-linear with respect to phosphor excitation levels

Gamma Correction Test Image



- Visually test linearity of intensities
- Average intensity of inner square should match intensity of outer square