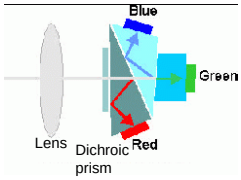
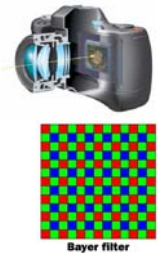
Introduction to Computer Vision
CSE 252a
Lecture 9

Color Cameras: Three kinds of pixels

3 Chip Camera



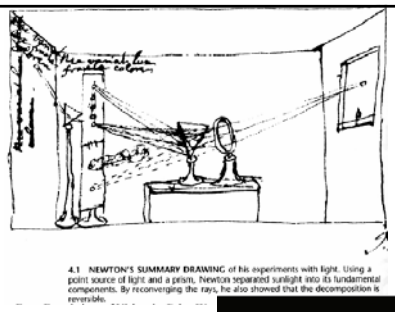


Optically split incoming light onto three sensors, each responding to different wavelengths

Single sensor with color mosaic overlaid.

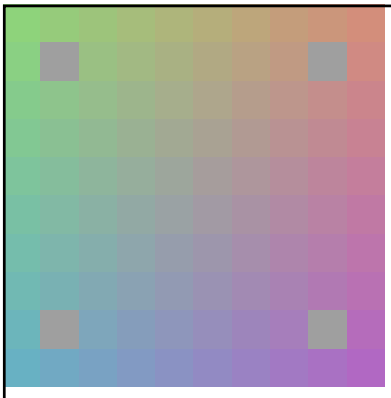
The appearance of colors

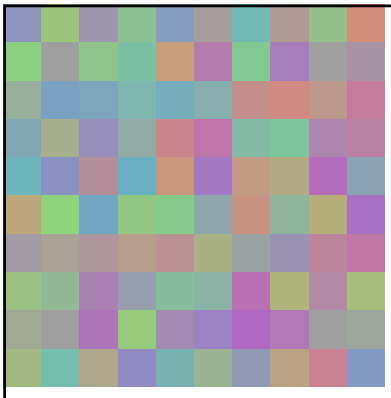
- Color appearance is strongly affected by (at least):
  - Spectrum of lighting striking the retina
  - other nearby colors (space)
  - adaptation to previous views (time)
  - "state of mind"

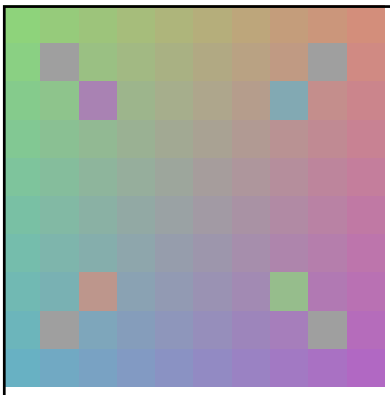


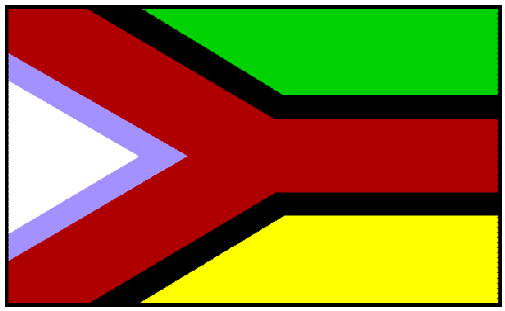
4.1 NEWTON'S SUMMARY DRAWING of his experiments with light. Using a point source of light and a prism, Newton separated sunlight into its fundamental components. By recombining the rays, he also showed that the decomposition is reversible.

From Foundations of Vision, Brian Wandell, 1995, via B. Freeman slides





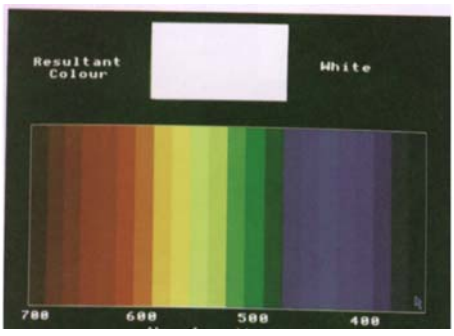




Color Afterimage: South African Flag

opponent colors
- Blue -> yellow
- Red -> green

Light Spectrum

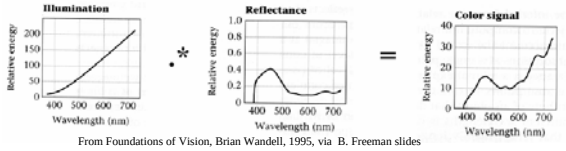


Talking about colors

1. Spectrum –
   - A positive function over interval 400nm-700nm
   - "Infinite" number of values needed.
2. Names
   - red, harvest gold, cyan, aquamarine, auburn, chestnut
   - A large, discrete set of color names
3. R,G,B values
   - Just 3 numbers

Color Reflectance

Measured color spectrum is a function of the spectrum of the illumination and reflectance

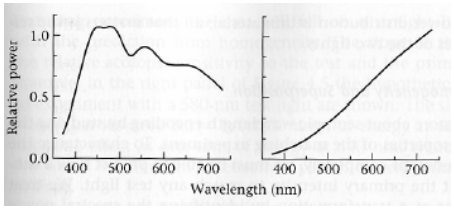


From Foundations of Vision, Brian Wandell, 1995, via B. Freeman slides

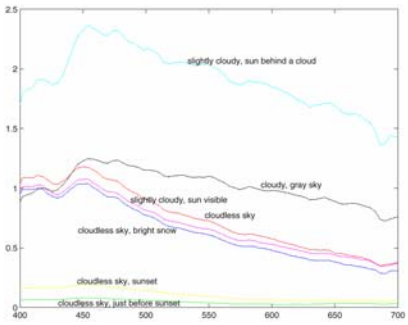
Illumination Spectra

Blue skylight

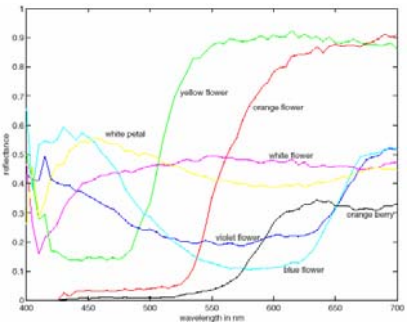
Tungsten bulb



From Foundations of Vision, Brian Wandell, 1995, via B. Freeman slides

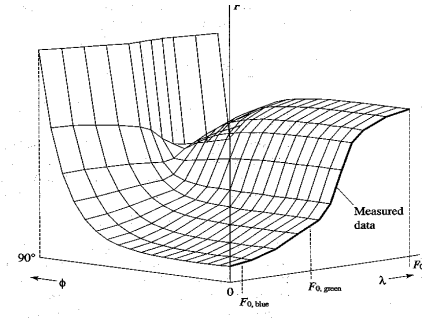


Measurements of relative spectral power of sunlight, made by J. Parkkinen and P. Silfsten. Relative spectral power is plotted against wavelength in nm. The visible range is about 400nm to 700nm. The color names on the horizontal axis give the color names used for monochromatic light of the corresponding wavelength --- the "colors of the rainbow". Mnemonic is "Richard of York got blisters in Venice".



Spectral albedoes for several different leaves, with color names attached. Notice that different colours typically have different spectral albedo, but that different spectral albedos may result in the same perceived color (compare the two whites). Spectral albedoes are typically quite smooth functions. Measurements by E.Koivisto.

Fresnel Equation for Polished Copper

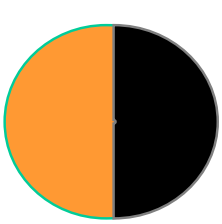


Dialectrics (e.g., plastics)

Diffuse + specular component

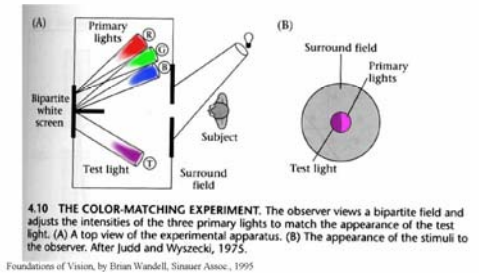
Specularity is the color of the light source

Color Matching



Not on a computer Screen

Color matching experiment

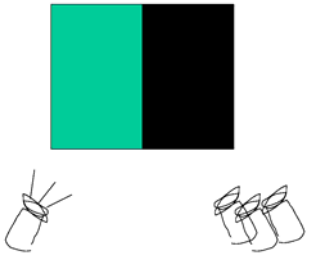


4.10 THE COLOR-MATCHING EXPERIMENT. The observer views a bipartite field and adjusts the intensities of the three primary lights to match the appearance of the test light. (A) A top view of the experimental apparatus. (B) The appearance of the stimuli to the observer. After Judd and Wyszecki, 1975.

Foundations of Vision, by Brian Wandell, Sinauer Assoc., 1995

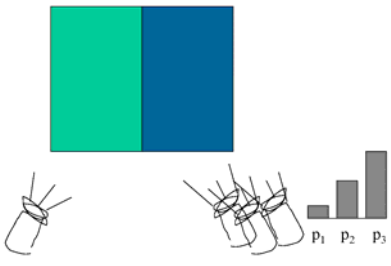
slide from T. Darrel

Color matching experiment 1



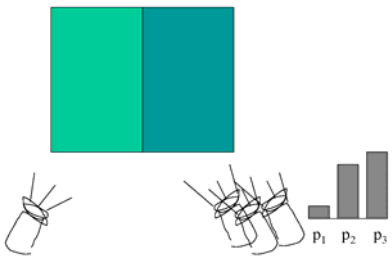
slide from T. Darrel

Color matching experiment 1



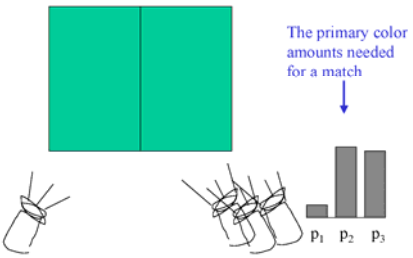
slide from T. Darrel

Color matching experiment 1

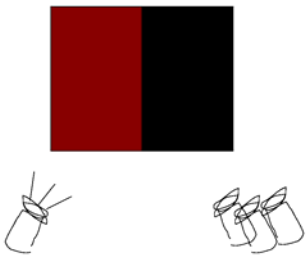


slide from T. Darrel

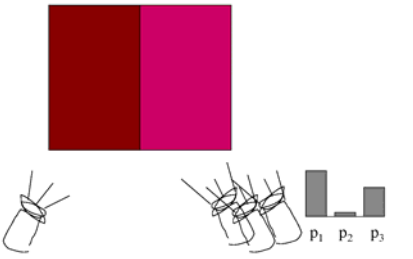
Color matching experiment 1



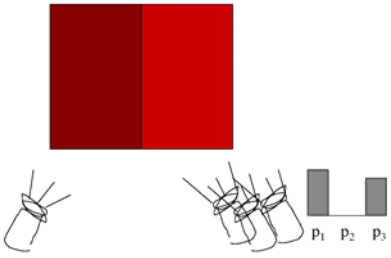
Color matching experiment 2



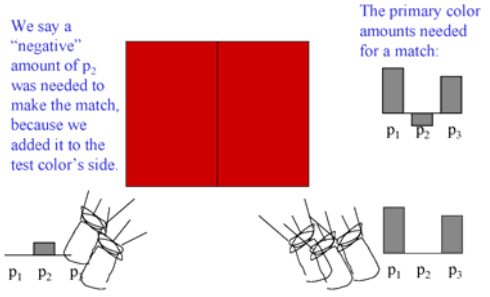
Color matching experiment 2



Color matching experiment 2



Color matching experiment 2



The principle of trichromacy

- Experimental facts:
  - Three primaries will work for most people if we allow subtractive matching
    - Exceptional people can match with two or only one primary.
    - This could be caused by a variety of deficiencies.
  - Most people make the same matches.
    - There are some anomalous trichromats, who use three primaries but make different combinations to match.

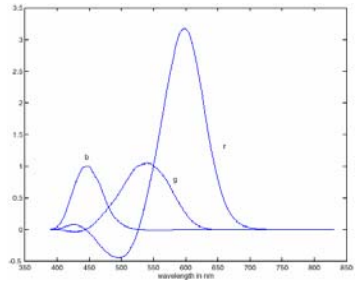
Color matching functions

- Choose primaries, say A(λ), B(λ), C(λ)
- For monochromatic (single wavelength) energy function, what amounts of primaries will match it?
- i.e., For each wavelength λ, determine how much of A, of B, and of C is needed to match light of that wavelength alone.

$$a(\lambda)$$
$$b(\lambda)$$
$$c(\lambda)$$

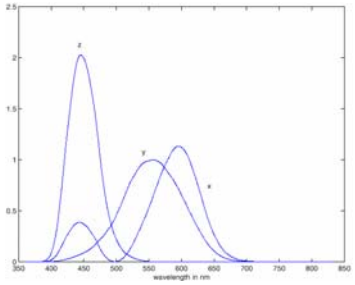
- These are color matching functions

RGB



RGB: primaries are monochromatic, energies are 645.2nm, 526.3nm, 444.4nm. Color matching functions have negative parts -> some colors can be matched only subtractively.

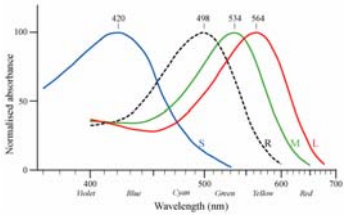
CIE XYZ



CIE XYZ: Color matching functions are positive everywhere, but primaries are imaginary. Usually draw x, y, where
x=X/(X+Y+Z)
y=Y/(X+Y+Z)

Three types of cones: R,G,B

Response of k'th cone = $\int \rho_k(\lambda) E(\lambda) d\lambda$



There are three types of cones
S: Short wave lengths (Blue)
M: Mid wave lengths (Green)
L: Long wave lengths (Red)

- Three attributes to a color
- Three numbers to describe a color