

Colour (1)

Colours and their origin

- spectral characteristics
- human visual perception

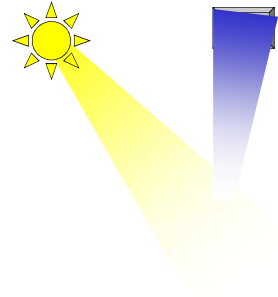
Colour spaces

Raster data

- colour models
- image representations
- single and multi-band (multi-channel) images
- colour lookup tables

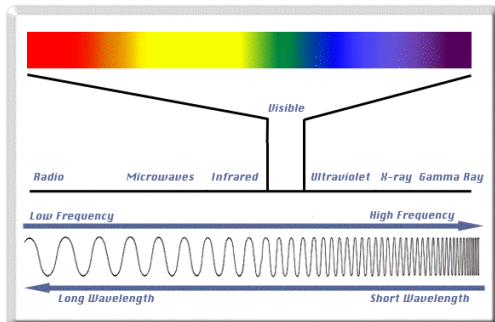
Rendering: Colour

- Given
 - Object surfaces ✓
 - Light sources ✓
 - Camera
- Compute
 - Colour of each pixel on the screen ✓
 - This is colour that bounces off the surface point and goes in the direction of the camera (viewer) ✓



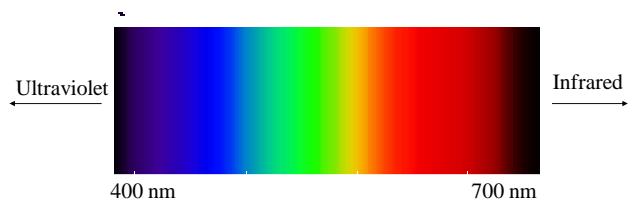
What is colour

Light – a part of electromagnetic spectrum



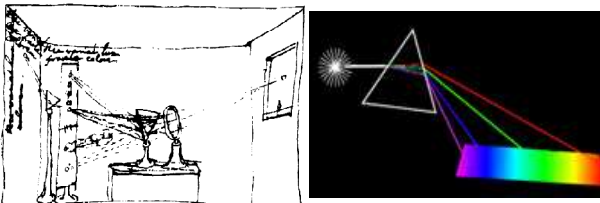
What is colour

Colour spectrum – visible light



What is colour

Newton's experiment

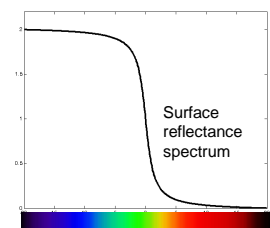
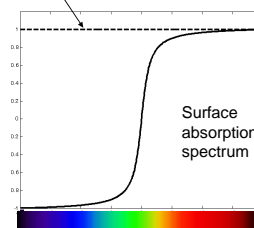


Conclusion:

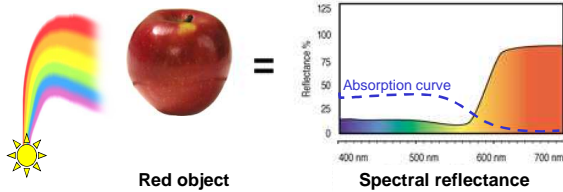
"White" light is a combinations of many different light wavelengths

What is colour

Spectrum of white light

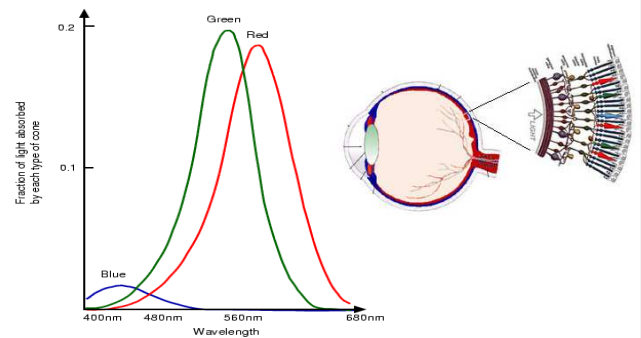


What is colour



What is colour

Human colour perception



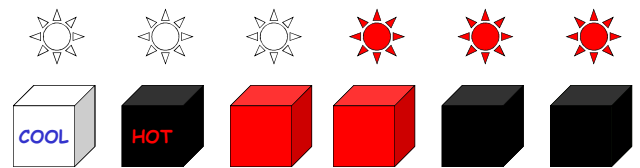
What is colour

- Colour is a percept

- White is a colour, the perception which is evoked by light that stimulates all three types of colour sensitive cone cells in the human eye in nearly equal amounts and with high brightness. [Wikipedia]
- Red is a colour, the perception of which is evoked by light that stimulates “red” sensitive cones in the human eye, and no other cones (“green” or “blue”)

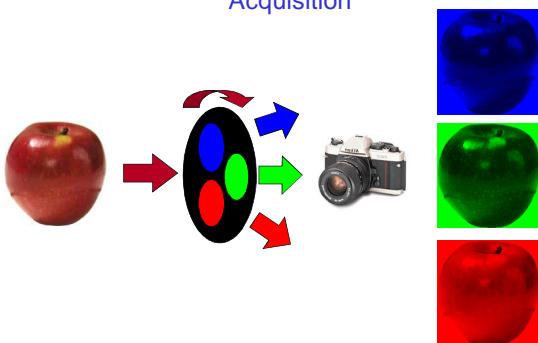
Deciphering colour

Object + Light



Colour images

Acquisition



Colour images

- Colour images have two components:
 - raster data - an array of pixels;
 - colour model - a description of how pixels are mapped to colours.
- A pixel is defined in terms of its components in a particular colour space

Colour spaces

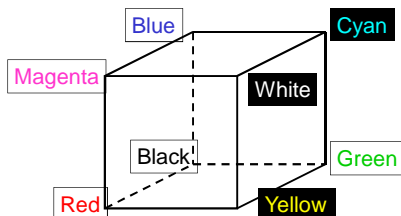
- A colour space represents a system for measuring colours
- Most colours can be represented using three colour components
- They are called the **primary colours** (or the primaries)

Colour spaces

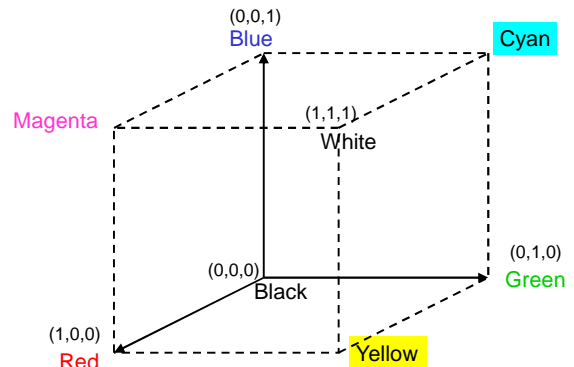
- There are many colour spaces.
- The choice of a particular space depends on the context in which we want to describe colours. The four most common colour spaces are:
 - RGB
 - HSV
 - CMY (K)
 - XYZ

RGB

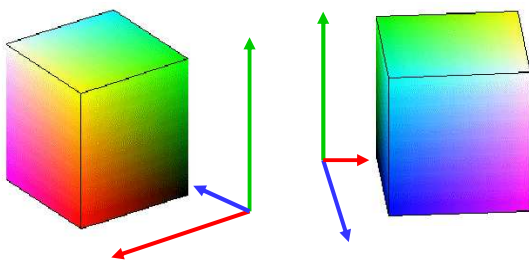
- Primaries: Red - Green - Blue
- Similar to colours detected by colour receptors in the eye
- Used in display technology



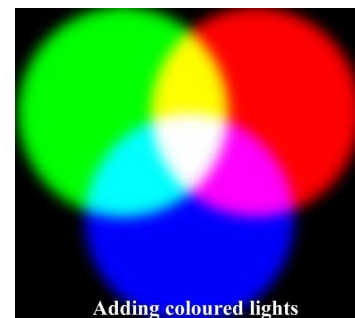
RGB



RGB



RGB – an additive system



Vector notation for colours (1)

[Primary1 Primary2 Primary3]
[R G B]

red = [1 0 0]

green = [0 1 0]

blue = [0 0 1]

yellow = red + green = [1 1 0]

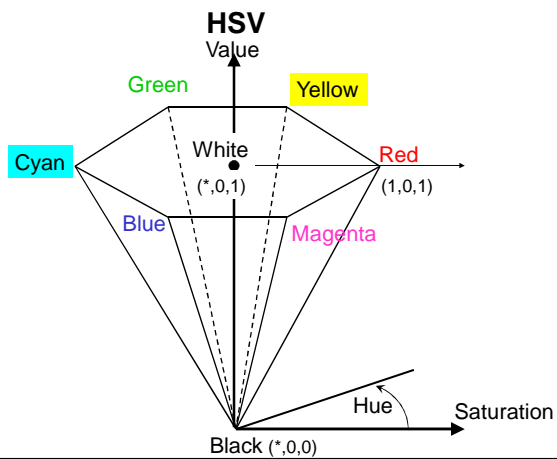
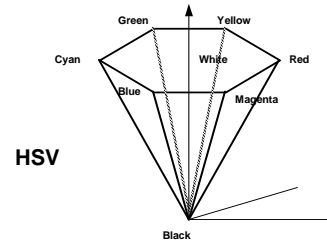
magenta = [1 0 1]

cyan = [0 1 1]

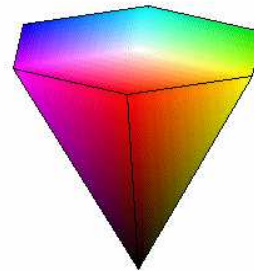
orange = [1 0.5 0]

HSV / HSL

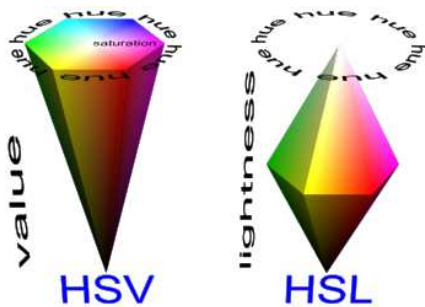
- Primaries: Hue - Saturation - Value
- Or: Hue - Saturation - Lightness
- Colour space related to subjective description of colours



HSV



HSV and HSL

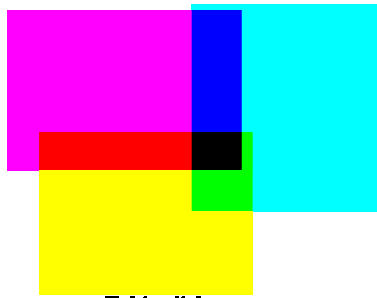


Source: http://www.bersoft.com/bimagem/help/hsv_hsl.png

CMY

- Primaries: Cyan Magenta Yellow
- Used in printing technology
- Complement of RGB
- Mixing is subtractive

CMY – subtractive system



Taking light away

CMY – subtractive system

[C M Y]

cyan = [1 0 0]
magenta = [0 1 0]
yellow = [0 0 1]

Example:

A surface appears yellow because, given white light

[1 1 1]

yellow pigment absorbs blue component of the spectrum

[1 1 1] - [0 0 1] = [1 1 0]

so a mixture of red and green (i.e. yellow) is reflected

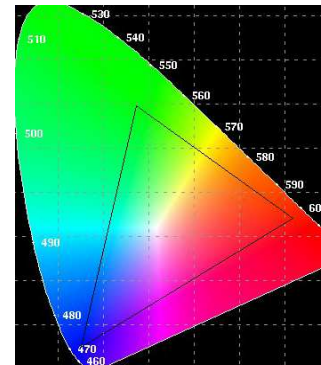
[1 1 0]

CIE XYZ

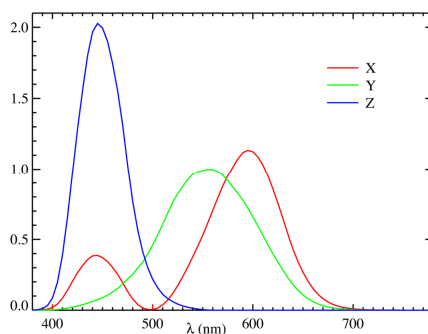
- CIE: Commission Internationale de l'Eclairage
- Primaries: X, Y, Z
- Based on colour perception by humans
- Device independent
- The most common representation of the CIE XYZ space is the CIE chromacity diagram

CIE XYZ

Chromacity diagram



CIE XYZ – colour matching functions A “standard” observer



Vector notation for colours (2)

[Primary1 Primary2 Primary3]

[R G B] pink = [1 0.7 0.7]

[H S V] pink = [0 0.3 1]

[C M Y] pink = [0 0.3 0.3]

Colour space conversion

- Colours can be converted from one space to another
- Conversion from RGB to CMY:
 $[C \ M \ Y] = [1 \ 1 \ 1] - [R \ G \ B]$
- Example: Convert green from RGB to CMY
 $[C \ M \ Y] = [1 \ 1 \ 1] - [0 \ 1 \ 0] = [1 \ 0 \ 1]$

Conversion from RGB to XYZ

- Each of the R, G and B primaries is a weighted sum of X, Y and Z primaries
- Weights expressed in matrix notation, e.g.

$$\begin{bmatrix} 0.41 & 0.21 & 0.02 \\ 0.36 & 0.71 & 0.12 \\ 0.18 & 0.07 & 0.95 \end{bmatrix}$$

- The matrix values are characteristic for a given graphics device

Conversion from RGB to XYZ

- Conversion implemented as a matrix multiplication

$$[X \ Y \ Z] = [R \ G \ B] \cdot \begin{bmatrix} 0.584 & 0.311 & 0.047 \\ 0.188 & 0.614 & 0.103 \\ 0.179 & 0.075 & 0.939 \end{bmatrix}$$

Homework



- Specify colour definitions for the following colours in the RGB, HSV and CMY colour spaces:
 - Black
 - White
 - Orange
 - Pink
- What colour will you get by illuminating a yellow surface with a green light?
- What colour will you get by illuminating a magenta surface with a yellow light?