EBU5303

Multimedia Fundamentals

Colours

Agenda

- Colour is a property of light
- Colour vision is a complex phenomenon
- There are different colour models
- RGB is used in computer monitors
- YUV/YCbCr are used for image compression
- CMYK is used for printing
- HSV is an intuitive colour model

Reading

http://burg.cs.wfu.edu/TheScienceOfDigitalMedia/Chapter2/ch2scienceofdigitalmedia.pdf

2.6 Color

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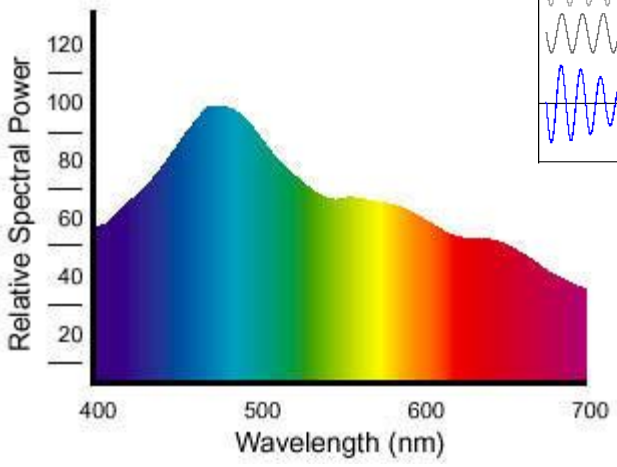
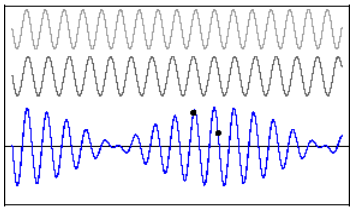
Light





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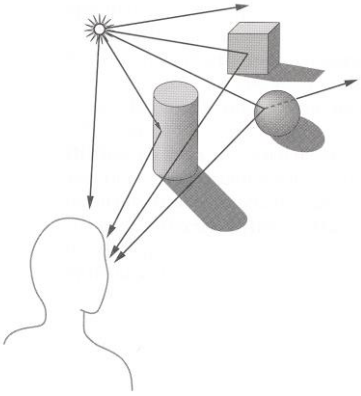
Properties of Colours

Colour is a property of light, not an object in itself.

Objects have no colour of their own, but merely the ability to reflect a certain section of the visible spectrum.

Objects reflect what we perceiv and absorb what we don't see.



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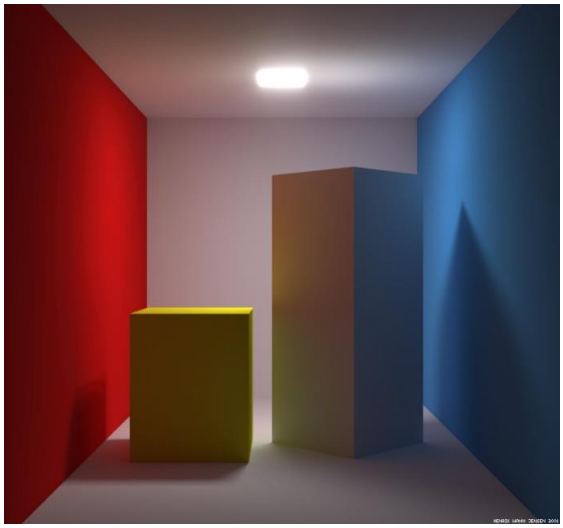
Properties of Colours



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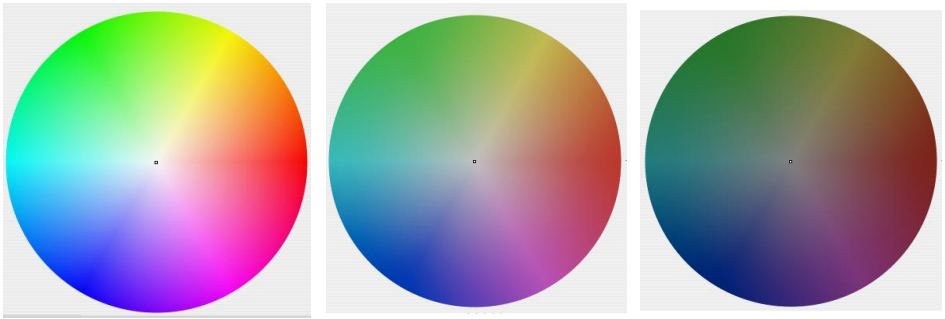
Properties of Colours

- Hue is the name of the colour (dominant wavelength).
- Saturation: a fully saturated colour is one with no mixture of white.
- Brightness is the extent to which an area appears to emit light.



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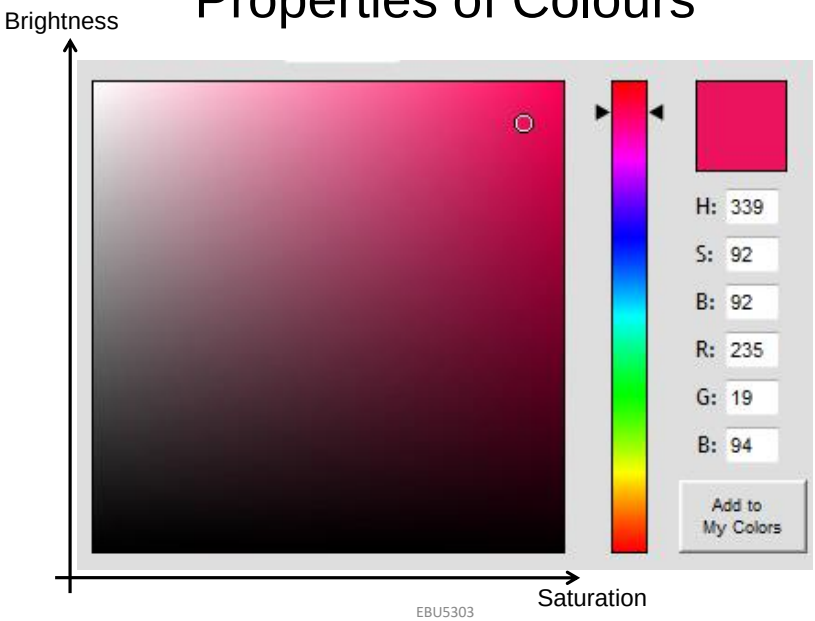
Properties of Colours



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Brightness and Luminance

- ***Brightness*** is a matter of subjective perception and has no precise mathematical definition.
- ***Luminance*** has a mathematical definition that relates a light's wavelength and power to how bright it is perceived to be.

Interestingly, lights of equal power but different wavelengths do not appear equally bright. The brightest wavelengths are about 550 nm.

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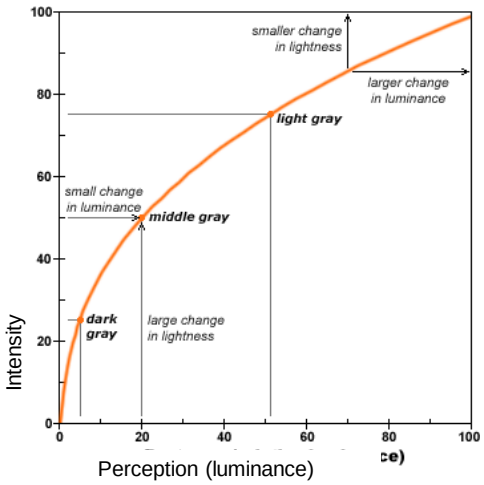
Perception: relative intensity

- We are not good at judging absolute intensity
- We perceive relative intensities, not absolute



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Summary so far …

- Colour is a property of light
- Objects reflect what we perceive
- They absorb what we don't see
- The hue is the name of the colour
- The saturation is the degree of mixture with white
- The brightness relates to the quantity of emitted light

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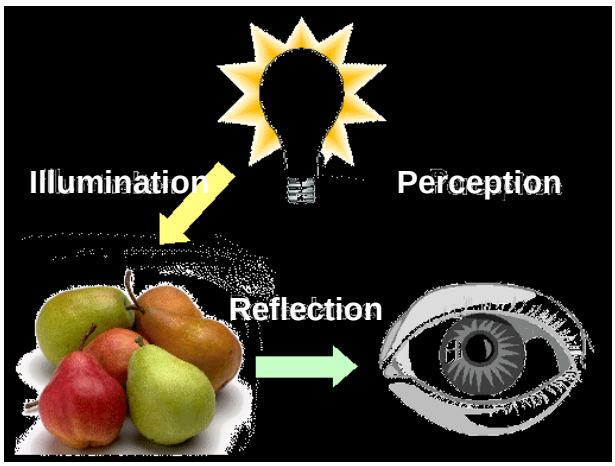
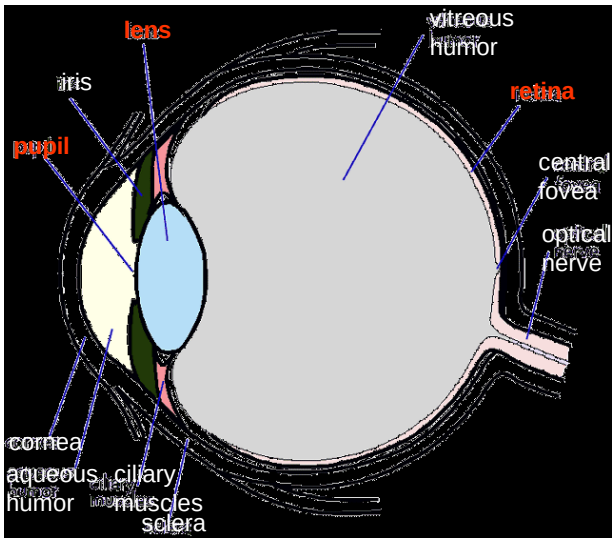
Colour vision



Colour vision



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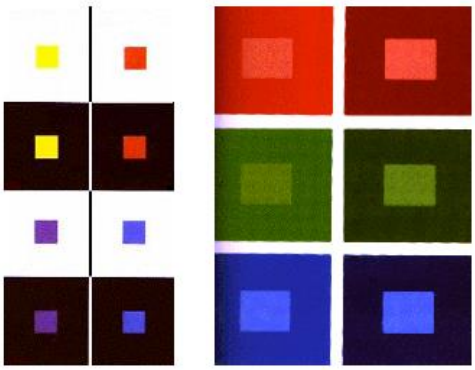
Colour perception is subjective

Perception of colour is also determined by the physical context of the object (number, size, proximity and energy characteristics of other objects in the field of view).



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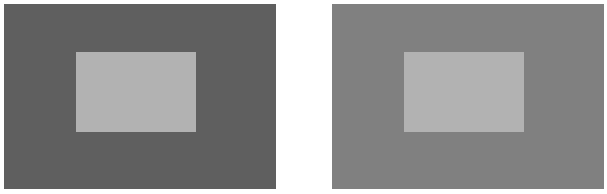
Colour perception is subjective

The brain has a major role in interpreting colour: perception of colour may be affected by previous experience and functioning of The brain.

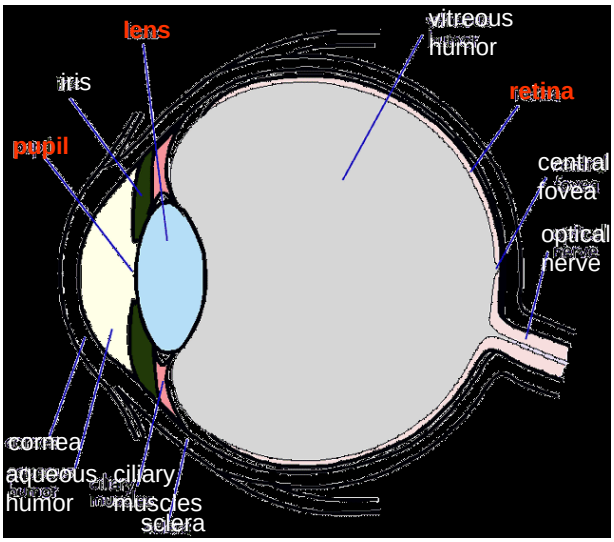
Perception

- Colour perception is difficult because:
  - It varies from person to person
  - It is affected by adaptation
  - It is affected by surrounding colours



Physiology of vision

The retina
- – Rods
- – Cones
  - • Color!



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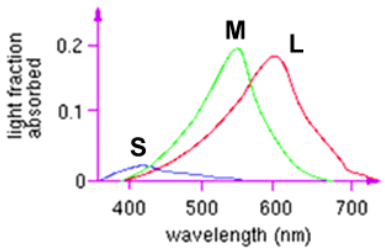
Physiology of vision: cones

- Cones → three types
  - – **L** or **R**, most sensitive to red light (610 nm)
  - – **M** or **G**, most sensitive to green light (560 nm)
  - – **S** or **B**, most sensitive to blue light (430 nm)



  - – Colour blindness results from missing cone type(s)

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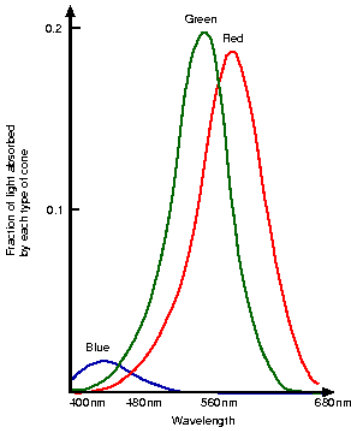
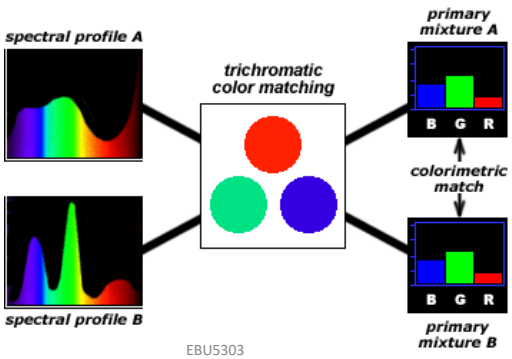
The Tristimulus Theory of Colour Vision

- Human perception of colour derives from the eye's response to 3 different groups of wavelengths, i.e. those corresponding to red, green and blue (RGB).
- Therefore any sensation of colour can be produced by mixing together suitable amounts of these colours.



Metamers

- A given perceptual sensation of colour derives from the stimulus of all three cone types.
- Identical perceptions of colour can thus be caused by very different spectra.



Summary so far …

- Colour vision is a complex phenomenon
- Colour perception is the result of sensations in the eyes and brain activity
- Colour perception is subjective
- The eye is sensitive to 3 groups of wavelengths : Red, Green and Blue (Tristimulus theory)
- Any colour can be created by mixing some R, G and B

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- HSV is an intuitive colour model

Colour models

- What is a colour model?
  - A colour model is an abstract mathematical model describing the way colours can be represented as sets of numbers

Colour models

- Why do we need colour models ?
  - Colour is a difficult thing to describe accurately.
  - In a model each colour has a numerical code, which can be used to reproduce exactly the colour intended.
  - With colour codes we can pass instructions to computers.

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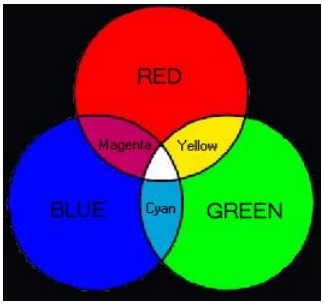
Using the RGB Scheme in Computers

- In the RGB model, we can define any colour value in terms of the proportions of R, G and B it contains.
- Any colour can be represented in the form (r, g, b).
- The number of bits used to hold a colour value is called the colour depth or pixel depth.

E.g. if 8 bits are used, then:

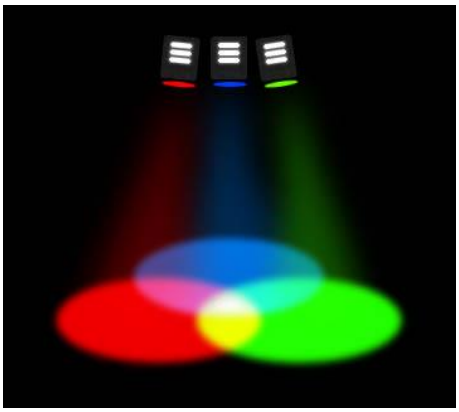
- (0, 0, 0) is black
- (255, 0, 0) is red
- (255, 255, 255) is white
- (100, 100, 100) is gray

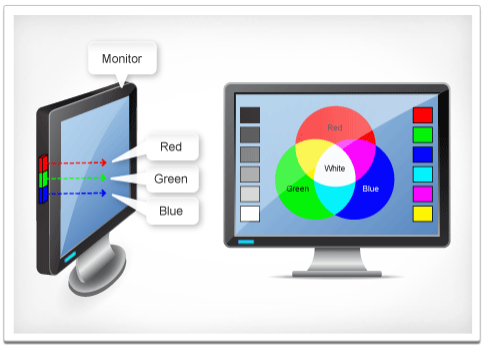
- The RGB model is used for colour monitors and most video cameras.



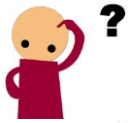
Additive Primary Colours

Using the RGB Scheme in Computers



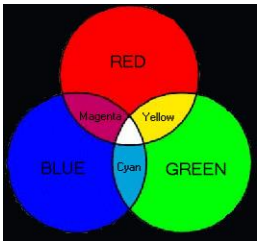


Questions ..



- What colours correspond to the eight corners of this cube?

- What does a straight line running from the origin (0,0,0) to (255,255,255) represent?

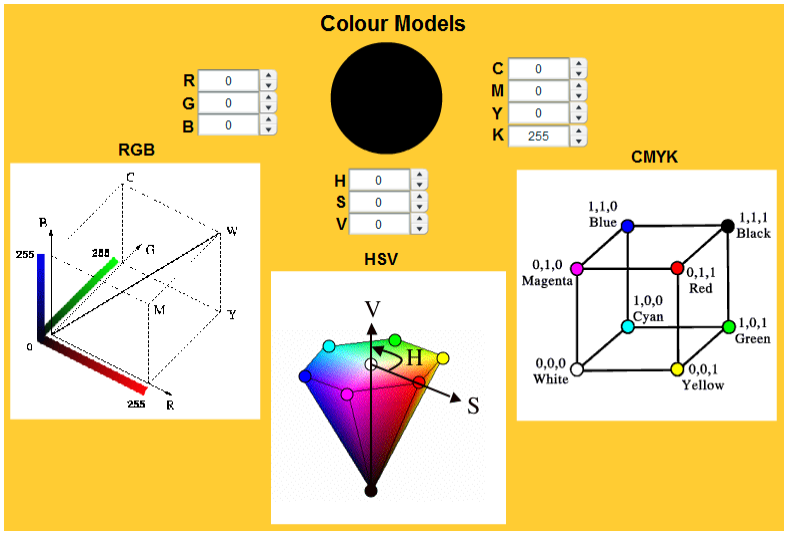


From R,G,B to Grayscale

Let an RGB color pixel be given by (R, G, B), where R, G, and B are the red, green, and blue color components, respectively. Then the corresponding grayscale value is given by (L, L, L), where:

$$L = 0.30R + 0.59G + 0.11B$$

Colour Converter



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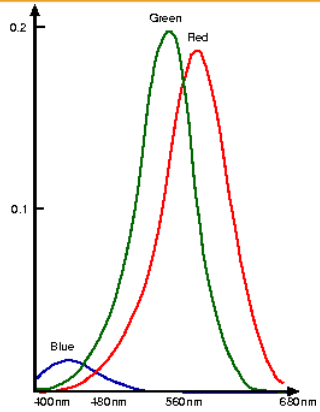
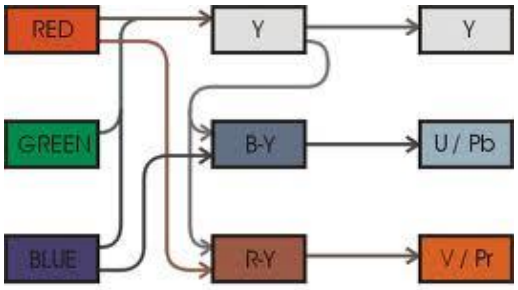
YUV

- The YUV model is a simple translation of the RGB model, separating all the luminance information (Y) from the colour (or *chrominance*) information (U, V).
- We will see later how YUV (in fact YCbCr) is used for image compression (JPEG).

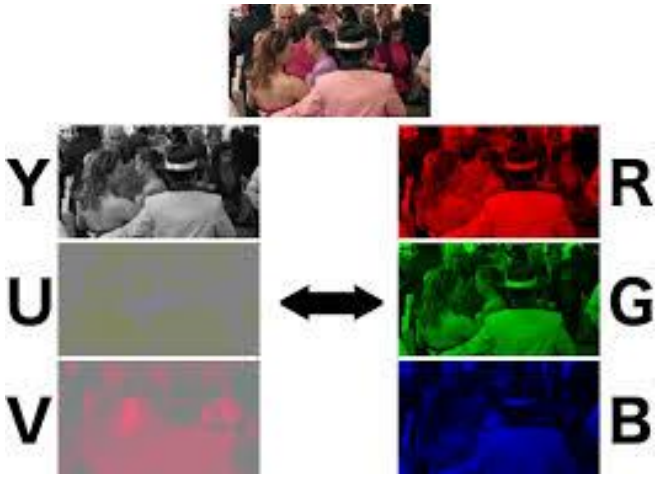
RGB to YUV

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$





RGB / YUV



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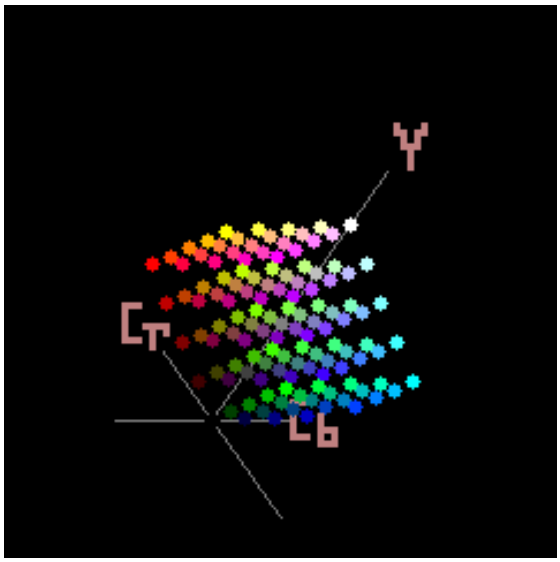
YCbCr



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RGB to YCbCr

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \quad \begin{matrix} Y \in [0, 255] \\ C_b \in [0, 255] \\ C_r \in [0, 255] \end{matrix}$$

YCbCr to RGB

$$\begin{aligned} R &= Y + 1.402 \cdot (C_R - 128) \\ G &= Y - 0.34414 \cdot (C_B - 128) - 0.71414 \cdot (C_R - 128) \\ B &= Y + 1.772 \cdot (C_B - 128) \end{aligned}$$

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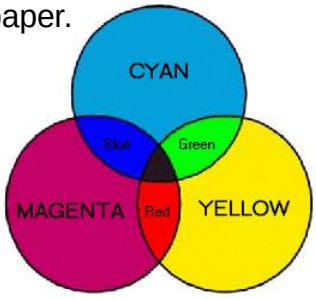
CMY(K) for printing

Subtractive Primaries CMYK

- The CMYK model is a subtractive model that is used in printing: C = W-R ; M = W-G ; Y = W-B
- Whereas the RGB model depends on a light source to create colour, the CMYK model is based on the light-absorbing quality of ink printed on paper.

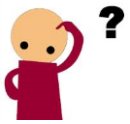
  It uses the subtractive primaries Cyan, Magenta and Yellow.

  In addition, because it is impossible to produce a pure black from these primaries, a Black (K) primary is added thus giving the CMYK model.



Subtractive Primary Colours

Question



Colour inkjet printers use the CMY model. When the cyan ink colour is sprayed onto a sheet of white paper, what colour would it appear under a green light? Why?

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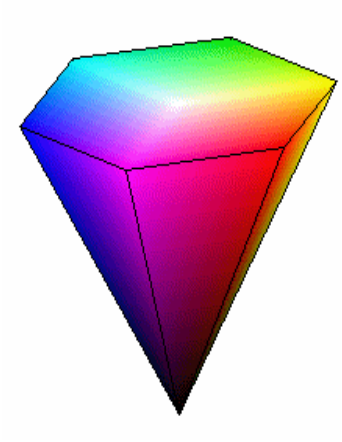
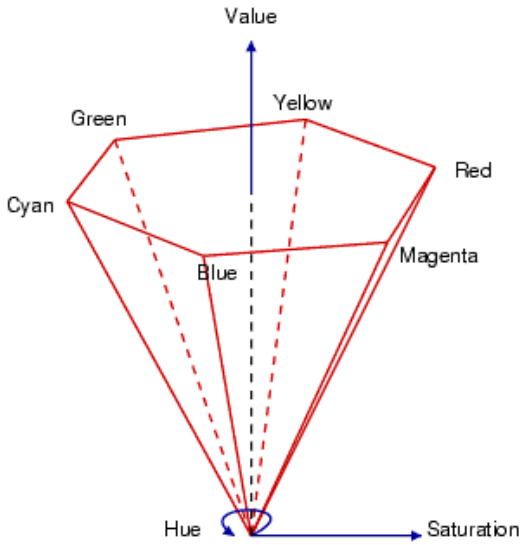
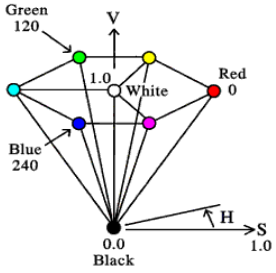
HSV

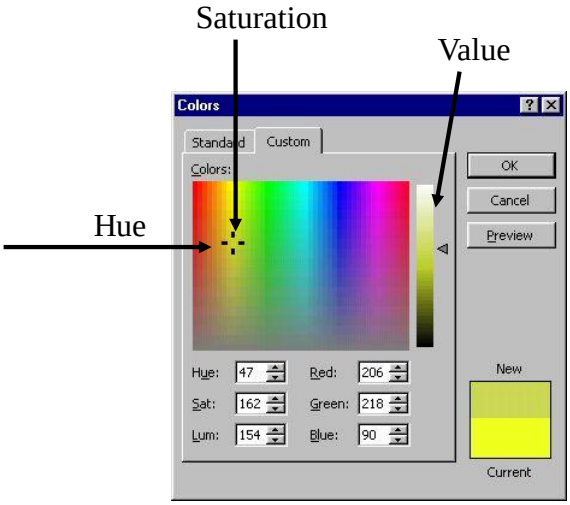



Value
Yellow
Green
Red
Cyan
Magenta
Blue
Hue
Saturation

45

HSV


Green
120
V
1.0
White
Red
0
Blue
240
H
S
0.0
Black
1.0


Saturation
Value
Hue
Colors
Standard
Custom
Colors:
OK
Cancel
Preview
Hue: 47
Red: 206
Sat: 162
Green: 218
Lum: 154
Blue: 90
New
Current

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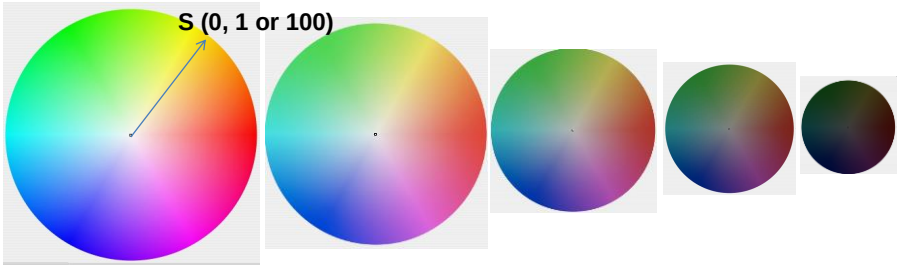
HSV



V (0, 1 or 100)

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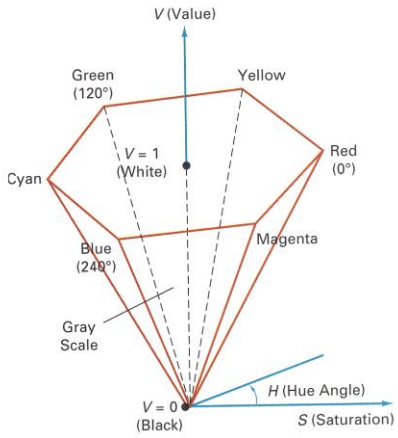
HSV



H	S	V	Color
0	1.0	1.0	Red
120	1.0	1.0	Green
240	1.0	1.0	Blue
*	0.0	1.0	White
*	0.0	0.5	Gray
*	*	0.0	Black
60	1.0	1.0	?
270	0.5	1.0	?
270	0.0	0.7	?

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Exercise

What RGB values and what HSV values could represent the following colours?

- Light grey
- Bright magenta
- Bright non-saturated red

Exercise

Consider the following three colours expressed using 24 bits, in the RGB colour model: Colour A = (220, 30, 20); Colour B= (100, 100, 100); Colour C = (50, 0, 50).

- Estimate the H, S, and V values for each of these colours in the HSV colour model (H can also be specified using a colour name rather than a value).
- Estimate the C, M, Y and K values for each of these colours in the CMYK colour model.

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For you to do:

Check out other existing models:

CIE XYZ, CIELAB, etc.

http://burg.cs.wfu.edu/TheScienceOfDigitalMedia/Chapter2/ch2scienceofdigitalmedia.pdf

2.6 Color