

EBU5303

Multimedia Fundamentals

Colours

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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

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Reading



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

2.6 Color

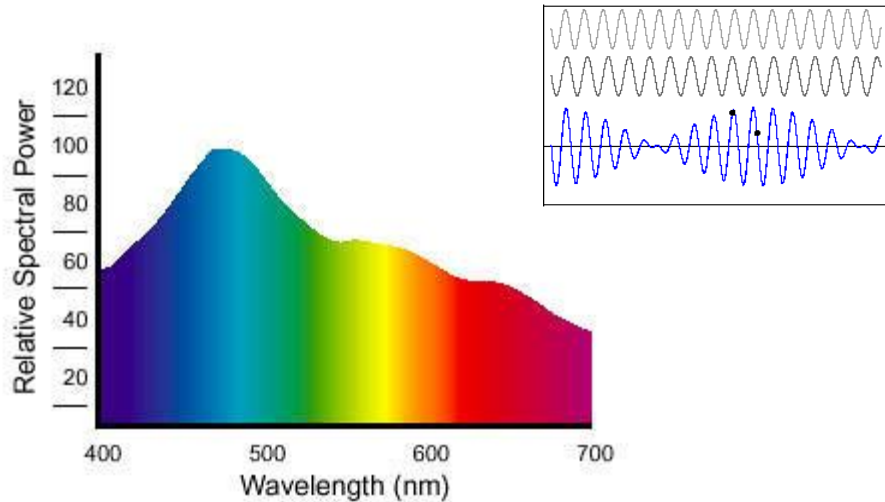
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Light



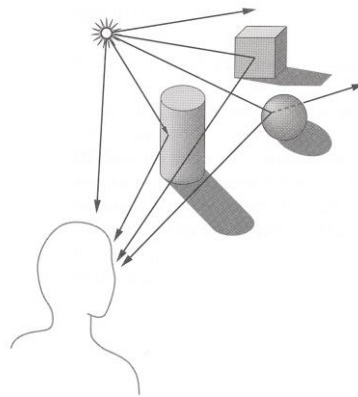
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Properties of Colours

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

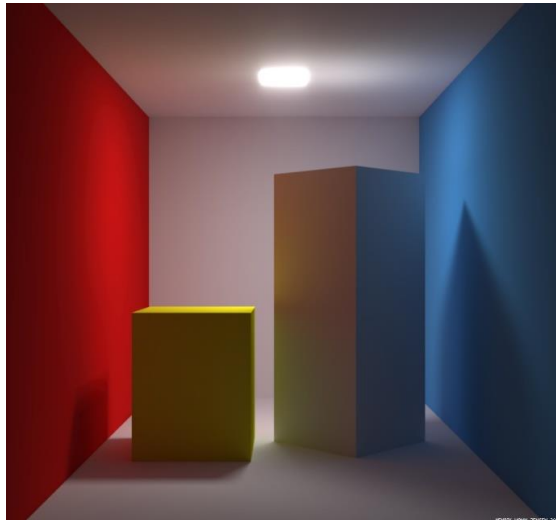
Objects have no colour of their own, but merely the ability to reflect a certain section of the visible spectrum.

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



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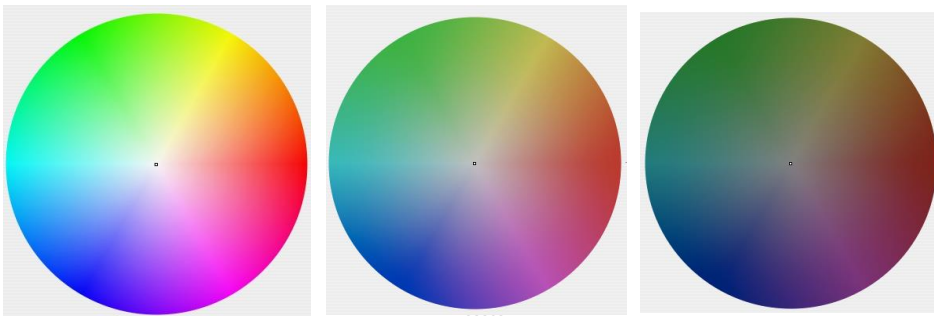
Properties of Colours

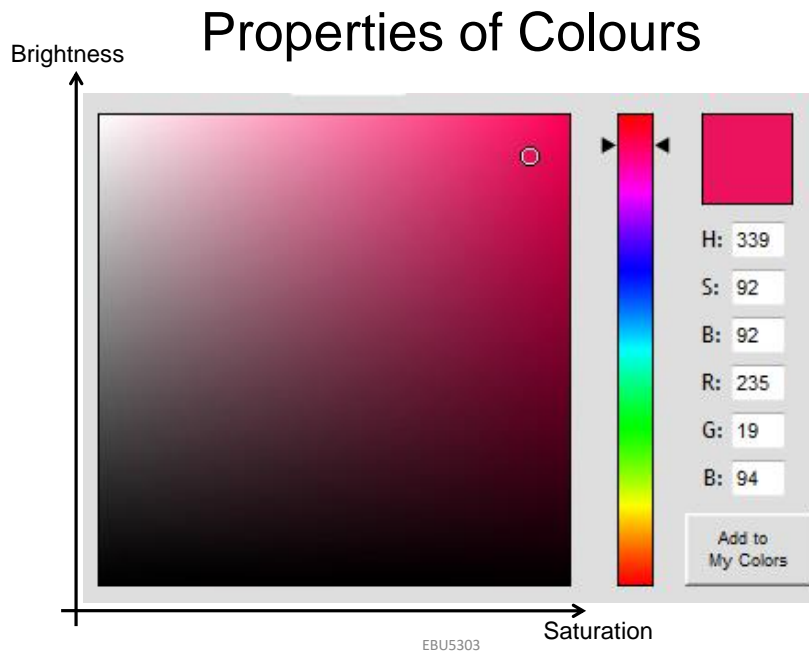


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Properties of Colours

- **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.





Brightness and Luminance

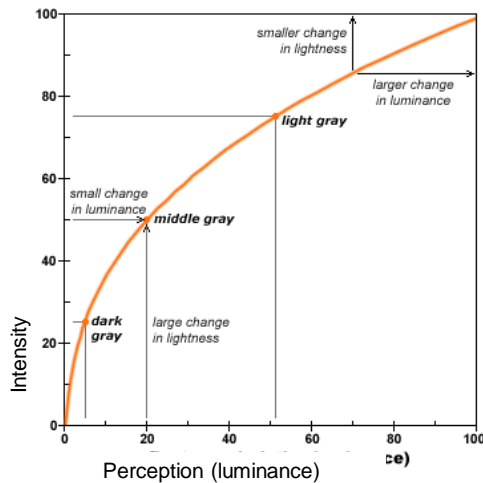
- **Brightness** is a matter of subjective perception and has no precise mathematical definition.
- **Luminance** has a mathematical definition that relates a light's wavelength and power to how bright it is perceived to be.

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



Summary so far ...

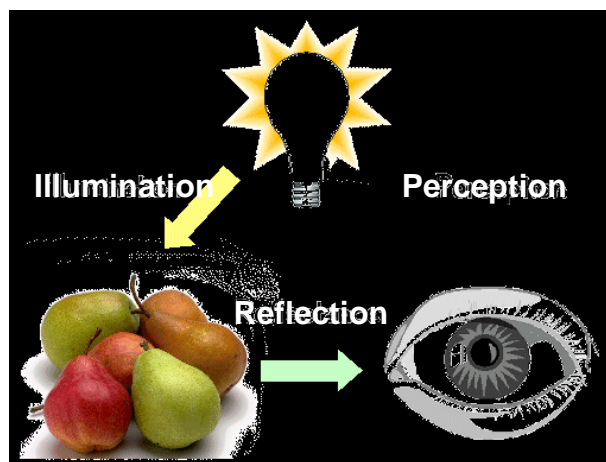
- Colour is a property of light
- Objects reflect what we perceive
- They absorb what we don't see
- The hue is the name of the colour
- The saturation is the degree of mixture with white
- The brightness relates to the quantity of emitted light

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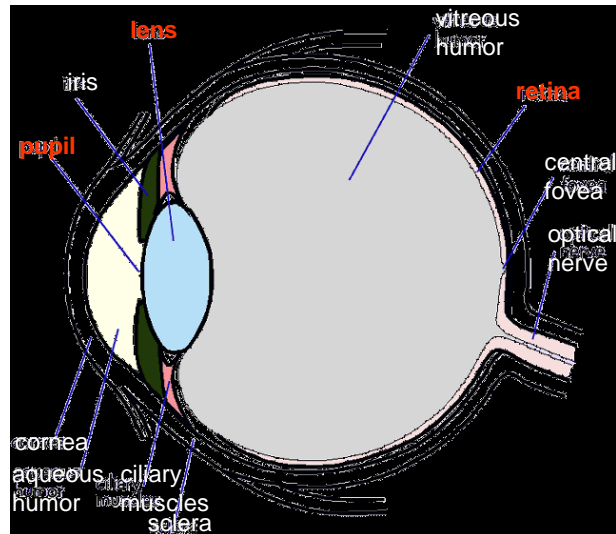
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Colour vision



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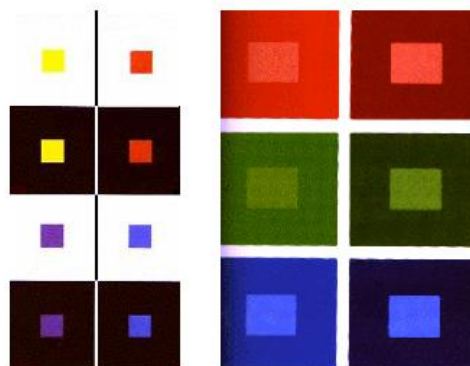
Colour vision



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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.



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Perception

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

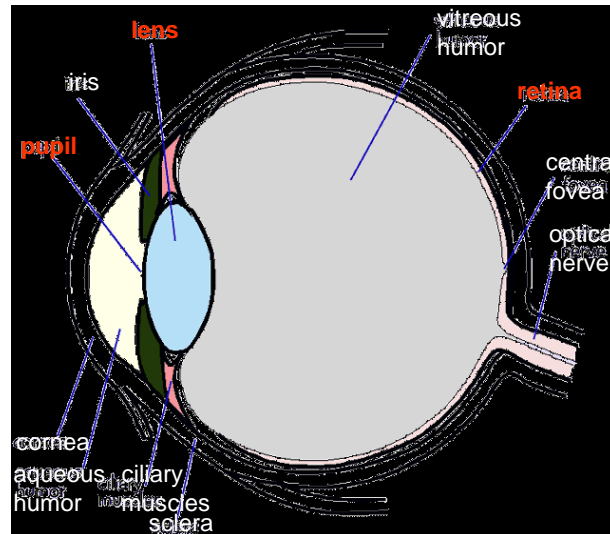


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Physiology of vision

The retina

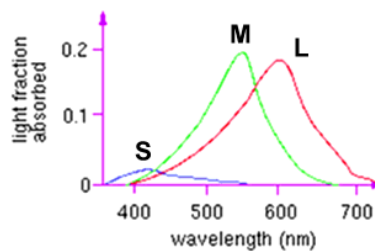
- Rods
- Cones
 - Color!



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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)

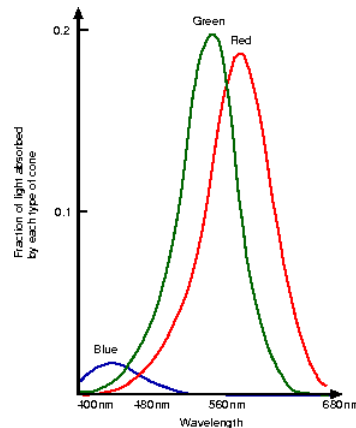


- Colour blindness results from missing cone type(s)

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The Tristimulus Theory of Colour Vision

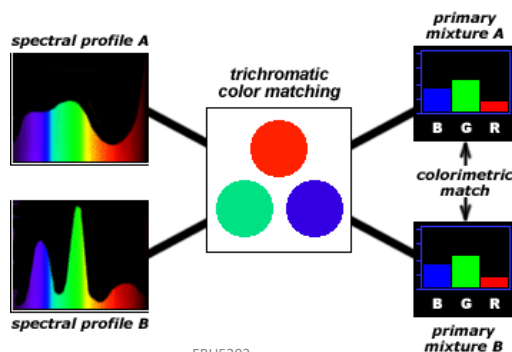
- Human perception of colour derives from the eye's response to 3 different groups of wavelengths, i.e. those corresponding to red, green and blue (RGB).
- Therefore any sensation of colour can be produced by mixing together suitable amounts of these colours.



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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.



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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

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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

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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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Colour models

- **RGB** is used in computer monitors
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- **CMYK** is used for printing
- **HSV** is an intuitive colour model

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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

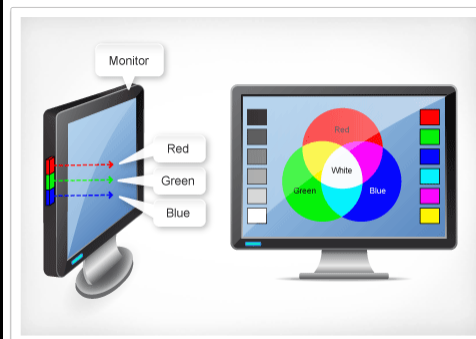
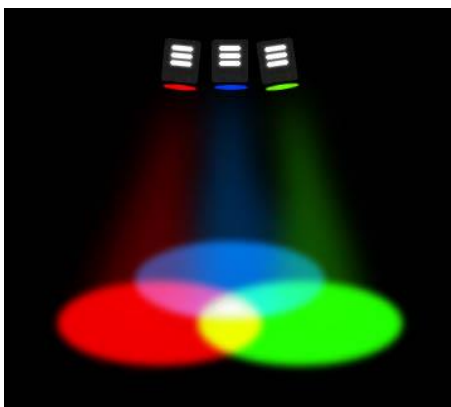


Additive Primary Colours

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

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Using the RGB Scheme in Computers

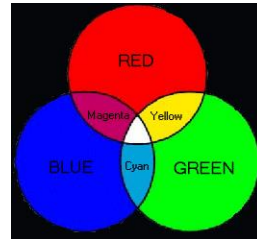
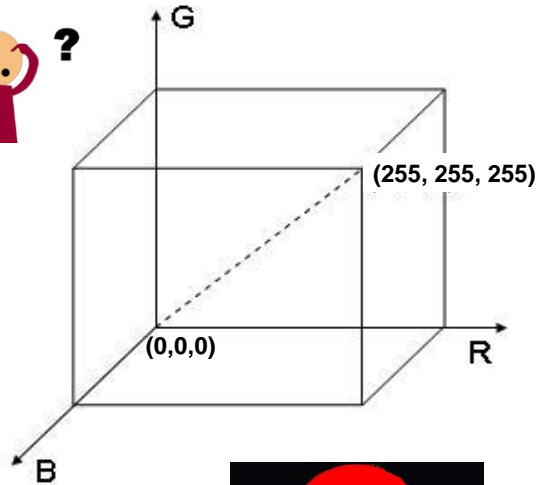


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Questions ..



- 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?



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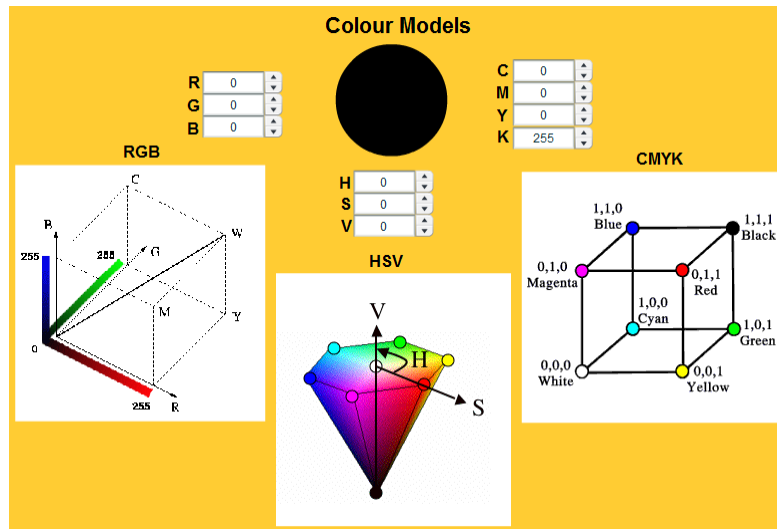
From R,G,B to Grayscale

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:

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

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Colour Converter



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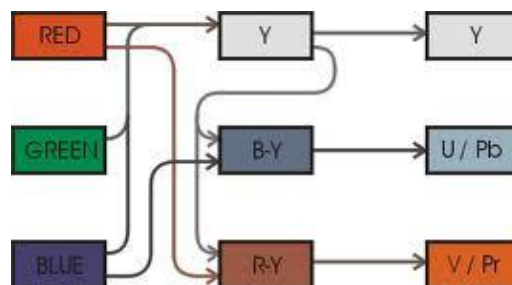
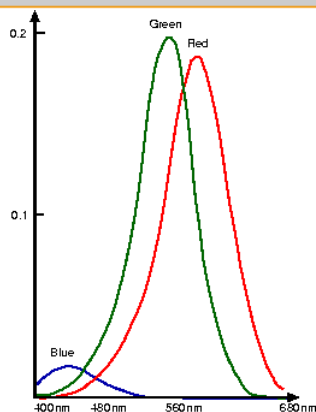
YUV

- 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).

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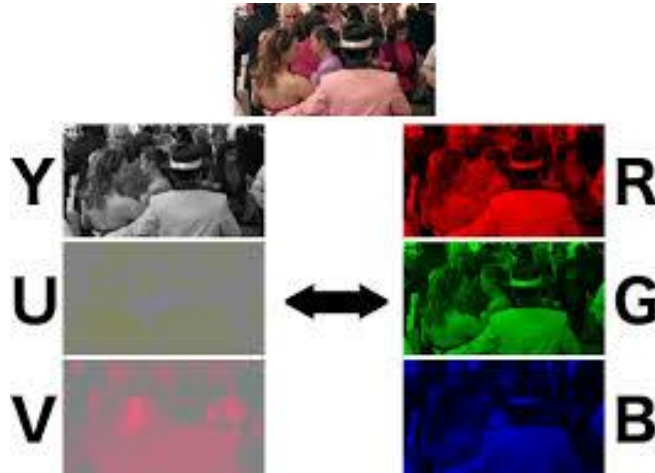
RGB to YUV

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



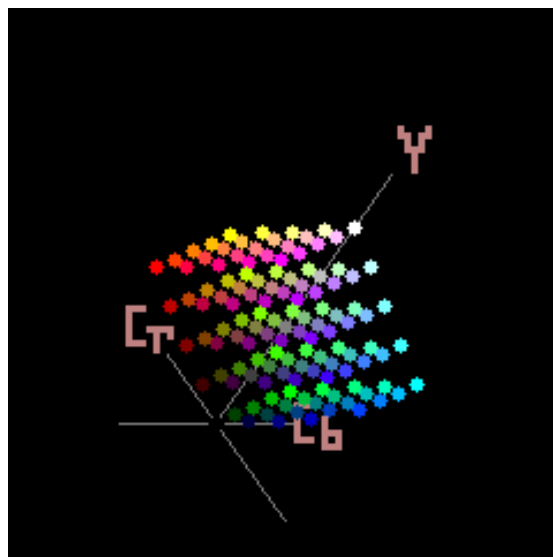
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RGB / YUV



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YCbCr



RGB to YCbCr

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

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



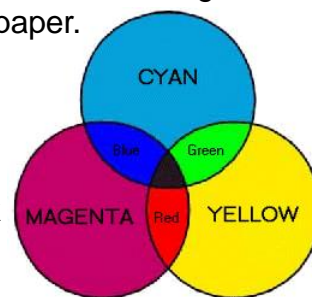
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Subtractive Primaries CMYK

- 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

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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?

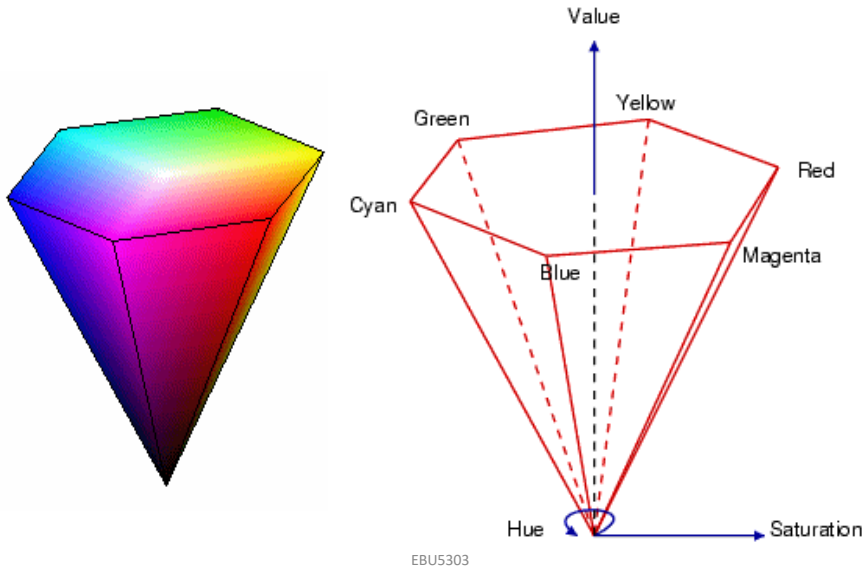
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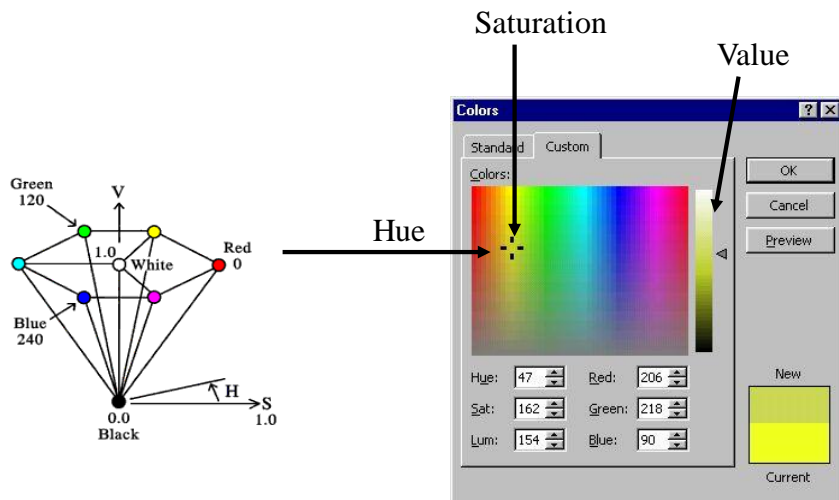
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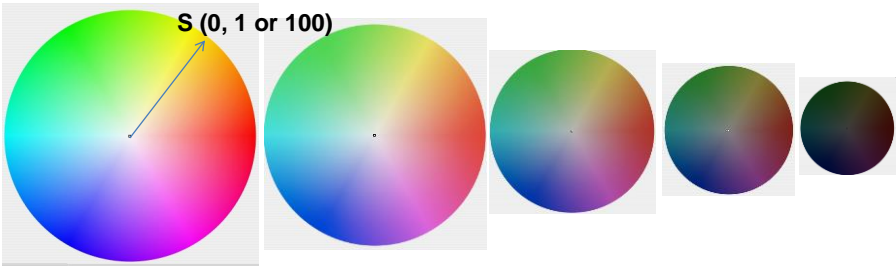
HSV



HSV



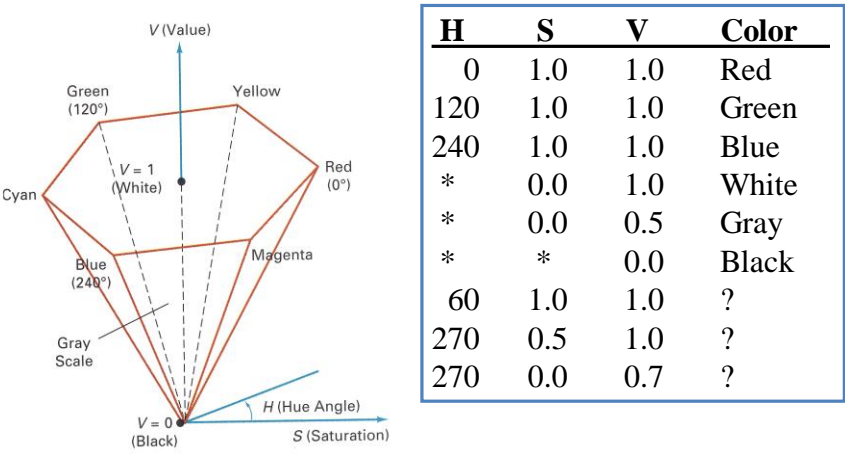
HSV



←
V (0, 1 or 100)

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HSV



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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

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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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FRIDAY split session

Bring your computer and download the colour converter from QMplus.

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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

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