

Computer Graphics

COMP4610/COMP6461

Introduction & Colour

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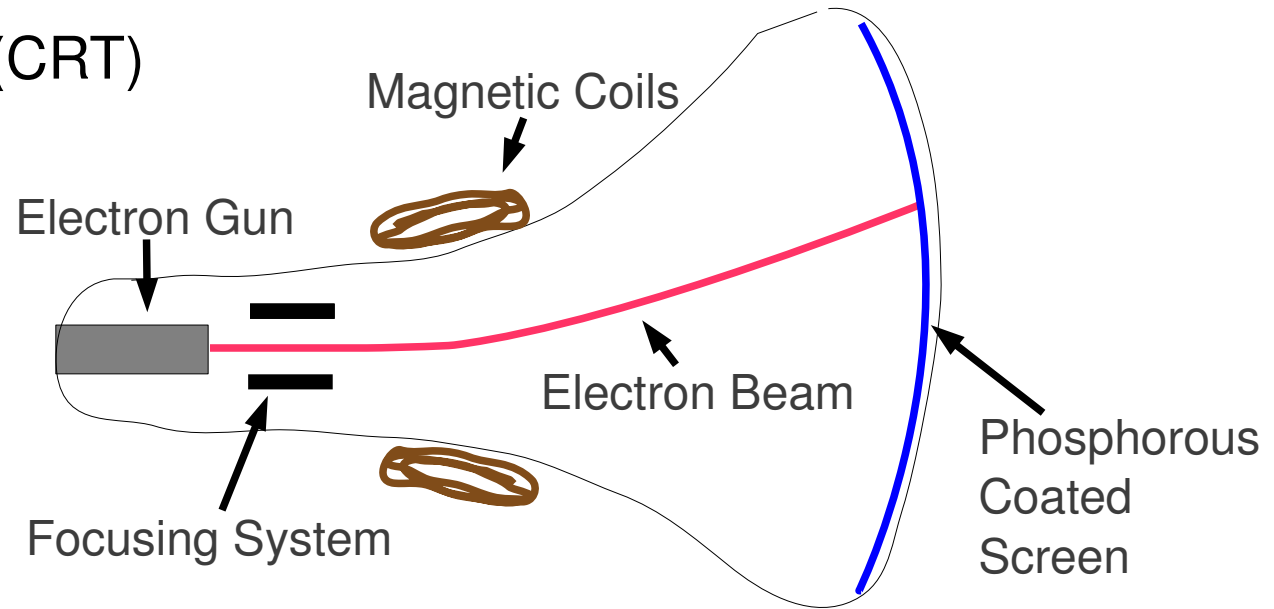
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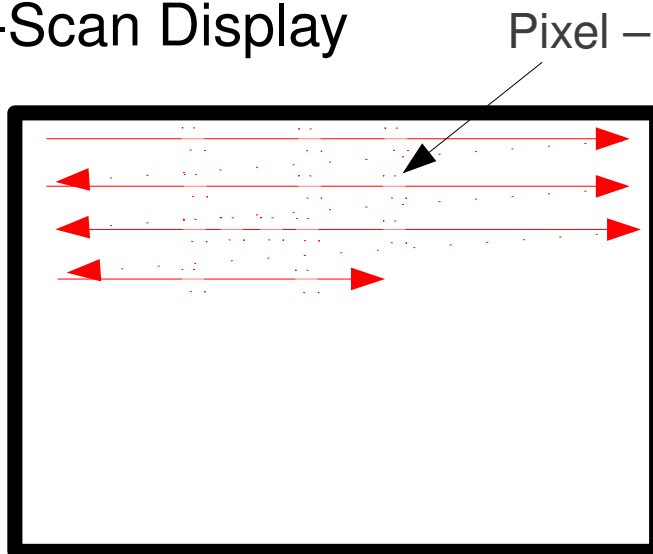
- Computer Graphics Uses (Chapter 1)
- Basic Hardware and Software (Chapter 2)
- Colour and our perception of colour (Chapter 12)

- Computer Graphics and its effects is ubiquitous modern society.
- The text(Hearn and Baker) list:
 - Graphs and Charts
 - Computer-Aided Design
 - Virtual-Reality Environments
 - Data Visualizations
 - Education and Training
 - Computer Art
 - Entertainment
 - Image Processing
 - Graphical User Interfaces

- Cathode-ray tube(CRT)



- Raster-Scan Display



Resolution is the number of none overlapping points that can be displayed. (number of columns and rows)

Frame buffer stores the picture

Depth (or bit planes) – bits per pixel

Aspect ratio = pixel columns/scan lines

- Resolution on different displays

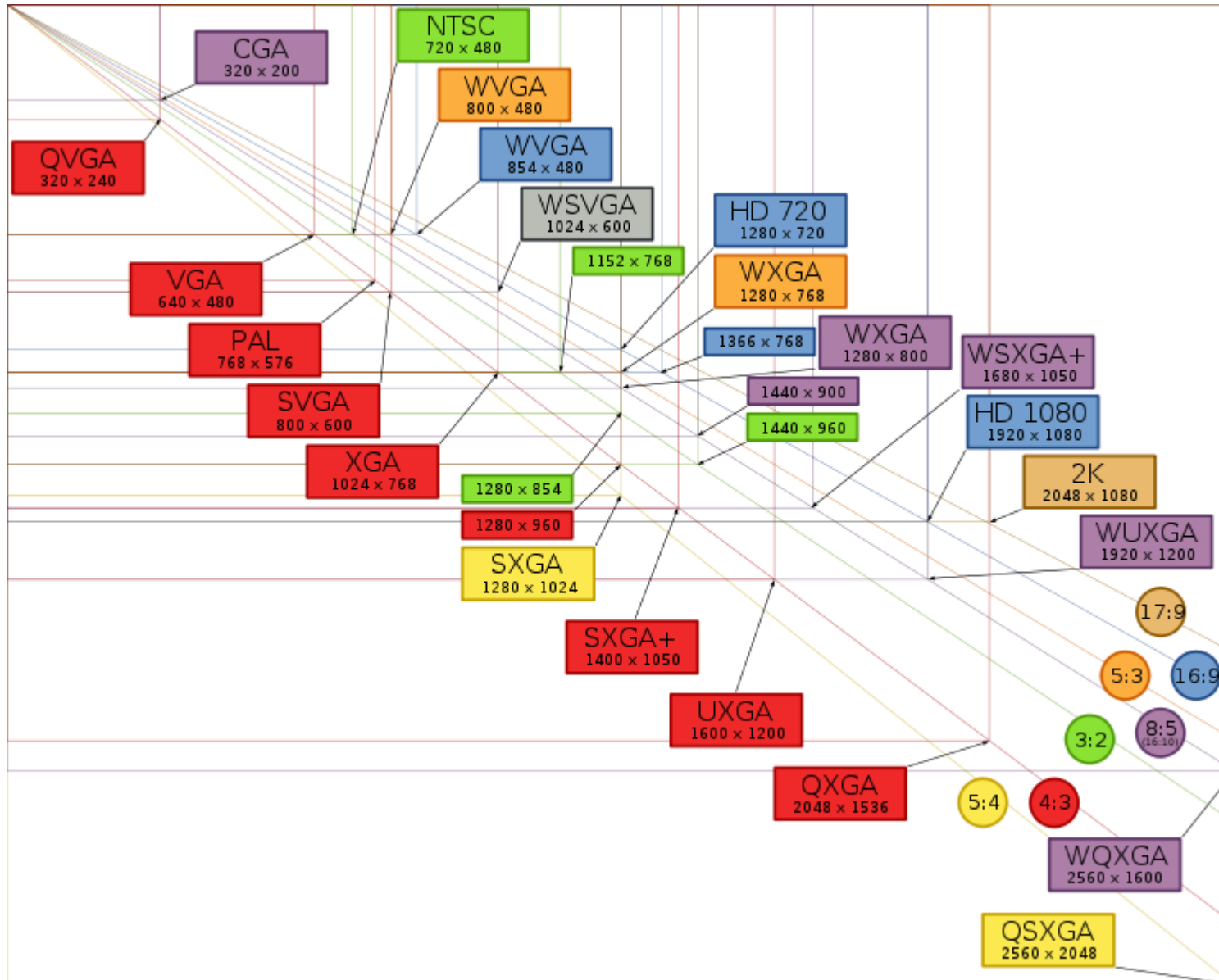
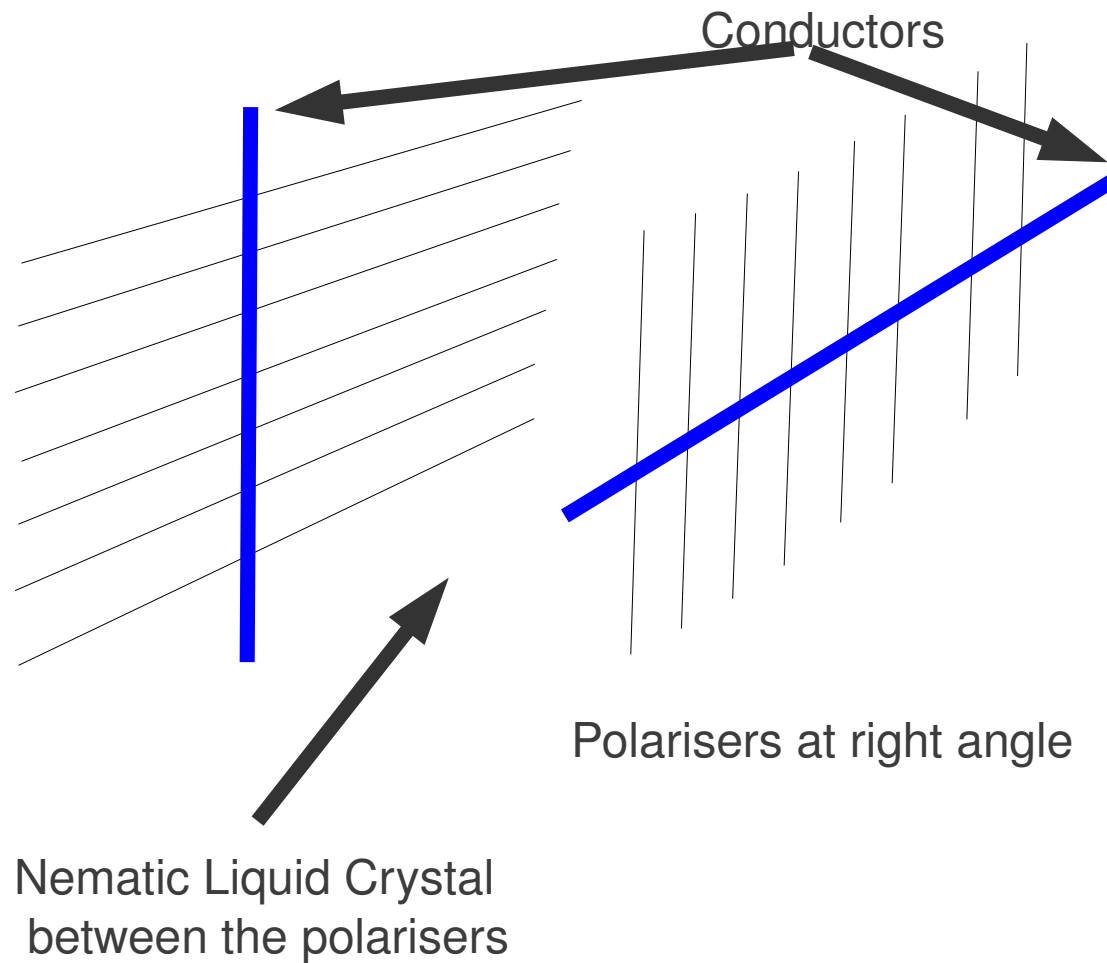
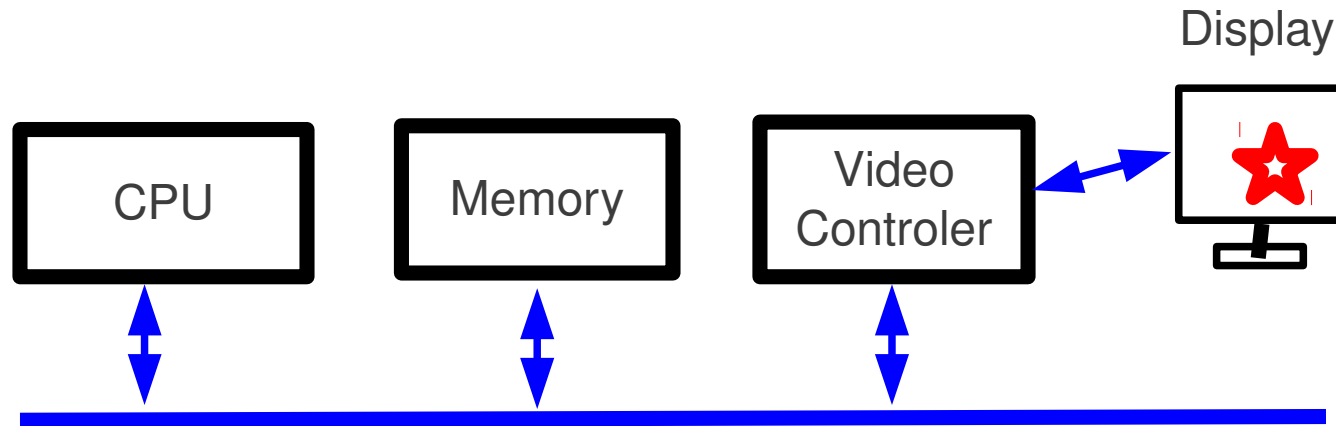


Image obtained from wikipedia, uncertain of original author. [Creative Commons Attribution-ShareAlike 3.0](#)

- Liquid-crystal displays (LCDs)

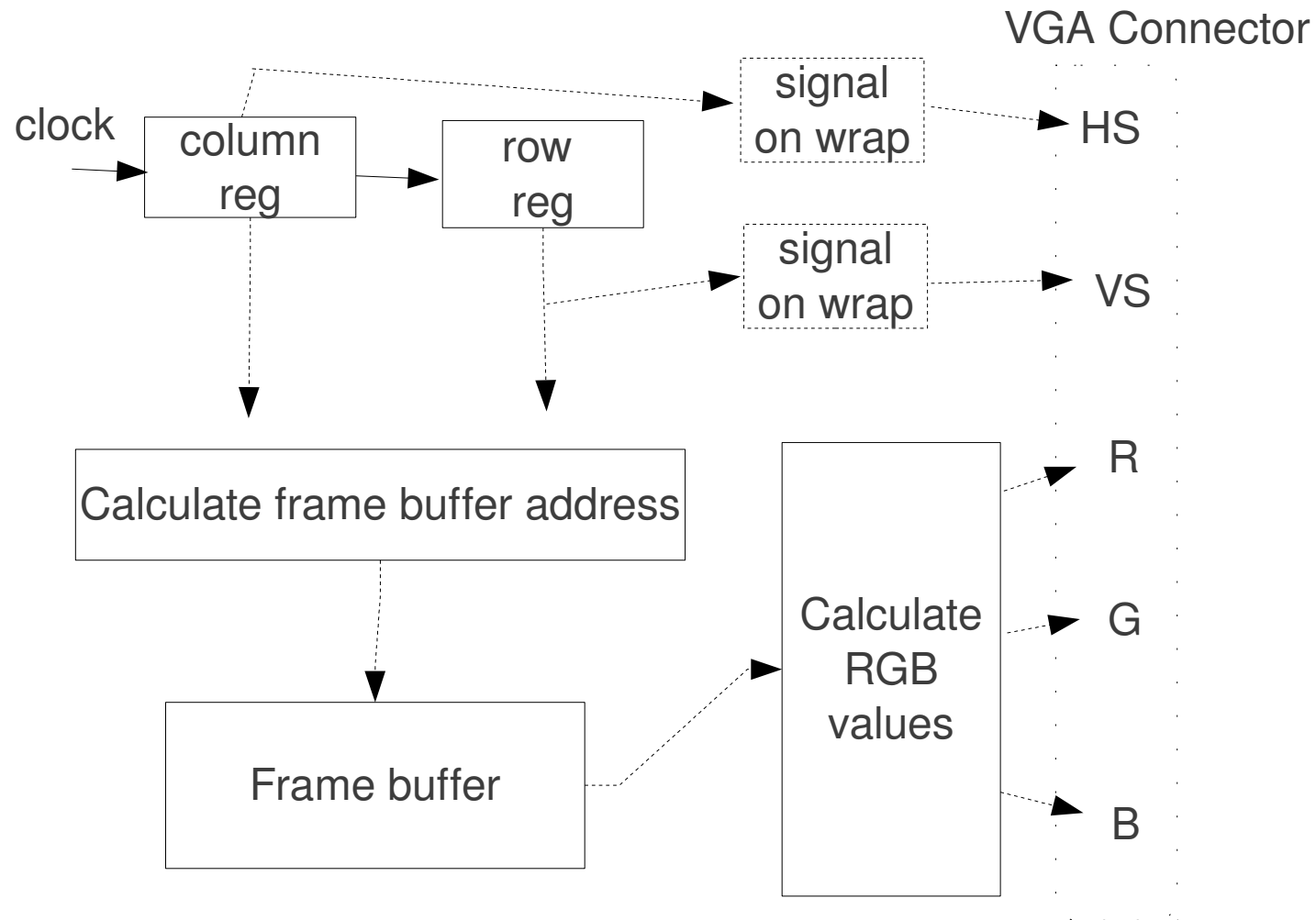


- Generally a special purpose processor will be used for driving the display.



- VGA uses horizontal sync(HS) and vertical sync(VS) signals along with RGB signals to transport an image to a display.

- Simple video controller for generating VGA



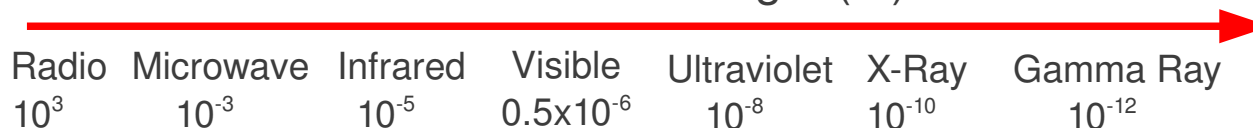
- Visible light is a small part of the electromagnetic spectrum.
- Light travels at the speed of light!! Which in a vacuum is:

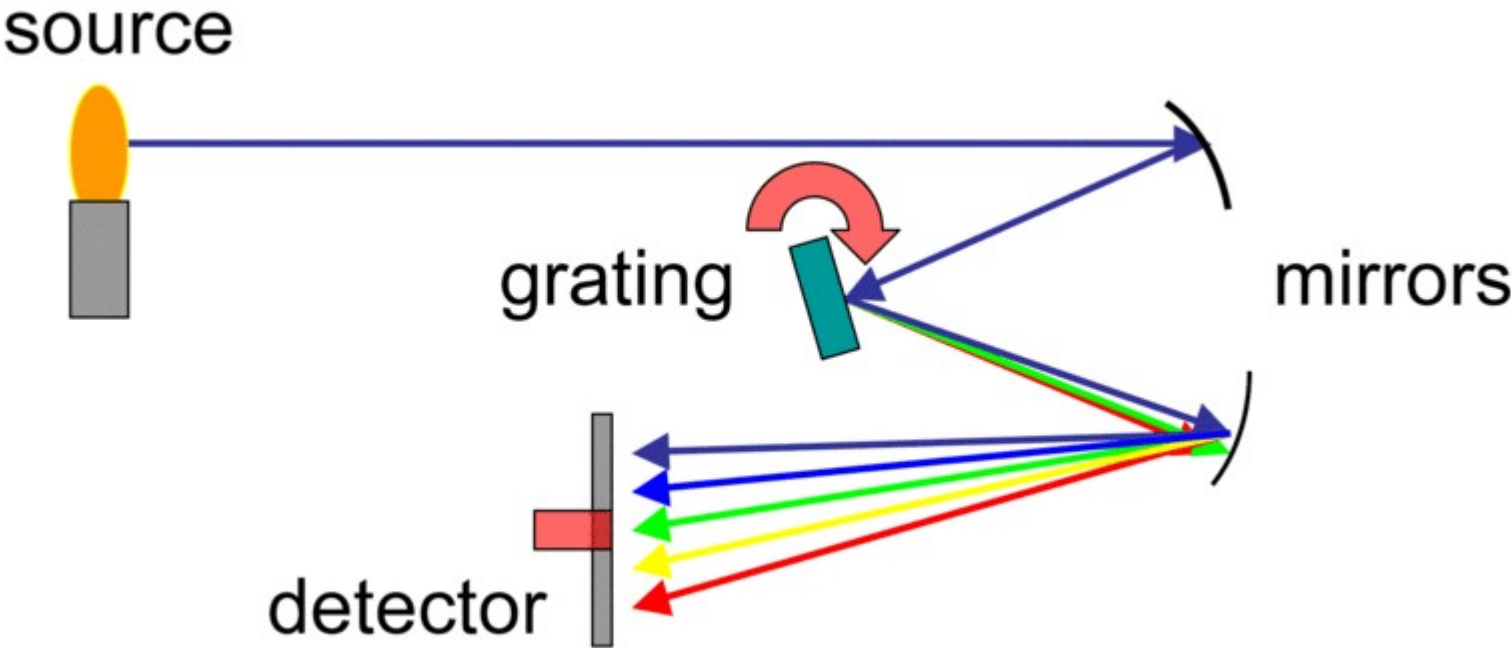
$$c = 299\,792\,458 \text{ m/s.}$$

- Light is made up from electric and magnetic field oscillating perpendicular to each other as it moves through space.
- Light has three main properties: intensity, wavelength(or frequency), and polarisation.
- The frequency and wavelength is related to each other by the speed of light.

$$c = \lambda f$$

wavelength (m)

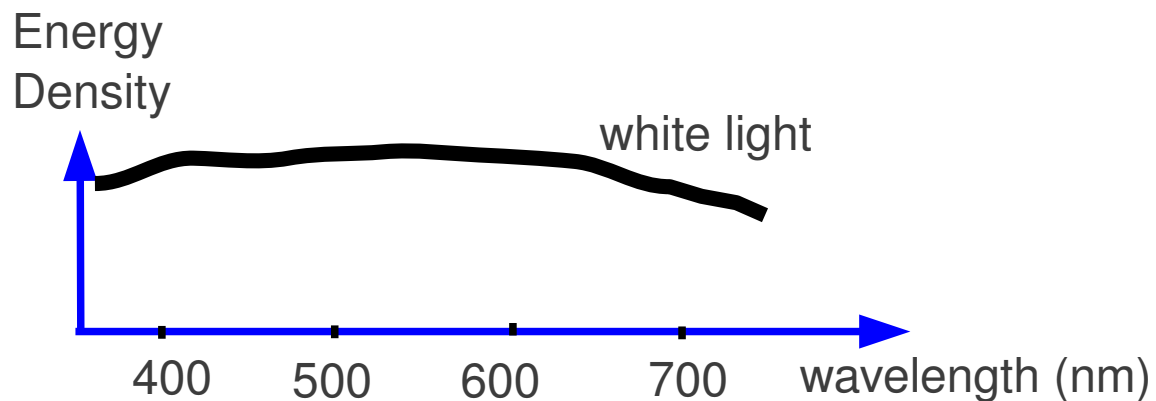
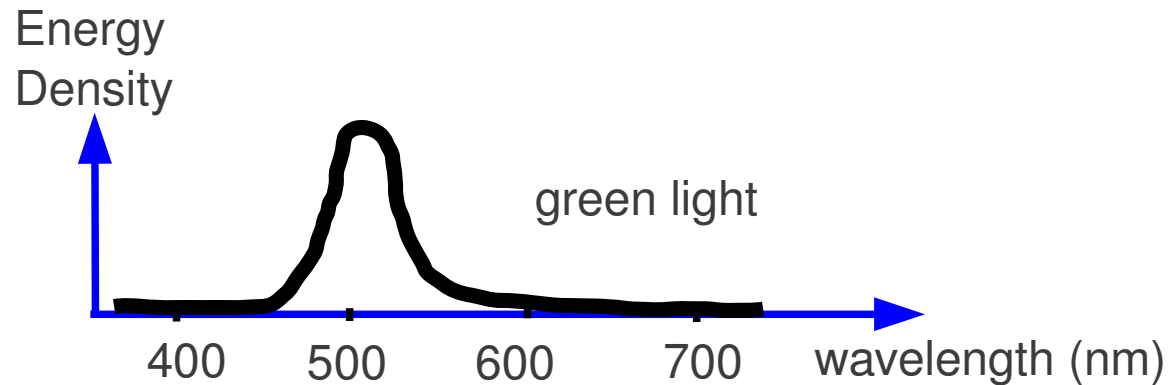




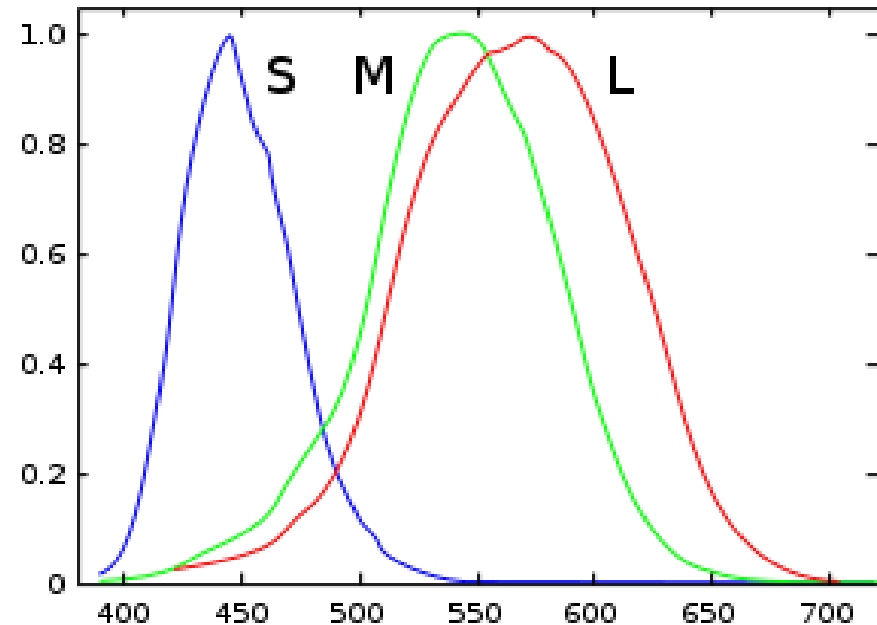
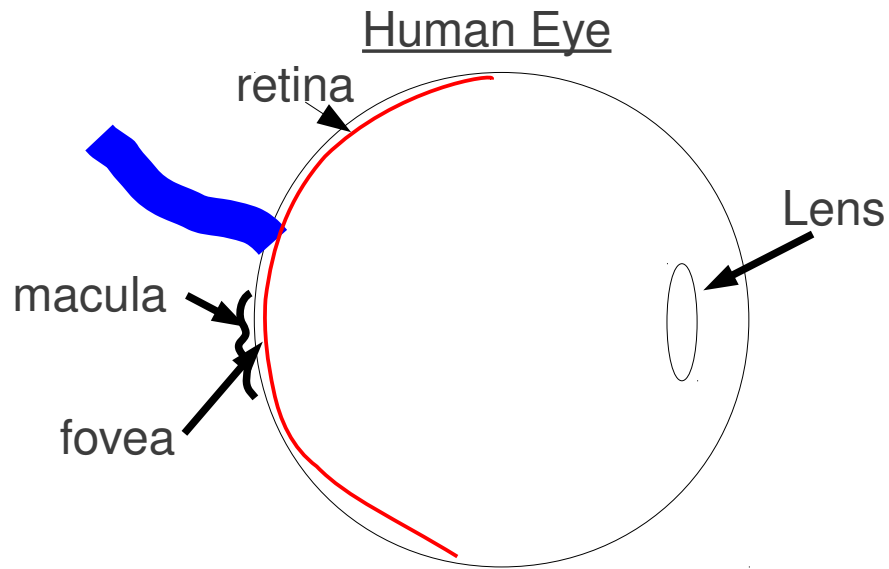
http://en.wikipedia.org/wiki/File:Spectrometer_schematic.gif

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- There is lots and lots of colours, as a single colour can be described by a function of energy density for different wavelengths (you need a Hilbert space to describe such functions!).

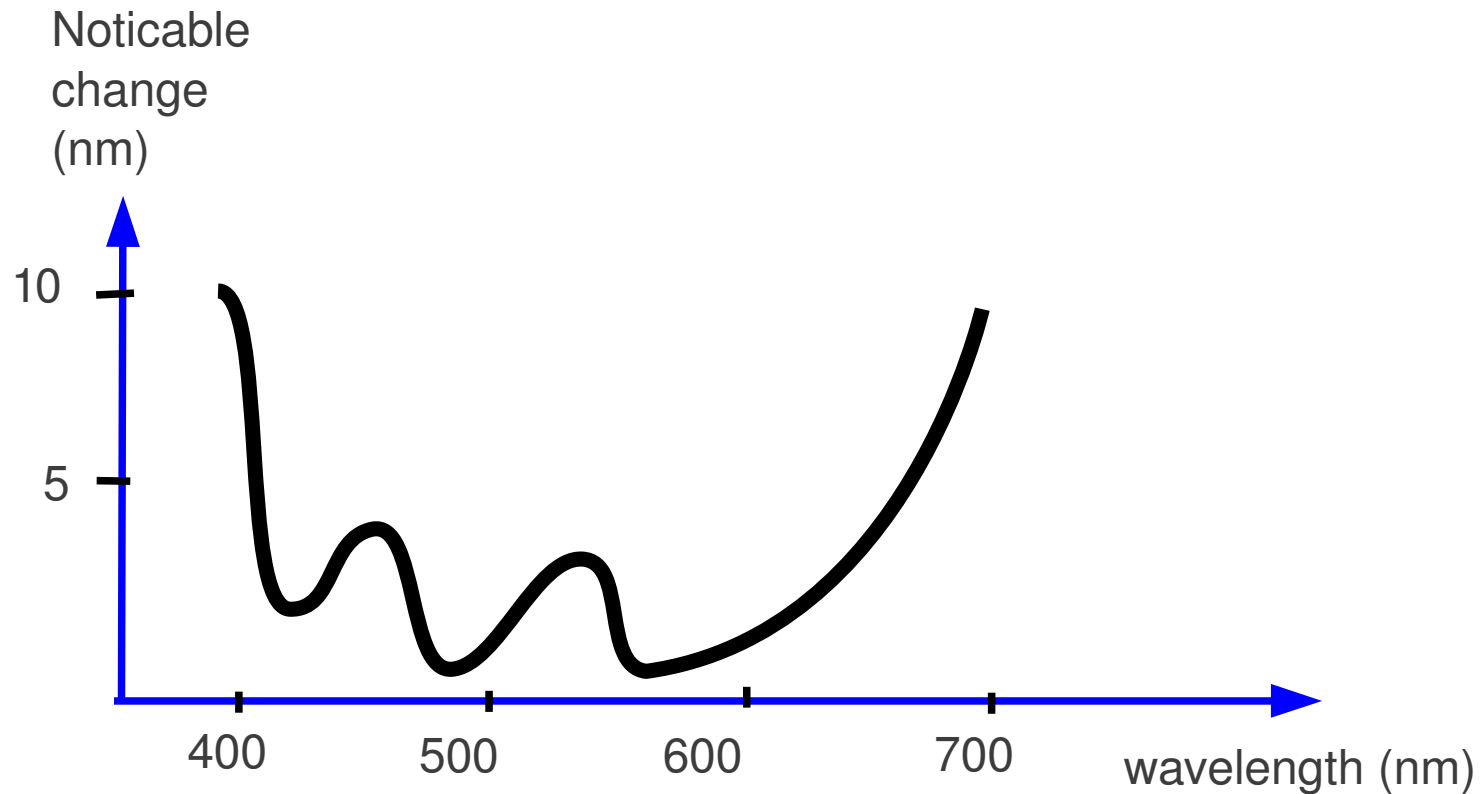


- Our eye makes life much simpler for us (people doing computer graphics!) as it reduces an infinite dimensional space down to a 3 dimensional space.
- The retina is light sensitive tissue lining the eye. The two main types of photo sensitive cells are cones and rods.



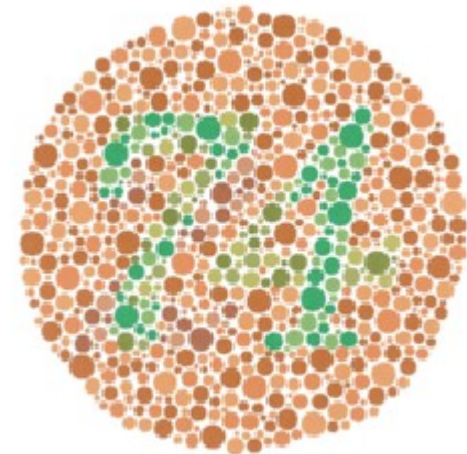
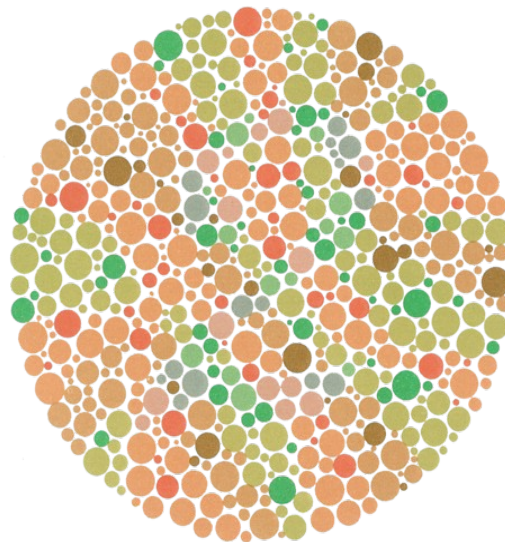
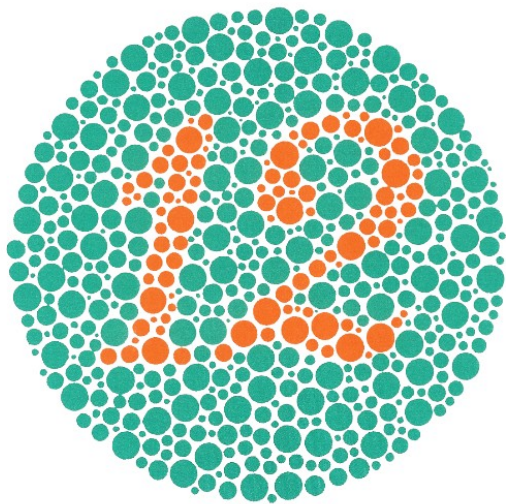
Simplified human cone response curves, based on Dicklyon's PNG version, itself based on data from Stockman, MacLeod & Johnson (1993) Journal of the Optical Society of America A, 10, 2491-2521d, image obtained from wikipedia under a Creative Commons Attribution 3.0 License.

- Just-noticeable color differences change as a function of wavelength.



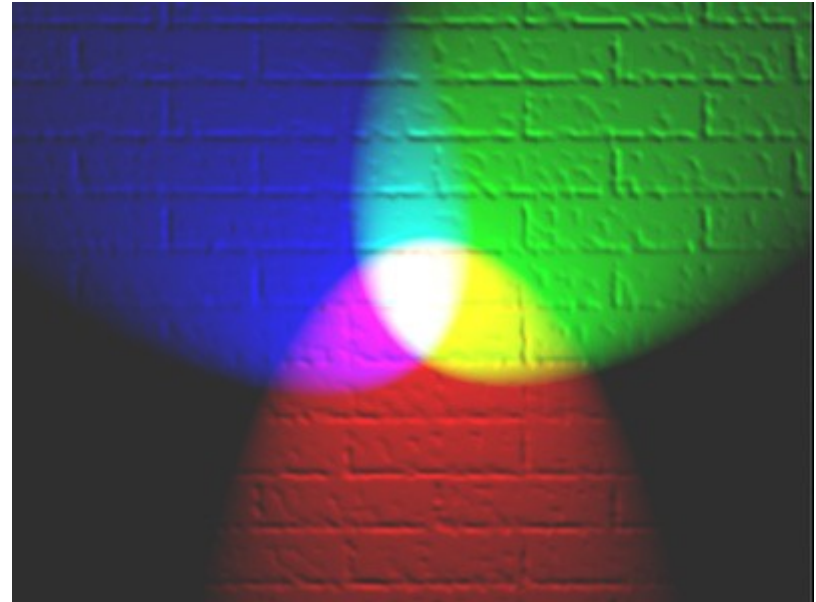
Based on graph in Fig 13.21 from *Computer Graphics*, Foley et.al.

- Ishihara Colour Plates help uncover deficiencies in people's colour perception.
- Colour perception limitations are not just for people with colour deficiencies.



This slide must not be used for diagnosis.

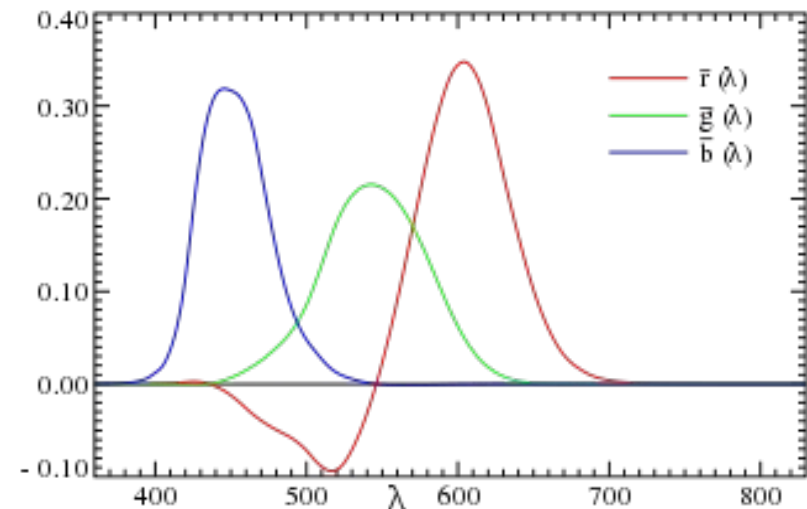
- When two light sources are combined the energy density functions of two different colours can be added together.
- To work out what colour we perceive we could, for each type of cone(S,M,L), integrate over the response curve times the energy density function.
- This integration preserves the additive property on the intensities we perceive.



Red, green and blue lights showing secondary colours.

Author : en>User:Bb3cxv, obtained from wikipedia under a Creative Commons Attribution-ShareAlike 3.0 license.

- In 1931 the International Commission on Illumination (CIE) created a standard for colour matching.
- Their colour matching can be done with standard primaries:
 - Red 700nm
 - Green 546.1nm
 - Blue 435.8nm
- These functions give us an objective way of mapping a real color(energy density function) to RGB values.



From http://en.wikipedia.org/wiki/CIE_1931_color_space

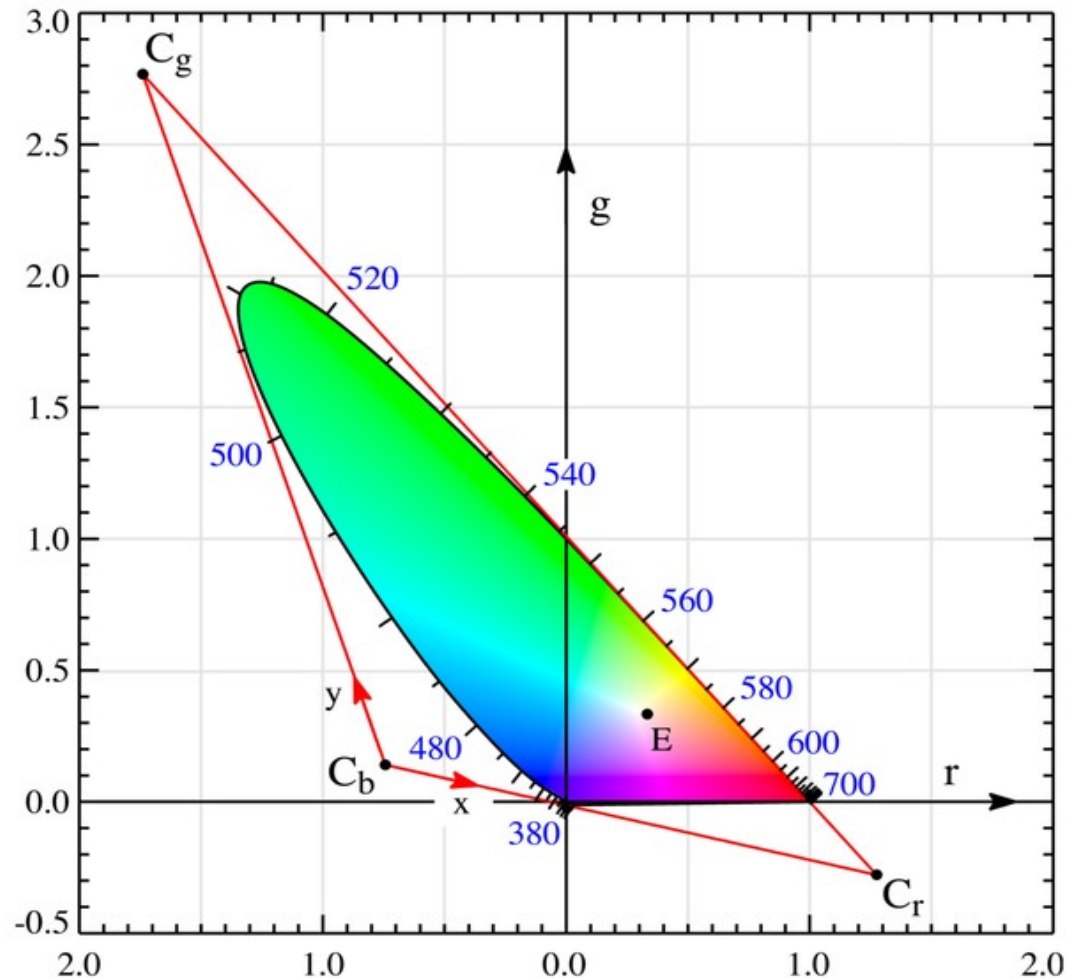
$$R = \int I(\lambda) \bar{r}(\lambda) d\lambda$$

$$G = \int I(\lambda) \bar{g}(\lambda) d\lambda$$

$$B = \int I(\lambda) \bar{b}(\lambda) d\lambda$$

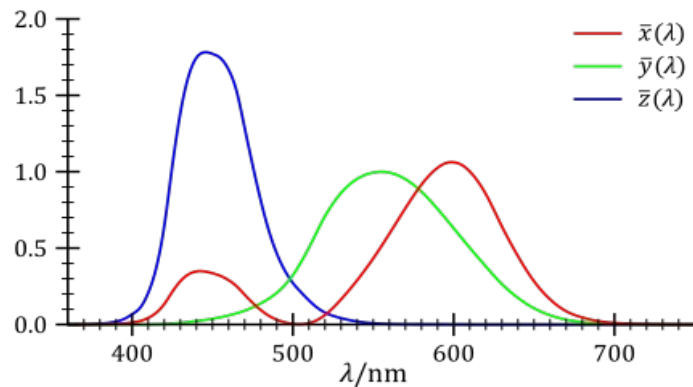
- By considering different colours all with the same total intensity we can compare colours in a 2 dimensional space.

$$r + g + b = 1$$

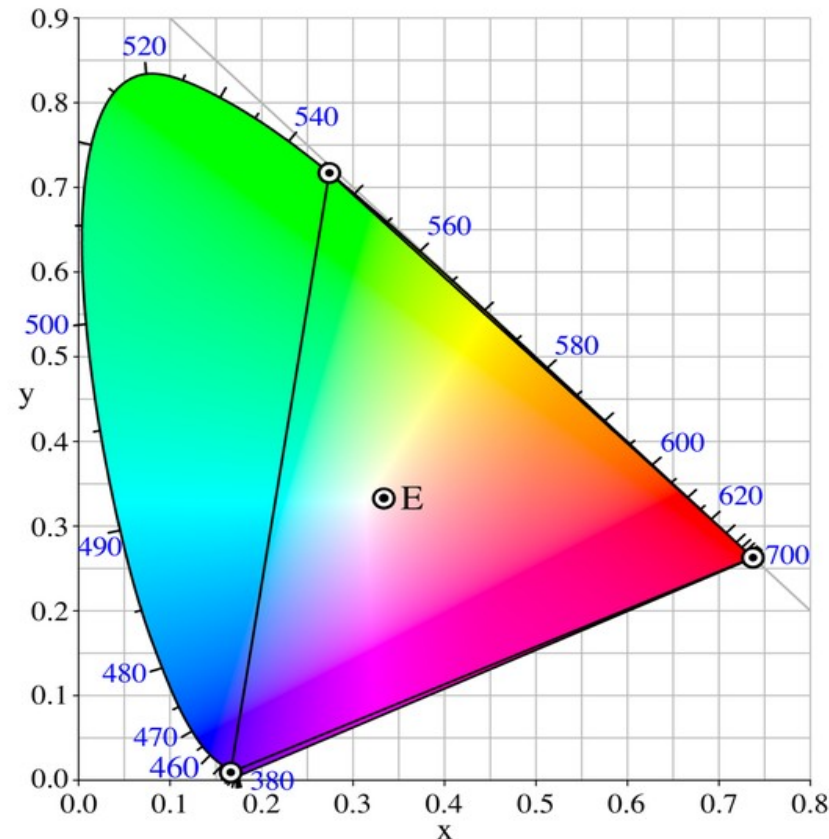


CIE 1931 chromaticity diagram showing the boundaries of the [00], [01], [10] triangle in xy space. Data from Wyszecki, Günter and Stiles, Walter Stanley (2000). Color Science: Concepts and Methods, Quantitative Data and Formulae, 2E, Wiley-Interscience.

- The CIE chromaticity diagram is useful for:
 - evaluating primaries;
 - determining complementary colours;
 - and working out the purity and dominant wavelength of a colour.

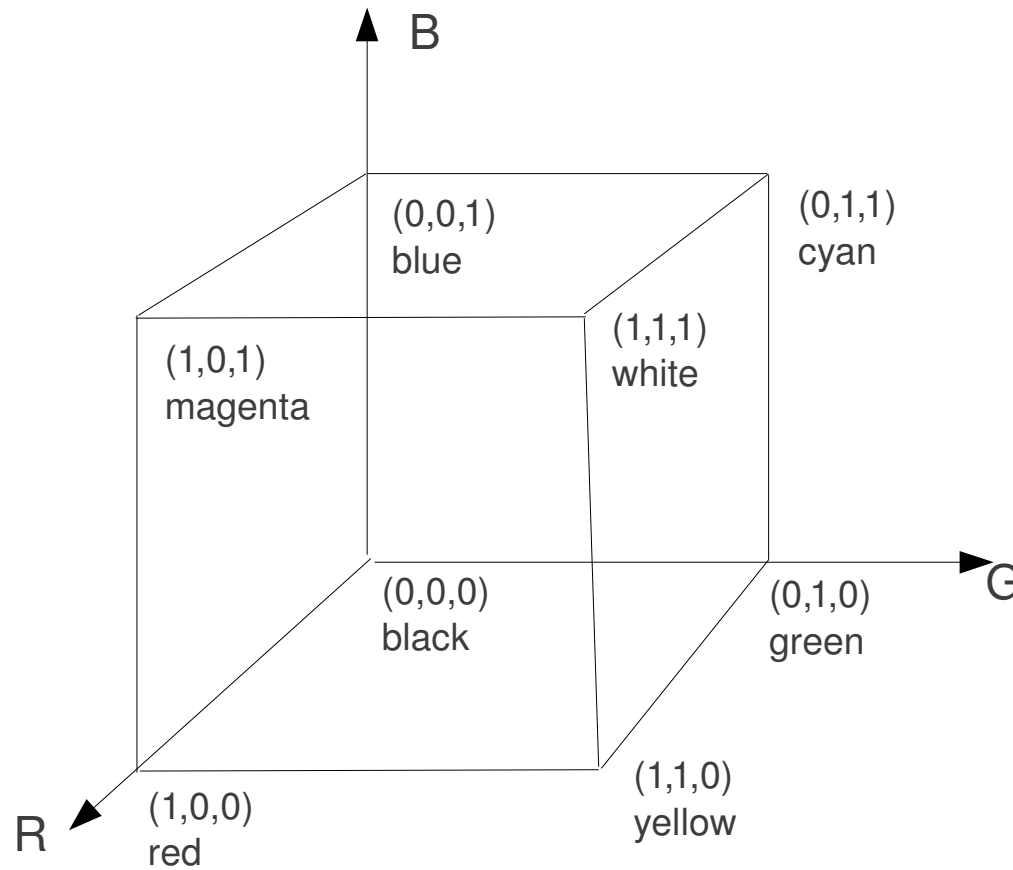


CIE XYZ Colour Model matching function.



From Wikipedia page CIE Color space image in public domain.

- The RGB model of colour can be represented by the unit cube. The dimensions are red, green, and blue.



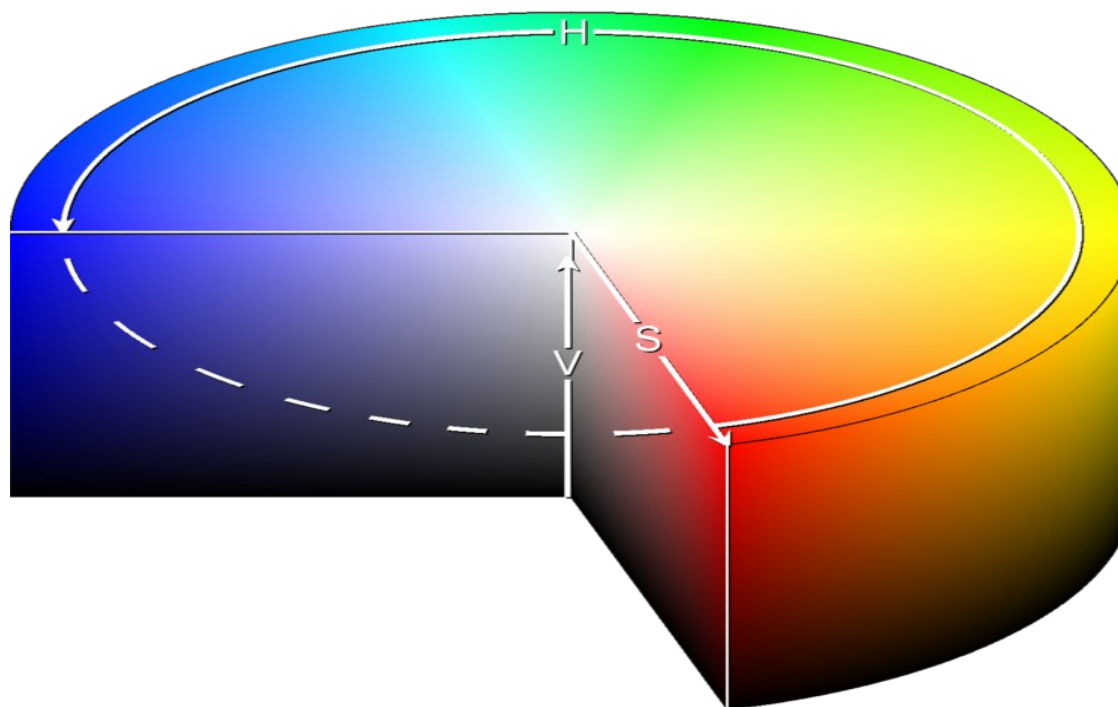
- The YUV colour model describes colours in terms of their luma (the Y part) and its chrominance(the UV part).
- Such a system is often used in an image pipeline as our sensitivity changes in brightness is more important than changes in chrominance. So formats can give more 'bits' for the Y part than the UV part.
- This type of format in is also used in PAL and NTSC(colour and black and white TVs can work from the same signal!).

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- Colour we see reflected off printed material is a subtractive process (unlike colour from a computer screen which is an additive process).
- The CMY Colour space enables us to deal with colours when using printers and the like.
- The primary colours in this case are: magenta, cyan, and yellow.
- There is a simple mapping between RGB and CMY colour spaces:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- The HSV Colour Model provides a more intuitive model for someone selecting colours in a computer application.
- The model is made up of: the H - hue, the S – saturation, and the V – value.



HSV cylinder by (3ucky(3all at en.wikipedia available under Creative Commons Attribution-ShareAlike 3.0