EBU5303

Multimedia Fundamentals

Colours

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Learning Objectives

- Relate colour properties with light.

- Compare colour models.

- Use the RGB model to encode a colour.

- Use the HSV model to describe a colour.

Reading

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

2.6 Color

Fundamentals of Multimedia, by Ze-Nian Li, Mark S. Drew, Jiangchuan Liu (3rd edition)

Chapter 4: Color in Image and Video

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
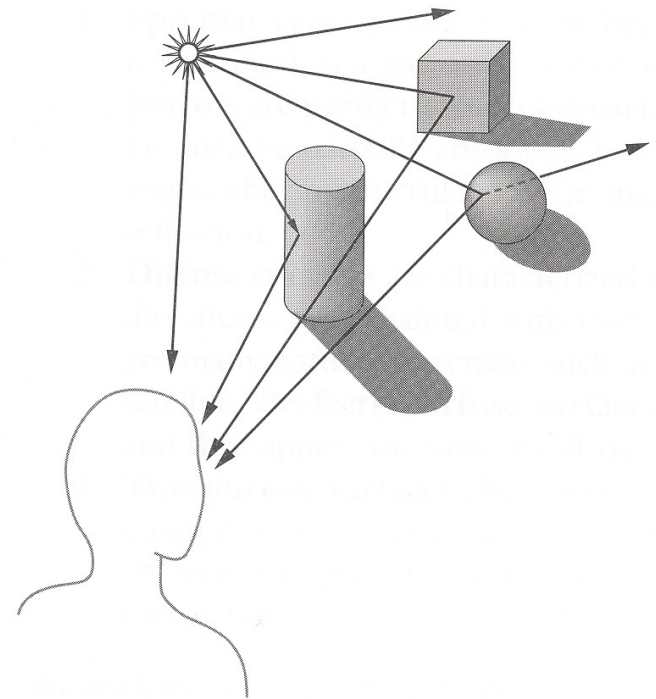- HSV is an intuitive colour model

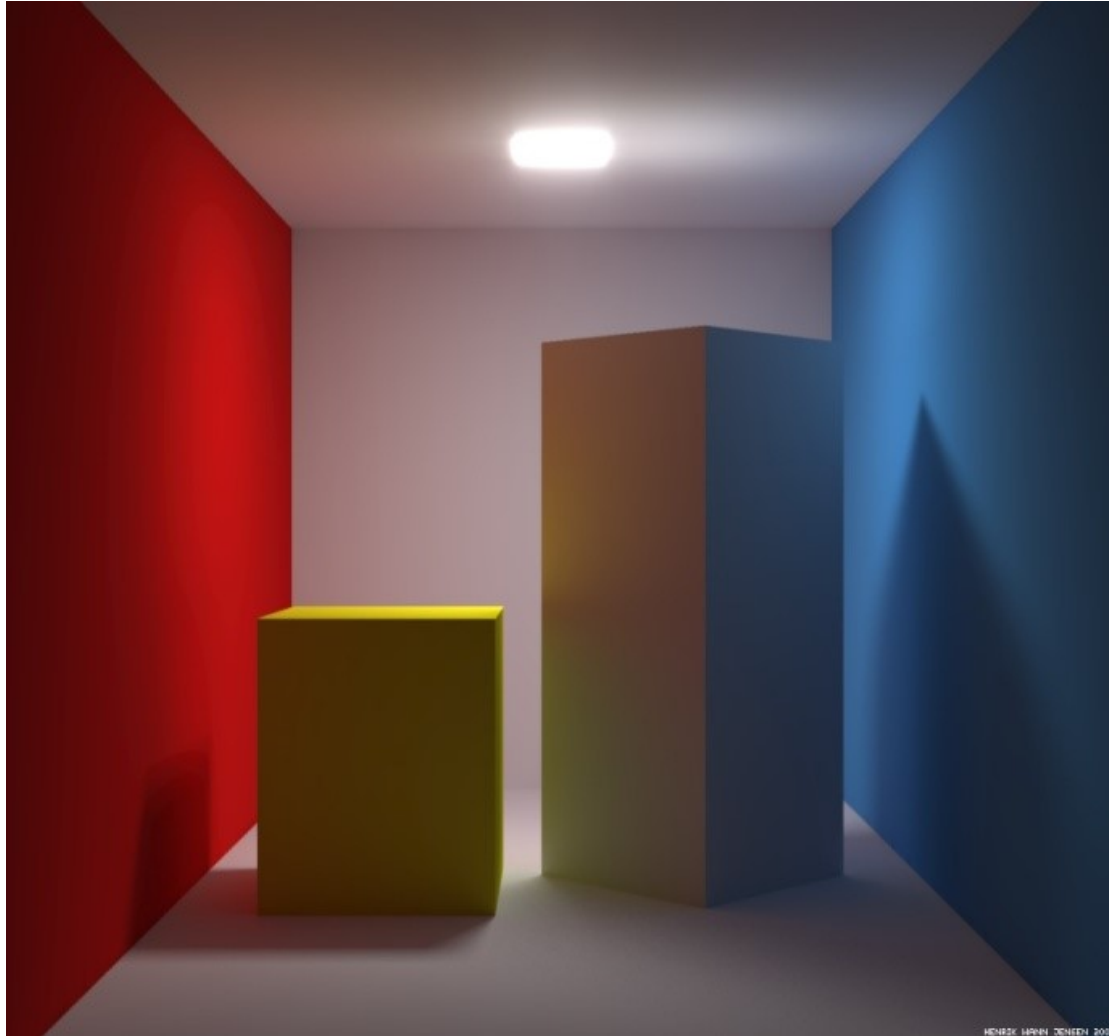# Light
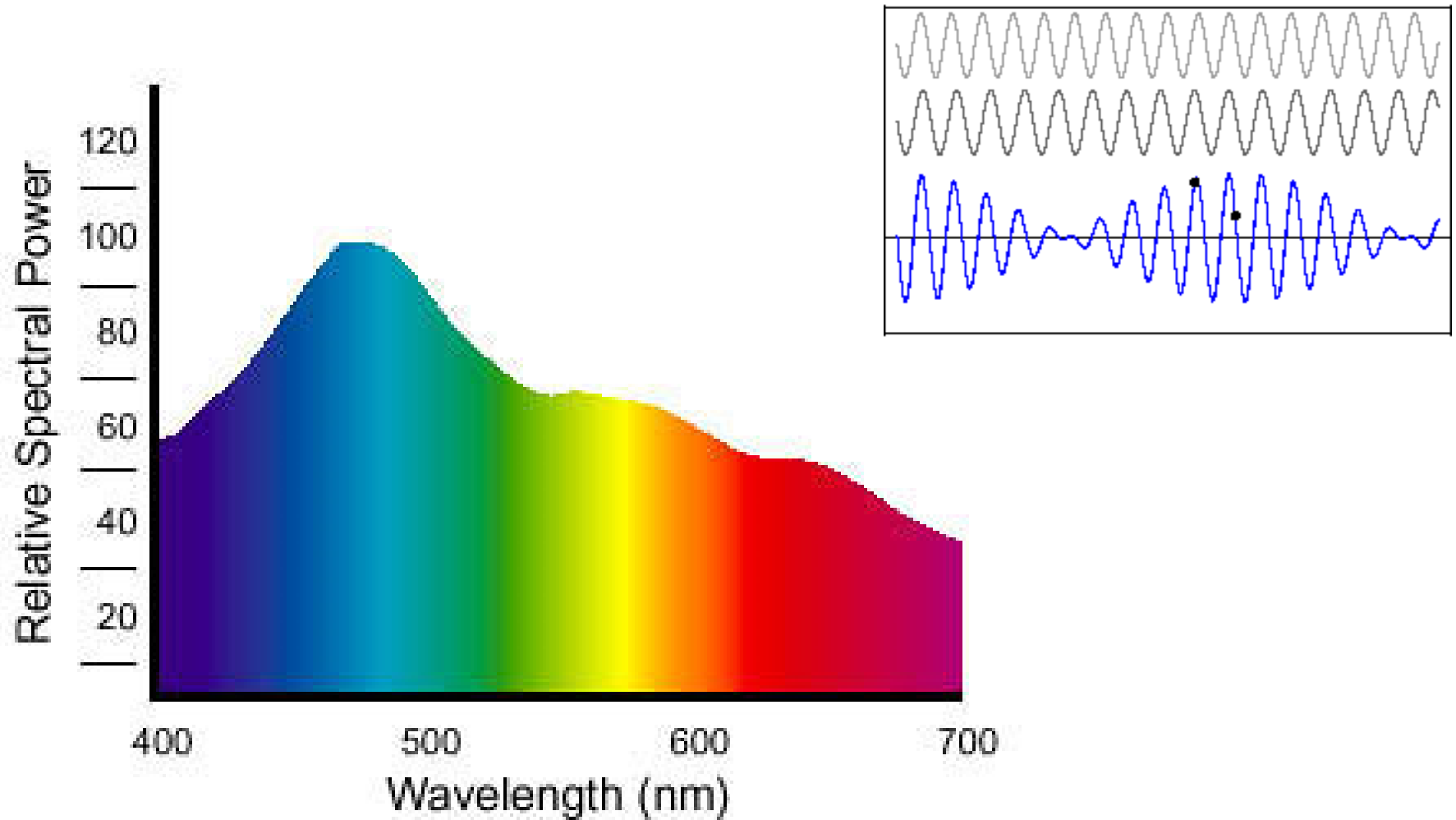
Properties of Colours

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.

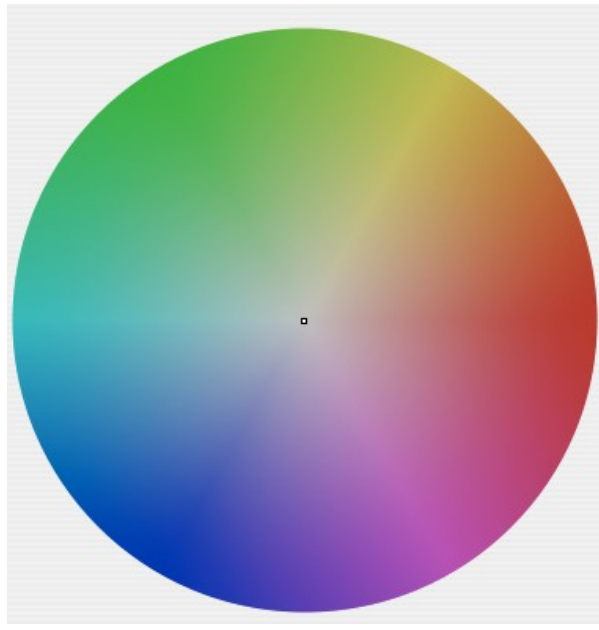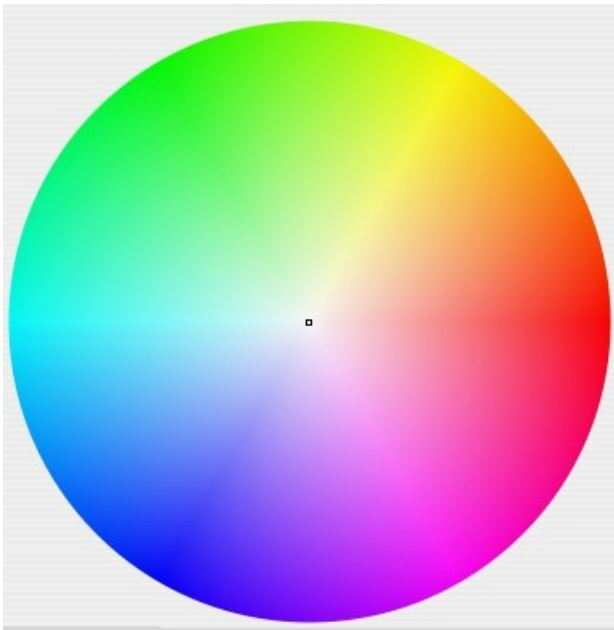Objects reflect what we perceive, and absorb what we don't see.
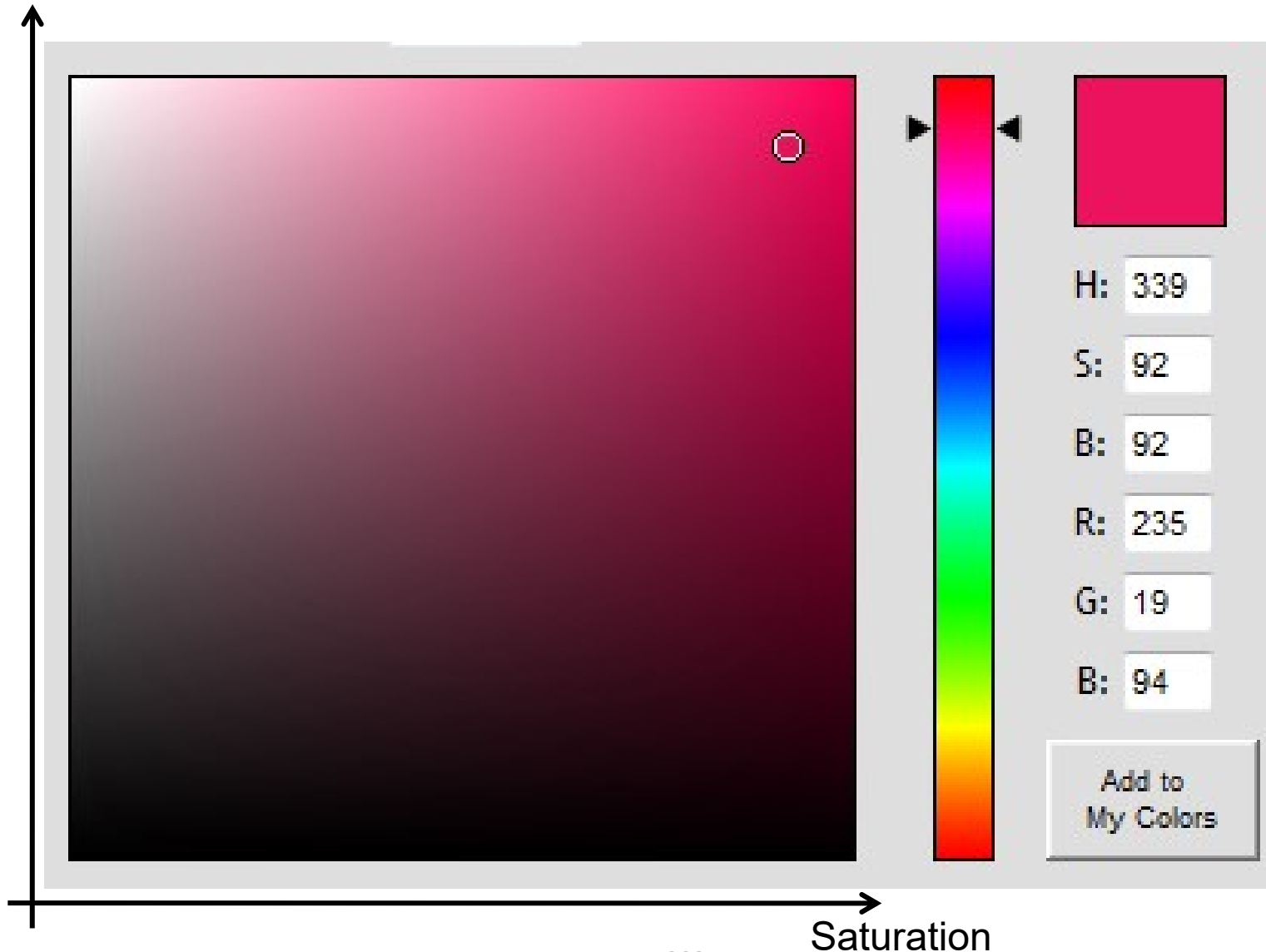
Properties of Colours

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.

Properties of Colours

Brightness

Saturation

H: 339
S: 92
B: 92
R: 235
G: 19
B: 94

Add to
My Colors

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.
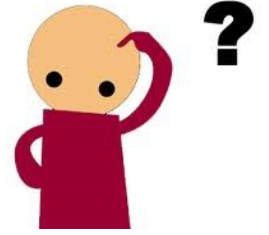
Interestingly, lights of equal power but different wavelengths do not appear equally bright.

Perception: relative intensity

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

Perception (luminance)
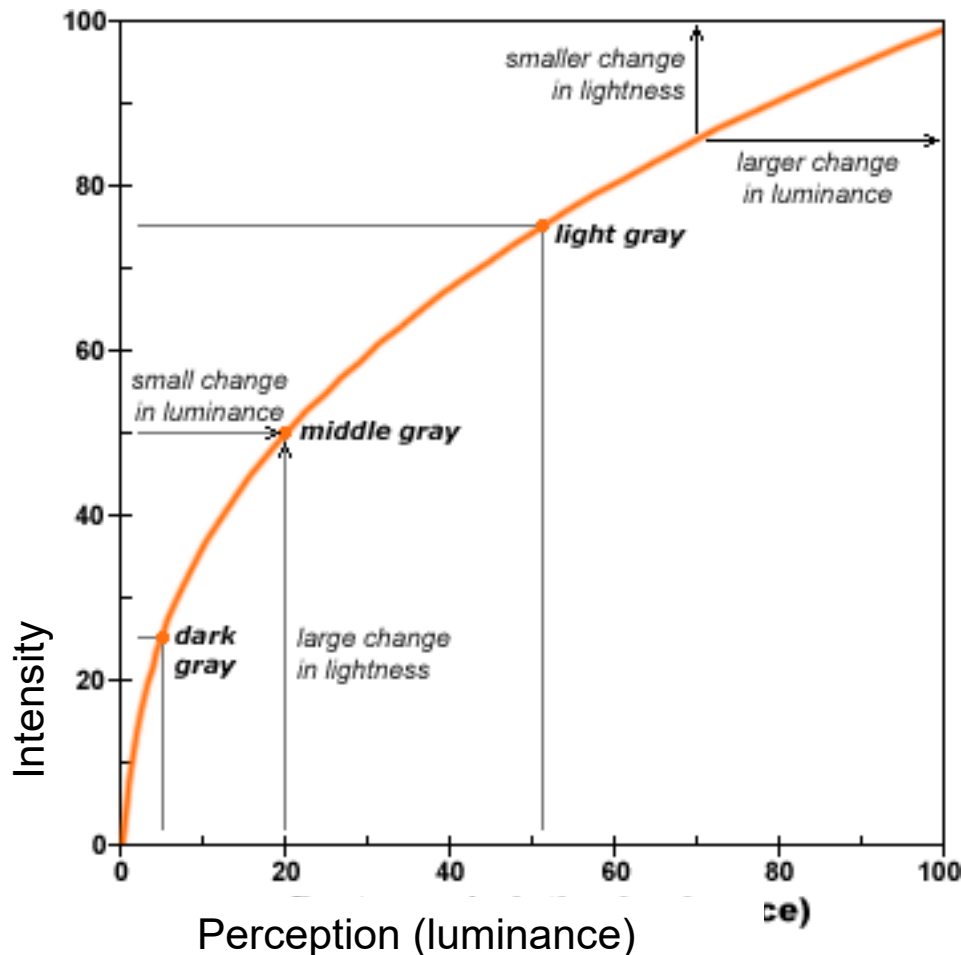
Questions…

- What the hue of a colour?

- What is saturation?

- What is the brightness of a colour?

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
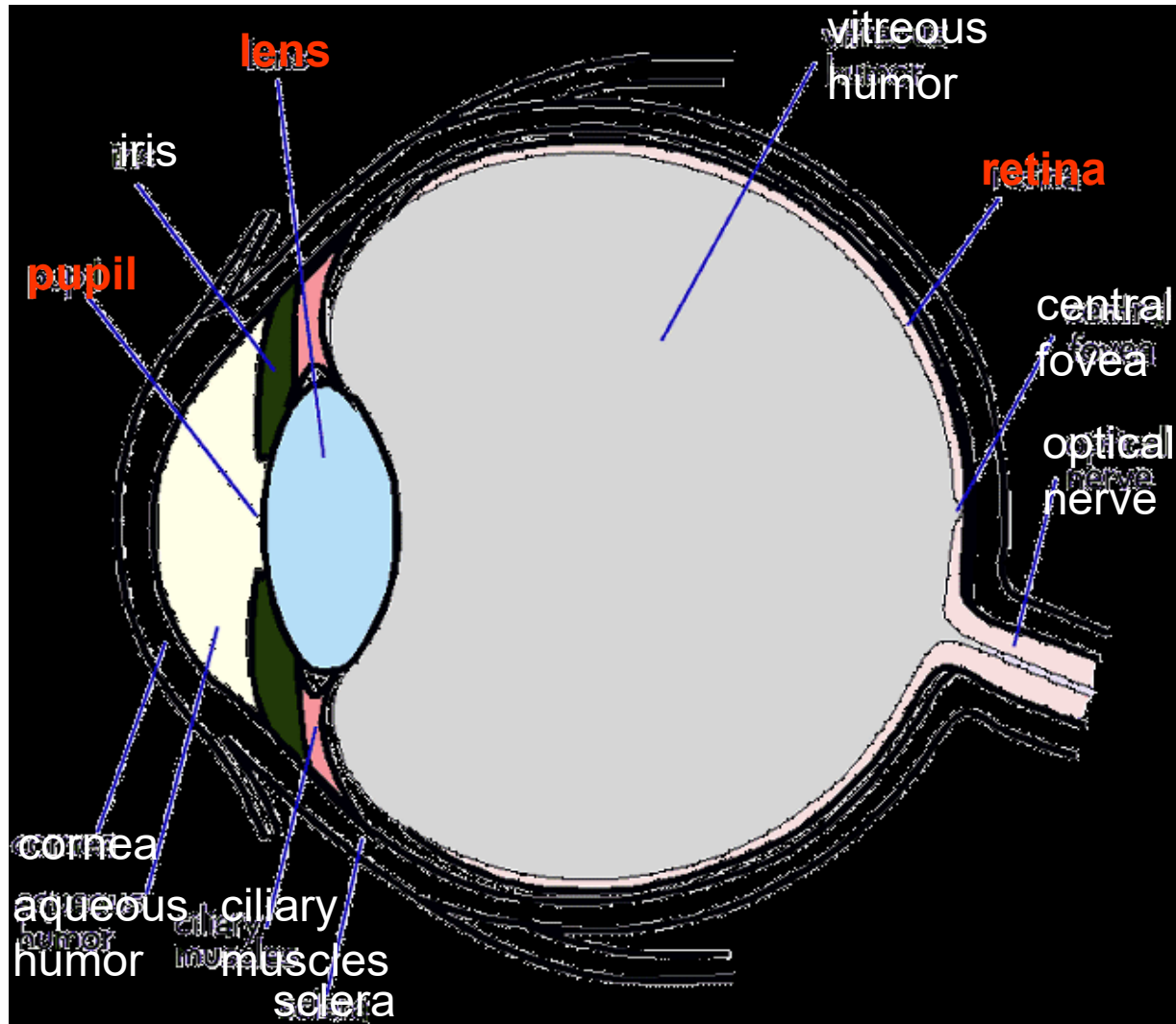
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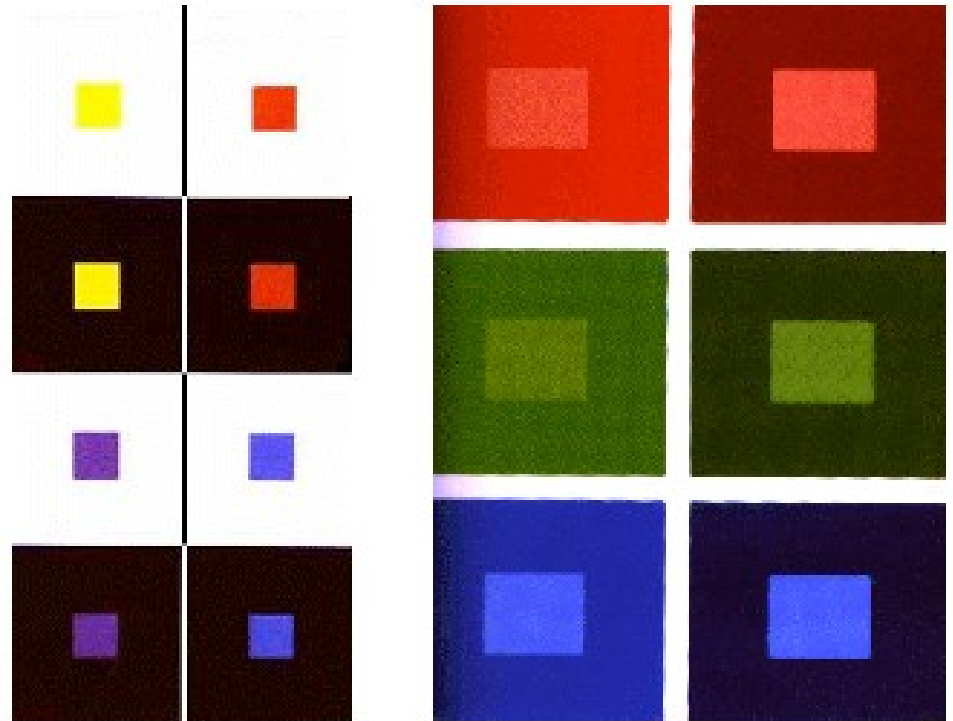- HSV is an intuitive colour model

Colour vision
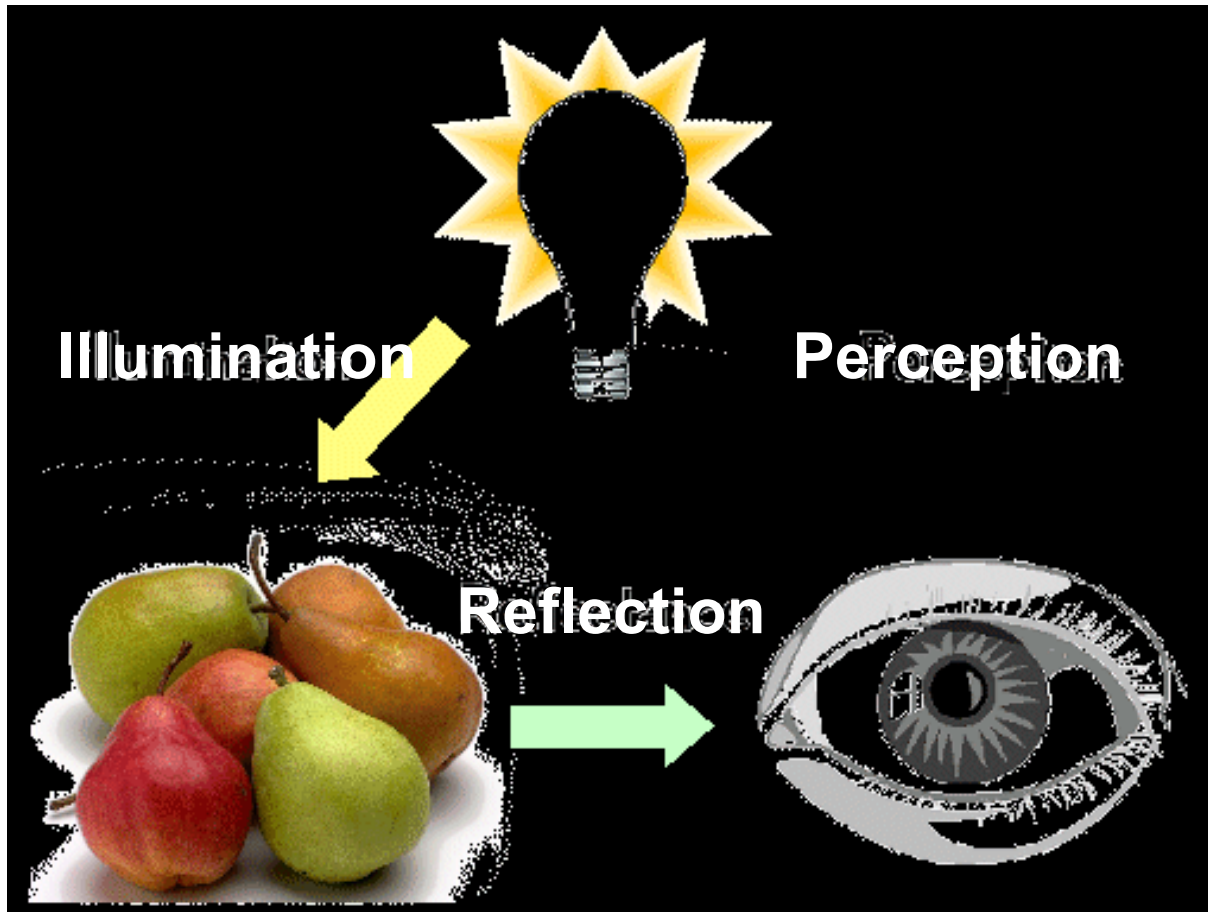
Colour vision

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).

Colour perception is subjective

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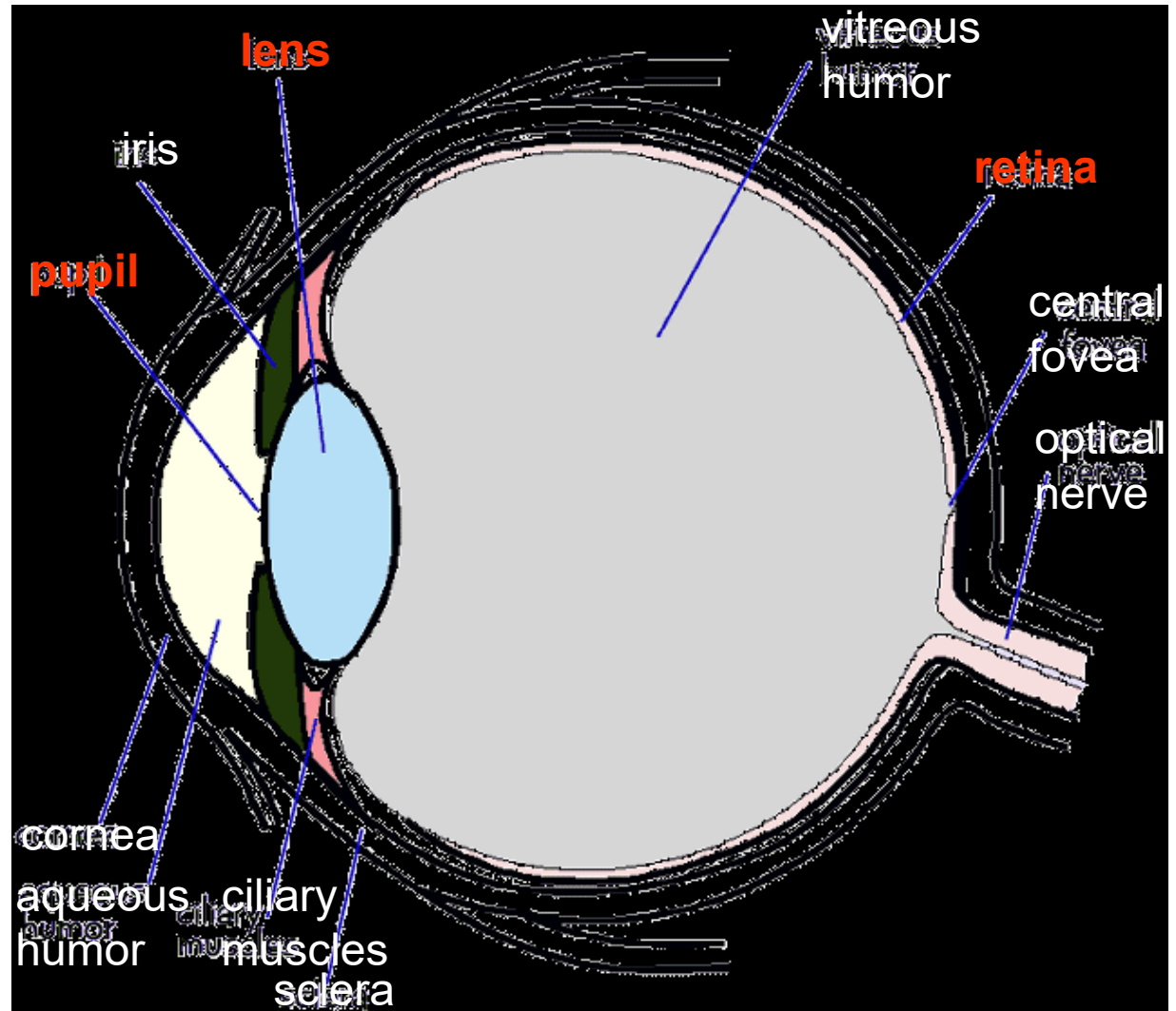by previous
experience
and functioning of
The brain.

The Stroop Effect

Orange Blue Yellow Purple Red Blue RED GREEN Blue Brown Yellow Orange Purple GREEN Red Green Pink Orange Brown Red Brown Green Yellow Purple Green Blue

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!

vitreous humor

lens

iris

retina

pupil

central fovea

optical nerve

cornea

aqueous humor

ciliary muscles

sclera

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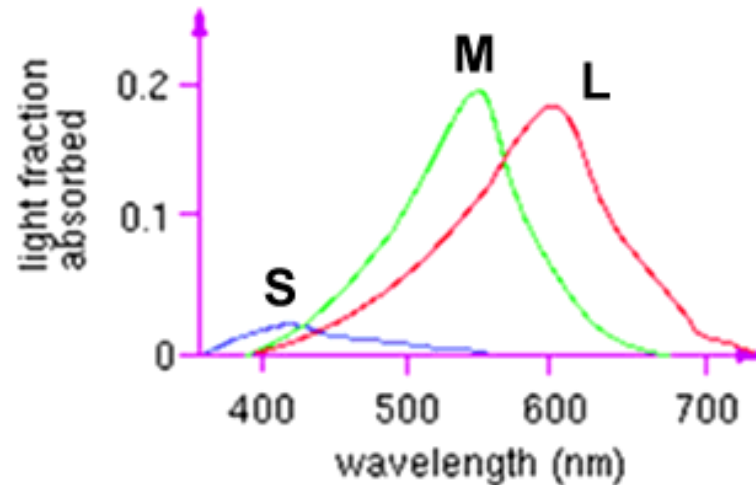
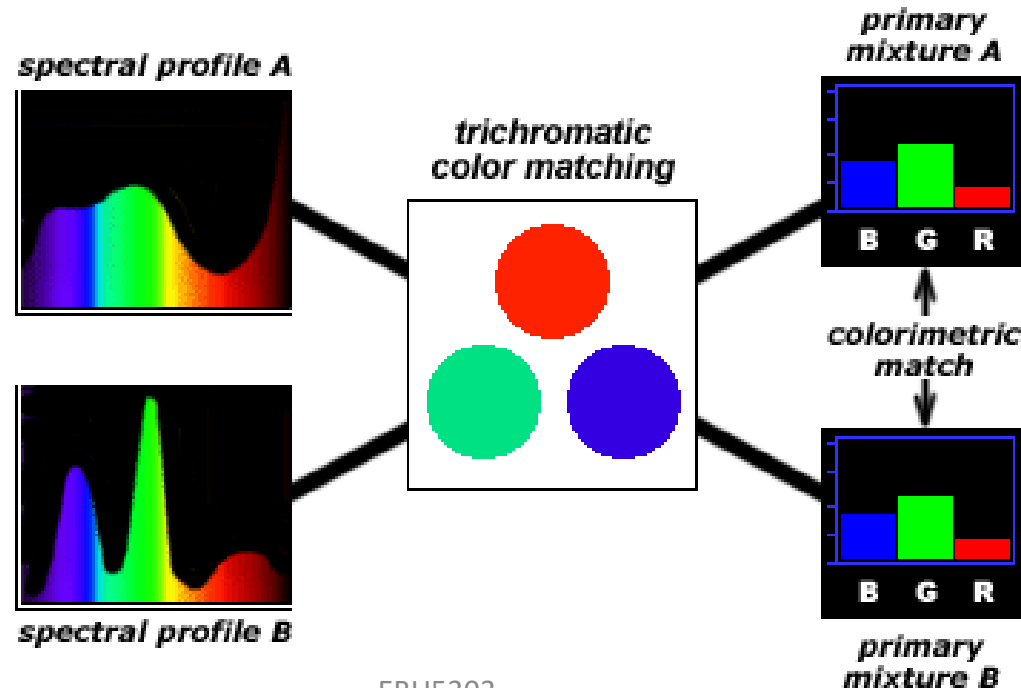
  - Colour blindness results from missing cone type(s)

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).

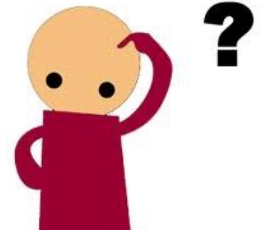- Therefore any sensation of colour can be produced by mixing together suitable amounts of these colours.
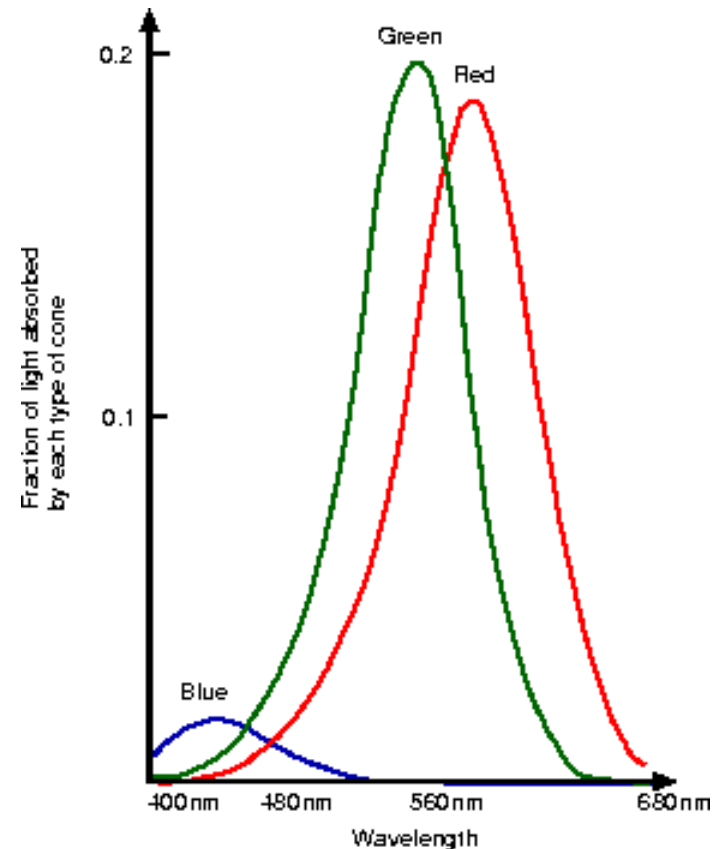
Metamers

- 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.

spectral profile A

spectral profile B

trichromatic color matching

primary mixture A

colorimetric match

primary mixture B

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Questions…

- What is the role of the cone cells in vision?

- What is the tristimulus theory about?

- What are metamers?

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

Agenda

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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.

Colour models

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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.
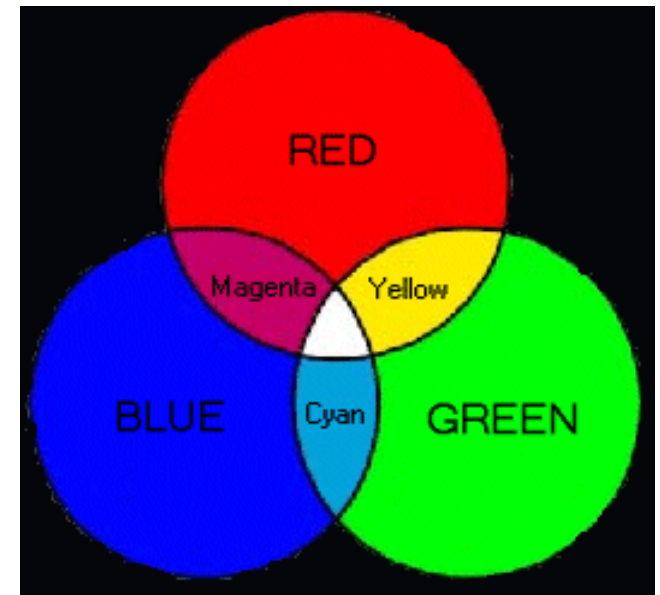
Additive Primary Colours

Using the RGB Scheme in Computers
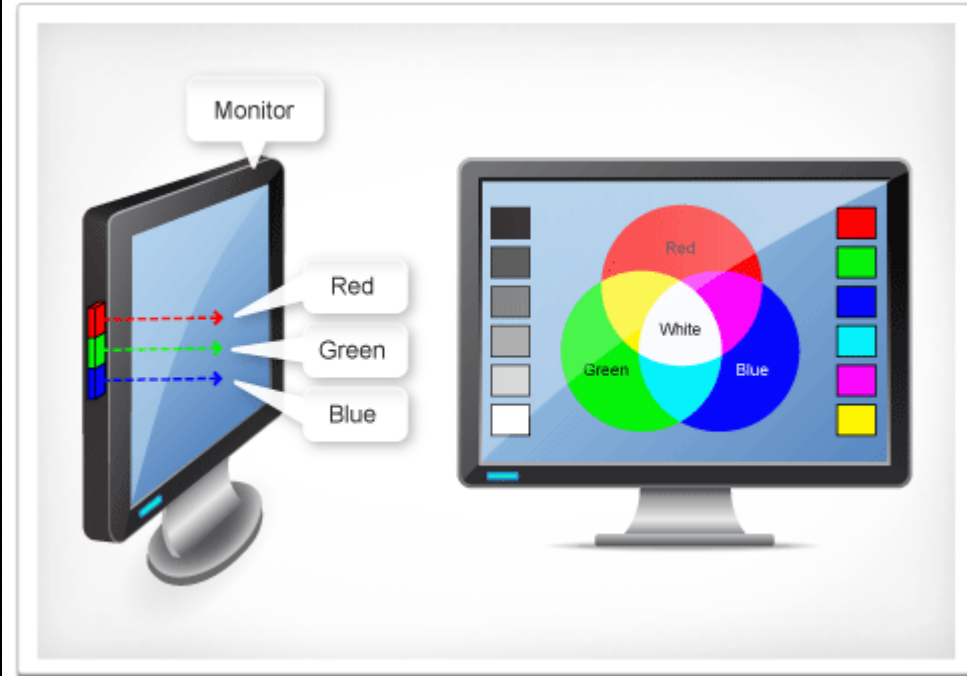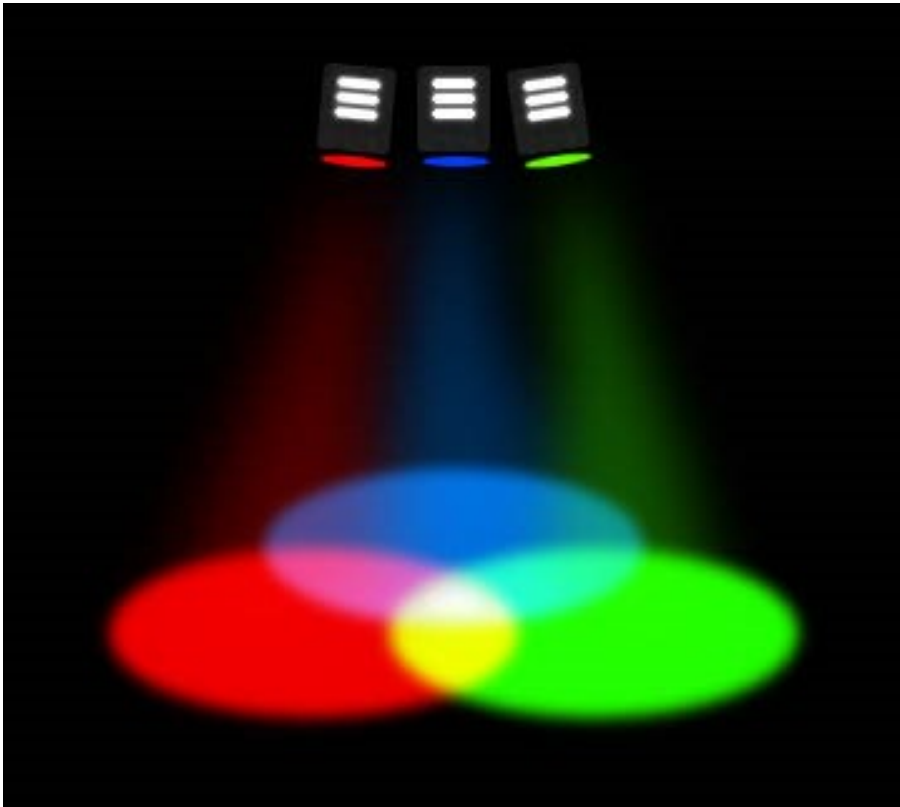
Questions ...
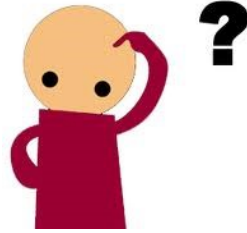
- What colours correspond to the eight corners of this cube?

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

(255, 255, 255)

(0,0,0)

G

R

B

RED

Magenta   Yellow

BLUE   Cyan   GREEN
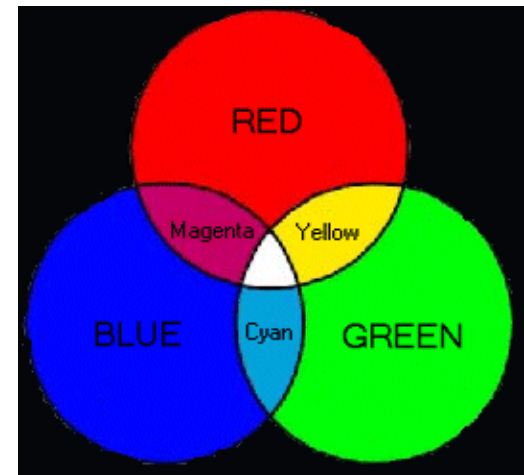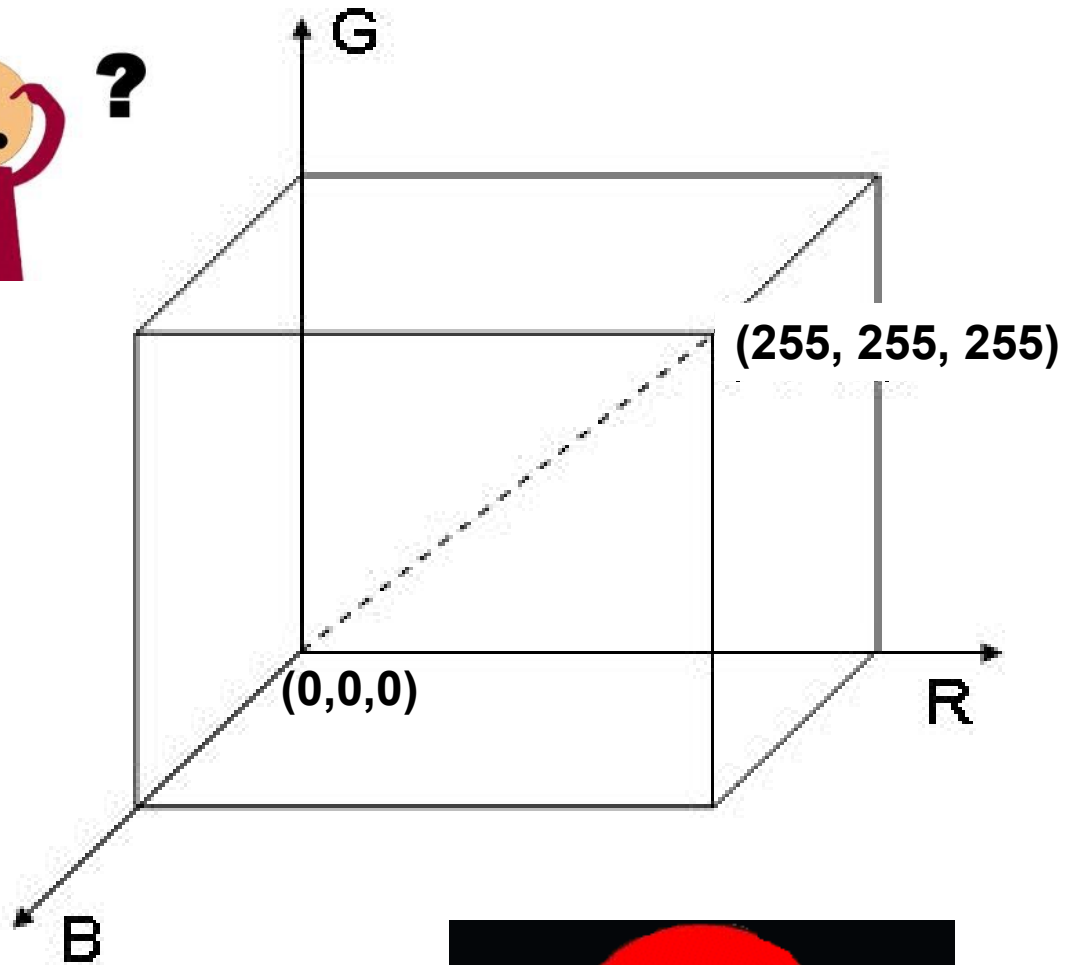
From R,G,B to Grayscale

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

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

Questions…
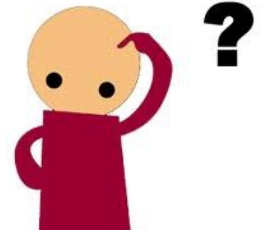
- Why is RGB said to be an additive colour model?

- How is the grayscale represented in the RGB model?

Exercises

- What (R,G,B) values would you use to encode a dark grey colour?

- What (R,G,B) values would you use to encode an unsaturated bright blue colour?

- How do you recognise a fully saturated colour in the RGB model?

Colour Converter
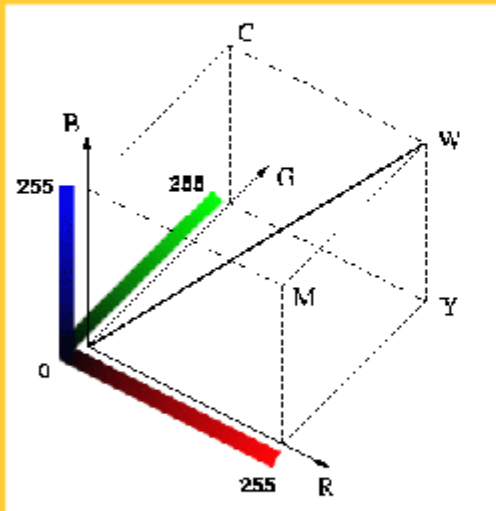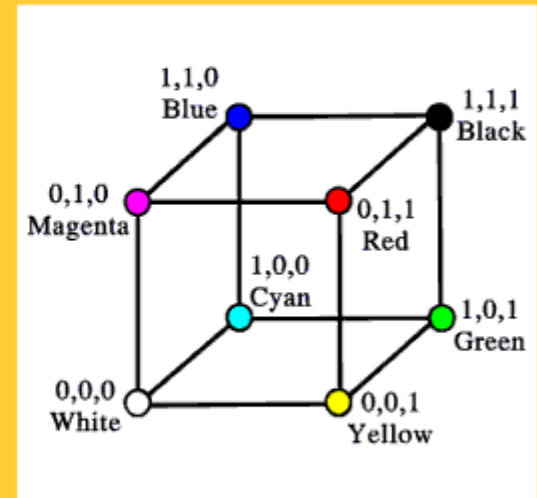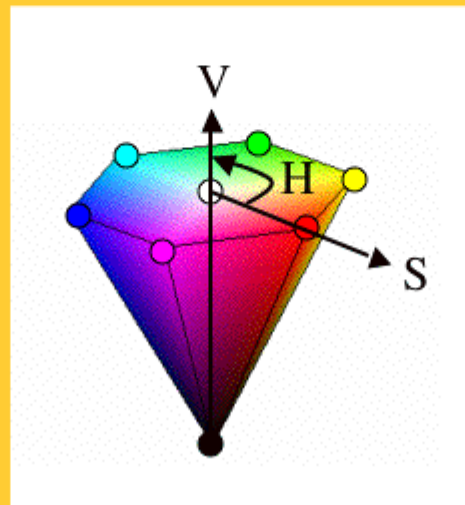
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YUV

- 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

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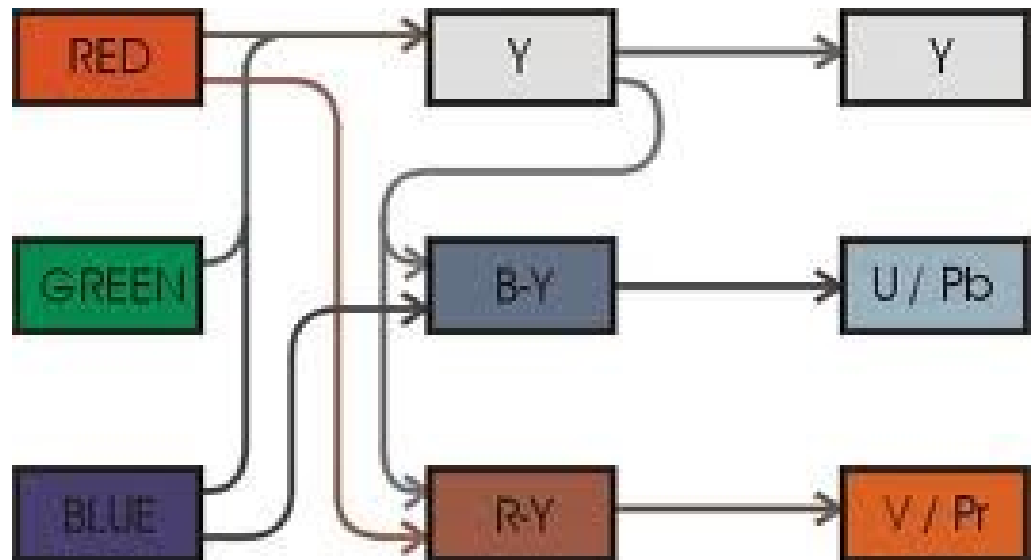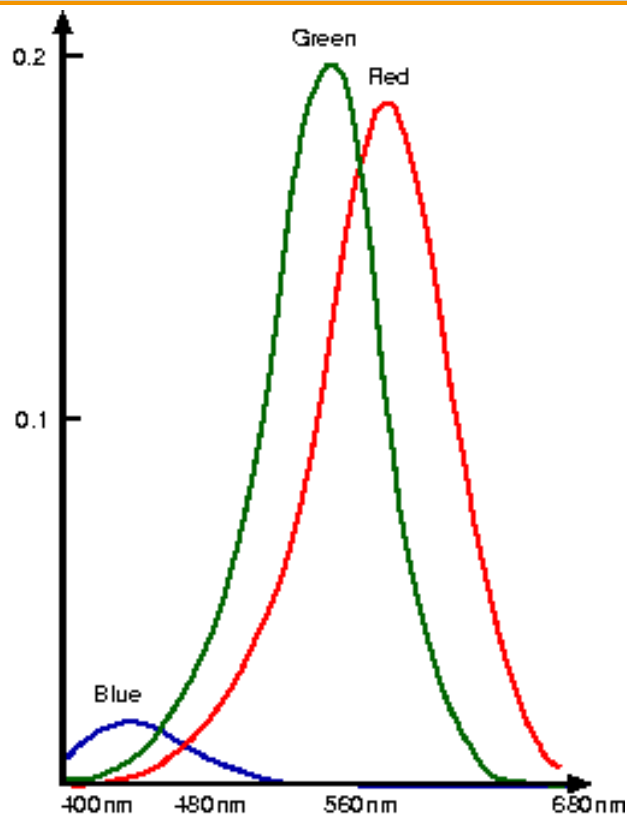
RGB / YUV
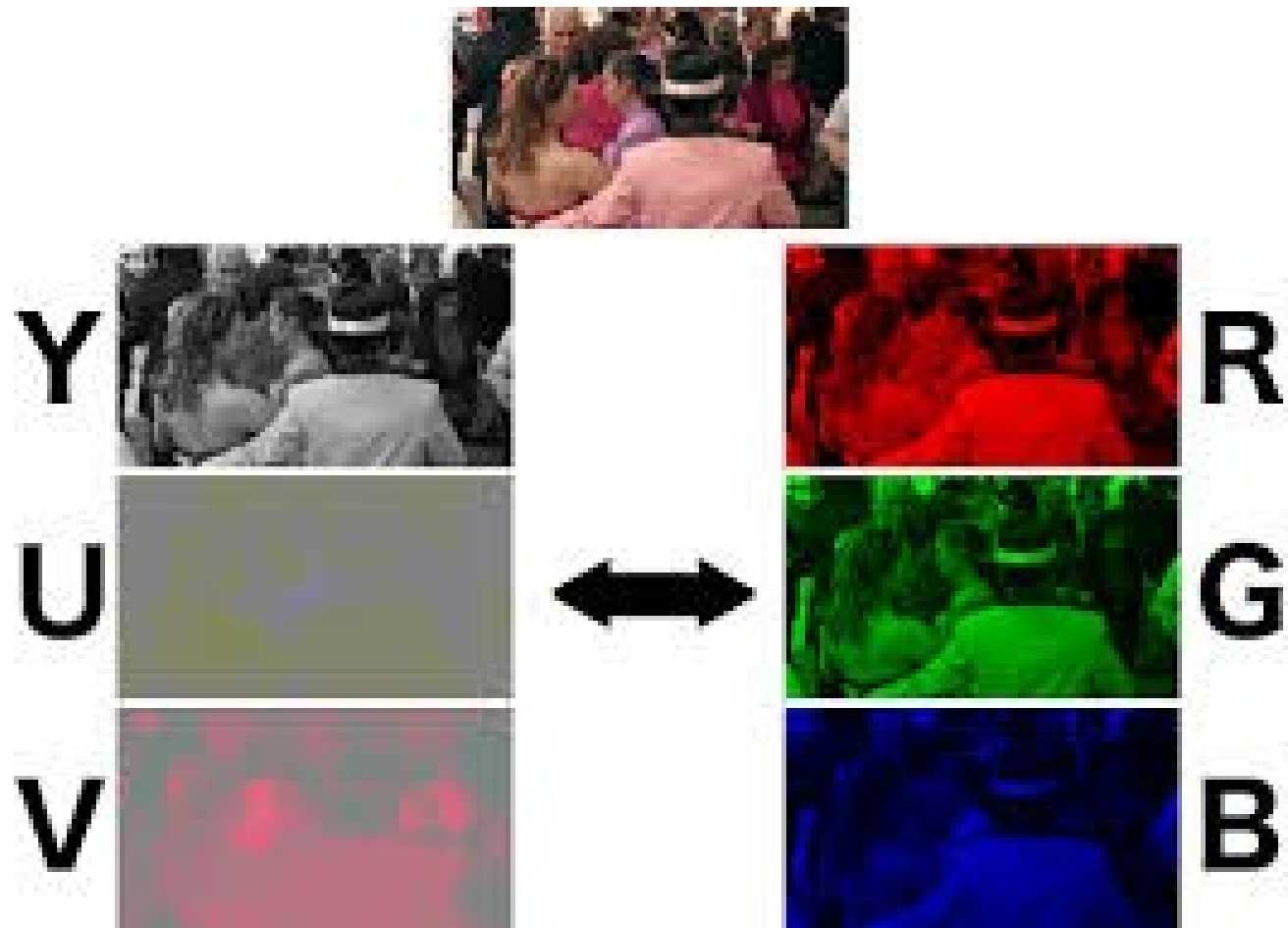
RGB to YCbCr

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

YCbCr to RGB

$$R = Y + 1.402 \cdot (C_R - 128)$$
$$G = Y - 0.34414 \cdot (C_B - 128) - 0.71414 \cdot (C_R - 128)$$
$$B = Y + 1.772 \cdot (C_B - 128)$$

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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.
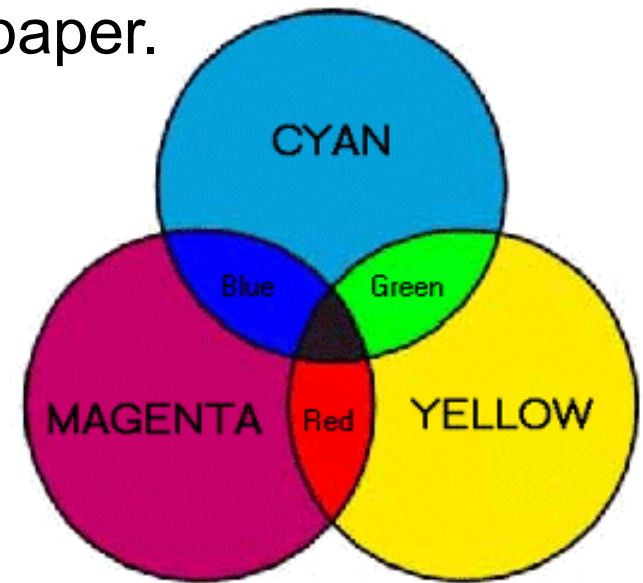
Subtractive Primary Colours

Questions…
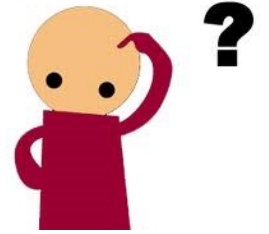
- Why is CMYK said to be a subtractive colour model?

- What is the difference between CMY and CMYK?

Exercises

- What (C,M,Y) values would you use to encode a fully saturated bright green colour?

- What (C,M,Y, K) values would you use to encode a fully saturated dark red colour?
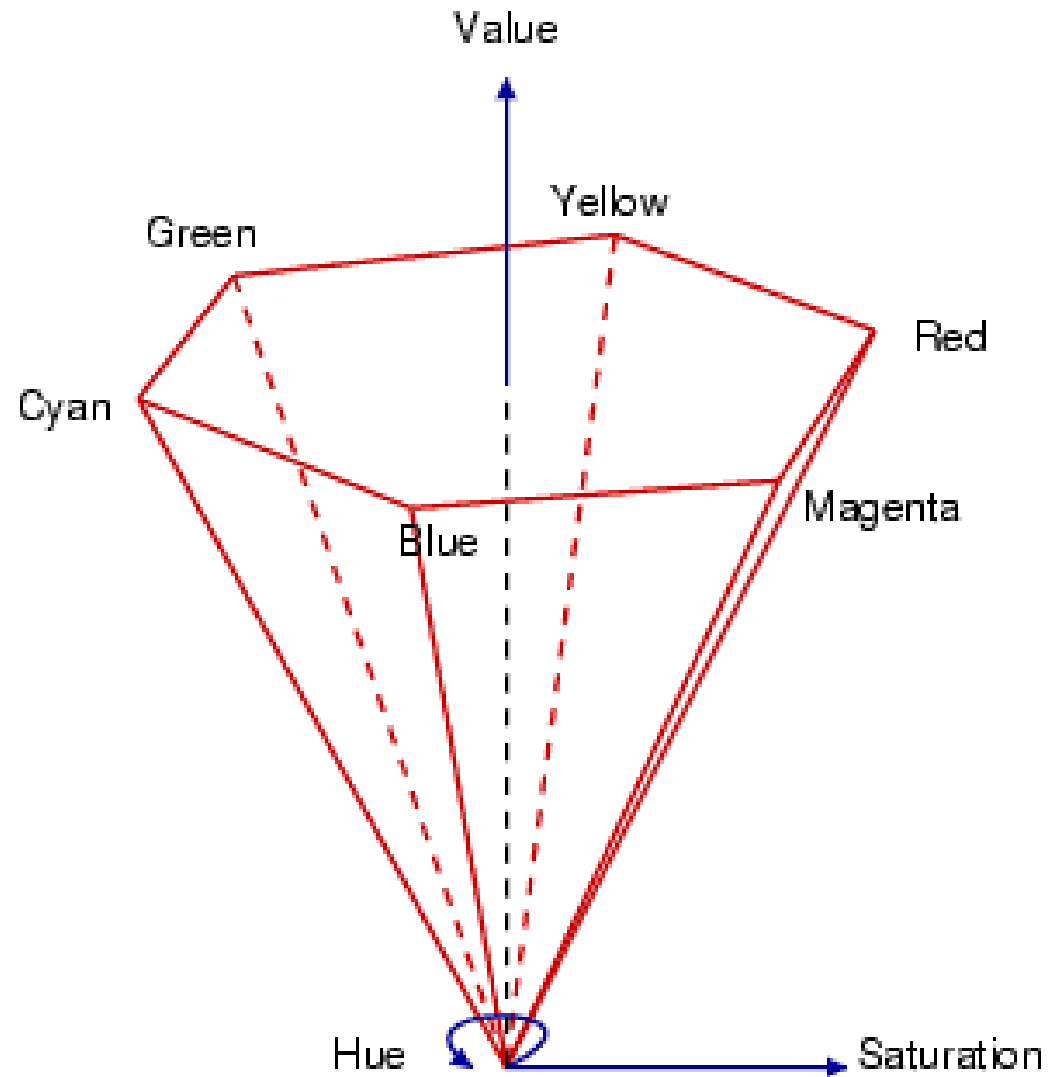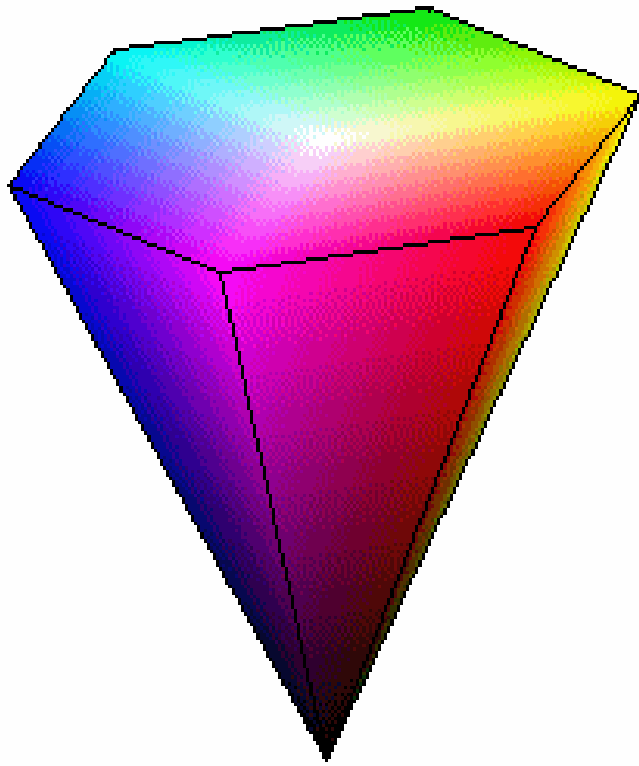
Colour Converter

Exercises

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?

- Cyan ink is spread onto a white sheet of paper. What colour will you see if the paper is illuminated with a magenta light?

- Yellow ink is spread onto a white sheet of paper. What colour will you see if the paper is illuminated with a blue light?
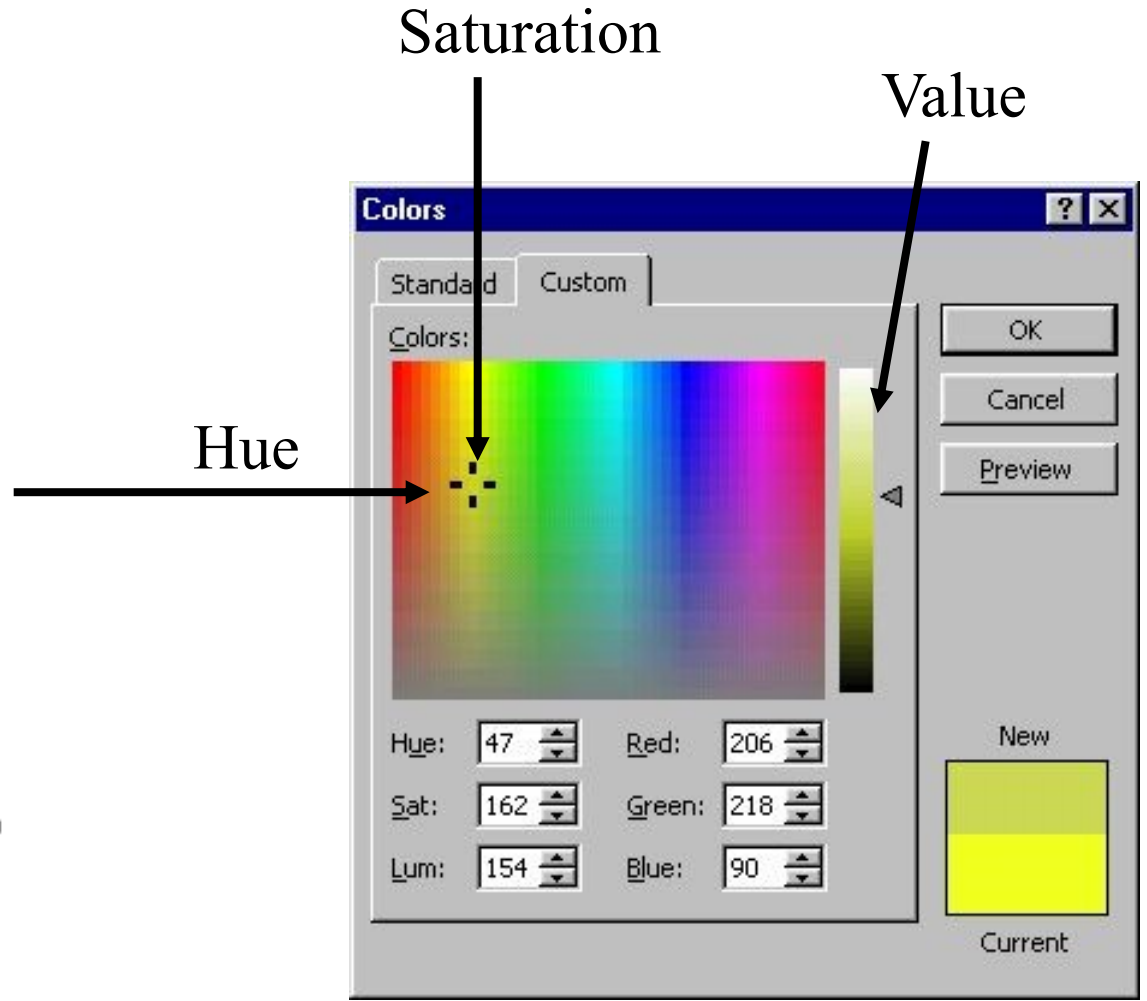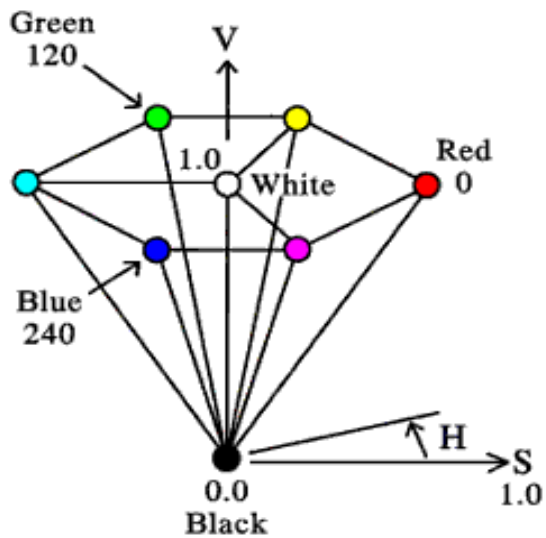
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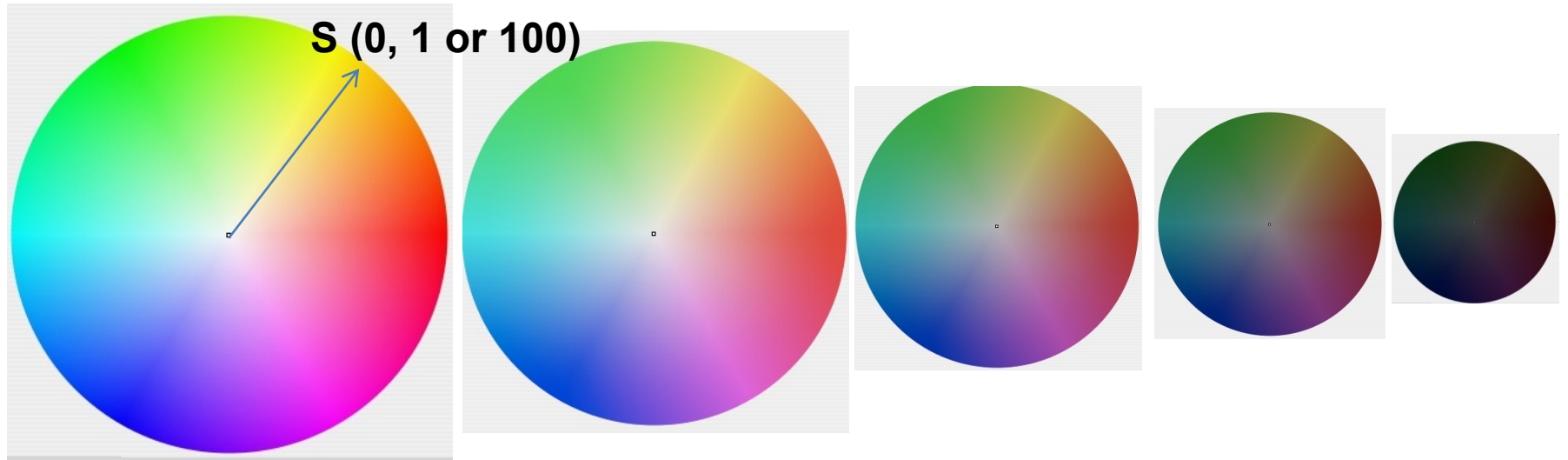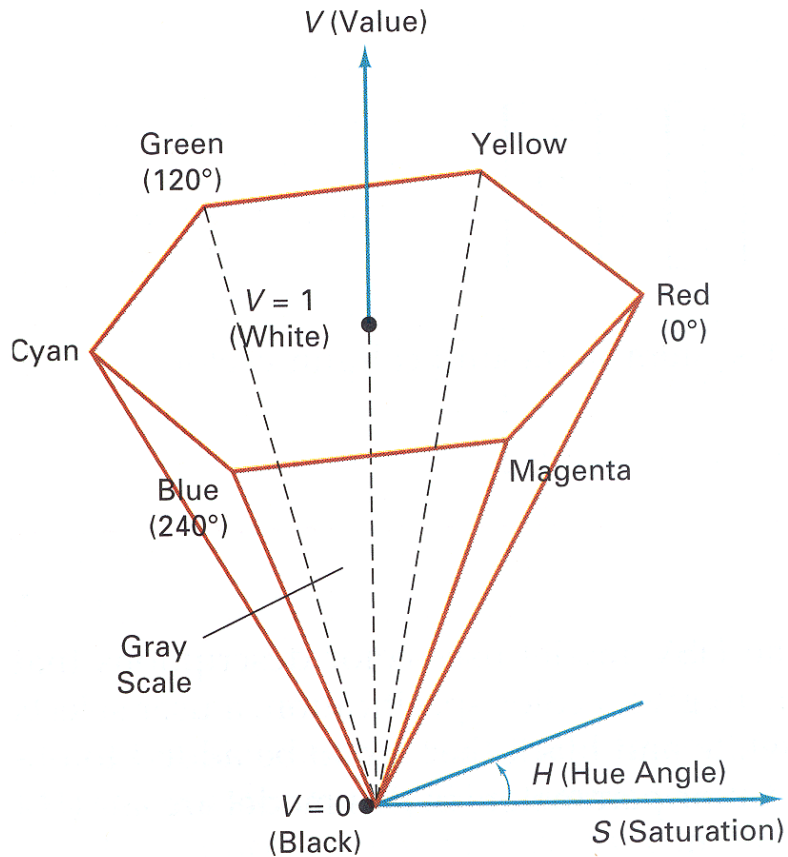- CMYK is used for printing
- HSV is an intuitive colour model

HSV

HSV

HSV

S (0, 1 or 100)

V (0, 1 or 100)

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	(yellow)
270	0.5	1.0	(purple)
270	0.0	0.7	(gray)

Questions…
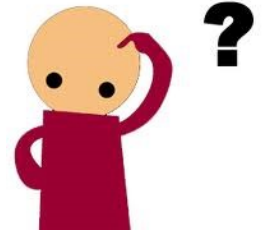
- In the HSV model, how is the hue represented?

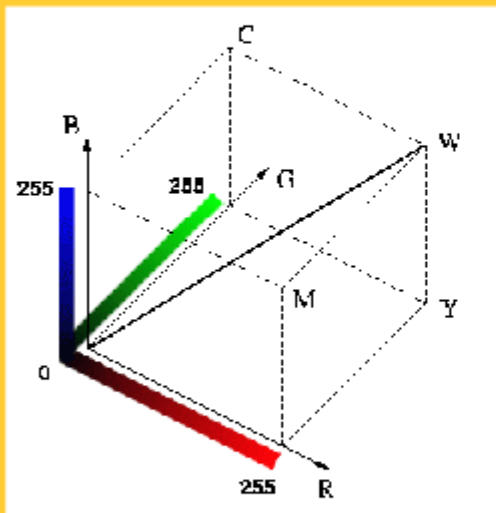- In the HSV model, how are S (Saturation) and V (Value) represented?

Exercises

- What (H,S,V) values would you use to encode a bright grey colour?

- What (H, S, V) values would you use to encode an unsaturated dark red colour?

- What (H, S, V) values would you use to encode a bright orange colour?
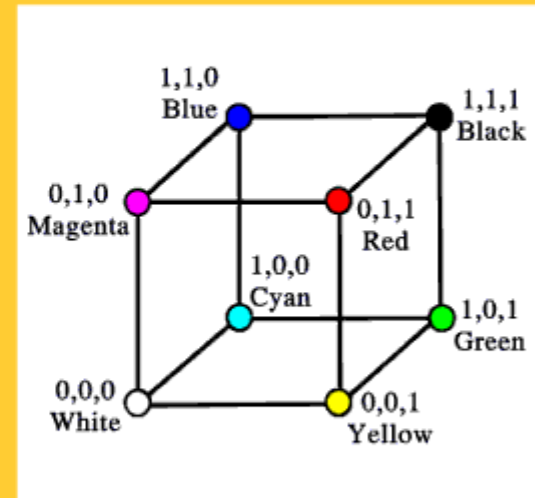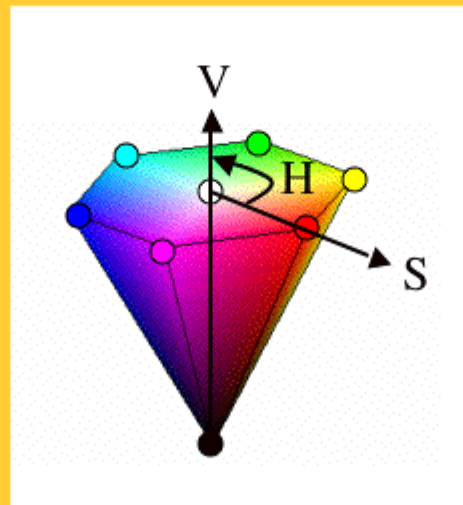
Colour Converter

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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Check out other colour models:

CIE XYZ, CIELAB, etc.

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

2.6 Color