

Image Processing

Topic 1: Digital Images

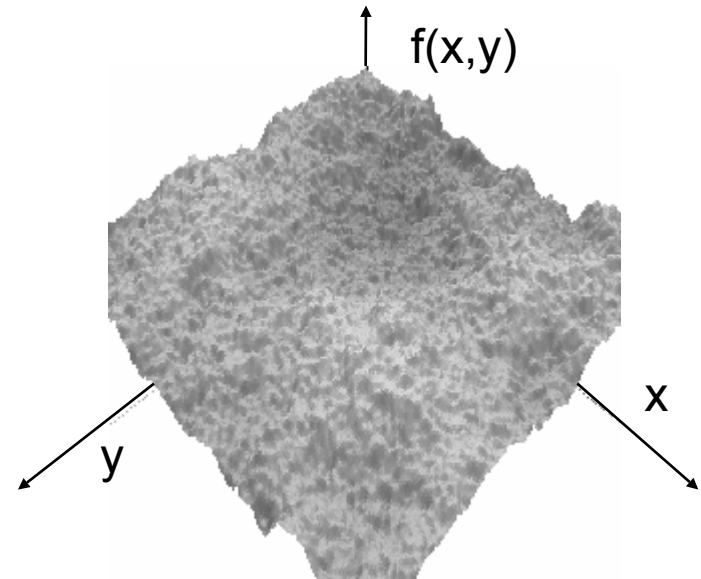
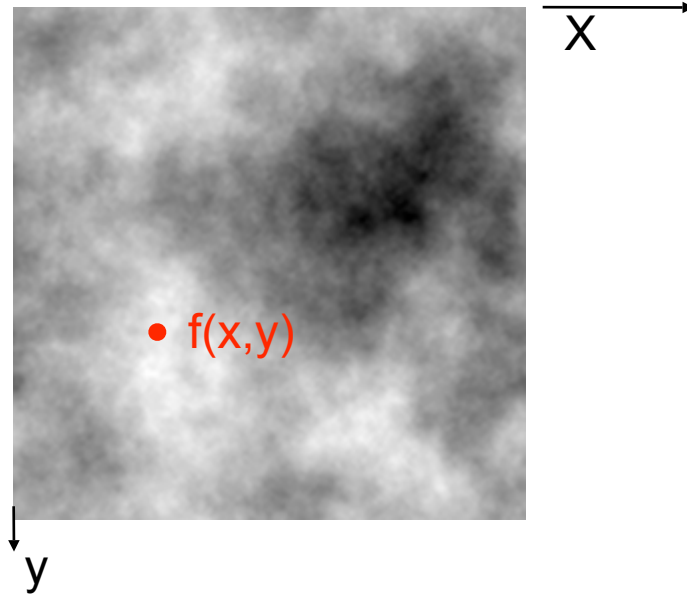
Digital Images

Monochrome Image = 2 dimensional light intensity function $f(x,y)$

where

(x,y) = spatial coordinates

$f(x,y)$ = grey level or brightness at point (x,y)



Discretisation

- Digital Images can be discretised in spatial coordinates and brightness
- **IMAGE SAMPLING** = digitisation of spatial coordinates (x,y)
- **GREY LEVEL QUANTISATION** = amplitude digitisation

Images = Matrix

- Consider image as a matrix
- Row and column indices identify a point on the image
- Matrix element gives grey level at that point
- Matrix elements are often called
 - Image elements
 - Picture elements
 - Pixels
 - pels

- Suppose image has $M \times N$ samples:-

$$f = \begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,M-1) \\ f(1,0) & & & \\ \cdot & & & \\ f(N-1,0) & f(N-1,1) & & f(N-1,M-1) \end{bmatrix}$$

How large is an image?

- Commonly N and M are integer powers of 2

$$N=2^n \quad M=2^k$$

**ie. For 512x512 image = $2^9 \times 2^9$
n=9 k=9**

- The number of grey levels, G, depends on the number of bits m used to store the grey level values

$$G=2^m$$

256 grey levels => m = 8 bits

- Storage for a digital image = N x M x m

For a 512 x 512 image with 256 grey levels, the storage required is

$$**512 \times 512 \times 8 = 2,097,152 \text{ bits} = 262,144 \text{ bytes} = 262 \text{ KB}**$$

Reducing Number of Grey Levels



256 Grey Levels



128 Grey Levels



64 Grey Levels



32 Grey Levels



16 Grey Levels



8 Grey Levels

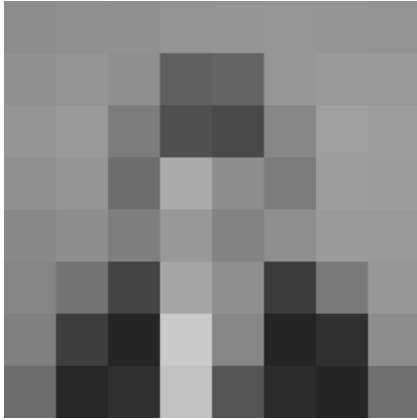


4 Grey Levels



2 Grey Levels

Reducing Spatial Resolution



N=8



N=16



N=32



N=64



N=128



N=256

Resolution

- Digital image is an approximation to a continuous image.
- How many samples and grey levels are required for a good approximation?
- Resolution (degree of discernable detail) depends on both
 - Number of samples
 - Number of grey levels
- Resolution increases as either of these values increases
- Required approximation depends on the application

Sampling



- Can introduce artefacts if not sampling at higher frequency than detail we wish to preserve
- Nyquist limits

Non Uniform Sampling

- If less detail is required, then one can lower the sampling rate
 - e.g., background of image
- Sampling can be increased in areas of interest or with more detail
 - e.g., the face



Colour

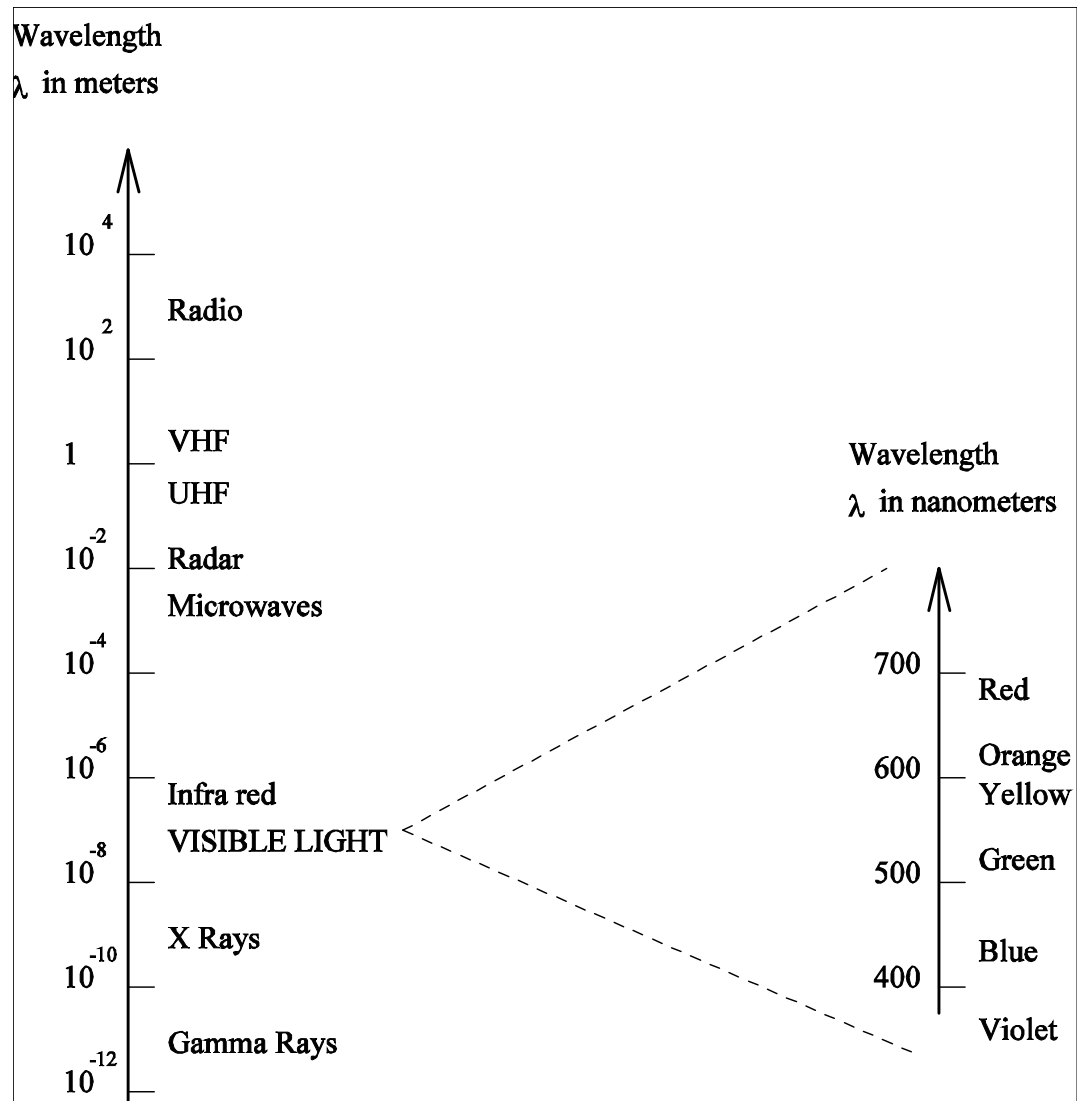
- A powerful descriptor that often simplifies object identification
- Human eye can distinguish thousands of colour shades and intensities, compared to only a couple of dozen shades of grey
- Full colour images
- Pseudo-colour images
 - A shade of colour is assigned to a particular monochrome intensity or range of intensities.

Light

- All objects are primary or secondary light sources
- Primary sources – emit light
 - Light bulb, sun
- Secondary sources – reflect or diffuse light
 - Ball, table, chair
 - A red ball appears red because it reflects only light with a red wavelength
- Light is part of electromagnetic spectrum

Electromagnetic Spectrum

- All visible light is in wavelength region from 350nm to 750nm

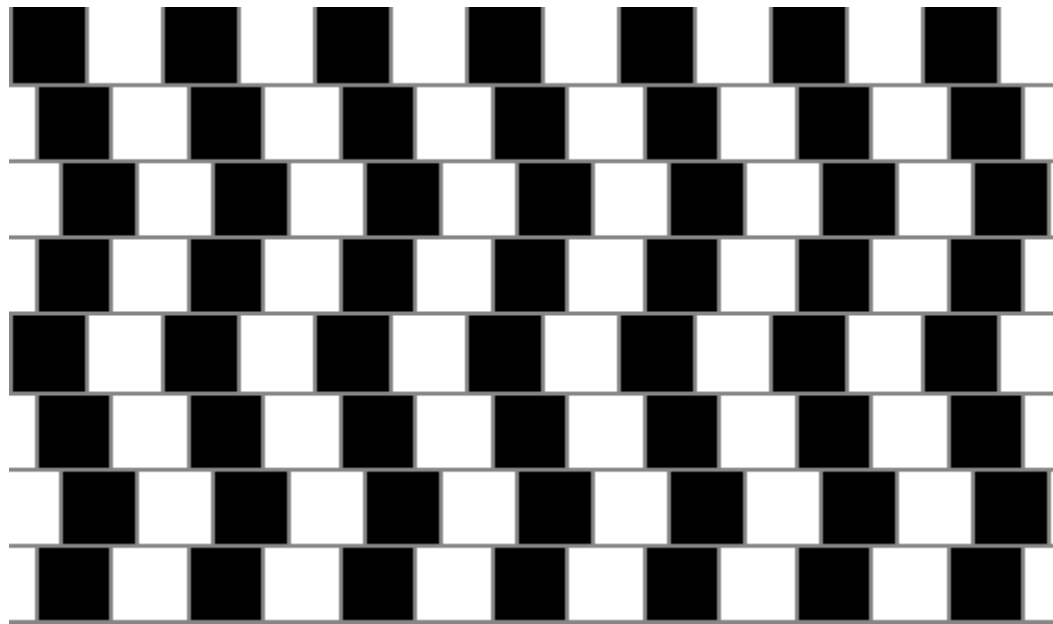


Perception

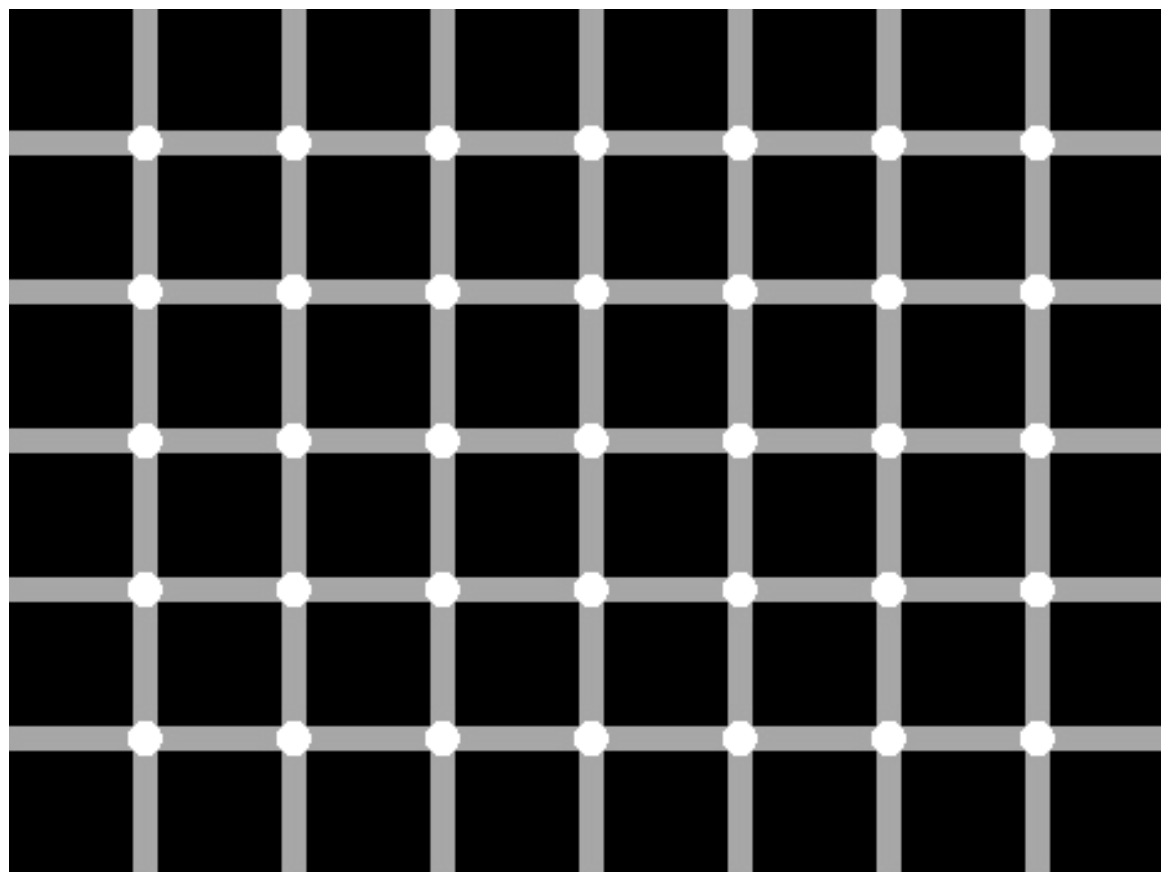
Human perception of light is described in terms of brightness, hue and saturation.

Hue	refers to the colour (red / orange / purple)
Brightness	how bright the light is
Saturation	sometimes called chroma, refers to how vivid or dull the colour is, its purity (amount of white light mixed with hue)

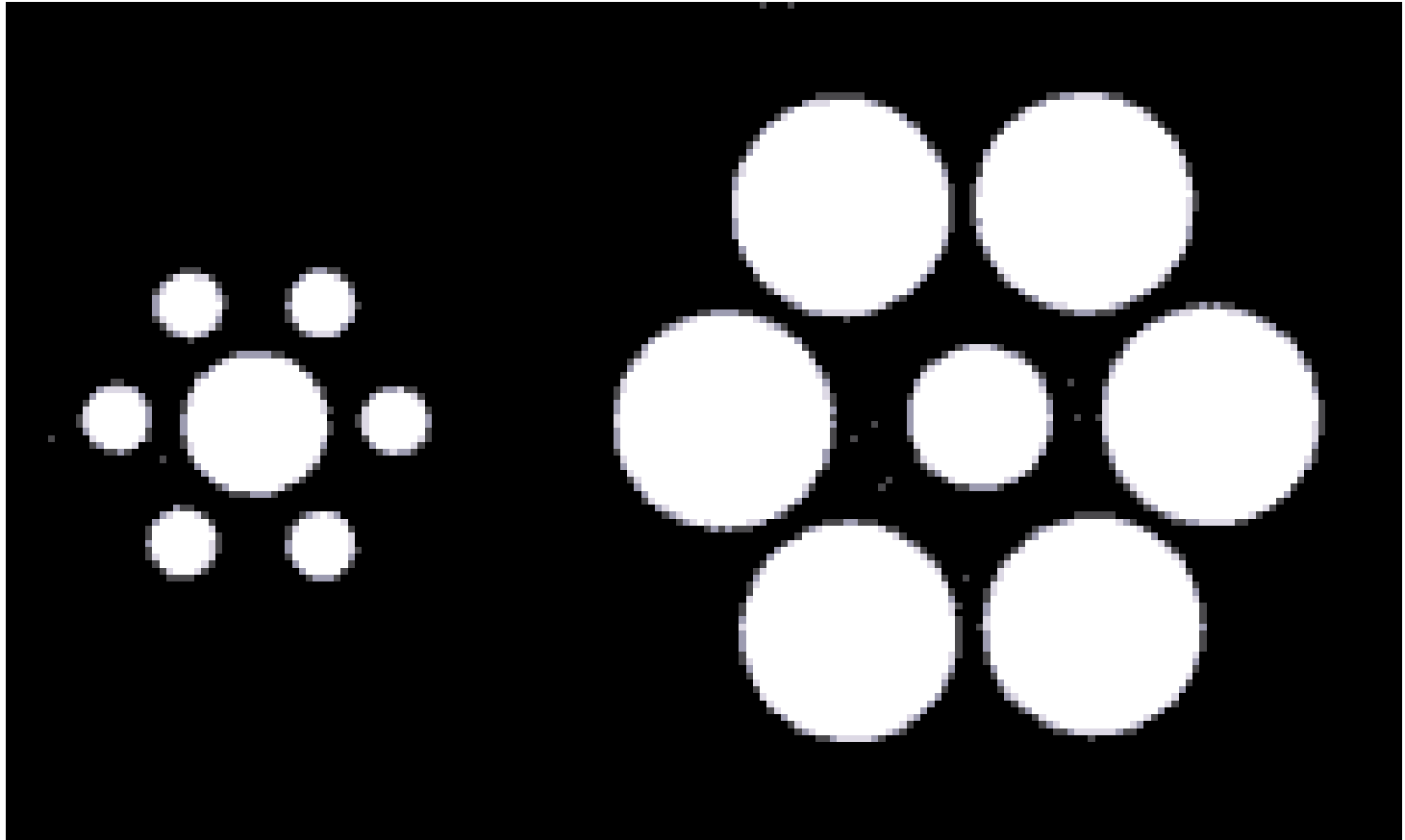
These are perceptual terms and depend on factors such as the past history of the observers exposure to visual stimuli and the environment in which the light is viewed.



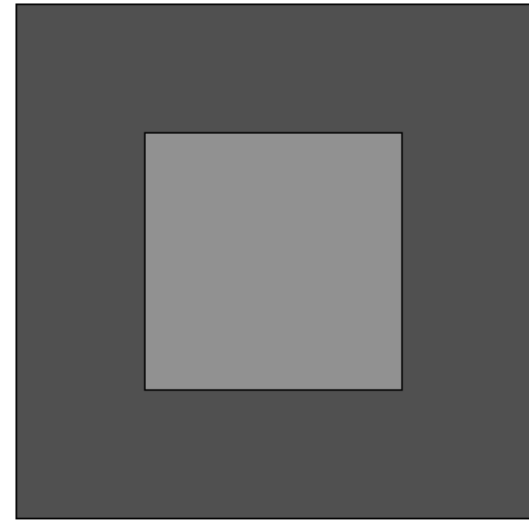
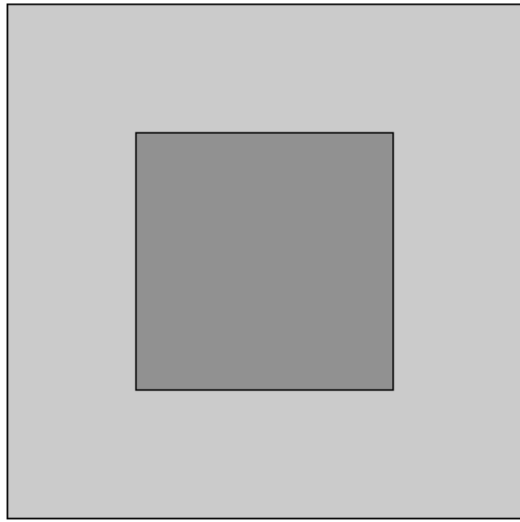
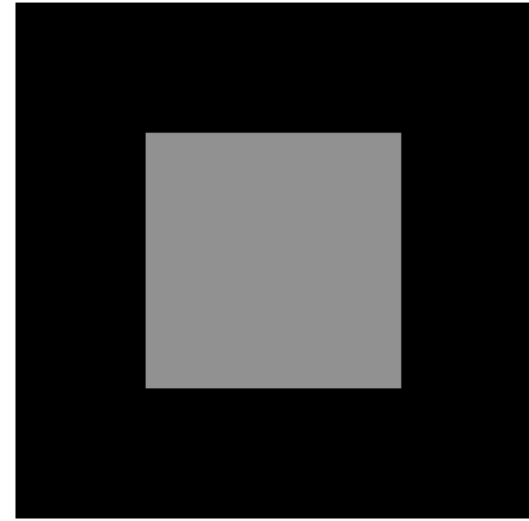
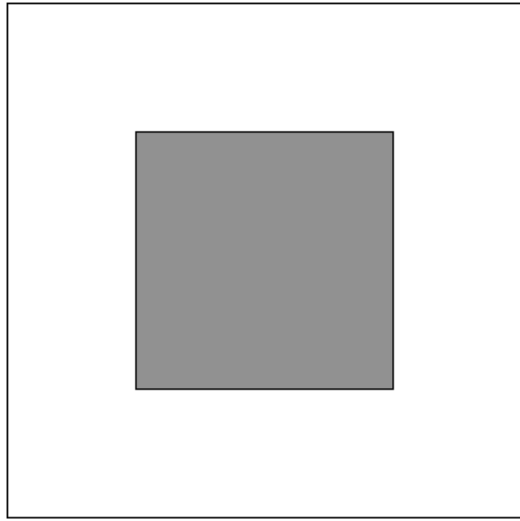
Are the horizontal lines parallel or do they slope?

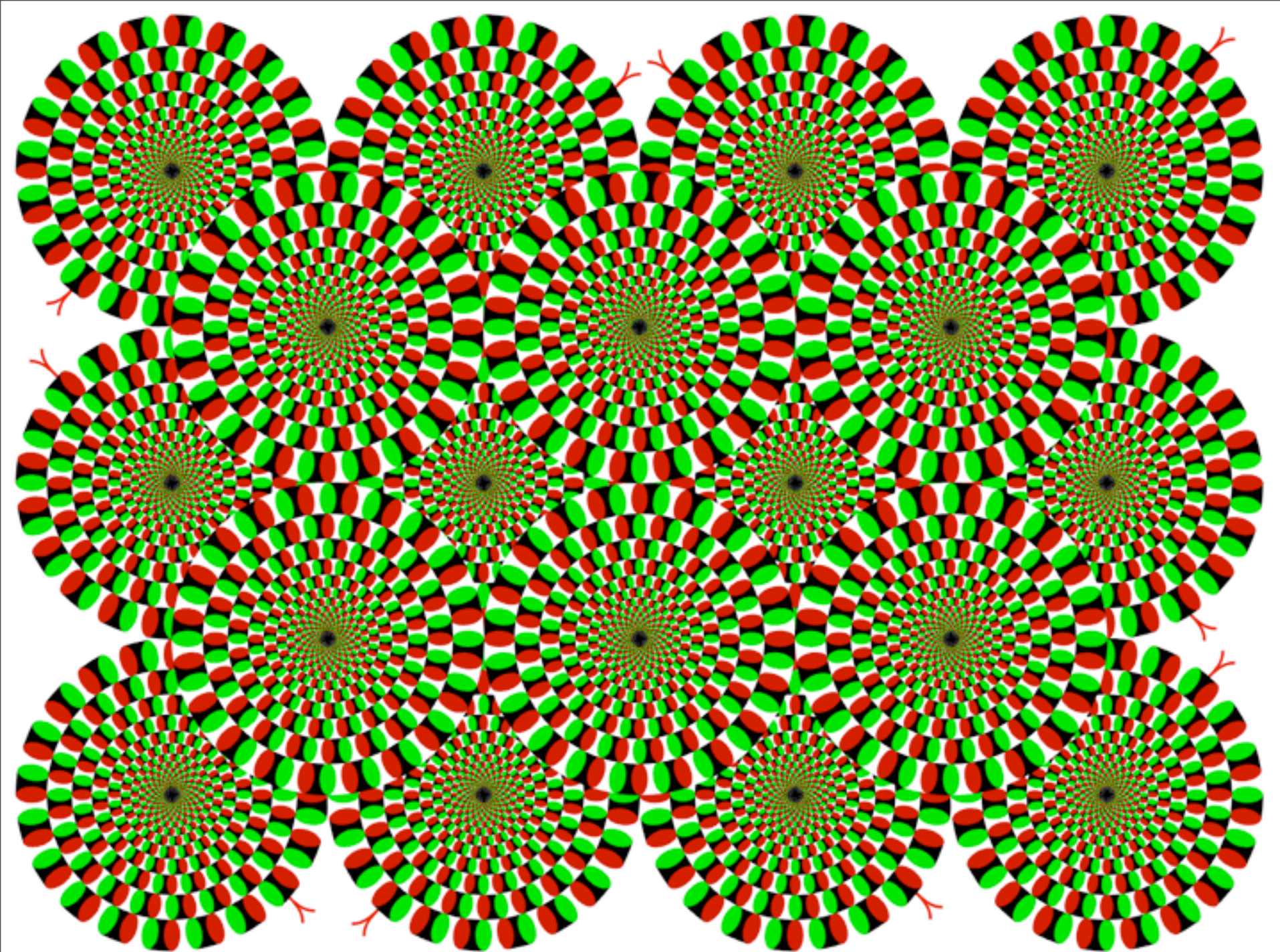


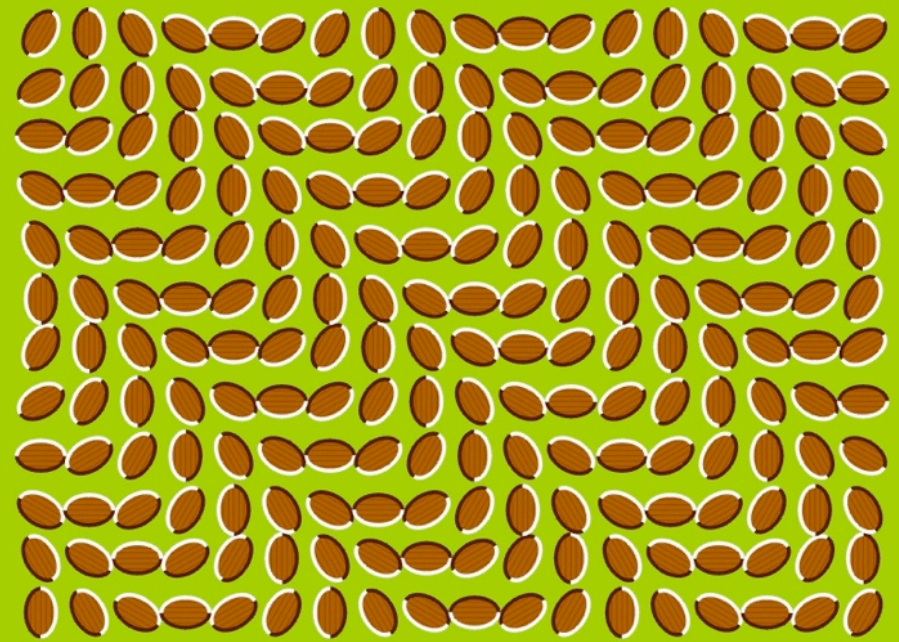
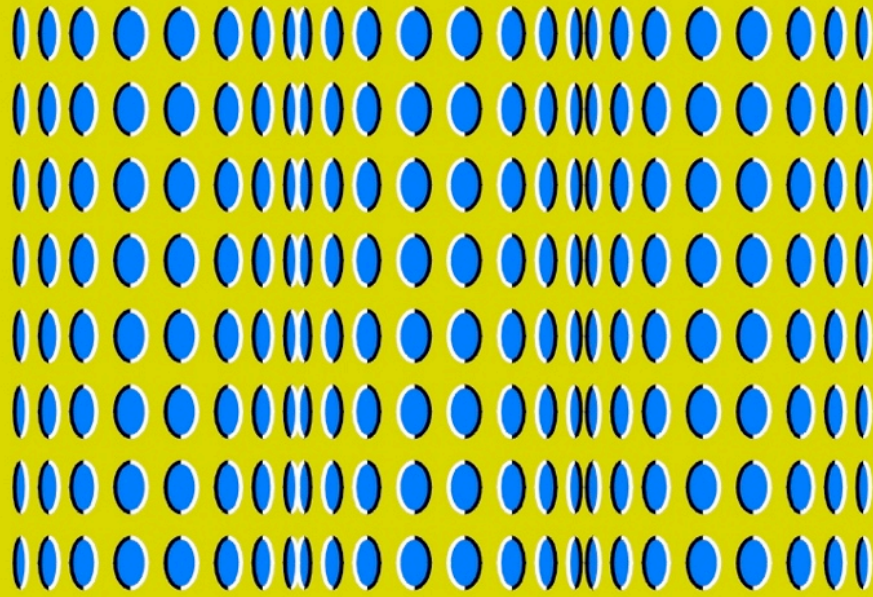
Count the black dots



Is the left centre circle bigger?







Colour

- Achromatic light
 - Devoid of colour
 - Only attribute is intensity
 - Grey level images
- Human eye sees all colours as the variable combinations of the “primary colours”

Red

Green

Blue

- CIE (Commission Internationale de l’Eclairage) designated these for standardisation purposes

Red

700nm

Green

546.1nm

Blue

435.8nm

Additive Colour Systems

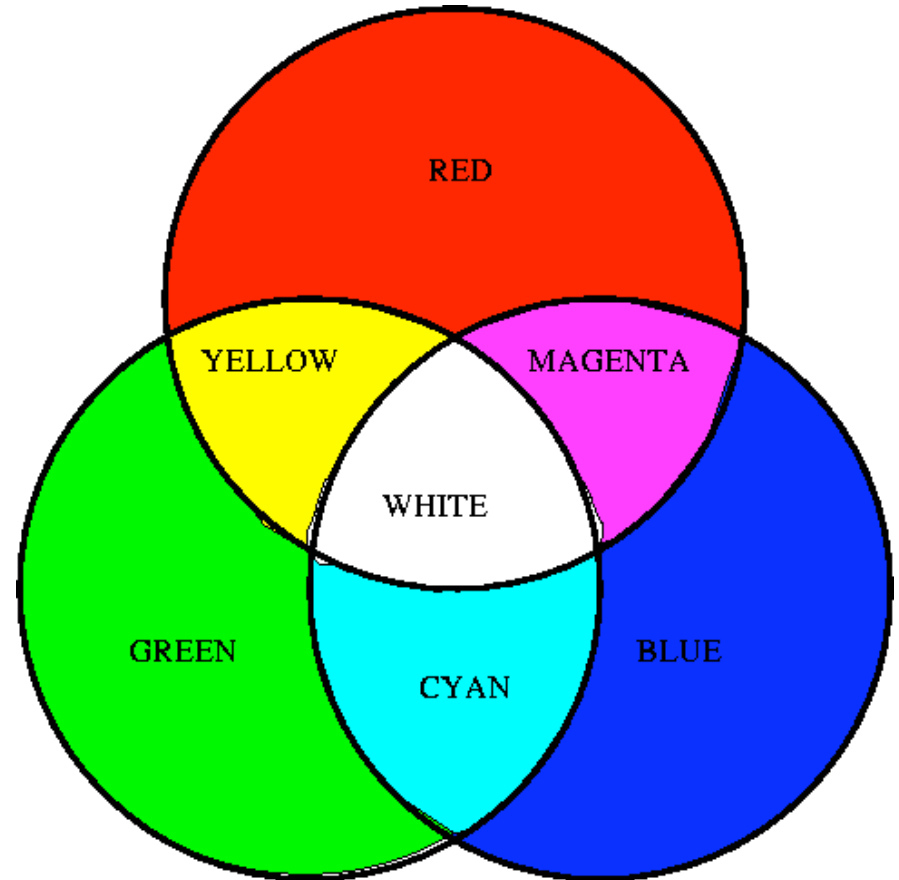
- The primary colours can be mixed to form the secondary colours

Yellow

magenta

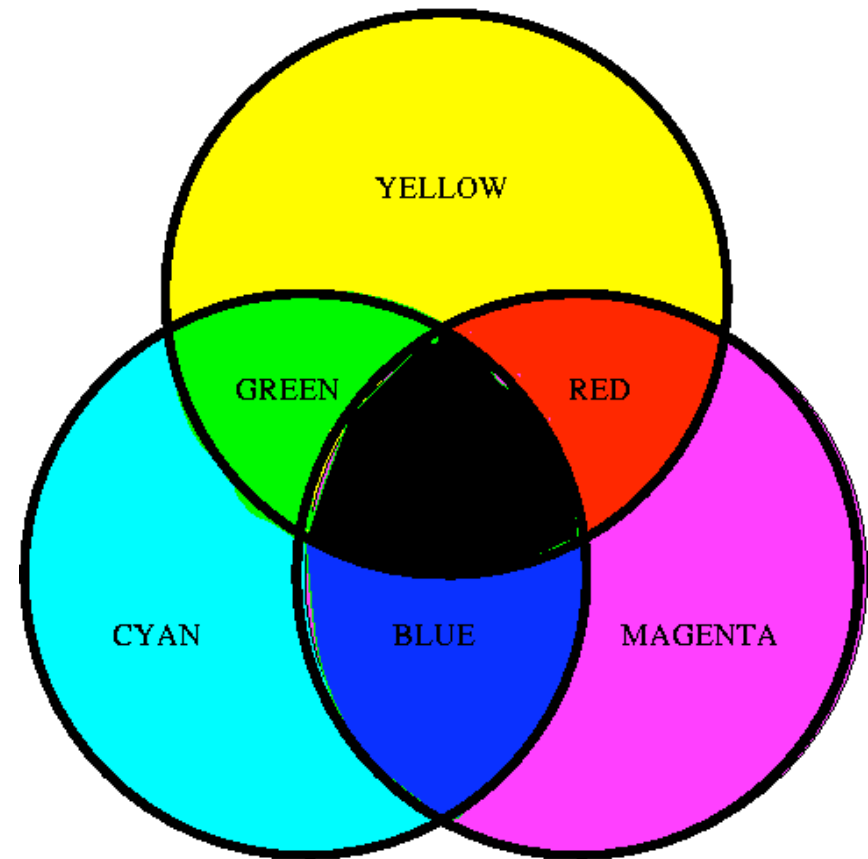
cyan

- ADDITIVE Colour Systems
- Mix all 3 colours to get white
- Colour TV



Subtractive Colour Systems

- Some wavelengths filters out and others reflected
- Primary colours are **Yellow magenta cyan**
- Secondary colours are **Red green blue**
- Equal combinations of all 3 primary colours produces black
- Colour Printers



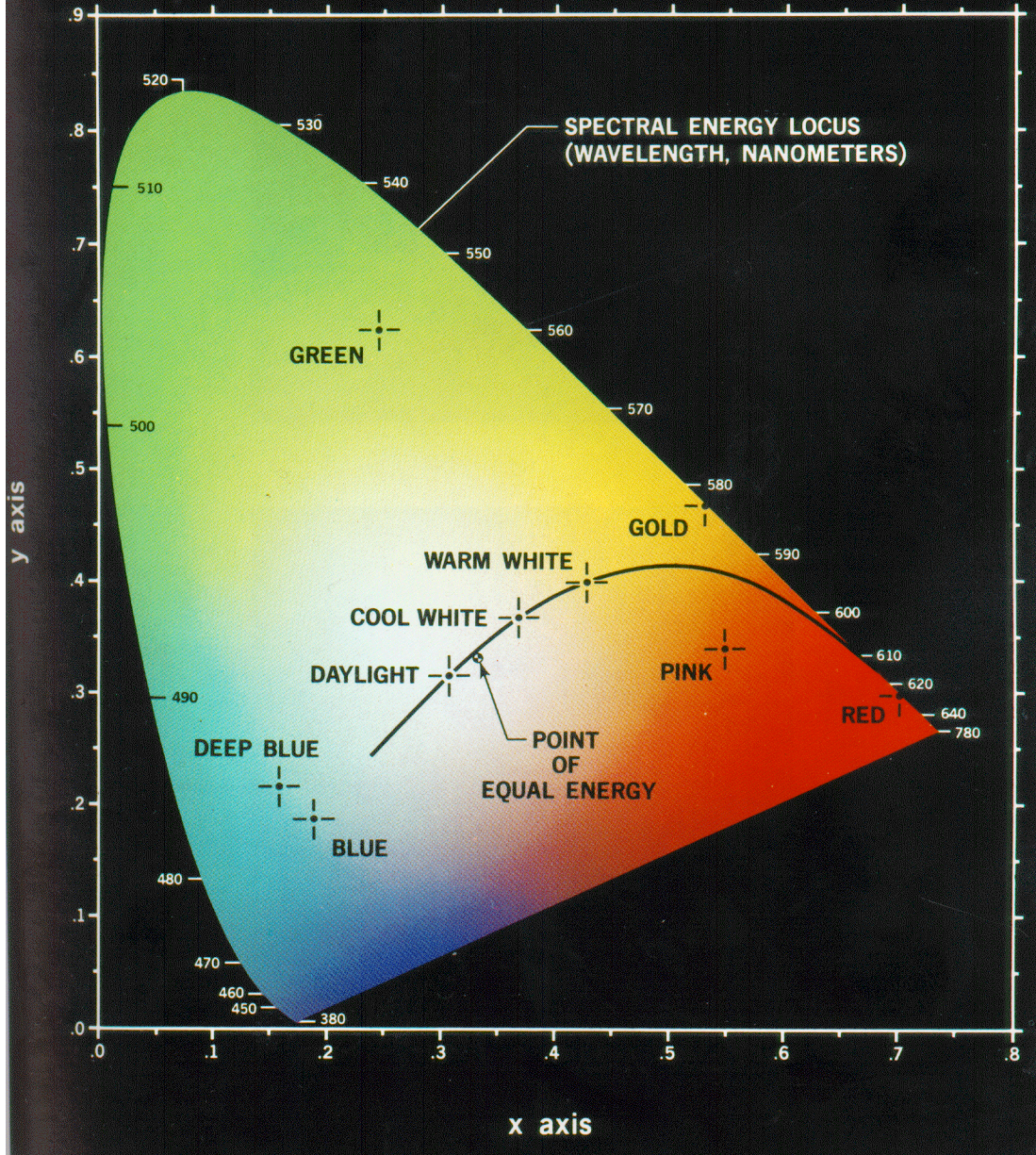
Chromaticity

- Brightness, hue and saturation are used to distinguish one colour from another
- Hue + saturation = chromaticity
- The amounts of red, green and blue needed to form any colour are known as the ***tristimulus values*** (X, Y and Z)
- Colour can be specified by its **trichromatic coefficients**

$$x = \frac{X}{X + Y + Z} \quad y = \frac{Y}{X + Y + Z} \quad z = \frac{Z}{X + Y + Z}$$

Where $x+y+z=1$ and hence $Z=1-x-y$

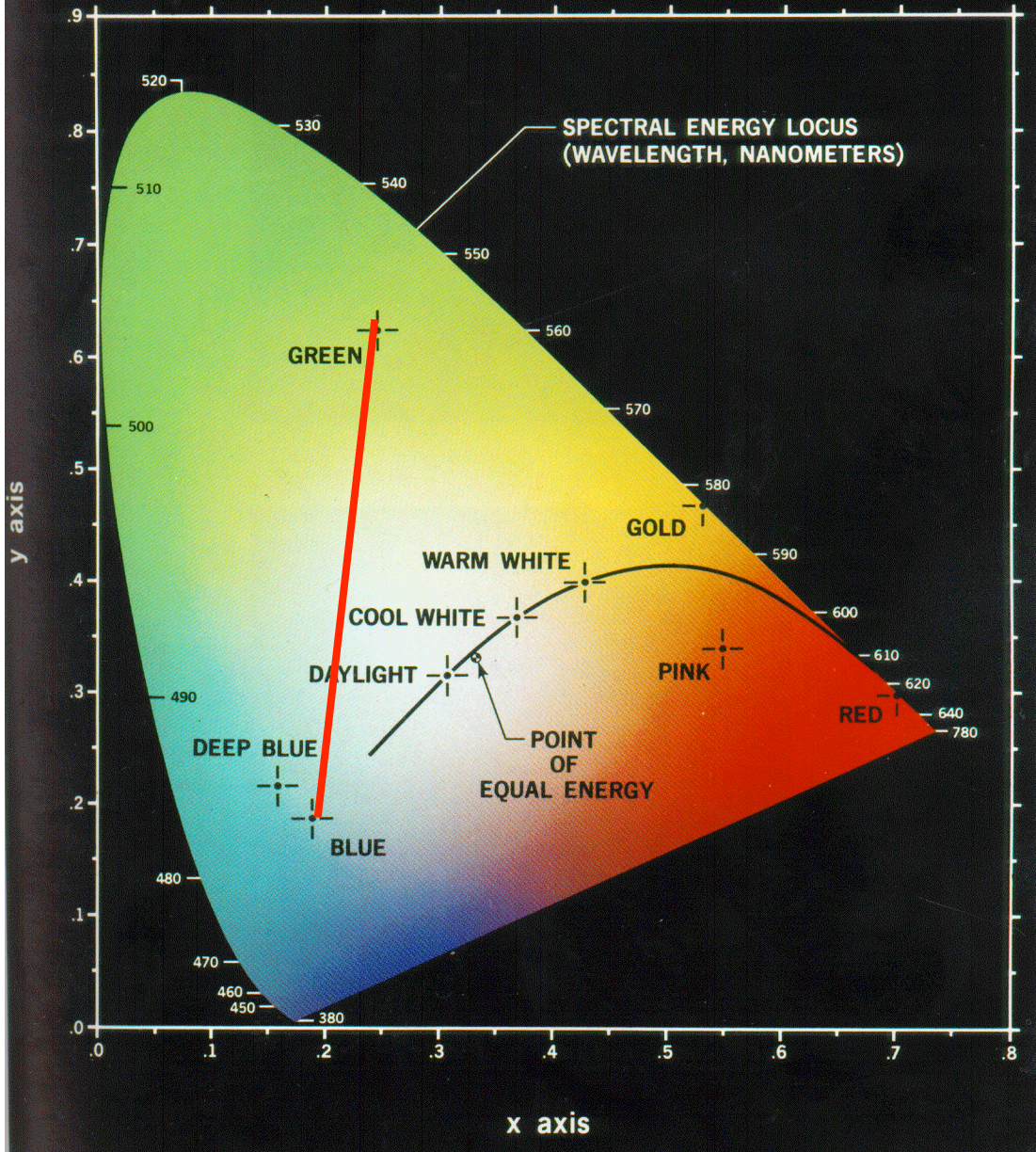
(C. I. E. CHROMATICITY DIAGRAM)



Chromaticity Diagrams

- Pure colours around boundaries
- Point of equal energy corresponds to equal fractions of 3 boundary colours
 - CIE Standard for white
- Saturation is maximum at boundary
- Saturation decreases to zero at point of equal intensity

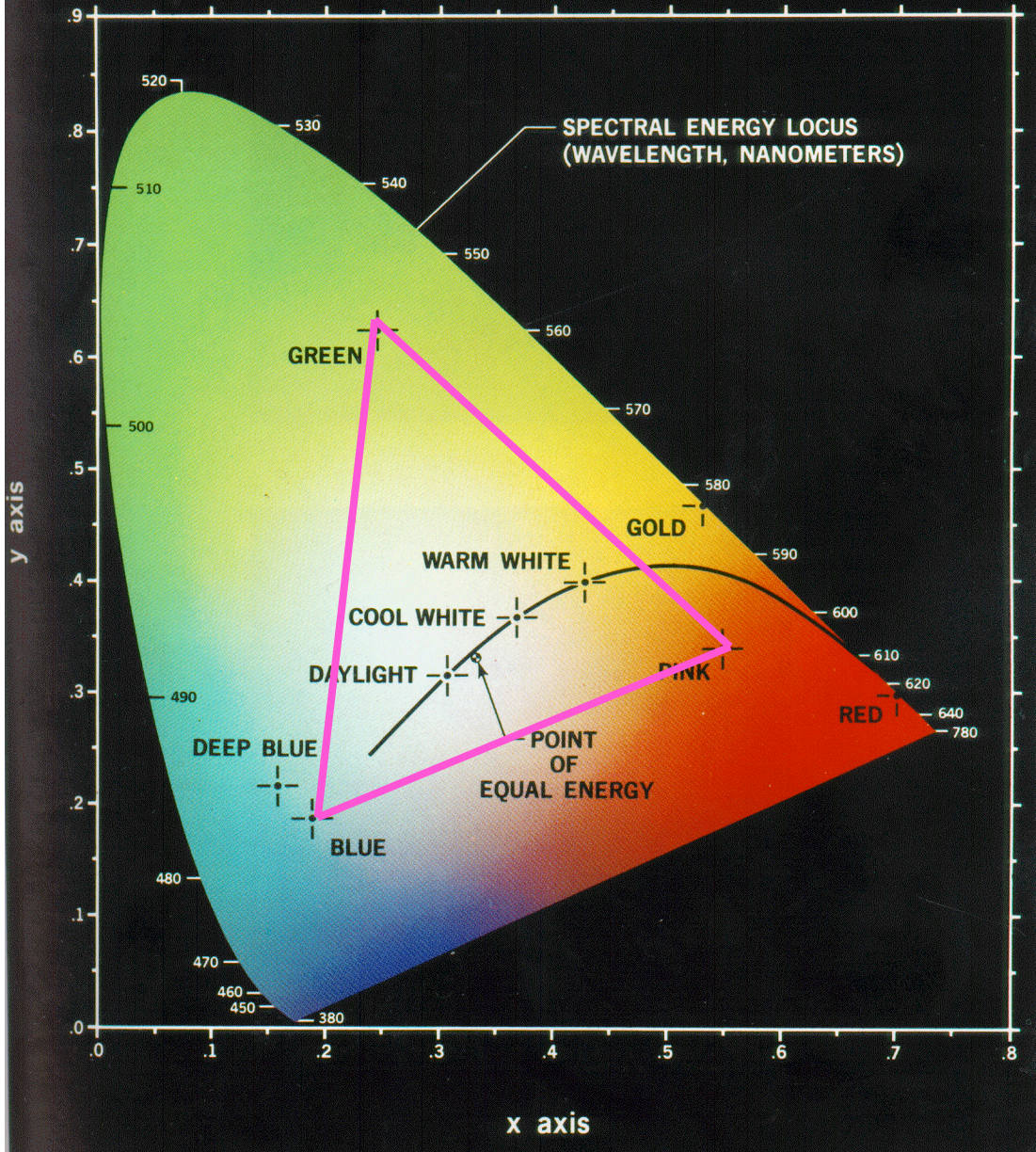
(C. I. E. CHROMATICITY DIAGRAM)



Straight line
between 2 points

All colours that can
be obtained
additively from
these 2 colours

(C. I. E. CHROMATICITY DIAGRAM)



Triangle between 3 points

Contains all colours that can be obtained additively from these 3 colours

Colour Models

- RGB – additive combination of Red, Green and Blue
- CMY – subtractive combination of Cyan, Magenta and Yellow
- CMYK – Cyan, Magenta, Yellow and BLACK
- HSI – Hue, Saturation and intensity
- YIQ – Luminance and Chrominance
 - Related to RGB

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

YIQ Model

- Y component - ***luminance***
 - Primarily responsible for the perception of brightness in a colour image
 - Can be used as a grey scale image
- I and Q components are called ***Chrominance***
 - Primarily responsible for the perception of hue and saturation of the colour image
- Advantage of YIQ
 - Process the Y component only – processed image will differ from unprocessed in its appearance of brightness
 - Most high frequency components of a colour image are in Y
 - Significant spatial lowpass filtering of I and Q does not significantly affect the colour image
 - Exploited in coding digital images (JPEG) and analog transmission of colour television signal