

# The Digital Camera

# Objectives

- Learn the construction of a camera to create digital images
- Understand the difference of color systems, color spaces
- Image formats, compressed images

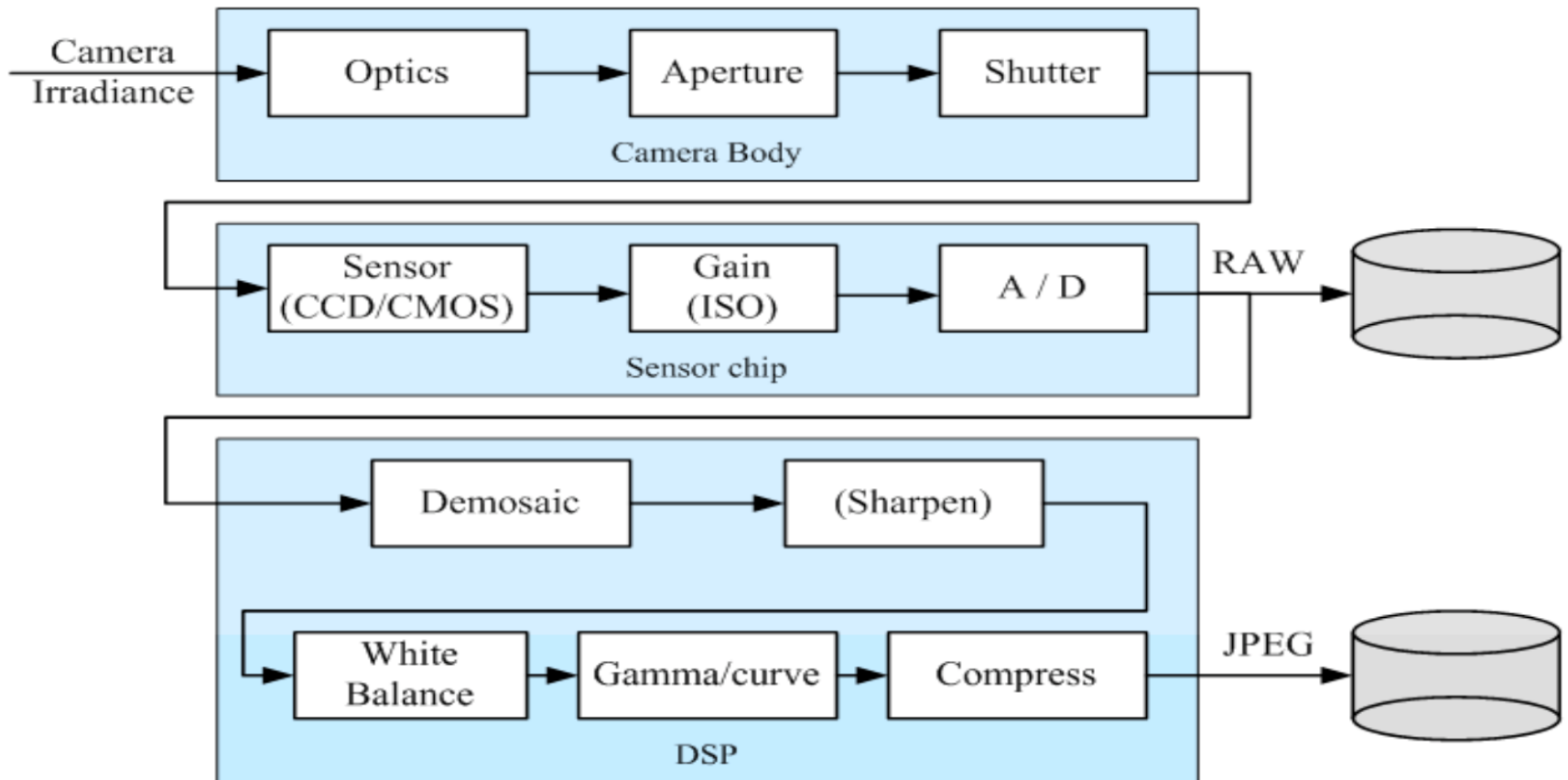
# The Digital Camera

- A digital camera is a camera that captures photographs in digital memory and the resulting files are in the format of digital images
- Digital cameras using optical system, typically using a lens with a variable diaphragm to focus light onto an image pickup device



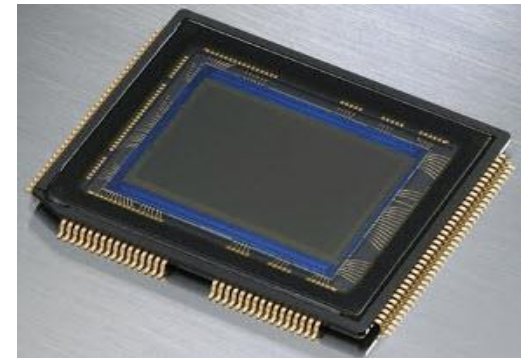
# The Digital Camera

- Camera models developed by Healey and Kondepudy (1994)



# How Camera produce Images

- The process:
  - Photons hit a detector
  - The detector becomes charged
  - The charge is read out as brightness
- Sensor:
  - CCD (charge-coupled device)
    - Most common
    - High sensitivity
    - high power
    - Cannot be individually addressed
    - blooming
  - CMOS
    - simple to fabricate (cheap)
    - lower sensitivity, lower power
    - can be individually addressed



- Shutter speed: controls the amount of light reaching the sensor and, hence, determines if images are under or overexposed
- Sampling pitch: the physical spacing between adjacent sensor cells on the imaging chip.
- Fill factor: the active sensing area size as a fraction of the theoretically available sensing area.
- Chip size:
  - Video and shoot cameras have traditionally used small chip areas ( 1/4 inch to 1/2 inch sensors)
  - Digital SLR cameras try to come closer to the traditional size 2 of a 35mm film frame.

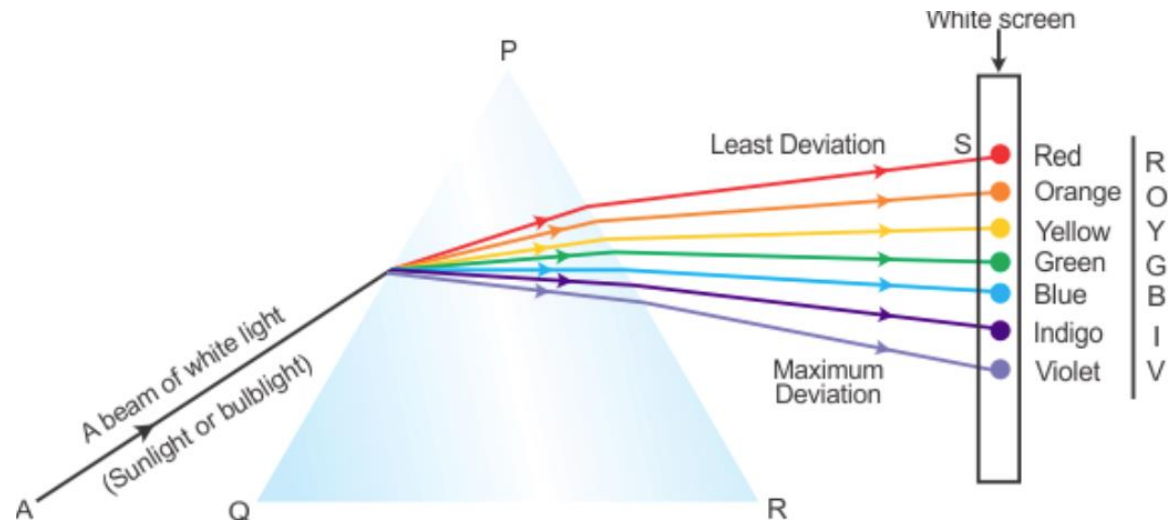
- Automatic Gain Control (AGC): adjusting amplification and black level to get a “good fit” of the incident light power to the range of the image
- Sensor noise: noise is added from various sources, which may include fixed pattern noise, dark current noise, shot noise, amplifier noise and quantization noise.
- ADC resolution. The final step in the analog processing chain occurring within an imaging sensor is the analog to digital conversion.

- Digital post-processing. Once the irradiance values arriving at the sensor have been converted to digital bits, most cameras perform a variety of digital signal processing (DSP) operations to enhance the image before compressing and storing the pixel values
- White balance: Adjustment of the mapping from measured spectral quantities to image RGB quantities

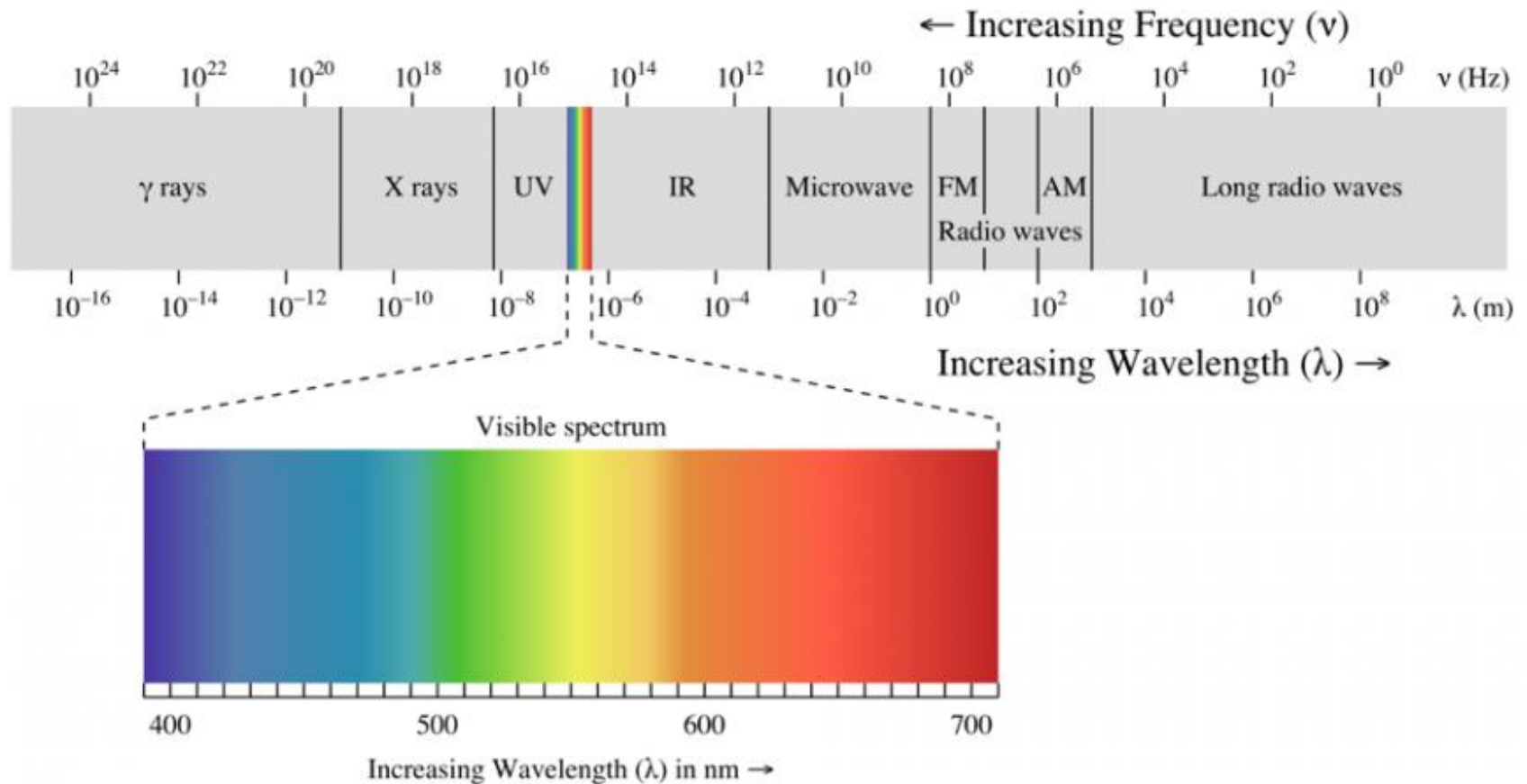


# What is color

- Color is the aspect of things that is caused by differering qualities of light being reflected or emitted by them.
- To see color, we must have light. When light shines on an object some colors bounce off the object and others are absorbed by it. Your eyes only see the colors that are bounced off or reflected.

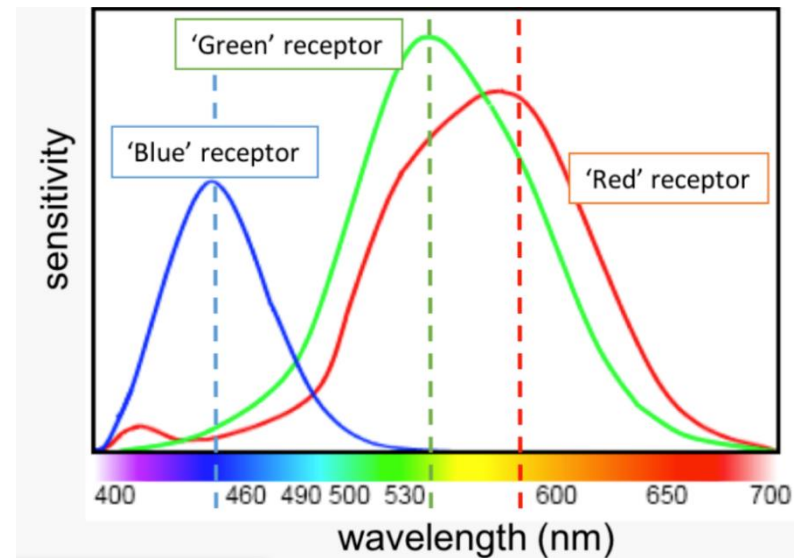
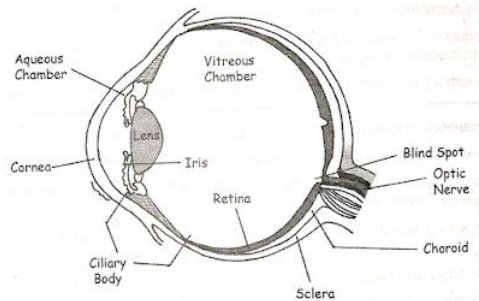


# Human color can see

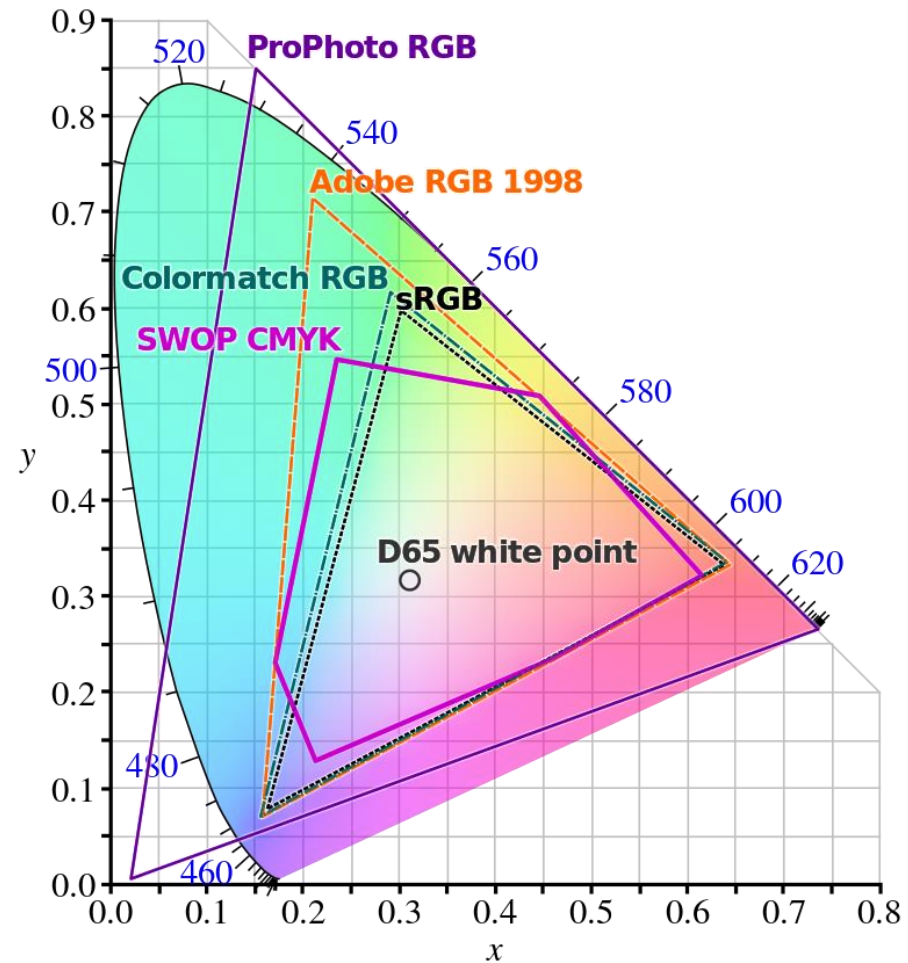


# Human eyes

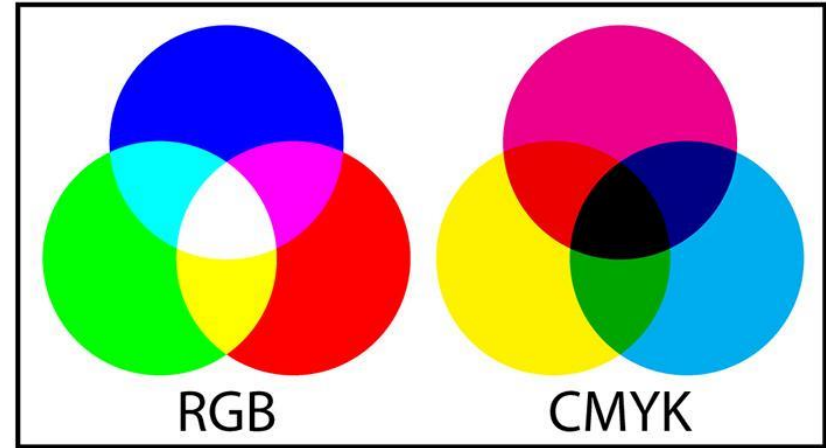
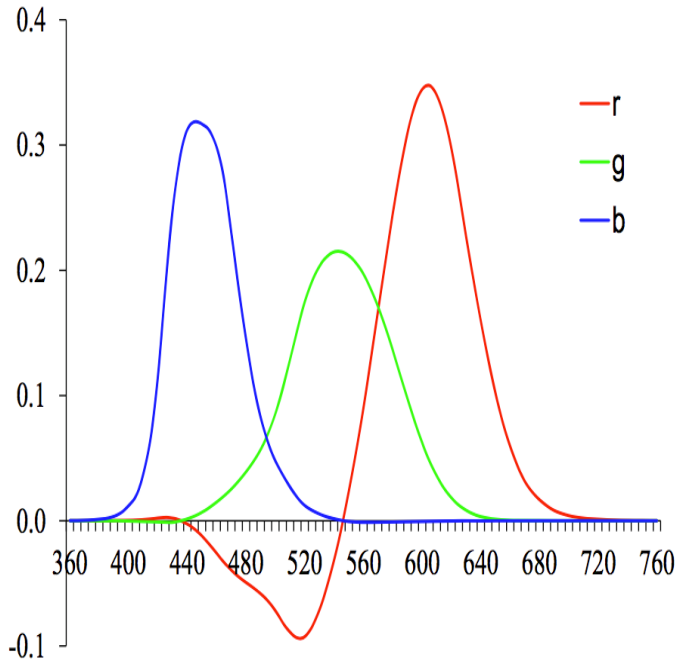
- The human eye is nearly spherical in shape.
- The wall of the eyeball comprises of three layers.
  - The outermost layer is sclera/ fibrous tunic.
  - Middle layer called vascular tunic ( choroid , ciliary body , iris)
  - Third which is the innermost layer is called retina (Retina is made of light sensitivity cells)



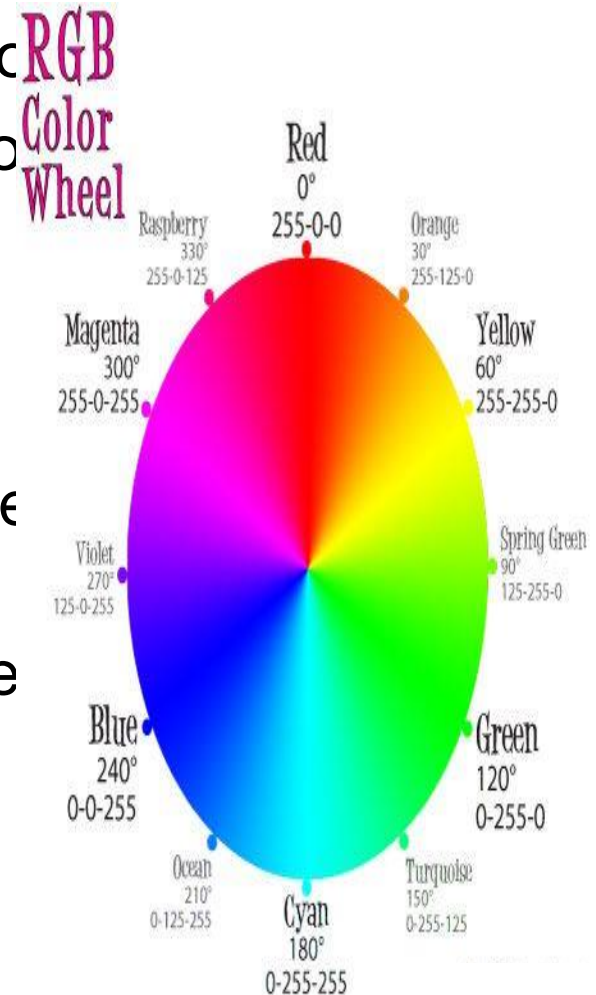
- A color space is a specific organization of colors.
- Color space:
  - CIE (Commission International d'Eclairage) establishes standards
  - CIE XYZ is a popular standard with everywhere positive response.
  - RGB requires a negative (subtractive) component in R response to render the complete color gamut of CIE XYZ.



- Standard CIE color matching functions

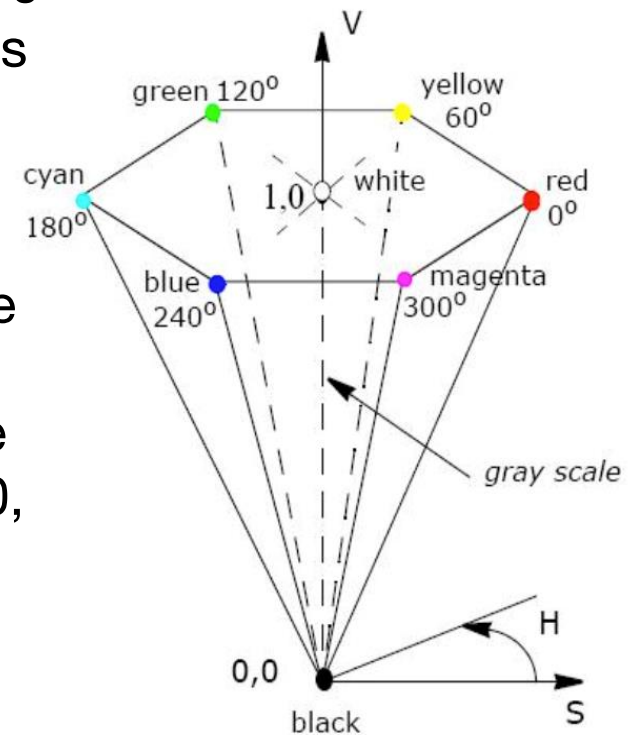


- Accurate color reproduction is commercially valuable
  - Many products are identified by color
- Few color names are widely recognized
  - About 10 languages
  - Personal name --> disagree. •
- Color reproduction problems increase digital imaging
  - Ensure that everyone sees the same



# Color space: HSV

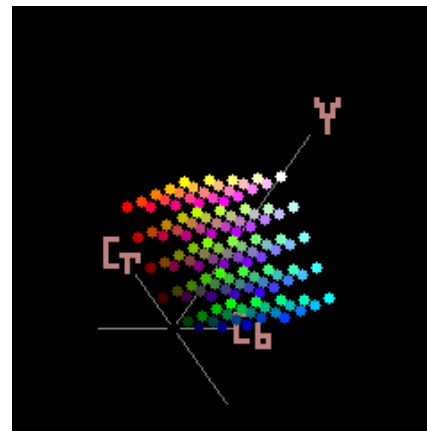
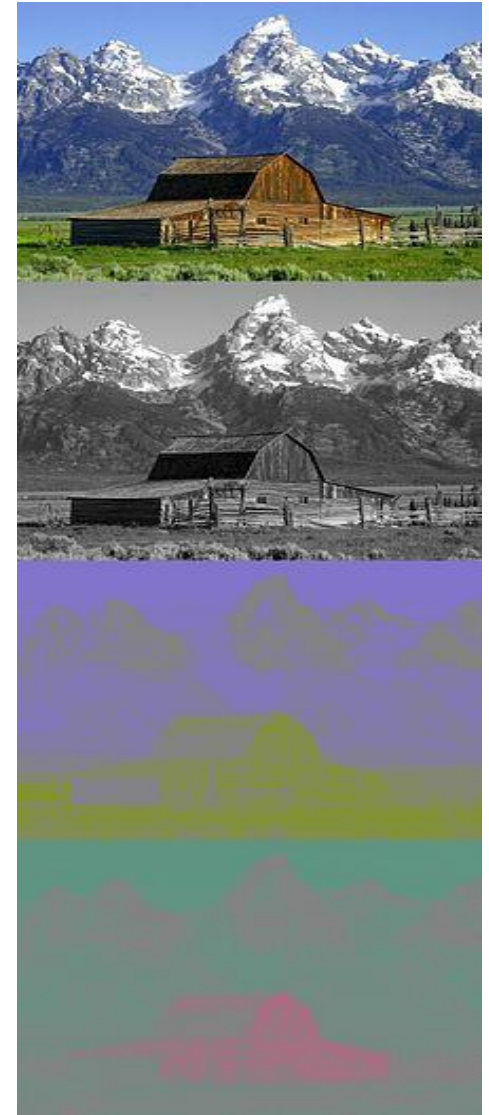
- Every color is represented by three components Hue ( H ), Saturation ( S ) and Value ( V )
- The Hue component describes the color itself in the form of an angle between  $[0,360]$  degrees: 0 degree mean red, 120 means green 240 means blue, 60 degrees is yellow, 300 degrees is magenta.
- The Saturation component signals how much the color is polluted with white color: the range of the S component is  $[0,1]$ .
- Black has a V coordinate of 0. At this point the values of H and S are irrelevant. The point  $S=0, V=1$  is white. Intermediate values of V for  $S=0$  (on the center line) are the grays. When  $S=0$  value of H is irrelevant (called by convention undefined). When S is not zero, H is relevant.





# Color space: YCbCr

- It is used as a part of the color image pipeline in video and digital photography systems.
- Y is the luma component and CB and CR are the blue-difference and red-difference chroma components.
- It is used for JPEG conversion





- The transformation from RGB to XYZ is given by:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{1}{0.17697} \begin{bmatrix} 0.49 & 0.31 & 0.20 \\ 0.17697 & 0.81240 & 0.01063 \\ 0.00 & 0.01 & 0.99 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- Chromaticity coordinates

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

- Color filter arrays: cameras use a color filter array (CFA), where alternating sensors are covered by different colored filters
- Color balance: attempt to move the white point of a given image closer to pure white (equal RGB values)

- The last stage in a camera's processing pipeline is usually some form of image compression
- Image compression algorithms start by converting the signal into YCbCr
- Technique : Discrete Cosine Transform (DCT), which is a realvalued variant of the discrete Fourier transform (DFT)
- The quality of a compression algorithm: peak signal-to-noise ratio (PSNR):

$$MSE = \frac{1}{n} \sum_{\mathbf{x}} \left[ I(\mathbf{x}) - \hat{I}(\mathbf{x}) \right]^2$$

## – Non-lossy schemes

- pbm/pgm/ppm/pnm: code for file type, size, number of bands, and maximum brightness
- tif (lossless and lossy versions)
- bmp
- gif (grayscale)

## – Lossy schemes

- gif (color)
- jpg
  - Uses Y Cb Cr color representation;
  - subsamples the color
  - Uses DCT on result
  - Uses the fact the human system is less sensitive to color than spatial detail

- TIFF(TaggedImageFileFormat)
  - More general than GIF
  - Allows 24 bits/pixel
  - Supports 5 types of image compression including:
    - RLE (Run length encoding)
    - LZW (Lempel-Ziv-Welch)
    - JPEG (Joint Photographic Experts Group)



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