EXERCISE 2:

Multimedia Databases SS 23

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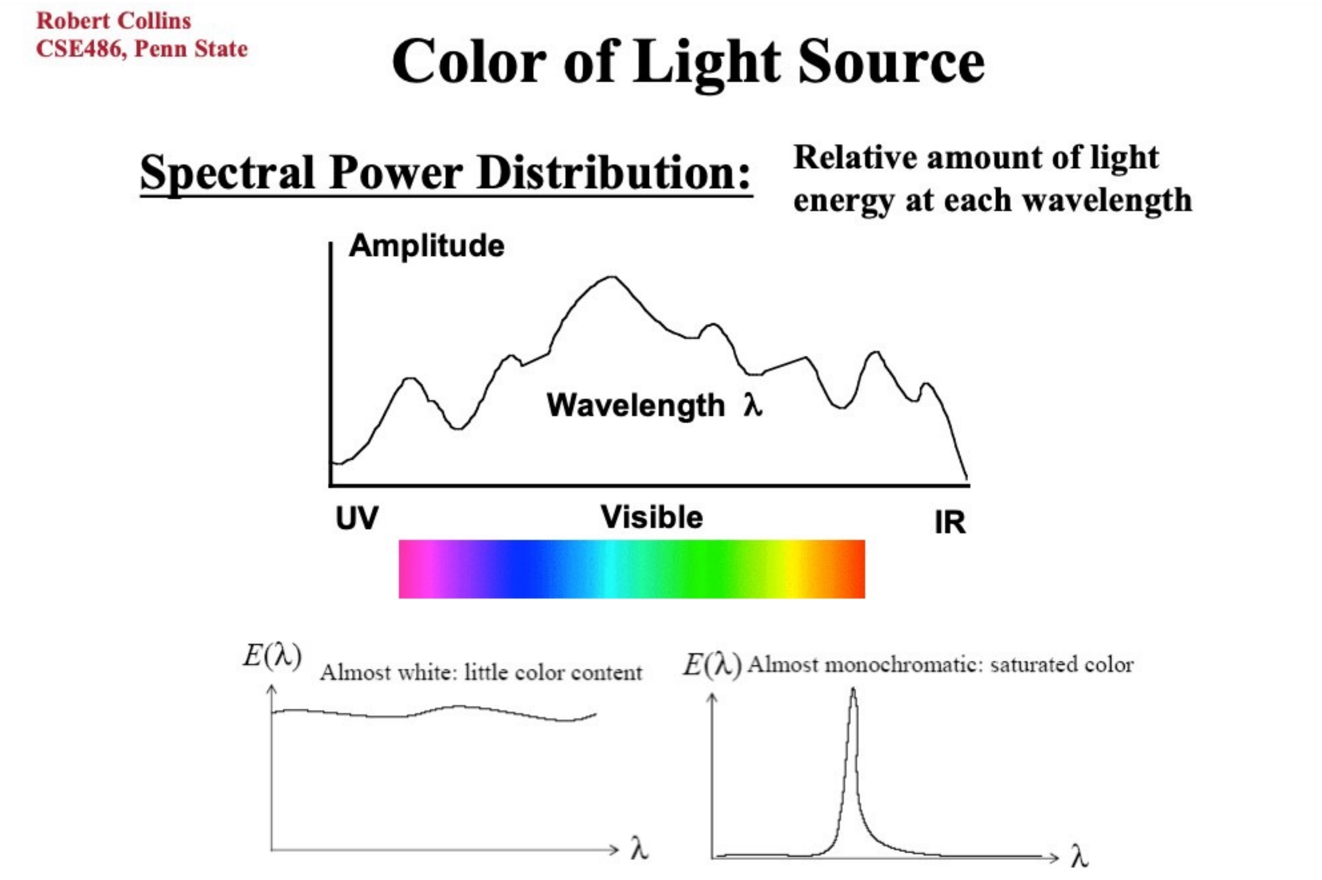
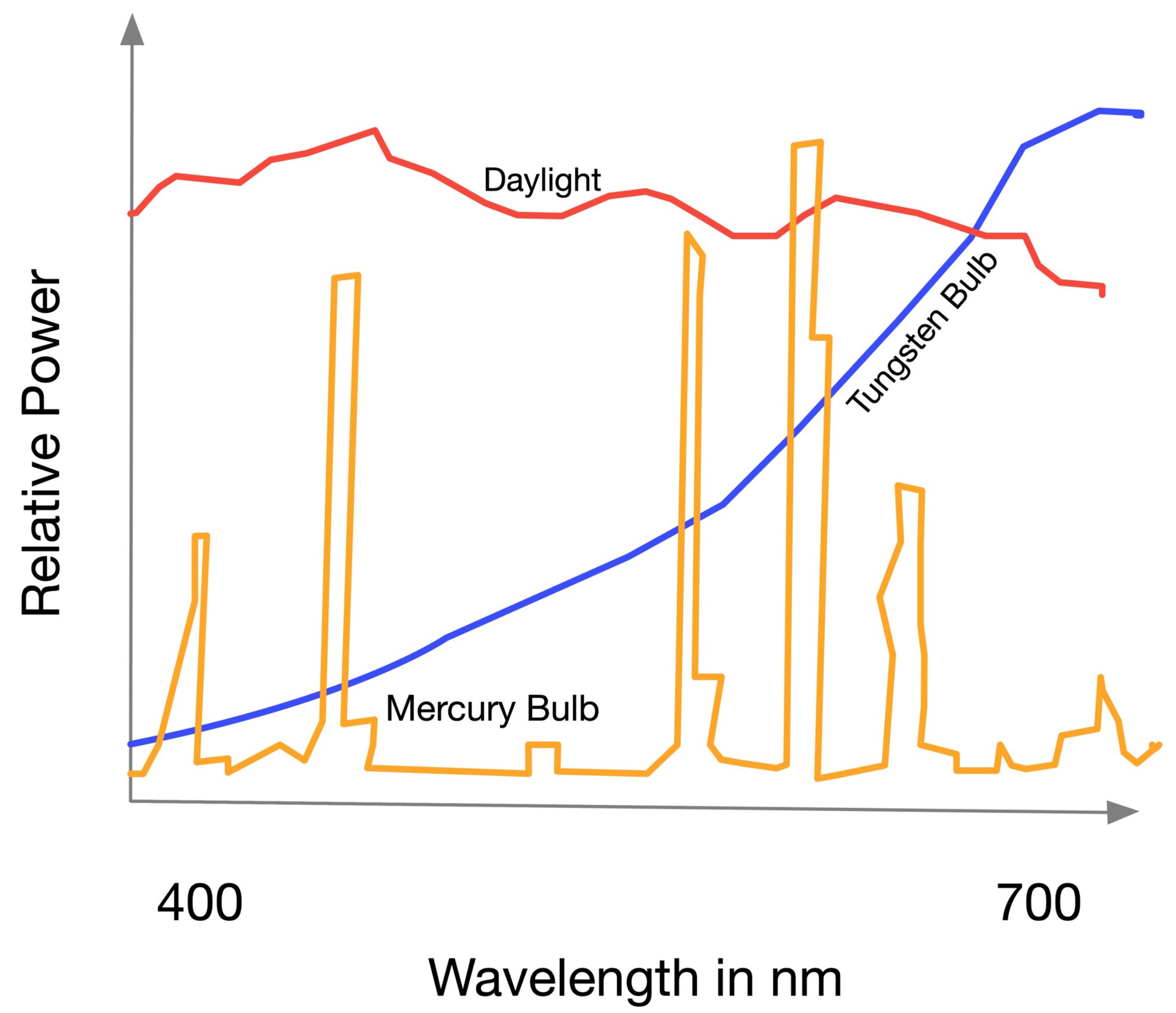
Task 1.1:



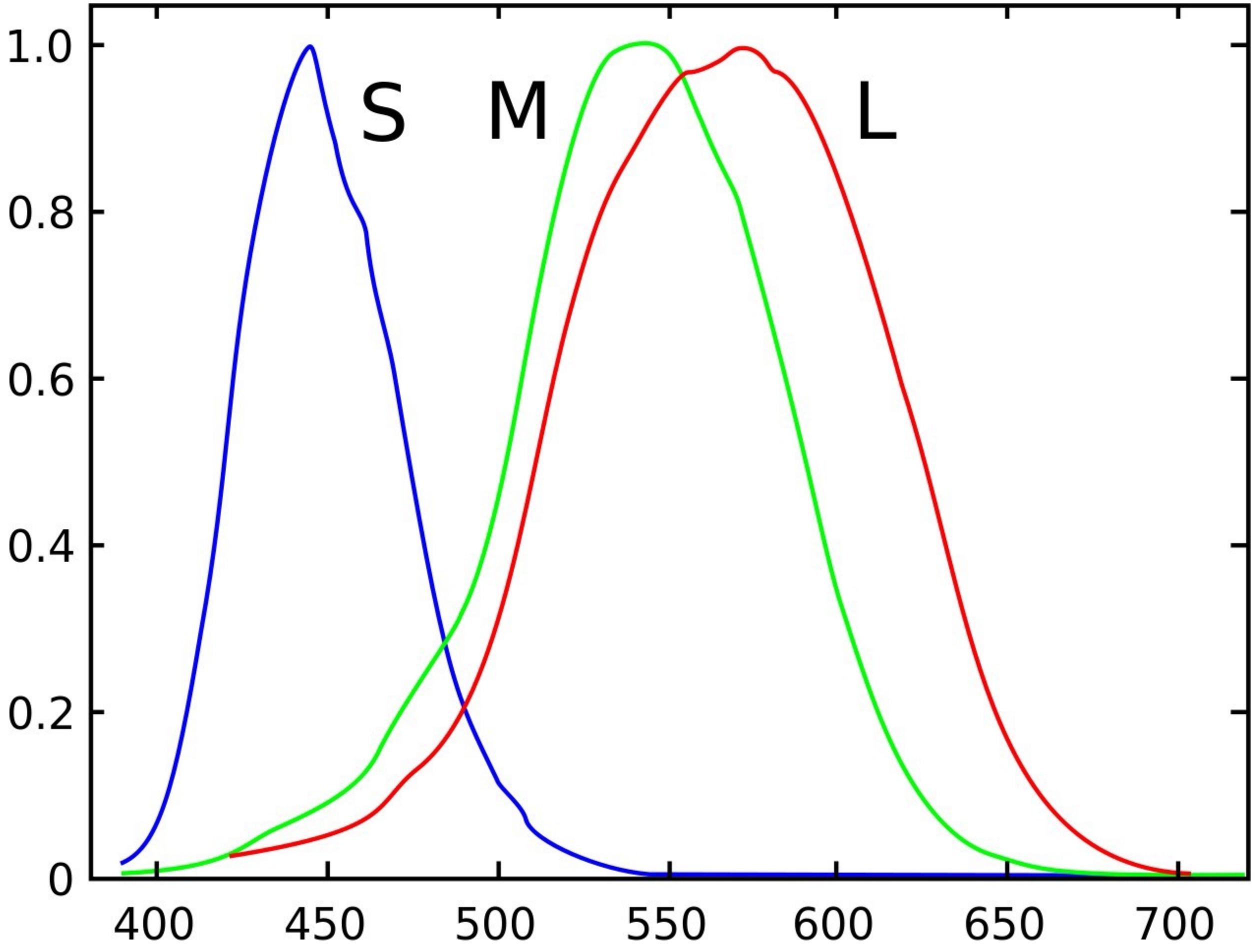
Source: http://www.cse.psu.edu/~rtc12/CSE486/lecture26.pdf

Task 1:1


Daylight
Tungsten Bulb
Mercury Bulb
Relative Power
400
700
Wavelength in nm

Task 1.2

Spectral sensitivity is the relative efficiency of detection, of light or another signal, as a function of the frequency or wavelength of the signal.



https://en.wikipedia.org/wiki/Spectral_sensitivity#/media/File:Cones_SMJ2_E.svg

Task 1.3: Metamers

Color stimuli that have different spectral radiant power distributions but are perceived as identical for a given observer i.e. different spectral profiles that produce exactly the same *relative* stimulation to the **L**, **M** and **S** cones

- **light metamers**, different spectral emittance curves perceived as the same color
- **material metamers**, two different surface reflectance curves perceived as the same color when each is viewed with the same light source
- **observer metamers**, different spectral profiles perceived as the same color due to limitations in the viewer's visual responses (colorblindness or dark adapted vision).

1.4: Chromatic Adaptation

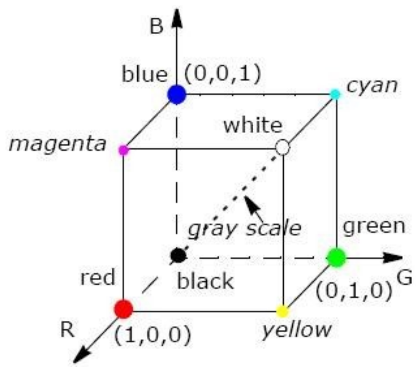
- In everyday life, illumination sources are changing constantly(full sunshine, cloudy conditions, indoor lighting etc)
- Measured spectrum of light reflected from a given object is constantly changing.
- Despite this, we perceive that “the light changed” not “all the objects changed color”.
- Rather like a camera with auto white balance, our eye constantly recalibrates to what it sees as “white light”, and all other colors are judged relative to that white.

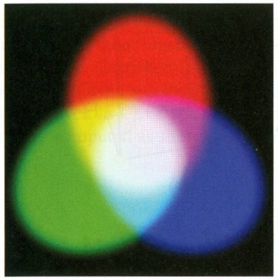
2.1: Color Model

- **What is a color model?**
  - Abstract Method for representing color information
  - Makes use of the characteristics of the human vision system.
  - Example: RGB represents a color as three dimensional vector
- **Two types: Additive & Subtractive Color model**

2.2: Additive Color Model

- **Lights are used to produce colors.**
  - Black represents the complete lack/absence of the primary colors.
  - White corresponds to **maximal** and **equal amounts of each of the primary colors.**
  - E.g.; RGB model
    - Black → (0,0,0) White → (1,1,1) s.t. **0** indicates absence of the primary color and **1** maximum amount of the specified primary color.
    - Additive primary colors:
      - Red, Blue, Green
    - Additive secondary colors:
      - Cyan, Magenta, Yellow
    - Complementary color pairs:
      - Red-cyan
      - Green-magenta
      - Blue-yellow



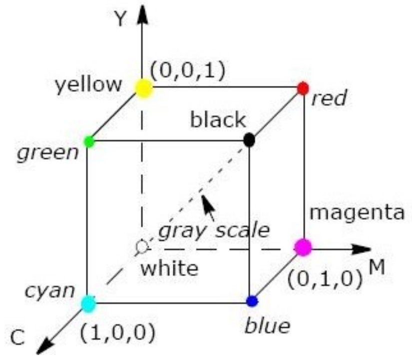


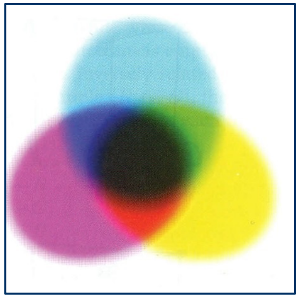
RGB model (additive)

- **Human perception is an additive system.**
- Hardwares/ Devices naturally modeled using an additive color model: television, computer monitors, LCD projectors, stage lighting, etc.

2.2: Subtractive Color Model

- **Pigments or dyes are used to produce colors.**
  - White represents the complete lack/absence of any pigment.
  - Black corresponds to **maximal** and **equal amounts of each of the primary colors.**
  - E.g.; CMY model
    - White → (0,0,0) Black → (1,1,1) s.t. **0** indicates absence of the primary color and **1** maximum amount of the specified primary color.
    - Subtractive primary colors:
      - Cyan, Magenta, Yellow
    - Subtractive secondary colors:
      - Red, Green, Blue
    - Complementary color pairs:
      - Magenta–green
      - Yellow–blue
      - Cyan–red

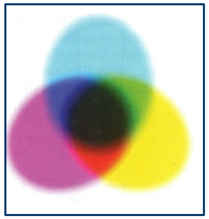




CMY model (subtractive)

- Subtractive color models tend to be more intuitive than additive ones.
- Hardwares/ Devices naturally modeled using a subtractive color model: ink-based printers, etc.

2.2: Color model



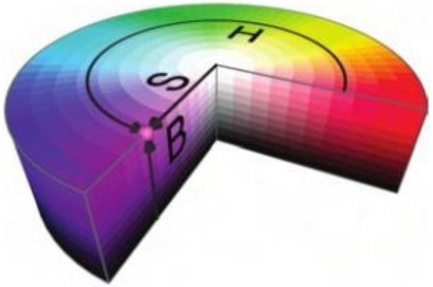
- **CMY (K) color model:**
  - Subtractive color model
  - CMY(K)= Cyan (1,0,0) Magenta (0,1,0) Yellow (0,0,1)
  - CMY model is inversely related to the RGB model
    - C = 1 – R
    - M = 1 – G
    - Y = 1 – B

$$\langle C,M,Y,K\rangle = \begin{cases} \langle 0,0,0,1\rangle & \text{if } \min(C',M',Y')=1,\\ \langle \frac{C'-K}{1-K}, \frac{M'-K}{1-K}, \frac{Y'-K}{1-K}, K\rangle & \text{otherwise where } K=\min(C',M',Y'). \end{cases}$$

  - What is the k?
    - K stands for „key“
    - (1,1,1) -> "pale black„
    - The black is used in the printer industry to achieve a deeper black than could be made by mixing the three primaries. It is also used to save printer ink.
  - The conversion from CMY to CMYK:

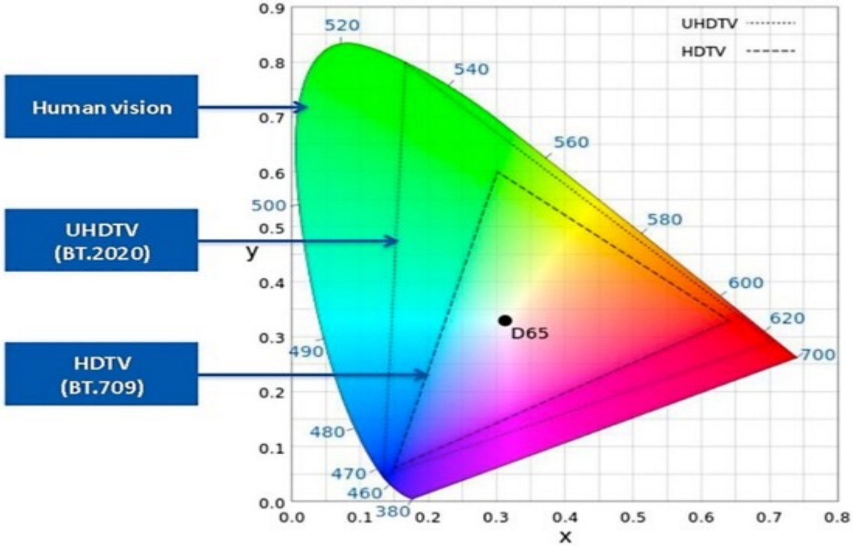
2.2: Color model

- **HSB color model:**
  - HSB = Hue Saturation Brightness
    - Hue = color (0-360)
    - Saturation = degree to which the hue differs from a neutral gray (0 no color saturation -1 full saturation)
    - Brightness = illumination level, from 0 (black, no light) to 1 (white, full illumination).
  - Designed to approximate the way humans perceive and interpret color.
  - **Advantages:**
    - (HS) and (B) treated separately
    - Complementary colors by shifting the h
    - Digital image processing



2.3: Can every color perceptible to the human eye be displayed as a combination of three primaries (R, G, B) ?

- The human vision has 3 types of cones.
- Each cone type has a different sensitivity curve in the color spectrum.
- RGB does a pretty good job of covering a large part of the color gamut, but not all (RGB fails at saturated cyan and yellow, for example).



2.4: Converting from RGB to CMYK

- Given a colour represented in RGB colour space as R = 0 0.2, G = 0.6, B = 0.3, what is it's representation in the CMYK colour mode?

$$\begin{pmatrix} \bar{C} \\ \bar{M} \\ \bar{Y} \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 0.8 \\ 0.4 \\ 0.7 \end{pmatrix}$$

$$K = min(\bar{C}, \bar{M}, \bar{Y}) = 0.4,$$

$$C = \frac{\bar{C} - K}{1 - K}, M = \frac{\bar{M} - K}{1 - K}, Y = \frac{\bar{Y} - K}{1 - K}$$

$$C = 0.67, M = 0, Y = 0.5$$

2.4: RGB to HSV

Color models
Converting RGB to HSV

- Conversion RGB -> HSV (from Gonzalez and Woods)
  1. $Compute\ White - ratio\ W = \min(R, G, B)$
  2. $(R', G', B') := (R - W, G - W, B - W)\ has\ only\ 2\ colorvalues <> 0$
  3. $Let\ B' = 0:\ Hue - the\ value\ lies\ between\ R\ and\ G:$
     $$H = G' * \frac{120}{R' + G'}$$
     $Let\ R' = 0:\ Hue - the\ value\ lies\ between\ G\ and\ B:$
     $$H = B' * \frac{120}{G' + B'} + 120$$
     $Let\ G' = 0:\ Hue - the\ value\ lies\ between\ B\ and\ R:$
     $$H = R' * 120/(R' + B') + 240$$
  4. $S = (\max(R, G, B) - W)/\max(R, G, B)$
  5. $V = \max(R, G, B).$

2.4: RGB to HSV

$W = \min(R,G,B) = \min(0.2,0.6,0.3) = 0.2$

Therefore,

$(R',G',B') = (R-W, G-W,B-W) = (0, 0.4,0.1)$

Since $R' = 0$,

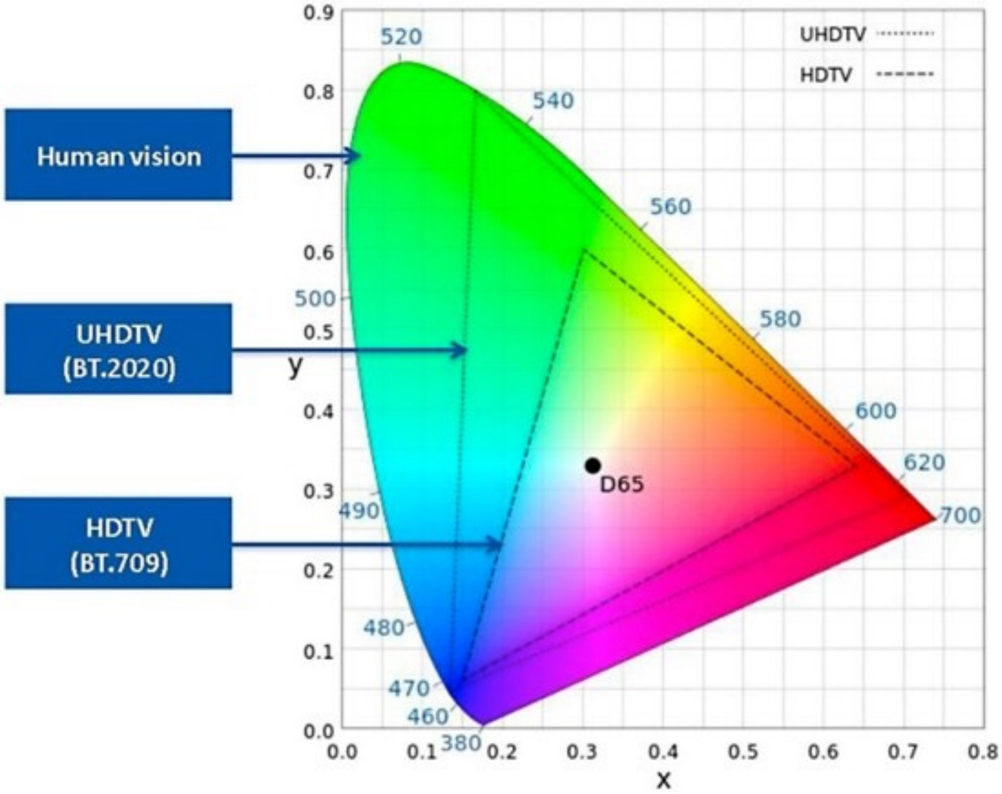
$H = (0.1 \times 120/0.5) + 120 = 144$ degrees

$S = (0.6 - 0.2)/0.6) = 0.66 = 66.7\%$,

$V = 0.6 = 60\%$.

3: Color Space

- A **color model** is a method of describing a color, a **color space** is the set of colors which can be displayed or reproduced in a medium



3.1: Color Space

There are multiple ways of doing the YCbCr↔RGB conversion. The general conversion is given by

```
Y  = Kr*R + Kg*G + Kb*B
Cb = (B-Y)/(1-Kb)
Cr = (R-Y)/(1-Kr) = R - G * Kg/(1-Kr) - B * Kb/(1-Kr)
```

and the other way around:

```
R = Y + Cr*(1-Kr)
G = Y - Cb*(1-Kb)*Kb/Kg - Cr*(1-Kr)*Kr/Kg
B = Y + Cb*(1-Kb)
```

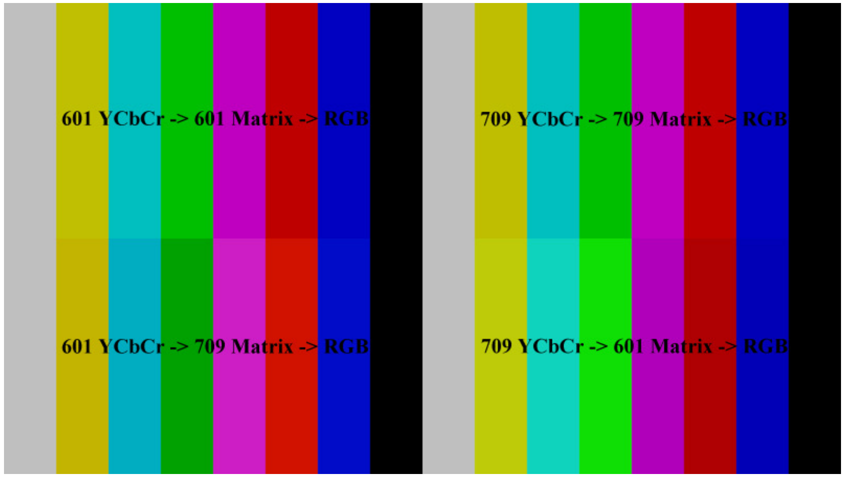
where

```
( 0.0 <= [Y,R,G,B] <= 1.0),
(-1.0 <= [Cb,Cr]   <= 1.0) and
Kr + Kg + Kb = 1
```

The red, green and blue coefficients (`Kr,Kg,Kb`) are standardized in specifications. The most common conversion coefficients are given below:

Standard	Kr	Kg	Kb
Rec.601/BT.601 [2], SMPTE 170M [3]	0.299	0.587	0.114
FCC [2]	0.300	0.590	0.110
Rec.709/BT.709 [2]	0.2126	0.7152	0.0722
SMPTE 240M [4]	0.212	0.701	0.087

3.1: Color Space



- **Color Model of Video:**
  - YCbCr
- **Conversation on Playback:**
  - YCbCr → RGB
- **Different coefficients on conversation**
  - **BT.601** Typically on SD Video
  - **BT.709** Typically on HD Video
  - **BT.2020** Typically on HDR Video
- **What went wrong with 2nd video?**
  - Video in YCbCr(BT.709)
  - Player chose coefficients based on resolution (BT.601)

3.2: CIE XYZ vs CIE L*a*b

Adapted from: http://web.mit.edu/6.813/www/sp18/classes/15-color/

CIE XYZ	CIE L*a*b
• CIE XYZ is an *additive*, *linear light* colorspace useful for calculating color mixtures, but is not **perceptually uniform**. • The distance apart of two colors in XYZ does not directly relate to how similar or different they appear. • *Chromatic adaptation* is also not well shown in XYZ.	• Oriented towards the physiological properties of human (color) perception. • The distance between two colors in Lab color space accurately predicts how similar or different they look. • All colors are chromatically adapted to a color temperature of 5000K (D50) so that measurements made under different conditions can be compared with each other.