

# An introduction to color and metamerism



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Color science workshop 2021-12-15

UVA C&R master-1

## Metameric retouches...



Source: Berns (2000) The Science of Digitizing Two-Dimensional Works of Arts for Color-Accurate Image Archives

## PART 1 - SPECTRAL THINKING



Geordi La Forge with his spectral glasses

# Precise Color Communication



KONICA MINOLTA

PRECISE COLOR  
COMMUNICATION

COLOR CONTROL FROM PERCEPTION TO INSTRUMENTATION



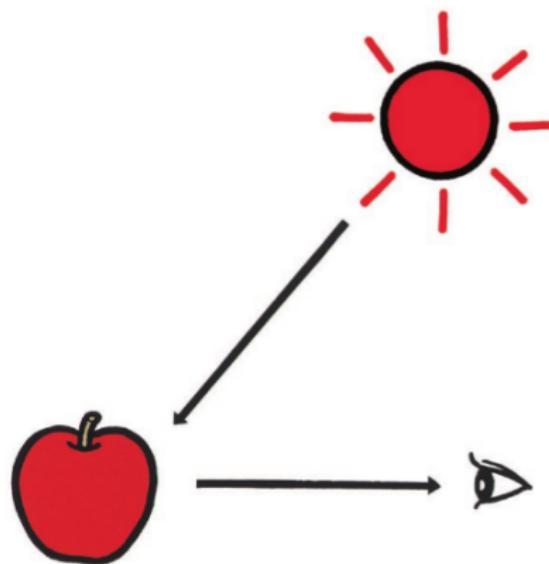
The best (short) online introduction into color

Why does an apple look red?



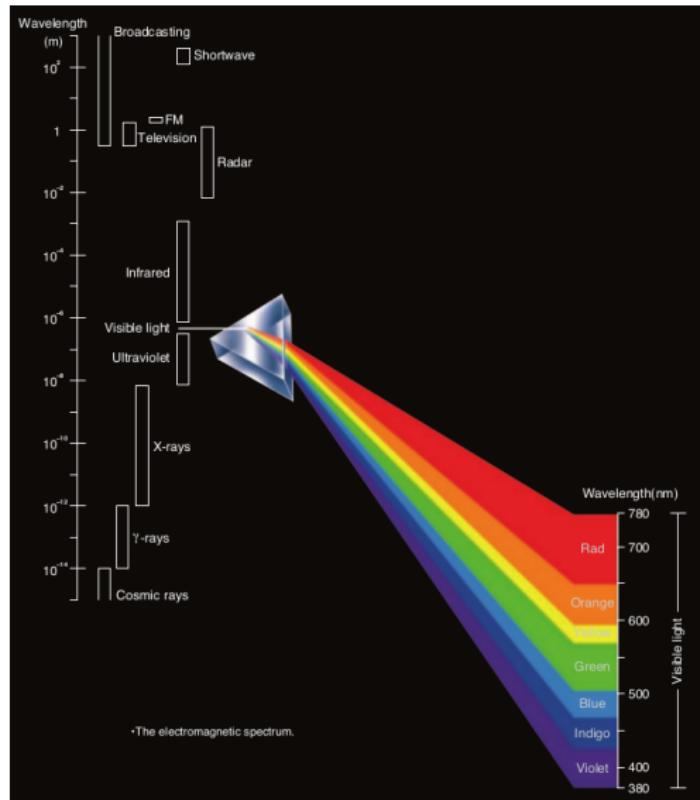
Can someone turn on the light?

## Light source - object - observer



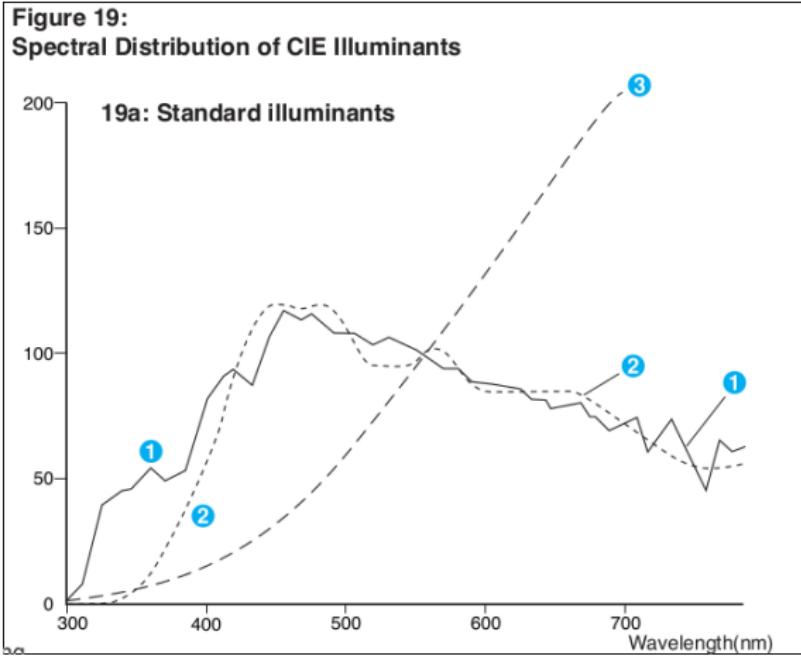
The color triangle

# The electromagnetic spectrum



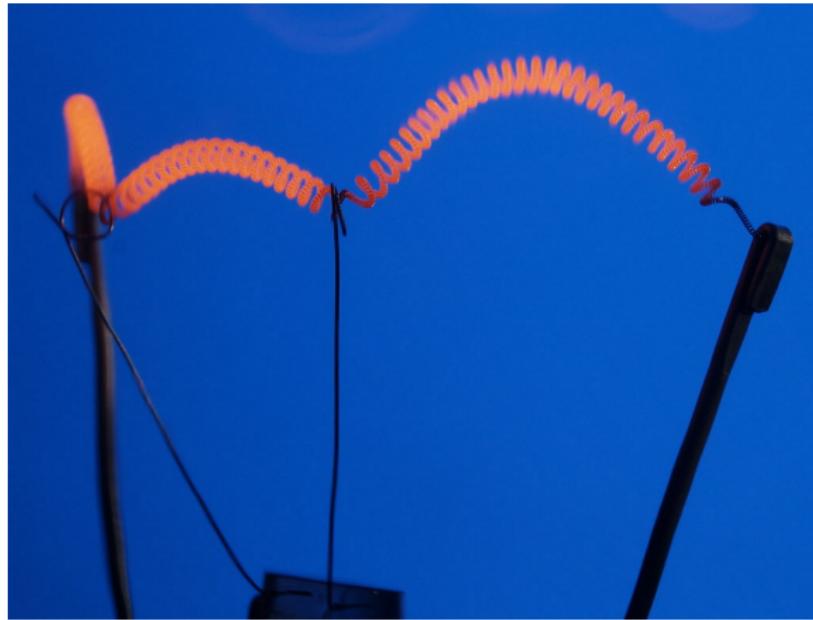
The visible spectrum between 400-700 nm

# CIE standard illuminants



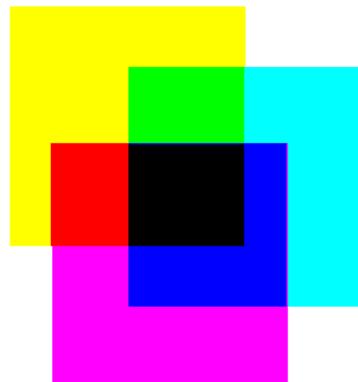
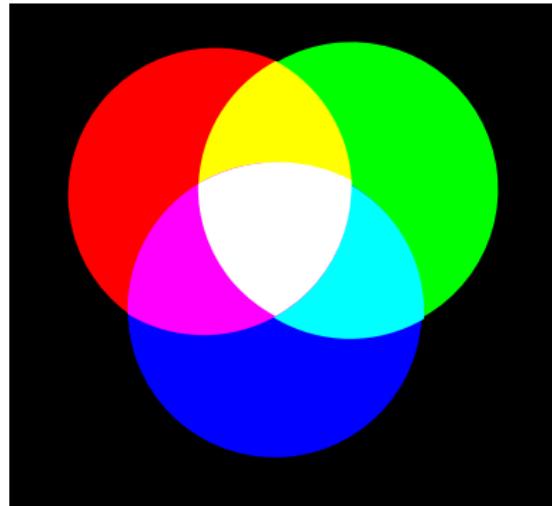
CIE standard illuminants D65(1), C(2) and A(3)

## Black body radiation



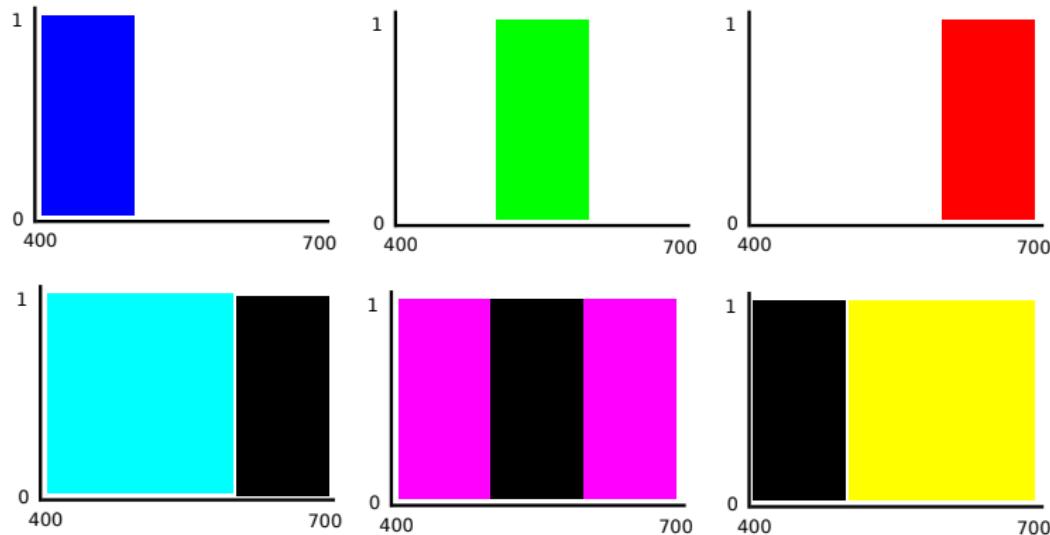
A glowing hot Tungsten filament

# Color mixing



Additive and subtractive color mixing

## Block spectra



Idealised block spectra for blue, green, red  
and cyan, magenta and yellow

# The reflectance of an apple

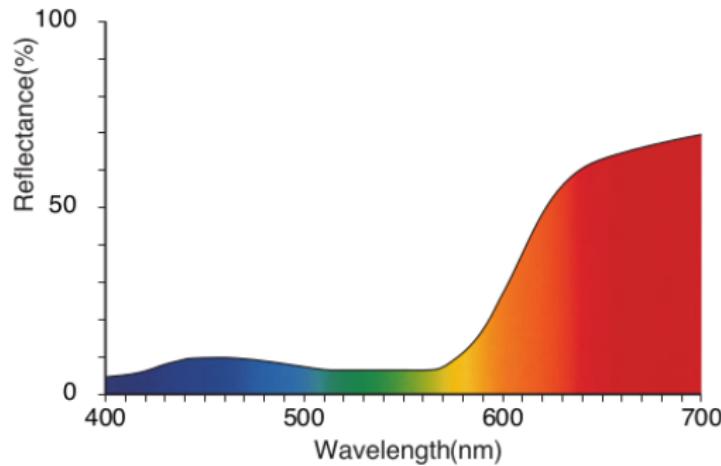
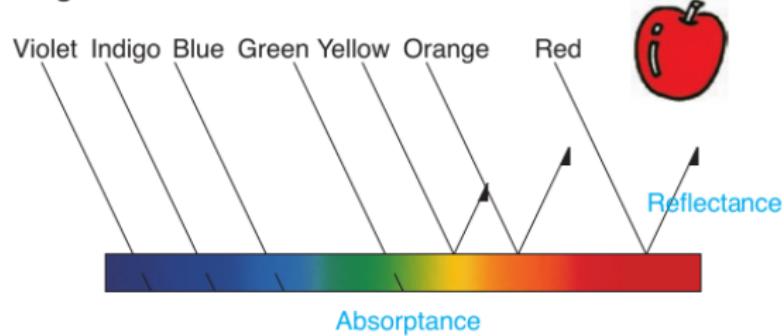
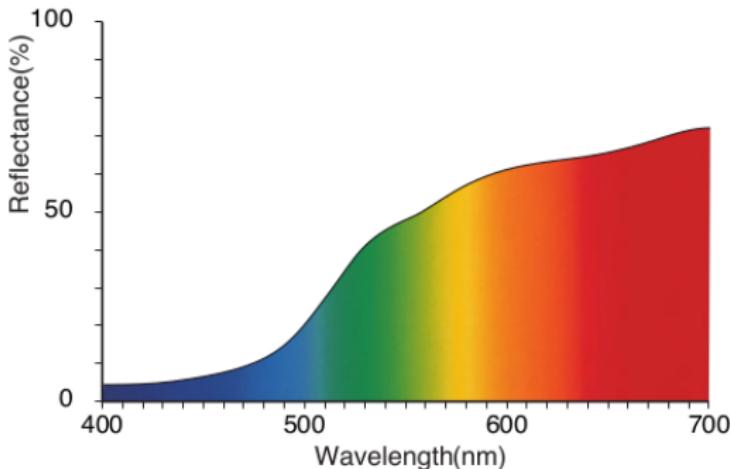


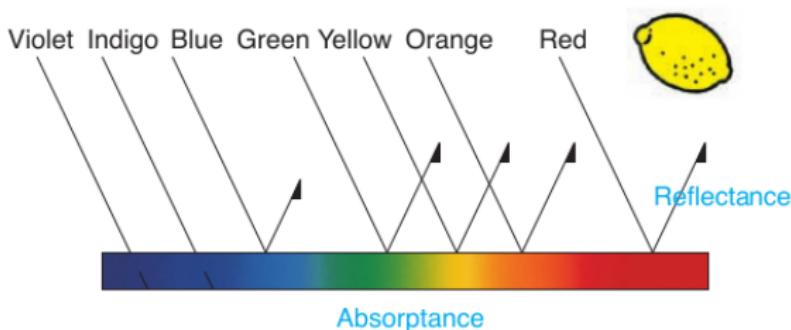
Figure 17b:



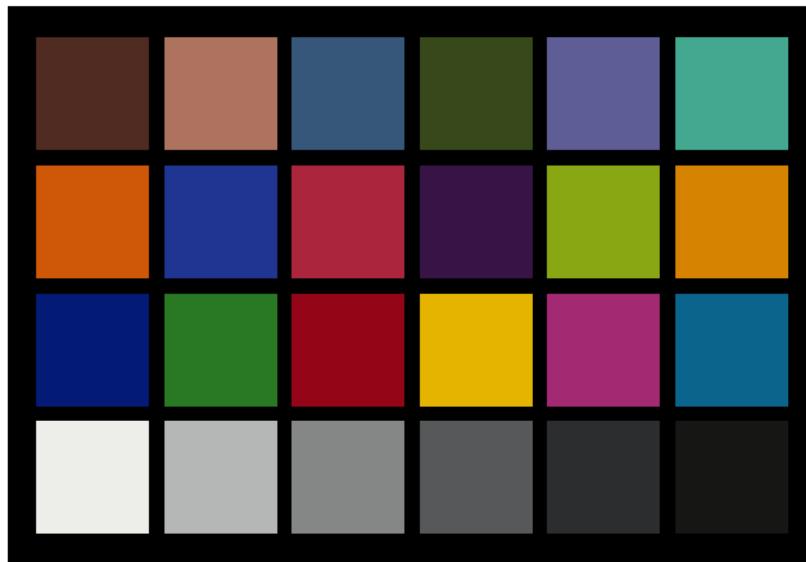
# The reflectance of a lemon



**Figure 18b:**

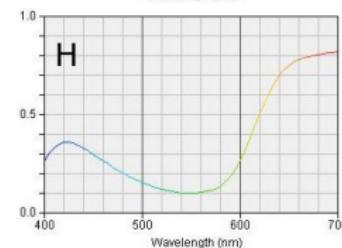
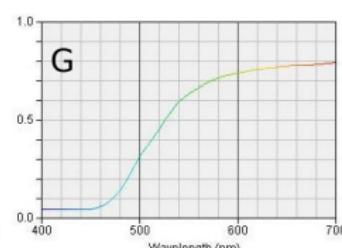
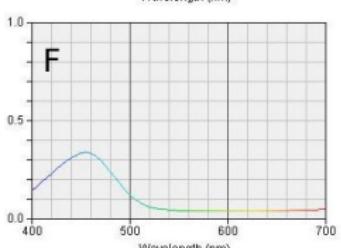
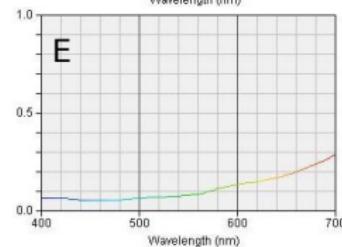
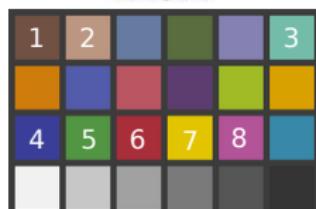
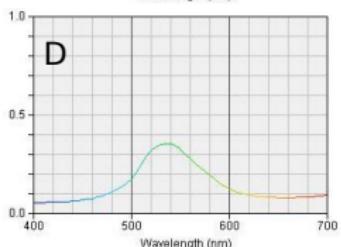
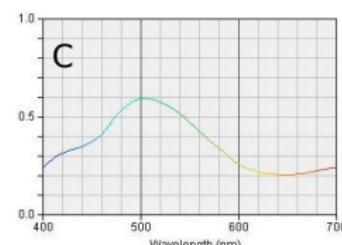
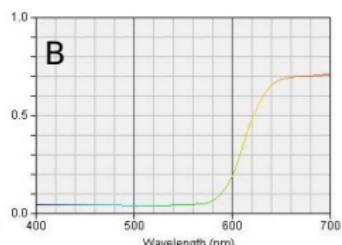
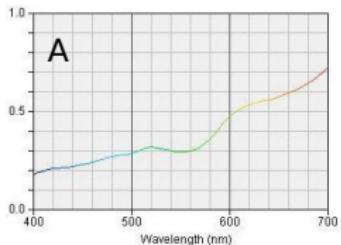


## Exercise 1: Spectral Thinking

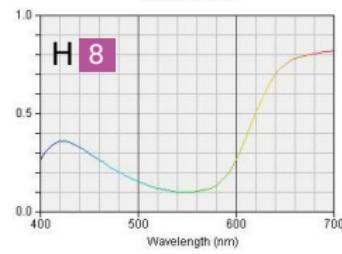
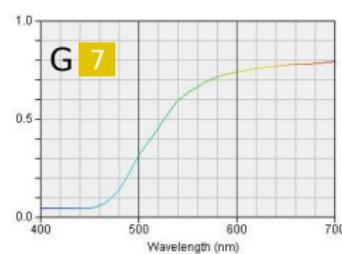
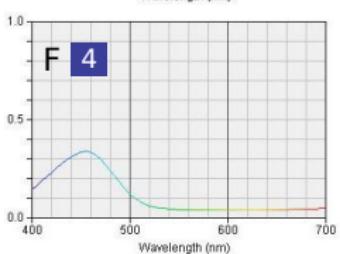
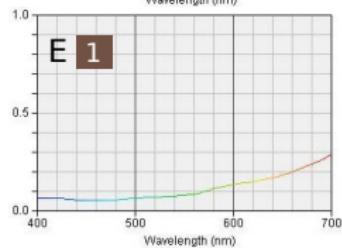
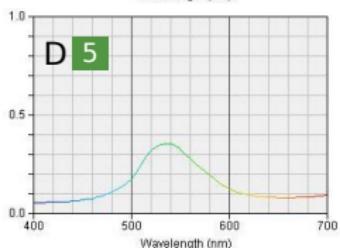
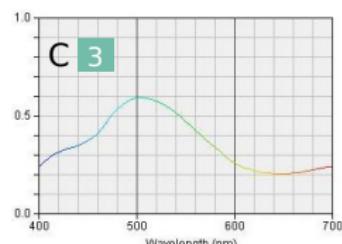
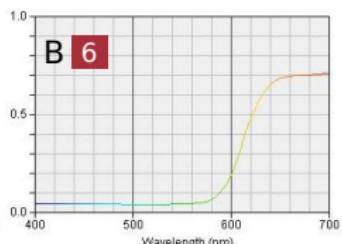
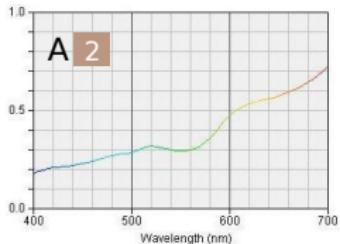


The X-Rite Color Checker card

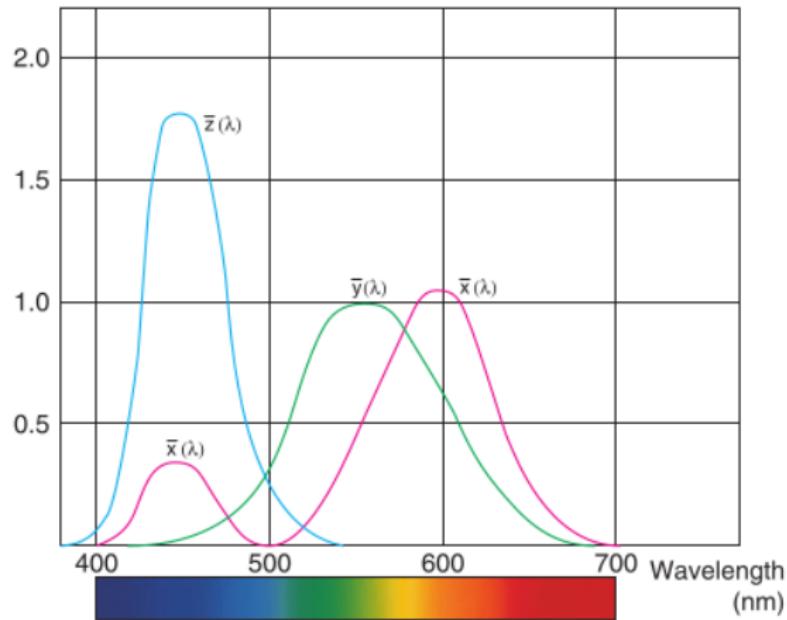
# Which spectrum is which color?



# Answers

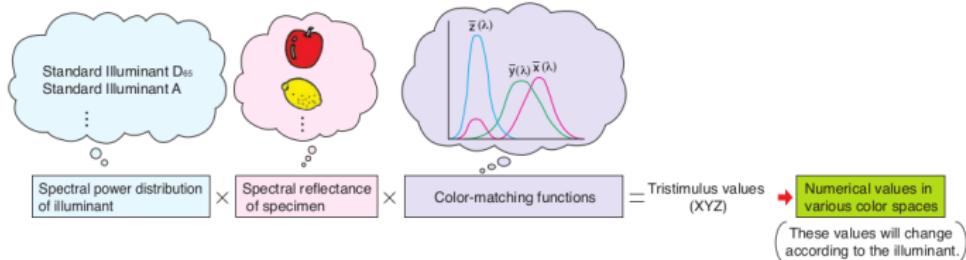


# The human eye



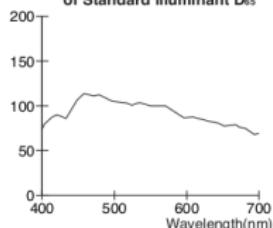
Spectral sensitivity functions for the three types of cone cells in the human eye

# Apple and lemon

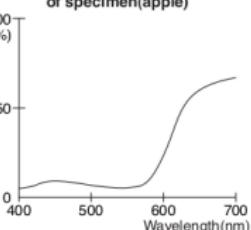


## Example 1

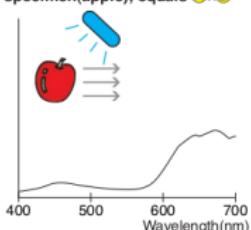
A Spectral power distribution of Standard Illuminant  $D_{65}$



B Spectral reflectance of specimen(apple)

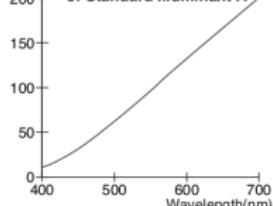


C Spectral power distribution of light reflected from specimen(apple); equals A'x(B)

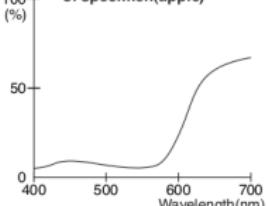


## Example 2

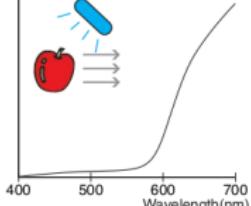
A' Spectral power distribution of Standard Illuminant A



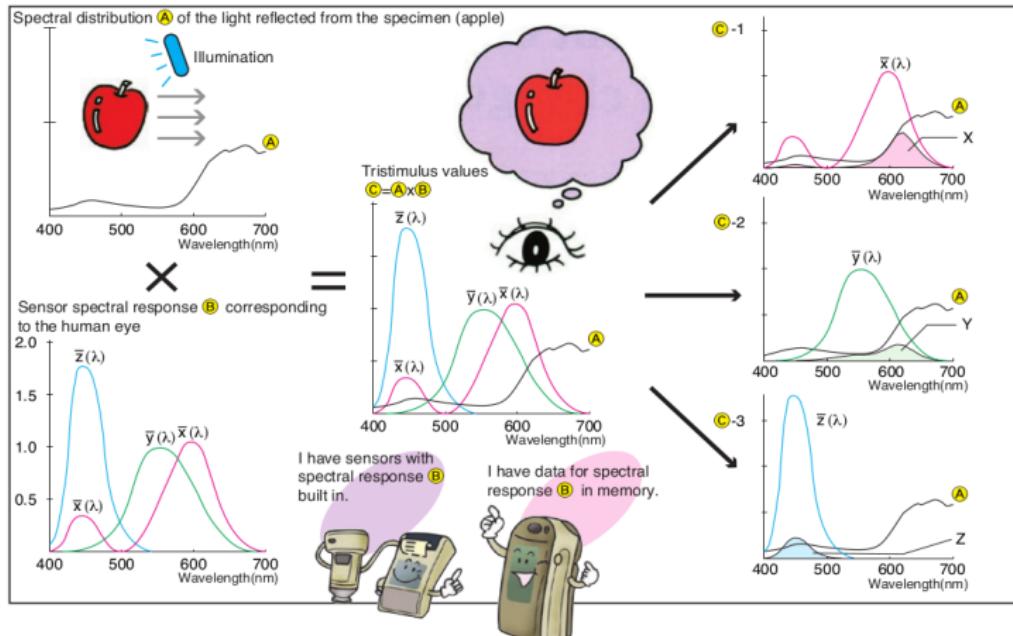
B Spectral reflectance of specimen(apple)



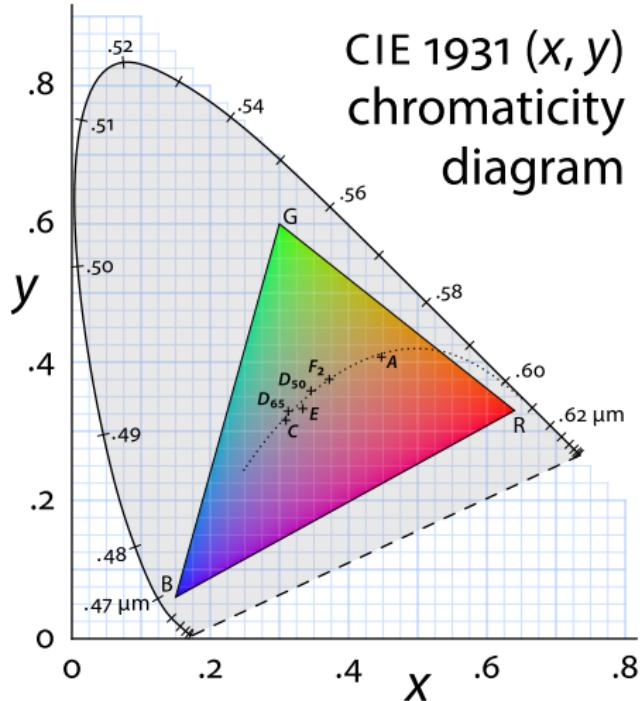
C' Spectral power distribution of light reflected from specimen(apple); equals A'x(B)



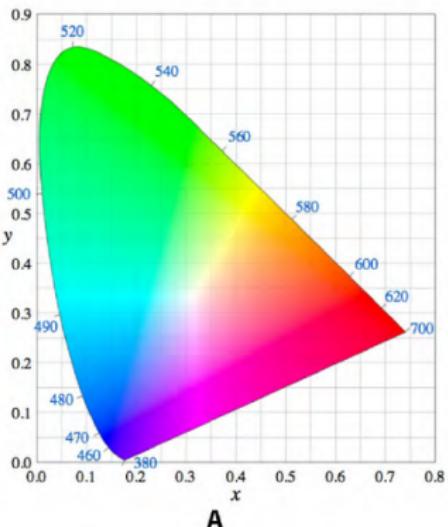
# Tristimulus XYZ



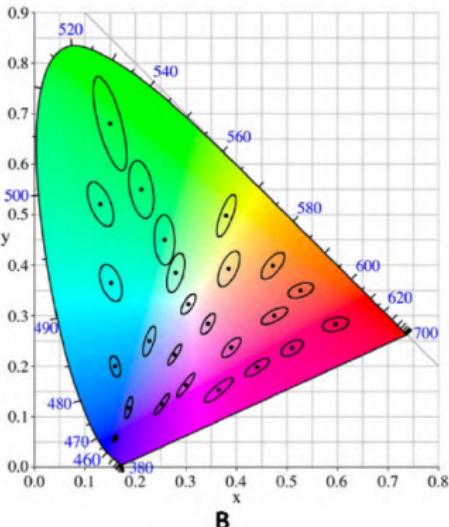
# The CIE chromaticity diagram...



... is a non-uniform color space



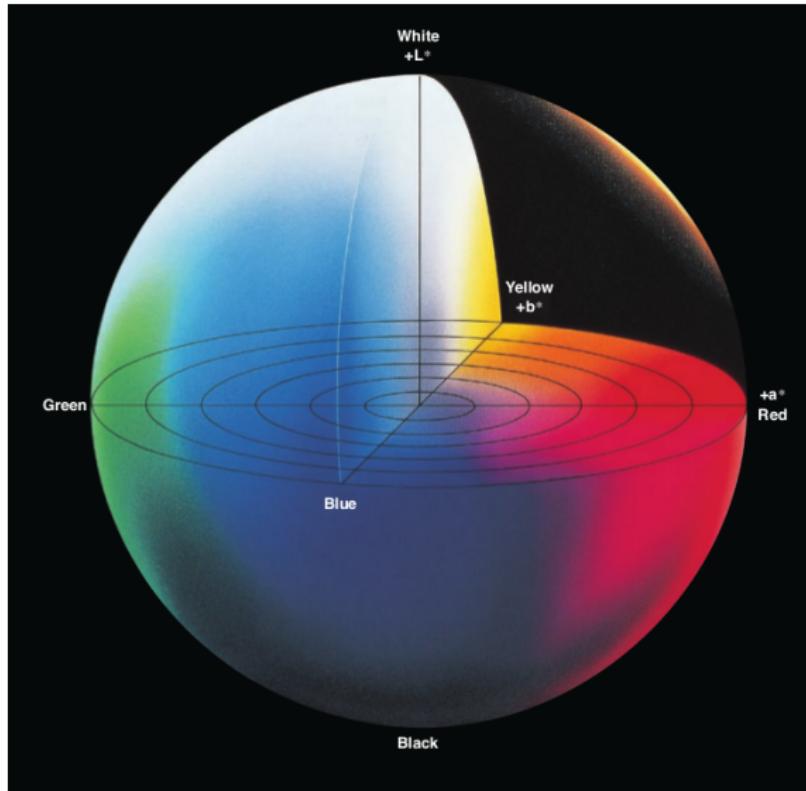
A



B

MacAdams ellipses showing just perceptible color differences

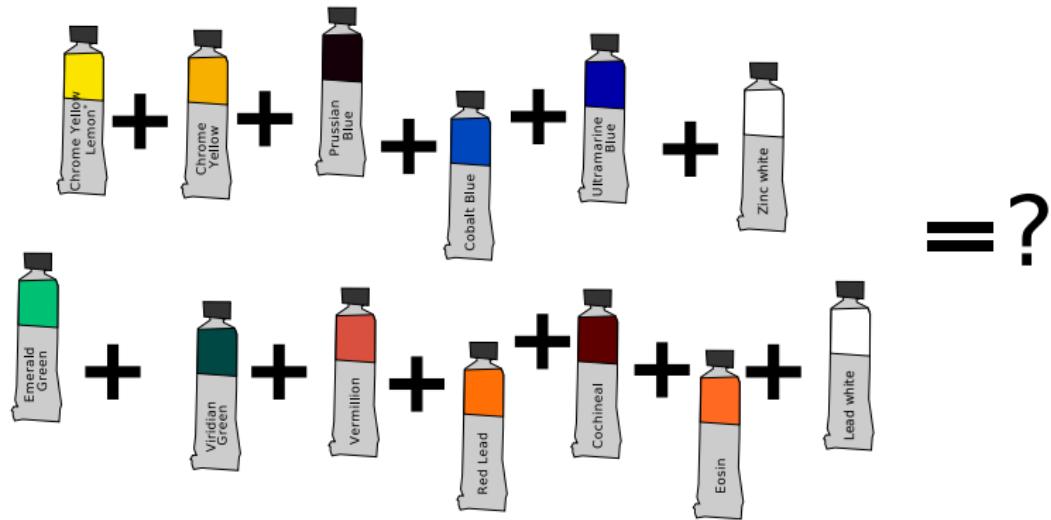
# Uniform color space $CIE - L^*a^*b^*$



## Color difference deltaE

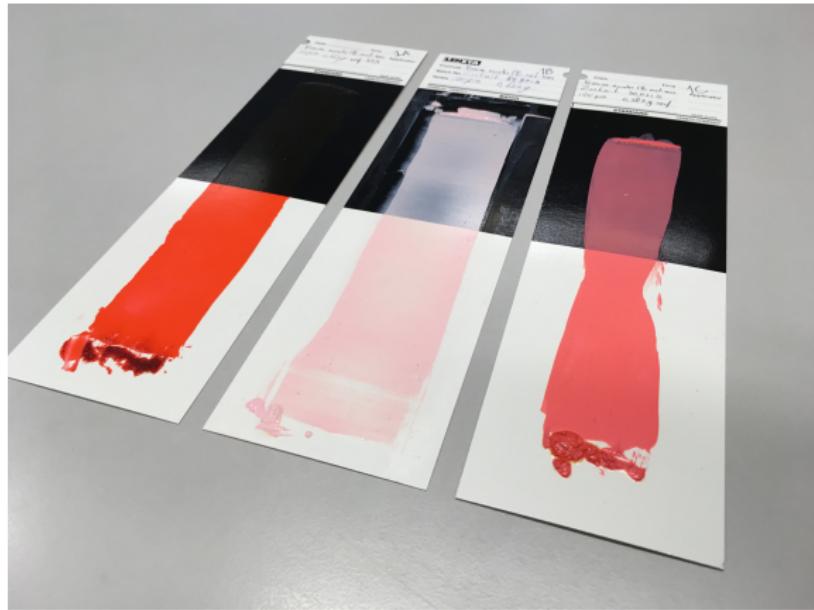
$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

## PART 2 - COLOR SCIENCE OF COLORANTS



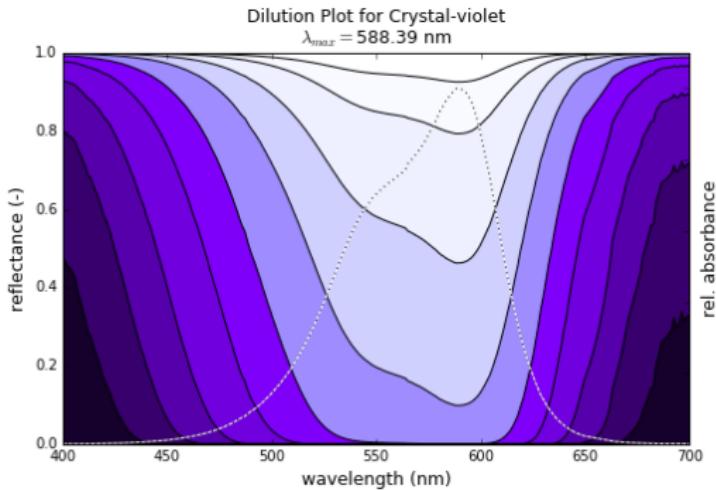
Reconstructing van Gogh's Field with Irises near Arles  
<https://www.youtube.com/watch?v=TkkEMimZmSs>

# Transparency , translucency and opacity



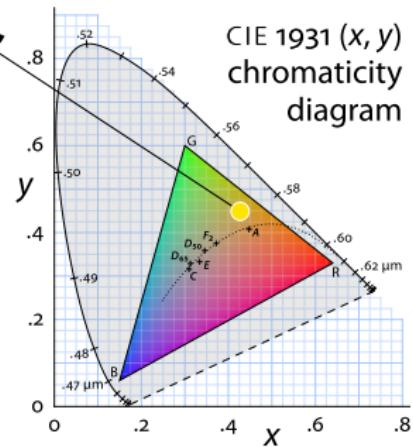
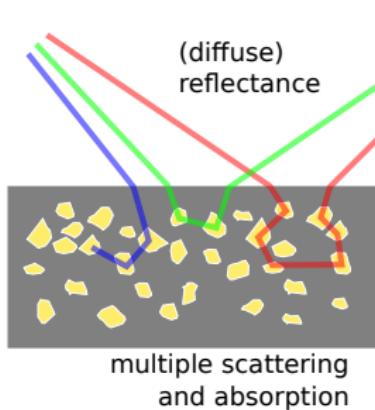
Transparent on black is black.

# Why are all inks black?



Subtractive mixing of crystal-violet dye solution.

# Multiple scattering and absorption



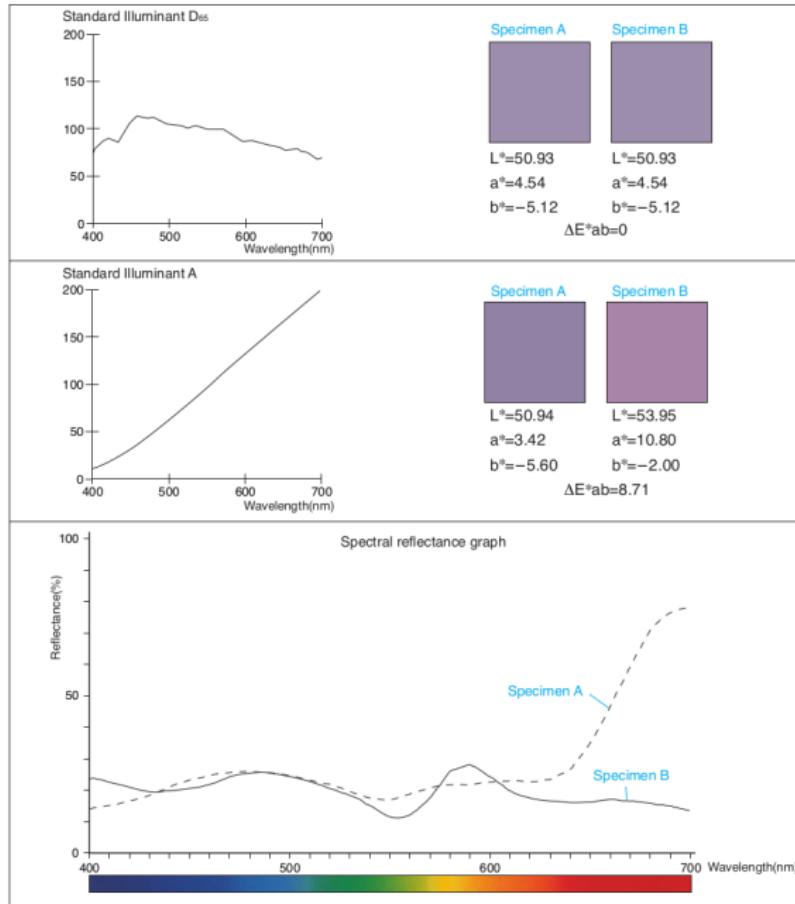
Multiple scattering and absorption in paints

## Kubelka-Munk theory

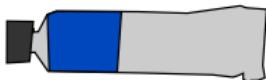


A translucent paint application modeled with KM-theory

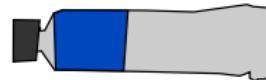
# Retouching and metamerism



## Exercise 2: Choosing blue to make green



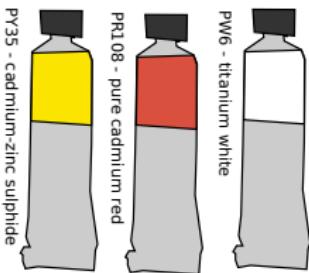
PB15 - phtalocyanine blue



PB28 - cobalt blue



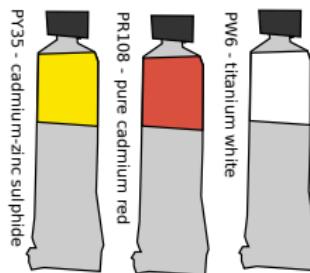
X



PY35 - cadmium-zinc sulphide

PR108 - pure cadmium red

PW6 - titanium white



PY35 - cadmium-zinc sulphide

PR108 - pure cadmium red

PW6 - titanium white



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