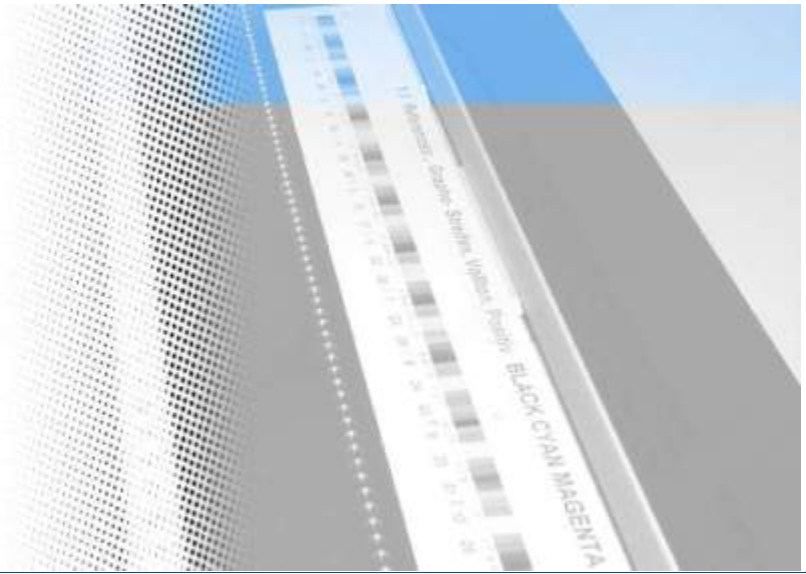
Color + Quality

1. Description of Color

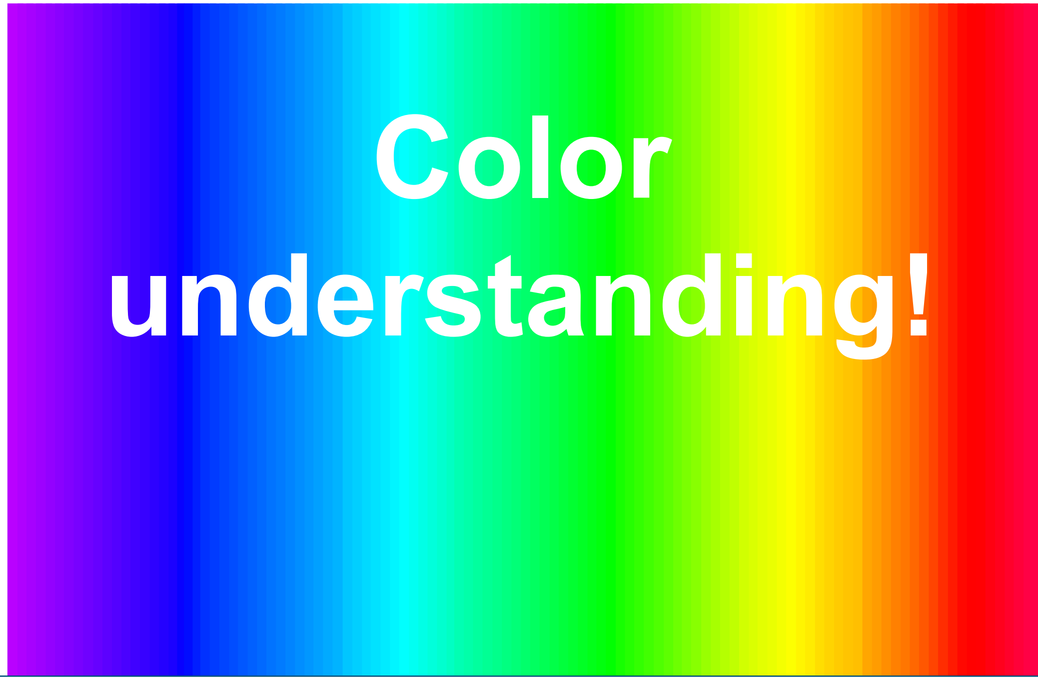
Agenda

- **Part 1: Description of color**
  - Sensation of color
  - Light sources
  - Standard light
  - Additive und subtractive color mixing
  - Complementary colors
  - Reflection and absorption
- **Part 2: Densitometry and colorimetry**
- **Part 3: Color systems**
- **Part 4: Observation conditions**



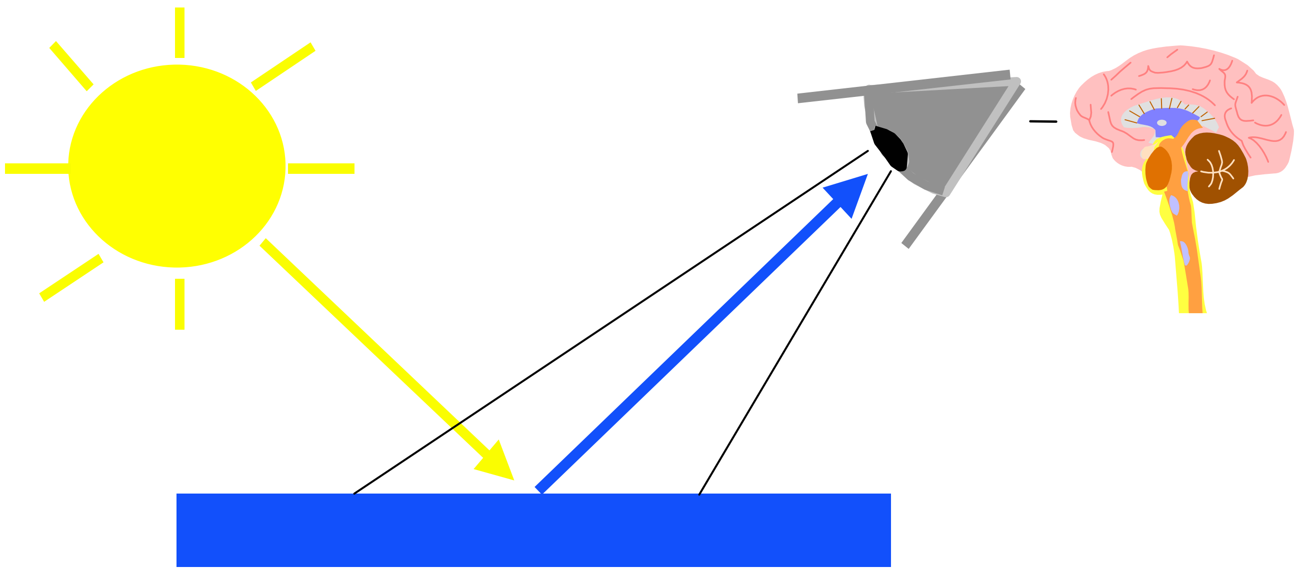
Description of color

- What makes colors visible? How does light affect perception?
- Light is the basic precondition for perceiving color. A light source is a body which emits light. However, most objects in our environment do not emit light.
- Illuminated objects are reflectors. They have no color of their own. Objects only reflect the light coming from the source. They are colorless.



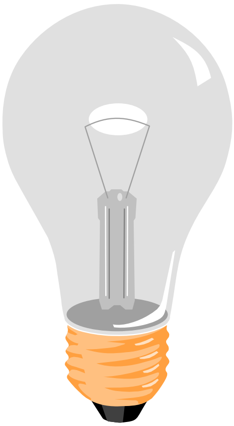
Description of color

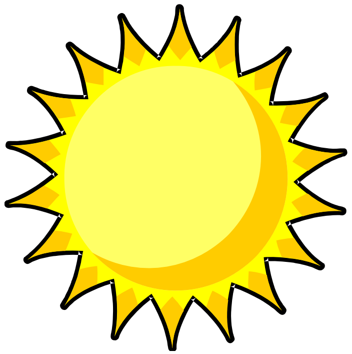
- An object which does not emit light has no color of its own. The impression of color only arises when it reflects light which shines on it.
- Perception of color is affected by the spectrum of the lighting, the reflected color of the object, and the characteristics of the viewer.



Light sources

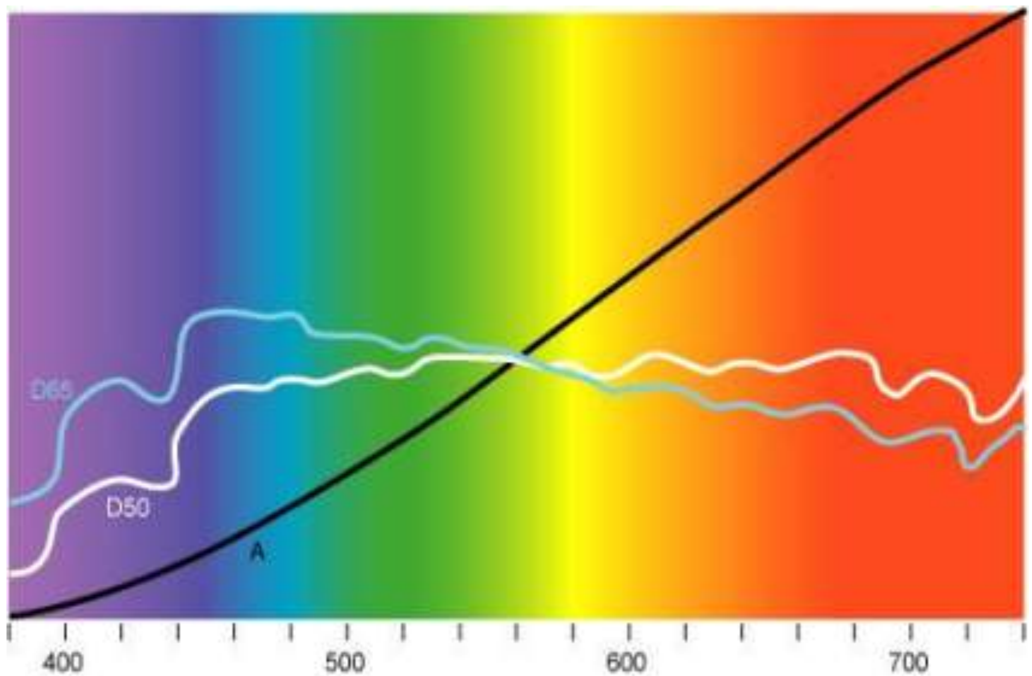
- The light source under which the object observes gives it its color.
- The color of the light is defined by its spectral composition.





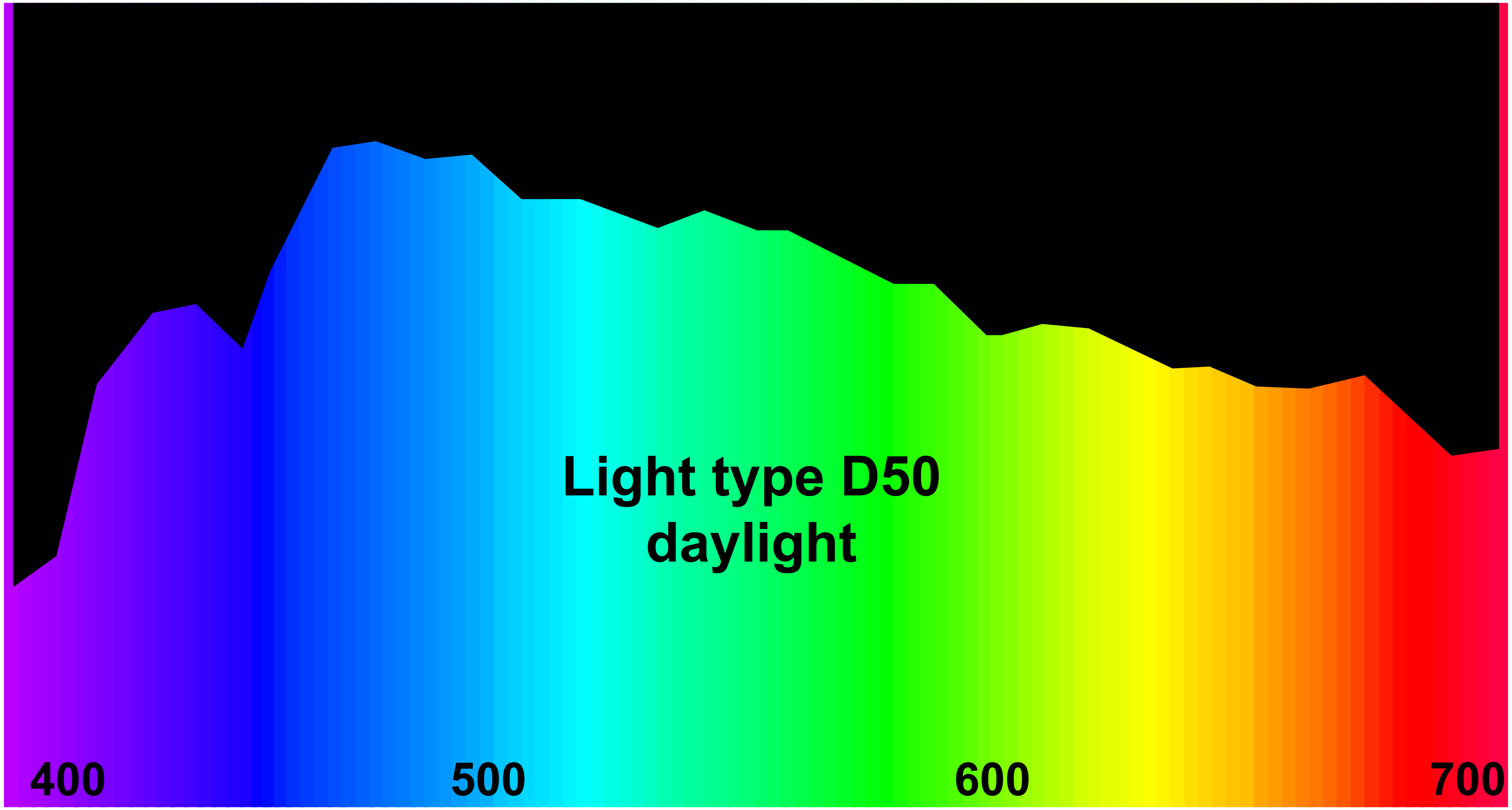
Standard light

- White light consists of light waves of various wavelengths. In blue light, the short wavelengths are predominant, and long wavelengths are predominant in red light.
- The spectral composition, and thus the color perception, depends on the light conditions.
- For standardisation, the radiation distribution is specified for various types of light in the range from 380 to 780 nanometres.



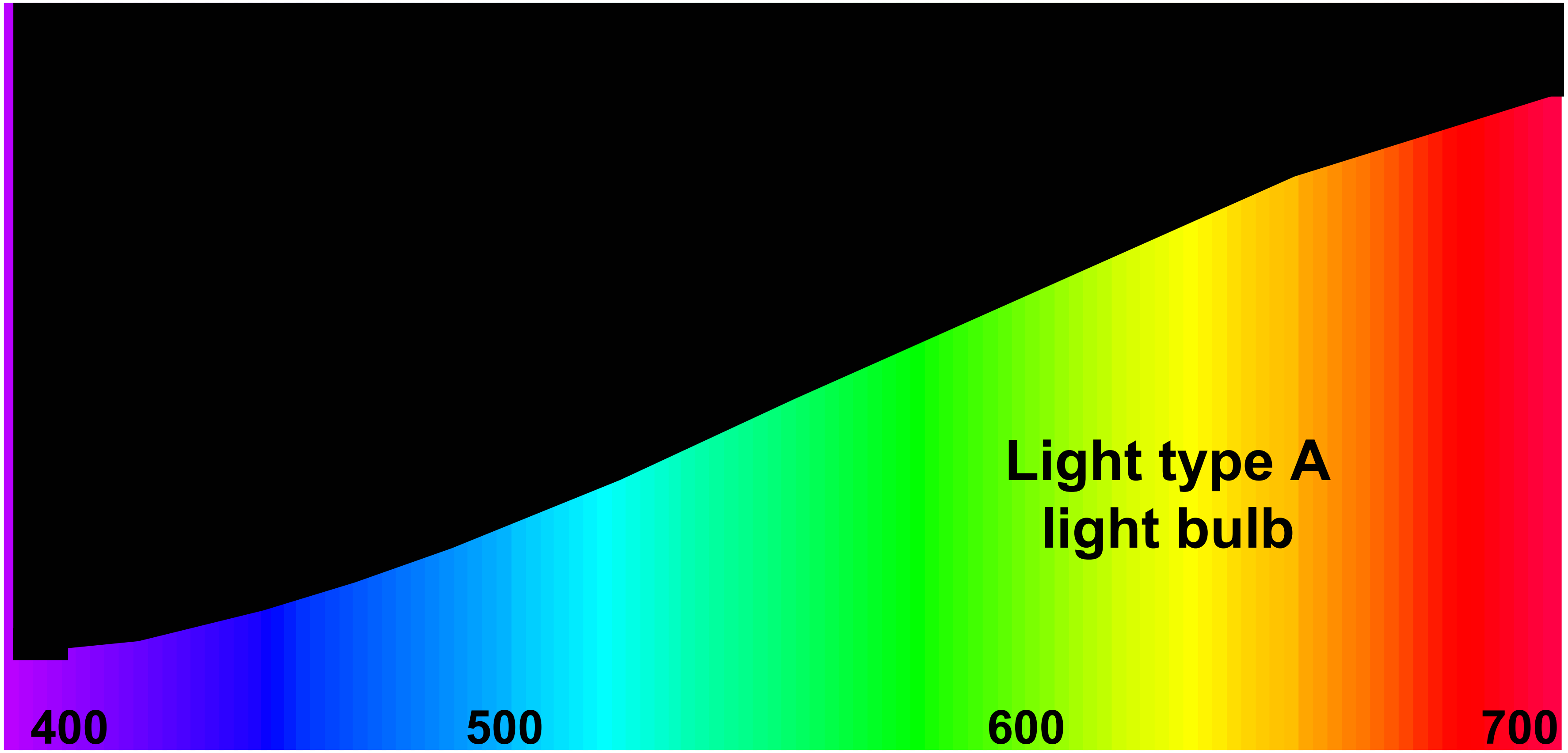
Light type D50

- The illustrations show the spectral distribution for the standardised light type D50.



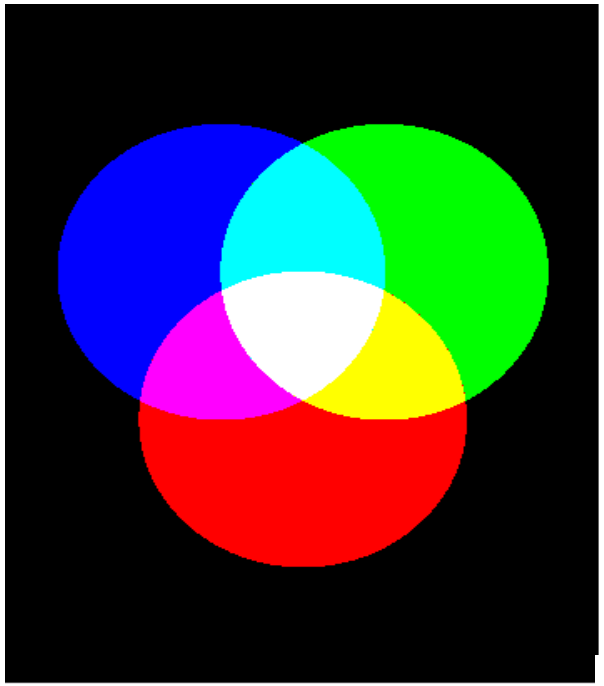
Light type A

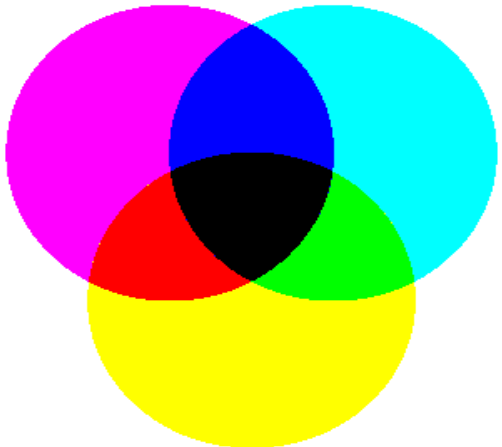
- Standardised light type D50 is similar to average daylight and has the highest intensity in the blue range. In standardised light A, the highest intensity is in the red range, which means it has a reddish hue.



Additive and subtractive color mixing

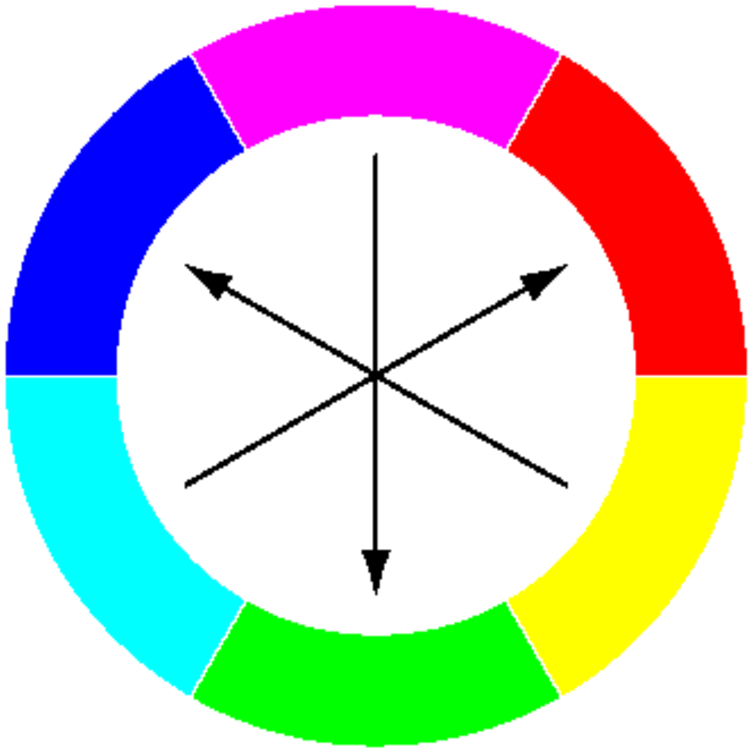
- With additive color mixing, differently colored light is superimposed. If the primary colors red, green and blue are superimposed, the result is white.
- Subtractive color mixing uses the primary colors cyan, magenta and yellow. With subtractive color mixing, various color components are taken away from white light. If all the components are subtracted, the result is black.





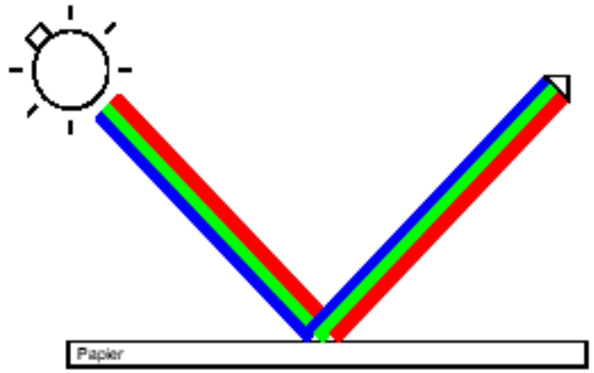
Complementary colors

- In a color wheel, complementary colors are depicted opposite each other. Complementary colors are defined as pairs of colors which, when added to each other, become white. In subtractive mixing, complementary colors become black.
- Printing ink is made of transparent substances which act as color filters.
- In order to measure printing colors using a densitometer, the filter with the complementary color is used.

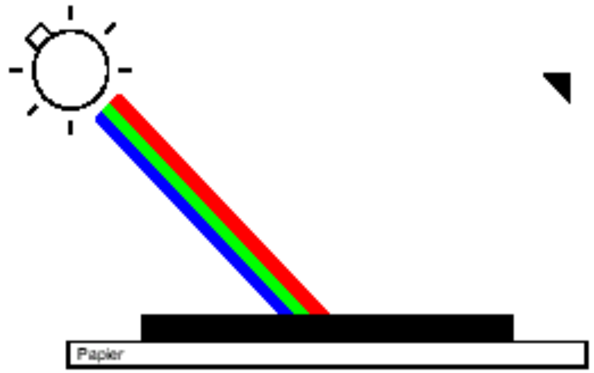


Reflection und absorption

- If white light shines on an ideal white surface, all color components are reflected, and the observer sees white.

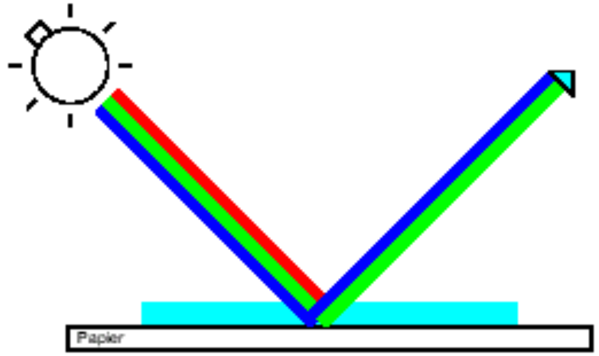


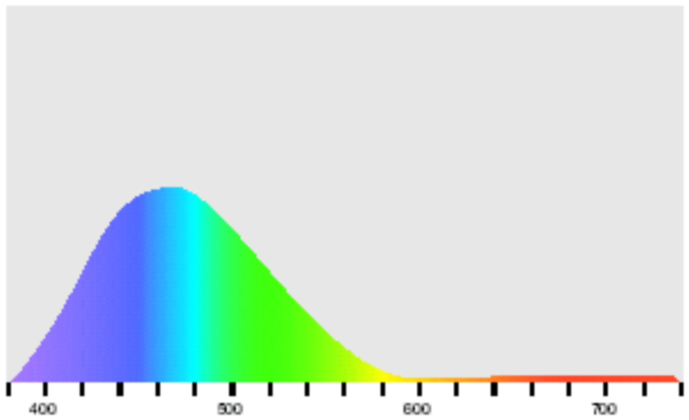
- If white light shines on a black surface, all color components are absorbed, and the observer sees black.



Reflectance Cyan

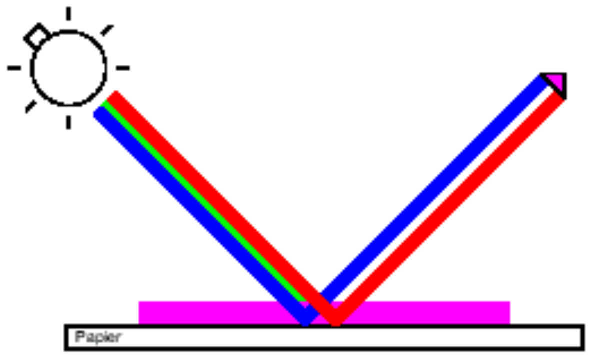
- If white light shines on cyan printer's ink, the complementary color red is absorbed.
- The blue and green components are reflected and mixed to appear cyan.

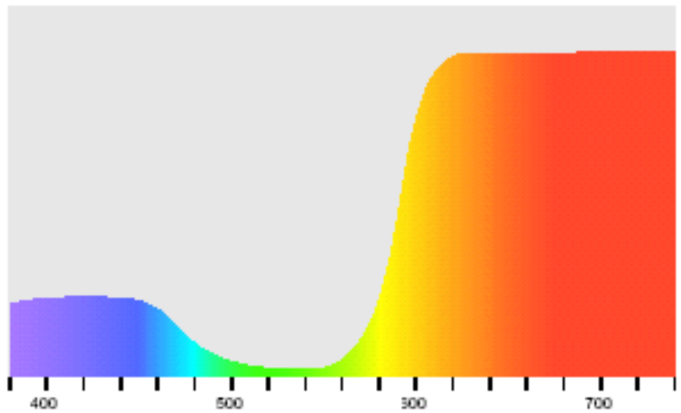




Reflectance Magenta

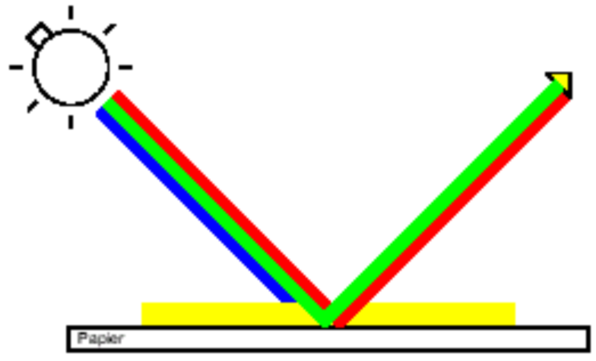
- If white light shines on magenta printer's ink, the complementary color green is absorbed.
- The blue and red components are reflected and mixed to appear magenta.

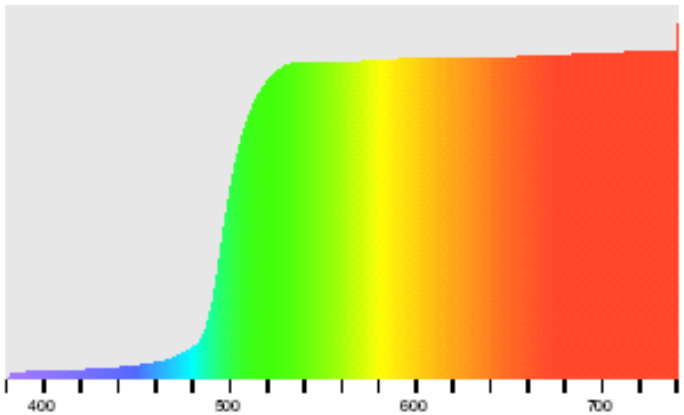




Reflectance Gelb

- If white light shines on yellow printer's ink, the complementary color blue is absorbed.
- The green and red components are reflected and mixed to appear yellow.





Part 2: Densitometry and colorimetry

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  - Ink film thickness and density
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  - Colorimetry in printing
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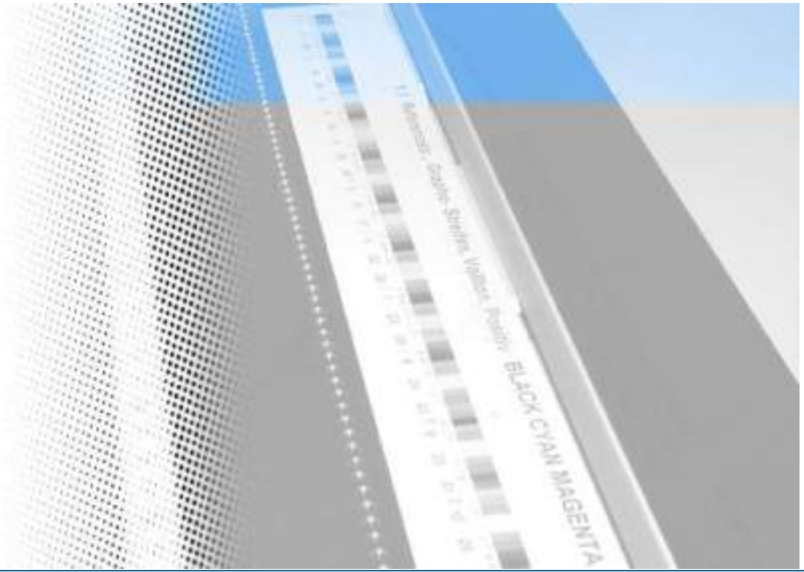

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Color + Quality

2. Densitometry and colorimetry

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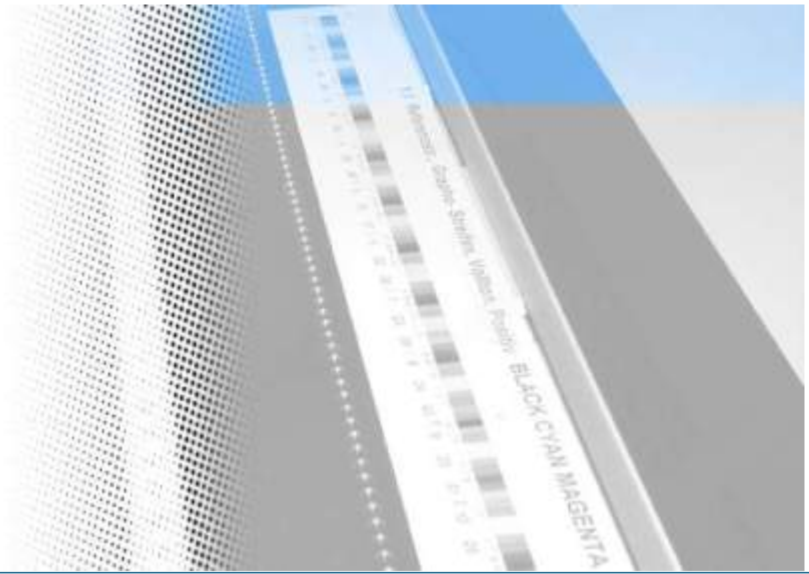


Densitometry and colorimetry

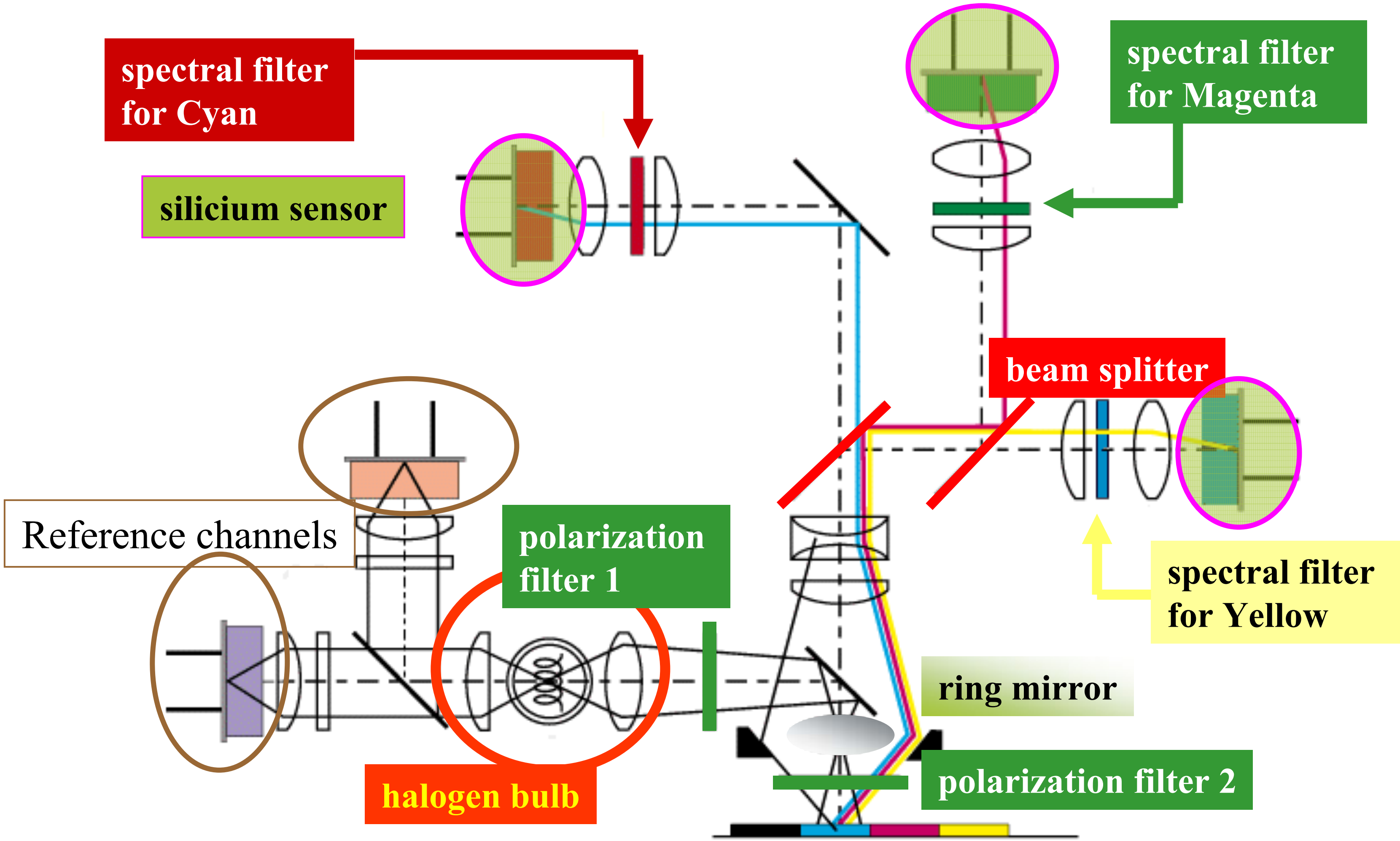
- Densitometry has proven to be the ideal measuring technique for regulating color in printing, because there`s a direkt relationship between ink film thickness and density.

  but...

- Density as a measured value does not represent the optical appearance of the color on the printed sheet. The density measurement does not give any definite information on color impression.

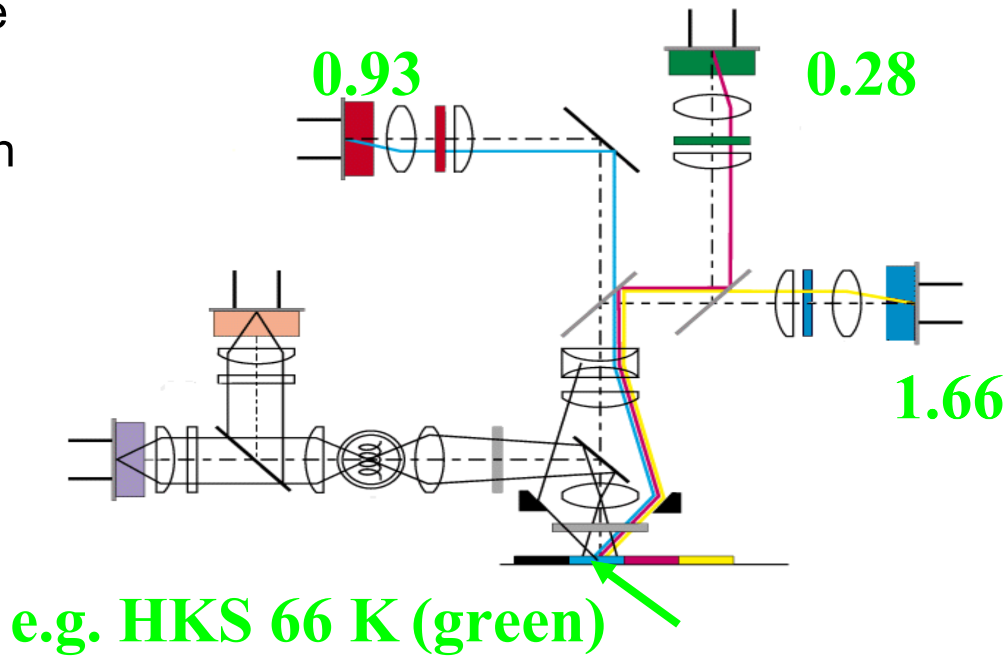
- Final assessment of the color is only possible using a colormetric measurement, which simulates the human perception.

Measuring principle of a densitometer



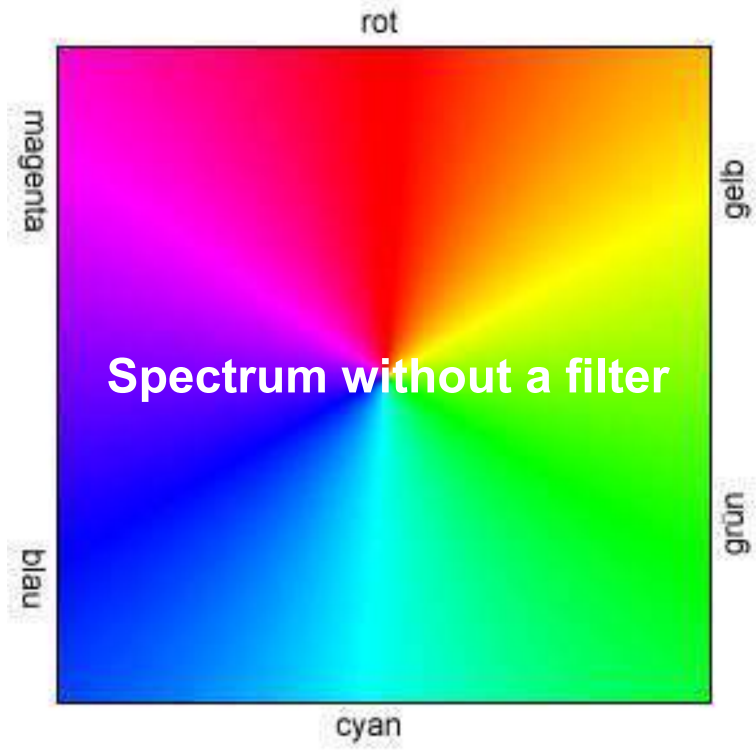
Measuring principle of a densitometer

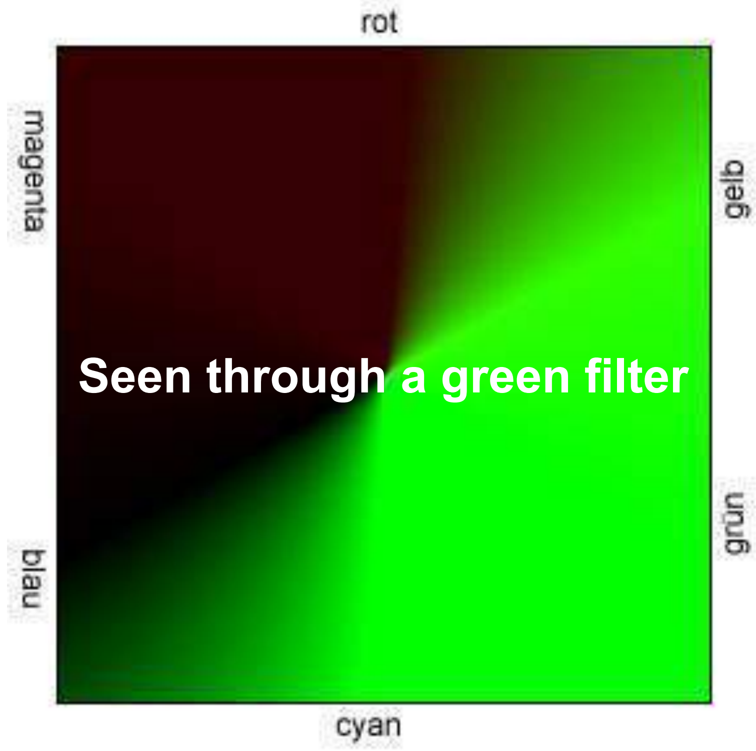
- At each measurement, simultaneous individual measurements are carried out in the 3 measuring channels and 2 reference channels.
- The individual measurements in the reference channel are for comparison.
- It provides ring-type illumination of the printing control strip at an angle of 45°. This compensates for predominant directions on the surface of the printing material.
- The three light beams are each passed through one of the interference filters and the amount of light which passes through is measured by a silicon detector.



Filter effects

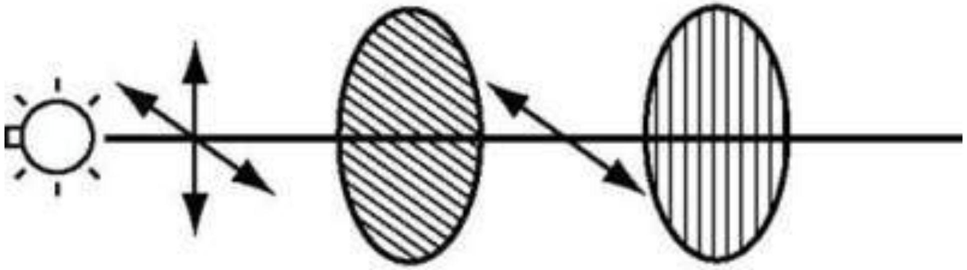
- Color filters in the ray path of a densitometer restrict the light to the wavelengths relevant for the printed color in question. As well as the basic rules of filter effects, a filter lightens its own color and darkens the complementary colors. The densitometer is used to calculate the measured ink film.





Polarization filter

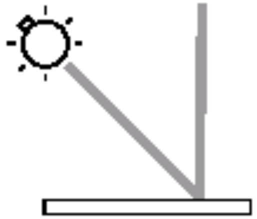
- Polarization filters suppress the surface gloss.



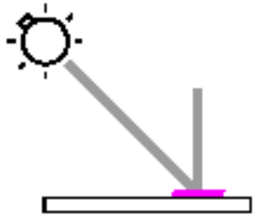
- With polarization filters a greater linearity is also achieved between ink film thickness and measured density, i.e. equal alteration of film thickness always produces equal alteration in density value.

Densitometric readings

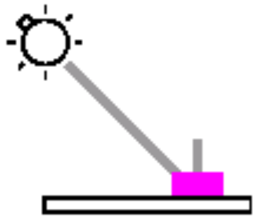
- The optical density is derived from the remission
- Calculating the density:
  D = - lg (β)
  D = lg 1/ β
- The less the reflectance, the greater is the ink film thickness and the (logarithmic) density.



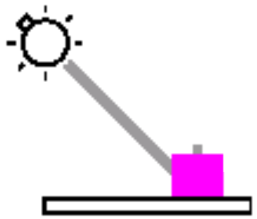
Density = - lg 0.9 = 0.05
Reflectance 90%



Density = - lg 0.5 = 0.30
Reflectance 50%



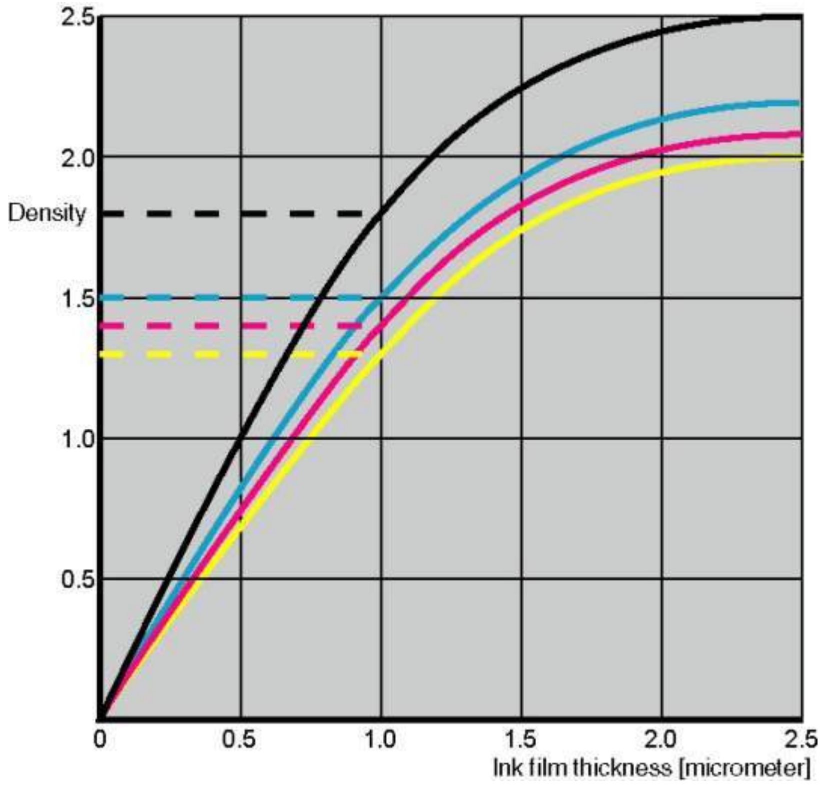
Density = - lg 0.1 = 1.00
Reflectance 10%



Density = - lg 0.01 = 2.00
Reflectance 1%

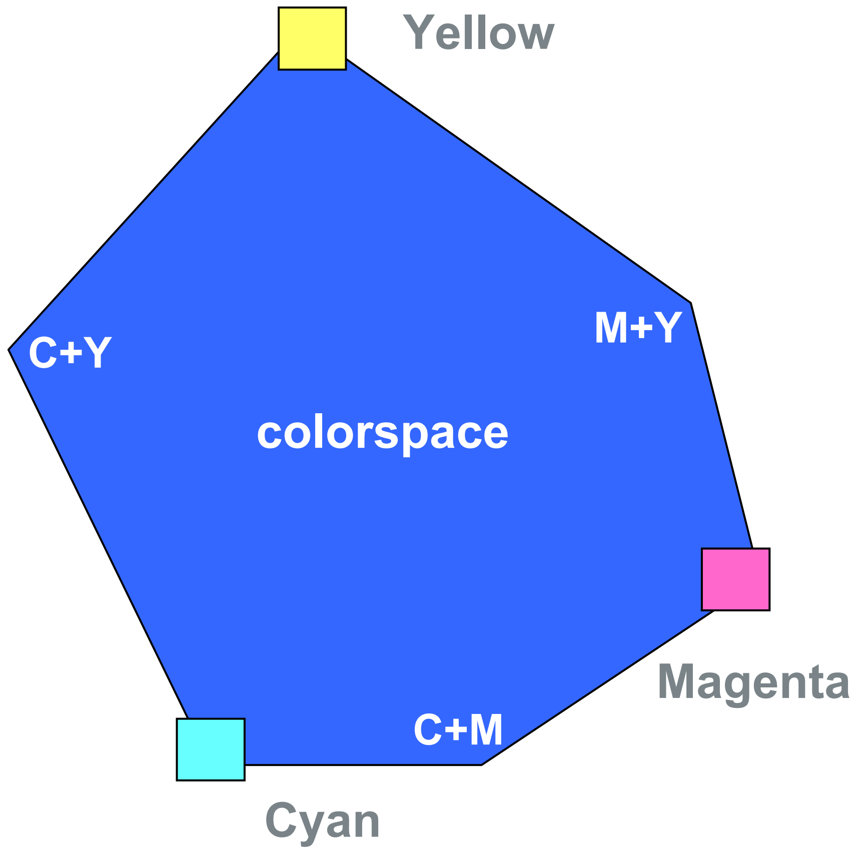
Ink film thickness and density

- In the range of normal film thicknesses for process colors (approx. 1/1000 mm) there is an almost linear relationship between density and film thickness.
- This means there is also a direct relationship to the ink slide opening.
- Therefore, the densities are highly suitable for recording and controlling the film thicknesses on the printed sheet.



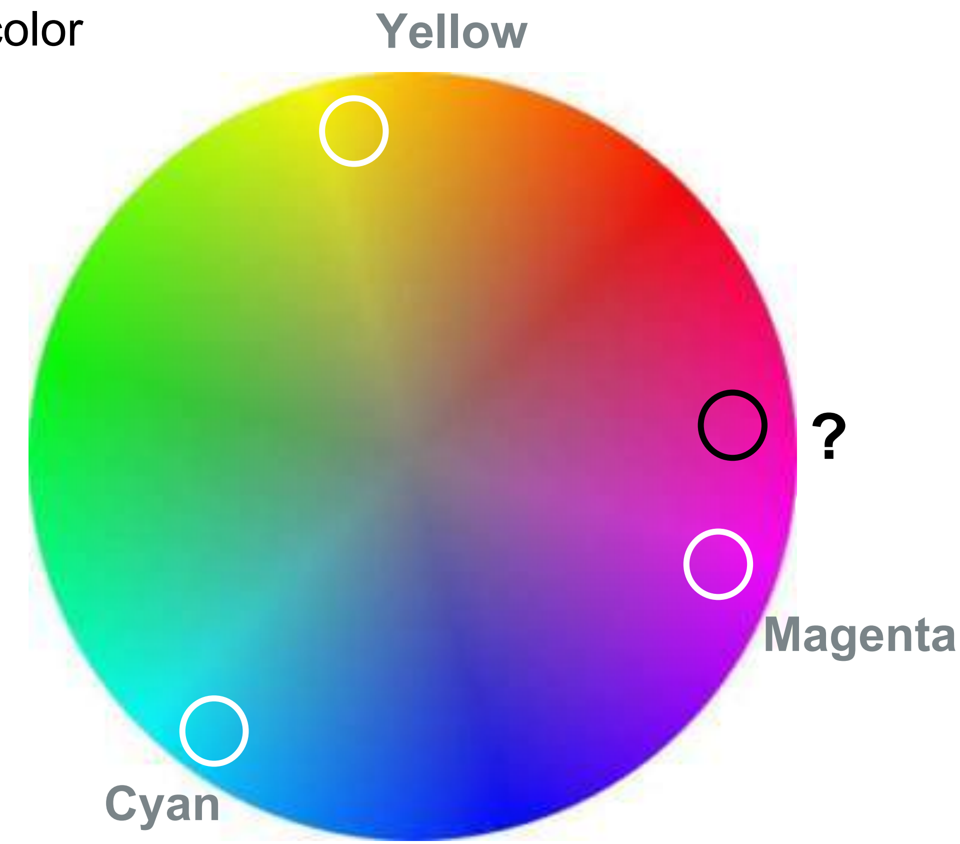
Densitometry in printing

- Density measurement is optimised for four-color superimposed printing.
- The process colors cyan, yellow and magenta are defined, standard colors. For printing, it is assumed that their color is correct.
- This means that only the film thickness needs to be checked.
- This is done using a densitometer.



Colorimetry in printing

- In order to make an objective assessment of the visual impression of a color, one needs a measurement and evaluation system that reproduces what the human eye sees. And this is what colorimetry provides.
- The color tone in the black circle can have the same density as the process color magenta. However, it is obviously not the same color.
- The task of colormetrics is to precisely define color tones.
- Colormetrics can be used to precisely compare different colors.

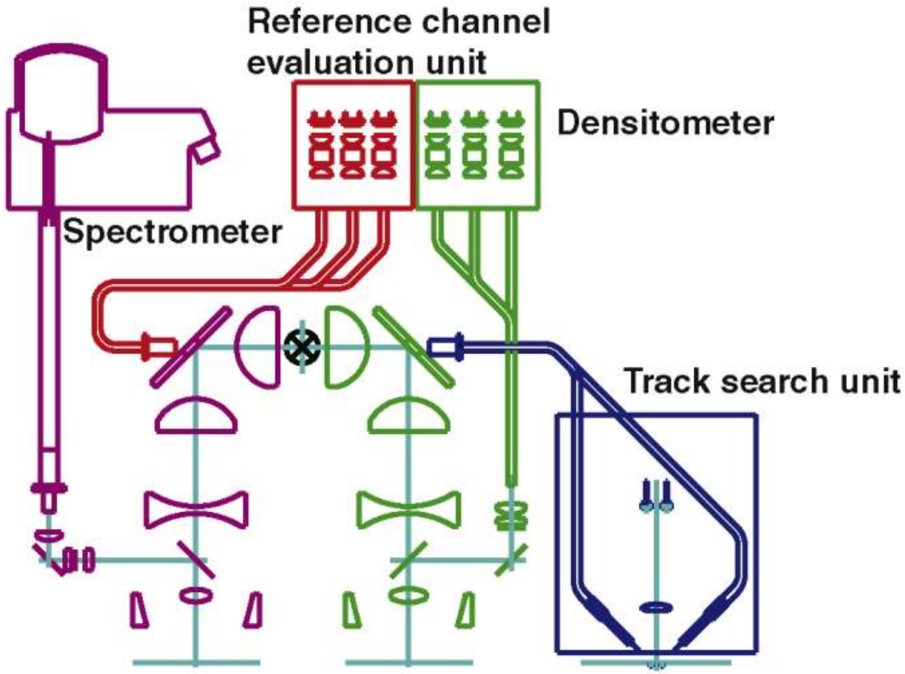


Quality control and regulation of special colors

- Colormetrics is required to obtain the correct target density value for density control of special colors. In order to do this, the color deviation from a required set color is measured on full surfaces.
- Densitometry cannot be used for this.

Consequence:

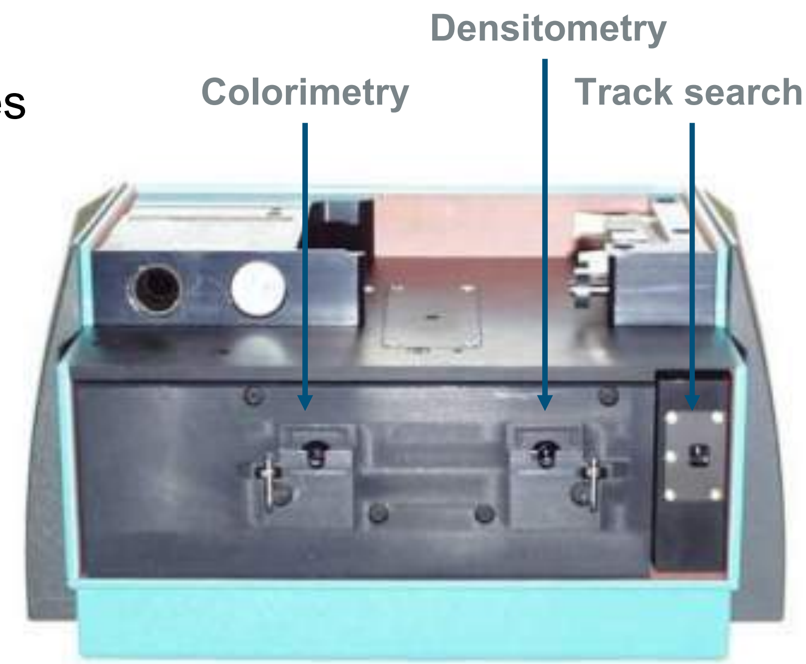
- The combination of densitometry and colorimetry provides an important prerequisite for standardised, high-quality printing.



Measuring principle FM 19 (ColorPilot)

ColorPilot - Further development of the CCI technology

- The proven densitometric measurement and regulation of CCI has been supplemented by colorimetric quality evaluation.
- The printing machine is still regulated in accordance with densitometrically measured values.
- The densitometric and colorimetric values in the print control strip are measured simultaneously.
- Measuring speed and regulating quality are the same as CCI.



Measuring head FM 19 (ColorPilot)

Part 3: Color systems

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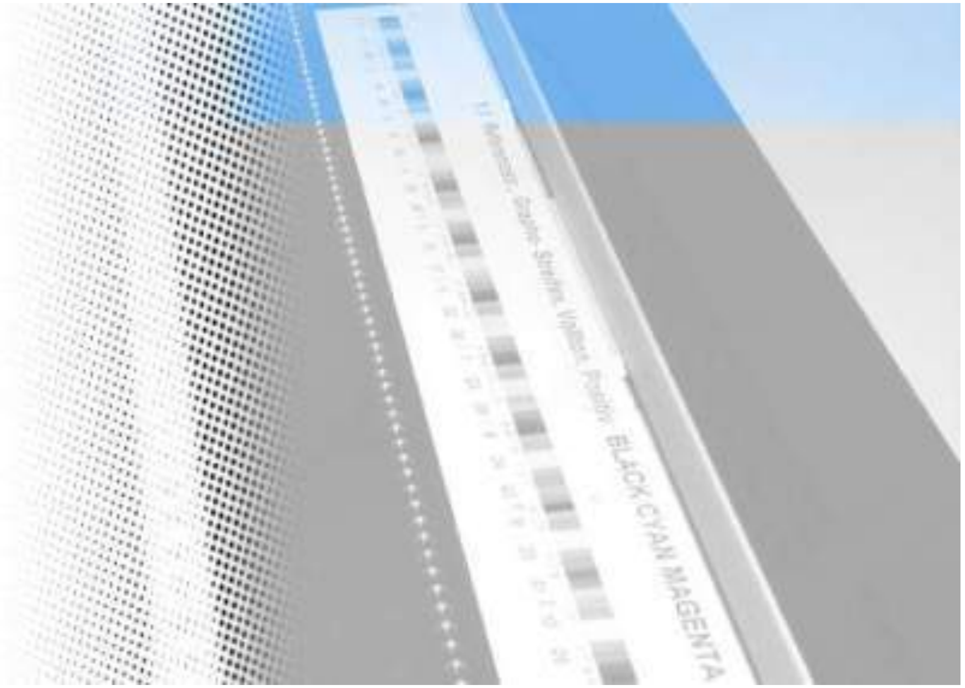
  - The 3 Dimensions of Color
  - Color systems
  - CIE- color systems
  - CIE - L*a*b* - system
  - Color difference ΔE
- **Part 4: Observation conditions**



Color + Quality

3. Color systems

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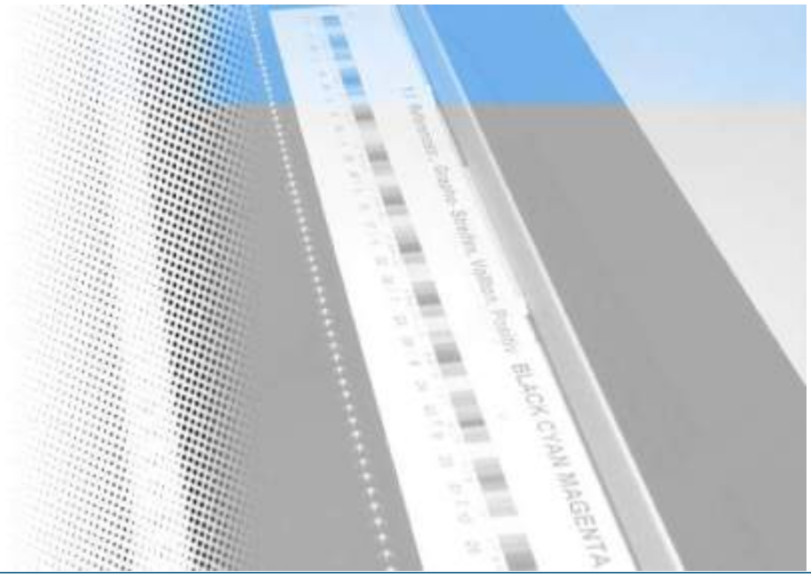
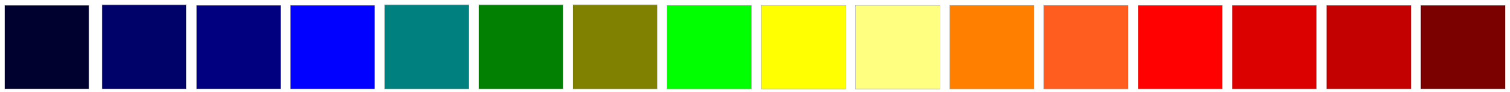


The 3 dimensions of color

1. Hue

2. Colorfulness

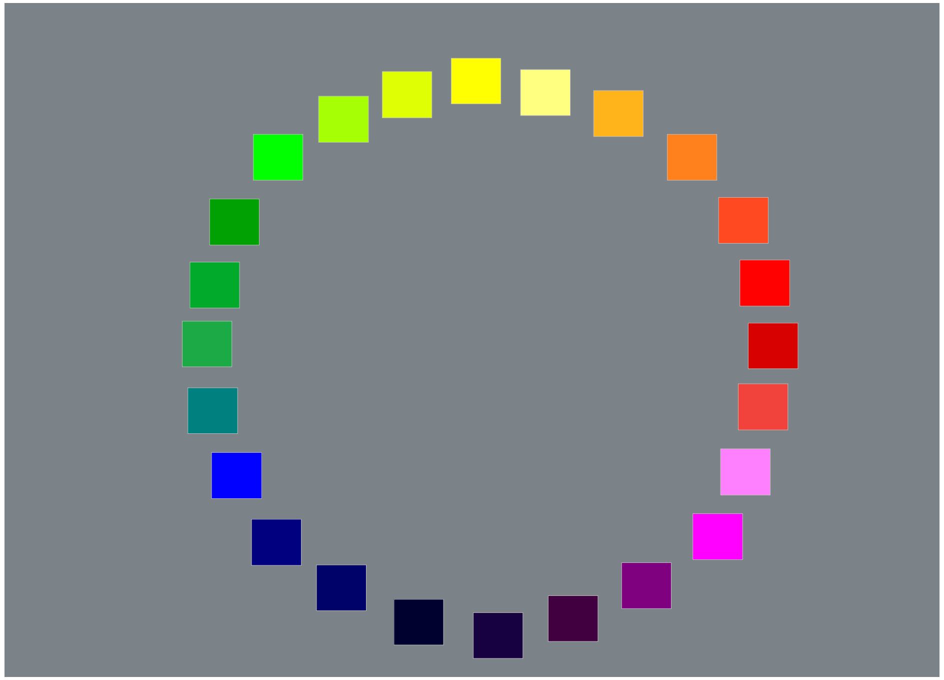
3. Brightness - value



- The visible spectrum consists of abutting hue. If the ends of the ribbon would be band together we received a hue circuit.

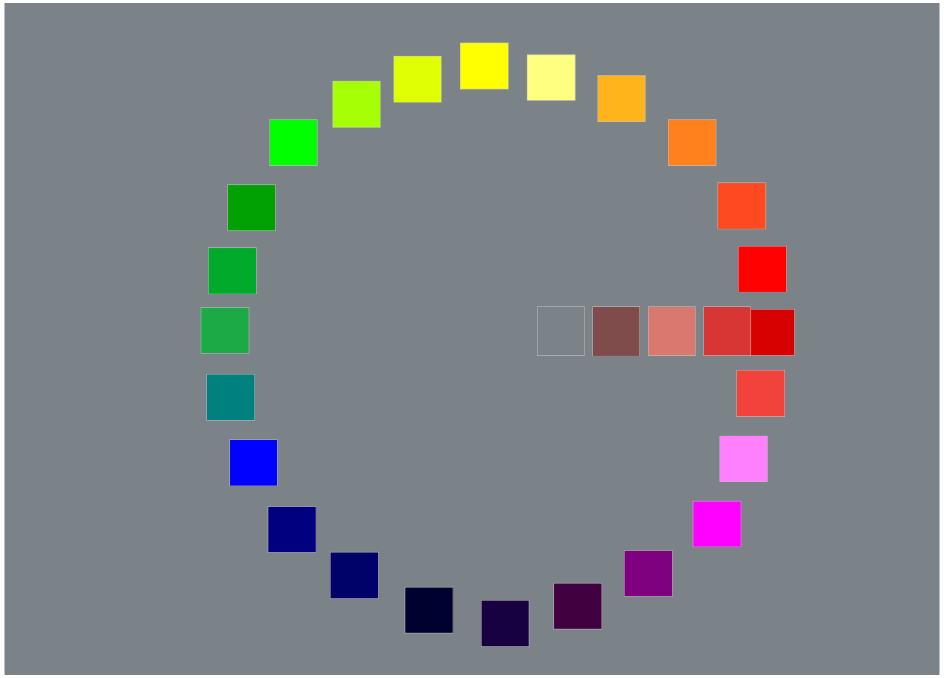
The 3 dimensions of color

- The hue/color forms the first dimension of the color.



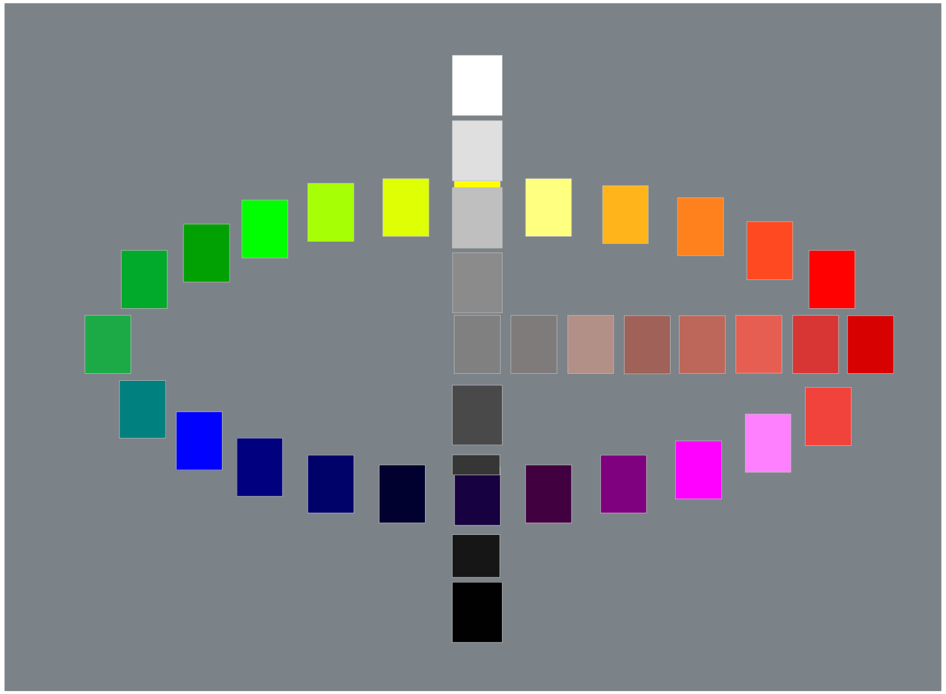
The 3 dimensions of color

- The second dimension, colorfulness describes the *saturation* of a color, taking its brightness into account.
- In this respect, white, grey and black occupy a special position - they are achromatic.
- Colorfulness = distance from grey



The 3 dimensions of color

- Identical hues/colors can have different levels of brightness (luminance).



Color systems

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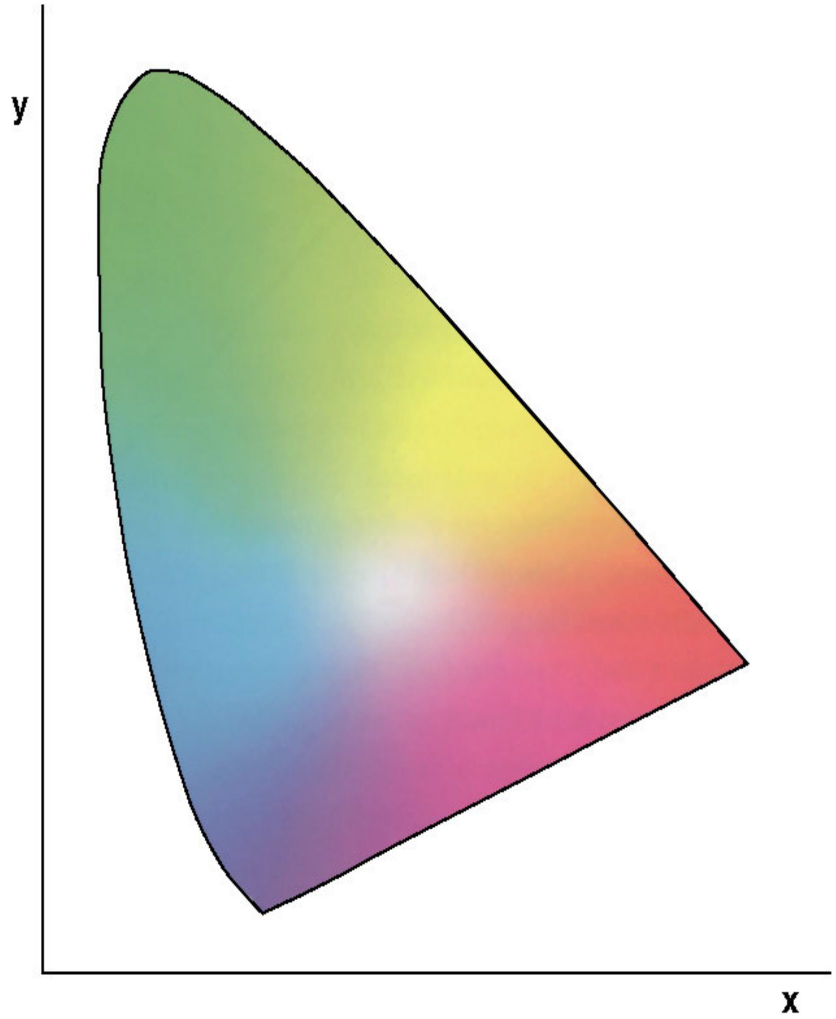
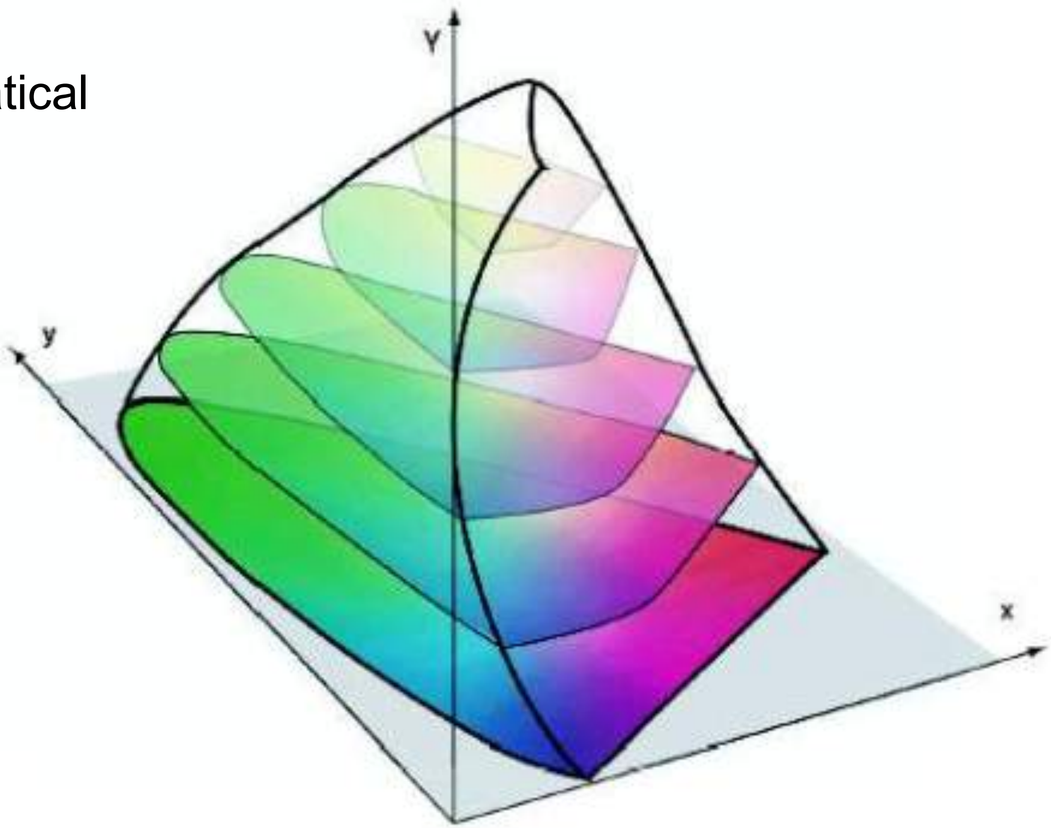
- In 1931, in the search for a clear definition regarding color impression, the so-called CIE System (”Commission Internationale de l’Eclairage”) was internationally agreed upon.
- So that different color shades can be compared with one another in an objective way, it must be possible to describe each shade using numerical values.
- Today, there are a huge number of different color systems (CIELAB, CIELUV, CIEXYZ, CIExyY etc.) The most important difference between these color systems lies in the distance between the colors.

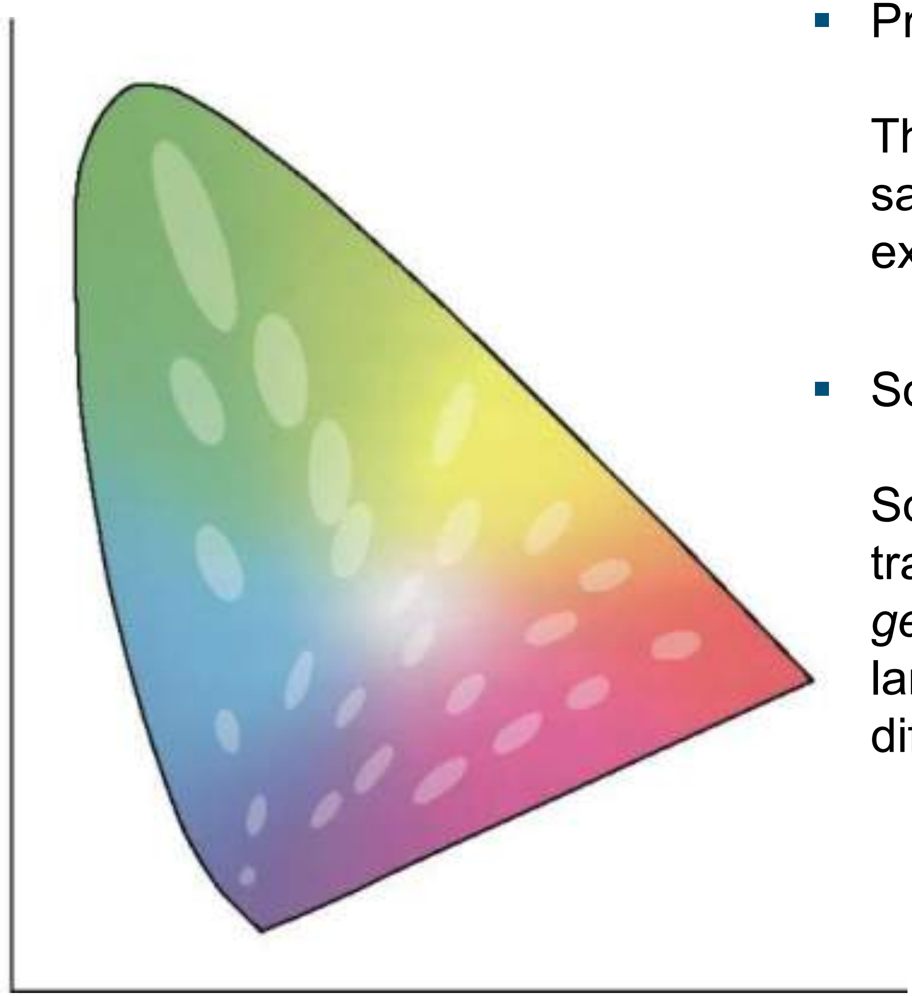


CIE - color systems

- In the visually evenly spaced color systems, a relationship is established between the perceived color difference and the color space in the color system.
- Three standard color values X, Y and Z are used in the CIE-XYZ-system. A mathematical transformation calculates these values to x and y and the brightness value (Y).



CIE - color systems



- Problem:

  The calculated color difference is not the same as the color difference really experienced.

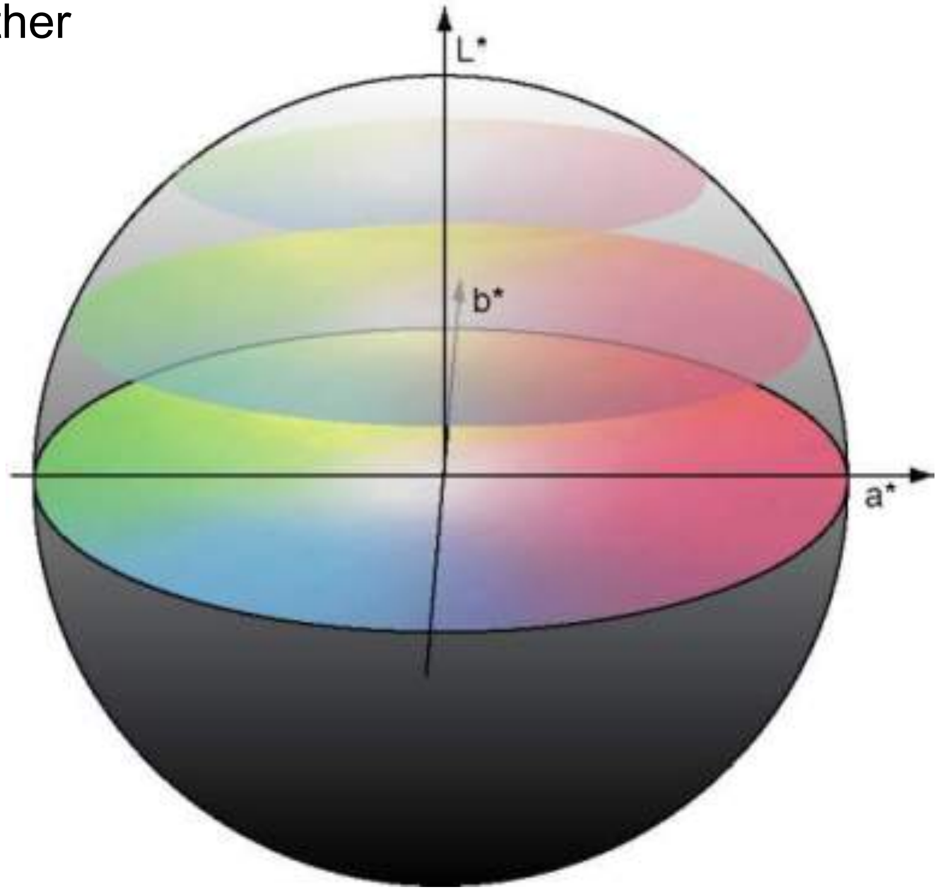
- Solution:

  Sophisticated co-ordinate transformation, make the calculated, *geometric* color difference correspond largely with the *perceived* color difference.

CIE - L*a*b* - system

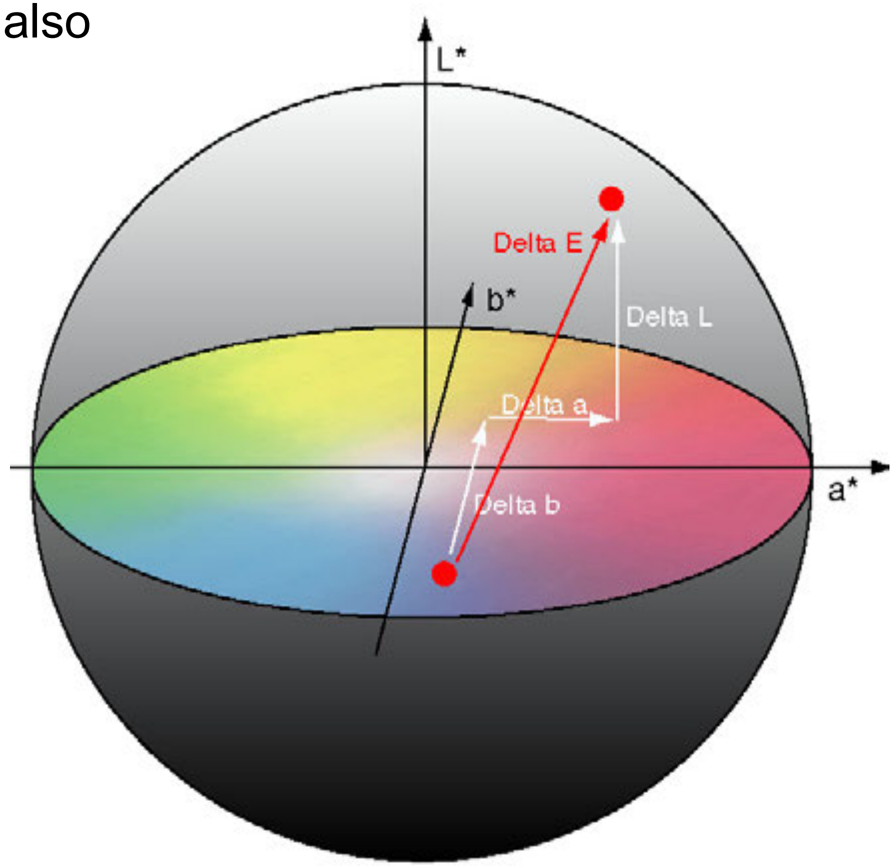
- The color difference system CIELab was introduced in 1976 as an evolutionary development. In this system, a color impression is given as the locus in a three-dimensional color area, in which the three axes are perpendicular to one another and are labelled L *, a *, b *.

- L → Brightness axis
  (0 = black, 100 = white)
- a → Red direction
  -a → Green direction
- b → Yellow direction
  -b → Blue direction



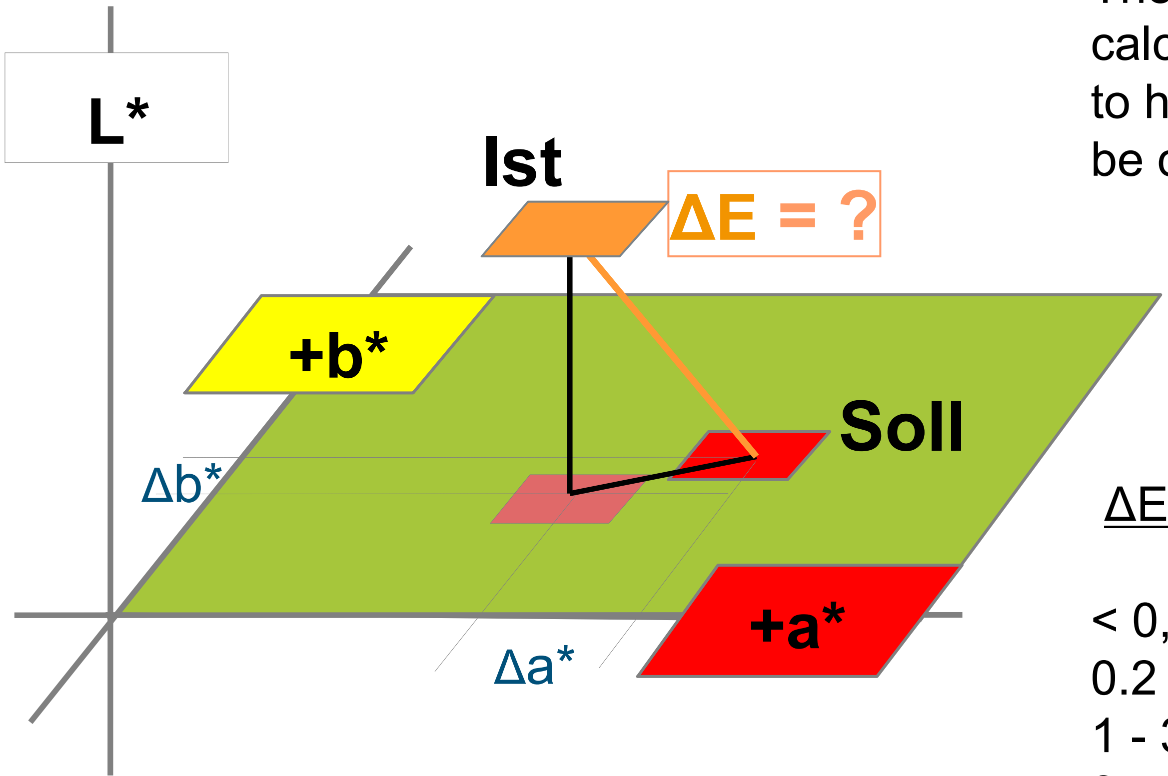
CIE - L*a*b* - system

- As opposed to other systems, the CIE - L*a*b* - system has the outstanding quality that the same ΔE color differences in the CIE - L*a*b* - system color space are also perceived by the human eye as being the same. And so in practice permissible color variation, in other words the tolerance range for a color, is given as the physical unit ΔE.



Color difference ΔE

- The distance between 2 points in the color area is denoted as ΔE.



The relationship of the calculated difference ΔE, to human perception can be divided as follows:

ΔE:	Value:
< 0,2	not observable
0.2 - 1	very slight
1 - 3	slight
3 - 6	average
> 6	large

Color difference ΔE

- A color measured in printed form (in this case, orange) is to be objectively compared with original (set value).

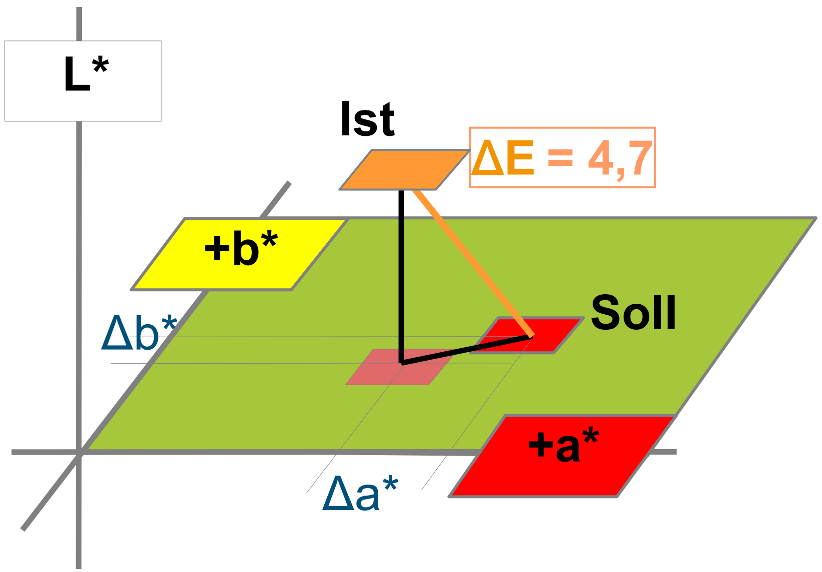
	Default set value	Measured actual value	Difference (actual-set)
L*	60,0	62,4	Delta L* = 2,4
a*	65,0	61,9	Delta a* = -3,1
b*	55,0	52,4	Delta b* = -2,6

- The calculation results in the following color difference:

$$\Delta E = \sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]}$$

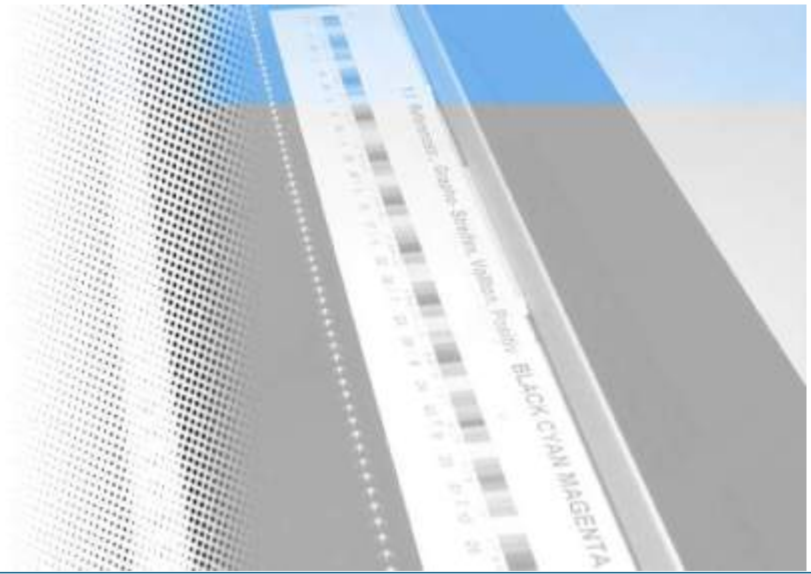
$$\Delta E = \sqrt{[2{,}4^2 + (-3{,}1)^2 + (-2{,}6)^2]}$$

$$\Delta E = 4{,}7$$



Part 4: Observation conditions

- **Part 1: Description of color**
- **Part 2: Densitometry and colorimetry**
- **Part 3: Color systems**
  - The 3 Dimensions of Color
  - Color systems
  - CIE - color systems
  - CIE - L*a*b* - system
  - Color difference ΔE
- **Part 4: Observation conditions**
  - Aspects of color perception
  - Simultaneous contrast
  - Metamerism
  - Color blindness
  - Printing quality is measurable!
  - Conclusion



Color + Quality

4. Observation conditions

Agenda

- **Part 1: Description of color**
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- **Part 3: Color systems**
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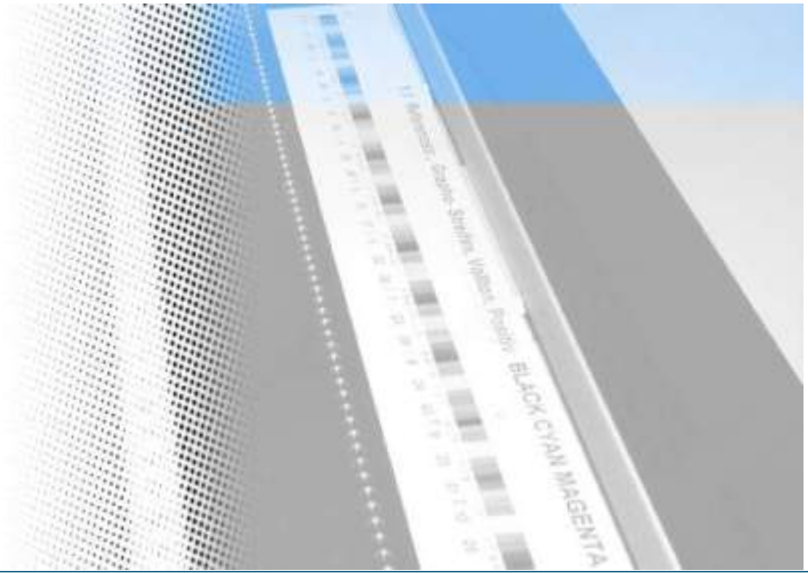
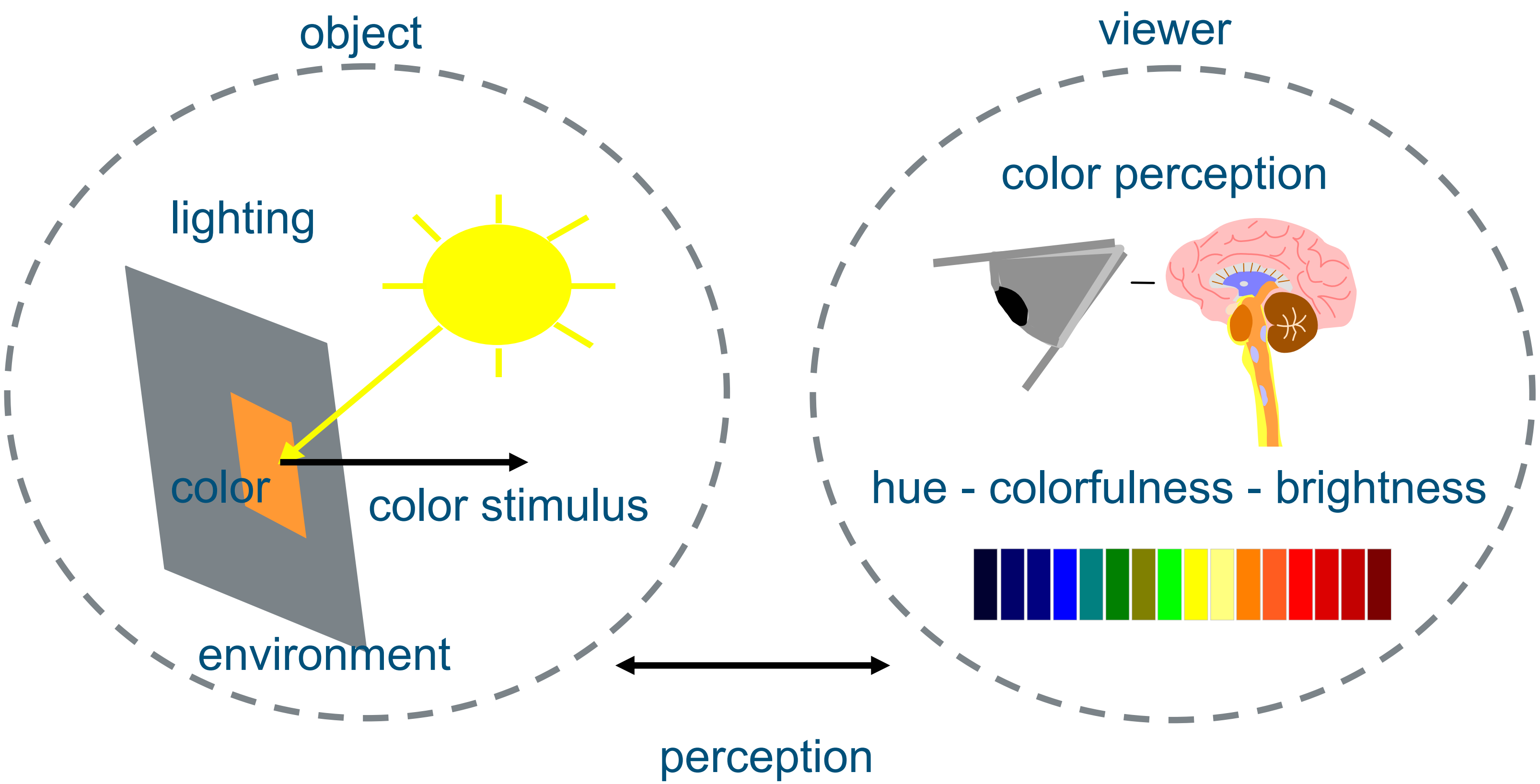


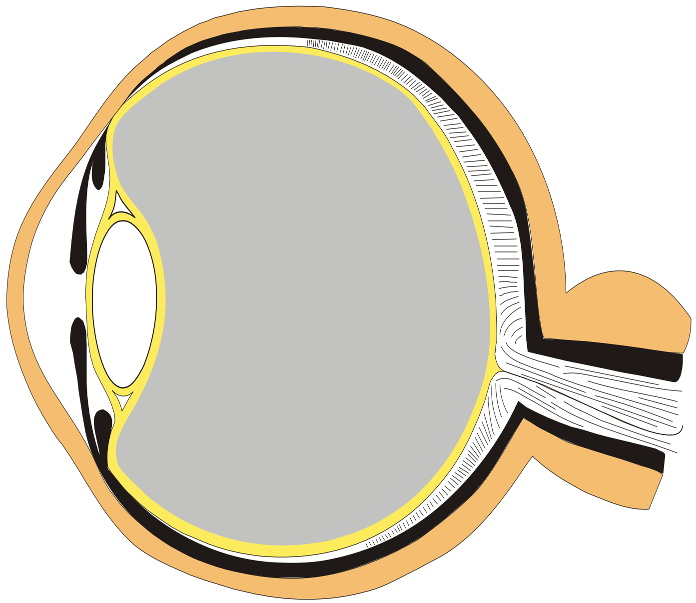
Aspects of color perception

- Why do we use color-measuring equipment?



Aspects of color perception

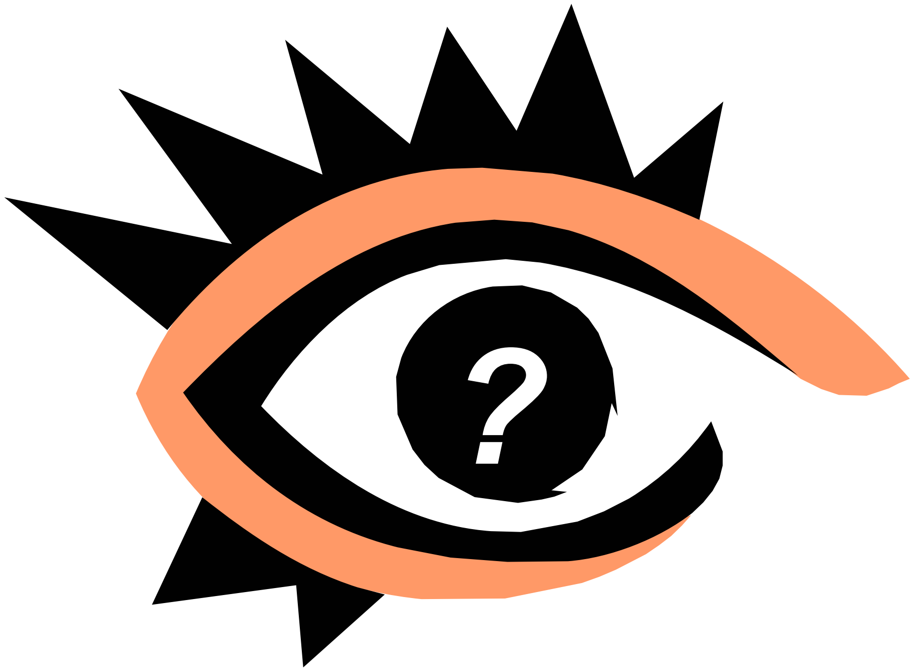
- The strongly simplified scheme (p. 3) shows the aspects of perceiving color:
- Perception of color is affected by the spectrum of the lighting, the color stimulus of the object and its environment, and the characteristics of the viewer – is qualitatively described by the terms hue, colorfulness and brightness.
- This makes it apparent that the process of perceiving color is not a purely passive process determined by the object, but also depends on the viewer, for example, depending on the condition of his eyes.



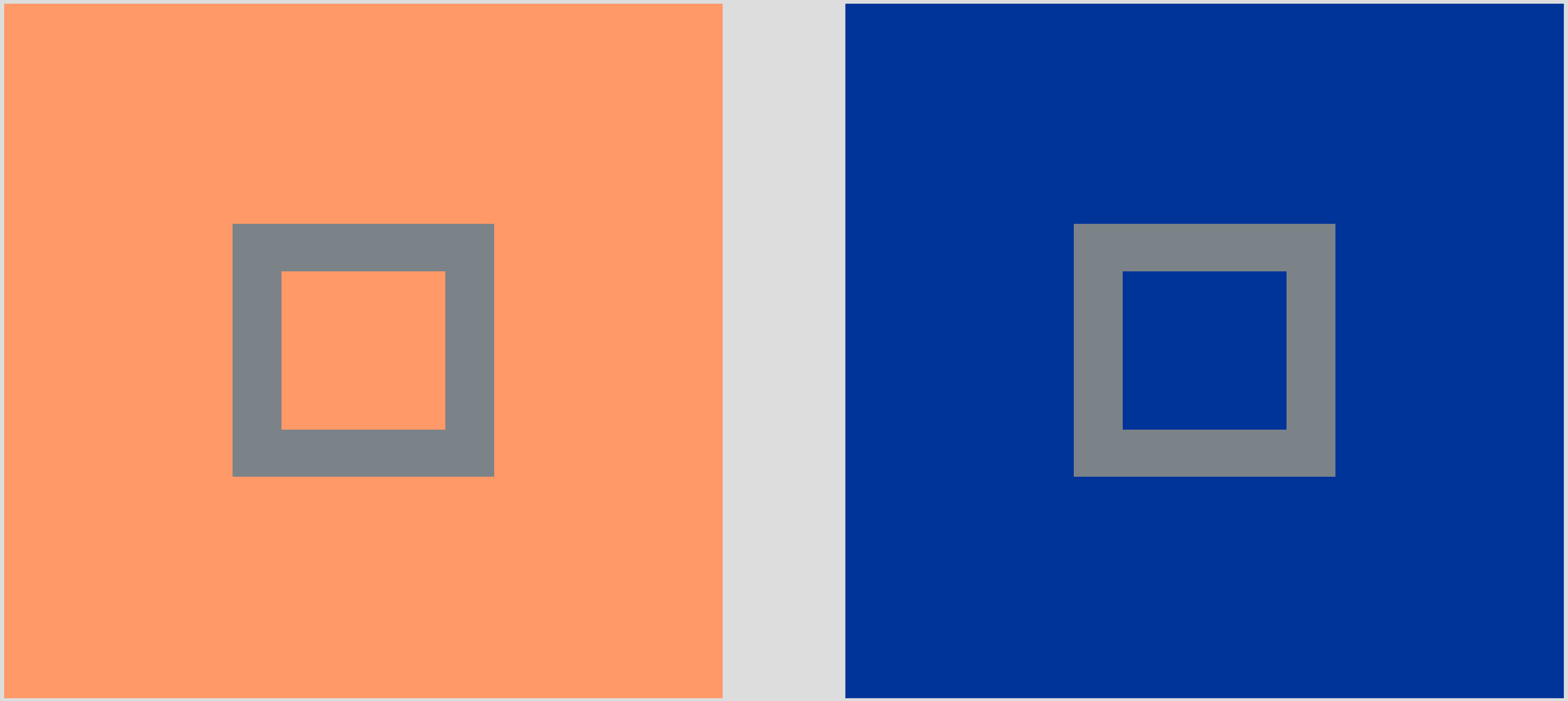
Different perception of color

Different perception of color depending on

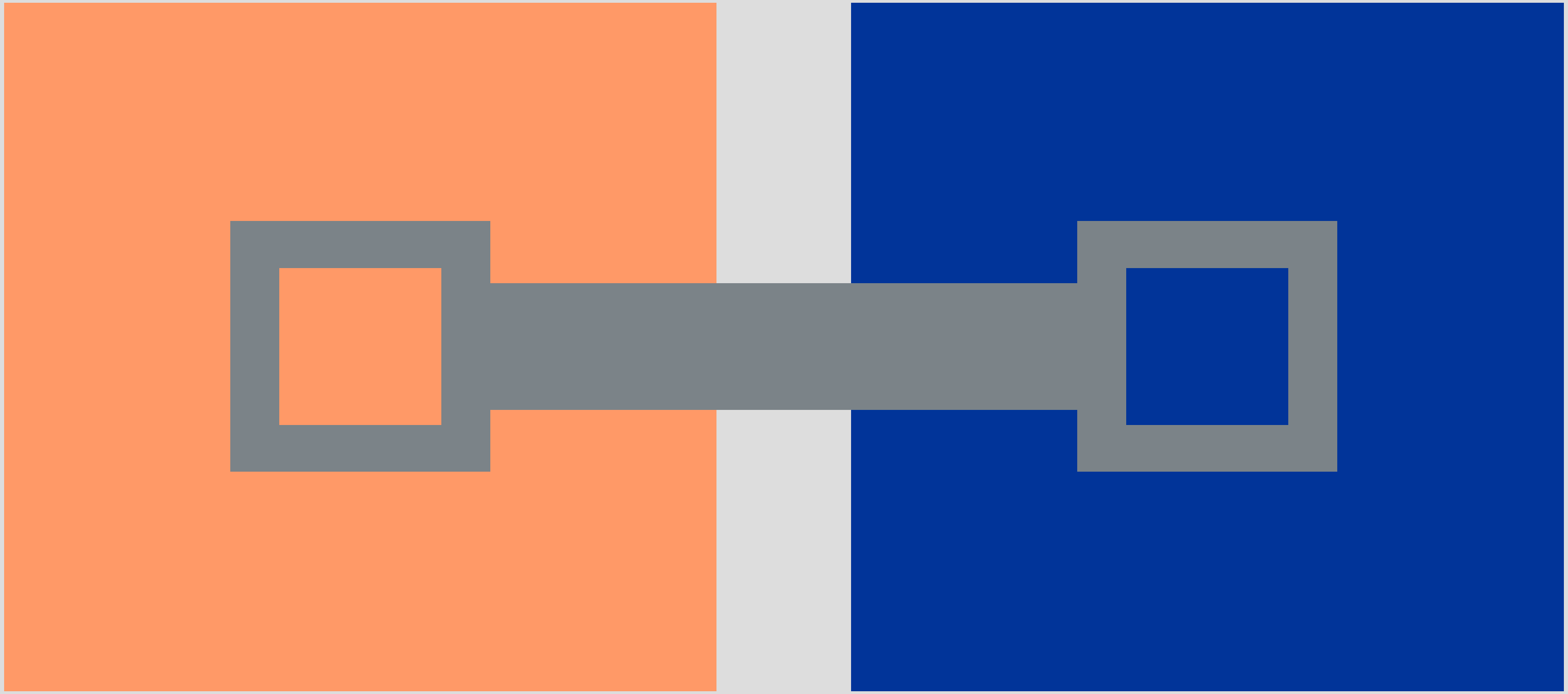
- Influence of background
- Color blindness
- Composition of light
- Inertia of the eyes
- …



Different tones of grey?

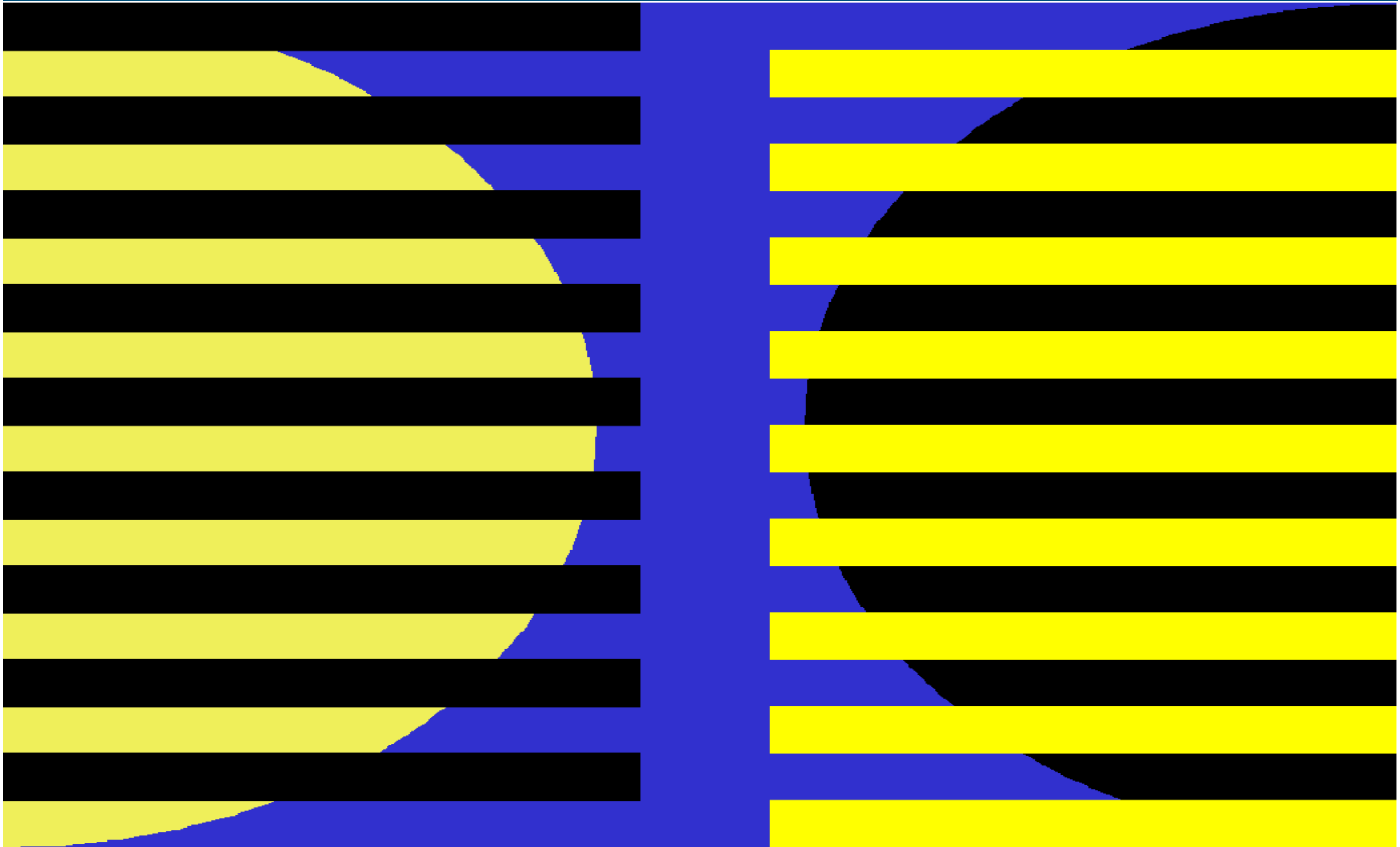


Same tones of grey!



Same blue?

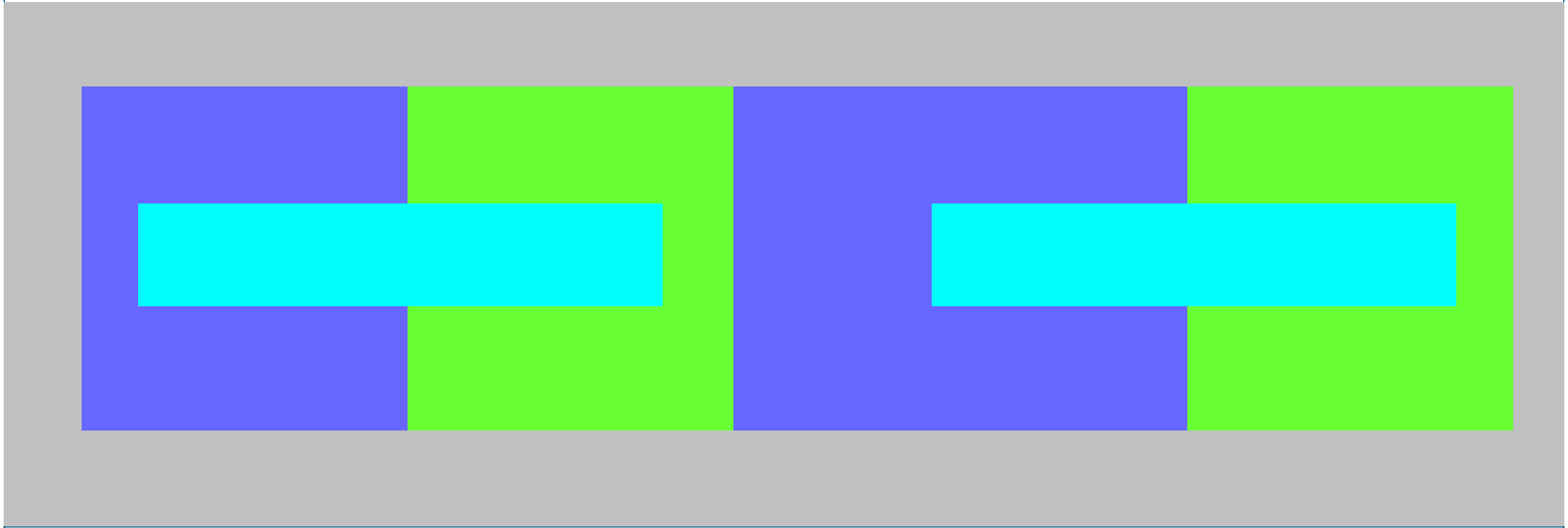
Same blue!



Simultaneous contrast

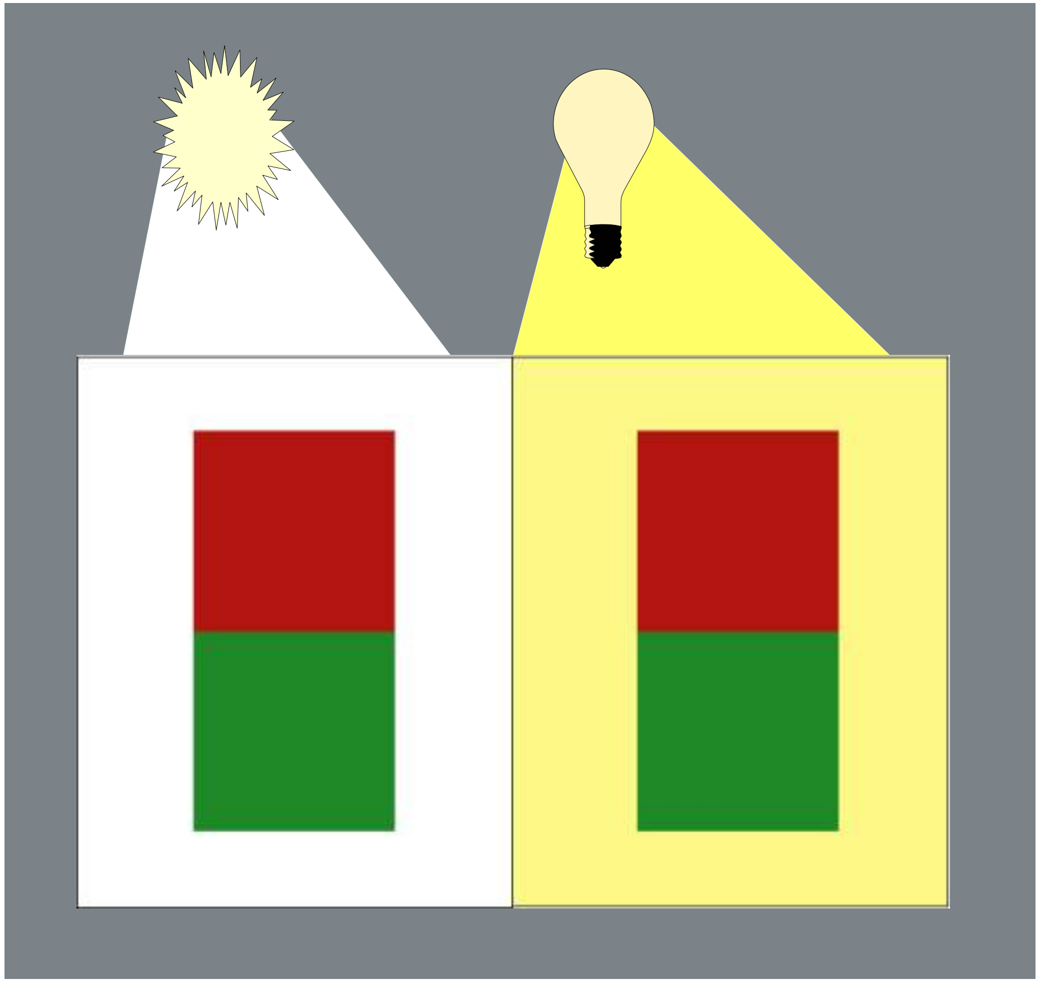
- Simultaneous contrast is the ability of the visual organs, to change the appearance of color nuances depending on the influence of color of the environment.

  The bright blue-green stripes have a yellowing effect on a blue background and a bluish effect on a green background



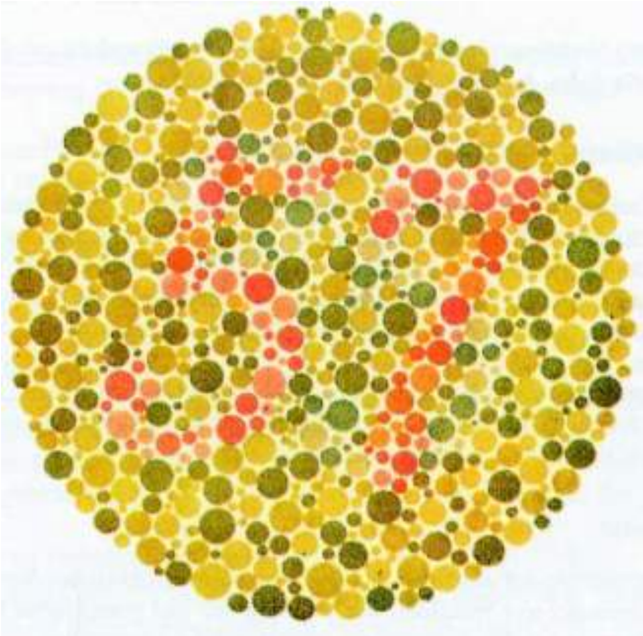
Metamerism

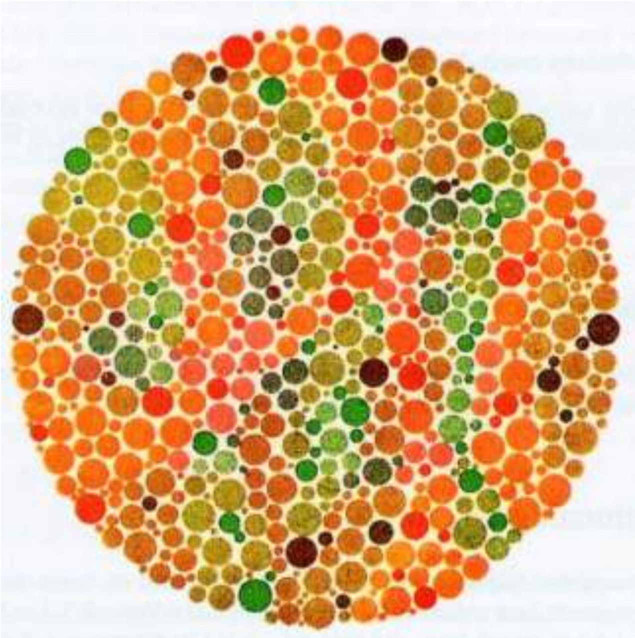
- The perception of a color is dependant on the light source, with which it is illuminated.
- If two colors are found to be the same under a light source, but however under another, they are different, this is called metamerism.



Color blindness

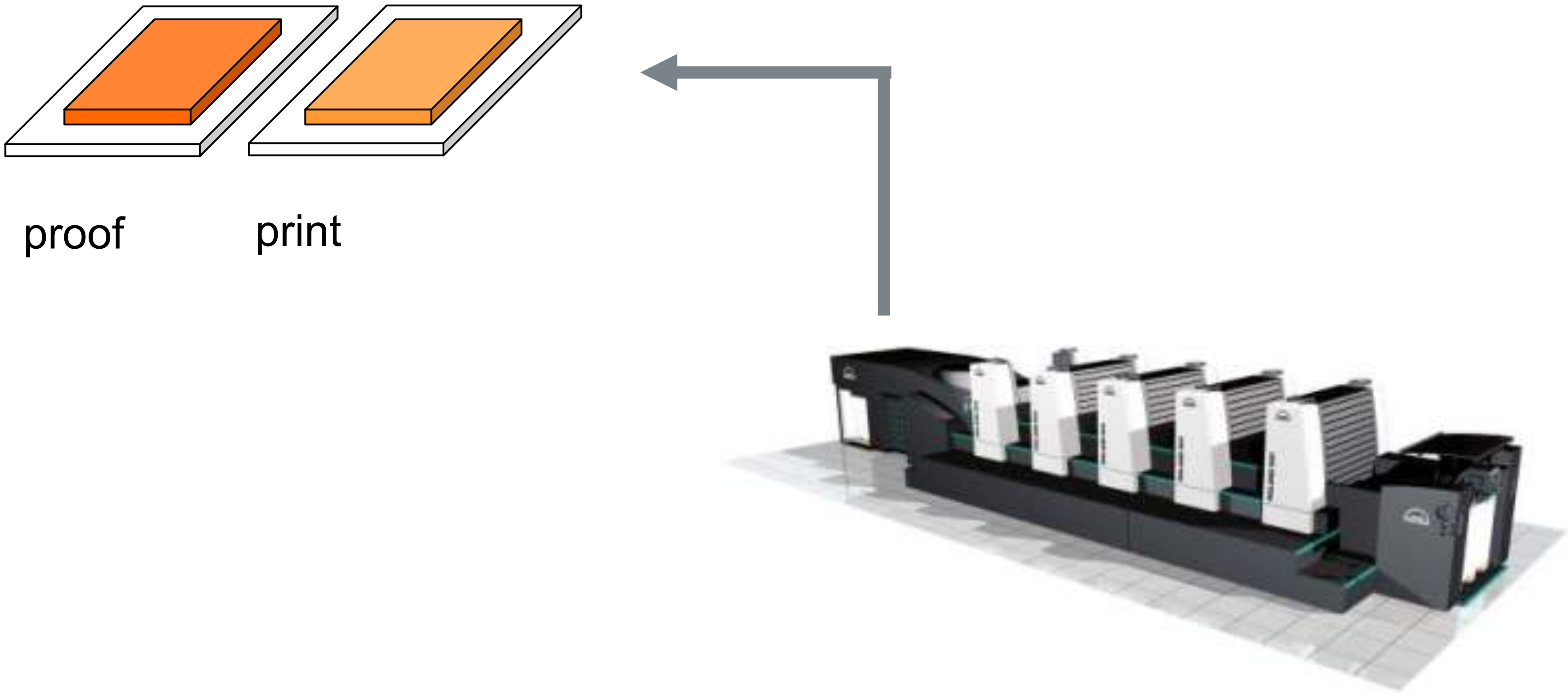
- There are different forms of color blindness. The most prevalent form is red – green.
- A pattern is generated to diagnose color blindness. These patterns appear the same to color blind people whereas the normal viewer can detect a difference and see the pattern (illustration on the left). In the right illustration color blind people see the figure 45.





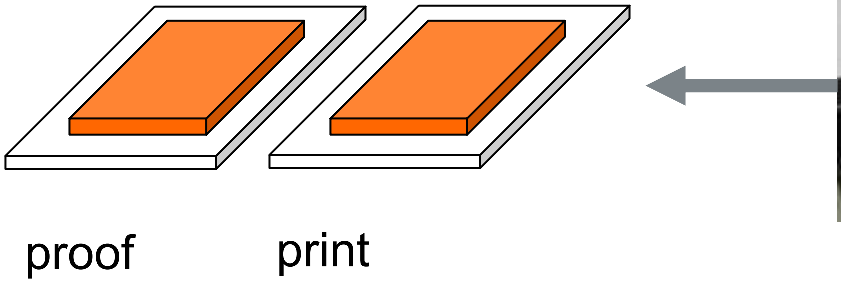
Printing quality is measurable!

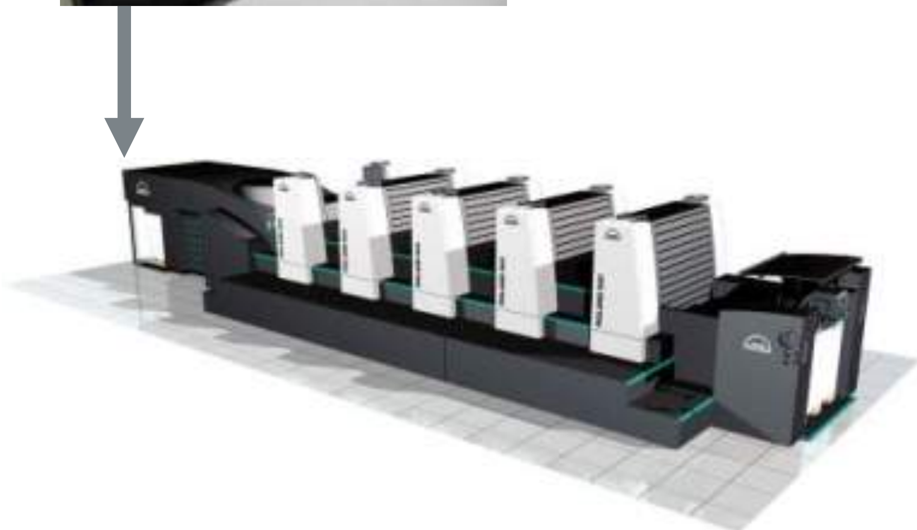
- Production <u>without</u> measurement
  - ☑ Result : outside of the tolerance range!



Printing quality is measurable!

- Production with measurement
  ☑ Result : within the tolerance range!





Conclusion

GRAPHO METRONIC

- The appearance of color is very complex and is influenced by different factors.
- Colors can be described using numerical values.
- The colorimetry defines colors uniquely.
- The colorimetry makes it possible to check the quality of colors.
- The densitometry controls the printing process.
- The combination of densitometry and colorimetry provides an important prerequisite for standardised, high-quality printing.

End!

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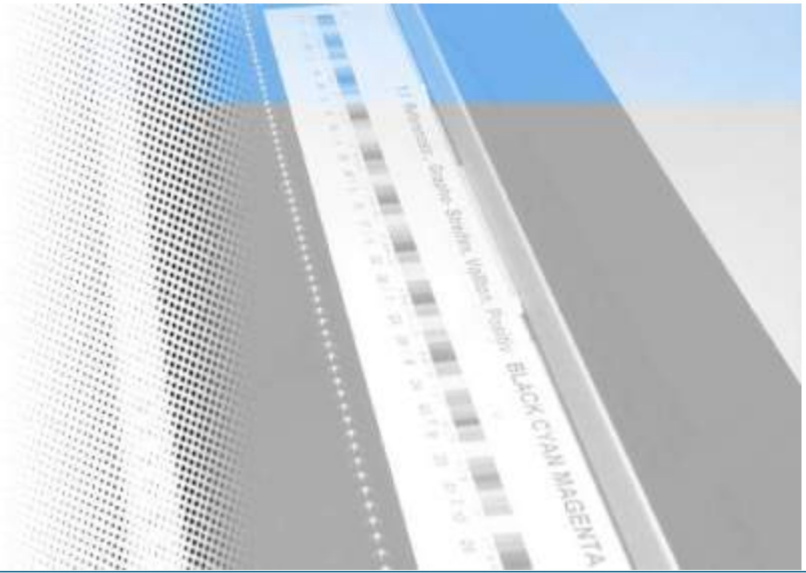

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