



## Basic colorimetric concepts

Correlating an original and a reproduction always requires evaluation from more than one point of view.

From the print of view of a printshop, the purpose of a colorimetric system is to supplement linguistic expressions with colorimetric values.

Here again, the first step is colour measurement. As soon as the measurement result is entered into the computer in the form of reflectance values, the computer weights this information on the basis of the three basic colorimetric evaluation criteria.

This evaluation indicates the way in which the colour stimulus is composed of the three primary colours red, green and blue. The result is therefore:

- one value for red (tristimulus value X),
- one value for green (tristimulus value Y) and
- one value for blue (tristimulus value Z).

These tristimulus values are the basis for any determination of colorimetric values or colour coordinates. They are determined from

- the spectral energy distribution of the selected light,
- the measured reflectance values,
- the three internationally accepted standard spectral value functions for the standard observer, as standardised in 1931 by the CIE (Commission Internationale de l'Eclairage [DIN 5033]).

This method is an instrumental attempt to "see" the colour stimulus in the same way as the human eye sees it, namely by weighting

- in the red region with a peak at 570 nm,
- in the green region with a peak at 535 nm and
- in the blue region with a peak at 445 nm.

(see Fig. 1 · The colour valence and colour perception sequence).

For example, when a comparison is made between an original – always referred to in standards as the "reference" – and a reproduction, the following tristimulus value may result:

| Reference  | Sample     | Difference         |
|------------|------------|--------------------|
| X0 = 11.02 | X1 = 13.51 | in the red: 2.49   |
| Y0 = 8.87  | Y1 = 9.91  | in the green: 1.04 |
| Z0 = 5.51  | Z1 = 5.59  | in the blue: 0.08  |

We can see immediately that although it is possible to calculate using these numbers, they give us no indication that correlates with our colour perception.

In addition, we have the fact that each colour region is governed by a different relationship between these different figures and our perception of a difference.

The tristimulus value X, Y and Z can, however, be converted into colorimetric values that can be associated with the real-world concepts of hue, intensity and purity. The CIELAB system deals with this problem of evaluating colour differences in terms of perception.

An understanding of CIELAB coordinates is therefore useful when working with a formula computer, and for evaluating formula recommendations.

# The color valence and color perception sequence

## Biological

Simplified representations

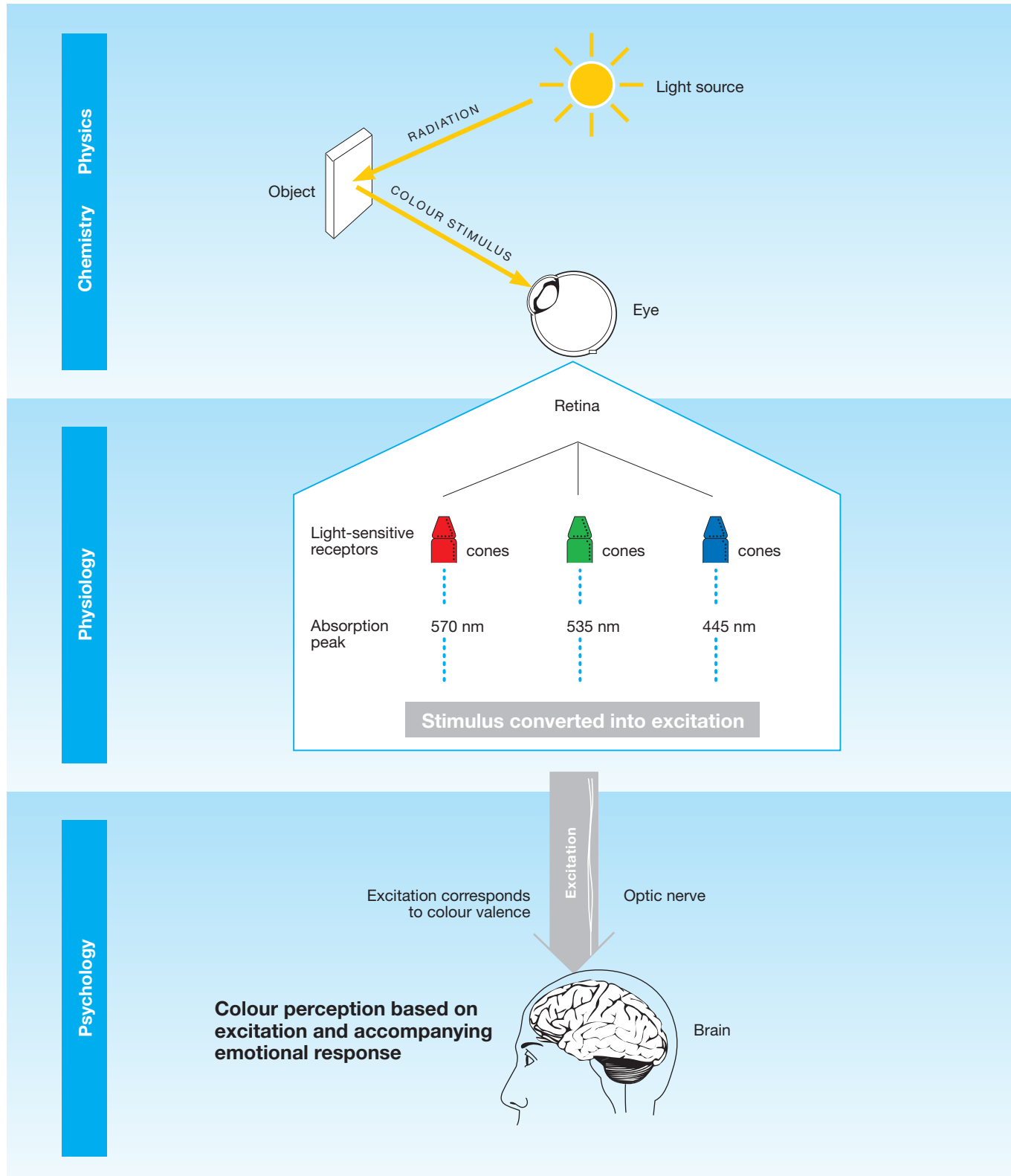
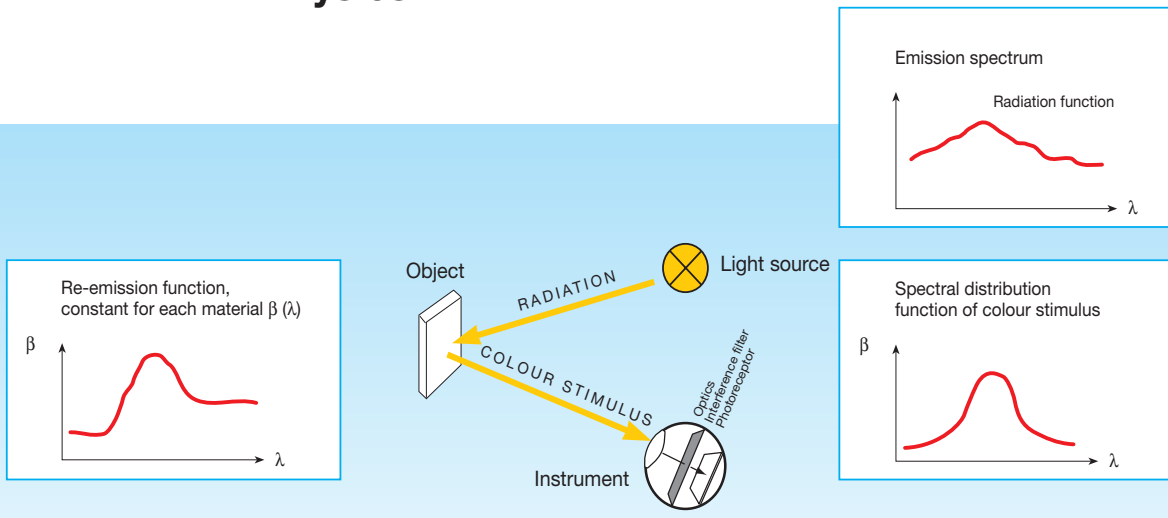
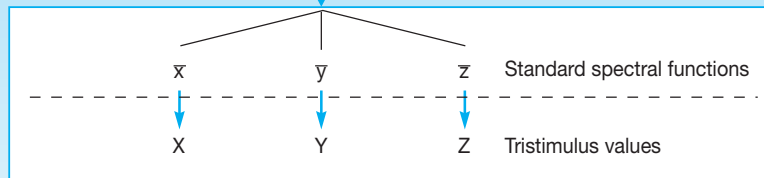


Fig. 1

# Physics



**Quantitative valence evaluation of colour stimulus**



**$X + Y + Z$    Colour valence**

Conversion into colour coordinates

$T \cdot S \cdot D$   
DIN 6164

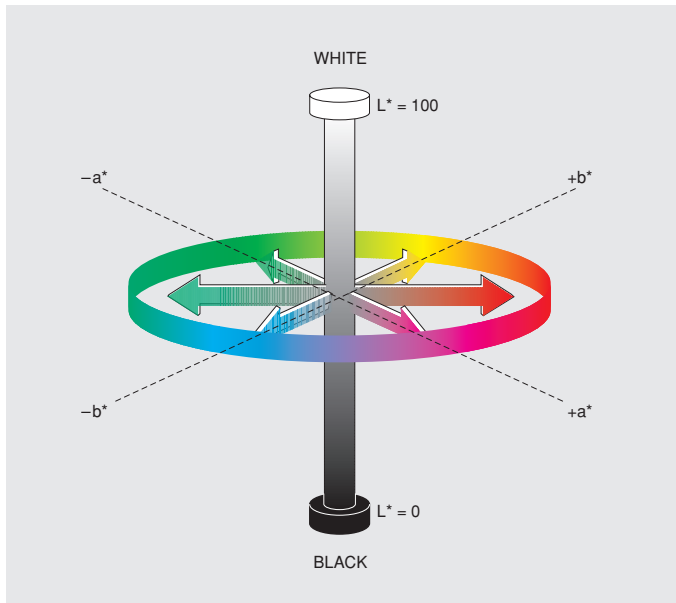
$L^* \cdot C^* \cdot H^*$   
or  
 $L^* \cdot a^* \cdot b^*$   
CIELAB  
DIN 6174

$x \cdot y \cdot Y$   
CIE

# An introduction to the CIELAB system

The appearance and shape of the CIELAB system and the CIELAB colour space can be imagined, in a simplified way, as a 100-story building with an air shaft in the centre (representing the luminance scale). The greatest luminance is present on the 100th floor ( $L^* = 100$ ). The lowest luminance (complete darkness or  $L^* = 0$ ) therefore exists on the ground floor. Every neutral grey value on the achromatic scale is located in between. The same principle applies on each floor, meaning on every CIELAB level: colour intensity increases with increasing distance from the centre. The CIELAB system does not use the term “colour intensity”, however, but has instead adopted the word “chroma” (abbreviated  $C^*$ ) for this concept.

By walking around the centre of the building once, one passes through the entire colour circle (fig. 2).



**Fig. 2**  
The CIELAB colour space, with coordinates  $L^*$ ,  $C^*$ ,  $H^*$  or  $L^*$ ,  $a^*$ ,  $b^*$

With this categorisation, we get three determining variables for each chromaticity coordinate or colour locus:

1. Luminance  $L^*$ , equivalent in meaning to “purity” or “greyness value”;
2. Chroma  $C^*$ , equivalent in meaning to “colour intensity” or “saturation”;
3. Hue  $H^*$ .

This CIELAB colour space was constructed from a mathematical conversion of X, Y and Z.

Since every point within the CIELAB colour space can therefore be described numerically, it is also possible to reproduce the difference between an original and a specimen in numerical terms:

$DL^*$  (delta L-star): luminance difference

$DC^*$  (delta C-star): chroma difference

$DH^*$  (delta H-star): hue difference

The particular advantage of this procedure is the excellent agreement between quantitative and perceived evaluations of difference. In other words, a value of two difference units (for example  $DH^* = 2$ ) is felt, in both visual and numerical terms, to be approximately twice as great as  $DH^* = 1$ .

The total colour difference (referred to as  $DE^*$  in accordance with DIN 6174) is calculated from  $DL^*$ ,  $DC^*$  and  $DH^*$ , but does not indicate the contribution provided by the individual components.

On each CIELAB level, the position of a colour point can also be described in another way besides with chroma and hue, namely by orienting on the red/green axis  $a^*$  and on the perpendicular yellow/blue axis  $b^*$ . This type of representation is of subordinate importance in practice because it is less graphic (see also Fig. 2).

DIN standard 6174 contains further details about colour difference calculations.