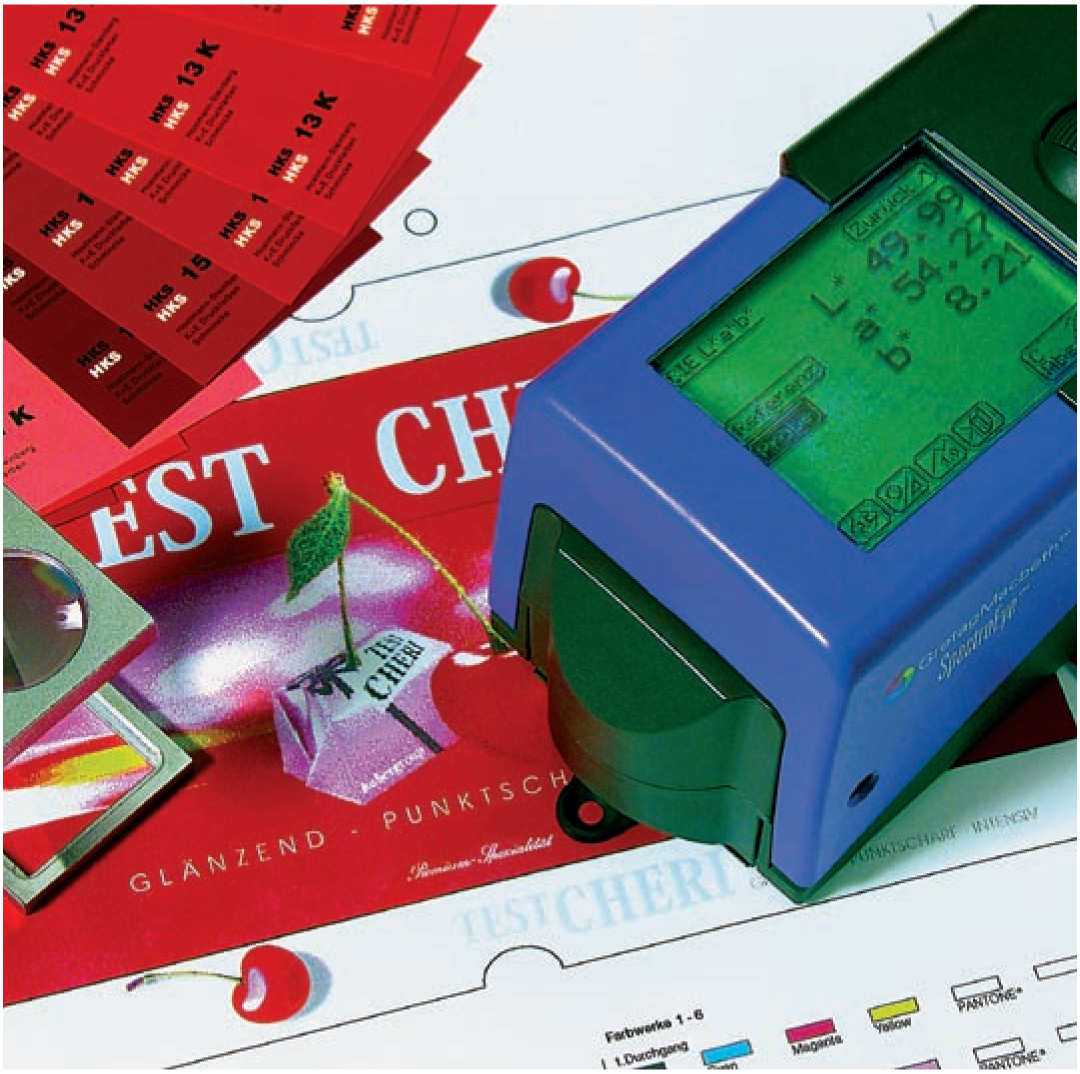
Technical information

23.01 E | 05.1996 | Sheet-fed offset | Color mixing systems

Computer-aided color-matching

Basic information for the print shop



Technical progress in the area of color formula precalculation (CFP) has reached a stage at which it has potential applications for print shops.

This technical information presents:

Ink formulation system applications and procedures

Components of the ink formulation system

Advantages of the CFP system

Tasks that the current system cannot perform

What are the prerequisites for using this system properly?

How can a print-shop operation use this system?

STEP ONE **Colorimetric readings of the original**

STEP TWO **Computer calculates formula recommendations**

STEP THREE **Formula recommendations are evaluated and applied by the color matcher**
A proof is pulled simulating press conditions

Basic colorimetric concepts

An introduction to the CIELAB system

It is very obvious that technological progress can provide assistance in matching colors. Some knowledge of the theoretical background is important, however.

Electronics and computers are becoming more and more important in our business. Almost 15 years ago, in fact, computers earned a place in the formulation departments of printing ink manufacturers. During this period, despite the increased memory capacity and calculating speed offered by the hardware, and despite improvements in user programs, costs have developed favorably. Because of this trend, acquisition of a modern ink formulation system has become a realistic possibility for print shops that often need to deal with special hues.

To help in making these judgments, some basic concepts will be explained below.

Ink formulation system applications and procedures

Components of the ink formulation system

The colorimetric instrument constituting the starting point for the color formulation precalculation (CFP) system is a spectrophotometer, which senses reflection values and presents them in the form of a reflection curve.

The computer, a PC with a color monitor, takes these reflection values, performs the calculation operations, and stores the results or outputs them to a printer (see cover picture).

This equipment can conveniently be arranged on a desktop. The software required – the formula calculation programs – have been successfully used in real-world applications for many years.

Advantages of the CFP system

- A print-shop's in-house matchings can be formulated from the most cost-effective components.
- When color originals are adjusted, metameric matchings can be avoided or detected in time.
- Residual inks can be included as formula components in other inks and thus re-used.
- Color deviations can be detected quantitatively by color difference measurement. Quality control thus becomes more objective.
- The time needed to prepare new formulas is reduced.
- Measurement data from color originals and in-house matchings can be stored in a sample file, so they are always accessible.

Tasks that the current system cannot perform

- Detecting (= measuring) color originals that are dirty, smudged, or less than 4 mm in diameter.
- Formulating metallic inks, bronze-effect inks, or fluorescent inks.
- The system is also not capable of replacing a proofing press, since the matching results must be checked by means of an actual print.

What are the prerequisites for using this system properly?

A print shop's requirements for each job also define the requirements for the inks used for mixing. The processing method can play a critical role in this connection. Selecting the correct basic inks is therefore an important factor.

It is best to define these basic inks in consultation with an ink manufacturer who stores reflection data – also called primary data – on a diskette, and can make them available in a form compatible with your system.

This division of labor saves the print shop the work of data input.

How can a print-shop operation use this system?

STEP ONE

Colorimetric readings of the original

The reflection values from a color original are recorded by simply placing it in front of the spectrophotometer's measurement opening. Press a button to start the measurement, and 10 seconds later the information has been recorded and is sent to the computer. Although the operating procedure is therefore very simple, it is important to understand the features that make the spectral process the most precise method of measuring color. In terms of illumination of the specimen, two factors are critical: the composition of the incident light, and the measurement geometry.

The measurement instrument's radiation source contains all the components of daylight, including UV and visible radiation, that are needed for full development of the optical properties of the printing stock and ink.

Fig. 1 shows the electromagnetic radiation spectrum, indicating the UV and visible sections. The wavelengths of visible light are between 400 and 700 nm (1 nm = 1 nanometer = $\frac{1}{1.000.000}$ mm). UV radiation begins at the short-wavelength end of the visible spectrum.

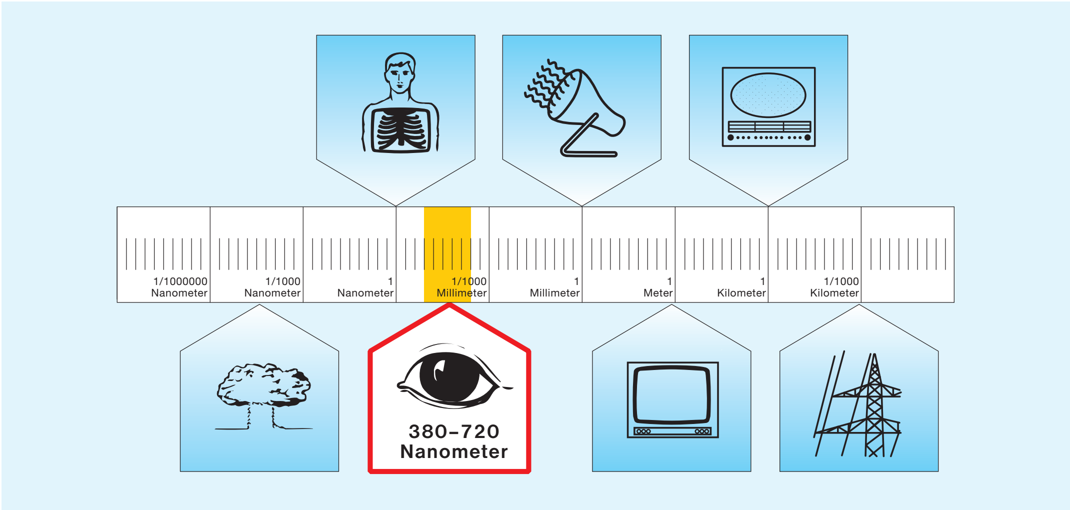


Fig. 1
The visible region, shown as part of the entire electromagnetic spectrum.

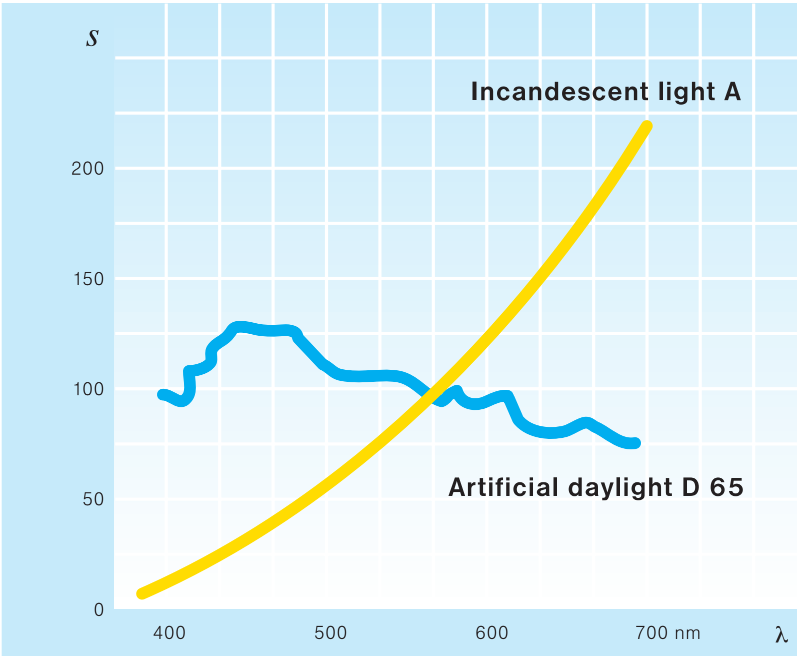


Fig. 2
Emission spectra of D 65 light and type A incandescent light.

No light source (including the sun) contains every wavelength at the same radiation intensity. There is always an uneven distribution of energy, which can be read off from the emission spectrum.

Fig. 2 compares artificial daylight (D 65) and type A incandescent light. If a color sample is illuminated, it will reflect and absorb characteristic portions of the incident light on the basis of its physical composition.

The portion reflected by the sample is determined both by the sample itself and by the incident radiation. The reflected portion is referred to as the “color stimulus”, since the term “color” is reserved for the color sensation evoked in the human brain by the color stimulus.

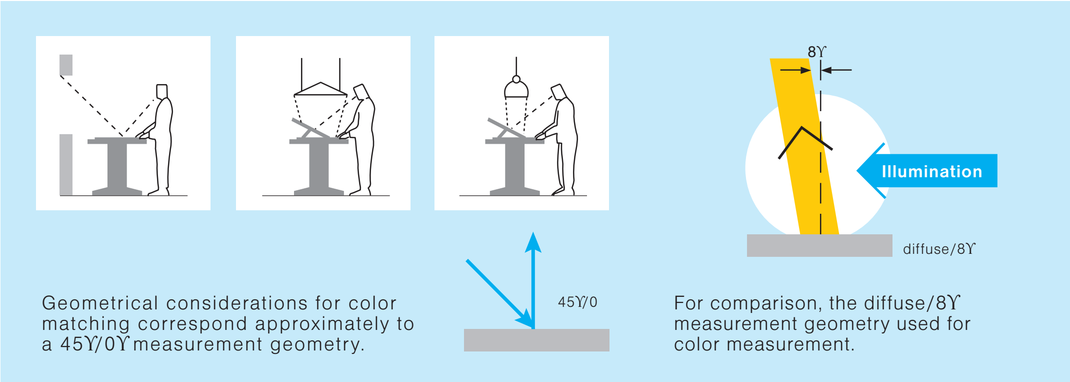


Fig. 3

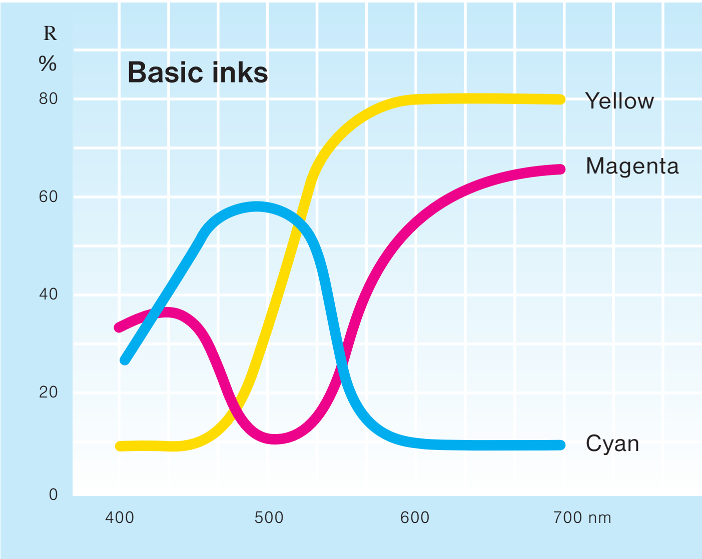


Fig. 4
Reflection curves for the three basic inks yellow, magenta and cyan, according to DIN 16 539.

Another important influence on the color stimulus is the illumination or measurement geometry, since the direction from which the light hits the sample, and the direction from which the sample is evaluated, are both important.

Two different types of measurement geometry are commonly used today:

- Beamed illumination under 45°
  – measurement under 0° (45°/0°)
- Diffuse illumination
  – measurement under 8° (d/8°).

Both types of measurement geometry are used today in the printing industry. Surface and gloss effects have a greater influence if the 45°/0° measurement geometry is applied. Values of the two types of measurement geometry cannot be compared with ohne another.

Visual assessments – without measuring device – are generally made at 45°/0° (fig. 3).

The actual color measurement analyzes the color stimulus between 400 and 700 nm in 10-nm steps, indicating for each step the value of the reflected portion in %. The result is presented as a reflection curve. An ideal white would come out as 100%, an ideal black as 0% (fig. 4).

STEP TWO

The computer calculates formula recommendations

Once the reflection values have been entered into the computer, a mathematical comparison is made between stored reflection data for the basic inks, and reflection data from the sample. The idea is to simulate the sample using the basic inks, and since there are usually several possibilities, several formula recommendations are provided. The computer also provides a commentary evaluating each formula recommendation in terms of its coloristic quality, indicating how far each recommendation deviates from the ideal, and in which direction.

More information on color difference evaluations is provided in the section on "Basic colorimetry concepts".

Fig. 5 shows an output report, which also indicates the material costs (in terms of basic inks) associated with each formula recommendation.

```
---------------------                             Datei: BVS1
 Rezeptur Ausgabe
---------------------                             Filmstaerke   :    1.00
      Standard Name : TAIGA-GRUEN
         400-540 nm   10.60   14.07   18.09   26.28   35.04   38.31   37.60   33.23
         560-700 nm   28.55   19.82   10.49    8.31    8.61    9.98   12.77   15.52

                                            Substrat Name : BVS
 ID  Rohwaren (1)    (2) Grundfarbe         Restfarben Name : ohne Restfarbe
---  --------------- --------------
 18  GELB   295              34.098
 31  ORANG  290               3.440
 80  BLAU   738              24.643
                     --------------         Farb Toleranzen   :
     Druckf.-Menge           62.180         DE(1)  10.00
  1  CLEAR 23199380          37.820
200  /                        0.000         Preis:    (3)  28.67 je Gew.Einheit
                     --------------                        28.11 je Vol.Einheit
     Gesamt-Menge           100.000
                                                            DE(1)  DE(2)  DE(3)
                                                            D65    A      TL84
                                                 Farbdifferenz 10 deg 10 deg 10 deg
                                            ----------------- ------ ------ ------
                                            CIELAB (4)      0.29   2.44   2.74


                                            Substrat Name : BVS
 ID  Rohwaren (1)    (2) Grundfarbe         Restfarben Name : ohne Restfarbe
---  --------------- --------------
 20  GELB   361              25.766
 31  ORANG  290               3.569
 80  BLAU   738              24.836
                     --------------         Farb Toleranzen   :
     Druckf.-Menge           54.170         DE(1)  10.00
  1  CLEAR 23199380          45.830
200  /                        0.0000        Preis:    (3)  14.24 je Gew.Einheit
                     --------------                        13.91 je Vol.Einheit
     Gesamt-Menge           100.000
                                                            DE(1)  DE(2)  DE(3)
                                                            D65    A      TL84
                                                 Farbdifferenz 10 deg 10 deg 10 deg
                                            ----------------- ------ ------ ------
                                            CIELAB (4)      0.32   2.25   3.39
```

The two recommendations differ as follows:

1. Type of formula components, shown in the "Raw materials" column.
2. Percentage composition, shown in the "Basic ink" column.
3. Cost per kg of prepared ink, in terms of formula components, shown under "Price".
4. Color difference evaluation for the difference between the calculated printing ink and the Taiga Green original, shown in the "CIELAB" line. Recommendation 1under DE(1) – meaning evaluation under type D 65 light – presents a color difference of 0.29 units according to CIELAB. When evaluated under type A light, DE(2) yields 2.44 difference units. The difference values for recommendation 2 are similar.

Fig. 5
Two formula recommendations for matching "Taiga Green"

It is also possible to specify residual inks as formula components.

The color measurement and formula calculation processes together take very little time, and can be completed in only a few minutes.

When compared with the conventional way in which a color matcher would process the same information, the advantages of the CFP system discussed earlier are very obvious.

STEP THREE

Formula recommendations are evaluated and applied by the color matcher
A proof is pulled simulating press conditions

In most cases, the computer formula which the color matcher selects as the most favorable of all the printed-out formula recommendations needs some correction.

Once a small specimen quantity has been prepared, therefore, the matcher's job is to check the calculation result by pulling a proof. The printing stock to be used for the production run constitutes an important component whose influence on the formula calculation is not completely taken into account, since all primary data refer to a standard stock.

This test proof can be subjected to a correction calculation, and ultimately lead to a final formula. This procedure is illustrated in fig. 6.

This chart once again illustrates how much the quality of the test proof influences the accuracy of the final formula. This formula is designed to allow a problem-free production run that does not have to be interrupted for corrections to the printing ink. To achieve this goal, the proofing method should produce a result that can be duplicated in the production run. The proofing unit is therefore a critical component of the formulation system.

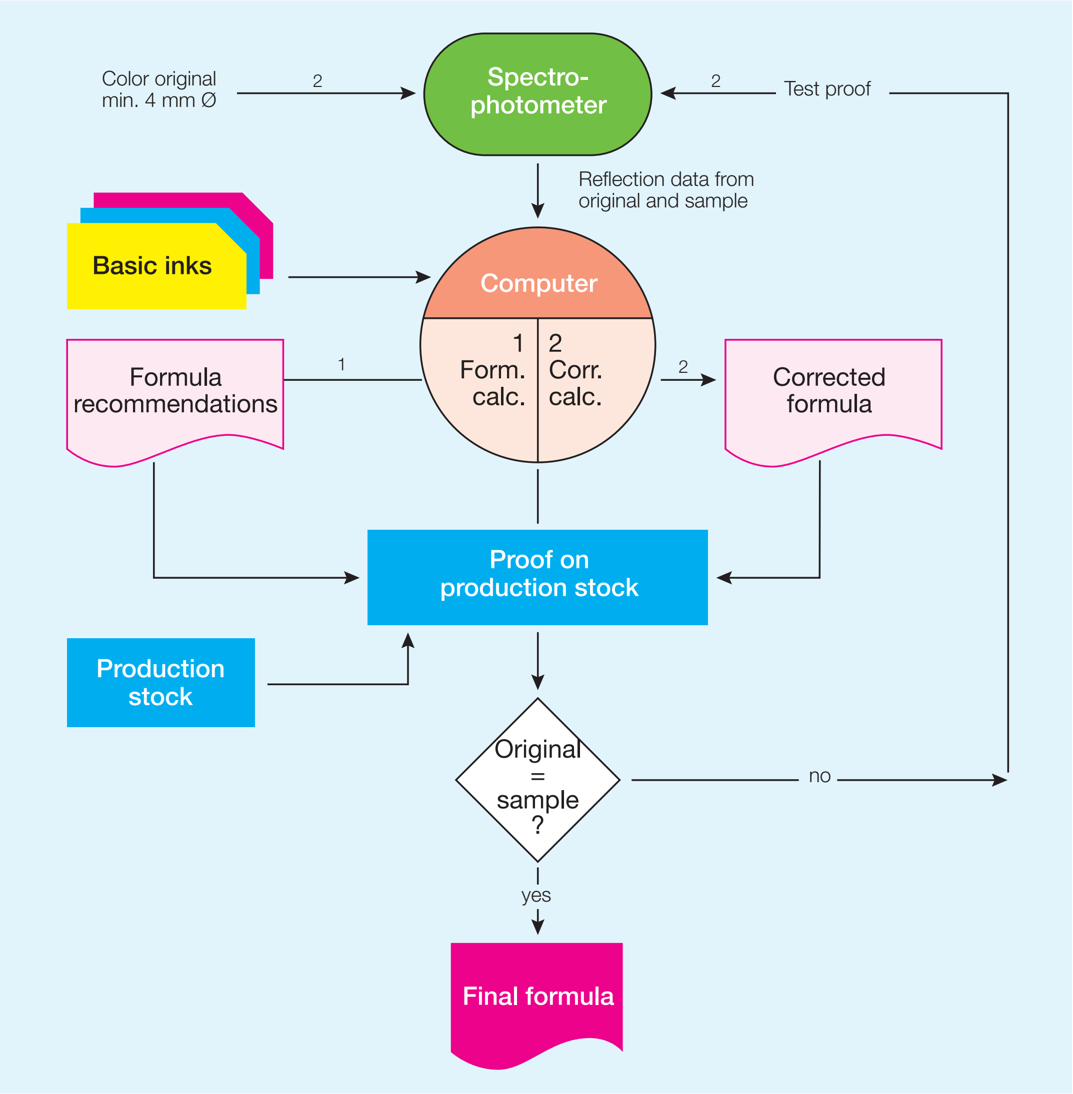


Fig. 6
Computer-aided ink mixing from basic inks

Basic colorimetric concepts

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

For a print shop's purposes, the goal of a colorimetric system is to supplement linguistic expressions with colorimetric measured values.

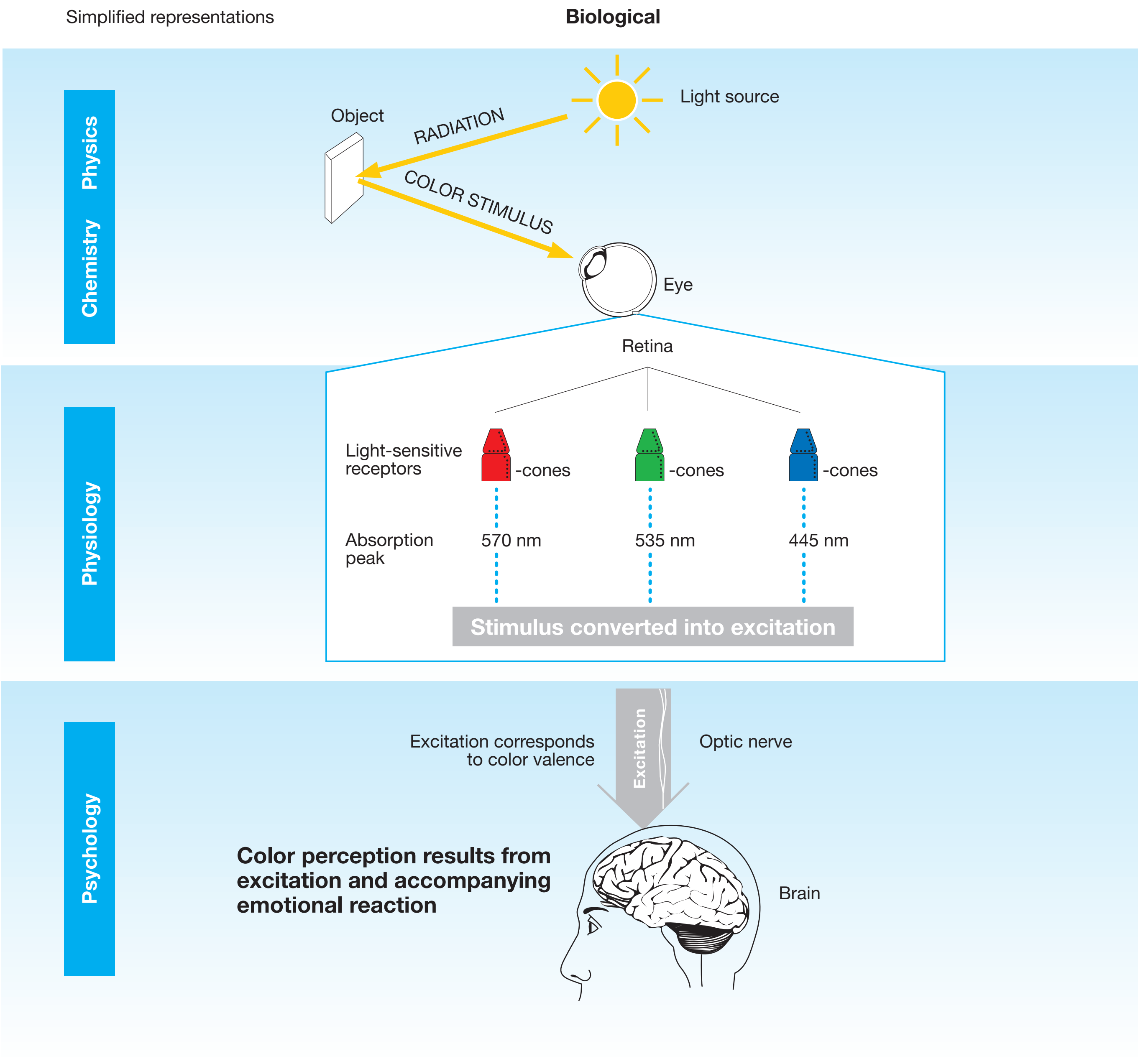
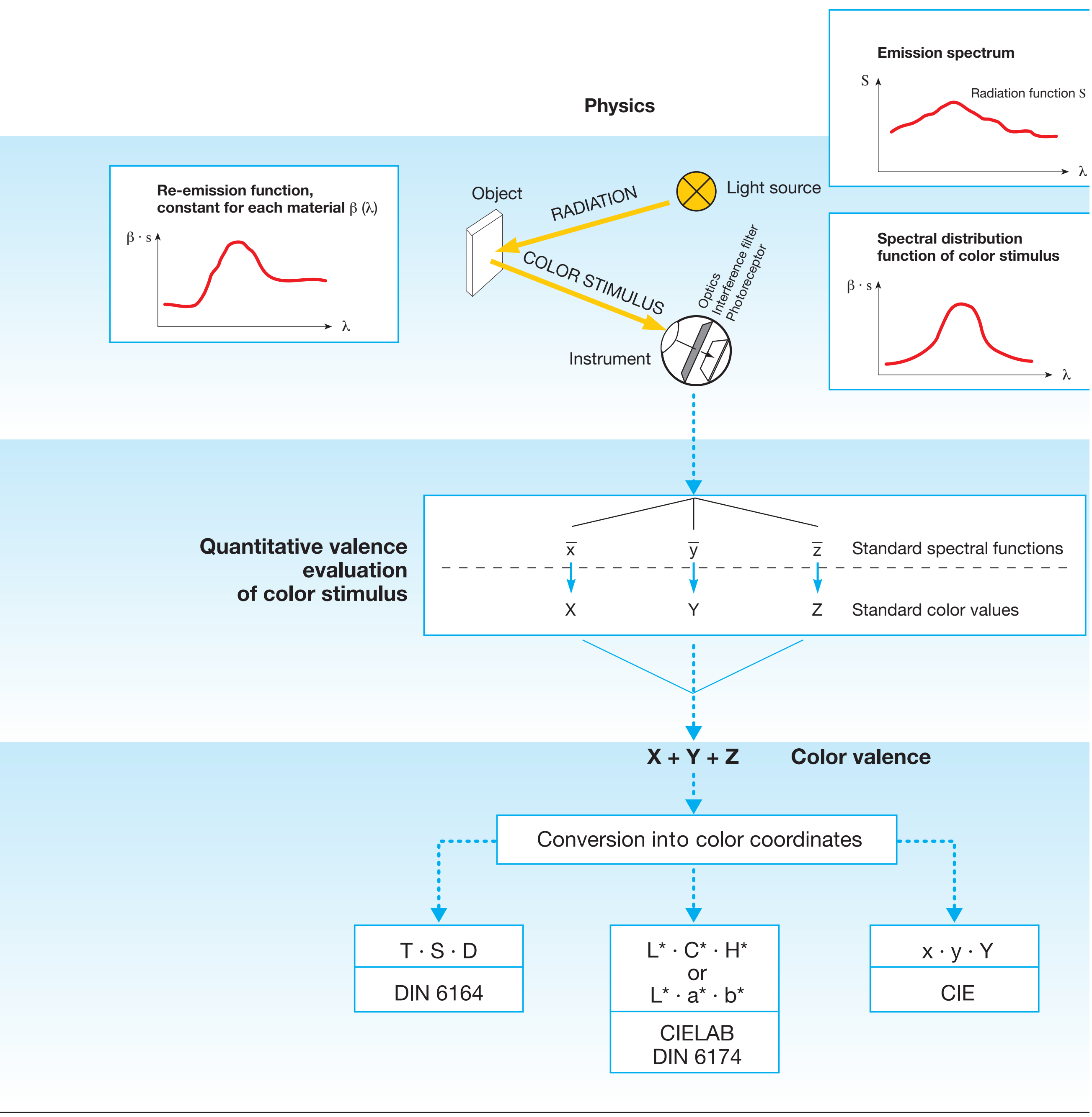


Fig. 7
The color valence and color perception sequence

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

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

one value for red (standard color value X);
one value for green (standard color value Y); and
one value for blue (standard color value Z).



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

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

This method is an instrumental attempt to "see" the color 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. 7 · The color valence and color 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 standard color values 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 signal that correlates with our color perception.

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

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

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

An introduction to the CIELAB system

The appearance and shape of the CIELAB system and the CIELAB color space can be imagined, in a simplified way, as a 100-story building with an air-shaft in the center (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: color strength increases with increasing distance from the center. The CIELAB does not use the term "color strength", however, but has instead adopted the word "chroma" (abbreviated C*) for this concept.

By walking around the center of the building once, one passes through the entire color circle (fig. 8).

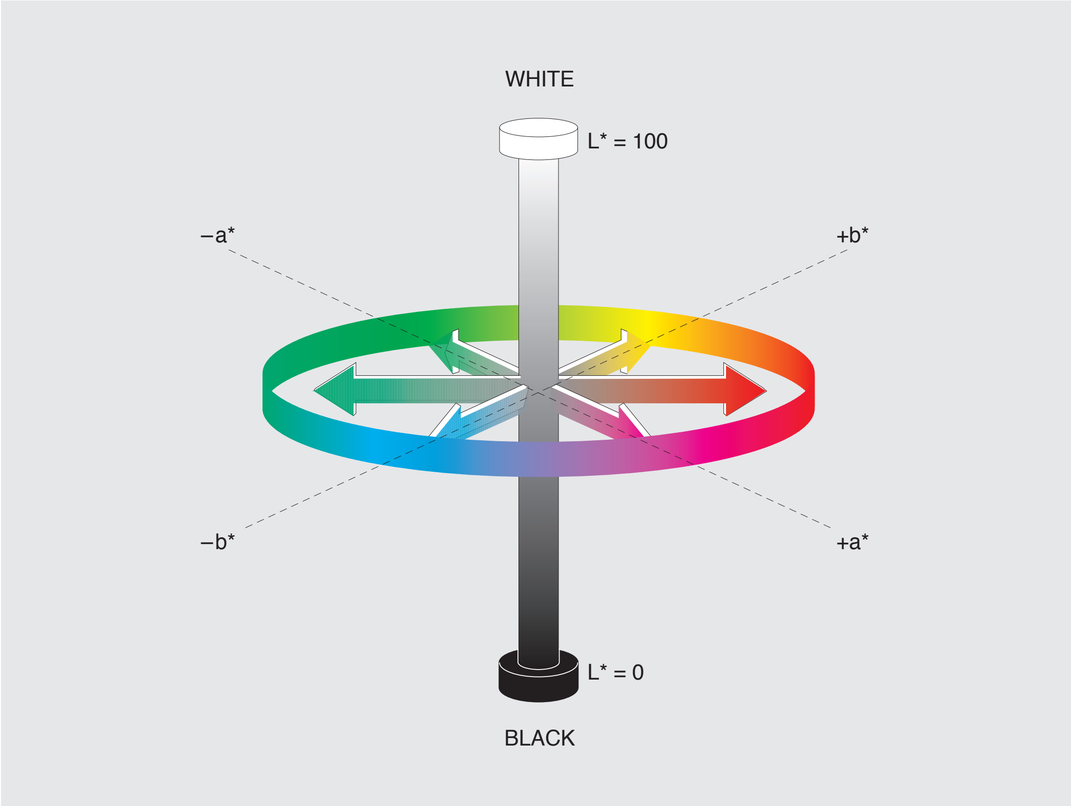


Fig. 8
The CIELAB color space, with coordinates L*, C*, H* resp. L*, a*, b*

With this categorization, we get three determining variables for each color location:

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

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

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

DL* (delta L-star): luminance distance

DC* (delta C-star): chroma distance

DH* (delta H-star): hue distance

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

The total color distance (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 color 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 for practice because it is less graphic (see also fig. 8).

DIN standard 6174 contains further details about color distance calculations.

Additional literature

DRUCKSPIEGEL-SEMINAR 87/88 Colorimetrics for repro and printing users

FRANK HÄUSER The creation of the color impression in autotypic color matching · Polygraph Verlag

PROF. DR. K. SCHLÄPFER Farbmetrik in der Reproduktionstechnik und im Mehrfarbendruck · UGRA