Chapter 4.

THE COLOUR

4.1. General remarks

Colour is a subjective psycho physiologic interpretation of the visible electromagnetic spectrum.

Luminous sensations or images, produced in our retina, are sent to the brain and interpreted as a set of monochromatic sensations which constitute the colour of the light.

The sense of sight does not analyze each radiation or chromatic sensation individually. For each radiation there is a colour designation, according to the frequency spectrum classification.

It is important to indicate that objects are distinguished by the colour assigned depending on their optical properties. Objects neither have nor produce colour. *They do have optical properties to reflect, refract and absorb colours of the light they receive, that is to say: the set of additive monochromatic sensations that our brain interprets as colour of an object depends on the spectral composition of the light that illuminates such an object and on the optical properties possessed by the object to reflect, refract or absorb*.

Newton was the first one to discover the decomposition of white light in the group of colours that forms a rainbow. When a white light beam went through a prism, the same effect as that indicated in Fig. 1 was obtained.

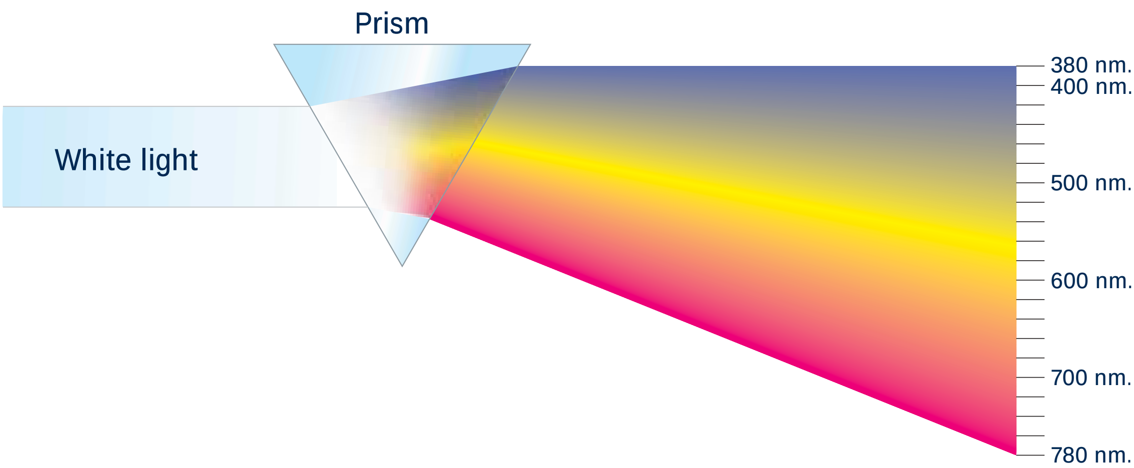

Figure 1. White light decomposition in the rainbow spectrum.

4.2. Colour classification according to the C.I.E. chromatic diagram

Subjective evaluations of object surfaces, in the same way they are perceived by the human eye, are interpreted bearing in mind colour attributes or qualities. They are the following:

a) *Lightness or brightness*: Luminous radiation received according to the illuminance possessed by the object. The further from black in the grey scale, the lighter the colour of an object. It refers to intensity.

b) *Hue or tone*: common name for colour (red, yellow, green, etc.). It refers to wavelength.

c) *Purity or saturation*: proportion in which a colour is mixed with white. It refers to spectral purity.

In order to avoid a subjective evaluation of colour there exists a chromaticity diagram in the shape of a triangle, approved by the C.I.E. It is used to treat sources of light, coloured surfaces, paints, luminous filters, etc. from a quantitative point of view.

All colours are ordered following three chromatic coordinates, x, y, z, whose sum is always equivalent to the unit ($x + y + z = 1$). When each of them equals 0.333, they correspond to the white colour. These three coordinates are obtained from the specific potencies for each wavelength. It is based on the fact that when three radiations from three sources of different spectral composition are mixed, a radiation equivalent to another with a different value may be obtained. The result is the triangle in Fig. 2, in which any two coordinates are enough to determine the radiation colour resulting formed by the additive mixture of three components.

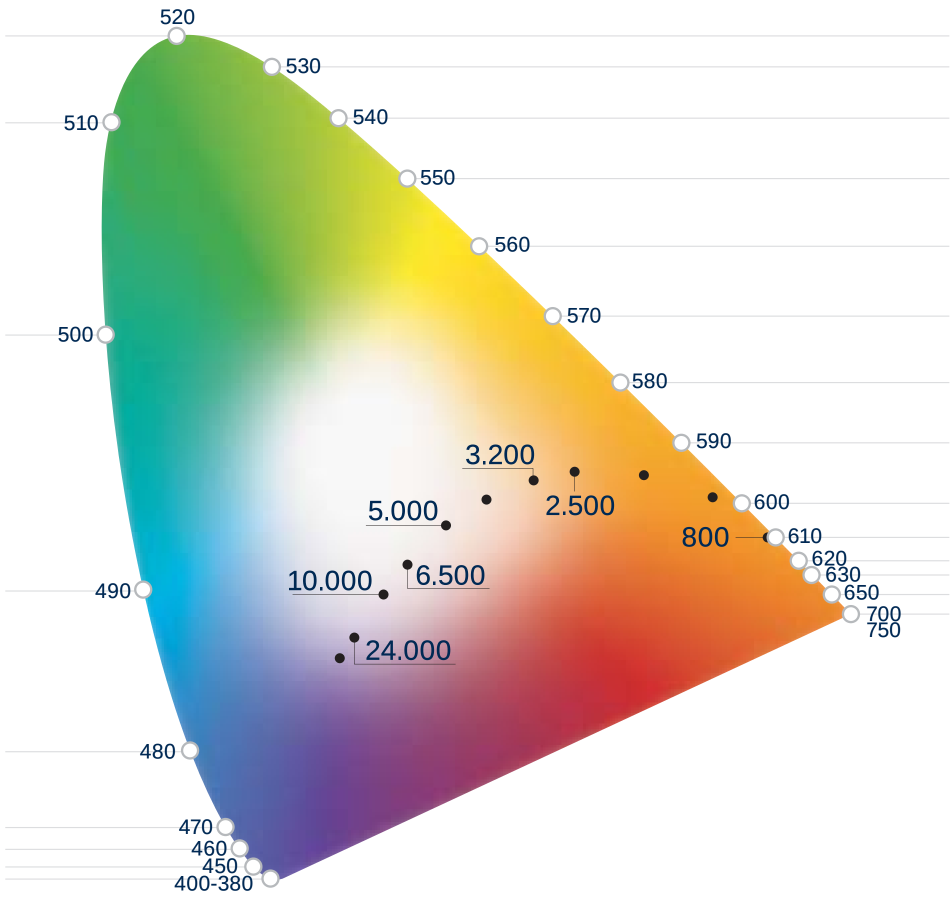

Figure 2. C.I.E. Chromaticity diagram

4.3. Colour temperature (T_C)

In the C.I.E. chromaticity diagram in Fig. 2, a curve has been drawn representing the colour emitted by a black body according to its temperature. It is known as *black body colour temperature curve, T_C.*.

Colour temperature is an expression used to indicate the colour of a source of light by comparing it with a black body colour, that is to say, a "*theoretical perfect radiant*" (object whose light emission is only due to its temperature). As any other incandescent body, the black body changes its colour as its temperature increases, acquiring at the beginning, a red matte tone, to change to light red later on, orange, yellow and finally white, bluish white and blue. For example, colour of a candle flame is similar to the one of a black body heated at about 1 800 K*. Then, the flame is said to have a "colour temperature" of 1 800 K.

Incandescent lamps have a colour temperature which ranges from 2 700 to 3 200 K, depending on their type. Their fleck is determined by the corresponding coordinates and is located virtually on the black body curve. Such temperature bears no relation at all with that of an incandescent filament.

Therefore, *colour temperature* is, in fact, a measure of temperature. It only defines colour and it can be applied exclusively to sources of light which have a great colour resemblance with the black body.

The practical equivalence between *colour appearance* and *colour temperature* is established arbitrarily according to Chart 1.

* K = Kelvin. Temperatures of Kelvin's scale exceed in 273 °C the corresponding ones in the centigrade scale.

Colour appearance group	Colour appearance	Colour temperature (K)
1	Warm	Below 3 300
2	Intermediate	From 3.300 to 5 300
3	Cold	Above 5 300

Chart 1

4.4. Colour rendering index *(R)*

Colour temperature datum is only referred to the colour of light, but not to its spectral composition which is decisive for colour reproduction. Thus, two sources of light may have a very similar colour and possesses, at the same time, very different chromatic reproduction properties.

The colour rendering index (R) characterizes the chromatic reproduction capacity of objects illuminated with a source of light. The R offers an indication of the capacity of the source of light to reproduce normalized colours, in comparison with the reproduction provided by a light as reference pattern.

Luminous sources	Tc (°K)	R.C.
Blue sky	10 000 a 30 000	85 to 100 (group 1)
Cloudy sky	7 000	85 to 100 (group 1)
Daylight.	6 000	85 to 100 (group 1)
Discharge lamps (except for Na)		
Daylight (halogene)	6 000	96 to 100 (group 1)
Neutral white	3 000 a 5 000	70 to 84 (group 2)
Warm white	Lower than 3 000	40 to 69 (group 3)
Discharge lamp (Na)	2 900	Lower than 40
Incandescent lamp	2 100 a 3 200	85 to 100 (group 1)
Photographic lamp	3 400	85 to 100 (group 1)
Candle flame or oil candle	1 800	40 to 69 (group 3)

Chart 2

Lamps colour rendering groups

In order to simplify the specifications for lamp colour rendering indexes of those used in lighting, colour rendering groups have been introduced as indicated in Chart 3.

Rendering group in colour	Rendering range in colour (R or R_a)	Colour appearance	Examples for preferible uses	Examples for acceptable use
1 A	R ≥ 90	Warm Intermediate Cold	Colour equalness, medical explorations, art galleries	
1 B	90 > R ≥ 80	Warm Intermediate	Houses, hotels, restaurants, shops, offices, schools, hospitals	
		Intermediate Warm	Printing, painting and textile industry, industrial work	
2	80 > R ≥ 60	Warm Intermediate Cold	Industrial work	Offices, schools
3	60 > R ≥ 40		Rough industries	Industrial work
4	40 > R ≥ 20			Rough work, industrial work with low requisites for colour rendering

Chart 3. Lamp colour rendering groups.

4.5. Colours and harmony psychic effects

It has been proved that colour in the environment produces psychic or emotional reactions in the observer. Hence, using colours in the adequate way is a very relevant topic for psychologists, architects, lighting engineers and decorators.

There are no fixed rules for choosing the appropriate colour in order to achieve a certain effect, since each case requires to be given a particular approach. However, there are some experiences in which different sensations are produced in the individual by certain colours.

One of the first sensations is that of heat or coldness. This is the reason why the expression "hot colours" and "cold colours" is mentioned. Hot colours are those which go from red to greenish yellow in the visible spectrum; cold colours the ones from green to blue.

A colour will be hotter or colder depending on its tendency towards red or blue, respectively.

On the one hand, hot colours are dynamic, exciting and produce a sensation of proximity. On the other hand, cold colours calm and rest, producing a sensation of distance.

Likewise, colour clarity also produces psychological effects. Light colours cheer up and give a sensation of lightness, while dark colours depress and produce a sensation of heaviness.

When two or more colours are combined and produce a comfortable effect, it is said that they harmonize. Thus, colour harmony is produced by means of selecting a colour combination which is comfortable and even pleasant for the observer in a given situation.

From all the above mentioned, it may be deduced that a knowledge of the spectral distribution curve of sources of light is necessary to obtain the desired chromatic effect.