Specifying colour

Introduction

This experiment is designed to introduce you to two categories of colour specification:

Phenomenological - describing colour in terms of our experience, or what we see,

Physical - either,
describing a colour in terms of its relationship to a known light source,
or,
describing a colour by the relative amounts of light from three reference light sources that are needed to visually match it.

This laboratory exercise will introduce you to one method of colour specification in each category.

A Phenomenological method

There are a whole host of colour systems that have been developed by scientists, artists and chemists. Indeed, the history of scientific investigation is full of writings on how colours may be described and explained. A few among the many who have written about colour are, Newton, Young, Goethe, Helholtz, Ostwald and Munsell. Some of the colour systems currently used are:

a) Ostwald system,
b) Munsell system,
c) Swedish Natural Colour System
c) Colour dimensions (Dulux paints)
d) British Standards, BS

Munsell developed the particular system that you are going to investigate. He was an American artist who developed his system around 1905. The particular reason for choosing this system in preference to others is that the light reflectance of a surface colour can be predicted quite simply from one of the colour variables. This is useful to designers of interiors because it allows them to easily estimate the light level within a room if the Value of the room surfaces is known.

The Munsell system describes colour in terms of three perceptual variables:

Hue describes the variation of colour that occurs as one moves through the spectral colours of a rainbow. The hue will describe the variation from red through orange, yellow, green, turquoise, blue to purple. If these hues are arranged in what appears to be a natural order, they form a circle.

Value describes the lightness of a surface. The darkest colour at the bottom of the scale has a Value of 1 and the lightest colour at the top of the scale has a Value of 10.

A good approximation of the reflectance of a surface is given by the relation:

$$\rho = V (V - 1) \%, \qquad 1$$

Where;

V = Value of the colour in the Munsell system,

ρ = Reflectance of the coloured surface as a %.

Chroma describes the strength of the colour. A pale colour has a low Chroma and the deeper the colour the higher will be its Chroma. The term Colour Saturation is sometimes used synonymously with the term Chroma.

The colours are arranged so that there appears to be an equal subjective interval between one colour and the colour next to it. This is true for all three of the scales.

The whole gamut of surface colours can be represented by a colour solid as is shown in Sheet 1 of the information booklet. For any given Hue, the Value and the Chroma may be arranged with Value being positioned along the vertical axis and Chroma being arranged along the horizontal axis as shown in Sheet 2 of the booklet.

Another useful aspect of the Munsell system is that it allows the user to easily see that there is a natural limit to the characteristics of some Hues. Thus it is not possible to have a high Value, high Chroma Blue Hue, nor a low Value, High Chroma Yellow Hue. This has important implications for the way designers choose colour schemes for interiors.

A Physical method

The Munsell method is appropriate for the description of surface colours, but it does not lend itself to the specification of the colour of light. Colour is one of the important characteristics of the light emitted from lamps and a method is required to describe it. The three most common ways of accurately describing the colour of light are:

a) Correlated colour temperature in Kelvin,
b) CIE Chromaticity co-ordinates,
c) Dominant wavelength and purity.

The experiment requires you to establish the colour chromaticity coordinates of a light source, and thus specify its approximate Correlated Colour Temperature.

Chromaticity Co-ordinates

A colour may be characterised by the amount of three different Primary Colours that when combined together match the colour of light being described. The three primary colours may be chosen arbitrarily, but usually the colours chosen are Red, Green and Blue.

This type of additive colour mixing is seen in colour television screens, where the colours seen are made up of red, green and blue pixels. Because these pixels are so small they are not separately seen, and therefore the overall effect produced is that of adding together, red green and blue light.

Maxwell's colour triangle in Figure 1 represents the addition of,

B amount of [Blue] primary plus
R amount of [Red] primary plus
G amount of [Green] primary,

Combine together to match colour C. This may be written as,

$$C[C] \equiv R[R] + G[G] + B[B]$$

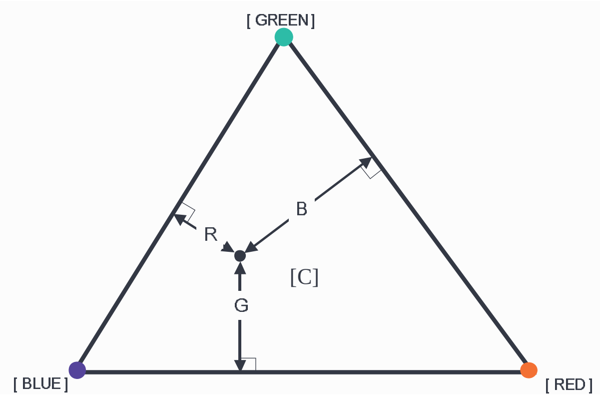

Figure 1 – Maxwell's colour triangle

The colour Chromaticity co-ordinates, r, g and b may be found from the amounts mixed together R, G and B, as follows,

$$r = \frac{R}{R+G+B},\ g = \frac{G}{R+G+B},\ b = \frac{B}{R+G+B}.$$

And so $r + g + b = 1$

In order that all real colours lie within the triangle formed by the colour Primaries used to describe the colours, three imaginary colour Primaries are chosen in place of the three real Primaries, Red, Green and Blue. These imaginary colours are known as CIE X,Y and Z primaries.

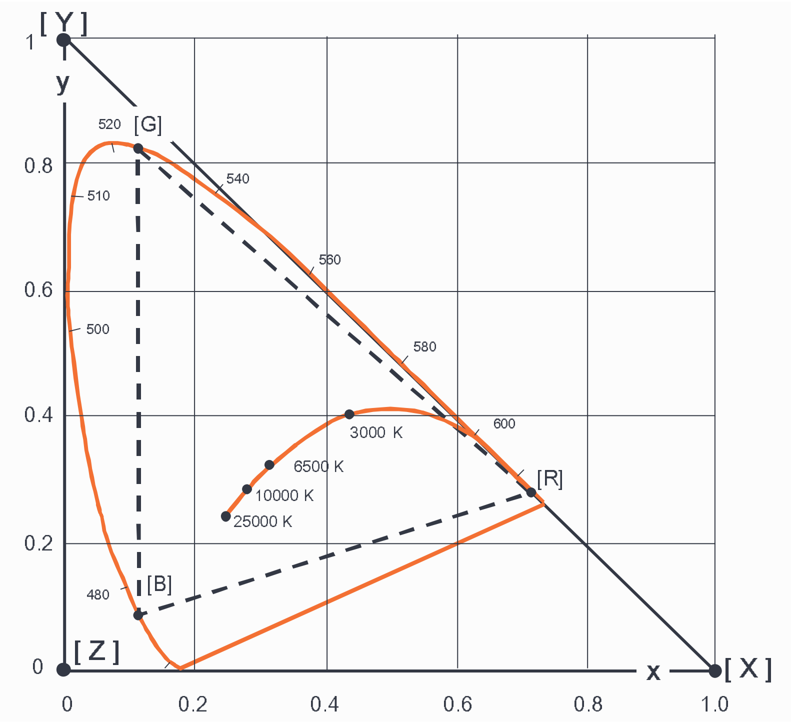

Figure 2 – CIE Chromaticity diagram

The CIE x,y and z chromaticity coordinates allow an accurate description of all colours and the Chromaticity diagram is different from the colour triangle only in that two of the axes are drawn horizontally and vertically. Because r + g + b =1 and x + y + z = 1, it is only necessary to quote two of the chromaticity co-ordinates, because the third is then automatically defined.

Also on Figure 2 is shown the locus of the colours from a full radiator.

Figure 2 is a chromaticity diagram that has been constructed using these CIE primaries X, Y and Z. Within the CIE diagram is drawn a Red, Green and Blue colour triangle. On this same diagram is drawn the locus of spectral colours. These are the colour appearances that result from viewing single wavelengths of radiation as are seen when a rainbow spreads the different wavelengths in the sky. It will be seen that the spectral colours lie outside the colour triangle formed by the Red, Green and Blue primary colours, but within the boundary of the X, Y and Z triangle.

If the amount of Red, Green and Blue light needed to visually match a colour C, then the CIE Chromaticity Co-ordinates may be found from the following expressions:

$$x_W = \frac{L_R x_R y_G y_B + L_G x_G y_R y_B + L_B x_B y_R y_G}{y_G y_B L_R + y_R y_B L_G + y_R y_G L_B}, \qquad 2$$

$$y_W = \frac{L_R y_R y_G y_B + L_G y_G y_R y_B + L_B y_B y_R y_G}{y_G y_B L_R + y_R y_B L_G + y_R y_G L_B} \qquad 3$$

$$z_W = \frac{L_R z_R y_G y_B + L_G z_G y_R y_B + L_B z_B y_R y_G}{y_G y_B L_R + y_R y_B L_G + y_R y_G L_B} \qquad 4$$

Where

L_R , L_G & L_B = the measured level of Red, Green or Blue light needed to match the white light,
x_R, x_G & x_B = the x chromaticity co-ordinates of the red, green and blue primaries,
y_R, y_G & y_B = the y chromaticity co-ordinates of the red, green and blue primaries,
x_W = the x chromaticity co-ordinate of the white lamp
y_W = the y chromaticity co-ordinate of the white lamp
z_W = the y chromaticity co-ordinate of the white lamp

The chromaticity co-ordinates of the Red, Green and Blue primaries used to match the white light are:

	CIE Chromaticity Co-ordinates of Primary colours [R],[G] and [B]		
Primary colour	x	y	z
[R] Red	0.6992	0.2849	0.0159
[G] Green	0.0867	0.7963	0.1170
[B] Blue	0.1428	0.0657	0.7915

TASK A

You have been provided with,

a) a series of colour patches that are all of one Hue.

b) a template that shows positions that can be occupied by the colour patches with which you have been provided.

You are requested to:

1 Plot the Reflectance versus Value on the Results sheet.

2 Given 20 number 1 ltr. cans of white paint and 20 number 1 ltr. cans of black paint, calculate the amounts of black and white paint that are needed to provide 2 ltr. of mid grey paint. Assume that white paint reflects 100% and Black paint reflects 5%, and that mid grey appears to be visually mid way between white and black.

3 When mixing the paints, state whether you would either,

a) start off with black paint and add the white paint to the black paint,

or

b) start off with white paint and add the black paint to the white paint.

4 Arrange the colour patches on the template so that they form a pattern that displays a uniform gradation of Value and Chroma. The lowest Values being at the bottom, and the lowest Chromas being to the left of the page. This may not be an easy task and you will need to consider the sequence of colours to see whether they form a regular change in appearance along both the Value and Chroma variables.

5 Use the chart that you have just arranged to identify the Value and Chroma of the three colours attached to the sheet 3 of the information booklet.

On the results sheet, write the Value and Chroma of each sample in the appropriate box and suggest a colour name for each sample. The colour name should be your own choice and not arrived at after discussion with other members of the laboratory group.

TASK B

You should use the Colour Comparator. A sketch diagram of this apparatus is shown in Figure 5 below.

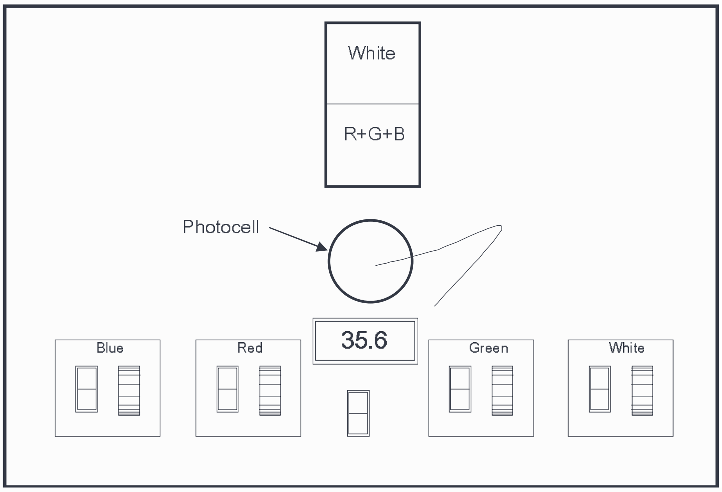

Figure 5 - Sketch of front of Colour Comparator

1 Use the photocell to ensure that the light reading from the top white light is less than 110. Ensure that the Red, Green and Blue lights are switched off when doing this.

2 Switch on the Red, Green and Blue lights, and then use the dimmer wheels to achieve a visual match with the upper white light.

3 The match should be as close as you can achieve, both in terms of brightness and colour. The brightness match can be checked by reading the light level top and bottom with the photocell.

4 On achieving a visual match, switch off the white lamp and then using the photocell measure the combined level of light from the three lamps Red, Green and Blue.

Then switch off the Green lamp and measure the light from the Blue and Red Lamp,

Then switch off the Red lamp and measure the light from the Blue Lamp.

5 Thus, calculate the level of light from the Red, Green and Blue lamps that matches the light from the white lamp.

6 Also calculate the average levels for the group.

7 Calculate the CIE Chromaticity Co-ordinates of the White lamp using the formulae 2 and 3 and 4.

8 Estimate the approximate Correlated Colour Temperature of the White lamp using the CIE chromaticity chart and the chromaticity co-ordinates previously established for yourself and for the whole group.