Colour

Colour is a ratio relating a human response to physical energy, like its audio counterpart the decibel. Colour fills our lives and affects our choices and preferences of objects as diverse as cars, clothes and food. It is used to promote corporate identity, to camouflage and provide information. Colour is among the 'newest' of measurements and significant advances are still taking place today. NPL has always been deeply involved in the development of colour specification and measurement.

What is colour?

The brain uses the sensation of colour to code proportions of different wavelengths of light. The colour of objects depends on: how they are illuminated, how they absorb or scatter light and how our eyes and brains react.
As spectral information is encoded by the eye and brain into three signals, only three numbers are needed to represent all possible colours.
The most popular systems plot colours within a cylindrical colour space with three co-ordinates: Hue, Brightness and Colourfulness.

How do we measure colour?

To measure colour, instruments attempt to replicate the extremely complicated human visual function. They start by evaluating the relative amounts of spectral light emitted, reflected, or transmitted by objects, and convert these to colour values such as Hue, Brightness and Colourfulness using a model of the human visual system known as the 'Standard Observer'*.

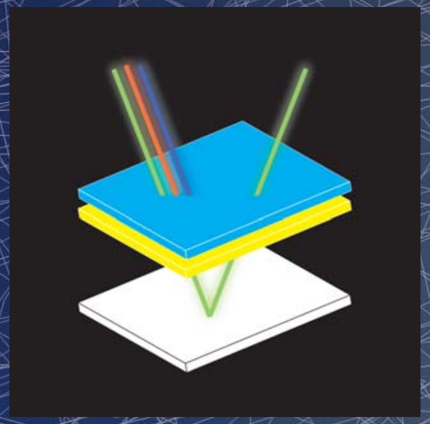
*The 'Standard Observer' is a model representing human colour vision internationally adopted by the International Commission on Illumination (CIE) in 1931.

Colour at NPL

The Standard Observer is based on experiments conducted in the late 1920s at NPL and Imperial College, London. NPL develops and accurately measures colour standards which are used throughout the world to ensure that colour measuring equipment from Bolton to Bangladesh will produce compatible results.

Adding and subtracting light generates ranges of colours

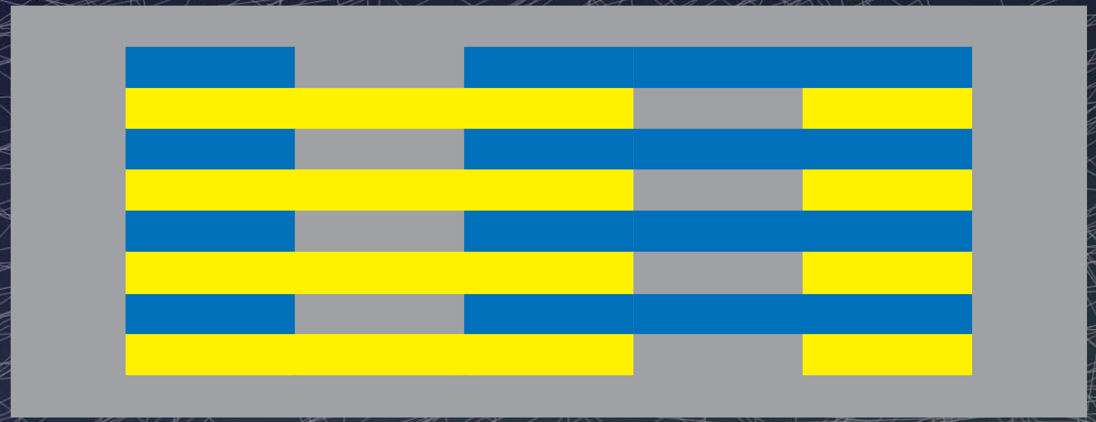
As colour is encoded using three numbers, only three 'primaries' are needed to create most colours. Close inspection of a TV shows that the wealth of screen colours are generated solely by dots of red, green and blue light. There are no yellow dots. Yellow is produced by ADDING equal amounts of red and green light. In colour printing and painting, three inks SUBTRACT red, green and blue light from the white paper to create a wide colour range. Magazines don't use green ink, an overlay of cyan and yellow absorbs all but the green.



The ink subtracts the red and blue light making it appear green

Why do things change colour?

Object colour depends greatly on illumination.
Two surfaces - say a bathroom suite and a painted wall - can match perfectly under daylight, but appear totally different when illuminated by a domestic tungsten lamp. This is because two different combinations of source spectra and object spectra may produce identical sets of signals in the visual system, so the objects have the same perceived colour. Changing the source spectrum means the same visual signals are no longer generated, so the colours no longer match. This effect, called metamerism, is the reason astute shoppers check that clothes combinations match in colour both within store and by daylight through the window.



Colour appearance

We don't see colour in isolation. Artists know that red can be made to appear redder by surrounding it by a complementary green. Classifying isolated colours in terms of three signals is just the start. Until very recently it was just not practical to research and measure the complexities of colour of real world scenes. However, the fastest of today's computers combined with digital imaging technology are making this possible for the first time.

What you see is not what you get!

It seems perfectly reasonable to expect computer monitor image colours to print faithfully. Yet the more critical users of multimedia are painfully aware that this just doesn't happen. Even for high quality, carefully adjusted systems, the different methods of generating colour means that the two devices will offer different gamuts of colour - some reds just won't print. Reflected printed colour is perceived differently from luminous monitor colour, and of course the printed colour will change under different lighting conditions.

Spectral colours

In 1669, Newton, aged only 27, was appointed Lucasian Professor at Cambridge. His first work in this post was in the area of optics. During the two plague years, he concluded that white light is not a simple entity. This idea contravened every scientist since Aristotle, but chromatic aberrations seen by Newton in a telescope lens convinced him otherwise. When he passed a thin beam of sunlight through a glass prism Newton noted the spectrum of colours that was formed.

Newton argued that sunlight is a mixture of many different types of rays, each refracted at slightly different angles, and that each type of ray produces a different spectral colour. The names he used to describe these colours became known as Newton's spectrum. He pointed out that the rays themselves are not coloured.

These spectral colours are shown below in order of energy (proportional to frequency and inversely proportional to wavelength).

Ultraviolet
Ultraviolet is not strictly light as it is invisible - mostly screened from the retina by the lens. Some substances absorb UV and re-emit as visible wavelengths (fluorescence).

Violet
Violet is at the extreme high energy limit of human vision. The edge of visibility changes significantly with age as the lens becomes more yellow.

Indigo
Indigo is a vegetable dye once used to give denim its distinctive colour. Possibly it was included in Newton's spectrum for mystical reasons

Blue
The sky appears blue because the amount of scattering of light is proportional to its energy. Light scattered by air particles makes the atmosphere a luminous blue.

Cyan
Cyan - Not one of Newton's colours. This has become significant as the colour of a printing ink primary.

Green
Why is grass green? Plants use red and blue light to manufacture sugars. We see the reflected unused green light.

Yellow
The yellowing of paper is countered by 'optical brightening agents' - chemicals which fluoresce UV into blue light.

Orange
The conversion of electrical to optical energy at only two orange wavelengths makes low pressure sodium vapour streetlights extremely efficient. However it does mean the only colours visible are shades of orange.

Red
Red promotes strong emotional responses world-wide. Used internationally to signify danger. Walls painted red have been shown to increase workplace tension.

Infrared
Not strictly light as infrared is not energetic enough to be detected by the eye.

If you have a measurement related scientific question contact us on:
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