Colour and light

The nature of colour

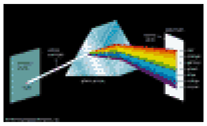

Figure 1: Newton's prism experiment.

Aristotle viewed all colour to be the product of a mixture of white and black, and this was the prevailing belief until 1666, when Sir Isaac Newton's prism experiments provided the scientific basis for the understanding of colour. Newton showed that a prism could break up white light into a range of colours, which he called the spectrum (see Figure 1), and that the recombination of these spectral colours re-created the white light. Although he recognized that the spectrum was continuous, Newton used the seven colour names red, orange, yellow, green, blue, indigo, and violet for segments of the spectrum by analogy with the seven notes of the musical scale.

Newton realized that colours other than those in the spectral sequence do exist, but noted that all the colours in the universe which are made by light, and depend not on the power of imagination, are either the colours of homogeneal lights [*i.e.*, spectral colours], or compounded of these.

Newton also recognized that rays, to speak properly, are not coloured. In them there is nothing else than a certain power to stir up a sensation of this or that colour.

Nevertheless, terms such as “blue light” are commonly used and normally do not produce any confusion.

The unexpected difference between light perception and sound perception clarifies this curious aspect of colour. When beams of light of different colours, such as red and yellow, are projected together onto a white surface in equal amounts, the resulting perception of the eye signals a single colour (in this case, orange) to the brain, a signal that may be identical to that produced by a single beam of light.

When, however, two musical tones are sounded simultaneously, the individual tones can still be easily discerned; the sound produced by a combination of tones is never identical to that of a single tone. A tone is the result of a specific sound wave, but a colour can be the result of a single light beam or a combination of any number of light beams.

A colour can, however, be precisely specified by its hue, saturation, and brightness—three attributes sufficient to distinguish it from all other possible perceived colours.

The hue is that aspect of colour usually associated with terms such as red, orange, yellow, and so forth. Saturation (also known as chroma, or tone) refers to relative purity.

When a pure, vivid, strong shade of red is mixed with a variable amount of white, weaker or paler reds are produced, each having the same hue but a different saturation. These paler colours are called unsaturated colours. Finally, light of any given combination of hue and saturation can have a variable brightness (also called intensity, or value), which depends on the total amount of light energy present.

The visible spectrum

Newton demonstrated that colour is a quality of light. To understand colour, therefore, it is necessary to know something about light. As a form of electromagnetic radiation, light has properties in common with both waves and particles. It can be thought of as a stream of minute energy packets radiated at varying frequencies in a wave motion.

Any given beam of light has specific values of frequency, wavelength, and energy associated with it. Frequency, which is the number of waves passing a point in a unit of time, is commonly expressed in units of hertz (1 Hz = 1 cycle / second).

Wavelength is the distance between corresponding points of two consecutive waves and is often expressed in units of nanometres (1 nm = 10^{-9} metres). The energy of a light beam can be compared to that possessed by a small particle moving at the velocity of light, except that no particle having a rest mass could move at such a velocity.

The name photon, used for the smallest quantity of light of any given wavelength, is meant to encompass this duality, including both the wave and particle characteristics inherent in wave mechanics and quantum theory.

The energy of a photon is often expressed in units of electron volts; it is directly proportional to frequency and inversely proportional to wavelength.

Light is not the only type of electromagnetic radiation—it is, in fact, only a small segment of the total electromagnetic spectrum—but it is the one form the eye can perceive.

Wavelengths of light range from about 400 nm at the violet end of the spectrum to 700 nm at the red end (see the Table). (The limits of the visible spectrum are not sharply defined but vary among individuals; there is some extended visibility for high-intensity light.)

At shorter wavelengths the electromagnetic spectrum extends to the ultraviolet region and continues through X rays, gamma rays, and cosmic rays.

Just beyond the red end of the spectrum are the longer wave infrared rays (which can be felt as heat), microwaves, and radio waves.

Radiation of a single frequency is called monochromatic. When this frequency falls in the range of the visible spectrum, the colour perception produced is that of a saturated hue.