



Kalcor University

The Art & Science of Color Measurement & Matching

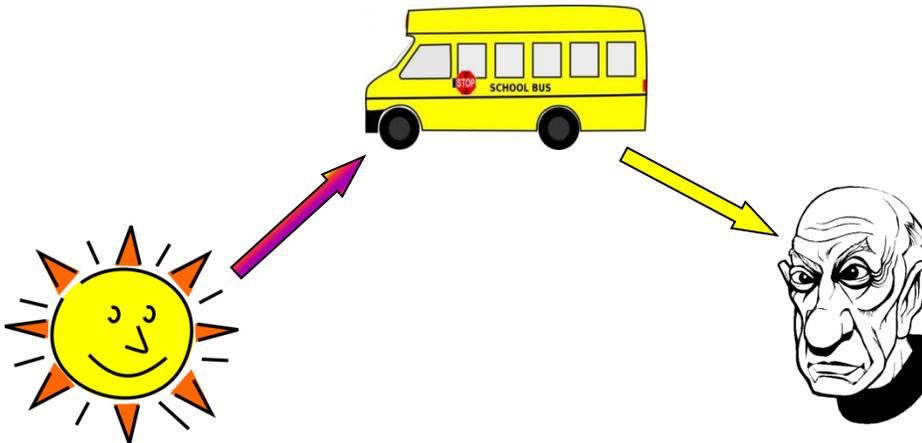


What size Crayon box did you grow up with? 8, 24... maybe the 64 crayon box with built in sharpener? Your palette may have grown in sophistication from yellow to dandelion or purple to Razzmic Berry. Today, a visit to the local Home Lowes or Home Depot has the same dizzying effect – so many colors.

A critical part of the paint formulator's job is frequently to produce the perfect shade – the exact color the customer needs. Maybe it is to perfectly match an existing color like John Deere Green, or maybe to devise some fashionable new look for a cellphone or perfume bottle. In either case understanding how color is perceived, and how it is measured is fundamental to talking about color. This paper briefly describes the science of color perception and measurement. Because as every engineer knows – you can't control it if you can't measure it.

How we perceive color.

There are three components necessary for us to see color; a light source, an object and our eye. Take this simple example:

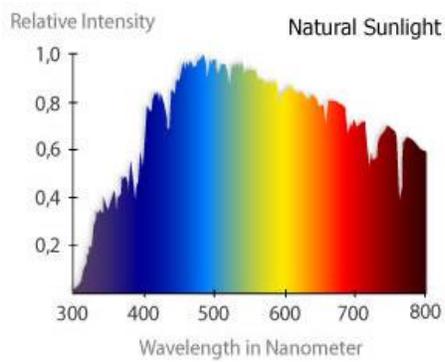


Here, Picasso sees the yellow schoolbus when sunlight strikes the bus and reflects yellow light to his eyes.

To measure color with some sort of apparatus we must substitute for these with mechanical components. Instead of the sun, a school bus and our eyes, color measurement systems incorporate a light source, our test specimen and color sensors. And, to describe color more precisely than using qualitative descriptions like redder or greener, we have devised a scale by which colors can be compared quantitatively.

Light Sources

We normally think of light sources as emitting some kind of white light. But we recall from Newton's famous prism experiment that white light is actually a mixture of many colors. We see a rainbow after a



rainstorm because water droplets acting like millions of tiny prisms divides the white light up into its constituents by refracting them. We might even recall the R-O-Y-G-B-I-V mnemonic for recalling that the rainbow colors go from red to violet in a continuous spectrum. In fact, by measuring the wavelength of these various colors we know that the visible spectrum ranges from about 400 to 700 nanometers.

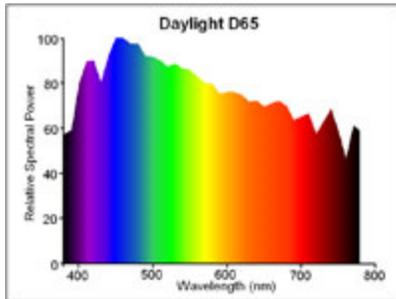
But artificial light is not exactly the same as sunlight. And various kinds of artificial light sources appear differently to our eyes as well. From bright tungsten lamps, to the blue cast of fluorescent lights to the yellow glow of sodium streetlights, we recognize that the light sources are different and that affects how objects look to us. Many people demur from buying an expensive suit in a department store until they can see it in more "natural" lighting. Ladies makeup mirrors often have settings for different kinds of light.

The two photos at right demonstrate the effect of the light source on two identical swatches of paint. The color cards in the top and bottom photos are the same – only the type of light source has changed. To describe color in a repeatable fashion, we must standardize the light source, describing accurately its spectral output.



One popular means to describe light sources is to compare their color temperatures. The color temperature of a light source is the temperature of an ideal black-body radiator that radiates light of comparable hue to that of the light source. Color temperature is conventionally stated in the unit of absolute temperature, the kelvin, having the unit symbol K.

Color temperatures over 5,000K are called cool colors, while lower color temperatures (2,700–3,000 K) are called warm colors. Daylight has a spectrum similar to that of a black body with a correlated color temperature of 6500K.

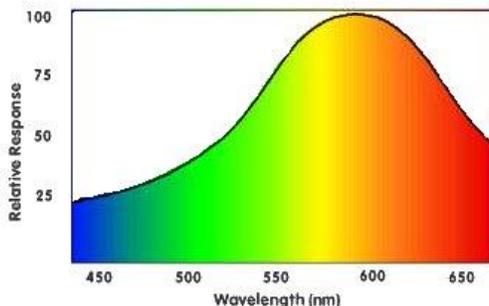
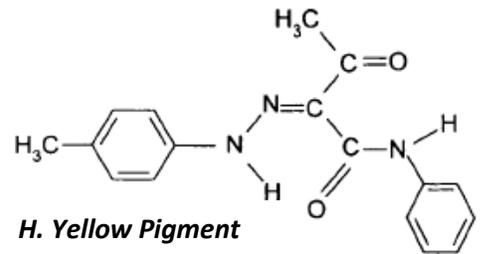


Natural daylight is often a preferred light source for evaluating color and so artificial lights have been developed that replicate the spectra of daylight. The CIE Standard Illuminant D65 is a common standard illuminant defined by the International Commission on Illumination (CIE). D65 corresponds roughly to a mid-day sun in Western Europe / Northern Europe; hence it is also called a daylight illuminant. D65 lamp sources are therefore common to color

measurement equipment, and color inspection booths with daylight settings rely on D65 lamps to replicate natural sunlight. The term illuminant metameric failure is sometimes used to describe situations where two material samples match when viewed under one light source but not another.

The Object

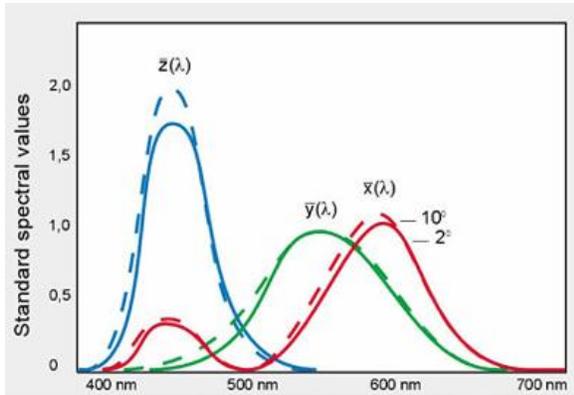
Objects modify light that strikes their surface. Different materials absorb various wavelengths of light and reflect others. Colorants such as dyes or pigments selectively absorb certain specific wavelengths while reflecting others. The wide range of organic and inorganic pigments available to the formulator creates a jumbo Crayon box they can choose from. Blending these pigments like an experienced perfumer does with exotic and subtle scents can create great beauty of a disastrous mess. This is truly the art of the color matching or creation process. Many aspects of paint pigments affect their appearance and performance in paints. The chemical structure and its interaction with other pigments and additives, the fineness of the pigment grind, the manner in which the pigment can be dispersed



Color Sensing

The final component of the color measurement system is the “eye” of the apparatus. In fact a great deal of work has been done by scientists and engineers to develop sensors that mimic the way our eyes perceive color. The human eye, which uses rods and cones as receptors for perceiving color, has a characteristic spectral sensitivity. It is the failure of different rods or cones that causes selective color blindness.

To construct a machine which “sees” colors as we do, engineers tune the spectral sensitivity of color sensors to replicate the same sensitivity of human eyesight. The CIE 1931 color standard is



Human spectral sensitivity to color
 Three cone types (ρ , γ , β) correspond roughly to R, G, B.

