Applications Note

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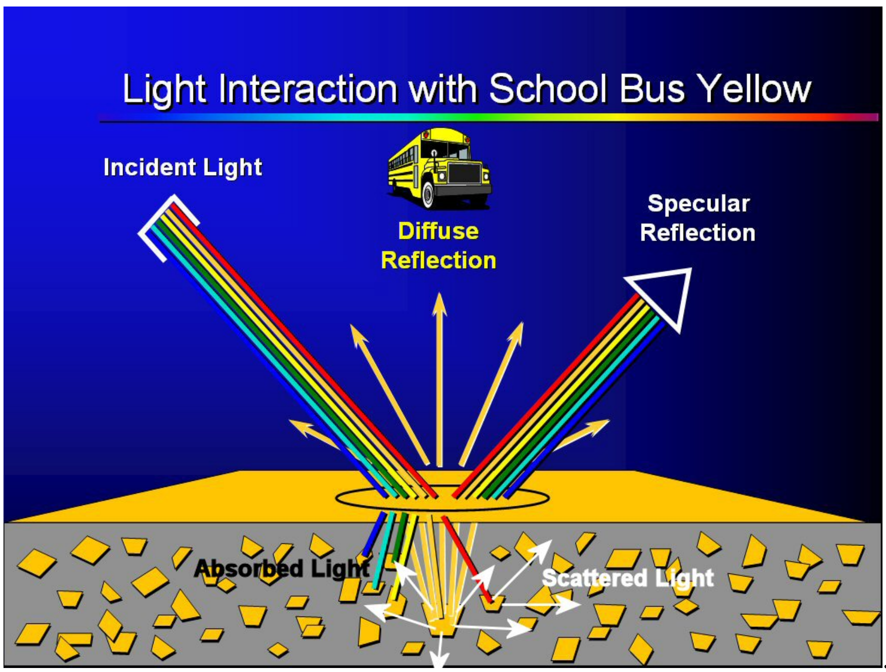
The Kubelka-Monk Theory and K/S

What happens to the light that is shined on a sample, as from the light source of a spectrophotometer? Some is reflected back to the instrument detector, some is absorbed by the colorants in the sample, and some of it is scattered in all directions within the sample.



For samples with opacities greater than 75%, the Kubelka-Monk equation (established in 1931) defines a relationship between spectral reflectance (R in %) of the sample and its absorption (K) and scattering (S) characteristics, as follows:

$$\frac{K}{S} = \frac{\left[1 - 0.01\,R\right]^2}{2\left[0.01R\right]}.$$

For instance, if spectral reflectance at a given wavelength is 55%, its K/S at that wavelength is calculated as follows:

$$\frac{K}{S} = \frac{[1 - 0.01 * 55]^2}{2[0.01 * 55]} = \frac{0.45^2}{1.1} = 0.184.$$

K/S values for the sample measured are calculated separately for each wavelength read. K/S may only be calculated for measurements made in a reflectance mode. K/S is a spectral data type, meaning it is calculated and displayed for each measurement wavelength in the Spectral Data Table of your EasyMatch QC or Universal software. K/S grows to infinity as reflectance decreases to zero, so the software may not display a K/S value for a particular wavelength or wavelengths if the reflectance is very low (i.e., less than 0.05%).

The Kubelka-Monk equation is useful when formulating colors for industries such as textiles, paper, and coatings. For these applications, it is assumed that the scattering (S) of a dye or pigment depends on the properties of the substrate or opacifier, while the absorption (K) of light depends on the properties of the colorant. The Kubelka-Monk equation is roughly linear with respect to colorant concentration, as follows:

$$K/S = kC$$

where

C = concentration of the colorant

k = a constant.

The Kubelka-Monk theory further extends to mixtures of colorants and asserts that the K/S value for a mixture of colorants is the sum of the K/S values of the individual colorants, as follows:

$$(K/S)_{\text{mixture}} = a(K/S)_{\text{colorant 1}} + b(K/S)_{\text{colorant 2}} + c(K/S)_{\text{colorant 3}} \ldots + (K/S)_{\text{base}}$$

where

a, b, c, etc. are the concentrations of the corresponding colorants.

This assumption can be practically applied when the appearance of finished materials must be related to the kinds and amounts of colorants put into them. It is what makes computer color formulation and color matching (as opposed to visual trial-and-error methods) possible. K/S values for all the individual colorants are first determined and are then stored in the computer for use any time those colorants are included in a mixture.

Bibliography

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