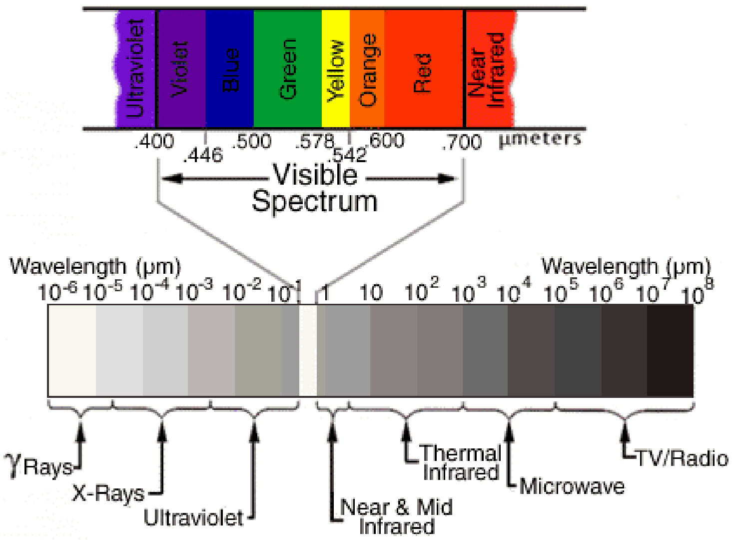
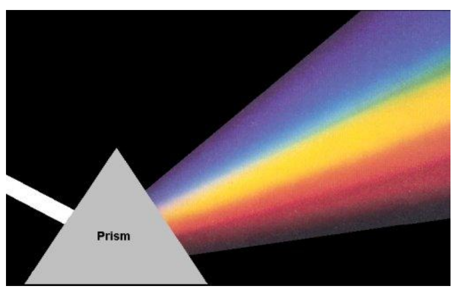
Brief Comments on Color
(Beyond CEM 101 … Not on CEM exams … some aspects discussed in Unit 11)

Color, as we perceive it, is a small portion of a broad range of energies known as the electromagnetic spectrum. Our eyes see only the visible light ("visible spectrum") portion of a continuous range of energies. Other (non-visible) energies are perceived by a variety of electronic devices.

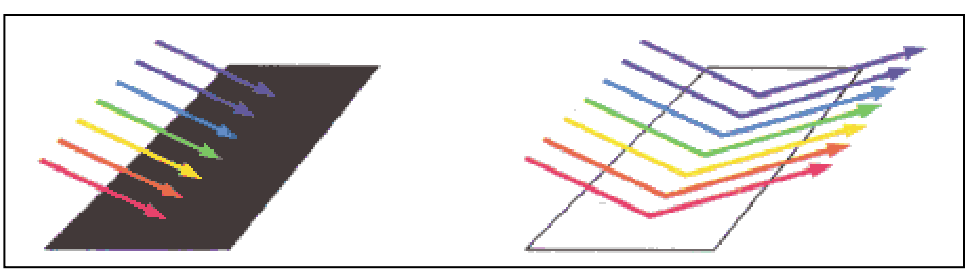


Sunlight (also called white light) is a mixture of colors that we perceive as a white color. The individual colors in white light can be visualized using an optical device called a prism. In nature, raindrops can act as a prism: white sunlight is dispersed into its component colors with the results called a rainbow. The order of colors, Red, Orange, Yellow, Green, Blue, Indigo and Violet (memory key: ROY G BIV) is always the same: from red to violet in order of increasing energy.

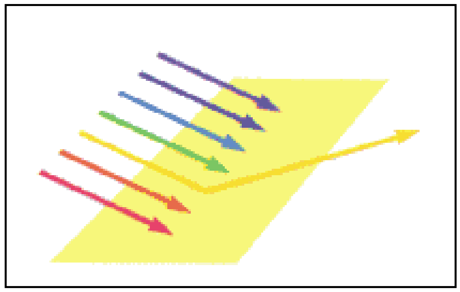


The color we see depends upon the path the light takes from its initial source to our eyes.

If all of the colors of the incoming light used to illuminate an object are absorbed, then we see the object as black. (Black is not a color; black is the designation for the absence of color.) This absorption of energy is why a black object typically is warmer than an identical white-colored object when both are left in direct sunlight. If all of the colors of the light are reflected from the object, then we perceive the object as being white.

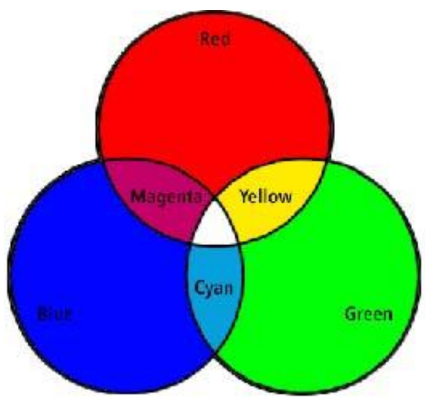


The color we see depends on which energies of light are selectively absorbed or reflected.
For example, when sunlight strikes an object we perceive as yellow, all of the colors of the rainbow, but yellow, are absorbed by the yellow-colored-object. Since only the yellow light is reflected, our eyes perceive the color as yellow. This selective absorption/reflection occurs for all the colors of the visible spectrum.



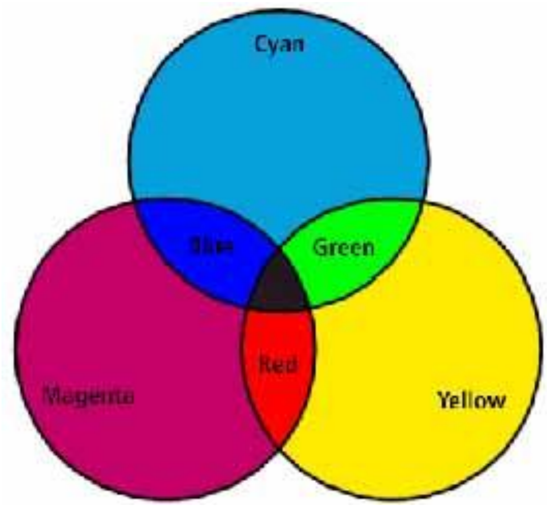
It turns out that all of the colors of light can be rendered from three "primary colors" of red, blue or green. In other words, various combinations of red, green, and blue light can be used to derive all the colors of light we see. This is why your eyes have three different sensors; one each for red, blue, and green. It is also why your television screen has each pixel or dot composed of an overlapping mixture of the three primary colors. By selectively illuminating various primary colors within the pixel or the human eye, all the colors can be rendered. The interaction of various light energies of the primary colors to form other colors is called color addition. **This addition of colors applies only to light, not pigments, dyes, or chemical compounds.** In other words, the rendering of colors depicted in the color wheel below applies only to shining lights of various colors and observing the results.

The Color Addition wheel: Colors formed from the primary colors of light



When dealing with the colors of objects: dyes, pigments, or inks, another scheme is used. This is because, as in the yellow reflected light illustration above, the colors of objects we see are a result of some colors being removed (absorbed) while others are merely reflected. So, since we are dealing with an absorption phenomenon, the colors we perceive are a result of the subtraction of various colors from white light. So, when dealing with dyes, inks, paints, and pigments, the primary colors are not red, green and blue, they are cyan, magenta, and yellow. The corresponding color wheel for the mixing of dyes, pigments, and inks is shown below:

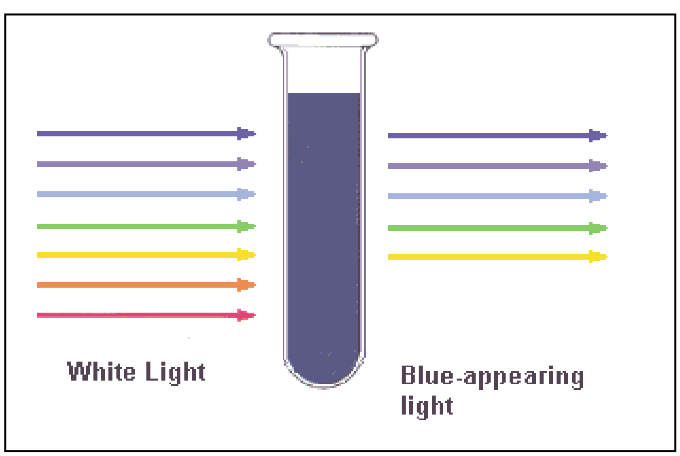
The Color Subtraction Wheel: Colors formed from the primary colors of pigments



Color subtraction (or absorption) also occurs when white light passes through colored transparent objects or liquids. This is the basis for a variety of "color correction" filters that photographers use on their lenses to selectively enhance various color tones. A table showing some of these "subtractions" is shown below:

Wavelength (Angstroms) Removed	Color Removed	Color Seen (Complementary color)
6800	Red	Blue-green
6100	Orange	Blue
5800	Yellow	Indigo
5600	Lemon Yellow	Violet
5300	Green	Purple
5000	Blue-green	Red
4800	Blue	Orange
4300	Indigo	Yellow
4100	Violet	Lemon Yellow

As an example, the absorption of red and orange to produce a blue light is shown below



Incidentally, this selective absorption of red and orange occurs in-water and accounts for the blue color of non-corrected underwater photographs or movies.

Finally, some chemical compounds, because of their internal chemical structure (which defines how the individual molecule reacts with light) are colored. So, their color, a physical property related to their chemical structure, has nothing to do with color addition or subtraction.

Bottom line: rules for coloring lights do not apply to chemical compounds.

Excellent Reference on the color of dyes and pigments:

Michael Wilcox, Blue & Yellow Don’t Make Green, Rockport Publishing, Rockport, MA, 1990, 120 pages.