



# It's a Colorful Life

## Unique Materials for Presenting Color Concepts

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A few years ago, I knew nothing about color. This was apparent the night my artist wife asked me why the primary colors of light are red, green, and blue, while the primary colors of painting are red, yellow, and blue. Why aren't they all the same? Or all different? Why is the third primary green for light, but yellow for painting? I realized that I had never been exposed to the field of color science (typical for many physicists) so I told my wife that I had no idea but that I would try to find out.

This led to my exploring numerous art, physics, chemistry, and color science books, as well as color science articles and Web sites: I found they often gave conflicting and inconsistent answers.

As I began to develop understanding, I started writing brief investigations about color science and creating hands-on color materials, when I found that none were available to demonstrate key concepts. I enjoy writing science curricula as a hobby and had already written or co-written other curricula with some success.

Over the course of about two years, my interest in color thus led to creation of the educational module *It's a Colorful Life*\* along with about a dozen unique color filters, color wheels, and posters.

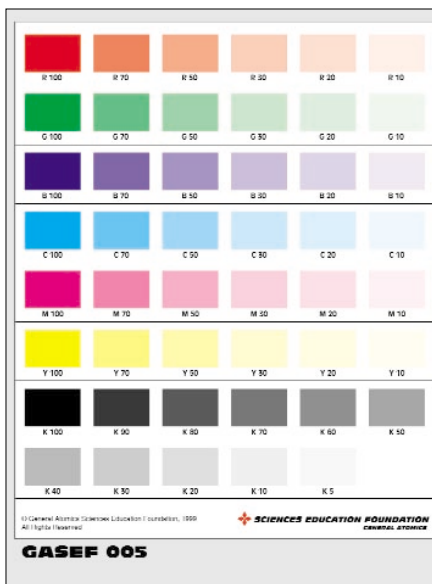
### Materials

When I began to develop this unit, since I could not find inexpensive color filters that would properly demonstrate additive and subtractive color mixing, I worked with the General Atomics graphic arts department to produce cyan (C), magenta (M), yellow (Y), red (R), green (G), and blue (B) films. Using the CMY films, the

\*To find out more about the General Atomics Sciences Education Foundation, which supports the development and production of these materials, visit <http://www.sci-ed-ga.org>. To order color materials, use the form posted at <http://www.sci-ed-ga.org/modules/materialscience/color/orderform.htm> Workshop PowerPoint presentations are posted at <http://www.sci-ed-ga.org/modules/>.

rules for subtractive color mixing ( $C/M=B$ ,  $M/Y=R$ ,  $Y/C=G$ ) can be demonstrated. Black results from overlapping complementary colors (R/C, G/M, B/Y).

Additional aspects of subtractive colors can be demonstrated using the CMY filters in conjunction with a color wheel: each of the CMY wheel filters can be placed on top of the color wheel to show



**Figure 1.** Color Gradient Transparency - Overlapping the CMYK transparency strips generates most of the colors produced by a color printer.

how that filter absorbs its complementary color of light. These small rectangular filters are useful for hands-on workshops with numerous participants.

I also created large circular CMY and RGB colored wheels, as well as large color wheels, which are useful for demonstration purposes. By using two color wheels together, it is easy to demonstrate how complementary colors are located on opposite sides of the color wheel. Just take one wheel, rotate it by 180°, and then place it on top of the other color wheel: the overlapped wheels turn completely black!

To demonstrate the construction of the color wheel in another way, I developed a series of three transparencies, one each for

the C, M, and Y contributions to the color wheel, so that when the three transparencies are overlapped, the color wheel results.

While the color films are useful for a basic understanding of subtractive color mixing, they do not demonstrate how a large variety of colors are produced. Therefore, I developed a series of gradient strips. By using the CMY and black (K) strips, a large range of colors can be generated. This leads directly to a demonstration of color printing: by examining color pages with a 30<sup>x</sup> microscope, students see a real-life example of color reproduction using CMYK.

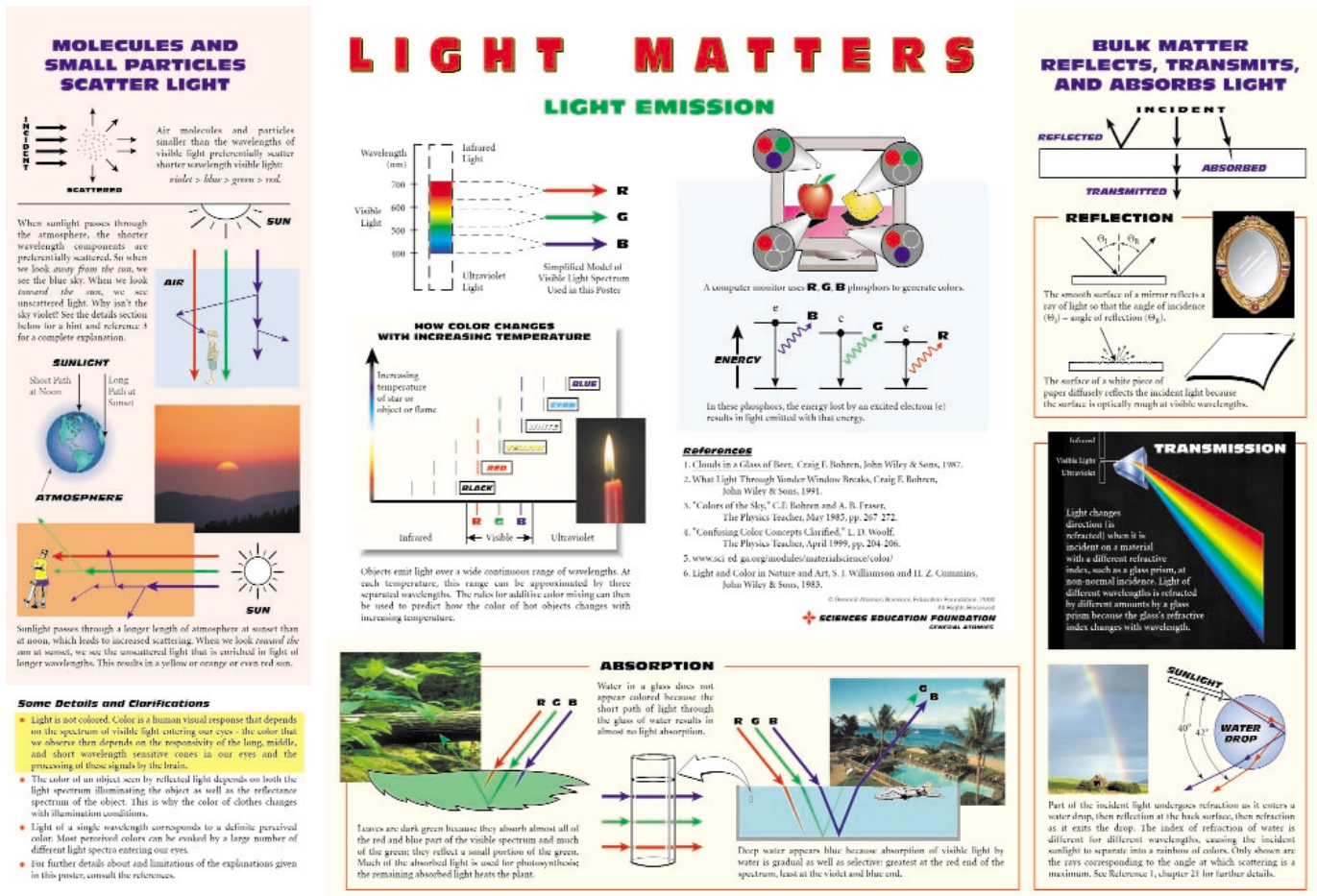
These strips also provide a nice way to demonstrate what is meant by hue (each strip has a different hue), saturation (each strip varies in saturation), and lightness (varied by placing a colored square on top of a K square).

Additive color mixing ( $R+G=Y$ ,  $G+B=C$ ,  $B+R=M$ ) can be demonstrated by holding one of these color filters in front of a slide projector and a second filter in front of a second slide projector. Placing a filter of the complementary color in front of the second slide projector produces white.

To make this demonstration easier, I mounted all the filters in standard slide mounts so they could be placed in a slide projector. I also developed RGBCMY slides with lightness values of 100, 75, 50, and 25%. Using slides with graduated lightness values, a larger color gamut can be produced, as can grays—for example, 50% gray results from using the 50% R and 50% C slides.

After students understand the principles of additive color mixing, they can explore how colors are made on a TV or computer monitor by examining the screen using an 8<sup>x</sup> magnifier.

Since artists use a different color wheel that is inconsistent with the rules for color mixing<sup>1, 2</sup> and because of the rampant confusion regarding the relationship between additive and subtractive colors, I developed a color wheel poster. This poster provides a side-by-side comparison of ad-



**Figure 2.** Light Matters Poster—This color poster describes the interaction of light with matter using pictures, diagrams and a written description. The poster is divided into three sections: light scattering, light emission, and the reflection, transmission, and absorption of light by matter.

ditive and subtractive color mixing, as well as complementary colors. Each aspect of color addition or subtraction is described in words and symbols, and is referenced to the color wheel. The written color unit makes extensive use of “color math” (such as  $R+G=Y$  or  $W-B=Y$ ) to describe these and many other color manipulations.

Most people are fascinated by the colors of nature—blue sky, blue water, red sunsets, rainbows—but have little idea of the factors in nature that give rise to them. Many scientists also have misconceptions. To address this situation, I developed a poster that shows the basic physics behind these colors in a graphical way. The poster uses the interaction of light with matter—reflection, transmission, absorption, and scattering—to frame these concepts.

**Presentations**

I have presented aspects of these investigations to elementary school students, parents, and teachers as part of a science course, teacher training session, and science day.

I have also conducted three-hour workshops at San Diego, California, and American Association of Physics Teachers science conferences for middle and high school teachers. I presented a short workshop to the education outreach meeting of OSA's San Diego chapter. The workshop has been conducted for high school physics teachers in conjunction with the American Physical Society's annual conferences. In testimony to the fact that color does indeed transcend all boundaries, I have also given versions of this workshop at a special color symposium of the American Chemical Society, and at an art association conference.

The response to the workshop has always been overwhelmingly positive. In particular, teachers involved in the workshop have been enthusiastic about the ma-

terials and the sample exercises. The demonstrations are invariably quite different from the approach they have been using in the classroom to teach color concepts. The opportunity to order the materials on the Web (see footnote) has inspired some of them to tackle the subject for the first time.

**Acknowledgments**

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**References**

1. L. D. Woolf, “Confusing color concepts clarified,” The Physics Teacher, **37**, 204-6, April 1999.
2. R. S. Berns, Principles of Color Technology, 3rd Ed., John Wiley and Sons, New York, 151-5 (2000).

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