Discovery Science Workshops: Homemade Grating Spectrometer

BY H. PHILIP STAHL

For the past four years I have joined other science, engineering, and medical professionals to participate in an annual event that you may wish to try in your own community—"Discovery Science Workshops." Organized by our local Junior Women's Club and Board of Education, this year's program was attended by over 500 elementary school students (about 25% of the entire elementary population) and their parents.

The event (held on a Saturday morning) consists of two, one-hour sessions followed by a group lecture. Both sessions offer 10–15 workshops each for both primary (K–2) and secondary (3–5) level students to choose from. This year a total of 52 workshops were presented. Some of the topics included:

- Insect eating plants;
- How to put a human skeleton together;
- The connection between music and waves;
- Toys based upon concepts of physics and chemistry;
- How to clean oil from bird feathers;
- Fiber optic communication; and
- Bug, bugs, and more bugs.

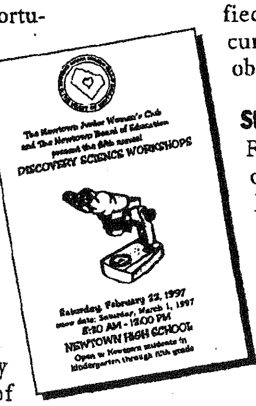
In one of my workshops, entitled "Color and Light," each student (with adult assistance) makes a grating spectrometer. My other workshops have offered students the opportunity to play with electricity and to make ice cream with liquid nitrogen.

Color and light

The workshop on color and light has three objectives: to illustrate that light is made of different colors; to demonstrate that colored light can be made by adding or subtracting light of other colors; and to explain that colored objects reflect certain wavelengths and absorb others.

The workshop starts by posing a question: What color is the light from the sun, an overhead projector, and a light bulb? Most students say white—but what is white? By using a refracting prism or sheet of diffracting plastic, I show them that "white" light is actually composed of a spectrum of colors.

While sunlight (because it is collimated) is ideal for showing this, weather is never guaranteed. Thus, I use an overhead projector, in a darkened room. A piece of cardboard with a slit cut out of it creates a "beam of light." While I find that the students all know that a prism makes a rainbow, they have no idea what a diffraction grating is. Fortunately, once they see it work, they simply accept it to be "magic" plastic. I point out to the older students that the order of colors is reversed between the prism and grating.



Building a spectrometer

I inform them that by using a small piece of magic plastic, each of them will make a spectrometer that will allow them to see the colors of light. Each student is given a paper tube (like from paper toweling; can be purchased in craft supply stores), two 4" × 4" squares of brown paper (a cutup grocery bag), two rubber bands, and a small 1" × 1" square of diffraction grating.[1]

We begin to make the spectrometers by placing a small "X" cut in one of the squares of paper, folding back the flaps to create a hole slightly smaller than the grating (about ¾" × ¾"). The grating then gets taped into the hole. Using rubber bands, each paper square (with and without the grating) is attached to one end of the tube. Finally, a small slit is cut into the solid paper, opposite the grating.

Before they can use their newly constructed spectrometers, the students must align the paper slit with the "magic" plastic. This is also an opportunity to show them how to use their spectrometer. The end of the tube with the slit is pointed toward a light. The children look into the plastic end and adjust the tube by rotating the slit until light is coming through it and colors appear beside (or parallel to) the slit. As this occurs, there are lots of "oohs" and "ahs." It is exactly at this point that you must stress to the children that they should never look directly at the sun!

Once everyone has a working spectrometer, I invite the students to look at some light bulbs setup around the room. Pandemonium immediately breaks out. After everyone (including the adults) have satisfied their fundamental curiosity, we discuss their observations.

Studying their observations

First, we talk about various "white" lights. Some have continuous color spectrums, while others have bright lines of color. I explain that normal light bulbs get hot and glow like the sun; we call these thermal sources. I draw a blackbody curve on the board and divide it into parts, labeling each part with a color: blue, cyan (explaining that cyan is just light blue), green, yellow, and red. I also explain that when our eyes see all these colors together, our brains call it white. I then explain that there are other types of lights (fluorescent, sodium, mercury vapor, etc.) that have materials in them that glow at specific colors when excited by electricity, but that the effect is the same. Our brain adds the colors together and calls it white. To illustrate this point, I draw another blackbody curve with small spectral lines and explain that we call sources that glow at a specific color (or wavelength) a spectral source.

If you are fortunate enough to have access to gas discharge lamps (mercury, sodium, helium, and hydrogen, etc.) then you can talk about how different materials have their own spectrum. Alternatively, you can tell your students that there are two types of street lights, mercury and sodium vapor, and that these two types have different spectra. The children can use their spectrometers to determine which type is on their street. At this point, sketch the two spectra and discuss the distinctive sodium doublet.

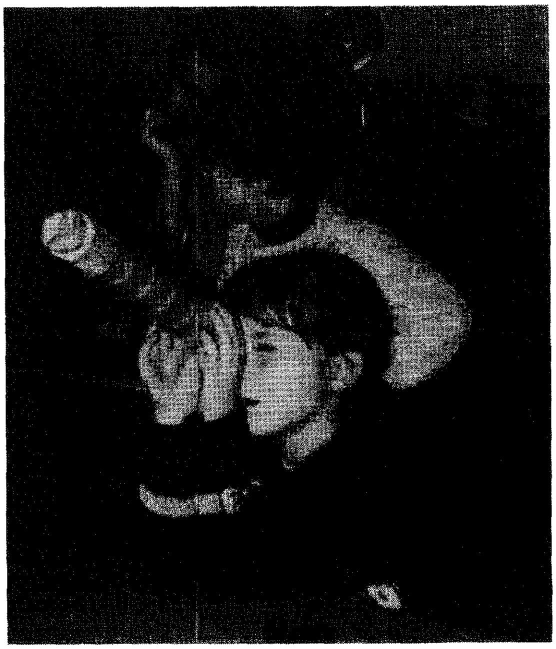
Color deficiency

Next, I ask if anyone in the class is color deficient. If so, I ask them to describe how the spectrum they see is different from what I drew on the board. Frequently, they need to look at the lights again. If no one in the class is color deficient, I describe what my son (who is color deficient) sees. For thermal sources, there is a large black "hole" in the middle of the continuous spectrum and specific colors are in different locations. For spectral sources, bright lines are missing.

Additive and subtractive color

Now that everyone knows white light is actually composed of colors, I explain how a TV makes color by mixing colors. To illustrate this, I place three projection TV filters (cyan, magenta, and yellow) on the overhead projector; colored plastic report covers can be used if TV filters aren't available. I then have the students say what color of light is produced by each filter: red, green, and blue. By using a prism or diffraction grating, it can be shown that each color is really a mix of colors. Using the board, I sketch each filter's spectra. Red and green make yellow, blue and green make cyan, and red and blue make magenta.

At this time the students are starting to fidget, so I invite them to use their spectrometers to look at some "colored" light bulbs. Again pandemonium rules for a few minutes. Once order is restored, we discuss what they saw. The black light is always the most interesting, with its deep blue and red spectra, which after some consideration makes perfect sense.



A "Color and Light" participant checks out the lights with her new spectrometer.

Next, I point out that another way to think about colored light is the "absence" of color. Yellow is the absence of blue, magenta is the absence of green, and cyan is the absence of red. Removing a color from white light to make colored light is called color subtraction. This is dramatically demonstrated by reflecting light from each filter onto the wall. The yellow filter reflects blue, the magenta filter reflects green, and the cyan filter reflects red. (Overlapping reflections from two filters can also be used to demonstrate color mixing.)

To continue with color subtraction, ask the students what color will be produced if two filters are overlapped. Refer to each filter's spectra to aid in this discussion. Test the student predictions by overlapping filters on the overhead projector. Yellow and cyan make green because green is the only color transmitted by both. The other colors are absorbed. Similarly, yellow and magenta make red, and cyan and magenta make blue. What color is produced when all three filters are overlapped? Why?

How we see colored objects

With my last 5–10 minutes, I pull out several brightly colored objects. I find that commercial packages such as cereal, toy, and detergent boxes work best. I ask how these colors are produced, then explain that in color subtraction, white light lands on the object, colored light is reflected (just like with the filters), and the other colors are all absorbed (again, just like with the filters).

I give each student a small 2" × 2" square of colored viewgraph material[2] to act as a filter and invite them to look at the packages through these filters. The packages appear entirely different when specific colors are filtered out.

Finally, my hour is up and the students *Continued on page 52*

In addition to the supplies listed in the article, here are some other materials that you'll need:

- One overhead projector and screen;
- Marker board & markers—black, blue, red, and green;
- Prism;
- Diffraction grating sheet;
- String of light sockets with plug;
- "White" bulbs: incandescent, fluorescence, sodium, and mercury (several of each);
- Color incandescent bulbs: yellow, red, blue, black, etc. (several of each);
- Chemical light sticks (several);
- Color filters: cyan, magenta, yellow (and/or report covers);
- Colorful food boxes and/or paints, markers, and paper;
- Pocket knives (several); and
- Scissors (several).

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How do cookies preserve state?

In two ways: one is by identifying your browser and the other is by collecting settings information during a session. For example, if on two different days you visit a site from behind a firewall, you may have different addresses, but, since the browser keeps a cookie with an ID number, the server knows it's the same browser from the previous session. Or if you are shopping at a Web store, a cookie holds item numbers of anything you select, acting as sort of an electronic shopping cart; when you reach the order form, a custom order is prepared for you. You can then confirm your order or place items back on the shelf.

Well, just about every Web site might want to know what's in my cookies!

Perhaps, but they can't find out. Browsers only return cookies to the servers that created them, so www.irs.gov will never know what you have been doing over at www.taxloops.org—not from cookies on your browser, anyway!

Sourdough cookies

So if cookies are so great, what's the controversy? There is a widespread fear that cookies can carry viruses, read your hard disk or even wipe it clean, and track your every move for sinister purposes. As explained earlier, a cookie is a line of text sent by your browser only to the Web site that put that cookie there in the first place. Below is an excerpt from the cookie FQM (frequently quoted misconceptions) to help you separate fact from fiction.

1. *Is information about me routinely collected when I access a Web site?* YES. When you request a Web page, you have to tell the browser where to send it. This information is placed into that server's log and can be analyzed. Other data regularly submitted with every request includes your browser type, computer platform, ISP, ISP's city, ISP's country, language, and domain.
2. *Can cookies gather information about me?* YES. Aside from that just mentioned, cookies can contain information you may have volunteered through forms. The issue is: Do you trust the requester of this information?
3. *Can cookies track my habits?* YES. Cookies can be used to track your movements across a single Web site. Again, it's a matter of trust, but it's also a pragmatic consideration: there is much information collected about you without cookies (see # 1).
4. *If a server can read my cookies, can't it read my hard drive, too?* NO. Cookies are not "read," they are "sent." This is a subtle, but important, distinction. Web servers cannot read anything off your hard disk.
5. *Can any Web operator know where I've been by reading my cookies?* NO. Cookies are only sent by your browser to the site that issued them. OSA cannot read cookies placed on your browser by other sites, nor can any other site read cookies placed by OSA.
6. *Can a cookie carry a virus?* NO. Remember that a cookie is only a single line of text in a text file called "cookie," found in your browser's folder. Viruses are small computer programs that need to first be executed to cause damage. They hide in other executables like programs, and macros.
7. *Can other technologies provide the same functionality as cookies?* YES. The combination of server databases with technologies like Java, Active-X, and JavaScript can perform better than cookies. However, cookies, ironically, require less dough!

How will OSA use cookies?

Five days before the OpticsNet Advisory Committee was to meet this summer to discuss—among other things—the fate of OpticsNet cookies, we experienced first hand the level of passion that exists on the subject. A new server statistics package started handing out cookies to OpticsNet visitors by default at a rate of six/page. E-mail began arriving within the hour. Needless to say, some reservations were expressed.

With this as a backdrop, the committee examined the question. Cookies will allow us to implement many applications that, without the simplicity and power of them, are very expensive to develop and maintain. Cookies will also help us manage OpticsNet, allowing us to allocate resources based on traffic patterns, to identify areas that are difficult to find, etc.

While sensitive to the controversy, the committee's conclusion was that much of it is a matter of perception. They reasoned that OSA members—OpticsNet's primary customers—already trust OSA with more personal information than can be gleaned with this technology. Members should not be denied the benefits of this technology just because it's misunderstood by some.

So they recommended that OpticsNet implement cookies to benefit members by providing more services at a lower cost.

The committee also recommended that OSA publicize its policy for using information gleaned from cookies and that an OpticsNet area be set up where the purpose of dispensed cookies (complete with their code) is available for public inspection.

Discovery Science Workshops

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are off to another workshop or the group lecture. But, later in the day, I often see the parents (and sometimes the students) looking at the sky and clouds through their spectrometers.

References

1. Diffraction gratings can be purchased from Edmond Scientific (609/573-6270). A 12" × 6" sheet (item J40,267) costs $9.00.
2. Overhead color transparencies can be purchased from any office supply store in a variety of colors, such as red, yellow, and blue.

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