

BUILDING A SPECTROSCOPE

grades 6–12

Objective

Build a simple, pocket-sized spectroscope from readily available materials and use it to examine different kinds of light sources in school, at home, and around the city.

Introduction

White light is a mixture of all colors of visible light. But not all light that appears white to the eye is made of the same mix of colors. The precise colors coming from a light source can be seen when its light is spread into a spectrum by a spectroscope. With this activity, you can make your own spectroscope and see all the colors that make up the light from different sources.

Spectroscopes contain a prism or diffraction grating that separates and spreads out light waves according to wavelength. Shorter wavelengths are diffracted, or deflected, more than longer ones. Our eyes see each wavelength of light as a different color. In a rainbow, or any other spectrum, the colors are arranged in order of their wavelength, with red having the longest wavelength and violet having the shortest.

Not every color of the rainbow is always present in what our eyes see as white light. If light from an incandescent bulb is spread into a spectrum, you see a continuous rainbow, in which one color bleeds into the next with no gaps between them. But fluorescent lights do not contain a complete rainbow. Their spectra contain bright lines of specific colors, with dark gaps in between. Fluorescent bulbs produce light only in these precise colors and no others.

Colored light may also be a blend of different colors. When seen through a spectroscope, red light from a neon sign reveals stripes of several different colors. A green “neon” sign may even include a stripe of violet.

Astronomers and chemists study spectral lines because they contain information about the light’s source. Many chemicals, especially gases, emit narrow lines of particular colors of light. Every element has its own spectral fingerprint, and their spectral lines can be used to identify them. The composition of stars, nebulae, the Sun, and the atmospheres of other planets are all studied by measuring the precise colors of light they produce, reflect, or absorb.

This spectroscope was designed by Dr. Alan Schwabacher of the University of Wisconsin at Milwaukee. For more information on how to make and use the spectroscope, including photos of each step of its assembly, visit his Web site at <http://www.uwm.edu/~awschwab/specweb.htm>

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Background Reading for Educators

Light: Its Secrets Revealed, available at

http://www.amnh.org/education/resources/rfl/pdf/du_x01_light.pdf

Materials

Spectroscope template (pg. 7)

Rubber cement and/or tape

Construction paper, heavy paper,
or manila file folder

A data or music CD you don't want,
such as a free AOL CD. (Two CDs will
make roughly 30 spectroscopes.)

Heavy-duty scissors

Procedure

Part One: Constructing a Simple Spectroscope

- 1] To make the spectroscope, simply copy the template onto thick paper, then cut it out and fold it up. Dark blue construction paper is recommended, but any opaque paper will do. To test paper for opacity, just hold it up to the light. If the paper leaks light, you can darken the inside with a black marker. (The printed side will be the outside.)
- 2] For a sturdier spectroscope, use a manila folder or card stock. If you can't copy or print the template onto the card stock, you can simply hold or tape the template over the cardboard to cut it.
- 3] Make a photocopy of the template for each student, then lead them through the following steps:
 - a] If you are using thin paper, color in the back of the template with a black marker or Sharpie before cutting.
 - b] Cut out the eyehole and the small light slit. Make sure to keep the slit only about 5 mm ($\frac{1}{2}$ cm) wide. The edges of the slit must be smooth and parallel, but the exact position of the slit is not critical. If you have trouble cutting this slit, you can widen the hole and make a smooth, narrow slit with two pieces of tape.

Blackened interior of spectroscope. Notice center placement of CD wedge.



Meg Cartough/AMNH

*** Teacher's Note**

You may wish to cut these slits for your students beforehand. If you are making several spectroscopes, a simple tool for making the slit can be made by taping together two single-edge razor blades. Approximately five layers of tape between the blades will space them correctly. Otherwise, a sharp knife and straight-edge work well.

- c] Cut out the template with scissors. Keep in mind, the solid lines are meant for cutting and the dotted lines are meant for folding. Don't forget to cut the lines between the lettered tabs.
- d] Cut a CD into wedges with heavy scissors. The correct shape is shown on the template. Each wedge will serve as the diffraction grating for one spectroscope. You can get about 16 wedges from one CD.

*** Teacher's Note**

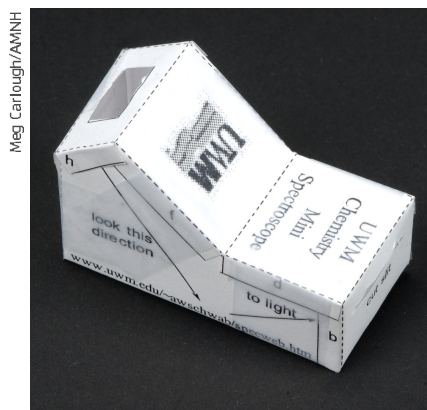
If the CD cracks when you cut it, heat it in warm water first. Recordable CDs, labeled CDR or CDR-W, are not as desirable because they have a colored coating that will filter some light, and they sometimes separate into layers when cut apart, but they will work.

- e] Using glue or tape, attach a CD wedge to the inside of the spectroscope (the backside of the template). Make sure the data side (the side of the CD with nothing printed on it) faces up.
 - f] Cover the tip of the CD wedge with tape or a black marker. If uncovered, this part will reflect light like a mirror.
 - g] Fold along the dotted lines to construct the spectroscope. The printed side should be out, with the CD piece inside. Keep in mind that this small wedge of CD is the spectroscope's diffraction grating!
 - h] Glue or tape the lettered tabs onto their matching letter in alphabetical order (a to a, then b to b, etc.). Rubber cement works well: simply coat all the tabs, let them dry, then close. Seal with tape, if necessary. Avoid cracks where light might leak in—but do not cover the slit!
- 4] Your students are now ready to use their new spectroscope. Have them look through the eyehole and point the slit in the direction of a light source until the correct angle is attained and bands of different colored light are seen on the CD. This might take a few tries. The light must go down through the slit, then bounce up to your eye.
- 5] Arrows on the sides of the spectroscope show you the angle to peer into the spectroscope, and the angle to point it at the source. If you hold your forefinger along the arrow labeled “to light,” you can simply point at the light source and look down into the eyehole. Note that you will not look directly at the light source, but at a reflection off the CD wedge.

! SAFETY NOTE

Unlike many commercial spectroscopes, the design of this spectroscope should prevent a direct view of the sun. Nevertheless, remind your students to **NEVER LOOK DIRECTLY AT THE SUN!**

Completed spectroscope.



Part Two: Observing Spectra

- 6] With your spectroscope, you will see that white light from various sources can be dramatically different.

Ask: What do you see when you look at fluorescent lights, incandescent lights, streetlights, gymnasium lights, or other light sources?

Explain: Colors that look the same to your eyes look very different in your spectroscope. For example, the light from your TV or computer screen has a very limited set of component wavelengths, yet it can appear as many colors. And lights that appear to be one color may actually contain several different colors.

- 7] At the minimum, make sure you have available in the classroom an incandescent bulb—such as those in an ordinary desk lamp—and a new fluorescent bulb—the long tubes often used in schools. Newer fluorescent bulbs show clear, distinct lines of red, yellow, green, blue, and purple, with black between them. This is much more impressive than the older fluorescent bulbs, which show bright lines overlaid on a pale rainbow.

Some interesting lights to examine are:

Neon signs. Be sure to compare different color signs.

Sodium lights (found in orange colored streetlights)

Mercury vapor lamps (found in bluish streetlights and most new car headlights)

LED lights (from a clock radio or watch)

Sunlight reflected off a piece of white paper, or coming indirectly through a window (don't look directly at the Sun)

Light reflected off different pieces of colored paper or transmitted through colored plastic

Gymnasium lights (some are metal halide)

Going a Step Further: Color Filters

- 8] Find any piece of yellow plastic you can see through. Look at an incandescent light through the spectroscope, then move the yellow plastic between the spectroscope and light. Repeat several times and observe what happens. Note that it lets red and green light through, not just yellow.

- 9] Because of the way your eyes work, what appears to be a single color may be the product of surprisingly different colors.

Explain: The color your eye perceives may not even be one of the colors in the mixture! This is very different from the way your ears work: if you hear an A note and a C note played together on a piano, you would not mistake the sound for a B note. But your eye and brain combine red and green light into yellow—the color between them on the spectrum. You can see yellow even when there is no yellow light present. Look at a TV screen or computer monitor through the spectroscope (or simply lean close and look at the dots). You will see that all colors that appear on the screen are really just a mixture of red, blue, and green.

Step Four: Explore the City!

- 10] Encourage your students to take their spectroscopes home and look at different lights at home or around the city at night:

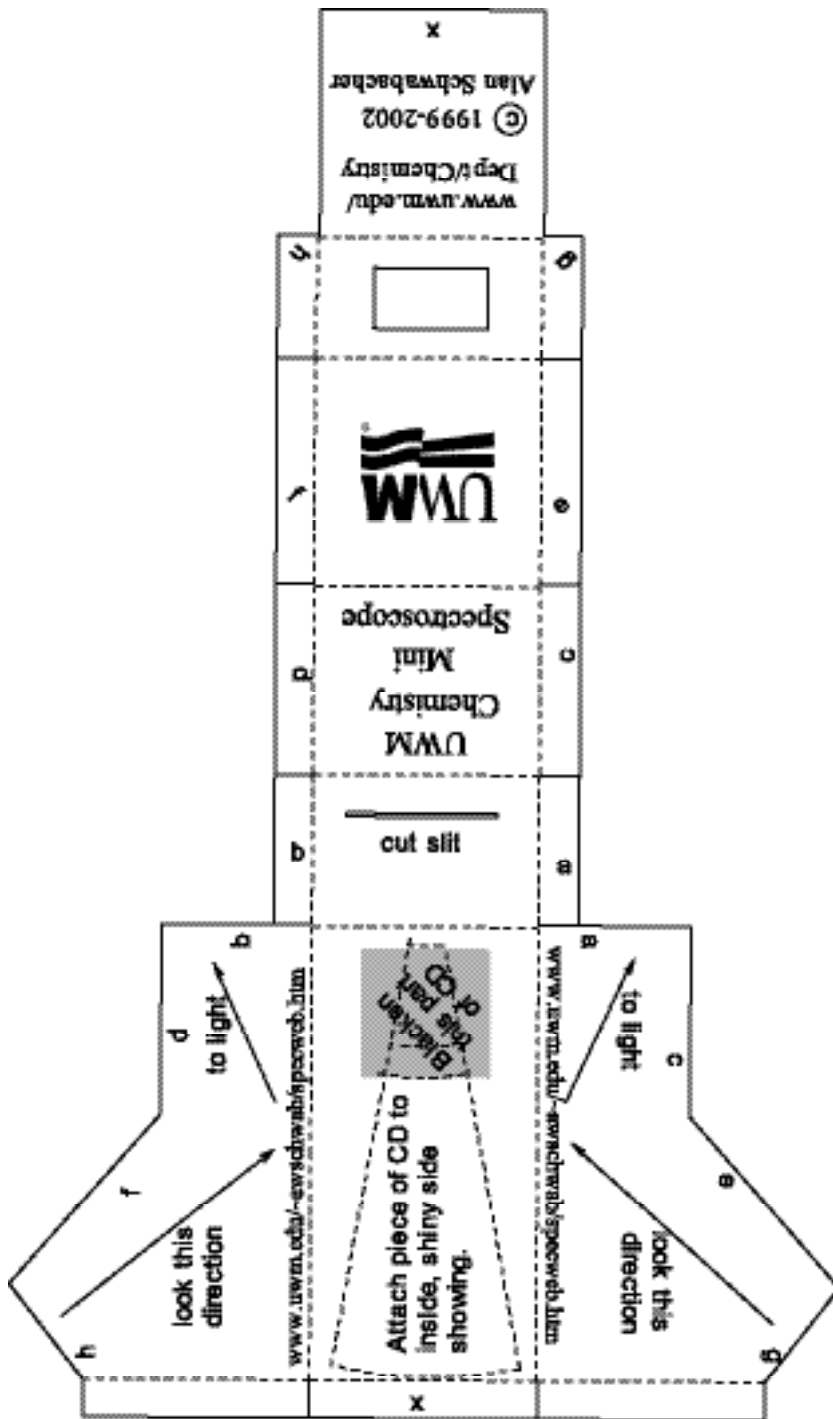
Some new cars have brake lights lit by red LED lamps, while most cars use an incandescent bulb covered by red plastic. Are their spectra different?

Some “neon” signs are red, some are green, etc. Keep in mind that pure neon gas has an orange-red appearance. If the “neon” sign is of another color than this, it means that the gas in the sign is not pure neon gas. Mercury, argon, and xenon are all added to neon gas to color neon signs. Sometimes there is no neon at all!

High-pressure mercury vapor lamps have different spectra from low pressure ones. High and low pressure sodium lamps look different, too. So do older and newer fluorescent lights. You can tell which is which by their spectra, using a spectral chart.

- 11] A full-color chart showing the spectra of nine common light sources can be found on the website of the Journal of Chemical Education, in an article titled “Challenges of Everyday Spectra,” by Stephen F. Jacobs. If you print out the spectral chart, you can use it to identify particular lights by their spectral lines. You can find the chart at <http://jchemed.chem.wisc.edu/Journal/Issues/1997/Sep/abs1070.html>.

SPECTROSCOPE TEMPLATE



UWM Chemistry
Mini Spectroscope

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See website for instructions:
www.uwm.edu/~awschwab/specweb.htm