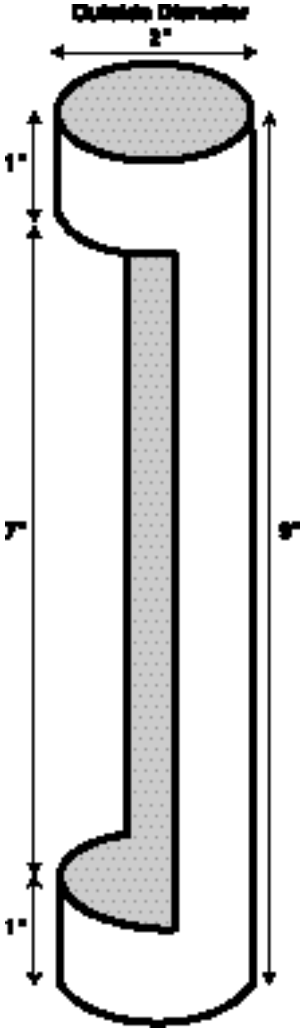
Spectroscopes

Advanced Version: How to Build and Use a Spectrometer



Materials

For each student:

- 12" x 16" darkly colored railroad board
- 9" cardboard tube 2" wide on the outside
- 1-3/4" cardboard tube 2" wide on the inside
- 2-1/4" cardboard disk with 1/4" hole in the center
- 1" square diffraction grating* (13,400 grooves/inch; not holographic)
- Masking tape
- Opaque tape (no light comes through)
- Scissors and/or a sharp blade (be careful)
- Wavelength scale (photocopy scales on page 5)
- Pair of marking template sheets (masters on pages 6-7)

Preparation

Photocopy the scale pieces. Make a marking template for the body of the spectrometer by photocopying the two parts on pages 6-7, cutting them out, and taping them together, making the arrow heads overlap exactly. Cut the cardboard tubes to proper lengths. Half of the 9" tube must be cut away, but only the central 7". An inch of tube at each end must remain intact. Cut out cardboard disks and, with a hole punch, punch holes in the centers.

* Available from science supply companies such as Edmund Scientific Co., 101 E. Gloucester Pike, Barrington, NJ; Frey Scientific, 905 Hickory Lane, Mansfield, OH 44905, (800) 225-3739; Science Kit & Boreal Laboratories, 777 E. Park Dr., Tonawanda, NY 14150-6784, (800) 828-7777. Optionally, you can use holographic diffraction grating, but the spread of colors will be narrower, so you would have to reduce photocopy the wavelength scale to calibrate for accurate readings.

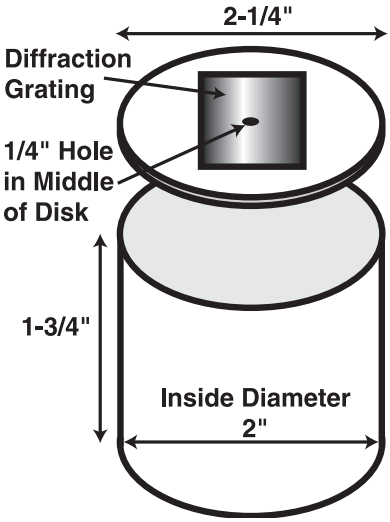
In Class

A Spectrometer — What Will It Do?

Our eyes perceive light in different colors. Some of the colors that we see are pure colors, but most of the colors we see are mixtures of different colors. A **spectrometer** can separate light that is a mixture of colors into a collection of pure colors. A collection of pure colors is called a **spectrum** (for more than one spectrum say spectra).

A spectrum that many people are familiar with is the one created when the pure colors that make up sunlight are separated as they shine on raindrops. It's a rainbow! The colors in a rainbow include every pure color that human eyes can see. Many of the spectra that the spectrometer shows you may look like rainbows. Some lights, however, produce only a few pure colors of light. Knowing what these colors are can give you information about what substances are giving off the light.

The spectrometer can give a measurement to describe each pure color. The spectrometer measures the color's **wavelength**. Light travels as a wave. The length between two crests of a light wave, its "wavelength," determines what color it is. Light that is a mixture of different wavelengths is not a pure color and will be separated by the spectrometer. Wavelengths are very small so inches or centimeters are impractical for describing wavelengths. The spectrometer measures wavelengths in Ångstroms. One Ångstrom (abbreviated, 1Å) is one ten-billionth of a meter. A typical visible lightwave is a few thousand Ångstroms. You can use the spectrometer to see how long the wavelength is for different colors of light. (Another common way to describe wavelengths is in nanometers, but most standard American reference books use Ångstroms. Conversion is very simple: 1 nm = 10 Å)

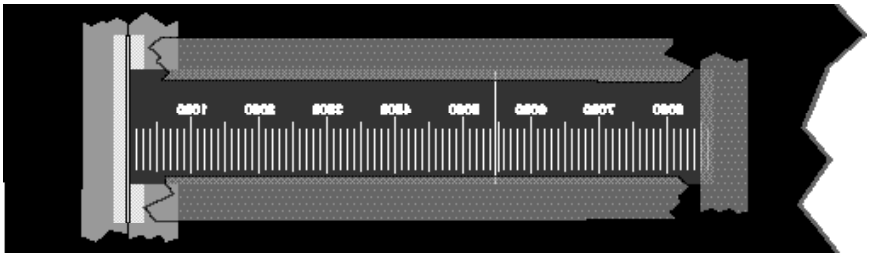


Putting it Together

To assemble the eyepiece of the spectrometer tape the cardboard disk to one end of the 1-3/4" cardboard tube. Use plenty of tape to make it strong and to keep light from leaking in through any cracks, but make sure that the tape is on the **outside**. The inside must slide freely over the end of the 9" tube. Next tape the 1" square of diffraction grating material over the hole in the disc. Be careful not to let tape cover the hole itself. Look through the hole at any bright light. (Not the sun!) Already it is possible to observe spectra. Bright lights in dark places work best. To observe spectra more clearly and to measure wavelengths you will have to build the body of the spectrometer.

The body of the spectrometer should be cut out of dark railroad board. Its outline can be traced onto the railroad board from the body template (master on pp. 6-7). The slot that is 1/4 inch wide is where the light shines into the spectrometer. Use the opaque tape to make this slot into a narrow slit. The narrower the slit, the more accurate the measurements can be. The wider the slit, the brighter the spectrum will appear. A slit 1mm wide is good. Use tape on both sides for extra strength.

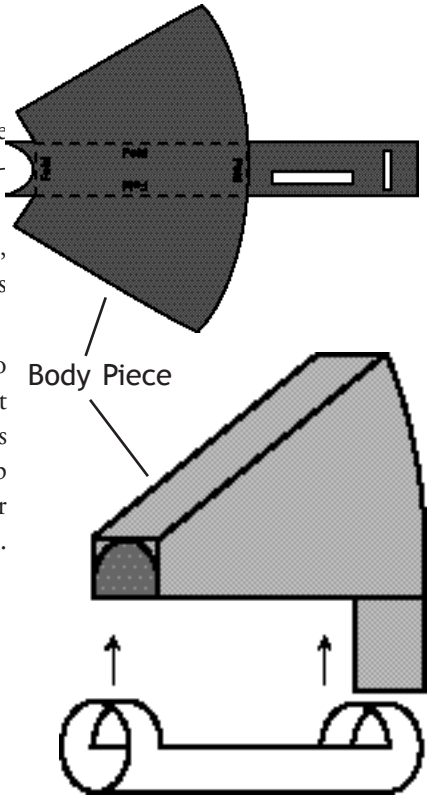
The other slot is the window for the wavelength scale. The wavelength scale must be cut out exactly along its edges. Tape it face down over the window so that its edge is exactly along the narrow slit but not covering it. Make sure that no tape covers either the slit or the window. It will appear as pictured below.

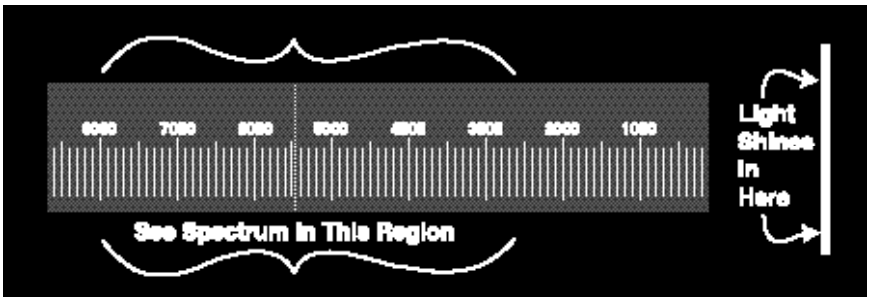


Fold the railroad board body in the four places shown. Tape the flap with the slit and the window to the curved edges of the railroad board so that the wavelength scale is still face down on the outside.

Taping flat things to curved edges is tricky. Do your best, use plenty of tape, but do not cover the slot or the window. One trick is to use a lot of little pieces of tape.

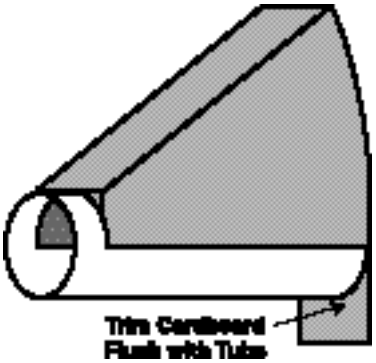
The 9" tube is the backbone of the spectrometer. Attach the railroad board to the 9" tube, as shown, making sure that the section of the tube that is cut out is inside the spectrometer. Trim away the overhanging part of the flap that has the slit and the window. Use enough tape to hold it all together and to seal up all the cracks, but never cover the slit or the window. Slide the eyepiece over the piece of tube that sticks out of the body and your spectrometer is complete.





Using Your Spectrometer

Look through the spectrometer toward a fluorescent light. You should see the light through the slit and somewhere around it a spectrum. At first it may be difficult to see a spectrum. Sometimes the spectrum shows up clearly only when the spectrometer is pointed slightly to one side of the light source. (Actually there are two spectra, one on either side of the light source.) Twist the eyepiece and the spectra will revolve around the slit. Position the eyepiece so that the spectra are on either side of the slit. One of them should lie on top of the wavelength scale.



The spectrum of a fluorescent light looks like a rainbow with a few brightly colored lines. The wavelength of the bright green line is about 5460Å. The final adjustment before taking any measurements is to pull the eyepiece in or out so that the bright green line appears on the dotted line on the wavelength scale. Tape the eyepiece into place. Now every color will appear on the scale in a position corresponding to its wavelength. If the eyepiece is moved for some reason, find a fluorescent light to readjust it correctly.

There are a few experiments that you can try right away. Look at any bright white light (but never the sun!). Most white light contains every wavelength that the human eye can see.

What is the shortest wavelength that you can see?
What is the longest wavelength that you can see?

Different people may be sensitive to slightly different ranges of wavelengths, so answers to these questions may vary from person to person.

Using crayons or colored pencils or markers, do your best to draw the spectrum of white light as you see it through your spectrometer. Label some of the colors with their wavelengths.

How many colors can you see in the spectrum of white light?

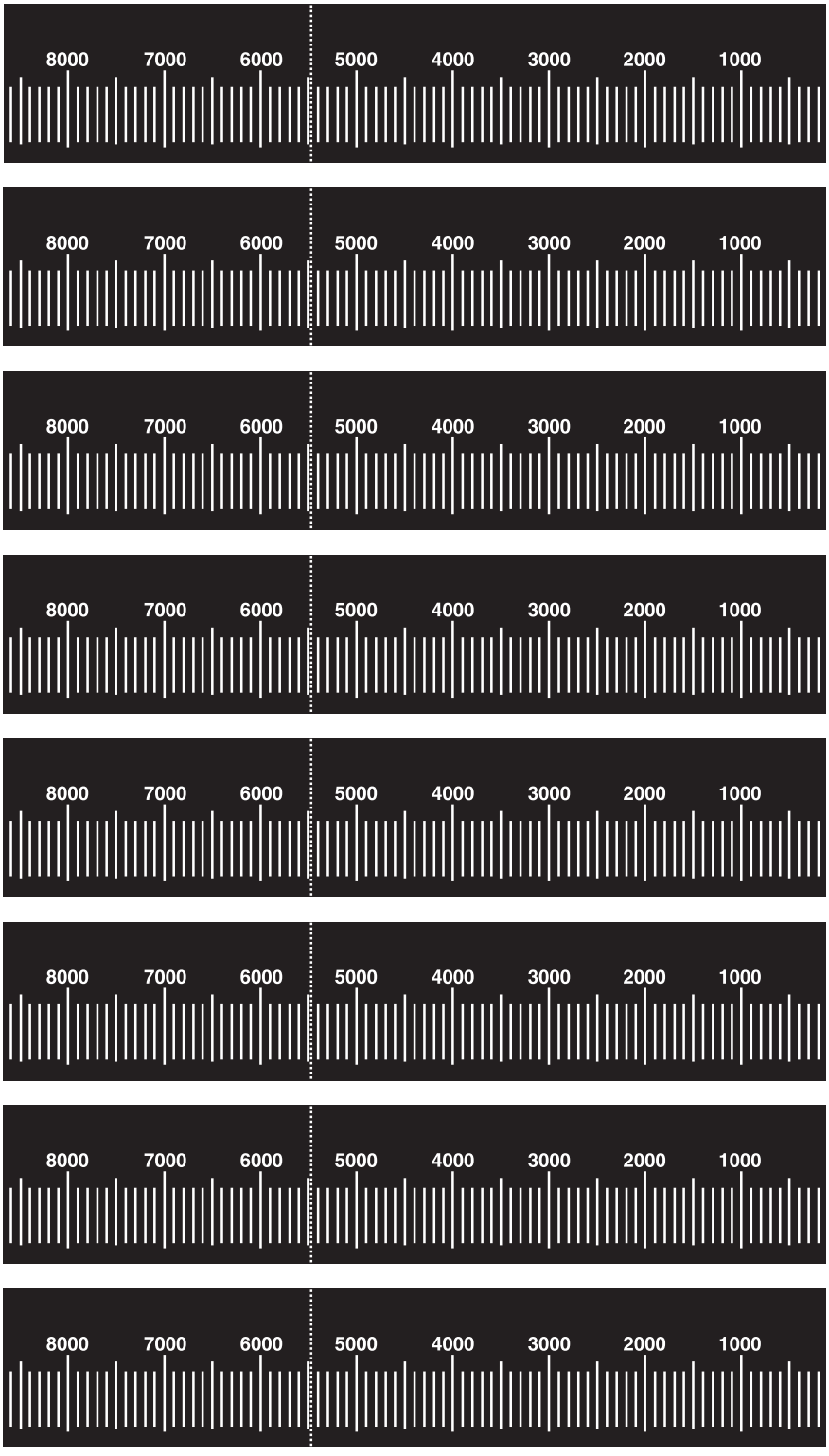
Isaac Newton divided the spectrum into seven colors; red, orange, yellow, green, blue, indigo, and violet. Actually there are an infinite number of different colors. For instance the part of the spectrum that looks red has many different kinds of red, but we have only the word "red" to describe them all. That is one reason why it is handy to be able to measure a color's wavelength. The wavelength describes the color exactly.

Use your spectrometer to look at colored lights. Some colored lights are simply white lights that shine through colored substances such as paint or colored glass or plastic. These substances filter out some wavelengths of light. Your spectrometer will tell you which wavelengths get through.

Some colored lights are made with substances that give off light with only a few wavelengths. Neon signs give off light only with certain wavelengths in the red, orange and yellow parts of the spectrum. Neon also gives off a wavelength in the green part of the spectrum, but the combined light always appears orange. Find a neon light and draw its spectrum, labeling the colors with the wavelengths that you measure. Some lights that people call 'neon lights' contain no neon at all. If you can find some of these lights to observe with your spectrometer, note the wavelengths of the colors that are given off. The wavelengths are unique to each element. This means that the wavelengths that you observe can be used to identify what substances are giving off the light.

Even some lights that look white have certain wavelengths that are particularly bright. Many street lights are good examples of this. So are fluorescent lights. The bright green wavelength that you observe when looking at a fluorescent light is given off by mercury. Look in a physics reference book such as *The Handbook of Chemistry and Physics* for a table that shows the wavelengths for the emission spectra of the elements to find out what elements are giving off the other colors that you see in your spectrometer. Happy spectrum watching!

Scales for Photocopying



Spectrometer Body Plate

- Copy these two pages on cardstock (or paste onto cardstock).
- Overlap corresponding arrows.
- Cut along solid lines.
- Fold along dotted lines.