



LET'S WONDER

## Colors of Light

with Judy &amp; Nancy

#OpticsAtHome

#SeeTheLight

### Optics Magic at Home with Judy & Nancy: THE COLORS OF LIGHT

WHAT ARE THE COLORS THAT MAKE UP WHITE LIGHT? IS EVERY LIGHT THE SAME?  
*In this lesson you will learn how to make a rainbow from an old CD-R and then make a spectroscope to look at the colors emitted by different light sources.*

#### ACTIVITIES & MATERIALS

##### Activity – 1 Make a Rainbow

1. An old recordable CD (CD-R) you don't need any more. (Save the case for an upcoming webinar.)
2. An index card or similar size piece of thin cardboard
3. Tape
4. Scissors
5. A flashlight with a single bulb or an LED keychain with a single bulb.

##### Activity 2 – Make a spectroscope

1. The piece of CD from Activity 1
2. A cardboard tube like a toilet paper tube or a paper towel tube cut in half
3. A small square of aluminum foil and a craft or other thin knife (with adult supervision) OR a piece of thin cardboard or dark construction paper and a pen or thick needle (like a tapestry needle)
4. Tape or glue

##### Activity 3 – The Colors of Lights

- A variety of light sources – phone screens, laptop monitors and TVs, colored light strings. Try to find lights that are visually similar colors like incandescent, white LED and fluorescent bulbs, or incandescent and LED bulbs of the same color. Two strings of Christmas lights, one incandescent and one LED, make an interesting comparison.

#### WHERE TO FIND MATERIALS

- The CD must be the kind you record yourself so you can remove the label. You can also purchase diffraction gratings from many science supply stores (such as Educational Innovations, [www.teachersource.com](http://www.teachersource.com)) and can be purchased in bulk (minimum order of 50) from Rainbow Symphony Store ([www.rainbowsymphony.com](http://www.rainbowsymphony.com)). Be sure to get "linear" gratings, not two-dimensional gratings.
- LED Finger lights are good for all kinds of optics experiments including this one. They come in several colors and can be found in dollar stores and online.

## PARENT AND TEACHER NOTES

In this lesson, children will create a *spectroscope* and use it to do elementary *spectroscopy* by breaking light into its component colors, or spectrum (plural spectra). Spectroscopy is important in many areas of science and technology, for example, for identifying plant diseases (looking at the spectrum of light reflected from leaves), studying the universe (the spectrum of light given off by stars, galaxies, and absorbed by dust clouds), matching paint colors, identifying unknown substances at a crime scene and more.

## BREAKING LIGHT INTO A SPECTRUM OF COLORS

White light is composed of all the colors of the rainbow- red, orange, yellow, green, blue, (indigo, if included) and violet - ROY G B(I)V. A light source's spectrum depends on how the light is produced. It is not possible to tell with the naked eye what colors are in the spectrum of a given light source, for example, all the colors on an LED screen are made with red, blue and green LEDs. Instruments used to study the color makeup of a light source can be very complex but there are some features common to all:

1. A device that spreads the light out into its “rainbow” spectrum of colors
2. Something to block out stray light from the surroundings
3. A thin entrance slit that lets in a sample of the light being studied
4. A sensor to detect the spectrum

You probably know that you can spread white light into a rainbow spectrum using a prism. But prisms are difficult to line up correctly. A diffraction grating (or just “grating”) is a series of very closely spaced grooves that bend light and cause it to spread out into its spectral colors. The CD used in this lesson is a kind of grating. Before the label is removed, the CD reflects white light as a rainbow (*reflective grating*) and after the label is removed light passes through the plastic and is spread into a spectrum (*transmission grating*).

The simple spectroscope in this lesson uses a cardboard tube to exclude room light and a slit (or hole) cut in a piece of aluminum foil to allow only a thin line (or spot) of light to enter and be examined. Your eye is the sensor! A more sophisticated *spectrometer* would use a sensor such as a camera to detect light and electronics to measure and display the spectrum.

A note on indigo: Some sources place the color "indigo" between blue and violet in the rainbow spectrum. Isaac Newton wanted seven spectral colors to match the seven notes of a musical scale. What he called indigo is closer to what we would now call blue, and blue was a blue-green. In any case, indigo is sometimes omitted especially in modern writings, although BIV certainly makes an easier to pronounce acronym than BV. (See below resources to learn more.)

## ACTIVITY 1 – MAKE A RAINBOW

1. First, look at the shiny side of the CD. You can easily see rainbow reflections from the fine grooves in the plastic.
2. The CD label must be removed to let light pass through. An adult should cut the CD into four equal quarters using sturdy scissors. Be careful of sharp edges! Try to round the edges if you can. If you use a purchased diffraction grating, be sure to handle it by the edges to avoid finger smudges.

- To remove the label, put a piece of sticky tape across the CD piece (and over the cut edge) and pull the tape off sharply. You may need to repeat with a new piece of tape to remove the whole label.
- Look through the clear plastic at a lamp or bulb (don't get too close to the bulb!).  
Rainbows!
- To project a rainbow onto a piece of paper or a wall you need to block off all but a small piece of the CD piece. Cut a 2-3 mm slit in the index card and hold it across the piece of CD as shown in Figure 1. Hold the CD and slit 10 cm or so from a piece of paper (or a wall). Shine a flashlight through the slit onto the paper. Move the flashlight around to get the brightest rainbow. Do you see one rainbow or two? Are they the same size? The CD grooves are curved which effects the appearance of the rainbows.

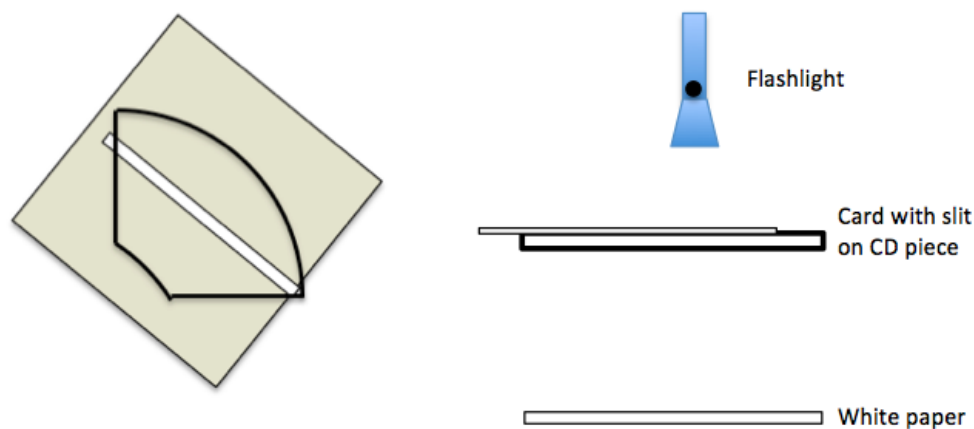


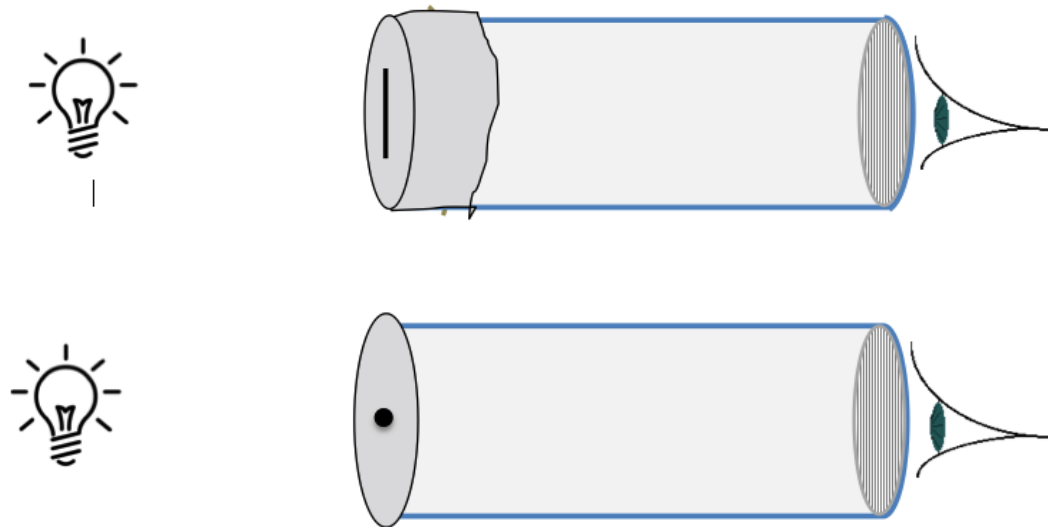
Figure 1 – Arrangement of the CD piece and slit, and projecting a rainbow on a piece of paper.

## ACTIVITY 2 – MAKE A SPECTROSCOPE

When you looked through the grating you may have noticed that there were several rainbows, depending on how many light sources were in the room. Making a spectroscope will allow you to concentrate on one light source at a time. You will use the stripped CD piece from Activity 1 to separate the colors of the spectrum. To limit the amount of light that enters the front end you can use a slit cut in aluminum foil (requires adult help with a sharp knife) OR a piece of thin cardboard or dark construction paper with a hole poked in the center.

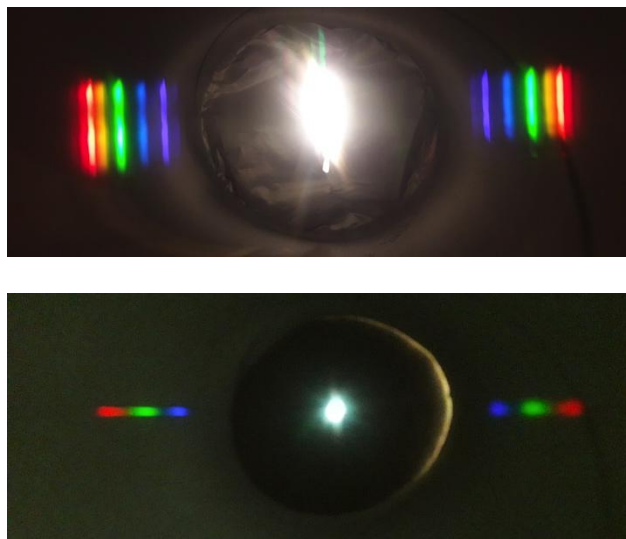
- Decorate the tube if you wish with markers, crayons or stickers.
- You don't need to cut the piece of CD from Activity 1 into a circle to fit the end of the tube, but it looks a bit neater if you do. Trace around the tube onto the CD piece and carefully cut it out. Tape (or glue) the edges of the CD to one end of the tube. If you bought a diffraction grating, tape it to the end of the tube.
- To use a slit in aluminum foil: Wrap the piece of aluminum foil over the other end of the tube keeping it as smooth as possible. With an adult's help, cut a small slit in the center with a sharp knife. Look through the tube at a light. Rotate the tube, holding the aluminum foil in place until the spectrum is spread out from side to side as in Figure 3. Then tape the foil to the tube. It's ok if the spectrum is tipped a bit, it just shouldn't be vertical.

4. To use cardboard instead of aluminum foil: Trace the end of the tube on a piece of thin cardboard and cut it out just a bit bigger than the tube. Use the tip of the ballpoint pen or the needle to poke a hole about 2-3 mm in the center. Glue or tape the cardboard circle onto the other end of the tube.



**Figure 2 – The cardboard tube spectroscope. (Top) This diagram shows a thin slit cut in aluminum foil on the front end. (Bottom) This tube uses a circle cut from thin cardboard instead of aluminum foil. You can see the cardboard circle is a bit bigger than the tube. These diagrams are not at all to scale!**

5. Your spectroscope is ready to use! Hold the CD end near your eye and point the slit or hole at a bright light. Look into the tube through the CD. **DO NOT LOOK AT THE SUN OR INTO A LASER.**



**Figure 3 – (Top) The view looking into the tube with a slit in aluminum foil and everything oriented properly. The photo was taken looking through the CD with the slit pointed at a compact fluorescent bulb. (Bottom) This is what it looks like with a small hole. Some light is leaking around the edge of the cardboard. The photo was taken looking through the CD with the slit pointed at a white patch on a laptop screen.**

### **ACTIVITY 3 – THE COLORS OF LIGHTS**

To use your spectroscope, look through the grating while pointing the slit or hole at a light source. You might need to get close to the bulb but be very careful if it is hot. The spectrum will appear on the inside of the tube as shown in Figure 3. Try comparing these light sources (if you have them):

1. Incandescent or LED, compact fluorescent “white” light bulbs, and white patch on a laptop screen. How are they different?
2. Two lights of the same color like a red LED lamp and a red incandescent or fluorescent lamp
3. Different colors on a laptop screen. How do you make yellow? Or purple?

Don’t forget to take a photo or video of your spectroscope or the spectra you observe and post it on Twitter, LinkedIn or Facebook to help inspire others. You might need another person to hold the spectroscope while you line up the camera to take the photo. Make sure to mention @OpticalSociety and use the hashtags #OpticsAtHome and #SeeTheLight.

### **A NOTE ON SAFETY**

It’s important to remind children not to look at the sun or into a laser beam. They often don’t know why this is dangerous so it is a good opportunity to talk about safety. You can look at the solar (or laser) spectrum by looking at the light reflected from white paper, that is, put the white paper in the sunlight and look at the paper with the spectroscope. For a laser, turn down the room lights and shine the laser on a piece of white paper. Look at the laser reflection with the spectroscope. When we do this activity with a class we provide stickers for the spectroscope tubes stating: DO NOT LOOK AT THE SUN OR INTO A LASER!

### **RESOURCES**

The Dumpster Optics Power Point slides for classroom use for this lesson:

<https://www.pblprojects.org/teaching-and-learning-optics-with-inexpensive-materials/>

Students making and using a spectroscope:

<https://youtu.be/YtZsDQLHdNc>

More about why Isaac Newton included indigo in the seven spectral colors:

[https://en.wikipedia.org/wiki/Indigo#Classification\\_as\\_a\\_spectral\\_color](https://en.wikipedia.org/wiki/Indigo#Classification_as_a_spectral_color)