



Building a Fancy Spectrograph

Middle School Grades

Lesson Summary

In this activity, students build and decorate their own spectrographs using simple materials and holographic diffraction gratings. After building the spectrographs, they observe the spectra of different light sources as a homework activity.

Prior Knowledge & Skills

- Ability to recognize and describe patterns
 - Experience collecting data
 - Knowledge of the general properties of visible light
- Complete lessons (optional):
- Patterns and Fingerprints
 - Graphing the Rainbow
 - Using Spectral Data to Explore Saturn and Titan

AAAS Science Benchmarks

The Nature of Science

Scientific Inquiry

The Nature of Mathematics

Patterns and Relationships

The Nature of Technology

Design and Systems

The Physical Setting

Structure of Matter

Motion

NSES Science Standards

- **Science as Inquiry:** Identify questions that can be answered through scientific investigation, Develop descriptions, explanations, predictions, and models using evidence
- **Physical Science:** Transfer of Energy
- **Science and Technology:** Abilities of technological design

NCTM Mathematics Standards

- **Algebra:** Understand patterns, relations, and functions

Colorado State Standards

- Mathematics Standards 3.4
- Science Standard 1, 2, 4, 5

Suggested background reading

Light

Teaching Time: One 40-minute period

Materials

Each Student Needs:

- 1- 7 inch Oatmeal container
 - 1- 3 x 5 Index card
 - 1 Exact-o knife
 - 1 Holographic diffraction grating
 - 1 Ruler
 - Colored pencils to draw the spectra
 - Copies of directions, questions, and homework pages
- To Share with the Class:
- Black spray paint or Duct Tape or Black Construction paper
 - Masking tape
 - 1 Incandescent light bulb
 - Thick black markers
 - Markers, aluminum foil, glue, and other materials to decorate the outside of container

Advanced Planning

Preparation Time: 40 minutes

1. Ask students to bring in oatmeal containers
2. Spray paint (or have students spray paint) the inside of the oatmeal container black (the day before activity).
3. If holographic diffraction gratings have been purchased in sheets, cut into 2" x 2" squares so that every student gets one square.
4. Build a spectrograph to demonstrate to students what the final product should look like.
5. Print copies of the student instructions.
6. Set up light bulb so the students have a continuous spectrum light source

Why Do We Care?

Spectrographs help astronomers establish what is inside the atmospheres of stars and planets by diffracting (or bending) light and creating a diffraction pattern. The patterns created are unique for different elements; the patterns astronomers see when they look through a spectrograph tell them what makes up the object or atmosphere.



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Group Size 1

Expendable Cost per Group \$4

Engineering Connection

Spectrographs are used both in ground-based telescopes and in space to help astronomers answer questions about what makes up atmospheres of planets and stars. Mechanical and electrical engineers build these spectrographs to help advance our knowledge of astronomy. Simple spectrographs, like the one you will build today, are similar to the first spectrographs astronomers used in the past.

Pre-Requisite Knowledge

Students should have some understanding of the nature of light i.e. rainbows are formed with light, light can be different colors, light can be obscured by physical objects, burning creates light, etc. Students should also be able to work with sharp cutting utensils and rulers.

Learning Objectives

After this lesson, students should be able to:

- Describe that light seen through a diffraction grating shows all of the colors of that light.
- Describe that lights that are the same look the same through the diffraction grating.
- Explain that patterns can tell us something about what kind of light we see.
- Explain that unaided, the human eye cannot see all of the colors of white light.

Materials

Students can bring in oatmeal containers.

Holographic diffraction gratings can be purchased in sheets or on card-mounted slides (Prices are from 2006) from:

Edmund Scientifics

<http://scientificsonline.com/search.asp?t=ss&ss=diffraction+grating&x=0&y=0>

A set of 2 12" x 6" sheets with 12,700 Grooves/in. costs \$7.95

A set of 15 2" x 2" card mounted slides with 12,700 Grooves/in. costs \$9.95

A set of 80 2" x 2" card mounted slides with 12,700 Grooves/in. costs \$39.95

Rainbow Symphony Store

<http://store.rainbowsymphonystore.com>

A set of 10 12" x 6" linear sheets with 500 Line/mm. costs \$25.00

A set of 50 2" x 2" linear calibrated card mounted slides with 500 Line/mm. costs \$20.00

A set of 100 2" x 2" linear calibrated card mounted slides with 500 Line/mm. costs \$35.00



Building a Fancy Spectrograph

Introduction / Motivation

Show students the PowerPoint presentation, “Spectrographs” on CDrom

Set up a prism, and have a slide projector pointing through the prism such that a rainbow is created. If a prism and slide projector are not available, use a rainbow as an example of light being diffracted by droplets in the clouds.

A diffraction grating is a special tool that acts like a prism, and a spectrograph is a special tool that allows you to channel light to your eyes. Pure white light is made up of a rainbow of colors that cannot be seen with your eyes. A rainbow is called diffracted light. Light is diffracted (or bent) by the water droplets in the air. A prism does the same thing to light from the projector. Some colors of light bend more than others, and the amount that they bend causes them to line up like a rainbow when they are diffracted. A holographic diffraction grating, like the kind we are going to use today, bends the light just like a prism or water droplets.

Today, we will create a spectrograph, which is a special tool that uses a diffraction grating. This will allow you to see things that you cannot see with just your eyes. Your job will be to explore light with this new tool just like a scientist, and to test your new tool, just like an engineer. Engineers have created different types of spectrographs to help answer questions that arise in astronomy. They test the spectrographs to see how well spectral lines can be seen. When you are building your spectrograph, think about the different factors that go into building it that may affect its accuracy.

Vocabulary / Definitions

Incandescent light bulb	A standard light bulb found in most households
Spectrum (plural: spectra)	The pattern light produces as can be seen through a spectrograph
Spectrograph (also Spectroscope)	A tool that allows the components of light to be seen easily with the eye.
Diffraction	When light bends, as through a prism or diffraction grating.
Diffraction Grating	Usually a piece of film designed to act like a prism.
Continuous Spectrum	The rainbow that white light is composed of that can be seen through a spectrograph.
Emission Spectrum	Bright lines that appear through the spectrograph against a dark background.
Absorption Spectrum	Dark lines that appear against the continuous spectrum seen through a spectrograph.
Light Source	Any object that produces light.



Building a Fancy Spectrograph

Procedure

Background

See Also: Background from the “Graphing a Rainbow” Activity.

When photons pass through a gas, they encounter atoms and molecules. The photons hit the atoms and molecules, and produce new photons. When we see this light (these photons) through a spectrograph, we see a pattern of light and dark bands called a spectrum. If the gas that we are looking at is a hot gas, we will see an emission spectrum (bright bands on a dark background). If the gas is cool, we will see an absorption spectrum (dark bands on a bright background). If two gasses contain the same material and one is hot and the other cool, the hot gas will produce bright lines in the exact same places that the cool gas will produce dark lines. Where the lines are, whether they are dark or bright, only depends on the material inside the gas. This makes it relatively easy to tell what material is inside of a gas.

The light sources that the students will be looking at in this activity will be emission spectra EXCEPT for the Sun’s spectrum. The solar spectrum is an absorption spectrum because the “atmosphere” is cooler than the source of the Sun’s light. Also, a few absorption lines in the solar spectrum are actually from Earth’s atmosphere, which you can’t avoid while on Earth.

With Students



Image 1

Cut a hole in the lid of the container
Source/Rights: LASP/ ITL



Image 2

Cut a hole in the bottom of the container
Source/Rights: LASP/ ITL

Project
SPECTRA!

Building a Fancy Spectrograph



Image 3
Half way done!
Source/Rights: LASP/ ITL

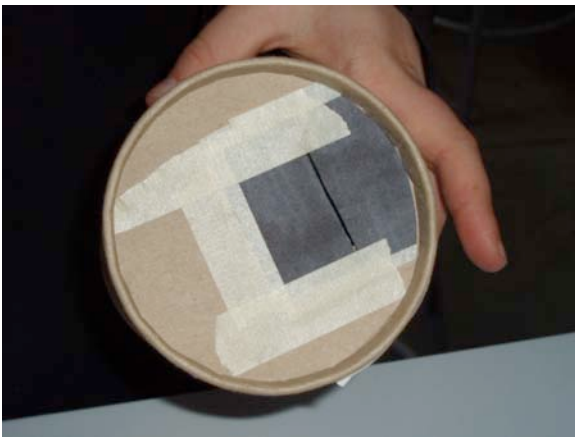


Image 4
Tape the index cards to the bottom of the container with a small gap between them.
Source/Rights: LASP/ ITL



Image 5
The finished product! Look through the lid, making sure that you see a complete, fairly wide rainbow when you look toward the light source.
Source/Rights: LASP/ ITL



Image 6

Your spectrum should appear as distinct colors on either side of the slit, as seen in this image.

Source/Rights: LASP/ITL



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Safety Issues

- Students should know the proper handling procedure for exacto-knives.
- Never have students look directly at the Sun, and advise students not to look at the Sun.

Troubleshooting Tips

Colorblind and vision-impaired children will have difficulty with portions of this lab. Students with corrective lenses will not have difficulty. Colorblind students can be paired with a student to assist them with the activity and the homework.

Students may need assistance adjusting the position of the grating so that a continuous spectrum appears. The lid must be rotated if a continuous spectrum is not visible. Also, the slit should be visible through the grating. The slit should not have any light leaking from the taped portion around it, or the spectrograph will not work properly. Make sure the index card is taped down so that the slit is perfectly straight, and that the students have used the “manufactured” edge of the card, not the edge that they have cut.

Students may be confused that they see two spectra through the slit. The diffraction grating produces two spectra, and both are a complete spectrum of the source. Make sure the students choose one or the other, but not both, to draw in the activity and on the homework.

The spectrum of the Sun is very faint through the diffraction grating. It should appear as thin, faint lines on top of the continuous spectrum. If it is cloudy, students will not be able to see the spectrum. Do not expect students to draw the lines exactly, but they should be able to see the very faint spectrum if they are looking carefully. An example appears here:



Image 7

The solar spectrum produced by a simple spectrograph.

Source/Rights: http://science.nasa.gov/spaceweather/eclipses/gallery_27oct04_page2.html, Jerry Xiaojin Zhu

Assessment

Pre-Lesson Assessment

Brainstorming: Ask students what they believe causes rainbows to form.

Post-Introduction Assessment

Class Discussion: Ask students if they are familiar with any light that cannot be seen with the naked eye. Accept many answers. Ask if they know of any animals that see differently than humans (i.e. snakes, dogs).



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Post-Activity Assessment

Engineering communication: Take students outside with their spectrographs, colored pencils, and homework page to look at the spectrum of the Sun. They can fill it in as their first light source.

Upon returning to the class, emphasize that engineers share information through dialogue, conferences, and by writing papers. Tell students that the way engineers get new ideas is through sharing with peers. Advise students to open their notebooks or engineering journals and write down something they did, discovered, or wondered about during the lab. They can use the questions as a guide, or come up with their own statements. Give them a few minutes to write, and then ask for volunteers to share. If no one volunteers, choose a student to share. After the student finishes talking, allow other students to comment (respectfully). When the students finish the discussion, highlight key ideas on the board. Some ideas may be incorrect, but are still worthy of discussion. Be wary of labeling an answer “right” or “wrong” but rather have students demonstrate or discuss why something does or does not make sense. Ask students to write about the activity and what they learned in their journals.

Note: When students complete the homework, call attention to the fact that the same light sources produce the same spectrum. Tie this to “Patterns and Fingerprints” and “Graphing the Rainbow” activities. Also, it is good to note that streetlights that appear blue or whitish blue to the naked eye are filled with mercury vapor, and streetlights that appear yellow are filled with sodium vapor, thus will have emission bands of the substance with which they are filled.

Activity Extensions

Complete the lesson, “Using a Fancy Spectrograph.”

References

Doherty, Paul, Rathjen, Don. Exploratorium Science Snacks. 1995/2006. Exploratorium: The Museum of Science, Art and Human Perception. 09/2006.

<http://www.exploratorium.edu/snacks/spectra.html>

Fisher, Diane. “Taking Apart the Light.” “The Technology Teacher.” March (2002).

Owner

Integrated Teaching and Learning Program and Laboratory, University of Colorado at Boulder

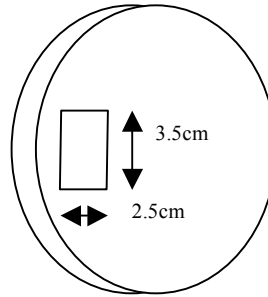
Contributors

Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder

Student Directions

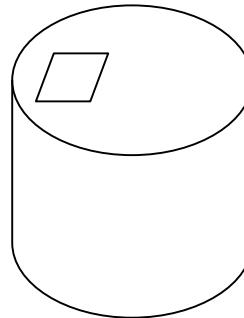
1. Cut a small slit off center in the lid of the container approximately 2.5 cm wide by 3.5 cm high.

Cut hole in lid off to one side.



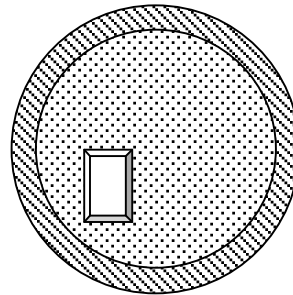
2. Cut a hole the same size roughly opposite the hole in the lid on the opposite side of the container.

Cut hole in container off to one side so that when lid is on, holes are roughly opposite one another.



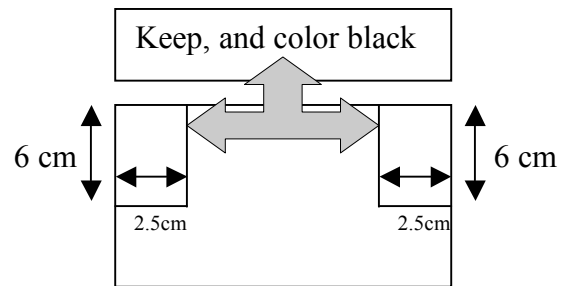
3. Careful not to cover any portion of the hole with tape, gently tape the diffraction grating to the inside of the lid.

Tape grating to hole on the inside of lid.



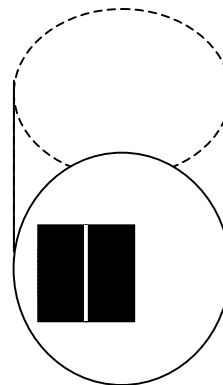
- Cut the index card 6cm long by 2.5cm wide. Use the straight edges of the card. You may have to trim this piece to fit your spectrograph later on.
- Color the index card pieces black using black marker.

Cut ends off of index cards, keep, trim, and color black



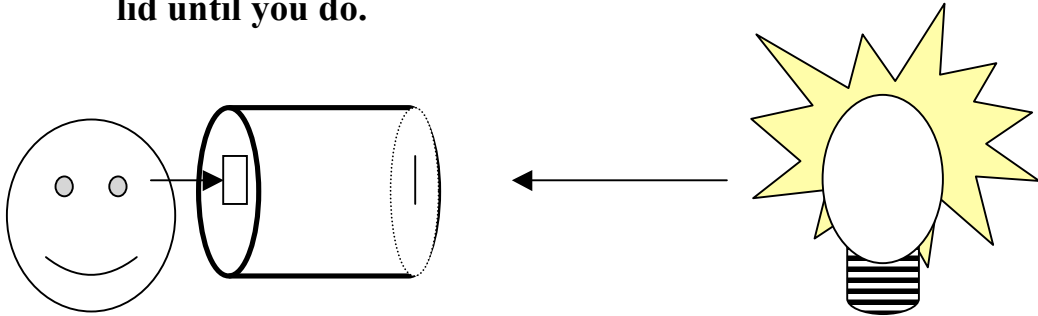
- Using the straightest edge of the index card pieces, tape over the hole in the bottom of the container so that they are almost touching, but not quite. Make a gap of less than 1 mm, as straight as possible. Tape using masking tape so that no light leaks into the box aside from the light coming through the gap (slit).

Tape index card pieces to bottom of box so that they make a very small slit < 1mm. Make sure to use the straightest edge to make the slit.



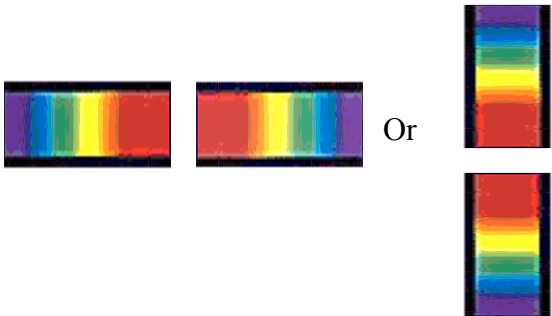
7. Put the lid back on, look through the lid, and point your spectrograph at the light source. You should see a continuous spectrum (a rainbow) very clearly. If you do not see a continuous spectrum clearly, rotate just the lid until you can see one.

Put the lid back on and look through the lid toward the light source. If you do not clearly see a rainbow, rotate the lid until you do.

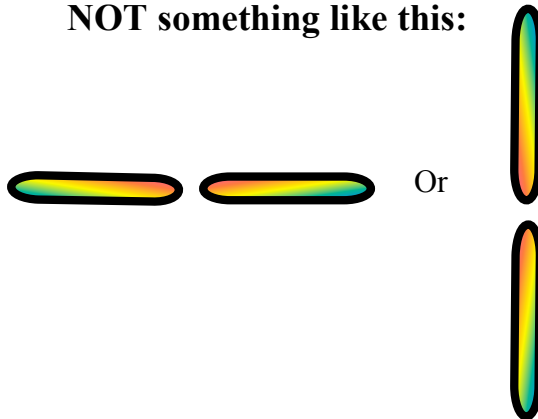


8. Once your spectrograph is finished, decorate the outside of your container.

You should see something like:



NOT something like this:



This is called a continuous spectrum. Both sides of the slit show a full continuous spectrum. When you are drawing the spectrum, just choose one or the other. Do not draw both.



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Questions

1. Draw the spectrum you see when you look at the light source.

2. When you look at the light bulb without using the spectrograph, what color is it? Can you see the colors of the spectrum with your naked eye?
3. If a spectrograph is a special tool that shows us what light is made from, what do you think makes up this light source?
4. Do you think that there are kinds of light that cannot be seen with the naked eye?
5. If light exists that cannot be seen, how could it be possible to observe it?



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Homework

Name _____

Take your spectrograph home with you and look at *eight* light sources. Make sure to look at at least three *different kinds* of light. For example, you could look at a normal light bulb, a street lamp, and a florescent light (like the kind found in most kitchens and some bathrooms). Other examples of light are bug zappers, candles, glow sticks, neon signs etc. You can use the Sun, but **NEVER** point your spectrograph directly at the Sun. Instead, place a piece of white paper on the ground or taped to a wall so that the Sun's light is shining on it, and point your spectrograph very close to the paper.

Record your observations in the table below. Be prepared to share your results with your class.

Light Source	Color of Light with Naked Eye	Spectrum (draw here, with calibration numbers if applicable)



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Light Source	Color of Light with Naked Eye	Spectrum (draw here, with calibration numbers if applicable)