Using a Fancy Spectrograph

Middle School Grades

Lesson Summary

In this activity, students use the spectrograph and homework from the activity "Building a Fancy Spectrograph." Students look at various light sources and make conjectures about composition.

Prior Knowledge & Skills

- Ability to recognize and describe patterns
- Experience collecting data
- Knowledge of the general properties of visible light

Complete lesson:

- Building a Fancy Spectrograph

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:** 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 60-minute period

Materials

Each Student Needs:

- Spectrograph from "Building a Fancy Spectrograph"
- Homework from "Building a Fancy Spectrograph"
- Colored Pencils
- Copy of directions

To Share with the Class:

- 1 Strand of multi-colored Christmas lights
- 1 Strand of clear white Christmas lights
- 1 Candle
- 1 Glow Stick
- (¼ Watt) night light with neon bulb
- 2-3 Extension cords

Advanced Planning

Preparation Time: 20 minutes

1. Have students build a simple spectrograph, using the associated "Building a fancy spectrograph" lesson.
2. Set up light sources around the room, making sure that there is distance between each source.
3. Make copies of the student pages.
4. Go over homework from "Building a Fancy Spectrograph."
5. Go over lesson.
6. Shut off lights.

Why Do We Care?

When astronomers look at the atmosphere of a planet or body in our Solar System or beyond, they are usually able to tell what the atmosphere is made from. When light from background stars shines through the atmosphere, using a spectrograph, they can tell what is inside the atmosphere.

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Activity Dependency "Building a Fancy Spectrograph" activity

Group Size 1 to 2

Expendable Cost per Group $1 (initial cost, items can be reused)

Engineering Connection

Spectrographs are used both in ground- and space-based telescopes to help astronomers figure out what stars, planets, and planetary atmospheres are made of. Mechanical and electrical engineers build these spectrographs to help advance our knowledge of astronomy. Engineering of a spectrograph determines what kind of light it can analyze. For example, the materials involved affect what can be seen through the spectrograph and whether spectral lines can be seen or "resolved" at all.

Pre-Requisite Knowledge

Students should have completed the activity "Building a Fancy Spectrograph" and the homework for that lesson before completing this one. 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.

Learning Objectives

After this lesson, students should be able to:

- Describe that light seen through a diffraction grating shows all of the component colors of that light
- Describe that identical light sources look the same through the diffraction grating
- Explain that patterns can tell us something about what kind of light we see

Materials

Notes on Materials:

Glow sticks can be purchased at big box stores, camping supply stores, and many grocery stores, and are especially easy to find around Halloween. Glow sticks range in price from $1-$4.00. Make sure to get the kind that needs to be cracked to glow.

¼ watt night-lights (sometimes called 0.25 or 0.3 Watt) can be purchased at some big box stores, hardware stores, and many grocery stores, and typically cost under $5.00.

Introduction / Motivation

Astronomers use spectrographs to figure out what the atmospheres of planets, moons, and other objects in the Solar System are made of.

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Using the spectrographs that you built, today we are going to look at some different light sources. We will gather information about these light sources and figure out how astronomers determine what an atmosphere is made of.

Think about the spectrograph that you built. There are many factors that went into the design of this spectrograph, even though it is a very simple one. Engineers must consider all aspects of a design, from the length of the spectrograph to the angles present in the spectrograph. Often, they use computer modeling to help them design better instruments, but they also brainstorm with other engineers or read papers that engineers have written to help them come up with better ideas. Take some time to think about the components of your spectrograph, and we will discuss the limitations our simple spectrograph has, and talk about its strengths, before we begin.

Vocabulary / Definitions

Incandescent light bulb	A standard light bulb found in most households
Spectrum (plural: spectra)	The pattern light produces when passed through a prism or diffraction grating, as 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 around an obstacle or through a small opening like those in a diffraction grating
Diffraction Grating	Usually a piece of film covered with very thin, parallel grooves
Continuous Spectrum	The rainbow that white light is composed in which each color is equally bright
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

Procedure

Background

See the Background section of the activity “Building a Fancy Spectrograph” and the “Graphing a Rainbow” activity.

Here are some examples of the types of spectra you can see with different lights:

Florescent light bulbs contain mercury vapor inside and a phosphorescent coating on the glass. The bright lines are from the vapor, and the continuous spectrum is from the phosphor. Depending on the quality of the bulb, one may or may not be able to see the continuous spectrum. If the bulb is very high quality, the continuous spectrum may be all that you can see. A lower quality bulb will only produce a line spectrum.

A candle (seen at a distance) will produce a continuous spectrum.

Incandescent bulbs and holiday lights will produce a continuous spectrum.

Glow or light sticks will produce an emission spectrum depends on the type of dye inside. A chemical reaction causes the atoms in the dye to become excited and release photons. Even if the packaging says "neon" it is not actually neon gas that fills the tube, and the spectrum will not match that of a neon source. Students may have difficulty centering the light in the slit and will need to hold the glow stick steady several inches from the slit to observe the spectrum. It needs to be fairly dark to observe the spectrum.
A ¼ watt night-light with a neon bulb will produce a neon emission spectrum. If the night-light is the "jewel" type, it will not produce a clear spectrum so the casing will need to be removed and the connections covered with electrical tape (before plugging it in). It is preferable to get one that is not a "jewel" style, as it is difficult to remove a casing, and removal of the casing poses the risk of shock. It needs to be fairly dark to see the spectrum, and students may have to adjust their distance to the light while maintaining the light in the slit.

With the Students

1. Tell students that their job as engineers today is to establish what makes up all of the light sources that are around the room. They will be using the spectrographs that they built in the previous "Building a Fancy Spectrograph" lesson.
2. Have students rotate though the stations, spending about 5 minutes at each different light source.
3. Using their worksheets and homework from "Building a Fancy Spectrograph," have students describe and draw the spectra of the various light sources around the room.
4. During the activity, walk around the room and ask students questions pertaining to the spectra they have drawn. Whenever possible, see if the student had used the same light sources from today's activity in the homework for "Building a Fancy Spectrograph" and help students draw comparisons between their drawings on the homework and their drawings during today's activity.

Safety Issues

- Students must understand fire safety as it pertains to the use of candles.

Troubleshooting Tips

Colorblind and vision-impaired children will have difficulty with 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 diffraction grating so that a spectrum appears in their spectrographs. The lid must be rotated if a spectrum is not visible.
Make sure all light sources have been tested prior to the lab to confirm that they are operational. It may be beneficial to have extra light sources in case one fails to operate.

Assessment

Pre-Lesson Assessment

Accessing prior knowledge: Go over homework from “Building a Fancy Spectrograph” and ask students questions pertaining to the light sources they drew. Ask them to make comparisons between their light sources and their neighbor’s light sources. Have them share their findings with the class. Highlight key concepts on the board based on their discussion.

Activity Embedded Assessment

Class discussion: Ask students what astronomers might gain from understanding the atmospheres of other planets. Reinforce the idea that without engineering technology such as spectrographs, scientists would be unable to determine what a planetary atmosphere contains. Ask students to brainstorm about the limitations and advantages of the spectrograph that they built.
Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Lesson Summary Assessment

Class discussion: At the end of this activity, students should be able to explain that light sources produce a specific pattern, and that the pattern does not change. Continuing the discussion period after the lesson is crucial. At the end of the unit, students should understand that the spectrum of a light source is different depending on what the light source is made out of, that sources that have an identical spectrum have an identical composition, and that gasses have a specific composition that can be seen by passing electricity through them or through a chemical reaction to produce light. Students can then better understand how astronomers gather information about what a body is composed of by examining light, and links can be made between this lesson and astrophysical data about the compositions of planetary atmospheres.

Activity Extension

The activity “A Spectral Mystery” can be completed if resources allow.

References

Doherty, Paul. Scientific Explorations and Adventures. 1999/2000. Paul Doherty/Exploratorium: The Museum of Science, Art and Human Perception. 09/2006.
http://isaac.exploratorium.edu/%7epauld/summer_institute/summer_day9spectra/spectra_exploration.html

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Student Directions

Part 1

Student Directions: Using your homework from "Building a Fancy Spectrograph" fill in the table below. If you did not use these light sources, find one or more students who did, and share their work to complete the table.

Light Source Description	Color with Naked Eye	Draw Spectrum
Frosted Incandescent Bulb		
Incandescent Bulb		
Florescent Bulb		

Part 2

Bring the tables and colored pencils to the light sources around the room, and complete the tables.

Light Source Description	Color with Naked Eye	Draw Spectrum
Night Light w/ Neon Light		
Christmas Lights (white)		
Christmas Lights (colored)		
Glow Stick		
Candle		

Using a Fancy Spectrograph

1. Does the spectrum of any of the lights change if you move farther away or closer to it? Explain.

2. What do you notice about the spectrum of individual colored Christmas lights? How do the different colored light's spectra compare to one another?

3. Which spectra look exactly the same?

4. Which spectra look similar, but are not necessarily exactly the same? Explain your answer.

5. How do the spectra of the colored Christmas lights compare to the spectra of the white Christmas lights? Keeping in mind that spectra help us understand what *light* is made of explain why this is.

6. You are looking at a light through your spectrograph and you don't know what it is, but it looks the same as the nightlight spectrum:
    a. What is the composition of the light?

    b. How do you know?

7. How does the spectrum from the frosted bulb compare to that of the unfrosted bulb?

8. From number 7, what can you conclude about the material that makes the bulb "frosted?"

9. How is the florescent bulb different from all of the other light sources? Explain.

Using a Fancy Spectrograph

Teacher's Key: Using a Fancy Spectrograph

1. Does the spectrum of any of the lights change if you move farther away or closer to it? Explain. *The spectrum of the lights should not change with distance unless the light source moves out of the slit. The spectrum remains the same because it does not depend upon distance, but on the composition of the light.*

2. What do you notice about the spectrum of individual colored Christmas lights? How do the different colored light's spectra compare to one another? *The Christmas lights all have a continuous spectrum, and all colors are identical to one another. Note: The colored lights may have some variation in the spectrum due to transmission through the color… red may have a darker or wider red line, for example. The color on the bulb acts like a filter, transmitting more of the color that the bulb is coated with. The students may or may not notice this, but it does not mean that the composition of the light is different (there are no emission or absorption features).*

3. Which spectra look exactly the same? *The white Christmas lights are the same as the colored Christmas lights, the frosted and unfrosted incandescent bulb, and the candle.*

4. Which spectra look similar, but are not necessarily exactly the same? Explain your answer. *The florescent bulb, the night light, and the glow stick all look similar, but they don't look the same because they all have different compositions.*

5. How do the spectra of the colored Christmas lights compare to the spectra of the white Christmas lights? Keeping in mind that spectra help us understand what *light* is made of explain why this is. *The white and colored Christmas lights look exactly the same. The light for both must also be the same, so the color in the colored lights does not effect (change) the composition of the light.*

6. You are looking at a light through your spectrograph and you don't know what it is, but it looks the same as the nightlight spectrum:
   a. What is the composition of the light? *Neon.*
   b. How do you know? *The nightlight's light is made from neon. If the spectrum of the nightlight is the same as the light you are looking at, it also must be neon because the pattern of the spectrum is always the same for neon light. Except a variety of responses that explain that the pattern will be the same for the two lights.*

7. How does the spectrum from the frosted bulb compare to that of the unfrosted bulb? *The two bulbs have the same spectrum.*

8. From number 7, what can you conclude about the material that makes the bulb "frosted?" *The part of the bulb that is frosted does not effect (change) the composition of the light.*

9. How is the florescent bulb different from all of the other light sources? Explain. *If the students had access to a low quality bulb, the bulb will have very sharp, bright lines (unlike any of the other sources) separated by dark spaces. These bright lines come from mercury. If you have a higher quality bulb, the spectrum should show bright lines with a fainter continuous spectrum background. It depends on the quality of the bulb.*