

Lesson Summary

This lesson introduces students to different ways of displaying visual spectra, including colored “barcode” spectra, like those produced by a diffraction grating, and line plots displaying intensity versus color, or wavelength. Students learn that a diffraction grating acts like a prism, bending light into its component colors.

Prior Knowledge & Skills

- Ability to recognize and describe patterns
- Experience interpreting data
- Visible light represents only a small portion of all light
- General understanding of energy

AAAS Science Benchmarks

The Nature of Mathematics

Patterns and Relationships

The Physical Setting

Motion

NSES Science Standards

- **Physical Science:** Transfer of Energy

NCTM Mathematics Standards

- **Geometry:** Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- **Algebra:** Understand patterns, relations, and functions

Colorado State Standards

- Mathematics Standards 2.1, 3.1, 3.4
- Science Standard 4

Suggested background reading

Light

Suggestion for modification

Inclusion of lessons on light and the electromagnetic spectrum will make this activity suitable for high school students.

Teaching Time: One 30-minute period

Materials

Each student needs:

- Copy of worksheet

Advanced Planning

Preparation Time: 10 minutes

1. Make one copy of student worksheet before activity.

Why Do We Care?

When passed through a prism or diffraction grating, light is broken up into its component colors. The resulting spectrum will have a characteristic pattern of light and dark that, when analyzed, reveals the composition of the light source. In this activity, students learn how a visual spectrum corresponds to a line plot, which is the way astronomers view spectra to help them determine what astronomical objects are composed of.



Graphing the Rainbow

Group Size 1

Expendable Cost per Group \$0

Engineering Connection

Understanding graphs and plots is crucial to engineering, as engineering in astronomy is driven by the need to obtain scientific data. Engineering methods are constantly improved and new types of engineering are created based upon the types of data needed to advance science.

Learning Objectives

After this lesson, students should be able to:

- Explain that light from different sources, when passed through a prism or diffraction grating, can be separated into component colors
- Explain the basic tools engineers use to view spectra
- Explain that those component colors appear in a unique pattern of bright and dark lines
- State two ways to display a spectrum
- Match a “barcode” spectrum with its corresponding line plot

Introduction / Motivation

Do you know how a rainbow is formed? It is created by light, and that light comes from the Sun. When the light passes through water droplets in the clouds, we can see the colors that light from the Sun makes that we cannot normally see with our eyes. All light makes a pattern, and today we will be exploring the patterns that are hidden in light that we cannot normally see unless we have special tools to see them. Any light source, whether it is a light bulb, a computer monitor, a star, or a planet-- when passed through a prism or a diffraction grating-- will display a unique pattern of bright and dark stripes called spectra (the plural of “spectrum”).

Prisms and diffraction gratings are tools we can use to see these patterns. Instrumentation developed by engineers can measure exactly how bright each color is, since this is a difficult thing to do with just our eyes. The instrumentation can assign a number value to the brightness that can be plotted on a graph where position on the x-axis (horizontal axis) represents color and the y-axis (vertical axis) represents brightness, or intensity.

Engineers develop instrumentation based upon the properties of light. Engineers create instrumentation to see spectral patterns of light and study the patterns to improve and develop new instrumentation. They usually use diffraction gratings. They also study the processes and the types of light that create specific spectral patterns. Engineers studying space science are interested in helping answer questions about the composition of planetary atmospheres, planetary moons, stars, and gasses within the solar system and universe.



Graphing the Rainbow

Vocabulary / Definitions

Word	Definition
Spectrum (plural: spectra)	The pattern light produces when passed through a prism or diffraction grating, as seen through a spectrograph
Spectrograph	A device that allows one to see a spectrum, which usually has a prism or diffraction grating inside
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

Students should be familiar with line graphing methods and understand that graphs can be used to represent physical data. Students should have some understanding of the nature of light, i.e. rainbows are formed with light, light can be different colors, etc.

White light, like that produced by an incandescent light bulb (with electricity passing through it) is composed of all of the colors of light in the rainbow combined. It simply looks white with our eyes. A diffraction grating (or a prism) acts to break the light into its component colors. Certain colors “bend” more than others through the grating or prism, which is why the colors line up, like a rainbow.

Light passing through a cool gas will produce what is called an absorption pattern when seen through a diffraction grating or a prism, and dark lines will appear in the continuous spectrum. The dark lines are actually created by the gas absorbing the energy of the light. We can identify the gas based on the distinctive pattern of lines that appear in the spectrum. Conversely, an emission spectrum is seen as bright lines against a dark background, and is produced a hot gas emitting photons. Again, the pattern the gas creates is dependent on the type of gas. A particular hot gas shows emission lines in the exact same places that the same cool gas shows absorption lines. The pattern does not change, but whether you see an absorption or emission pattern through the grating does change depending whether the gas is hot or cool. The resulting spectrum will have a characteristic pattern of light and dark that, when analyzed, reveals the composition of the light source.



Graphing the Rainbow

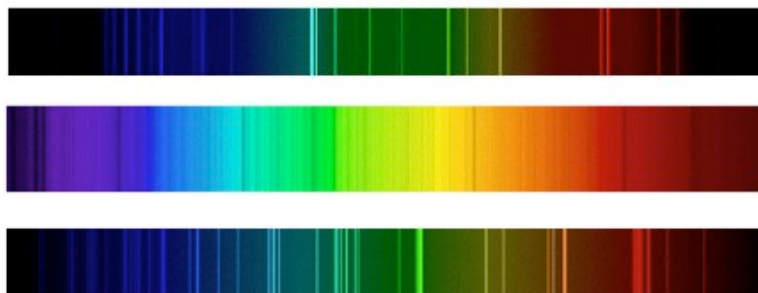


Figure 1
Emission and Absorption spectra
Source/Rights: LASP

With the Students

1. Hand out student worksheet.
2. Using the student worksheet as a guide, demonstrate how a visible light pattern can be graphically represented in different ways. An overhead projection of the second student worksheet page may be beneficial to have on hand.
3. Walk around the room to talk to individual students about the graphs from the student worksheet.
4. Ask students questions about what they see in the plots and why the pictures correspond to a specific graph on the student worksheet.

Troubleshooting Tips

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

Assessment

Pre-Lesson Assessment

Class discussion: Ask students what they can tell you about light. Probe them for what they already know and understand.

Activity Embedded Assessment

Class Discussion: Ask students why they think the light forms rainbows or patterns when passed through a prism or diffraction grating. Note to teachers: the bending of light through a prism does not have to do with varying speeds of the colors! All colors travel at the same speed.

Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment



Graphing the Rainbow

Think-Pair-Share activity: Ask students to discuss with a peer about what steps an engineer takes before designing an instrument that studies light. Randomly select groups to share. Discuss ideas as a class.

Graphing: Graphing and plotting are tools all engineers use. Plotting and graphing real world situations allows engineers to analyze whether a tool is working, how to design an effective tool, and can be used to create software to look at data (just like the data in this activity). Ask students to graphically represent a real-world situation, such as driving at a certain speed, at some point coming immediately to a complete stop, and then resuming that same speed. Another example could be a plot representing descending from the top of a flight of stairs to arrive at some distance at the bottom, which could be a distance vs. time plot. Perhaps, have the students represent what it would look like if they stopped on a stair for a very long time. This will establish whether they understand how graphing spectra is a representation of a real situation that occurs with light (as opposed to motion, distance, or some other variable). It will also establish whether the students can apply what they have learned in a different context from this activity. Ask students to come up with their own “real world” graphs, and ask volunteers to explain their graphs to the class.

Activity Extensions

Continue the spectroscopy unit by completing the associated activity, “Using Spectral Data to Explore Saturn and Titan” activity.

References

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

Owner

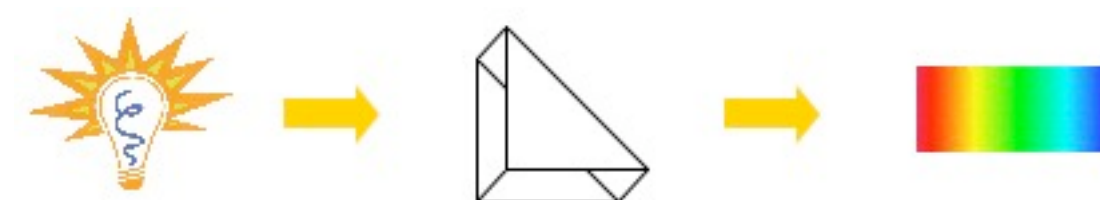
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Contributors

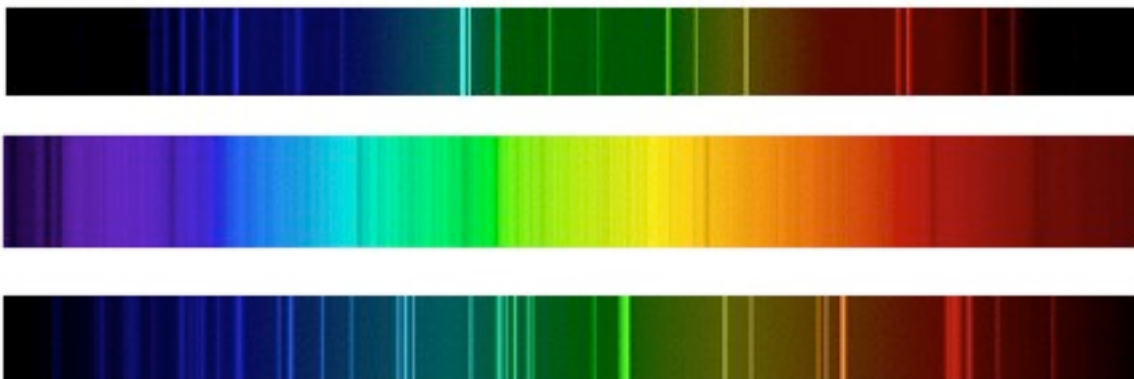
Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder

Graphing the Rainbow Student Worksheet

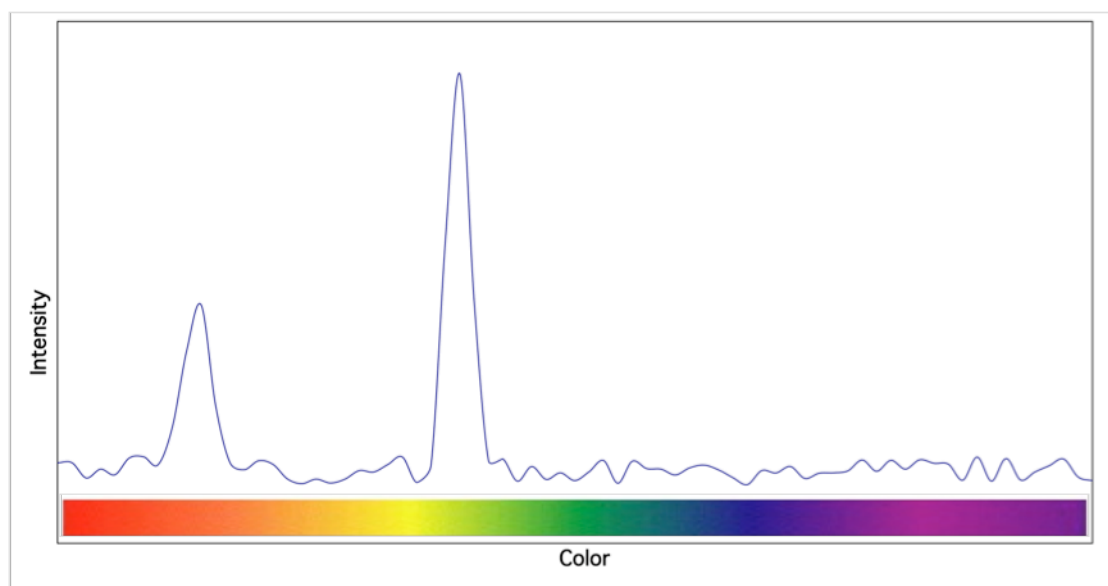
When light from any source—a light bulb, a computer monitor, a planet—passes through a prism or a diffraction grating, it produces a unique rainbow pattern.



The pattern may be mostly bright with a few dark stripes, or dark with a few bright stripes, or some combination.



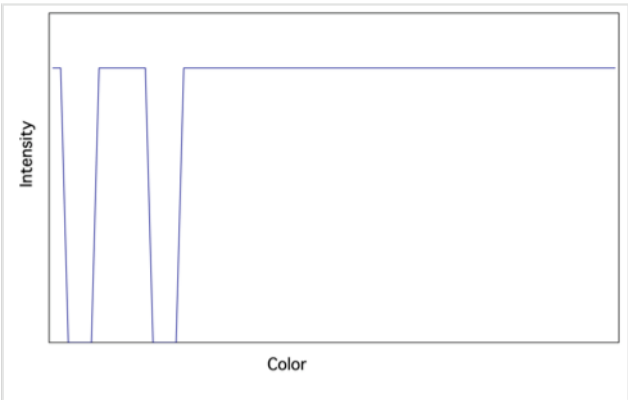
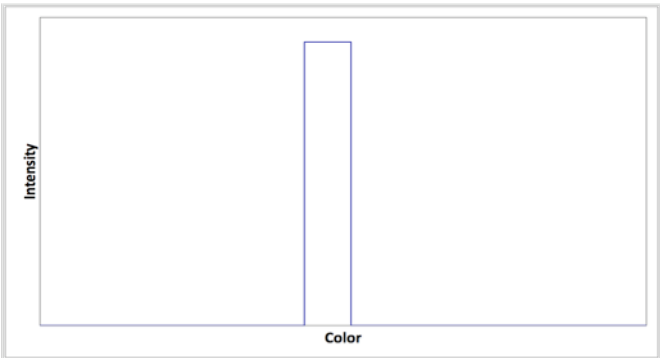
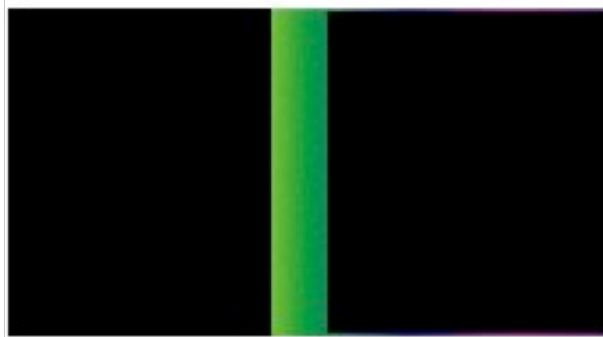
The intensity of each color of light can be plotted on a line graph like the one below.





Graphing the Rainbow

Look at the following examples. Each of the spectra on the left can also be displayed as a line plot, as shown on the right. Bright colors have high intensity, as shown along the y-axis. The first spectrum is called a continuous spectrum. In a continuous spectrum, every color has the same intensity.

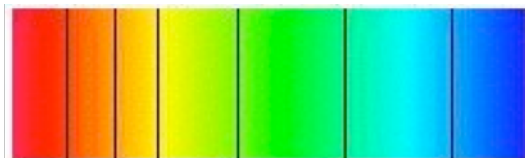
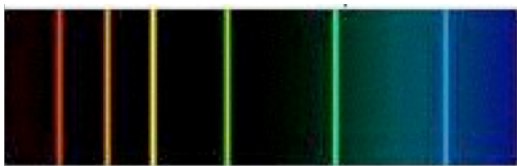
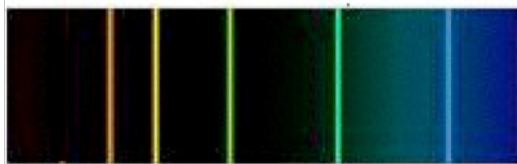
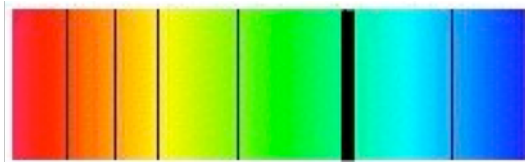
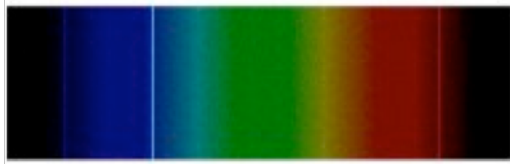


Project
SPECTRA!

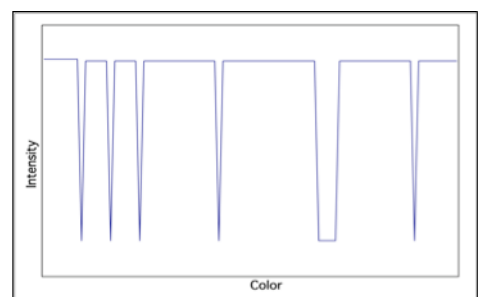
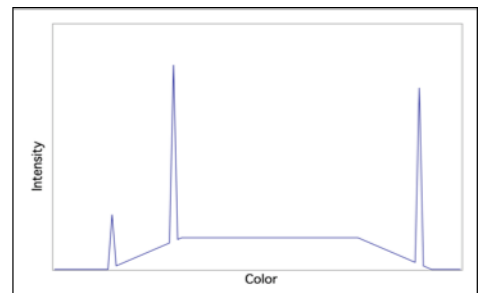
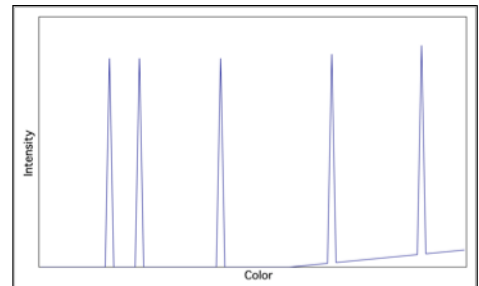
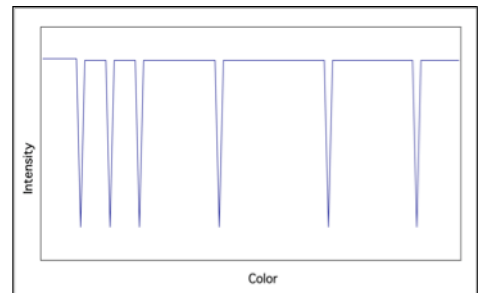
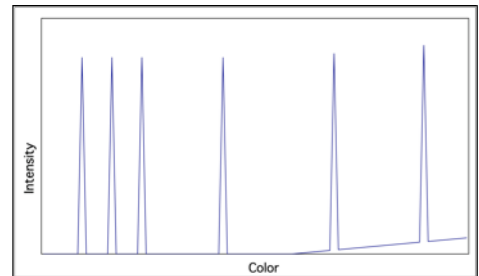
Graphing the Rainbow

Now, try matching each of the spectra from column A with its corresponding line plot from column B.

A



B



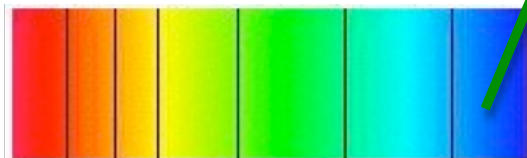
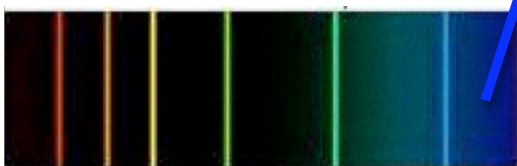
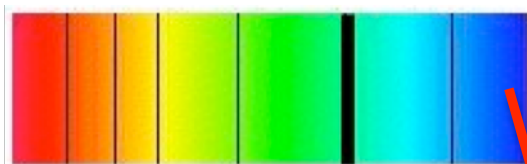


Graphing the Rainbow

Teacher's Key: Graphing the Rainbow

Now, try matching each of the spectra from column A with its corresponding line plot from column B.

A



B

