



A Spectral Mystery

Middle School Grades

Lesson Summary

Students use the spectrograph from the “Building a Fancy Spectrograph” lesson to gather data about light sources. Using the data they’ve collected, students are able to make comparisons between different light sources and make conjectures about the composition of a mystery light source.

Prior Knowledge & Skills

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

Complete lessons:

- Building a Fancy Spectrograph
- Using 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

Suggested background reading

Light

Teaching Time: One 40-minute period

Materials

Each Student Needs:

- Spectrograph from “Building a Fancy Spectrograph”
- Colored Pencils
- Copy of directions

To Share with the Class:

- 1 Power supply for gas discharge tubes
- 1 Tube of Oxygen gas
- 1 Tube of Nitrogen gas
- 1 Tube of Air
- 1 Additional tube (your choice)
- 1 “Mystery tube” that could be either Oxygen, Nitrogen, or duplicate of the additional tube
- Any additional tubes

Advanced Planning

Preparation Time: 20 minutes

1. Complete the “Using a Fancy Spectrograph” lesson
2. Set up light sources
3. Make copies of the student pages
4. Label the gas discharge tubes with their names, but label the duplicate tube “Mystery.”
5. Shut off lights

Why Do We Care?

When light from background stars passes through a planetary atmosphere, scientists can use a spectrograph to determine what that atmosphere contains. The way they do this is by comparing the results they get from their spectrographic data with laboratory measurements of spectra. Using tools like gas discharge tubes, lab measurements are made just like the ones from this lab, without which scientists would be unable to tell what an atmosphere of an object has within it.



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Activity Dependency “Building a Fancy Spectrograph” activity and “Using a Fancy Spectrograph” activity

Group Size 1

Expendable Cost per Group \$12.50 (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. Building the spectrographs for space satellites is a special challenge, and requires engineering lightweight materials as well as durable equipment that can withstand the rigors of space travel.

Pre-Requisite Knowledge

Students should have completed the lesson “Building a Fancy Spectrograph” and “Using a Fancy Spectrograph.”

Learning Objectives

After this lesson, students should be able to:

- Describe how patterns can tell us something about what kind of light we see
- Explain the equipment engineers use to understand atmospheric constituents
- Explain what makes up the Earth’s atmosphere

Materials

Material Notes:

If resources allow, it would be beneficial to have several power supplies to set up stations around the room for students to visit.

The extension activity uses gas discharge tubes. Gas discharge tubes produce an emission spectrum that can be seen when electricity runs through the tube, exciting the atoms in the gas. Although expensive, when handled properly, gas discharge tubes can last for years. Power supplies and gas discharge tubes can be purchased from (Prices are from 2006):

Edmund Scientifics http://scientificsonline.com/product.asp_Q_pn_E_3060914

115-V power supply for spectrum tubes costs \$199.95

Oxygen, Air, and Nitrogen gas tubes cost \$29.95 each

Gas tube prices range from \$29.95--\$49.95

Rainbow Symphony Store <http://store.rainbowsymphonystore.com>

Spectrum Tube Power Supply costs \$199.00

Nitrogen gas tubes cost \$35.00

Gas tube prices range from \$35--\$43.00



Image 2

A Spectral Emission Tube in a Power Supply

Source/Rights: http://scientificsonline.com/product.asp_Q_pn_E_3060914

Introduction / Motivation

The Earth's atmosphere contains gases that block some kinds of light before they can reach telescopes on the ground. So, to get a complete picture of stellar and planetary spectra, spectrographs are often launched into space, where they don't have to look through the Earth's atmosphere.

Some space spectrographs stay relatively close to Earth, but others, like those aboard NASA's Cassini mission to Saturn, travel out into deep space, where they can take an even closer look at the planets.

Getting a spectrograph into space is very challenging because the materials that are sent into space need to meet strict weight, strength, and temperature requirements. The instruments must also have a way to point accurately at a planet or body while collecting data about the object, and have a way to send the information back down to Earth.

Spectrographs can also be engineered to attach to telescopes on Earth, but then the telescope is looking through the Earth's atmosphere, and it is more difficult to figure out what the atmosphere of a planet contains. When you have to look through the Earth's atmosphere, dark bands from the Earth's atmosphere will appear in your spectrum, creating spectrographic "blind spots" in which scientists cannot learn anything about the objects they are studying.

How do scientists and engineers know what is inside of an atmosphere at all? When astronomers look at the atmosphere of a planet or body in our Solar System or beyond, they analyze the spectrum of the atmosphere and match the spectral lines with the lines of known chemicals and elements.

Using your spectrographs today, we are going to look at a few different light sources. We will gather information about these light sources and figure out what is inside of an atmosphere.



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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.

Procedure

Background

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

Light from the Sun travels through the Earth’s atmosphere. On its trip through the Earth’s atmosphere, the light encounters many atoms and molecules. When light encounters an atom or molecule, it is sometimes absorbed, creating an absorption spectrum. When looking up through the Earth’s atmosphere through a spectrograph, lines from the Earth’s atmosphere will appear in the spectrum. Sometimes the lines are so big and broad, all of the light coming through the atmosphere is absorbed, making it impossible to view the spectra of anything outside of Earth’s atmosphere at that wavelength. For example, we cannot see much of anything through the atmosphere in the ultra violet region of the spectrum because the ozone in our atmosphere absorbs most of it, a very good thing for us! Regions where there are few atmospheric absorption lines in Earth’s spectrum are called “transmission windows.” The visible wavelength range is one transmission window. Even in a transmission window, it is difficult to view the spectra of other objects because some lines from the Earth’s atmosphere are still present. These lines need to be removed before we can tell what gasses are from the object and which are really constituents of Earth’s atmosphere. They are typically removed using computer modeling.

Understanding what the Earth’s atmosphere contains is crucial to creating an accurate computer model. Usually, a reference spectrum is created in a laboratory in a very similar way to the way this activity is done; a spectrograph is used to analyze the air inside a tube of gas at different wavelengths. It is possible to accurately determine what exactly is inside the Earth’s atmosphere this way.

In this activity, the students will be able to look at the spectrum of air, nitrogen, and oxygen and establish that these are the major constituents of air because the combined spectra of oxygen and

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nitrogen look like the spectrum of air. This is, of course, a very simplified “model” of the atmosphere, but enough to give students an idea of how the atmospheric constituents are established.

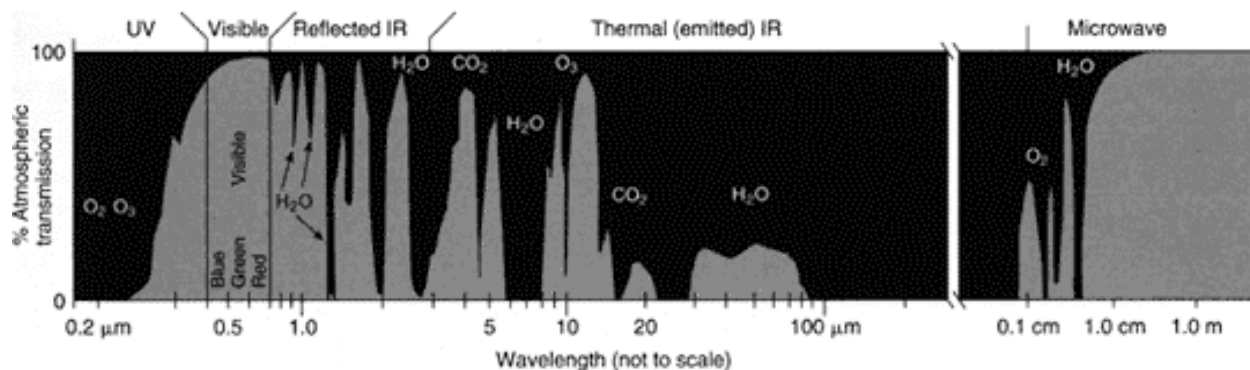


Image 3

The grey regions of this diagram show atmospheric windows. At the wavelengths these windows correspond to, we can do ground based observing of astronomical bodies. In the black regions, the wavelengths are opaque from the ground, and we need to do observing from space, above the atmosphere.

Source/Rights: http://earthobservatory.nasa.gov/Library/RemoteSensing/remote_04.html

With the Students

1. Tell students that their job as engineers today is to establish what makes up the air we breathe and also that they need to figure out the composition of the “Mystery” tube. They will be using the spectrographs that they built in the “Building a Fancy Spectrograph” activity.
2. Set up the nitrogen gas discharge tube in the power supply.
3. Have small groups of students look at nitrogen and draw a picture of the spectrum.
4. Set up the oxygen gas discharge tube in the power supply.
5. Repeat Step 3 with oxygen.
6. Set up the “other” gas discharge tube.
7. Repeat Step 3 with “other.”
8. Set up the air gas discharge tube.
9. Repeat Step 3 with “air.”
10. Set up the mystery tube.
11. Repeat Step 3 with the mystery tube.
12. Have students figure out what air contains.
13. Lastly, have the students try to figure out what is contained in the “Mystery” tube.



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Safety Issues

Gas discharge tubes will get very hot. They should only be removed by a teacher.

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 grating so that a spectrum appears. The lid must be rotated if a spectrum is not visible.

Make sure all gas discharge tubes have been tested prior to the lab to confirm that they are operational.

Assessment

Pre-Activity Assessment

Think-Pair-Share: Ask students to share with a peer about how scientists and engineers determine what an atmosphere of a planet contains. Have a few groups share their ideas with the class.

Activity Embedded Assessment

See “Using a Fancy Spectrograph.”

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

Activity Summary Assessment

Worksheet Discussion: Review and discuss the worksheet answers with the entire class. Use the answers to gauge students’ mastery of the subject.

Poster Presentation: Have groups of students draw a poster of the types of equipment, materials, and other resources (i.e. people) that are needed to put a spectrograph into space. After 10 minutes, have groups present their posters to the class.

References

Grastang, Roy, Stern, Raul, Robertson, Scott, et.al. ASTR 1010 Laboratory: Introduction to Astronomy. 1987/2005. Keith Gleason/Sommers-Bausch Observatory, University of Colorado. 10/2006 <http://lyra.colorado.edu/sbo/manuals/astr1010/20-spectroscopy.pdf>

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



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Student directions

Part 3

You will find tubes with labels on them. One tube is labeled “Mystery” tube. Another tube is labeled “Air.” It is filled with the air that we breathe. Your job is to look at the spectra of all of the tubes, figure out what is inside “Air” and what is inside the “Mystery” tube. DO NOT remove the tubes without teacher assistance. They may get very hot, and could burn you.

Light Source Description	Color with Naked Eye	Draw Spectrum
Nitrogen		
Oxygen		
Other (Write name in space)		
Air		
Mystery tube		



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1. What do you think is inside “Air?”
2. What do you think is inside the “Mystery” tube?
3. How do you know what is inside of the “Air” and “Mystery” tubes? Explain.