

Module 1: Introduction to Light and Spectra

In this first activity module, students will be introduced to the visible and infrared portions of the electromagnetic spectrum, take a spectral measurement using the ALTA hand-held reflectance spectrometer, and receive an introduction to the Moon Mineralogy Mapper / Chandrayaan-1 Mission.

Activity 1-1. Experimenting with Color Filters (45 minutes)

Students begin their exploration of the properties of light. They observe different colors of construction paper using colored filters as eyeshades and discuss their findings. Based on their observations, students make and test predictions of the appearance of other colors through the colored filters.

Activity 1-2. Making Observations of Spectra (60 minutes)

This activity introduces the concept of a spectrum, including both visible light and wavelengths that are not visible to human eyes. Students observe a light spectrum, created using a diffraction grating and an overhead projector. Students experiment with observations of the spectrum, using their color eyeshades and construction paper, and a solar-cell and sound amplifier to detect near-infrared light through sonification.

Activity 1-3. Fingerprints of Light (20 minutes)

This introductory activity introduces students to the useful tools of observation and comparison as a means of classifying and potentially identifying similar features/objects. Students will compare collected fingerprints, classify and describe them as analogous to looking at spectra.

Activity 1-4. Introduction to the ALTA Spectrometers (60 minutes)

Using the ALTA reflectance spectrometer, students take readings of different colored objects at different wavelengths, and graph a reflectance spectrum for those objects. Students compare their reflectance spectra graphs and observe that different objects have different spectra.

Activity 1-5. Spectrometers in Action (30 minutes)

Students collect reflectance spectra and discover that objects that appear similar can have different spectra. Students discuss the advantages of a high-resolution spectrum to identify objects, and learn about the Moon Mineralogy Mapper / Chandrayaan-1 mission.

Activity 1-1: Experimenting with Color Filters

Overview

In this 45-minute exploration, students begin their exploration of the properties of light. They observe different colors of construction paper using colored filters as filter strips and discuss their findings. Based on their observations, students make and test predictions of the appearance of other colors through the colored filters.

Learning Outcomes

The student will:

- interpret the relationship between an object's appearance or color and the light reflected off of that object.
- compare reflection and absorption of light by an object.
- describe the role of predictions and testing in the process of science.

Key Concepts

- An object's appearance or color depends on the light reflected off the object that reaches our eyes.
- Objects absorb some colors of light and reflect other colors of light.
- Scientific investigation includes making observations and making and testing predictions.

Materials

For each student:

- Two different 2" x 6" strips of color sheets (color filters)
(Gels may be purchased from a variety of locations, including <http://stagelightingstore.com/>, <http://www.stagespot.com>, and <http://www.premier-lighting.com>. Gels come in 20x24" sheets; each will produce 40 sets of filter strips. Recommended Roscolux colors include: red #27, blue #74, green #90, orange #23, and blue-green #95. Prepared paddles of colored gels can be purchased at <http://store.rainbowsymphonystore.com>.)



-Or-

One color paddle with multiple color filters (from Oriental Trading Company, etc. or a *cheaper and more accessible option is to purchase plastic, transparent, colored report covers and cut them in strips and place in a zip lock bag.*)

For each group of 4 to 5 students:

- Sheets of colored construction paper: red, dark blue, yellow, green, orange, and two additional colors. **Alternative:** Consider using M&M's or Skittles.
- Observation Sheet

Preparation

Cut the color filters into 5 by 15 centimeter (2 by 6 inch) strips, with two different colors for each of your students. Note: Each sheet will make 40 strips.

The Activity

Guided Inquiry

Hypothesis

1. Give each student two different color filter strips. Alternative: hand out one set of color paddles.
2. Invite students to hold the color strip in front of their eyes. Ask your students to predict how the different colors of paper will look behind the colored filter. Students should record their predictions.
3. Model with your students how to record their predictions on their Observation Sheet 1.
4. Remind the students never to look directly at the Sun with their filter strips; even dark filter strips will not protect their eyes. Also keep in mind, some students may have partial or complete color-blindness. Depending on the severity of the condition, some of the color-related activities may be difficult for them.

Making Observations

1. Organize the students into groups of four to five, making sure that each group has all of the different colored strips.
2. Give each group a sheet of red, dark blue, yellow, orange, and green construction paper.
3. Next, have your students observe the different sheets of construction paper through their filter strips, describing what they look like, i.e., does the paper look brighter or darker? Students should record their observations on their group's Observation Sheet 1. While comments may vary, in general the blue filter strips will make red construction paper look dark grey and will make the blue construction paper appear brighter than the other papers. The red filter strips will do the opposite.
4. Ask the students to remove their color filter strips and discuss their recorded observations. They should look for patterns, and write down their thoughts. Encourage the students to test their predictions. Did their predictions match their observations? Ask each group to devise an explanation for their observations.

Making Conclusions

1. Ask your students to devise their own experiment using the color filters, record their observations, and arrive at conclusions.
2. Invite each student to share their research findings with the class.
3. Be prepared for the possibility that your students may be unaware that they are color-blind. They may be disturbed by this discovery. Alternately, if the student is comfortable with discussing their vision, it may be a useful point of discussion and observation.
4. To make the activity accessible for students who are color-blind, you might use textured or patterned surfaces in addition to the colors.

Opportunities to Explore

Invite the students to observe clothes and objects in the room, and to share what they see. Students may comment that objects appear darker or brighter, or appear to be a different color. As they discuss their observations, ask them to look for patterns. Your students may notice that light colored objects still appear bright through most filters, but darker colored objects only appear bright through some filters. For instance, dark red objects will be much brighter through a red filter than through a blue filter.

Class Discussion

As a class, invite the students to share their groups' predictions, outcomes, and any explanations they have devised.

Possible Discussion Questions

1. **What do the students think of the various explanations from the groups? Are there any that they think may be mistaken, if so, why? Are there ways to test any of them?**
[Let the students critically examine each group's hypotheses. You may want to point out that important aspects of "doing science" include arriving at results, sharing those results, evaluating each others work, and proposing alternative ideas.]
2. **What do the students think the point of the activity was?**
[Answers may vary greatly, but could include observing colors, testing how color filters affect objects' appearances, and studying how filters absorb colors of light.]
3. **Which aspects of science did your students do today?**
[Answers could include making observations, making predictions, testing predictions, and forming hypotheses.]
4. **We need light in order to see. How does light help us observe something?**
[In order for us to see something, light is reflected off that object and into our eyes.]
5. **How does light allow us to see an object's color?**
[The object absorbs some wavelengths or colors of light, and reflects other wavelengths or colors of light. The wavelengths that are reflected give the object its "color."]
6. **What did the color filter strips do to the light before it reached our eyes?**
[The filter strips absorbed some of the colors of light, and allowed other colors to pass through. The filter strips did not add color.]
7. **If red filter strips allowed red and orange light through, what would dark blue paper look like through red filter strips? Why do red filter strips make yellow and white paper look red?**
[Almost all of the light reflected off of the blue paper was absorbed by the red filter, making the blue paper appear black. Yellow and white papers reflect many colors; red filters absorb most of these colors but allow the red light to pass through, making those sheets of paper appear red.]

Note: Animals found in various environments on Earth benefit from the color filtration, absorption and reflection of light. For example, animals and plants living in aquatic environments have adapted so that their coloration is minimized to keep predators away. This explains why many living things in the deep ocean are a bright red color. Encourage students to test this themselves.

Team Members:

Date:

Observation Sheet: Experimenting with Colored Filters**Team prediction****Fill in the color of the paper and the filter, and circle how bright *you predict* the paper will look:**If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.If the paper is _____, then it will look **very bright/bright/dark/very dark** through a _____ filter.**Data Collection****Fill in the color of the paper and the filter, and circle how bright the paper looks:**_____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter._____ paper looks **very bright** **bright** **dark** **very dark** through a _____ filter.**Team discussion**

1. Did your observations match your predictions? Why/why not?
2. Are there any patterns to what you see?
3. Why do the different colored papers look different through colored filters?
4. What environments and settings found naturally does light absorption and refraction through color filters play an important role?

Activity 1-2: Making Observations of Spectra

Overview

This 60-minute activity introduces the concept of a line spectra and how scientists use this as a tool for analysis and exploration. Students discover that visible light is comprised of different colors through building a spectroscope of common household materials. As an extension, students experiment with observations of the spectrum, using their color filters, construction paper and a solar-cell and sound amplifier to detect near-infrared light through sonification. [Modified from activities in *NASA's Active Astronomy Educator's Guide*, *NASA: Cool Cosmos; Build Your Own Spectrometer*, and *NASA LAUNCHPAD: Analyzing Spectra* (NASA-EG-2010-07-011-LaR)]

Learning Outcomes

The student will:

- Design a spectroscope to identify basic properties of visible light
- Identify elements based on spectral properties
- Explain how wavelengths are used in scientific investigations

Key Concepts

- White light is made of many different colors, or wavelengths of light.
- When white light is divided into its different wavelengths, we call it a spectrum.
- Each color of light has a corresponding wavelength.
- There are wavelengths of light that are not visible to the human eye.
- Scientific investigation includes making observations, making and testing predictions, and sharing and skeptically examining explanations.

Materials for Observing Spectra

Demonstration

- White, blue, and red light source
- Prism
- Whiteboard, Posterboard, or white banner paper
- Tape

For each student

- Spectrum Observation Notes

For the class: Per Group of 3

- | | |
|---|---|
| • color filters or color paddles used in Activity 1-1 | • scissors |
| • Spectroscope Instructions | • tape |
| • fluorescent light source | • ruler |
| • Incandescent light source (flashlight) | • colored pencils |
| • CD or DVD | • aluminum Foil |
| • 1 cereal Box (any size) | • protractor triangle or 60° angle template |

Materials for Extension (Optional)

Receiver Circuit

- Solar cell
- Amplifier/Speaker
- Audio cable with 1/8 inch mini-plug on one end
- 2 jumper cables with alligator clips on both ends
- 9 volt battery for amplifier/speaker
- Small Phillip's-head screwdriver to open amplifier/speaker
- Small handheld fan

For the audio detector, the mini Audio Amplifier is available at suppliers such as Radio Shack (277-1008), as are alligator clip cables; the photocell is available from suppliers such as Solar World (#3-300).

Infrared Camera

- Infrared camera*
- BNC to VGA adaptor (male to male)
- DC power adaptor
- Video projector
- Remote control for TV, DVD, or similar electronic device

**For the infrared camera, a mini lipstick camera is available from suppliers such as LDP LLC (XNiteCamBtBW) and the rest of the materials are available at many A/V and electronics stores.*

Preparation—Demonstration

1. Close the blinds and turn off most of the lights making the classroom fairly dark.
2. Tape the white banner paper or posterboard to the front of the room, unless you use a whiteboard.
3. Load the NASA Launchpad: Neon Lights—Spectroscopy in Action (<http://www.nasa.gov/audience/foreducators/nasaclips/search.html?terms=neon&category=0000>)

The Activity

Addressing Prior Knowledge

1. Write ROY G BIV on the board. Ask the students what they know about what this means. (This stands for the colors of the rainbow in order – red, orange, yellow, green, blue, indigo, violet.)
2. Direct students to draw in their notebooks how a rainbow is produced. (Light is being refracted by small water droplets in the atmosphere.)
3. Tell students that you can create a rainbow without water and the sun's light in the classroom.
 - Turn the lights off and shine a white light through a prism. Be sure the light exiting the prism shines on a screen or board.
 - Ask the students to share what they observe. (Students will observe that the light exits at a different angle than it entered.)

- Lead students to understand that the light is being refracted by the prism as it travels through the prism and white light is composed of all of the colors of the rainbow and that each color represents a specific wavelength of light. As the white light passes through a prism, the different wavelengths of light are refracted at different angles so the individual colors can be observed.)
4. Ask students to predict what will happen if a blue light is used instead of a white light. Shine a blue light through a prism and ask the students to compare their predictions to their observations. (Students should observe that the blue light exits at a different angle than the white light.)
 5. Ask students to predict what will happen when red light is used. Shine a red light through a prism and ask the students to discuss what they observe.
 6. Pick a student to use markers to draw on the poster sheets where the red light begins and ends. Ask other students to do the same for the other colors of light.

Questions to consider with your students

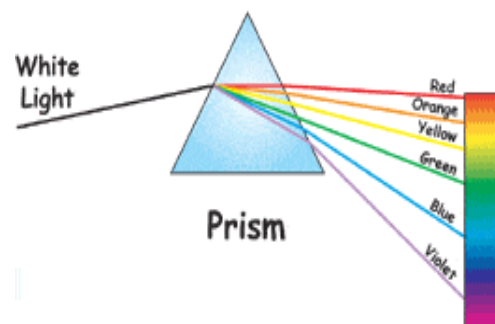
- Are the marks in the “right” place? If not, why not?
- Do all of your students see colors exactly the same way?
[Individuals see variations in colors differently, so students may have differing opinions on where the tape should be.]

Alternatives for Accessibility

Note: Some students may have partial or complete color-blindness. Depending on the severity of the condition, some of the color-related activities may be difficult for them. If you have a student or students who is/are color-blind, pair them up with other students who are not and ensure that the group discussion includes good descriptions of the width and relationship of the various color zones within the spectrum. Any diagrams or sketches may include patterns or textures rather than colors to represent the changes in color.

Be prepared for the possibility that your students may be unaware that they are color-blind. They may be disturbed by this discovery. Alternately, if the student is comfortable with discussing their vision, it may also be a useful point of discussion and observation.

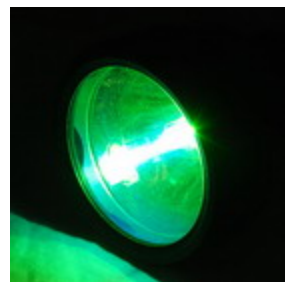
7. Keeping the prism and the light source location constant, shine each colored light through the prism and on to a white board or white poster paper. Mark the position of the red light on the board.
8. Next, distribute materials, including Spectrum Observation Notes and allow students to collect observations of incandescent light (if available) and fluorescent. Review the terms and your expectations prior. Review the sheet before allowing students to proceed.



Hypothesis

1. Next, distribute the color paddles or filters used in the 1-1. Demonstrate how to use these with their partner to make observations.
2. Ask the students to predict what they will see when they look at the spectrum with their color eyeshades, and share those predictions with a partner.

“If I look at _____ color with my spectroscope,
the _____ colors will shine through.”



Make Observations

1. Invite the students to observe the spectrum through their color filters and describe which colors they can see and which colors have disappeared. Remind the students never to look directly at the Sun with their eyeshades; even dark eyeshades will not protect their eyes.
2. Ask students what they see?

[Red and orange light will be easily seen through the red eyeshades, but green and blue light will not. Blue will be easily seen through the blue eyeshades, but yellow and orange will not.]

Sharing Explanations

As a class, invite the students to discuss their conclusions.

[Students may suggest that their filters block some colors of light, but allowing other colors of light through to be seen. Other students may guess that the filters have added color to the lights.]

Recognize and Analyze Alternative Explanations

Invite the other students to add any points that may support or refute the ideas.

[For instance, if the filters were adding color, then a red filter should turn the entire spectrum of light red, rather than simply making some of the spectrum disappear.]

Class Discussion

Spend time after all of the observations to analyze and synthesize the students' thoughts and understanding.

1. **What do the students think the point of the activity was?**

[Answers may vary greatly, but should include the terms “light” and “spectrum”.]

2. **Which aspects of science did the students do today?**

[Answers could include using technology, making observations, making predictions, testing predictions, and forming hypotheses.]

Class Discussion [continued]

1. What is a spectrum? How did your class create one?

[A spectrum is white light spread out into its component colors. The class created a spectrum using an overhead projector as the source of white light, and a diffraction grating to spread the light out into different colors.]

2. What did the filters do to the spectrum of light?

[The filters absorbed some of the colors of light and only allowed a few of the colors to pass through. Introduce the term “absorption” if the students haven’t used it.]

3. Are there parts of the spectrum that humans can’t see? Which parts of the spectrum can our eyes detect?

[We can see the visible light, red, orange, yellow, green, blue, and violet. We cannot see infrared light, and other types of radiation. Invite the students to name other types of radiation, such as x-rays, UV or ultraviolet light, radio waves, and gamma rays.]

4. If your class had an ultraviolet camera, where should the students point it to look for ultraviolet light in our spectrum? [We would look past the blue end of the spectrum.]

5. In what way could looking at objects in different colors or frequencies give us useful information?

6. Ask students to think of examples of different invisible colors or wavelengths of light, that we use to look at objects?

[Examples include having x-rays to check for broken bones, or using ultraviolet light at a crime scene to check for clues. Some students may have seen pictures of stars, planets, or galaxies in x-rays, infra-red, or other wavelengths.]

Extension

Set Up the Video Camera (optional)

Infrared Camera - If you plan to use an infrared camera, turn it on by plugging it into a DC power adaptor, and plug the power adaptor into the wall. Attach the BNC-VGA adaptor to the camera's video cable, then plug it into the *input for video* on your video projector.

1. Turn on the video projector (facing a different direction from the projected spectrum) and point the infrared camera at the spectrum. Observe the video to make sure it works. NOTE: you will not see the infrared part of the spectrum until you cover the camera with colored filters.

Prepare the Audio Photocell Detector

1. The first important but often forgotten step: install a 9V battery in the audio amplifier.
2. Plug the 1/8-inch mini plug into the "input" of the audio amplifier. Clip a jumper cable to one of the leads on the photocell, and clip the other end of the jumper cable to one of the leads of the audio cable. Use the second jumper cable to connect the other lead from the photocell to the other lead of the audio cable.

Infrared Camera Experiment (Optional)

1. Inform the students that there are cameras that can "see", or detect infrared light.
 - a. Turn on the video projector with the infrared camera attached, and point the camera at different objects in the room, allowing the students to see its view.
 - b. Describe the camera as a visible and infrared camera sensitive to low light levels, and ask the students what that means.
2. Point the infrared camera at the projected spectrum on the wall and tell the students that the camera is overloaded by the amount of light.

Hypotheses / Questions

- a. **What will the camera see through a blue filter?** [It will show light where the blue part of the spectrum is, and some red light, and infrared light.]
- b. **What will the camera see through a deep red filter?**
[It will show only red and infrared light.]
- c. **What will the camera see through a blue and red filter together?**
[It will show a little of the deep red light, and infrared light.]

1. Using a remote control for a TV, VCR, DVD, etc., observe what happens on the infrared camera when you push buttons on the remote control.
 - **What does the camera show about the remote controller?**
[When in use, the controller emits light (infrared) that the camera can detect.]
 - **Why would a TV remote controller emit infrared light?**
[So it won't interfere with your viewing pleasure.]

Photocell Detector/ Audio Receiver Circuit Experiment (Optional)

1. Share with the students that you are going to use an instrument to examine the light.
 - a. Show the students the photocell detector/ audio receiver and switch it on.
 - b. Demonstrate that the amplifier/speaker emits a noise when the photocell is placed in front of a light, such as the projector light, and that the noise is louder when the light is interrupted by a small fan (the instrument is sensitive to changes in light levels).
 - c. Then slowly pass the photocell in front of the spectrum that is being projected on the wall, holding the fan in front of the photocell.
2. Ask students the following questions:
 - a. **Which colors or frequencies of light can the photocell detect?**
 - b. **Are there any visible colors that it cannot detect?**
[It does not detect the purple light as well as the other colors.]
 - c. **How does the detector respond when it is moved from yellow to orange to red and beyond?**

See *The Active Astronomy* curriculum, developed for the SOFIA mission, that includes additional activities on the spectrum and on transforming energy from one form to another.

<http://www.sofia.usra.edu/Edu/materials/activeAstronomy/activeAstronomy.html>

Activity 1-2: Making Observations of Spectra

STUDENT

Make-your-own spectroscope Instructions

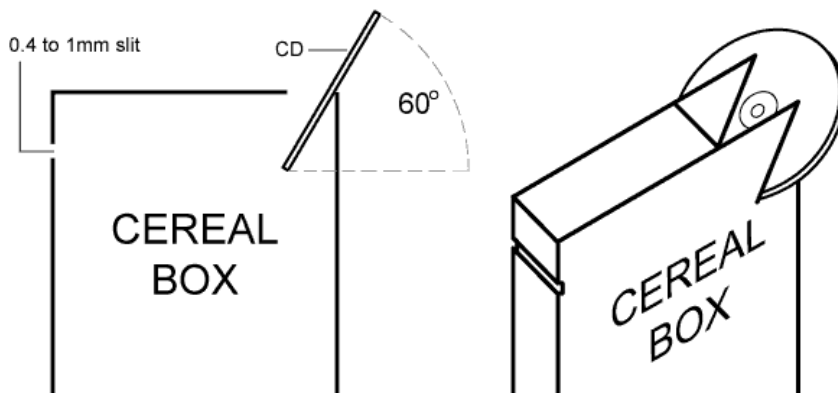
Modified from NASA: Cool Cosmos; Build Your Own Spectrometer)

1. You will need the following materials:

- Fluorescent light source
- Incandescent light source
- CD or DVD
- 1 Cereal Box (any size)
- Scissors
- Tape
- Ruler
- Colored pencils
- Aluminum Foil
- Protractor triangle or 60° angle template



This is a schematic of the model:



<p>2. On the top of the box, measure in 1.5 inches and make a mark.</p>	
<p>3. Using the 90 degree edge of the triangle...draw a guideline across the width of the box.</p>	
<p>4. Cut along the guideline, then unfold the flaps you just made. Cut off the flaps.</p>	

5. Place the short edge of the triangle along the top edge of the box and draw a 3 inch line towards the center of the box: Using those lines as guides...cut two 3" slits on both sides of the cereal box as shown.



6. Flip the box over and do the same thing on the other side.

7. Slide the CD into the slits as shown.



8. Now you're going to cut a rectangle out on the opposite long side of the box as shown. The rectangle should be the width of the box and one inch high. The top of the rectangle should be about half an inch from the top of the box. To cut it, first poke a hole towards the top of the box with a pen. Then, cut a rectangle using the hole as a starting point.



9. Take enough aluminum foil to cover the hole and fold it in half. place the creased side towards the middle of the hole and tape it in place.



10. Take a second piece of foil and cover the bottom half of the hole. You want to leave a gap between the two pieces of foil. This gap should be between .4 and 1mm. Too wide and the spectra gets blurry. Too narrow then not enough light gets in.



11. Tape the top of the box closed.

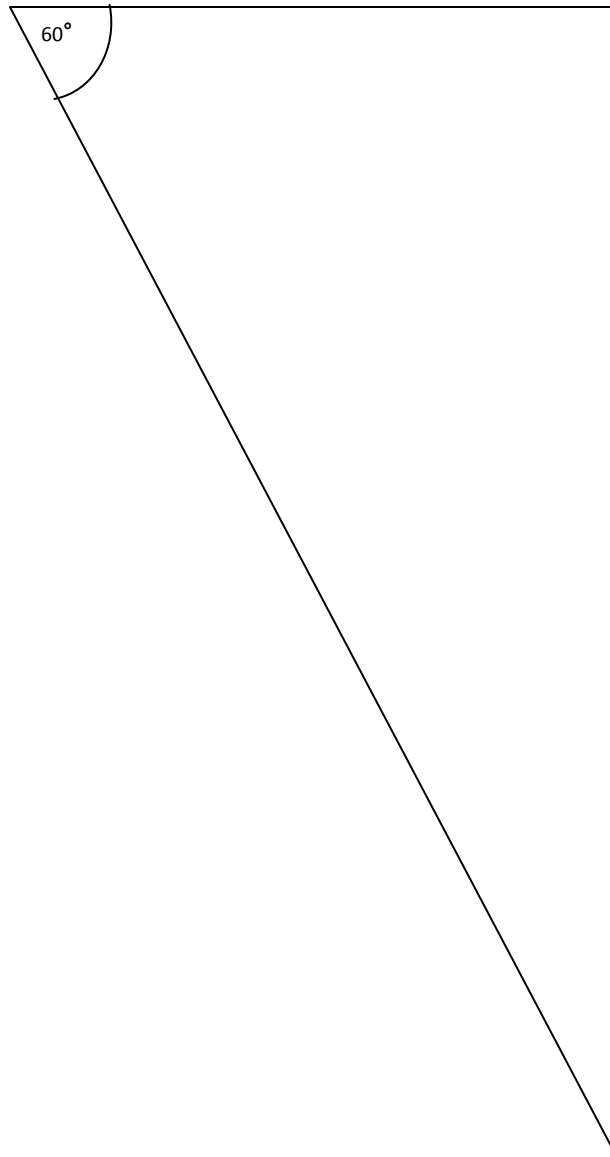


12. Point the slit at a bright light bulb, and look into the square hole. You should see something like the picture. Explore light by looking at other light sources.



Activity 1-2: Making Observations of Spectra

60° Template



Activity 1-2: Making Observations of Spectra

STUDENT

Spectrum Observation Notes

Student Name: _____

SAFETY: DO NOT LOOK DIRECTLY AT THE SUN.

Point your spectrometer to a white wall in sunshine or at some clouds instead.

Building Background:

1. Point the spectroscope towards a fluorescent light source. Observe and record your observations:
2. Point the spectroscope towards an incandescent light source. Observe and record your observations:
3. What differences did you observe between the spectra from a fluorescent light versus an incandescent light?
4. Why do you think that the different lights had different spectra?

Making Predictions:

Use your colored filters to make observations with your spectroscope.

5. Predict your findings with an hypothesis statement:

- a. "If I look at _____ color with my spectroscope, the _____ colors will shine through."
- b. "If I look at _____ color with my spectroscope, the _____ colors will shine through."
- c. "If I look at _____ color with my spectroscope, the _____ colors will shine through."
- d. "If I look at _____ color with my spectroscope, the _____ colors will shine through."

Activity 1-2: Making Observations of Spectra

STUDENT

Student Name: _____

Spectrum Observation Notes

Collecting Data:

Make your observations and record your results. Do not change your original hypotheses.

Color Filter	Colors Visible	Colors Not Visible

Making Conclusions:

1. What is a spectrum? How did your class create one?
2. How did the filters affect the spectrum of light you observed?
3. Are there parts of the spectrum that humans can't see? Which parts of the spectrum can our eyes detect?
4. In what way could looking at objects in different colors or frequencies give us useful information?

Activity 1-3: Fingerprints of Rocks

Overview

In this 20-minute activity, students will discover the unique properties of fingerprints and how this property relates to the spectral signature of rocks. In this lesson, students develop familiarity with tools used in the scientific process: comparison, observation, description and communication. This introductory activity provides the background to prepare students for spectral analyses as a means of identifying rocks and minerals by their key properties.

Learning Outcomes

The student will:

- Observe similarities and differences in fingerprints.
- Describe their observations.
- Classify their observations and results.

Key Concepts

- Characteristics found in fingerprints may be similar, and classified by their patterns.
- Fingerprints can be used to identify a person using comparative analyses.
- All matter, such as rocks and minerals, possess observable and measureable properties, but no two are identical, similar to fingerprints.

Materials (For each group of 3 to 5 students)

- Ink pad
- Baby wipes or access to a sink and soap
- Copy of Student Fingerprint Data Sheet
- Index Card (per person)
- Ruler

The Activity

1. **Pose the following questions to your students, “How are we “unique” from one another? Which of these properties can be measured or quantified? What tools does the government use to identify and track people of interest?”** Begin a discussion on ways to identify people. Responses may include appearance, name, photo identification, signatures, and fingerprints.
2. **Show the class a picture of a fingerprint. Ask students to make observations (qualitative and quantitative) of these prints. Also, ask about the ways fingerprints are used? What other technologies are used, like fingerprints, to give information? (DNA sequences, barcodes, etc.)**
3. **Tell the class that they will model the process of collecting fingerprints. Divide the class into groups of three to five people per group, and give each group a fingerprint worksheet, an ink pad, and a means of cleaning their hands.** Instruct the students to take each other’s fingerprints (one fingerprint per student) on the handout using the ink pads. Ask the students to press firmly to get a clear print.

Observing

Lead each group into a discussion comparing their fingerprints.

1. What do you observe about the fingerprints you just collected? List qualitative and quantitative observations.
2. What are some similarities in the fingerprints? What are some differences?

Classifying

Invite the students to identify at least two characteristics of the fingerprints, and to classify the fingerprints into categories based on those characteristics.

1. Students classify characteristics and record their data on the student handout.

Sharing Explanations

Invite the students to share their reasoning.

1. Students should describe general fingerprint patterns such as whorl, arch, and loops.

Identifying and Recording

Have students create a Finger Print Card on an index card of their prints or use the Finger Print Data Sheet. Students should use opposing sides of the card for each hand. Under their prints, they should quantitatively and qualitatively describe their fingerprints in paragraph form and in data tables. Students should also label their prints. [DO NOT have them write their names on the card!]

1. Students classify characteristics and record their data on the student handout.

Class Discussion

Lead a large group discussion comparing the finding of the characteristics and categories of fingerprints. Use the discussion as a lead-in to how rocks have their own “fingerprints”.

1. View the images of rocks. What do you observe? How may we tell one from the other?
2. Discuss that many of the rocks on the surface of the Moon may look similar, but they contain different minerals or amounts of minerals. Engage students in a brainstorm about how we can observe the Moon rocks if we cannot take a trip to get samples.

How might we identify the minerals that make up lunar rocks from a distance (or remotely)?

Tell students that each mineral reflects very specific amounts of the different wavelengths of electromagnetic radiation, so each mineral has a characteristic spectrum of reflected light- giving it a spectral “fingerprint”.



Moon rocks. Image: Courtesy NASA

Extension

Math Connections

1. Collect student predictions as a large group as to how many fingerprints have arches, loops, or whorls. Ask students to explain their predictions.
 - a. Why do you think there will be more whorls than arches? Explain your reasoning.
2. Create a prediction chart on the board. Create a graph of predictions for each category: bar or pie. Fractions and/or percentages can be included if students have a strong background with fractions and percentages.

Record student data collected by the groups:

- How many fingerprints arch?
 - How many fingerprints have loops?
 - How many whorls?
3. Compare the two graphs. Lead a discussion on the results.
 - a. What do you observe?
 - b. What conclusions can you make from the data? Explain your reasoning.

Activity 1-3: Fingerprint of Rocks

STUDENT

Student Fingerprint Data Sheet

1. In the boxes below, carefully collect a clean fingerprint from the same finger (e.g., index finger or thumb) from each of your team members. DO NOT write your name by your print!

2. Observe the different fingerprints and answer the following questions:
- a. What are some similarities in the prints? What are some differences in the prints?
 - b. Classify the fingerprints into categories based on the characteristics and explain your reasoning:

3. Collect and analyze data:
- a. To the right, create a data table using the main features you identified and number of times those features were found in all of the prints above.

Fingerprint Features	#

- b. What was the most common feature?
- c. What was the least common feature?
- d. How might rocks have their own “fingerprints”?

Activity 1-4: Introduction to the ALTA Reflectance Spectrometer

Overview

In this 60-minute activity, students use the ALTA handheld reflectance spectrometer to take readings of different colored objects at different wavelengths, and create a graph of a reflectance spectrum for those objects. Students compare their reflectance spectra graphs and observe that different objects have different spectra, or “fingerprints”.

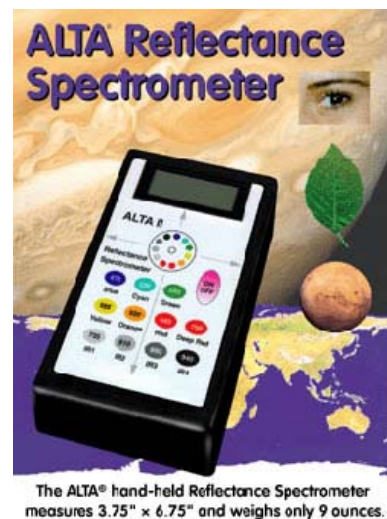
Learning Outcomes

The student will:

- record measurements of the amount of light reflecting from a surface using an ALTA reflectance spectrometer
- construct a graph from the reflectance spectrum data
- compare reflectance spectra
- predict that different objects have their own unique spectra

Key Concepts

- The ALTA Reflectance Spectrometer can be used to measure the amount of light that is reflected off of an object at 11 specific wavelengths.
- The data can be used to construct a graph of the reflectance spectrum for an object.
- Each object has its own unique reflectance spectrum, like a fingerprint.
- Scientific investigation often includes the use of technology to gather, analyze, and interpret data.



Materials

- 1 ELMO or document camera (recommended but not necessary)

For each group of three to four students:

- Bag of various and familiar materials for the students to analyze, such as colored construction paper, a variety of fabrics, foam sheets, magazines, etc. Ensure that a variety of materials colors with different hues and lusters with flat surfaces are available.
- 2 sheets of white paper such as copier paper
- 1 Calculator
- 1 copy of Tips on Using the ALTA
- 2 copies of the Reflectance Datasheet
- 2 copies of the Spectrum Graph
- *1 ALTA reflectance spectrometer

**Reflectance spectrometers can be ordered for loan from <http://www.lpi.usra.edu/education/products/spectrometer/loan.shtml>. Note: 1 9-volt battery per unit will be needed. South Carolina teachers: Contact Dr. Cassandra Runyon to borrow these. Contact her at runyonc@cofc.edu. Alternatively, spectrometers may be purchased through Vernier Software <http://www.vernier.com/>*

Preparation

1. Plan to break your class into groups of three to four students each, with one ALTA spectrometer per group.
2. Check each ALTA reflectance spectrometer to make sure that it has a working battery and that numbers appear on the digital display when turned on. NOTE: You may have to hold down the On/Off button for a second or two to turn the unit On or Off.

The Activity

1. Divide the class up into groups of three to four each.
2. Review with your class, the “Fingerprints of Rocks” activity and the similarities and differences observed in their different fingerprints. Have them discuss it briefly within their groups.
3. Explain that materials also have a type of ‘fingerprint’; therefore each material has a characteristic “reflectance spectrum.” Scientists can use this information from a distance, such as from orbit around a planet, to identify substances, such as minerals.
4. Introduce students to an ALTA spectrometer, and let the students know that they will use these instruments to gather the reflectance spectra of different objects.
 - The ALTA spectrometer emits energy and measures how much of that energy is reflected back (in mV). Using a mathematical formula, we can identify what the percent reflectance is. Seven bands in the visible portion of the spectrum and two bands in the infrared portion of the spectrum are measured by the ALTA spectrometer. Show students that the back of the instrument has a round hole where light passes, with buttons in the front that go with each of the bands (and light emitting diodes, or LED, bulbs).
5. Model for students how to activate the ALTA spectrometer using an ELMO or document camera. Show students the main features of the spectrometer. Some of the spectrometers may turn themselves off immediately; the students will need to toggle with the on/off button until it stays on. If there is no reading on the digital display, the spectrometer is off. You may have to check the battery.
 - **What do the students see on the back of the spectrometer?**
[There is a circle of 11 little lights LED’s (light-emitting diodes) with another similar-looking object in the middle.]
 - **What do the students see on the front of the spectrometer?**
[There are 11 buttons, in addition to the On/Off button, each with a different color and a different number that color’s wavelength.]
6. Distribute the spectrometers after reviewing classroom expectations. Direct the students to turn the instrument on and experiment with pushing the different buttons on the front, and observing the LED’s on the back. If they are having difficulty pushing the buttons hard enough or holding down the buttons, recommend that they use a pencil eraser to push the buttons. (Caution: Please make sure that you do not touch any of the bulbs because it could affect the measurements and damage the instrument. Please handle the instruments with care because they are very fragile.)
 - **What do the students see when they push the “blue” button after turning it on?**
[The blue led on the back lights up and remains lit while you hold the button down.]

- **What happens when they push one of the “IR” buttons on the front?**

[One of the infrared LED’s on the back “lights up” but at a wavelength our eyes cannot see.]

7. Ask the students to observe the numbers on the front.

- **What do the numbers do when the students hold the bottom of the ALTA over a desk or book? What happens when students hold it up in the air?**

[The numbers change and increase with increased brightness, until they overload the detector at which point the ALTA gives a “1”.]

- **What do the numbers do when the students cover up the back?**

[They go down.]

8. Direct students to place the ALTA flat onto a colorful surface (such as a book, a coat, etc.) and push two or three of the buttons (one at a time) and observe the numbers. Ask them to place the ALTA onto a white piece of paper and repeat the same buttons, comparing the numbers.

- **How were the numbers different?**

[The numbers should be much higher for the white piece of paper.]

- **What could the reflectance spectrometer be measuring?**

[Answers may include “color” or “brightness” or “light;” a better answer is the amount of light that is reflecting off of an object.]

- **Which part of the ALTA could be taking the measurements?**

[The object in the center of the LED’s on the back is a detector, measuring the amount of light that is entering it.]

9. Share with the students that the light detector measures the amount of light it receives, and displays that amount as a number on the front of the ALTA, measured as voltage.

- **Why are the numbers higher when the ALTA is held up in the air?**

[Light from the room is entering the detector. This may include fluorescent lights, sun light and reflected light]

- **Why are the numbers so low when the ALTA is completely covered up?**

[No light is getting into the detector. “Dark Voltage” is the number that each ALTA reads when it is receiving absolutely no light or the reading given when the instrument is placed over a material, without a button being pressed. It’s the random energy entering into the sensor. This value will have to be subtracted from future values.]

- **Do the ALTAs have the same numbers for the “Dark Voltage”?**

[Each ALTA detector will be slightly different, producing different numbers.]

- **Why do different colored light bulbs turn on when you press the buttons on the front?**

[The different colors can emit specific wavelengths of light, a unique number value, which will reflect off of a surface and into the detector, so that we can measure how well an object reflects that particular wavelength of light. The values of energy that is being reflected back at the sensor are measured in millivolts (mV).]

- **Why are the numbers higher for a white sheet of paper than a dark object?**

[More light is bouncing off of the white paper and into the detector. Light colors reflect, dark colors absorb.]

- **Why do we have to have a “white paper reading”?**

[Measuring percentages requires that we know how much energy would be reflected at 100% reflectance. Therefore, we use a small stack of plain white paper so it reflects almost all of the energy back to the instrument and gives us a reference value.]

10. Invite the groups to collect spectra for different objects.

- a. To do this, they will collect readings of different wavelengths of light reflecting off of two objects, and then graph the data.
- b. Give each student a blank copy of the Tips on Using the ALTA, two Reflectance Datasheets, a calculator, and two Spectrum Graphs and ask them to write their names and a description of their material.

11. Model with your students how to calibrate the instrument and document your standard on the datasheet.

- a. Discuss the word “calibration” (to adjust an instrument against a standard to ensure precision) and the need to perform this standardization test.
- b. One way to measure how much light of each wavelength is being reflected is to measure the percentage (%) of light reflected, by comparing the light reflected from an object to the light reflected from a bright standard material, such as white paper.
- c. Direct the students, working in groups, to place their ALTA face-down on two stacked sheets of blank white paper and press the different wavelengths (colors) one at a time. All of the students in each group should record the numbers for each of the 11 wavelengths on their Reflectance Datasheets in the “white paper” column. Note: if the readings are changing (dropping) rapidly, direct the students to record the first high number.

12. Students should also record the “Dark Voltage” (the number displayed when none of the buttons are being pushed and the ALTA’s detector is completely covered).

Gathering Data

1. Next, the groups should place the ALTA directly onto the materials they are analyzing, and push the different wavelengths (colors) one at a time, and record the number for each of the 11 frequencies on their Reflectance Datasheet. Students in the groups can share roles: the group data recorder, the ALTA user, the recorder, and the calculator.
2. Using the calculators, have the groups follow the instructions on their Reflectance Datasheet to determine the percentage (%) of reflectance for the different materials at each of the 11 frequencies. They should record these values to two decimal places.

Analysis

1. The students should fill out their Spectrum Graphs with the final numbers from their Reflectance Datasheet.
2. Discuss graphing as a class and model one example of a spectrum graph if the students have limited graphing experiences.

- **Where is the x-axis for the graphs? What does it indicate?**
[The horizontal x-axis indicates different frequencies of light.]
- **Where is the y-axis for the graphs? What does it indicate?**
[The vertical y-axis indicates the percentage of light reflected off of their object.]
- **Do the students' graphs have any peaks or high points? If so, at what wavelengths? What does that tell them about the objects?**
[Objects reflect more of the light at those wavelengths; red objects will reflect more red and orange light, for instance.]
- **Do the students' graphs have any 'valleys' or low points? If so, what does that tell them about the objects?**
[The objects absorb most of the light at those wavelengths.]
- **Are there any strange graphs with unusual numbers (close to 0 or higher than 1)? What are possible sources of error?**
[Buttons may not have been held down during the readings, too much light might enter the ALTA, the battery may be running low, the calculations may have been incorrect.]

Sharing Conclusions

Invite each group (one at a time) to present their results, then as a class discuss the similarities and differences in their spectra.

- **Do any materials have identical spectra or does each have a different spectrum?**
[Although some of the spectra may be similar, different materials should have different spectra. However, with only 11 data points, the ALTA cannot always show these differences.]

Class Discussion

Invite the students to reflect on the activity and analyze their results.

- **What do the students think the point of this activity was?**
[Answers could include taking data and learning to use the ALTA, or may even include learning about the spectrum and learning about light.]
- **Which aspects of science did your students do today?**
[Answers could include using technology, collecting data, putting those data into a readable format of a graph, making predictions and testing predictions.]
- **How did each student's spectrum compare to the others in his or her group? How did the different groups' spectra compare to each other?**
[Different objects have different spectral "fingerprints;" each object had a unique spectral graph.]
- **What does the ALTA record? How might this be useful?**
[The ALTA measures the amount of light that is reflected off of an object, for different wavelengths of light. Scientists could use the reflectance spectrum to identify a mysterious substance.]
- **How is the ALTA similar to the human eye?**
[Both the human eye and the ALTA can measure the amount of light we see, at different wavelengths or colors of light.]

- **In what ways can the ALTA detect more than we can?**
[It can detect four different infrared wavelengths.]
- **How might the ALTA be improved to collect more data about the spectrum of an object?**
[More wavelengths could be added.]
- **How might spectrometers on spacecraft help us learn about other planets?**
[It is much easier to fly an instrument like a spectrometer past a planet than landing on that planet. Spectrometers can take reflectance spectra of those planets to help us identify their makeup.]

Activity 1-4: Introduction to the ALTA Reflectance Spectrometer

Student Name: _____

Team Members:

Material Description:

Dark Voltage Constant:

Color	Wavelength in Nano-meters	White Paper Reading	Dark Voltage Constant	White Paper Reading - Dark Voltage (A)	Sample Reading	Dark Voltage Constant	Sample - Dark Voltage (B)	Sample / White Paper	$\frac{(B \div A) \times 100 \text{ or } ([\text{Sample} - \text{Dark Voltage}] \div [\text{White} - \text{Dark V}]) \times 100 = \% \text{ Reflectance}}$
Blue	470								
Cyan	525		same			same			
Green	560		same			same			
Yellow	585		same			same			
Orange	600		same			same			
Red	645		same			same			
Deep Red	700		same			same			
Infrared 1	735		same			same			
Infrared 2	810		same			same			
Infrared 3	880		same			same			
Infrared 4	940		same			same			

Activity 1-5: Spectrometers in Action

Overview

In this 30-minute activity, students collect reflectance spectra and discover that objects which appear similar can have different spectra or “fingerprints”. Students discuss the advantages of a high-resolution spectrum to identify objects, and learn about the Moon Mineralogy Mapper / Chandrayaan-1 mission.

Learning Outcomes

The student will:

- collect data and graph the spectra of two different substances that look alike, using the ALTA spectrometer.
- compare the different spectra.
- infer the potential uses of reflectance data.

Key Concepts

- Each object has a unique reflectance spectrum.
- Data from a reflectance spectrum can be used by scientists to identify objects remotely.
- The Moon Mineralogy Mapper will be used remotely by scientists to analyze rocks on the surface of the Moon.
- Scientific investigation includes observations, gathering, analyzing, and interpreting data, and using technology to gather data.

Materials

For classroom:

- ELMO or document camera, not required
- Student Behavior Checklist
- Collaborative Group Rubric

For each group of three-four students:

- 1 copy of the Reflectance Data Sheet, from Activity 1-4: Introduction to the ALTA Reflectance Spectrometer
- 1 copy of the Spectrum Graph
- 1/3 sheet of white construction paper
- 1/3 sheet of black construction paper [Note: do not use black cardstock; it may not work for this experiment.]
- 1 black marker
- 1 ALTA reflectance spectrometer
- 1 calculator
- Scissors
- Zip-seal bag
- Ruler

Materials list is continued on next page.

For each student:

- To hold all students equally accountable in their collaborative groups, it is recommended that each child receive a duplexed copy of the Reflectance Data Sheet and the Spectrum Graph to be turned in for a grade.

Preparation

1. Test your black construction paper ahead of time; look at the infrared reflectance raw numbers. If they are lower than 200, you will need a different type of construction paper. Most types of black construction paper yield numbers higher than 800 for infrared voltages.
2. Cut one small square, about 5 by 5 centimeters (2 by 2 inches), out of black construction paper. Draw a similar-sized square using black marker on white construction paper. Fill it in and cut the square out.
3. Place both squares in zip-seal bag for future use.
4. Ensure each ALTA reflectance spectrometer's batteries are working properly.

Engaging Prior Knowledge

1. Holding up the two black squares you prepared in advance, ask your students to identify the difference between the pieces of paper.
 - a. **Can your students at the back of the room tell the difference? What about the students at the front of the room?**
 - b. **Are there times when scientists would like to examine something that is too far away for them to touch? Can the students name examples?**
[Scientists might want to examine moons, planets, and stars to learn more about them.]

The Activity

1. Explain your expectations. Explain to the group that $\frac{1}{2}$ of the class will measure a 5cm x 5cm square on a white piece of paper, color it black, then cut it out. The remainder will measure the same size on a black piece of construction paper and cut it out. (NOTE: If time is an issue, consider doing Steps 3 and 4 in advance.)
2. After you describe your expectations, give each group an ALTA, a Reflectance Worksheet, a Spectrum Graph, and a calculator.
3. Divide your class into groups of three-four students each and distribute the materials to your groups.

Hypothesize

1. Ask the groups to predict what the spectrum of the black squares will look like.
 - a. **Will the spectrum of the construction paper that has been colored black with marker will look similar or different to the black construction paper?** [Accept all answers.]
 - b. **Based on our what we learned from Activity 1-4, did we learn that dark materials have a high or low reflectance value?** [Students may suggest that there will be low numbers—low reflectance—for most wavelengths.]

- c. Guide students through creating two hypotheses statements, one for each type of black square. Encourage students to make their own hypothesis, rather than agreeing with others in the class.

"If the paper is _____, then the reflectance value will be _____."

"If the paper is _____, then the reflectance value will be _____."

Gathering Data

1. Direct students to divide the tasks among group members. One person will be needed to use the reflectance spectrometer, one to record the data on the datasheet, one to compute the numbers (using the calculator), and one to take the lead on graphing the results. NOTE: We recommend that all students be responsible for submitting their own datasheet and graph. This holds all children accountable.
2. Quickly review how to operate the instrument, collect data, as well as briefly discuss the "dark voltage" and the role of a standard.
3. Next, monitor the groups as they collect reflectance data from plain white paper with their ALTA, as in the last activity, to have a standard for comparison. Students should also record the dark voltage for their ALTA.
4. Instruct teams to collect the data for their black squares and fill out their datasheets.
5. For early finishers, have students repeat these steps with the other square in their bag. Have students perform calculations and graph (See Analysis Section below) as homework.

Analysis

1. As groups complete their data collection, instruct each team to graph the reflectance data for either the black construction paper square or the black-colored white construction paper.
2. Ask the students to decide how to best compare the spectra to see if they are alike or different.

Class Discussion

1. Show the different groups' spectra on the ELMO or document camera. As a class, invite the students to share their results and analyze their conclusions.
 - **Are the spectra similar or different? If there are differences, what can they be attributed to?**
[The spectra with black marker are much lower in the infrared range than the black construction paper. The chemicals in the black marker are darker in infrared.]
 - **Can two substances that look alike have different spectra?**
[Yes they can, particularly at wavelengths that our eyes can't see. Materials made of different chemicals will absorb different wavelengths of light. Objects with identical chemical makeup have identical spectra.]
 - **What do the students think the point of this activity was?**
[Answers could include that objects which look alike to us can still have very different spectral measurements.]

- **Which aspects of science did your students do today?**

[Answers could include making a discovery, using technology, taking data, making predictions and testing predictions.]

- **We discovered that different materials have different spectra, even when they look alike. How might this be a useful tool on the Moon or Mars?**

[Scientists can use this to help identify different materials, like rocks, minerals, and resources.]

2. Compare the range of wavelengths visible to humans to the wavelengths taken by the ALTA spectrometer.

- **What colors do most humans see? How many different shades of color can people see?**

[People see visible light. The cones in human eyes can detect red, green and blue, but our brains use that information to detect differences between hundreds to thousands of different shades of color.]

- **In what ways can the ALTA detect more than our own spectrometers—our eyes—can see?**

[It can measure four different infrared wavelengths.]

- **In what ways is the ALTA limited? How could it collect more information, and why would those changes be useful?**

[The ALTA can only give us a spectrum with 11 data points - 11 wavelengths. More wavelengths would give us more details, and make it easier for scientists to identify specific materials.]

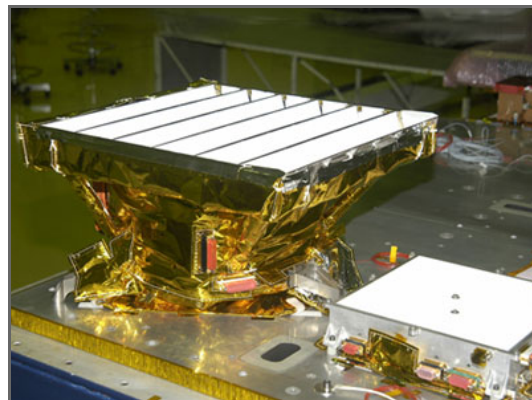
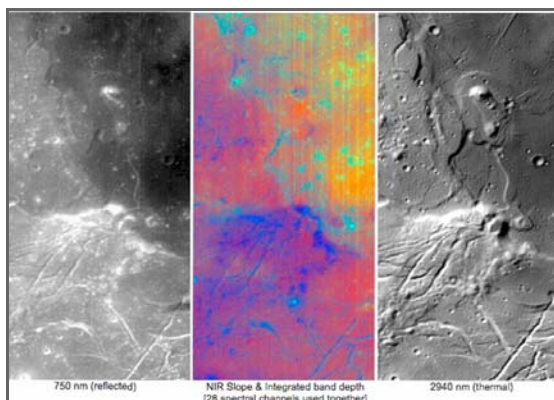
- **How might spectrometers on spacecraft help us learn about other planets?**

[Spectrometers could take reflectance spectra of materials on those planets to help us identify them.]

3. Describe the Moon Mineralogy Mapper (M3), a spectrometer on Chandrayaan-1 that recently orbited the Moon and to collect a detailed set of spectra (with 261 different measured wavelengths, covering all of the visible spectrum and the near-infrared wavelengths) of the Moon's surface. Ask your students how these data will provide more information about the Moon.

- **How would a more detailed spectral map help scientists?**

[It would make it easier to identify the types of rocks and minerals on the Moon.]



TIPS for Using the ALTA Reflectance Spectrometer

1. You need to **HOLD DOWN** the buttons to take readings.
2. What happens if you place the ALTA down flat and don't turn on any of the lights?
 - You still have a number. The ALTA's photodetector and electronics do not go to zero. This is the "Dark Voltage" and should be recorded on your datasheet.
3. You need a **large, somewhat flat surface for more accurate readings**. Try not to let outside light into the detector.
4. Begin with taking the data for two stacked pieces of white paper.
5. If the numbers keep changing while you are holding the button, pick the first high number.
6. Work in groups of three: one to operate the instrument, one to record the data, and the third to do the calculations.