Module 1

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

Activity A. Experimenting with Color Filters (30 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 B. Making Observations of Spectra (30-50 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 C. 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 D. Spectrometers in Action (25 minute)
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 A: Experimenting with Color Filters

Overview

In this 30 minute exploration, 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.

Learning Objectives:

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 gels sheets (color filters) and
- 4 pipe cleaners
  Or
- One color paddle with multiple color filters

For each group of 4 to 5 students:

- One-hole punch
- Scissors
- Sheets of colored construction paper: red, dark blue, yellow, green, orange, and two additional colors
- Student Data Sheet: *Experimenting with Color Filters* ***(Link to URL)***

Gels can 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 eyeshades. Recommended Roscolux colors include: red #27, blue #83, green # 91, orange #23, and blue-green #95.

Prepared paddles of colored gels can be purchased at http://store.rainbowsymphonystore.com

Preparation:

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

The Activity:

1. Making the Color Eyeshades: Give each student two different color filter strips and four pipe cleaners. Ask your students to punch one hole in both ends of each strip, about 1 centimeter (1/2 inch) from the edge. Ask students to pull a pipe cleaner halfway through each hole. The students should bend the pipe cleaners in half and twist the two halves together. By curling the ends of the pipe cleaners behind their ears, your students now have two color eyeshades to wear over their eyes or glasses.

   

   Alternative: hand out one color paddles per student.

To maintain standards of hygiene, the students should not share eyeshades.

For their safety, students wearing dark colored gels should remain seated.

Remind the students never to look directly at the Sun with their eyeshades; even dark eyeshades will not protect their eyes.

2. 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 object still appear bright through most filters, but darker colored objects are only bright through some filters. For instance, dark red objects will be much brighter through a red filter than through a blue filter.

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.

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.

To make the activity accessible for the students who are color blind, you might use textured or patterned surfaces in addition to the colors.

3. Organize the students into groups of 4 to 5, making sure that each group has all of the different colored eyeshades. Give each group a sheet of red, dark blue, yellow, orange, and green construction paper.

4. Ask your students to observe the different sheets of construction paper through their eyeshades, describing what they look like—does the paper look brighter, darker, or a different color? Students should record their observations on their group's *Student Data Sheet*. While comments may vary, in general the blue eyeshades will make red construction paper look dark grey and will make the blue construction paper appear brighter than the other papers. The red eyeshades will do the opposite.

5. Ask the students to remove their color eyeshades and discuss their recorded observations and look for patterns.

6. Pass the two other colors of construction paper out to the groups. Each group should write a prediction of what they will observe if they look at the new colors through their eyeshades.

7. Encourage the students to test their predictions. Did their predictions match their observations? Ask each group to devise an explanation for their observations.

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

9. Invite your students to discuss their findings.

   What do the students think of the various explanations from the groups? Are there any that they think may be mistaken—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.]

   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.]

   Which aspects of science did your students do today? [Answers could include making observations, making predictions, testing predictions, and forming hypotheses.]

   We need light in order to see. What does light do to let us see something? [In order for us to see something, light is reflected off that object's surface and into our eyes.]

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."]

What did the color eyeshades do to the light before it reached our eyes? [The eyeshades absorbed some of the colors of light, and allowed other colors to pass through. The eyeshades did not add color.]

If red eyeshades allowed red and orange light through, what would dark blue paper look like through red eyeshades? Why do red eyeshades 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 looked 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.]

Background

Seeing Color

In order to see an object that is not emitting light, there must be some light reflecting off of that object, and some of that light must be reflected from the object and into our eyes. Most materials absorb specific wavelengths, or colors, of light and reflect the rest.

When we see white, all of the colors or wavelengths have been reflected off the object. Materials that absorb almost all of the light appear black. We can still see black objects, because they still reflect some light.

Team Members

________________________________ ________________________________
________________________________ ________________________________

Observation Sheet: Experimenting with Colored Filters

Descriptions can include: bright, very bright, dark, very dark, or a color:

_________ *colored paper looks* _______________________ *through a* __________ *filter.*
_________ *colored paper looks* _______________________ *through a* __________ *filter.*
_________ *colored paper looks* _______________________ *through a* __________ *filter.*
_________ *colored paper looks* _______________________ *through a* __________ *filter.*
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_________ *colored paper looks* _______________________ *through a* __________ *filter.*
_________ *colored paper looks* _______________________ *through a* __________ *filter.*

Talk with your team: Why do the different colored papers look different through colored filters? Are there any patterns to what you see?

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____
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Can you make some predictions based on your observations so far? Try to predict what a different colored sheet of construction paper that you haven’t used yet would look like through the different filters.

_________ *(colored) paper will look* _________________________ *through a blue filter.*
_________ *(colored) paper will look* _________________________ *through a red filter.*

Now test your predictions:

_________ *(colored) paper appeared* _________________________ *through a blue filter.*
_________ *(colored) paper appeared* _________________________ *through a red filter.*

Discuss with your team: did your observations match your predictions? Do you have a theory to explain your observations?

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Activity B: Making Observations of Spectra

Overview

This 30 to 50 minute 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.

Learning Objectives:

The student will:

- define what is meant by a "spectrum."
- describe different wavelengths of visible light as different colors.
- describe some wavelengths of light that are not visible to human eyes.

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 or frequency of light has a corresponding wavelength.
- There are frequencies or 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 each student:

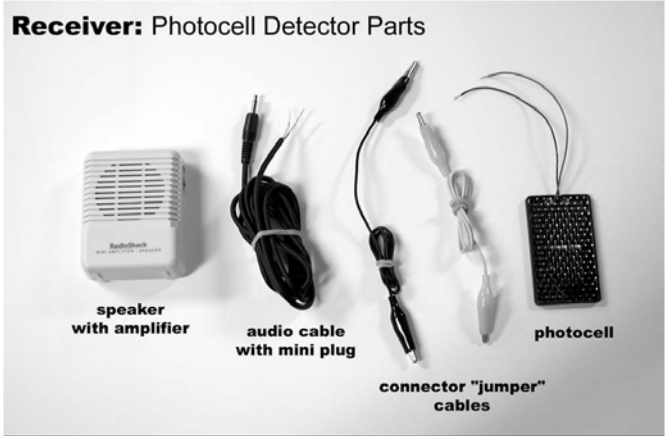
- Color eyeshades or color paddles from *Activity A*

For the class:

- A dozen sheets of various-colored construction paper
- 1 Diffraction grating
- 1 Overhead projector
- 1 roll of masking tape
- Scissors

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

Infrared Camera (Optional)

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

Diffraction Grating material comes in sheets from suppliers such as Learning Technologies (PS-08A or PS-08B) and from Sargent Welch (WL3820).

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).

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.

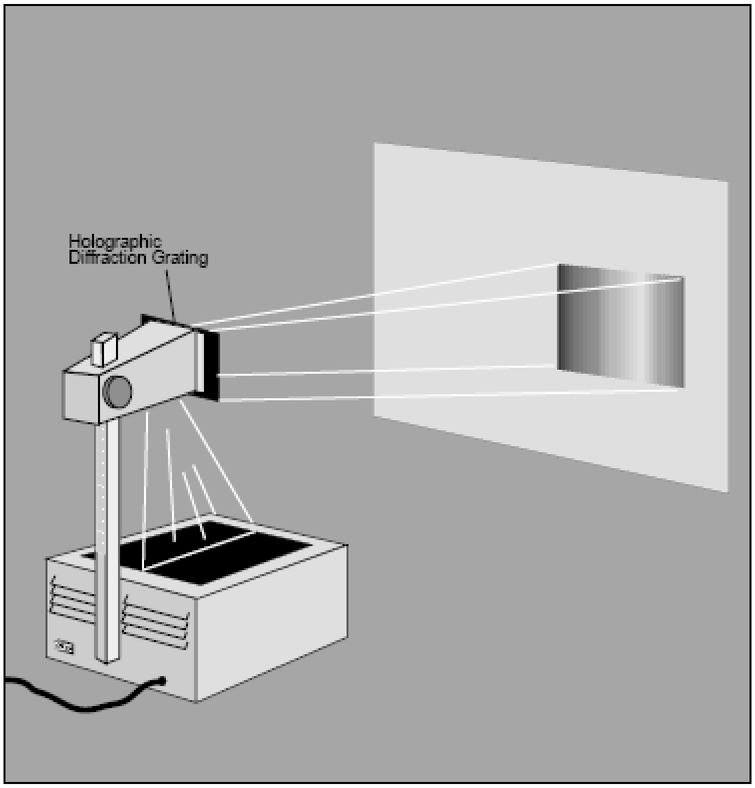
Preparation:

1. Set up the overhead projector so that it can project onto a flat white surface (screen or wall) in a dark part of the classroom.

2. Cut a small slit ½ centimeter (¼ inch) wide, but at least 10 centimeters (4 inches) long in the middle of the construction paper. Place the construction paper on the projector's glass so the only light emerging from the projector passes through the slit.

3. Turn on the overhead projector—you should see a white line of light projected onto the screen or wall.

4. Place a sheet of diffraction grating over the top portion of the overhead projector projecting the light. Adjust the sheet and projector until you



can clearly see one or two spectra clearly on the wall. Tape the diffraction grating in place.

5. If you plan to use the infrared camera (optional), 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. 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.

6. Build the audio photocell detector. Install a 9V battery in the audio amplifier. 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.

Receiver: Photocell Detector

Note: Audiocable can be connected to photocell directly with small wire nuts, or soldered. Wrap with electrical tape, or use shrink tubing to insulate.

The Activity:

1. Begin with a class discussion about light. Ask the students to describe what they know about light -- ask them what happens when light passes through a prism, what makes a rainbow, etc. Invite them to describe or define terms: white light, visible light, frequency, wavelength, colors, reflect, refract, absorb.

2. Turn on the overhead projector and explain that you are using a diffraction grating to break up the projector's white light into its colors—its spectrum. The diffraction gradient acts like a prism. Ask the students to identify which colors they see.

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.

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.

3. Pick a student to place pieces of masking tape on the wall where the red light begins and ends. Ask other students to do the same for the other colors of light.

   Are the marks in the "right" place? If not, why not? Does everyone see colors exactly the same way? [Individuals see variations in colors differently, so students may have differing opinions on where the tape should be.]

4. Ask the students to predict what they will see when they look at the spectrum with their color eyeshades.

   Which colors will "come through?"

5. Invite the students to observe the spectrum through their color eyeshades and describe which colors they can see and which colors have disappeared.

   What do 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 red and orange will not.]

To maintain standards of hygiene, the students should not share eyeshades.

For their safety, students wearing dark colored gels should remain seated.

Remind the students never to look directly at the Sun with their eyeshades; even dark eyeshades will not protect their eyes.

6. Experiment with the light. Hold a sheet of colored construction paper against the wall so that part of the spectrum is projected onto the paper. Invite the students to describe (without their eyeshades) any changes they see in the spectrum. Repeat with other colors of paper. After two colors have been used, invite the students to predict what they will see when for particular colors of paper. After sharing their predictions, students should test them. In general, colors of light should still be visible when reflected off a similar color paper, but will be absorbed when a dark, different color paper is used.

7. As a class, invite the students to share explanations of their observations. Students may suggest that their eyeshades act as filters, blocking 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.

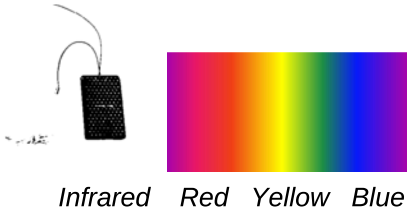
8. Invite the other students to add any points that may support or refute the ideas. For instance, if the eyeshades were adding color, then a red eyeshade should turn the

entire spectrum of light red, rather than simply making some of the spectrum disappear.

9. Share with the students that you are going to use an instrument to examine the light. Show the students the photocell detector/ audio receiver and switch it on. 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). 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.

    Which colors or frequencies of light can the photocell detect? Are there any visible colors that it cannot detect? [It does not detect the purple light as well as the other colors.]

    How does the detector respond when it is moved from yellow to orange to red and beyond? Does the detector make noise when it is in the 'black' area beyond the red light? Can it still detect light? What type of light could that be? [The photocell is sensitive to infrared light.]



Infrared Camera Experiment **(Optional)**

10. Let the students know that there are also cameras that can see infrared light. 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. Describe the camera as a visible and infrared camera sensitive to low light levels, and ask the students what that means.

11. 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. Tell the students you are going to put color filters in front of the camera, and invite them to predict what the camera will see.

    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.]

    What will the camera see through a deep red filter? [It will show only red and infrared light.]

    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.]

12. Find a remote control for a TV, VCR, DVD, etc. Observe it with the infrared camera, while pushing 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.]

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

    What do the students think the point of the activity was? [Answers may vary greatly, but should include the terms "light" and "spectrum".]

    Which aspects of science did the students do today? [Answers could include using technology, making observations, making predictions, testing predictions, and forming hypotheses.]

    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.]

    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 yet.]

    What happened to the light from the spectrum when it hit the colored construction paper? [Some of the light was absorbed by the construction paper, so it could not be seen.]

    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.]

    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.]

    In what way could looking at objects in different colors or frequencies give us useful information? Can the students think of times we use different colors of light, or wavelengths that are invisible to us 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.]

Extensions

Active Astronomy developed for the SOFIA mission 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

Background

Properties of Light

White light, such as light from the Sun or from an overhead projector, is made up of different wavelengths of light, some of which we can see, and some of which are invisible to our eyes. Certain materials (e.g., a diffraction grating, a prism, a raindrop) will refract or bend the light and separate the wavelengths, allowing us to see a variety of colors separately.

The wavelength of light is directly related to energy; red light has a longer wavelength and less energy than yellow light, while green light has a shorter wavelength and more energy, and blue/violet light has the highest energy and shortest wavelength of the visible spectrum.

Many students do not realize that radiation is another term for light, and that there are many types of radiation or wavelengths of light that we cannot see. Radio waves are a type of light, with the longest wavelength, followed by infrared light, then visible light, then ultraviolet light. The shortest wavelengths of light are x-rays and gamma rays. Each of these is a type of radiation—a different range of wavelengths of light.

A wavelength of light has an associated frequency. Red light, with its longer wavelength, has a lower frequency than yellow light. Blue light has a still higher frequency and a shorter wavelength. Ultraviolet light has even shorter wavelengths, more energy, and higher frequencies. Gamma rays have the highest frequencies and energy and the shortest wavelengths, while radio waves have the lowest frequencies and energy, and the longest wavelengths.

Photocell Detector / Receiver Circuit

The receiver circuit uses a photocell to detect the IR signal and convert it back to an electrical signal for the speaker. The photocell (or solar cell) produces an electric current when exposed to light. Because of the way speakers are constructed, a changing current is needed to produce a sound in the speaker; a constant current will not produce a sound. When a constant light source illuminates the photocell, it produces a constant current and no sound is produced. Students should hear static, if anything, when a constant light source illuminates the photocell. When the light changes in brightness, the current produced by the photocell also changes accordingly, and the speaker will produce a sound. If the light is turned on and off (as happens if you move your hand back and forth in the beam of light), you will hear series of “pops” each time the light is turned back on. If the light varies because of a changing electrical current from an audio source, you will hear music from the speaker.

Activity C: Introduction to the ALTA Reflectance Spectrometer

Overview

In this 60 minute activity, students use the ALTA reflectance spectrometer to 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.

Learning Objectives:

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.
- Scientific investigation includes observations, gathering, analyzing, and interpreting data, and using technology to gather data.

Materials:

For the class:

- An ink pad
- Baby or kids wipes, or access to a sink and soap

For each group of 3 to 4 students:

- Copies of the Fingerprint Form
- Familiar materials for the students to analyze, such as a colored construction paper, a variety of fabrics, magazines, etc.
- A small sample (2 tablespoons) of Lunar Soil Simulant
- A small sample (2 tablespoons) of white sand
- 2 sheets of white paper such as copier paper
- 1 ALTA reflectance spectrometer
- 1 Calculator
- 2 copies of the *Reflectance Worksheet*
- 2 copies of the *Spectrum Graph*

Preparation:

1. Plan to break your class into groups of 3-4 students each, with one ALTA spectrometer per group.

2. Check each ALTA reflectance spectrometer—make sure that it has a battery in it, and that numbers appear on the digital display when you turn it on.

The Activity

1. Invite the students to describe how they can identify someone. Hold a brief class discussion on ways we use to identify people. Discussion may include appearance, photo identification cards like driver's licenses, their knowledge of personal information, and fingerprints.

2. Divide the class into groups of 3 to 8 students. Pass out a fingerprint card to each group, and pass around 1-3 ink pads. Ask the students to each use an ink pad to ink either their thumbs and slowly press their thumb into one of the boxes on their fingerprint card.

3. Ask each group to hold a quick discussion.

   What are some of the similarities for some of their fingerprints? What are some of the differences? Can they identify at least two different characteristics for fingerprints? Can they group the fingerprints by characteristics?

4. Let your class know that materials also have a type of fingerprint—each material has a characteristic "reflectance spectrum." Scientists can use this information from a distance to identify substances, such as minerals.

5. Give each group of 4 students an ALTA spectrometer. Ask the students to turn on the ALTA spectrometer. Some of the spectrometers may turn themselves off immediately; the students will need to play with the on/off button until it stays on. If there is no reading on the digital display, the spectrometer is off.

   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. Ask the students to 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.

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. Ask the students to place the ALTA flat onto a surface (such as a book, a coat…) and push two or three of the buttons (one at a time) and look at the numbers. Ask them to then 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.]

    Why are the numbers so low when the ALTA is completely covered up? [No light is getting into the detector. The number that each ALTA reads when it is receiving absolutely no light is called its "Dark Voltage".]

    Do the ALTAs have the same numbers for the "Dark Voltage"? [Each ALTA detector will be slightly different, producing different numbers.]

Why are there different colors of light bulbs that turn on when you press the buttons on the front? [The different colors can emit specific wavelengths of light, 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.]

Why are the numbers higher for a white sheet of paper than a dark object? [More light is bouncing off of – reflecting from - the paper and into the detector.]

10. Invite the groups to collect spectra for different objects. To do this, they will collect readings of different wavelengths of light reflecting off of objects, and then graph the data. Give each student a copy of the *Reflectance Worksheet* and the *Spectrum Graph* and ask them to write their names and a description of their material.

11. Inform your students that they will need a standard or calibration for their ALTAs. 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. Direct the students, working in groups, to place their ALTA flat 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 Worksheets*. 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.

13. 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 Worksheets*. Students in the groups can share roles: the group data recorder, the ALTA user, the calculator, and the grapher.

14. Using the calculators, have the groups determine what the percentage of reflectance is for their material for each of the 11 frequencies, by following the calculations on their *Reflectance Worksheet*.

15. The students should fill out their *Spectrum Graph* with the final numbers from their *Reflectance Worksheet*. Discuss graphing as a class or model one example of a spectrum graph if the students have limited graphing experience.

    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 which 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.]

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

    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.]

17. 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 – 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 could the ALTA be improved to collect more data about the spectrum of an object? [More wavelengths could be 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 what they are made of.]

Background

The ALTA Reflectance Spectrometer

Each frequency or color of light has an associated wavelength. On the ALTA spectrometer, there are LEDs that emit specific wavelengths of light, which can reflect off of a surface. The shortest wavelength for the ALTA is emitted by a blue LED at 470 nanometers (nm) (4.7×10^{-7}m), and the longest wavelength is emitted by an infrared LED at 940 nanometers (9.4×10^{-7}m).

Each ALTA is slightly different, due to variations in the electrical components, lamps, and light sensors, so each ALTA has its own unique sensitivity to different wavelengths of light. Readings can change over time, due to temperature and other variables.

Using the ALTA

When measuring an object's reflectance using the ALTA, the students should hold down the ALTA and see if the dark voltage (the reading without any of the LED's turned on) is within one or two numbers as the dark voltage they had when the ALTA was pressed against a flat surface. If it is not, then outside light is getting in, and they should re-position the ALTA until the numbers are close to the dark reading, before they begin to press other buttons.

Some of the buttons on the ALTA need to be pressed hard to turn on the LED; if students' data seem unusual (if multiple readings are around 20-30) ask them to try again. If students have difficulty pressing or holding the button down, have them use the eraser end of a pencil to push the buttons.

Fingerprint Chart

Names of Scientists on Team

A ______________________________ B ______________________________

C ______________________________ D ______________________________

E ______________________________ F ______________________________

G ______________________________ H ______________________________

A **B** **C** **D**

E **F** **G** **H**

Descriptions of key characteristics of fingerprints:

____

____

____

____

Group by characteristics:

1st group: ______________________________

2nd group: ______________________________

3rd group: ______________________________

4th group: ______________________________

Reflectance Worksheet

Names of Scientists on Team

Sample Description

Dark Voltage Constant

Color	Wavelength in Nanno-meters	White Paper Reading	Dark Voltage Constant	White Paper - Dark Voltage (A)		Sample Reading	Dark Voltage Constant	Sample - Dark Voltage (B)		**B / A** ***or*** [Sample – Dark V] / [White – Dark V]
Blue	470									
Cyan	525									
Green	560									
Yellow	585									
Orange	600									
Red	645									
Deep Red	700									
Infrared 1	735									
Infrared 2	810									
Infrared 3	880									
Infrared 4	940									

Activity D: Spectrometers in Action

Overview

In this 25 minute activity, 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.

Learning Objectives:

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 each group of 3-4 students:

- 2 copies of the *Reflectance Worksheet*
- 2 copies of the *Spectrum Graph*
- 2 sheets of white or bright construction paper
- 1 sheet of black construction paper [*Note: do not use black cardstock; it may not work for this experiment.*]
- 1 black markers
- 1 ALTA reflectance spectrometers
- 1 calculator

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. Many 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.

3. Draw a similar-sized square using black marker on white construction paper. Fill it in and cut the square out.

4. Check each ALTA reflectance spectrometer—make sure they are working properly.

The Activity

1. Holding up the two black squares you prepared in advance, ask your students to identify the difference between the pieces of paper.

   Can your students at the back of the room tell the difference? What about the students at the front of the room?

   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.]

2. Divide your class into groups of 3-4 students each. Give each group an ALTA, two *Reflectance Worksheets,* two *Spectrum Graphs*, a sheet of black construction paper, a sheet of white construction paper, two calculators, and a black marker.

3. Ask each group to color part of the white construction paper with the black marker, so that at a 5 by 5 centimeter (2 by 2 inch) section is completely black.

4. Ask the students to predict what the spectrum of the construction paper will look like, and whether the construction paper that has been colored black with marker will look similar or different. Students may suggest that there will be low numbers—low reflectance—for most wavelengths.

5. Have the groups determine which student will be conducting which task. One person will be needed to use the reflectance spectrometer, one to record the data, one to compute the numbers, and one to graph the results.

6. The groups should collect reflectance data from the white construction paper or plain white paper with their ALTA, as in the last activity, to have a standard for comparison. They should also record the dark voltage for their ALTA.

7. Invite the teams to collect and graph the reflectance data for the black construction paper and the black-colored white construction paper.

8. 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 can 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.]

9. 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.]

10. Describe a specialized spectrometer that can measure 261 different wavelengths, which together cover all of the visible spectrum and the near-infrared wavelengths.

    How would a more detailed spectrum help scientists? [It would make it easier to identify the types of rocks and minerals on the Moon.]

11. Describe the Moon Mineralogy Mapper (M^3), a spectrometer that will be flown on Chandrayaan-1 to orbit the Moon and take a detailed spectrum of the different points of the Moon's surface. Ask your students how this would provide more information about the Moon.

Background

Colored Materials

Paper, marker, and crayon have different colors because different pigments have been added to the original materials. Different types of black construction paper may have different reflectance spectra because of the different processes used to make them black.

Facilitator Background: The Moon Mineralogy Mapper (M^3)/ Chandrayaan-1

Moon Mineralogy Mapper (M^3) is one of two instruments that NASA is contributing to India's first mission to the Moon, Chandrayaan-1, which is scheduled to be launched in 2008. M^3 will provide the first spectroscopic map of the entire lunar surface at high resolution, revealing the minerals of which it is made.

The instrument will detect electromagnetic radiation with wavelengths from 430 to 3000 nanometers (0.43 to 3 microns), which covers visible light and the near-infrared. M^3 will divide the approximately 2600 nanometer range to which it is sensitive into 261 discrete bands, each of which is only 10 nanometers wide. This is considered very high spectral resolution, and will enable M^3 to detect the fine detail required for mineral identification. Spatial resolution will be similarly high. From its vantage point 100 kilometers above the lunar surface, M^3 will be able to resolve features as small as 70 meters in size.

The individual spectra collected by M^3 will be combined to form a detailed picture or map of the lunar surface. Each picture or map that M^3 produces will show mountains, craters, or plains like a regular camera, but in a very narrow range of wavelengths (the 10-nanometer sliver of the spectrum that constitutes one spectral channel). It's like taking a picture using a filter that allows only one precise color of light through the lens (similar to Activities 1 and 2). But M^3 will take 261 such pictures simultaneously, each in its own "color." To identify the spectral fingerprint of a particular portion of the lunar surface, one would plot the light intensity of each of the 261 channels, noting how bright each pixel is at each wavelength. Plotting this on a graph produces a spectrum. Each mineral has its own unique spectrum, identified by taking spectrographic readings in a laboratory.

The accompanying slide show will provide some more information and background material on the mission and why we are going back to the Moon.

For more information, go to
http://moonmineralogymapper.jpl.nasa.gov/INSTRUMENT/

Reflectance Worksheet

Names of Scientists on Team

Sample Description

Dark Voltage Constant

Color	Wavelength in Nanno-meters	White Paper Reading	Dark Voltage	White Paper - Dark Voltage (A)		Sample Reading	Dark Voltage	Sample - Dark Voltage (B)		**B / A** ***or*** [Sample – Dark V] / [White – Dark V]
Blue	470									
Cyan	525									
Green	560									
Yellow	585									
Orange	600									
Red	645									
Deep Red	700									
Infrared 1	735									
Infrared 2	810									
Infrared 3	880									
Infrared 4	940									