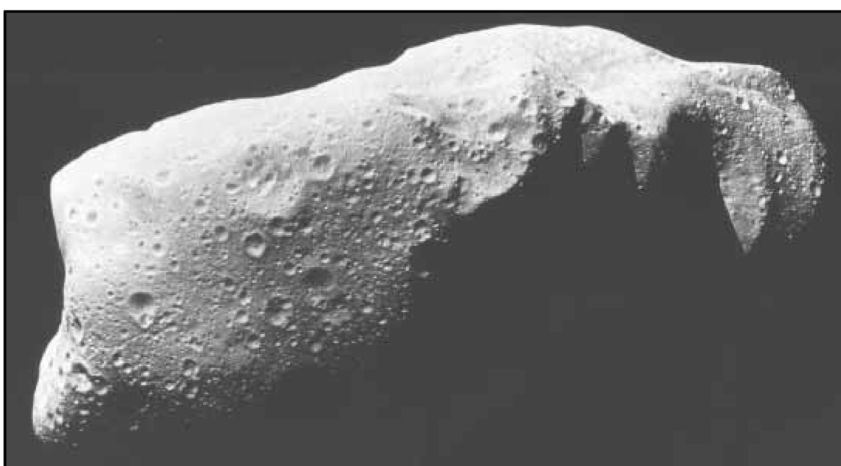
Exploring Meteorite Mysteries

Lesson 5 — Looking at Asteroids

Objectives

Students will:

- gather data by observing, measuring, and manipulating objects.
- record observations, analyze data and draw analogies.
- compare samples of similar materials.
- measure and record the brightness of light in a spectrum produced from a prism.
- discover that white light is composed of the spectrum of colors and that some light is invisible to the human eye.
- participate in introductory quantitative spectroscopy experiments.
- set up and conduct an experiment to analyze reflected light.
- recognize that different materials reflect different proportions of incident light.



Asteroid Ida

"Where do they come from?"

About This Lesson

This lesson is about the connection between meteorites and asteroids. The activities in this lesson focus on ways to look at asteroids because some scientists think that some meteorites are fragments of asteroids. The lesson centers on remote sensing techniques using light. Students consider the brightness (reflectivity), textures, and colors of materials.

The lesson is arranged as three work stations, an optional station, and a central station with the Meteorite Sample Disk. The Meteorite Sample Disk or photographs of the meteorites must be available so students may examine the meteorite samples in light of the experimental results at each station. This lesson could be done simultaneously by four separate groups, one for each station, as no station relies on the results of another. All stations except Station 1 could be used as independent exercises.

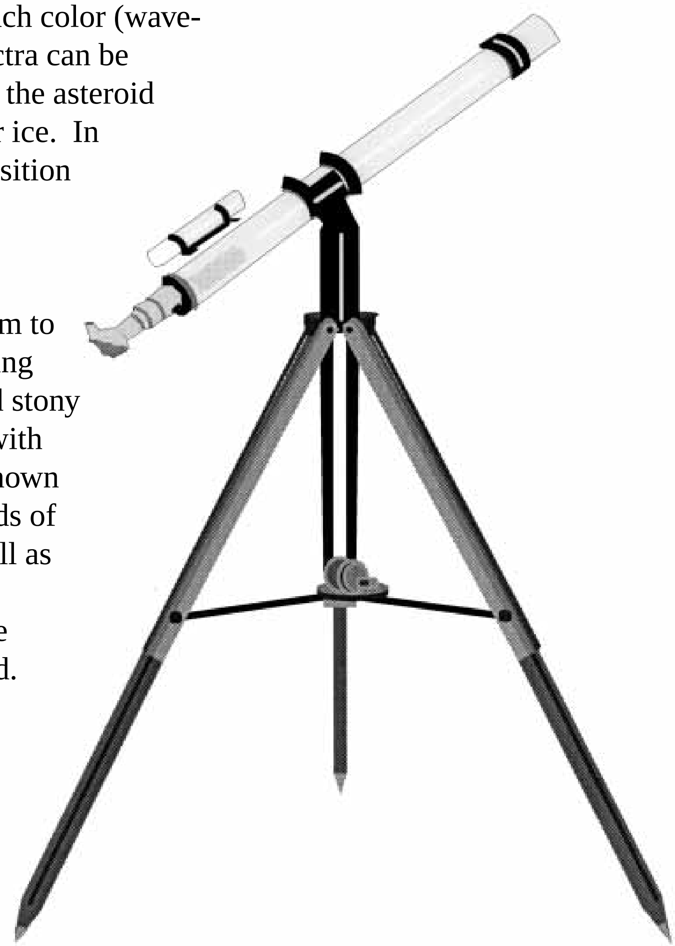
Background

Most meteorites that land on Earth are thought to come from the asteroid belt. The connection between meteorites and asteroids was suggested as soon as the asteroid belt was discovered. Asteroids come in many sizes, from 900 km down to the limits of visibility in Earth based telescopes at about 1 km. Astronomers assume that there are abundant dust size asteroid fragments also.

It is almost certain that some meteorites came from asteroids. We know this because some meteorite orbits have been traced to the asteroid belt. Scientists have learned this by triangulating meteorite orbits from photographs of meteors.

Many meteors are linked to comets. Yearly meteor showers occur as the Earth passes through the debris left by passing comets. But no meteorites are known to have come from meteor showers. Scientists think this is because the meteors in showers are made mostly of ice and dust, which melt and vaporize when they encounter the Earth's atmosphere. However, someday scientists may find meteorites from comets.

There are many different kinds of meteorites, as shown in the Meteorite Sample Disk, and scientists wondered if there might also be different kinds of asteroids. Since we have not yet sampled asteroids directly, scientists have had to rely on telescopic measurements of the colors (spectra) of asteroids. In spectroscopy studies, light from asteroids (reflected sunlight) is taken into the telescope, directed through a prism or diffraction grating, and spread out into its spectrum. Then the scientists measure how bright the light is at each color (wavelength) in the spectrum. These reflection spectra can be characteristic of certain minerals or metals on the asteroid surface, or even indicate the presence of water ice. In this way, astronomers can estimate the composition of asteroids and try to correlate them with meteorites.



There are asteroid color spectra types that seem to be similar to most types of meteorites, including some chondrites, some achondrites, irons, and stony irons. But there are many types of asteroids with spectra that do not correspond to spectra of known meteorites. Perhaps there are many more kinds of materials in the asteroid belt just waiting to fall as meteorites. On the other hand, there may be effects on the surfaces of asteroids that change their colors in ways we do not now understand.

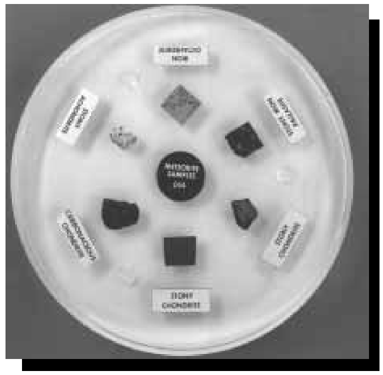
Additional information is available in the Teacher's Guide and in the background sections of Lesson 4 (pg. 4.2) and Lesson 17 (pg. 17.1).

Lesson 5 — Looking at Asteroids

Station 1: Meteorite Sample Disk

Objective
Students will:

- observe, and compare meteorites.



Procedure
Students will proceed to this station to answer questions from other stations.

About This Station
The meteorites are used to reinforce student's observation and deduction skills.

Materials for Station 1
- ❑ Meteorite Sample Disk
- ❑ magnifier
- ❑ binocular microscope *(optional)*

Station 2: Test Your Metal

Objectives
Students will:

- observe and compare samples of metal and record their observations.
- prepare samples for observation.

Procedure

Advanced Preparation

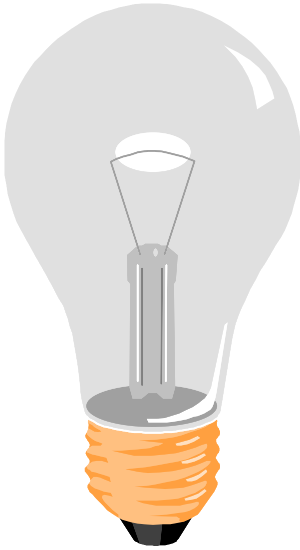
1. Set up station with nail and file, a sheet of white paper, and a magnifying glass.

Classroom Procedure

1. Students examine the nail or metal pipe. Have one student in each group file the nail or metal pipe until they have a small pile of fine filings. Students examine the iron filings (without spilling or losing them) noting their size, shape, and color. Particularly note the variations of color. Students should take notes on their observations in their lab notebook or on the Lab Sheet. Answer questions found on separate sheet after experiment.
2. At the Meteorite Sample Disk, students should examine the metal in at least two of the meteorite samples and record their observations in their lab notebook or Lab Sheet. ***Note**: Help students determine how they can tell metal from the other minerals in the meteorite samples by reading the descriptions provided with the Meteorite Sample Disk.*

About This Station
By looking at iron metal and then making very small iron filings, students will observe how different something can be when different sizes and surface treatments are viewed. Careful observations of the meteorites will reveal that the metal looks different from sample to sample.

Materials for Station 2
- ❑ large nail or small piece of metal piping
- ❑ metal file
- ❑ one sheet of white paper
- ❑ Lab Sheet (pg. 5.9)
- ❑ Questions (pg. 5.11)
- ❑ magnifier *(optional)*
- ❑ pencil/pen



About This Station

Through demonstrations and analysis, students will discover that different materials reflect different proportions of the light that strikes them. The proportion of light that is reflected ("reflectance") is shown to be important in determining the compositions of distant objects (e.g. asteroids).

Materials for Station 3

- ❑ 8 cm squares of construction paper; one each of red, black, blue, and white
- ❑ 1 thermometer
- ❑ incandescent light source
- ❑ 2 ring stands or other tall supports for clamps
- ❑ two clamps or other means of supporting equipment *(duct tape)*
- ❑ cardboard large enough to shield thermometer
- ❑ ~50 cm square of non-shiny black paper or cloth *(blotter paper works well)*
- ❑ Lab Sheet (pg. 5.9)
- ❑ Questions (pgs. 5.11-5.12)
- ❑ pencil/pen

Suggest they look for shiny spots or rusty spots. Also help students consider that there might be differences in the composition of the metal, the size of grains, surface roughness, and the way the metal was treated in the laboratory.

3. Students can then return to the station, re-examine the iron filings, and record their observations comparing the appearance of iron filings with the iron in the meteorite samples.
4. Clean area before next group arrives.

Lesson 5 — Looking at Asteroids

Station 3: Reflections on Light and Heat

Objectives

Students will:

- set up and conduct an experiment to analyze reflected light.
- observe that different materials reflect different proportions of incident light.

Background See the information with the questions on page 5.11.

Procedure

Advanced Preparation

1. Set up experiment so that:
   - light is incident on the black paper or cloth at approximately a 45° angle,
   - the thermometer bulb is located in the path of light reflected at 45°,
   - the cardboard shields the thermometer from direct light (see Figure 1).

Classroom Procedure

1. Place color construction paper squares on the large black paper so that the incident light shines equally on all colors, and they are all viewed easily.
2. Rank the relative brightness of the papers. Touch each paper, and rank the relative temperatures of the papers. Record the results on the lab sheets. Remove all papers from under the lights.
3. Adjust the temperature experiment equipment. Read the thermometer and record the temperature.

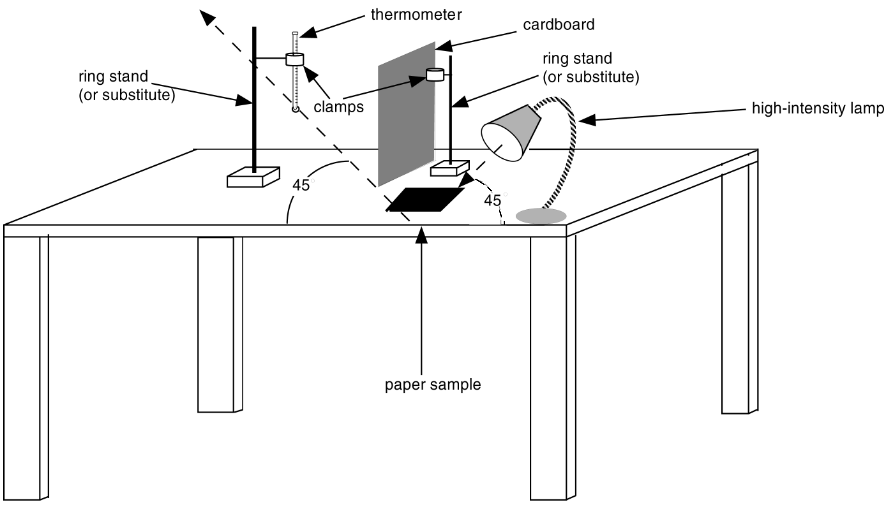


Figure 1

4. Place one colored piece of paper where the incident light will strike it at a 45° angle. Wait five minutes and read the thermometer; record the results. Allow thermometer to return to room temperature.
5. Repeat for each color of paper. Groups may do only one color if there are time limitations. Share data.
6. After completing the experiment answer the questions found on the separate sheet.
7. Discuss experimental results. (See Background pg. 5.2)

Lesson 5 — Looking at Asteroids

Station 4: The Visible Spectrum and Beyond!

Objectives

Students will:

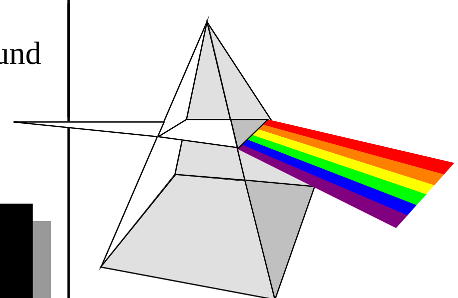
- measure and record the brightness of light in a spectrum produced from a prism.
- observe that white light is composed of the spectrum of colors and that some electromagnetic energy is invisible to the human eye.
- participate in introductory quantitative spectroscopy experiments.

Vocabulary

electromagnetic spectrum, spectroscopy, infrared, ultraviolet, voltage

Vocabulary

reflectance, reflected, diffracted, incident light, incandescent light, emit



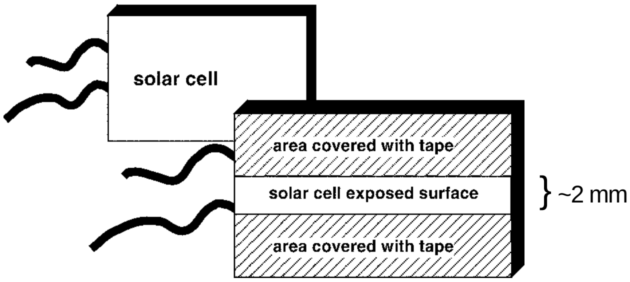
About This Station

The teacher will display a visible spectrum using light from an overhead projector (or other light source). As an introduction to quantitative spectroscopy, students will measure and record parts of the electromagnetic spectrum. Students will discover that white light is composed of the spectrum of colors, that the energy output of the electromagnetic spectrum can be measured, and that some wavelengths of the spectrum are invisible to the human eye.

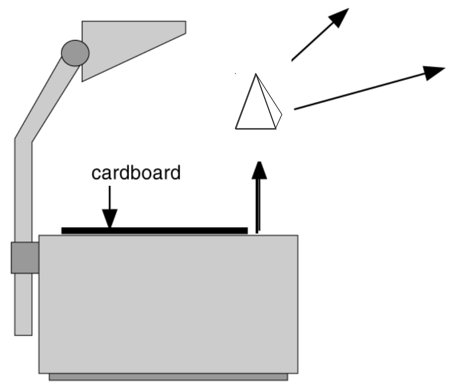
Station 4: Method 1

<u>Materials for Station 4 (Method 1)</u>

- ❑ voltmeter *(or other means of measuring power output, ex: small motor-driven fan, solar energy kit, etc.)*
- ❑ solar cell, masked with tape so that light can hit a patch only about 2-3 mm wide



- ❑ tape *(duct or electrical)*
- ❑ overhead projector *(as light source)*
- ❑ glass prism
- ❑ cardboard to cover most of projector surface *(to reduce glare from projector)*
- ❑ white poster or other surface for "catching" color spectrum
- ❑ wall chart with electromagnetic spectrum
- ❑ Lab Sheet (pg. 5.10)
- ❑ Questions (pg. 5.12) Distribute after experiment
- ❑ pencil/pen



<u>Procedure</u>

<u>Advanced Preparation</u>

1. Teacher will need to experiment with available materials to make a suitable spectrum. A spectrum can be produced with the prism held almost at the edge of the projection surface, and held parallel to the nearest edge of the projection surface (approximately parallel to the lines in the projection lens). Then rotate the prism around an axis parallel to the projection surface until the spectrum projects onto the wall. See the diagram above right.
2. Electromagnetic spectrum chart should be available to students. Include additional instructions if prepared lab sheet is not used. Try this first to make explanations easier. ***Note**: If you are familiar with using a diffraction grating, you may prefer to use it with an overhead projector to display a visible spectrum.*

<u>Classroom Procedures</u>

1. Turn on overhead projector with light projecting onto ceiling or upper wall.
2. Use cardboard to block extra light from overhead projector.
3. Allow light from projecting surface to pass through prism.
4. Experiment with positions and angles to create the most clearly defined spectrum possible.
5. "Catch" light spectrum on a poster board, and tape the poster on the wall.
6. Connect the voltmeter (or motor, etc.) to the solar cell.
7. Orient the solar cell so that only a single color of light hits the unmasked band (see solar cell diagram above left). Move the solar cell through the spectrum on the wall, noting the **relative** power from each spectral color (either voltage on the voltmeter, or how fast the motor runs). Be sure to move the solar cell above and below the spectrum, i.e. beyond the red (Infrared or IR) and beyond the violet (Ultraviolet or UV).
8. Record information on Lab Sheet, answer Questions, and discuss results.
   ***Note:** Be sure to test areas bordering, but away from the spectrum for control purposes. Also, some new projectors have IR filters to reduce heat, therefore you may not get power in the IR range.*

Station 4: Method 2

Procedure

Advanced Preparation

1. Make an opaque screen approximately 25 cm square from a piece of cardboard or poster board. Cut a 5 cm-diameter hole out of the middle. Tape two pieces of opaque paper or aluminum foil over the hole so that there is a vertical gap between them that is no wider than 1 mm.
2. Arrange the equipment and darken the room. Adjust equipment so projector light does not extend around the edges of the opaque screen, and the visible spectrum is displayed on the screen.

Classroom Procedures

1. See steps 6-8 in procedure for Method 1.

Questions

1. Why is there power output beyond the red light? **There is electromagnetic energy at wavelengths that our eyes cannot see; students have probably had experience with infrared — TV remote controls operate using infrared.**
2. Why might the solar cell produce little power from blue or purple light, even though we can see blue and purple? **The solar cell is not as sensitive to blue and purple as our eyes are.**

Materials for Station 4 (2)

- ❑ slide projector
- ❑ opaque screen *(see materials and instructions below)*
- ❑ glass prism
- ❑ supports for screen and prism *(books and or tape)*
- ❑ projection screen or white poster board
- ❑ Lab Sheet (pg. 5.10)
- ❑ Questions (pg. 5.12) Distribute after experiment

Lesson 5 — Looking at Asteroids

Optional: The Color Black

Objectives

Students will:

- set up and conduct a simple liquid chromatography experiment.
- record observations and draw analogies.

***Note**: Chromatography is not used by scientists to determine the composition of asteroids, however, this is an easy, inexpensive laboratory exercise that reinforces the concept of separating useful data to analyze a complex system.*

About This Station

By a simple chromatography experiment, students will learn that one color may be made up of a mixture of different colors just as white light is a combination of light at different wavelengths. This will introduce the concept that the color of an object (asteroid) can be used to infer the composition of the object.

Vocabulary

chromatography, wick, absorbent

Materials for The Color Black

Amounts will vary according to the method of presentation. Group size from 4-6.

- ❑ 4 black felt-tipped, water soluble markers ***(each marker a different brand)***
- ❑ 4 transparent containers *(beaker-like)* with water at a 2 cm depth
- ❑ 8 pieces of filter paper, approximately 10 cm x 2 cm *(coffee filters work well)*
- ❑ 4 pencils or wooden sticks
- ❑ absorbent paper
- ❑ scissors
- ❑ The Color Black worksheet (pgs. 5.13-5.14)
- ❑ map pencils or crayons
- ❑ ball-point pen
- ❑ metric ruler

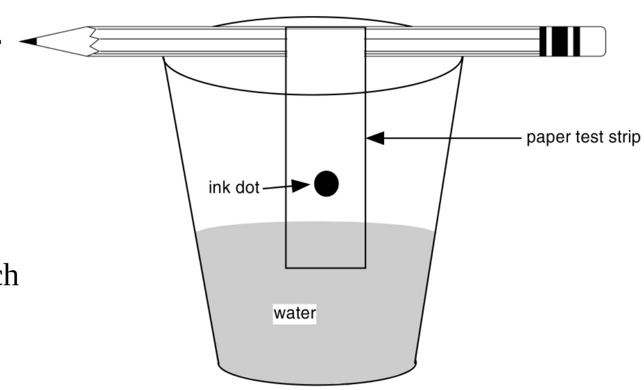
Procedure

Advanced Preparation

1. Assemble materials.
2. Cut filter paper as needed so that there are two strips for each marker.
3. Prepare containers of water, one per marker. Students re-use water but not papers.
4. Make sure absorbent paper is on hand for spills and for the finished chromatograms.

Classroom Procedure

1. Select a marker, two strips of filter paper, a pencil, and a container of water.
2. Using the marker, place a dot about 3 cm from one end of a strip. Make a second dot of equal size using the same marker on the second strip of paper. You should have two identical strips.
3. At the opposite end, using a ball point pen, label each strip with the brand name of the marker and a student's initials.
4. Place one of each pair of strips on a sheet of absorbent paper. Place the matching strip next to it for a reference strip for later comparison.
5. Repeat for all four markers (group members may do this simultaneously).
6. On the worksheet, under Filter Description, describe the color of the dots for each marker and note if any have tints of a different color in them.
7. Record what you predict will happen when the strip is suspended in water.
8. Take the filter paper strip from the absorbent paper and wrap the labeled end around the middle of a pencil so that the paper will stay in place when the pencil is lifted.
9. Carefully place the dot end in the container of water so that the filter paper, **but not the dot**, is in the water. Rest the pencil on the rim of the container, rolling the strip up or down if necessary (see diagram). Repeat for each filter paper strip.
10. Allow adequate time (~ 3 minutes) for the water to wick up the paper. When the water reaches the top of the paper, carefully remove it from the water and place it on the absorbent paper next to the reference strip.
11. Compare the original black dot with the water treated dot (chromatogram).
12. On the worksheet, write a description of each of the four chromatograms.
13. Answer questions and discuss results.



Lesson 5 — Looking at Asteroids

Lab Sheet: Stations 2-4

Name________________

Date_________________

Station 2: Test Your Metal

Describe what happened to the metal when you made the iron filings. What did the filings look like? Describe any changes and explain.

Metal In Meteorites Description

Meteorite name	Description of the metal	Does the metal resemble the iron filings? (describe how it is alike or different)
______________	______________________	______________________________________
	______________________	______________________________________
______________	______________________	______________________________________
	______________________	______________________________________

Station 3: Reflections on Light and Heat

Paper Color	Brightness 1= bright 4 = not bright	Touch Temp. 1= hottest 4 = coldest	Thermometer Reading before after
Black			
Red			
Blue			
White			

Reflectance Bar Graph (show color verses degrees)

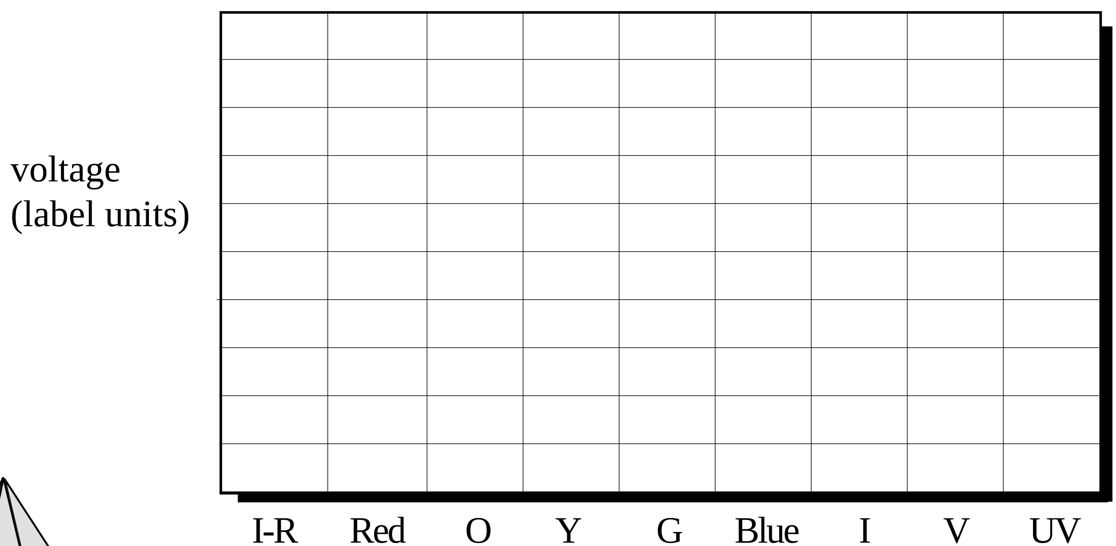
Station 4: The Visible Spectrum and Beyond

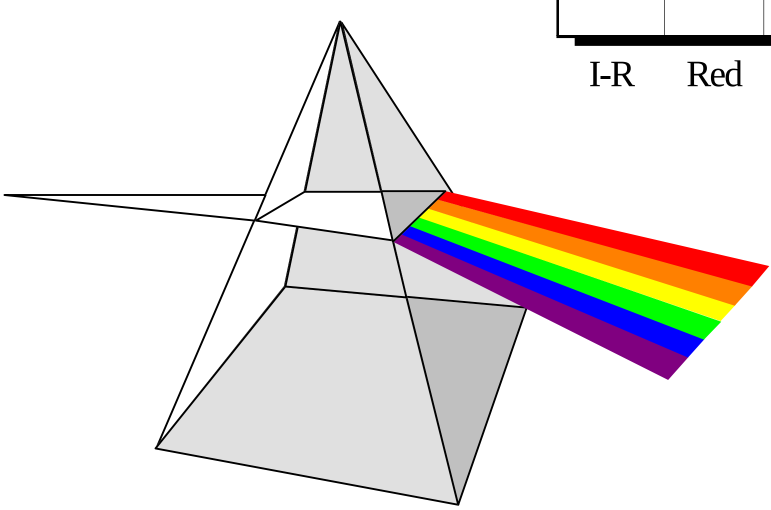
Which bands generate the greatest power?

Color	Volt Meter Reading or Relative Motor Power

Control Area	

Graph of Voltage vs. Color of Light





Lesson 5 — Looking at Asteroids

Questions: Stations 2-4

Name________________

Date_________________

Teacher Note: *use these questions* ***after*** *each station, do not distribute before activity.*

Station 2: Test Your Metal

1. Why are the iron filings dark and the metal in some of the meteorites shiny?

2. If an asteroid were made of metal, would it be shiny?

Station 3: Reflections on Light and Heat

1. Which color reflected the most light?

   Was that color hottest to the touch?

   Did the color which was hottest to the touch cause the highest temperature on the thermometer?

   Why did this happen?

2. Scientists can understand more about the surface composition and texture of asteroids by measuring how much visible and infrared energy is reflected or emitted. Scientists can measure the surface temperatures of asteroids by measuring how much absorbed solar energy they emit as infrared energy.

   Return to the meteorite disk to consider these questions based on your experimental results: Do you think an asteroid made of carbonaceous chondrite material would be hotter or colder than an asteroid of achondrite material? Why?

How do you think an iron meteorite's infrared reflectance would be compared to a carbonaceous chondrite's reflectance?

How would its distance from the Sun affect the temperature of an asteroid?

3. **Advanced**: You measured color reflectance of objects. Scientists measure color brightness of planetary bodies and compare those levels of brightness to known levels. In this way they are able to classify asteroids according to their components. For example, frozen water (ice) would look white and,) therefore, very bright.

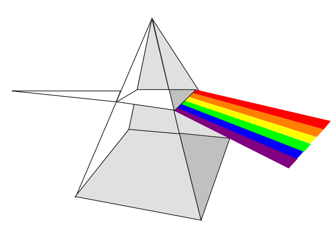
   Using your findings, how would we set up a comparison table for analyzing reflectance?

Station 4: The Visible Spectrum and Beyond

1. Why is there power output beyond the red light?

2. Why might the solar cell produce little power from blue or purple light, even though we can see blue and purple? Hint: Think about how sensitive our eyes are and the sensitivity of the solar cell.

3. Can you feel heat from the infrared?



Lesson 5 — Looking at Asteroids

The Color Black

Name________________

Date_________________

Filter Description

____

____

____

____

Chromatogram Description

____

____

____

____

Prediction

Student Background *(Read after completing The Color Black station.)*
Just as you have probably attempted to create new colors for art by mixing colors you already have, many colors are a combination of two or more colors (e.g. red + yellow = orange). **The experiment you have conducted works the other way.** You started with the "new" color — black — and revealed which colors were used to create it.

It's rather like when you have a mixture of colored candies and want to know how many candies of each color are in the bag. They have to be separated first. We often go from general observations to specific ones in our attempts to understand things. For example you could start with a bag of colored candies as a general observation and then be specific and state that you have 6 yellow candies, 7 green ones, 4 red ones.

Substances have specific properties (color, shape, texture). The more properties we can identify, the greater our ability to understand and classify new substances. The better we can classify, the better we can see relationships among substances, objects, organisms, and occurrences. That process is similar to a detective's work and can be VERY exciting!

Scientists are working as detectives to determine the composition of the asteroids. The color of the surface of an asteroid gives scientists clues to its mineral content.

Another way scientists investigate the composition of asteroids is to look at the light reflected from the surface of an asteroid. Then they compare that light signature or spectrum with spectrum of known substances on Earth. This technique is used to compare asteroids and meteorites. They attempt to determine whether asteroids have similar compositions to known meteorite types.

The chromatography experiment you completed is **not used by scientists** to determine the composition of asteroids. This experiment was designed so that you could easily experience the investigative process of science and to allow you to see that substances are often made of more than you realize!

Neither of the techniques to determine mineral compositions on asteroids works as easily as the liquid chromatography experiment you have conducted. However, you now have experience as an investigative scientist.

Questions *(Use only after you have completed the experiment.)*

1. What clues gave you a hint that the black inks might be made of different colors?

2. Did any of the chromatograms have similar colors in similar places? Explain.

Return to the Meteorite Sample Disk to consider the next question.

3. Write a short comparison among the black meteorite samples, comparing and contrasting how black they are, and whether they are different shades or tints of black.

4. What techniques do scientists use to determine the mineral content of asteroids?

5. How can meteorites help scientists understand more about asteroids?

6. **Extra:** Most asteroids are quite dark, and reflect only 10-20% of the light that hits them. This is very much like the Moon, where the bright areas of the Moon (the highlands) reflect about 20% and the dark areas (the mare) reflect about 10%. Using references available in your classroom, investigate the composition of the different parts of the Moon and why they are brighter or darker.