JOURNEY through the UNIVERSE

Building a Permanent Human Presence in Space

Grades K-4

Lesson 1: There's More to Light than Meets the Eye

The United States and its partners around the world are building the International Space Station (ISS), arguably the most sophisticated engineering project ever undertaken. The ISS is an orbiting laboratory where astronauts conduct research in a variety of disciplines including materials science, physiology in microgravity environments, and Earth remote sensing. The ISS provides a permanent human presence in low Earth orbit. This lesson is one of many grade K-12 lessons designed to bring the ISS experience to classrooms across the nation. It is part of *Building a Permanent Human Presence in Space*, one of several Education Modules developed for the *Journey through the Universe* program.

September 2007

Lesson 1: There's More to Light than Meets the Eye

Lesson at a Glance

Lesson Overview

Students will explore the concept that not all light is visible to the human eye. Although UV light is not visible, it can still be harmful, causing sunburns or skin cancer. Students will use special beads to detect UV light around the school. They will then conduct an experiment to determine what types of materials are best for blocking UV light on Earth, as well as in space.

CAUTION: This lesson suggests looking at a number of light sources with a spectroscope. NEVER look directly at the Sun. The Sun is far too intense and will permanently damage the eye almost instantly.

Lesson Duration

Two 45-minute class periods

Core Education Standards

National Science Education Standards

Standard B3: Light, heat, electricity, and magnetism

- Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object.

Standard D2: Objects in the sky

- The sun provides the light and heat necessary to maintain the temperature of the earth.

Essential Question

- What materials can protect us from ultraviolet light?

Concepts

Students will learn the following concepts:

- Not all light is visible to the human eye.
- UV light cannot be seen, but can be harmful at the same time.
- We can use tools like UV beads to detect the presence of UV light.
- UV light comes from the Sun and is usually not present indoors.
- Certain materials are better than others at stopping UV light.
- The atmosphere protects us from most of the UV light emitted from the Sun.

Objectives

Students will be able to do the following:

- Identify sunlight as a source of ultraviolet light.
- Describe the atmosphere's role in blocking UV radiation.
- List materials that will block ultraviolet light.

Science Overview

There is more to light than the human eye can see. There is a lot of light that cannot be seen at all, and there are some kinds of light that can injure people. Ultraviolet light is an example of light that is not visible to the human eye but that can cause injury (sunburn) with enough exposure. How is ultraviolet light different from light that the eye can see? How can exposure to ultraviolet light be detected, and how can people protect themselves from it?

Taking Light Apart

Light from the Sun, or from a lamp, is a mixture of many colors, a wider range of color than what the eye can see. "White" light really is a blend of colors—for example, lighting for live performances on a stage combines colored spotlights to make "white" light. In reality, the colors of light do not mix at all. "White" is how the brain interprets the combination of colors that the eye receives. "Color" itself is a creation of the brain, a way to perceive which sorts of light come from a light source, and which do not.

The full range of color vision a rainbow shows. Violet is on the inside of the bow, red is on the outside of the bow, and there is a range of colors in the middle. The rainbow has colors because the colors in sunlight are spread out by fine water droplets in the air, allowing the mix of colors that was always there to be seen. There are other ways to spread out the colors. A prism will spread the colors in a beam of light, like in a rainbow, to show what is called a spectrum. The amount of light of each color in a spectrum tells about the nature of the light source. Scientists use spectra of objects to discover what materials are in celestial objects, in chemical samples, or in objects here on Earth.

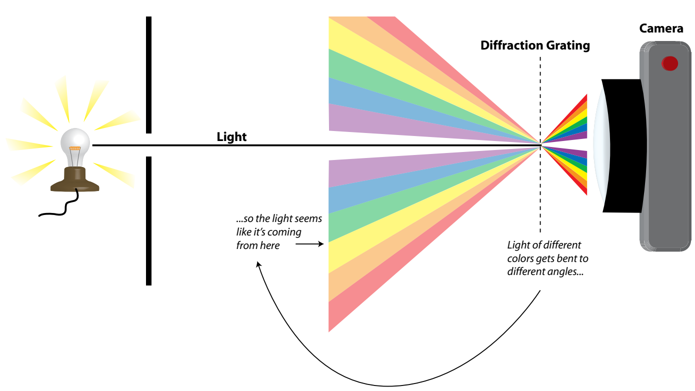


Figure 1a: Use a spectroscope to see light's spectrum. Light goes through a narrow slit, then through a diffraction grating that bends the light according to its color.

Figure 1b: Light from a clear, blue sky, viewed through a diffraction grating spectroscope. You can see the slit and the spectrum, off to the side.

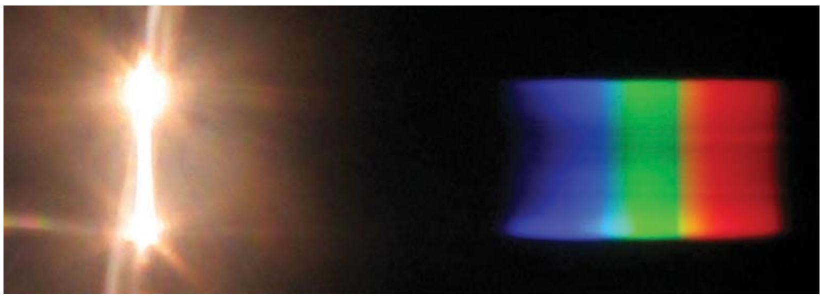


Figure 1c: Light from a regular incandescent light bulb, viewed through a spectroscope. The range of colors is a smooth continuum.

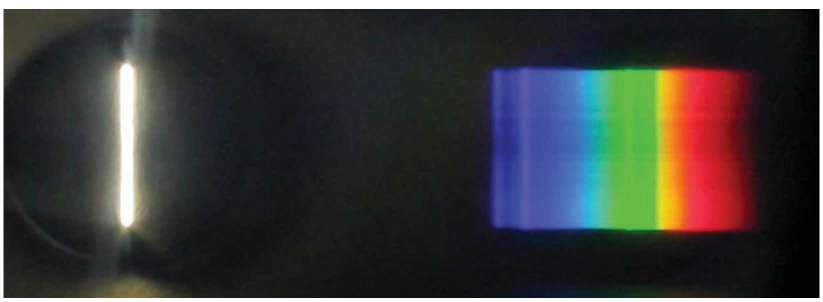


Figure 1d: Light from a long fluorescent tube, viewed through a spectroscope. The range of colors is a smooth continuum with a few lines of brighter color in the green and violet.

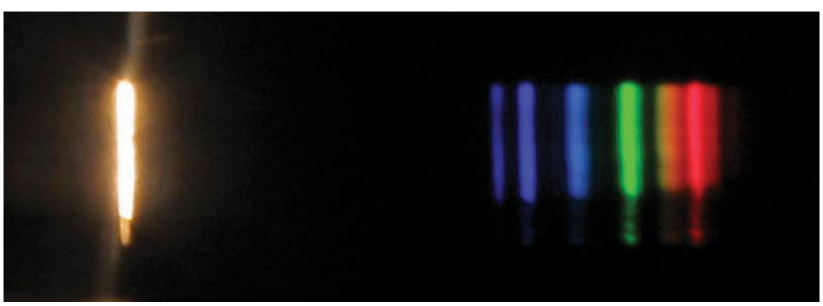


Figure 1e: Light from a compact fluorescent lamp, viewed through a spectroscope. The range of colors is a set of bright lines of color with no light in between.

A diffraction grating is a special plastic sheet that spreads out the colors from a light source to display the spectrum. A pocket spectroscope holds a diffraction grating just in front of the eye, looking at a slit in an opaque cap a few inches away. The photographs in Figure 1 show spectra of a few light sources photographed directly through an inexpensive spectroscope, about $2. The blue sky has a smooth rainbow spectrum, as does the incandescent bulb, which has less blue light in it and a little more red light than the blue sky. A long fluorescent tube looks similar, but with a few colors that are extra-bright, and less red light than the incandescent lamp.

The spectrum of a compact fluorescent lamp is very different from the others in Figure 1: a set of bright colored lines separated by black, instead of the continuous distribution of colors seen in the other light sources. If a spectrum is black where a particular color belongs, then the spectrum has no light of that color. The compact fluorescent lamp uses a mix of distinct colors to make "white" light. In this case, there are some colors missing, which is why objects can look a little different in sunlight than they do under indoor lighting.

More Colors than the Eye Can See

Each of the spectra photographed in Figure 1 includes a region of pure violet light on the left side of the blue. It is easy to see the violet with the eye, but it does not show up in the photograph. The camera that took the pictures does not capture this color—the range of the camera's color vision is not as wide as the range of human color vision. Some animals, like bees, can see a wider range of colors than people can see. Bees can choose between flowers that look different only in ultraviolet light. Compared to bees, every human being on Earth is partially color blind. The narrow range of light that human eyes can see is called the visible spectrum.

The colors in the visible spectrum are a guide to understanding light outside the range that people can see. Figure 2 sketches the colors in the visible spectrum, oriented like the spectra in Figure 1. The order of the colors from right to left can be remembered by the invented name Roy G. Biv: red-orange-yellow-green-blue-indigo-violet.

On one side of red is the color orange. On the other side of red is ... what? Both the camera and the eye see nothing there. There actually is light there, however, called "infrared," which means "beneath red." The limited color sensitivity of the human retina cannot see infrared light, but still it is there. Skin can absorb infrared light and be warmed by it, the same way that visible light is absorbed by skin and makes it

Figure 2: A sketch of colors in the visible spectrum. The order of colors from right to left can be remembered as "Roy G. Biv" (red, orange, yellow, green, blue, indigo, violet). There is an infinite number of colors smoothly varying from one end of the spectrum to the other. What colors go to the right and the left of the visible spectrum?

feel warm. Many off-the-shelf video camcorders are able to see some infrared light.

At the other end of the visible spectrum is the color violet. On one side of violet is the deep blue color called indigo. On the other side of violet is ... what? Both the camera and the eye see nothing there. There actually is light there, however, called "ultraviolet" (UV), which means "beyond violet." Human eyes cannot see ultraviolet light, but bees can see a little of it. UV light causes sunburn, and excessive exposure to it over many years can cause skin cancer. UV light exposure, accumulated over many years, damages the surface of the eyes and can cause cataracts.

Beyond ultraviolet light are other colors of light that are equally invisible and that can be harmful: X-rays and gamma rays. In the other direction, past infrared light, lie microwaves and radio waves. Earth's atmosphere is nearly transparent to visible light, the kind that human eyes are adapted to see. Most of the non-visible colors of light are blocked by the air, so that little or none of it reaches the surface of the Earth.

The surface of the Earth is relatively protected from the Sun's ultraviolet light, X-rays, and gamma rays. In space, without the protection of the Earth's atmosphere, it is possible to be exposed to damaging amounts of UV light and others. In order to live and work in space, astronauts need protection that lets them see visible light, but stops them from being exposed to ultraviolet light.

Light in Space

The Sun produces many kinds of light. Earth's atmosphere protects us, letting through only a narrow range of light and mostly blocking light that is harmful. When astronauts go into space, they no longer are protected by the Earth's atmosphere. The main purpose of space suits and spacecraft is to hold air and to protect astronauts from the vacuum of space. They also stop the unfiltered sunlight from reaching the astronauts' skin. Inside the spacecraft, it's no problem for astronauts to work, because their work is inside. Outside the spacecraft, astronauts need space suits to protect them.

The main danger to astronauts is from cosmic X-ray and gamma-ray radiation and ultraviolet light from the Sun. A space suit provides some protection from radiation. The best protection is to spend as little time as possible outside the spacecraft, and to limit time spent above Earth's protective atmosphere. A space suit is excellent protection from ultraviolet light over most of its surface, but it needs to have a clear window on the helmet for the astronaut to see through.

Protecting astronauts' eyes from ultraviolet light, while letting through visible light, is an important feature in designing a space suit faceplate. When astronauts go outside the Space Shuttle or the International Space Station to work, they will be outside for hours at a time. Astronaut safety and the effectiveness of the mission requires that the faceplate on the helmets be designed to protect the astronauts. This is the design challenge that students face in this lesson, as well as investigating materials that could be used in different parts of the space suit to protect astronauts during an Extra-Vehicular Activity—an EVA, or "space-walk."

NOTES:

There's More to Light than Meets the Eye

Lesson at a Glance

Science Overview

Conducting the Lesson

Resources

Conducting the Lesson

Warm-Up & Pre-Assessment

Teacher Materials

- One or more spectroscopes (available from Edmund Scientific, model #3120406, six scopes for $8.95, at http://scientificsonline.com)

Preparation & Procedures

1. Introduce students to the notion of ultraviolet (UV) light by talking about sunburn. Ask students how people get sunburned. (*Desired answer: by being in the Sun too long without proper protection such as clothing or sunscreen*) Ask students why the light from lamps inside their home or school does not cause sunburn. (*Desired answer: it is a different kind of light*) Tell students that some types of light cannot be seen with their eyes, but can be detected by other parts of the body, like skin. Skin detects UV light by getting tan, sunburn, or freckles.

2. Allow students to look at different sources of light with a spectroscope (e.g., classroom light versus the sky or different kinds of lamps). Warn students to NEVER look directly at the Sun. Ask students what they see through the spectroscope. (*Desired answer: different colors*) Ask students what they notice about the bands of color they can see through the spectroscope as they look at different light sources. (*Desired answer: the bands may be different*) Ask students why the bands of color appear different. (*Desired answer: not all light sources are the same*) Ask students if there is anything between violet and the slit in the cap or farther from the slit than red in the color spectrum. Allow students to share their ideas.

3. Explain to students that the spectroscope shows only visible light; they would need other tools to detect UV light. Tell students that UV light would appear just beyond the purple (violet) band on the light spectrum. Tell students that you just happen to have some tools for detecting UV light.

Notes:

There's More to Light than Meets the Eye

Lesson at a Glance

Science Overview

Conducting the Lesson

Warm Up & Pre-Assessment

Activity: UV Protection

Lesson Wrap-Up

Resources

Activity: UV Protection

In this activity, students will use beads that are sensitive to UV light to explore this type of invisible radiation. They also will look at the effectiveness of different substances and materials for blocking UV light.

Student Materials (per class)

- 2 lamps (any wattage bulbs)
- Digital camera (optional)

Student Materials (per group)

- Plastic wrap (3 small squares, approx. 3 in x 3 in each)
- 9 black 35-mm film canisters (can find at local film development stores where they trash or recycle them)
- Sunscreen with SPF 6 or 8 (about 1/2 tsp.)
- Sunscreen with SPF 30 (about 1/2 tsp.)
- 45 UV beads (27 for use in film canisters; another 18 for 6 students to have 3 each) available from Teacher Source at http://www.teachersource.com, $6.95 for 240 beads)
- 1 pair of Sunglasses (with UV Protection)
- 2 small paintbrushes
- Water (enough to fill one film canister)
- Black T-shirt or fabric square, approximately 3 in x 3 in
- White T-shirt or fabric square, approximately 3 in x 3 in
- Paper clip (small enough to fit in the film canister)
- Baseball cap

Student Materials (per student)

- 1 pipe cleaner
- Student Worksheet 1
- Student Worksheet 2

Preparation & Procedures

1. This activity does not require sunny weather. Sufficient UV radiation can penetrate cloudy skies.

2. The activity can be done as a class or in cooperative groups.

3. In the *Warm-Up & Pre-Assessment*, students discussed sunburn, a negative effect of UV light. Tell students that the atmosphere, or air all around us, helps to protect us from much of the UV light from the Sun. Ask them to brainstorm who might be at higher risk for

receiving too much UV light. (*Desired answer: people who live on top of mountains, pilots, astronauts*) Ask students how we could protect astronauts, who do not have the protection of the atmosphere, from UV light in space. (*Desired answer: use materials to block the UV light*) Ask students how they could determine what the best materials to use would be. (*Desired answer: perform an experiment or try things out*) Tell students that that is exactly what they are going to do.

4. Getting sunburn is one way to detect UV light. A safer way to detect UV light is with a UV detector. Tell your students that they will use beads with a special pigment or dye that changes color when exposed to UV light. These beads are UV detectors. They are going to use them to look for places with UV light around the school.

5. Have students assemble UV bracelets by stringing three beads on a pipe cleaner and wrapping it around their wrists. Hand out the grade appropriate version of Student Worksheet 1.

6. Allow your students to expose their beads to a number of indoor light sources, such as the light from a lamp, overhead projector, and overhead lights in the classroom. Students will record results on the data table in Student Worksheet 1. The beads likely will remain white because most indoor lighting does not emit much UV light.

7. If you have a window in your room, students may notice that the beads change colors when they hold them next to the window. Have students go outside or place their beads outside the window and observe them. Have students record their observations on the data table in Student Worksheet 1.

8. Ask students where they found the most UV light. (*Desired answer: outside*) Ask students where they should conduct their experiment to determine which materials can protect astronauts from UV light. (*Desired answer: outside*) Ask students what type of materials they should test. (*Desired answer: sunscreen, clothing, water; accept all logical answers*)

TEACHING TIP

For K-2 students, choose the light sources students should test or let the class choose. Make sure one of the locations is outside. Write these locations in the Data Table in Student Worksheet 1 on an overhead projector. Have students copy these into their own data table.

9. Find an area in full sunlight. Have students put three UV beads in each film canister and one of the following materials over the top. As a class or in groups, have your students test the following nine scenarios. You may add canisters based on student suggestions.
   - Canister 1 (control) – Set it on a desk or the ground with nothing over it.
   - Canister 2 – Lay a piece of white T-shirt material over it.
   - Canister 3 – Lay a piece of black T-shirt material over it.
   - Canister 4 – Put sunglasses over this canister.
   - Canister 5 – Put a baseball cap over this canister.
   - Canister 6 – Fill this canister with water. String the beads on a paper clip so they will sink.
   - Canister 7 – Cover this canister with a square of plastic wrap.
   - Canister 8 – Cover this canister with plastic wrap and then thinly coat the wrap with sunscreen (SPF 6 or 8) using a paintbrush
   - Canister 9 – Cover this canister with plastic wrap and then thinly coat the wrap with sunscreen (SPF 30) using a paintbrush

Teaching Tip

For younger students, you may want to stop the activity after completing Student Worksheet 1. Students will have learned that not all light is visible to the human eye but can be detected by other methods. Or for highly motivated students, you may continue the activity so students can determine which materials block UV light.

10. Students must let each canister sit for five minutes in the sunlight.

11. After five minutes, students need to check the canisters one at a time and record results on the data table in Student Worksheet 2. They will need to look quickly because the beads will change color when they open the canister to the sunlight.

Lesson Adaptations

Talented and Gifted: Discuss the ozone layer, the layer of the atmosphere which blocks most of the UV light from reaching Earth. The ozone layer has received a lot of attention because it has been thinning in some areas in recent years due to human actions, allowing more UV radiation to reach the surface of the Earth.

Teaching Tip

If you have access to a digital camera, capture the color of the UV beads when they are taken out of the canisters. This will help reduce the chance of obtaining false readings.

Reflection & Discussion

1. Have students discuss the results as a class and list which materials blocked UV radiation. Use the class data to develop ways to protect our skin from too much UV light. (*Desired answer: they can use one, or a combination, of the materials that blocked UV light*)

2. Ask students if these same materials could protect astronauts from UV in space. (*Desired answer: yes, but there is much more UV in space so they would need to be extra careful*) Ask students why there is more UV radiation in space. (*Desired answer: there is no air, or atmosphere, to protect the astronauts*) Discuss with students what astronauts wear in space, and ask them to consider why astronauts need space suits. (*Desired answer: Astronauts wear space suits to breathe. Because there is more UV radiation in space, astronauts' space suits also need to give them more protection from UV light than people need on the ground*)

Transfer of Knowledge

Astronauts need to be able to see out of their helmets when they are working in space, while being protected from harmful UV radiation. In order for students to apply what they have learned, have them explore different materials, or a combination of materials, which will allow astronauts to protect themselves from UV radiation and still be able to see.

Extensions

- Invite the school nurse or a dermatologist to talk with students about the importance of using sunscreen to protect themselves from ultraviolet light.
- Students can take UV beads home to continue looking for UV light. Use the beads to record the earliest time in the morning and the latest time at night that UV can be detected. Use the beads to find out if UV light passes through car windows; check the front and side windows. Check all light sources at home, including lamps, television and computer screens, and outdoor bug lights.

Placing the Activity Within the Lesson

In this activity students were able to indicate sources of UV radiation. Discuss with students how they performed an experiment to determine which types of materials were able to block that radiation. Ask students how they were able to apply this information to determine how they could protect themselves and astronauts from this radiation.

Assessment Criteria for Activity

4 Points

- All observations are complete.
- Observations accurately describe the results.
- Good use of adjectives to describe the observations.
- Writing is clear and understandable.

3 Points

- All observations are complete.
- Observations describe the results.
- Writing is understandable.

2 Points

- Observations are few, but acceptable.
- Observations attempt to describe the results.
- Writing is somewhat understandable.

1 Point

- Observations are not complete.
- Observations do not describe the results.
- Writing is difficult to understand.

0 Points

- No observations are complete.
- Observations are off topic and unrelated.
- Writing is unreadable.

NOTES ON ACTIVITY:

Lesson Wrap-Up

Lesson Closure

In this lesson, students learned that not all light is visible to the human eye. Students used tools, UV beads, to detect one form of this light. Ask students if they know of any other type of light that cannot be seen by the human eye. (*Desired answer: infrared*) Ask students what tools, commonly used by soldiers, can be used to see this type of light. (*Desired answer: infrared goggles*) Tell students that many types of light exist in addition to the light we can see, including UV light which they explored in this lesson.

NOTES:

There's More to Light than Meets the Eye

Lesson at a Glance

Science Overview

Conducting the Lesson

Warm Up & Pre-Assessment

Activity: UV Protection

Lesson Wrap-Up

Resources

Resources

Internet Resources & References

Student-Friendly Web Sites:

Amazing Light
	http://www.discovery.panasonic.co.jp/en/library/lib07lit/l07015.html

How Light Works
	http://www.howstuffworks.com/light.htm

Teacher-Oriented Web Sites:

Journey through the Universe
	http://journeythroughtheuniverse.org/

Pro Teacher – Light
	http://www.proteacher.com/110017.shtml

Teacher Answer Key

Student Worksheet 1

1. Most students should only find UV light from natural sunlight.

2. They could tell because the beads changed colors.

Student Worksheet 1

1. The black T-shirt, sunglasses, and SPF 30 sunscreen should have all blocked the UV light.

2. Students should be able to tell because these beads did not change color in the sunlight.

3. All of these materials could help protect astronauts in space.

Grades K-2 Student Worksheet 1

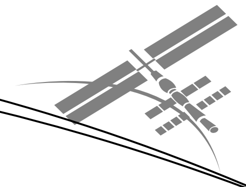
Name ____ Date ___________

What happened to the COLOR of the UV beads? Write what you saw in the table below.

Light Source	What I Saw

Question:

The UV beads change color when there is ultraviolet (UV) light. Where did you find UV light?



Grades 3-4 Student Worksheet 1

Name ____ Date ___________

Record your observations from your UV bracelet in the data table below.

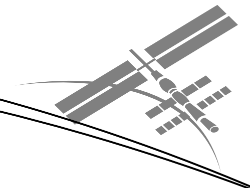
Light Source	What I Saw

Questions:

1. Where did you find ultraviolet (UV) light?

2. How could you tell there was UV light?

JOURNEY through the UNIVERSE



Student Worksheet 2

Name ______________________________________ Date ___________

Record your observations from your experiment in the data table below.

Canister	Observation
1. Control	
2. White T-shirt	
3. Black T-shirt	
4. Sunglasses	
5. Baseball cap	
6. Water	
7. Plastic Wrap	
8. Sunscreen (SPF 6 or 8)	
9. Sunscreen (SPF 30)	

Questions:

1. Which materials blocked the ultraviolet (UV) light?

2. How could you tell?

3. Do you think any of these materials would block UV light for the astronauts? If so, which ones?