Activity Four: Test Materials for a Radiation Shield

Educator Notes

Challenge

Students will use UV-sensitive beads to test a variety of materials to determine if they are suitable for shielding against ultraviolet (UV) radiation.

Suggested Time

45 to 60 minutes

Learning Objectives

Students will

- Discuss how Earth's atmosphere and magnetic field protect us from some harmful solar and galactic cosmic radiation.
- Test various materials for their ability to shield against UV radiation.

Curriculum Connection

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-PS4-2 Waves and their Applications in Technologies and Information Transfer: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. – PS4.B: Electromagnetic Radiation: When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves. *Crosscutting Concepts* • Structure and Function: The way an object is shaped or structured determines many of its properties and functions. • Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.	*Science and Engineering Practices* • Engaging in Argument From Evidence: Argumentation is the process by which explanations and solutions are reached. • Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. • Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
Technology (ISTE)	
Standards for Students • Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts, and make meaningful learning experiences for themselves and others. – 3d: Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories, and pursuing answers and solutions.	*Standards for Students (continued)* • Innovative Designer: Students use a variety of technologies within a design process to identify and solve problems by creating new, useful, or imaginative solutions. – 4d: Students exhibit a tolerance for ambiguity, perseverance, and the capacity to work with open-ended problems.
Mathematics (CCSS)	
Mathematical Practices • CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others.	*Mathematical Practices (continued)* • CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically.

Preparation Time

15 to 30 minutes

- Read the Introduction and Background, Educator Notes, and Student Handout to familiarize yourself with the activity.
- Print copies of the Student Handout.
- Gather and prepare all supplies listed on the materials list.
- Set up separate stations for each of the materials to be tested. The following materials will be tested to determine if they can shield against UV light:

- **Window glass**. This test must be done first. Students will place the UV beads against the window of the classroom to test whether the glass can shield against UV light. Once they verify that the windows and building provide sufficient shielding, they can proceed to test the other materials using the sunlight outside or a portable UV light source.
- **Metal can**. Students will place the UV beads in the palm of their hand or on a hard surface (such as a book) and cover the beads completely with the metal can.
- **Cotton fabric**. Students will wrap or cover the UV beads with a single layer of cotton fabric (such as a T-shirt).
- **Water**. Students will place the UV beads inside a clear plastic cup filled with water.
- **Clear plastic cup**. Students will place the UV beads in the palm of their hand or on a hard surface and cover the beads completely with the clear plastic cup.
- **Opaque plastic cup**. Students will place the UV beads in the palm of their hand or on a hard surface and cover them completely with the opaque plastic cup.
- **Foam cup**. Students will place the UV beads in the palm of their hand or on a hard surface and cover them completely with the foam cup.
- **Orange plastic pill bottle**. Students will place the UV beads inside the pill bottle and seal the lid.
- **Sunglasses**. Students will place the UV beads in the palm of their hand and cover them completely with a lens from a pair of sunglasses to test if the lens can shield against UV light. This test may work better if done in pairs, as it can be a challenge to keep light from penetrating gaps between the lens and the students' hands.
- **Paper envelope**. Students will place UV beads inside a paper envelope and seal it.
- **Sunscreen**. Students will place the UV beads inside a container that successfully shields UV light (such as a foam cup) and cover it with plastic wrap. Students will secure the plastic wrap in place with a rubberband and coat the exterior of the plastic wrap with sunscreen before they expose the cup to sunlight.

- Prepare the initial demonstration.
  - Use sunscreen to completely coat the outside of one or more sandwich bags, leaving one control bag with no sunscreen. When placed in the sunlight, the UV beads in the bag(s) protected by sunscreen will not turn as dark as the beads in the control (unprotected) bag. The darkness level of the beads will be affected by the sun protection factor (SPF) level of the sunscreen used, as seen in the image below.
  - Make sure to test the demonstration ahead of time.

Ultraviolent (UV) beads after exposure.

Share With Students

Brain Booster

Astronauts traveling into deep space will no longer be protected by the Earth's atmosphere and magnetosphere. They will be exposed not only to UV rays, but also to space radiation. Current spacecraft materials cannot block all of the radiation, so astronauts in space are exposed to more than the average person on Earth. For longer missions away from low Earth orbit, more protection from space radiation will be needed. NASA is already working on how to make the spacecraft safer by using different materials to provide protection.

Learn more: https://www.nasa.gov/topics/moon-to-mars/preparing-to-go

On Location

NASA has teamed with the U.S. Department of Energy (DOE) Office of Science to establish the NASA Space Radiation Laboratory (NSRL) at the DOE's Brookhaven National Laboratory. NSRL scientists use beams of ions to simulate cosmic rays and assess the risks of space radiation to human space travelers and equipment.

Learn more: https://www.nasa.gov/analogs/nsrl

***Note**: UV-sensitive beads can be purchased through several online retailers. Be sure to read the instructions, as brands may vary in color, how quickly they change colors, and how quickly they turn back to white.*

Materials

Per Student or Team

- ☐ 5 or 6 UV-sensitive beads
- ☐ Copy of Student Handout and blank paper
- ☐ Pipe cleaners or ribbon for making bracelets, key chains, or zipper pulls (optional)

Per Class

- ☐ Metal can (soup can)
- ☐ Cotton fabric (T-shirt)
- ☐ Water
- ☐ 2 clear plastic cups
- ☐ Opaque plastic cup
- ☐ 2 foam cups
- ☐ Orange plastic pill bottle
- ☐ Sunglasses
- ☐ Paper envelope
- ☐ Sunscreen
- ☐ Plastic wrap
- ☐ 2 or more plastic sandwich bags
- ☐ Rubberbands
- ☐ Optional: UV light source (blacklight) if access to sunlight is not available

Safety

- UV-sensitive beads present a choking hazard to children under the age of 3.
- If recycling used orange pill bottles, make sure they have been cleaned and any labels showing contents or personal information have been removed.
- If using a UV light source such as a blacklight, use eye protection and avoid direct contact with skin for prolonged periods of time.

Introduce the Challenge

- Show the class the two (or more) sandwich bags you prepared earlier. Do not tell them that any of the bags have been treated with sunscreen. Fill the bags with UV-sensitive beads. They should look identical before exposure to sunlight. Explain what happens to UV beads when they are exposed to UV light from the Sun or a blacklight. Take the class outside to observe what happens to the different bags of beads. Watch as the beads in the control bag become significantly darker than the beads protected by sunscreen. Challenge students to explain why this happens. Do not share the answer if the class has not yet figured it out.
- Return to the classroom and explain that the purpose of the investigation is to test a variety of materials to determine if those materials are suitable for shielding against UV radiation.
- Provide each student or team with five or six UV-sensitive beads, a copy of the Student Handout, and blank paper.
- If needed, the activity can be shortened by assigning each student or team only a few materials to test. Their findings can then be shared during a group discussion.

Facilitate the Challenge

Ask, Imagine, and Plan

- Provide context for this activity using the Introduction and Background information in this guide, focusing on the New Challenges Ahead: Radiation Shielding section.
- Engage students with the following discussion questions:
  - As astronauts venture beyond low Earth orbit and the protection of Earth's atmosphere and magnetosphere, what dangers will they face due to increased exposure to radiation?
  - What types of materials do you think will best protect against UV radiation? Why?

Test

- Demonstrate the procedure for testing materials. The beads should be completely covered with the testing material before students take them outside into the sunlight, and they should not be uncovered again until students return inside. A false positive can occur if sunlight penetrates gaps around the material or the beads are accidentally exposed.
- Students will test the UV beads with each material in the sunlight for about 10 seconds.
- Because it can take a few minutes for the beads to completely return to the white color after exposure, students or teams may pair up and share beads within the group to save time.
- Assist students or groups that are having problems and answer any questions as they move through each station.
- Allow the groups to bounce around to available stations to prevent long lines.
- Optional: Allow students to keep all or some of the UV beads to encourage continued awareness of UV radiation. Consider supplying pipe cleaners or ribbons to make bracelets, key chains, or zipper pulls. Students can even thread the beads onto their shoelaces.

Share

- After the investigation is complete, ask students again why one bag of beads in the class demonstration was darker than the other. If necessary, use guiding questions to allow the class to discover the difference between the bags. Identify the experimental bag(s) coated in sunscreen versus the control bag left unprotected.
  - Why did the beads in the bag(s) coated in sunscreen still change color?
  - Is it important to wear sunscreen when in the water? Why or why not?
  - What are other effective ways to protect your skin from harmful UV radiation?
- Engage students with the following discussion questions:
  - Why is it important for sunglass lenses to have UV protection? Discuss the results from the sunglass lens test.
  - Why is it important for medicine need to be protected from UV radiation? Discuss the results from the orange pill bottle test.
  - Did any of the results surprise you? Why?
  - Which materials might make good shielding for the walls of a space habitat?
  - Which materials might make good windows for a space habitat?
  - What other materials would you like to try in this experiment?

Extensions

- Expand the investigation to include different types of sunglasses (e.g., with and without polarizing filters) or different types of sunscreen (SPF, brand, and mineral-based).
- Find other materials that are semitransparent to visible light but block UV light (as sunglasses do).
- Find materials that block visible light (opaque) but allow UV light to pass through (some camera filters and “tan-through” fabrics).
- Research materials NASA is investigating for radiation shielding in space and identify the pros and cons of various solutions.

Reference

Modified from Exploring Ultraviolet (UV) Light From the Sun: https://sunearthday.nasa.gov/2007/materials/UVdetector.pdf

Additional Resource

- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

Activity Four: Test Materials for a Radiation Shield

Student Handout

Your Challenge

Use UV-sensitive beads to test a variety of materials and determine if they are suitable for shielding against ultraviolet (UV) radiation.

Ask, Imagine, and Plan

- During the demonstration, why did the beads in one bag become much darker than the beads in the other bag?
- As astronauts venture beyond low Earth orbit and the protection of Earth's atmosphere and magnetosphere, what dangers will they face due to increased exposure to radiation?
- What types of materials do you think will best protect against UV radiation? Why?
- On your own paper, create a data table like the example below, adding a new row for each material tested. Record your hypothesis or prediction in your data table before testing any material.

Test

Perform tests on the materials at each station and fill in the results, making notes about any observations on your data table.

Material (List each test material in a new row)	Hypothesis (Do you think the beads will be white, faintly colored, or dark colored?)	Results (White, faintly colored, or dark colored)	Does this material make a good shield against UV light? Why or why not?	Notes
Window glass				

Share

- Did any of the results surprise you? Why?
- Which materials might make good shielding for the walls of a space habitat?
- Which materials might make good windows for a space habitat?
- What other materials would you like to try in this experiment?

Fun Fact

Radiation isn't all bad! It is an essential tool for sterilization. One method of preserving fresh or packaged food is to expose it to ionizing radiation, which is a process known as cold pasteurization. This process kills any microbes that could cause spoilage or disease. UV radiation is also used to sterilize surfaces to ensure clean working conditions.

Learn more: https://www.fda.gov/food/buy-store-serve-safe-food/food-irradiation-what-you-need-know

Career Corner

Radiobiology is an interdisciplinary science that examines the biological effects of radiation on living systems. Radiobiologists incorporate fundamentals of biology, physics, astrophysics, planetary science, and engineering in their research to better understand the relationship between radiation and biology and to solve problems in this field.

Learn more: https://www.nasa.gov/hrp/elements/radiation/miniseries

Appendix: STEM Standards and Practices

Next Generation Science Standards (NGSS)

https://www.nextgenscience.org/

Alignment of Activities With NGSS Disciplinary Core Ideas				
Motion and Stability (MS) Standard	**Assess the Structural Integrity of a Space Module**	**Design and Build a Space Habitat**	**Experiment With Water Filtration**	**Test Materials for Radiation Shielding**
Forces and Interactions				
MS-PS2-1		✓		
Waves and Their Applications in Technologies and Information Transfer				
MS-PS4-2				✓
Engineering Design				
MS-ETS1-1	✓	✓		
MS-ETS1-2			✓	
MS-ETS1-3	✓	✓		
MS-ETS1-4			✓	
Ecosystems: Interactions, Energy, and Dynamics				
MS-LS2-1			✓	
MS-LS2-5			✓	

Alignment of Activities With NGSS Crosscutting Concepts				
Concept	**Assess the Structural Integrity of a Space Module**	**Design and Build a Space Habitat**	**Experiment With Water Filtration**	**Test Materials for Radiation Shielding**
Patterns				
Cause and Effect	✓	✓	✓	✓
Scale, Proportion, and Quantity				
System and System Models	✓	✓		
Energy and Matter				
Structure and Function				✓
Stability and Change			✓	
Interdependence of Science, Engineering, and Technology	✓	✓		
Influence of Engineering, Technology, and Science on Society and the Natural World			✓	

NGSS Science and Engineering Practices

https://ngss.nsta.org/PracticesFull.aspx

Alignment of Activities With NGSS Science and Engineering Practices				
Practice	Assess the Structural Integrity of a Space Module	Design and Build a Space Habitat	Experiment With Water Filtration	Test Materials for Radiation Shielding
Asking Questions and Defining Problems	✓	✓		
Developing and Using Models	✓	✓	✓	
Planning and Carrying Out Investigations	✓	✓		✓
Analyzing and Interpreting Data			✓	✓
Using Mathematics and Computational Thinking				
Constructing Explanations and Designing Solutions	✓			
Engaging in Argument From Evidence			✓	✓
Obtaining, Evaluating, and Communicating Information				

International Society for Technology in Education (ISTE) Standards for Students

https://www.iste.org/standards/for-students

Alignment of Activities With ISTE Standards for Students				
Standard	Assess the Structural Integrity of a Space Module	Design and Build a Space Habitat	Experiment With Water Filtration	Test Materials for Radiation Shielding
Knowledge Constructor				
3d			✓	✓
Innovative Designer				
4a	✓	✓		
4c		✓		
4d	✓	✓		✓
Computational Thinker				
5c	✓	✓	✓	
Global Collaborator				
7c	✓	✓	✓	

Common Core State Standards (CCSS) for Mathematics

http://www.corestandards.org/Math/

Alignment of Activities With CCSS Grade Level Content Standards by Domain				
Standard	**Assess the Structural Integrity of a Space Module**	**Design and Build a Space Habitat**	**Experiment With Water Filtration**	**Test Materials for Radiation Shielding**
6th Grade				
CCSS.MATH.CONTENT.6.NS.B.3	✓			
CCSS.MATH.CONTENT.6.SP.B.5	✓	✓	✓	
7th Grade				
CCSS.MATH.CONTENT.7.G.B.6		✓		
8th Grade				

Alignment of Activities With CCSS Standards for Mathematical Practice				
Practice	**Assess the Structural Integrity of a Space Module**	**Design and Build a Space Habitat**	**Experiment With Water Filtration**	**Test Materials for Radiation Shielding**
CCSS.MATH.PRACTICE.MP1	✓	✓		
CCSS.MATH.PRACTICE.MP2			✓	
CCSS.MATH.PRACTICE.MP3	✓	✓	✓	✓
CCSS.MATH.PRACTICE.MP4				
CCSS.MATH.PRACTICE.MP5	✓	✓	✓	✓
CCSS.MATH.PRACTICE.MP6	✓	✓	✓	
CCSS.MATH.PRACTICE.MP7				
CCSS.MATH.PRACTICE.MP8				