Solar Kit Lesson #9
Properties of Solar Radiation: Reflection, Transmission, and Absorption

TEACHER INFORMATION

LEARNING OUTCOME
After using a solar panel as a radiation meter to distinguish how well various materials reflect or transmit solar radiation, students are able to predict reflection and transmission properties for various materials, and test their predictions using their sense of touch.

LESSON OVERVIEW
Through experimentation, students observe and record levels of solar radiation reflected off and transmitted through various materials. They apply the results to potential consumer choices.

GRADE-LEVEL APPROPRIATENESS
This Level II Physical Setting lesson is intended for use in home and careers, physical science, and technology education classrooms in grades 6–9.

MATERIALS:
Per work group
- one 1 V, 400 mA mini–solar panels* with alligator clip leads
- one 45-degree mount for the solar panel
- digital multimeter
- a flat board such as a clipboard painted with flat black paint
- 30 cm of masking tape
- squares of materials, approximately 10 x 20 cm
    - Mirror
    - Window glass
    - Frosted glass
    - Aluminum foil
    - Unpainted copper sheeting
    - Wood
    - Waxed paper
    - Clear plastic wrap
    - Cellophane: clear, yellow, red, blue, green
    - Construction paper: black, yellow, red, blue, green

If working without the Sun,
- 150-watt incandescent bulb with lamp

* Available in the provided Solar Education Kit; other materials are to be supplied by the teacher

SAFETY

Tell students not to look directly at the Sun or at a direct reflection of the Sun. Permanent eye damage can result. Sand or tape any sharp-edged materials students will be handling such as glass or thin metal.

TEACHING THE LESSON

Preparation: Prepare one 45-degree solar panel mount for each team as described in figure 1. Cut out and assemble the test materials.

Suggested Approach: Crumple up several pieces of paper and throw them at a group of students. Ask students to describe how these pieces of paper and the group interacted. Some may have been caught; these were "absorbed" by the group. Others would have passed through or been "transmitted" through the students to the floor. And others may have bounced off or been "reflected" off students, desks, or chairs. Use the ensuing discussion to define *reflection, transmission*, and *absorption*.

If some students throw crumpled paper back at you or others, you can discuss how that piece of paper was absorbed and then "reradiated" by the group. This is a phenomenon that occurs in some materials (think of phosphorescent materials) but tell students that they will not be exploring such materials today.

Discuss the mathematical relationship between reflection, transmission, and absorption: incident solar radiation (I) must equal reflected (R) plus transmitted (T) plus absorbed (A) radiation.

$$I = R + T + A$$

Demonstrate how to use an ammeter and a panel's conversion curve to obtain milliamps and then convert to watts per square meter (W/m^2). (See the Solar Kit lesson *Calibration Curve for a Radiation Meter*). Distribute the handout *Transmission, Reflection, and Absorption* and have students follow the instructions.

If time for the activity is limited, groups can run either the transmission or reflection lab, then share their data prior to predicting the absorption capacities of the materials.

If weather conditions are unsuitable, or a proper sunlit space is not available for students to work with radiation directly obtained from the Sun, a 150-watt incandescent lamp can serve as an alternative. Keep any lamp at least 120 cm away from the solar panel or it might melt the protective cover.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

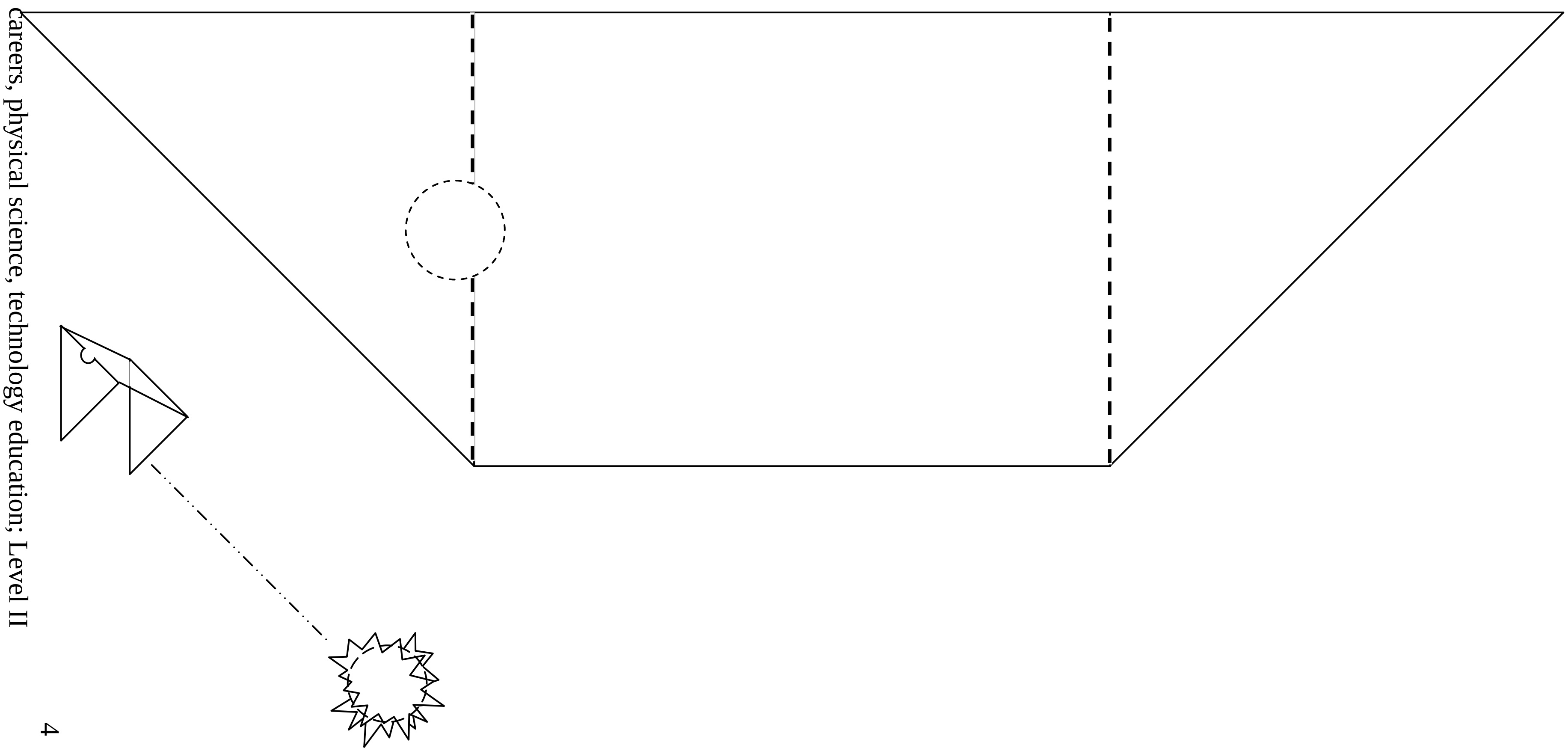
Data Collection: Results will vary due to several variables, especially variations in positioning and holding the solar cell and light conditions.

The mirror and aluminum foil should show the highest level of reflection. Window glass and clear plastic sheeting should show the highest level of transmission. The mirror, aluminum foil, copper sheeting, wood, and construction paper should not transmit light energy.

Students should be expected to predict that the darker colored construction papers, black-painted copper sheeting, and wood will absorb the most light energy.

Figure 1: Template for solar panel 45-degree mount

Use this template to prepare a 45-degree solar panel mount for each team. Prepare each mount out of stiff cardboard. Each mount will be cut to the shape of the template. Cut out an opening for the solar panel wires as shown by the circle. Fold the wings of the mounts 90 degrees along the dashed lines. Students will use double-sided tape to hold the solar panel to the inside of the mount for the lab on reflection.



Review Questions:

1. Students should use mathematical reasoning and deduce that materials that perform poorly as reflectors and transmitters must be absorbing the radiation while materials that perform very well as reflectors or transmitters must not absorb much radiation. Students should cite the fact that reflected plus transmitted plus absorbed radiation must add up to the incident solar radiation.
2. Students should have noticed that smooth surfaces reflect more light than dull or rough surfaces and that a surface that reflects high levels of light absorbs less light.
3. Students should have noticed that materials having dark colors absorb more light than light-colored materials and that a material that absorbs high levels of light transmits less light.
4. Students should identify items such as distance between the material and the solar panel, consistent positioning of the material, and angle of incidence of the light source.
5. Answers will vary but they should accurately use information on how colors and materials affect the amount of solar radiation that is absorbed, reflected, or transmitted.
6. Answers will vary but they should accurately use information on how colors and materials affect the amount of solar radiation that is absorbed, reflected, or transmitted. Ideally a solar panel cover would look dull, indicating that very little light is reflected.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This lesson was adapted from *Renewable Energy Activities for Junior High / Middle School Science*, prepared for the U.S. Department of Energy by the Solar Energy Project in cooperation with the New York State Education Department and the State University of New York Atmospheric Sciences Research Center (out of print).

BACKGROUND INFORMATION

Radiation incident upon a surface is typically described as interacting with the surface in one or more of three ways: it will be absorbed into the material, transmitted through the material, or reflected off the material. The proportions of each will depend on the wavelengths of the radiation, the chemical composition and physical structure of the material, and the angle of incidence at which the radiation strikes the material.

Hard polished surfaces reflect light differently from rough textured surfaces. The amount of radiation reflected also depends on the angle of the incident light, with low angles of incidence typically reflecting more light than high angles of incidence. Radiation can reflect off a surface more or less equally in all directions at once or in only one direction as light reflects off a mirror. Radiation reflected in all directions is called “diffuse reflection” and radiation reflected as occurs off a mirror is called “specular reflection.”

Materials that absorb many wavelengths of visible light look darker to us than those that absorb fewer wavelengths.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematical Analysis Key Idea 3: Critical thinking skills are used in the solution of mathematical problems.

Scientific Inquiry Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

Standard 3—Mathematics: Students will understand mathematics and become mathematically confident by communicating and reasoning mathematically, by applying mathematics in real-world settings, and by solving problems through the integrated study of number systems, geometry, algebra, data analysis, probability, and trigonometry.

Key Idea 4: Students use mathematical modeling/multiple representation to provide a means of presenting, interpreting, communicating, and connecting mathematical information and relationships.

Key Idea 5: Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data.

Key Idea 7: Students use patterns and functions to develop mathematical power, appreciate the true beauty of mathematics, and construct generalizations that describe patterns simply and efficiently.

Standard 4—The Physical Setting: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved.

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www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Chris Mason at cmason@nesea.org.

(STUDENT HANDOUT SECTION FOLLOWS)

Name(s) ___________________________

Date _______________________________

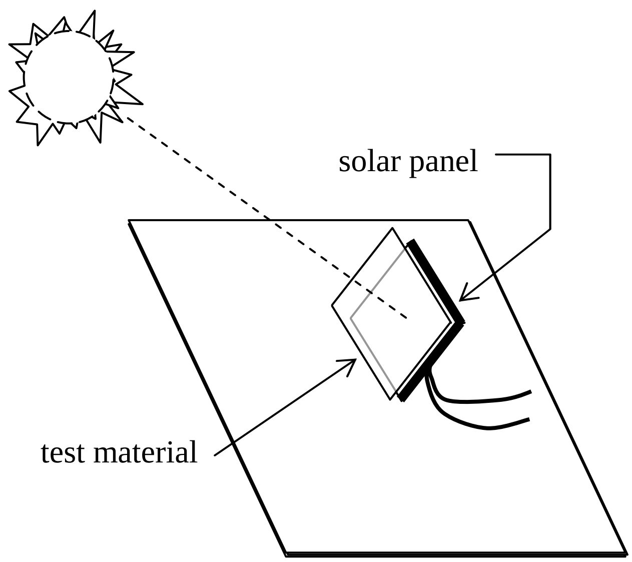
Transmission, Reflection, and Absorption

What happens when solar energy strikes an object? Here are three possibilities: it may be transmitted through the object, the object may reflect the solar energy, or the object may absorb it. Most objects do all three, to a greater or lesser extent.

It is useful knowledge to understand how different materials transmit, reflect, and absorb solar radiation. For instance, in the case of a solar cell, it is important to coat the surface with a material that is a poor reflector—we want as much light as possible to enter the cell. Accordingly, creating comfortable, well-lit homes, schools, and offices requires an understanding of which building materials transmit, reflect, and absorb solar radiation. After experiencing this lesson you may even begin to select the color and texture of new clothing purchases depending on the strength of sunlight during the seasons.

You are now going to distinguish how well various materials reflect or transmit solar radiation. From the data obtained, you will then predict how well each material absorbs solar radiation.

Transmission

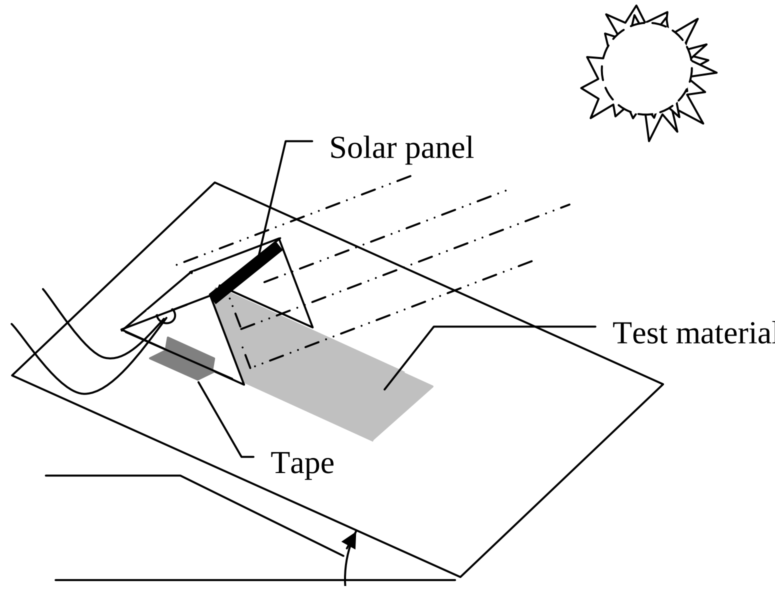


1. Tape one edge of the solar panel to a flat board such as a clipboard. Be careful not to cover any of the photovoltaic cells with tape. You should now be able to tilt the solar panel toward the Sun.

2. Connect an ammeter to the solar panel leads. Position the board and tilt the solar panel so the ammeter shows the highest reading possible. Prop the solar panel in this position with a heavy bulky object such as a text book and leave it this way for the rest of the transmission tests.

3. In turn, cover the solar panel with each piece of material. For each material, record the ammeter reading in milliamps (mA) under "As a Transmitter" in the Data Table.

4. When you have finished testing all materials, use the ammeter readings and the solar panel's calibration curve to calculate the intensity of light that was transmitted through each material. Record this as watts per square meter (W/m^2) under "As a Transmitter" in the Data Table.



Tilt the b
solar pane

5. On the basis of your observations, rate each test material's ability to transmit light. Record *excellent*, *good*, *fair, poor*, or *no ability* in the Data Table.

Reflection

6. Use double-sided tape on the back of the solar panel to secure it to the inside of the cardboard mount (the triangular wings wrap around the panel's sides) with the wire leads fed through the hole. Use tape to secure the cardboard mount (with solar panel) to the board as shown in the diagram so the face of the solar panel is directed toward the board.

7. Place the board on the table with the open side of the mount directed toward the Sun. Tilt the board until the solar panel does not show a shadow. (Or, if using an incandescent lamp, position the lamp so the solar panel does not cast a shadow.) You may have to tilt up either the front or the back of the board depending on where the Sun is in the sky. Secure the board in this position for the remainder of the reflection tests.

8. Place the mirror on the board in the test material location as shown in the diagram. Record the ammeter reading as "mA" under "As a Reflector" in the Data Table.

9. Remove the mirror and replace it in turn with each remaining test material. Make sure each test material is placed in the exact same position as the mirror. Record the ammeter reading for each test material in the Data Table.

10. For each material, use the ammeter reading and the solar panel's calibration curve to calculate the intensity of light that was reflected off the material. Record this as "W/m^2" under "As a Reflector" in the Data Table.

11. On the basis of your observations, rate each test material's ability to reflect light. Write *excellent*, *good*, *fair*, *poor*, or *no ability* in the Data Table.

Absorption

12. Review the data you collected and how you rated each material's ability to reflect and transmit light. For each test material, predict its ability to absorb light. Write *excellent*, *good*, *fair*, *poor*, or *no ability* in the Data Table.

13. Predict which of the materials would become the warmest and which the coolest if left lying out in the Sun. Use your sense of touch to test your prediction.

Review Questions:

1. What reasoning did you use to predict which materials would be the best or worst absorbers of light?

2. How did the texture of the material seem to affect its ability to reflect light? Absorb light?

3. How did the color of a material seem to affect its ability to transmit light? Absorb light?

4. What variables did you control to make sure that the material being tested was the only factor influencing the readings?

5. Using what you learned, what exterior and interior colors and materials would you want in a car if you lived in a hot sunny climate? What colors and materials would you pick if you lived in a cold sunny climate?

6. What properties of transmission, reflection, and absorption of light would you look for in a material used to cover a solar electric panel? Describe how you would expect this material to appear (such as dull, shiny, dark or light colored, etc.).

Name(s) ____

Date _______________

Data Log

Material	As a Transmitter			As a Reflector			As an Absorber
	mA	W/m^2	Description	mA	W/m^2	Description	Conclusion
Mirror							
Window Glass							
Frosted Glass							
Aluminum Foil							
Copper Sheeting: Unpainted							
Black-painted							
Wood							
Waxed Paper							
Clear Plastic Wrap							
Cellophane: Clear							
Yellow							
Red							
Blue							
Green							
Construction Paper: Black							
Yellow							
Red							
Blue							
Green							