Solar Education for NY
SchoolPower ...Naturally

Solar Kit Lesson #10
Properties of Solar Radiation: Direct and Diffuse Light

TEACHER INFORMATION

LEARNING OUTCOME
Students become habituated to observing conditions in the sky such as location of the Sun and types of clouds. They come to understand the patterns of cloud cover that affect solar energy production.

LESSON OVERVIEW
Students establish a long-term study of direct and diffuse solar radiation. They collect and display data, demonstrate the concept of percentage, interpret data, and make predictions. The data can readily be transferred to computer data-management software such as spreadsheets.

In this lesson, students:
- use an ammeter to collect data
- interpret data on direct and diffuse solar radiation
- display data in numerical and graphical forms
- use a graphical technique to determine and display percentage of direct versus diffuse solar radiation
- predict how factors such as differing weather conditions or times of day affect levels of direct and diffuse solar radiation
- adjust their predictions after interpreting new knowledge
- identify how differing weather conditions or times of day affect levels of direct and diffuse solar radiation

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

MATERIALS
If you choose to send a different team outdoors each day for the long-term study, you will need one of each of the following bulleted items. If you choose to have the class work in teams at the same time for the long-term data collection, you will need one of each of the following bulleted items per team.
- Two 1 V, 400 mA mini–solar panels* with alligator clip leads
- Digital multimeter or ammeter
- 11 x 17 inch sheet of dark-colored construction paper
- Tape

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

Per work group

- Student handouts
- Graph paper
- Scissors

SAFETY

Tell students not to look directly at the Sun. Permanent eye damage can result. Instead, direct them to use a maximum current reading to indicate when a solar panel faces the sun directly. Have them look at other parts of the sky, not at the Sun, to determine sky conditions.

TEACHING THE LESSON

This lesson includes an introductory discussion, a demonstration on how to collect data on solar radiation, a demonstration on how to graphically determine percentage, and a long-term student study. Each of the first three components could take a class period. The structure of the long-term class study is flexible and should be designed to address the needs and resources of your class.

Preparation: Form an 11-inch-deep box with a solar panel at the bottom by folding a sheet of 11 x 17 inch dark-colored construction paper around the edges of a mini–solar panel. Direct the face of the panel into the box. Tape the construction paper to the solar panel to form an open box with the panel as the bottom.

Remember, if you choose to have the class work in teams all at the same time for the long-term data collection, you will need one 11-inch-deep box for each team.

Opening Discussion: Discuss with students why, in a room having seven windows, it is bright enough to see even when no sunlight is shining directly into the room and the electric lights are not turned on. Define *direct light* and *diffuse light*. Ask students their estimation of how much light from the Sun reaches Earth's surface directly from the Sun (direct light) and how much light reflects off gases in the atmosphere before it arrives at Earth's surface (diffuse light). Manage to slip into the conversation various weather conditions such as days having heavily overcast skies (when hardly any direct radiation reaches Earth) or clear sunny days (when the direct radiation could be in the 90% range). Write on the chalkboard, chart, or overhead transparency phrases that students come up with, such as "hardly any" or "almost all."

Introduce the concept of percentage as a more accurate way of representing terms such as *hardly any*, *almost all*, *about half*, *none*, or *all of it*. Draw a scale on the board from 0% to 100% using 10% increments. Define *0%* as "none of it" and *100%* as "all of it." Work with the class to determine where phrases generated in the previous discussion might fit on the scale.

Tell the students that they will apply the concept of percentage as they study direct and diffuse light over the next month or two.

Measuring Direct and Diffuse Radiation: Distribute the handout "Direct and Diffuse Light – Data Sheet." Use a solar panel and ammeter as follows to demonstrate to students how to collect

data. Asking a few students to assist, or rotating students through the process of taking measurements themselves, should be helpful.

Connect the ammeter to the leads of a mini–solar panel, positive to positive and negative to negative. Set the scale to read 0–500 mA. Explain that using the solar panel and meter in this manner provides a simple way of indicating how much light shines on the panel. Take the class outside to an open location.

Total or global radiation: Point the solar panel directly at the Sun. Adjust it until the ammeter reading is at a maximum. Have students record how many milliamps it produces. Explain that this number represents the total light energy shining on the panel. This is called global radiation.

Diffuse radiation*:* Point the solar panel toward the widest section of sky. Then use your hand to shade the solar panel. Hold your hand about one foot from the solar panel. Measure how many milliamps it produces. Have students record this information. Explain that this number represents only the light energy that has been reflected onto the solar panel. Ask students to name objects that reflected the light energy. They may mention trees, buildings, and gases in the atmosphere.

***Direct radiation*:** Use the mini–solar panel in the 11-inch-deep box. Point the solar panel directly at the Sun so that there are no shadows on the panel. Have students record how many milliamps it produces. Explain that this number represents the light energy that came directly from the Sun.

Analyzing Data: Back in the classroom, help students make bar graphs of the data they collected. Discuss with students what their data reveals. How did the amount of direct light compare to the total amount of light? How did the amount of diffuse light compare to the total amount of light?

Draw a scale on the board from 0% to 100%, using 10% increments. Define *0%* as “no light” and *100%* as “all light.” Tell students that the total or global radiation they measured is “all the light” (100%). Work with the class to determine where the amount of direct and diffuse light they measured should fit on the scale.

Determining percentage: Have students cut out the bar they drew to represent global radiation. Help them fold it into 10 equal parts. Have students unfold it and draw lines at each crease. Explain how their bar now represents a scale from 0% to 100%. Demonstrate how to place this next to the bars they drew for diffuse and direct light so that the bottom of each bar lines up. Have students mark on the global radiation bar where the tops of the direct and diffuse bars reach. Tell students to label each mark as “direct” or “diffuse.”

Have students transfer these marks to the graph on their data sheet. Tell them to shade the column below each mark, using a different color for each column.

Student Predictions: Distribute the handout “Prediction Sheet I.” Have teams of students predict the following:

The weather conditions and time of day that global radiation will come almost totally from

1) diffuse radiation and
2) direct radiation.

Save these diffuse radiation predictions for students to reference during the long-term study.

Long-Term Study: Set up a long-term study that meshes with the equipment you have available and your class and school schedules. You may wish to send a different team outdoors each day or at different times each day to take readings and then, on a daily or weekly basis, assign to the class some of the teams' data as practice for graphing and analysis. You could have the entire class work in teams and take readings on days having differing weather conditions, making sure to take readings at different times of the day as well.

In any situation, have students compare their predictions, in writing, to what the data is showing them. Have them write down adjustments they wish to make to their predictions. Keep these writings with the original team prediction sheet.

Final Data Analysis: Once the teams have collected all of the data, assemble and display all data sheets in a systematic manner. For instance, display morning and midday readings in different parts of the classroom with sunny conditions posted on the top and the worst weather conditions posted on the bottom. Pass out the handout "Prediction Sheet II" and have each team predict what portion of the total light the diffuse and direct radiation would contribute under the following conditions:

Early morning, clear blue skies
Early morning, hazy whitish skies
Early morning, heavily overcast skies
Midday, clear blue skies
Midday, hazy whitish skies
Midday, heavily overcast skies

Allow the teams time to review the displayed data and identify the accuracy of their predictions.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

Results will vary due to light conditions. On heavily overcast days, students will measure hardly any direct radiation, while on clear sunny days the direct radiation could be in the 90% range. The percentage of direct radiation will be less in the morning than at midday under similar weather conditions.

Values for direct and diffuse radiation will add up to plus or minus 5% of 100% due to the inaccuracies in the measurement process.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This lesson is adapted from *Thames & Kosmos Fuel Cell Car & Experiment Kit Lab Manual*, Thames & Kosmos, LLC, Newport, RI, 2000.

BACKGROUND INFORMATION

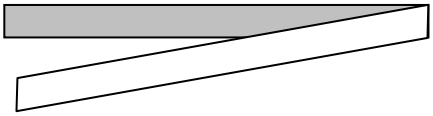
The sky provides light even where the Sun is not shining because the gases in the atmosphere reflect and scatter light. This portion of the light reaching us from the Sun is known as diffuse radiation. Light straight from the Sun is known as direct radiation.

On a clear day, the sky looks blue because the blue portion of sunlight is scattered most easily by gases in the atmosphere. The reds and yellows pass through these gases more easily, giving the impression that the Sun is yellow or red. Larger particles of dust and water vapor in the atmosphere cause more colors to be scattered. When these are present in the atmosphere, the sky becomes whitish or hazy.

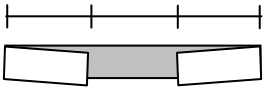
The term *percent* comes from the phrase *per centum*, meaning "by the hundred." It refers to looking at a whole as being made of 100 equal parts where one part in a hundred is a percent.

Folding a strip of paper into 10 equal parts:

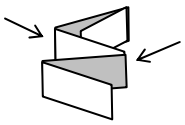
1) Fold the strip in half.



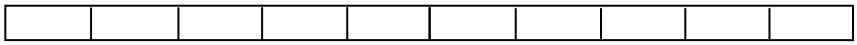
2) Fold each end toward the middle so you see three equal-size sections.



3) Fold creases on both sides of the middle section.



4) Unfold and mark the creases.



REFERENCES FOR BACKGROUND INFORMATION

Columbia On-line Encyclopedia. New York: Columbia University Press, 2002. New York: Bartleby.Com, 2002

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 1: Abstraction and symbolic representation are used to communicate mathematically. (elementary)

Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions. (elementary and intermediate)

Key Idea 3: Critical thinking skills are used in the solution of mathematical problems. (elementary and intermediate)

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

Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. (elementary and intermediate)

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena. (elementary and intermediate)

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 1: Students use mathematical reasoning to analyze mathematical situations, make conjectures, gather evidence, and construct an argument. (elementary and intermediate)

Key Idea 2: Students use number sense and numeration to develop an understanding of the multiple uses of numbers in the real world, the use of numbers to communicate mathematically, and the use of numbers in the development of mathematical ideas. (elementary and intermediate)

Key Idea 3: Students use mathematical operations and relationships among them to understand mathematics. (intermediate)

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

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. (elementary and intermediate)

Key Idea 6: Students use ideas of uncertainty to illustrate that mathematics involves more than exactness when dealing with everyday situations. (elementary and intermediate)

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. (elementary and intermediate)

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 1: The Earth and celestial phenomena can be described by principles of relative motion and perspective. (elementary)

Key Idea 2: Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land. (elementary and intermediate)

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

Standard 5—Technology: Students will apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs.

Key Idea 2: Technological tools, materials, and other resources should be selected on the basis of safety, cost, availability, appropriateness, and environmental impact; technological processes change energy, information, and material resources into more useful information. (elementary)

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design. (elementary and intermediate)

Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems. (elementary)

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions. (elementary and intermediate)

Standard 7—Interdisciplinary Problem Solving: Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Key Idea 1: The knowledge and skills of mathematics, science, and technology are used to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena. (elementary and intermediate)

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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 _____

Direct and Diffuse Light – Data Sheet

Time of day_____

Condition of sky _____

Radiation Type	**Ammeter Reading**	
Global radiation	_____	(Point the solar panel at the Sun.)
Diffuse radiation	_____	(Point the solar panel at the sky and shade it from the Sun.)
Direct radiation	_____	(Point the solar panel in the box directly at the Sun.)

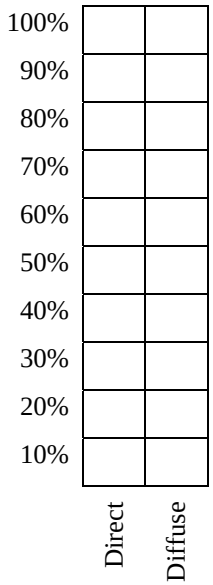
Data Analysis

1) On a separate sheet of paper, construct a bar graph showing your measurements for global, diffuse, and direct radiation.

2) Cut out the bar for global radiation and fold it into 10 equal parts. Draw lines at each crease.

3) Mark on the global radiation bar where the tops of the direct and diffuse bars reach.

4) Transfer these marks to the following graph. Shade the column below each mark. Use a different color for each column.

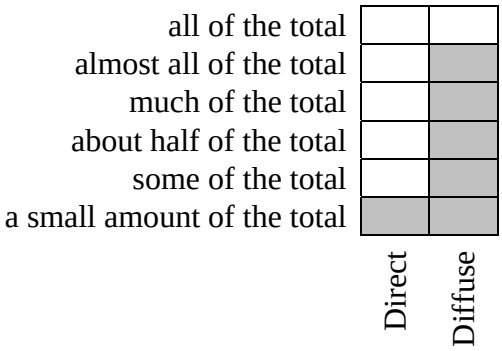


Name(s) _____

Date _____

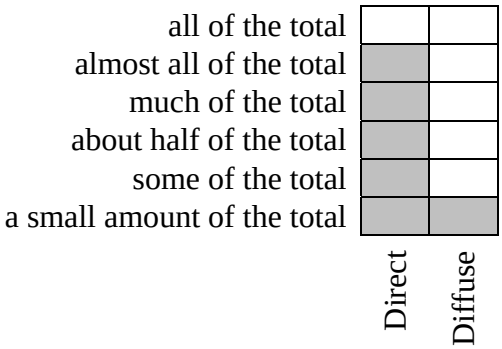
Direct and Diffuse Light – Prediction Sheet I

Graph 1



1) Predict two scenarios showing what time of day and under what weather conditions you will see the results in graph 1.

Graph 2



2) Predict two scenarios showing what time of day and under what weather conditions you will see the results in graph 2.

Name(s) _____

Date _____

Direct and Diffuse Light – Prediction Sheet II

Early morning, clear blue skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		

Midday, clear blue skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		

Early morning, hazy whitish skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		

Midday, hazy whitish skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		

Early morning, heavily overcast skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		

Midday, heavily overcast skies

	Direct	Diffuse
all of the total		
almost all of the total		
much of the total		
about half of the total		
some of the total		
a small amount of the total		