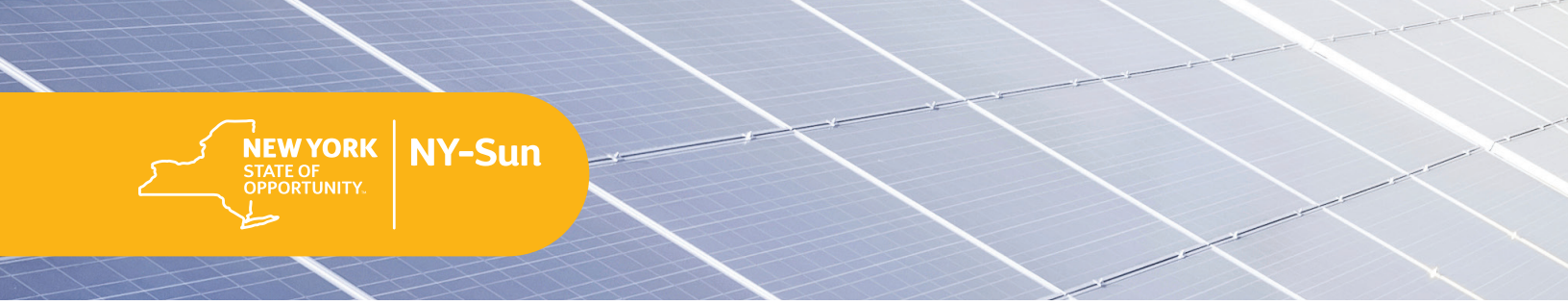



# Properties of Solar Radiation: Direct and Diffuse Light

Suggested Level: Grades 6 through 9

## 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 spreadsheets.

In this lesson, students will complete the following:

- 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

## 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
- Alligator clip wires
- Digital multimeter or ammeter
- 11 x 17 inch sheet of dark-colored construction paper
- Tape

***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 (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 down 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 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 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 the following:

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 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 with 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 STUDENT RESPONSES

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.

## BACKGROUND INFORMATION

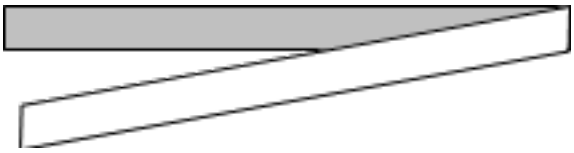
The sky provides light even where the sun is not shining because the gases in the atmosphere reflect and scatter light. This portion of the light reaching us from the sun is known as diffuse radiation. Light straight from the sun is known as direct radiation.

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.

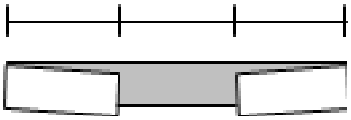
The term percent comes from the phrase per centum, meaning “by the hundred.” It refers to looking at a whole as being made of 100 equal parts where one part in a hundred is a percent.

Folding a strip of paper into 10 equal parts:

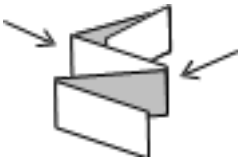
1) Fold the strip in half.



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.

***(STUDENT HANDOUT FOLLOWS)***

Name _____ 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.) |

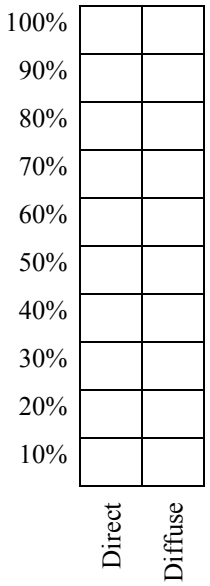
**Data Analysis**

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.

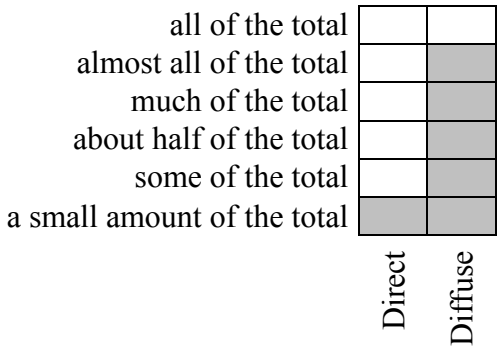
4) Transfer these marks to the following graph. Shade the column below each mark. Use a different color for each column.



Name _____ Date _____

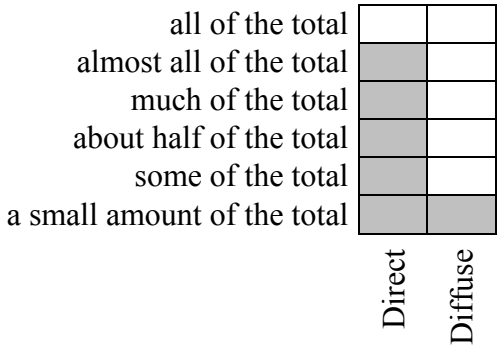
## Direct and Diffuse Light – Prediction Sheet I

### 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 _____ 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 | | |