Name: ______________________________

Date: ____ / ____ / ____ Class Hour: ____

MEASURING SUNLIGHT:
THE PYRANOMETER

INTRODUCTION:

Measuring the power of sunlight--it's important to be able to do when working with solar panels.

In this lesson you will measure the sun's **irradiance** (radiant power received by a surface per unit of area) with an instrument used in the solar industry called a **pyranometer**. You'll quantify irradiance as the Watts of sun energy that strike a square meter of a given surface (Watts / square meter, or **W/m^2**). Naturally, the square meter of surface those in the solar industry are most interested in is a square meter of solar panel surface . Accordingly, they are interested in knowing how to orient and install solar panels to receive maximum energy from the sun.

By the end of this activity you'll know how to use a pyranometer. More importantly, you'll learn about some of the variables that have an effect on the sunlight received by a solar panel and be able to assess the effect of those variables.

Activity:

1. Your teacher will introduce you to your pyranometer, describe how it works, and show you how to operate it. Your teacher will also review where and how to make and take irradiance measurements with it. Ask questions of your teacher as needed to correctly carry out the lab procedure.

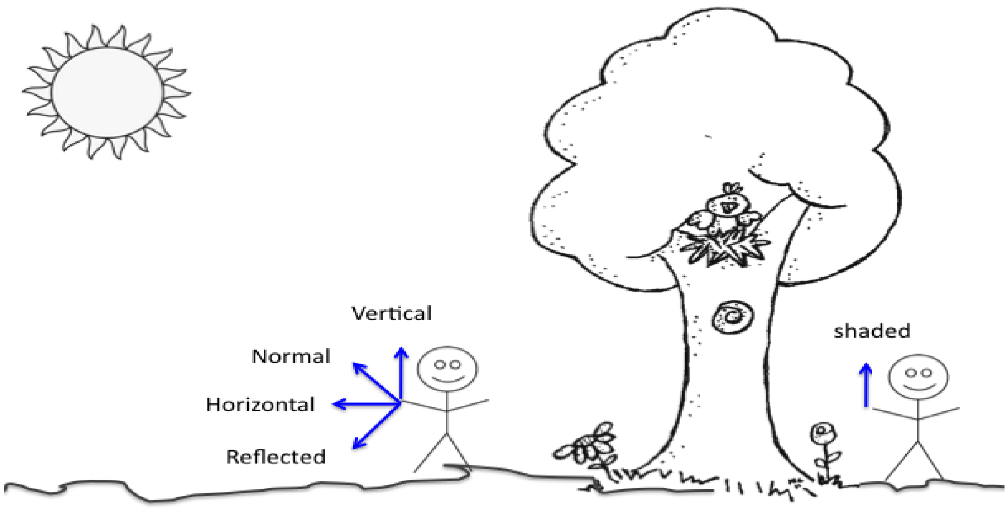
2. Go outside to take and record irradiance measurements in your data table as instructed.

3. If requested to do so, pool your class data. Take averages for each orientation and situation.

4. Discuss your use of the pyranometer. Ask questions about how you used it today, and questions about its use and application in the solar industry.

5. Write high quality answers to the questions that follow to **Show What You Know**.

Illustration 1:



Data Table:

Orientation and Situation	My measured Irradiance (W/m²)	Class average Irradiance (W/m²)
Vertical and in sunlight	*	*
Normal and in sunlight	*	*
Horizontal and in sunlight	*	*
Reflected and in sunlight off of a light surface	*	*
Reflected and in sunlight off of a dark surface	*	*
Vertical and in the shade	*	*

Show What You Know

1. In **Table 1.0** below, rank the six orientations and their situations in order from highest irradiance to lowest irradiance using the best data available.

Table 1.0

Orientation and Situation	Irradiance (W/m^2)
*	*
*	*
*	*
*	*
*	*
*	*

2. How did reflected irradiance differ depending on the color of the reflecting surface?

*

3a. About what percent of available solar radiation is reflected from the ground from a *dark* surface? Completely show how you calculated your answer in the space available.

Percent of available solar radiation reflected from dark surface:

*

Math work: *

3b. About what percent of available solar radiation is reflected from the ground from a *light* surface? Completely show how you calculated your answer in the space available.

Percent of available solar radiation reflected from light surface:

*

Math work: *

4. About what percent of available solar radiation is available in the shade? Completely show how you calculated your answer in the space available.

Percent of available solar radiation available in the shade:

*

Math work: *

5. You've decided to install a solar PV panel array--congratulations! It will be a fixed array, bolted in position on the roof.

Doing some research, you decide to install them facing 180°, which of course is due south. In this orientation, or "azimuth," your solar panels will face "solar noon." This is the time of the day when the sun is highest in the sky and at its greatest intensity. It's also the time of day that splits the day in half. There is the same amount of daylight after solar noon as there is before solar noon.

Now do some more research. What should be the tilt angle of your solar panels--at what angle should they be "tilted up" in order to receive the most power from the sun? Discuss what you learned in this activity in answering the question.

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6. What is the biggest advantage to installing a solar panel system that moves with the sun (a "tracking" system)? Discuss what you learned in this activity in answering the question.

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7. Bifacial solar modules are relatively new to the solar PV market. Bifacial modules produce solar electric power from both the front and back of the panel. As you can see in **Illustration 1.0** below, the back side of bifacial modules has a clear covering applied to it. When installed over a highly reflective surface, an additional 25% solar production from the back of the module can be achieved.

Illustration 1.0

Use data you collected and what you have learned in this activity to describe what kind of surface would be ideal to have a few feet behind a fixed, ground mounted array of bifacial solar PV modules.

*

8. The majority of solar systems that are installed are fixed in position. List and explain at least three disadvantages of tracking solar systems that help to explain why they are installed less often than fixed solar systems.

8-1) *

8-2) *

8-3) *

9. Let's say at solar noon on a clear day, a one square meter fixed-in-place solar panel is receiving 1000 W/m^2 of sunlight. With an efficiency rating of 20%, the solar panel will produce 200 W/m^2 of usable electricity at that time. If the panel were able to produce at this "full capacity" all day it could produce 4,900 Watt-hours of usable electricity:

$$200\,Watts\ X\ 24\ hours = 4900\,Wh$$

This quantity is the same as 4.9 kWh of electricity:

$$200\,\cancel{Watts}\ X\ 24\ hours\ X\ \frac{1\ kiloWatt}{1000\,\cancel{Watts}} = 4.9\ kWh$$

However, the amount of electricity produced by this one square meter solar panel will never be equal to its full capacity. In fact, on a typical day, the panel might only produce 1.0 to 1.2 kWh of usable electricity - less than 25% of its full capacity. [A solar array that produces electricity at 20% of its full capacity would be said to have a Capacity Factor of 20%.]

List and briefly explain at least five circumstances that keep any solar panel from producing at its full capacity, even on a good day. You must discuss what you learned in this activity in developing your answers.

9-1) *

9-2) *

9-3) *

9-4) *

9-5) *

10. The world map in **Illustration 2.0** is also available in color on the internet. It shows average solar radiation received on land across the earth. Note the greatest irradiance values (dark) are found through "the middle" of the earth--from about 30° south of the equator to about 30° north of it. Why are average irradiance values so much greater there, and less (sometimes a lot less) in other world regions? You must discuss what you learned in this activity in developing your answer.

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Illustration 2.0