Solar Education for NY

SchoolPower ...Naturally

Solar Car Series: During what part of the day can the most Sun power be collected?

SPN LESSON #15

TEACHER INFORMATION

LEARNING OUTCOME

After observing solar power changes on a flat solar panel, students are able to describe the relationship between panel position and power output.

LESSON OVERVIEW

Students go outside to make direct but safe observations of the Sun. They note the position of the Sun in the sky and determine how that position relates to Sun power as collected on a flat (horizontal) solar panel. Concurrently, students review understandings of the Sun and Earth: the size and shape of the Sun, the shape of Earth, the Sun-to-Earth distance and the relationship of that distance to the shape of Earth's orbit. They also review/preview certain weather information.

GRADE-LEVEL APPROPRIATENESS

This Level II Physical Setting lesson is intended for use with students in grades 5–8.

MATERIALS

Light source (2), for teacher demonstration Solar cells
Chalk
Motors with propeller or spinner One-minute timers Thermometers
Outdoor work area in sunlight
Pinhole projector and/or sunshield (both optional)

SAFETY

Title 8 of Education Law, Section 141.10, indicates that school districts are responsible for establishing guidelines whenever a "potential eye hazard" exists, so check with your supervisor on this issue. In any case, a precautionary warning should be made to students about the danger of looking continuously and directly at the Sun. [Pinhole projectors can safely be used to project the Sun's image on white, stiff paper.

During what part of the day can the most Sun power be collected? 15.2

TEACHING THE LESSON

Set aside one period plus parts of three others for this lesson.

A. Teacher demonstration:

1. Connect one set of student materials. Demonstrate the proper way to connect the voltmeter leads to the solar cells and select voltmeter output. Place a light source at a distance from the solar cell so that the voltmeter indicates some voltage present. Discuss/review with the students through a question-and-answer format what is occurring and why. *[Light energy is being absorbed by the solar panel and is converted into electricity.]*

2. Move the light source closer to the solar cell so that the voltage increases. Ask students why the rate of spin has increased. *[The light energy is more concentrated or intense.]*

3. Move the light source back to its original position and turn on a second light source. Discuss with students why the rate of spin is again greater than the original rate when only one light source was used. *[Twice as much light is being produced by the two light sources.]*

4. Ask students rhetorically if the amount of energy received on Earth's surface is always the same or does the energy vary as in this demonstration. Are the reasons the Sun's energy varies the same as this demonstration shows (energy varies in accordance with distance from the Sun; the amount of energy produced by the Sun changes), or is there some other explanation? Students will do an activity that will start them on their way to answering thisquestion.

B. Pass out student handouts. Give students time to read page 1.

C. Review procedures with students. Remind them that they will be working in groups (three students per group is ideal). Make sure they collect all the data asked of them. Remind them to be careful about looking at the Sun (even if you decide to handle this part on your own and not involve them). (If students are going to use pinhole viewing devices, demonstrate how they work by using one of the indoor light sources to project its image on a sheet of paper before students go outside.)

D. Warn students to be gentle with the fragile solar panels. (You may want to mount them on a protective board.) Have students gather in groups and pick up equipment.

E. Designate the outside work area.

Lesson Extensions

This activity could be a part of a sequence of investigations within a meteorology section of your course of studies or energy transformation investigations.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION (Numbers in brackets are NYSED Intermediate Science Core Major Understandings [Standard #: Major Understanding #])

1. Earth spins once on its axis every 24 hours, so we come back to the same position in relation to the Sun at the same time each day.

2. In early morning the Sun is low in the eastern sky; it rises higher during the middle of the day in the southern sky (it is never directly overhead in New York State); and in late afternoon it is low in the western sky.
3. (Answers will vary.) Unless there was cloud cover (any amount), the energy-Sun data collected at the same time of day was about the same.
4. (Answers will vary.) "No" should be the typical answer. (The teacher should review the idea that weather is the state of atmospheric conditions at a given location for a short period of time.)
5. (Answers will vary.) The temperature and humidity changed. (The temperature and humidity will usually change over a period of three days and so does sunshine.)
6. Either: (a) Yes, the air became warmer and more humid; or yes, the air became drier and cooler.
or (b) No, the air stayed about the same in regard to temperature and humidity.
7. Either: (a) Yes, a line of thunderstorms (indicated by cumulonimbus clouds, which are tall and columnar) came through the area and blocked the Sun (this is a cold front); or yes, high, wispy clouds were gradually replaced by lower and thicker layers of clouds (this is a warm front).
or (b) No, the clouds were scattered with no particular pattern.
8. Yes, thicker clouds appeared to interfere with sunlight, lowering the number of spins.
9. The greatest amount of energy was collected at noon (or 1 p.m. during daylight savings time).
10. Light energy is changed to electricity.
11. The Sun is highest in the sky (not overhead) at that time.
12. The most important variable in controlling the amount of energy collected by the solar cell is the height of the Sun in the sky. This variable is the angle between the Sun's rays and the solar cell if the cell is fixed in position. By orienting a line segment between two parallel lines representing solar rays, one can show that the distance is shortest between the parallel lines when the line segment is perpendicular to them, corresponding to the greatest solar intensity.
13. (Hypothesis Building) Build reflectors around the solar panel, or change the angle of the panel to face the Sun more directly, etc.
14. Answers will vary.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

Junior Solar Sprint, *So…You Want to Build a Model Solar Car* [NREL/BK-820-30826: revised 8/23/01]

BACKGROUND INFORMATION

This activity is the first of several preliminary classroom investigations leading to an understanding of the scientific phenomena underlying the operation of, and the eventual building of, a competitive model solar car. This competition is sponsored by the Junior Solar Sprint (JSS) Program, developed originally under the auspices of the U.S. Department of Energy and currently sponsored by the Northeast Sustainable Energy Association (NESEA) and the U.S. Army. Visit NESEA at www.nesea.org for complete information and more learning activities.

The purpose of this activity is to gain a more complete understanding of the natural solar and meteorological aspects of the solar car, and of solar energy collection in general, so that this information can be effectively used to modify the design components of the model solar car.

Solar energy absorption by the solar panel is optimized when the angle of insolation approaches perpendicular. Student-collected data should reveal this pattern, as collection closest to noon should produce the greatest number of spins on their motors.

The meteorology and astronomy components of the activity will give students the opportunity to explore weather information as they experience it and to think about some astronomy phenomena about which they might be able to deduce an explanation. Many of the questions are meant to stimulate thought and to lead to meaningful classroom discussion and clarification during post–data collection review.

The embedded astronomy questions in the data collection section of the activity ask the student to use the shape of the Sun (circular in appearance, the Sun represents a spherical shape in three dimensions) as a model for the shape of Earth. The gravitational forces acting within both bodies pull evenly in all directions around the gravitational center, producing this shape. Since both bodies also rotate about an axis, there is a slight bulging effect at the equator of both the Sun and Earth that technically changes the shape to an oblate spheroid. The Sun appears very large compared to more distant stars because it is so much closer to Earth. Earth remains in a nearly circular orbit (an ellipse of low eccentricity) about the Sun. Therefore, the Sun-to-Earth distance remains fairly constant (and the Sun looks about the same size on a day-to-day basis).

The Sun appears to move across the sky at a constant rate of 15° per hour, controlled by the rate of spin of Earth. Slight variations in the length of the solar day occur as a result of slight variations in the rate of Earth's movement in its orbit around the Sun. Because of these motions, the Sun will appear to be in about the same position in the sky at the same time of day over a short period of time (the duration of this activity). Over longer periods of time, the Sun will appear at different elevations in the sky, depending on the season of year, and will reach a maximum elevation on June 21 and a minimum on December 21. During the day the Sun appears to rise in the eastern sky. The position of sunrise also varies with the season. It usually rises due East on March 21 and September 23 but, as a result of changes in the orientation of Earth's axis in relation to the Sun, it rises north of East on June 21 and south of East on December 21.

Recording weather data and observations may reveal a change in air mass accompanied by the passage of a frontal boundary. Air masses are high-pressure units of air that have acquired the characteristics of a source region. Air masses affecting New York State usually originate over central/northern Canada (these air masses consist of cold, dry air) or the greater Gulf of Mexico region (these air masses consist of warm, moist air). As these air masses replace one another, usually a warm front precedes the maritime tropical (mP) air mass from the Gulf and a cold front precedes the continental polar (cP) air mass from Canada. The warm front is usually preceded by a series of clouds starting with extremely high cirrus (mare's tail) clouds. These clouds are gradually replaced by a series of lower and thicker stratus (horizontally layered) clouds, which produce long, steady rain events. The passage of a cold front is usually marked by the passage of a line of cumulonimbus (thunderhead) clouds, followed by a wind shift from the southwest to the northwest. The air behind each of these fronts is characteristic of the trailing air mass.
Clouds can be very effective reflectors of solar energy, blocking 60% or more of incoming radiation energy from the Sun. In general, the darker the cloud, the greater the amount of energy blocked by the cloud.

The more perpendicular the Sun's rays are to the collecting surface, whether that is Earth's surface or the surface of the solar panel, the more concentrated the energy will be and the greater the solar gain. This perpendicularity leads to greater solar energy collection and increased production of energy by the solar panel, as well as to warmer temperatures on Earth.

REFERENCES FOR BACKGROUND INFORMATION

Strahler, Arthur, *The Earth Sciences*, Harper & Row, 1963. This book in any of its many editions is an invaluable reference.

Any of several Earth science texts and review books (such as Hess et al., Spaulding) are helpful.

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(STUDENT HANDOUT SECTION FOLLOWS)

Name___________________________________

Date ___________________________________

During what part of the day can the most Sun power be collected?

Topic: During what part of the day can the most Sun power be collected? [Before you continue, write a brief hypothesis that addresses this question.]

____

____

Materials needed: Thermometer Solar cell Voltmeter
Timer
Outdoor work area with sunlight
Pinhole projector and/or sunshield (optional) Procedure (working in small groups is advised):

1. Assemble the equipment necessary to collect the sunlight data.
2. Take the equipment outside. Place the solar cell and voltmeter apparatus on a flat surface such as a sidewalk or table. Mark the location of the solar cell with chalk so that you can return to that same spot for further data collections.
3. Stand so that you are not blocking the sunlight to the solar cell. Connect the voltmeter as instructed by your teacher. Observe the DC voltage produced by the solar cell during a two-minute time period while one member of your group observes the Sun for cloud cover. BEING CAREFUL NOT TO LOOK CONTINUOUSLY AND DIRECTLY AT THE SUN, this observer should indicate to the group when clouds cover the Sun and how thick the clouds are. The rest of the group should observe the changes in voltage output from the solar cell to see what the **highest** and **lowest** voltages are during this two-minute period. Record your data below.

DATA TRIAL #1:
DATE:________________TIME OF DAY: _________________

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

4. Make a note of where the Sun is in the sky by locating a landmark on Earth's surface that the Sun is directly above when observed from your data collection area.

The Sun is directly above: ___________________________________

5. Record the temperature and humidity of the air outside.

Temperature:________°C.

Humidity: Very dry [--------------------------------] Very Humid (Place a check mark along the line that best indicates your group's opinion) or calculate an actual value.

6. Collect data for two more two-minute time trials. Record the data in the chart below. Be sure to have your observer watch for cloud cover over the Sun as before.

DATA TRIAL #2: DATE: TIME OF DAY:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

DATA TRIAL #3: DATE: TIME OF DAY:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

7. Calculate the average of the *highest voltages* recorded during your group's three data trials today (add the three data trials together, then divide by three).

Average highest voltage on day 1:_________________volts (rounded to the nearest hundredth volt)

8. Record this number on your teacher's MASTER DATA SHEET when you go inside.

9. Your group will be repeating the steps above on at least two more days decided upon by your teacher. Before you go inside on this first day, take a few minutes to answer the questions below regarding the source of energy for this activity.

During what part of the day can the most Sun power be collected?

A. Describe the shape of the Sun: ____
B. What do you think the shape of Earth would be when seen from the Sun?

____

C. If the Sun is only an average-size star, why does it look so large and why does it provide us with so much more energy than other stars?

____

D: If Earth and the Sun are in motion in space, why do they stay together and why does the Sun's apparent size change so little during the year?

____

10. **DAY 2** DATA COLLECTION: Record the data the same way you did on day 1. DATE:_TIME OF DAY: ___

The Sun is directly above: __________________________________

Temperature:_________°C; Humidity: very dry [--------------------------------] very moist

DATA TRIAL #1:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

DATA TRIAL #2:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

DATA TRIAL #3:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

Average highest voltage on day 2:_________________volts (rounded to the nearest hundredth volt)

11. **DAY 3** DATA COLLECTION: Record the data the same way you did on day 1. DATE:_TIME OF DAY: ___

The Sun is directly above: __________________________________

Temperature:_________°C; Humidity: very dry [--------------------------------] very moist

DATA TRIAL #1:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

During what part of the day can the most Sun power be collected?

DATA TRIAL #2:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

DATA TRIAL #3:

Output Voltage:	Amount of Cloud Cover:
Highest Voltage =	
Lowest Voltage =	

Average highest voltage on day 3:__________________volts (rounded to the nearest hundredth volt)

12. In the space below make a copy of the cumulative data chart collected by all classes during this activity.

13. In the space below construct a line graph of the cumulative data showing the relationship between the ***time of day*** and the ***average highest voltage***. [The assumption is that it is a self-contained class that meets all day, or that the teacher has several classes of the same subject that will pool their information for this graph.]

During what part of the day can the most Sun power be collected?

DEVELOP YOUR UNDERSTANDING

Answer the following questions, particularly on the basis of the information gathered during this activity.

1. Why does the Sun appear to be at about the same position in the sky on each of the days you collected your data?

2. How did the Sun's position in the sky change from its early morning position to its late afternoon position?

3. How did the data collected at the same time compare from day to day?

4. Was the weather the same each day you collected your data? ______________
5. How did the temperature and humidity compare? ______________________
6. Did the type of air mass over your area change during the collection period? ________ If so, describe the change. ____

7. Were any of the clouds present during your data collection caused by the passage of a weather front close to or through your area? ______________________________ Describe the pattern of clouds that led your group to this conclusion.

8. Did the weather affect the collection of the solar data? ______________________ Explain how. _____________

9. At what time of day was the greatest amount of energy collected from the sunlight?

10. How did the solar collector change the energy it received from the Sun?

11. Why do you think the greatest amount was collected at that time? _____________

12. What variable is most important in controlling the amount of energy collected by the solar cell? ____
13. What could your group do to increase the amount of solar energy collected by the solar cell mounted on the model solar car? ________________________________

14. Briefly design an experiment that would allow your group to test the hypothesis suggested by your response to item 13 above.