CCMR Educational Programs

Title:	**Energy and the Angle of Insolation**
Date Created:	August 10, 2006
Latest Revision:	August 10, 2006
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Appropriate Level:	Grades 8-10
Abstract:	Sun rays arriving at the Equator have high angles of incidence; radiation at low latitudes is more intense than at higher latitudes. The angle of incidence changes during a year producing seasonal climatic changes. The angle of incidence changes from sunrise to sunset. Photovoltaic cells are devices that capture the sun's energy and produce electricity.
Time Requirement:	One 45 minute block to introduce the material. One 85 min block to conduct the angle of insolation lab.
NY Standards Met:	• 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. • Standard 2— Students will access, generate, process, and transfer information, using appropriate technologies. • 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. • 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 • Standard 4 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. Key Idea 2: Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land. Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.
Sections to Document:	Background Purpose Materials Procedure Questions References
Materials:	(Students will work in groups of two or three) • solar panel • two patch cords (red and black) • digital current meter • one light source • plastic protractor paper on page 12 • graph paper • 30 cm ruler

ENERGY AND THE ANGLE OF INSOLATION

Name:_______________________________ Date:____________

Team members: ____

Background

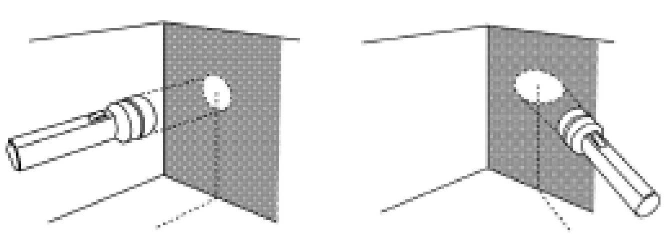
The main source of energy for all Earth's processes is the Sun. The **Solar Constant** is the average amount of solar radiation that reaches the earth's upper atmosphere on a surface perpendicular to the sun's rays. The solar constant has been calculated as 1353 Watts per square meter

After reaching our planet some of the solar energy is reflected, absorbed or scattered by the atmosphere, and some portion reaches the surface. **Insolation** is the incoming solar radiation that heats the Earth's surface.

The **Angle of incidence** is the angle at which solar radiation strikes the Earth's surface. It varies with latitude, season, and time of day, and has a direct effect on the amount of solar energy received at any location.

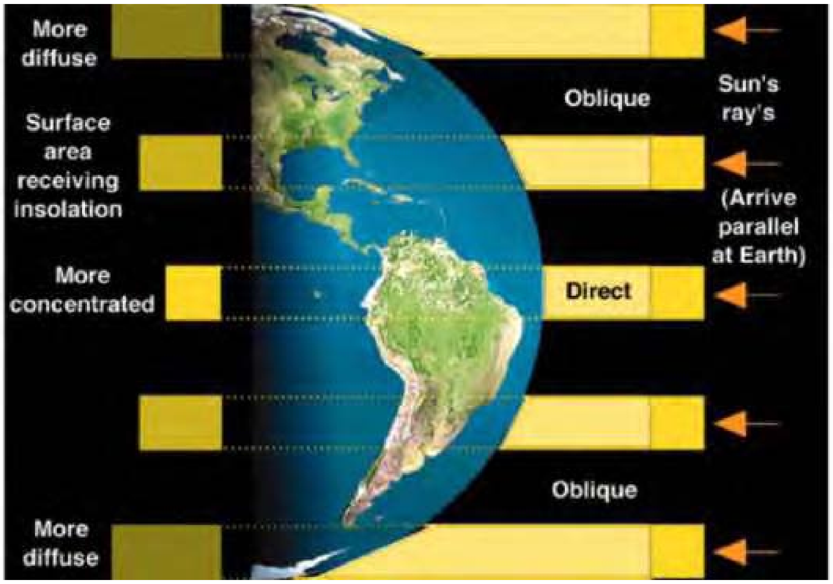
Angle of incidence and intensity of insolation; your teacher will shine a flashlight directly at a chalkboard so that it is exactly 1 meter away from the board and the angle at which the light strikes the blackboard is 0 degrees (perpendicular, straight-on). We can say the **angle of incidence** is 0 degrees at a distance of 1meter. The outline of this circular spot of light will be marked in chalk. If we now change the angle of incidence to 45 degrees the spot of light will be an ellipse, which will be marked in chalk as before. In both cases, the flashlight is 1 meter away from the center of the spot of light it makes on the board. But is the area inside each chalk figure the same?

If the flashlight is emitting the same number of photons in each case we should be able to compare the areas of the circle and the ellipse to see if there is a difference. If there is a difference then the smaller area is receiving a larger number of photons per unit of area and a solar cell placed flat on the chalkboard in this area would generate more current.



Angle of incidence and latitude: Because the Earth is rounded, at lower latitudes the sun rays arrive perpendicularly, making a 90^0 angle with the surface. The intensity of insolation is greater at the Equator. At higher latitudes, the angle is smaller. The intensity of insolation is lowest at the poles.

Examine the graph to answer the questions below.

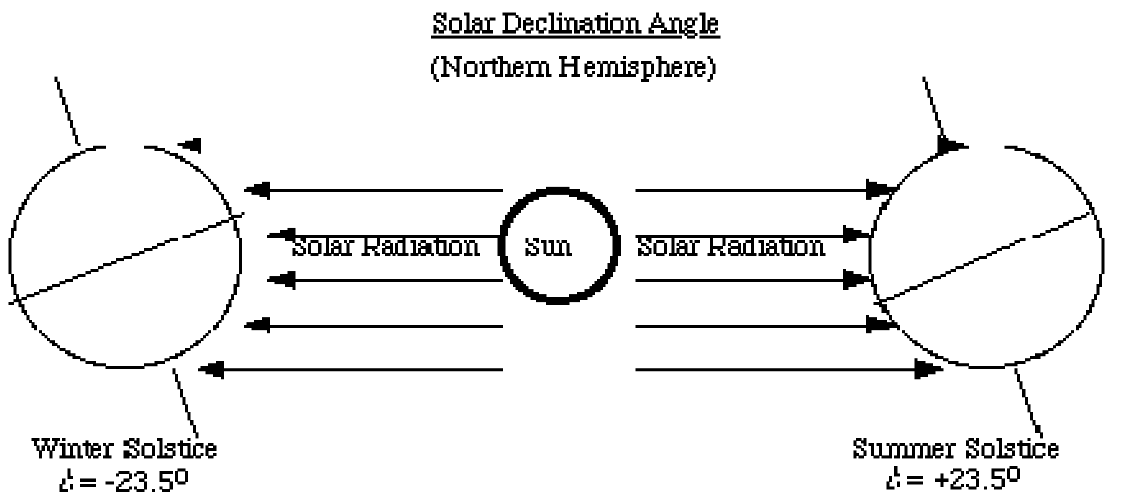


Which latitude has an angle of incidence equal to 90^0?

Where in the earth is the greater amount of intensity of insolation?

Angle of incidence and the Seasons:

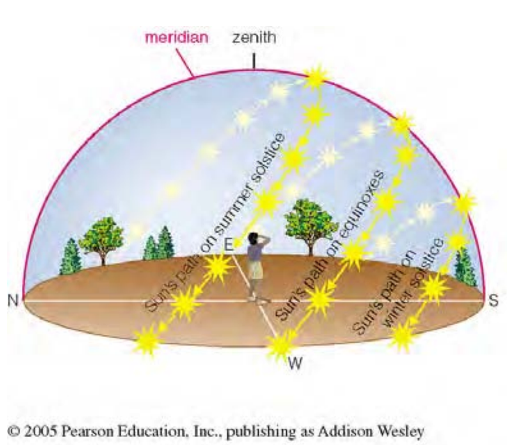
The earths' axis is tilted about 23.5^o. Viewed from the Northern hemisphere, on June 21 the earths' axis is tilted 23.5^o toward the sun. On December 21 the earths' axis is tilted 23.5^o away from the sun. The solar declination angle is 0^o on equinox dates. Changes in the solar declination angle as the earth revolves around the sun create cyclic changes in solar radiation and temperature. These radiation changes result in seasonal cycles.

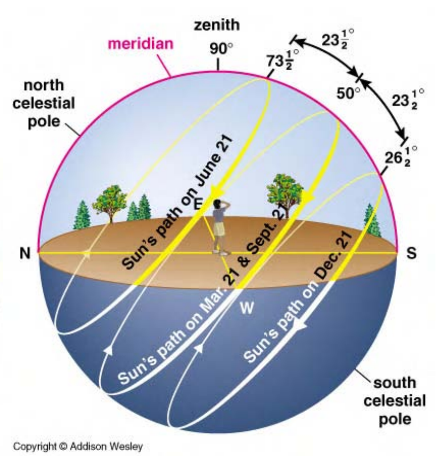


Dec. 21/22 Jun. 21/22

Angle of incidence in one day

As a consequence of the Earth's rotation, we observe the sun making a daily arch in the sky. At sunrise, the sun appears low in the horizon, the solar rays have a very low angle of incidence. The intensity of insolation is also low. At noon, the sun reaches the highest altitude; the angle of incidence and the intensity of insolation are the highest of the day. The angle of incidence and the amount of insolation will decrease until the sun disappears in West at sunset. Due to the tilt of the Earth, the sun never falls with a 90^0 angle of incidence at the Northern latitudes.

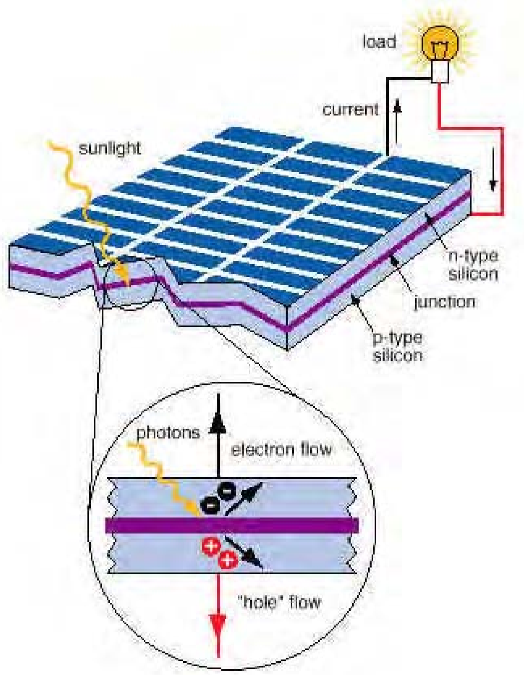




Electric energy from the sun

Modern human populations use mostly **fossil fuels** like petroleum, coal or natural gas to produce energy for cooking, transportation, heating, cooling and all industrial processes. The explosive demand of fossil fuels combined with an apparent depletion of those materials is promoting the use of alternative **sustainable energy sources** like wind, biomass, rivers, sunlight, etc.

Solar energy can be harnessed with a **photovoltaic cell**. This device converts light directly into electricity when photons, the "particles" in a beam of light, knock electrons loose from the atoms they strike. These electrons flow in one direction creating a current of electricity. The amount of electricity produced is dependent of two factors; first, the amount of light received by the surface and second, the material that makes the surface.



Using advanced microscopy, material scientists are designing new materials that are rapidly improving the efficiency of photovoltaic cells. The latest generation of solar panels is smaller, thinner, and cheaper than previous ones. Architects are designing buildings where solar energy is used instead or as supplement of traditional forms of energy.

Purpose: after finishing this lab you will be able to:

1. Examine the relationships between angle of incidence and energy.
2. Describe how the angle of insolation varies in one day, in one year, at different points in the Earth.
3. Propose the placement of solar panels that would produce the greatest savings to a home.

Materials:

solar panel
two patch cords (red and black)
digital current meter
one light source
plastic protractor or make a paper protractor using template attached
graph paper
30 cm ruler

Procedure:
A. Measure current at different angles of incidence

1. Fold the sheet of paper with the protractor drawing in three along the dotted lines. The drawing should appear on the outside. Fold the paper again so the paper protractor stands vertical on the table.

2. Ensure the meter switch is in the **OFF** position. Use the patch cords to connect the alligator clips to the solar panel (clip the red on the positive and the black on the negative) and the to meter **CURRENT** terminals (black to COM and red to mA)
Turn the Load selector knob to the **A circuit; stop at 20milliamperes**. See if a number appears in the "Ampere" meter. If nothing appears, then check your connections. If a negative number appears, you have the connections reversed.

3. Adjust your solar panel and light source so the angle of incidence is exactly at 90 degrees. (The panel directly facing the light source). Ensure the solar panel is placed exactly 30cm from the light source, or at whatever distance your teacher recommends. Place a 30 cm ruler, and keep it there. Then turn on the light. And check so is shinning on the center of the solar panel.

4. Look at the current as displayed in the ammeter window. When the reading is steady, record the current in table 1 below.

5. Using your paper protractor, and keeping the lower end at the center of the protractor, measure the current every 10 degrees.

Table 1. Current received at different angles of incidence.

Angle of incidence degrees)	90	80	70	60	50	40	30	20	10
Current (mA)									

6. Draw a line graph that has the angle of incidence on the horizontal axis, and the current on the vertical axis. Each measurement is a point in the graph.

7. Turn the meter off and return it to your teacher.

B. Graph monthly and Daily Insolation

Table 2. Average monthly global insolation year 2000. Southern latitudes have negative values; Northern latitudes are positive. Source www.aom.giss.nasa.gov/solar.html

Latitude (degrees)	Insolation (W/m^2)
-90	173.9
-80	179.7
-70	198.3
-60	237.9
-50	285.8
-40	330.1
-30	367.1
-20	394.7
-10	411.7
0	417.4
10	411.5
20	394.3
30	366.5
40	329.4
50	285.0
60	236.9
70	197.3
80	178.5
90	172.8

Table 3. Hourly solar radiation on March 21, 1990 in Syracuse, NY. Source: National Climatic Data Center Solar and Meteorological Surface Observation Network (SAMSON)

Hour	Insolation
	(W/m^2)
1	0
2	0
3	0
4	0
5	0
6	2
7	34
8	116
9	187
10	170
11	313
12	327
13	232
14	275
15	217
16	165
17	81
18	19
19	0
20	0
21	0
22	0
23	0
24	0

1. Draw a line graph of data on table 2. Use latitude as the independent variable.
2. Draw a line graph of data on table 3. Use hour as the independent variable.

Questions

1. What is the relationship between the angle of incidence of light and the amount of energy collected on a surface?

2. Why is it important to keep the center of the solar panel the exact same distance away from the light source for each different angle? Is this important when using sunlight as a source?

3. Why is that places located at low latitudes have tropical climates?

4. Syracuse, NY is at 43 degrees north latitude, Compare the length of daylight and angle of the sun on Dec 21 to the length of daylight and angle of the sun on Jun 21.

5. On the equinox all parts of the Earth receive 12 hours of day and night. If the poles receive the same amount of time of insolation then why are the poles colder at that time?

6. Why is it colder at sunrise and sunset and warmer in the middle of the day?

7. You are designing your dream house in Upstate New York. In order to use free energy from the sun, you will be installing solar panels on the roof. What side of the house will have the panels? Why?

8. Where in the world could you have a home where all the electricity needs could be supplied by solar cells? Would you get the same amount of electricity every day of the year? Explain your answer.

References:

READ on 10-Aug-06 http://www.bpa.gov/energy/n/projects/fuel_cell/education/Docs/2-SolarPanelOrientation.pdf

READ on 10-Aug-06 http://rredc.nrel.gov/solar/glossary/

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READ on 10-Aug-06 http://www.eere.energy.gov/RE/solar_photovoltaics.html

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