

2. Insolation and the Seasons

Driving Questions

The earth revolves around the sun once a year in an almost-circular (elliptical) path. The earth also rotates around an axis that is tilted about 23.5° from a line perpendicular to the plane of its path around the sun.

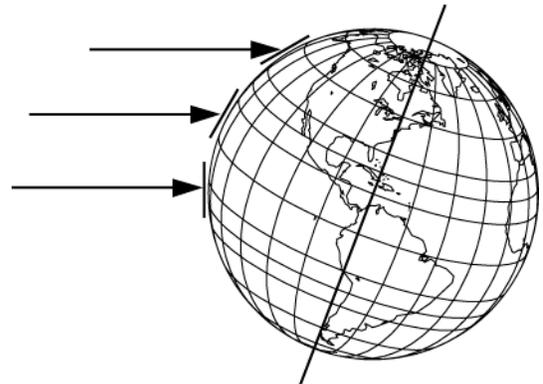
- ◆ How are these characteristics about the earth's movements related to the change in temperatures observed through the seasons?
- ◆ What affect does the angle of solar insolation have on the amount of solar energy delivered to a given area?
- ◆ Why do the warmest temperatures of the year often occur a month or two after the summer solstice?
- ◆ Why do the coldest temperatures of the year often occur a month or two after the winter solstice?

Background

Energy from the sun is by far the most important factor in our weather and climate. Solar radiation comprises more than 99.9% of the energy that warms the earth, drives the winds, and stirs the ocean currents. The solar energy that the earth receives is called insolation.

When the surface of the earth directly faces the sun at a 90-degree angle, insolation is highest. As the angle increases between the surface and the rays of sunlight, the same amount of energy is spread over a larger region and the insolation is reduced. This is known as the projection effect and is the reason why polar regions are much colder than equatorial regions. Therefore, the amount of insolation that a part of the earth receives during the day depends on the latitude at that part of the earth.

Earth spins daily around its axis (axis of rotation), which is tilted to approximately 23.5 degrees relative to its orbit around the sun. Thus, no matter the time of year, one part of the planet is always exposed to more direct insolation than another. As the earth orbits the sun, the amount of insolation will change at any particular location, causing the seasons to change. With its elliptical orbit, the distance from the earth to the sun varies by only 5 million miles, or about 3% of the average distance from the sun (the average distance from the sun is about 150 million miles) over the course of one year. The earth is closest to the sun (perihelion) around January 4th each year and furthest from the sun (aphelion) in early July.



At any point during the day, the amount of energy that a particular part of the earth receives changes due to the earth's rotation. One half of the earth receives sunlight, while the other half receives none. During rotation, the amount of sunlight reaching a specific location can vary due to terrain, latitude, and many other factors.

Materials and Equipment

For each student or group:

- ◆ Temperature sensor
- ◆ Small tripod base and rod
- ◆ Three-fingered clamp
- ◆ Protractor
- ◆ Scissors
- ◆ Cardboard, 15 x 15 cm
- ◆ Black construction paper, 15 x 15 cm
- ◆ Drinking straw
- ◆ Tape, roll
- ◆ Glue, bottle

Safety

Add this important safety precaution to your normal laboratory procedures:

- ◆ Do not look directly at the sun.

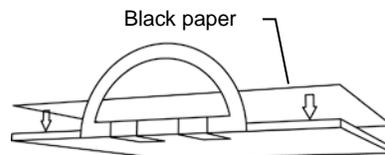
Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Part 1 – Make the solar panel and test it at 90° insolation

Set Up

1. ☐ Make a solar energy collection panel as follows:
 - a. Glue a piece of black construction paper to the surface of the cardboard.
 - b. Tape the protractor to it so it is perpendicular to the surface of the cardboard.
2. ☐ Tape the straw to the protractor so that it is perpendicular (90°) to the cardboard and the end of the straw is about 0.5 cm from the surface of the cardboard.
3. ☐ Tape the temperature sensor to the cardboard with its end near the center of the cardboard.
4. ☐ Take your solar panel, temperature sensor, data collection system, and rod stand outside. Find a sunny location sheltered from the wind.
5. ☐ Secure the solar panel using the tripod stand and 3-fingered clamp.

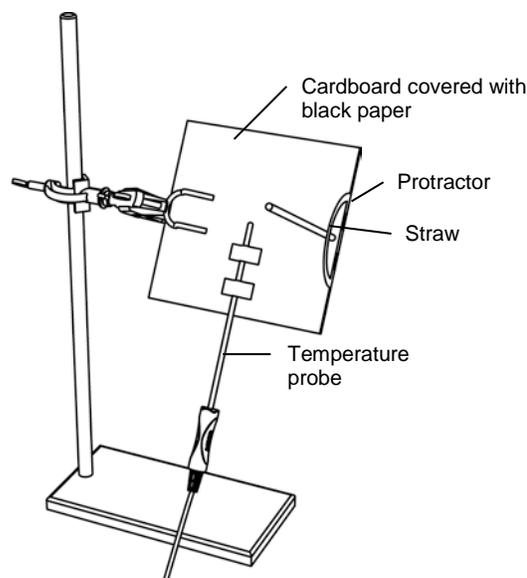


CAUTION: Do not look directly at the sun when performing the next step.

6. ☐ Arrange the angle of the surface of the cardboard so it is perpendicular (90°) to the sun and the straw is pointing at the sun.

Hint: When the surface of the cardboard is perpendicular to the sun, the light coming through the straw will be focused into a tight spot on the solar panel, and the shadow of the cardboard will be at its smallest size.

7. ☐ Start a new experiment on the data collection system.
8. ☐ Connect the temperature sensor to the data collection system.
9. ☐ Set up an appropriate display to view the data while it is being collected.



Insolation and the Seasons

10. Why did you cover the surface of the cardboard with black paper?

11. You will be testing three experimental situations with the cardboard positioned at:

- ◆ 90° relative to the light source
- ◆ 60° relative to the light source
- ◆ 30° relative to the light source

Will the position of the cardboard influence its temperature after 5 minutes at that position? Why?

Collect Data

12. Start data recording.

13. Record data for 5 minutes.

14. Write your data run number here _____.

15. Stop data recording.

Part 2 – Test the solar panel at 60° insolation

Setup

16. Remove the solar panel and take it to a shaded location.

17. Remove the straw and tape it 30° from perpendicular on the protractor such that when the straw is perpendicular to the sun, the solar panel will be angled towards the horizon 30°, resulting in an angle of insolation of 60°.

18. Fan the solar panel to increase the rate of cooling. When it returns to approximately its original temperature, secure it to the tripod stand.

19. Align the solar panel as you did before. This will angle the solar panel towards the horizon 30° from the last setup, and it will thus receive insolation at 60° .

CAUTION: Do not look directly at the sun.

Collect Data

20. Start data recording.
21. Record data for 5 minutes.
22. Write your run number here _____.
23. Stop data recording.
24. Remove the solar panel and take it to a shaded location.

Part 3 – Test the solar panel at 30° insolation

25. Repeat the procedure in Part 2 using a 60° tilt of the solar panel towards the horizon, and thus an angle of insolation of 30° .
26. Write your run number here _____.
27. Save your file, and clean up according to your teacher's instructions.

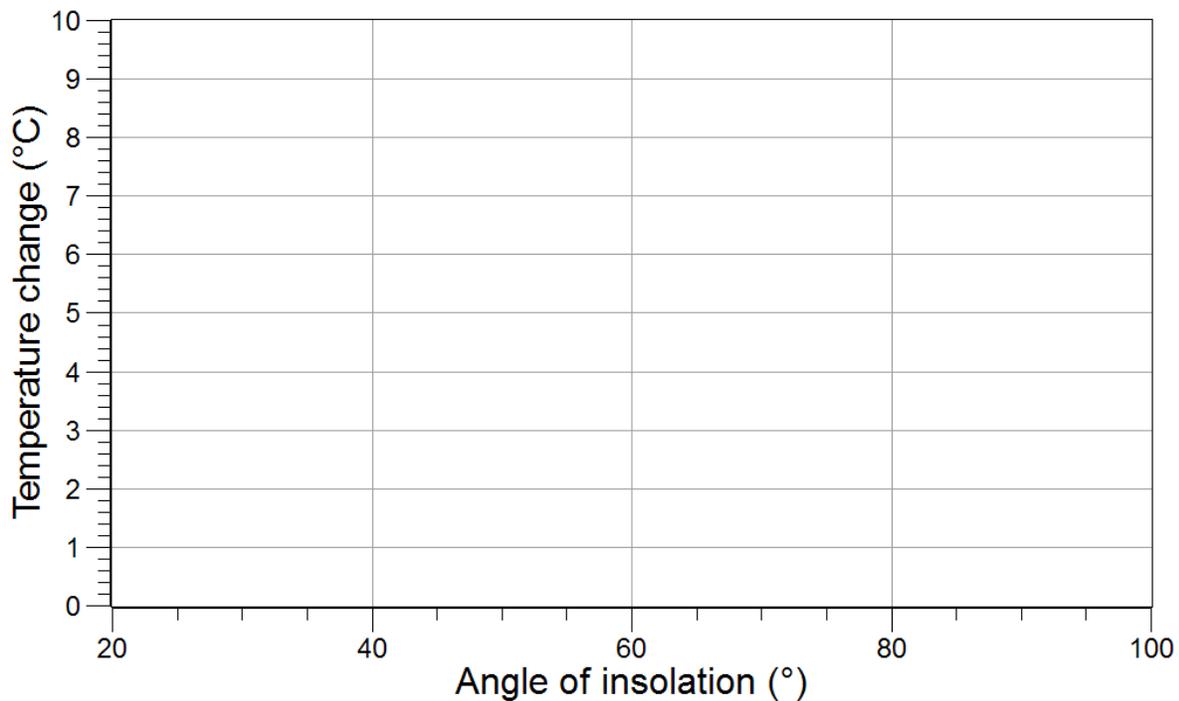
Data Analysis

1. Find the minimum and maximum temperatures for the three data runs and calculate the change in temperature.
2. Enter these values in Table 1.

Table 1: Temperature comparison at different angles of insolation

Angle of Insolation	Minimum Temperature	Maximum Temperature	Δ Temperature
90°			
60°			
30°			

3. Plot a graph of angle of insolation on the y-axis with change in temperature on the x-axis. Label the overall graph, the x-axis, the y-axis, and include units and scales on the axes.



Analysis Questions

1. Compare your results with your predictions.

2. What is the independent variable (the parameter you controlled) in this experiment?

3. What is the dependent variable (the parameter that changed) in this experiment?

4. What parameters did you try to hold constant in this experiment (controlled variables)?

5. Is the relationship between change in temperature and angle of insolation a linear one? Explain.

Synthesis Questions

Use available resources to help you answer the following questions.

1. Using the results of this activity and what you know about the motion of the earth around the sun as well as the tilt of the earth's rotational axis relative to its orbital plane, explain why seasons occur.

2. Why are seasons more pronounced the further you move away from the equator?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

- 1. During wintertime in the northern hemisphere, the earth's North Pole is:**
 - A. Tilted towards the sun relative to the South Pole
 - B. Tilted away from the sun relative to the South Pole
 - C. The same distance from the sun relative to the South Pole
- 2. During summertime in the southern hemisphere, the earth's North Pole is:**
 - A. Tilted towards the sun relative to the South Pole
 - B. Tilted away from the sun relative to the South Pole
 - C. The same distance from the sun relative to the South Pole
- 3. At the spring and fall equinoxes, the earth's North Pole is:**
 - A. Tilted towards the sun relative to the South Pole
 - B. Tilted away from the sun relative to the South Pole
 - C. The same distance from the sun relative to the South Pole
- 4. The warm temperatures of summer in the northern hemisphere north of the tropics occur primarily because:**
 - A. The earth is closer to the sun
 - B. The days are longer
 - C. The northern hemisphere is tilted towards the sun
 - D. Wind patterns change to bring warmer temperatures
- 5. The Tropic of Cancer and Tropic of Capricorn, respectively, are circles of latitude on the earth that mark the northernmost and southernmost latitudes at which the sun may be seen directly overhead (at the June solstice and December solstice, respectively). These circles of latitude are located at approximately**
 - A. 0° latitude
 - B. 23.5° latitude
 - C. 30.0° latitude
 - D. 60.0° latitude
 - E. 90.0° latitude