What Causes the Seasons?

Have you ever wondered why temperatures are cooler in the winter and warmer in the summer? This happens because the Earth's axis is tilted. The Earth remains tilted as it revolves around the sun. Because of this tilt, different locations on the Earth receive different amounts of solar radiation at different times of the year. The amount of solar radiation received by the Earth or another planet is called *insolation*. The *angle of insolation* is the angle at which the sun's rays strike a particular location on Earth. When the north end of the Earth's axis points toward the sun, the Northern Hemisphere experiences summer. At the same time, the south end of the axis points away from the sun and the Southern Hemisphere experiences winter.

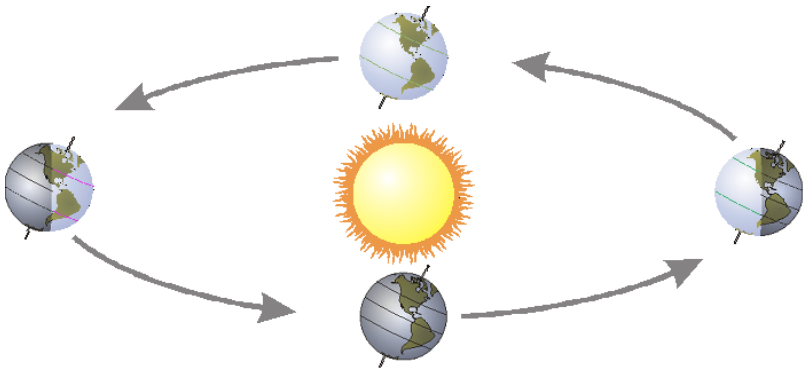

Figure 1

In this experiment you will investigate the relationship between angle of insolation and temperature change due to energy absorption from a simulated sun—a light bulb.

OBJECTIVES

- Monitor simulated warming of your city by the sun in the winter.
- Monitor simulated warming of your city by the sun in the summer.
- Interpret your results.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Temperature
ring stand
utility clamp
globe of the Earth
masking tape
metric ruler
lamp with 100 W equivalent bulb
20 cm length of string

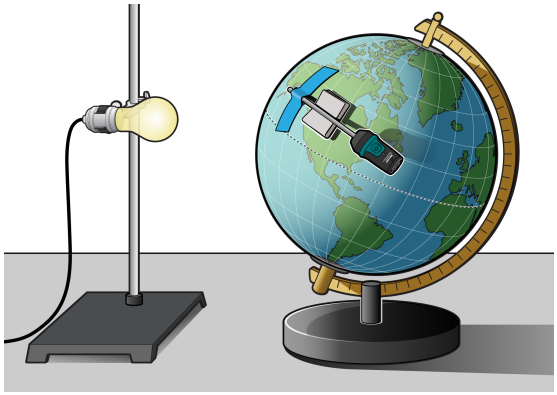

Figure 2

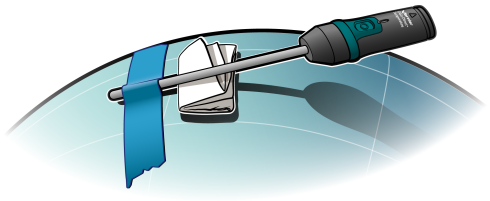

Figure 3

PROCEDURE

1. Prepare the light bulb (simulated sun).
   a. Fasten the lamp to a ring stand as shown in Figure 2.
   b. Stand the ring stand and lamp in the center of your work area.
   c. Position the globe with the North Pole tilted away from the lamp as shown in Figure 2.
   d. Position the bulb at the same height as the Tropic of Capricorn. **Note**: The sun is directly over the Tropic of Capricorn on December 21, the first day of winter.

2. Tape the Temperature Probe to the globe.
   a. Find your city or location on the globe.
   b. Tape the Temperature Probe to the globe with the tip of the probe at your location. Place the tape about 1 cm from the tip of the probe.
   c. Fold a piece of paper and wedge it under the Temperature Probe to keep the tip of the Temperature Probe in contact with the surface of the globe as shown in Figure 3.

3. Position the globe for winter (in the Northern Hemisphere) data collection.
   a. Turn the globe to position the North Pole (still tilting away from the lamp), your location, and the bulb in a straight line.
   b. Cut a piece of string 20 cm long.
   c. Use the string to position your location on the globe 20 cm from the bulb. **Note**: Do not turn on the lamp until directed in Step 6.

4. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.

5. Click or tap Mode to open Data Collection Settings. Change Rate to 0.1 samples/s and End Collection to 300 s. Click or tap Done.

6. Collect winter data.
   a. Click or tap Collect to start data collection.
   b. After the first temperature reading has been taken, turn on the lamp.
   c. When data collection stops after 5 minutes, turn the lamp off.

7. Record the beginning and final temperatures.
   a. When data collection is complete after 5 minutes, a graph of temperature *vs*. time will be displayed. To examine the data pairs on the displayed graph, click or tap any data point. As you tap each data point, the time and temperature values of the point are displayed. **Note**: You can also adjust the Examine line by dragging the line.
   b. Record the beginning and final temperatures (to the nearest 0.1°C) in your data table.

8. Position the globe for summer data collection.
   a. Move the globe to the opposite side of the lamp.
   b. Position the globe with the North Pole tilted toward the lamp. **Note**: This represents the position of the Northern Hemisphere on June 21, the first day of summer.
   c. Turn the globe to position the North Pole, your location, and the bulb in a straight line.
   d. Use the string to position your location on the globe 20 cm from the bulb.
   e. Do not turn on the lamp until directed in Step 9.

9. Collect summer data.
   a. Let the globe and probe cool to the beginning temperature that you recorded in Step 8.
   b. When the globe and probe have cooled, click or tap Collect to start data collection.
   c. After the first temperature reading has been taken, turn on the lamp.
   d. When data collection stops after 5 minutes, turn the lamp off.

10. Record the beginning and final summer temperatures using the Step 7 procedure.

DATA

	Winter	Summer
Final temperature (°C)		
Beginning temperature (°C)		
Temperature change (°C)		

PROCESSING THE DATA

1. In the space provided in the data table, subtract to find the temperature change for each season.
2. How does the temperature change for summer compare to the temperature change for winter?
3. During which season is the sunlight more direct? Explain.

4. What would happen to the temperature changes if the Earth were tilted more than 23.5 degrees?

5. As you move the globe from its winter position to its summer position, the part of the globe closest to the bulb changes. Describe how it changes.

6. What other factors affect the weather in a region?

EXTENSION

Repeat the experiment for other locations in the Northern and Southern Hemispheres.

What Causes the Seasons?

1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software or app (e.g., Logger *Pro* and Graphical Analysis). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information. **Note**: The printed version of the book and the PDF of the entire book (found in the Electronic Resources) include only the Logger *Pro* versions of the experiments.
2. If you use globes with adjustable tilt, make sure the tilt is 23.5 degrees.
3. You may wish to use a fan to cool the globe and probe between runs.
4. If you have 150 watt bulbs available, you may wish to use them to obtain larger temperature changes.
5. Longer data-collection periods can be used.
6. Encourage your students to collect data for other cities and locations as suggested in the extension.
7. The Surface Temperature Sensor also works well for this experiment.
8. If you are collecting data with EasyData (calculators), the following procedure can be used to display graphs of 2 (or 3) successive runs:
   a. After the first run, select [File] from the Main screen, and then select **STORE RUN**.
   b. Select [OK] to store your latest data and overwrite the data in Lists 3 and 4 (L3 and L4).
   c. Collect data for another run. **Note**: Do not save your last run.
   d. From the Graph screen, select [Adv] and then select **L2 AND L3 VS L1** (or **L2, L3 AND L4 VS L1** if you have 3 runs).
9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.
10. If you are using Go Direct sensors, see Visit **www.vernier.com/start/go-direct** for information about how to connect to your sensors in Graphical Analysis.

ESTIMATED TIME

We estimate that this experiment can be completed in one 45–60 minute class period.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions	ESS1.B: Earth and the Solar System ESS2.D Weather and Climate PS3.B Conservation of Energy and Energy Transfer PS4.B Electromagnetic Radiation	Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

SAMPLE RESULTS

	Winter	Summer
Final temperature (°C)	19.4	21.8
Beginning temperature (°C)	17.8	17.9
Temperature change (°C)	1.6	3.9

ANSWERS TO QUESTIONS

1. See the Sample Results.
2. Answers will vary. In the Sample Results, the summer temperature change is 2.3°C greater than the winter temperature change.
3. In the Northern Hemisphere, the sunlight is more direct in the summer because the earth is tipped toward the sun. A greater amount of solar radiation is directed at a smaller area.
4. If the Earth were tilted at a greater angle, summers would be warmer and winters would be colder.
5. When the globe is rotated from its winter position to its summer position, the lamp goes from a position directly above the Tropic of Capricorn in the Southern Hemisphere to a position directly above the Tropic of Cancer in the Northern Hemisphere.
6. Other factors that affect weather in an area include proximity to water, movement of air masses, and geographic features.