9. Seasons

What Makes us Fall Into Winter?

Driving Question

How does the earth's position in its revolution around the sun give us the seasons?

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Flashlight
- ☐ Meter stick or straightedge
- ☐ String, to suspend paper model (~1 m)
- ☐ Sticky tape
- ☐ Marking pens, various colors
- ☐ Protractor
- ☐ Compass
- ☐ Thumbtack or pushpin (optional)
- ☐ Scissors
- ☐ Sheet of tag board, card stock, or construction paper, 12" x 18"

Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not shine any light directly into others' eyes
- Use caution with sharp objects such as scissors and compass points

Thinking about the Question

You have experienced bright, sunny days in the winter as well as in the summer. You have probably noticed, however, that a winter sun is not able to warm you as much as a summer sun. In fact, if you live in a climate that has very cold winters, you may even have observed that the sun can shine on snow and ice all day long without melting it. How is it possible for the sun to shine so brightly, yet give so much less warmth than it does in the summer? The answer lies in the fact that the sun's light strikes the earth at more of an angle in the winter, while in the summer the sun's light strikes the earth more directly.

As you know, the Olympic Winter Games are held every four years, always at a cold, snowy location. Since the Games began in 1924 with the participation of sixteen European and North American countries, they have always been held during the northern hemisphere's winter, usually in February. Likewise, the Summer Games have been held in the northern hemisphere's summer. With only two exceptions, Melbourne, Australia in 1956, and Sydney, Australia in 2000, the Summer Games have been held in the northern hemisphere. Currently, over 200 nations participate in the Olympic Summer Games. What are some of the issues associated with holding the Summer and Winter Games primarily in the northern hemisphere? In your lab group, discuss the following questions:

1. When do countries in the southern hemisphere experience summer and winter?

2. If the Summer Games are held in Australia in July, in what season will the athletes compete?

3. When could an alpine nation in the southern hemisphere, such as Argentina or Chile, host the Winter Games?

4. How would northern hemisphere athletes be able to train for the Winter Games if they were held in the southern hemisphere?

During the year, there are four dates that are very special because they divide the year into the four seasons: winter, spring, summer, and autumn. These dates have been known since ancient times, and used to mark and regulate many of our most important human activities, such as planting and harvesting crops, organizing religious festivals, locating compass directions for navigation and for situating certain types of buildings. These dates are the solstices and equinoxes.

You may already know that a solstice occurs in June and again in December, and that the equinoxes occur in March and again in June. Discuss with your lab group members what season begins on each of these dates. Does the same hold true for both hemispheres? Be prepared to share your thoughts with the rest of the class.

Sequencing Challenge

☐ **The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.**

Construct a paper circle to represent Earth, using either a compass or a thumbtack and string.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Label each part of the Earth model. Tape a light sensor to the Tropic of Cancer.	Cut out the circle and fold it in half and in fourths to make creases in the paper to represent the equator and the polar axis.	Connect a light sensor to the data collection system. Record light data from the flashlight shining on the Tropic of Cancer.

Investigating the Question

☐ **Note:** When you see the symbol "❖" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. Is it possible to fold a paper circle so that it contains two creases that are at right angels to each other? If so, how could it be done?

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   b. How will the light intensity change when you shine a flashlight almost straight on to the light sensor compared to shining it at an angle to the light sensor?

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Part 2 – Making a model of the earth

In this part of the activity, you will use your geometry math skills to construct a circle, several diameters and chords, and to measure angles.

2. ☐ Using the method your teacher shows you, construct a large circle on your paper. As you work, be sure to mark the center of the circle to use as a landmark for some folds you will make in the following steps.

3. ☐ Cut out the circle. The circle represents the earth.

4. ☐ Fold the circle in half, making sure the fold goes right through the center of the circle. This crease represents Earth's equator. Why is it so important that this fold makes a crease right through the center of the circle?

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5. ☐ Fold the circle into quarters, forming a second crease that represents Earth's polar axis, the imaginary line that connects the north and south poles. To make this fold, first fold the circle in half at the equator, then in half again. When you open the circle up, you will have made a crease perpendicular to the equator.

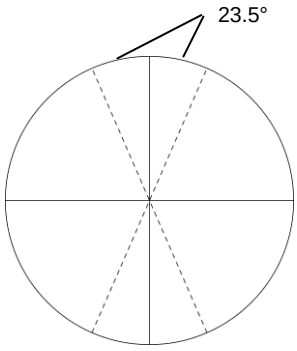
6. ☐ Use a meter stick or straightedge and marking pens to draw in the equator and label it with its name and zero degrees of latitude. Also mark East and West on the appropriate end of the equator.

7. ☐ Draw in and label the polar axis in the same way you did for the equator. Also mark North and South on the appropriate end of the polar axis. The north pole is at 90 degrees of latitude.

8. ☐ Use the protractor to mark an angle of 23.5 degrees off the north pole.

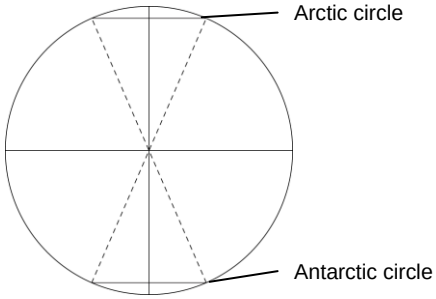
9. ☐ Construct a radius that forms the 23.5 degree angle with the polar axis.

10. ☐ Use the protractor to make three more radii, each forming 23.5 degree angles with the polar axis, to the right and to the left of the north and south poles. Your radii should form an "X" as in the diagram. These radii form diameters, which now represent the degree of Earth's tilt off its polar axis.



11. ☐ Construct a chord that connects the top of the "X." This chord represents the Arctic circle, which is located at 66.5 degrees north latitude. Draw and label the Arctic circle.

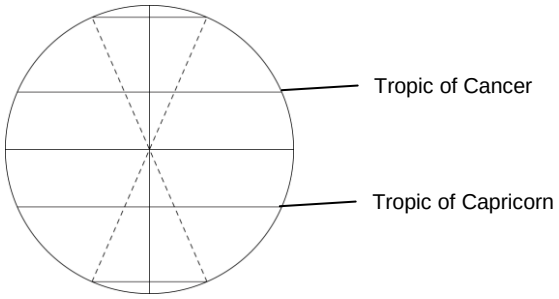
12. ☐ Construct a chord that connects the bottom of the "X." This chord represents the Antarctic circle, which is located at 66.5 degrees south latitude. Draw and label the Antarctic circle.



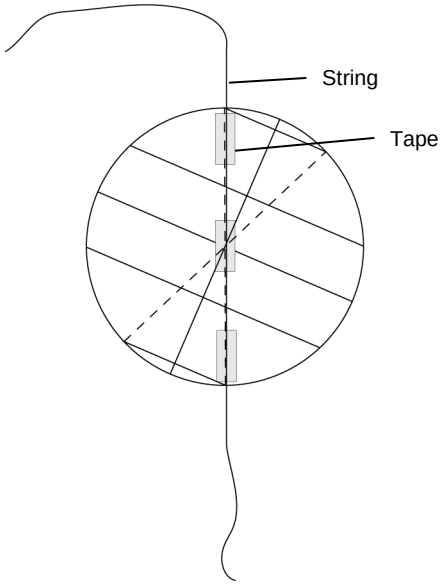
13. ☐ Use the protractor to mark angles that are 23.5 degrees above and below each half of the equator. Do not draw in these radii; make a mark on the circumference of the circle where the radii would intersect.

14. ☐ Construct a chord by connecting the two marks 23.5 degrees above the equator. This chord represents the Tropic of Cancer, which is located at 23.5 degrees north latitude. Draw and label the Tropic of Cancer.

15. ☐ Construct a chord by connecting the two marks 23.5 degrees below the equator. This chord represents the Tropic of Capricorn, which is located at 23.5 degrees south latitude. Draw and label the Tropic of Capricorn.



16. ☐ Tape string carefully along the diameter that connects the *left* side of the Arctic circle to the *right* side of the Antarctic circle. If you let your earth model hang from the string, the north pole should be angled to the right (at about where 1:00 would be on the face of a clock). Attach the string so that it extends beyond the edges of the circle.



Part 3 – Modeling and measuring Earth's seasons

17. ☐ Use tape to attach the light sensor to your earth model, directly on the Tropic of Cancer so that the black opening is even with the circumference. By measuring light intensity on the Tropic of Cancer, which hemisphere are you using as the reference for your seasons?

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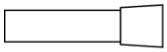
18. ☐ Start a new experiment on the data collection system. (1.2)

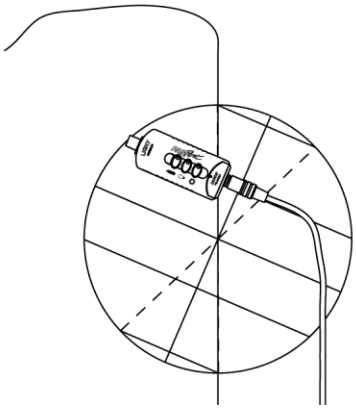
19. ☐ Use the sensor extension cable to connect the light sensor to the data collection system. (2.1) Select the maximum sensitivity range (0 – 2.6 lux) for the light sensor.

20. ☐ Display Light Intensity on the y-axis of a graph with Time on the x-axis. ◆(7.1.1)

21. ☐ Hold the earth model by the string, both from the top and the bottom. If necessary, tape your paper earth to the wall or blackboard according to your teacher's instructions. Notice how the axis tilt causes the Tropics of Cancer and Capricorn to be angled.

22. ☐ Model the sun as follows: standing about a meter away from the model, shine a flashlight onto the opening of the light sensor. Be sure to hold the flashlight so its beam is horizontal (parallel to the floor).





23. ☐ Darken the room.

24. ☐ Begin data recording. ◆(6.2)

25. ☐ After you have recorded between 20 and 40 seconds of light intensity data, stop recording. ◆(6.2)

26. ☐ Remove the tape from the light sensor. Now tape the light sensor on the Tropic of Cancer pointing in the opposite direction.

27. ☐ Take the model earth around to the opposite side of the sun.

28. ☐ Shine the flashlight onto the opening of the light sensor, as you did before. Hold the flashlight so its beam is horizontal (parallel to the floor), at the same height above the ground as before. Why is it so important to the model that the sun remains in the same place all the time?

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29. ☐ Begin data recording. ◆(6.2)

30. ☐ After you have recorded between 20 and 40 seconds of light intensity data, stop recording. ◆(6.2)

31. ☐ Observe your graph of light intensity data. You may need to adjust the scale of the graph to view all of your data. ◆(7.1.2) Record your observations below.

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32. ☐ Save your experiment according to your teacher's directions. ◆(11.1)

Answering the Question

Analysis

1. How did your predictions from Part 1 compare to your results in Part 2?

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2. How did your predictions from Part 1 compare to your results in Part 3?

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3. What season were you modeling when the north pole of your paper earth was tilted toward the flashlight? What season was modeled when the north pole was tilted away from the sun?

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4. Review your graph of light intensity versus time. What evidence do you see in your data that different amounts of light energy strike the earth's surface during different seasons?

5. Recall the demonstration at the beginning of this lab activity involving the flashlight shining on the graph paper. How does this demonstration relate to the angle of the light hitting the light sensor on you paper earth?

6. According to the work you did with your model earth, is it possible for the part of the model above the Arctic circle to receive no light from the flashlight's beam? If so, when is this possible (which season were you modeling at the time)?

7. Based on your knowledge of geography and of Earth's night and day cycle, where and when does this actually happen?

8. Alaska, in the United States, is often referred to as the "Land of the Midnight Sun." Where on your paper earth would you tape the light sensor to model and record data for this scenario?

9. The Tropic of Cancer in the northern hemisphere marks the farthest point north on the earth where the sun's rays strike the earth's surface directly straight on. This happens just once in each year. On which of the four special days (equinoxes or solstices) and at what time in the day does this happen?

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10. Based on earlier class discussion and on your light intensity data, why do you think that the surface of the earth receives more of the sun's light and heat energy in the summer compared to the winter?

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Multiple Choice

☐ **Circle the best answer or completion to each of the questions or incomplete statements below. You may want to look at a globe as you answer these questions.**

1 The earth is tilted on its axis by:

A. 66.5 degrees
B. 23.5 degrees
C. 90 degrees

2. Farmers in ancient Egypt would have awaited which of these special days to signal the wait for the Nile River's flood and the beginning of the spring planting season?

A. March equinox
B. June solstice
C. September equinox

3. Inhabitants of the _____ experience winter between June and September.

A. Equatorial region
B. Southern hemisphere
C. Northern hemisphere

4. The Olympic Winter Games are held every four years during _____, from the perspective of the inhabitants of the southern hemisphere.

A. The winter
B. The spring
C. The summer

5. Which of the following does *not* actually happen?

   A. Earth travels in an elliptical path around the sun every 365 days, causing a regular cycle of summer, autumn, winter, and spring we call the seasons.
   B. The axis on which the earth is tilted shifts back and forth to vary the North Pole's angle, creating the seasons.
   C. In part of the earth's trip around the sun, the north pole happens to be tilted toward the sun, while in the opposite part of the trip, it happens to be tilted away from the sun.

6. The Tropic of Capricorn is the point farthest south on the earth's surface where:

   A. The solstices can occur
   B. Ancient people would have been able to observe an equinox
   C. Light from the sun strikes the earth's surface directly

7. Light from the sun that strikes the earth's surface is less intense when it:

   A. Does not spread out at all
   B. Strikes the surface directly
   C. Spreads out over a larger area

8. Organize the following in order from the least amount of the sun's energy to the greatest amount of the sun's energy falling on one location:

   A. June solstice in New Zealand, September equinox in New Zealand, December solstice in New Zealand
   B. June solstice in Canada, September equinox in Canada, December solstice in Canada
   C. December solstice in New Zealand, September equinox in New Zealand, June solstice in New Zealand

9. Which best describes the arrival of spring in the northern hemisphere?

   A. As the earth experiences September equinox, its path around the sun brings it closer to having the North Pole tilted directly away from the sun.
   B. As the earth experiences March equinox, its path around the sun brings it closer to having the North Pole tilted directly toward the sun.
   C. As the earth experiences December solstice, its path around the sun brings it to the point where the North Pole is tilted directly away from the sun.

10. Which statement is *not* accurate?

   A. Rotation refers to the earth spinning on its axis, giving us the regular cycle of night and day.
   B. Revolution refers to the earth traveling in an elliptical path or orbit around the sun, giving us the regular cycle of seasons.
   C. The terms rotation and revolution refer to the same types of motion found throughout the solar system.

Key Term Challenge

☐ **Fill in the blanks from the randomly ordered words below. Note that not all of the words may be used:**

solstice	equinox	hemispheres	Tropic of Cancer
Tropic of Capricorn	equator	axis	tilt
revolution	orbit	rotation	seasons
poles			

1. A/an _____occurs once in June, when the day is longest in the northern hemisphere, and once in December when the day is shortest in the northern hemisphere.

2. The _____ is located at zero degrees latitude, meaning that it is neither north nor south, but exactly in the middle, while the _____ are located at 90 degrees of latitude.

3. On Earth, it takes 365 days to complete one _____ and to experience all of the seasons, while it takes 24 hours to complete one _____and experience a complete cycle of night and day.

4. The _____ are the result of the earth's tilt on its axis relative to its path around the sun.

5. The earth is divided into two _____ which experience opposite seasons during any given month.

6. At 23.5 degrees of south latitude there is an imaginary line, called the _____ _____ on maps, and marking the farthest point south that the sun's rays strike the earth directly.

7. Earth's _____ is tilted by 23.5 degrees, with the result that we experience seasons because the surface of our planet receives sunlight at different angles depending on our path around the sun.