Teacher Guide: Seasons: Why do we have them?

Learning Objectives

Students will…

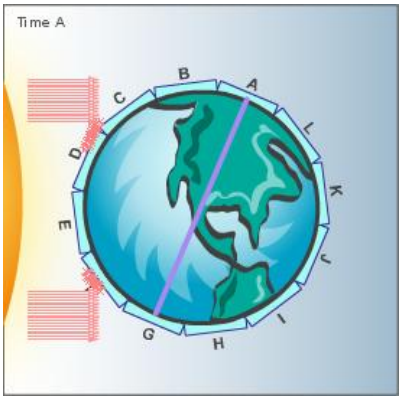
- Explore the relationship between the angle of the Sun's rays and the amount of solar energy that strikes the ground.
- Measure the amounts of solar radiation that strike different parts of Earth's surface on December 21 and June 21.
- Explain what causes the seasons.
- Understand that seasons are opposite in the northern and southern hemispheres:
  - December 21 is the start of winter in the northern hemisphere and the start of summer in the southern hemisphere.
  - June 21 is the start of summer in the northern hemisphere and the start of winter in the southern hemisphere.

Vocabulary

direct sunlight, Earth's axis, equator, indirect sunlight, northern hemisphere, North Pole, season, solstice, southern hemisphere, South Pole, summer solstice, winter solstice

Lesson Overview

The changing of the seasons affects our lives every day, but surprisingly few people can actually explain what causes these changes to occur. Probably the most common misconception is that seasons happen because of the changing distance between Earth and the Sun.



The *Seasons: Why do we have them?* Gizmo™ shows that it is the *angle* of sunlight that determines how much solar energy reaches Earth's surface. The more direct the sunlight, the hotter it will be. Because Earth's axis is tilted, the angle of sunlight that strikes a location will vary throughout the year.

The Student Exploration sheet contains two activities:

- Activity A – Students explore the relationship between the angle of sunlight and the amount of energy that strikes a surface.
- Activity B – Students measure the solar radiation that hits different parts of Earth's surface on December 21 and June 21.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Do you know what causes the seasons?** (15 – 20 minutes)
   Ask students to write down why they think seasons happen on a sheet of paper. The next day, read the different theories anonymously. Have your students vote on which theory they think is best. Afterwards, discuss the different theories and try to come to a consensus about the merits of each theory. Which theory explains the fact that summer in the northern hemisphere occurs when it is winter in the southern hemisphere?

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
   - How does the angle of the plate relate to the amount of energy it receives?
   - How does the angle of the plate affect how hot it will get?
   - Why is it warmer at the equator than at the poles?
   - Why is it warmer in the summer than the winter?
   - What season is it in the southern hemisphere right now?
   - Suppose Earth's axis were not tilted. Would we still have seasons?
   - What would seasons be like if Earth's axis were even more tilted?

5. **Follow-up activity: The angle of sunlight** (1 – 2 months)
Once a week, measure the angle of the Sun at noon. You can do this by measuring the length of the shadow of a vertical object of known height. To calculate the angle, you can use trigonometry:

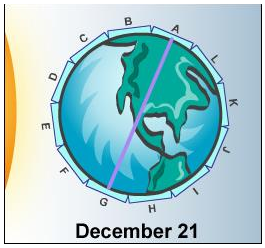
$$\theta = \tan^{-1}\left(\frac{h}{l}\right)$$

Where *h* is the height of the object and *l* is the length of the shadow. A more basic method is to make a scale model of the triangle on a sheet of paper, using centimeters instead of meters to measure distances. With this method, the angle can be measured directly with a protractor. (See the **Selected Web Resources** on page 3 of this document.)

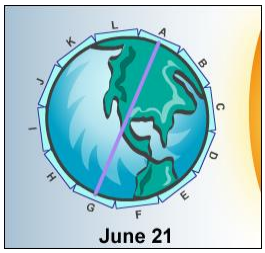
Every time you measure the angle, measure the air temperature as well. After you've collected enough measurements, graph your results. Northern hemisphere students will see that the angle decreases from June 22 to December 21, and increases from December 22 to June 21. Southern hemisphere students will see the opposite trend. The temperature graph will be much more erratic but will show the same general trend.

Scientific Background
Seasons on Earth are caused by the 23.5˚ tilt of Earth's axis and the orbit of Earth around the Sun. The four dates that mark the seasons are the two *solstices* (on or near December 21 and June 21) and the two *equinoxes* (on or near March 21 and September 23).

On December 21, the North Pole is tilted away from the Sun, and the South Pole is tilted toward the Sun. Locations in the southern hemisphere (plates E, F, and G on the diagram) will experience the most direct sunlight and the longest daytime of the year. This is the summer solstice in the southern hemisphere. In contrast, locations in the northern hemisphere (plates A, B, and C) will experience the least direct sunlight and the shortest daytime of the year. December 21 is the winter solstice in the northern hemisphere, the start of winter.



On June 21, the North Pole is tilted toward the Sun, and the South Pole is tilted away from the Sun. In the northern hemisphere (plates A, B, and C), the summer solstice is the longest day of the year, and the day with the most direct sunlight. In the southern hemisphere (plates E, F, and G), this date is the winter solstice, the shortest day of the year and the day that the noon sun is lowest in the sky.



On the equinoxes (March 21 and September 23), neither the North Pole nor the South Pole are tilted toward the Sun. On these days, both hemispheres receive the same amount of sunlight. All locations on Earth experience a 12-hour day and a 12-hour night on those dates.

The seasonal changes are most extreme in the polar regions. Above the Arctic Circle (66.56° N), the Sun never rises on December 21, and the Sun never sets on June 21. The opposite is true for locations south of the Antarctic Circle (66.56° S). Locations in tropical areas experience much less variation in day length and intensity of solar radiation during a year.

Astronomy Connection: The tilt of Earth's axis

Currently, Earth's axis is tilted at an angle of 23.44°. This tilt remains the same as Earth orbits the Sun, and accounts for the seasonal variations that occur through a year. Over time, however, this value varies about 2.5° in a regular cycle with a period of 41,000 years. Earth's axis also *precesses*, or describes a circle, with a period of 26,000 years. (Earth's axis is currently aligned with Polaris, but in the past Earth's axis has pointed at other stars.)

Similar cycles occur in other aspects of Earth's orbit. For example, the *eccentricity* of Earth's orbit, or how elliptical the orbit is, varies with a period of 413,000 years. Together these variations, called *Milankovitch cycles*, help explain the regular Ice Ages that Earth has experienced in the past several million years.

Selected Web Resources

The seasons: http://csep10.phys.utk.edu/astr161/lect/time/seasons.html
Seasons explanation: http://www.astronomy.org/programs/seasons/index.html
Measuring shadows: http://www.sciencenetlinks.com/lessons.cfm?BenchmarkID=11&DocID=7
Milankovitch cycles: http://www.emporia.edu/earthsci/student/howard2/theory.htm

Related Gizmos:
Summer and Winter: http://www.explorelearning.com/gizmo/id?656
Seasons: Earth, Moon, and Sun: http://www.explorelearning.com/gizmo/id?468
Seasons in 3D: http://www.explorelearning.com/gizmo/id?463
Seasons Around the World: http://www.explorelearning.com/gizmo/id?465
Heat Absorption: http://www.explorelearning.com/gizmo/id?655