Reason for the Seasons

Materials

For the class:

- ◊ one or two globes mounted so that the axis of rotation is tilted to 23.5° from vertical
- ◊ a bright light source (lamp with at least a 75-watt bulb and without a shade)

Vocabulary

Orbit: The path followed by one body revolving about another body.

Ellipse: An oval; a closed curve in which the sum of the distances from two fixed points to any point on the curve is constant.

Axis: A straight line about which a figure or body is symmetrical.

Rotation axis: A straight line around which a body rotates.

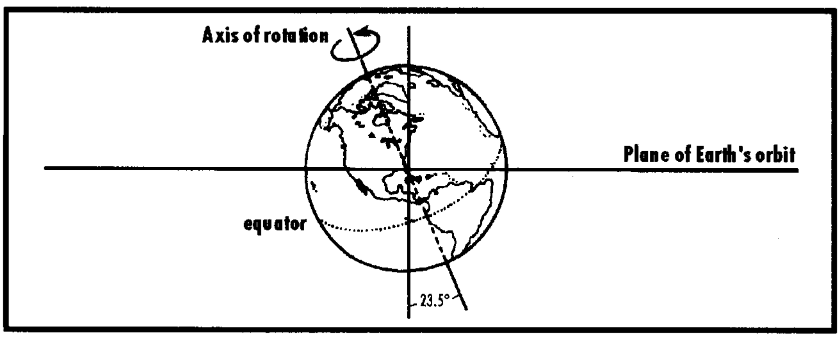
What Is Happening?

Earth travels around the Sun in a slightly elliptical orbit. Because of this orbit, Earth's distance from the Sun varies slightly depending on where Earth is in its orbit. Contrary to popular opinion, however, Earth's seasons are only slightly related to this small variation in the planet's distance from the Sun. This is one of the most common misconceptions in astronomy. Mistakenly, people think that when Earth is farthest away from the Sun, it is winter; and when Earth is closest, summer occurs. The change in distance is, in fact, not great enough to cause any significant change in temperature. As a matter of fact, Earth is closest to the Sun in January, when it is winter in the Northern Hemisphere. Furthermore, if distance from the Sun determined the seasons, then all of Earth should have the same season at the same time. This is not the case. When it is summer in the Northern Hemisphere, it is winter in the Southern Hemisphere.

Instead, the reason Earth has seasons has to do with the angle at which Earth rotates as it revolves around the Sun. Generally, when objects rotate, they rotate around a vertical axis, just like a spinning top or a basketball spinning on someone's finger. Earth, however, rotates around an axis tilted relative to its orbit. The angle of the tilt is 23.5° from vertical (see figure 5).

Due to this tilt of Earth's rotation axis, some parts of Earth receive more vertical rays of Sunlight and others receive more slanting rays. Slanting rays of sunlight are less intense and do not cause as much heating as more vertical rays of sunlight. In summer in the Northern Hemisphere, the north pole is tilted toward the Sun, as shown in figure 6. This arrangement allows for the more vertical rays of sunlight to strike the Northern Hemisphere and, therefore, the United States.

In winter, the direction of tilt is the same as in summer, but since Earth is now on the opposite side of the Sun, the Southern Hemisphere is tilted toward the Sun and the Northern Hemisphere is tilted away (see figure 7). The rays that



(Not to scale)

FIGURE 5 Tilt of Earth's Rotational Axis

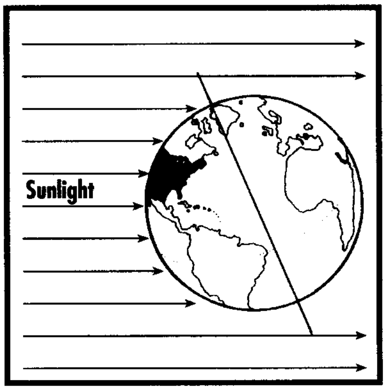


FIGURE 6
Summer in the Northern Hemisphere

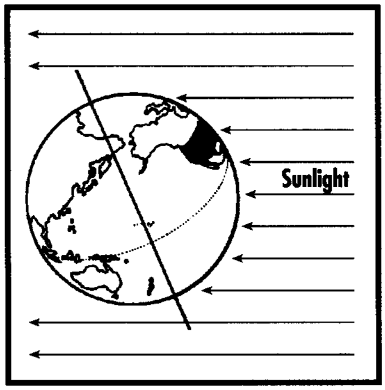


FIGURE 7
Winter in the Northern Hemishpere

strike the Northern Hemisphere are more slanting and do not cause as much heating. Fall and spring are simply the points between these two extremes.

Another consequence of having a tilted axis is that the day's length varies throughout the year. This further contributes to seasonal temperatures; the longer the day, the more energy received from the Sun to warm the atmosphere and the less time for that warmth to dissipate.

This explains seasonal temperature variations, but day-to-day changes are moderated by Earth's atmosphere. That is why the hottest and coldest days of the year rarely occur on the summer and winter solstices, respectively.

Important Points for Students to Understand

- ◊ Earth's distance from the Sun has little to do with the seasons.
- ◊ The seasons are caused by Earth's axis of rotation being tilted 23.5° from the vertical with respect to its orbital plane.
- ◊ When a hemisphere is tilted toward the Sun, summer occurs, and when it is tilted away from the Sun, winter occurs there.
- ◊ Earth's orbit is only slightly elliptical; not nearly as elliptical as most people think.
- ◊ Slanting rays of sunlight do not heat the surface of Earth as much as vertical rays of sunlight.

Time Management

This demonstration should take less than half a class period.

Preparation

Misconceptions can be very hard to correct in students. One strategy for addressing misconceptions is making the students aware of their own ideas. This can be accomplished in the activity by having the students write out their understanding of why seasons occur before doing the activity. This serves three purposes. First, it gains the students' attention. Second, it makes them aware of their own beliefs. Finally, it provides a resource to help the teacher focus instruction on misconceptions that the students identify.

In this activity, one or two globes and a bright light are used to demonstrate why the seasons occur. Be sure that the light source is operable.

For further information, refer to Reading 12, "Reason for the Seasons."

Suggestions for Further Study

Most textbooks depict Earth's orbit as much more elliptical than it actually is. Students could plot a scale model of Earth's true orbit to see that it more closely resembles a circle than an ellipse. This would enable them to see that distance is not a factor in the seasons. Include instructions on how to draw ellipses of varying eccentricity.

Students may also be interested in trying to devise a more graphic way of explaining the reason Earth has seasons. It would be informative for them to study other planets to learn if they have seasons.

Suggestions for Interdisciplinary Reading and Study

Seasons are a common theme in music, literature, and art. Encourage students to find all kinds of music (classical, popular, folk) that have references to the seasons. The poem "Winter Moon" (at the beginning of Activity 11) by Langston Hughes provides a bridge from astronomy to meteorology. Ask the students what changes occur in the atmosphere from season to season to make the Moon appear different. In many locations, winter air is much less humid than at other times, making for a much sharper image of the Moon. The poem "Seasons" (at the beginning of this activity) by Evelyn Nitso provides a description of each season.

Answers to Questions for Students

1. The light should have been brighter on the United States on the globe which had the United States tilted toward the Sun. In the diagram for the procedure section for this activity, this would be the globe on the right.
2. When the United States is tilted away from the light (the Sun), it receives more slanting rays of sunlight, and the light is therefore not as intense.
3. As the globe was walked around the light, the students should have observed a cycle of increasing and then decreasing intensity depending on where the globe was originally positioned in the orbit.
4. Winter and summer occur on opposite sides of the light when the intensity of light on the United States is the dimmest and brightest respectively. Fall and spring occur on opposite sides of the light half-way between winter and summer.
5. Somewhere in the Southern Hemisphere. Chile, for example.
6. Yes. For example, winter in the northeastern part of the United States is much longer and colder than in the southeast. This is because the farther north and south from the equator, the shorter the winter days are.
7. Depends on the present season. Generally, it would be the opposite of what the season is in the United States. If it is spring in the United States, it would be fall in Australia. This is because Australia is in the Southern Hemisphere and the United States is in the Northern Hemisphere.
8. They would have to have a tilt in their axes of rotation just as Earth has. It would not have to be a 23.5° tilt, however.