Does Earth-Sun Distance Cause Seasons?

This document is from a draft version of The Space Science Sequence for grades 6–8, Unit 2, *Why Are There Seasons?* produced by the Great Explorations in Math and Science (GEMS) project at Lawrence Hall of Science, University of Califonia, Berkeley in collaboration with the NASA Sun-Earth Connection Education Forum and the NASA Kepler mission.

To find out how to obtain the entire Space Science Sequence or the specific GEMS teacher guide, The Real Reasons for Seasons, visit the GEMS website:

http://www.lhsgems.org

UNIT 2

Why Are There Seasons?

Many of us hold onto and embellish our erroneous personal explanations for the seasons throughout all the years of school, and we become very good at fitting new information into our old, comfortable private models. Our students often do the same. They arrive in class with their own frameworks and preconceptions, sometimes also called alternate conceptions.

No single experience is likely to move all of your students from their initial conceptions to a full and accurate understanding. Research indicates that one of the best ways to get people to correct their misconceptions is to provide them with revealing experiences and allow time for them to compare and discuss alternative ideas/explanations so they themselves discover the flaws in their own thinking.

Common Misconceptions About Seasons People say, "When the Earth is closer to the Sun, we have summer; when the Earth is farther from the Sun, we have winter."	Many people think that the Earth's orbit around the Sun is a skinny (elongated) ellipse, causing Earth's distance from the Sun to vary dramatically at different points.	Many think that the Sun is "off-center" within our orbit, again causing Earth to be closer or farther away from the Sun at different times.	Some people know that the Earth's tilt has something to do with the seasons, and they think that the tilt makes us significantly closer to the Sun at certain times of the year.
What's wrong with those ideas?	The Earth's orbit is indeed elliptical, but it is not at all "skinny." It is very nearly a perfect circle.	True, the Sun is at one focus of Earth's elliptical orbit, but the orbit is so nearly circular that the Earth-Sun distance remains very nearly constant throughout the year.	The tilt of the Earth is a key factor, but the tilt does **not** make any significant difference in the **distance** to the Sun. Because the distance from the Earth to the Sun is so enormous, the difference in distance caused by the tilt is not significant.

If it's not distance, what DOES cause the seasons?

1. The Earth spins on its north-south axis, and the spin axis is tilted so that the North Pole points at the North Star all the time. As the Earth revolves around the Sun, the northern hemisphere is tilted toward the Sun at some times of the year (A) and away from the Sun at the other part of the year (B).

2. When the Northern Hemisphere is tilted toward the Sun, it has summer because:

   a. There are more hours of daylight.

   b. Sunlight strikes the Northern Hemisphere at a higher angle (more perpendicular), making the sunlight more intense on the ground (or water), and resulting in more heating.

Unit 2. Why Are There Seasons?

Session Summaries

Session 2.1 Seasons Questionnaire
Sudents answer questions about seasons. Their responses will give you an idea of their current understanding of seasons and related concepts. Most of the subsequent activities refer back to this questionnaire, in a deepening re-examination of concepts, and to help students construct their revised ideas. Students begin modeling the distance from the Earth to the Sun by drawing a football field, placing the Sun on the 50-yard line, and making the maximum change in Earth-Sun distance less than 1 yard.

Key concepts added to a classroom Concept Wall during this session:
• Scientists use models to demonstrate and explain how nature works.
• (Review) The Earth spins once every 24 hours; Earth orbits the Sun once a year.

Session 2.2 Distance to the Sun and Temperature The class sets up yet another scale model of the of the Earth-Sun system and finds that distance to the Sun is very large compared with the size of the Earth. They find out that the true shape of the Earth's orbit around the Sun is very nearly a perfect circle. The class revisits and discusses question #3 of the questionnaire. They then examine graphs of *Temperatures Around the World* in different months of the year. They discover interesting relationships in temperature changes—that the pattern of temperature change from summer to winter in one hemisphere is reversed with respect to the opposite hemisphere. Students then discuss the evidence they have so far in evidence circles to affirm or reject the idea that the Earth-Sun distance is responsible for seasons.

Key concepts added to Concept Wall during this session:
• The Earth's orbit is nearly circular; this is evidence that seasons are not caused by changes in Earth's distance from the Sun.
• Different parts of the Earth have different average temperatures at the same time; this is evidence that seasons are not caused by changes in Earth's distance from the Sun.
• Scientific explanations are based on evidence from investigations.

Session 2.3 Days and Nights Around the World
Students graph and analyze number of hours of daylight from cities around the world. They find a mirror pattern similar to the patterns the saw in analyzing Temperatures Around the World.

Key concepts added to Concept Wall during this session:
• Different parts of the Earth have different day lengths at the same time; this is evidence that seasons are not caused by changes in Earth's distance from the Sun.

Session 2.4. Modeling Seasons
Students create a model of the Sun-Earth system to arrive at the best explanation for what causes the changes in number of hours of daylight in different seasons. Using model Earths around a light bulb Sun, students first model an Earth with no tilt. Then they tilt the Earth's north pole toward a fixed "north star" on the wall, and model one of the real reasons for seasons. They observe the different day lengths of cities marked on the model Earths.

Key concept added to Concept Wall during this session:
• The Earth's north pole is tilted toward the North Star as the Earth orbits the Sun; this orientation is what affects day length for different locations on Earth.

Session 2.5. Intensity of Sunlight
Students extend the model of the previous session to see how the intensity of sunlight striking the ground is affected by the angle at which the sunlight hits the ground in different seasons.

Key concept added to Concept Wall during this session:
• Summertime sunlight falling on the Earth at a higher angle is more intense than the wintertime sunlight that falls at a more of a slant.

Session 2.6. Seasons Unraveled.
In closure, students return to the survey, discuss the entire unit, and summarize the various elements they have found that help explain the causes of seasons.

Key concept added to Concept Wall during this session:
The main causes of the seasons are that the tilt of Earth's apin axis results in:

a. Varying hours of daylight at different times of year and
b. Varying intensity of sunlight striking the ground at varying angles resulting in variation in heating at different times of year.

CORE SEQUENCE

Unit 2:
Why are there Seasons?

SESSION 2.2

Distance to the Sun

Session 2.2 Overview

Sun-Earth Scale Model

The scale of the Earth-Sun system is a key to understanding seasons. The class sets up another scale model of the of the Earth-Sun system, this time in metric units and with a 3-D Sun. They find that distance to the Sun is enormous compared with the size of the Earth. In an optional ellipse drawing activity, students can find out that the true shape of the Earth's orbit around the Sun is very nearly a perfect circle.

Evidence Circle: Do Changes in the Earth-Sun Distance Cause the Seasons?

Students discuss the evidence they have so far (Scale models and Temperature data) in evidence circles to affirm or reject the idea that the Earth-Sun distance is responsible for seasons.

What You Need

For the class:

❒ 1 overhead projector
❒ 1 Model Sun—10 cm (4") diameter ball
❒ 1 Model Earth, 1 mm diameter ball of clay on a pin or toothpick
❒ 1 hula hoop *or* large round embroidery hoop

For each group of 3–4 students:

❒ 1 *Apparent Size of the Sun* sheet
❒ 1 *ruler*

For each student:

❒ 1 pencil
❒ *(Optional)* 1 calculator

Getting Ready

1. Decide where would be the best place to take the class for the short scale model activity at the beginning of the session. Find a spot that will allow you to place a 1 mm model Earth 10 meters away from the 10 cm model Sun. Do this by pacing off 10 long strides in a straight line. If you're lucky, this can be done along a diagonal in the classroom between opposite corners, with some nudging of desk positions.

2. Make a copy of the Apparent Size of the Sun sheet for each group of 3–5 students.

A Sun-Earth Scale Model

1. A 3D metric Sun-Earth scale model. In the previous session, we made a 2-D paper football field model of the Earth-Sun system in a drawing using yards and miles to tell scale. If you have already done the Sun-Earth model in Unit 1 Session 1.2, then tell the students the class will bring back that model briefly: it was a 3 dimensional scale model using metric units. The scale of the model is 140,000 km = 1 cm. Have students write down that scale on a piece of paper as their record of this scale model. The Earth in this model is smaller than the classroom globe: only about 1 mm in diameter, or less than the size of most pinheads. Hold up the 1 mm diameter ball of clay on the tooth-pick or pin. Have students write down the scale size of Earth (1 mm). If you have not done the Unit 1 Session 1.2 model activity, now ask, **"At this scale, how big do you think the Sun would be?"** Hold up the 10 cm diameter ball. Have students write down the scale size of the Sun (10 cm).
Reiterate: Scale size of Earth: 1 mm. Scale size of Sun: 10 cm.
Scale: 1 cm ≈ 140,000 km.

2. How far is the Sun in this model? Ask "At this scale (140,000 km = 1cm), how far away from Earth should the Sun be?" [About *10 meters* from the Earth.] Have them record 10 m on their paper as the distance from Earth to Sun in this model.

3. Pace the scale distance to the Sun. Explain (or remind) the students that in this scale model a meter in very rough terms is about one "pace," about the distance of one large step as one is walking. In a suitable location, pace off the distance to the Sun in this scale model, having a student walk 10 "giant"paces from the model sun. Invite students to students go near the model Earth location 10 meters from the model sun, and see that it looks about the same size as the real Sun in the sky.

4. About question # 5 on the Seasons Questionnaire [Is Earth's orbit shaped more like an ellepse, an oval or a circle?]. Remind the class of the size of the Earth at this scale: less than the size of the head of a pin. Ask **"Is Earth's orbit shaped more like a skinny ellepse, an oval or a circle?"** [Circle]

5. About question #4 on the Seasons Questionnaire [Does Earth's tilt make part of the Earth closer to the Sun?]. Explain that some people may have thought the United States is closer to the Sun in June. Ask, "Does a tilt of the Earth really make the United States closer enough in summer to make a big difference in temperature?" In regard to this question, have students

Sample calculation:

	Diameter [in km]	Distance from Earth	Scale Diameter	Scale Distance
Earth	12,750	0	~ 1 mm	0
Moon	3,480	384,400	0.25 mm	2.75 cm
Sun	1,390,000	149,600,000	~ 10 cm	10.7 meters

LANGUAGE OF SCIENCE

SPACE SCIENCE-SPECIFIC VOCABULARY
- **ellipse**
- **orbit**
- **hemisphere**
- **latitude**
- **equator**
- **longitude**

SCIENCE INQUIRY VOCABULARY
- **evidence**
- **model**

If time allows, you might want to give your students the actual diameters and distances and ask them to compute the scale model's diameters and distances. Have them divide the values below by 140,000*:
[Moon optional]

	Diameter [in km]	Distance from Earth
Earth	12,750	0
Moon	3,480	384,400
Sun	1,390,000	149,600,000

* If you have a 10 cm diameter model Sun, the scale of the model is

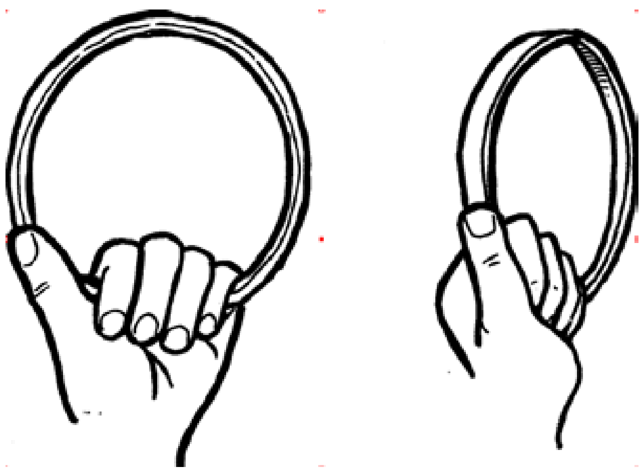
(1,390,000 km) ÷ (10 cm) ≈ 140,000 km/cm

This scale can also be expressed 1 cm ≈ 140,000 km.

compare the diameter of the model Earth (clay) with the distance to the Sun in the model. They should start to see that the tilt of the Earth makes a negligible difference in the vast distance from the Sun to the Earth.

6. Optional Activities on Shape of Earth's Orbit. If you have time (an extra class session), you can have students try any or all of the activities *Football Field Model of the Earth-Sun System*, *What is the Shape of Earth's Orbit*, or *Apparent Size of the Sun*.

Earth is actually closest to the Sun in winter. Tell the students that not only does the distance from the Earth to the Sun not change much relative to the entire distance, but Earth is actually very slightly closer to the Sun on January 4, which is winter in North America! Have the students record this fact on on their paper as well.



Why do most books depict Earth's orbit more like a skinnier ellipse rather than a circle? It's because they are show the circular orbit at an oblique angle. You can illustrate this very well with a circular object such as a hula hoop or embroidery hoop. Just rotate so students see different views, most of which are varying degrees of skinny ellipses, and only circular when viewed "face on."

Evidence Circle: Do Changes in the Earth-Sun Distance Cause the Seasons?

1. Challenge the students to work in small groups to answer the question "Do changes in the Earth-Sun Distance cause the seasons?" Each stucent must not only give an answer to the question, but must provide a written justification based on evidence they have gathered.

2. Add these key concepts to Concept Wall for this session:

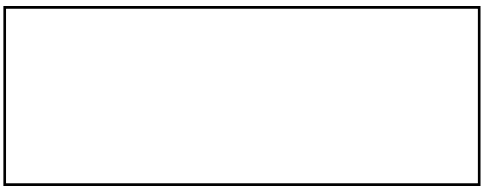
- The Earth's orbit is nearly circular; this is evidence that seasons are not caused by changes in Earth's distance from the Sun.
- Different parts of the Earth have different average temperatures at the same time; this is evidence that seasons are not caused by changes in Earth's distance from the Sun.
- Scientific explanations are based on evidence from investigations.

Optional: Football Field Model of the Earth-Sun System

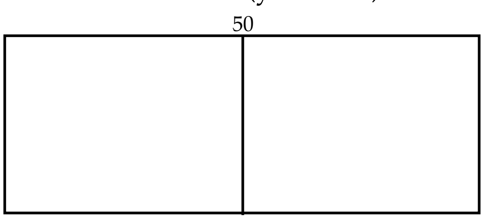
1. Is the Earth-Sun distance really the key to why we have seasons? Tell the students that we would like to get a true sense of the Sun-Earth distance by making some scale models of the Sun-Earth system, starting with a model on a football field. Say that scientists often use scale models to help them understand things they have difficulty observing directly.

2. Draw a football field. Show students how to draw a football field by having them duplicate the following steps that you demonstrate, drawing a football field on the board or overhead projector.

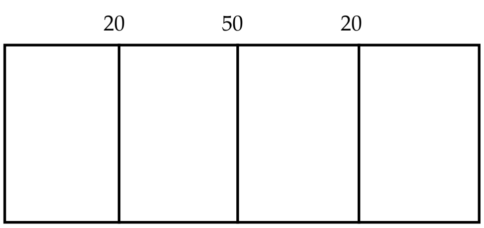
a. Draw rectangle.



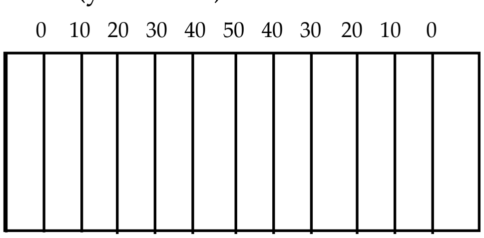
b. Divide rectangle into two part with vertical line down the middle. Label it “50” (yard line)



c. Divide each of those part in two with vertical lines. Label them “20” (yards)

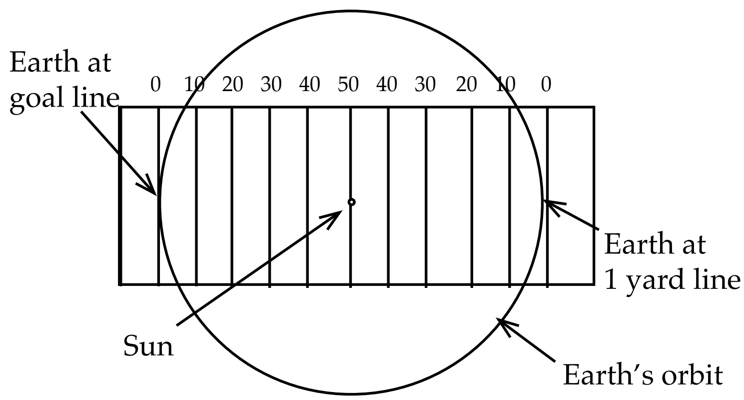


d. Divide each of those parts in thirds. Label them “0”, “10”, “30”, and “40” (yard lines)



Remember there are end zones where the goal posts are. Since this is a football field, naturally we are using English measuring units for th time being.

3. Put the Sun and Earth on the football field. Put a “Sun” in the middle of the 50 yard line, making it about 1/2 yard wide (very small). Explain that on this scale, each yard line is about 2 million miles, or 10 yards represents 20 million miles. The real Sun is very roughly a million miles in diameter ≈ 1/2 yard on this scale. Tell the students that the real Earth is roughly 8000 miles across, which would be less than 1/200 of a yard (hardly even visible on this scale). Earth would be about on the Goal line (0 yard line) on this scale, about 50 yards away from the Sun. Have the students put a tiny dot on the goal line.



4. Earth-Sun distance stays nearly constant as Earth orbits the Sun. The variation in Earth-Sun distance is less than a yard on this scale. So on the opposite goal of the football field, the Earth’s orbit would pass near the 1 yard line. Ask students to draw a circle representing Earth’s orbit around the Sun, making one side of the circle go through one goal line, and the other side of the circle go through the 1 yard line near the opposite goal.

5. Does Earth’s distance from the Sun change by enough to cause the seasons? Ask if any students think they might consider changing one of their answers on the Questionnaire. Tell them that they’ll make yet another model in the next session.

Optional:

What Is the Shape of Earth's Orbit?

In this session, students discover that the true shape of the Earth's orbit around the Sun is very nearly a perfect circle. This can help to dispel the common misconception that seasons are caused by variation in the distance from the Sun to the Earth.

What You Need

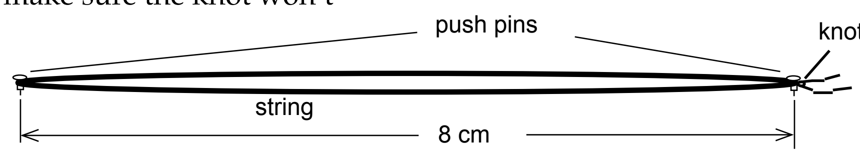
For every pair of students:

- ❒ a 25 cm piece string or twine—not stretchy
- ❒ 1 pencil and 1 sheet of blank paper
- ❒ 2 push pins or thumb tacks
- ❒ a stack of newspaper, at least the thickness of the pins or tacks students will use

The real Sun is about 1.4 million kilometers across and about 150 million kilometers away from Earth.

Getting Ready

1. You'll need one smaller loop per pair of students. Cut one 25 cm piece of string per pair of students. Make each piece of string into a loop by tying the ends together so that the loop measures 8 cm when stretched flat. An easy way to do this is to stick two push pins in a thick piece of cardboard, 8 cm apart, and tie the string around the push pins. Test to make sure the knot won't slip.



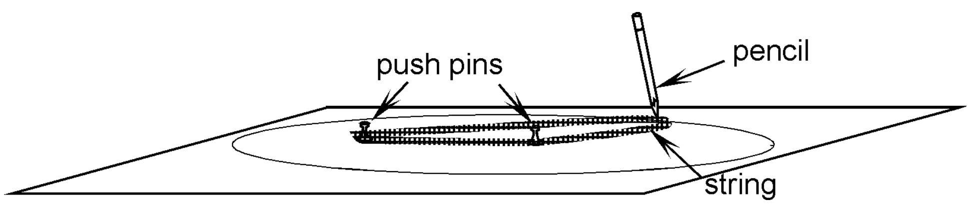
3. Put a large piece of paper at least 14 x 14 inches on a bulletin board where the class can see it for demonstration of ellipse drawing technique. Ideally, mount it where you can push two pins into the surface. If you don't have a bulletin board, you may need to put cardboard or another such surface onto the wall for this demonstration. Use the steps in #4 below to practice drawing an ellipse before class.

The Shape of the Earth's Orbit

1. Explain that an ***ellipse*** is an oval shape, but a very precise and symmetrical oval. All objects in the solar system, including planets, comets, and asteroids, revolve around the Sun in elliptical orbits.

* A near-Earth asteroid is one whose orbit brings the asteroid close to Earth's orbit.

2. Demonstrate how to draw an ellipse by drawing a "near-Earth" asteroid's orbit* as follows:
   a. Make two pen marks 6 cm apart on a piece of paper on the bulletin board.
   b. Stick a push pin through each pen mark and into the bulletin board.
   c. Drape the string loop you made from a 40 cm piece of string over the push pins.
   d. Ask for a volunteer at this point to hold one of the push pins steady.
   e. Hold the other push pin steady and pull the string taut with the tip of a marking pen.
   f. Draw the ellipse, keeping the string taut at all times. Empahisize while you are drawing the importance of keeping the string taut as you draw the ellipse as well as having two people work together to make sure the push pins stay firmly in place while making the ellipse.



3. Explain that each point where a push pin goes in is called a ***focus*** of the ellipse. Mention that the plural of focus is ***foci*** (FOE-sigh). Point out that the comet orbit that you drew is fairly "skinny, or elongated, not circular." Explain also that in the orbits of planets (as well as comets or asteroids) the Sun remains fixed at only one of the foci of the ellipse.

4. Assign the students to draw two orbits: one near-Earth asteroid with foci separatted by 5 cm, and one Earth orbit, with foci separated by 0.5 cm. They will work with a partner, and take turns; one will help keep the push pins steady while the other is drawing. Each pair of students will get a string loop, two push pins, and a stack of newspaper.

5. Ask, "Which orbit is more circular, the asteroid's or Earth's?" [Earth's] Explain that, while it is true that Earth's orbit is slightly elliptical, it is very nearly a circular ellipse. Point out that if the Sun is always at a focus of the ellipse and the foci are very close together, then the Sun is very close to the center of the ellipse.] So, not only is the Earth's orbit almost circular, but the Sun is in the center of the orbit.

6. Suggest to students to have another look at Seasons Questionnaire question #3 and decide if they might need to reconsider which answer correct.

Apparent Size of the Sun

With a ruler, measure the apparent size of the Sun at each of the four dates/images on this page.

1. Are they different apparent sizes, and if so why?
2. In what month is Earth at perihelion, the closest approach to the Sun in its orbit?
3. In what month is Earth at aphelion, its farthest distance from the Sun in its orbit?
4. What percent change is there from Earth's greatest distance to Earth's closest distance to the Sun?