Global Design for the Seasons

Grade Level:	**Total Time Required:**
5	2-3 periods (50 minute each), approximate

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Lesson Objectives

Students will be able to:

1. Describe how the Earth rotates on an axis and how this rotation causes day and night and affects the length of shadows observed during different times throughout the day.
2. Describe how the Earth revolves in an orbit around the sun, how this motion changes the length of daytime and nighttime, and how the location of the Earth in the orbit around the sun corresponds to the seasons.
3. Design a prototype shade for a restaurant's outdoor table to maximize shade for a given time of year and a given restaurant location.

Indiana Standards:

5.ESS.2 Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

3-5.E.1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Next Generation Science Standards:

Discipline Core Ideas

5.ESS1.B The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year.

3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Science/Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence

Crosscutting Concepts

2. Cause and effect: Mechanism and explanation.

Science Concepts and Vocabulary

Term	*Defined by a scientist or engineer*	*Defined by a 5th grade student*
Tilt of Earth's axis of rotation	The angle between the Earth's axis of rotation and a line perpendicular to the plane of the ecliptic; varies slightly and is about 23.5 degrees.	The Earth's axis runs from the North to the South pole and is at an angle or tilt.
Rotation of Earth	The rotation (spinning) of the Earth around its axis. The axis currently points approximately to the North Star (Polaris); within about 0.7 degrees. When viewed from above the North pole, the Earth rotates to the East (counterclockwise).	The Earth spins on its axis, which runs from the North to the South pole, like the spinning of a top.
Orbit	The gravitationally curved path of an object around a point in space. Orbiting is also called revolution. Planetary orbits are generally elliptical.	The path that a planet takes as it goes around the Sun.
Scale	The ratio of a dimension (such as length), diagram in a model relative to the corresponding actual size (on the Earth or on an object). Scale is often written as 1:100 (or other number) meaning that the model (map or diagram) is 1/100 times the size of the actual object.	The size of an object (3-D object, geographic area, etc.) relative to the size of a model.
Sun angle (above horizon)	The angle between the Sun and the horizon. Also known as Sun altitude.	The angle between the Sun and the horizon.
Solstice	When the Sun is highest in the sky as viewed from the N or S pole. The dates when this occurs are approximately June 21 for the North pole, and December 21 for the South pole.	"First day of summer or winter."
Equinox	Time when nighttime hours are equal at all locations on Earth. These dates are approximately March 21 for the North pole, and September 21 for the South pole.	"First day of spring or fall."
Equator	The intersection of the Earth's (a sphere's) surface with the plane perpendicular to the Earth's axis of rotation and midway between the poles.	The imaginary line circling the Earth in the middle between the North and South poles.
Hemisphere	A half of the Earth (a sphere), usually divided into Northern and Southern halves by the equator.	The Earth can be divided into halves. ex., The half between the Equator and the South pole is the Southern Hemisphere.
Latitude	The angular distance of a place North or South of the Earth's equator, usually expressed in ° or minutes.	Imaginary lines circling the Earth that are parallel to the equator, but are above or below the equator.

Equipment, Materials, and Tools

Materials		
Styrofoam blocks or clay	3” Styrofoam sphere	Styrofoam Plates
Toothpicks	Print template for 3-D building model	Clay
Plastic straws	Print template for latitude marks	Foam Board
Fine tip felt pen	Print template for N and S American continents	String
Bamboo skewers	30 cm dowels (or equivalent)	Poster Board
Glue	Flat Sticks	Pipe cleaner
Tape	Card Stock	Craft Sticks

Tools		
Scissors	Rulers	Protractors
Electric lamp socket and light bulb (60 watt)	Flashlights	

Optional: Use, for example, a 2”x 4”x 6” wooden block , a cup, or a dollhouse table to represent the outdoor seating table and chairs for the Design Activity on page 8.

Basic Science Content and Online Simulation Tools

The Earth rotates about an axis that is positioned between its North and South poles. This axis is tilted at 23.5° with respect to a plane perpendicular to the Earth’s elliptical orbit (see Figure 1). The Earth completes one full rotation each day, and this rotation is responsible for the daily changes in the length and direction of shadows and the occurrence of daytime and nighttime. The Earth also travels around the sun and completes one full revolution approximately every 365 days (or 1 year). The positions of the Earth within its orbit with respect to the sun are directly responsible for the seasons (i.e., winter, summer, fall, spring) that are experienced at different locations on Earth. In Figure 1, the position of the Earth is shown for June 20th. Locations on Earth can be identified by a location’s particular latitude. Common lines of latitude are shown in Figure 1.

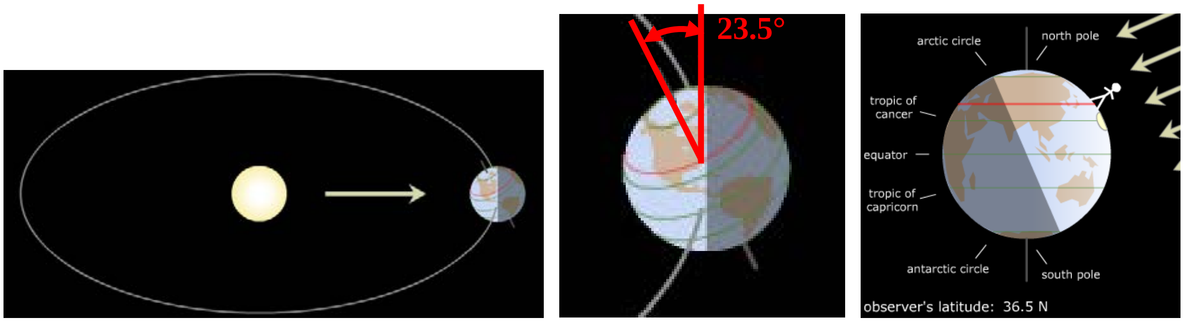


Figure 1 Image of the Earth's revolution (orbit) around the sun. The 23.5° tilted N-S axis of the Earth is also shown. From NAAP Seasons and Ecliptic Simulator: http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html

Within this inquiry-design activity, an Earth-Sun scale model will be constructed to help students understand how the length and direction of shadows changes during different times of the day and different times of the year, and how this is influenced by the position of a location on Earth (i.e., its latitude) with respect to the Sun. Using an online computer simulation tool, the students will also explore how any location on Earth will be positioned at different angles with respect to the Sun's rays during different days during the year.

The University of Nebraska-Lincoln Astronomy Education Group has developed an online interactive model that illustrates the motion of the Sun and Earth and how this motion affects the seasons on Earth. As part of the Nebraska Astronomy Applet Project (NAAP), a series of online lab modules have been developed to introduce students to the basics of astronomy. Using the NAAP Basic Coordinates and Seasons Lab, students can explore the motion of the Earth and how it relates to seasons on the Earth.

NAAP Basic Coordinates and Seasons Lab, Seasons and Ecliptic Simulator:
http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html
Student Guide: http://astro.unl.edu/naap/motion1/naap_motion1_sg.pdf

The following page contains a screen-shot of the Seasons and Ecliptic Simulator. In the left-most box, students can click and drag the Earth to different positions along its orbit around the Sun. These positions correspond to the month and day in the lower box. In the upper-right box, the students can click and drag the stick figure on the surface of the Earth to change where the "observer" is located on Earth (e.g., a student in Indiana vs. Australia), described in terms of latitude ° in the Northern or Southern Hemisphere. The lower-right box then displays the angle at which the sun's rays will hit the surface of the Earth at the location of the stick figure observer. This angle is reported as the "Sun's altitude" (also known as the "Sun angle"). So, as shown in Figure 2, if the location of the observer and the time of year are known, the maximum (Noontime) angle that the Sun's rays hit the Earth can be determined using this simulation tool.

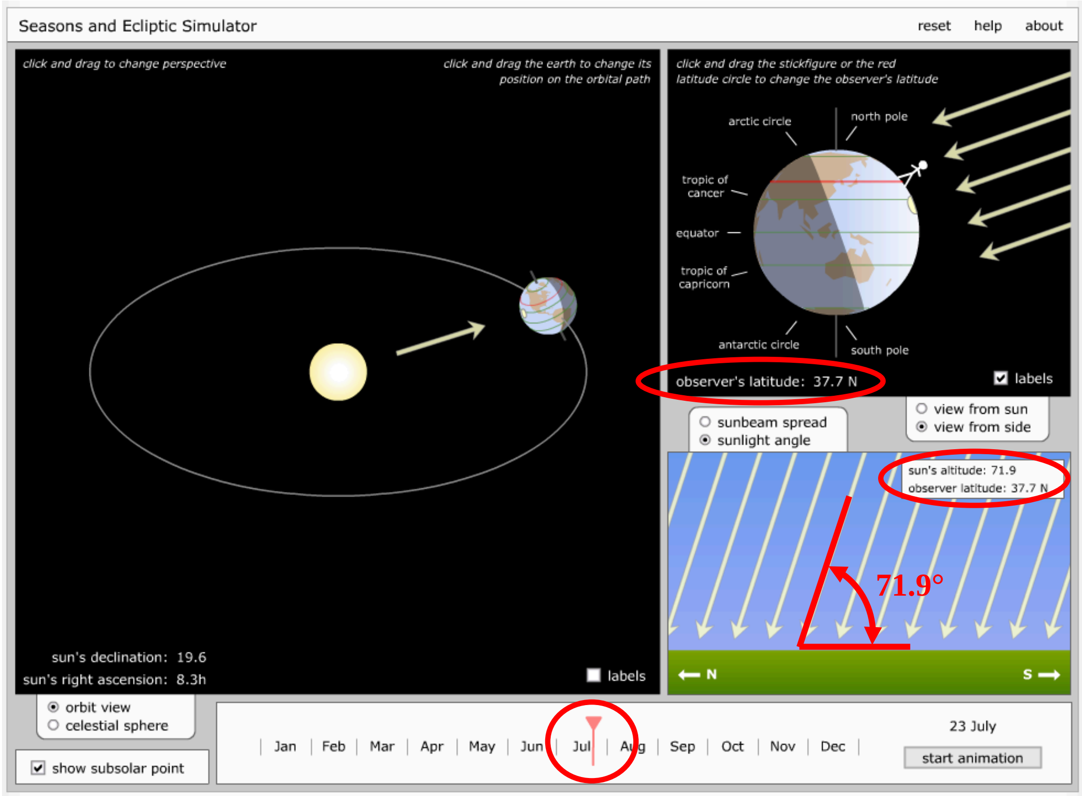


Figure 2 Screen-shot of the Seasons and Ecliptic Simulation. For July 23 at Noon at a latitude of 37.7° North, the Sun's rays will hit the surface of the Earth at an maximum Sun angle of 71.9° relative to the surface of the Earth. From NAAP Seasons and Ecliptic Simulator: http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html

Table 1: Latitude of different locations on Earth. N indicates latitudes in the Northern Hemisphere while S indicates latitudes in the Southern Hemisphere.

Location	Latitude	Location	Latitude
Anchorage, Alaska, USA	61.2° N	Hong Kong, China	22.3° N
Oslo, Norway	60.0° N	Honolulu, Hawaii, USA	21.3°N
London, England	51.5° N	Mex.ico City, Mex.ico	19.4° N
Montreal, Quebec, Canada	45.5° N	Bogota, Colombia	4.6° N
Rome, Italy	41.9° N	Island of Madagascar	20.0° S
Lafayette, Indiana, USA	40.4° N	Rio de Janeiro, Brazil	22.9° S
Indianapolis, Indiana, USA	39.8° N	Sydney, Australia	33.8° S
Tokyo, Japan	35.7° N	Cape Town, South Africa	33.9° S
Giza, Egypt	30.0°N	Buenos Aires, Argentina	34.6° S
Orlando, Florida, USA	28.5° N	Falkland Islands	51.7 ° S

Synopsis of Engineering Design Activity

Synopsis of the Design Activity:

Problem:	The outdoor tables and chairs at a restaurant are in the sun during lunchtime and need to be shaded.
Goal:	Design and build a prototype that will provide shade to an outdoor table and chairs during lunchtime (Noon) in the month of June at the five different international locations of the restaurant chain.
Who is the client:	The Lemonade & Smoothies Company
End-User:	Customers of The Lemonade & Smoothies Company
What is the design:	Design and build a prototype that will provide shade to an outdoor table and chairs during lunchtime (Noon) in the month of June at the five different international locations of the restaurant chain.
Criteria:	• Structure must shade the one table and its four chairs at Noontime in June at the specified international location. • Structure should be at least 2 meters tall. • Structure must stand up on its own.
Constraints:	• May only use the materials available • Time

Lesson Plan #1
Introductory Activity: How does the Earth move in relation to the Sun (rotation and revolution)?

Time: One 50 minute class period (plus teacher time to construct the Earth-Sun model)

Procedure:

Use the Earth-Sun physical model in the following demonstrations and explorations to help the students understand the rotation and revolution of the Earth around the Sun (For a description of how to construct and use the model, see page 10).

<u>Part I: Understanding the position of the Earth's tilt</u>

1. The Earth's tilt is the inclination of the axis of rotation. Note the 23° tilt of the Earth's axis in the Earth-Sun Model.

2. Also show the daily rotation of the Earth; counterclockwise when viewed from above the North polar axis of rotation (North Pole).

3. Note that this rotation will occur continuously, and be completed 365 times during one Earth orbit, although we will not be able to show continuous rotation during demonstration of the yearly orbit.

<u>Part II: Understanding a day – Earth rotation</u>

Demonstrate rotation (counterclockwise) of the Earth around the Sun. Determine which direction is North in your classroom and always keep the Earth oriented so that the tilted axis of the Earth is inclined towards the North.

<u>Part III: Understanding seasons – Earth revolution</u>

1. Demonstrate revolution (also counterclockwise) of the Earth around the Sun. Determine which direction is North in your classroom and always keep the Earth oriented so that the tilted axis of the Earth is inclined toward the North (See Step 7 in "Instructions for Building the Earth-Sun Model").

2. Introduce the concept of seasons related to the position of the tilted Earth in its orbit. Illustrate position of the Earth during winter, spring, summer, and fall in the Northern Hemisphere. Note the lighting of the polar regions during the seasons and the angle of the Sun's rays that impact the Earth in the different seasons and at different latitudes. Discuss Solstice and Equinox. Show that similar seasons exist in the Southern Hemisphere but at opposite times as compared to the northern hemisphere.

3. Optional: Demonstrate that the seasonal variations change depending on latitude. For example, in the tropical regions (near the equator), seasons do exist but the Sun is “high in the sky” during much of the day throughout the year and the length of day does not change markedly. However, in the polar regions (greater than about 50° latitude, both N and S), the Sun is relatively “high in the sky” only during summer (for that hemisphere) and is very “low in the sky” (or may not even rise above the horizon for latitudes above 63°, N and S) in daylight hours during winter. In addition, the length of day varies greatly with season in the polar regions so that there can be up to 24 hours of daylight in summertime in polar regions and as few as zero hours of daylight in wintertime in the polar regions.

Part IV – Understanding shadows

The Sun angle changes throughout the day due to Earth’s rotation. To help your students understand the relationship of the Sun angle and the length of shadows, below is a link to a Shadow Tracing activity you can do with your students.

http://www.cgtp.duke.edu/~plesser/outreach/kenan/Activity%204%20Shadow%20Tracing.pdf

Lesson Plan #2
Design Challenge – Shading a Table

Time: one or two 50 minute class sessions

Procedure:

1. Distribute the design challenge. Assign each team one latitude and sun angle (see Table 1 in the Design Activity brief).

   Ask: *What is the goal?*
   Who is the user or client?
   What is the problem?
   What are the constraints?
   What materials will you use?

2. Instruct students to develop his/her individual plan in his/her design notebooks. Encourage students to label their sketches, include dimensions, and list the materials they will use.

3. Instruct students to work in small teams to share their plans. Next, instruct students to decide on one plan or design and to select a representative from the team to share his/her plan to the teacher for his/her approval.

4. Once teams have teacher approval they may construct their design to shade the table.

Lesson Plan #3
Design Challenge – Testing your design

Time: One 30 minute class session

Procedure:

1. The shading of the picnic table for various Sun angles can be tested using the flashlight held at different angles above the horizontal (horizon). Each team should try to design a shade for their latitude that meets the goals and constraints of the design challenge. Use the flashlight to illuminate (as the Sun's rays would) the shaded table and to measure the angle of the light relative to the vertical direction as illustrated in Figure 3.

Figure 3. Left – Use of a flashlight to illuminate a model. Right – The angle of the flashlight (90 - A_s) can be measured and the flashlight angle adjusted using a protractor taped to the flashlight as shown here.

2. Have each team share their shade information and designs with the entire class and demonstrate that they work (according to the design goals) for their latitude.

Discussion Questions and Redesign options:

3. If you design a shade system that works well at Indianapolis, IN at noon in June, will it still work well at 10 AM? At 4 PM? At 6 PM? Why or why not? If necessary, how would you change your design to ensure the seating area is shaded at these times?

4. Sydney, Australia; Antananarivo, Madagascar; Oslo, Norway; and Honolulu, Hawaii are at different latitudes above and below the equator. If you design a shade system that works well at each location in June, will the shade system still be able work well in December? Why or why not? If necessary, how would you change your design to ensure the seating area is shaded in December?

Design Activity

Shading a Table

SLED
Science Learning through Engineering Design

The Lemonade & Smoothies Company has been so successful that they are about to expand from their first store in Indianapolis, IN to four other locations throughout the world. These locations include Sydney, Australia; Antananarivo, Madagascar; Oslo, Norway; and Honolulu, Hawaii. The Lemonade & Smoothies Company has hired you to design structures to provide shade for individual outdoor tables and chairs at their store in Indianapolis, IN. The Lemonade & Smoothies Company also intends to install the shade system that you develop at their new locations around the world. Therefore, the structure must be designed to successfully provide shade during noontime (maximum sun angle) for each location during the month of June.

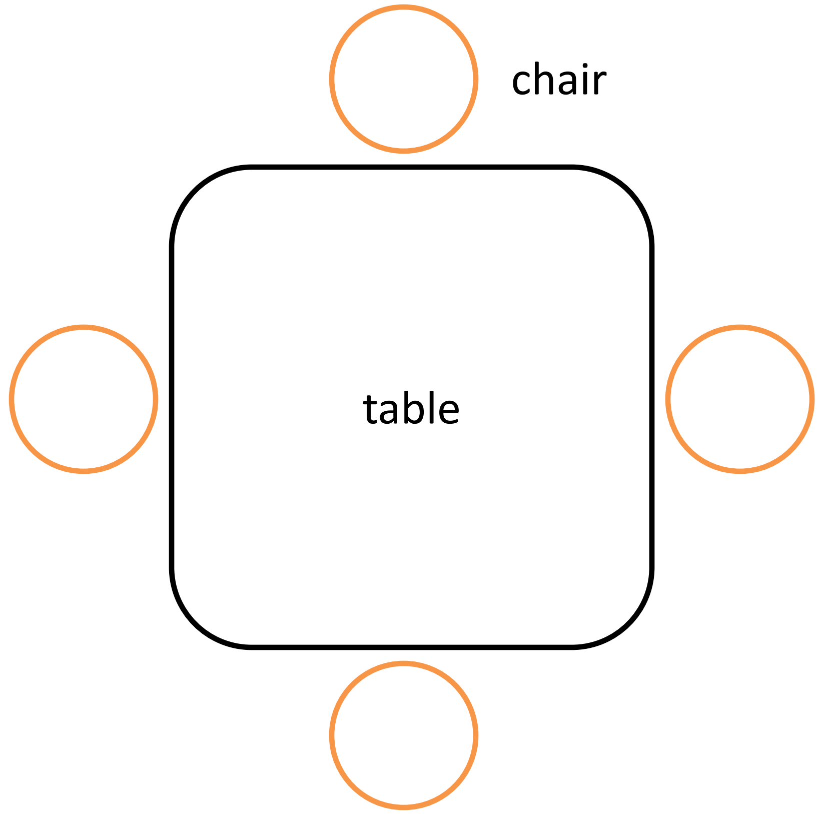
Design requirements:

- The structure should shade the entire table and seating area at noontime at your latitude in June but should allow some Sun at early and late hours of the day (low Sun angles).
- The structure should be at least 2 meters tall (20 centimeters for your model).
- Must stand up on its own but can be fixed (permanent location) or moveable depending on season.
- Must be affordable (low cost). The list below shows the materials available and the cost of each item.

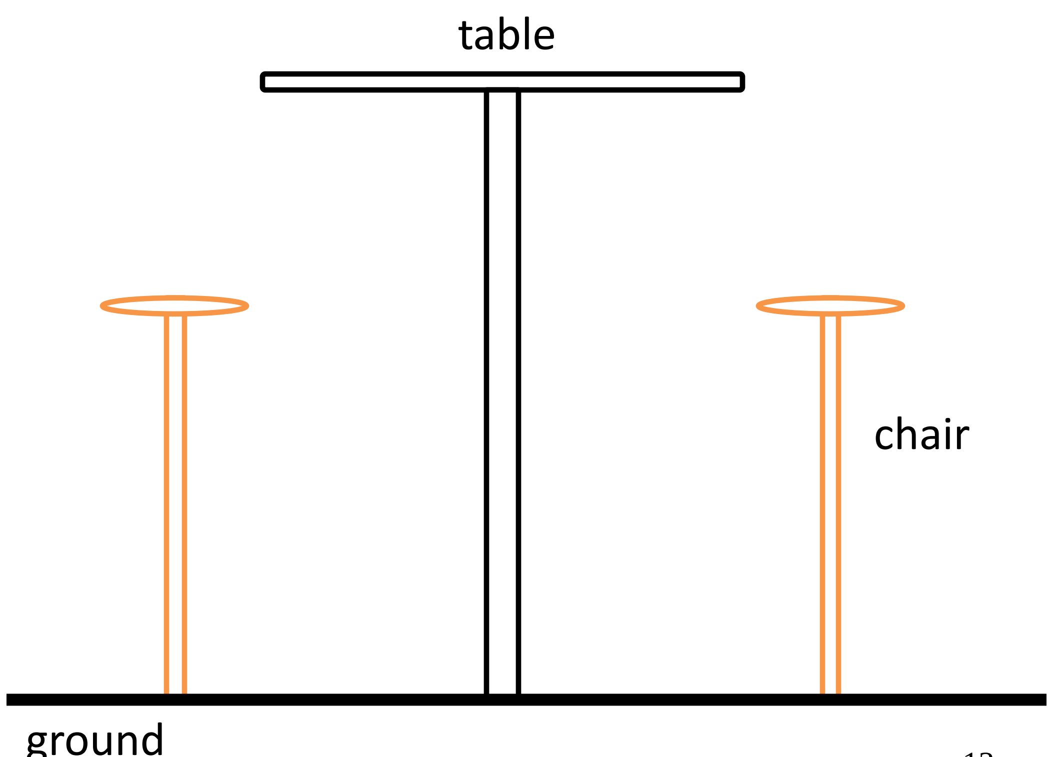
Materials (most can be cut to size) and prices

30 cm dowels (or equivalent)	$1.00 each
Flat Sticks	$0.50 each
Tape	Free
Card Stock	$1.00 per sheet
Styrofoam Plates	$2.00 each
String	$0.05 per cm
Clay	$3.00 per strip
Poster Board	$0.05 per square cm
Foam Board	$0.10 per square cm
Pipe cleaner	$0.05 each

Top View, 10 cm = 1 m



Side View, 10 cm = 1 m



Lesson Extensions and Resources

Resources:

NAAP Basic Coordinates and Seasons Lab, Seasons and Ecliptic Simulator:
http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html
Student Guide: http://astro.unl.edu/naap/motion1/naap_motion1_sg.pdf

Gould, Alan; Willard, Carolyn; and Pompea, Stephen; *The Real Reasons for Seasons – Sun-Earth Connections: Unraveling Misconceptions about the Earth and Sun*, GEMS, Lawrence Hall of Science, University of California, Berkeley, 2001, 124 pages. (Available from Amazon.com: http://www.amazon.com/Lawrence-Hall-Of-Science-Reasons/dp/B004430I6U/ref=sr_1_2?ie=UTF8&qid=1332512186&sr=8-2)

Wiebke, Heidi; Rogers, Meridith; and Nargund-Joshi, Vanashri; Sizing up the Solar System. *Science and Children*, v. 48, September, 2011, 36-41.

Wilcox, Jesse; and Kruse, Jerrid; Springing into Inquiry, *Science Scope*, v. 35, February, 2012, 26-31.

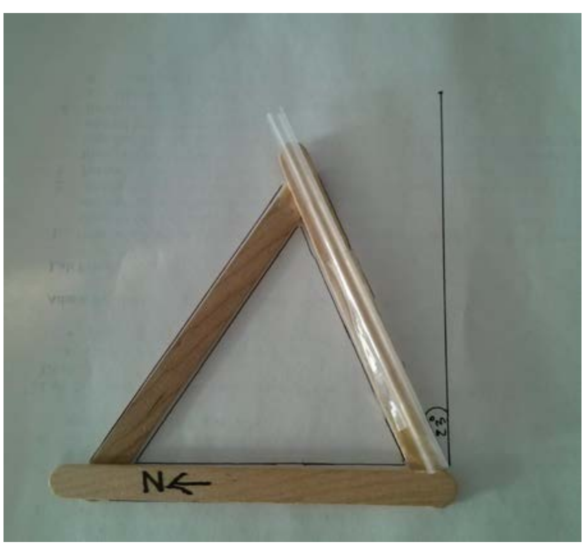
Instructions for building the Earth-Sun Model:

For teacher-led demonstrations and explorations by student groups, construct one or more Earth-Sun models. The models are not to scale, but work well to illustrate the movements of the Earth (revolution and rotation), the Sun's rays hitting Earth at different time of the year, the effect of latitude on energy received from the Sun, and the effect of the tilt of the Earth. The model elements are illustrated in the following figures and steps, and the captions include information for construction and use of the models in demonstrations and student exploration.

Figure 4. List of materials needed to build the Earth-Sun model. Left – Electric light socket and 60 watt soft white bulb. Middle – Plastic straws, "corn cob" sticks or skewers, 3 inch diameter, smooth surface Styrofoam ball. Right – craft sticks, binder clip, and string.

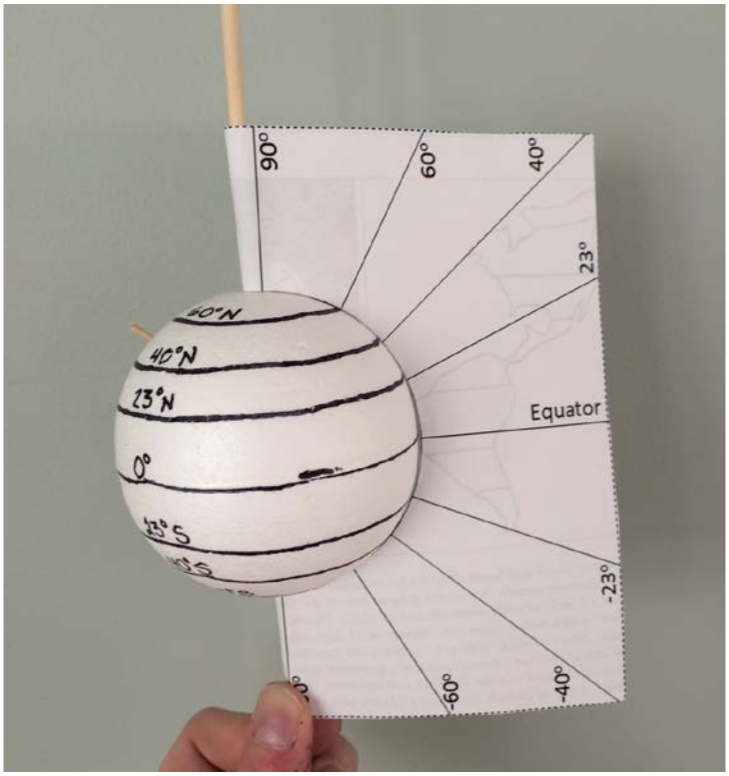
1. Print and use the template on page 19 as a guide for creating the structure to support the Earth model as shown below.

2. Align and glue craft sticks by first placing a craft stick in position on leg 'a', then another on leg 'b'. Glue together and then place the final craft stick across leg 'c'. Glue together as shown here. Cut a straw and tape it to stick on Leg "b" as shown. Use a ruler to verify the approximate lengths of each stick as shown. The stick on Leg 'a' is 11.5 cm, Leg 'b' is 11 cm, and Leg 'c' is about 11.2 cm. The main goal is to ensure that the stick on Leg 'b' is at an angle of about 22-23° from the vertical.

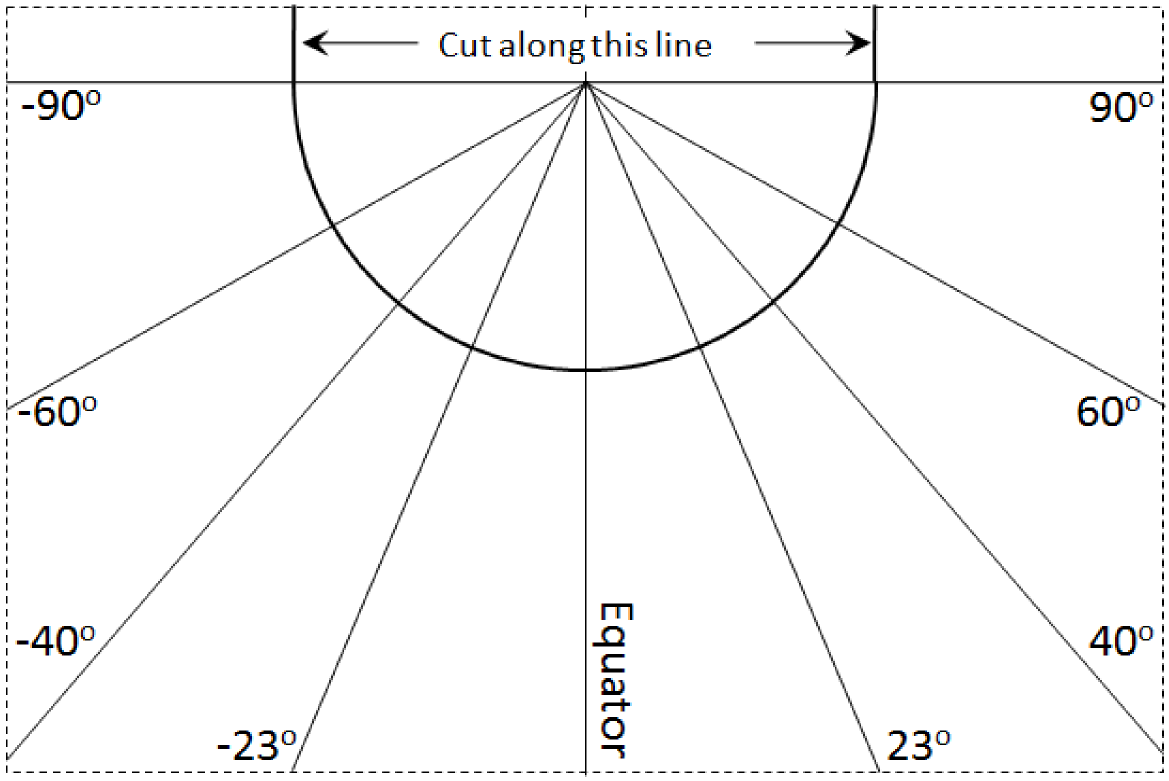


3. Using one of the skewers, puncture the Styrofoam ball until the skewer goes all the way through it as shown.

4. Print the template below and cut it out along the dashed edge and bold line. Place it on model Earth sphere so that the top edge of the cut out semicircle is at the North pole and the bottom edge of the semicircle is at the South pole. Make a dot on the model at each intersection of a latitude line (i.e., 60, 40, 23, 0, -23, -40, -60). Rotate the Earth model a small amount and repeat until dots are all around the sphere. Connect the dots with smooth lines using a fine point marker to complete the selected lines of latitude. Label the latitudes on the sphere.

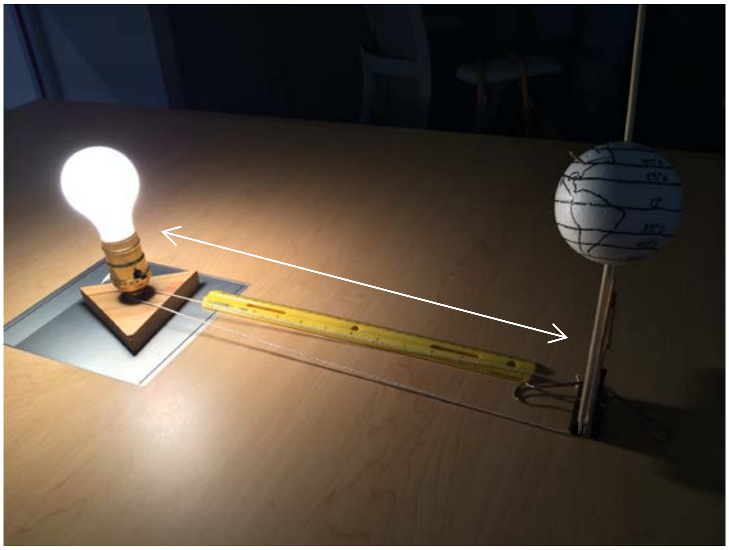


Print on heavy paper, then cut out rectangle (dashed lines), then cut out half circle



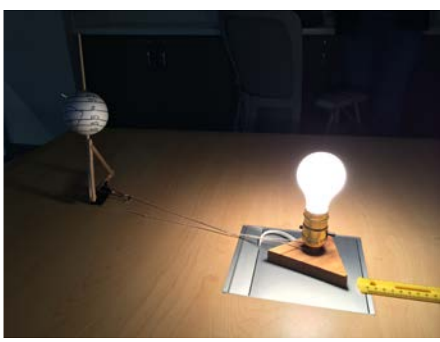
5. Using the map of North and South America shown on the left, cut out and place the map of these two continents so that it aligns with the latitude lines that were drawn in step 4. The final image of the Earth model is shown on the right. To finish the model, attach a binder clip towards the center.

6. Place the model Sun in the middle of the table approximately 30-40 cm away from the Earth as shown. To maintain the distance, you can loop string or yawn around the base of the bulb socket and the base of the straw on the Earth model.

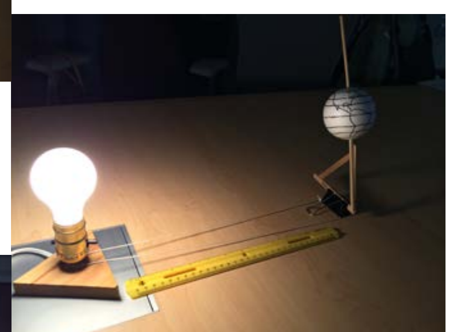


7. Move the Earth model around the Sun in a circular, counterclockwise, orbit as shown. Note that the North arrow is kept in the same direction at all locations (such as pointing to the North wall of your classroom) in the orbit of the Earth around the Sun.

Position B
Winter

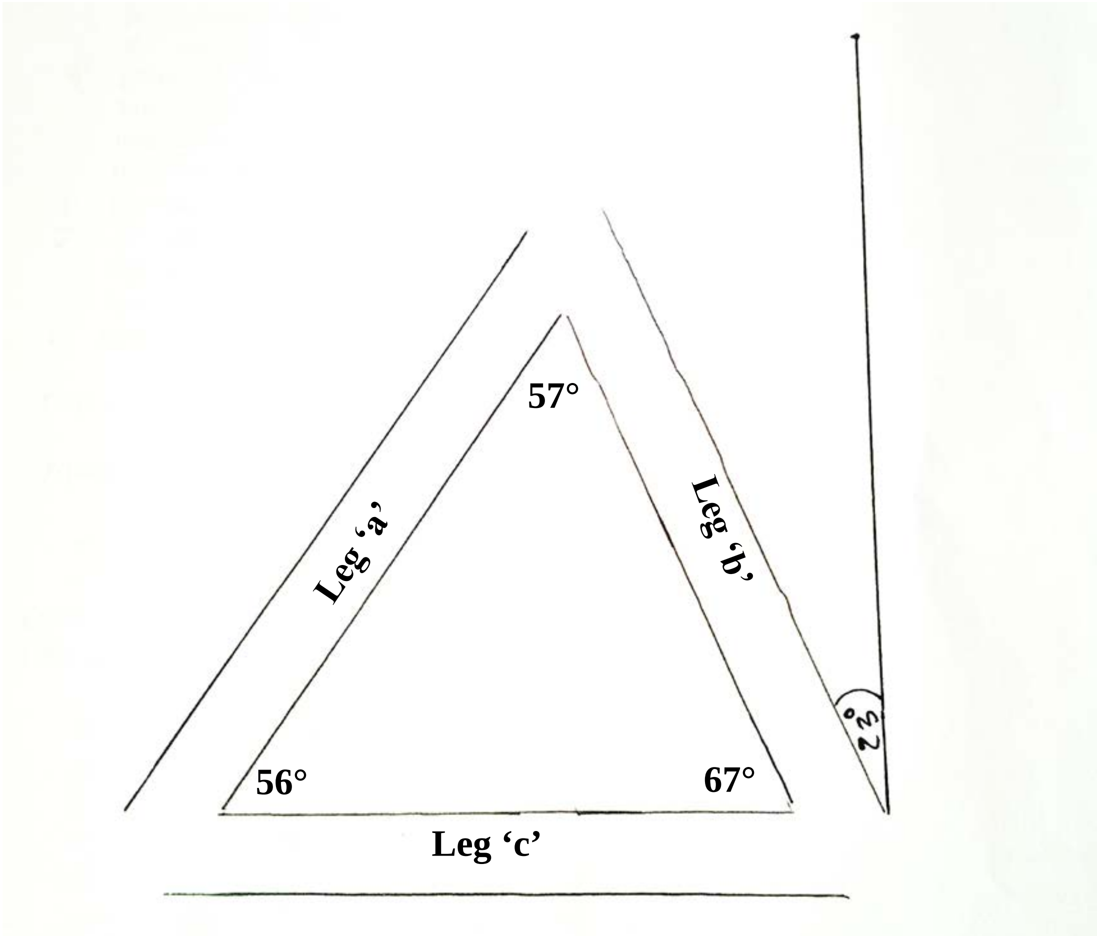


Position C
Spring



Position A
Autumn

Position D
Summer


57°
Leg 'a'
Leg 'b'
56°
67°
Leg 'c'