Contents

Contents

Contents

Why Teach *Seasons*?

In a famous educational study, a group of Harvard graduates were asked to explain the change in seasons. The most common response was that the warm weather of summer occurs because at that time Earth is closer to the sun. This is not only wrong, but it is also illogical, because Earth's orbit is almost circular. So why is it that even our most talented students cling to folk science and remain spectacularly uninformed about the natural world in which they live?

George D. Nelson offered a probable explanation in his article "Science Literacy for All: An Achievable Goal?"

> The present science textbooks and methods of instruction, far from helping, often actually impede progress toward science literacy. They emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, recitation over argument, and reading rather than doing. They fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities. (*Optics and Photonics News*, Education Issue 19 (9): 42)

For years teachers have tried to "teach" seasons better and have dragged out the globe and flashlight in a darkened room. Students would watch passively as their teacher tried to maintain interest with prompts such as, "Can you see what's happening here?" Those students who were not off-task in the dark mouthed, "Yes." However, very little long-term learning was going on with this weak demonstration.

In ***Squared Away: Seasons***, student learning will be real and long-term. Your students will use Seasons Observatory models to replicate on a tabletop what is happening in space. They will use flashlights, not for just a momentary observation, but for a sequence of observations. They will record what they see, make graphs, and discuss findings. For example, most students at some point can recite that seasons are opposite in the Northern and Southern Hemispheres, but they are clueless about the mechanics that make this true. With a Seasons Observatory and their collection of data on daylight hours, your students can confidently present evidence that proves opposite seasons.

You may worry that using limited classroom time to explore science concepts like *Seasons* takes away from other topics. True, but that can be said of thousands of science topics that cannot be covered in a school year.

However, there are two compelling arguments to spend your class time with the *Seasons*. First, this unit clearly addresses the new Next Generation Science Standards (NGSS). The Disciplinary Core Ideas and the Science and Engineering Practices specifically reference the use of models "to describe, test, and predict more abstract phenomena" and to explain that Earth's "seasons are a result of (axial) tilt and . . . the differential intensity of sunlight on different areas of Earth across the year." Second, and probably more important, your students' time will be well spent in this unit using their models and skills of scientific inquiry. They will not just "cover" the topic of seasons, but they will create a deep understanding of seasons that will provide a solid basis for further relevant study in space science and global climate change.

Unit Time Chart

Depending on your students' ages, prior knowledge, and the length of your science period, you may complete one square in two to four days. The lesson plans for each instruction block, or "square," are designed for 45 to 60 minutes with some out-of-class time required. If your class is made up of younger students or students with disabilities or if the assessments indicate that your students need more instruction, then the lessons will definitely take the full hour. If your students are already familiar with rotation and revolution, you may administer the Square One Test and begin at Square Two Test, saving four days. Also, as students become more familiar with the models, some groups will complete two days of lessons in one class period. At the end of each square, there is a list of optional activities related to the concepts presented in the square. Use these to differentiate your science lessons.

Instruction Block One
Days 1 and 2
Days 3 and 4

- Pretest
- **Square One concepts** (blue)
- Build models
- Group Investigation 1
- Quick Team Quiz 1
- Square One Test
- (Optional Activities)

Instruction Block Two
Days 5 and 6
Days 7 and 8

- **Square Two concepts** (red)
- Group Investigations 2–3
- Quick Team Quiz 2
- Square Two Test
- (Optional Activities)

Instruction Block Three
Days 9 and 10
Days 11 and 12

- **Square Three concepts** (green)
- Group Investigations 4–5
- Quick Team Quiz 3
- Square Three Test
- (Optional Activities)

Instruction Block Four
Days 13 and 14
Days 15 and 16

- **Square Four concepts** (purple)
- Group Investigations 6, 7, 8
- Quick Team Quiz 4
- Square Four Test
- (Optional Activities)
- Posttest

Golden Square

- **Optional**
- **Golden Square concepts** (yellow)
- Individual (or team) Golden Square Challenge

Seasons Observatory Construction

Materials

The Seasons Observatory is easily constructed from commonly available materials:

- Paper patterns (pages 100 and 101)
- Adhesive
- 1 straw
- 1 skewer
- 1 gallon plastic storage bag

You will also need a regulation table tennis (Ping Pong) ball.

Preparation

1. Prepare the paper patterns by copying or printing the pattern pages. Glue the patterns to single-ply cardboard or cardstock. Office supply stores usually sell cardstock in sheets. Old manila file folders or empty cereal boxes work well too.

2. The patterns can be glued with a thin layer of white glue diluted 50-50 with water. However, the easiest, fastest, and best way is to use spray adhesive. (The 3M Company's *Super 77 Multipurpose Adhesive* works exceptionally well.) Bonding the patterns and cardboard with white glue or spray adhesive is a messy process. It's more time-efficient for you to glue the patterns and cardboard beforehand and distribute the resulting sheets ready for cutting. Note that when using spray adhesive, you should do the job outdoors on a driveway or other place to provide adequate ventilation, preventing anyone from breathing in the spray, and to keep the spray off other surfaces in the classroom.

Step 1: Cutting the pieces

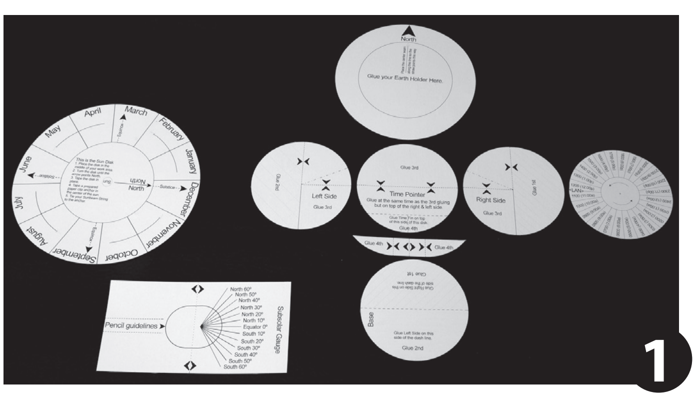
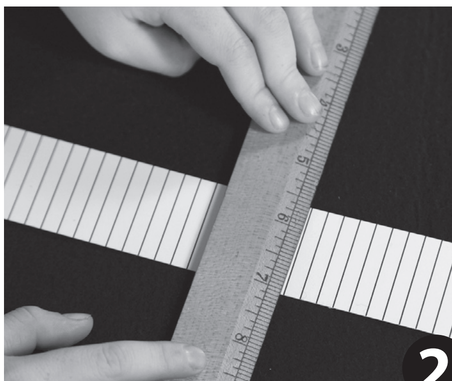


Figure 1 shows all of the Seasons Observatory pieces needed by one team. The large disk to the left is the Solar Disk. The rectangle underneath the Solar Disk is the Subsolar Point Gauge. All of the remaining pieces will make the Earth Holder.

Cut out the pattern pieces. Note that the left and right sides of the Earth Holder require a cut halfway through each disk. This cut is defined by a solid line (all other lines are dotted or dashed).

Step 2: Folding the pieces

All folds are indicated by a dotted line. Figures 2 and 3 show how to make a sharp fold. First, place a ruler on the paper just short of a dotted line. Then use your fingers to press the cardboard against the ruler edge.


2


3

As you can see in Figure 4, all but two folds are inside corners—the fold is made as if to close the sides together. These folds are identified by two arrow heads (→ ←) pointing toward each other. However, the Subsolar Point Gauge fold and the center fold of the Time Fin are outside corners—the fold is made as if to open up the sides. These folds are identified by two arrow heads pointing away from each other (← →).

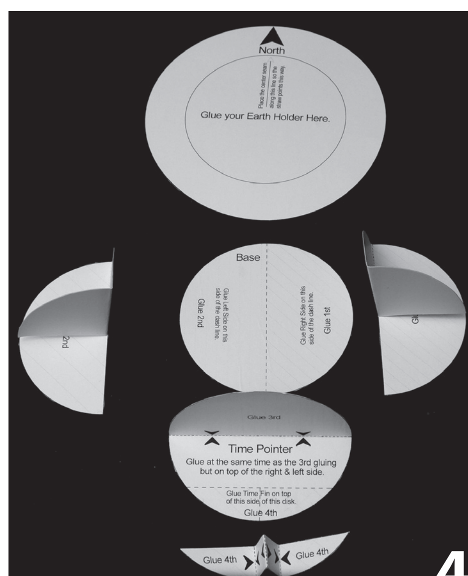
a. Make two inside folds in the right side.

b. Make two inside folds in the left side.

c. Make three folds in the Time Fin. Make the center outside fold first, and then fold the two outboard inside folds.

d. Make a single inside fold in the Base.

e. Make a single outside fold in the Subsolar Point Gauge.



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Teaching tip
From time to time, take a moment to review vocabulary. Make a word wall or word chart of all new vocabulary as you introduce each word.

Vocabulary

- Rotate
- Rotation
- Revolve
- Revolution
- Orbit
- Axis
- Clockwise
- Counterclockwise

Teaching tip
Before beginning Square One, take time to administer the Pretest and correct it so that you have some ideas of student's pre-knowledge.

Instruction Block One

Days 1 and 2

Square One Concepts*—Students will understand:*

- Many ancient peoples used myths and many modern people use folk science to explain what they don't understand.
- Thousands of years before space travel, ancient astronomers were great scientists who used observation and mathematics to form theories to explain what they saw in the night sky.
- Earth rotates (spins) counterclockwise around its axis every 24 hours.
- Earth revolves (orbits) counterclockwise around the sun every 365¼ days/1 year.
- Earth's orbit, although slightly elliptical, is nearly round in shape.

Materials

See page 23 for a list of materials for making the Seasonal Observatory and Subsolar Point Gauge.

Duplicate

- **Pretest/Posttest***—two per student*
- **Cooperative Group Work Rubric***—one class copy to post and 1 per team folder*
- **Essay 1, Ancient Astronomers Were Very Smart***—class set*
- **Seasons Observatory Patterns** (3)*—one set per team plus one set for you*
- **Essay 2, Rotation and Revolution***—class set*

Before the lesson

1. Correct the pretest so that you have a general idea of student pre-knowledge and can better prepare your instruction. (Answer key on page 31.)
2. If you decide to make the models yourself, prepare one Seasons Observatory for each team in your class. These models are durable enough to be shared with other classes. See the Seasons Observatory Construction instructions on page 25. You can also load the pages from the CD onto your computer to better view the photos and instructions.
3. If your students will construct the models, prepare the model pieces ahead of time. Duplicate the patterns, affix them to poster board, and collect other materials. After gluing patterns to poster board, allow time for the glue to dry. See pages 25 for complete instructions.

4. Before presenting the directions to the class, make a Solar Disk, Earth Holder, and Subsolar Point Gauge for yourself and to use as a model for the students.

Technology tip
If you have a SmartBoard™ or digital projector, copy the directions from the CD and project them to guide students as they work.

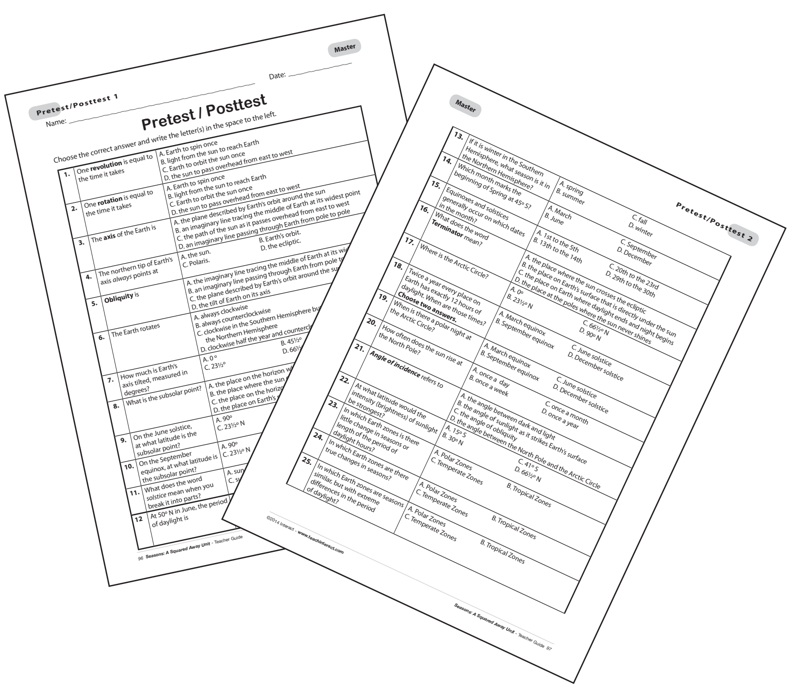
Teaching tip
For safety and to save time, make sure that you or another adult pushes skewers through the Ping Pong balls before giving them to the students.

Lesson plan schedule, Days 1 and 2

- Unit Introduction
- Discussion of the importance of cooperative group work
- Essay 1, Ancient Astronomers Were Very Smart
- Seasons Observatory and Subsolar Point Gauge
- Essay 2, Rotation and Revolution

Answer key for *Pretest/Posttest*

1. C	2. A	3. D	4. C
5. D	6. B	7. C	8. D
9. C	10. B	11. C	12. B
13. B	14. C	15. C	16. C
17. C	18. A and B	19. D	20. D
21. B	22. A	23. B	24. C
25. A			



Lesson Plan

Days 1 and 2

1. Student Introduction to *Squared Away*

- If this is the first time students have worked with a Squared Away unit, read or retell the student Introduction. If they are familiar with Squared Away, review how the unit will run in your classroom.

Squared Away was originally a nautical term used to announce that the sails of a Square Rigger sailing ship were correctly set. The Navy came to use it to describe sailors who completed a task with competency, as in, "He was right squared away!" In this unit, you will learn all about what causes Seasons. When you can demonstrate competency working with the scientific concepts in this unit, you will be considered "Squared Away."

A Squared Away Unit is divided into 5 instructional blocks or squares. At the end of each square you will be tested on specific content and skills. When you have demonstrated you have mastered the material, then you will be awarded a colored square. When you have earned four squares, you will be declared, "Squared Away." Your teacher may decide to assign a fifth square called the Golden Square. In order to earn a "Golden Square," you must go beyond the basic level of understanding and achieve an exemplary score on a challenging task that requires higher thinking skills.

You will be working in teams of 3, 4 or 5 in activities designed to help you develop a clear understanding of why we have seasons. To accomplish this, you will use a table top Seasons Observatory. With each observation, you will connect what you see on the table top to what is happening in space. You will also learn about the lines on a globe, times of Soltices and Equinoxes in Earth's orbit, and the effect the tilt of Earth's axis has on daylight hours and temperatures around the world.

The more thoughtfully you complete these activities, the deeper your understanding will be. Don't miss the opportunity to share what you are learning with your parents.

- Review the roles and responsibilities that will change only four times—after they take a *Squared Away* test.
- Discuss the importance of good cooperative work and review briefly the **Cooperative Group Work Rubric** in the folder.
- Allow teams 2 minutes to come up with a team name that has to do with astronomy or seasons. Have **Writers** write their team name neatly on the folder.

Technology tip
You can project the Introduction on a SmartBoard™ or digital projector.

Teaching tip
If you would rather have students read the inroduction on their own, you can download it from the CD and create a handout.

Teaching tip
Use the Concept Content Rubrics and Cooperative Group Work Rubrics to award points to teams. Keeping track of points sometimes motivates teams to make stronger efforts. A rating of 4 = 10 points, 3 = 7 points, 2 = 4 points, and 1 = 1 point.

Small group

2. What Really Causes Seasons?

Read or retell this introduction to the Seasons unit.

Ancient Astronomers

For thousands of years, ancient astronomers have been keen observers of the night sky. Although they had no idea that Earth was part of a solar system, they still watched the skies and kept careful records. These astronomers eventually realized that the occurrence of the Sun, Moon, and specific stars were constant and predictable.

Mythology

While ancient astronomers were observing and testing new scientific theories, the average person relied heavily on mythology to explain what they could not understand. For example, most ancient Greeks believed that Helios, the Sun God, rode his golden chariot across the sky each day from east to west. Helios had a sister, the Moon goddess Selene, who also drove her own chariot across the sky. These myths seem like fairy tales now, but they were strong beliefs for people without science.

Folk Science

Today most modern people don't believe in myths, but they have developed their own "folk science" to explain natural phenomena. A famous study of Harvard graduates found many believed Earth was hotter in the summer because it was closer to the Sun—that's totally wrong! And you will prove it in your investigations.

You are scientists

From now on, you will not need to rely on myths or folk science. With the help of a Seasons Observatory models, you will re-create on a tabletop what happens out in space. With all the new information you discover, you will *confidently* and *correctly* answer the key question of this unit—What really causes *seasons*?

3. Essay 1, Ancient Astronomers Were Very Smart

- Give Managers copies of Essay 1, Ancient Astronomers Were Very Smart,

Read or say

Teaching tip
Many people have become accustomed to referring to our planet as "the Earth." However, we don't say "the Saturn" or "the Mars." Throughout the unit, therefore, we refer to our planet as "Earth" without the article "the."

Teaching tip
Essay 1 provides an opportunity to teach reading skills in science. It also provides context for understanding ancient scientists and appreciating all those scientists accomplished with geometry and simple instruments. Therefore, if time is short, you can assign this essay for homework and move right to making the models.

Technology tip
If you have a SmartBoard® or digital projector, copy the Essay from the CD and allow students to come to the board to underline the words that their team believes answer the question.

Teaching tip
You may choose to make the models by yourself outside of class time and give them to students to use. They are quite durable and could be used with more than one class if students are careful with the tape. Also, you can use a hot-glue gun that will make them even more durable.

Teaching tip
Be certain to demonstrate the suggested folding technique and have students practice folding before making models.

Teaching tip
Try to have students work with you step by step. It's possible to glue the wrong pieces together and create a non-working observatory.

Technology tip
If you have a SmartBoard^tm^ or digital projector, copy the directions from the CD and project them to guide students as they work.

Teaching tip
If your students have learned about rotation and revolution from other Squared Away titles or another source, review this quickly to save time. Then assign Essay 2 as homework.

for their teams. Read as a whole class or as a team activity, with the Reader reading the essay as the others follow along.

- After students read both pages, Leaders can organize their teams to answer the Focus Questions. They should underline the text that answers each question. To prevent students from underlining too many words, stress the importance of reading the Question words: What? When? Where? Why? How?
- After 5 minutes or so, ask the teams to report their answers. Compare teams' answers and come to a consensus on the correct answers.

4. Seasons Observatory and Subsolar Point Gauge

- If you have decided to ask your students to make their own Seasons Observatories, give Managers the materials. Duplicate the directions from the **Seasons Observatory Construction** directions on pages 25–29.
- When construction is complete, store Seasonal Observatories in gallon-sized storage bags with team names. Also give students the Ping Pong ball on a skewer to store, but do not give out flashlights until they are needed in Square Three. See pages 62–74.

5. Essay 2, Rotation and Revolution

- Give **Managers** enough copies of **Essay 2, Rotation and Revolution**, for all team members. Read as a whole class or as a team activity, with the Reader reading the essay as other students follow along.
- After students read both pages, Leaders can organize their teams to answer the Focus Questions. They should underline the part of the paragraph that answers each question. To prevent students from underlining too many words, stress the importance of reading the Question word: What? When? Where? Why? How?
- After 5 minutes or so, ask teams to report their answers. Compare the answers among teams and come to a consensus on the correct answers.
- When reviewing, introduce Rotato Potato. Put eyes and a nose on a real potato and rotate it counterclockwise in your hand. As silly as it sounds, most students actually don't ever get mixed up again.

6. Review Vocabulary

- From time to time, take a moment to review vocabulary.
- Make a word wall or word chart of all new vocabulary as you introduce each word.

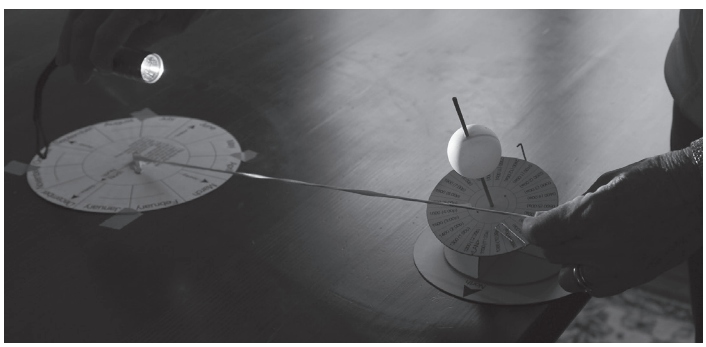
Investigation 6
Finding the Arctic and Antarctic Circles

I. Prepare your Seasons Observatory.

1. Turn the Sun Disk toward north and tape it to the center of the table.
2. Using the Sunbeam String as a guide, position the Earth Holder for the middle of March.
   - Be sure the Sunbeam String is directly under Ping Pong ball Earth and the holder axis is pointing north.
   - Tape the holder to the tabletop.
3. Practice using the flashlight.
   - The flashlight beam represents a ray of sunlight coming from the center of the sun toward the center of Earth along the Sunbeam String.
   - Hold the flashlight so that it is ***at the same height*** as Ping Pong ball Earth.

II. Find the Terminator at equinox.

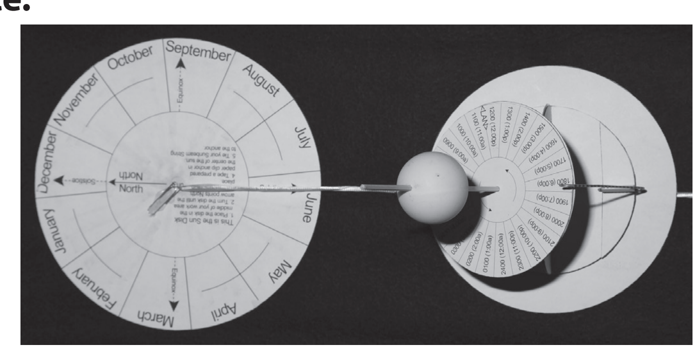
1. Shine the flashlight on Ping Pong ball Earth. Look closely at the Terminator (the shadow line) on Ping Pong ball Earth when it is in the March position.



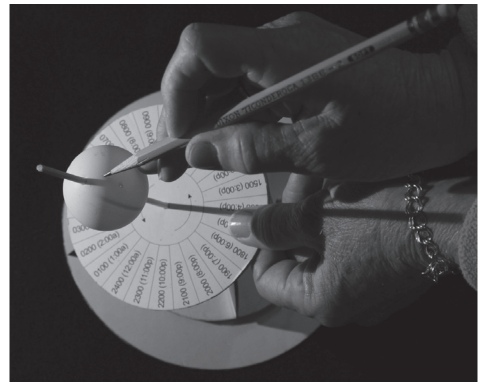
2. One-half of Earth is always in sunlight. If you have set up the Seasons Observatory correctly, at equinox the Terminator shadow will line up with the axis and pass through the North and South Poles.
3. Move the Earth Holder to the September position. Repeat steps 1 and 2. Do you have the same result? You should see that exactly half of Earth is in sunlight, with the Terminator passing through the poles.

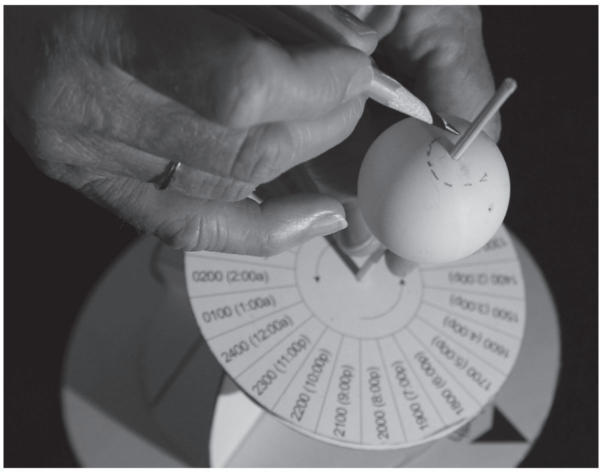
III. Find the Arctic Circle at June solstice.

1. Set the Earth holder at the June Solstice position.
2. Carefully shine the light on Ping Pong ball Earth.
3. Look for the Terminator.



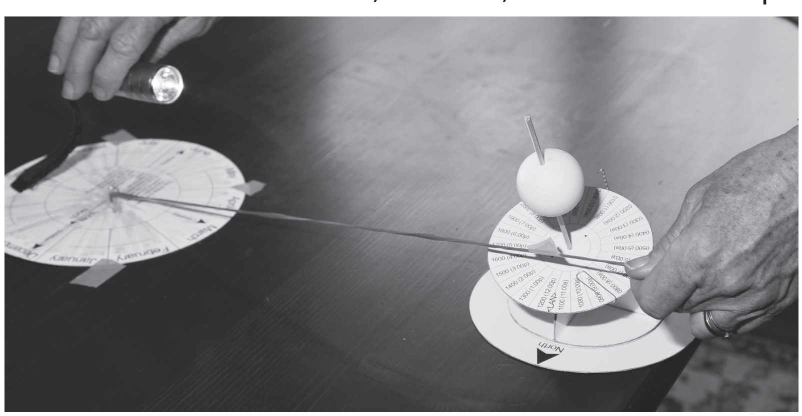
4. In tiny increments, rotate Ping Pong ball Earth and make a mark at the top edge of the Terminator.
5. When you have turned a complete rotation, you will see that you have drawn a dotted line circle marking the terminator shadow around the North Pole (skewer).
6. On the June solstice this circle around the North Pole is in constant sunlight and is called the Arctic Circle.





IV. Find the Arctic Circle at December solstice.

1. Set the Earth holder at the December solstice position.
2. Carefully shine the light on Ping Pong ball Earth.
3. Look again for the Terminator.
4. As you slowly turn Ping Pong ball Earth, watch the Terminator. What do you notice? When you have turned a complete rotation, you will see the Terminator has followed the circle you marked around the North Pole. However, this time, the circle is in complete darkness.



5. Remember that the obliquity of Earth is 23½º. Can you compute the latitude of the Arctic Circle?

North Pole 90º N – 23½º = _____º N