Seasons:
A Squared Away Unit

v1.0.1

Learn Through Experience

About the author

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Grades 5-8

Introduction to *Squared Away* Units

"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 the phrase to describe sailors who completed a task with competency, as in, "He was right squared away!" We have adopted the term to describe students who demonstrate competency in specific content and skills.

> Developing student competency is the major goal of all *Squared Away* units.

Each *Squared Away* unit allows both teachers and students to concentrate on basic concepts that can be mastered in a relatively short period of time. The basic subconcepts are taught in four instruction blocks called squares. The daily activities are interactive, exploratory, and reflective—all best practices to maximize student learning. By the end of each square, students must demonstrate mastery of the subconcepts. After completing four squares, students may be considered "squared away." However, to earn a Golden Square, students must go beyond the basic level indicating that they achieved an exemplary score on a final test/project or mastered a final task requiring higher-level thinking skills.

Levels: The units are designed as complete, stand-alone lessons. Although written for grades 5–8, the content may be used for instruction, enrichment, or remediation.

Differentiation: You are encouraged to reteach and scaffold the learning so that all students master the concepts. Investigations take place in cooperative group settings that allow for peer teaching and support for students with learning difficulties. An extensive list of optional activities follows each instruction block and provides opportunities for independent or group investigations. The Golden Square activities offer even more challenges for your more talented students.

Student grouping: Students may work in *Squared Away* units as individuals, in pairs, or in heterogeneous teams of three or four. When working in groups, students are responsible for their own learning and for supporting the learning of their teammates. All units provide Cooperative Group Work Rubrics.

Lessons: Most squares are divided into more than one day of lessons. The lessons begin with a list of concepts to be taught, materials needed, and a lesson-plan schedule.
Some parts of the lessons are scripted and you are asked to READ or RETELL the information. Throughout the lessons, there are Teaching tips and technology tips that will help you adapt the unit to your classes.

Assessments and Rubrics: All units include a pretest/posttest to be administered before starting and after completing the unit. You will also assess students daily to check mastery of content and to determine points of confusion. Part of the assessments requires students to explain orally or in writing what they understand. Students may retake assessments until they achieve mastery. The units provide quizzes, tests, and rubrics. There are many opportunities in the daily lessons, optional activities, and assessments for students to demonstrate Gardner's Multiple Intelligences.

Timeline: The lesson plans address four basic instruction blocks, or squares, and one additional block to achieve a Golden Square. Each square may take two or more days to complete, depending on the instructional time available and/or students' grade level and prior knowledge.

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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.

Seasons

A Squared Away Unit

Purpose

Most students can say they know what the word seasons means. However, most are totally unaware of how and why Earth has seasons. What is worse is that many have significant misperceptions about the topic. But teaching "seasons" has always been problematic and generally relied too much on textbook diagrams and whole-class demonstrations involving a globe and flashlight.

However, today's best practices in science require students to conduct investigation and make scientific conclusions. This *Squared Away* unit is based on best practices. It will charge your students to construct their own learning by making working models that will generate specific data. By graphing and analyzing this real data, they will discover what is truly behind seasons on Earth.

Next Generation Science Standards

(Standards are from the Next Generation Science Standards website, MS.Space Systems, http://www.nextgenscience.org/msess-ss-space-systems.)

Students who demonstrate understanding can:

- **MS-ESS1-1:** Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
- **MS-ESS1-2:** Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
- **MS-ESS1-3:** Analyze and interpret data to determine scale properties of objects in the solar system.

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena. (MS-ESS1-1), (MS-ESS1-2)

Analyzing and Interpreting Data

Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. (MS-ESS1-1)

- Analyze and interpret data to determine similarities and differences in findings. (MS ESS1-3)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

ESS1.B: Earth and the Solar System

- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause-and-effect relationships. (MS-ESS1-1)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-3)

Systems and System Models

- Models can be used to represent systems and their interactions. (MS-ESS1-2)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-ESS1-1), (MS-ESS1-2)

Knowledge, skills, and attitudes

Knowledge—*Your students will understand*:

- Earth rotates (spins) counterclockwise around its axis every 24 hours.
- Earth revolves (orbits) counterclockwise around the Sun every 365¼ days/1 year.
- Obliquity means "tilt."
- Earth's obliquity (tilt) is 23½º from perpendicular.
- Earth's axis is an imaginary line through the center of Earth from pole to pole.
- At the current time, the axis through Earth points to Polaris, the North Star.
- From Earth, Polaris marks the place in the sky around which all stars appear to rotate.
- The North Star can be located in the Northern Hemisphere by using the circumpolar stars of the Big Dipper and Little Dipper.
- That the math terms of *point*, *line*, and *plane* may be used when describing concepts in astronomy.
- The ecliptic is a plane passing through the orbit of Earth and extending infinitely into space.
- The seasons progress spring to summer to fall and to winter as Earth follows its path in orbit around the sun.
- Earth is in a specific location in its orbit when equinoxes and solstices occur.
- December and June solstices occur on opposite sides of Earth's orbit 6 months apart.
- March and September equinoxes occur on opposite sides of Earth's orbit 6 months apart.
- Latitude, which is a mapping system designed by Eratosthenes, an ancient Greek mathematician, assumes that a person is drawing an angle from the center of Earth to intersect the outside surface of Earth. 20º angle = 20º latitude.
- The equator is at latitude 0º.
- The Tropic of Cancer is at 23½º N and the Tropic of Capricorn is at 23½º S.
- The subsolar point is the place on Earth's surface directly under the sun.

- Subsolar points are at specific Earth locations depending on Earth's position in its orbit.
- At the solstices, the subsolar points are on the Tropic of Cancer (June) and Tropic of Capricorn (December).
- At a solstice (meaning "sun-stop"), the subsolar point stops moving northward or southward and begins to move back toward the equator.
- The subsolar point crosses the equator twice a year at the equinoxes.
- Seasons are opposite in the Northern and Southern Hemispheres.
- The area between the Tropic of Cancer and Tropic of Capricorn is known as the tropics.
- If the obliquity of Earth increased, then the area between the tropics would increase.
- LAN stands for Local Apparent Noon.
- Hours of daylight + hours of darkness must always = 24 hours.
- The period of daylight at the equator is always only 12 hours long.
- At the equinoxes, all parts of Earth have 12 hours of daylight.
- The range of daylight hours in the tropics is small but grows wider and wider as one moves away from the equator toward to poles.
- The terminator is the shadow line on Earth where daylight ends and night begins.
- Earth's obliquity of 23½º determines the latitude of the Arctic Circle at 66½º N and the Antarctic Circle at 66½ ºS.
- A day when the sun does not set is called a polar day.
- A day when the sun does not rise is called a polar night.
- The Arctic Circle marks the latitude where there is one polar day when the sun does not set (June solstice) and one polar night when the sun does not rise (December solstice).
- The Antarctic Circle marks the latitude where there is one polar day when the sun does not set (December solstice) and one polar night when the sun does not rise (June solstice).
- Because of Earth's obliquity, the sun rises only once each year and sets only once each year at the North and South Poles. In between, there are 6 months of polar days and then 6 months of polar nights.
- At latitudes north of the Arctic Circle and south of the Antarctic Circle, the number of polar days or polar nights increases as one nears the poles.

- The angle of incidence in the context of seasons is the angle at which the sun's rays hits the surface of Earth.
- Within the tropics, the angle of incidence is close to 90º, but away from the tropics the angle becomes more and more shallow.
- The shallower the angle of incidence, the dimmer and weaker the sun's rays.
- Although there are very long daylight hours at the poles, the angle of incidence is so shallow that the sunlight is too weak and dim to warm the Polar Zones.
- Seasons at the poles are generally defined by length of daylight hours.
- There is little change of seasons in the tropics, where the daylight hours and daytime temperatures are the same all year.
- Only in the Temperate Zones (between the tropics and the circles) are there true changes of seasons because there are changes in daylight hours and sunlight strong enough to affect temperature.

Skills—*Your students will learn how to*:

- Create a Seasons Observatory—tabletop model of Earth tilted on its axis and in its orbit around the sun.
- Use models to replicate and better understand rotation and revolution.
- Use models to replicate and better understand and the effect of obliquity (axial tilt) on equinoxes and solstices.
- Use models to replicate and better understand the effect of obliquity (axial tilt) on length of daylight hours.
- Use models to replicate and better understand the derivation of the lines on the globe (equator, Tropic of Cancer and Tropic of Capricorn, Arctic and Antarctic Circles).
- Use models to determine sunrise and sunset at different locations on Earth and at different locations along its orbit.
- Explore the effect of angle of incidence on the brightness of light.
- Use a protractor to measure and draw angles.
- Use text cues (headings, focus questions, titles), illustrations, and graphic organizers to improve comprehension of science texts.

Attitudes—*Your students will appreciate that:*

- 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.
- They can use the scientific methods and models to accurately describe, predict, test, and confirm an explanation of what they see in the night sky.
- Earth's orbit, although slightly elliptical, is nearly round in shape.
- Because seasons are opposite in the Southern Hemisphere, scientists now refer to the equinoxes and solstices by month rather than season: March equinox, June solstice, September equinox, and December solstice.
- Change of seasons is something that only certain parts of the world experience.

Content overview

This *Squared Away* unit is designed to be concept specific and is, therefore, grade-level independent. It is very effective as a concept introduction/reinforcement unit for a wide range of student ability. The investigations will give students opportunities not only to discover science concepts but also to communicate their understanding to teammates and classmates.

Square One concepts (blue square)—Students learn how ancient astronomers used only careful observation and basic mathematics to accurately describe and explain what they observed in the night sky. In students' first activities, they discover and model the difference between rotation and revolution. Each team builds a Seasons Observatory to begin its investigation. Team members model the ecliptic and Earth's axial tilt (obliquity), the location and significance of Polaris, and Earth's counterclockwise rotation and revolution. With the Seasons Observatory, students determine Earth's orbital position at the time of solstices and equinoxes.

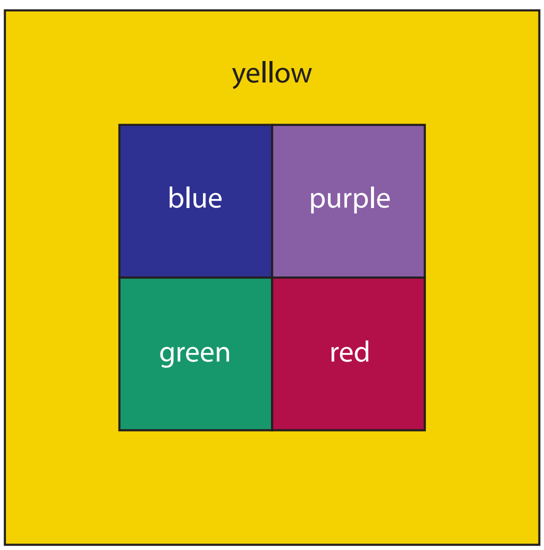
Square Two concepts (red square)—Students learn about latitude, a system of mapping designed by an ancient Greek mathematician Eratosthenes. Students use the Seasons Observatory to trace the sun's subsolar position (position on Earth directly under the sun) on model Earth as it travels in its orbit around the sun. These tracings reveal the effect of obliquity; the Earth zone we call the tropics; and the location of special lines of latitude, including the equator, the Tropic of Cancer, and the Tropic of Capricorn. They also discover the exact latitude location of the subsolar point at the equinoxes (0º) and at the solstices (23½º N and 23½º S).

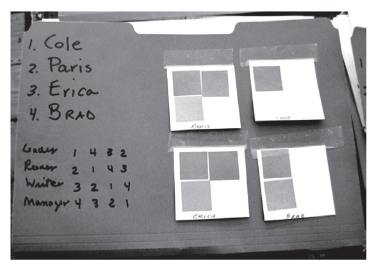
Square Three concepts (green square)—Using the Time Disks on their Seasons Observatories and their flashlights, students determine the times of sunrise and sunset at different latitudes on Earth. From the day length data they gather at different latitudes in the Northern Hemisphere; they construct bar graphs of daylight hours within seasons. They also use researched data from latitudes in the Southern Hemisphere to create graphs that prove seasons are opposite in the Northern and Southern Hemispheres.

Square Four concepts (purple square)—Students use their Seasons Observatories and flashlights to trace the Arctic and Antarctic Circles on their model Earths. They discover polar days when the sun never sets and polar nights when the sun never rises. They investigate the effect of the angle of incidence on polar regions that may have almost 24 hours of daylight—"Land(s) of the Midnight Sun." After putting together all they have learned about Earth's orbit, obliquity, day length at different latitudes, subsolar points, and the effect of the angle of incidence, student can discuss seasons in the three main kinds of climate zones of Earth (Tropical Zone, Temperate Zones, and Polar Zones).

Golden Square concepts—Using what they know about the effect of the orbit and obliquity on Earth's seasons, students predict seasons on exoplanets.

Making the individual award squares



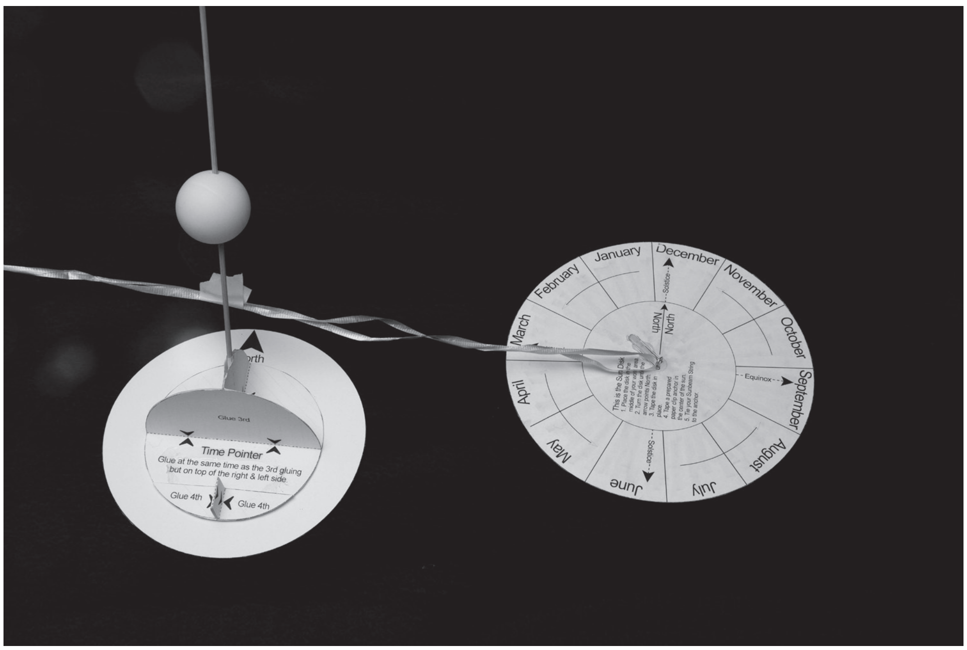


Teaching tip
Attach the background squares to the team folders so students do not lose track of them.

Award squares can be created from four pieces of construction paper, each a different color. First, cut the paper into 1-inch strips and then cut those strips into 1-inch squares. The four colors used here are suggestions; however, use only yellow paper for the Golden Square. Cut a 2¼-inch plain white square that will form the backing. You or your students will paste their earned squares on the backing as they complete each instructional square. Make a 3½-inch yellow square for each Golden Square. (You may choose to trim the backing before affixing the four-square to the Golden Square.)

Making models

This unit requires the teacher or small groups of students to build a Seasons Observatory, Time Disk, and Subsolar Point Gauge. These models require readily available materials, such as patterns (provided in this book), Ping Pong balls, wooden skewers, spray adhesive, and flashlights. If your school budget is limited, ask your PTO/PTA to contribute toward or donate materials. Directions for determining the number of these items and their preparation are on page 23.



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

General Directions

Seasons

Instruction blocks (squares)

This unit is divided into four instruction blocks, or squares, that address specific instructional objectives related to seasons. The concepts in each square are sequential and build on the knowledge and skills learned in the square before it. Always evaluate the tests of one square before going on to the next.

Student grouping

Students may work in this *Squared Away* unit in teams of three or four. Create your teams before the first lesson. Generally, the most successful teams are mixed in terms of gender, science sense, and study skills.

Student roles rotate after each Square Test. You may combine roles when necessary. Extra team members rotate in and out of roles. (For teams of three, combine Leader and Reader.) Change roles only after each individual Square Test.

Leader: Organizes the team and directs team members as needed. He/she is the official timekeeper and checks that the day's assignments are complete. The Leader also keeps the team motivated and on-task.

Reader: Reads handouts and/or activity directions, clarifying and repeating as necessary

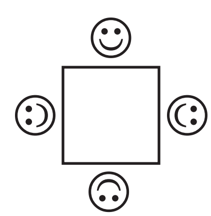
Writer (Recorder): Writes the team's responses and uses the calculator

Manager: Collects and returns supplies, handouts, and materials needed for the team's daily work. The Manager maintains the team folder and hands it in to you at the end of each day.

Teaching tip
Some of the investigations in Seasons work better if specific tasks are not assigned to specific roles. In those cases, the Leader directs the team with the explicit direction that everyone must be involved in the investigation.

Classroom arrangement

Organize students around four desks that will serve as a table for the activities. Allow as much space as possible between groups so that students can converse among their teammates without distractions.



Supplies and duplicated materials

The supplies you need to gather and the list of handouts you need to duplicate are listed at the beginning of each lesson section in each square."

A complete list of supplies is on page 23. You will find most of what you will need right in your classroom. Consider photocopying all of the handouts ahead of time and storing them in order in a hanging file.

Student folders

Create a folder for each team, listing the names of team members on the front. Inside the folder, attach one copy each of the **Cooperative Group Work Rubric** and the **Content Concept Rubric**. On the outside cover, paste blank background squares and make a role assignment chart. Review the duties of each role before beginning an instructional square. Decide where in the classroom you want students to store and retrieve folders and models each day.

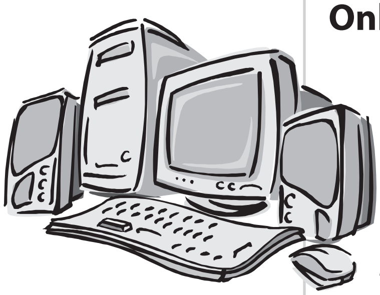
Lesson plans and timeline

Squared Away lesson plans begin with a concepts list, materials list, and vocabulary list. A lesson schedule matches the headings within the numbered lesson steps. Always read through the day's lesson ahead of time to familiarize yourself with how the lesson should proceed and how the concepts are developed. Specific concepts are introduced in a specific order to minimize confusion. The lessons take about 45 minutes or more, depending on your students' prior knowledge, and are arranged within instructional blocks, called squares. If you need more class time to reteach students who are having difficulty, allow those who are squared away to work on the Optional Activities.

Technology in the classroom

The essays, photos, and instructions for Seasons may be uploaded to a SmartBoard™, computer, or digital projector so that all students may share the information or instruction. Consider using a document camera to share student graphs, Stop/Think/Draw/Write answers, or drawings.

Online resources



Use search engines and online encyclopedias to find the most current information to use in your class. Before starting the unit, explore Google or Bing or the NASA website and build a list of URLs with their links in a classroom computer folder that you and your students can readily access. When searching Google, click on "image." Add the "+" symbol and the words video or photo for more specific searches. If you intend to show students a YouTube video, be certain to look at it ahead of time. There are many videos available, but too many are filled with incorrect information.

Stop/Think/Draw/Write

In every lesson, students are asked to stop, think, draw, and write about something they have been studying. Research supports enhanced understanding and recall when students are asked to process new information in writing. Following is the recommended procedure:

- Students first work individually. While they work, walk around and check that students who have finished early have included all they know. Tell students to check their spelling and to work neatly.
- Allow individuals 3 to 4 minutes to complete their work. Reconvene the teams.
- Have students share what they wrote or drew with their team.
- Then ask teams to choose one teammate's explanations and drawings to share with the whole class.
- Go over the correct answers with the class and have students correct their STDW papers.
- Use the Concept Content Rubric to assess team answers. Reinforce correct explanations and correct those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the chalkboard. Ask students to correct their papers, if necessary.
- If your students maintain science notebooks, you may decide to have them add these pages to their notebooks. Otherwise, have students keep their pages in the folder until they need to take them home to study them. Ask them to put their names and team name on each sheet. They should staple new pages to existing pages so that all their work is together. Check these drawings and writings daily as quick informal assessments. Award team points if you are using team competition as an incentive. See page 103 for a blank copy of **Stop/Think/Draw/Write** without specific prompts.

Chart paper activity

Best practices encourage teachers to help students focus on their learning they are learning. It recommends that students examine the validity of the concepts they are constructing. Asking students to first post their initial understanding and then revisit it as new investigations take place is a good way to adopt best practices. This practice also helps students to abandon folk science and replace it with accurate scientific understanding.

Square Review Essays

Before assigning any final assessments, have students read the Square Review Essay that recaps what they have done in the current square. This makes a good homework study sheet or a start for a team discussion before taking the Quick Team Quizzes.

Assessments

The Pretest and Posttest are identical and are administered at the beginning and at least one week after the end of the unit. Administer the Pretest before Instruction Day 1, and remind students not to guess on the Pretest. The Pretest will reveal students' prior knowledge so you can be more confident about the pace of your lessons. The Pretest may also reveal incorrect ideas students may have picked up or developed on their own. The posttest will let you know how competent your students have become with the content and skills presented in the unit.

Teaching tip
Sometimes some students "hide" during group work, allowing the more vocal students to answer all the questions and make all the comments. Create a seating chart for each day of instruction. When you call on a student, make a checkmark near his/her name. If the student seems confused, circle the checkmark.

Cooperative Group Work Assessment is ongoing and important to the success of this unit. Students need to work together, taking responsibility for their own learning and helping their team members to succeed. Post the **Cooperative Group Work Rubric** and tape one copy inside each team folder. During the instruction square, occasionally refer to the rubric and comment on how the teams are working. Praise good work and, when necessary, point out where teams could improve. At the end of each square or the end of a teaching day, assess every team member using the Cooperative Group Work Rubric as your guide. At the end of the unit, give students a copy of the rubric with an overall assessment of his/her group work.

The Concept Content Rubric is provided for assessing student understanding when they draw their answers or write short essay answers. See pages 19–21 for exemplars. Tape one copy of this rubric inside the team folders. Use this rubric to provide maximum feedback to the students. Informal assessments are also ongoing and important. At different times during the lesson, take a moment to ask students individually or as teams to explain what they understand or to demonstrate something they have just learned. You can ask them to respond orally or to quickly write an explanation to share. If you detect confusion in one student, it may indicate a general confusion..

Quick Team Quizzes take about 5 minutes to administer, but they allow you to make a final check before distributing the individual tests. Each team member gets his or her own paper to complete, but when all of the team members have finished, they compare answers. If there is a discrepancy among the answers, the team discusses the answers and what the team members were thinking. You may also pair teams to compare answers. Always remind students of the Cooperative Group Work Rubric and their responsibility to be kind and supportive. After 3 to 5 minutes, go over the correct answers with the whole class, addressing any questions they may still have.

Individual Square Tests should be administered at the end of each square, either at the end of an instructional class period or at a later time. Separate the desks and insist that students work individually on these assessments.

- Before beginning a new square, evaluate student answers for the Square Test to determine the need to reteach some concepts. When grading the Square Tests, do not rely on percentage. Use the Concept Content Rubric to assess whether or not your students are ready to go on to the next square. To earn a 4 or 3, students must have three or fewer errors, and those errors should be minor. However, even if a person had only two errors, but confused equinox and solstice, they should only earn a 2 (Nearly there).

- Hopefully most of your scores will be 4, 3, and 2. Generally, only a few students will be confused about one or two test questions. Create small special groups, review, and retest. The retest should be a new copy of the same test with those items he/she must redo circled or highlighted. Students who earn a 1 will need much more attention and time for reteaching.

- The second, third, and fourth Square Tests contain questions from the previous squares, so the fourth test may be considered a make-up exam for the three previous squares. The Posttest will serve as a final assessment, but you should administer that a week after you finish the unit.

The Golden Square Challenge is a fifth assessment given after students work with the more difficult concept of applying what they have learned about seasons on Earth to two other planets that have different obliquity. Not all students will earn the Golden Square. To achieve a Golden Square, students must complete a three-part challenge. In the first two parts, students synthesize what they have learned about seasons and apply it to discuss seasons on two very different exoplanets. In Part III, they discuss which planet would be more habitable for humans and why. See page 92 for Golden Square Challenge materials. Use the Concept Content Rubric to grade students' work.

Answer Keys for all activities and assessments are at the end of the lesson plans for each square.

Reinforcing and reteaching concepts

The timeline of this unit depends on your students' prior knowledge and the length of your science period. It is often difficult to find time to reteach students who do not grasp concepts on the first round. However, it is essential that you work with struggling students before they are overwhelmed. Consider stopping after Square Two and again after Square Three to work with students who still need help. Consider allowing the students who have mastered concepts to work on the **Optional Activities** while you work with those who need more instruction.

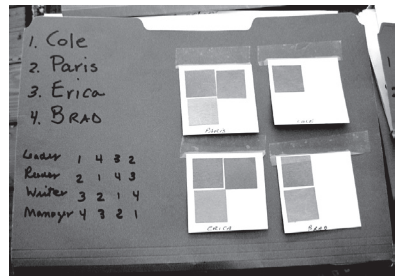
Teaching tip
Because you retest using the same Square Test, do not return tests to students. Tell them concepts they misunderstood and direct them to the activity or Quick Team Quiz, which they can take home.

Teaching tip
To earn a square, your students should earn a rating of at least a 3 on their tests. They can earn a 3 for answering almost all of the questions correctly. If they miss a key question, award only a 2, reteach, and allow students to retake the test for a higher score. Reserve a rating of 4 for perfect or near-perfect tests.

Team competitions

One goal of this unit is for all students to work cooperatively to learn the content. However, awarding points for good teamwork and appropriate student behavior may add incentive for better effort. Consider grading classwork and teamwork using the rubrics provided and award a score of 4, 3, 2, or 1. Consider giving scores for neatest folder, being first on-task, finishing on time, and so on. Keep a daily running tally to encourage students to do their best. Because it is much more difficult to earn a score of 4 than a 2, consider weighting the scores so that a 4 = 10 points, a 3 = 7 points, a 2 = 4 points, and a 1 = 1 point.

Awarding squares



Although the lesson plans suggest awarding squares at the beginning of an instructional period, the most efficient way to award points is to glue the squares onto student folders and announce the names as you distribute them.

If possible, notify students ahead of time as to why they are not going to earn a square that day. Stress that they will eventually earn their squares, and arrange a time to reteach and retest them. Consider giving students a portion of a square to indicate that they have mastered some of the content.

Your classes may be too "grown up" to respond well to collecting squares. In that case, you may choose to acknowledge achievement in other ways. Consider posting a wall chart with check marks, offering class privileges (free time, prizes, etc.) or whatever else will help motivate your students.

Final award celebration


Special Award

Recently we have been working on a special Math unit called *Squared Away*. "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!" We have adopted the term to describe students who demonstrate competency in specific content and skills.

Students could only master the concepts and skills of this *Squared Away* unit by learning a great deal about phases of the Moon and eclipses. During this unit, they used models to develop their understanding and were required to demonstrate with words and drawings all that they discovered. They learned what causes the Moon's phases, and they learned the names of the phases and what position of the Moon caused each phase. They also learned about solar and lunar eclipses, including the positions of the Sun, Moon, and Earth necessary for an eclipse to occur.

Congratulations to

For being Squared Away in phases of the Moon and eclipses

With the successful completion of the individual Square Four Test, students are considered Squared Away in Seasons. However, consider waiting until you run the Golden Square Challenges to celebrate. This will give you more time to work with those students who are close to finishing the four squares. It would be best if all your students successfully completed the four instructional squares. The Golden Square Challenges are just that—challenges—and not essential to being considered Squared Away. However, give special recognition to all those who do achieve a Golden Square.

Design a celebration appropriate to your students' ages and your available time and resources. Give one of the two Special Award Certificates to acknowledge student achievement.

Using the Concept Content Rubric for Science

Concept Content Rubric

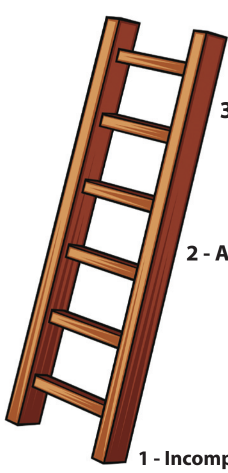
❹ **Exemplary**—You demonstrated a *clear* understanding of the concept. You *accurately* and *completely* described/drew the concept in detail using correct vocabulary. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

❸ **Expected**—You demonstrated a *good understanding* of the concept. You *accurately* described/drew the concept using some *detail* and *correct vocabulary*. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

(If your evaluation is Level 2 or 1, strive to correct your work at least to Level 3.)

❷ **Almost There**—You demonstrated *some* understanding of the concept. However, you did not describe/draw it as accurately or completely as needed and some of your vocabulary was incorrect. Or you did not communicate your understanding clearly because of spelling or grammatical errors. You may need to meet with your team or teacher to learn the concept more completely, or you may need to redo your work, correcting the errors.

❶ **Incomplete**—You demonstrated *little* or *no understanding* of the concept, so you could not describe/draw/label it. You need to meet with your team or teacher to relearn the material.



Sample student work

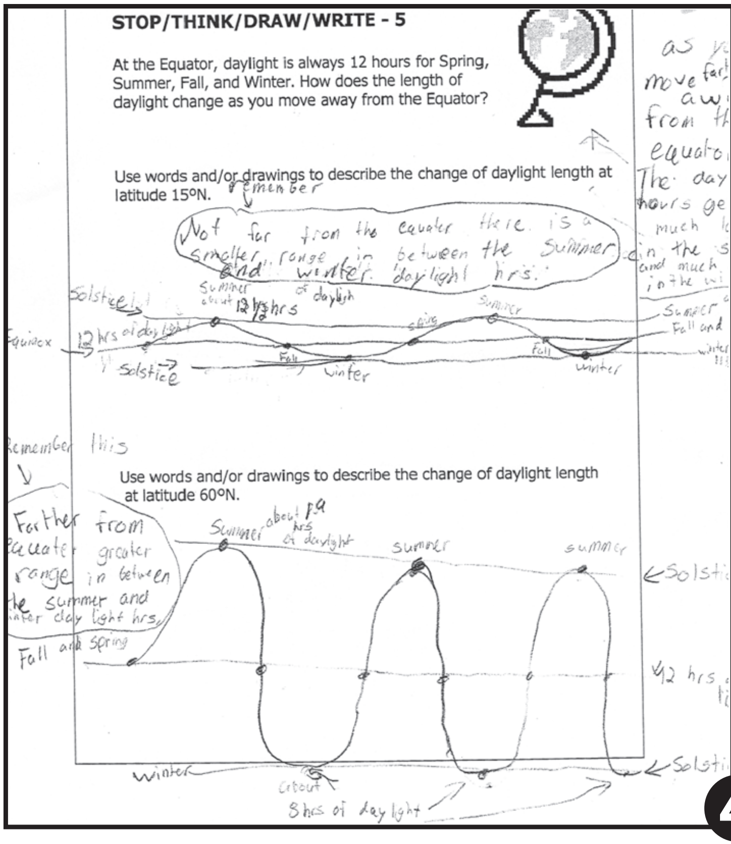
For this assessment, students were asked to explain with drawings and words how the length of daylight changes as one moves farther away from the equator. On the next three pages, you will see six exemplars of student work. The students with a rating of Exemplary, 4, clearly understood that at the solstices the range of daylight hours increases as one moves farther from the equator—much longer days in the summer and much shorter days in the winter. They made clear graphs with labels noting equinox and solstice events.

The student who earned a rating of Expected, 3, correctly described the basic concept but provided only minimum proof.

The student with a rating of Almost There, 2, showed that he knew the days would get shorter at higher latitude. The drawings showed a narrow Tropical Zone at 15º and a range of daylight hours in the graph. However, he did not adequately explain all that he knew.

In one of the samples earning a rating of 1, the writer made graphs for 15º and 60º that looked too much alike, and his words didn't make sense. The work of the other student who earned a rating of 1 shows no understanding of the concepts.

The mention of "subsolar point" in the first question is not relevant to this STDW. The steep graph answer in the second question (latitude 15º) belongs in the third question (latitude 60º).


STOP/THINK/DRAW/WRITE - 5

At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

as you move farther away from the equator The day hours get much longer in the summer and much shorter in the winter

Use words and/or drawings to describe the change of daylight length at latitude 15ºN.

remember

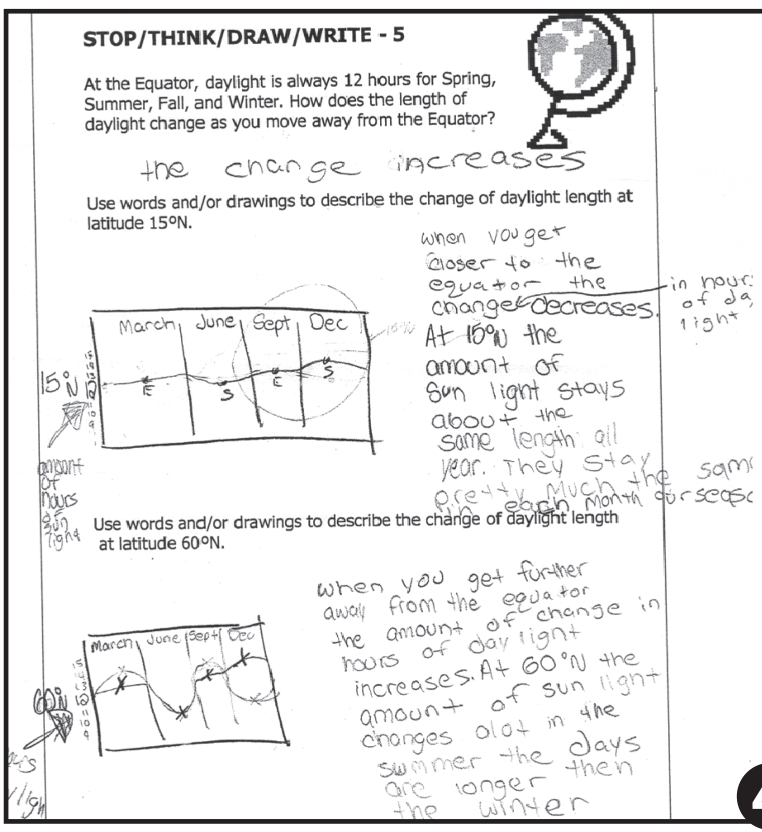
Not far from the equator there is a smaller range in between the summer and winter daylight hrs.

Remember this

Use words and/or drawings to describe the change of daylight length at latitude 60ºN.

Farther from equator greater range in between the summer and winter day light hrs.

4


STOP/THINK/DRAW/WRITE - 5

At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

the change increases

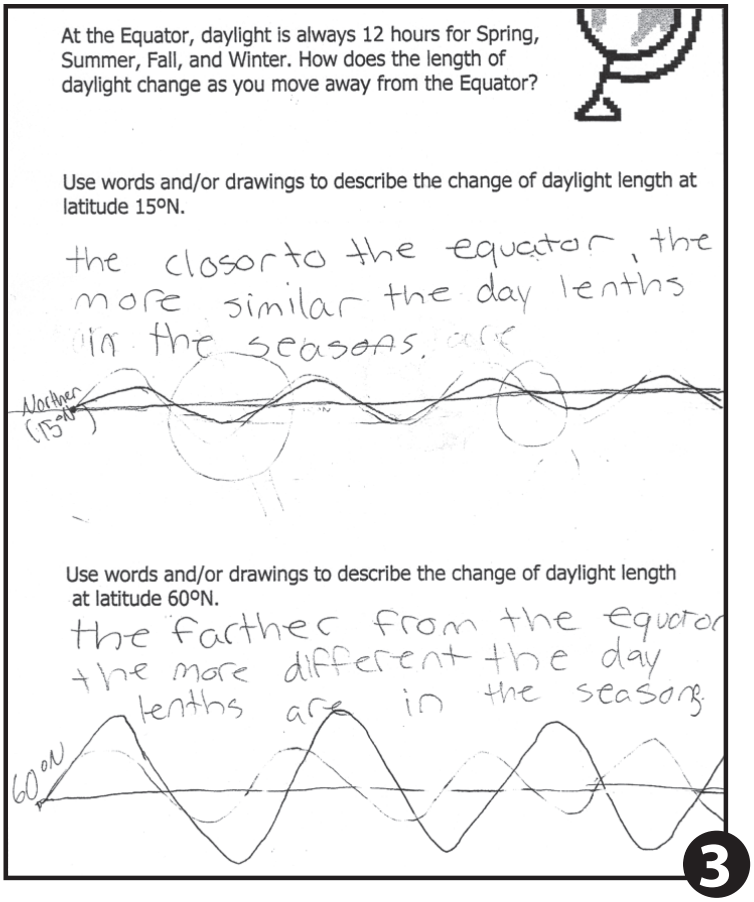
Use words and/or drawings to describe the change of daylight length at latitude 15ºN.

when you get closer to the equator the change in hours of daylight decreases. At 15ºN the amount of sun light stays about the same length all year. They stay pretty much the same each month or season

Use words and/or drawings to describe the change of daylight length at latitude 60ºN.

when you get further away from the equator the amount of change in hours of daylight increases. At 60ºN the amount of sun light changes alot in the summer the days are longer then the winter

4


At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

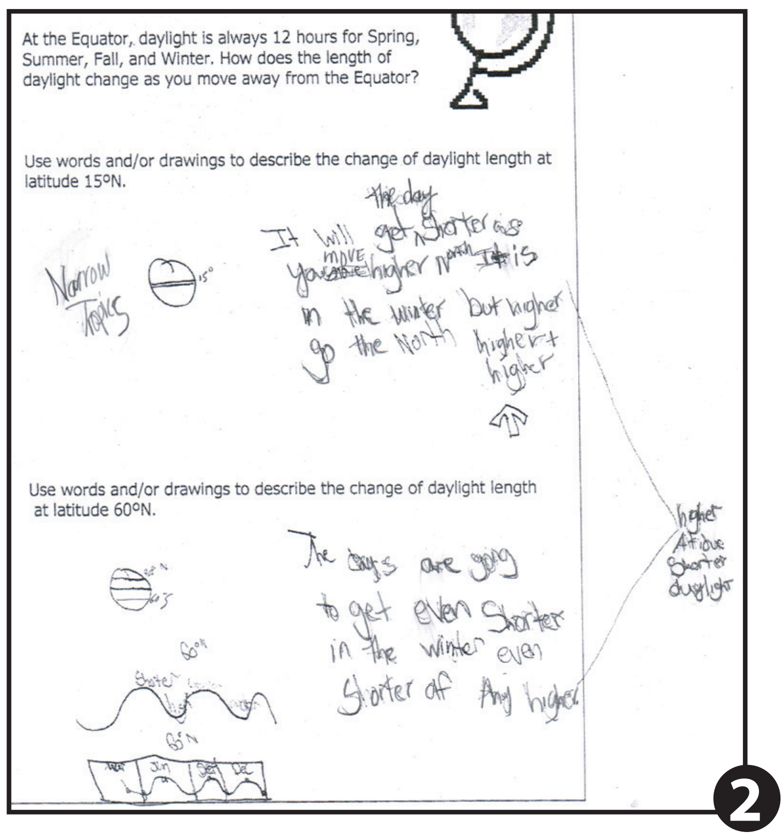
Use words and/or drawings to describe the change of daylight length at latitude 15ºN.

the closor to the equator, the more similar the day lenths in the seasons. are

Use words and/or drawings to describe the change of daylight length at latitude 60ºN.

the farther from the equator the more different the day lenths are in the seasons.

3


At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

Use words and/or drawings to describe the change of daylight length at latitude 15ºN.

It will the day get shorter as you move higher north it is in the winter but higher go the North higher + higher

Use words and/or drawings to describe the change of daylight length at latitude 60ºN.

The days are going to get even shorter in the winter even shorter at Any higher

2

STOP/THINK/DRAW/WRITE - 5

At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

because the subsolar point changes

Use words and/or drawings to describe the change of daylight length at latitude 15ºN.

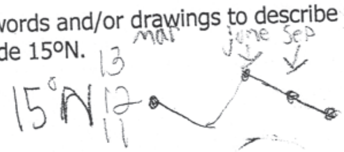
Use words and/or drawings to describe the change of daylight length at latitude 60ºN.

1

STOP/THINK/DRAW/WRITE - 5

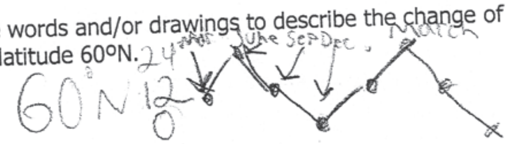
At the Equator, daylight is always 12 hours for Spring, Summer, Fall, and Winter. How does the length of daylight change as you move away from the Equator?

Use words and/or drawings to describe the change of daylight length at latitude 15ºN.



the days are shorter because that part,

Use words and/or drawings to describe the change of daylight length at latitude 60ºN.



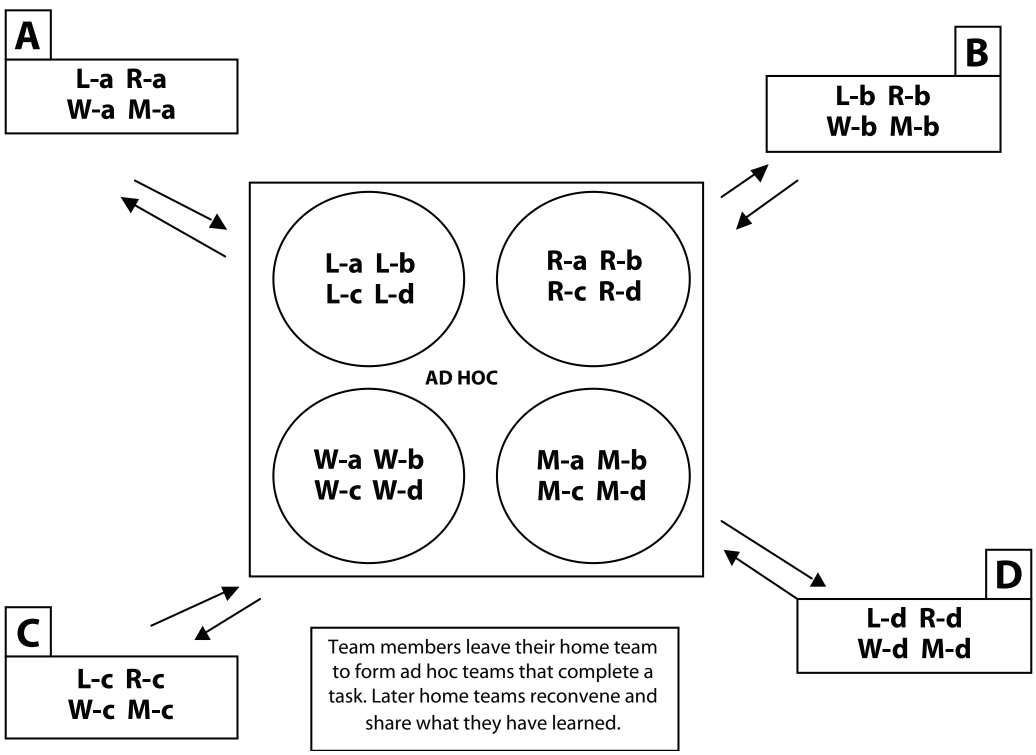
1

Jigsaw Groupings

For example: In this unit, students are asked to determine daylight hours at four different latitudes.

Leaders from all of the teams (A,B, C and D) leave their home teams and meet as an ad hoc group (L-a, L-b, L-c, L-d) to determine daylight hours at a specific latitude. **Readers** form another ad hoc team (R-a, R-b, R-c, R-d) to determine daylight hours at a second latitude.
And so on. . . .

When the tasks are complete, the home teams reconvene and jigsaw the information they have gained. The **Leader (L-)**, **Reader (R-)**, **Writer (Recorder; W-)**, and **Manager (M-)** all provide important information to their team. When that information is combined, it will inform the whole team and allow members to make a graph and draw conclusions regarding latitude and day length.



Special Directions
Before Starting This Unit

1. Read through the **Teacher's Guide** to familiarize yourself with the content and materials.
2. Purchase or acquire the following materials. These materials are readily available at low cost. If money is an issue, consider asking your local PTA or PTO to help.
   - Flashlight—*one per team*
   - Ping Pong ball—*one per team*
   - Skewer —*one per team*
   - Spray adhesive (3MCompany Super 77 Multipurpose Adhesive — optional but preferred)—*one per teacher*
   - White glue—*one per team*
   - Hot-glue gun (optional but preferred)—*one per teacher*
   - Single-ply cardboard, oak tag, poster board or file folders (18x24) —*one per team*
   - Ribbon or string for Sunbeam String (12–18 inches long)—*one per team*
   - Large paper clips—*five per team*
   - Paper plate—*one per teacher*
   - Markers or crayons—*one set per team*
3. See page 25 for the directions for building the Seasons Observatory. Here are a few things to keep in mind:

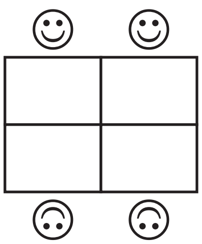
   A. You may choose to build the models yourself. A class set requires one observatory (solar disk, sunbeam string, earth holder, Ping Pong Earth, subsolar point gauge, and time disk) for each team. The models are sturdy enough that more than one class can share a set.

   B. You may choose to have each team build a model together. Duplicate the **Seasons Observatory Construction** instructions and have students work with you as you make class sets.

   C. Prepare Ping Pong ball Earth. ***Important:*** *This job is for an adult, who should prepare the skewers and Ping Pong ball Earths ahead of time. Asking students to do this step could invite injury and damaged Ping Pong balls.*

- Make sure the printed label on the ball is at the South Pole.
-  Use a pushpin to put two holes on either side of the Ping Pong ball at the poles. Wiggle the pin so that the hole is bigger than the pin's point.
- Put the skewer into the pinhole at the North Pole and push the skewer through the ball to the pinhole on the far side. Sometimes it is a little difficult to match up the skewer and the far-side hole, but with practice, this becomes easier.
- The skewers need be only 6 to 7 inches long. Snip off the pointed end to the proper length.

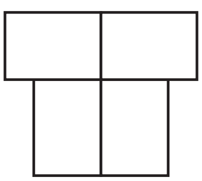
4. Organize the **teams** and prepare the **team folders**. See student folders, page 12.



5. Read the **unit introduction.**

   Read or retell the Introduction to a Squared Away unit at the beginning of Lesson One, page xx. If you prefer that your students read this on their own, photocopy it and distribute it as their first handout.

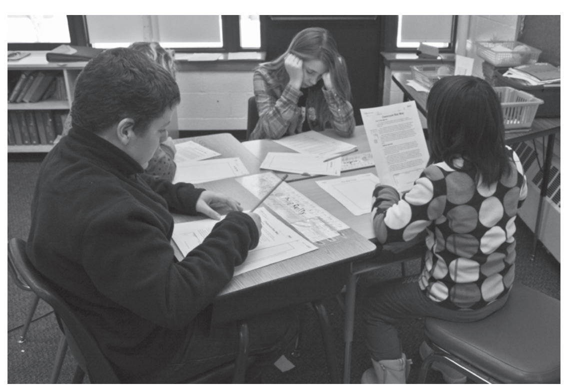
6. **Photocopy** the handouts and collect the materials for Days 1 and 2 before beginning Square One. Many teachers photocopy the entire unit and store handouts in hanging folders.



7. If you decide to award squares, prepare the awards background square (see page 8) and the colored squares. Attach them to folders. If you decide the use a chart, explain the chart when you explain the unit.

8. On the day you begin the unit, announce the teams and assign student roles. Review the duties of each role using the Cooperative Group Work Rubric.

9. Administer the Pretest.



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

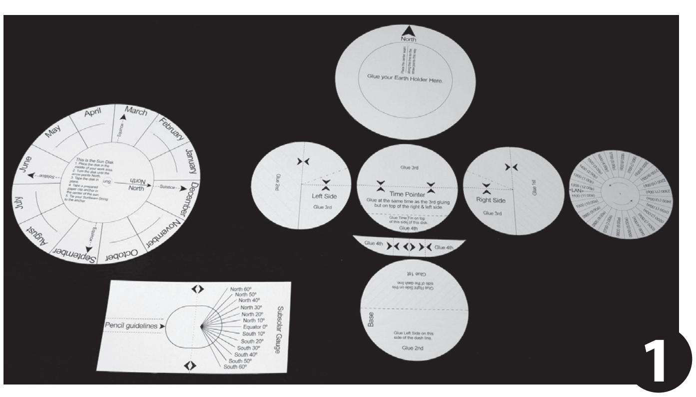
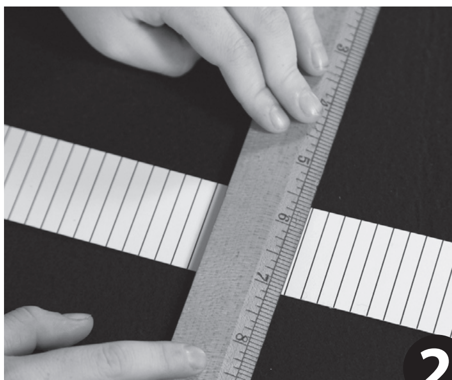


Figure 1 shows all of the Seasons Observatory pieces needed by one team. The large disk to the left is the Solar Disk. The rectangle underneath the Solar Disk is the Subsolar Point Gauge. All of the remaining pieces will make the Earth Holder.

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.

4

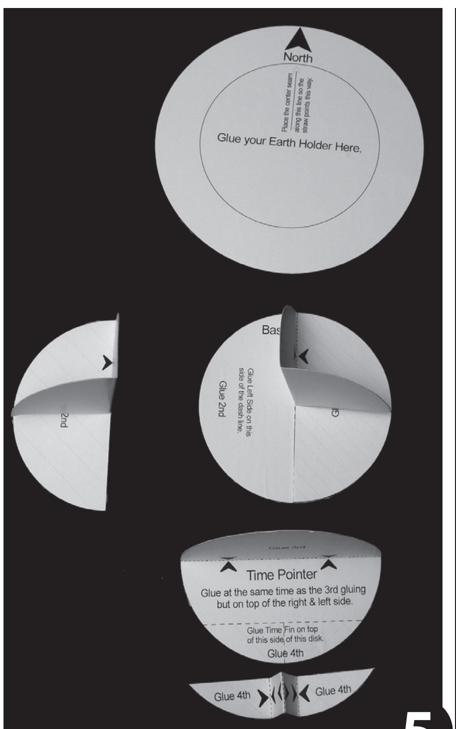
Step 3: Gluing the Earth Holder

The pieces of the Earth Holder can be glued with full-strength white glue and then held in place with large paper clips while the glue dries. However, using a half-inch-sized dot of hot glue is so much faster. Depending on your management style, you can have students come to your work station for you to use the hot-glue gun, or you can use an extension cord to move from team to team as they call you. Either way, use a large piece of corrugated cardboard as a work surface for the gluing.

Begin with the six pieces of the Earth Holder as shown above, folded and ready for gluing. The Holder will be built on top of the Base disk (the medium-sized disk in the middle).

a. Glue the right side to the Base (see Figure 5).

b. Glue the left side to the Base (see Figure 6).



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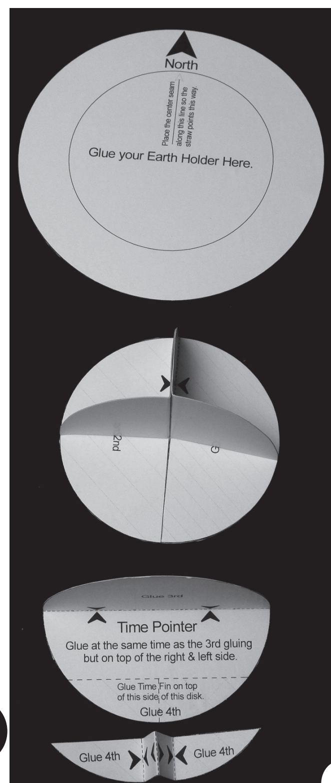

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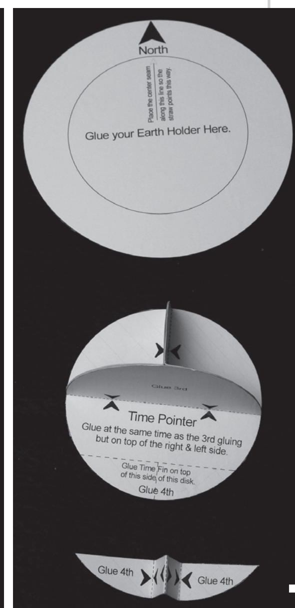
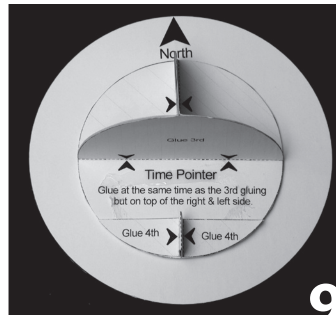


7

c. Glue the Time Pointer to the base and to the back parts of the left and right sides (see Figure 7). Important: Do not glue the front parts of the left and right sides to each other at this time. They will be pressed together and you will be tempted to glue them, but you must wait until Step 3g!

8

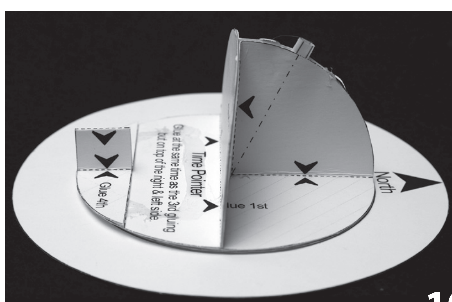


9

d. Glue the Time Fin to the back edge of the Time Pointer (see Figure 8).

e. Glue the base to the North Pointer. Align the fin-like front part of the left and right sides with the North arrow (see Figure 9).

f. Push a short piece of soda straw into the front parts of the left and right sides as shown in Figure 10. Use the dot-dash line as a guide. Try to get the straw as close as possible to the angle of the dot-dash line, even if that means that the straw does not go all the way to the bottom.



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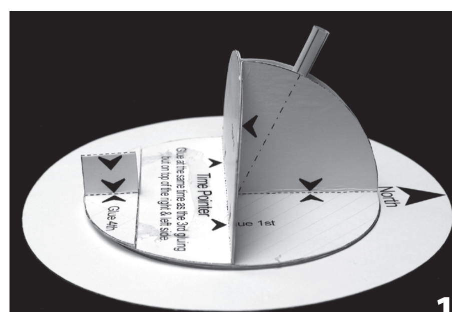


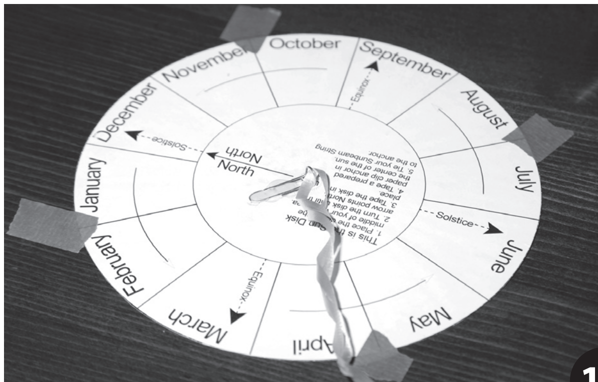
11

g. Now finally you can glue the front parts of the left and right sides together and trim off the excess straw (see Figure 11). Note the hot glue showing on both sides of the straw.

Step 4: Preparing the Solar Disk

a. Use a pair of pliers to put a 90-degree bend in the small end of a paper clip. When the unbent part of the paper clip is lying flat, the bend should stick up like a little loop. Use white glue—or, better, hot glue—to attach the paper clip so that the loop is in the center of the Solar Disk.

b. Tie a string or ribbon to the loop so that the string will reach from the center to the edge of student work surfaces.

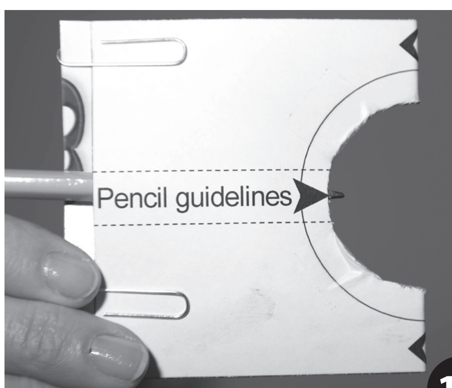


12

Step 5: Preparing the Subsolar Point Gauge

a. You folded the Subsolar Point Gauge in Step 2; now you must cut out the C-shaped center. Do this carefully because you will be cutting through two layers of cardboard.

b. Place a pencil inside the dotted pencil guidelines and use two large paper clips to hold it in place (see Figure 13).



13

Step 6: Preparing the Time Disk

Cut out the two pieces of the disk and glue them together.

Last, if students have created their own models, distribute gallon-sized plastic zipper bags. Have students label the bags and store all bits of their Observatories in these bags throughout the investigation.

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

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

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.

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.

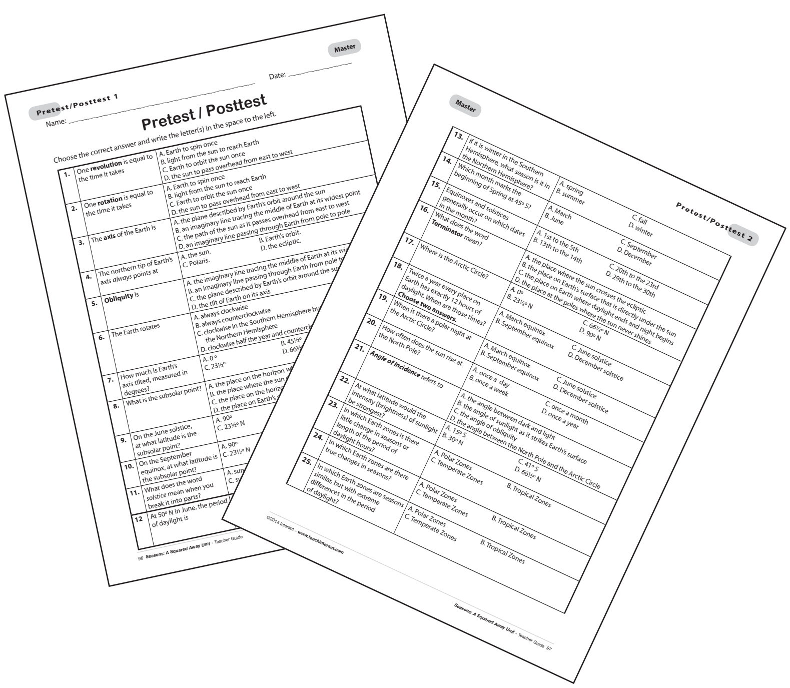
4. Before presenting the directions to the class, make a Solar Disk, Earth Holder, and Subsolar Point Gauge for yourself and to use as a model for the students.

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			



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

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.

Read or say

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*?

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.

3. Essay 1, Ancient Astronomers Were Very Smart

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

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.

Instruction Block One

Days 3 and 4

Square One Concepts—*Students will understand:*

- The ecliptic is an imaginary plane passing through the orbit of Earth and extending infinitely into space
- Earth's axis is an imaginary line through the center of Earth from pole to pole.
- *Obliquity* means "tilt."
- At the current time, the axis through Earth points to Polaris, the North Star.
- From Earth, Polaris marks the place in the sky around which all stars appear to rotate.
- Polaris can be located in the Northern Hemisphere by using the circumpolar stars of the Big and Little Dipper constellations.
- The math terms of *point*, *line*, and *plane* are defined and related to the ecliptic.
- The seasons progress from spring to summer to fall and to winter as Earth follows its path in orbit around the sun.
- Earth is in a specific location in its orbit when equinoxes and solstices occur.
- December and June solstices occur on opposite sides of Earth's orbit 6 months apart.
- March and September equinoxes occur on opposite sides of Earth's orbit 6 months apart.

Materials

- Paper plate, marker, blank paper
- Seasons Observatory (Sun Disk, Earth Holder, Sunbeam String)—*one per team*
- "What Causes Seasons?" chart paper.

Duplicate

- **Stop/Think/Draw/Write 1**—*class set*
- **Investigation 1, Exploring Earth in Its Orbit**—*one per team*
- **Earth's Orbit Observations**—*class set*
- **Stop/Think/Draw/Write 2**—*class set*

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.

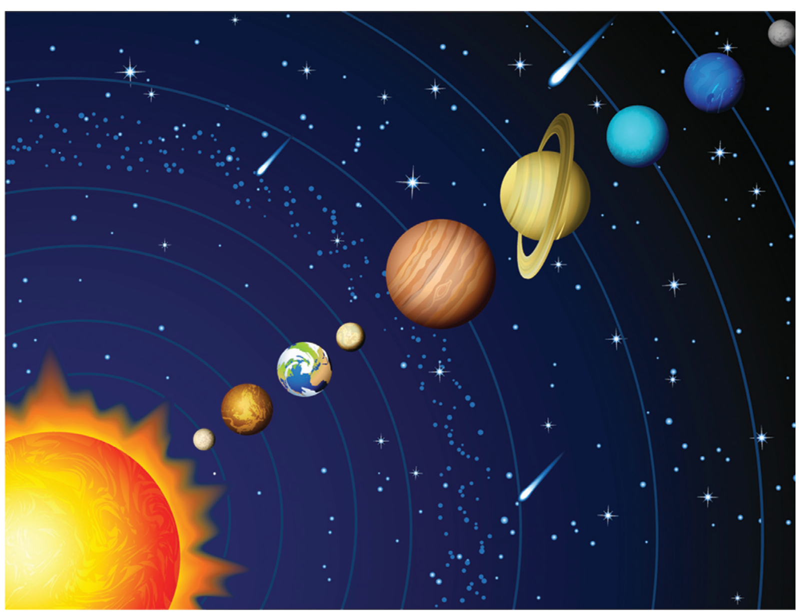
Vocabulary

- Ecliptic
- Polaris
- Circumpolar constellations
- Obliquity
- Solstice
- Equinox

- **Square One Review Notes**—*class set*
- **Quick Team Quiz 1**—*class set*
- **Square One Test**—*class set*

Lesson plan schedule, Days 3 and 4

- Stop/Think/Draw/Write 1
- Chart paper activity: What Causes Seasons?
- Polaris and circumpolar stars
- Obliquity
- The Ecliptic: Stop/Think/Draw/Write 2
- Investigation 1, Exploring Earth in Its Orbit
- Chart paper activity revisited
- Square One Review Notes
- Quick Team Quiz One
- Square One Test
- Optional Activities One



Lesson Plan

Days 3 and 4

1. Stop/Think/Draw/Write 1

- Explain that there are one or two of these challenges in every square. They are designed to prompt students to gather their thoughts and express what they know.
- Give **Managers** enough copies of **Stop/Think/Draw/Write 1** for their teammates. This challenge has the following prompt: *Use drawings and words to describe Earth's rotation and revolution in space*.
- Students should work individually. Walk around and check that students who have finished early have included all they know. Tell students to check their spelling and work neatly.
- Allow teams 5 or 6 minutes to complete their work. Reconvene the teams.
- Have students share with their team what they wrote or drew. Then ask teams to choose one teammate's explanations and drawings to share with the whole class.
- Use the **Concept Content Rubric** to assess team answers. Reinforce correct explanations and correct those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the board. Ask students to correct their papers, if necessary.
- Have the team **Managers** put all the pages into the team folder or allow students to put them in their science notebooks.

Individual

Small group

2. Chart paper activity: What Causes Seasons?

Whole class

- Spend about 2 minutes or less to ask students what they think they know about seasons. Tell them you will write, on chart paper, what they say, but it does not mean that what they say is correct. These answers mark a starting point.
- One of your students may say something about Earth tilting on its axis. Pursue the vocabulary with questions such as, "What is an axis? What does it mean to tilt? Does it always tilt the same way? Are you certain? What do you think?"
- Ask if students if they are wondering about anything on this topic or have questions related to seasons. Add these to the chart paper.
- Put away the chart paper for the time being. You will bring it out again to revise after they run each investigation.

Teaching tip
Look on pages 17–21 to see how to use the Concept Content Rubric. The exemplars will help you guide students to more complete answers. Praise what they have written, but encourage them to correct their answers or to copy the correct answer on the back of their pages.

3. Polaris and Circumpolar Stars

Read or say

Read or Retell:

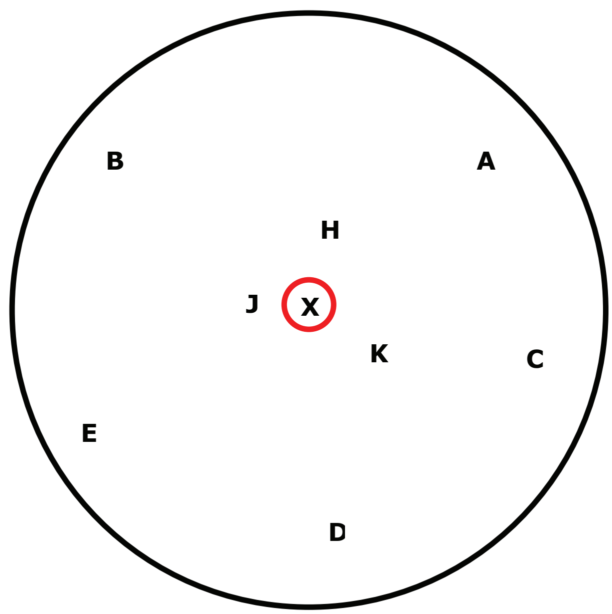
For centuries people noticed that some constellations rose and set and some seemed to go round and round about a single star in the sky. The ancient Greeks figured out what was going on. By drawing an imaginary line through Earth from pole to pole, one could draw Earth's axis. This imaginary axis would point to a star that apparently does not move in the night sky. Today, we call this single star *Polaris*, or the *North Star*. The constellations that do not rise or set but circle Polaris are called *circumpolar constellations*.

Teaching tip Modern photographers have set up cameras to film the stars moving around Polaris all through the night, creating a field of concentric circles.

STOP Show a simple demonstration.

Technology tip If you have a SmartBoard[tm] or digital projector, use Google Images to find photos and drawings of Polaris, circumpolar constellations, and precession.

- Prepare a paper plate to look something like the plate at the right. Circle the center letter **X** in red. Hold the plate toward the class and turn it clockwise (Earth spins counterclockwise, but the star field appears to move clockwise). What do they notice about the letters? Answer: They all move, except the **X** in the middle.

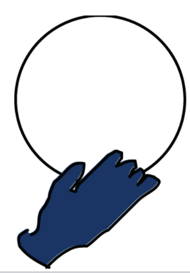


- Cover a piece of the lower half of the plate with your hand. Spin the plate again slowly. Ask students to note that the outer letters "rise" and "set" while the inner letters (H, J, K) go around the **X**. Therefore, H, J, and K are circumpolar constellations.

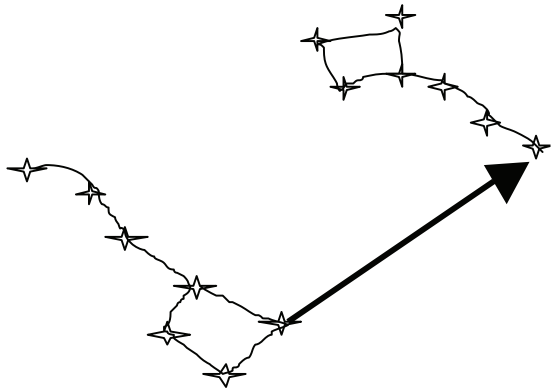
Read or say

Read or Retell

In the Northern Hemisphere you can find Polaris by first locating two circumpolar asterisms—the Big Dipper and Little Dipper.



Teaching tip An asterism is a recognizable pattern of stars that may be part of an official recognized constellation.



Teaching tip
Make a quick sketch to show students how to use the pointer stars of the Big Dipper to find Polaris, which is at the end of the handle of the Little Dipper.

Read or say

These are actually part of the constellations Ursa Major and Ursa Minor—Big Bear and Little Bear—named by the Greeks thousands of years ago. Locate the two pointer stars that form the outer edge of the Big Dipper. These stars point toward the handle of the Little Dipper. Polaris is at the end of the handle of the Little Dipper.

STOP You may or may not want to include this paragraph. If you decide not to use it, skip to the next step in the Lesson Plan.

Read or Retell

Read or say

Polaris has not always been Earth's polar star. Over the course of 70 years, Earth's axis wobbles 1º away from its current position. This is not a problem during a couple of hundred years, but over thousands of years, the wobble changes the position significantly. For example, 2,000 years ago the Egyptians built the Great Pyramids to point at their polar star. Because Earth's axis changes 1º every 70 years, our North Star is now 28º away from where theirs was.

Teaching tip
The topic of precession is beyond the scope of this unit, although you may want to include it. Earth ''wobbles" a bit as it spins, causing the axis to precess and changing where it is pointing by 1º every 70 years. The polar star position will precess for another 26,000 years before it returns to the location of our Polaris.

4. Obliquity

- Earlier, students may have referred to "the tilt of the Earth on its axis." They have just learned that the ancient Greek astronomers visualized an axis through the center of Earth pointed toward the North Star.
- Write *obliquity* on the board and explain that this is a *big* word for a simple concept. *Obliquity* refers to Earth's tilt.
- Have students practice saying the word—oh-BLEEK-wit-tee.
- When you refer to Earth's tilt, reinforce the word *obliquity*.

5. The Ecliptic

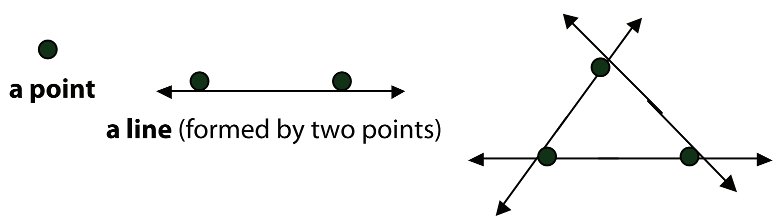
Read or say

Read or Retell

You are going to use what you know about Polaris and your team's Seasons Observatory to observe, gather data, and begin to draw conclusions about the seasons. In order for this model to work, you must make two assumptions:

Assumption 1: We are building a model of space on the table and the tabletop is the ecliptic. The ecliptic is an imaginary plane passing through the orbit of Earth and extending infinitely into space.

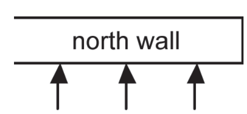
What's a plane, you may ask? A point is a single position. If you have two points and connect through them, you have a line. You need three points to define a plane.



and a plane (the space formed by connecting three or more points)

Assumption 2: Because of its obliquity, Earth's axis points at Polaris, which is millions of miles away, not just a few feet away. For this model to work, you must assume that the whole north wall of the classroom faces toward Polaris.

When using the Seasonal Observatory, always make sure the axis through Earth is pointed toward the north wall.



Teaching tip
Stop for a very brief geometry lesson. Draw a point. Draw two points and connect them with lines going through the points. Draw three points and enclose a plane. Explain that the plane, like the lines, goes on and on.

Teaching tip
Do not post a single star on the north wall.

Teaching tip
The concept of parallax is beyond the scope of this unit. You may choose to investigate the effect of parallax and why we need to use the whole north wall, rather than one point on it.

Investigation 1, Exploring Earth in Its Orbit

Teaching tip
Reinforce the new vocabulary. Ask students to look at Ping Pong ball Earth and the skewer, which represents Earth's axis. The axis is tilted showing Earth's obliquity.

Small group

- Give each **Manager** a team copy of **Investigation 1, Exploring the Earth in Its Orbit** and enough copies of **Earth's Orbit Observations** for all team members.
- Go over the directions with the whole class for Parts I, II, and III of **Investigation 1, Exploring Earth in Its Orbit**. Direct students to the sheet labeled **Earth's Orbit Observations**. The **Writer** will complete Part A with the help of the team. Walk around as teams work. Reinforce good cooperative group work.

- Check each **Writer's** drawing. (See the Square One Answer Key on page 43.) Make certain all of the axes point toward the north wall and that the equinoxes are in the side positions and solstices are at top and bottom. Direct other team members to make their own copies of Part A of **Earth's Orbit Observations**.
- Have the teams reflect on and discuss what they have discovered. In their teams, have all students answer the questions 1 through 7 of **Earth's Orbit Observations**.
- If ending the period now, allow team members to take home their papers to study. If continuing the class, have teams study and discuss their papers together before assigning **Stop/Think/Draw/ Write 2**.
- Have each **Manager** collect all of the pieces of the team's Seasonal Observatory and put them into the large plastic bag for storage.
- Take a moment to review the **Cooperative Group Work Rubric** and ask students and teams to do a self-evaluation. Point out what you'd like to see improve. Congratulate teams that worked well together.

6. The Ecliptic: Stop/Think/Draw/Write 2

- Give **Managers** enough copies of **Stop/Think/Draw/Write 2** for their teammates.
- Students should work individually. While they work, walk around and check that those who have finished early have included all they know. Tell students to check their spelling and work neatly.
- Allow teams 5 or 6 minutes to complete their work. Reconvene the teams.
- Normally, you would evaluate these papers, but it is a good time to have students do a self-evaluation. Have students share what they wrote or drew with their teams. Then ask teams to choose one teammate's explanations and drawings to share with the whole class.
- Use the **Concept Content Rubric** to assess team answers. Reinforce correct explanations and correct those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the chalkboard. Ask students to correct their papers if necessary.

7. Chart paper activity revisited

Take out the original "What Causes Seasons?" chart paper to see if students have answered any questions from this first investigation. Add the word obliquity to the chart paper, near the words "tilt on its axis," if possible.

Teaching tip
Much of the early astronomy was done in the Northern Hemisphere. The old names used to be summer and winter solstices and autumnal and vernal equinoxes. Now scientists refer to the equinoxes and solstices by month rather than season: March equinox, June solstice, September equinox, and December solstice.

Teaching tip
Consider awarding team or individual scores using the Cooperative Group Work Rubric. Award teams points (a rating of 4 = 10 points, 3 = 7 points, 2 = 4 points. and 1 = 1 point).

Individual

Small group

8. Square One Review Notes

The **Square One Review Notes** page allows students to review the activities and key concepts before the quiz or test. Ask the **Managers** to come to you for the Review Notes page. Depending on your quiz and test schedule, allow students to read these as teams or in pairs or take them home to study.

Teaching tip
All answers are on the last page of each lesson plan.

9. Quick Team Quiz One

Individual

- Ask the **Managers** to come to you for the **Quick Team Quiz 1**. Allow only a short time (about 5 minutes) for students to answer questions individually.
- When the individuals in each team have finished the quiz, team members should *work together* to correct the team papers. Team **Leaders** should read questions and members should share answers and agree which are correct. Members should help other team members who made errors. Remind students of the **Cooperative Group Work Rubric**.

Whole class

- As a whole class, present the correct answers on the board and answer any questions. Tell **Leaders** to put all quiz papers neatly in the team folders and give the folders to you, or give the quizzes to students to take home and study.

10. Square One Test

Individual

- Before moving on to Square Two, administer the **Square One Test** to individuals, not teams. Separate student desks for privacy. When students have finished, collect the tests.

Teaching tip
You may give the test immediately after the quiz, or give students the test at the beginning of the next class. If not, give it as the first activity the next time you meet. Allow students to take home their correct quizzes to study.

- While students are taking the test, consider using the time to assess students' overall cooperative group work during Square One. Using the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1 to 4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what they can do to improve.
- Correct the tests and evaluate your students' mastery of concepts in Square One. Reteach, if necessary, and retest. Those who have passed Square One can do the **Optional Activities 1** on page 46.

Square One Answer Key

Essay 1, Ancient Astronomers Are Very Smart

Focus Questions

Ancient astronomers were scientists.

3,000 years ago.

The Greeks were the first to calculate Earth's size.

It may have contained the world's first computer.

Geometry means "measurement of Earth."

Mathematics was a universal language among scientists, allowing them to share knowledge.

Egypt India, and China knew astronomy.

The fall of the Roman Empire.

Most knowledge was lost when libraries were burned.

War, famine, and plague.

Manuscripts were stored in monasteries.

Scientific feats of the sixteenth century occurred 500 years before a human went into space.

Essay 2, Rotation and Revolution

Focus Questions

Always Moving

- 1000 mph
- 66,000mph

Rotation

- Yes
- 24 hours (1 day)
- Counterclockwise

Sunrise, Sunset, Moonrise, Moonset

- East
- West

Revolution

- 1 year (365¼ days)
- Counterclockwise
- Nearly circular
- Cannot be true because in a nearly circular orbit the Earth is never really closer to the sun

REV or RO?

1. Ro
2. Rev
3. Ro
4. Ro
5. Rev
6. Rev
7. Ro

Teaching tip

You can start Square Two activities with students who are ready to move on and reteach students who do not answer most of the test questions correctly. However, do not let this second group get too far behind the first.

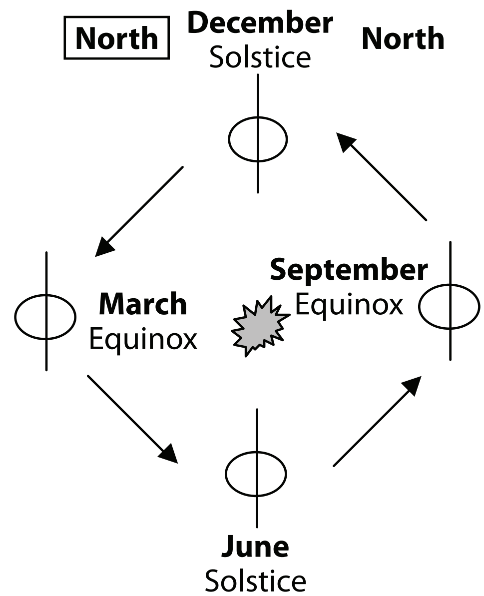
Stop/Think/Draw/Write 1

Insist on labels for drawings and questions. Students' rotation drawings should show Earth spinning counterclockwise. Their revolution drawings should show Earth orbiting the sun.

Bonus: 24 hours. 364¼ days.

Earth's Orbit Observations

Part A: See diagram at right.



Part B:

1. solstice
2. equinox
3. Six months
4. Six months
5. December
6. June
7. Polaris
8. almost round
9. no
10. no

Stop/Think/Draw/Write 2

See the drawing for Earth's Orbit Observations.

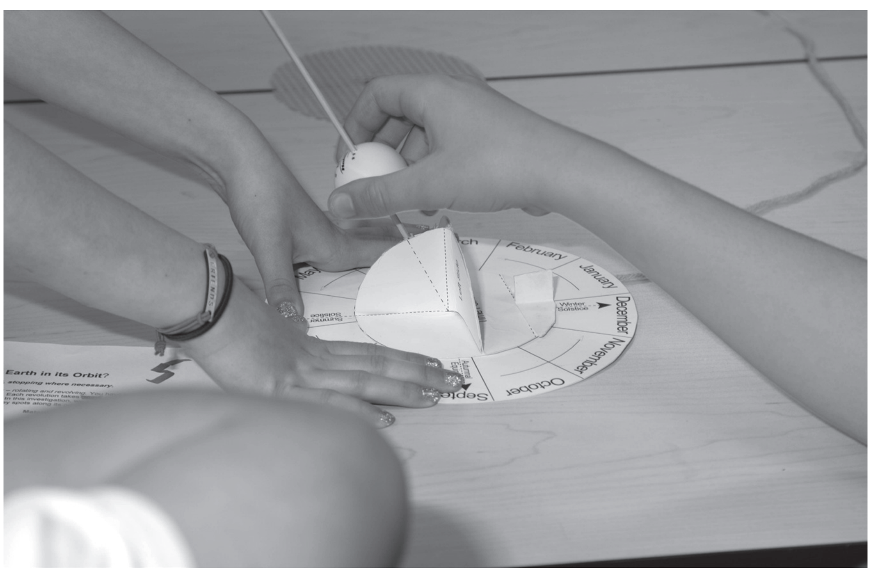
Quick Team Quiz One

1. A and C
2. B and D
3. B
4. The axis is an imaginary line passing through the North and South Poles.
5. The orbit is the Earth's path around the sun.
6. June and December
7. March and September
8. June

9. It is a constellation that travels around the polar star and does not set.
10. The tabletop
11. The ecliptic is an imaginary plane described by Earth's orbit and extending forever in all directions.
12. Obliquity is the tilt of Earth on its axis.

Square One Test

1. C
2. A
3. D
4. C
5. C
6. D
7. B
8. March and September
9. June and December



Whole class

or

Small group

or

Individual

Teaching tip
The quotation marks cause the search engine to find resources that use both words.

Optional Activities One

1. **Read** one of the many books in your library about Earth's rotation and revolution, such as the ones below. Include the rotation and revolution of Earth's satellite, the moon.

   Balchin, Jon. *100 Scientists Who Changed the World.* (2005)

   Krupp, E. C. *The Big Dipper and You.* (1989)

2. **Journal writing** is an excellent way for students to reinforce their own learning. Following is a list of prompts that you can give individual students, teams, or the whole class. Allow students to write for at least 3 minutes. Direct them to share what they wrote with their team. Then ask for volunteers to share with the whole class. Look for common comments and strategies that students write.

   - **Prompt 1:** We are constantly trying to understand the world around us. Sometimes we create an idea in our head to explain what we see. What idea that you used to believe about the seasons has been changed by what you have learned so far?
   - **Prompt 2:** If you and your family were living at 70º N latitude, what season would be your favorite and why?
   - **Prompt 3:** If you have ever lived or visited a place at a latitude that is significantly different from that of your home, describe the seasonal differences between home and this place.

3. Ask students to **research** one of the following topics and to prepare a short oral **report**, written report, and/or poster to share with their classmates. Make a timeline when appropriate. To use the Internet for your research, put the **highlighted words** in your search engine using quotation marks. Here are some to consider.

   - Study more about rotation and revolution. Type either or both words into a search engine. For example, typing "**rotation+ planet**" will yield specific websites. If you want photos, choose "**images**" and then type "**planet**."
   - Research famous astronomers from ancient India or China. Type quotation marks around the astronomers' names when using a search engine. Aryabhata,
   - Type "**Aryabhata**" into a search engine to find out about an Indian astronomer who lived in the late 5th Century.

- Type "**Johannes Kepler**" into a search engine to find out about an amazing scientist/mathematician who figured out "**Kepler's Laws of Planetary Motion**."
- Research ancient astronomical constructions, such as Stonehenge, in England
- Type "**circumpolar star**" into a search engine to find more information about Polaris .
- Research the process of precession. Then make a poster with a short report to explain why Polaris will not always be our north star.

4. **Real-life situations**

   - **Tracking the Big Dipper at night**: After sunset, go outside and look for the Big Dipper. Using the pointer stars on the dipper bowl, locate the star at end of the handle of the Little Dipper. That star is Polaris. You are going to make four drawings one hour apart. Each drawing will show both dippers in relation to each other. Label Polaris. Because they are circumpolar, the position of the dippers should change over a four-hour period. If you have the time, repeat this exercise four times over the course of 10 to 14 days. Make a poster showing your drawings with the times and explain your observations and explain what they mean.
   - **Current space events:** Type "**night sky + today**" in a search engine. See what planets or special constellations are visible tonight.
   - **Write a rap** that explains difference between rotation and revolution.

5. **Math application—measurement**

   Question: Is the time between equinoxes and solstices the same? Is it the same year to year? You can discover the answer to these and other questions you might have by applying the information you can find on the website http://www.timeanddate.com. Explore the different topics on this web page, such as equinoxes and solstices. There's also a day-to-day calculator that counts days between dates. Use the information on this website to answer the questions above. Write a report, make a graph, or prepare an oral report with your findings.

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

- Latitude
- Parallels
- Tropic of Capricorn
- Tropic of Cancer
- Subsolar point
- Equator
- Equinox
- Solstice
- Protractor

Instruction Block Two

Days 1 and 2

Square Two Concepts*—Students will understand*:

- Latitude, a mapping system designed by Eratosthenes an ancient Greek mathematician, assumes that a person is drawing an angle from the center of Earth to intersect the outside surface of Earth. A 20º angle = 20º latitude.
- The equator is at 0º latitude.
- The Tropic of Cancer is at 23½º N and the Tropic of Capricorn is at 23½º S.
- The subsolar point is the place on Earth's surface directly under the sun.
- Subsolar points are at specific Earth locations depending on Earth's position in its orbit.
- On a solstice (meaning "sun-stop"), the subsolar point stops moving northward or southward and begins to move back toward the equator.
- The area between the Tropic of Cancer and Tropic of Capricorn is known as the tropics.

Materials

- Flashlight
- Plain paper
- Seasons Observatory (Sun Disk, Earth Holder, Sunbeam String)—*one per team*
- Construction paper—*one piece*
- Ball of yarn or string
- Painter's adhesive tape
- Paper clips
- "What Causes Seasons?" chart paper

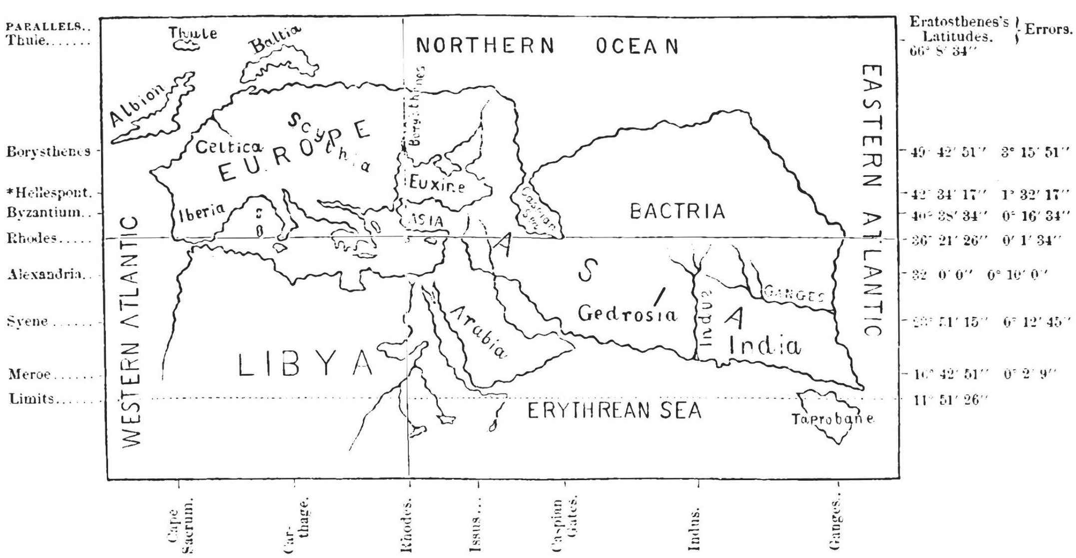
Duplicate

- **Essay 3, Eratosthenes**—*class set*
- **Latitude Activity**—*class set*
- **Investigation 2, Tracing the Subsolar Points on Earth**—*one per team*
- **Investigation 2 Team Observation Sheet**—*one per team*

- **Investigation 2 Individual Observation Sheet**—*class set*
- **Stop/Think/Draw/Write 3**—*class set*

Lesson plan schedule, Days 1 and 2

- Awarding squares
- Introduction
- Essay 3, Eratosthenes
- Introduce or review using a protractor
- Latitude Activity
- Introduce the subsolar point
- Investigation 2, Tracing the Subsolar Points
- Stop/Think/Draw/Write 3
- Chart paper activity revisited



World map as conceived by Eratosthenes.

Lesson Plan

Days 1 and 2

Teaching tip
Explain to students who have not yet mastered the first concepts that they will shortly, and you will award them their squares as soon as they do. Consider awarding parts of squares to recognize content that these students have mastered.

Awarding squares

Arrange the room and send students into teams. Students will rotate their roles today. As you hand out the folders, announce which students have mastered the concepts in Square One and award them the First Squares (blue).

1. Introduction

Read or say

Read or Retell

Teaching tip
Write the words on the board or chart paper. Refer back to them at the end of the investigations.

Have you ever wondered about the lines you see on a globe? Do any of you know the special names for these lines? (Typical answers include equator, longitude, latitude, Tropic of Cancer, and Tropic of Capricorn, and some students may even mention the Arctic and Antarctic Circles.)

Teaching tip
Use the Concept Content Rubric or Cooperative Group Work Rubric to award points to teams. Keeping track of points sometimes motivates teams to make stronger efforts.

In the last square, you investigated Earth's orbit, and now you know that there are four key events that occur at certain points during the year. In March and September, there are equinoxes. In June and December, there are solstices. You will discover how these events relate to the lines on the globe and help to explain why we have seasons. In this square you are going to discover who invented the system of the special lines on a globe, called latitude, and why those lines are located in specific places.

Whole class

or

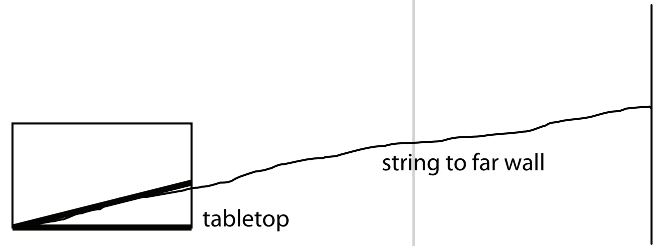
Small group

Essay 3, Eratosthenes

- Give **Managers** enough copies of **Essay 3, Eratosthenes** and the **Latitude Activity** handouts for his team members. Read as a whole class or as a team activity with the **Reader** reading the essay as the others follow along.
- After reading both pages of the essay about Eratosthenes, ask the **Leaders** to 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 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.

Technology tip
If you have a SmartBoardTM 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.

- Now ask students to pretend the classroom is a sphere and you are going to do what Eratosthenes imagined. Draw a 15º angle on a piece of construction paper. Set it on a desk. Hold a ball of string or yarn at the angle's vertex and have students extend the angle to the far wall. Ask a student to place his or her hand on the wall to mark the point. Then turn the angle to face another place along the wall and ask a second student to mark that place. Continue for several movements of the angle, and students will see the appearance of the "latitude" line on the wall.



2. Introduce or review using a protractor

- Depending on students' previous math experience, this may take 5 minutes or a whole period. You may use other math resources to make sure students know how to use this tool.
- Demonstrate how to find 46°. They need to find 45º first and then go one more toward 50º.

3. Latitude Activity

- Give students the **Latitude Activity** page and allow them time to cut out the protractor. Note that the scale runs 0º to 180º one direction and the same in the other direction so that 0º appears on both sides of the equator. The 90º point marks the North Pole.
- Work through the 20º latitude line on the board as a whole-class activity. Tell students that all of the angles in this activity are less than 90º, so students will be using 0º to 90º on the left and 0º to 90º on the right to mark two points. Measure 20º on both sides of the circle. Students should connect the points to form the latitude line of 20º N. Tell them to label it on both sides of the circle.
- Show students that they can invert the circle to measure the southern latitudes; 90º will then mark the South Pole.
- Ask students to write their names on their papers and store them in their folder. (They will need the papers later.)

4. Introduce the subsolar point

- Roll a piece of paper around the end of a flashlight to create a tube that makes a narrow beam. Shine the beam directly onto a surface. This light beam represents sunlight and the point where it hits the surface is a ***subsolar point***.—the place where the Sun's rays (sunbeams) fall directly on Earth.

- Tell students that at any given moment, there is a subsolar point on Earth, where the sun's rays fall directly on Earth. (This point moves as Earth rotates.) However, the sun's rays do not fall directly all over Earth—only within a certain region, which they will discover in Investigation 2.

Teaching tip
The key to good results is to be certain that the Sunbeam String lines up on the ball (not the Earth Holder) and that there is good contact between pencil and ball.

5. Investigation 2, Tracking Subsolar Points on Earth

- Give the **Managers** enough copies of **Investigation 2, Tracing the Subsolar Points on Earth**, for team members. Read as a whole-class or as a team activity, with the **Reader** reading the directions as the others follow along.
- Go over the procedure for running the investigation. Direct students to the **Investigation 2 Team Observation Sheet**. They have tracings to make each month, but they make observations on 8 months only.
- While students work, walk around to be certain they have remembered to orient the observatory to the north wall. Make sure that the **Subsolar Point Gauge** is oriented to the rays of the sun.

Individual

- The last sheet is the **Individual Observation Sheet**. Students need to work alone, but they can use the data their team collected to answer the questions on the Individual sheet. (See the answers on page 57.)
- Collect students' papers and direct the **Leader** to put the rest of the work in the student folder. Evaluate students' observations before the next class.

Teaching tip
You may also choose to use this as an informal assessment. In that case, allow students to work alone and then collect their work. Do a whole-class review of the correct answer.

6. Stop/Think/Draw/Write 3

Describe what the solstices have to do with the Tropic of Capricorn and Tropic of Cancer. Have students first work alone, then share with their team, and, finally, share team answers with the whole class. Students should correct their papers.

Whole class

7. Chart paper activity revisited

- Spend about 2 minutes or less to ask students what more have they learned about seasons. Add their answers to the chart paper activity from Square One. However, do not add any incorrect answers to the chart. Question students' thinking and write the comment on another page to be revisited later.
- Ask if there is anything that they want to take off the chart.
- Ask if they have any new questions they have related to seasons. Add these to the chart paper.
- Put away the chart paper. You will bring it out again after each investigation.

Instruction Block Two

Days 3 and 4

Square Two Concepts*—Students will understand*:

- If the obliquity of Earth were to increased, then the area between the tropics would increase.
- At the solstices, the subsolar points are on the Tropic of Cancer (June) and Tropic of Capricorn (December).
- The subsolar point crosses the equator twice a year at the equinoxes.

Materials

- Seasons Observatory
- Ping Pong ball Earth and Subsolar Point Gauge
- Wide-tipped markers or crayons to color graphs

Duplicate

- **Obliquity and Lines on the Globe**—*class set*
- **Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?**—*class set*
- **Stop/Think/Draw/Write 4**—*class set*
- **Stop/Think/Draw/Write 5** (optional)—*class set*
- **Square Two Review Notes**—*class set*
- **Quick Team Quiz Two**—*class set*
- **Square Two Test**—*class set*

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

- Latitude
- Parallels
- Tropic of Capricorn
- Tropic of Cancer
- Subsolar point
- Protractor
- Latitude
- Axis
- Obliquity

Lesson plan schedule, Days 3 and 4

- Review Investigation 2 results
- Obliquity and Lines on the Globe
- Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?
- Stop/Think/Draw/Write 4
- Stop/Think/Draw/Write 5 (optional)
- Chart paper activity revisited
- Square Two Review Notes
- Quick Team Quiz Two
- Square Two Test
- Optional Activities Two

Lesson Plan

Days 3 and 4

1. Review Investigation 2 results

Go back over the results of Investigation 2 and return students' observation sheets. Have students correct their observation sheets and keep them to study.

2. Obliquity and Lines on the Globe

- Remind students of how to draw latitude lines with a protractor.
- Give **Managers** copies of the **Obliquity and Lines on the Globe** sheet and have them follow the directions.
- Correct the sheets as a class. Remind students to write neatly, spell correctly, and capitalize when needed.

Teaching tip
Students must prepare neat drawings with accurate labels. Use this as an opportunity to reinforce this necessary science standard.

3. Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?

- Give **Managers** copies of **Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?**, one for every member of his or her team.
- Go over the directions as a class. Note that they should take the Earth ball *out of its holder* to investigate the different degrees of obliquity.
- Have teams complete the question in the third and last student. When all teams finish, discuss the answers. Play particular attention to when there is 0º obliquity, and ask what would happen if the obliquity were less or greater than 40º.

Whole class

Small group

4. Stop/Think/Draw/Write 4

There are two prompts on this page: Part I asks students to recall 23½º, and Part II asks them to imagine an obliquity of only 15º. Have students work alone, then share with their teams, and, finally, share team answers with the whole class. Students should correct their papers and then put them in the folder or take them home to study.

Teaching tip
You can assign Stop/Think/Draw/Write 5 for homework.

5. Chart paper activity revisited

- Spend about 2 minutes or less to ask students what more have they learned about seasons. Add their answers to the chart paper activity from Square One. However, do not add any incorrect answers to the chart.

Question students' thinking and write the comment on another page to be revisited later. Students should begin to see that location of the subsolar point is important to seasons.

- Ask if there is anything that they want to take off the chart.
- Ask if they have any new questions they have related to seasons. Add these to the chart paper.
- Put away the chart paper. You will bring it out again after each investigation.

6. Square Two Review Notes

Small group

Give **Managers** copies of the **Square Two Review Notes**. Allow teams to read it together and talk about Eratosthenes, latitude, Investigation 2, solstice, and obliquity.

Teaching tip
All answers are on the last page of each lesson plan.

7. Quick Team Quiz Two

Individual

- Separate the desks again and ask the **Managers** to come to you for **Quick Team Quiz 2**. Allow only a short time (about 5 minutes) for students to answer questions *individually*.

Small group

- When the individuals in each team have finished the quiz, team members should *work together* to correct the team papers. Team Leaders should read questions and members should share answers and agree which are correct. Members should help other team members who made errors. Remind students of the **Cooperative Group Work Rubric**.

Whole class

- As a whole class, present the correct answers on the board and answer any questions.
- Tell **Leaders** to put all quiz papers neatly in the team folders and give the folders to you, or give the quizzes to students to take home and study. **Managers** should return all supplies and check to see that the work area is cleared.

8. Square Two Test

Individual

- Before moving on to Square Three, administer the **Square Two Test** to individuals, not teams. Separate student desks for privacy. When students have finished, collect the tests.
- While students are taking the test, consider using the time to assess students' overall cooperative group work during Square Two. Using the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1 to 4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what they can do to improve.

Teaching tip
You may give the test immediately after the quiz, or give students the test at the beginning of the next class. If not, give it as the first activity the next time you meet. Allow students to take home their correct quizzes to study.

- Correct the tests and evaluate your students' mastery of concepts in Square Two. Reteach, if necessary, and retest. Those who have passed Square Two can do the **Optional Activities 2** on page 60.

Square Two Answer Key

Essay 3, Eratosthenes

Answers to focus questions Essay 3:

- 2000 years ago
- He was a librarian and had access to great books of knowledge.
- He calculated the number of degrees of tilt of Earth on its axis and the circumference of Earth at the equator.
- 25,000 miles (24,901.55 miles)
- Latitude and longitude
- Inside the center of Earth
- Equator (0º)
- 40º above the equator and 40º below the equator
- Protractor
- Lines never meet (intersect)

Investigation 2 Team Observation Sheet

March: 1. equinox; 2. on the equator	April: no observation
May: northward	June: 1. solstice; 2. northward
July: no observation	August: southward
September: 1. equinox; 2. equator; 3. six	October: no observation
November: southward	December: 1. solstice; 2. southward
January: no observation	February: northward

Globe: Tropic of Cancer, equator, Tropic of Capricorn.

Investigation 2 Individual Observation Sheet

1. They stop going northward and southward.
2. solstice
3. They are on the equator.
4. equinox
5. Subsolar points can only be found between the Tropic of Cancer and the Tropic of Capricorn.

Teaching tip
You can start Square Three activities with students who are ready to move on and reteach students who do not answer most of the test questions correctly. However, do not let this second group get too far behind the first.

6. June
7. December
8. The path of the subsolar points stops going northward in June and southward in December.
9. The tropics can be found between 23½º N and 23½º S or between the Tropic of Cancer and the Tropic of Capricorn.

Bonus: 23½º N. It's the point where subsolar points stop going northward and begin to head southward.

Stop/Think/Draw/Write 3

Drawings and words should confirm that solstices occur at the Tropic of Cancer and the Tropic of Capricorn and that the sun's subsolar points only go this far northward or southward and then they stop and head back toward the equator.

Obliquity and Lines on the Globe

Drawing should be labeled correctly and the tropics colored yellow. Subsolar points are found only between the Tropic of Cancer and the Tropic of Capricorn.

Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?

What Did You Find? If Earth's obliquity were decreased to 0º, the tropics region would be narrower.

What Did You Find? If Earth's obliquity were increased to 40º, the tropics region would be wider.

Conclusion: When the obliquity changes, the tropics change. Greater obliquity means a wider tropics area. Smaller obliquity means a narrower tropics area.

Stop/Think/Draw/Write 4

Part I: Earth's obliquity 23½º, Tropic of Cancer 23½º N, Tropic of Capricorn 23½º S

Part II: Earth with obliquity of only 15º would have tropics at 15º N and 15º S, a narrower band.

Stop/Think/Draw/Write 5

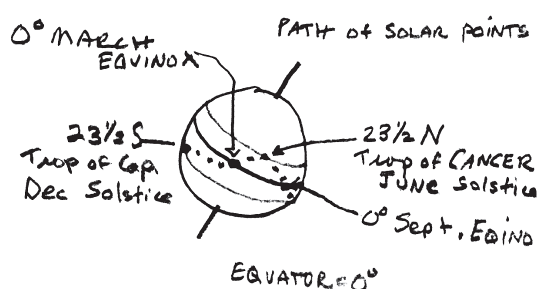
Obliquity of 23½º connects all of the words, creating location of tropics and solstices. The equinox and equator connect with 0º (location of subsolar points).

Quick Team Quiz Two

1. imaginary line that passes through Earth pole to pole
2. B
3. equinox
4. the point on Earth directly under the sun
5. 0º
6. tilt of Earth
7. moves northward
8. moves southward
9. B
10. 23½º S
11. 23½º N
12. 23½º
13. solstice

Square Two Test

1. B
2. C
3. C
4. March and September
5. December and June
6. C
7. D
8. 23½º N
9. 0º
10. sun stop
11. Drawing and labels should show subsolar point moving upward until 23½º N, stopping and heading southward through the equator, on to 23½º S where it stops again and heads north. It should be clear that the subsolar points occur only in the tropics.



Optional Activities Two

1. **Read** biographies of famous scientists, such as these:
   - Lasky, Kathryn. *The Librarian Who Measured the Earth*. (1994)
   - Dash, Joan. *The Longitude Prize*. (2000)
   - Sobel, Dava. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. (1995)
2. **Journal writing** is an excellent way for students to reinforce their own learning. Following is a list of prompts for individual students, teams, or the whole class. Allow students to write for at least 3 minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.

   Whole class *or* *Small group* *or* *Individual*

   - **Prompt 1:** We are constantly trying to understand the world around us. Sometimes, we create an idea in our head to explain what we see. What idea that you used to believe about seasons has been changed by what you have learned so far?
   - **Prompt 2:** If Earth's obliquity was 45º, describe the new latitudes of the equator, Tropic of Cancer, and Tropic of Capricorn. Explain where the subsolar points would be on equinox and solstice.
3. Ask students to **research** one of the following topics and to prepare a short oral **report**, written report, and/or poster to share with their classmates. Make a timeline when appropriate. To use the Internet for your research, type the **highlighted words** into a search engine using quotation marks. Here are some to consider.

   Teaching tip
   The quotation marks cause the search engine to find resources that use both words.

   - Study more about "**Eratosthenes**" and how he measured the Earth's circumference.
   - Research "**ancient calendars**" and note that some used to start at equinox. (October was the eighth month.)
   - Type "**Loughcrew Cairns + Ireland**" into a search engine and report on the reason people gather there at the equinoxes.
   - Type "**axial tilt + right hand rule**" into a search engine; you will discover that there are two systems for measuring obliquity. Report on the difference between the two, especially when NASA reports on the planet Venus.
   - Type "**equatorial sundial**" into a search engine. You will find sundials that don't look like the ones you usually think of when someone says "sundial."

4. **Real-life situations**

   - **Creating a working sundial:**

     Materials

     1 stick about 12 inches long

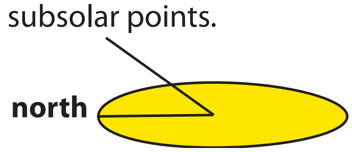
     10 pegs about 3 inches long

     On a day when the sun is shining and you have the opportunity to record at least once per hour, set up a 12-inch stick in the ground in an area that does not fall into shade. Starting at 9 a.m., go outside and place a small peg in the ground to mark where the shadow line falls. Continue going outside every hour on the hour and putting a peg into the ground to mark the shadow. What do you notice about the pegs? Are they evenly spaced? What happens at noon? Are you on Daylight Savings Time? If yes, how does that affect the noon hour? Photograph your working sundial and report your findings to your class.

   - **Current space events:** Go to the Time and Date website (http://www.timeanddate.com/calendar/seasons.html) to find the dates for equinoxes and solstices 5 years before and 5 years after the current year. Use a calendar or online day counter (see the Date to Date Calculator at http://www.timeanddate.com) to count the number of days between each equinox and solstice. Are there always the same amount of days in between? Is one part of Earth's orbit longer than another?

   - **Write a rap** that explains obliquity and/or subsolar points.

5. **Math application—geometry**
   Latitude is important when making sundials.



   - Using a protractor, draw and cut out the gnomons for 4 different latitudes: 20º, 40º, and 60º. (The gnomon is the center piece that puts the shadow on the face of the sundial. In order to be accurate, the corner of the gnomon that faces north in the Northern Hemisphere (and south in the Southern Hemisphere) must form an angle that matches the location's latitude.)

   - Try to figure out what the gnomon must look like at the equator.

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

- Sunrise
- Sunset
- Terminator
- Range

Instruction Block Three

Days 1 and 2

Square Three Concepts*—Students will understand:*

- LAN stands for Local Apparent Noon.
- Hours of daylight + hours of darkness must always = 24 hours.
- Daylight at the equator is always 12 hours long.
- At the equinoxes, all parts of Earth have 12 hours of daylight.
- The range of daylight hours in the tropics is small but grows wider and wider as one moves away from the equator toward the poles.

Materials

- Seasons Observatory
- Subsolar Point Gauge
- Flashlights—*one per team*
- Wide-tipped colored markers or crayons (black and yellow) to color graphs—*class set*

Duplicate

- **Investigation 4, Finding Daylight Hours at ___° N**—*one per team*
- **Day and Night Calculations Page**—*one per team*
- **Daylight Hours Record Page**—*class set*
- **Graphing Daylight Hours for Latitudes**—*class set*
- **Stop/Think/Draw/Write 6**—*class set*

Lesson plan schedule

- Awarding squares
- Introduction
- Jigsaw grouping
- Investigation 4, Finding Daylight Hours at ___° N
- Day and Night Calculations Page
- Daylight Hours Record Page
- Graphing Daylight Hours for Latitude(s) ______
- Stop/Think/Draw/Write 6

Lesson Plan

Days 1 and 2

Awarding squares

Arrange the room and send students into teams. Students will rotate their roles today. As you hand out the folders, announce which students have mastered the concepts in Square Two and award them the Second Squares (red). Announce the names and award blue squares to those who have also caught up and mastered Square One.

Teaching tip Explain to students who have not yet mastered the second concepts that they will shortly, and you will award them their squares as soon as they do. Consider awarding parts of squares to recognize content that these students have mastered.

1. Introduction

Read or Retell

Read or say

Question: What is so special about 23½º?

The key number to remember in this unit is 23½º, which describes Earth's obliquity. It defines where the subsolar point moves across Earth's surface throughout its orbit. Starting at the equator (0º), the subsolar point apparently travels northward as far as the Tropic of Cancer (23 ½º N), and then changes direction and travels southward across the equator (0º) as far south as the Tropic of Capricorn (23½º S), and then heads northward again, back to the equator.

This 23½º obliquity not only affects the subsolar point; it affects the number of daylight hours in different locations on Earth. Where on Earth do you think experiences the longest periods of daylight, or the most hours of daylight at a time?

In Square Three, we will use the Seasons Observatory to investigate daylight hours. The number of daylight hours is obviously important to seasons because sunlight is needed to warm the land.

Teaching tip Answers should include obliquity, Tropic of Cancer, and Tropic of Capricorn.

Teaching tip Use a globe or sketch on the board to show the movement of the subsolar point.

Teaching tip Some may guess different latitudes. Conduct an informal poll and post the results.

Teaching tip Use the Concept Content Rubrics or Cooperative Group Work Rubrics to award points to teams. Keeping track of points sometimes motivates teams to make stronger efforts.

2. Jigsaw grouping

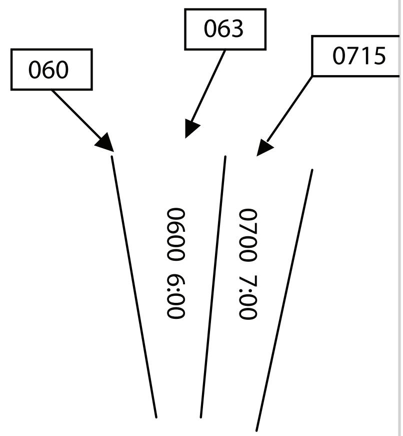
Small group

- Divide teams into jigsaw groups by asking all the Leaders to move to Jigsaw Group 20º, all the Readers to Jigsaw Group 30º, all the Writers to Jigsaw Group 40º, and all the Managers to Jigsaw Group 50º. In their jigsaw groups, students will be investigating sunrise and sunset at their specific latitude.
- Hand out the Seasons Observatories, one per jigsaw group. Have the member of the jigsaw group whose Seasons Observatory is being

- used take responsibility for keeping his or her team's observatory safe and complete.
- Give each jigsaw group enough copies of Investigation 4, Finding Daylight Hours at ___° N so that each member can have one.
- Give each team a flashlight.

3. Investigation 4, Finding Daylight Hours at ___° N

- Read aloud the instructions for parts I and II while teams read along. Have students look at the photos. Then check that each team has used the Subsolar Point Gauge to mark with a +.their specific latitude.
- Read the directions for Part III to set the LAN. It's important to set the LAN and then clip the two disks together with a paper clip so that they now move together.
- For Part IV, Measure sunrise, make sure that the Sunbeam String goes under the ball itself, not the center of the Earth Holder. Demonstrate with one team how to measure sunrise. Reinforce the concept of the Terminator. The time begins at the line marking the hour so students can determine 15-minute intervals within the hour mark. They should record their data on the Day and Night Calculations Page. See the picture in Part IV.



- Follow the directions for Part V, Measure sunset.
- Demonstrate Part VI, Calculate daylight hours, using the **Day and Night Calculations Page**. Students should use military time to make the subtraction easier. If there is a need for "borrowing" (for example, 17:15 – 6:30), tell students to change 17:15 to 16:75 and then subtract. Then have team members mark the daylight hours on the **Daylight Hours Record Page**.
- Send students off to complete Part VII, calculating sunrise and sunset for March, June, September, and December. If time allows, let them go back to complete the calculations for the months in between.
- Each jigsaw group member should translate his or her daylight data to a daylight graph for their assigned latitude.
- When each jigsaw group has completed at least the data collection and graphing for March, June, September, and December, send members back to their original teams.

Teaching tip
Explain how jigsaw grouping works. Students must understand that they are completing an activity with a temporary group and must bring back the data to their own team. See pages 22 for instructions.

Teaching tip
Most students want to play with the flashlights for a minute or so. Allow them 2 to 3 minutes and then bring them back to the task.

Teaching tip
Modeling the first measurement as a whole class works best. Older students, however, may be able to follow the instructions on their own.

Teaching tip
Although you may choose to give a responsibility to each team member for this activity, teams will most likely be able to figure out their own system. Simply insist that each team member has something to do to help his or her team.

Teaching tip
This activity works well with only the four months of March, June, September, and December. However, using the models to collect real data is a good experience and if you have time, do all 12 months.

4. Investigation 4, continued

- Have students connect the graph lines on the **Daylight Hours Record Page** freehand from March through December and then lay out their graphs for all team members to look at.
- Have them put their graphs in order from 20º to 50º and notice that the graphing lines look like small "hills" for 20º, but at 50º the "hills" are steep.
- Have them discuss the difference between those latitudes close to the equator and those farther away. What might the graph look like for 10º? For 70º?

5. Graphing 2 Years of Daylight Hours for Latitude(s) _____

- Ask Managers to distribute the Graphing 2 Years of Daylight Hours for Latitude(s) ___ page.
- Next, have students transfer their data to Graphing 2 Years of Daylight Hours for Latitude(s) ___ page, the graph showing two years of data. (They should repeat the same data two times across the two years.) Again, have them connect the data points freehand—no rulers!
- Ask students to color their graphs. The area above the line should be dark and the area below should be light.
- Ask students to compare the four different charts, noting:

  Which latitudes have days with long daylight hours? (higher latitudes)

  Which latitudes have days with very short daylight hours? (higher latitudes)

  When does the whole world have exactly 12 hours of daylight? (equinoxes)

- Allow teams to work together for all the questions, or do this like the Quick Team Quiz format in which they work alone and then compare answers.

6. Stop/Think/Draw/Write 6

- Hand out **Stop/Think/Draw/Write 6**. Tell students to think about the latitudes they have investigated and predict what the daylight hours graph would look like at two latitudes, 10º and 60º. Have students work alone, then share with their teams, and finally share team answers with the whole class. Students should correct their papers.

Teaching tip
The two-year graph clearly shows a sine wave. Remind students that all this data is observable, constant, and predictable.

Small group

or

Individual

Teaching tip
Black and yellow crayons work well.

Technology tip
If you have a document camera, you can copy the graphs and project them to a SmartBoard™ or a computer screen.

Teaching tip
If you don't have class time, use this as a homework assignment.

Teaching tip
Explain you are looking for rough estimations, not exact graphs. The key is that at the equinoxes, the graphs are at 12 hours. At the solstices for 10º, the range between longest and shortest is small because both are just about 12 hours. At the solstices for 60º, the day length ranges are great and the graph is very steep—18 to 20 hours of daylight in summer and fewer than 6 hours in winter.

Instruction Block Three

Days 3 and 4

Square Three Concepts*—Students will understand*:

- Seasons happen at opposite times in the Northern and Southern Hemispheres
- Because seasons happen at opposite times in the Southern Hemisphere than they do in the Northern Hemisphere, scientists now refer to the equinoxes and solstices by month rather than season. March equinox, June solstice, September equinox, and December solstice

Materials

- Wide-tipped colored markers or crayons to color graphs

Duplicate

- **Understanding Daylight Hours—***class set*
- **Investigation 5, Daylight Hours in Different Hemispheres**—*class set*
- **Graphing Daylight Hours in Different Hemispheres**—*class set*
- **Stop/Think/Draw/Write 7**—*class set*
- **Square Three Review Notes**—*class set*
- **Quick Team Quiz Three**—*class set*
- **Square Three Test**—*class set*

Lesson plan schedule, Days 3 and 4

- Review Stop/Think/Draw/Write 6
- Understanding Daylight Hours
- Investigation 5, Daylight Hours in Different Hemispheres
- Chart paper activity revisited
- Square Three Review Notes—class set
- Quick Team Quiz Three—class set
- Square Three Test—class set
- Optional Activities Three

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

- Daylight hours
- Northern Hemisphere
- Southern Hemisphere

Lesson Plan

Days 3 and 4

1. Review Stop/Think/Draw/Write 6

Go back over the results of Stop/Think/Draw/Write 6, stressing that the higher the latitude, the greater the range of daylight hours.

2. Understanding Daylight Hours

- Give **Managers** copies of **Understanding Daylight Hours**, one per team member

Small group

- Run this as a team activity, with each **Reader** reading the questions and each **Leader** leading the discussion.

Whole class

- Correct the sheets as a class.
- Return to the informal poll you gave at the beginning of this square, and ask the same question: Where on Earth do you think experiences the longest periods of daylight, or the most hours of daylight at a time?
- Just for fun, ask students why Sherlock Holmes was convinced that a witness was lying when she said, “While I am on vacation in the tropics, I often go for a swim about 8 p.m., just as the sun is setting.”

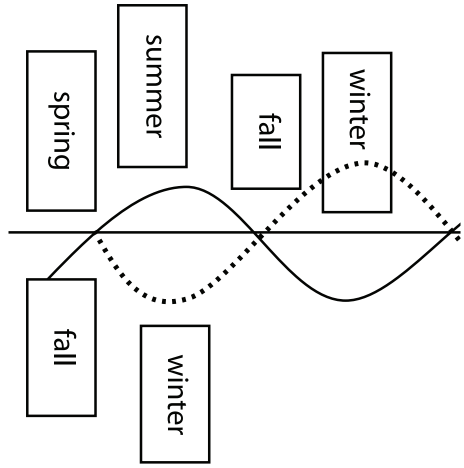
3. Investigation 5, Daylight Hours in Different Hemispheres

- Give **Managers** one copy of each of the following for every team member: **Investigation 5, Daylight Hours in Different Hemispheres** and **Graphing Daylight Hours in Different Hemispheres**.
- This time assign different latitudes to each member of the same team: Managers, 20º; Writers, 30º; Readers, 40º; and Leaders, 50º. Have students plot their assigned northern latitudes on their charts and connect the data points freehand with a solid line.

Small group

- Next, have teams label spring, summer, fall, and winter above the month data points on the graph.
- When they have completed the Northern Hemisphere data, have students plot the Southern Hemisphere data and connect the dots freehand with a dotted line.
- Finally, have students label spring, summer, fall, and winter below the month data points on the graph to label seasons in the Southern Hemisphere.

- Discuss what the graphs reveal: seasons happen at opposite times in the Northern and Southern Hemispheres. Longest periods of daylight hours occur in summer and the shortest periods of daylight are in winter. The equinoxes are always at 12 hours, but whether or not the hemisphere is moving into fall or spring depends on whether the next event is summer or winter. June used to be called the "summer" solstice, but that ignores summer in the Southern Hemisphere, which occurs in December. Now scientists refer to the June event as the June solstice, which works in either hemisphere.



Technology tip
If you have a document camera, you can copy the graphs and project them to a SmartBoard^{tm} or a computer screen.

4. Stop/Think/Draw/Write 7

Individual

Small group

Use words and drawings to explain why seasons happen at opposite times in the Northern and Southern Hemispheres. Have students first work alone, then share with their team, and finally share team answers with whole class. Students should correct their papers.

5. Chart paper activity revisited

Whole class

- Spend about 2 minutes or less to ask students what more have they learned about seasons. Add their answers to the chart paper activity from Square Two. However, do not add any incorrect answers to the chart. Question students' thinking and write the comment on another page to be revisited later.
- Ask if there is anything that they want to take off the chart.
- Ask if they have any new questions they have related to seasons. Add these to the chart paper.
- Put away the chart paper. You will bring it out again after each investigation.

Teaching tip
Students will begin to see that daylight hours are important to seasons.

6. Square Three Review Notes

Small group

Give **Managers** copies of the Square Three Review Notes. Allow teams to read it together and talk about the Terminator, sunrise, sunset, hours of daylight, and opposite seasons in Northern and Southern Hemispheres.

Teaching tip
All answers are on the last page of each lesson plan.

Individual

Small group

Whole class

7. Quick Team Quiz Three

- Separate the desks again and ask the **Managers** to come to you for **Quick Team Quiz Three**. Allow only a short time (about 5 minutes) for students to answer questions *individually*.
- When the individuals in each team have finished the quiz, team members should *work together* to correct the team papers. Team **Leaders** should read questions and members should share answers and agree which are correct. Members should help other team members who made errors. Remind students of the **Cooperative Group Work Rubric**.
- As a whole class, present the correct answers on the board and answer any questions.
- Tell **Leaders** to put all quiz papers neatly in the team folders and give the folders to you, or give the quizzes to students to take home and study. **Managers** should return all supplies and check to see that the work area is cleared.

Teaching tip
You may give the test immediately after the quiz, or give students the test at the beginning of the next class. If not, give it as the first activity the next time you meet. Allow students to take home their correct quizzes to study.

Individual

8. Square Three Test

- Before moving on to Square Four, administer the **Square Three Test** to individuals, not teams. Separate student desks for privacy. When students have finished, collect the tests.
- While students are taking the test, consider using the time to assess students' overall cooperative group work during Square Three. Using the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1 to 4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what they can do to improve.
- Correct the tests and evaluate your students' mastery of concepts in Square Three. Reteach, if necessary, and retest. Those who have passed Square Three can do the **Optional Activities 3** on page 73.

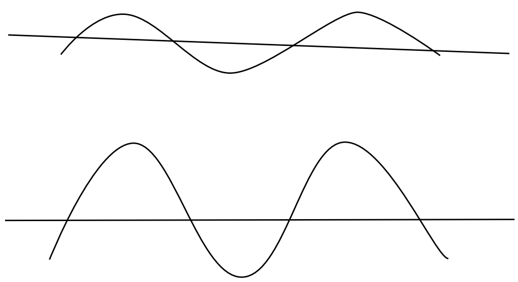
Square Three Answer Key

Investigation 4, Finding Daylight Hours at ____° N

The closer to the equator, the narrower the range of daylight hours. The farther from the equator, the greater the range of daylight hours.

Stop/Think/Draw/Write 6

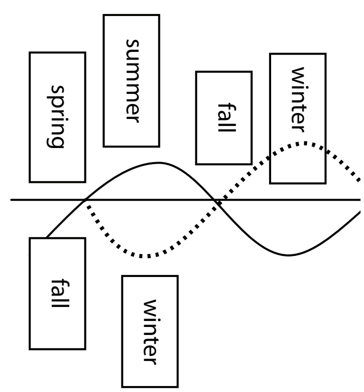
For the two latitudes, at the equinox, the daylight hours must be at 12 hours. For the solstices, at 10º, the graph will be gentle with a narrow range near to 12 hours. At the 70º latitude, the graph will be steep, even to 24 hours of daylight or darkness. However, at equinox, it should come back to 12 hours.



Understanding Daylight Hours

1. Ws on shortest periods of daylight hours
2. SUM on longest periods of daylight hours
3. All days are the same length.
4. Some days have 24 hours of daylight; some have 0 daylight hours.
5. This is a trick question. W can be on December or June, depending on the hemisphere.
6. Equinoxes are always on March and September.
7. Equinoxes are always on March and September.
8. grows smaller
9. grows larger
10. All answers are 12 hours.

Investigation 5, Daylight Hours in Different Hemispheres



Stop/Think/Draw/Write 7

Student should redraw the graph they made for Investigation 5 (see above) to explain that seasons are opposite in the two hemispheres because the longest period of daylight hours indicates summer and shortest period of daylight hours indicates winter. The graph shows that the seasons happen at opposite times in the hemispheres.

Teaching tip
You can start Square Four activities with students who are ready to move on and reteach students who do not answer most of the test questions correctly. However, do not let this second group get too far behind the first.

Quick Team Quiz Three

1. spring, summer, fall, winter
2. the tilt of Earth
3. the place on Earth's surface directly under the sun
4. twice
5. equinox
6. 23½º N
7. moves northward
8. 0º
9. 10 hours
10. 12 hours
11. greater
12. equal night
13. between the 20th to 23rd
14. summer
15. spring

Square Three Test

1. C	2. B
3. A	4. B
5 D	6. A
7. D	8. A
9. A	10. B
11. C	12. C

Optional Activities Three

1. **Read** biographies of famous scientists, such as the following:
   - Saari, Peggy and Stephen Allison. *Scientists: The Lives and Works of 150 Scientists.* (1996)
   - Burns, Khephra and William Miles. *Black Stars: NASA's African American Astronauts.* (1995)
   - Yannuzzi, Della A. *Mae Jemison: A Space Biography.* (1998)
2. **Journal writing** is an excellent way for students to reinforce their own learning. Following are prompts you can give individual students, teams, or the whole class. Allow students to write for at least 3 minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.
   - **Prompt 1:** We are constantly trying to understand the world around us. Sometimes, we create ideas in our heads to explain what we see. What idea that you used to believe about the night sky has been changed by what you have learned so far?
   - **Prompt 2:** If you moved to a place in the Southern Hemisphere that was at the same latitude as your current address only south of the equator (45ºS rather than 45ºN), describe how the milestones of the year (holidays, school openings, your birthday) would be celebrated differently.

Whole class
or
Small group
or
Individual

3. Ask students to **research** one of the following topics and to prepare a short oral **report**, written report, and/or poster to share with their classmates. Make a timeline when appropriate. To use the Internet for your research, type the **highlighted words** into a search engine using quotation marks. Here are some to consider.
   - Type "**terminator + daylight**" into a search engine. Find out why the Terminator on the moon looks different from the Terminator on Earth.
   - Research "**Daylight Savings Time**" on the Internet. What was the thinking behind the plan?

Teaching tip
The quotation marks cause the search engine to find resources that use both words.

4. **Real life situations**
   - **Check out the Time and Date website**: Type http://www.timeanddate.com into a search engine. On this website, you will find

     Sunrise and sunset for locations all around the world

     A current day/night world map

Tips on how to better photograph sunrises and sunsets

Posters with photos of sunrise and sunset

- **Look at sunrise**: Check the time of sunrise and get up early to take five photos: 10 minutes before dawn, 5 minutes before dawn, at dawn, 5 minutes after dawn, and 10 minutes after dawn.
- **Look at sunset**: Check the time of sunset and be ready to take five photos: 10 minutes before sunset, 5 minutes before sunset, at sunset, 5 minutes after sunset, and 10 minutes after sunset.
- Check out the **Sun Calculator** on the following website. Type http://www.suncalc.net.
- You can put in your location and see graphically where and when the sun rises and set at different times of the year.

5. **Math applications**

- **Graphing**: Use data from daylight hours in different latitudes over 12 months to make a poster showing the range of daylight hours. Add the seasons for each.

  Compare: San Francisco, California, USA, 37º48′ N, and Melbourne, Victoria, Australia, 37º47″ S

  Compare: Columbia, South Carolina, USA, 34º N, and Cape Town, South Africa, 33º55′ S

- **Measurement**: Make a poster that explains time zones. Explain how they relate to lines of longitude. Explain the significance of the International Date Line.

Instruction Block Four

Days 1 and 2

Square Four Concepts*—Students will understand*:

- The Terminator is the shadow line on Earth where daylight ends and night begins.
- Earth's obliquity of 23½º determines the latitude of the Arctic Circle at 66½º N and the Antarctic Circle at 66½º S.
- A day when the sun does not set is called a *polar day*.
- A day when the sun does not rise is called a *polar night*.
- The Arctic Circle marks the latitude where there is one polar day when the sun does not set (June solstice) and one polar night when the moon does not rise (December solstice)
- The Antarctic Circle marks the latitude where there is one polar day when the sun does not set (December solstice) and one polar night when the moon does not rise (June solstice).
- Because of Earth's obliquity, the sun rises only once each year and sets only once each year at the North and South Poles. In between, there are 6 months of polar days and then 6 months of polar nights.
- At latitudes north of the Arctic Circle and south of the Antarctic Circle, the number of polar days or polar nights increases as one nears the poles.

Materials

- Seasons Observatory
- Flashlights—*one per team*
- Oak tag or poster board (8½ x 11 inches)—*one per team*

Duplicate

- **Investigation 6, Finding the Arctic and Antarctic Circles**—*one per team*
- **Understanding the Arctic and Antarctic Circles**—*class set*
- **Lines on the Globe**—*class set*
- **Stop/Think/Draw/Write 8**—*class set*
- **Investigation 7, Sunrise and Sunset at the Poles**—*one per team*
- **Polar Days and Polar Nights Recording Sheet**—*class set*

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

- Terminator
- Polar day
- Polar night

Teaching tip
Use the Concept Content Rubrics or Cooperative Group Work Rubrics to award points to teams. Keeping track of points sometimes motivates teams to make stronger efforts.

Lesson plan schedule, Days 1 and 2

- Awarding squares
- Introduction
- Investigation 6, Finding the Arctic and Antarctic Circles
- Understanding the Arctic and Antarctic Circles
- Stop/Think/Draw/Write 8
- Investigation 7, Sunrise and Sunset at the Poles

Lesson Plan

Days 1 and 2

Awarding squares

Arrange the room and send students into teams. Students will rotate their roles today. As you hand out the folders, announce which students have mastered the concepts in Square Three and award them the Third Squares (green). Announce the names and award blue squares to those who have also caught up and mastered Squares One and Two.

1. Introduction

Read or Retell

We have discovered several reasons why 23½º is probably the key number to remember in this unit. It describes Earth's obliquity, it affects the subsolar point that defines the tropics, and it also explains why we have a range of daylight hours.

Spoiler alert! Earth's 23½º obliquity also has something to do with Arctic and Antarctic Circles.

In Square Four, we will use the Seasons Observatory to discover the Arctic and Antarctic Circles. We will also find what is very special about the North and South Poles. Finally, we will discover why it is that "true" seasons that change from spring to summer to fall to winter occur only in specific parts of the world and not throughout the world. Square Four answers all of the remaining questions about why and where we have seasons.

Investigation 6, Finding the Arctic and Antarctic Circles

- Give **Managers** copies of **Investigation 6, Finding the Arctic and Antarctic Circle**s, and a flashlight.
- Go over the pictured directions on the two investigation pages as a whole group first, or set the teams to work.
- Because of the ambient light in most classrooms, it may be necessary to bring the Earth Holder closer to the Sun Disk so that the flashlight beam is bright enough to make a discernable Terminator. Remind students to keep the flashlight at the same height as Earth and to point it directly down the Sunbeam String.
- Walk around as students work to make sure that each Seasons

Teaching tip
Explain to students who have not yet mastered the third square concepts that they will shortly, and you will award them their squares as soon as they do. Consider awarding parts of squares to recognize content that these students have mastered.

Read or say

Teaching tip
Most students cannot help but want to play with the flashlights. Allow them 2 to 3 minutes and then bring them back to the task.

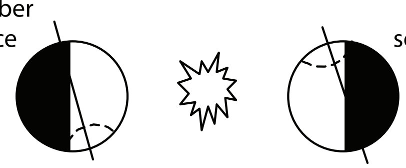
Teaching tip
Although you may choose to give a responsibility to each team member for this activity, teams will most likely be able to figure out their own system. Simply insist that each team member has something to do to help his or her team.

- Observatory is set up properly and that the teams are all working together.
- When all groups have completed their circles, go over the math to show how they can derive the latitude of the Arctic Circle 66½° N (90 – 23½ = 66½).

2. Understanding the Arctic and Antarctic Circles

- Give **Managers** copies of **Understanding the Arctic and Antarctic Circles** sheet for every team member.

Teaching tip
Make drawings on the board to clarify that half of Earth is always lit.



Small group

- Have students complete the sheet as a team, agreeing on answers as they work together.

Whole class

- When all teams have finished, have a whole-class discussion in which students share their answers. Clarify any misperceptions and have students correct their papers and take them home to study.
- Hand out the **Lines on the Globe** sheet and assign as class work or homework. Insist that students spell and capitalize their labels correctly.

3. Stop/Think/Draw/Write 8

Individual

Have students work alone, then share with their team, and finally share team answers with whole class. Students should correct their papers.

4. Investigation 7, Sunrise and Sunset at the Poles

- Give each **Manager** one copy of **Investigation 7, Sunrise and Sunset at the Poles** for his/her team and enough copies of the **Polar Days and Polar Nights Recording Sheet** for each team member.
- Have students complete the investigation as a team, but each student should record the findings on his or her own Recording Sheet.
- When all the teams have finished, have them stop and conduct a whole-class discussion in which teams share their data.

- Draw the recording table on the board or chart paper and have each team report its findings. Mark the first team's results with the letter A, the second team's with the letter B, and so on for all of the teams. (See example below.)

Example Month	North Pole is in Sunlight	North Pole is in Darkness
MAR	A C D	B
APR	A B C D	
MAY	A B C D	
JUN	A B C D	
JUL	A B C D	
AUG	A B D	C
SEP	B	A B C D
OCT		A B C D
NOV		A B C D
DEC		A B C D
JAN		A B C D
FEB	C	A B D

- Students can see that although not all teams agreed on the exact months, the poles are in light for 6 months and in darkness for 6 months.

5. Investigation 7 continued

- Ask teams to discuss and answer the Data Analysis questions at the bottom of the Recording Sheet.
- Reconvene the whole class and discuss the answers to the questions.
- The students will be most surprised with the answer to questions 6 and 7. Answers: Once per year.
- Ask students to predict on what two days of the year the sun will rise and the set at the North Pole. Answer: It rises on the March equinox and it sets on the September equinox.

Read or Retell

You may wonder how there are 12 hours of daylight at the North Pole on the day before the September equinox but 0 hours of daylight on the day of the equinox. That happens because when the sun rises on the day of the September

Teaching tip
Move the Earth Holder closer to the Sun Disk so that the Terminator is very clear.

Whole class

Teaching tip
The students are working with handheld flashlights and cardboard models. It's probable that the data will be mixed. However, the trend will be obvious and accurate.

Small group

Whole class

Read or say

Teaching tip
You may decide that this explanationis too abstract for your students. You may want to have them do some Internet research for video that shows the sun's path around the horizon at the poles.

Teaching tip
Explain that unlike at our latitudes, at the North Pole the sun does not rise in the east and follow a path to the west. At the North Pole, there is no east or west. Every direction is south. The sun only travels around the horizon . . . all 360º.

Teaching tip
Explain to students that the change between darkness and light at the poles is not like switching a light on and off. For many days after the September equinox, there is some light at the horizon, much like we see around sunset. And there is early dawn light for many days before the sun rises again on the March equinox.

Technology tip
Look at the NASA website, YouTube, and other digital sites to see photographs and video of the sun at the most northern and southern latitudes.

equinox, it rises at the horizon at noon, and as Earth rotates, the sun remains at the horizon for 12 hours. The next day, the sun never comes above the horizon, and it remains below the horizon at the North Pole for 6 months, until the March equinox.

You may also wonder how there can be just 12 hours of daylight on the March equinox, but the next day there are 24 hours of daylight. On the day of the March equinox, the sun rises at noon at the horizon but does not set at the North Pole for another 6 months. As Earth rotates, the sun follows a 360º path all around the horizon. It remains above the horizon the next day and the next—a little higher in the sky than it was the day before. The sun appears to continue to spiral higher and higher in the sky until the June solstice, when it appears to stop and then starts to spiral downward toward the horizon again.

As you know, whatever happens at the North Pole also happens at the South Pole, but in the opposite season. Therefore, at the South Pole the sun rises on the September equinox and finally sets on the March equinox.

Keep in mind that the poles at 90º N and 90º S are not the same as the Arctic and Antarctic Circles. In the area between the poles and the circles are the Polar Zones, which have varying numbers of polar days and polar nights. There is one polar day and one polar night at the Arctic and Antarctic Circles (66½º N and 66½º S). But as you move closer and closer to the poles, the number rises toward 6 months of polar days and 6 months of polar nights. At the exact North and South Poles, the sun rises only once a year and it sets only once a year.

6. Ending the lesson

- Invite students to talk with their parents about sunrise and sunset at the poles. Most adults are unaware of the phenomenon and the science behind it.
- Ask students to put away the materials.
- Have students master the vocabulary and reread the review notes for past squares. Invite students to retake any square tests they may have failed.

Instruction Block Four

Days 3 and 4

Square Four Concepts*—Students will understand*:

- The angle of incidence in the context of seasons is the angle at which the sun's rays hits the surface of Earth.
- Within the tropics, the angle of incidence is close to 90º, but away from the tropics the angle becomes more and more shallow.
- The more shallow the angle of incidence, the dimmer and weaker the sun's rays.
- Although there are very long periods of daylight hours at the poles, the angle of incidence is so shallow that the sunlight is too weak and dim to warm the Polar Zones.
- Seasons at the poles are generally defined by length of daylight hours.
- There is little change of seasons in the tropics, where the daylight hours and daytime temperatures are the same all year.
- Only in the Temperate Zones (between the tropics and the circles) are there true changes of seasons, because there are changes in the number of daylight hours and sunlight strong enough to affect temperature.

Materials

- Quarter-inch graph paper—*one per team*
- Oak tag or poster board (8½ x 11 inches)—*1 per team*
- Tape—*one per team*
- Protractors—*one per team*
- Flashlights—*one per team*
- Yellow, green, and blue crayons, markers or colored pencils—*two sets per team*

Duplicate

- **Investigation 8, Why Isn't It Hot at the Poles?**—*class set*
- **Quarter-inch Graph Paper**—*one per team*
- **Stop/Think/Draw/Write 9**—*class set*
- **Seasons Zones of Earth Map**—*class set*
- **Square Four Review Notes**—*class set*

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.

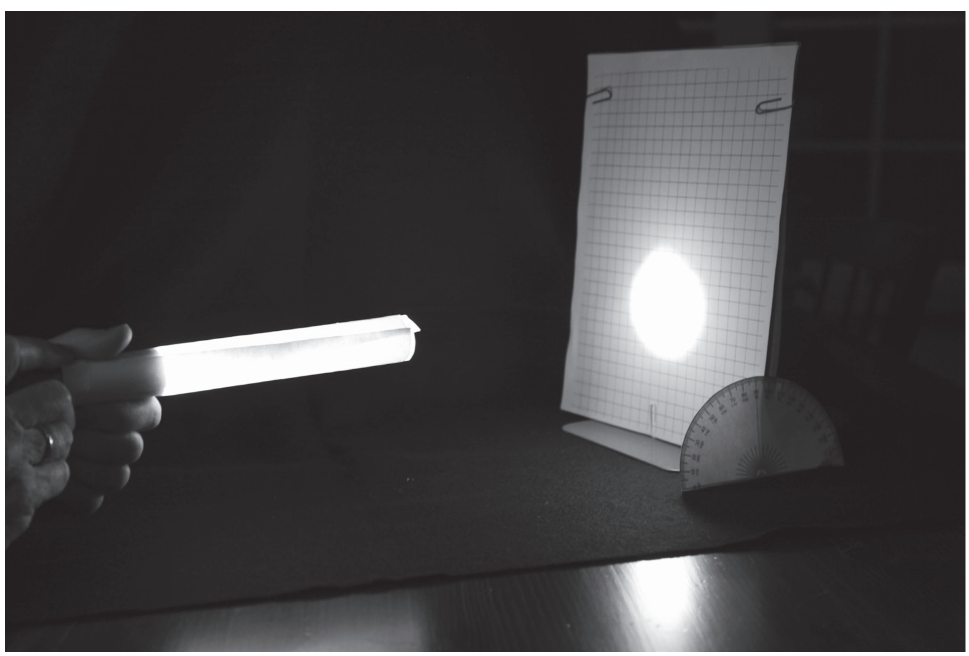
Vocabulary

- Daylight hours
- Angle of incidence
- Brightness
- Dimness
- Tropical Zone
- Temperate Zone
- Polar Zone

- **Quick Team Quiz Four**—*class set*
- **Square Four Test**—*class set*

Lesson plan schedule, Days 3 and 4

- Review
- Investigation 8, Why Isn't It Hot at the Poles?
- Stop/Think/Draw/Write 9
- Chart paper activity revisited
- Square Four Review Notes
- Quick Team Quiz Four
- Square Four Test
- Are you done yet?
- Optional Activities Four



Lesson Plan

Days 3 and 4

1. Review

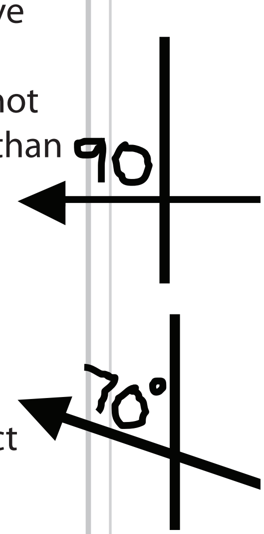
Review why the sun only rises and sets once a year at the poles. This may be a difficult concept for students to wrap their heads around, but they did measure for themselves using the Season Observatory models to prove this scientific truth.

2. Investigation 8, Why Isn't It Hot at the Poles?

Read or Retell

Read or say

We have learned that an increased number of daylight hours often means higher daytime temperatures and a warmer climate. We have discovered that there are some places north of the Arctic Circle and south of the Antarctic Circle that have days of extreme daylight length. Some are even in daylight for 20 to 24 hours of every day. Yet we know that it's never hot inside the Arctic and Antarctic Circles. There must be more than just daylight length to explain what is going on.



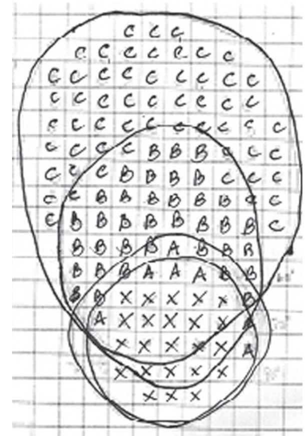
In this last Investigation, you are going to investigate the question, "Why isn't it hot at the poles?" To understand the answer to this question, you need to understand the term *angle of incidence*. In the context of seasons, the angle of incidence refers to the angle at which the sun's rays intersect Earth. At the equator and under the solar point, the rays intersect directly at 90º. As light hits the curved surface of Earth away from the equator, the angle of incidence becomes shallower. Sometimes in the tropics, the angle is at 90º because the solar point moves within the tropics. However, above 23½º N and below 23½º S, the angle can be increasingly shallow (less than 90º).

In Investigation 8, you will discover how the angle of incidence changes at latitudes beyond 23½º N and 23½º S. Let's see what happens when a certain amount of sun energy is spread over a larger and larger area.

- Give **Managers** copies of **Investigation 8, Why Isn't It Hot at the Poles?**, one per team. Also give each team a flashlight, tape, a piece of poster board, and quarter-inch graph paper.

Small group

- Run this as a team activity with the Reader reading the directions and the Leader directing his/her team to complete the necessary tasks.
- Recording requires students to count the total squares included in the flashlight's ray. Students must put letters into the quarter-inch blocks where the flashlight's beam reaches. They should write a letter in a square only if it is entirely inside of the flashlight beam. Instruct them to put an X in the squares for 90° angle of incidence, the letter A in squares for a 75° angle, the letter B for a 55° angle, and the letter C for a 35° angle.



- Ask students to graph their results. Although there may be little change between 90° and 75°, there is a very great difference as the angle of incidence gets increasingly shallow. Students should note that the light beam grows dimmer and dimmer.

3. Stop/Think/Draw/Write 9

Individual

Have students work alone, then share with their team, and, finally, share team answers with whole class. Students should correct their papers.

Technology tip
If you have a document camera, project accurate maps to a SmartBoard[tm] or a computer screen.

4. Seasons Zones of Earth Map

- Give **Managers** enough copies of the map for all team members. Distribute sets of crayons, markers, or colored pencils to share.
- Review the directions so that students understand where to put labels and how to color the map.
- Remind students they should be able to define the three zones in each hemisphere of the world. The key vocabulary is Polar Zone, Tropical Zone, and Temperate Zone. However, geographers also include hemisphere modifiers for the zones. For example, *Northern Temperate Zone* refers to the area between 23½° N and 66½° N.

Whole class

5. Final team and whole class discussion of Seasons

- Give Managers enough copies of *What do Seasons Look Like Around the World?* for each team member.
- Have students answer the questions as individuals or as teams. Call the whole class together for discussion.

6. Final chart paper activity

Whole class

- Spend about 2 minutes or less to ask students what more have they learned about seasons. Add their answers to the chart paper activity from Square Three.
- Ask if there is anything that they want to take off the chart.
- Ask if they have any new questions they have related to seasons. Add these to the chart paper.
- Conduct final briefing on the chart paper, pointing out all the folk science they have rejected and all the true science they have gained.

Teaching tip
Students will understand that the causes of the seasons has to do with the length of the period of daylight hours in conjunction with angle of incidence. Earth's obliquity causes changes in the length of periods of daylight hours and the location of the subsolar point.

7. Square Four Review Notes

Small group

Give **Managers** copies of the **Square Four Review Notes**. Allow teams to read it together and talk about the Terminator, Arctic and Antarctic Circles, sunrise and sunset at the poles, angle of incidence, and the zones of Earth that experience "true" seasons that change from spring, to summer, to fall, to winter.

8. Quick Team Quiz Four

Individual

- Separate the desks again and ask the **Managers** to come to you for **Quick Team Quiz 4.** Allow only a short time (about 5 minutes) for students to answer questions *individually*.
- When the individuals in each team have finished the quiz, team members should work together to correct the team papers. Team **Leaders** should read questions and members should share answers and agree which are correct. Members should help other team members who made errors. Remind students of the **Cooperative Group Work Rubric**.
- As a whole class, present the correct answers on the board and answer any questions.
- Tell **Leaders** to put all quiz papers neatly in the team folders and give the folders to you, or give the quizzes to students to take home and study. **Managers** should return all supplies and check to see that the work area is cleared.

Teaching tip
All answers are on the last page of each lesson plan

Whole class

9. Square Four Test

Individual

- Administer the **Square Four Test** to individuals, not teams. Separate student desks for privacy. When students have finished, collect the tests.
- While students are taking the test, consider using the time to assess students' overall cooperative group work during Instruction Square One.

Technology tip
You may give the test immediately after the quiz, or give students the test at the beginning of the next class. If not, give it as the first activity the next time you meet. Allow students to take home their correct quizzes to study.

Using the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1 to 4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what they can do to improve.

- Correct the tests and evaluate your students' mastery of concepts in Square Four. Make a list of those students who have earned a square, award their purple square to them, and allow them to do the Optional Activities 4. For those who have not completed all four Squares, reteach and retest as necessary.

10. Are you done yet?

You may stop at this point, having completed the four squares of *Squared Away* for Seasons. However, if you want to challenge your students further, you may assign the Golden Square activities. These are more difficult and you should expect only 50 percent or fewer of your students will be able to successfully complete the activity. See page 92 for Golden Square Activities and Challenges.

11. Posttest

One week after you finish the unit, give the **Posttest**.

12. Awards

With the successful completion of the **Square Four Test**, students are considered "Squared Away." However, consider waiting until you run the **Golden Square Challenge** to celebrate. This will give you more time to work with those students who are close to finishing the four squares. It would be best if all your students successfully completed the four instructional blocks. The **Golden Square Challenge** is just that, a challenge, and not essential to being considered "Squared Away." However, give special recognition to all those who do achieve a Golden Square. Design a celebration appropriate to your students' ages and your available time and resources. Give Special Award Certificates (pages 169 and 170) to acknowledge each student's achievement.

Square Four Answer Key

Investigation 6, Finding the Arctic and Antarctic Circles

Students draw the Arctic Circle on their Ping Pong ball Earth following the Terminator line in the investigation.

Understanding the Arctic and Antarctic Circles

1. line between darkness and light
2. pole to pole
3. one-half
4. sunlight
5. darkness
6. sunlight
7. darkness
8. 66½º N
9. 66½º S

1. June solstice
2. December solstice
3. December solstice
4. June solstice
5. any area inside the Arctic or Antarctic Circles

Lines on the Globe

Insist on proper spelling and capitalization.

Top globe: Arctic Circle, Tropic of Cancer, equator

Lower Globe: equator, Tropic of Capricorn, Antarctic Circle

Stop/Think/Draw/Write 8

When Earth rotates on June solstice, the Terminator line describes a polar day at the Arctic Circle, when the sun does not set. At the same time, the Terminator in the Southern Hemisphere describes a polar night at the Antarctic Circle, when the sun does not rise. This path of the Terminator is due to the obliquity of Earth, which is 23½º. When you take 23½° from 90°, the difference is 66½º, the location of the Arctic and Antarctic circles.

Investigation 7, Sunrise and Sunset at the Poles

Students should find that at the poles, the sun is generally above the horizon or below the horizon for 6 months of the year. Therefore, the sun only rises once and only sets once each year.

Polar Days and Polar Nights Recording Sheet

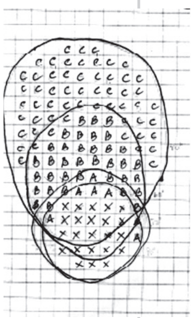
Chart should show a pole in sunlight for 6 months and a pole in darkness for 6 months.

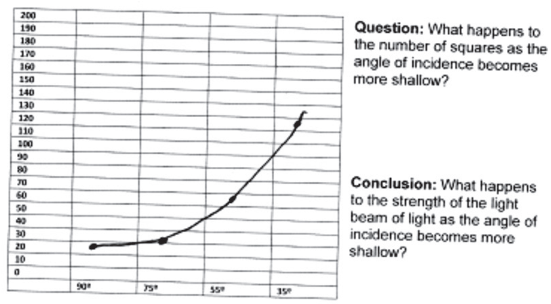
1. September
2. March
3. September equinox and March equinox
4. 6 months
5. 6 months

6. once
7. once

Investigation 8, Why Isn't It Hot at the Poles?

The graph paper record-keeping looks like this:





There should be the smallest amount in the X group and a few more in the A group. The B group should have almost twice as many as the A group, and the C group should have at least three times as much as the A group.

Stop/Think/Draw/Write 9

Why is it never hot at the poles? Because of the physics behind the angle of incidence, sunlight that arrives at the poles is very dim. The shallower the angle, the larger the area is lit, but the more the intensity is dimmed. Although the number of daylight hours approaches 24, the sun is too weak at the poles to cause it to be hot.

Zones of Earth Map

North of 66½º N and South of 66½º S are the Polar Zones, colored blue. Between 23½º N and 23½º S is the Tropical Zone, colored yellow. Between 23½º N and 66½º N and 23½º S and 66½º S are the Temperate Zones, colored green. Be sure the labels are neat and spelled correctly.

What Do Seasons Look Like Around the World?

Tropical Zones a) Temperature is hot. There are 12 hours of daylight. b) Temperature is hot. There are 12 hours of daylight. c) No true changes in seasons. One is just like the other.

Polar Zones a) Temperature is cold. There are 18 to 24 hours of daylight. b) Temperature is cold. There are 18-24 hours of darkness. c) No true changes in seasons. Only two seasons, one of light and one of darkness.

Temperate Zones a) Temperature is warm. Daylight hours are longer > 14 hours. b) Temperatures are cold. Daylight hours are shorter < 10 hours a day. c) Temperate Zones have true changes in season.

Quick Team Quiz Four

1. June solstice
2. June solstice
3. 20th to 23rd
4. 0º
5. equal night
6. March and September
7. Arctic Circle
8. 14 hours
9. line between darkness and light
10. a day when the sun doesn't set,
11. Temperate Zone
12. Polar Zones
13. once a year
14. B
15. The sun is too dim at the poles.
16. Polar 66½º N and North Pole (90º N) and 66½º S and South Pole (90º S); Tropical between 23½º N and 23½º S; Temperate between 23½º N and 66½º N and between 23½º S and 66½º S

Square Four Test

1. C
2. C
3. A
4. D
5. B
6. A and B
7. C
8. D
9. D
10. D
11. C
12. D
13. B
14. C
15. A

Whole class

or

Small group

or

Individual

Teaching tip
The quotation marks cause the search engine to find resources that use both words.

Optional Activities Four

1. **Read** biographies of famous scientists, such as these:
   - Christianson, Gale E. *Isaac Newton and the Scientific Revolution*. (1996)
   - Stille, Darlene R. *Extraordinary Women Scientists*. (1995)
   - Spangenburg, Ray. *Carl Sagan: A Biography*. (2008)
   - Datnow, Claire L. *Edwin Hubble: Discoverer of Galaxies.* (2007)
2. **Journal writing** is an excellent way for students to reinforce their own learning. Following are prompts you can give individual students, teams, or the whole class. Allow students to write for at least 3 minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.
   - **Prompt 1:** If you were to move far north, almost to the North Pole, your life would be so different from where you live now. Describe a day in January and a day in early July at 80° N latitude.
   - **Prompt 2:** There are populations that live very close
3. **Research and report**
   - Ask students to **research** one of the following topics and to prepare a short oral **report**, written report, and/or poster to share with their classmates. Make a timeline when appropriate. To use the Internet for your research, type the **highlighted words** into a search engine using quotation marks. Here are some to consider.
   - Type "**Antarctica**" into a search engine. Report on the land area, countries that have research stations there, and treaties restricting what can and cannot happen there.
   - Research the major explorers of Antarctica. Type "**Richard Evelyn Byrd**, " "**Ernest Shackleton**," "**Roald Amundsen**," and "**Robert F. Scott**" into a search engine.
   - Type "**Arctic Ocean**" into a search engine. There is a frozen ocean at the highest northern latitudes, unlike Antarctica, which is a large continent. Report on exploration of the Arctic Circle, including the history of the Northwest Passage voyages of "**Henry Hudson**."
   - Type "**Robert Peary**" and "**Matthew Henson**" into a search engine to find out about attempts to travel to the North Pole.

- Type "**USS Nautilus**" and "**USS Skate**" into a search engine to find out how these ships were important to the history of exploring the North Pole.

4. **Real life situations**

   Investigate the angle of incidence at a sunny window: Choose a south-facing window. Cut a 1-inch square in a piece of cardboard and tape it to the window. Repeat Investigation 8, but use sunlight rather that a flashlight. Hold the graph paper so that it makes an intensely bright square. That would be the angle of incidence, 90º perpendicular. Next, using the protractor, decrease the angle of incidence and watch how the lit area increases, but at a dimmer brightness.

5. **Math application—geometry**

   Equinox:

   First example: Suppose your latitude is 50º N. The subsolar point is a 0º.

   1. Subtract the subsolar point from your latitude: 50 – 0 = 50.
   2. Subtract that answer from 90º (90 – 50 = 40).
   3. In this first example, the sun at its highest point would only by 40º above the horizon at the equinox. Evaluate this answer by drawing the angle with a protractor.

   June Solstice:

   Second example: Suppose your latitude is 50º N. The subsolar point is a 23½º N.

   1. Subtract the subsolar point from your latitude. 50 – 23½ = 26½.
   2. Subtract that answer from 90º (90 – 26½ = 63½).
   3. In our second example, the sun at its highest point would by 63½º above the horizon at the June solstice. Evaluate this answer by drawing the angle with a protractor.

   December Solstice:

   Third example: Suppose your latitude is 50º N. The subsolar point is a 23½º S. (We will designate southern latitudes as negative numbers.)

   1. Subtract the subsolar point from your latitude. 50 – (-23½) = 73½.
   2. Subtract that answer from 90º (90 – 73½ = 16½º).
   3. In our third example, the sun at its highest point would be only 16½º above the horizon at the December solstice. Evaluate this answer by drawing the angle with a protractor.

Instruction Block Five

Golden Square Challenge: Seasons on Exoplanets

Square Five Concepts—*Students will understand:*

- Exoplanets, also known as extrasolar planets, are planets outside our solar system orbiting a different star.
- Obliquity affects the length of the period of daylight hours on all planets.
- Obliquity affects seasons on all planets.
- All planets orbiting a star will have an axis pointed toward a singular point.
- All planets orbiting a star will have solstices and equinoxes.
- Seasons can be predicted and described on exoplanets.

Materials

For the Earth model: pushpin, small Styrofoam ball with pin, miniature marshmallow with toothpick, or Ping Pong ball Earths—*1 per student*

Duplicate

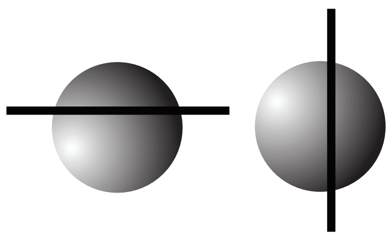
Golden Square Challenge (4 pages)

Lesson Plan

Golden Square Challenge: Seasons on Exoplanets

1. Introduce the Golden Square Challenge. Let students know that this is, in fact, a challenge that most will find difficult. However, allow all students to take the challenge if they'd like to try.

2. Students may need an Earth model to figure out what is happening with both 0º and 90º obliquity. If you don't have enough models, you can give students one of the suggested materials above. The simplest and least effective is a sole pushpin. Students can use the pin end for an axis and the pin top itself as a misshapen planet. The balls or marshmallows would work better.



3. Go over the directions. Make sure students understand that Parts I and II are meant to guide their thinking and give them a chance to show what they know. The final question—which planet is more habitable—should be answered using what they have revealed in the first two parts. Encourage them to bullet their pros and cons.

4. After the students have answered the Golden Square Challenge and turned in their papers, discuss their ideas as a whole class. Only a few of your students will probably demonstrate enough information for you to award them a Golden Square. Debrief to give all students the benefit of the challenge. Praise students for any conclusions they derive.

Teaching tip
If you think this challenge is beyond your individual students, you can design this to be a team cooperative challenge. Have teams work and share as a whole class. Then allow individual students to answer Part III.

Teaching tip
Tell students that obliquity differences occur throughout our solar system. Mercury's obliquity is about 0° and Uranus' obliquity is 97°. However, our discussion of habitability does not work, because Mercury is not in a Goldilocks zone and Uranus is a gaseous, not a rocky, planet.

<table>
<tr><th colspan="2">Answer Key</th></tr>
<tr><td>Part I ALPHA</td><td>Part II ZETA</td></tr>
<tr><td>Alpha Obliquity 0º</td><td>Zeta Obliquity 90º</td></tr>
<tr><td>Equinoxes
Every day is an equinox because every day has 12 hours of daylight and 12 hours of night.</td><td>Equinoxes
2 times a year like Earth
At the March and September positions of its orbit.</td></tr>
<tr><td>Solstices
There are no solstices because the subsolar point stays at the equator never moving north or south.</td><td>Solstices
2 times a year like Earth
the subsolar point spirals and “stops” at the North Pole in the June and spirals downward to the South Pole in the December position of its orbit
The whole northern hemisphere is in sunlight in June and in darkness in December.</td></tr>
<tr><td>Subsolar Points
The subsolar point traces the equator all day every day of the year.</td><td>Subsolar Points
The subsolar point traces a spiraling pattern from one pole to the other and back again, crossing the Equator 2x a year.</td></tr>
<tr><td>Angle of incidence
The angle of incidence in any one location remains the same throughout the year.</td><td>Angle of incidence
At all locations, the angle of incidence around the planet varies.
During some parts of the year a location may have a 90º angle of incidence with the sun directly overhead. Other times, at the same location, the subsolar point will pass below the horizon giving an effective angle of 0º.</td></tr>
<tr><td>Daylight hours
There are always 12 hours of daylight every day all year regardless of where it is in its orbit.</td><td>Daylight Hours
All locations on Zeta will experience daylight hours from 0 hours to 24 depending on where Zeta is in its orbit.</td></tr>
<tr><td>Seasons
No “seasons” per se. Just different temperatures because of angle of incidence.
Seasons are not affected by orbit position.</td><td>Seasons
Seasons are opposite in Northern and Southern Hemispheres
Very extreme seasons from pole to pole Zeta as it follows its orbit</td></tr>
</table>

Answer Key

Part III

Accept any answer that is well developed. Most students will choose Alpha. Students might choose Zeta because living in a narrow band around the equator might have less extreme variations of temperature. Students who choose Zeta but not at the equator must explain how people would have to move or set up artificial climate control centers for wild fluctuations in temperature.

Pros for Alpha:

- Constant seasonal weather
- Latitude determines how hot or cold
- Length of period of daylight hours is the same every day all year
- Predictable living conditions and growing seasons

Cons for Zeta

- Extremely variable temperatures at every latitude
- Extremely variable daylight hours at every latitude
- Long periods with no daylight
- Extreme seasonal differences that have an impact on living conditions and growing food

Name: ______________________________ Date: ______________

Pretest / Posttest

Choose the correct answer and write the letter(s) in the space to the left.

1.	One **revolution** is equal to the time it takes	A. Earth to spin once B. light from the sun to reach Earth C. Earth to orbit the sun once D. the sun to pass overhead from east to west
2.	One **rotation** is equal to the time it takes	A. Earth to spin once B. light from the sun to reach Earth C. Earth to orbit the sun once D. the sun to pass overhead from east to west
3.	The **axis** of the Earth is	A. the plane described by Earth's orbit around the sun B. an imaginary line tracing the middle of Earth at its widest point C. the path of the sun as it passes overhead from east to west D. an imaginary line passing through Earth from pole to pole
4.	The northern tip of Earth's axis *always* points at	A. the sun. B. Earth's orbit. C. Polaris. D. the ecliptic.
5.	**Obliquity** is	A. the imaginary line tracing the middle of Earth at its widest point B. an imaginary line passing through Earth from pole to pole C. the plane described by Earth's orbit around the sun D. the tilt of Earth on its axis
6.	The Earth rotates	A. always clockwise B. always counterclockwise C. clockwise in the Southern Hemisphere but counterclockwise in the Northern Hemisphere D. clockwise half the year and counterclockwise the other half
7.	How much is Earth's axis tilted, measured in degrees?	A. 0 º B. 45½º C. 23½º D. 66½º
8.	What is the subsolar point?	A. the place on the horizon where the sun shines at sunrise B. the place where the sun crosses the ecliptic C. the place on the horizon where the sun shines at sunset D. the place on Earth's surface that is directly under the sun
9.	On the June solstice, at what latitude is the subsolar point?	A. 90º B. 0º C. 23½º N D. 23½º S
10.	On the September equinox, at what latitude is the subsolar point?	A. 90º B. 0º C. 23½º N D. 23½º S
11.	What does the word *solstice* mean when you break it into parts?	A. sun place B. solar star C. sun stop D. solar path
12	At 50º N in June, the period of daylight is	A. the same length as period of night B. much longer than the period of daylight at the equator C. much shorter than the period of daylight at the equator D. the same length as period of daylight at the equator

13.	If it is winter in the Southern Hemisphere, what season is it in the Northern Hemisphere?	A. spring B. summer	C. fall D. winter
14.	Which month marks the beginning of Spring at 45º S?	A. March B. June	C. September D. December
15.	Equinoxes and solstices generally occur on which dates in the month?	A. 1st to the 5th B. 13th to the 14th	C. 20th to the 23rd D. 29th to the 30th
16.	What does the word **Terminator** mean?	A. the place where the sun crosses the ecliptic B. the place on Earth's surface that is directly under the sun C. the place on Earth where daylight ends and night begins D. the place at the poles where the sun never shines	
17.	Where is the Arctic Circle?	A. 0º B. 23½º N	C. 66½º N D. 90º N
18.	Twice a year every place on Earth has exactly 12 hours of daylight. When are those times? **Choose two answers.**	A. March equinox B. September equinox	C. June solstice D. December solstice
19.	When is there a polar night at the Arctic Circle?	A. March equinox B. September equinox	C. June solstice D. December solstice
20.	How often does the sun rise at the North Pole?	A. once a day B. once a week	C. once a month D. once a year
21.	***Angle of incidence*** refers to	A. the angle between dark and light B. the angle of sunlight as it strikes Earth's surface C. the angle of obliquity D. the angle between the North Pole and the Arctic Circle	
22.	At what latitude would the intensity (brightness) of sunlight be strongest?	A. 15º S B. 30º N	C. 41º S D. 66½º N
23.	In which Earth zones is there little change in seasons or length of the period of daylight hours?	A. Polar Zones C. Temperate Zones	B. Tropical Zones
24.	In which Earth zones are there true changes in seasons?	A. Polar Zones C. Temperate Zones	B. Tropical Zones
25.	In which Earth zones are seasons similar, but with extreme differences in the period of daylight?	A. Polar Zones C. Temperate Zones	B. Tropical Zones

Cooperative Group Work Rubric

	1 Exceeds Expectations	2 Meets Expectations	3 Nearly There	4 Ineffective
Contributing	I consistently contribute to the group by sharing my opinions and ideas.	I usually contribute to the group by sharing my opinions and ideas.	I sometimes contribute to the group by sharing my opinions and ideas.	I rarely contribute to the group by sharing my opinions and ideas.
Listening	I actively listen to and support other people's opinions, ideas, and efforts.	I usually listen to and support other people's opinions, ideas, and efforts.	I sometimes listen to and support other people's opinions, ideas, and efforts.	I rarely listen to and support other people's opinions, ideas, and efforts.
Teamwork	I actively encourage all members to participate and work together.	I often encourage all members to participate and work together.	I occasionally encourage all members to participate and work together.	I rarely encourage all members to participate and work together.
Problem solving	I consistently help my team to work through problems by actively seeking and suggesting solutions.	I often help my team to work through problems by seeking and suggesting solutions.	I sometimes help my team to work through problems by seeking and suggesting solutions.	I do not try to help my team to work through problems or to suggest any solutions.
Staying on-task	I consistently stay on the task and complete the work required.	I stay on the task and complete the work required.	I stay on the task some of the time and complete some of the work required.	I am often off-task and do not complete the work required.

Concept Content Rubric

4 **Exemplary**—You demonstrated a **clear** understanding of the concept. You *accurately* and *completely* described/drew the concept in detail using *correct labels*. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

3 **Expected**—You demonstrated a *good understanding* of the concept. You *accurately* described/drew the concept using *some detail* and *correct labels*. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

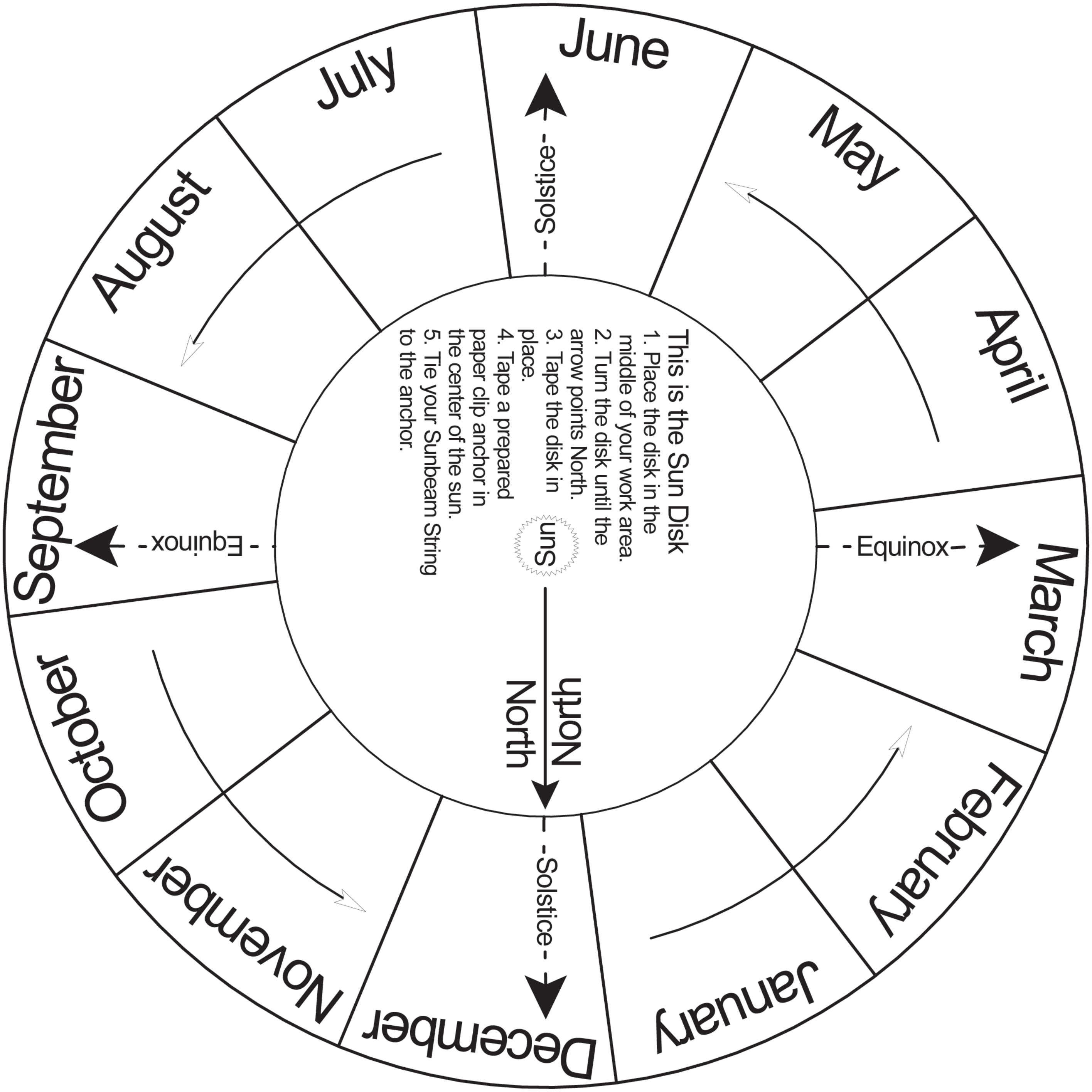
2 **Nearly There**—You demonstrated *some* understanding of the concept. However, you did not describe/draw it as accurately or completely as needed and some of your labels were incorrect. Or you did not communicate your understanding clearly because of spelling or grammatical errors. You may need to meet with your team or teacher to learn the concept more completely, or you need to redo your work and correct the errors.

1 **Incomplete**—You demonstrated *little or no understanding* of the concept, so you could not describe/draw it. You need to meet with your team or teacher to relearn the material.

If your evaluation is a 2 or 1, strive to correct your work to at least level 3.

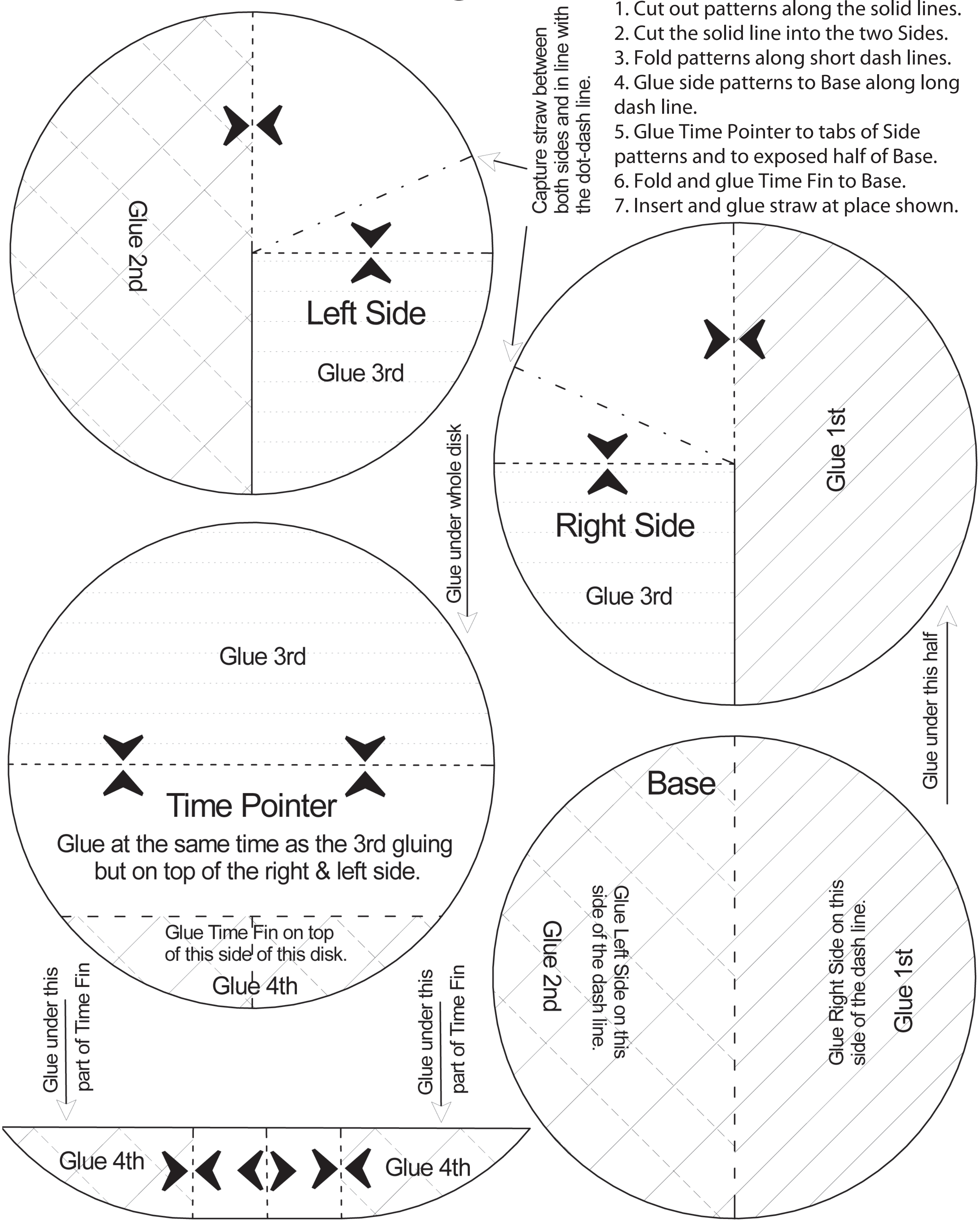
Pattern Page 1 - Earth's Orbital Position Sun Disk

Cut out the overlay along the outer circle.



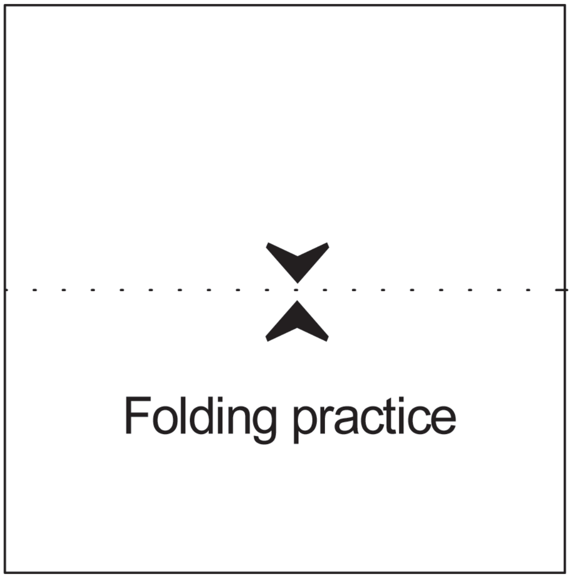
Pattern Page 2- Earth Holder

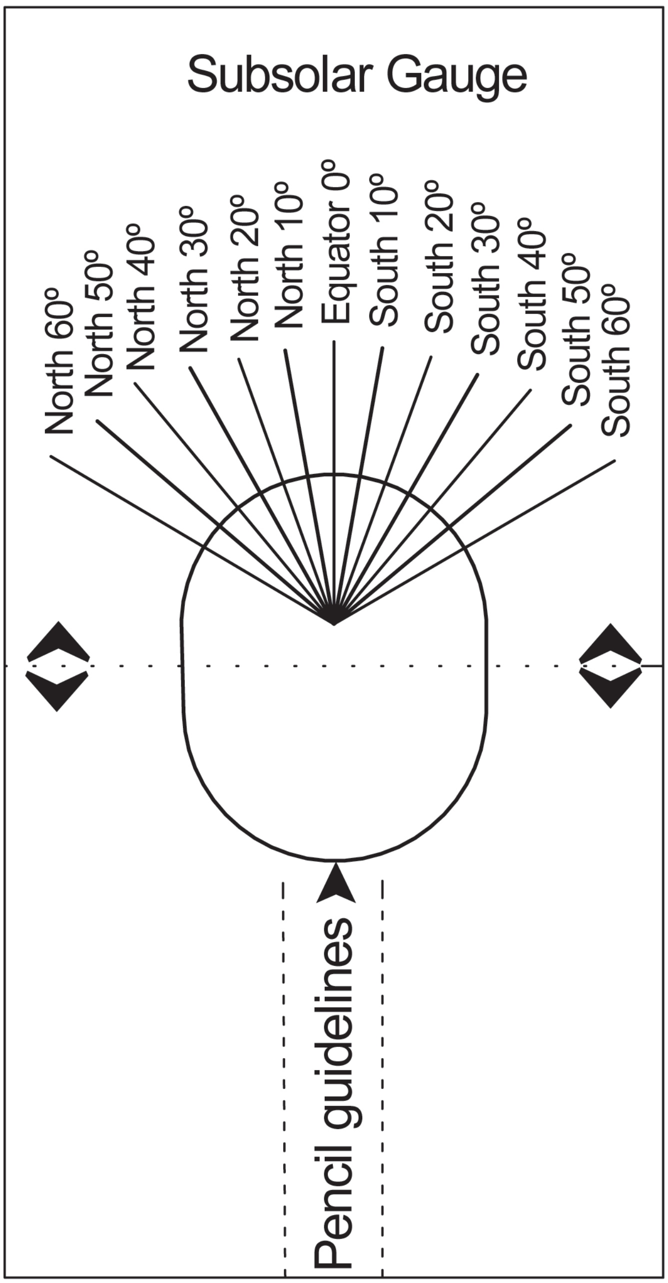
1. Cut out patterns along the solid lines.
2. Cut the solid line into the two Sides.
3. Fold patterns along short dash lines.
4. Glue side patterns to Base along long dash line.
5. Glue Time Pointer to tabs of Side patterns and to exposed half of Base.
6. Fold and glue Time Fin to Base.
7. Insert and glue straw at place shown.

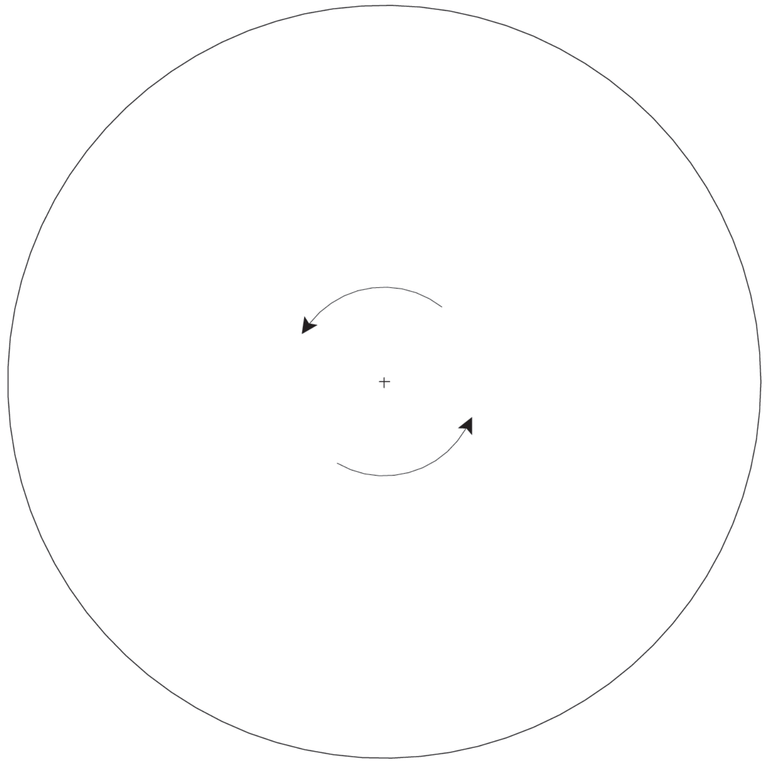


Pattern Page 3

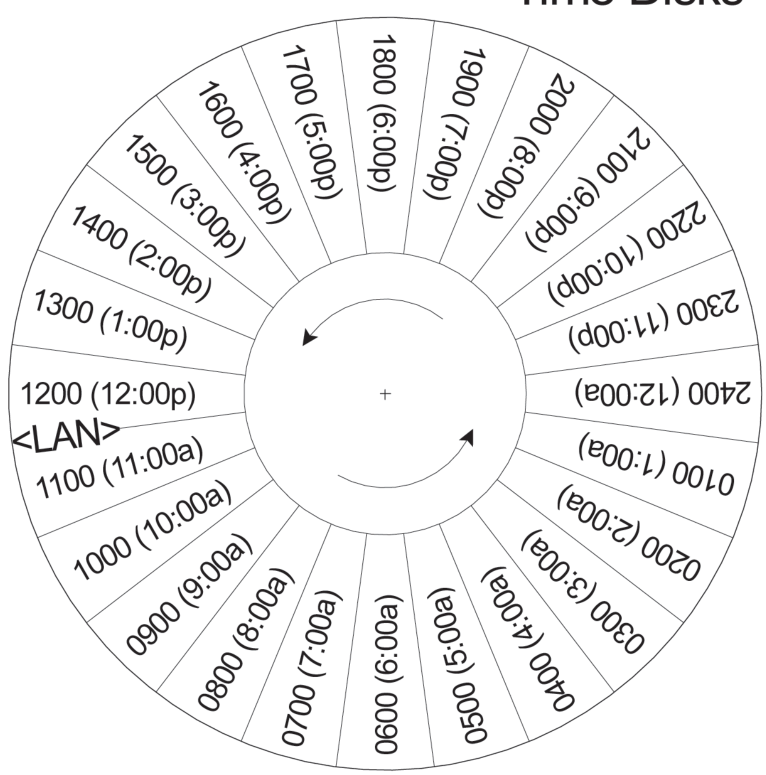
1. Cut out the overlay along the outer circle.
2. Practice folding the practice piece.
3. Fold the Subsolar gauge along the dotted line.







Time Disks



Name: ______________________________ Team: ______________

Stop/Think/Draw/Write Template

(Be sure your labels are spelled correctly)

Essay 1
Ancient Astronomers Were Very Smart

Focus Questions
How were ancient astronomers different from the average people living long ago?

You have heard about ancient peoples and their myths, but living at the same time were ancient scientists who did not rely on mythology to explain what they saw in the night sky. They diligently made observations, carefully drawing and recording what they saw. They were the first to use basic mathematics with science to formulate ideas that explained their universe. They proposed theories, predicted happenings, and then watched to see if they were right. In many cases, they were able to divine great truths.

How many years ago did ancient astronomers start to make star charts and other observations of the night sky?

Which people were the first to calculate the size of Earth?

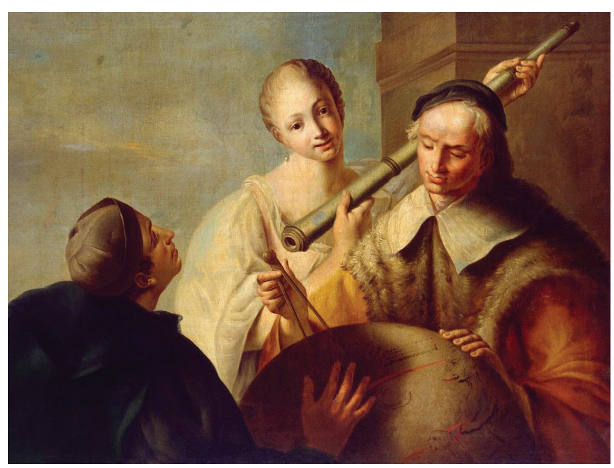
Why was the shipwreck from 300 BCE an important find for science?

The Babylonians, who were the first to develop writing, began keeping records and creating star charts more than 3,000 years ago. The Egyptians also created star charts so they could align their Great Pyramids to the polar star of that time. The Greeks, too, were great astronomers and record keepers. They calculated the size of the Earth and were the first to postulate that the sun and not the Earth was at the center of a solar system. Recently scientists have recognized that a mechanical device found in a Greek shipwreck from 300 BCE might have been the world's first computer. It might have been able to predict moon phases and the position of the Earth, moon, sun, and possibly some planets.

What does *geometry* mean?

How did mathematics help the spread of knowledge?

The Greeks obviously knew that mathematics was the key to understanding science. For example, the word *geometry* is the combination of two Greek words: *geo* ("Earth") and *metre* ("measurement"). From the very beginning they developed math concepts to measure and confirm what they observed, and they created common symbols and formulas. Mathematics became a universal language among these scientists, and this allowed them to share information.



What other great civilizations shared what they knew about astronomy?

During the next five centuries, people traveled the ancient world, exploring and trading, all the while taking their knowledge with them. In time, astronomers from Egypt to India to China shared what they had learned independently, and together they began to understand the science in their world.

What event probably caused the end of science discovery in the ancient world?

Why was it so terrible that people burned libraries?

This time of great scientific discovery and sharing of knowledge, however, lasted only until the middle of the fifth century. At that time, the Roman Empire fell, and different rulers throughout western Europe began to war among themselves. Without the structure of powerful Rome, chaos and devastation spread. One of the worst outcomes was the burning of libraries. So much of the knowledge of the ancient world was destroyed.

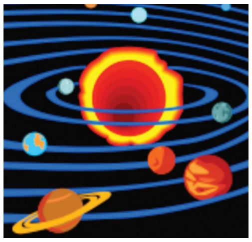
What are three things that contributed to the Dark Ages?

Where were some of the books and manuscripts safely stored?

The next thousand years are sometimes called the Dark Ages, because people suffered war, famine, and plague. These conditions left no time for study or education, so there was little or no science exploration for centuries. Eventually the wars subsided and the European governments became more stable. Scientists and scholars retrieved some of the remaining ancient manuscripts that had been preserved in monasteries. Slowly they began to rediscover what had been lost.

Why is it impressive that sixteenth-century scientists could discover so much about our planet and its solar system?

By the sixteenth century, scientists Copernicus, Galileo, and Kepler were using telescopes and more mathematics to define astronomy and much of what we now know about our solar system. Their discoveries were extraordinary feats of science because they occurred more than five hundred years before man launched a rocket into space.



Essay 2
Rotation and Revolution

Focus Questions
How fast is Earth spinning when measured at the equator?

How fast is Earth moving in its orbit?

Always moving

If you sit quietly and look skyward, you do not have any sensation of movement. You may see clouds pass overhead, or over a period of time you may see the moon or sun travel from the eastern to the western sky. If asked, though, you would say you weren't moving. In fact, you are aboard a planet that is spinning on its axis at a rate of 1,000 miles per hour when measured at the equator. At the same time Earth is hurtling along its orbit around the sun at an astounding average speed of 66,000 miles per hour.

Do Earth, the sun, planets, and the moon all rotate?

How long does it take Earth to rotate?

If viewed from space, looking at the North Pole, what direction does Earth rotate?

Rotation

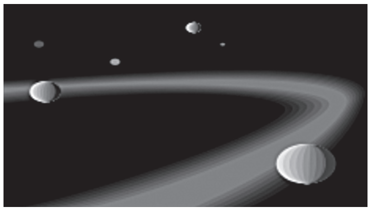
Objects *rotate* (spin) in space. Earth, the moon, other planets, the sun, and stars all rotate. Their rate of rotation is known and observable. Earth spins once every day, completing the spin in just short of 24 hours. From space, when looking down at the North Pole, Earth appears to be rotating in a *counterclockwise* direction.

From what direction does the sun always rise?

To what direction does the sun always set?

Sunrise, sunset, moonrise, moonset

Because ancient peoples did not know they were on a rotating planet, they misinterpreted the movement of the sun and moon across the sky. They believed that every morning the sun rose in the east, traveled across the sky, and set in the west. The moon, which rose at different times during the day and night, also always rose in the east and traveled to the west. But eventually some ancient astronomers figured it out: The sun and moon were not moving—Earth was rotating! However, only a few early scientists believed our planet was part of a system with the sun at its center. That heretical theory was not confirmed until the 1600s and was not accepted until much later.



How long is Earth's one revolution around the sun?

In what directions does Earth revolve?

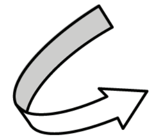
What shape is Earth's orbit?

If Earth's orbit is nearly circular, what happens to the folk science that says "Summer is hot because Earth is closer to the Sun"? Can it be true?

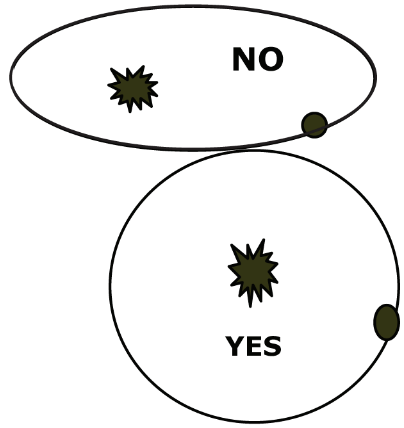
Revolution

In our solar system, Earth and other planets *revolve* around (*orbit*) the sun. It takes Earth a year (365¼ days) to complete its path around the sun.

From space looking down on our solar system, Earth appears to be revolving in a *counterclockwise* direction.



NOTE: You have heard that Earth's orbit is elliptical. It is, but it is only *slightly elliptical*. Scientists agree that Earth's orbit is *nearly circular*.



Which of the following describes Rotation (RO)? Which describes Revolution (REV)?

1. ______ Spinning top?
2. ______ Car on a racetrack?
3. ______ Ping Pong ball Earth model spinning around the skewer?
4. ______ Body turning around a point inside itself?
5. ______ Body turning around a point outside itself?
6. ______ Earth model moving around sun?

7. Then there's Rotato Potato. What does he show?

Name: ____ Team: _______________

Stop/Think/Draw/Write 1

Use words and/or drawings to describe Earth's rotation and revolution in space.
(Be sure your labels are spelled correctly)

ROTATION

REVOLUTION

Bonus: How much time does it take to complete one Earth rotation?__________

How much time does it take to complete one Earth's revolution?_____________

Investigation 1
Exploring Earth in Its Orbit

Remember that Earth is always in motion, rotating and revolving. You have learned that Earth orbits, or revolves, around the sun. Each revolution takes 365¼ days. This means that for each revolution, there are 365¼ rotations. In this investigation, we will imagine that we are taking snapshots of Earth's movements at four key spots along its orbit. We will also look at the folk science belief that we have summer when Earth gets closer to the sun.

I. Before you start:

Your team must know these terms:

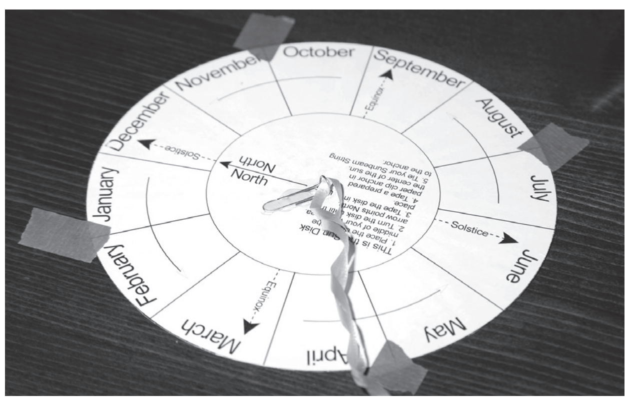
- rotation
- revolution
- axis
- Polaris (North Star)

Materials you will need:

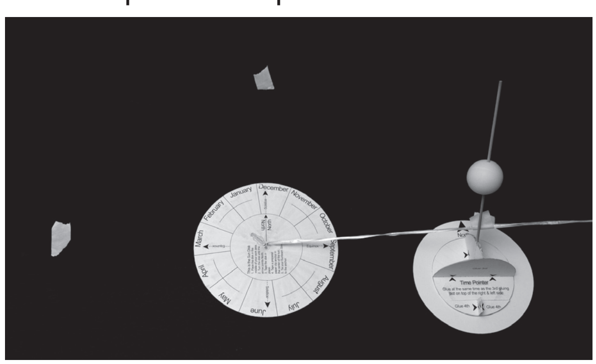
- Investigation 1, Exploring Earth in Its Orbit—1 per team
- Earth's Orbit Observations—4 per team
- Seasons Observatory
- Sun Disk
- Sunbeam String
- Paper-clip anchor
- Tape

II. Prepare the Seasons Observatory working as a team.

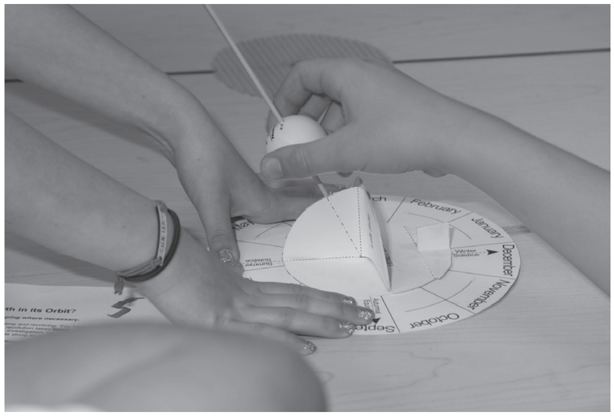
1. Tape the paper-clip anchor in the center of Sun Disk and tie your Sunbeam String to the anchor.
2. Place the Sun Disk in the center of your table, and tape it in place.



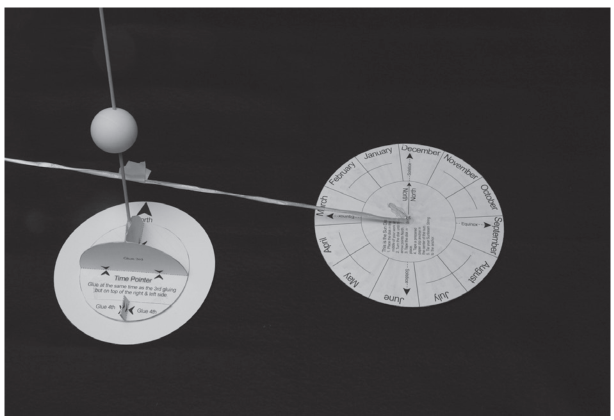
3. Using the Sunbeam String as a guide, mark four places (solstices and equinoxes) on the orbit around the Sun Disk with pieces of tape.



4. Place your Earth axis (skewer) into the straw in the Earth Holder. Check that the axis lies at the correct tilt by comparing it to the dot-dash line on the side of the holder. Adjust the tilt if necessary.

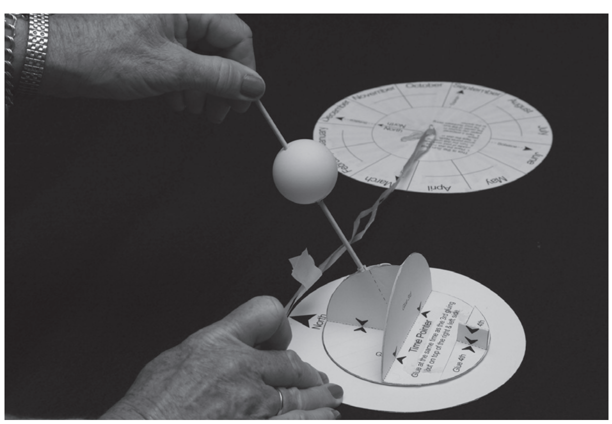


5. Use the Sunbeam String to position the Earth Holder so that the March arrow points toward the Sun Disk and Earth's North Pole axis points toward the north wall.



III. Model rotation—In each team:

- **Reader**: Read directions aloud while **Leader** directs team.
- **Recorder**: Hold steady the Seasons Observatory base.
- **Manager**: Model the changing days by rotating Earth Ping Pong ball—gently spinning the skewer between thumb and forefinger. 3 complete spins = 3 days. Remember to spin in the correct direction—counterclockwise.



- **Leader**: Review **rotation**, Earth's daily motion, with the team.

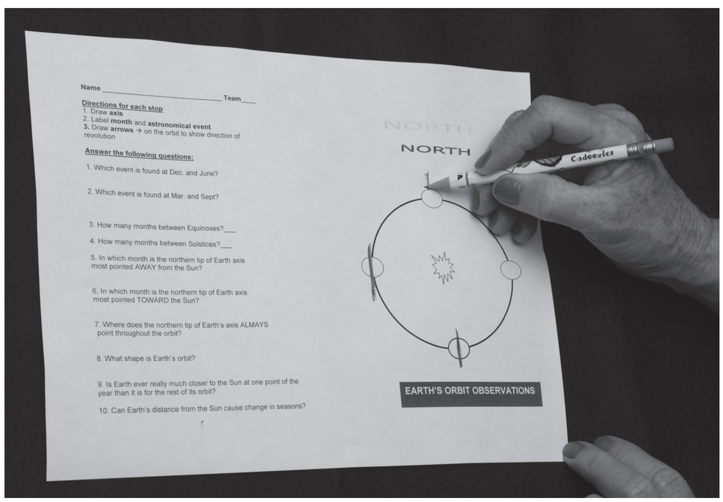
IV. Model revolution of orbit—In each team:

- **Reader**: Read directions aloud while Leader directs team.
- **Entire Team:** Review revolution, the orbiting of Earth around the sun.
- **Leader**: Move the Earth Holder counterclockwise, keeping the axis pointed toward the north wall around the orbit, saying all the months while moving the Earth Holder counterclockwise.
- **Reader, Recorder, and Manager**: Repeat the modeling of revolution from March to March.

V. Record observations on the Earth's Orbit Observations page.

Part A:

- **Reader**: Read the directions here that tell each team member what to do.
- **Recorder**: Draw the axis at the March location and label the month and the event (solstice or equinox). You will repeat for the June, September, and December locations.



- **Leader**: Move the Earth Holder along the orbit, keeping the axis pointing north until the December arrow points toward the sun.
- **Manager**: Check location with the Sunbeam String.
- Repeat these steps for September and June.

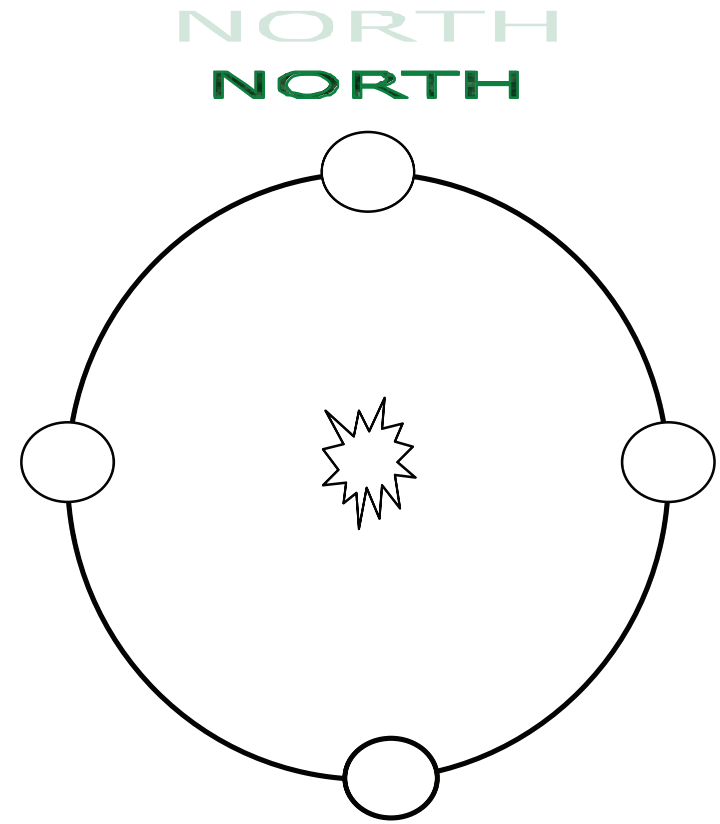
STOP When all observations are done, have your teacher check your drawing. When approved, all team members should copy what the Recorder drew on their own papers.

Part B: As a team, discuss and answer the questions.

Earth’s Orbit Observations

Name: ______________________________ Team: ______________

Part A: On the diagram at the right, follow these steps for each stop in Earth’s orbit.
1. Draw the **axis**.
2. Label the **month** and **astronomical event**.
3. Draw **arrows** → on the orbit to show the direction of revolution.



Part B: Discuss and answer the following questions.

1. Which event is found in December and June?

2. Which event is found in March and September?

3. How many months are there between equinoxes?___

4. How many months are there between solstices?___

5. In which month is the northern tip of the Earth axis pointed furthest away from the sun?

6, In which month is the northern tip of Earth axis pointed most toward the sun?

7. Where does the northern tip of Earth’s axis always point throughout the orbit?

8. What shape is Earth’s orbit?

9. Is Earth ever really much closer to the sun at one point of the year than it is for the rest of its orbit?

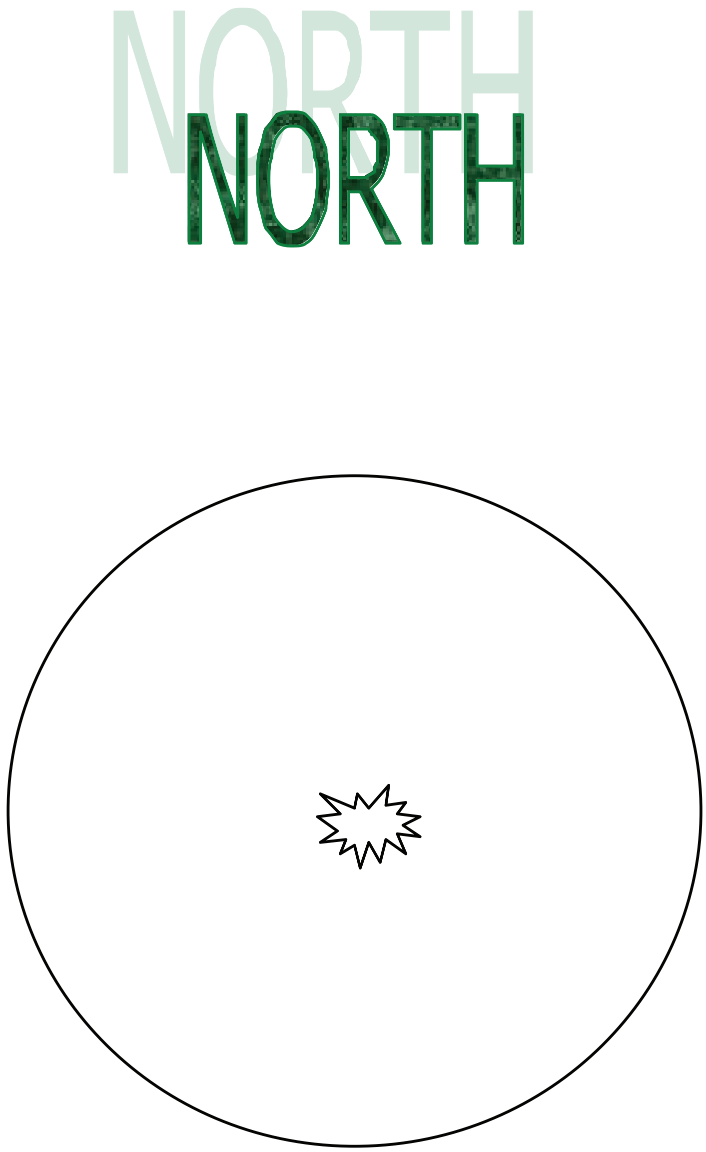
10. Can Earth’s distance from the sun cause a change in seasons?

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 2

Use words and/or drawings to describe the months and locations of solstices and equinoxes in Earth's orbit. Keep in mind where North is and show the direction of Earth's orbit with arrows.

(Be sure your labels are spelled correctly)

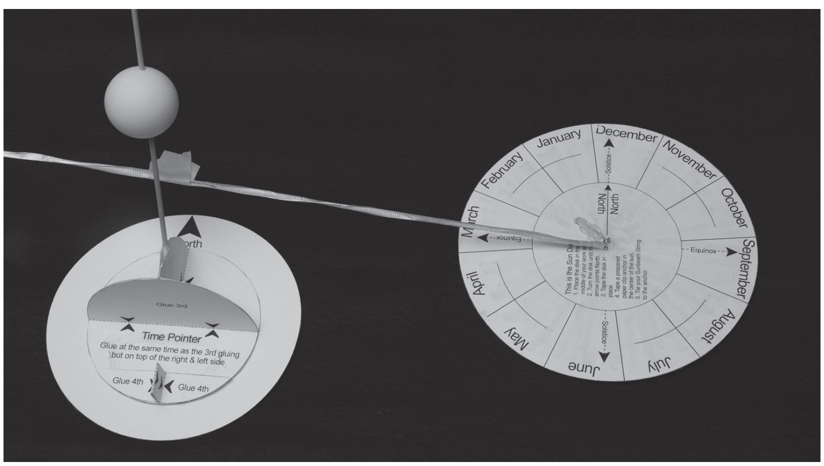


Square One Review Notes

In Square One, we discovered that ancient astronomers were exploring and making theories about the moon and stars. They applied mathematics and models to further explain what they saw. However, the average person living in ancient times had little exposure to science and used myths to explain his or her world. Today, modern scientists continue to use science and math and create theories that they test to explain what we see in the night sky. However, the average person today who doesn't know science relies heavily on "folk science," which can be incorrect.

We learned that the ancient astronomers figured out that an ***axis*** through Earth from pole to pole would point to a star that did not appear to move during the night. They also noticed some patterns of stars: they do not rise or set but move around and around the polar star (circumpolar constellations) Today, our polar star is **Polaris**, and Earth's axis at the North Pole always points toward Polaris no matter where it is in its orbit around the sun.

We used our **Seasons Observatories** for the first time in Square One to complete **Investigation 1, Exploring Earth in Its Orbit**. The Observatory contained a Sun Disk, Sunbeam String, and Earth Holder. There were also a Subsolar Point Gauge and a Time Disk, which we will use later. To use the Seasons Observatory and model what was happening in space, we had to assume that the north wall of our classroom would represent Polaris and that the tabletop would be the **ecliptic**, which is the plane created by the orbit of the Earth in space.



We learned a big word—**obliquity**—which refers to the tilt of the Earth. We revisited **revolution** and **rotation** and learned that these words, when applied to Earth's movement in space, meant to revolve (orbit) and rotate (spin). We learned that although Earth's orbit is elliptical, it is only slightly elliptical. In fact, Earth's orbit is nearly round. We completed **Investigation 1, Exploring Earth in Its Orbit**. We noted the four astronomical events in four key positions in Earth's s orbit: **equinox**, **solstice**, **equinox**, and **solstice**. From the observations we realized that the solstices occur six months apart in June and December, and the equinoxes occur in March and September, also six months apart. We confirmed that one silly folk science explanation could not be true: Earth's orbit is **almost round**, so there is no one time when its orbit brings Earth so much closer to the sun that it would affect the seasons. Therefore, summer could not be caused by Earth being closer to the sun.

Name: ______________________________ Team: ______________

Quick Team Quiz One

1.	Earth ____________ every 24 hours.	Choose **two** correct answers that fill in the blank: A. spins B. orbits C. rotates D. revolves
2.	Earth ____________ every 365¼ days.	Choose **two** correct answers that fill in the blank: A. spins B. orbits C. rotates D. revolves
3.	Which statement is true? When looking from ABOVE the North Pole. . .	A. Earth rotates and revolves clockwise. B. Earth rotates and revolves counterclockwise. C. Earth rotates clockwise and revolves counterclockwise. D. Earth rotates counterclockwise and revolves clockwise.
4.	What is Earth's **axis**?	
5.	Where does the northern tip of Earth's **axis** always point?	
6.	What is Earth's **orbit**?	
7.	In which two months do the **solstices** occur?	
8.	In which two months do the **equinoxes** occur?	
9.	In which month does the Earth's axis point mostly toward the sun?	
10.	What is a circumpolar constellation?	
11.	What is the **ecliptic** in our classroom model?	
12.	What is the **ecliptic** in space?	
13.	What does **obliquity** mean when talking about Earth?	

Name: ____________________ Team: __________

Square One Test

1.	One **revolution** is equal to the time it takes	A. Earth to spin once. B. Light from the sun to reach Earth. C. Earth to orbit the sun once. D. the sun to pass overhead from east to west.
2.	One **rotation** is equal to the time it takes	A. Earth to spin once. B. light from the sun to reach Earth. C. Earth to orbit the sun once. D. for the sun to pass overhead from east to west.
3.	The **axis** of the Earth is	A. an imaginary line tracing the middle of Earth at its widest point. B. the plane described by Earth's orbit around the sun. C. the path of the sun as it passes overhead from east to west. D. an imaginary line passing through Earth from pole to pole.
4.	The northern tip of Earth's axis **always** points at	A. the sun. B. Earth's orbit. C. Polaris. D. the ecliptic.
5.	The **ecliptic** is	A. the imaginary line tracing the middle of Earth at its widest point. B. an imaginary line passing through Earth from pole to pole. C. the plane described by Earth's orbit around the sun. D. the tilt of Earth on its axis.
6.	**Obliquity** is	A. the imaginary line tracing the middle of Earth at its widest point. B. an imaginary line passing through Earth from pole to pole. C. the plane described by Earth's orbit around the sun. D. the tilt of Earth on its axis.
7.	The Earth rotates	A. always clockwise. B. always counterclockwise. C. clockwise half the year and counterclockwise the other half. D. clockwise in the Southern Hemisphere but counterclockwise in the Northern Hemisphere.
8.	In which two months do the **equinoxes** fall?	and
9.	In which two months do the **solstices** fall?	and

Essay 3 Eratosthenes

276 BC–195 BC

Focus Questions
How long ago did Eratosthenes live?

Why is where he worked important?

What two famous calculations did he make?

How big is Earth at the equator?

What system did he invent?

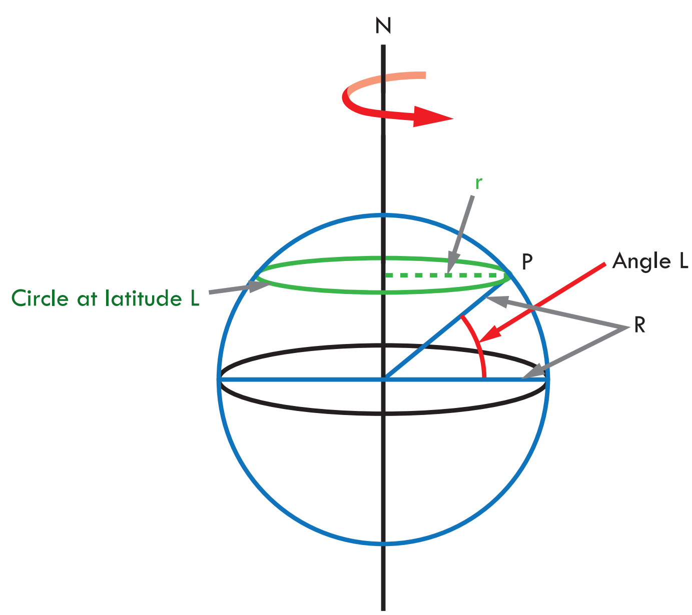
Take a moment to try to pronounce the name of this famous Greek mathematician, geographer, and poet: Eratosthenes. *E-ra-TAHS then-eez*. It's a good name to remember, because he was one those ancient scientists who more than 2,000 years ago used mathematics to uncover the truths of astronomy. He was born in Cyrene, Libya. He moved to Alexandria, Egypt, where he became one of the first librarians at the Great Library of Alexandria. He made many significant discoveries by using mathematics and observations.

Eratosthenes was the first Greek scientist to calculate the number of degrees of Earth's axial tilt. Using that information, he used simple ***geometry*** and sunlight shining into two wells, one at the equator and one at the Tropic of Cancer (500 miles apart), to calculate the circumference of Earth at the equator. His answer was about 25,000 miles, very close to Earth's actual circumference of 24,901.55 miles.

He has also been recognized as the father of geography. ***Geography*** comes from the Greek words geo meaning "Earth" and *graph*, meaning "writing."

He invented the system of latitude and longitude and was one of the first to make a map of the known world.

Eratosthenes will be a key figure in your understanding of latitude.



When Eratosthenes was designing the system of latitude, where did he imagine he was?

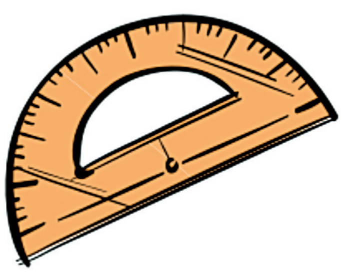
What is the base of all the angles he measured?

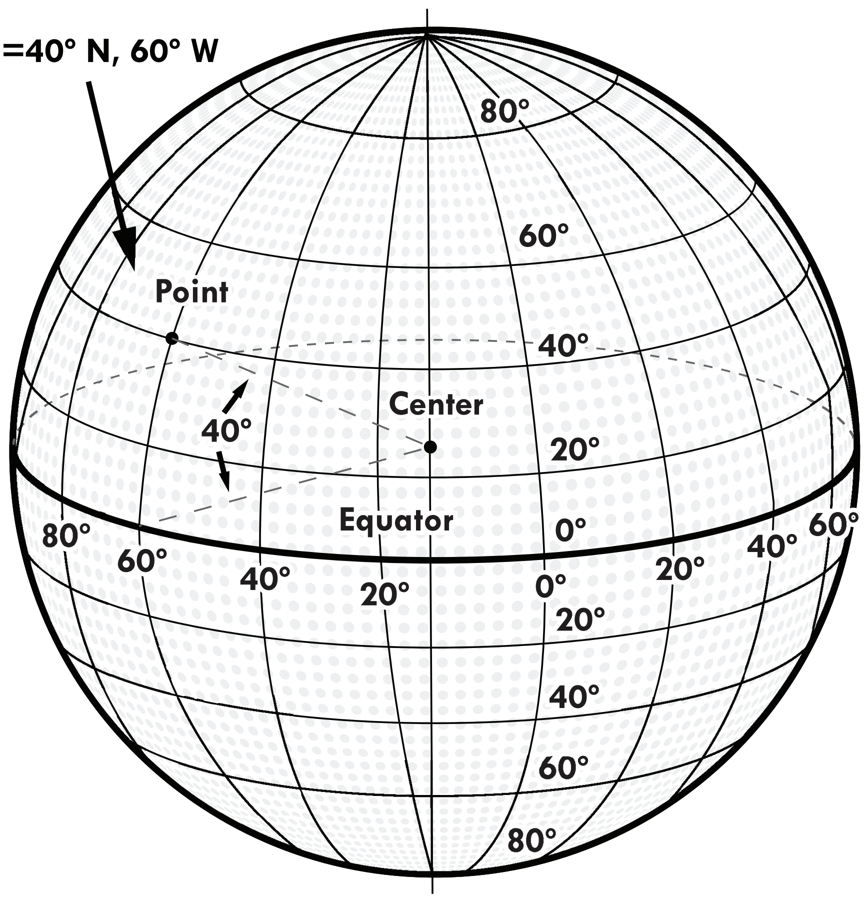
For a moment, imagine you are Eratosthenes and think like he did. He imagined he was inside a sphere at its center. He imagined making a 40º angle with the vertex at the center of Earth and with the equator 0º as the base. The point where the second side of the angle extends from the center above the equator to Earth's surface would be 40º North latitude. If he moved around the central point inside the sphere, that angle would create a series of points all around the sphere—all of which would be 40º North of the equator. The system worked for every angle from 0º to 90º North and from 0º to 90º South.

How is 40º N different from 40º S?

What geometric tool do you need to measure angles?

What does it mean when two lines are parallel? Use a dictionary, if you need to.





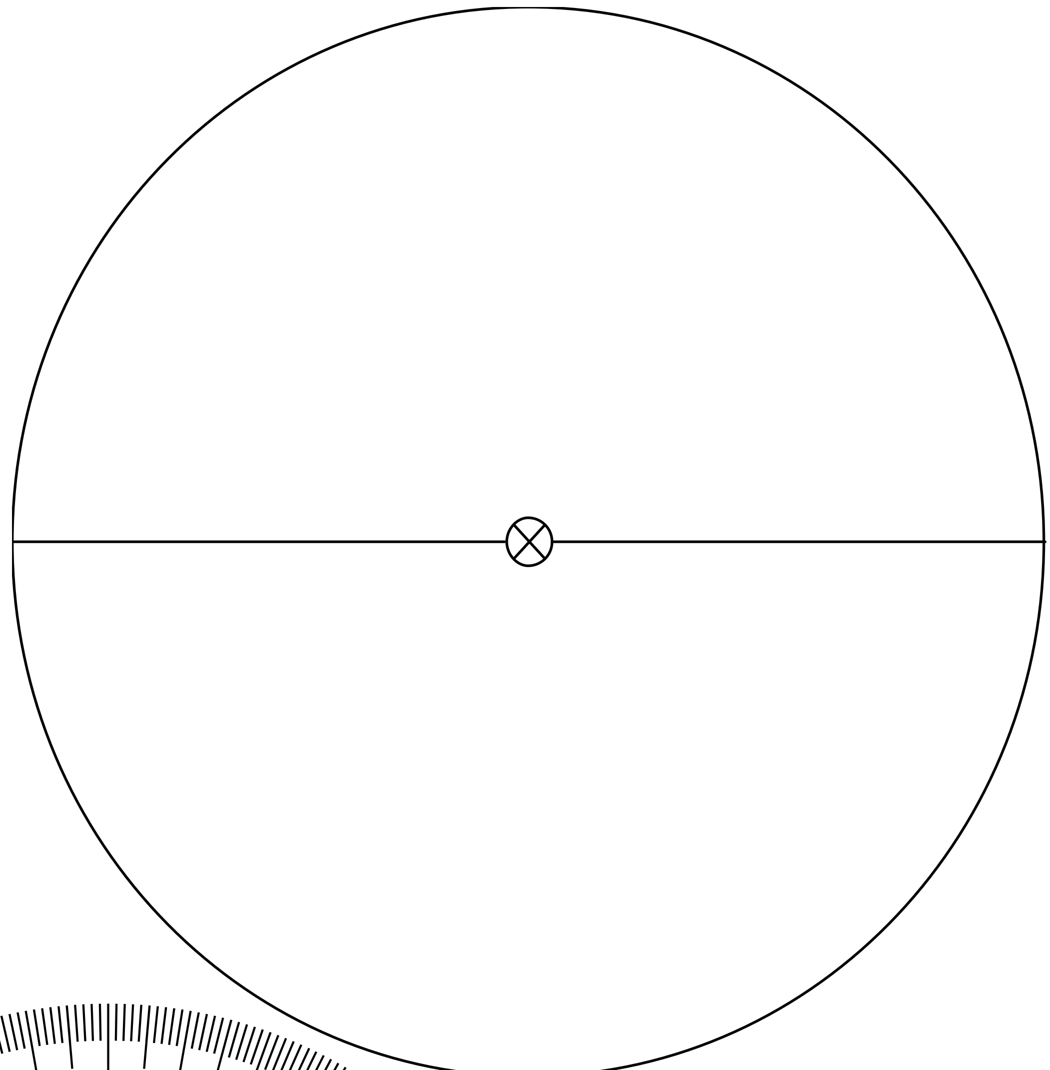
Now you are going to use a protractor and create a series of latitude lines on a drawing of Earth. You will discover why *latitude lines* are sometimes called *parallels*.

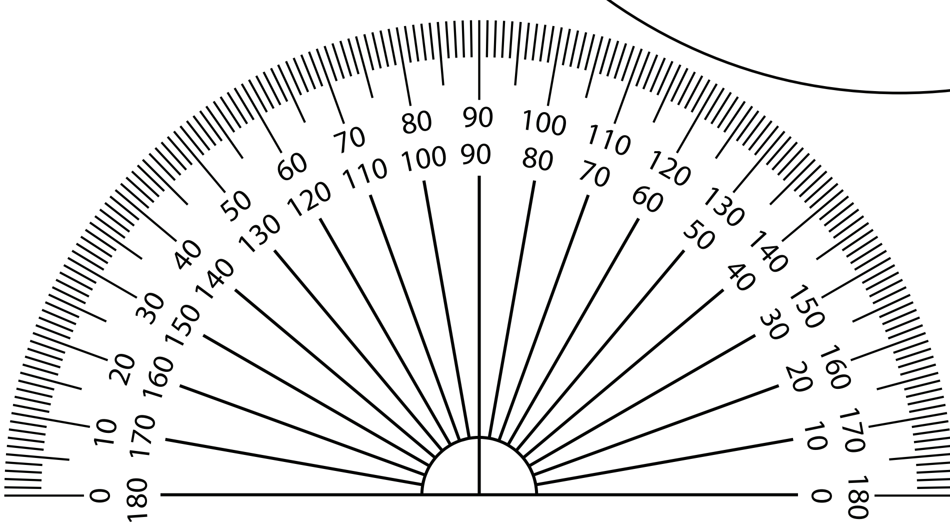
Name: ____ Team: _______________

Latitude Activity

Cut out the protractor at the bottom of this page. You will need it to perform these steps:

1. Mark the center line 0º equator.
2. Draw and label latitude lines at 20º N, 41º N, 65º N, 76º N.
3. Next, draw and label latitude lines at 20º S, 41º S, 65º S, and 76º S.





Investigation 2
Tracing the Subsolar Points on Earth

You have probably heard of *the tropics* as a warm place that is somewhere south of where you live. In this investigation you will discover exactly where the tropics are and why they exist.

Before you start:

Your team must know these terms:

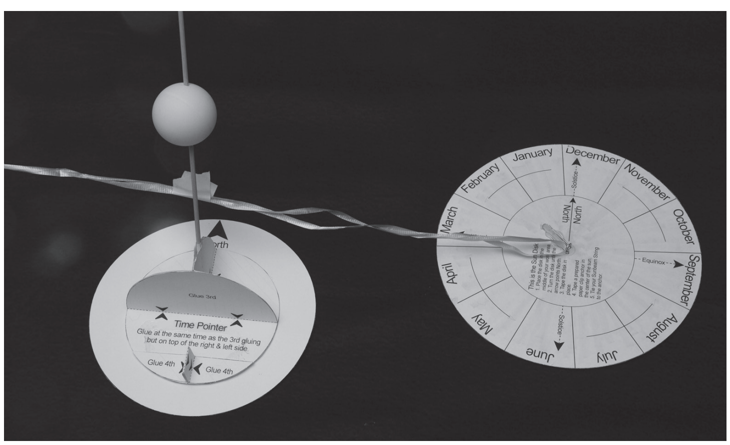
- rotation
- equinox and solstice
- revolution
- subsolar point—the place on Earth's surface that is directly under the sun

Materials you will need:

- Investigation 2, Tracing the Subsolar Points on Earth—*1 per team*
- Investigation 2, Team Observation Sheet—class set
- Investigation 2, Individual Observation Sheet—*1 per student*
- Subsolar Point Gauge
- Seasons Observatory
- Sun Disk
- Sunbeam String
- Short length of painter's tape
- Pencil
- 3 Paper clips

I. Prepare your Seasons Observatory.

1. Set up the Seasons Observatory with the Sun Disk in the middle. Whenever you advance the observatory along the orbit, be sure to use the Sunbeam String to guide you from the sun's center through the middle of the month and on to the observatory.
2. Place your mounted Earth in the straw of the Earth Holder. Adjust the tilt if necessary.



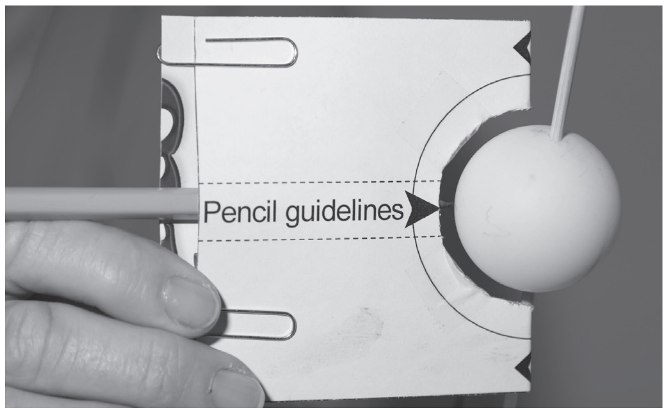
3. Position the Earth Holder in orbit so that the North Pole axis points toward the chosen north wall and the March equinox arrow points from the sun mat in March to Earth.
4. Remember: *Earth is always in motion, rotating and revolving. In this investigation, we will imagine that we are taking snapshots of Earth's rotation once a month as it revolves around the sun.*

II. Prepare and use the Subsolar Point Gauge.

1. Imagine a ray of light that travels from the center of the sun's surface to the center of

Earth's surface facing the sun. This place on Earth's surface is the **subsolar point**. In this investigation, your team will use the **Subsolar Point Gauge** to accurately trace the path of the subsolar points on your Ping Pong ball Earth. The Sunbeam String shows the line of the subsolar point.

2. Using the Subsolar Point Gauge requires some skill. The pencil must be like an arrow coming from the center of the sun toward the center of Earth. Line it up with the Sunbeam String. The ball must be tucked inside the gauge touching the side.
3. You may have to move the pencil point in or out to get good contact with the Ping Pong ball.



III. Run the investigation.

Your team is now ready to begin the team investigation. To achieve good results, all team members must follow the instructions carefully and use the Seasons Observatory with a delicate touch.

- **Reader**: Reads the directions as the team works. Using the Sunbeam String, sets up the first position (March equinox) and advances the Seasons Observatory to each observation month.
- **Leader**: Holds the Subsolar Point Gauge in the correct position, lining up the gauge with the Sunbeam String. Keeps the pencil point in contact with the Ping Pong ball as it spins.

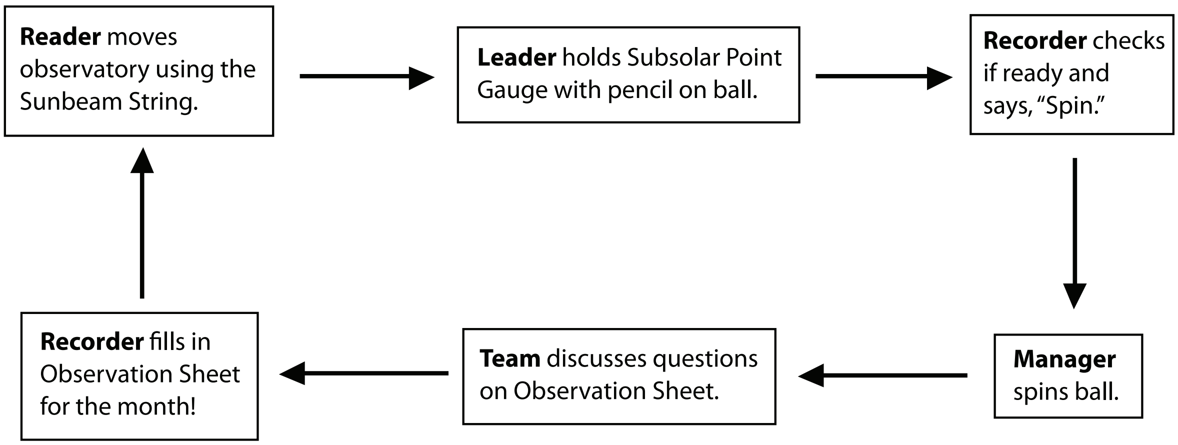
- **Manager-Rotator**: Holds the Seasons Observatory in place and slowly spins the skewer once at each position. (Each spin represents one day per month.)
- **Recorder**: Checks that everything is ready *before* anyone spins anything:

  Is the Earth Holder in the correct position in line with the Sunbeam String?

Is the Subsolar Point Gauge aimed correctly, with the ball inside and along the Sunbeam String?

Is the pencil point in contact with the Ping Pong ball?

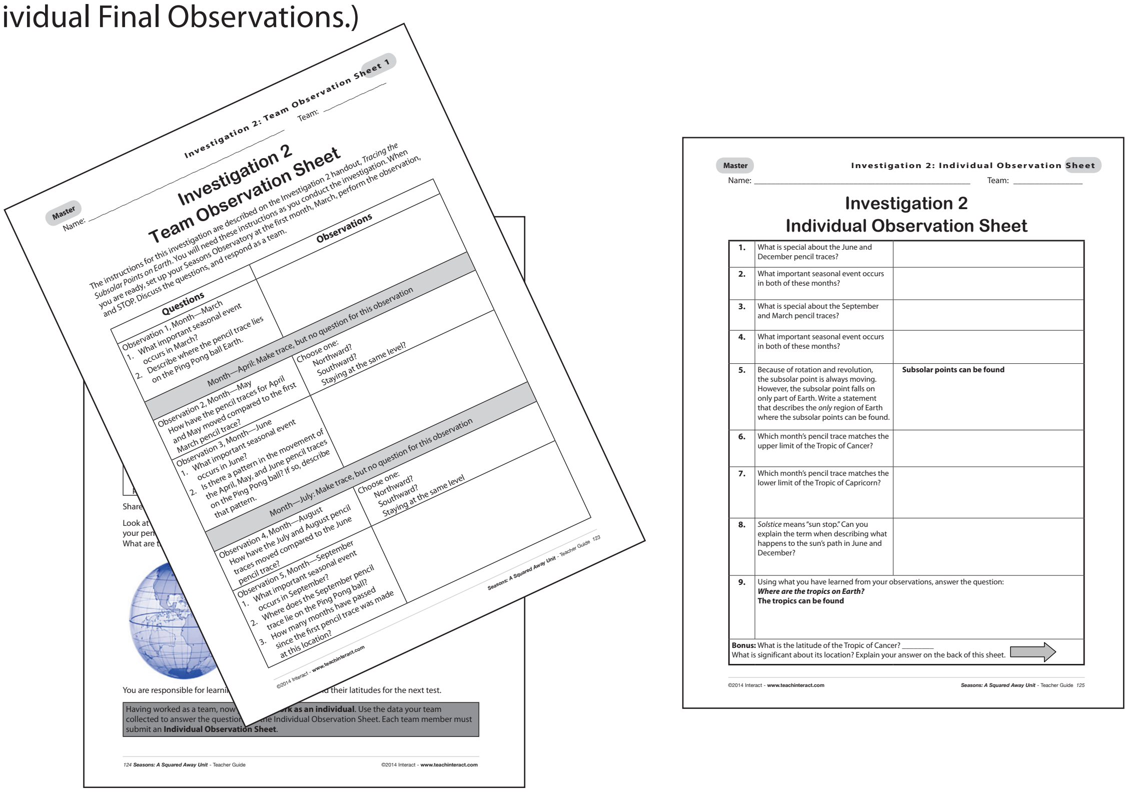
If all is ready, *only* then can the Recorder tell the Manager-Rotator it's okay to spin to the skewer.



STOP! The **team** discusses the observation questions for the month they were observing. The **Writer** writes the observation answers. The **Leader** makes sure that everyone contributes to the discussion.

IV. Interpret the results of the investigation.

When the **Recorder** has recorded all the information for eight of the twelve months on the **Team Observation Sheet**, *every team member* must complete the **Individual Observation Sheet**. (You may work together and share the data, but you all must still create your own Individual Final Observations.)



Name: ______________________________ Team: ____________

Investigation 2
Team Observation Sheet

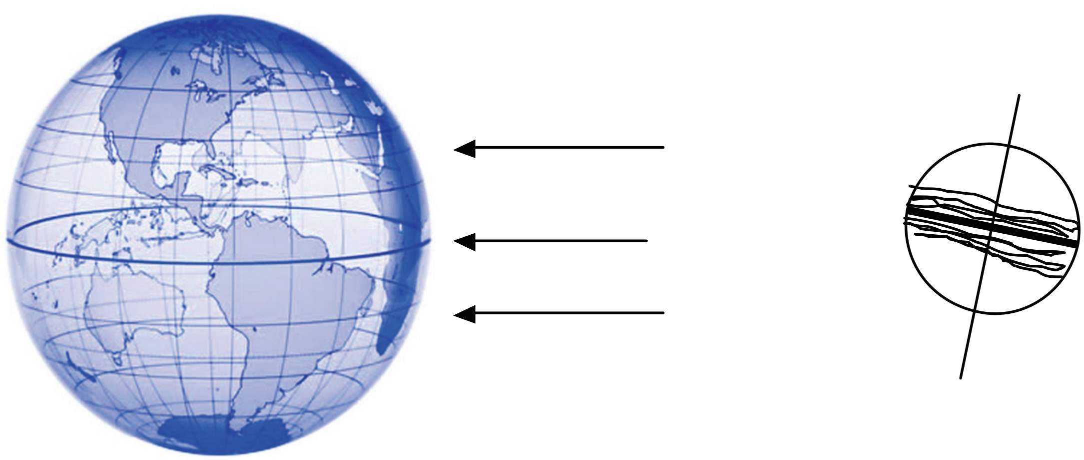
The instructions for this investigation are described on the Investigation 2 handout, *Tracing the Subsolar Points on Earth*. You will need these instructions as you conduct the investigation. When you are ready, set up your Seasons Observatory at the first month, March, perform the observation, and STOP. Discuss the questions, and respond as a team.

Questions	Observations
Observation 1, Month—March 1. What important seasonal event occurs in March? 2. Describe where the pencil trace lies on the Ping Pong ball Earth.	
Month—April: Make trace, but no question for this observation	
Observation 2, Month—May How have the pencil traces for April and May moved compared to the first March pencil trace?	Choose one: Northward? Southward? Staying at the same level?
Observation 3, Month—June 1. What important seasonal event occurs in June? 2. Is there a pattern in the movement of the April, May, and June pencil traces on the Ping Pong ball? If so, describe that pattern.	
Month—July: Make trace, but no question for this observation	
Observation 4, Month—August How have the July and August pencil traces moved compared to the June pencil trace?	Choose one: Northward? Southward? Staying at the same level
Observation 5, Month—September 1. What important seasonal event occurs in September? 2. Where does the September pencil trace lie on the Ping Pong ball? 3. How many months have passed since the first pencil trace was made at this location?	

Investigation 2 Team Observation Sheet, page 2	
Month—October: Make trace, but no question for this observation	
Observation 6, Month—November How have the October and November pencil traces moved compared to the September pencil trace?	Choose one: Northward? Southward? Staying at the same level?
Observation 7, Month—December 1. What important seasonal event occurs in December? 2. Is there a pattern in the movement of the October, November, and December pencil traces on the Ping Pong ball? If so, describe that pattern.	
Month—January: Make trace, but no question for this observation	
Observation 8, Month—February How have the Jan. and Feb. pencil traces moved compared to the Dec. pencil trace?	Choose one: Northward? Southward? Staying at the same level

Share your observations with the rest of your class.

Look at a globe and find the equator. Now look for any special lines on the globe that match where your pencil trace lines end and begin. *What names* do we give these special lines on the globe? What are the latitudes of each of the three locations?



You are responsible for learning these three locations and their latitudes for the next test.

Having worked as a team, now you must **work as an individual**. Use the data your team collected to answer the questions on the Individual Observation Sheet. Each team member must submit an **Individual Observation Sheet**.

Name: ______________________________ Team: ____________

Investigation 2
Individual Observation Sheet

1.	What is special about the June and December pencil traces?	
2.	What important seasonal event occurs in both of these months?	
3.	What is special about the September and March pencil traces?	
4.	What important seasonal event occurs in both of these months?	
5.	Because of rotation and revolution, the subsolar point is always moving. However, the subsolar point falls on only part of Earth. Write a statement that describes the *only* region of Earth where the subsolar points can be found.	**Subsolar points can be found**
6.	Which month's pencil trace matches the upper limit of the Tropic of Cancer?	
7.	Which month's pencil trace matches the lower limit of the Tropic of Capricorn?	
8.	*Solstice* means "sun stop." Can you explain the term when describing what happens to the sun's path in June and December?	
9.	Using what you have learned from your observations, answer the question: ***Where are the tropics on Earth?*** **The tropics can be found**	

Bonus: What is the latitude of the Tropic of Cancer? _________
What is significant about its location? Explain your answer on the back of this sheet.

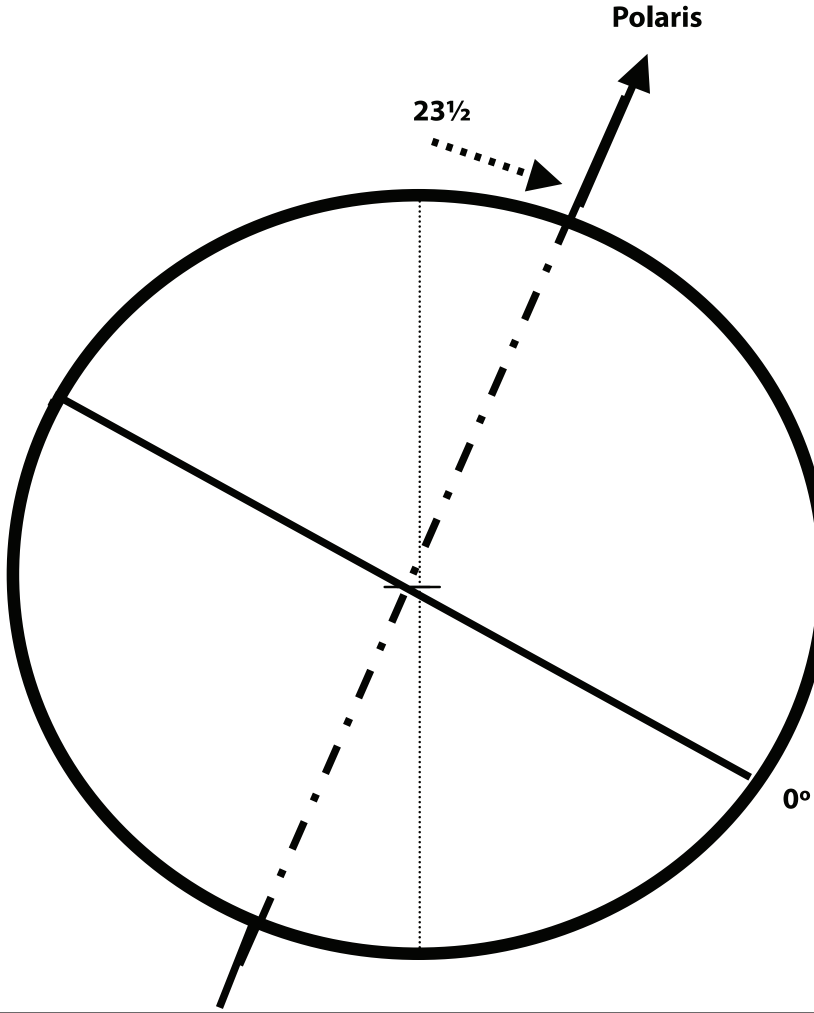
Name: ____ Team: _______________

Stop/Think/Draw/Write 3

Use words and/or drawings to describe what the solstices have to do with the Tropic of Capricorn and the Tropic of Cancer.
(Be sure your labels are spelled correctly)

Name: ______________________________ Team: ______________

Obliquity and Lines on the Globe



***Obliquity* is the big word for the tilt of Earth on its axis.**

If Earth were not tilted, its axis would look like the thin line in this drawing going straight up and down. But its obliquity (tilt) is 23½º from 90º. Follow the directions below. **Place *all* labels outside the circle.**

1. Label the axis.
2. Label the obliquity.
3. Label the equator.
4. Now draw two latitude lines: 23½º N and 23½º S.
5. Label the Tropic of Cancer and the Tropic of Capricorn.
6. Color the space between the tropics yellow.
7. Look again at the tracings on your Ping Pong ball Earth. Complete this sentence:

Subsolar points are found only between______________________________

____

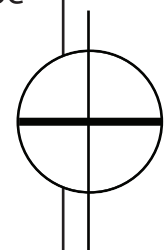
Investigation 3

What Happens to the Tropics Region When the Obliquity Changes?

You have probably heard of *the tropics* as a warm place that is somewhere south of where you live. In this investigation you will discover exactly where the tropics are and why they exist.

Prediction: If Earth's obliquity were decreased to 0º, would the tropics region be

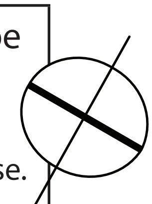
wider? narrower? stay the same?



Investigate using your Subsolar Point Gauge and your Ping Pong ball Earth. Take it out of its base. Hold it straight up and down. Move it around its orbit to the events in March, June, September, and December. There is no need to spin the ball, but use the Subsolar Point Gauge to make a mark on the ball at each place. What did you find?

Prediction: If Earth's obliquity were increased to 40º, would the tropics region be

wider? narrower? stay the same?



Investigate using your Subsolar Point Gauge and your Ping Pong ball Earth. Take it out of its base. Hold it straight up and down. Move it around its orbit to the events in March, June, September, and December. There is no need to spin the ball, but use the Subsolar Point Gauge to make a mark on the ball at each place. What did you find?

Conclusion: What Happens to the tropics region when the obliquity changes?

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 4

(Be sure your labels are spelled correctly)

Part I:

What is Earth's obliquity in degrees?____________________

What is the latitude of the Tropic of Cancer?____________________

What is the latitude of the Tropic of Capricorn?____________________

Part II:

Imagine that Earth's obliquity was *only 15º*. Using words and/or drawings, explain what would happen to the location of the Tropic of Cancer and the Tropic of Capricorn.

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 5

Use words and/or drawings to describe how the following words are all connected in some way. Your recent investigation tracing subsolar points will help you.
(Be sure your labels are spelled correctly)

Equinox

23½º S

Tropic of Cancer

Equator

0º

Solstice!

Tropic of Capricorn

23½º obliquity

23½º N

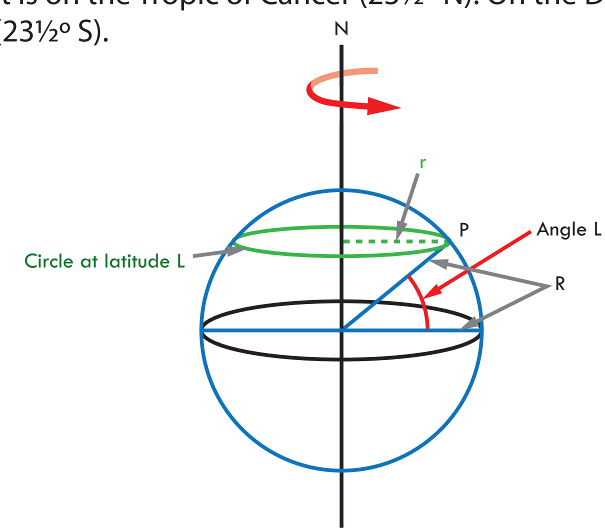
Square Two Review Notes

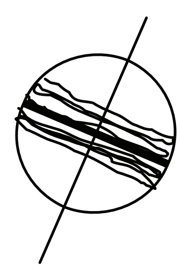
In Square Two, we began by reading the biography of **Eratosthenes**, a famous scientist and mathematician who lived more than 2,000 years ago. Using geometry, he figured out how big Earth measured at the equator—approximately 24,000 miles. He also designed the system for latitude that we still use today. He imagined himself inside a sphere and making angles with the equator as a base. The latitude was determined by extending the side of an angle until it met the side of the sphere. This latitude system measured 0º to 90º N in the Northern Hemisphere and 0º to 90º S in the Southern Hemisphere. We used a protractor to make latitude lines on a circle.

Next we began **Investigation 2, Tracing the Subsolar Points on Earth**. To do this investigation, we had to understand that the **subsolar point** is the place on Earth directly under the sun. The subsolar point is **constantly moving** across Earth's surface as Earth rotates. We used the pencil in the Subsolar Point Gauge to trace the path of the subsolar point on the Earth ball as it orbited around the Sun Disk. We discovered that starting in March, the tracings spiraled northward until June, when they stopped moving north. Then the tracings spiraled southward through the equator until December, when the tracings stopped moving south. In January and February, the tracings spiraled northward again to the equator in March. The tracings created a band we call "the tropics" that extended from the **Tropic of Cancer** through the **equator** to the **Tropic of Capricorn**. Our tracings on the model Earth proved that the subsolar points can only be found between the tropics. We noted that in both June and December we have a **solstice**, a perfect word that means "sun stop."

Next we revisited the word **obliquity**—and completed **Investigation 3, What Happens to the Tropics Region When the Obliquity Changes?** We discovered that Earth's obliquity of **23½º** causes the Tropics of Cancer and Capricorn to be at **23½º N** and **23½º S**. Just like the tracings on the model Earth, we realized the width of the band we call the tropics is affected by the degrees of obliquity. If Earth's obliquity were less, then the tropics band would be more narrow. If Earth's obliquity were greater, then the tropics band would be wider. If the obliquity measured 0º, then there would be no Tropic of Cancer or Tropic of Capricorn because the subsolar point would always be on the equator.

We also discovered that we knew exactly where the subsolar point was on four days of the year. On the March and September equinoxes, the subsolar point is on the equator 0º. On the June Solstice, it is on the Tropic of Cancer (23½º N). On the December solstice, it is on the Tropic of Capricorn (23½º S).





Name: ______________________________ Team: ______________

Quick Team Quiz Two

1.	What is Earth's axis?	
2.	What is Earth's **equator**?	A. the ecliptic B. the imaginary line that circles Earth at its widest point C. the imaginary line that passes through the poles D. an imaginary line marking the northern edge of the tropics
3.	What astronomical event occurs every March?	
4.	What is a **subsolar point**?	
5.	At what latitude is the subsolar point on the September equinox?	
6.	What is **obliquity**?.	
7.	Starting in February, as Earth revolves through March, April, and May, the subsolar point moves northward moves southward stays the same	
8.	Starting at the June solstice, as Earth revolves through July and August, the subsolar point moves northward moves southward stays the same	
9.	The subsolar point crosses the equator	A. four times a year B. twice a year C. once a year D. twelve times a year
10.	What is the latitude of the Tropic of Capricorn?	
11.	What is the latitude of the Tropic of Cancer?	
12.	What is the obliquity of Earth measured in degrees?	
13.	What name do we give to the event when the subsolar point stops moving northward or southward?	

Name: ______________________________ Team: ______________

Square Two Test

1.	The ***axis*** of the Earth is	A. an imaginary line tracing the middle of Earth at its widest point. B. an imaginary line passing through Earth from pole to pole. C. the path of the sun as it passes overhead from east to west. D. the plane described by Earth's orbit around the sun.
2.	How much is Earth's axis tilted, measured in degrees?	A. 90º B. 0º C. 23½º D. 360º
3.	What is **obliquity**?	A. the speed of Earth in its orbit B. the part of Earth that is in shadow C. the tilt of Earth's axis D. the plane of Earth in its orbit
4.	In which two months do the equinoxes fall?	and
5.	In which two months do the solstices fall?	and
6.	Where is the Tropic of Capricorn found?	A. 23½º N B. 0º C. 23½º S D. the equator
7.	What is the **subsolar point**?	A. the place where the sun crosses the ecliptic B. the place on the horizon where the sun shines at sunrise C. the place on the horizon where the sun shines at sunset D. the place on Earth's surface that is directly under the sun
8.	On the June solstice, at what latitude is the subsolar point?	
9.	On the March equinox, at what latitude is the subsolar point?	
10.	What does the word ***solstice*** mean when you break it into parts?	
11.	On the back of this test, use drawings and words to explain what the word *solstice* has to do with the Tropic of Capricorn and the Tropic of Cancer.	

Investigation 4
Finding Daylight Hours at _____º N

You have probably heard of *the tropics* as a warm place that is somewhere south of where you live. In this investigation you will discover exactly where the tropics are and why they exist.

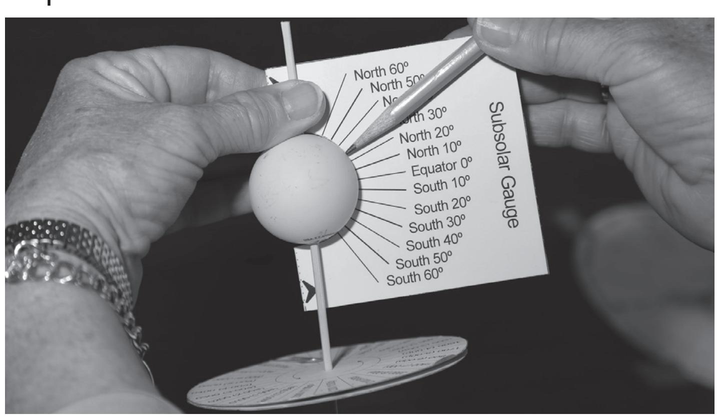
I. Prepare your Seasons Observatory.

1. Turn the Sun Disk toward north and tape it to the center of the table.
2. Bend a paper clip into a Time Disk pointer.

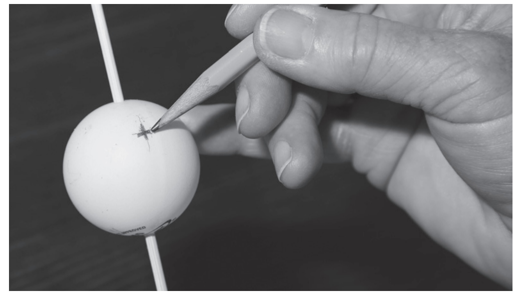
3. Using the Sunbeam String as a guide, position the Earth Holder for the middle of March. Be sure the Sunbeam String is directly under Ping Pong ball Earth and the holder axis is pointing north. Then tape the holder to the tabletop.
4. The flashlight beam represents a ray of sunlight coming from the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

II. Use the Subsolar Point Gauge to mark a specific latitude.

1. Take Ping Pong ball Earth from its holder and hold the gauge against it so that the arrows near the fold line up on the axis

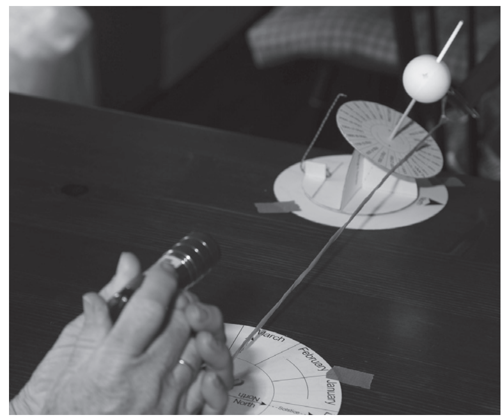


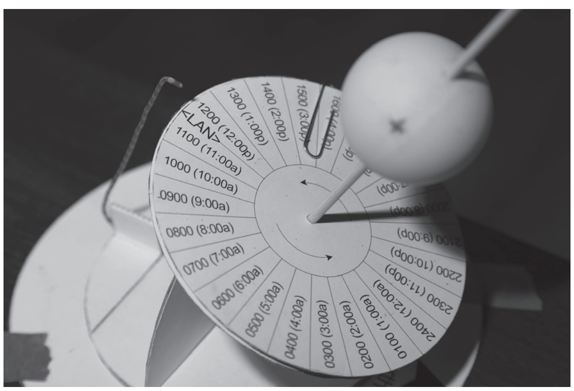
2. Use the latitude markers on the gauge to locate your assigned latitude on Ping Pong ball Earth.
3. Using the pencil, make a + that is just big enough to be seen easily.
4. Replace Ping Pong ball Earth in its holder.



III. Set the LAN.

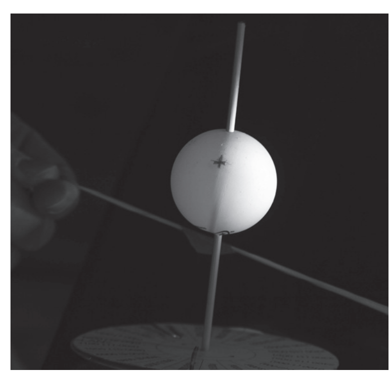
1. Remove the paper clip that held the Time Disk and Earth Base together so the Time Disk moves freely.
2. Turn the axis so that your marked Earth position + is facing directly toward the sun along the Sunbeam String. Your + is now at Local Apparent Noon (LAN).
3. Next, turn the Time Disk so that the Time Pointer is pointing at the LAN marking on the Time Disk.
4. Re-clip the Base and Time Disks with the paper clip. Time Disk and Earth now will turn together.





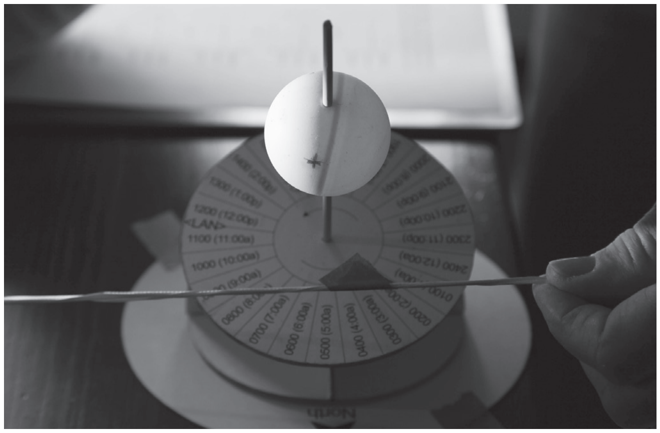
IV. Measure sunrise.

1. Hold the flashlight over the Sun Disk with its beam aimed at the same height as Ping Pong ball Earth.
2. Bring your + into nighttime by turning the Time Disk counterclockwise so that the + is turned away from the flashlight.
3. Slowly rotate the Time Disk counterclockwise. Watch the sunrise Terminator carefully, and stop exactly when it lies right on top of your +.
4. Check the Time Dial and the Time Pointer to find the time of sunrise. Announce the time.
5. Write the time on the **Day and Night Calculations Page** in the Sunrise box using military time (for example, 6:15 a.m. is 0615) on the Sunrise line of the page.



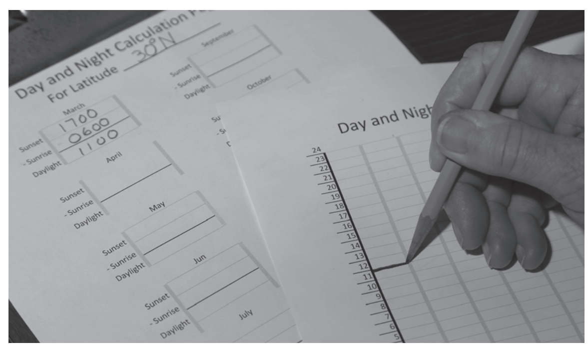
V. Measure sunset.

1. Hold the flashlight over the Sun Disk with its beam aimed at the same height as Ping Pong ball Earth.
2. Cause the day to pass by rotating Ping Pong ball Earth slowly counterclockwise using the Time Dial. Your + will move toward the Terminator at the end of day.



3. When the sunset Terminator lies exactly on top of your +, STOP!
4. Check the Time Dial and Time Pointer to find the time of sunset. Announce the time.
5. Write the time using military time on the Sunset box of the **Day and Night Calculations Page**. Remember: 6:30 PM is 1830.

VI. Calculate daylight hours.



1. Subtract sunrise time from sunset time and announce the length of daylight.
2. The whole team marks the daylight hours on its **Daylight Hours Record Page** with just a line (refer to picture).

VII. Repeat.

Move the Earth Holder and repeat for June, September, and December. If you have time, do all the months.

Team: ____

Day and Night Calculations Page

	March
sunset	
sunrise	
daylight	

	April
sunset	
sunrise	
daylight	

	May
sunset	
sunrise	
daylight	

	June
sunset	
sunrise	
daylight	

	July
sunset	
sunrise	
daylight	

	August
sunset	
sunrise	
daylight	

	September
sunset	
sunrise	
daylight	

	October
sunset	
sunrise	
daylight	

	November
sunset	
sunrise	
daylight	

	December
sunset	
sunrise	
daylight	

Name: ______________________ Team: ____________

Daylight Hours Record Page

24												
23												
22												
21												
20												
19												
18												
17												
16												
15												
14												
13												
12												
11												
10												
9												
8												
7												
6												
5												
4												
3												
2												
1												
0												
	March	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**

Directions: Plot each day length in the column for its month. Estimate portions of hours; for example, 6 hrs 30 min = ½ block.

7	
6	▬

Name: ______________________________ Team: ________________

Graphing 2 Years of Daylight Hours for Latitude(s)

Graph data for this year, and then graph the same data for next year.

	this year												next year										
Hours daylight	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	December	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	December
24																						
23																						
22																						
21																						
20																						
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8																						
7																						
6																						
5																						
4																						
3																						
2																						
1																						

Name: ______________________ Team: ______________

Stop/Think/Draw/Write 6

At the equator, daylight is always 12 hours for spring, summer, fall, and winter. But think about the latitudes you have investigated, and predict what the daylight graph would look like for these two locations.

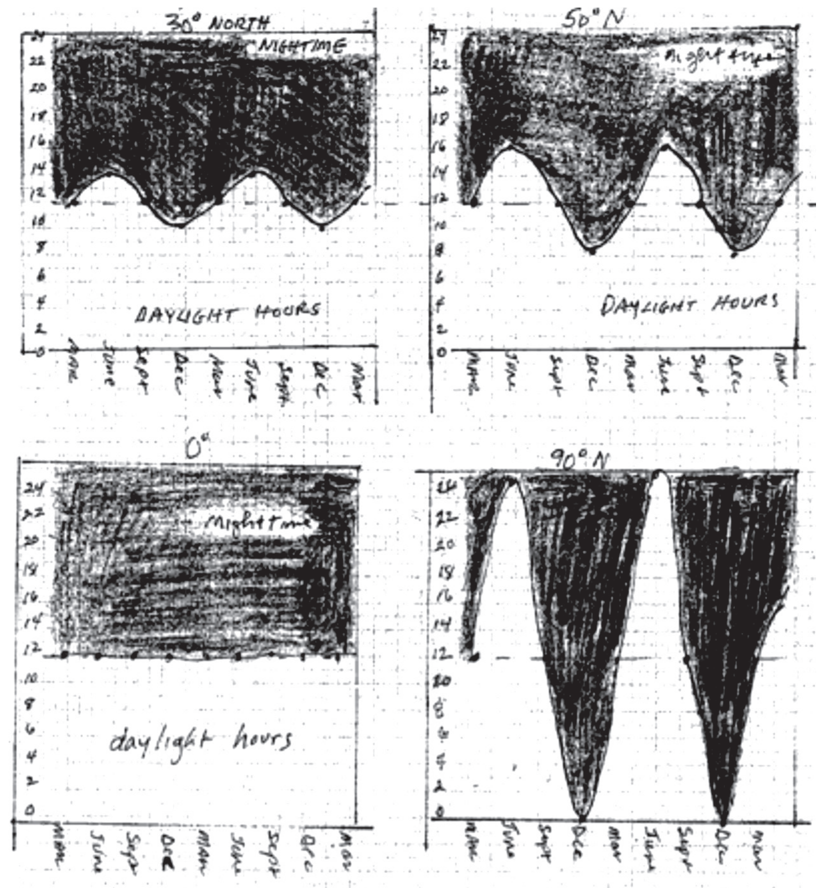
DAYLIGHT HOURS AT 10º N LATITUDE				
24				
22				
20				
18				
16				
14				
12				
10				
8				
6				
4				
2				
0				
Hours	**March**	**June**	**September**	**December**

DAYLIGHT HOURS AT 60º N LATITUDE				
24				
22				
20				
18				
16				
14				
12				
10				
8				
6				
4				
2				
0				
Hours	**March**	**June**	**September**	**December**

How does the length of daylight change as you move farther away from the equator?

Name: ______________________________ Team: ______________

Understanding Daylight Hours



1. Find and label Ws for WINTERS on the 30° N chart.
2. Find and label SUM for SUMMER on the 50° chart.
3. What is so special about the 0° chart?
4. What is so special about the 90° N chart?
5. Mark Ws for WINTER on the 0° chart.
6. Put an X on the equinoxes on the 90° N chart.
7. Put an X on the equinoxes on the 0° chart.
8. As you move *closer* to the equator, does the range (from shortest to longest hours of daylight) grow smaller? or larger?
9. As you move *farther* from the equator, does the range (from shortest to longest hours of daylight) grow smaller? larger?
10. How many hours of daylight in March at 30° N? ________ at 50° N?_________ at 0°?_______ and at 90° N?________

Bonus: If time permits, color the daylight hours yellow.

Name: ______________________________ Team: ______________

Investigation 5
Daylight Hours in Different Hemispheres

Scientists look for patterns. Below are actual data sheets for daylight hours of cities *near* different latitudes around the world. You will have an opportunity to graph different combinations of these daylight hours and see what pattern emerges.

Northern Hemisphere

Latitudes	MARCH 21	JUNE 21	SEPTEMBER 21	DECEMBER 21
20º S	12h	13h 15m	12h 15m	11h
30º S	12h	14h	12h 15m	10h 15m
40º S	12h 15m	15h	12h 15m	9h 15m
50º S	12h 15m	16h 30m	12h 15m	8h

Southern Hemisphere

Latitudes	MARCH 21	JUNE 21	SEPTEMBER 21	DECEMBER 21
20º S	12h	11h	12h	13h
30º S	12h	10h	12h	14h 15m
40º S	12h	9h 15m	12h	15h 15m
50º S	12h	7h 45m	12h 5m	16h 45m

Note: The data came from cities NEAR the latitudes, because data was not available for locations directly at each latitude. All time was rounded up or down to nearest 15 minutes.

Name: ____ Team: _______________

Graphing Daylight Hours in Different Hemispheres

You are graphing Latitude _____

Directions:

1. Mark the data points on the graph for the daylight hours at your assigned latitude in the Northern Hemisphere. Connect the points with a solid line.
2. Above each point, write the appropriate season (spring, summer, fall, or winter) in the Northern Hemisphere.
3. Now graph the data for daylight hours in the Southern Hemisphere at your assigned latitude. Connect the points with a dotted line: • • • • • •
4. Below each point, write the appropriate season (spring, summer, fall, or winter) in the Southern Hemisphere.

Hours daylight	March	April	May	June	July	August	September	October	November	December
24										
23										
22										
21										
20										
19										
18										
17										
16										
15										
14										
13										
12										
11										
10										
9										
8										
7										
6										
5										
4										
3										
2										
1										
0										

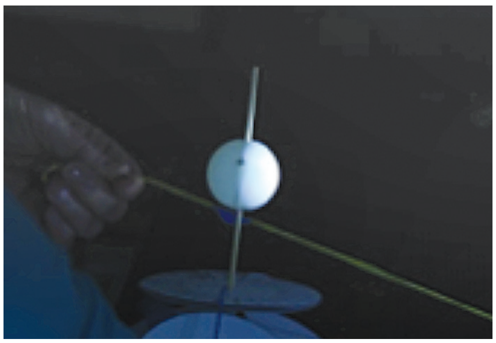
Name: ______________________________ Team: ____________

Stop/Think/Draw/Write 7

Use words and drawings to explain why seasons occur at opposite times in the Northern and Southern Hemispheres.
(Be sure your labels are spelled correctly)

Square Three Review Notes

In Square Three, we modified our Seasons Observatory by adding a Time Disk to the Earth Holder. This Time Disk showed times written in military time from 0000 to 2400 hours. At noon (1200) were the letters **LAN**, an abbreviation for **L**ocal **A**pparent **N**oon. With this new tool we were able to note sunrise and sunset for several locations on Earth as it traveled in its orbit around the sun.



We began **Investigation 4, Finding Daylight Hours at ____° N**. First we separated into jigsaw teams. Each member of our team joined with members of other teams to investigate a particular northern latitude (20º N, 30º N, 40º N and 50º N). We all followed the same procedure and used the Subsolar Point Gauge to mark a **+** on our Earth ball at our assigned latitude. Next, we rotated the ball counterclockwise, watching until our **+** came to the **Terminator** (line between light and darkness). We read the Time Disk to get the time of **sunrise**. We continued the rotation until our + crossed the Terminator again and noted the time of **sunset**. We graphed the hours of daylight for the equinoxes and solstices. Then we each returned to our own team with our graphs and information.

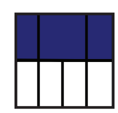
When we compared our graphs, we discovered that latitudes close to the equator all had approximately 12 hours of daylight. At solstice, however, the number of hours of daylight varied greatly as the latitude location moved farther away from the equator. In fact, the farther from the equator, the greater range of daylight hours—much longer periods of daylight hours to much shorter periods of daylight hours. When we colored the graphs as a team, we were amazed that latitude did not affect daylight hours at the equinox. All over the world there was always only 12 hours of daylight on the March equinox and September equinox.

From the graphs we also discovered that if the summer daylight hours were 2 hours longer than 12 hours (14 hours long), then the winter daylight hours would be 2 hours shorter than 12 hours (10 hours). The key is that whatever the range of hours, the total hours must add up to 24. In this example 14 + 10.

In **Investigation 5, Graphing Daylight Hours in Different Hemispheres**, we used actual data from the Time and Date website to graph daylight hours of locations at particular northern and southern latitudes. We discovered that the daylight hours in southern latitudes were opposite to when daylight hours occurred in northern latitudes. For example, on a particular day in the Northern Hemisphere, there were 14 hours of daylight and 10 nightime hours. At the same time in the Southern Hemisphere, there were 10 hours of daylight and 14 nightime hours. Because periods of daylight are longest in summer and shortest in winter, we determined that the seasons occurred at opposite times in the Northern and Southern Hemispheres. For example, in March, areas above the equator were going into spring. In the same month, below the equator areas were going into fall. The shortest periods of daylight hours above the equator were in December (winter in the United States). The shortest periods of daylight hours below the equator were in June (winter in Australia)

Name: ______________________________ Team: ______________

Quick Team Quiz Three

1.	Starting in March in the Northern Hemisphere, list the seasons in order. 1. 2. 3. 4.
2.	What is **obliquity**?
3.	What is a **subsolar point**?
4.	How many times a year does the **subsolar point** cross the equator?
5.	What astronomical event occurs every September
6.	At what latitude is the **subsolar point** on the June solstice?
7.	Starting at the March equinox, as Earth revolves through April and May, the subsolar point moves northward. moves southward. stays the same.
8.	At what latitude would you expect a daylight graph that looks like this? 
9.	If a location's longest day is 14 hours long, what is the length of its shortest day?
10.	If a location is at 45° N latitude, how long is its day length on the September equinox?
11.	What happens to the range of daylight hours as you move farther from the equator?
12.	If you broke the word *equinox* into two parts, what does it mean?
13.	Equinoxes and solstices generally occur on which dates of a month?
14.	What season is it in the Southern Hemisphere in December?
15.	What season is it in the Southern Hemisphere in September?

Name: ______________________________ Team: ______________

Square Three Test

1.	How much is Earth's obliquity, measured in degrees?	A. 90º B. 0º	C. 23½º D. 360º
2.	What is the **subsolar point**?	A. the place where the sun crosses the ecliptic B. the place on Earth's surface that is directly under the sun C. the place on the horizon where the sun shines at sunset D. the place on the horizon where the sun shines at sunrise	
3.	Where is the Tropic of Cancer found?	A. 23½º N B. 0º	C. 23½º S D. 50º N
4.	On the September equinox, at what latitude is the subsolar point?	A. 23½º N B. 0º	C. 23½º S D. 50º S
5.	Which latitude would have the greatest range of daylight hours?	A. 20º N B. 30º S	C. 40º S D. 50º N
6.	Which latitude would have the smallest range of daylight hours?	A. 20º N B. 30º S	C.40º S D. 50º N
7.	At which latitude would you expect the longest period of daylight hours?	A. 20º N B. 30º S	C.40º S D. 50º N
8.	If a location is at 60º N latitude, how long is its day length on the September equinox?	A. 12 hours B. 14 hours	C. 16 hours D. 20 hours
9.	Which latitude has 12 hours of daylight every day, all year long?	A. 0º B.12º N	C. 23½º S D. 90º S
10.	If it is winter in the Northern Hemisphere, what season is it in the Southern Hemisphere?	A. spring B. summer	C. winter D. fall
11.	Which month marks the beginning of spring at 30º S?	A. March B. June	C. September D. December
12.	Equinoxes and solstices generally occur on which dates in the month?	A. 1st–5th B. 13th–14th	C .20th–23rd D. 29th–30th

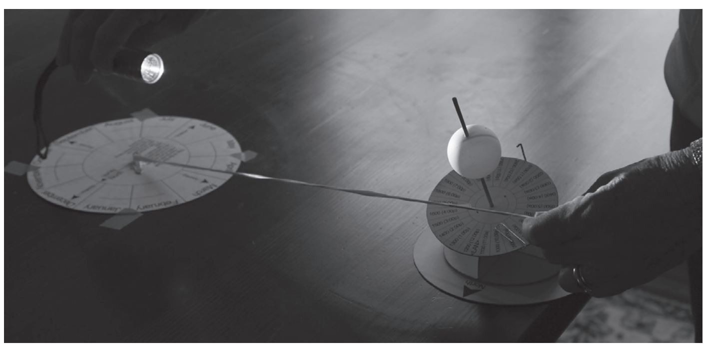
Investigation 6
Finding the Arctic and Antarctic Circles

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.

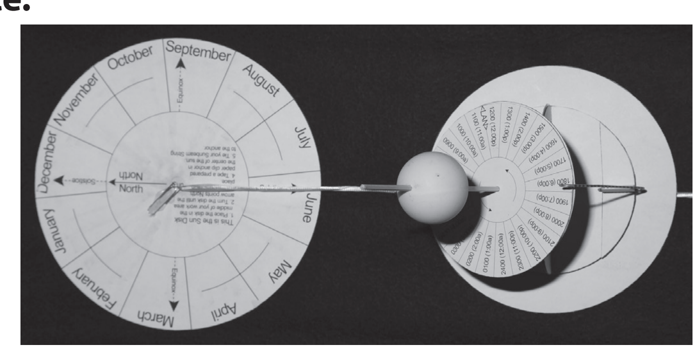
1. Shine the flashlight on Ping Pong ball Earth. Look closely at the Terminator (the shadow line) on Ping Pong ball Earth when it is in the March position.

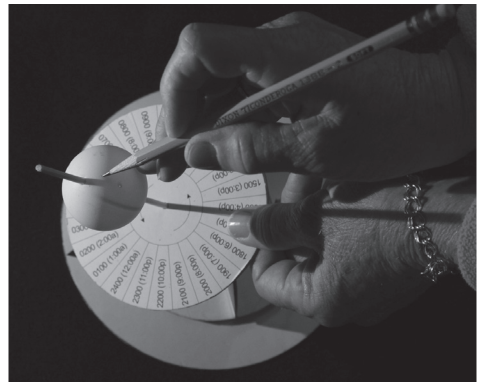


2. One-half of Earth is always in sunlight. If you have set up the Seasons Observatory correctly, at equinox the Terminator shadow will line up with the axis and pass through the North and South Poles.
3. Move the Earth Holder to the September position. Repeat steps 1 and 2. Do you have the same result?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

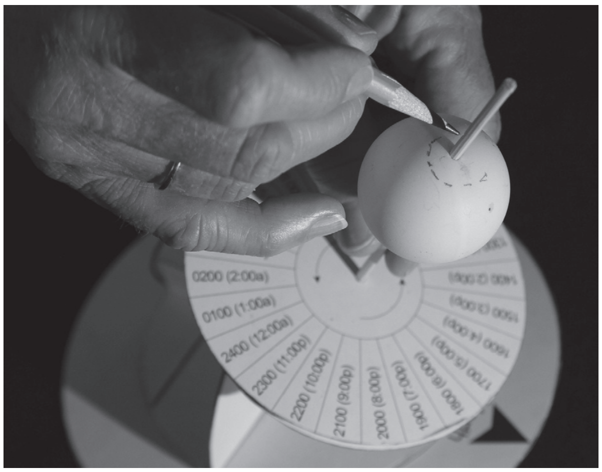
III. Find the Arctic Circle at June solstice.

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.



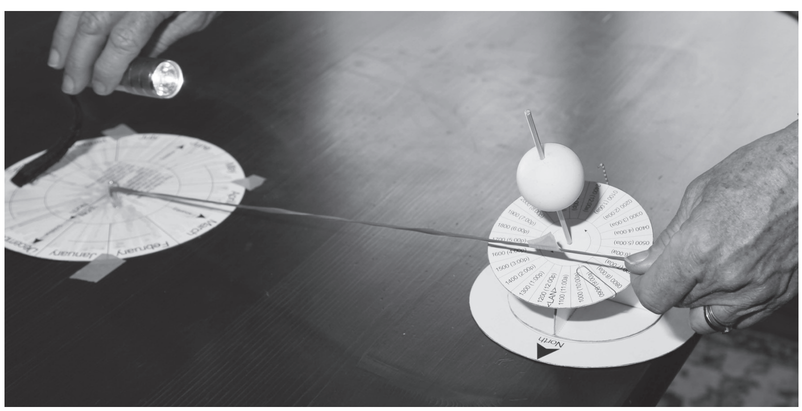


4. In tiny increments, rotate Ping Pong ball Earth and make a mark at the top edge of the Terminator.
5. When you have turned a complete rotation, you will see that you have drawn a dotted line circle marking the terminator shadow around the North Pole (skewer).
6. On the June solstice this circle around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

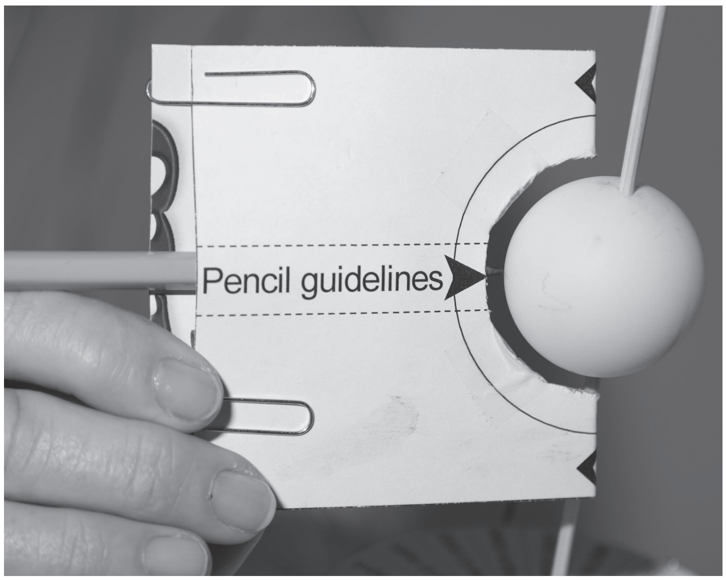


5. Remember that the obliquity of Earth is 23½º. Can you compute the latitude of the Arctic Circle?

North Pole 90º N – 23½º = _____º N

V. Find the Antarctic Circle.

1. Although the Seasons Observatory can model the Antarctic Circle, it is difficult to make observations directly on the under side of Ping Pong ball Earth.
2. Remember that the Northern and Southern Hemispheres have opposite seasons. Because the Arctic Circle was in total sunlight at the June solstice, then at the June solstice, the Antarctic Circle was in total darkness
3. At the December solstice when the Arctic Circle was in total darkness, the Antarctic Circle was in total sunlight.



4. Remember the obliquity of Earth is 23½º. Can you compute the latitude of the Antarctic Circle?

South Pole 90º S – 23½º =______° S

Name: ____ Team: _______________

Understanding the Arctic and Antarctic Circles

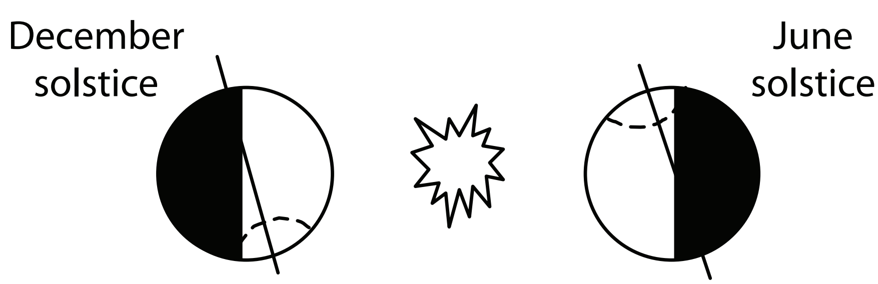
Using what you have learned from the models, answer the following questions about the Arctic Circle and the Antarctic Circle.

1. What is the Terminator? _____________________________________
2. Where does the Terminator pass through at an equinox? ______________
3. At an equinox, how much of Earth is in sunlight? ________
4. At the June solstice, the Arctic Circle is in ____________. (darkness or sunlight)
5. At the June solstice, the Antarctic Circle is in ____________. (darkness or sunlight)
6. At the December solstice, the Arctic Circle is in ____________. (darkness or sunlight)
7. At the December solstice the Antarctic Circle is in ____________. (darkness or sunlight)
8. The latitude of the Arctic Circle is _______.
9. The latitude of the Antarctic Circle is _______.

A day when the sun does not set is called a **polar day**. A day when the sun does not rise is called a **polar night**. The Arctic and Antarctic Circles mark the latitudes on Earth where there is one polar day and one polar night per year.

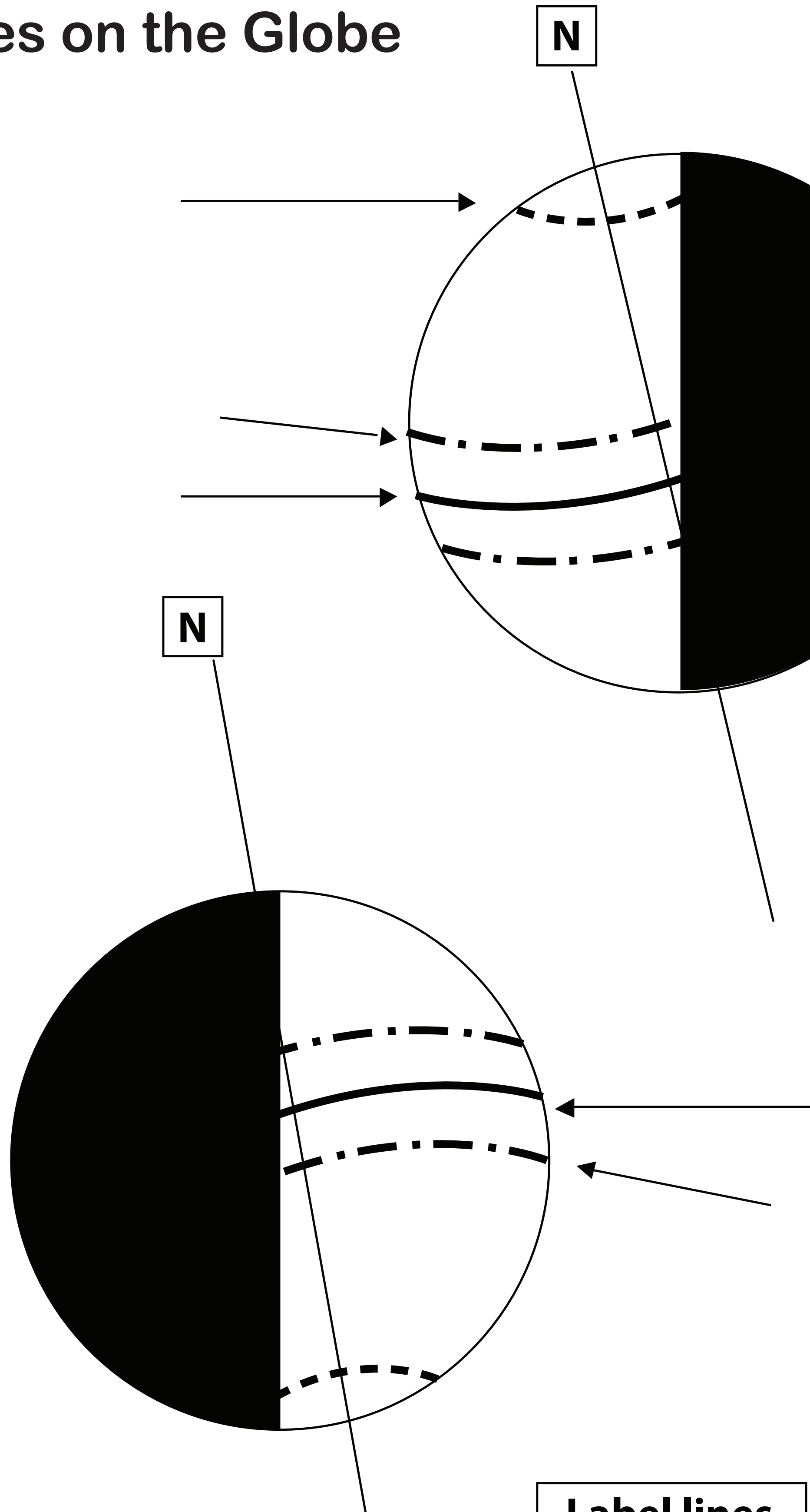
1. When does the polar day occur at the Arctic Circle?__________________
2. When does the polar night occur at the Arctic Circle?________________
3. When does the polar day occur at the Antarctic Circle?________________
4. When does the polar night occur at the Antarctic Circle?________________
5. Where in the world might you find places with a nickname of "Land of the Midnight Sun"?

____



Name: ________________________________ Date: ________________

Lines on the Globe



Label lines.

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 8

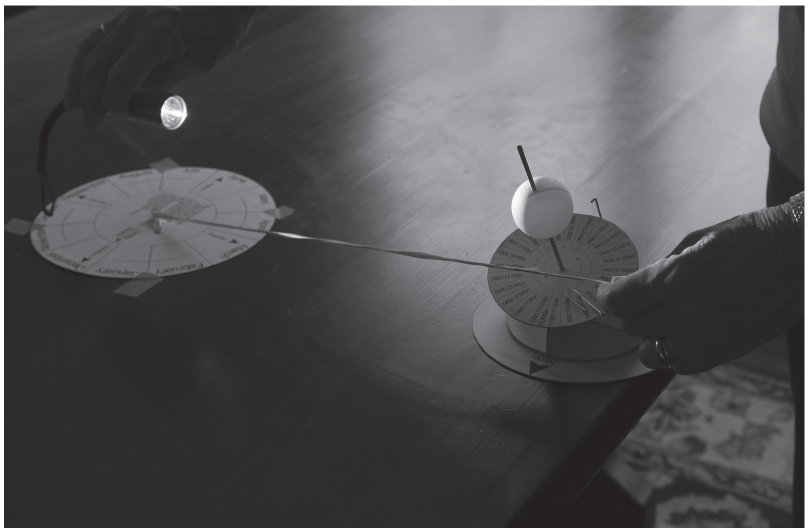
In drawings and words, explain why the Arctic and Antarctic Circles are located at latitude 66½º N and 66½º S.

(Be sure your labels are spelled correctly)

Investigation 7
Sunrise and Sunset at the Poles

I. Prepare your Seasons Observatory.

1. Set up your Solar Disk and Earth Holder correctly at the March equinox.
2. Be sure the Sunbeam String is directly under Ping Pong ball Earth and the holder axis is pointing north.



3. Hold the flashlight so that it is at the same height as Ping Pong ball Earth, and shine it down the Sunbeam String.

II. Determine the polar days between equinoxes.

1. Shine the flashlight on Ping Pong ball Earth. Look closely at the Terminator (the shadow line) and the North Pole on Ping Pong ball Earth when it is in the March equinox position.
2. If you have set up the Seasons Observatory correctly, the Terminator should pass through the axis so that from the North Pole to the South Pole, exactly half Earth is in sunlight.
3. Follow the directions on the **Polar Days and Polar Nights Recording Sheet**. Stop when you have completed all of your observations. Your teacher will be discussing your results before you do the analysis part of this investigation.

III. Analyze data.

Because we are using cardboard models and handheld flashlights, some of the data you collected may not agree with that of other teams. Your teacher will show you how to use the data that all teams have collected to help you make accurate conclusions.

Name: ____ Team: ______________

Polar Days and Polar Nights Recording Sheet

- Shine the flashlight on Ping Pong ball Earth. Look closely at **the Terminator** (the shadow line) and the North Pole on Ping Pong ball Earth when it is in the March equinox position. Record your observation below by putting an **X** in one of the columns.
- Move the Earth Holder to April and then on to other months in order around Earth's orbit, recording your observations below.

Month	North Pole Is in Sunlight	North Pole Is in Darkness
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
January		
February		

STOP and share your results with other teams.

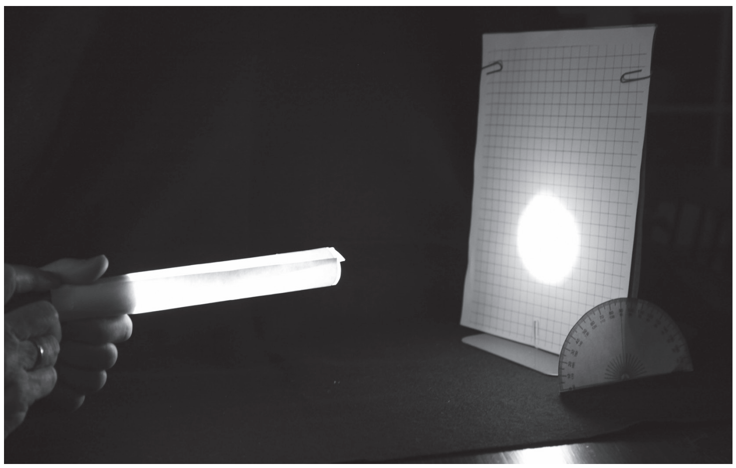
Data Analysis (Do this *after* sharing with other teams.)

1. In what month did the North Pole fall into darkness? ____________
2. In what month did the North Pole come back into sunlight? ____________
3. What astronomical events correspond to the answers for questions 1 and 2? __________________________ and _____________________
4. Polar days are days when the sun does not set. How many months of polar days are there at the North Pole? _______ months
5. Polar nights are days when the sun does not rise. How many months of polar nights are there at the North Pole? _______ months
6. How many times a year does the sun rise at the North Pole? ______
7. How many times a year does the sun set at the North Pole? _______

Investigation 8
Why Isn’t It Hot at the Poles?

For data collection:

1. Attach your graph paper to the poster board with tape or paper clips.
2. Fold the poster board 1½ inches on the bottom and attach it to the tabletop with tape.
3. Ask a partner to hold the protractor at the side edge of the poster board, and make sure that the poster board is at 90º.



4. Make a paper roll around the flashlight end to better focus the beam. Hold the flashlight steady about 6 inches from the graph paper and ask a team member to trace its beam.
5. Move the poster board to the 75º mark on the protractor, and repeat step 4.
6. Move the poster board two more times to the 55º and 35º marks on the protractor, and repeat step 4.

For data counting:

1. First, place an X in the complete squares that were covered by the first beam at 90º. Count only complete squares.
2. Next, place As in the new complete squares for the second beam (75º).
3. Place Bs in the new complete squares for the third beam 55º, and, finally, place Cs in the new complete squares in the fourth beam for 35º.

Number	
X	
A	
B	
C	

X = ______

A + B = total Bs ________

X + A = total As ________

B + C = total Cs ________

200				
190				
180				
170				
160				
150				
140				
130				
120				
110				
100				
90				
80				
70				
60				
50				
40				
30				

Question: What happens to the number of squares as the angle of incidence becomes shallower?

Conclusion: What happens to the strength of the light beam of light as the angle of incidence becomes shallower?

Name: ____________________ Team: ____________

Stop/Think/Draw/Write 9

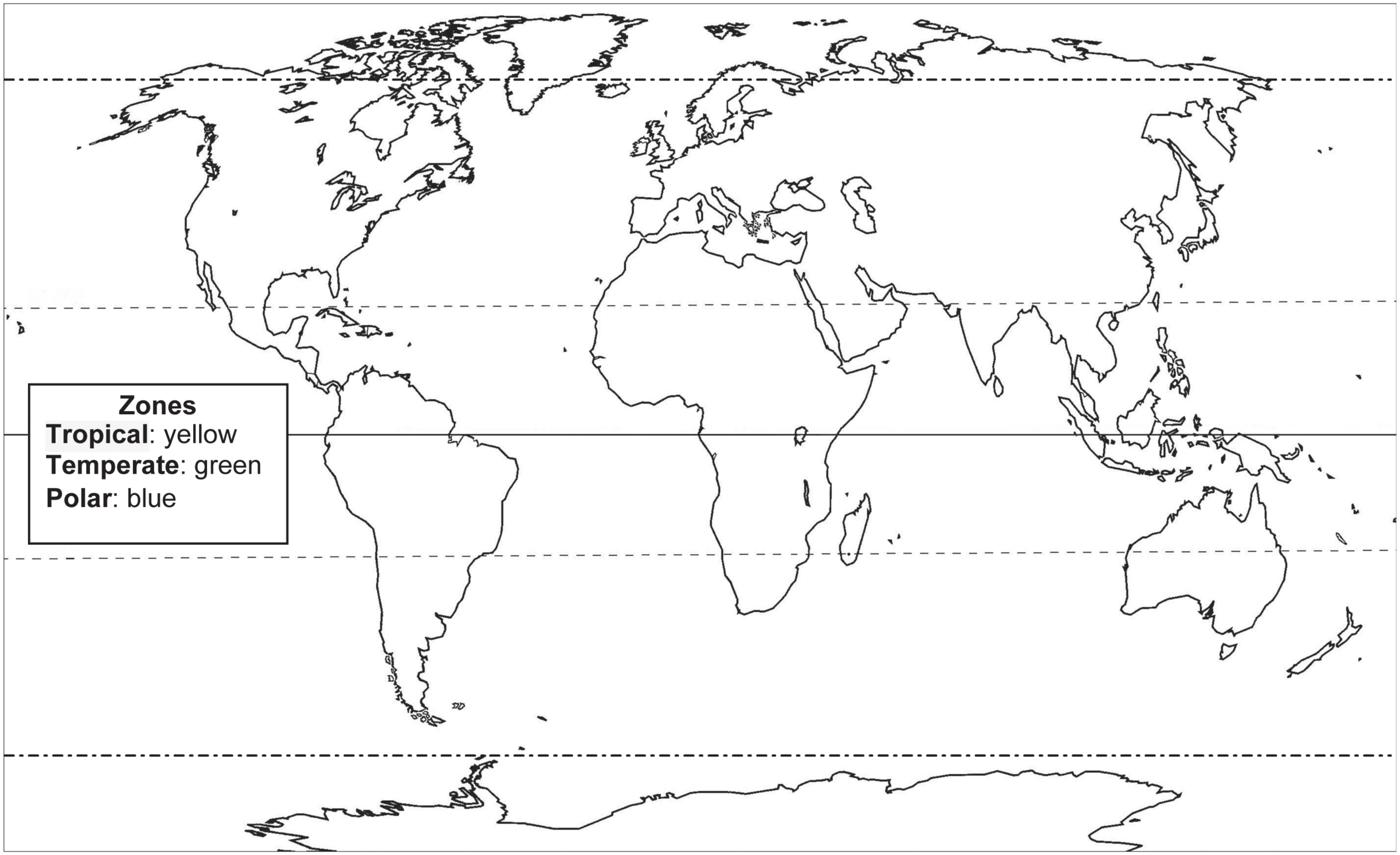
Use words and drawings to explain why it's never hot at the poles, even though there are parts of the year when there the poles experience more than 18 hours of daylight.

(Be sure your labels are spelled correctly)

Name: ______________________________ Team: ______________

Seasons Zones of Earth Map

Color the landmasses using the Zones key. Then place the following labels where indicated:
Place on the left: 23½º N, 23½º S, 0º, 66½º N, 66½º S
Place on the lines: equator, Tropic of Cancer, Tropic of Capricorn, Arctic Circle



Name: ______________________________ Team: ______________

What Do Seasons Look Like Around the World?

As part of a team or whole class discussion, answer the following questions

The Tropical Zones:

a. What does summer look like in the Tropics?
- Temperature?
- Daylight hours?

b. What does winter look like in the Tropics?
- Temperature?
- Daylight hours?

c. Do the tropical zones have "true" changes in season?

The Polar Zones:

a. What does summer look like in the Polar Zones?
- Temperature?
- Daylight hours?

b. What does winter look like in the Polar Zones?
- Temperature?
- Daylight hours?

c. Do the Polar Zones have "true" changes in season?

The Temperate Zones:

a. What does summer look like in the Temperate Zones?
- Temperature?
- Daylight hours?

b. What does winter look like in the Temperate Zones?
- Temperature?
- Daylight hours?

c. Do the Temperate Zones have "true" changes in season?

Square Four Review Notes

In Square Four, we started putting together the final understanding of what causes seasons. We began with **Investigation 6, Finding the Arctic and Antarctic Circles**. Using the **Seasons Observatory** again, we put the Earth ball at its June Solstice location. Next we rotated the ball counterclockwise, shining the flashlight and watching the Terminator (the line between light and darkness) and the North Pole. Using the Terminator as a guide, we marked the edge of darkness for one full rotation. On the June solstice, it defined a circle we guessed was the **Arctic Circle**.

Going back to Earth's obliquity, we subtracted 23½º from 90º and discovered the answer was 66½º. In fact, the Arctic Circle and its opposite, the Antarctic Circle in the Southern Hemisphere, are at latitudes 66½º N and 66½º S. At the June solstice, it was obvious that at the Arctic Circle there were 24 hours of daylight (a polar day) because there was sunshine all day long. We moved the Earth ball to the December solstice location and observed. This time the Arctic Circle was in total darkness through a rotation, meaning there were 0 hours of daylight and 24 hours of darkness (a polar night).

Next we began **Investigation 7, Sunrise and Sunset at the Poles**. To our surprise, we discovered that at the poles the sun rises only once a year and sets only once a year. Finally, we completed **Investigation 8, Why Isn't It Hot at the Poles?** We created an experiment using graph paper, a file folder, and a protractor. We shined the flashlight directly onto the graph paper, replicating a subsolar point with light striking Earth directly at a 90º angle. We took three more measurements having an increasingly shallow angle of incidence.This replicated sunlight shining at shallow angles onto Earth at latitudes above the tropics. As we lowered the sun angle, we saw that the light covered more area on the graph paper. However, as the area grew bigger, the intensity of the light grew dimmer. We learned we were investigating the **angle of incidence**. This explained why it isn't ever hot at the poles even though the sun is up all day. Because of shallow angles of incidence, the sunlight at the poles is just too weak.

Finally we had all the pieces to explain seasons. The key is ***obliquity***, the tilt of Earth on its axis. It causes the very hot **tropics**, or **Tropical Zone**, just above and below the equator where the subsolar point constantly travels nearby and the daylight hours are close to 12 hours. The seasons in the tropics are consistently hot and mostly only calendar events. That is, if someone were to wake up on any given day, he/she would have no idea what season it was unless they looked at a calendar. There are no changes in temperature or daylight hours. Obliquity also causes the polar regions to be cold. There are times of the year when there is little or no daylight. And even when there is daylight for 24 hours, the **angle of incidence** is low and the sunlight very dim. The biggest change in seasons in the **Polar Zones** are the change in the number of daylight hours each day.

But there is the wide third area of Earth called the **Temperate Zones** between 23½º N and the Arctic Circle and 23½º S and the Antarctic Circle. In this area there are a variety of lengths of periods of daylight hours and places where the angle of Incidence is not too shallow. Therefore, the sunlight is not too dim. With longer periods of daylight hours and a higher angle of incidence, the sun actually warms the Temperate Zones during the summer. Shorter days and longer nights at the same latitudes produce cold winters. People who live in the Temperate Zones can actually experience and enjoy changes in seasons from spring to summer to fall and, finally, to winter throughout the year.

Name: ______________________________ Team: ____________

Quick Team Quiz Four

1.	What is the day having the longest daylight hours at the Arctic Circle?
2.	What is the day having the shortest daylight hours at the Antarctic Circle?
3.	On what dates in the month do most equinoxes and solstices occur?
4.	At what latitude is the subsolar point on the September equinox?
5.	If you split the word *equinox* into two parts, what is the meaning of each part?
6.	In which two months does the whole world have exactly 12 hours of daylight
7.	What special latitude line do you find at 66½º N?
8.	If a location's shortest period of daylight hours is 10 hours, what is the length of its longest period of daylight hours?
9.	What is the **Terminator**?
10.	What's a **polar day**?
11.	What do we call the climate zone between the Tropic of Capricorn and the Antarctic Circle?
12.	What do we call the climate zones that lie inside the Arctic and the Antarctic Circles?
13.	How often does the sun rise at the North Pole?
14.	What is the **angle of incidence**? A. the angle between dark and light B. the angle made by a sunbeam and the surface of Earth C. the angle of obliquity D. the angle between the North Pole and the Arctic Circle
15.	If an increase in the length of the period of daylight hours is one of the reasons for warmer temperatures, why isn't it hot at the North Pole when the sun is up all day?
16.	What are the latitudes of the three climate zones? Polar Zones Tropical Zone Temperate Zones

Name: ______________________________ Team: ______________

Square Four Test

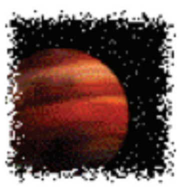
1.	What does the word ***Terminator*** mean?	A. the place where the sun crosses the ecliptic B. the place on Earth's surface that is directly under the sun C. the place on Earth where daylight ends and night begins D. the place at the poles where the sun never shines	
2.	Where is the Antarctic Circle found?	A. 23½° N B. 0°	C. 66½° S D. 90° N
3.	On the June solstice, at what latitude is the subsolar point?	A. 23½° N B. 0°	C. 66½° S D. 90° N
4.	Which latitude would have days with the *shortest* period of daylight hours?	A. 23½° N B. 0°	C. 50° S D. 70° N
5.	At 50° N in June, the period of daylight hours is	A. the same length as at the equator B. much longer than at the equator C. much shorter than at the equator D. the same length as the period of nighttime hours	
6.	Twice a year every place on Earth has exactly 12 hours of daylight. **Choose two answers**.	A. March equinox B. September equinox	C. June solstice D. December solstice
7.	Equinoxes and solstices generally occur on which dates in the month?	A. 1st–5th B. 13th–14th	C. 20th–23rd D. 29th–30th
8.	When is there a polar night at the Arctic Circle?	A. March equinox B. September equinox	C. June solstice D. December solstice
9.	When is there a polar day at the Antarctic Circle?	A. March equinox B. September equinox	C. June solstice D. December solstice
10.	How often does the sun set at the North Pole?	A. once a day B. once a week	C. once a month D. once a year
11.	What is the **angle of incidence**?	A. the angle of obliquity B. the angle between dark and light C. the angle made by a sunbeam and the surface of Earth D. the angle between the North Pole and the Arctic Circle	
12.	At what latitude would the intensity (brightness) of sunlight be weakest?	A. 15° N B. 30° N	C. 41° N D. 66½° N
13.	There is little change in seasons or daylight hours in which Earth zones?	A. Polar Zones B. Tropical Zones C. Temperate Zones	
14.	There are true changes in seasons in which Earth zones?	A. Polar Zones B. Tropical Zones C. Temperate Zones	
15.	In which Earth zones are seasons similar but with extreme differences in the period of daylight?	A. Polar Zones B. Tropical Zone C. Temperate Zones	

Golden Square Challenge

Four hundred years ago, it was heretical to even suggest that there might be other beings living on planets somewhere outside our solar system. However, today scientists speculate there may be billions of ***exoplanets**** just in our own Milky Way galaxy. In fact, between 1995 and 2013, scientists actually discovered almost 900 exoplanets. They used both direct methods (high-powered telescopes) and indirect methods (detecting the wobble of the star caused by a planet revolving around it). These newly found exoplanets are so very far away that we can never travel to them. However, using various instruments, scientists can predict probable surface conditions on an exoplanet as it passes through its seasons in orbit around its star.

One of the biggest factors as to whether a planet might be habitable by human-like beings depends if the planet is a gas planet like Jupiter or a rocky planet like Earth. Another consideration is to determine if it revolves in a habitable zone called the Goldilocks Zone. It is not too close to a star—too hot for life. It is not too far away from a star—too cold for life. But rather it is in the "just right" position, neither too hot nor too cold.

For this Golden Square Challenge, you are a famous astronomer who has been searching for planets outside our solar system. Tonight you have found two new exoplanets that are rocky planets like Earth in habitable orbits and have rotation and revolution times similar to Earth's. Which of the two is more habitable for a future expedition from Earth?



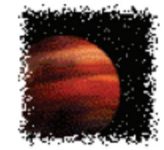
You have determined that the first exoplanet, Alpha, has an obliquity of 0º, and the second exoplanet, Zeta, has an obliquity of 90º.

On the next page you will be asked to think about both planets, what seasons look like on each, and then answer the question below. This is not a creative writing assignment. It is a science writing assignment. Use what you have learned in this unit to form your response.

Which of the two planets, Alpha or Zeta, is the more habitable planet, and why? Explain the pros and cons of both planets in your answer.

****Exoplanets*** (also known as "extrasolar planets") are planets outside our solar system orbiting a different star.

Golden Square Challenge Part I



Planet Alpha rotates once every 24 hours. It revolves in an almost circular orbit around its star in 360 days. Its axis points to a polestar in constellation Scorpio. It has an obliquity of 0º.

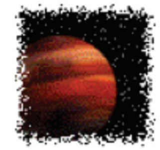
Some things to think about for ALPHA • obliquity of Alpha • equinoxes and solstices • subsolar points on Alpha • angle of incidence on Alpha • daylight hours on Alpha • seasons on Alpha	

Golden Square Challenge Part II

Planet Zeta rotates once every 24 hours. It revolves in an almost circular orbit around its star in 360 days. Its axis points to a polestar in constellation Orion. It has an obliquity of 0º.

Some things to think about for ZETA • obliquity of Zeta • equinoxes and solstices • subsolar points on Zeta • angle of incidence on Zeta • daylight hours on Zeta • seasons on Zeta	

Golden Square Challenge
Part III



From what you have discovered in Parts I and II, answer the following question:

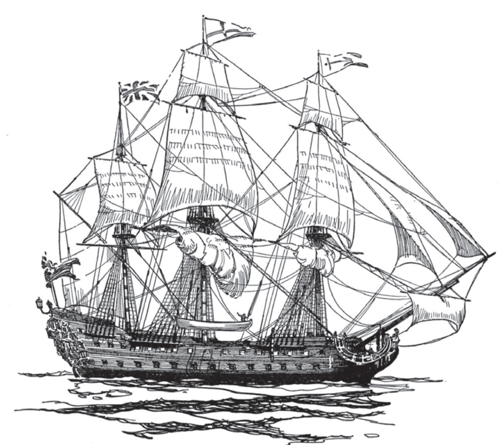
Which of the two planets, Alpha or Zeta, is the more habitable planet, and why?
In your answer, you MUST EXPLAIN the pros and cons of BOTH planets.

Special Award

Recently we have been working on a special science unit from a series called Squared Away. “Squared Away” was originally a nautical term used to announce that the sails of a Square Rigger sailing ship were correctly set. Sailors came to use it to describe those who completed a task with competency, as in, “He was right squared away!” We have adopted the term to describe students who demonstrate competency in specific content and skills.

Students could only master the concepts and skills of this Squared Away unit by learning a great deal about why we have seasons. During this Seasons unit, students used models to develop their understanding and were required to demonstrate with words, drawings, and graphs all that they discovered. They used obliquity, equinox, solstice, and subsolar points to discover where the Tropics of Cancer and Capricorn are found. They used the Terminator and Earth’s orbital position to discover the length of periods of daylight and to determine where the Arctic and Antarctic Circles are found. Their investigation of angles of incidence demonstrated why it is never warm at the poles. All of these different concepts used together explained why although Earth’s obliquity causes seasons all around Earth, true changes in seasons occur only in Earth’s Temperate Zones.

Congratulations to



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For Being Very Squared Away in
Knowing Why We Have Seasons!

Special Award

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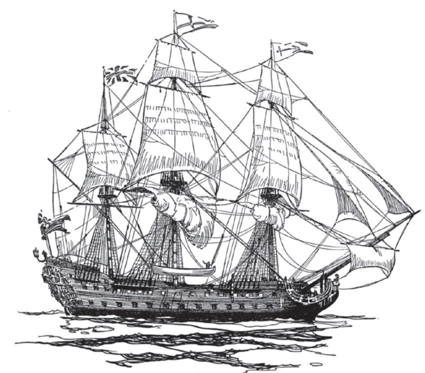
Some students also earned a Golden Square. They had to use excellent thinking skills to complete the Golden Square Challenge, which required them to predict and describe seasons on two undiscovered exoplanets, one having an obliquity of 0º and the other with an obliquity of 90º.

Congratulations to



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For Being Very Squared Away in Knowing Why
We Have Seasons and Earning a Golden Square!

Teacher Feedback Form

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