Phases of the Moon:
A Squared Away Unit

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Learn Through Experience

About the author

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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 instructional blocks. The daily activities are interactive, exploratory, and reflective—all best practices to maximize student learning. By the end of each block, students must demonstrate mastery of the subconcepts. After completing four blocks, 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 either grades 2–4 or 5–8, the content may be used for instruction, enrichment, or remediation.

Differentiation: Teachers 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. The Golden Square activities provide challenges for all student levels.

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 team mates. All units provide Cooperative Group Work Rubrics.

Lessons: The lessons begin with a list of concepts to be taught, materials needed, and a lesson-plan schedule. Each lesson is divided into parts that specifically list an objective followed by the teaching plans to achieve the objective.

Assessments and rubrics: All units include a pretest/posttest to be administered before starting and after completing the unit. You 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 and one block to achieve a Golden Square. These may take five or more days depending the instructional time available and/or your students' grade level and prior knowledge.

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Phases of the Moon

A Squared Away Unit

Purpose

Although all students are aware that the Moon changes its appearance over the course of a month, many may not know what causes the Moon to change. This is not surprising. When asked, an alarming number of Harvard graduates could not explain what causes the phases of the Moon. However, in the next few days your students will create models of the phases of the Moon and of solar and lunar eclipses. By the end of this unit they will have discovered what truly causes the phases of the Moon and how eclipses occur.

Educational standards

National Science Education Standards

- As a result of their activities in grades 5–8, all students can develop descriptions, explanations, predictions, and models using evidence, and can communicate scientific procedures and explanations.
- As a result of their activities in grades 5–8, all students should develop an understanding of the Earth in the solar system, realizing that most objects in the solar system are in regular and predictable motion, and that those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.

National Center on Education and the Economy New Standards Performance Standards, 1997

Earth and Space Science Concepts

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions, and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard. In particular, the student demonstrates understanding of the Earth in the solar system, including such phenomena as the predictable motions of planets, moons, and other objects; how those motions cause days, years, moon phases, and eclipses; and the Sun's role as the major source of energy for phenomena on the Earth's surface.

Scientific Thinking

The student uses scientific concepts to explain a variety of observations and phenomena, and uses evidence from reliable sources to develop descriptions, explanations, and models.

National Council of Teachers of Mathematics Principles and Standards for School Mathematics

Number and Operations Standard for Grades 6–8

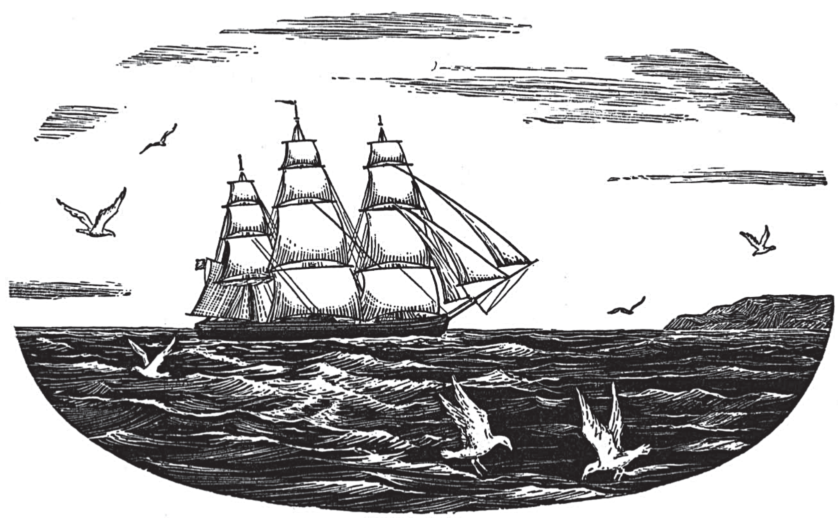
All students should understand and use ratios and proportions to represent quantitative relationships.

Representation

All students should use representations to model and interpret physical, social, and mathematical phenomena.

Connections

All students should recognize and apply mathematics in contexts outside of mathematics.



Knowledge, skills, and attitudes

Knowledge*—Your students will:*

- Understand that ancient astronomers recorded lunar and solar movements and events, and developed theories to explain what they saw
- Understand that early astronomers believed the solar system was geocentric (with Earth at its center) and that scientists proved that it is heliocentric (Sun-centered)
- Understand the comparative distances between the Earth and Moon and between the Earth and Sun
- Understand that the Sun, Earth, and Moon move in predictable orbits at predictable speeds
- Understand the difference between rotation and revolution
- Understand that the Moon revolves around the Earth as the Earth revolves around the Sun
- Understand that the Earth takes $365\frac{1}{4}$ days to revolve around the Sun (one year)
- Understand that the Earth rotates once approximately every 24 hours (one day)
- Understand that the Sun and Moon rise in the east and set in the west because of the counterclockwise rotation of the Earth
- Understand that it takes about $29\frac{1}{2}$ days for the Moon to go from one full Moon to the next (one month)
- Understand that one half of the Moon is lit by the Sun at all times
- Understand that the appearance of the Moon changes as it moves in its orbit around the Earth
- Understand what it means when the Moon is waxing or waning
- Understand that the changing appearance of the Moon has a predictable order
- Understand that the predictable order of changes in the Moon's appearance are called "phases"
- Understand that the Moon's phases are, in order: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last (third) quarter, and waning crescent

- Understand that the Moon rotates, but that the Moon's time of revolution and rotation are the same ($29\frac{1}{2}$ days)
- Understand that an orbit in which the revolution and rotation are the same is called a "synchronous" orbit
- Understand that, because of the Moon's synchronous orbit, the same side of the Moon always faces the Earth
- Understand that when the Moon passes directly between the Earth and the Sun, there is a solar eclipse
- Understand that when the Earth passes directly between the Sun and the Moon, there is a lunar eclipse

Skills—*Your students will learn how to:*

- Use math to determine scale
- Use scale to show the relative difference in the distances between the Earth and Moon and between the Earth and Sun
- Demonstrate "rotation," "revolution," and "synchronous orbit"
- Approximate the speed of the Earth in its orbit around the Sun and the speed of the Earth's rotation
- Use models of the Moon to demonstrate the phases of the Moon
- Working from models, make two-dimensional drawings of Moon phases
- Create models of the Moon, Earth, and Sun in solar and lunar eclipses
- Working from models, make two-dimensional drawings of eclipses
- Identify the phases of the Moon
- Identify where the Moon is in its orbit by looking at its phase
- Read an essay and answer focus questions on the content
- Use the Internet, especially the NASA Web site, to find graphics and video models of the Moon (phases and eclipses)
- Write paragraphs explaining the concepts demonstrated in models, including the phases of the Moon and what must happen before we experience a lunar or solar eclipse
- Estimate the passage of time by the looking at the phases of the Moon

Attitudes—*Your students will appreciate that:*

- Early humans used the phases of the Moon to keep track of time

- Centuries ago, scientists figured out what caused the phases of the Moon and eclipses
- To complete its orbit around the Sun in one year, the Earth must be traveling at a great speed (approximately 66,000 m.p.h.) through space
- To complete one rotation in one day, the Earth must be spinning at a great speed (approximately 1000 m.p.h.)
- To complete its orbit around the Earth in one month, the Moon must be traveling at a great speed through space
- Creating models helps people visualize natural phenomena
- They understand more about Moon phases and eclipses than do many college graduates

Content overview

This *Squared Away* science unit is designed to be concept-specific and is, therefore, grade-level independent. It is very effective as a concept introduction/reinforcement unit and can also serve as an efficient remediation unit. Although students may work individually, the lesson plans direct students to work in teams as they complete activities. These investigations will lead students not only to discover science concepts, but also to communicate their understanding to their teammates and classmates.

Square One concepts (blue square)—Students read an essay about the history of astronomy and build scale models of the Sun, Earth, and Moon.

Square Two concepts (red square)—Students participate in activities that describe rotation, revolution, orbits, and synchronous orbits. They graphically display the different units of time based on the rotation and revolution of the Moon and Earth.

Square Three concepts (green square)—Students create models, arranging the Earth, Moon, and Sun to demonstrate the phases of the Moon. They discover that, although one half of the Moon is always lit by the Sun, the Moon we see from Earth appears different as it moves in its orbit.

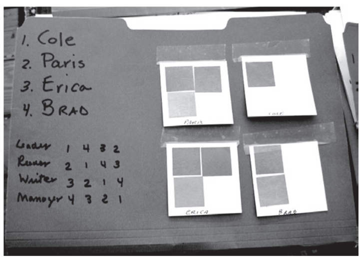
Square Four concepts (purple square)—Students investigate lunar and solar eclipses using models. They discover why eclipses are relatively rare occurrences, and they demonstrate that the phases of the Moon cannot be caused by the Earth's shadow.

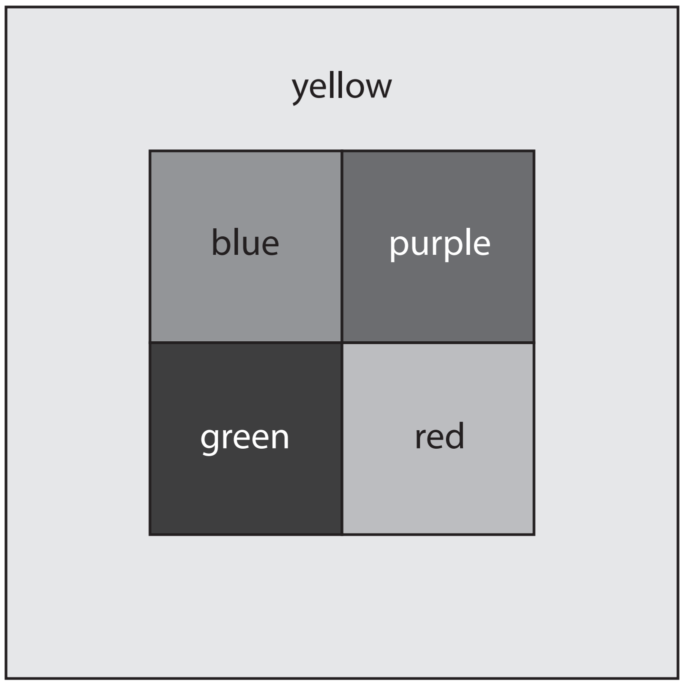
Golden Square concepts—Students investigate the phases of Venus. Like the Moon's phases, Venus's phases depend on its position relative to the Sun and the Earth.

Making the individual award squares

Award squares can be created from four different colored pieces of construction paper. Cut the paper first into one-inch strips, and then cut those strips into one-inch squares. The four colors are only suggestions; however, use yellow paper only for the Golden Square. Cut a 2¼-inch, plain white square to form the backing. Students will paste their earned squares on the backing as they complete each instruction block. Make a $3\frac{1}{2}$-inch yellow square for each Golden Square. (You may choose to trim the backing before affixing the four-square to the Golden Square.)

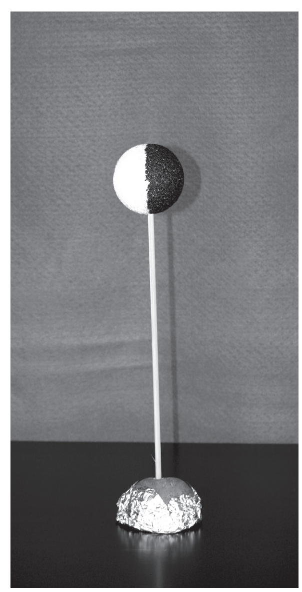
Teaching tip
Attach the background squares to the team folders so students do not lose track of them.





Making models

This unit requires students to create and manipulate models of the Moon, Sun, and Earth. You will need at least two Styrofoam balls—one small ball (1"–1¼") and one medium-sized ball (2"–2¼")—and two wooden skewers for each team. If the school budget is limited, ask your PTO/PTA to contribute to your materials. Styrofoam balls are found in most craft stores. You will also need some flat black latex paint to create the unlit side of the Moon. Directions for preparing the models are on page 13.



Unit Time Chart

Depending on the students' ages, prior knowledge, and the length of your science period, you may complete one group of concepts per instructional block. Block lesson plans are designed for 60 minutes. If a class is made up of younger students, disabled students, or students that assessments indicate may need more instruction, then the block lessons will take more time. Older students may complete an instructional block in 45 minutes. At the end of each instructional block is a list of optional activities.

Instruction Block One

- Pretest
- **Square One concepts** (blue)
- Optional activities
- Quick Team Quiz 1
- Individual Square One Test

Instruction Block Two

- **Square Two concepts** (red)
- Optional activities
- Quick Team Quiz 2
- Individual Square Two Test

Instruction Block Three

- **Square Three concepts** (green)
- Optional activities
- Quick Team Quiz 3
- Individual Square Three Test

Instruction Block Four

- **Square Four concepts** (purple)
- Optional activities
- Quick Team Quiz 4
- Individual Square Four Test

Instruction Block Five

- **Golden Square concepts** (yellow)
- Optional activities
- Team Golden activity
- Individual Golden Square Challenges

Assessment Block

- Final review
- Posttest (one week later)
- Awards ceremony

General Directions

Phases of the Moon

Instruction blocks

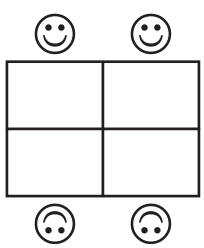
This unit is divided into four instruction blocks that address specific instructional objectives related to phases of the Moon. Each block is sequential and builds on the knowledge and skills learned in the block before it. Always evaluate the tests of one block before going on to the next.

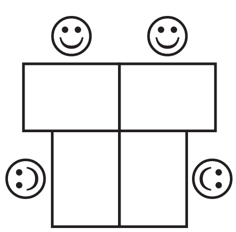
Student grouping

Students may work in this *Squared Away* unit in teams of 3–4. 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 *only* after each Square test. You may combine roles when necessary. Extra team members rotate in and out of roles. (Combine Leader and Reader for teams of three.)

> **Leader:** organizes the team and directs team members as needed. He/she checks that the day's assignments are complete and makes sure teammates submit all assignments. He/she organizes the team folder at the end of each day and hands it in to the teacher. The Leader also keeps the team motivated and on-task.
>
> **Reader:** reads handouts and/or activity directions, clarifying and repeating as necessary
>
> **Writer:** writes the team's responses and uses the calculator
>
> **Manager:** collects and returns supplies, handouts, and materials needed for the team's daily work.





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 photocopies you need to prepare are listed at the beginning of each lesson. Most supplies can be found in your classroom. There are special supplies for the Styrofoam models listed with the directions on page 13. Consider photocopying all the handouts ahead of time and storing them in order in a hanging file.

Student folders

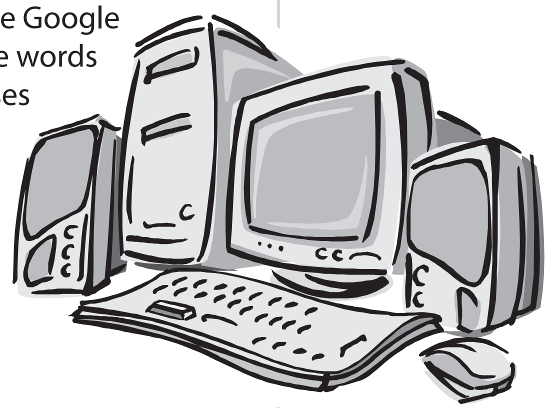
Create a folder for each team, listing the names of team members on the front. Inside the folder, attach one copy each of the Cooperative Group Work Rubric and the Content Concept Rubric. On the outside cover, paste blank background squares and make a role assignment chart. Review the duties of each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

Lesson plans and timeline

Squared Away lesson plans begin with a concepts list and materials 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 special order to minimize confusion. The lessons are arranged in instructional blocks that will take about 60 minutes or more, depending on your students' prior knowledge. The five instructional blocks may be broken into ten lessons if students need more time to process the concepts. This arrangement will give you more class time to reteach students who are having difficulty, while those who are squared away may work on extension activities.

Online resources

Use search engines and online encyclopedias to find the most current information to use in your class. Before starting the unit, use Google or Bing, or the NASA Web page. Add the "+" symbol and the words *video*, *pictures*, or *photo*. For example, entering "Moon phases +video" into a search engine will give you Web sites with animations or actual video for students to watch on the classroom computer or on a Smart™ board. Put this list of URLs with their links in a classroom computer folder that you and your students can readily access.



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 some incentive for better effort. Consider grading classwork and teamwork using the rubrics provided and award four, three, or two points. Consider giving points for neatest folder, being on-task first, finishing on time, etc. Keep a daily running tally to encourage students to do their best.

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. If your students maintain science notebooks, you may decide to have students add these pages to their notebooks. Otherwise, have students keep their pages in the folder. 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. There is a blank copy of **Stop/Think/Draw/Write** without specific prompts on page 61 of this guide.

Assessments

The pretest and posttest are identical and are administered at the beginning and the end of the unit. Administer the pretest before Instruction Lesson One. The pretest will reveal students' prior knowledge so you can be more confident about the pace of your lessons. The posttest will let you know how competent your students have become with the content and skills presented in the unit. Give the posttest at least one week after you complete the unit. Both pretests and posttest should be corrected in the same manner. With questions that require students' written and drawn responses, correct each answer using 4-3-2-0 scoring, where four recognizes an answer that demonstrates clear understanding, three recognizes good understanding, two recognizes some understanding, and zero recognizes little or no understanding.

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 block, 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 block 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. Tape one copy of this rubric inside the team folders. Use this rubric to provide maximum feedback to the students and to allow you to check off items on the class **Content/Skills Checklist**. See page 15 for more on the **Concept Content Rubric**.

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. Use the available check sheets daily to keep track of skills students have learned or still need to learn.

Quick team quizzes take about five 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 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 3–5 minutes, go over the correct answers with the whole class, addressing any questions they may still have.

Individual Square Tests are given at the end of each instruction block. You may administer them at the end of an instructional class period or at a later time. The second, third, and fourth Individual Square Tests contain questions from the previous instructional blocks, so the fourth test may be considered a final exam for the four blocks. Separate the desks and insist that students work individually on these assessments. Before beginning a new instruction block, evaluate student answers for the Individual Square Test to determine the need to reteach some concepts. Generally only a few students are confused about one or two test questions. Create ad hoc 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. Follow this procedure for each Individual Square Test.

The Golden Square Challenge is a fifth assessment given after students work with a more difficult concept: the phases of Venus. Not all students are expected to earn the fifth, Golden Square. Use the **Concept Content Rubric** and grade each question. To achieve a Golden Square, students must earn 12–16 points on the four tasks.

Answer keys for all activities and assessments are found at the end of the lesson plans for each instructional block.

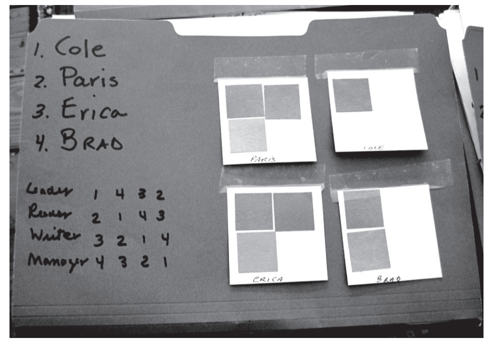
Reinforcing and reteaching concepts

The timeline of this unit depends on your students' prior knowledge and the length of your science period. It is also often difficult to find time to reteach students who do not grasp concepts on the first round. However, working

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.

with struggling students before they are overwhelmed is essential. Consider stopping after Instruction Block Two and again after Instruction Block Three to work with students who still need help. Consider allowing the students who have mastered concepts to work on the optional extra activities while you work with those who need more instruction.

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 why they are not going to earn a square that day. Stress, though, 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

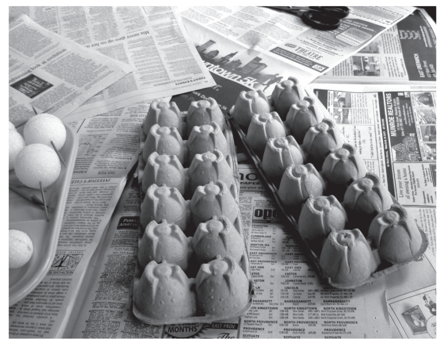
With the successful completion of the Individual Square Four Test, students are considered Squared Away. However, consider waiting until you run the Golden Square Challenges to celebrate. This will give you more time to work with those students who are close to finishing the four squares. It would be best if all your students successfully completed the four instructional blocks. 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' age and your available time and resources. Give one of the two **Special Award Certificates** to acknowledge each student's achievement.

Making Models

Materials

- 2 egg cartons
- 1 small nail
- Styrofoam balls (minimum of one small, one larger per team)
- black latex paint (one quart)
- wooden skewers (one per ball)
- toothpicks (one box)
- white (or carpenter's) glue
- small foam paint brush
- plastic gloves (one pair)
- aluminum foil and small potatoes for bases (one per ball)

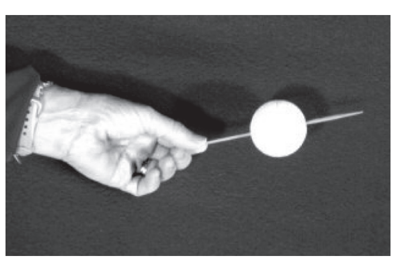


Directions

1. Remove the tops from two egg cartons and turn the cartons upside down. If the cartons are wobbly, crush the center dividers until they lie flat.
2. Use the nail to poke a small hole in the bottom of each egg section. Make certain that a toothpick will stand up in and not drop through the hole.
3. Insert one toothpick into what would be the North Pole of a Styrofoam ball.
4. Make a mark at the approximate equator of the ball.
5. Place a second toothpick at what would be the South Pole of the ball. Make sure the toothpicks are opposite one another.


Step 2


Step 4


Step 5

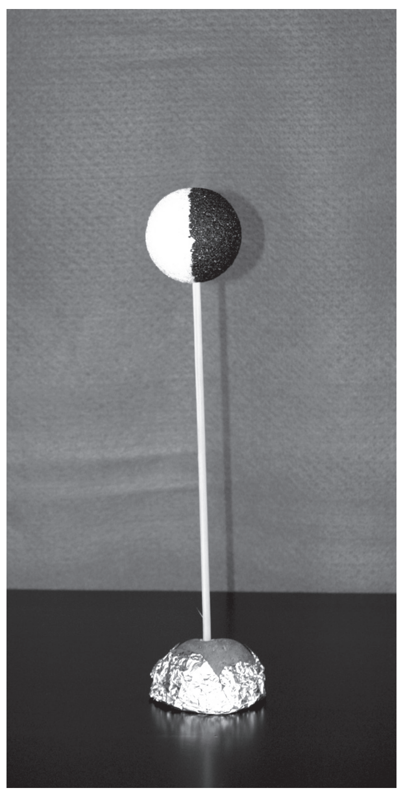
6. Holding the North Pole toothpick, carefully dip the ball into the paint up to the equator marking. Wipe the excess paint off the ball using the foam paint brush. Stand South Pole toothpicks in prepared egg cartons. Let them dry for 24 hours.


Step 6

Step 7

7. Take out the toothpicks and insert a skewer into the South Pole holes. Remove, add a drop of glue to the hole, and reinsert the skewer. Allow the glue to set.

8. Cut a potato in half. Place the flat side on a square of foil and wrap the bottom. Insert the square end of the skewer into the top of the potato piece to form a stand.



Step 8

Using the Concept Content Rubric

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 labels*. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

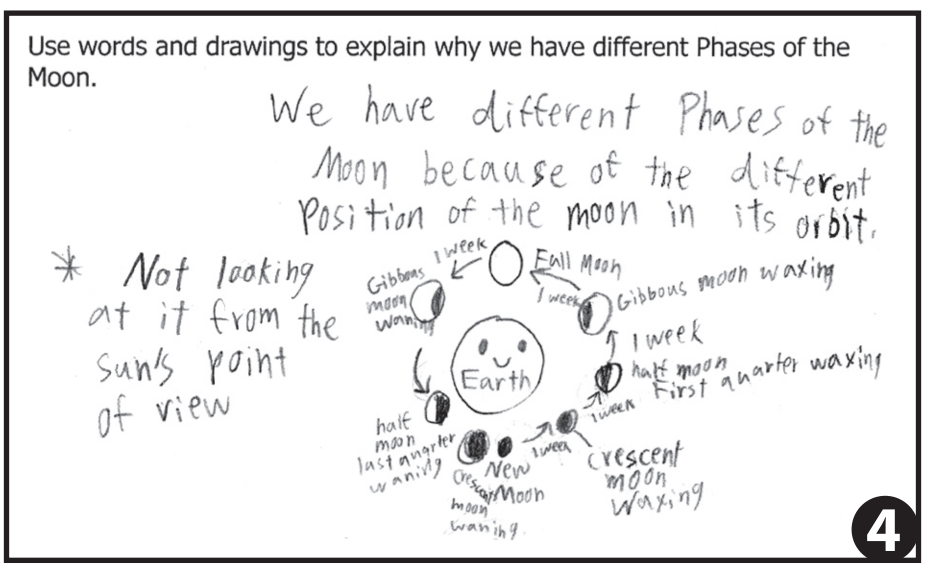
❸ **Expected**—You demonstrated a *good understanding* of the concept. You *accurately* described/drew the concept using *some detail* and *correct labels*. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

(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 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 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 it. You need to meet with your team or teacher to relearn the material.

Sample student work



Use words and drawings to explain why we have different Phases of the Moon.

We have different phases of the moon because the moon orbits the earth while the earth orbits the Sun so phases of the moon are caused by the Position it is in.

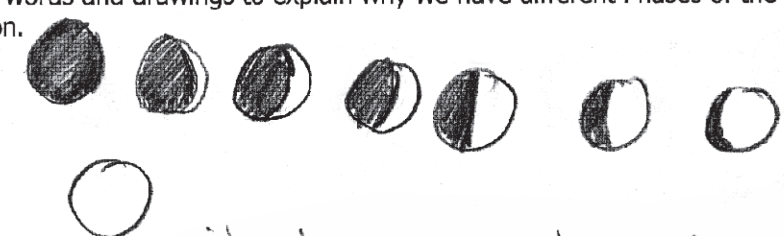
3

Use words and drawings to explain why we have different Phases of the Moon.

because of the position of the moon and the earth is always spining

2

Use words and drawings to explain why we have different Phases of the Moon.



We have it because the moon and earth is spining around and round.

2

Use words and drawings to explain why we have different Phases of the Moon.

Becase the earth is moving

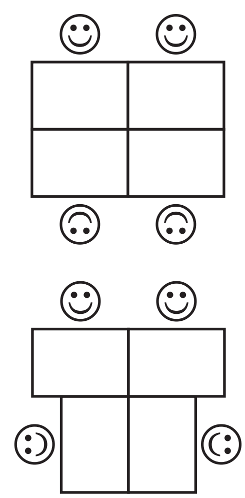
1

Before Starting This Unit

1. Read through the **teacher's guide** to familiarize yourself with the content and materials.
2. Prepare the **Styrofoam Moon and Earth models**—at least one pair per team. See page 13 for instructions.
3. Organize the **teams** and prepare the **team folders**. See page 9.
4. **Unit introduction** and **pretest**
    - Photocopy and hand out the unit's introduction. Tell students what they will be learning over the next week or so.
    - Administer the pretest to all students individually before starting this unit. Correct each answer to the student response questions using the Concept Content Rubric's 4-3-2-0 scoring system, where four recognizes an answer that demonstrates clear understanding, three recognizes good understanding, two recognizes some understanding, and zero recognizes little or no understanding. Having a general idea of student pre-knowledge will help you pace your instruction.

Individual

5. **Photocopy** the handouts and collect the materials before beginning Instruction Block One.
6. If you decide to award squares, prepare the awards background square and the colored squares. Attach them to folders. If you decide the use a chart, explain the chart when you explain the unit.
7. On the day you begin the unit, **arrange the room**. (See right.) Announce the teams. Assign student roles. Review the duties of each role using the Cooperative Group Work Rubric.



Instruction Block One

Introducing Earth, Moon, and Sun

Square One concepts*—Students will:*

- Understand that ancient astronomers recorded lunar and solar movements and events, and developed theories to explain what they saw
- Understand the difference between geocentric and heliocentric models of the universe
- Understand the difference between elliptical and circular orbits
- Understand how to create scale models
- Understand the comparative sizes of the Sun, Earth, and Moon
- Understand the comparative distances between the Earth and Moon and between the Earth and Sun

Materials

Consider assembling these in large envelopes ahead of time.

- Metric rulers—*two per team*
- Ribbon or string three meters long
- Centimeter paper—*one sheet per team*
- Scissors and calculators—*one each per team*

Reproducible handouts

Pretest/posttest—*two per student*

Cooperative Group Work Rubric—*one class copy to post, and one per team folder*

Content Concept Rubric—*one class copy to post, and one per team folder*

Essay 1A: Ancient Astronomers—*one per student*

Essay 1B: Measuring the Earth, Moon, and Sun—*one per student*

Stop/Think/Draw/Write 1—*one per student*

"You Do the Math" worksheet for scale models—*one per student*

Making Scale Models—*one per team*

Quick Team Quiz One—*one per student*

Square One Test—*one per student*

Lesson plan schedule

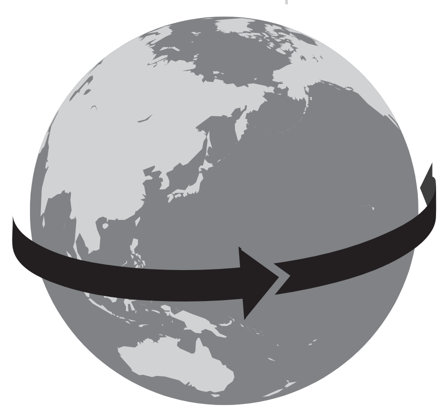
- Pretest
- Essay 1A: Ancient Astronomers
- Stop/Think/Draw/Write 1
- Essay 1B: Measuring the Earth, Moon, and Sun
- Stop/Think/Draw/Write
- "You Do the Math" for scale
- Making scale models
- Optional activities
- Quick Team Quiz One
- Square One Test

Teaching tip
It is important to divide the lesson into two parts, separating the two different essays with a **Stop/Think/Draw/Write** activity. Students need time and opportunity to process the new information.

Answer Key for *Pretest/Posttest*

Look at page 15 to see how to score each answer. The answers below that require drawings would be scored +3. There should be labeled drawings for a +4 score.

1. Rotate means to spin.
2. Revolve means to orbit or go around.
3. The Sun is at the center of the solar system.
4. The Earth is at the center of the solar system.
5. Heliocentric
6. Circle versus ellipse (drawing)
7. Elliptical
8. Arrow showing counterclockwise
9. 24 hours
10. $29\frac{1}{2}$ days
11. $365\frac{1}{4}$ days



12. $29\frac{1}{2}$ days

13. One-half

14. The phases of the Moon are caused by its changing position as it orbits the Earth.

15. Waxing means getting larger, waning means getting smaller.

16. The Moon rises in the east and sets in the west.

17. (See Essay 3, page 79, for the full answer.)

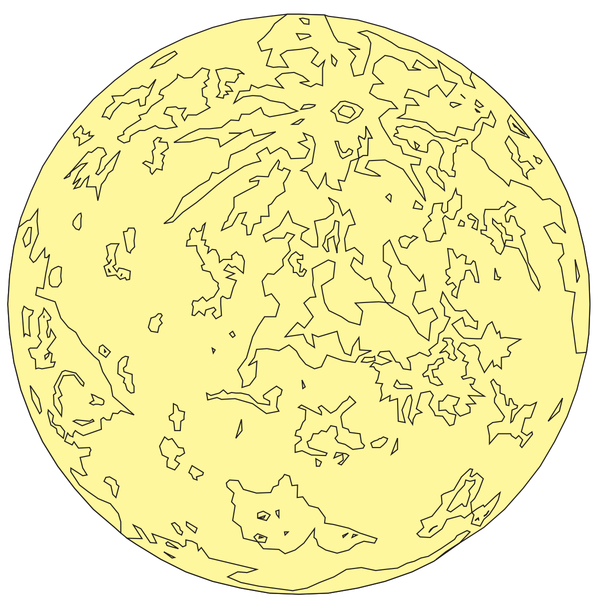
18. Sun → Moon → Earth, with shadows away from the Sun and the Moon's shadow falling on part of Earth

19. New

20. Sun → Earth → Moon, with the Moon in Earth's shadow

21. Full

22. The Moon's orbit around the Sun is not directly in line with Earth's orbit, so usually the shadow misses the Earth.



Lesson Plan

Introducing Earth, Moon, and Sun

1. Essay 1A: Ancient Astronomers

- Give Managers copies of **Essay 1A: Ancient Astronomers** for each of their team members. Go over the essay as a whole-class activity.
- Make sure that students understand any new vocabulary introduced in the essay: *BCE*, *CE*, *archaeologists*, *astronomers*, *solar*, *lunar*, *heliocentric*, and *geocentric*.

2. Stop/Think/Draw/Write 1

Small group

- After completing the discussion of **Essay 1A**, give team Managers copies of **Stop/Think/Draw/Write 1** to distribute to their teammates. Have students fill in their names and the date. Then ask students explain the difference between *geocentric* and *heliocentric* in the space provided. Allow teams 3–5 minutes to complete their work.

Teaching tip
Remind students that when asked to draw, they should work quickly using simple sketches. Labels should be clear and spelled correctly.

Whole class

- Within their teams, have students share what they wrote or drew. Then ask each team to choose one teammate's explanations and drawings to share with the whole class.
- Using the **Content Concept Rubric**, have the whole class assess team answers. Reinforce correct explanations and clear up any confusing or inaccurate answers. Summarize the explanations and model the correct drawings on the chalkboard.
- Send students back to their teams to correct all their papers, if necessary.

3. Essay 1B: Measuring the Sun, Earth, and Moon

Whole class
or
Small group

- Give copies of **Essay 1B: Measuring the Sun, Earth, and Moon** to each team Manager to distribute to their team members. Go over the essay as a whole-class activity or as a team activity. Review roles if assigning a team activity.
- Make certain students understand any new vocabulary introduced in the essay: *diameter*, *kilometers* and *miles* (1 km equals 0.6 mile), *elliptical orbit*, *average*.
- Decide whether you are using kilometers or miles (see the Teaching Tip to the right).

Teaching tip
Note that the distances are given in kilometers and miles. Using miles is easier when the students do the math, because the essay gives the distance to the Moon as about a quarter million miles. The Sun then is $4 \times 93 = 372$ (or almost 400) times farther away than the Moon. The Sun is also about 400 times larger than the Moon.

4. "You Do the Math" for Scale

Whole class

- Give Managers copies of the worksheet "**You Do the Math" for Scale**, one for each of their teammates. Go over the handout as a whole-class activity. This may take more time if students are not familiar with scale.
- Show students how to cancel zeros when doing division of large numbers. Allow students to use calculators, if necessary.

For example: 3000/150,000
= 3~~000~~/150,~~000~~
= 3/150
*= **50***

5. Making scale models

Small group

Bright Idea
Review roles when assigning a team activity.

- Give Team Managers one copy of Making Scale Models for their team. Tell team Managers to collect materials for their team in order to complete the **Making Scale Models** activity.
- Allow teams five minutes to complete **Part One**. When teams have finished, have teams check each other's measurements. Reinforce correct measurements and clear up any mistakes. Remind them that scale allows them to make valid comparisons.
- Direct students to **Part Two**. Allow students to work independently for 3–5 minutes. When they finish they should send the Leader to you with their length of string showing the scaled distance between the Earth and the Moon. (The string piece will be less than one centimeter.)

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.

6. Stop/Think/Draw/Write 1

Individual

- When teams have finished with the activity, students should work individually to answer the prompts on the bottom of the handout. While they work, walk around and check that students who have finished early have included all they know. Remind students to work neatly and check their spelling.

Small group

- Allow teams 3–4 minutes to complete their work. Have students first share what they wrote or drew with their team. Then ask each team 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 clear up those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the chalkboard. Ask students to correct their papers if their explanations were incorrect or confusing.

- Have the team Managers put all the pages into the team folder. Check the students' work each night as an informal assessment. If the pages reveal that anyone is confused, be sure to create an opportunity to reteach the concept before the next class.
- Consider awarding and keeping track of team points.

Teaching tip
When time permits, have team Leaders orally quiz their teams on content covered during the instructional blocks.

7. Quick Team Quiz 1

Individual

- Ask the Managers to come to you for **Quick Team Quiz 1**. While students are working individually, walk around the room clarifying and instructing.

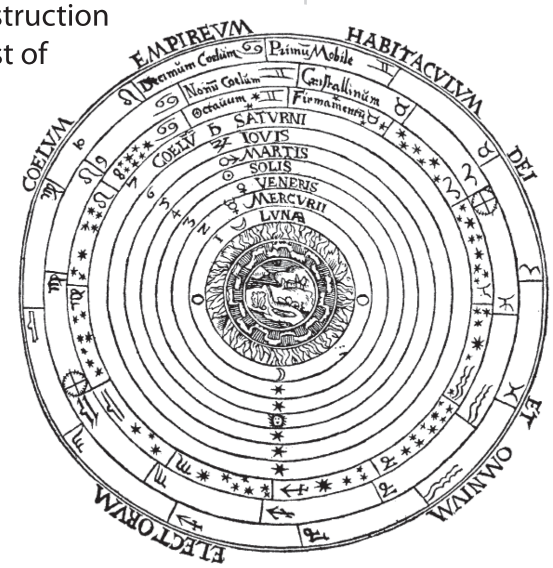
Small group

- When the individuals in each team have finished **Quick Team Quiz 1**, the teams should correct the papers. Team members should help other team members who made errors.
- Present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz 1** papers neatly in the team folders and give the folders to you.

8. Square One Test

Individual

- Administer the **Square One Test** to individuals, not teams. Separate desks for privacy. Collect tests when students have finished.
- While students are taking their tests, use the time to assess the students' cooperative group work. Use the **Cooperative Group Work Rubric** as your guide. Assess each student and assign a score from 1–4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.
- Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block One before starting Instruction Block Two. Reteach and retest if necessary. Make a list of those students who have earned a square.



9. Square One Answer Key

Stop/Think/Draw/Write 1

1. Heliocentric: draw the Sun at the center and planets orbiting. Geocentric: draw Earth at the center and the Sun and stars orbiting.
2. Heliocentric is true.
3. The Earth's orbit around the Sun should be an ellipse.

Making Scale Models

1. 93 cm
2. 0.238 cm

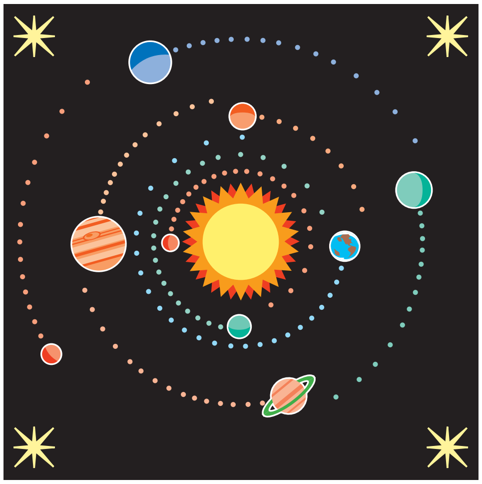
Challenge: 400 times

Quick Quiz 1

1. B
2. A
3. A
4. A
5. A
6. B.

Square One Test

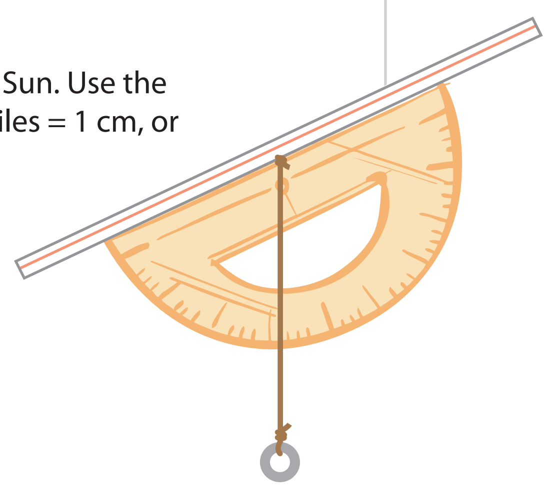
1. The Sun is the center of the solar system.
2. The Earth is the center of the solar system.
3. Heliocentric
4. Earth's orbit drawn as an ellipse
5. A



Optional Activities One

Directions: Post the list of optional extra activities and let students choose what to do. Or, cut the optional activities list below into strips of paper that students may choose or draw by lot.

1. Find equivalences. For example, 93 million miles equals how many trips around the Earth at the equator? 93,000,000/24000 = 3875 trips around the Earth. Find other equivalencies.
2. Although the Earth is 3.6 times larger than the Moon when we compare the diameters, the Moon has $\frac{1}{6}$ of the mass of the Earth. That means that the gravity on the Moon is $\frac{1}{6}$ of that on Earth. If a person weighs 60 pounds on Earth, he/she would weigh only ten pounds on the Moon. Make a chart of common items or people with their weight on the Earth and their weight on the Moon.
3. Research the many myths associated with the Moon or the Sun. Write summaries of at least three different tales. Or, rewrite a myth, adding detail and other elements of storytelling. (Google "Moon myths.")
4. Research ancient astronomers. Use Internet research to write a short biography of one of the following: Aristotle, Aristarchus, Ptolemy, Galileo, Nicolaus Copernicus, Tycho Brahe, Johannes Kepler, or Sir Isaac Newton. Research more recent astronomers such as Edmond Halley or Edwin Hubble.
5. Create a timeline of famous events in astronomy.
6. Research NASA and the Apollo program or the Soviet program that captured the first look at the far side of the Moon.
7. Research ancient archaeological sites such as Stonehenge, Carnac, Newgrange, Ireland's Boyne Valley, and Egypt's Giza complex.
8. Research ancient astronomers and astronomy among the Mayans, Sumerians, Indians, and Chinese.
9. Make scale models of the Earth, Moon, and Sun. Use the diameter of the Moon for the scale: 2200 miles = 1 cm, or 3500 km = 1 cm.
10. Make a model of an astrolabe using a protractor, washer, string, and straw. Use it to measure the Moon's height in degrees above the horizon.



11. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Allow students to write for at least three 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: What were some of ways that ancient astronomers kept track of what they saw in the sky?
    - Prompt 2: Write the steps you would follow to make a scale model comparing the Earth and the Moon.
    - Prompt 3: If you were comparing the relative size difference between the Earth and the Moon, what comparisons could you make? For example, if the Moon were a grape, what would the Earth be? Support your comparisons using actual numbers.

12. **Out-of-class assignments**

    - Ask students to look through newspapers, magazines (*Scientific American, Discover, Smithsonian,* etc.), or online to find scientific information about the orbits of Earth and the Moon around the Sun, and to share what they learn with their classmates. Check out the NASA website and make a list of other Web addresses that students can use.
    - Ask students to Google "How to draw an ellipse" to find videos that show them how to draw an ellipse. Have them demonstrate to the class how to draw an ellipse.

Instruction Block Two

Rotation and Revolution: Sun, Earth, and Moon

Square Two concepts*—Students will:*

- Understand that the Sun, Earth, and Moon move in predictable orbits at predictable speeds
- Understand the difference between rotation and revolution
- Understand that the Sun and Moon rise in the east and set in the west because of the counterclockwise rotation of the Earth
- Understand the Moon revolves around the Earth as the Earth revolves around the Sun
- Understand that the Earth takes $365\frac{1}{4}$ days to revolve around the Sun (year)
- Understand that the Earth rotates approximately every 24 hours (day)
- Understand that it takes $29\frac{1}{2}$ days for the Moon to go from one full Moon to the next (month)
- Understand that the Moon is in a synchronous orbit and that its time of revolution and rotation are the same
- Understand that the Moon rotates, but is in a synchronous orbit so we always see the same side
- Appreciate that the Earth and Moon are traveling at a great speed through space

Materials

- Glue or tape—*one per team*
- $2\frac{1}{4}$"-square background pattern piece—*one per student*
- 1" blue square—*one per student*
- Index cards reading EAST and WEST—*five sets*
- Index cards reading SUN, EARTH, and MOON—*one set*
- Graph paper—*one sheet per student*

Reproducible handouts

Essay 2: Rotation and Revolution—*one per student*

Stop/Think/Draw/Write 2—*one per student*

Teaching tip

Make five sets of two 4" × 6" index cards. One card of each set reads EAST; the other reads WEST.

Make one set of three 4" × 6" index cards. One card of each set reads SUN; the second reads EARTH, and the third reads MOON.

"You Do the Math" for comparing speeds—*one per student*

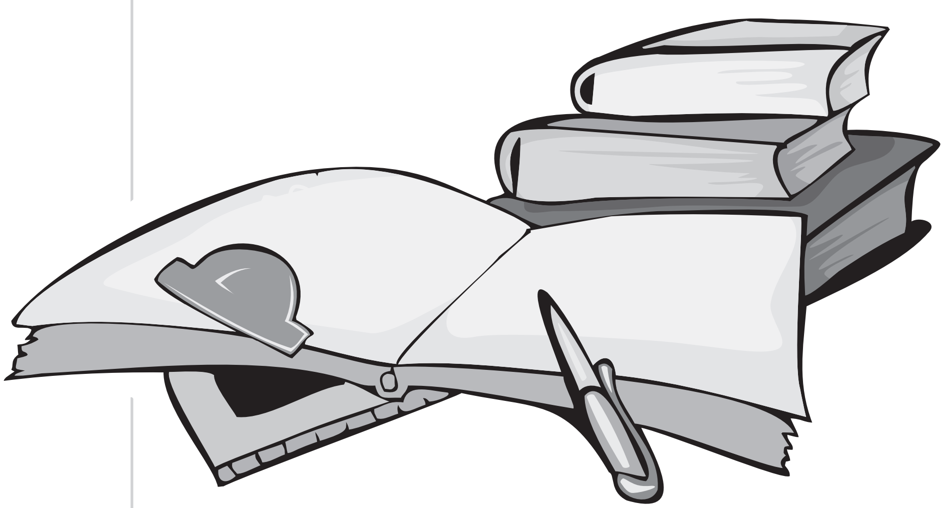
Optional Activities—*one per student*

Quick Team Quiz Two—*one per student*

Square Two Test—*one per student*

Lesson plan schedule

- Award squares
- Essay 2—first part
- Students walk/spin, modeling **rotation**
- Stop/Think/Draw/Write 2
- Essay 2—second part
- Students model **revolution** and **synchronous orbit**
- Stop/Think/Draw/Write
- "You Do the Math" for **comparing speeds**
- Optional activities
- Quick Team Quiz 2
- Square Two Test



Lesson Plan

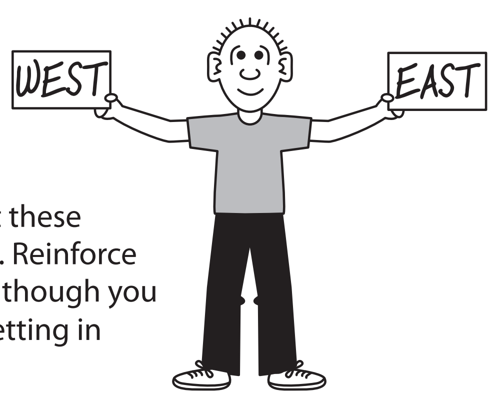
Rotation and Revolution: Sun, Earth, and Moon

1. Awarding squares

- Arrange the room and send students into teams. If you have not already done so, announce/award the first squares (blue) to students who have mastered the first concepts in Instruction Block One.
- Assign new student roles, reviewing the duties of each role and the Cooperative Group Work Rubric.

2. Essay 2: Rotation and Revolution

- Give enough copies of **Essay 2: Rotation and Revolution** to each team Manager for every member of his/her team.
- Go over the first three paragraphs of the essay as a whole-class activity or as a team activity. Tell students to stop at the black line. (Review roles if assigning a team activity.) Make sure that students understand any new vocabulary introduced: **rotate**, **rotation**, **counterclockwise**.
- Clear a space in the middle of the room and ask the whole class to sit on the floor or sit on chairs in a large circle. Keeping students seated during these activities will minimize silliness and horseplay.
- **Rotation:** Ask one student to "act out" rotating (spinning). Ask other students to also demonstrate rotation. Remind them to spin in a counterclockwise direction. Reinforce the action and the words **rotate** and **rotation**. Stress that it takes the Earth about 24 hours to rotate once.
- **Sunrise, sunset, moonrise, moonset**: Ask one team of students to come to the front of the class and give each student a set of EAST/WEST cards. Have students hold their cards at arm's length, away from their bodies. Have them stand with their backs to you and announce that you are the Sun. Ask them to start to rotate (spin) slowly in a counterclockwise direction looking down their left arm. When they can see you (the Sun), they should stop and note that their sign reads EAST. They should continue to spin slowly, but now keeping their eyes on you. When you disappear from view, they should be looking down their right arms at their sign that reads WEST.



- Ask this team to sit down and repeat these instructions for the rest of the teams. Reinforce that you (the Sun) are not moving, although you appear to be rising in the east and setting in the west.

Small group

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

Whole class

or

Small group

Teaching tip
Sometimes you will read that the Moon orbits every 27 days. Sometimes you will read that it orbits every 29 days. It depends how you are measuring. If the Earth were stationary, then it would take only 27.3 days for the moon to revolve around it. This is the *sidereal* month. However, the Earth is not stationary. As the Moon orbits the Earth, the Earth and Moon are moving on a path around the Sun. It takes 29.5 days for the Moon to reach the same point as seen from Earth. This is a *synodic* month. We use the synodic month number because it matches the time between one full moon and the next.

3. Stop/Think/Draw/Write 2

Small group

- When teams have all experienced rotation, give Managers copies of **Stop/Think/Draw/Write 2**. Send students back to their desks to work. Have them individually complete the two prompts above the dark line.
- Allow students 3–4 minutes to complete their work. Have them first 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.
- 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 their explanations were incorrect or confusing.

4. Part two of Essay 2

Whole class

or

Small group

- Go over the bottom two paragraphs of the essay below the black line as a whole-class activity or as a team activity. Make certain students understand any new vocabulary introduced: **revolve**, **revolution**, **synchronous orbit**.
- **Revolution:** Reestablish the clear space in the middle of the room and ask the whole class to again sit on the floor or sit on chairs in a large circle. Ask one student to represent the Sun. Tell him/her to stand in the middle of the room and give him/her the SUN sign. Give a second student the EARTH sign to represent the Earth and tell him/her to slowly revolve (orbit) around the first student. Remind the student to move in a **counterclockwise** direction. Reinforce the action and the words **revolve** and **revolution**. Stress that it takes the Earth 365 $\frac{1}{4}$ days to revolve once around the Sun.
- Ask a new Earth student to slowly demonstrate rotation and revolution around the Sun. Have him/her complete seven days of the orbit while spinning. Students should spin slowly seven times as they revolve. You may ask students to extrapolate how many times the Earth student should rotate if he/she were going around the whole orbit. (365 $\frac{1}{4}$ days)
- Ask a third student to join the demonstration. This person represents the Moon and should hold the Moon sign. He/she should revolve around the Earth as the Earth spins and moves along its orbit around the Sun.
- **Synchronous orbit**: Ask two students for a new demonstration—a synchronous orbit. Put the first student in the middle and hand him/her an EARTH sign. Give the second student the MOON sign and ask him/her to revolve around the Earth, but always keeping the front of his/her body facing the Earth.

Teaching tip
To reinforce the concept of time passing, start the Earth student at the beginning of the school year (September). At the completion of $\frac{3}{4}$ of the orbit, announce it is December; at the completion of $\frac{3}{4}$ the orbit, announce it is springtime; at $\frac{3}{4}$ the way around, announce it is June and school is getting out. As the Earth student approaches the starting point, announce it is September again.

Bright Idea
A mnemonic to help students remember the different meanings:
ROTATE (spin like a Top)
REVOLVE (Orbit)

Teaching tip
It is important to give the students enough room to demonstrate the movements. Also, insist that everyone move in slow motion to prevent falling and potential injury.

- Ask the other students what the Moon student had to do to maintain a position where the front of his/her body always faced the Earth student. (Turn or spin.) Demonstrate a second time with a second pair of students.
- Refer to the wording of Essay 2 about synchronous orbits to help students understand why we had never seen the far side of the Moon before the Russians took a picture of it.

5. Stop/Think/Draw/Write 2

Small group

- After students have satisfactorily demonstrated revolution, send them back to their teams to complete the two prompts at the bottom of **Stop/Think/Draw/Write 2**.
- 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 students 4–5 minutes to complete their work. Have them first 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.
- 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 their explanations were incorrect or confusing.
- Have the team Managers put all the pages into the team folder. Check the students' work each night as an informal assessment. If the pages reveal that someone is confused, be sure to create an opportunity before the next class to reteach the concept.

6. "You Do the Math" for comparing speed

Small group

Teaching tip
The easiest way to explain the speed of the Earth's rotation at the equator is to have students imagine that they are in a spaceship hovering over the equator. It would be 24 hours for the Earth to make one full rotation under the spaceship. At the equator, the Earth has a circumference of about 24,000 miles. Using the formula of R = D/T, students can calculate 24000/24. Therefore, at the equator, the rate of rotation = 1000 m.p.h.

- Give Team Manager copies of the **"You Do the Math"** worksheet for comparing speed and tell them to collect materials for their team.
- Go over the directions as a whole-class activity. Review the rubric that you will use to evaluate their work.
- Walk around the room as students work to make sure they are completing their graph neatly and correctly. When teams have finished, ask the teams to critique their teammates' graphs using the rubric. (Allow students to redo their graphs for homework if their teams and you agree that the graphs did not earn a three or four.) Have the team Managers put all the graphs into the team folders. Check the students' work each night as an informal assessment.

Individual

7. Quick Team Quiz 2

- Ask the Managers to come to you for the **Quick Team Quiz 2**. While students are working individually, walk around the room clarifying and instructing.
- When the individuals in each team have finished **Quick Team Quiz 2**, the teams should correct their papers. Team members should help other team members who made errors.

Small group

- Present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz 2** papers neatly in the team folder and give them to you.

Individual

8. Square Two Test

- Administer the Square Two Test to individuals, not teams. Separate student desks for privacy. Collect tests when students have finished.
- While students are taking their tests, consider using the time to assess the students' cooperative group work. Using the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from one to four to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.
- Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Two before starting Instruction Block Three. Reteach and retest if necessary.

9. Square Two Answer Key

Stop/Think/Draw/Write 2

1. Rotate—to spin
2. The Earth rotates counterclockwise. This motion causes the Sun and Moon to apparently rise in the east and set in the west.
3. Since the Moon's rotation and revolution both take the same amount of time, the Moon rotates and revolves once in the same $29\frac{1}{2}$-day period. The same side of the Moon always faces the Earth.
4. Revolve—to orbit or go around

"You Do the Math"—Comparison of Speed Using Graphs

Jet—part of first block

Bullet—1 $\frac{1}{2}$ blocks

Shuttle—8 $\frac{1}{2}$ blocks

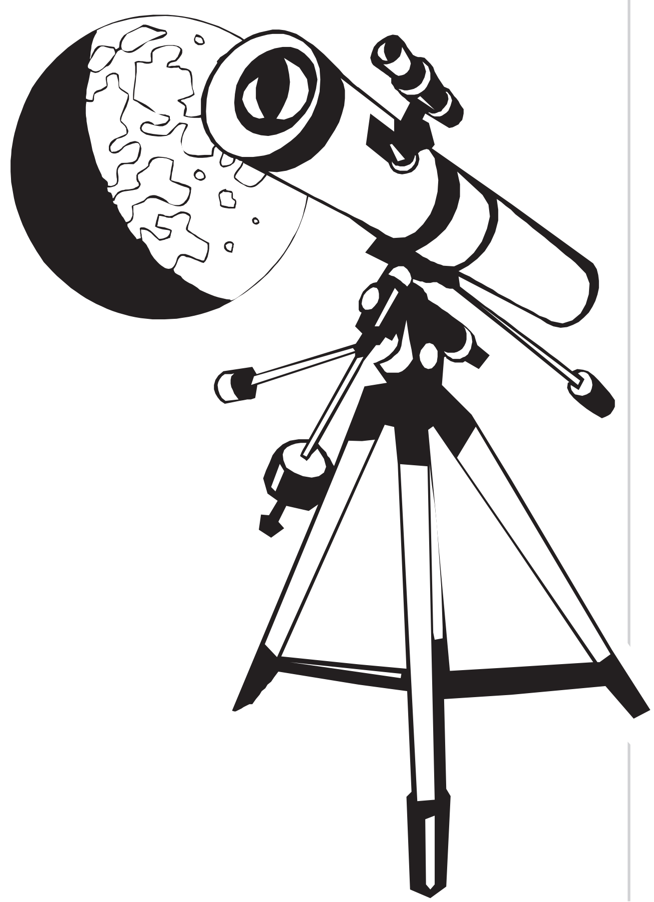
Earth—33 blocks

Quick Quiz 2

1. J
2. G
3. M
4. M
5. K
6. O
7. A
8. D
9. F
10. D
11. A
12. F

Square Two Test

1. A
2. B
3. C
4. C
5. B
6. B
7. A
8. B



Optional Activities Two

1. **Graphing**
   Have students make graphs comparing the times of revolution and rotation of the Earth and Moon. Or have students make graphs of the rotation and revolution of other planets in our solar system.

2. Write a poem or rap to help someone understand the difference between **rotation** and **revolution**.

3. Research Roman, Greek, Native American, or other myths about the passage of the Sun across the sky (for example, Apollo in his golden chariot).

4. Research what the motion of the Sun over a 24-hour period looks like on June 21 at the North Pole. Make a poster to explain what a person would see.

5. Using the formula $T = \frac{D}{R}$, ask students to find the answers (the necessary information is on the handouts):

   - How long would it take the space shuttle to fly to the Moon?
   - How long would it take the space shuttle to fly to the Sun?
   - How long does it take the light from the Sun to reach Earth at 186,000 miles per second?
   - How long would it take a jet to fly to the Moon?
   - How long would it take a jet to fly to the Sun?

6. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Choose one or two for each instructional block, or give one prompt per team.

   - Prompt 1: Explain why the Moon's rotation and revolution take the same amount of time.
   - Prompt 2: Explain what would happen on Earth if the planet were to suddenly fall into a synchronous orbit around the Sun.
   - Prompt 3: The speed at which the Earth is spinning has been slowing down a few seconds per year. In a million years, would the day of rotation be longer or shorter? Explain your thinking.

7. **Real-life situations**
   As homework, ask students to look in the newspaper or online to find the times of sunrise and sunset. Ask them to graph the times over the period of a week.

Instruction Block Three

Phases and the Moon's Orbit

Square Three concepts—*Students will:*

- Understand that one-half of the Moon is lit by the Sun at all times
- Understand that the appearance of the Moon changes as it moves in its orbit around the Earth
- Understand that the predictable changes in the appearance of the Moon are called **phases**
- Understand what it means when the Moon is **waxing** or **waning**
- Understand that the Moon's phases have a predictable order: **new**, **waxing crescent**, **first quarter**, **waxing gibbous**, **full**, **waning gibbous**, **last (third) quarter**, and **waning crescent**

Materials

- Red square—*one per student*
- Glue or tape—*one per team*
- Styrofoam ball model of the Moon—*one per team*
- Sheet of paper to roll into a "telescope"—*one per student*

Reproducible handouts

What Do You See?—*one per team*

Phases of the Moon Flash Cards—*one per student*

Galileo's Observation: Activity Sheet 1—*five per team*

Galileo's Observation: Activity Sheet 2—*one per team*

Essay 3: Phases of the Moon—*one per student*

Stop/Think/Draw/Write 3—*one per student*

Quick Team Quiz 3—*one per student*

Square Three Test—*one per student*

Lesson plan schedule

- Awarding Squares
- Understanding Galileo's observations
- Working with Models of the Moon
- Essay 3: Phases of the Moon
- Stop/Think/Draw/Write 3
- Phases of the Moon Flash Cards (prepare sets ahead of time)
- Quick Team Quiz 3
- Square Three Test

Lesson Plan

Phases and the Moon's Orbit

1. Awarding Squares

Whole class

and

Small group

- Arrange the room and send students into their teams. If you have not already done so, announce/award the Second Squares (red) to students who have mastered the concepts in Instruction Block Two. Also award First Squares to the students who have caught up and mastered Instruction Block One concepts.
- Assign new student roles, reviewing the duties of each role and the **Cooperative Group Work Rubric**.

2. Optical illusions

Whole class

or

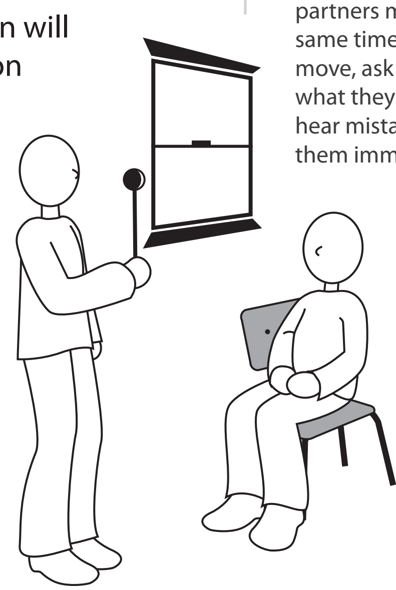
Small group

- Give each Managers one **What Do You See?** handout. Either as a whole-class or team activity, discuss how we look at things but sometimes misperceive what we are looking at. Once we "know" what's going on, we can correct our perceptions.
- Let students understand that looking at different phases of the Moon can be a lot like looking at an optical illusion.

3. Pretending to be Galileo

Teaching tip
Pretending to be Galileo is a whole-class activity. As partners work in the center of the room, the rest of the class should be watching. The repetition helps them remember the phases. For efficiency, have the partners move at the same time and, as they move, ask them to declare what they see so you can hear mistakes and correct them immediately

- Clear a space in the middle of the room. Set three or four chairs in a row separated by 6–8 feet with the chair <u>backs</u> towards the windows. Establish that the windows represent the Sun. The rest of the class should be seated around the chairs.
- Divide teams into groups of two. Give each pair one Moon model. One person of the pair will sit in the chair and the other person will hold one Moon model. Have the person holding the Moon model stand behind the chair with the dark side of the Moon facing out—in other words, with the lit side towards the window (Sun).
- Before sitting down, ask the second member of the pair to look at his/her partner's Moon model and declare what they see. They will say that they see the dark side. Tell them that this phase is the *new Moon*.
- Now ask the partner to sit sideways with his legs on the right side of the chair. Ask the person holding the Moon model to move counterclockwise until he/she is standing in front of his/her seated partner. It is essential that the Moon-model holder keep the white side of the



models facing the "Sun" (the windows). Ask the partner to declare what he/she sees (*half Moon* or *first quarter*).

- Have the seated partner turn so that his/her legs are hanging over the front of the chair. Ask the partner to move counterclockwise to stand in front of his seated partner. Make sure the white side of the model is facing the "Sun." Ask the partner to declare what he/she sees (*full Moon*).
- Ask the partners to move again and declare what they observe (*half Moon* or *third quarter* or *last quarter*).
- Have partners switch roles and repeat. Before they sit down in the class, ask them three questions: "How much of the Moon is always lit?" (Half.) "What caused them to see different phases?" (The position of the Moon in its orbit.) "How long does it take the Moon to revolve around the Earth?" ($29\frac{1}{2}$ days.)
- Repeat for all teams.

4. Galileo's observations

Small group

- Give Managers six copies of **Galileo's Observations: Activity Sheet 1** (the Moon orbit chart) and five copies of **Activity Sheet 2**. Each student will fill in his/her own Moon chart. The extra Moon chart is for the center of the team activity. Also give each team one Styrofoam Moon.
- Ask the Readers in each team to read the directions on **Galileo's Observations: Activity Sheet 2**.
- When all the teams are ready, hand them a Styrofoam model of the Moon. Tell them that the side painted black is the far side of the Moon—the side that is facing away from the Sun. The white side shows the sunlit side.

Important! The Styrofoam models are fragile! Remind students to treat them with care.

5. Work with models of the Moon

- Help students follow directions in steps two through five. Have the Writers shade the dark side of the Moon using a pencil (markers are too messy). When you are certain that students are following the directions, allow them to complete the rest of the directions independently.
- Collect Moon models and store carefully.

6. Essay 3: Phases of the Moon

Whole class

or

Small group

- Give enough copies of **Essay 3: Phases of the Moon** to each team Manager for every member of his/her team.
- Go over the first two paragraphs of the essay as a whole class activity or as a team activity. Tell students to stop after reading **What Galileo saw**.

Discuss the "pock-marked" Moon. Most of the craters were formed years ago, so why didn't they erode away? (No wind or water erosion.) Why do meteors still hit the Moon? (No atmosphere to cause them to burn up.)

- When students finish reading the essay, have them label their shaded drawings. It should reinforce what they discovered on their own. Make certain students understand any new vocabulary introduced: *phase*, *new*, *crescent*, *half* or *quarter*, *gibbous*, *full*, *waxing*, and *waning*.

7. Stop/Think/Draw/Write 3

Individual

or

Small group

- When teams have all experienced what Galileo realized, have them individually or as a team complete the three prompts.
- Allow students 3–4 minutes to complete their work. Have them first 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.
- 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 their explanations were incorrect or confusing.

8. Phases of the Moon Flash Cards

Small group

- You may want to cut out the student **Phases of the Moon Flash Cards** ahead of time. Then all students need to do is fold the cards in half and secure with tape or glue. Otherwise, hand out the sheet and allow students time to cut out and prepare a set.
- Give students time as a team to use the flash cards. It is not necessary for students to know "*waxing crescent*" to earn a three (expected). They need only "*crescent*." However, if you want students to earn a four (exemplary), they need to know *waxing* and *waning phases* and where they occur in the *orbit*.

9. Quick Team Quiz 3

Individual

- Ask the Managers to come to you for **Quick Team Quiz 3**. While students are working individually, walk around the room clarifying and instructing.

Small group

- When the individuals in each team have finished **Quick Team Quiz 3,** the teams should correct their papers. Team members should help other team members who made errors.
- Present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz 3** papers neatly in the team folder and give them to you.

Individual

10. Square Three Test

- Administer the **Square Three Test** to individuals, not teams. Separate desks for privacy. Collect tests when students have finished.
- While students are taking their tests, consider using the time to assess the students' cooperative group work. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.
- Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Three before starting Instruction Block Four. Reteach and retest if necessary.

Square Three Answer Key

Stop/Think/Draw/Write 3

1. Sunlight continually falls on one side of the Moon.
2. The different positions of the Moon in its orbit around the Earth cause it to appear different to observers on Earth.
3. It takes 3–4 days for a phase to change. It takes much less time for the Earth to spin, so the phase doesn't change.

Quick Quiz 3

Oct 4 = full, Oct 8 = gibbous (waning), Oct 11 = last quarter (waning), Oct 14 = crescent (waning), Oct 18 = New, Oct 22 crescent (waxing), Oct 25 1st quarter (waxing), Oct 29 = gibbous (waxing), Nov 2 = full

Using the Moon to Find the Sun

1. Draw the Sun below the horizon to the east.
2. Sunset
3. Sunrise
4. The Sun is shining on the other side of the Earth.

Challenge: 1st quarter Moon is visible during the day and sets after the Sun, third quarter is visible during the day but sets before the Sun.

Square Three Test

1. B	5. D	9. C	13. B
2. B	6. C	10. A	14. A
3. B	7. A	11. B	15. B
4. B	8. E	12. A	16. A

Optional Activities Three

1. **Flash cards**

   - Make a new set of flash cards, separating the fronts from backs. Mount on construction paper and allow students to play "Memory."
   - Directions: Turn all cards face down. The first player turns over two cards and tries to match them. If they match (for example, a diagram of the full Moon and the words "full Moon"), the player keeps the pair. If not, the second player turns over two more cards and tries to match them. Have students race to see who can put the flash cards of different phases in order.

Teaching tip
Have an answer key with which players can check their answers.

2. **Myths and legends**
   Have students write poetry, myths, stories, etc. explaining the phases of the Moon. Here's an example written many years ago, "What the Little Girl Said" from *The Congo, and Other Poems* by Vachel Lindsay, (1879–1931).

   The Moon's the North Wind's cooky.
   He bites it, day by day,
   Until there's but a rim of scraps
   That crumble all away.

   The South Wind is the baker.
   He kneads clouds in his den,
   And bakes a crisp new Moon that greedy
   North Wind eats again!

3. **Research**

   - Create a poster that explains the history of the telescope that Galileo used and how it works.
   - Create a poster that shows the difference between Galileo's telescope and the radio telescopes we use today.
   - Create a poster of the Hubble telescope and explain why this has been so important to modern astronomy.
   - Make a timeline of modern astronomical discoveries from 1900 to today.
   - The full Moon has lots of nicknames, including Harvest Moon, Hunter's Moon, etc. Find other lunar names, when they occur, and the stories behind the names.

4. **Mapmaking**
   Create a labeled map of both sides of the Moon. Include a paragraph that explains the different markings you see on the Moon's surface.

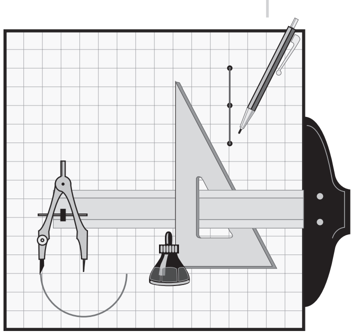
5. **Tides**
   The primary cause of ocean tides is the gravitational pull of the Moon. The Sun's gravitational pull also contributes to the tides. Another cause is the centrifugal force of the Earth as it rotates. Investigate the tides and make a poster explaining these influences.

6. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Choose one or two for each instructional block, or give one prompt per team. Allow students to write for at least three minutes. Direct them to first share what they wrote with their team. Then ask for volunteers to share with the whole class. Look for common comments that students write.

   - Prompt 1: Explain what causes the phases of the Moon.
   - Prompt 2: If the Sun stopped shining, would the Moon be the brightest thing in the sky? Explain your answer.
   - Prompt 3: During the *new Moon*, is the side showing the Man in the Moon facing the Earth, or is it facing away from the Earth? Explain your answer.

7. **Real-life situations**

   - **Tracking the Moon**. Have students keep track of the phases of the Moon over the course of a month. If possible, use the Internet to find the times of moonrise and moonset.
   - **Tracking the tides**. Have students keep track of high and low tides over the course of a week. (Use the Internet or a newspaper to find the times.) Make a graph or chart to show the times, and write a paragraph explaining the time differences. Have them then predict the tides for the next week and check how accurate their predictions were.
   - **Using the Moon to Find the Sun.** Distribute the worksheet found on page 80. Ask students to complete questions 1-4 and the Challenge. Direct students to look for the Moon when they go home and from its location, predict where the Sun must be. In class the next day, ask students to create a drawing to describe what they saw (including neighborhood landmarks) and when they saw it. Ask this same question again two weeks when the phase has changed.



Instruction Block Four

Eclipses

Square Four concepts*—Students will:*

- Understand that sometimes when the Moon passes between the Earth and the Sun, there is a **solar eclipse**
- Understand that sometimes when the Earth passes between the Sun and the Moon, there is a **lunar eclipse**
- Understand that eclipses cannot occur in all phases of the Moon
- Draw two-dimensional drawings of eclipses from models
- Write paragraphs explaining lunar and solar eclipses as demonstrated in models

Materials

- Green Square—*one per student*
- Glue or tape—*one per team*
- Small Styrofoam ball for a model of the Moon—*one per team*
- Medium-sized Styrofoam for a model of the Earth—*one per team*
- Black construction-paper shadows—*one per model*
- Common pins—*three to four per ball*

Reproducible handouts

Discovering Eclipses—*one per student*

Essay 4: Eclipses—*one per student*

Stop/Think/Draw/Write 3—*one per student*

Quick Team Quiz Four—*one per student*

Square Four Test—*one per student*

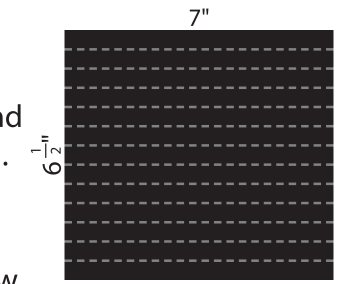
Lesson plan schedule

- Awarding Squares
- Review
- Working with Models of the Moon
- Essay 4: Eclipses
- Stop/Think/Draw/Write
- Quick Team Quiz 4
- Square Four Test
- Awards or Golden Square

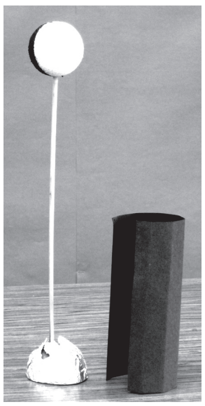
Lesson Plan

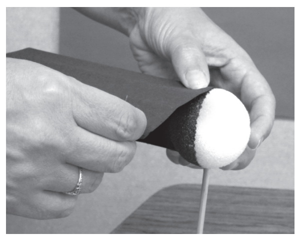
Eclipses

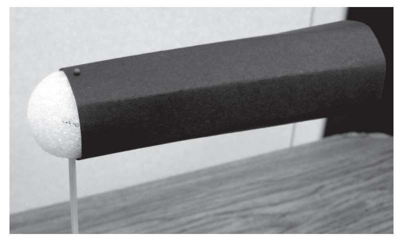
1. Before starting the lesson



- Cut a 6$\frac{1}{2}$" × 7" rectangle of black construction paper for every medium-sized Styrofoam ball, and a 5" × 7" rectangle for every small Styrofoam ball.
- Fold the paper lengthwise every half inch or so.
- Pin the black rectangle along the painted shadow edge of the models, leaving the white side totally uncovered.







2. Awarding Squares

Whole class

- Arrange the room and send students into teams.
- Announce/award the Third Squares (green) to students who have mastered the concepts in Instruction Block Three. Also award squares to the students who have caught up and mastered Instruction Blocks One and Two concepts.
- Assign new student roles, reviewing the duties of each role and the **Cooperative Group Work Rubric**.

3. Review

Take a moment to review what students have learned so far. Congratulate them for their ongoing achievement in understanding:

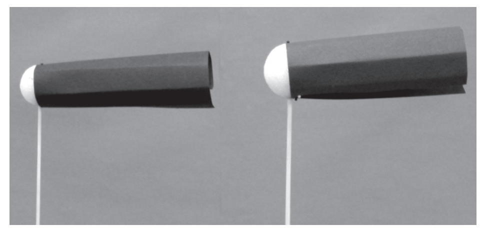
- Heliocentric vs. geocentric views of the solar system
- Elliptical vs. circular orbits
- Relative distances in space between Earth and Sun and between Earth and Moon
- Rotation vs. revolution
- Why the Sun, Moon, and stars all appear to rise in the east and set in the west

- Important numbers including 24 hours, $365\frac{1}{4}$ days, and $29\frac{1}{2}$ days
- Synchronous orbit
- The great speed of Earth's orbit (66,000 m.p.h. compared to the 4400 m.p.h. speed of a bullet)
- Phases and their positions in orbit

4. Work with models

Small group

- Give Managers one Moon model (a small Styrofoam ball) and one Earth model (a larger Styrofoam ball) with eclipse shadows.
- Give them copies of the **Discovering Eclipses** handout. Have teams follow the directions and stop after answering question three.



5. Essay 4: Eclipses

- Give Managers copies of **Essay 4: Eclipses**. Go over the essay as a whole-class activity or as a team activity. Students may do better to read in pairs.
- Be certain that students understand the vocabulary introduced in the essay, including: *eclipse*, *solar eclipse*, *lunar eclipse*, and *partial eclipse*.
- After students have read **Essay 4: Eclipses**, have them complete the last two columns. Collect the models.

6. Stop/Think/Draw/Write 4

Individual or *Small group*

- When teams have completed the **Discovering Eclipses** activity and have read **Essay 4: Eclipses**, have them individually or as a team complete the three prompts.
- Allow students 3–4 minutes to complete their work. Have them first 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.
- 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 their explanations were incorrect or confusing.

7. Quick Team Quiz 4

Individual

- Ask the Managers to come to you for the **Quick Team Quiz 4**. While students are working individually, walk around the room clarifying and instructing.

Small group

- When the individuals in each team have finished **Quick Team Quiz 4**, the teams should correct their papers. Team members should help other team members who made errors.
- Present the correct answers on the board and answer any questions. Tell Leaders to collect all the **Quick Team Quiz 4** papers neatly in the team folders and give them to you.

Individual

8. Square Four Test

- Administer the **Square Four Test** as individuals, not teams. Separate student desks for privacy. Collect tests when students have finished.
- While students are taking their tests, consider using the time to assess the students' cooperative group work. Using the **Cooperative Group Work Rubric** as your guide, assess each student, and assign a number from one to four to describe their cooperative behavior.
- Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Four. This is a cumulative test covering content in Squares One, Two, Three, and Four. You may forego a retest and award a missed square if the student correctly answers the cumulative questions. Reteach and retest if necessary so that everyone masters the content and can be declared "Squared Away."

9. Are you done yet?

- You may stop at this point, having completed the four Squares in *Phases of the Moon*. However, if you want to challenge your students further, you may assign them the Golden Square activities. These are more difficult activities, so you should expect only half or fewer of your students to successfully complete the activities. See the next lesson block for Golden Square activities and challenges.

Individual

10. Posttest

- One week after you finish the unit, give the posttest.

Whole class

11. Awards

- With the successful completion of the **Square Four Test**, students are considered "Squared Away." However, consider waiting until you run the Golden Square Activities 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 complete the four instructional blocks (see page 12). 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' age and your available time and resources. Give **Special Award Certificates** to acknowledge each student's achievement.

12. Square Four Answer Key

Discovering Eclipses

In the first column, the answer is "yes" for the new Moon and "no" for all the others. In the second column, the answer is "yes" for the full Moon and "no" for all the others. In the third column, the answer is "yes" for the full Moon and "no" for all the others. In the fourth column, the answer is "yes" for the new Moon and "no" for all the others.

Stop/Think/Draw/Write 4

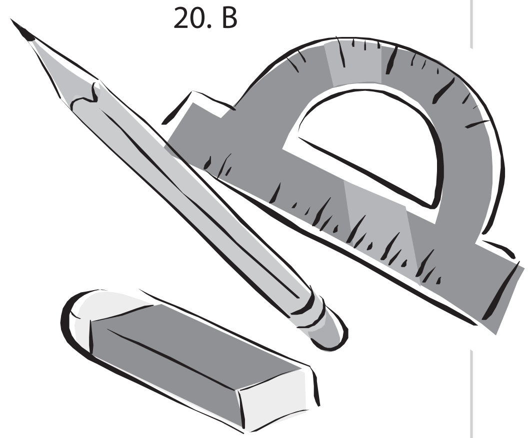
1. Sun, Moon, Earth. Shadows facing away from sun. The Moon's shadow falls on Earth.
2. Sun, Earth, Moon. Shadows facing away from Sun. Moon in Earth's shadow.
3. Shadows fall like parallel lines. The shadows of half Moons never meet the Earth and the Earth's shadow never meets the Moon.

Quick Quiz 4

1. A	4. B	7. B
2. C	5. C	8. C
3. A	6. A	9. A

Square Four Test

1. B	9. C	17. B
2. A	10. D	18. A
3. B	11. A	19. A
4. A	12. B	20. B
5. B	13. E	
6. B	14. C	
7. C	15. C	
8. A	16. A	



Optional Activities Four

1. **Models**
   Create models or posters of lunar and solar eclipses.

2. **Myths, legends, and other writings**

   - Before they had the explanation of science, Native Americans, Vikings, Romans, and others were deeply concerned when the Moon turned "blood red" or something blotted out the Sun on an otherwise sunny day. Using the library or the Internet, research the myths and rituals associated with eclipses.
   - Write a myth of your own to explain eclipses.
   - Write a poem or rap about eclipses.
   - Research and retell a story that relates to eclipses. For example, Mark Twain used the prediction of an eclipse in *A Connecticut Yankee in King Arthur's Court,* and there is a story that Columbus escaped a tough situation in Jamaica by using his knowledge that an eclipse was coming.

3. **Research**
   There is much more information you can learn about eclipses by researching in the library or online. Consider creating posters or models to explain some of the following:

   - Make a poster comparing the different kinds of *solar eclipses,* including *annular eclipses*, *total eclipses*, *hybrid eclipses*, and *partial eclipses*.
   - Make a poster comparing the different kinds *lunar eclipses*, including *total eclipses*, *penumbral eclipses*, and *partial eclipses*.
   - Make a timeline of recorded *lunar* or *solar eclipses*.

4. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Choose one or two for each instructional block, or give one prompt per team. Allow students to write for at least three minutes. Direct them to first share with their team what they wrote. Ask for volunteers to share with the whole class. Look for common comments that students write.

   - Prompt 1: Explain why eclipses do not occur at every phase of the Moon.
   - Prompt 2: Explain why we don't have a lunar eclipse every month.
   - Prompt 3: Why does the Moon turn a reddish color when it passes into the Earth's shadow?

Instruction Block Five

Golden Square Challenge: Phases of Venus

Square Five concepts*—Students will:*

- Understand that the "Morning Star" and the "Evening Star" are actually Venus
- Understand that Venus has phases like the Moon
- Understand that the phases of Venus are caused by its position in its orbit, the position of the Sun, and the position of the Earth—the viewing point
- Appreciate that when Galileo discovered the phases of Venus, he had proof that the geocentric theory of the solar system was wrong, and Venus's phases supported the heliocentric theory

Materials

- Purple Square—*one per student*
- Manila drawing paper (18" x 24")—*one per team*
- Small Styrofoam ball for a model of Venus—*one per team*
- Medium-sized Styrofoam ball for a model of Earth— *one per team*

Reproducible handouts

Discovering Eclipses—*one per student*

Essay 5: Phases of Venus—*one per student*

Venus, Earth, and Sun Activity Sheets—*one per team*

Golden Square Challenges—*one per student*

Stop/Think/Draw/Write Golden Assessment—*one per student*

Lesson plan schedule

- Awarding Squares
- Essay 5: Phases of Venus
- Working with Models of Venus, Earth, and the Sun
- Golden Challenges
- Celebration and awards
- Posttest

Lesson Plan

Golden Square Challenge: Phases of Venus

Whole class

1. Awarding Squares

- Arrange the room and send students into teams. Announce/award the Fourth Squares (purple) to students who have mastered the concepts in Instruction Block Four. Also award squares to the students who have caught up and mastered other block concepts.
- Assign new student roles, reviewing the duties of each role and the **Cooperative Group Work Rubric**.

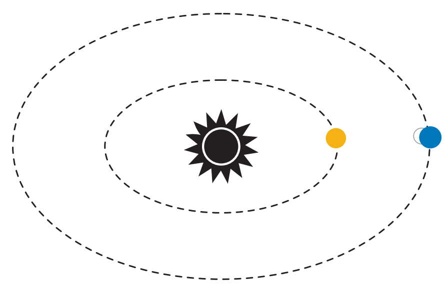
Whole class
or
Small group

2. Essay 5: Phases of Venus

- Give Managers copies of **Essay 5: Phases of Venus**. Go over the essay as a whole class activity or as a team activity.

Small group

3. Working With Models of Venus, Earth, and the Sun



- After students have read the **Essay 5: Phases of Venus**, divide teams into pairs and give managers the handout for **Working with Models of Venus, Earth, and the Sun**. Go over these directions with the whole class. Allow pairs to work with the models and discuss the questions listed on the page one of the activity. Walk around checking and listening in on conversations as teams work. Allow them 15–20 minutes to work with models.

Individual

4. Golden Square Challenges

- Collect the model pages and ask students to separate their desks for privacy before distributing the **Golden Square Challenges**, which are individual challenges. Remind students that because these challenges are more complex, they should take their time, carefully read the questions, and remember what they have learned. With a little thought, they can apply what they know about phases of the Moon to understanding the phases of Venus.
- Consider allowing those students who still have not mastered concepts in Squares One through Four to retake their **Square Tests** before giving them the **Golden Square Challenge**. Remind all students to label their answers.

5. Golden Square Answer Key

Working with Models of Venus, Earth, and the Sun

2. a) Facing the Sun
   b) Half
   c) Always away from the Sun

3. a) The farthest point
   b) The closest point
   c) Halfway around
   d) Between half and new
   e) Between half and full

4. a) Facing the Sun
   b) Half
   c) Its dark side is facing the Earth
   d) Partly because it is so far away, and because the Sun lies directly between Earth and Venus

Golden Square Challenge

Task 1. Shadows are all facing away from the Sun.

Task 2. New is c, crescent is f, half is a, gibbous is e, and full is b.

Task 3. a) C b) B

c) 4 cm d) 26 cm

Task 4. The most accurate answer is "crescent," which is the brightest because it is the closest (except for the new phase, which cannot be seen from Earth. However, "half" is also a reasonable answer because it is a bigger phase and not all that far away.

6. Celebration and Awards

Whole class

- See the Final Award Celebration Information on page 12 of this guide. There are two different awards. Give the first award to students who are "Squared Away." Give the second award to students who are "Squared Away" and who also earned the Golden Square.

7. Posttest

Individual

- At least one week after you finish the unit, give the posttest. Share with students how much they have learned since beginning the unit.

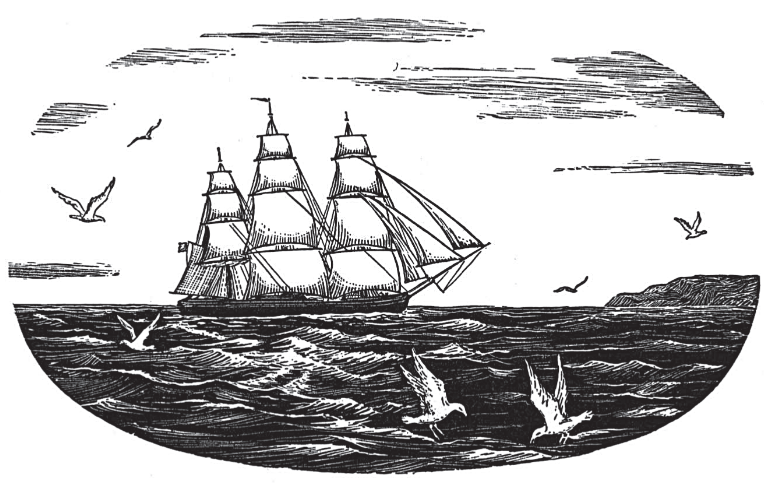
Introduction

"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 eclipses and the phases of the Moon. When you can demonstrate competency working with these concepts, you will be considered "Squared Away."

This unit is divided into five instructional blocks. At the end of each block you will be tested on specific content and skills. When you have demonstrated that 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 test that requires higher level thinking skills.

You will be working in teams of three, four, or five with activities designed to teach you about planetary rotation, the revolution of the Moon around the Earth, and the revolution of the Earth around the Sun. You will learn how the positions of the Earth, Moon, and Sun affect the Moon's phases and the eclipses we see.

You will be working with models that will help you to visualize what is happening in space. You will relate what the models reveal to what you see from Earth. You will also make careful two-dimensional drawings of the models and write paragraphs explaining what you discover. The more thoughtfully you complete these activities, the deeper your understanding will be. Don't miss the opportunity to share what you are learning each day with your parents.



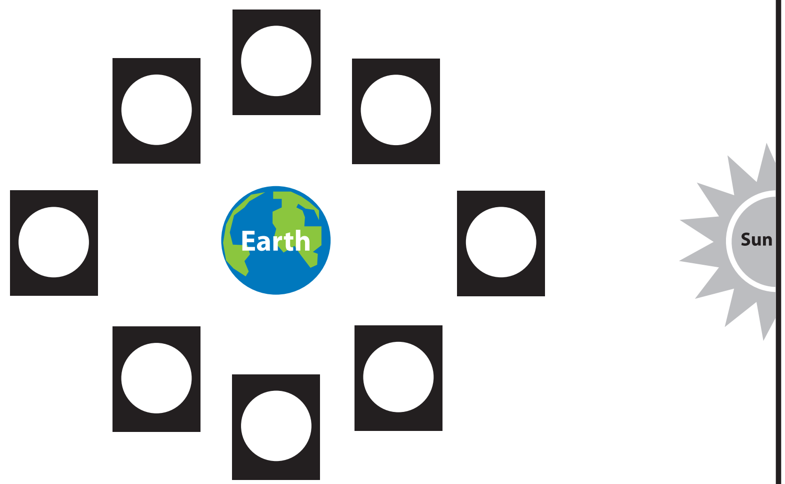
Name: ______________________________ Date: ______________

Pretest/Posttest

Write your answers to the questions in the space to the right. You are encouraged to make drawings with labels to help you answer the questions more completely. Try to show what you know and to use correct spelling in your labels.

Score		
	1. Describe and/or make a drawing to explain the term **rotate**.	
	2. Describe and/or make a drawing to explain the term **revolve**.	
	3. Draw and describe the **heliocentric** theory of the solar system? Label your drawing.	
	4. Draw or describe the **geocentric** theory of the solar system. Label your drawing.	
	5. Which theory (#3 or #4) was proven to be correct?	

	6. Draw and label a **circular orbit** and an **elliptical orbit**.		
	7. What kind of orbit does the Earth have?		
	8. Draw an arrow that shows a counter-clockwise direction.		
	9. How long does it take for the Earth to complete one spin?		
	10. How long does it take for the Moon to complete one spin?		
	11. How long does it take for the Earth to go around the Sun once?		
	12. How long does it take for the Moon to go around the Earth once?		
	13. How much of the Moon is always lit?		
	14. Explain with words and/or labeled drawings what causes the phases of the Moon?		
	15. Explain the difference between **waxing** and **waning**.		
	16. Fill in the blanks with N, S, E, or W (for north, south, east, or west).	The Moon rises in the ____________ and sets in the___________.	

	17. Draw the **phases of the Moon** in order. Label the **phases of the Moon** in order.	
	18. Draw the positions of the Earth, Moon, and Sun for a **solar eclipse**. Draw the **shadows** and label your drawing.	
	19. In what **phase of the Moon** do we have a **solar eclipse**?	
	20. Draw the positions of the Earth, Moon, and Sun for a **lunar eclipse**. Draw the **shadows** and label your drawing.	
	21. In what **phase of the Moon** do we have a **lunar eclipse**?	
	22. Why don't we have a **solar eclipse** every month?	

Cooperative Group Work Rubric

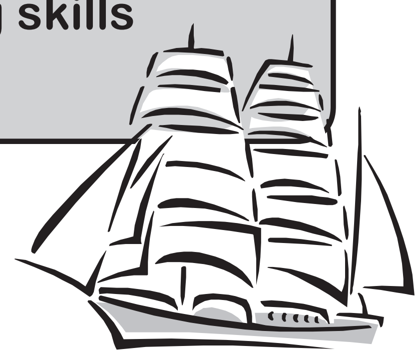
4 **Exemplary**—You *consistently* and *actively* help your classmates achieve their goals whether you are working in a team, with a partner, or by yourself. You communicate well with others, encouraging them and helping them understand the lesson. You *willingly* share materials and responsibilities.

3 **Expected**—You *usually* help your classmates achieve their goals whether you are working in a team, with a partner, or by yourself. You *generally* communicate well with others, encouraging them and helping them understand the lesson. You share materials and responsibilities.

2 **Nearly There**—You *sometimes* help your classmates achieve their goals and help them understand the lesson.

1 **Must Do Better**—You *do very little* to help your classmates achieve their goals or understand the lesson.

If your evaluation is less than expected, try to use your cooperating skills more consistently.



Cooperative Group Work Rubric

	4 Exceeds Expectations	3 Meets Expectations	2 Nearly There	1 Must Do Better
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 work through problems by actively seeking and suggesting solutions.	I often help my team work through problems by seeking and suggesting solutions.	I sometimes help my team work through problems by seeking and suggesting solutions.	I almost never try to help my team find solutions or work through problems,
Staying on-task	I consistently stay on the task and complete the work required.	I usually 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 hardly ever 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 **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 labels were incorrect, or you did not communicate your understanding clearly because of spelling or grammatical errors. You need to redo your work, correcting the errors. You may need to meet with your team or teacher to learn the concept more completely.

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.

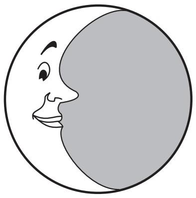
If your evaluation is 2 or 1, strive to correct your work to at least level 3.

Content/Skills Checksheet

Student names																									
Square One Concepts—*Students will:*																									
Understand that ancient astronomers recorded lunar and solar movements and events, and developed theories to explain what they saw																									
Understand the *comparative distances* between the Earth and Moon and between the Earth and Sun																									
Understand the difference between *heliocentric* and *geocentric* theories of the solar system																									
Understand how to make a *scale model*																									
Understand the difference between *elliptical and circular orbits*																									
Use the Internet, especially the NASA Web site, to find graphics and video models of Earth, Moon, and Sun																									
Interpret a fraction in a context																									
Square Two Concepts—*Students will:*																									
Understand that the Sun, Earth, and Moon move in *predictable orbits* at predictable speeds																									
Appreciate that the Earth and the Moon are traveling at a great speed as they orbit																									
Understand the difference between *rotation* and *revolution*																									
Understand the Moon *revolves* around the Earth as the Earth *revolves* around the Sun																									
Understand that the Earth *rotates* approximately every 24 hours (one day)																									
Understand that the Sun and Moon rise in the east and set in the west because of the *counterclockwise rotation* of the Earth																									
Understand that the Earth takes $365\frac{1}{4}$ days to revolve around the Sun (one year)																									
Understand that it takes about $29\frac{1}{2}$ days for the Moon to revolve around the Earth (one month)																									
Understand that the Moon is in a *synchronous orbit*, meaning that its time of revolution and rotation are the same																									
Understand that, because of its synchronous orbit, the same side of the Moon always faces the Earth																									

Content/Skills Checksheet — **Student names**																									
Square Three Concepts—*Students will:*																									
Discover the *phases of the Moon* by moving a ball representing the Moon in an orbit around the position of Earth																									
Understand that one-half of the Moon is lit by the Sun at all times																									
Understand that the appearance of the Moon changes as it moves in its orbit around the earth																									
Understand that the changes in the Moon's appearance are called *phases*																									
Understand what it means when the Moon is *waxing* or *waning*																									
Understand that the Moon phases have a predictable order																									
Estimate the passage of time by the looking at the phases of the Moon																									
Draw two-dimensional drawings of phases from models																									
Identify the different phases of the Moon: *new, waxing crescent, first quarter* (*half*), *waxing gibbous, full, waning gibbous, third quarter* (*half*), *waning crescent*																									
Identify where the Moon is in its orbit by identifying its phase																									
Write a paragraph explaining the phases of the Moon as demonstrated in models																									
Square Four Concepts—*Students will:*																									
Understand that sometimes when the Moon passes between the Earth and the Sun, there is a **solar eclipse**																									
Understand that sometimes when the Earth passes between the Sun and the Moon, there is a **lunar eclipse**																									
Draw two-dimensional drawings of eclipses from models																									
Write paragraphs explaining lunar and solar eclipses as demonstrated in models																									
Golden Squares Concepts—*Students will:*																									
Understand that Venus, like the Moon, has phases																									
Understand that the phases of Venus, like the phases of the Moon, depend on the locations of the Earth, Venus, and Sun																									
Appreciate how Galileo's discovery of the phases of Venus helped to support the theory of a heliocentric solar system																									

Name: ______________________________ Team: ______________



Stop/Think/Draw/Write

(Be sure your labels are spelled correctly)

Essay 1A: Ancient Astronomers

From earliest times, ancient man has watched and recorded the motion of the Sun and Moon across the sky. Most primitive societies created myths and legends to explain the Moon's phases, the path of the Sun, and eclipses. However, thoughtful people long ago understood that there might be answers more accurate than just stories. These ancient astronomers tried to make some sense out of what they saw.

Evidence of ancient astronomers

Archaeologists have found evidence that 30,000 years ago, prehistoric humans started keeping records. There are cave drawings of the night sky in western Siberia. Archaeologists have also found notches on animal bones in France and Africa that marked the cycles of the Moon. These notches were made over 10,000 years ago. They have found calendars based on solar and lunar cycles made by ancient Sumerians in the Middle East and Maya in Central America. Other artifacts and writings also show that, more than two thousand years ago, astronomers from China, India, Egypt, and Greece began to use mathematics to try to create a model of the Earth in the universe.

What did they see?


Ptolemy

When ancient peoples looked at the sky, they had no idea that they were on a planet spinning in space and orbiting the Sun. From their point of view, they were stationary and the heavens moved above them. The Sun and Moon appeared to move across the sky, rising in the east and setting in the west.

In 150 CE*, Ptolemy, a Roman citizen living in Egypt, wrote a book that formalized the theory that the Earth was the center of the universe. He believed the Sun, Moon, and stars all traveled around the Earth. This is a **geocentric,** or Earth-centered, model. It was accepted as true science for the next 1000 years.

What was really happening?

Five hundred years before Ptolemy, Aristarchus of Samos in ancient Greece proposed that the Sun was the center of the universe. This is a **heliocentric,** or Sun-centered, model. However, his work was lost. But in 1543 CE, a Polish astronomer named Copernicus wrote a book presenting the logical arguments for a Sun-centered model. In the 1600s, Johannes Kepler further studied Copernicus's work. He even developed three laws of physics describing how planets orbit the Sun.

The heliocentric theory became controversial in 1632 when Galileo used it and a new invention (the telescope) to explain the night sky. Galileo's scientific views collided with the religious views of the time. However, the Scientific Revolution of the 17th century was underway as Newton, Halley, and others gathered more and more evidence showing the Earth in orbit around the Sun. At the same time in other parts of the world, scientists were using observation, modeling, and mathematics to come to the same conclusion.

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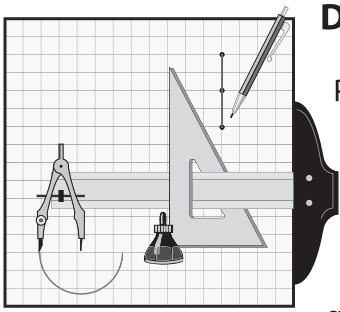
* **CE** means the "Common Era" and is used to describe what used to be called AD (Anno Domini, a Latin phrase meaning "in the year of our Lord"). **BCE** means "Before the Common Era" and is used to describe what used to be called BC (Before Christ).

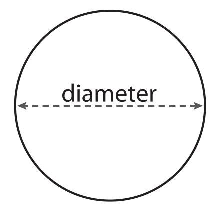
Essay 1B: Measuring the Sun, Earth, and Moon



Diameters of the Sun, Earth, and Moon

Prehistoric men had no clue about the size of the Sun, Moon, or stars, nor did they know how far away these objects were from Earth. Eventually ancient astronomers began to use mathematics to further understand their model of the universe.

About 2400 years ago, a Greek named Erathostenes used simple geometry to estimate the size of the Earth, and his estimate was very close. Others, like Ptolemy, made estimates that were very inaccurate. In the 1600s, Kepler and other scientists used math to make even better estimates. However, it was only recently, with the invention of radar, lasers, satellites, and atomic clocks, that we could very accurately measure the sizes and distances of objects in space.

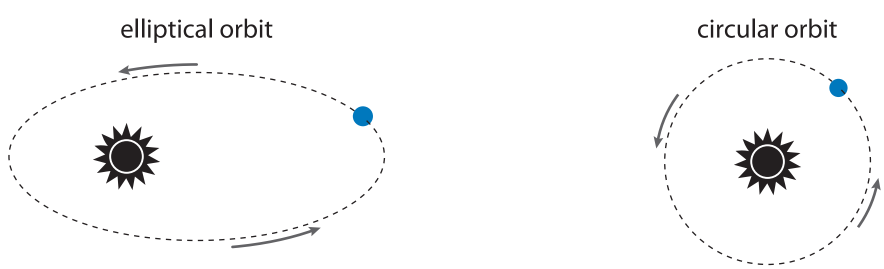


As we now know, the Moon is much smaller than the Earth and tiny compared to the Sun. The following chart shows their diameters:

Diameters (rounded)	Km	Miles
Moon	3500	2200
Earth at the equator	12,800	8000
Sun	1,400,000	870,000

How far away are the Moon and the Sun?

The Earth revolves around Sun in an **elliptical orbit**, not a **circular orbit**. If the Earth's orbit were circular, the distance between the Sun and Earth would always be the same regardless of the time of the year. In an elliptical orbit, the Earth is sometimes closer to, and sometimes farther away, from the Sun. Because the distances vary, we used a number that is the **average** distance.



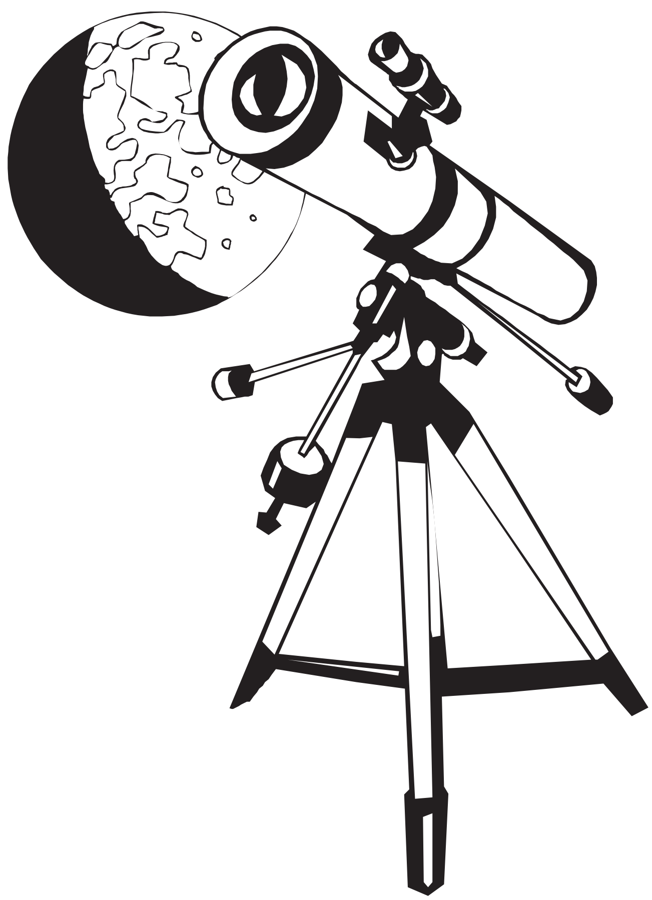
The Moon also travels around the Earth in an elliptical orbit. Depending on the time of the month, the Moon is either closer to or farther away from the Earth. The distance number we use is also an average.

The chart below shows the average distances between the Moon and Earth and between the Earth and Sun.

Average Distances (rounded)	Km	Miles
Moon to Earth	384,400	239,000
Earth to Sun	149,000,000	93,000,000

Making sense of what you see

Every time you look at the night sky, you are not unlike all those ancient astronomers. In this *Squared Away* unit, you will learn to make sense of what you see. You will use observation, mathematics, and models to develop a deeper understanding, specifically, of the phases of the Moon and what happens during an eclipse. Your understanding will be more complete and accurate than the prevailing theories held by some of the greatest minds of history.



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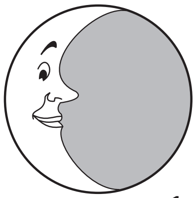


Stop/Think/Draw/Write 1

(Be sure your labels are spelled correctly!)

1. Ancient astronomers were always trying to figure out what they saw in the sky. Two theories emerged. Draw/write about the **heliocentric** and **geocentric** theories. Be sure to label your drawings.

Heliocentric	Geocentric

2. Which theory turned out to be true? ______________________________

3. Draw the Sun and Earth in an elliptical orbit.

Name: ______________________________ Date: ______________

"You Do the Math"

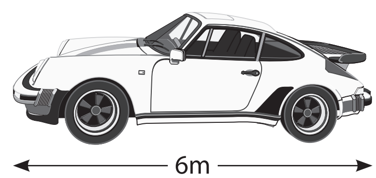
Worksheet for Scale Models

It is not enough just to read a number, especially a large number, and assume you understand what it represents. This is especially true when measuring objects in space. The Moon looks bigger than the Sun, but the Moon is much closer to the Earth than the Sun is. Just how far away is the Moon? How much farther away is the Sun? How does the Moon compare in size to the Earth? To the Sun? Only by making scale models of the Earth, Moon, and Sun can you fully compare and appreciate both the size and distance differences among these three objects in space.

In order to create scale models, you need to get the measurement of an actual object and establish the scale.

How to determine the scale model size

Example 1: The easiest scales are one-to-one scales such as "one meter equals one centimeter." In this scale, if a car were six meters long, then the scale drawing of the car would be six centimeters long.



Example 2: You have worked often with scale when doing map work. In maps, an example of a common scale might be "one centimeter equals one hundred miles." With this scale, you could draw a map of a continent that is 2500 miles long and 1500 miles wide on a sheet of loose-leaf paper, and the scale drawing would only be 25 cm by 15 cm.

Think about this: If the scale were "200 km = 1 cm," how long would your drawing of a 600 km road be? (Hint: How many 200 km sections are in a 600 km road?)

Practice

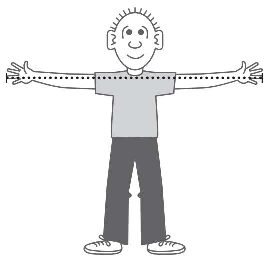
1. If a satellite were orbiting 10,000 km above the Earth, how far would that be on a scale drawing with the scale of "2000 km = 1 cm"?
2. If the scale were "10,000 km = 1 cm," how long a line would you draw to show the 6000 km distance between Chicago and London? (Hint: The answer can be less than one centimeter.)

   This chart shows some big numbers associated with the Earth, Moon, and Sun.

	Moon	Earth	Sun
Average distance from Earth	384,400 km 230,640 miles		149,000,000 km 93,000,000 miles
Actual diameter	3500 km 2200 miles	12,800 km 8000 miles	1,400,000 km 840,000 miles

Name: ______________________________ Date: ______________

Making Scale Models



100 cm = about one arm

Materials for your team

- meter stick
- centimeter ruler
- calculators
- ribbon or string three meters long
- centimeter paper
- scissors

Math Shortcut:

$$\frac{150{,}000}{3000} = \frac{150}{3} = 50$$

Part One

The average distance from the Earth to the Sun equals 93,000,000 miles, or 149,000,000 kilometers.

Do the math to scale the distance from the Earth to the Sun.

Use the scale of 1,000,000 miles (or km) = 1 cm.

$$\frac{\_\_\_\_\_\_\_\_}{1{,}000{,}000} = \_\_\_\_\_\_\_\_\_\_ \text{ cm}$$

Using the answer you calculated in the block above, cut a piece of string or ribbon to scale to show the average scaled distance between the Earth and Sun.

Part Two

The average distance from the Earth to the Moon equals 230,640 miles, or 384,400 kilometers.

Do the math to scale the distance from the Earth to the Moon.

Use the scale of 1,000,000 miles (or km) = 1 cm.

$$\frac{\_\_\_\_\_\_\_\_}{1{,}000{,}000} = \_\_\_\_\_\_\_\_\_\_ \text{ cm}$$

Using the answer you calculated in the block above, cut a piece of string or ribbon to scale to show the average scaled distance between the Earth and the Moon.

Compare the two lengths of string.

CHALLENGE: How many times farther away from the Earth is the Sun, than the Moon? __________

Name: ______________________________ Team: ______________

Quick Quiz 1

1. The **heliocentric** theory of the solar system states that…

   A. the Earth is in the center of the solar system, and the Sun, Moon, and stars move around it

   B. the Sun is in the center of the solar system, and the Moon and Earth move around it

   C. the Moon is the center of the solar system, and the Sun moves from east to west

2. The **geocentric** theory of the solar system states that…

   A. the Earth is in the center of the solar system and the Sun, Moon, and stars move around it

   B. the Sun is in the center of the solar system and the Moon and Earth move around it

   C. the Moon is in the center of the solar system and the Sun moves from east to west

3. What kind of solar system is the Earth in?

   A. Heliocentric

   B. Geocentric

   C. Lunar-centric

4. In an **elliptical orbit**, a planet is sometimes closer and sometimes farther away from its Sun.

   A. True

   B. False

5. In a **circular orbit**, a planet is always the same distance from its Sun.

   A. True

   B. False

6. If the scale is 1 cm = 1000 km, what is the scaled distance for 150,000 km?

   A. 15 cm

   B. 150 cm

   C. 1500 cm

Name: ______________________________ Team: ____________

Square One Test

1. Describe (or draw and label) the **heliocentric** theory of the solar system.

2. Describe (or draw and label) the **geocentric** theory of the solar system.

3. Which theory was proven to be correct? ____________________

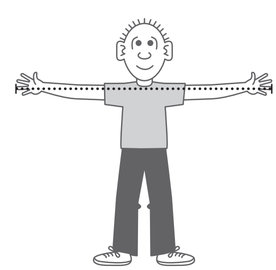
4. Draw and label an **elliptical orbit**.

5. Thinking in terms of scale, if the Earth were almost an arm's length (93 cm) away from the Sun, how far away would the Moon be from the Earth?

   A. Less than a centimeter

   B. Two centimeters

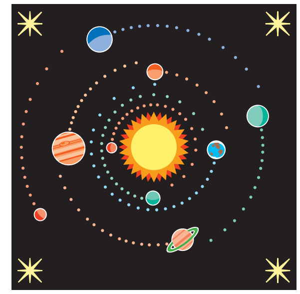
   C. Ten centimeters



100 cm = about one arm

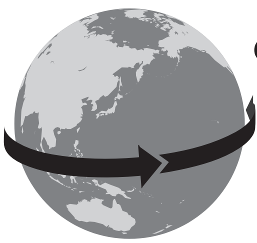
Essay 2: Rotation and Revolution

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 might say that you weren't moving. In fact, you are aboard a planet that is spinning on its axis at a rate of 1000 miles per hour when measured at the equator. At the same time, this same planet is hurtling along its orbit around the Sun at an astounding average speed of 66,000 miles per hour.

Rotation



Objects **rotate** (spin) in space. The Earth, Moon, other planets, the Sun, and the stars all rotate. Their rate of rotation is known and predictable. The Earth spins once every day, just short of 24 hours. The Moon spins once every month. From space, when looking down at their north poles, the Earth and Moon appear to be rotating in a **counterclockwise** direction.

Sunrise, sunset, moonrise, moonset

Because early humans did not know they were on a rotating planet, they misinterpreted the movement of the Sun and Moon across the sky. It appeared that every morning the Sun rose in the east, traveled across the sky, and set in the west. Although the Moon rose at different times during the day and night, it too always rose in the east and set in the west. Early humans thought they had figured things out—the Earth stood still and the sky circled around the Earth—but they were wrong. The Sun was not moving. Instead, the Earth was rotating.

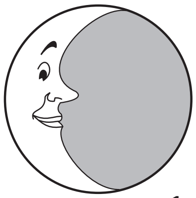
Revolution

In our solar system, the Earth and other planets **revolve** around (**orbit**) the Sun. It takes the Earth a year ($365\frac{1}{4}$ days) to complete its elliptical path around the Sun. The Moon revolves around the Earth once every month ($29\frac{1}{2}$ days). The rates of the Earth's and the Moon's revolutions are known and predictable. To an observer parked in a spaceship and looking down on our solar system from above Earth's north pole, all the planets would appear to be revolving in a counterclockwise direction.

Synchronous orbit

You have probably noticed that the Moon's rotation and revolution both equal one month's time. ($29\frac{1}{2}$ days) That's because the Moon is in a **synchronous orbit**. The Moon spins at the same rate as it orbits the Earth. The result of this synchronous orbit is that the same side of the Moon always faces the Earth. The side we see is the side showing the "Man in the Moon." When we see a half Moon, we are seeing one-half of the "Man in the Moon." No one had ever seen the far side of the Moon before the Soviet Luna 3 probe took a photograph of it in 1959.

Name: ______________________________ Team: ______________



Stop/Think/Draw/Write 2

(Be sure your labels are spelled correctly!)

1. Use drawings and words to describe what it means to *rotate*.

2. Use drawings and words to explain why it appears that the Sun and the Moon rise in the east and set in the west.

3. The Moon is in a *synchronous orbit*. What does that mean?

4. Use drawings and words to explain what it means to *revolve*.

Name: ______________________________ Team: ______________

"You Do the Math"

Comparison of Speed Using Graphs

70,000 m.p.h.				
60,000 m.p.h.				
50,000 m.p.h.				
40,000 m.p.h.				
30,000 m.p.h.				
20,000 m.p.h.				
10,000 m.p.h.				
2000 m.p.h.				
Miles per hour speeds are averaged and rounded	Jet (600 m.p.h.)	Bullet (3000 m.p.h.)	Space shuttle (17,000 m.p.h.)	Earth in its orbit (66,000 m.p.h.)

Name: ______________________________ Team: ______________

Quick Quiz 2

Write the letter of your answer on the line. Choose your answers from the list on the right. You may use a letter **more than once** and some answers you will not use at all.

1. To revolve means to ______
2. To rotate means ______
3. The Sun rises in the ______
4. The Moon rises in the ______
5. The Moon sets in the ______
6. The Sun passes across the sky because of ______
7. The time it takes for Earth to rotate once is ______
8. The time it takes for Moon to rotate once is ______
9. The time it takes for the Earth to go around the Sun once is ______
10. The time it takes the Moon to go around the Earth once is ______
11. Length of a day ______
12. Length of year ______

A. 24 hours
B. 24 days
C. $29\frac{1}{2}$ hours
D. $29\frac{1}{2}$ days
E. $365\frac{1}{4}$ hours
F. $365\frac{1}{4}$ days
G. Spin
H. Synchronous
I. Elliptical
J. Orbit, or go around
K. West
L. South
M. East
N. North
O. Rotation of the Earth
P. Revolution of the Earth
Q. Revolution of the Moon

Name: ______________________________ Team: ______________

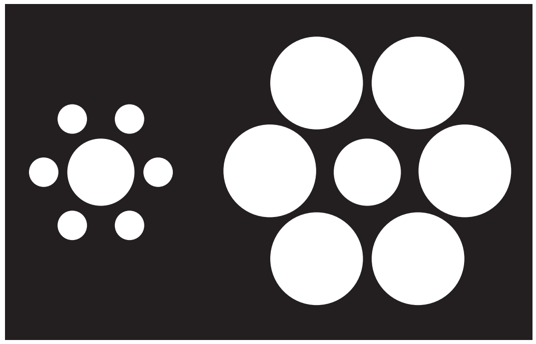
Square Two Test

1. To **revolve** means to…
   A. orbit
   B. spin
   C. go backwards
2. To **rotate** means to…
   A. orbit
   B. spin
   C. go backwards
3. The Sun rises in the east and sets in the west because…
   A. the Sun moves around the Earth in a counterclockwise direction
   B. the Earth moves around the Sun in a counterclockwise direction
   C. the Earth spins in a counterclockwise direction
4. How long does it take the Earth to *rotate* once?
   A. $29\frac{1}{2}$ days B. $365\frac{1}{4}$ days C. 24 hours
5. The Moon rises in the…
   A. north B. east C. west
6. How long does it take the Earth to **revolve** once?
   A. $29\frac{1}{2}$ days B. $365\frac{1}{4}$ days C. 24 hours
7. How long does it take the Moon to go around the Earth once?
   A. $29\frac{1}{2}$ days B. $365\frac{1}{4}$ days C. 24 hours
8. The Moon rotates and revolves in the same amount of time because…
   A. it spins counterclockwise
   B. it is in a synchronous orbit
   C. it is in an elliptical orbit

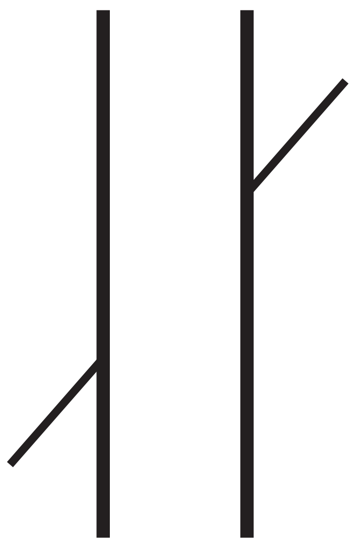
Name: ____________________ Date: ____________

What Do You See?

Which center circle is bigger?

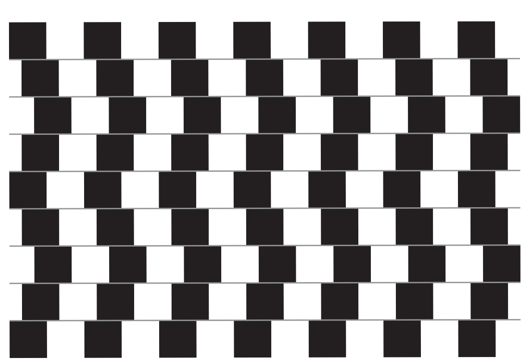


If you extend the lines, will the diagonal line on the right meet the diagonal line on the left?



Which of the two line segments is longer?

Do the horizontal lines run straight across the page, or do they slope?

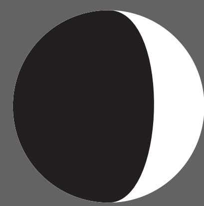


Phases of the Moon Flash Cards

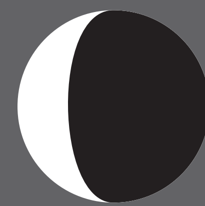
Directions: Cut on the black dashed lines and fold on the white dashed lines to create flash cards.

Top

Top



Top

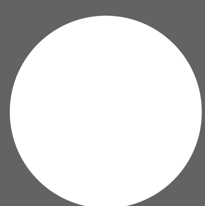


New

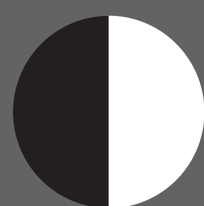
Waxing crescent

Waning crescent

Top



Top



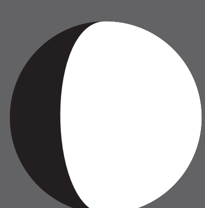
Top

Full

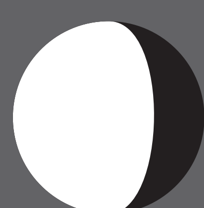
Waxing half
1st quarter

Waxing half
3rd quarter

Top



Top



Top

Waxing =

Waning =

Waxing gibbous

Waning gibbous

"Waxing" means
getting bigger.

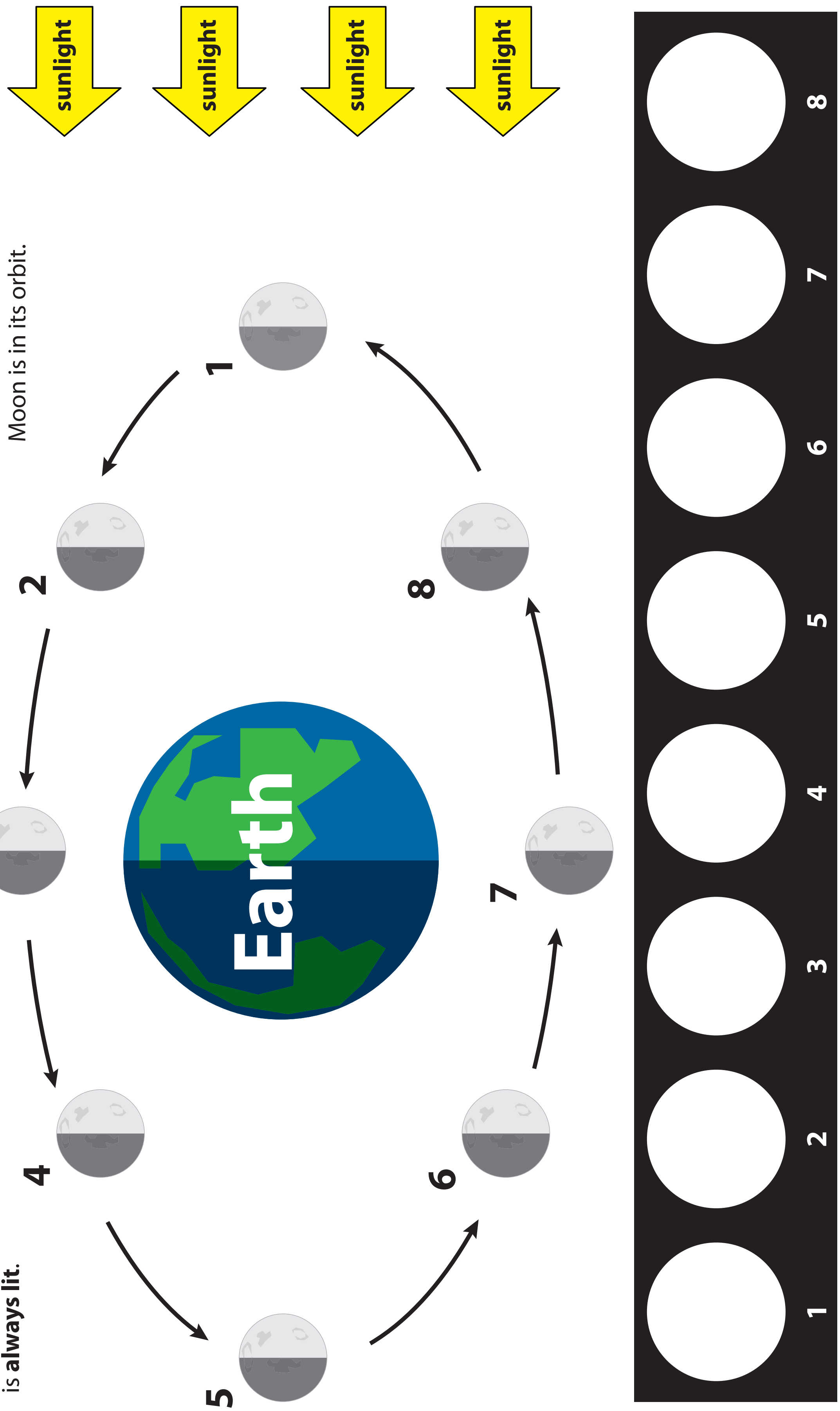
"Waning" means
getting smaller.

Name: ____________________ Team: ____________________

Galileo's Observations: Activity Sheet 1

What we see changes because of where the Moon is in its orbit.

$\frac{1}{2}$ of the Moon is **always lit.**



Galileo's Observations: Activity Sheet 2

In 1610, Galileo first began to use the telescope. He observed the Moon, other planets with their moons, and the stars of the Milky Way. Although a self-educated scientist, Galileo was also a trained artist. He created detailed notebooks of what he saw.

Today you are going to re-create Galileo's observations.

1. Put one copy of Activity Sheet 1 (Moon-orbit diagram) in the center of a desk or table. Each team member should also keep one sheet to complete as an individual activity.
2. Place your Moon model in position one. Be certain the light side of the Moon is facing the side marked "Sun."
3. Roll a piece of paper to make your "telescope," stand as if you were standing on the Earth, and make sure your telescope is at the same height as your Moon.
4. Look through the telescope. Let everyone in your team stand at the same position and look through their telescopes. If your team has done this correctly, you should all have seen a totally dark Moon. Draw what you see by shading in all of the Moon shape in position 1 on Activity Sheet 1.

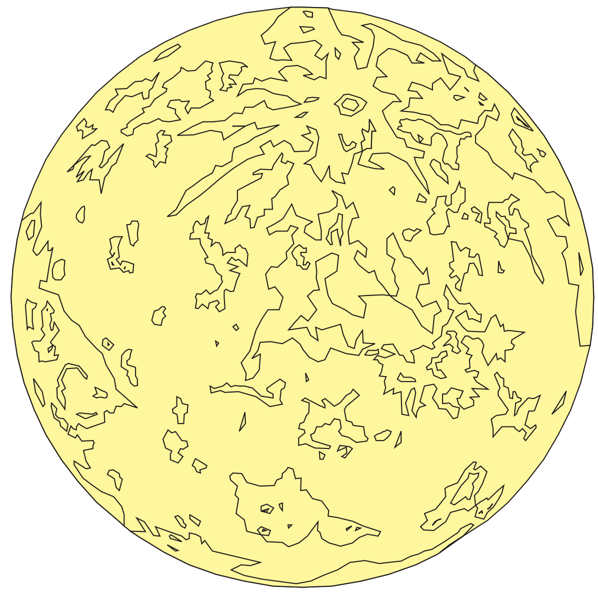
5. Move your Moon counterclockwise to the second position. Be certain the light side of the Moon is still facing the side marked "Sun." You must move to stand as if you were standing on Earth.
6. Repeat steps three and four, this time shading in position 2 on Activity Sheet 1. This time, a narrow slice of the right side of the Moon should be lit. Leave that slice of the Moon white. Shade <u>only</u> the black part you see. Keep track of whether the left or right side is lit.
7. Continue moving the Moon counterclockwise, observing and drawing. You should all check your team's work as they shade less and less of the Moon until the whole Moon is visible at position 5. Starting with position 6, more and more of the Moon will be shaded. Note that it is now the right side that is shaded.
8. After you read **Essay 3: Phases of the Moon,** you will come back to label your drawings.

Essay 3: Phases of the Moon

Although ancient astronomers observed and recorded the Moon's phases, it was Galileo who first observed them through a telescope and made detailed drawings of what he saw.

What Galileo saw

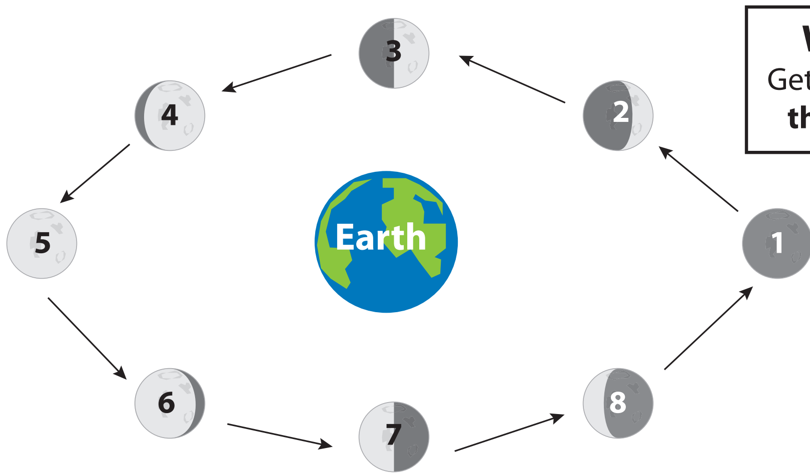
Aristotle and other ancients thought the Moon was like a beautiful pearl hanging in the sky. Through the telescope, Galileo could see that the Moon was not a smooth sphere. The light and dark blotches he saw looked like mountains and seas. In fact, when early scientists made maps of the Moon's surface, they used names such as Montes Apenninus (Apennine Mountains), Oceanus Procellarum (Ocean of Storms), and Mare Tranquillitatis (Sea of Tranquility). The Moon's surface does not contain any seas or oceans, but is marked by huge craters caused by meteors smashing into the surface.



Phases of the Moon

Galileo realized that the Moon does not make its own light. Rather, moonlight is reflected light from the Sun. Therefore, one-half of the Moon is always lit by the Sun, but what we see from Earth looks different each night of the month.

As Galileo made careful drawings of the phases of the Moon, he realized that it was the position of the Moon in its orbit that caused the different appearances of the Moon over the course of one month. At the beginning of its orbit, we see none of the lit side (**new Moon**, position 1), and halfway around the Moon's orbit we see all of its lit side (**full Moon**, position 5). In between those two phases are the nearly full (**gibbous Moon**, positions 4 and 6), half full (**half Moon** or **quarter Moon**, positions 3 and 7), and a sliver of a moon (**crescent Moon**, positions 2 and 8).



Waxing—
Getting larger **on the right side**

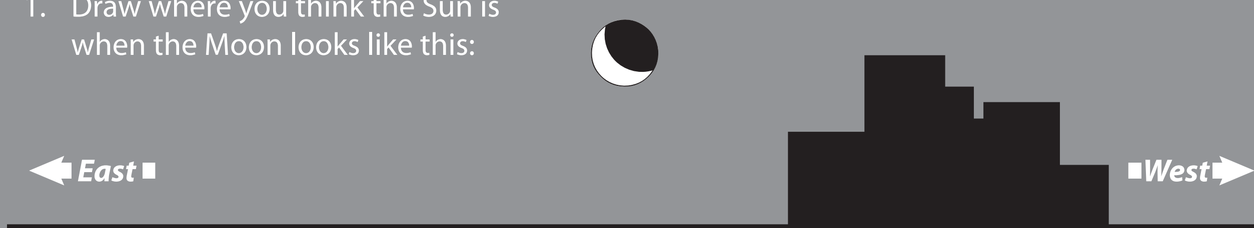
Name: ______________________________________ Date: ______________

Using the Moon to Find the Sun

Look at the angle of the Moon and you can find the Sun.

In your mind, draw two lines forward from the edge of the crescent.
You can tell that the Sun is below the horizon in the west.

1. Draw where you think the Sun is when the Moon looks like this:

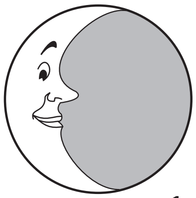


2. In the first box, what time is it: sunrise or sunset? ____________________
3. In the second box, what time is it: sunrise or sunset? __________________
4. The full Moon rises at sunset and sets at sunrise. When it is directly overhead, where is the Sun?

   ____

5. Think about quarter Moons. Make two drawings like the ones above on the back of this page. In the first drawing, draw the first-quarter Moon and the Sun. In the second drawing, draw the third-quarter Moon and the Sun.

Name: ______________________________ Team: ____________



Stop/Think/Draw/Write 3

(Be sure your labels are spelled correctly!)

1. Explain why one-half of the Moon is always lit.

2. Use words and drawings to explain why we have different phases of the Moon.

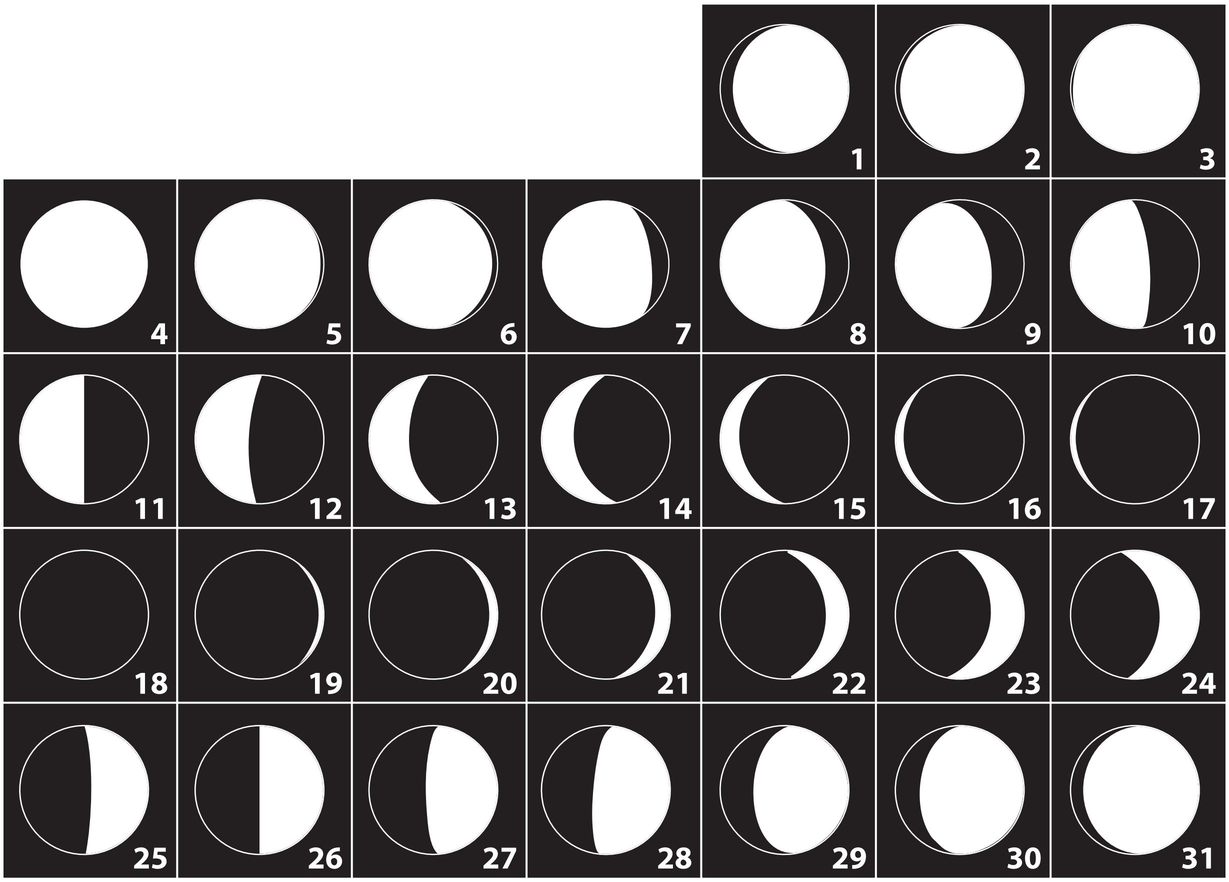
3. Explain why it is the same phase of the Moon in Australia as it is in the USA.

Name: ______________________________ Team: ______________

Quick Quiz 3

October

Sunday Monday Tuesday Wednesday Thursday Friday Saturday



Look at the calendar above. Write the phase of the Moon for the dates listed below:

crescent full gibbous quarter (first or last)

Add the following words to earn a higher score:

waxing waning

Oct. 4 ______________________

Oct. 8 ______________________

Oct. 11 ______________________

Oct. 14 ______________________

Oct. 18 ______________________

Oct. 22 ______________________

Oct. 25 ______________________

Oct. 29 ______________________

Nov. 1 ______________________

Name: ______________________________ Team: ______________

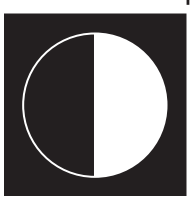
Square Three Test

1. The phases of the Moon are caused by…
   - A. the shadow cast by the Earth on the Moon
   - B. the position of the Moon in its orbit
   - C. the rotation of the Earth in 24 hours

2. How much of the Moon is always lit?
   - A. Most of it
   - B. Half of it
   - C. Depends on where it is in its orbit

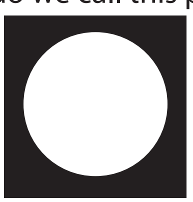
3. What does **waning** mean?
   - A. Getting bigger
   - B. Getting smaller

4. What do we call this phase of the Moon?



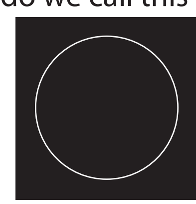
   - A. Gibbous
   - B. Half
   - C. New
   - D. Full
   - E. Crescent

5. What do we call this phase of the Moon?



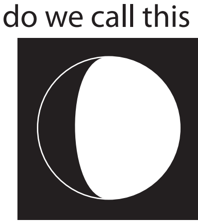
   - A. Gibbous
   - B. Half
   - C. New
   - D. Full
   - E. Crescent

6. What do we call this phase of the Moon?



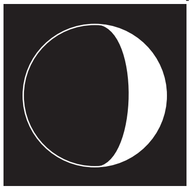
   - A. Gibbous
   - B. Half
   - C. New
   - D. Full
   - E. Crescent

7. What do we call this phase of the Moon?



   - A. Gibbous
   - B. Half
   - C. New
   - D. Full
   - E. Crescent

8. What do we call this phase of the Moon?



A. Gibbous
B. Half
C. New
D. Full
E. Crescent

9. How long does it take for the Moon to change from one full Moon to the next?

A. 24 hours
B. 14 days
C. $29\frac{1}{2}$ days

10. How long does it take the Moon to **rotate** once?

A. $29\frac{1}{2}$ days
B. $365\frac{1}{4}$ days
C. 24 hours

11. How long does it take the Earth to **revolve** once?

A. $29\frac{1}{2}$ days
B. $365\frac{1}{4}$ days
C. 24 hours

12. How long does it take the Moon to go around the Earth once?

A. $29\frac{1}{2}$ days
B. $365\frac{1}{4}$ days
C. 24 hours

13. The Moon rotates and revolves in the same amount of time because…

A. it spins counterclockwise
B. it is in a synchronous orbit
C. it is in an elliptical orbit

14. To **revolve** means to...

A. orbit
B. spin
C. go backwards

15. To **rotate** means to...

A. orbit
B. spin
C. go backwards

16. Because of the Moon's **synchronous orbit**…

A. the same side of the Moon always faces Earth
B. the phases are different in the northern and southern hemispheres
C. the Moon always rises in the east

Name: ______________________________ Team: ______________

Discovering Eclipses

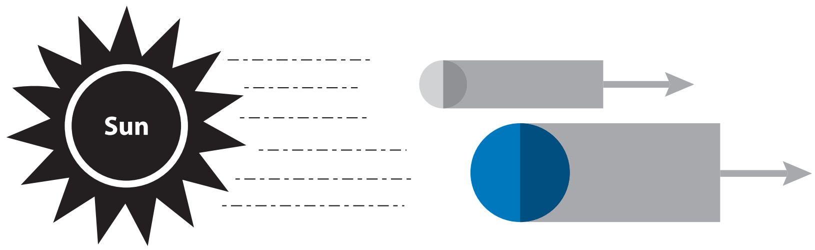
1. Put the Earth in the center of your table. Align its shadow to face away from the Sun.
2. Move the Moon model to the **new Moon** position. Be certain its shadow faces away from the Sun.
3. For each Moon phase, fill in the first two empty columns of the chart below:
4. After reading **Essay 4: Eclipses**, fill in the last two columns.

Phase	**Yes or No** Might the Moon's shadow fall on the Earth?	**Yes or No** Might the Earth's shadow fall on the Moon?	**Yes or No** Possible **lunar eclipse**?	**Yes or No** Possible **solar eclipse**?
New Moon				
Waxing crescent Moon				
First-quarter Moon				
Waxing gibbous Moon				
Full Moon				
Waning gibbous Moon				
Third-quarter Moon				
Waning crescent Moon				

Essay 4: Eclipses

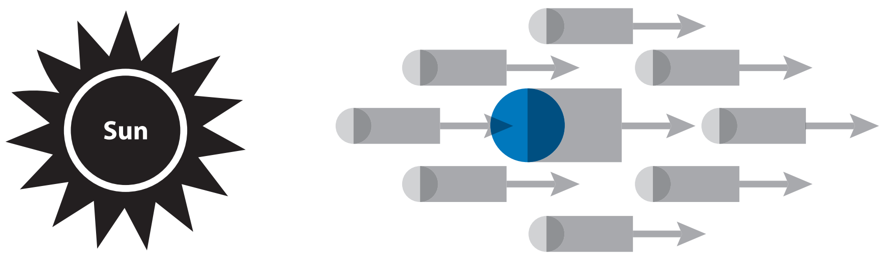
From your experiences with Moon models, you know that the phases of the Moon are not caused by shadows from the Earth. However, shadows are the key to eclipses. As you remember, one half of the Moon and the Earth are lit by the Sun at all times. When sunlight reaches the Moon and the Earth, a huge shadow forms behind them.

Remember, all shadows fall directly behind the lit object. Lines formed by the shadows of two objects side by side will run parallel and never cross.



Where and when do eclipses happen?

Think about the Earth and Moon in space. Picture them with sunlit sides facing the Sun and shadows behind them trailing away from the Sun. The diagram below shows the Moon in all its phases. There is only one place where the Moon's shadow might fall on the Earth, and only one place where the Earth's shadow might fall on the Moon. At these two places, there may be an eclipse.



What is a lunar eclipse?

Look above to see how the Sun, Earth, and Moon must be arranged in order for the Earth's shadow to fall on the Moon. Which phase would that be?

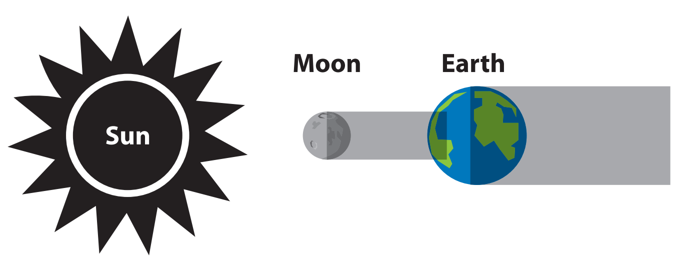
____

In a lunar eclipse, the Moon moves into the shadow behind the Earth.

What is a solar eclipse?

Look at the diagram on the previous page to see how the Sun, Earth, and Moon must be arranged in order for the Moon's shadow to fall on the Earth. Which phase would that be?

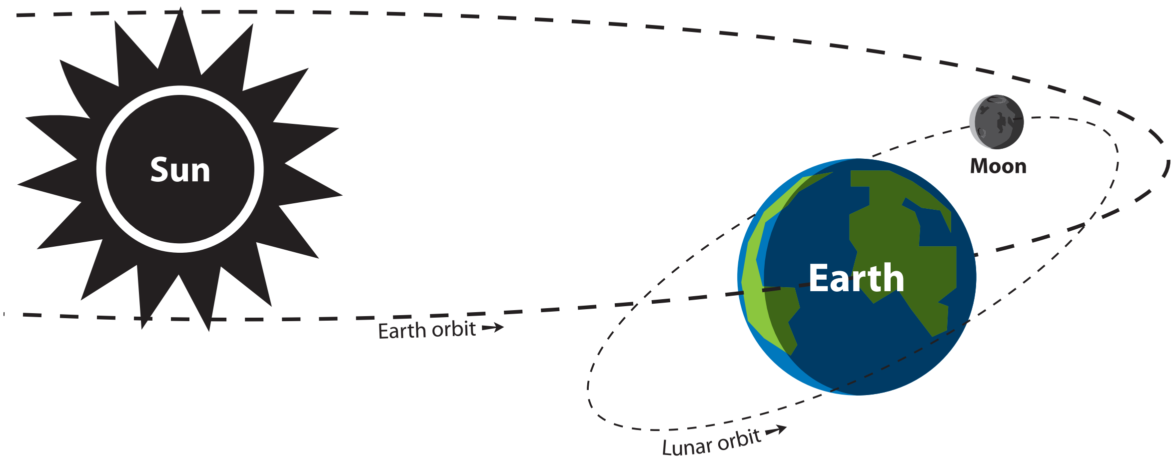
____



In a solar eclipse, the Moon moves so that its shadow falls on the Earth, blocking our view of the Sun.

Why don't we have eclipses every month?

The Moon's orbit does not line up directly with the Earth's orbit. In fact, its orbit is tilted about five degrees out of the plane of the Earth's orbit. This means that in most months, the Moon and its shadow are either above or below the Earth, and also above or below the shadow of the Earth.

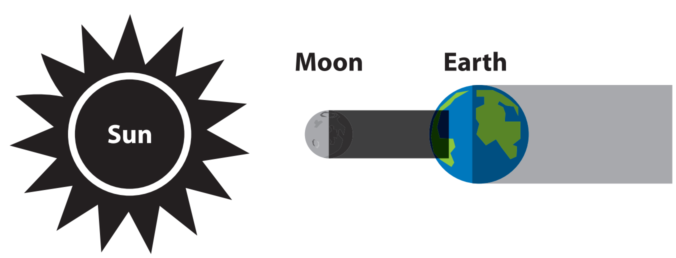


How often do we have lunar eclipses?

Lunar eclipses occur predictably, but not every year. Sometimes there are two to four a year, followed by a long period when there are none. When there is a lunar eclipse, everyone on the night side of the Earth can see it. When there is a total lunar eclipse, the entire Moon travels into the shadow of the Earth and appears to turn a deep shade of red.

How often do we have solar eclipses?

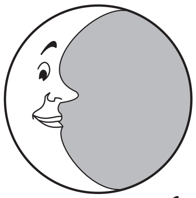
We have a solar eclipse somewhere on the daylight side of the Earth two to five times a year. However, because the Moon is small compared to the Earth, it blocks the Sun totally in only a small area of the Earth. Therefore, when a total solar eclipse occurs, only a small number of people on Earth actually see it.



Are all eclipses total eclipses?

No, we usually have partial eclipses. That means sometimes the Earth's shadow only covers a piece of the Moon, and sometimes the Moon blocks only a part of the Sun from view.

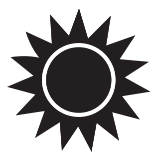
Name: ______________________________ Team: ____________



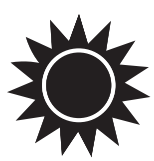
Stop/Think/Draw/Write 4

(Be sure your labels are spelled correctly!)

1. Add the Moon and the Earth to the Sun drawing below. Draw their shadows to show a **solar eclipse**.



2. Add the Moon and the Earth to the Sun drawing below. Draw their shadows to show a **lunar eclipse**.



3. Explain why we don't have an eclipse when the Moon is in a first- or third-quarter phase.

Name: ______________________________ Team: ______________

Quick Quiz 4

1. We can have a **lunar eclipse** when the Moon's phase is…

   A. full B. half C. new

2. We can have a **solar eclipse** when the Moon's phase is…

   A. full B. half C. new

3. **Solar** means having to do with the…

   A. Sun B. Moon C. Earth

4. **Lunar** means having to do with the…

   A. Sun B. Moon C. Earth

5. **Geo-** means having to do with the…

   A. Sun B. Moon C. Earth

6. During a **total eclipse of the Sun**, only a small part of the Earth sees the Sun blocked.

   A. True B. False

7. During a **total eclipse of the Moon**, only a very small part of the Earth sees the Moon in shadow.

   A. True B. False

8. During a **lunar eclipse**, the Moon…

   A. disappears

   B. blocks the Sun

   C. turns dark red

9. We don' t have a **solar eclipse** every month because…

   A. the Moon's shadow is above or below the Earth's orbit

   B. the sky is too cloudy

   C. the Earth's shadow is too small

Name: ______________________________ Team: ______________

Square Four Test

1. What does **lunar** mean? Having to do with the…
   A. Sun B. Moon C. Earth

2. What does **solar** mean? Having to do with the…
   A. Sun B. Moon C. Earth

3. When you draw a model of a **lunar eclipse**, what is the order for the Sun, Moon, and Earth?
   A. Sun, Moon, Earth B. Sun, Earth, Moon C. Earth, Sun, Moon

4. When you draw a model of a **solar eclipse**, what is the order for the Sun, Moon, and Earth?
   A. Sun, Moon, Earth B. Sun, Earth, Moon C. Earth, Sun, Moon

5. We don't have an **eclipse** every month because…
   A. the Earth's shadow doesn't reach the Moon
   B. the Moon's shadow is usually above or below the plane of the Earth's orbit of the sun
   C. the Moon is traveling too fast

6. How much of the Moon is always lit?
   A. Most of it
   B. Half of it
   C. Depends on where it is in its orbit

7. The **phases of the Moon** are caused by…
   A. the shadow cast by the Earth on the Moon
   B. the rotation of the Earth in 24 hours
   C. the changing position of the Moon in its orbit

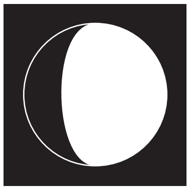
8. A **solar eclipse** occurs during which phase of the Moon?
   A. New B. Half C. Full D. Gibbous

9. A **lunar eclipse** occurs during which phase of the Moon?
   A. New B. Half C. Full D. Gibbous

10. What do we call this **phase** of the Moon?

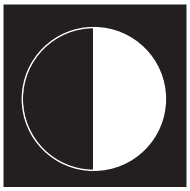
   A. Gibbous D. Full
   B. Half E. Crescent
   C. New

11. What do we call this **phase** of the Moon?



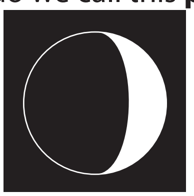
A. Gibbous
B. Half
C. New
D. Full
E. Crescent

12. What do we call this **phase** of the Moon?



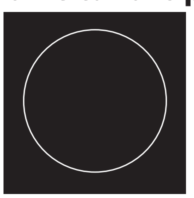
A. Gibbous
B. Half
C. New
D. Full
E. Crescent

13. What do we call this **phase** of the Moon?



A. Gibbous
B. Half
C. New
D. Full
E. Crescent

14. What do we call this **phase** of the Moon?



A. Gibbous
B. Half
C. New
D. Full
E. Crescent

15. How long does it take for the Moon to change from one **full Moon** to the next **full Moon**?

A. 24 hours
B. 14 days
C. $29\frac{1}{2}$ days

16. To **revolve** means to…

A. orbit
B. spin
C. go backwards

17. How long does it take the Earth to **revolve** once?

A. $29\frac{1}{2}$ days
B. $365\frac{1}{4}$ days
C. 24 hours

18. How long does it take the Moon to go around the Earth once?

A. $29\frac{1}{2}$ days
B. $365\frac{1}{4}$ days
C. 24 hours

19. Because of the Moon's **synchronous orbit**…

A. the same side of the Moon always faces Earth
B. the Moon's phases look different in Earth's northern and southern hemispheres
C. the Moon always rises in the east

20. To **rotate** means to…

A. orbit
B. spin
C. go backwards

Essay 5: Phases of Venus

What the telescope revealed

In 1610, Galileo aimed his new telescope to watch a bright "star" that appeared at sunrise and sunset. Like most astronomers of his day, Galileo already knew that this was not a star at all, but a planet named Venus. This planet was only visible in the twilight just before sunrise or just after sunset.

Phases

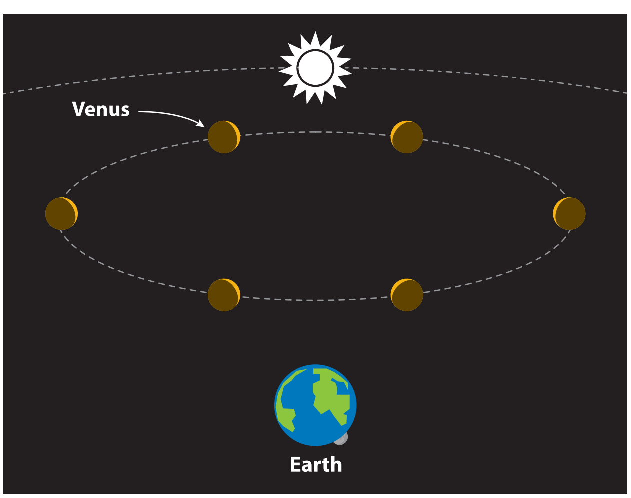
Galileo knew from watching without a telescope that this morning and evening "star" sometimes appeared brighter and sometimes dimmer. With his telescope he was able to see that Venus first appeared as a full sphere. Then over time, it appeared to be a half-sphere. With more time, it became crescent-shaped. Galileo realized that Venus, like the Moon, had phases.

Something unexpected

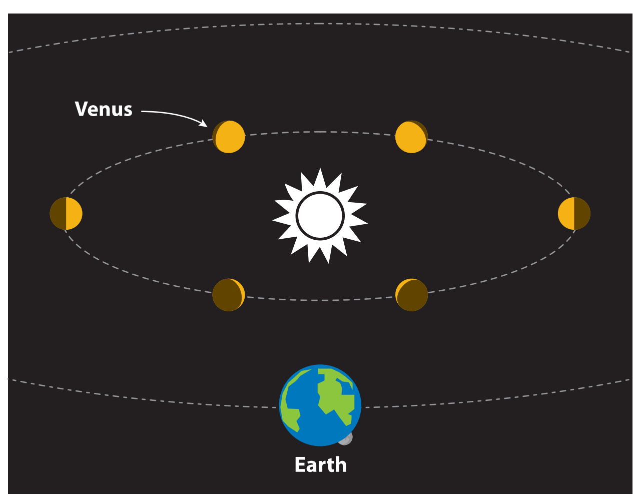
Galileo knew that as the Moon's phases grew, moonlight became brighter and brighter. The full Moon was the brightest phase. However, that was not true of Venus's phases. As Venus's phases became smaller, Galileo realized that the planet was actually getting brighter. He assumed correctly that the increased brightness was because Venus was getting closer to Earth. At some point, Venus disappeared, and Galileo figured that it disappeared into its "new" phase. Later Venus reappeared, but this time as a morning "star," and again it was a bright crescent. As the planet grew larger to a half phase and still larger to a gibbous phase, it grew dimmer and harder to see, because Venus was moving farther and farther away. Galileo never saw Venus in its "full" phase because, when the planet was a full sphere, it lay directly on the opposite side of the Sun from Earth, and so it was impossible to see.

Geocentric vs. heliocentric theories

Galileo's discovery of the phases of Venus added evidence to the theory that we live in a **heliocentric** solar system, because if the Earth were the center of the Solar System, Venus would always be between the Earth and Sun and always appear the same—a crescent.



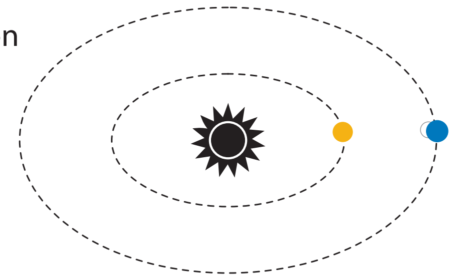
Geocentric System



Heliocentric System

Name: ______________________________ Date: ______________

Working With Models of Venus, Earth, and the Sun



Directions: The following activity will help prepare you to work on the Golden Square Challenge by yourself. Work with your partner and use the models and questions to help you discover what Galileo discovered 400 years ago.

1. Cut out the little circle marked **Venus** and place it on the inside orbit between the Sun and Earth. This is Venus.

2. Move Venus around its orbit and discuss the following questions: Remember to keep Venus's lit side toward the Sun.

   a) In each position, where is Venus's sunlit side?

   b) How much of Venus is always lit?

   c) Where is the shadow of Venus pointing?

3. When we look at the Moon from Earth, the Moon phases change when the Moon changes its position in its orbit around the Earth. When we look at Venus from Earth, we can watch Venus as it changes its position in its orbit around the Sun. Assume you looking at Venus from Earth, and then discuss the following questions:

   a) Where would you expect the **full** Venus?

   b) Where would you expect the **new** Venus?

   c) Where would you expect a **half** Venus?

   d) Where would you expect the **crescent** Venus?

   e) Where would you expect the **gibbous** Venus?

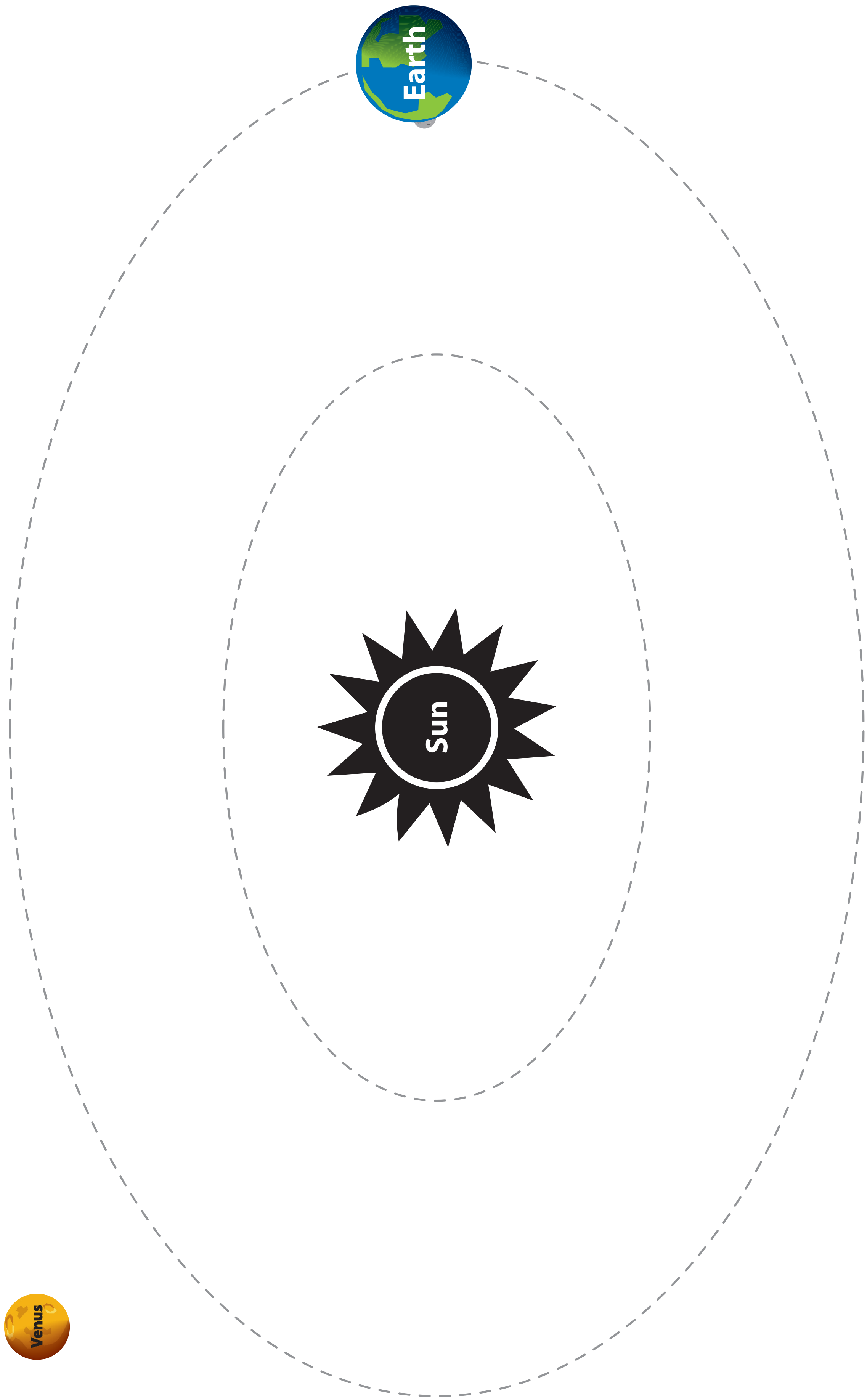
4. We also talked about distances in space. Discuss these questions:

   a) Where is Venus when it is farthest away from Earth?

   b) Where is Venus when it is closest to Earth?

   c) Why might we be unable to see Venus, even though it is at its closest distance?

   d) Why might we be unable to see Venus, even though it is in its **full** phase?

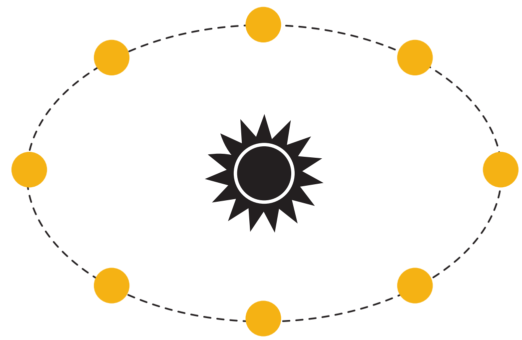

Earth
Sun
Venus

Name: ______________________________ Team: ______________

Golden Square Challenge

Directions: Label the Earth and Sun. Follow the directions step by step. Check off the number as you complete each task.

Task 1: Showing how the Sun lights Venus

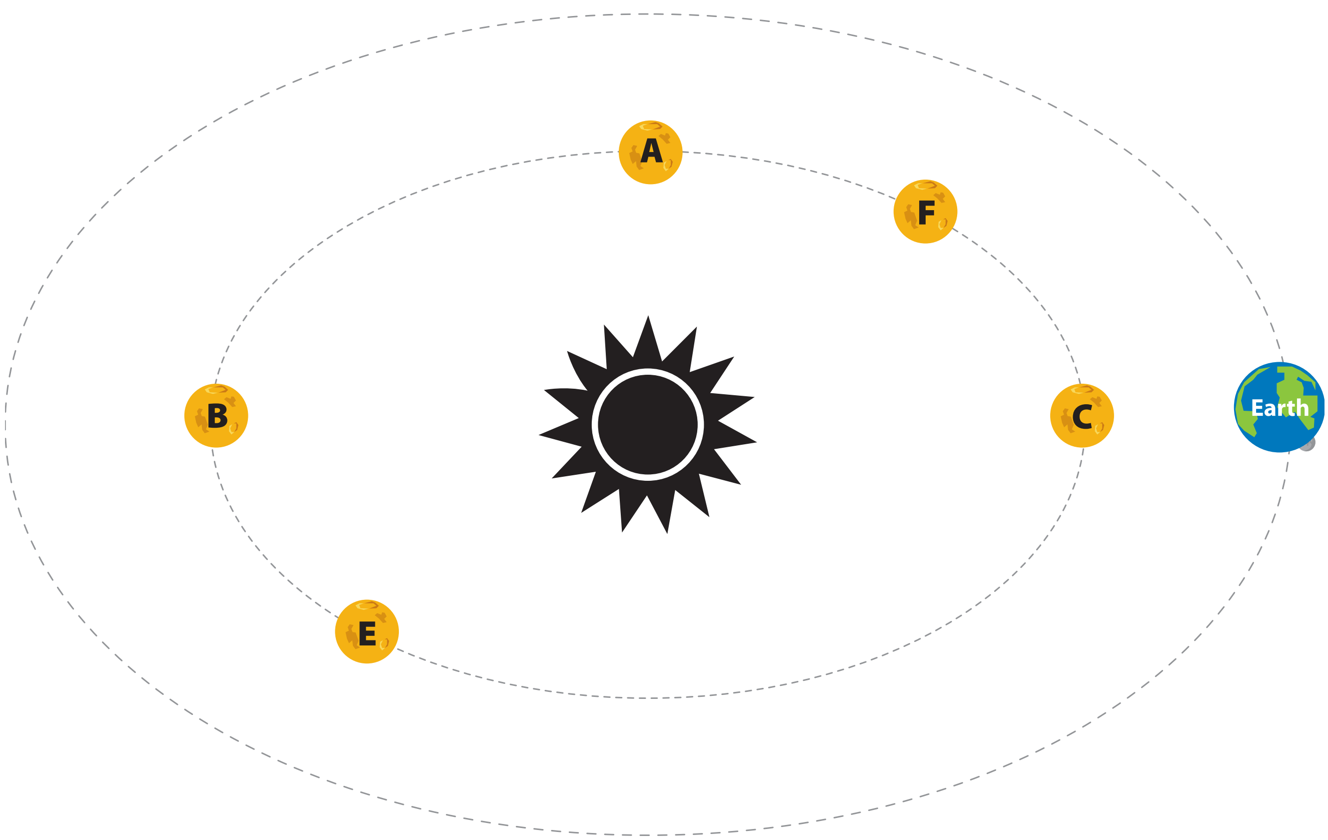


The drawing to the right shows Venus in orbit around the Sun. Pretend you are in a space ship hovering above the solar system. Show how Venus is sunlit in its orbit by drawing its shadows.

Task 2: Phases of Venus

Look at this model. Each Venus position is identified by a letter from A to F. For each position, tell what phase of Venus you would expect to see from Earth.

_______ = New _______ = Crescent _______ = Half _______ = Gibbous _______ = Full



Task 3: Distances in space

a) What letter in the diagram for Task 2 marks the position of Venus when it is closest to the Earth? _____

In this position, Venus is only about 40 million miles from Earth.

b) What letter in the diagram for Task 2 marks the position of Venus at its farthest from Earth? ______

Here, Venus is about 260 million miles from Earth.

Using the scale of "one centimeter equals ten million miles"…

c) How many centimeters will show the closest distance to Venus? _______ cm

d) How many centimeters will show the farthest distance to Venus? _______ cm

Task 4: Drawing conclusions

Which phase of Venus do you think is the brightest phase that we can see from Earth? Reread your answers in Tasks 1, 2, and 3.

The brightest phase of Venus that I can see from Earth is the ________________ phase.

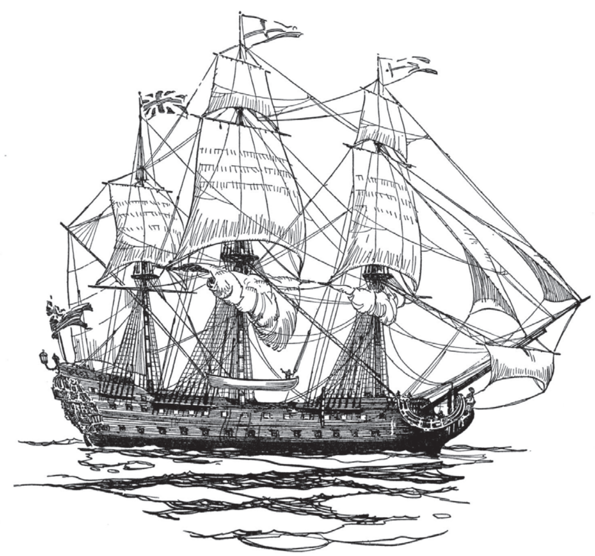
Stop/Think/Draw/Write to explain your answer.

Special Award

Recently we have been working on a special science 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 causes 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



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For Being Squared Away in
Phases of the Moon and Eclipses

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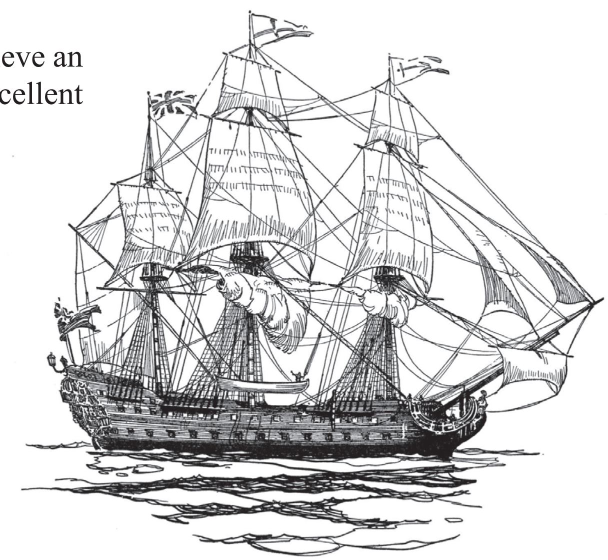
Only some students also earned a “Golden Square.” These students had to achieve an exemplary score on the difficult Golden Square Challenge, which required excellent science thinking skills to understand the phases of Venus.



Congratulations to

____

For Being Squared Away in
Phases of the Moon and Eclipses

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