5 The Moon's Orbit

MODELING

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students develop and use a three-dimensional model that illustrates how the Moon's orbital plane is not aligned with Earth's orbital plane around the Sun. This phenomenon explains why there are solar and lunar eclipses a few times a year but not during each lunar cycle. This activity provides an assessment opportunity for the first part of Performance Expectation MS-ESS1-1 relating to the Earth–Moon–Sun system.

Teacher's Note: The second part of Performance Expectation MS-ESS1-1 relating to Earth's tilt and seasons is assessed in the "Earth on the Move" activity.

NGSS CORRELATIONS

Performance Expectations

MS-ESS1-1: Develop and use a model of the Earth–sun–moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Disciplinary Core Ideas

MS-ESS1.A The Universe and Its Stars: Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

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

Science and Engineering Practices

Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings.

Developing and Using Models: Develop and use a model to describe phenomena.

Crosscutting Concepts

Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Patterns: Patterns can be used to identify cause-and-effect relationships.

Common Core State Standards—Mathematics

MP.4: Model with mathematics.

6.RP.A.1: Understand the concept of a ratio, and use ratio language to describe a ratio between two quantities.

Common Core State Standards—ELA/Literacy

WHST.6-8.2: Write informative/explanatory texts to examine and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

INVESTIGATIVE PHENOMENA AND SENSEMAKING

The Moon appears to change its shape over time.

In this final activity involving sensemaking around the Moon's phases, students connect their conceptions and observations from outside the classroom with the experience and knowledge from their learning experiences. They further engage in sensemaking by using a model to communicate their ever-growing understanding of the cycle of the Moon's phases.

WHAT STUDENTS DO

Students manipulate a physical model of the orbital plane in which the Moon travels as it orbits Earth. This three-dimensional model allows students to investigate why eclipses, both lunar and solar, are relatively rare. This activity is the final opportunity in this unit for students to cement their understanding of why the Moon's orbit results in changing moon phases as seen from Earth.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Visual Aid 5.1, "Orbital Plane"
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD)

- *For each group of four students*
  - 1 Moon Orbit Template
  - 1 Earth model: a medium white foam ball attached to a stick
  - 1 Sun model: a large white foam ball attached to a stick
  - 1 Moon model: a small white foam ball with a hole in it
  - 1 blue stick
  - 2 orange sticks
  - 2 green sticks
  - 2 red sticks
  - 1 purple stick
  - 1 foam board with labeled holes, 8.5" x 8.5"
  - 1 piece of 3" x 3" foam
  - * 1 blank sheet of paper
  - * 1 marker

- *For each student*
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD) (optional)

* *not included in kit*

The DEVELOPING AND USING MODELS (MOD) Scoring Guide can be found in the Assessment tab in the back of this Teacher Edition.

If this is the first time you are teaching this activity, you need to set up the foam boards. Attach an Earth and Moon positions template to each large foam board and use one of the sticks to push a hole into the foam board at each labeled location. Make sure to push the stick all the way into the foam until it reaches the bottom. Do the same for the small foam board using the Sun position template. You may find it helpful to tape down the templates so the holes stay lined up with use from class to class.

Complete the Procedure as described in the Student Book yourself before leading this activity. It is important that you understand how to use the model before having your students begin this activity.

TEACHING SUMMARY

GET STARTED

1. Students are introduced to the concept that the Moon's orbit around Earth is on a plane that is not aligned with Earth's orbital plane around the Sun.

   Have students read the introduction and guiding question.

DO THE ACTIVITY

2. Students use a model to describe the Moon's orbit.
   a. Have students use the model to investigate one orbit of the Moon around Earth.
   b. Assist groups as they draw the Moon's orbital plane.
   c. Use Visual Aid 5.1, "Orbital Plane," to illustrate what the Moon's orbital plane looks like.

BUILD UNDERSTANDING

3. Students refer to their models and the previous activities to explain the phases of the Moon and eclipses.
   a. Have students answer Analysis items 1 and 2, and review the items as a class.
   b. (MOD ASSESSMENT) Analysis item 3 can be assessed using the MOD Scoring Guide.
   c. Ask students to share how their understanding of moon phases has evolved.

TEACHING STEPS

GET STARTED

1. Students are introduced to the concept that the Moon's orbit around Earth is on a plane that is not aligned with Earth's orbital plane around the Sun.

   Have students read the introduction and guiding question.

   Use the introduction to formally define the terms *solar eclipse* and *lunar eclipse*. Explain that students will use a model to investigate why these events occur.

DO THE ACTIVITY

2. Students use a model to describe the Moon's orbit.
   a. Have students use the model to investigate one orbit of the Moon around Earth.

      Have students set up their model as is diagrammed in Part A of the Student Book. Make sure that students place the model Sun—the large

white foam ball standing upright in the 3" x 3" foam—directly in front of position #1 such that the Sun, position #1, the Earth, and position #5 are all perfectly aligned. Part A of the Procedure has students model the first half of the Moon's orbit by placing sticks in a specific order into their foam board. It is important that students follow these steps correctly, as it will allow them to identify the pattern. To help students recognize the pattern, make sure that they pay attention to what the model is representing. Since students were told in the introduction that the Moon orbits on a plane, and the model is showing the Moon's orbit, the sticks used in this activity must create a flat surface even if that surface is tilted relative to the table. To verify that students understand this concept, make sure to check their work in Procedure Step 4 when they complete the orbital plane.

The final two steps of Part A ask students to connect this model with what they have learned in previous activities. Make sure that groups are able to identify when the full moon, new moon, and first quarter moon occur in this new model. If students have trouble, have them refer to their drawings in the previous activity, where they drew the location of the Moon relative to Earth for different moon phases.

b. Assist groups as they draw the Moon's orbital plane.

Part B of the Procedure has students place a piece of paper on the sticks used to model the Moon's orbit in Part A and then mark on the paper the different locations of the Moon in its orbit. Once students have finished this, they should be left with a circular orbit that shows the Moon's orbit around Earth in two dimensions.

c. Use Visual Aid 5.1, "Orbital Plane," to illustrate what the Moon's orbital plane looks like.

This Visual Aid shows the Moon and Earth to scale such that it is clear that they are not in the same plane as Earth and the Sun at all points during the Moon's orbit.

Make sure that students keep their models constructed and available on their desks as they transition to the Analysis. Many of the Analysis items ask questions where it will be helpful for students to refer to their models. Explain to students that they will be allowed to use their models, but if an Analysis item requires individual work, it will be important for each student to take turns with the model rather than share their work.

BUILD UNDERSTANDING

3. Students refer to their models and the previous activities to explain the phases of the Moon and eclipses.

   a. Have students answer Analysis items 1 and 2, and review the items as a class.

      Analysis items 1 and 2 offer opportunities to make sure that students understand what was being modeled in this activity and how it relates to what they have modeled and investigated in previous activities. It is very important that students are able to refer to and understand their models from this activity because Analysis item 3 is an assessment opportunity that relies on this understanding. It may help to physically demonstrate Analysis item 1b by borrowing a group's model and showing students where the Moon is in its orbit as it travels from position #2 to position #4. Have the class help you identify which phases this movement corresponds to.

      Before students work to complete Analysis item 3, demonstrate how the model can be used to show different relative orientations of the Moon's orbital plane relative to the Earth and Sun. To do this, take a model and simply move every stick to the next numbered position (move the stick in position #1 to position #2, and so on). Explain that by moving the sticks, it is possible to model the different alignments of the Moon's orbital plane relative to the Earth and Sun.

   b. (MOD ASSESSMENT) Analysis item 3 can be assessed using the MOD Scoring Guide.

Learning Pathways

      Make sure that students keep their models set up while completing Analysis item 3, as the questions require them to use their models. A sample Level 4 response is provided in Sample Responses to Analysis. This is the first part of the assessment of Performance Expectation MS-ESS1-1.

   c. Ask students to share how their understanding of moon phases has evolved.

      Analysis item 4 asks students to reflect on how their understanding has changed since beginning the unit. Allow students to share what they have learned so far in this unit. While it is common for students to have and keep misconceptions related to the Moon's phases, asking students to identify what they've learned is useful in a few ways. First, as an informal assessment, it allows you to see if their understanding has improved. Second, it helps students gain confidence in their abilities to challenge their own understanding of different topics and concepts. It is very important that students be willing to have their ideas and conceptions challenged because the next topic covered in this unit may require students to integrate new ideas into their understanding of the Earth's seasons.

This is a good time to revisit the second driving question ("How can we use observations and models to understand the Moon phases?") for this sequence of learning. Revisit the question, and add to or revise students' ideas as needed.

STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

- Students with learning disabilities: Break up the activity by having whole-class discussions rather than having students record their thoughts in their science notebooks.
- English learners: Have students work in groups where one person is in charge of reading the Procedure and the other group members are tasked with manipulating the model. Add the words *solar eclipse*, *lunar eclipse*, and *orbital plane* to the word wall, and have students enter the words and their definitions in the glossary in their science notebooks or in their personal vocabulary logs.
- Academically gifted students: Have students reflect on the different models used in this sequence and determine the advantages and disadvantages of each model.

SAMPLE RESPONSES TO ANALYSIS

1. The Moon takes about 29 days to orbit Earth. In this activity, there were eight positions the Moon could be in.

   a. How many days would it take for the Moon to get from position #2 to position #4 in its orbit?

   From position #2 to #4 is $^2/_8$ of the cycle. $^2/_8$ of 29 days is 7.25 days.

   b. What phases would the Moon go through as it traveled from position #2 to position #4?

   In position #2, it is a waxing crescent. Position #3 is a first quarter. Position #4 is a waxing gibbous.

2. In Step 9, you created a two-dimensional drawing of the Moon's orbit. What information about the Moon's orbit is missing from the two-dimensional drawing?

   The drawing doesn't show that the orbital plane of the Moon is tilted when compared to the plane of the Sun and the Earth.

3. (MOD ASSESSMENT, MS-ESS1-1) There are two points during the Moon's orbit around Earth when the Moon, Earth, and Sun are all in the same plane. In your model, this is represented when the Moon is on the green stick such that the Moon, Earth, and Sun are all at the same height.

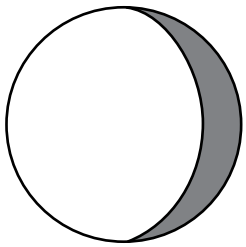
   a. If the Moon is on the green stick in position #6, in what phase is the Moon? Draw what that phase looks like, and explain why it looks that way.

   b. If the Moon is on the green stick in position #1, in what phase is the Moon? Explain what people on Earth would observe.

   c. When the green stick is in position #1, what color stick should be in position #5? Explain.

   SAMPLE LEVEL 4 RESPONSE

   a. If the Moon is in position #6, it would be a waning gibbous. It looks this way because we on Earth can see most, but not all, of the half of the Moon lit up by the Sun.



   b. If the Moon is in position #1, it would be a new moon. Since the Moon is on the green stick, that means it would be in the same plane as the Sun and Earth, so this would result in a solar eclipse. That is, the Moon would block sunlight from reaching part of Earth.

   c. The sticks follow a pattern that results in an orbital plane. So, following that pattern, I see that if the green stick is in position #1, then position #5 also has a green stick.

4. **Reflection:** How have your ideas about the reason for the phases of the Moon changed since you began this unit?

   Students' responses will likely vary. A sample response is shown here:

   I thought the Moon had phases because Earth was blocking sunlight from getting to the Moon. Now I know that Earth only blocks light from the Moon during an eclipse and that the moon phases are because of how much we can see of the portion of the Moon facing the Sun.

EXTENSION

Students are encouraged to visit the *SEPUP Third Edition Solar System and Beyond* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition** for more information about eclipses of the Sun and Moon.

REVISIT THE GUIDING QUESTION

Why don't we see lunar and solar eclipses more often?

For a lunar eclipse to happen, Earth, the Moon, and the Sun all have to be in the same plane during a full moon phase. For a solar eclipse to happen, Earth, the Moon, and the Sun all have to be in the same plane during a new moon phase. Since the Moon's orbit is tilted relative to Earth's orbit around the Sun, there are only certain times each year when these necessary alignments occur.

This activity completes a sequence of learning around the second driving question, "How can we use observations and models to understand the Moon phases?" The driving questions are identified in the Phenomena, Driving Questions, and SEPUP Storyline overview. Revisit students' ideas, and add to or revise them as needed.

ACTIVITY RESOURCES

KEY VOCABULARY

lunar eclipse

orbital plane

solar eclipse

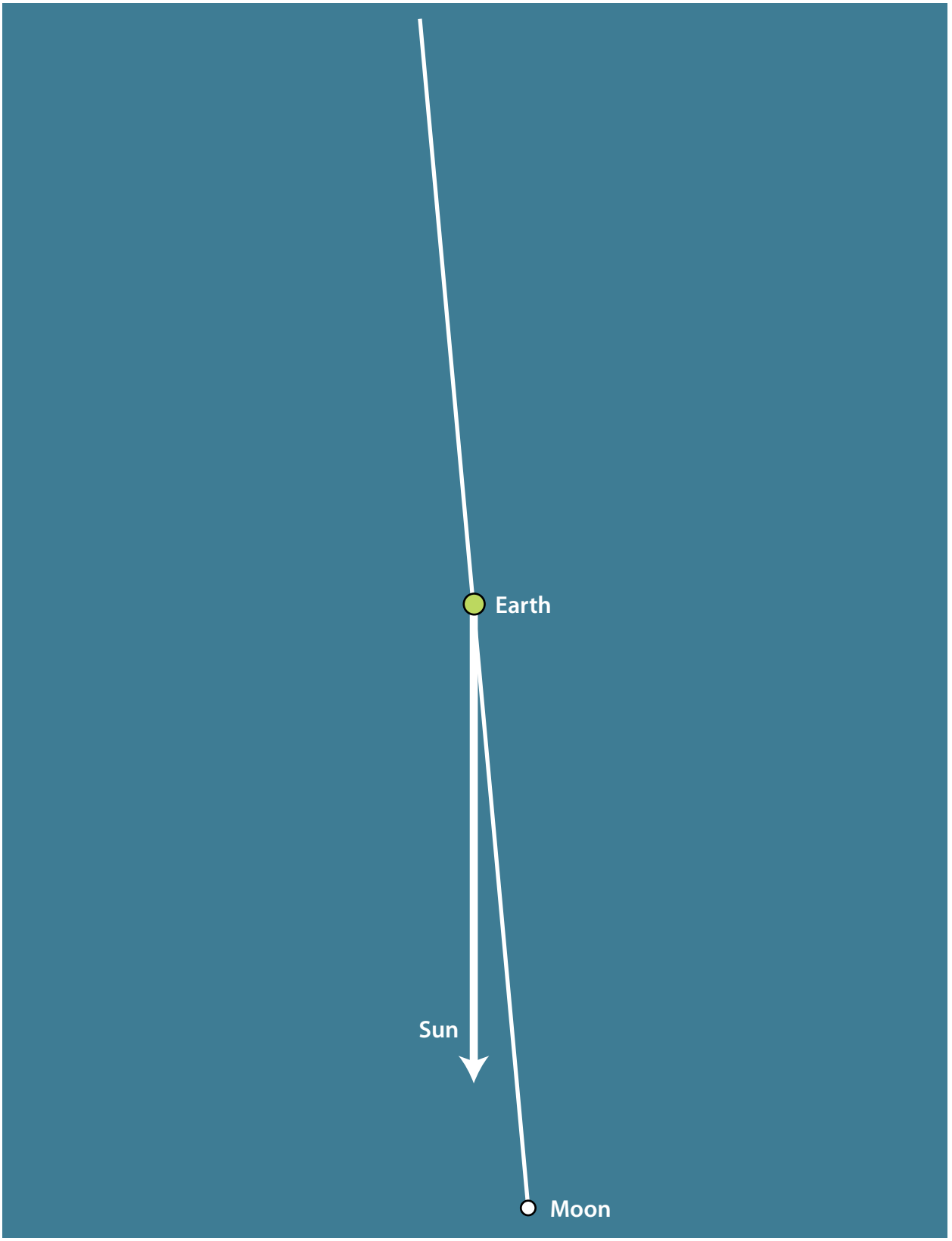
BACKGROUND INFORMATION

THE MOON'S ORBITAL PLANE

Relative to Earth's orbital plane around the Sun, the Moon's orbital plane is inclined by about 5 degrees. Since these two planes intersect one another, there are two moments each month when the Moon, the Sun, and Earth, are all in the same plane. If one of these moments occurs during a full moon or a new moon, then an eclipse will occur. The pattern of when eclipses will occur was discovered before the Common Era (BCE), which was well before orbital mechanics was understood or described mathematically. The phase of the Moon during which the Moon, the Sun, and Earth are all on the same plane changes over time for two reasons. First, Earth is moving relative to the Sun, so the 5-degree inclination of the orbital plane changes in orientation over time. Second, the Moon's orbit around Earth undergoes *precession*, which means that its orbital path around Earth changes over time.

VISUAL AID 5.1

ORBITAL PLANE



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