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 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. 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.

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 regarding 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*

If this is the first time you are teaching this activity, you need to set up the foam boards. To set up the foam boards, attach a Moon Orbit Template to each foam board and use one of the sticks from this activity to push a hole into the foam board at each of the labeled locations. Make sure to push the stick all the way into the foam until it reaches the bottom of the foam. Notice the number associated with each hole on the Moon Orbit Template. Remove the Moon Orbit Template from each foam board and use a marker to label each of the holes on each foam board as shown on the template. Should the marks ever fade from the foam, you can pass out the Moon Orbit Template and have students complete this activity with the template attached to the foam board.

Complete the Procedure as described in the Student Book before leading this activity. It is important that you understand the model and 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 them as a class.

   b. (MOD ASSESSMENT) Analysis item 3 in this activity 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 investigate why these events occur using a model.

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.

      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 students to identify the pattern. To help students recognize the pattern, make sure they pay attention to what the model is representing. Since the model is showing the Moon's orbit, students were told in the introduction that the Moon orbits on a plane, so 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 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 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 sharing 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 them as a class.

Analysis items 1 and 2 offer opportunities to make sure students understand what was being modeled in this activity and how that 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 that movement corresponds to.

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

Make sure 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. For more information, see Teacher Resources III, "Assessment."

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. Secondly, 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.

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 $^{2}/_{8}$ ths of the cycle. $^{2}/_{8}$ ths of 29 days is 7.25 days.

   b. What phases would the Moon go through as it travelled 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) 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.

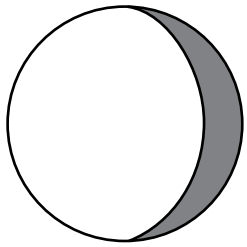
   a. If the Moon is on the green stick in position #6, in what phase is the Moon? Draw what that phase looks like, and explain why it looks that way.

   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. And 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 of, 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 may vary. One 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 Space 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.

ACTIVITY RESOURCES

KEY VOCABULARY

lunar eclipse

orbital plane

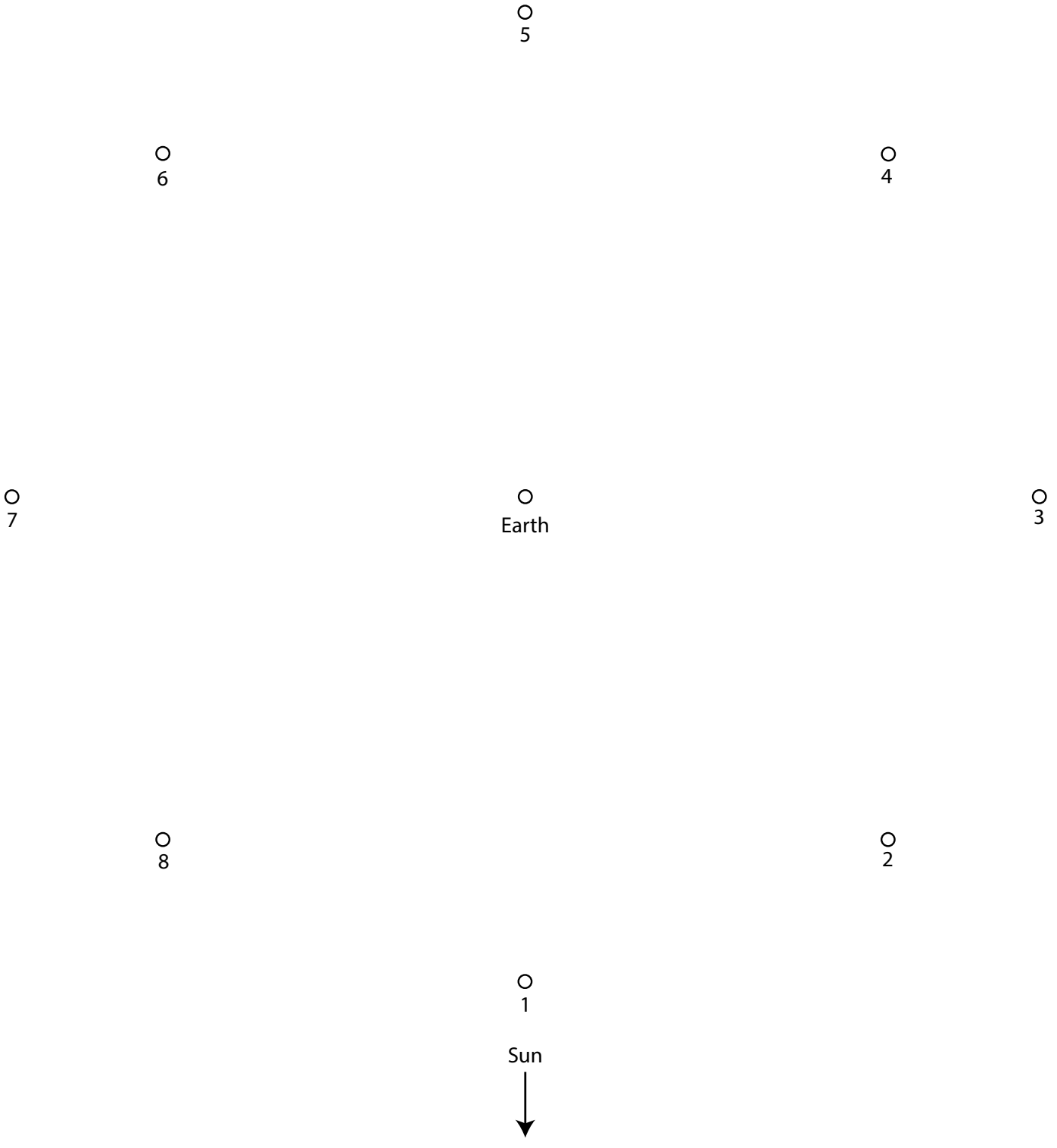
solar eclipse

BACKGROUND INFORMATION

THE MOON'S ORBITAL PLANE

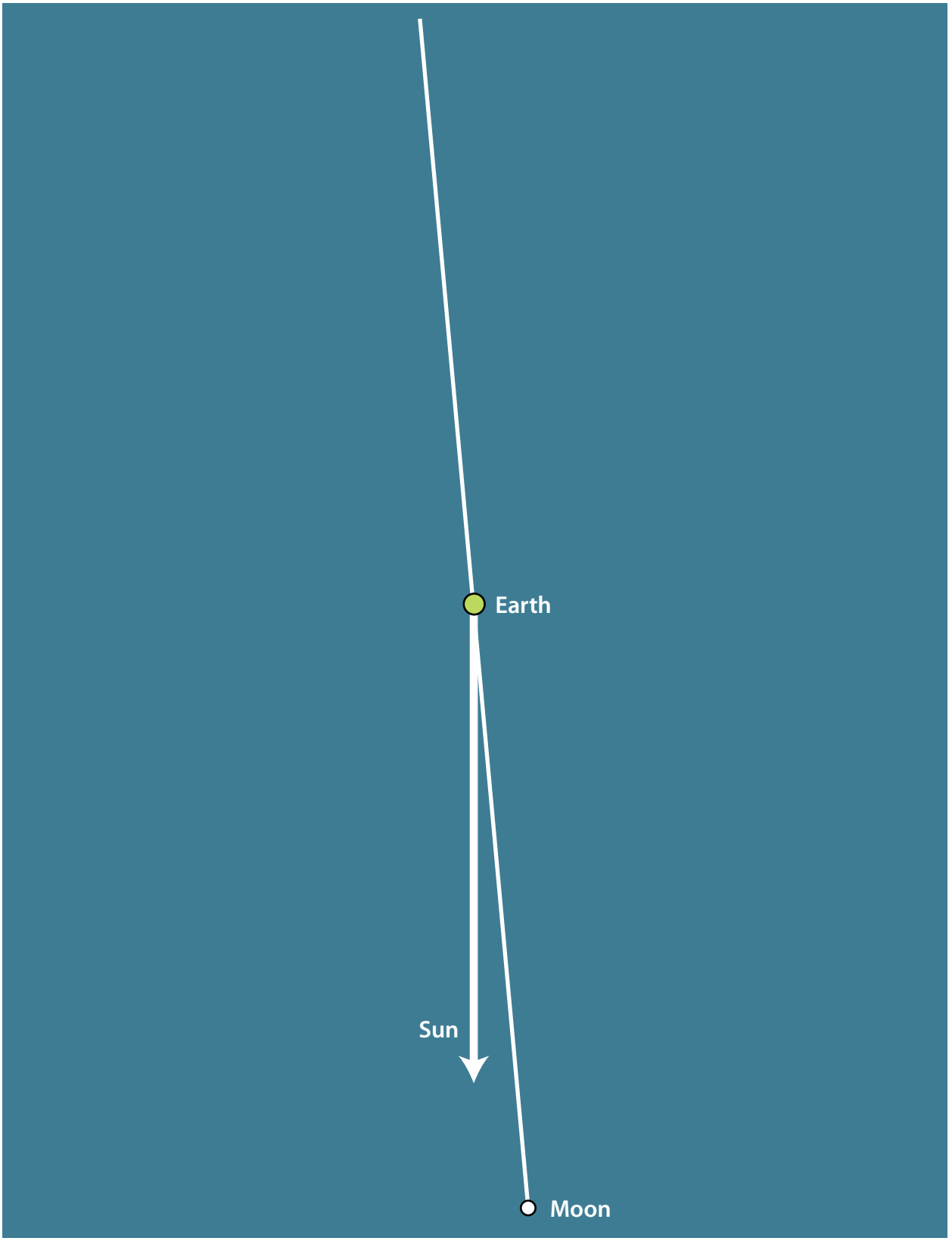
Relative to Earth's orbital plane around the Sun, the Moon's orbital plane is inclined by about 5 degrees. Since these two planes intersect one another, there are two moments each month when the Moon, the Sun, and Earth, are all in the same plane. If one of these moments occurs during a full moon or 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. The first is that 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 its orbital path around Earth changes over time.

MOON ORBIT TEMPLATE



VISUAL AID 5.1

ORBITAL PLANE



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