



kingdom in peril



Kingdom in Peril

Grades: 6-8

Prep Time: ~20 min

Lesson Time: 145 - 190 minutes



WHAT STUDENTS DO: Explore the arrangement of Sun, Earth, and Earth's moon necessary to generate eclipses.

Students will assume the role of a 17th century monarch who must learn and understand eclipse phenomena to save the kingdom from revolt. Students will explore the arrangement of the Sun, Earth, Moon system, and inclination of the Moon's orbit necessary to generate solar and lunar eclipse patterns experienced on Earth. They will explore the shadow zones and likelihood of observing these phenomena.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE AND WHAT IS EARTH'S PLACE IN IT?

NGSS Core Question: ESS1: Earth's Place in the Universe

What are the predictable patterns caused by Earth's movement in the solar system?

ESS1.B: Earth and the Solar System

INSTRUCTIONAL OBJECTIVE (IO)

Students will be able to

Explain predictable eclipse patterns using a model to discover and demonstrate the evidence of phenomena at different scales such as the Moon's inclination (orbital plane) in combination with the position of the Sun, Earth, Moon system.

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1.0 Materials

Required Materials:

Please Supply:

- Computer or Laptop – 1 per student
 - Supported Browsers: Chrome; Edge; Firefox; Safari
- Image projection for umbra/penumbra mini lesson
 - See Step 3E and Teacher Guide (Q) Umbra/Penumbra Diagram

Please Print:

From Student Guide

- | | |
|--|-----------------|
| (A) An Ominous Event (Optional) | - 1 per student |
| (B) Modeling the Sun – Earth – Moon System | - 1 per student |
| (C) Selecting a Royal Advisor | - 1 per student |
| (D) Introduction to Solar and Lunar Eclipses | - 1 per student |
| (E) Investigating Eclipses | - 1 per student |
| (F) Confronting Flaws | - 1 per student |
| (G) Modeling Eclipses in other Sun-Planet-Moon Systems | - 1 per group |
| (H) Explaining Predictable Eclipses | - 1 per student |

Optional Materials:

From Teacher Guide

- (I) Modeling the Sun – Earth – Moon System (KEY)
- (J) Selecting a Royal Advisor (KEY)
- (K) Introduction to Solar and Lunar Eclipse (KEY)
- (L) Investigating Eclipses (KEY)
- (M) Confronting Flaws (KEY)
- (O) Modeling Eclipses in other Sun-Planet- Moon Systems (KEY)
- (P) Explaining Predictable Eclipses (KEY)
- (Q) Umbra/Penumbra Diagram

From Alignment Documents

- (N) Kingdom in Peril Alignment Rubrics



2.0 Unit Timeline

Kingdom in Peril Unit Timeline:

Time:

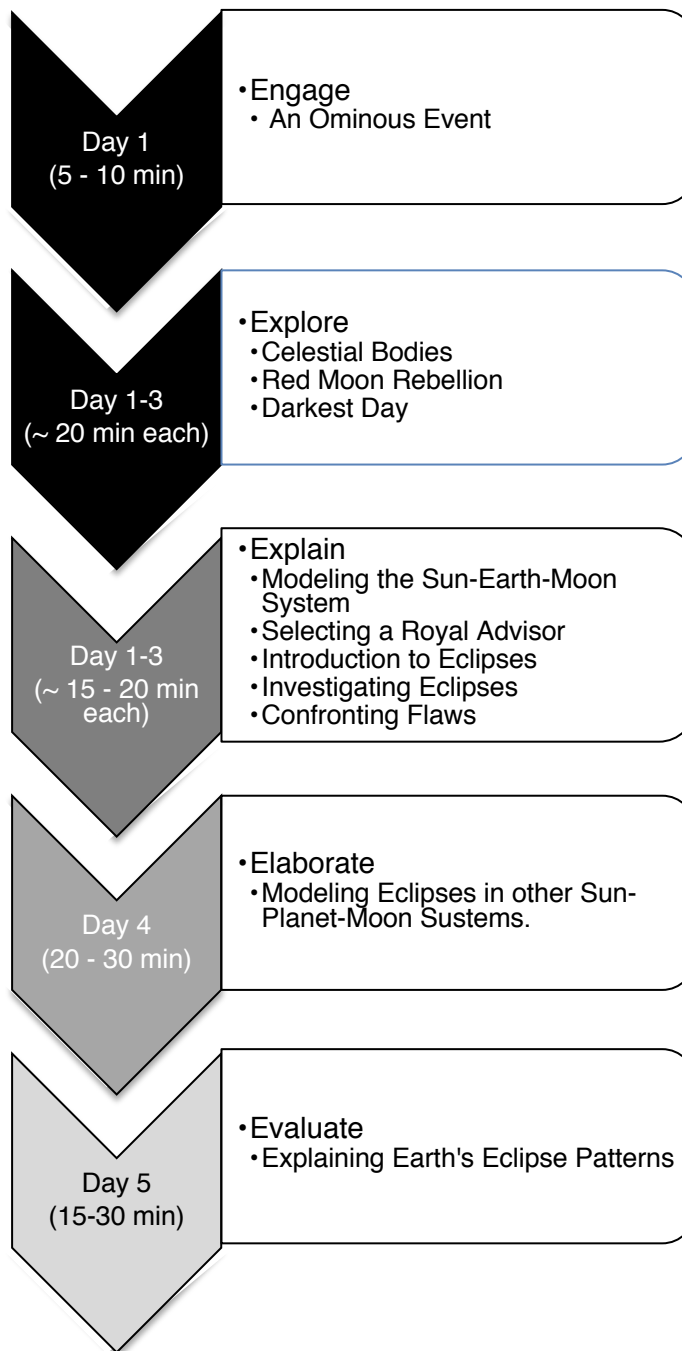
- 145 - 190 minutes

Materials:

- Student Guide pages

5-E Inquiry Process:

- The arrow color represents the 5-E step students will be primarily engaging in for that class session



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3.0 Vocabulary

aether (ether)	a term in medieval science for the material that fills space between objects in the universe; Aristotle added aether, the fifth element, to the four classical elements: Earth, air water and fire
analyze	consider data and results to look for patterns and to compare possible solutions
angle of inclination	a term used to describe orbits; the angle between the plane of Earth's orbit around the Sun and the plane of the Moon's orbit around Earth.
celestial bodies	any natural object located outside Earth's atmosphere including, Sun, Moon, planets, asteroids and comets
criterion	characteristic or fact used to judge or consider something
duration	the range of time between the beginning and end of an event
eclipse	a phenomenon when the Moon or Earth blocks the Sun creating a shadow and preventing an observer from seeing another object in space.
empirical evidence	knowledge gained through direct or indirect observation
enlightenment/renaissance	period in Europe between the 14th and 17th centuries when there was a surge of interest in and production of art and literature
hypothesis	tentative explanation of a phenomenon that is testable
lunar	relating to or resembling the moon
model	a representation of an idea, an object, process or system that is used to describe and explain phenomena that can't be experienced directly
observations	specific details recorded to describe an object or phenomenon
observatory	a special building for studying stars, planets, weather, etc.
omen/ominous	an event regarded as a sign of good or evil
orrery	model of our solar system representing how the Sun, planets and Earth's moon move through space.
orbital plane	the planets' orbits line up with each other making a kind of flat disk called the orbital plane
orbital period	the time it takes to complete one orbit
penumbra	the partially shaded outer region of a shadow
predict	to declare what will happen based on reason and knowledge

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portend	a sign or warning that something significant is about to happen
proclamation	the public or official announcement of an important matter
solar system	the Sun and the objects that revolve around it
umbra	the fully shaded inner part of a shadow



4.0 Procedure

PRIOR KNOWLEDGE AND SKILLS

- A. Solar System
- B. Moon Phases
- C. Models (scale)

PREPARATION

- A. Reserve computers or tablets for exploration days.
- B. Visit the links below for access to the digital learning experiences and additional resources.
- C. Enroll students in each lesson for *Kingdom in Peril* unit if you would like to make their progress available outside of class and track the analytics of their learning behavior. The entire unit contains the following lessons:
 - a. [Ep.1: Celestial Bodies](#)
 - b. [Ep.2: Red Moon Rebellion](#)
 - c. [Ep.3: Darkest Day](#)
- D. PRINT THE FOLLOWING:
 - Student **Recording Sheets (A-F, H)** – 1 per student
 - Student **Recording Sheets (G)** – 1 per group

STEP 1: ENGAGE (~ 5 -10 minutes)

Set Up the *Kingdom in Peril* Unit

- A. Students can be engaged via the story narrative of rebellion contained within the digital learning experience.
 - B. (OPTIONAL Engagement) Prior to starting the lessons, hand out **(A) An Ominous Event** recording sheet. Read the text and have students answer the questions to generate interest in the lesson. As an alternative, teacher can read the text and conduct a class discussion.
- 🍏 Teacher Tip:** Student answers will vary but will likely include volcanic eruptions, Earthquakes, meteor showers, asteroid and meteoroid impacts, eclipses or even tornadoes and other extreme weather events. Students will probably point to lack of understanding of natural phenomena by ancient peoples to justify the behaviors. Some may point to other ways of knowing such as religious or spiritual beliefs.



- C. Guide students through a discussion about how people know things. How do you know when your birthday is? How do you know how to get to school or how to get home from school? How do you know that when you release a ball it will drop to the ground? Tradition, experience, spiritual or religious beliefs and science are all ways of knowing. Science is the only method that relies upon empirical evidence to support knowledge.
- D. Hand out or assign computers and ask students to access the ***Celestial Bodies*** lesson linked above. If students have been enrolled, they will have a link in their email inviting them to the lesson.

STEP 2: EXPLORE (~ 60 minutes for all three sections)

Kingdom in Peril Simulations

- A. Students will complete their exploration of eclipses in sections, alternating between EXPLORE and EXPLAIN activities.
- 🍏 **Classroom Management Tip:** If the next class will be using the same computers and you are not enrolling students into the lessons to track progress, ask students to click the “Restart Lesson” icon in the lower left corner. This will ensure your next group starts at the beginning of the simulation, however student progress will be lost.
- 🍏 **Recording Sheet Tip:** Students are required to collect data and record it on recording sheets throughout the EXPLORE and EXPLAIN activities. Both the digital lessons and the student recording sheets utilize the quill symbol (seen left) as a visual reminder to write down information.
- 🍏 **Teacher Tip:** If students seem to be stuck in an activity, it isn’t responding in a way that seems correct, or if an error occurs, students can attempt to refresh their browser or click on the “Restart Lesson” icon in the lower left corner. “Restart Lesson” will clear all of their progress and bring them back to the start screen. Hitting the browser’s “Refresh” button will not restart the activity.
- 🍏 **Teacher Tip:** If you would like to analyze student interactions in this activity, you can sign up to join the [Infiniscope Teaching Network](#) and enroll your class into the activity. By enrolling, you will gain access to the analytics of the activity by student to see how students progressed through the activity. You also have the ability to adopt the activity and adapt it to the specific needs of your classroom, school, or community.
- 🍏 **Teacher Tip:** To promote vocabulary acquisition, understanding and engagement, the vocabulary list can be provided to students before exploration begins. Instruct students to use the list whenever they encounter unfamiliar terms. In addition, students can be asked to record additional vocabulary with which they are unfamiliar and seek teacher assistance.



STEP 3: EXPLAIN (~ 45 - 60 minutes)

- A. Hand out **(B) Modeling the Sun-Earth-Moon System** recording sheet, **(C) Selecting a Royal Advisor** recording sheet, and **(D) Introduction to Solar and Lunar Eclipses** recording sheet. Students will complete these recording sheets in order as they work through the **Celestial Bodies** digital experience.
- 🍏 **Teacher Tip:** Celestial Bodies is the first in a series of three digital experiences in the Kingdom of Peril unit. Upon completion of **Celestial Bodies**, **Red Moon Rebellion** or **Darkest Day** can be completed in any order.
- B. If students are completing **Red Moon Rebellion**, hand out **(E) Investigating Eclipses** recording sheet. Students will complete this recording sheet as they work through the digital experience.
- C. If students are completing **Darkest Day**, hand out **(F) Confronting Flaws** recording sheet (Page 1 ONLY!). Students will complete this recording sheet as they work through the **Darkest Day** digital experience.
- D. Once students have completed the Darkest Day experience, hand out **(F) Confronting Flaws** recording sheet (Page 2). To capture a summative assessment of their understanding of inclination of Moon's orbit.
- E. At the completion of all three digital experiences, have students review the predictions made on **(D) Introduction to Eclipses** recording sheet and revise as needed.
- F. Conduct a mini lesson to introduce the concepts of umbra and penumbra.
1. Show students the image linked in **materials**.
 2. Explain that the shadows of celestial bodies have distinct parts. Two of these affect eclipses. The dark inner portion of a shadow is the umbra. This region gets smaller as it goes away from the light source. The second part of the shadow is the penumbra. It is the lighter shading outside the umbra. The Penumbra gets larger as it goes away from the light source. Increasing the distance between the celestial body and the Sun results in the areas of both the umbra and penumbra decreasing.
 3. Have students take notes and sketch the image labelling the umbra and penumbra on the back of Recording Sheet **(D) Introduction to Eclipses**.
 4. Have students look at Recording Sheet D: Solar and Lunar Eclipse and analyze their drawings. Ask them to think about what solar and lunar eclipses look like from Earth (the inset box on the orrery simulation).
 5. Instruct students to predict whether Earth's experience of a solar eclipse is due to the umbra and/or the penumbra of the shadow cast upon it. Write the prediction next to the solar eclipse diagram on **(D) Introduction to Eclipses** Recording Sheet.
 6. Repeat the process in step five for lunar eclipses recording their predictions next to the lunar eclipse diagram on **(D) Introduction to Eclipses** Recording Sheet.

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7. Show brief video explanations to confirm or refute student predictions:
 - The *Moon's Role in a Solar Eclipse* <https://svs.gsfc.nasa.gov/12648> and
 - *NASA Understanding Lunar Eclipses* https://www.youtube.com/watch?time_continue=74&v=INi5UFpales

STEP 4: ELABORATE (~ 20 - 30 minutes)

Modeling Eclipses in Other Sun-Planet-Moon Systems

- A. Hand out **(G) *Modeling Eclipses in Other Sun-Planet-Moon Systems*** Recording Sheet. Students will complete the task according to instructions on the recording sheet.
- B. Conduct a class discussion allowing groups to share their work. Draw attention to the development of alternate hypotheses eliciting explanations from students.
- C. Lead a conversation with students pointing out every planet-moon system operates slightly differently from Earth's. While we can use Earth as a baseline of information, the variables of eclipse phenomena are different on other planets. For example, Mars' moon, Phobos, is much smaller than Earth's moon, so a solar eclipse looks different than one on Earth. Relatively speaking, Phobos orbits Mars approximately every 8 hours, and has nearly 1 degree inclination, therefore eclipses occur much more frequently on Mars, but with shorter duration.
- D. Show *Mars' Moon Phobos Eclipses the Sun, as Seen by Curiosity* <https://www.youtube.com/watch?reload=9&v=OyZoD7BRTtg> Point out that this video is taken in real time with Phobos completing an eclipse in nearly 30 seconds.
- E. As an observer on Mars, you may expect to see an eclipse every 8 hours respectively. However, the planet rotates during those 8 hours, so the position of the next eclipse changes. You would need to travel ~1,444km to the east in order to observe the next eclipse. Additionally, Mars is revolving around the Sun and changing seasons, just as Earth does. You would observe the eclipse moving slightly north in latitude during the northern summer and slightly south in latitude during the northern winter.

STEP 5: EVALUATE (~ 15 - 30 minutes)

Explaining Earth's Eclipse Patterns

- A. At the conclusion of the *Kingdom in Peril* unit and the elaboration task discussion, hand out **(H) *Explaining Earth's Eclipse Patterns*** recording sheet. Students will use their recording sheets to develop a comprehensive explanation for the eclipse patterns observed on Earth.



5.0 Evaluation/Assessment

Use the *(N) Kingdom in Peril Alignment Rubrics* as a formative and summative assessments, allowing students to improve their work and learn from mistakes during class, but also providing final assessment of the learning activities. The rubrics evaluate the activities using the Next Generation Science Standards, NRC Framework, Common Core State Standards, and 21st Century Skills

6.0 Extensions

1. [Martian Solar Eclipses](#)
2. [Apparent Sizes of Moons](#)
3. [Evaluating a Lunar Eclipse](#)
4. [Path of Totality Infiniscope Exploration](#)

**(A) An Ominous Event (OPTIONAL Recording Sheet)**

Name: _____

Complete the following before starting the *Kingdom in Peril* Unit.

The following is an account of 16-century Aztecs in Mexico describing what happened during a natural event. Read the following account and then describe what you believe could have been happening to cause this kind of reaction.

There was a tumult and disorder. All were disquieted, unnerved, frightened. Then there was weeping. The common folk raised a cup, lifting their voices, making a great din, calling out shrieking. People of light complexion were slain as sacrifices; captives were killed. All offered their blood. They drew straws through the lobes of their ears, which had been pierced. And in all the temples there was the singing of fitting chants; there was an uproar; there were war cries.

Adapted from Bernardino, ., Anderson, A. J. O., Dibble, C. E., & Jay I. Kislak Reference Collection
(Library of Congress). (1950). *General history of the things of New Spain: Florentine codex*.

Describe what natural event you believe could have caused the Aztec people of the 16th century to react in this way. Propose reasons for these reactions from ancient civilizations.

**(B) Modeling the Sun – Earth – Moon System**

Name: _____

- ✍ **Hint:** Throughout this unit you will be collecting data from the Kingdom in Peril. It is important to read the questions on the recording sheet as you move through the unit. A quill symbol appears in the digital experience and on the recording sheets to remind you to record data before moving to the next slide.

Complete the following as you learn how to use the orrery.

- ✍ 1. Sketch the relative positions of the Sun - Earth – Moon model displayed in the system view of the orrery. Label the three celestial bodies represented.

SYSTEM VIEW OF THE ORRERY

- ✍ 2. What do you observe about the shadows cast upon Earth by the Moon? Describe your observations.

- ✍ 3. After experimenting with shadows, rotate the shadow so that Earth, Moon and Sun are visible on the orrery. Make a detailed drawing of what you see, including the dark and light shadow zones, Earth, Moon and Sun.

Sketch

**(C) Selecting a Royal Advisor**

Name: _____

1. As the ruler of your kingdom, you need to select knowledgeable people to advise you on various matters. As you meet possible royal advisors, complete the chart below to indicate the type of knowledge the advisor possesses and how they know it. Does their knowledge come from:

- personal experience
- stories passed down through generations
- spiritual beliefs
- personal explanations of events
- observations and records of actual events

Advisor	 Information Provided	Way of Knowing
Duke Gryvain		
Elwin the Wise		
Lord Thistle		
Lady Wright		



2. Explain who is selected as the royal advisor and why. How was it determined that the information was credible compared to the other advisors?

**(D) Introduction to Solar and Lunar Eclipses**

Name: _____

1. Use the spaces below to record the positions of the Sun, Earth and Moon in solar and lunar eclipses. Include the shadow in your diagram. Make sure to indicate that your drawings are not to scale.

Solar Eclipse**Lunar Eclipse**

2. Explain the relative positions of Sun, Earth and Moon for solar and lunar eclipses. Describe the shadows that form the eclipses.

**(E) Investigating Eclipses**

Name: _____

In this simulation you will be collecting information about eclipses that will help you answer three key questions to save your kingdom from an impending revolt. Record your observations in the charts below then answer the key questions.

When will the revolt happen?

	Lunar	Solar
Number of eclipses on record		
Shortest interval		

1. Your sources tell you that an eclipse is going to be used to signal a revolt. How soon could an eclipse occur?

Where will the eclipse take place?

	Lunar	Solar
Portion of Earth on which eclipse is visible		
Duration	end time - start time = duration	end time - start time = duration
Relative shadow size	Earth's shadow is _____ than the Moon.	Moon's shadow is _____ than Earth.

2. You have a large kingdom, spread across several continents. Which type of eclipse is most likely to be seen by your whole kingdom? Explain your answer.

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✍ **Why are the traitors using a blood Moon as their signal?**

**(F) Confronting Flaws (1 of 2)**

Name: _____

The orrery (model of the Sun – Earth - Moon system) helps explain solar and lunar eclipses. In this digital experience you discover that the orrery needs to be calibrated. You will determine the problem, collect data and revise the model to accurately reflect solar eclipses.

- ✍ 1. What was the problem with the orrery?

- ✍ 2. Summarize the experiments conducted by completing the data table below. Write each orbital tilt as you test it and record the result.

Results of Adjustments to Orrery Eclipse Model

Adjustment	Radius	Speed	Tilt (°)			
			____°	____°	____°	____°
Result						

**(F) Confronting Flaws (2 of 2)**

Explain how the tilt (inclination) of the Moon's orbit is a factor in the pattern of observed solar eclipses. Use results from the adjustments to explain the conclusion.

**(G) Modeling Eclipses in Other Sun-Planet-Moon Systems**

Name: _____

Fill in the missing information using the link below.

<https://solarsystem.nasa.gov/moons/mars-moons/deimos/by-the-numbers/> Change the celestial body being compared to Deimos using the  below Earth.

Comparing Earth and Mars Lunar Systems

	Mars		Earth
Distance from Sun (km)	227,900,000		149,600,000
Mean Diameter of Planet (km)	6779		12742
Number of Moons	2		1
Name of Moon	Deimos	Phobos	Moon (Luna)
Orbital Period	~ 30 hours	~ 8 hours	~ 27 days
Average Orbit Distance (km)			
Equatorial Diameter (km) Diameter = 2 x radius			
Orbital Inclination	0.93°	1.093°	5°

Work with your team to complete the following hypotheses regarding the patterns of Mars eclipses relative to Earth eclipses. Remember a hypothesis is a possible explanation, so there may be multiple answers. Discuss and consider all ideas before recording your hypotheses.

1. **Frequency:** Mars is expected to have _____ (more/less)

frequent eclipses than Earth because

2. **Duration:** Mars is expected to have _____ (longer/shorter)

eclipses than Earth because

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(H) Explaining Earth's Eclipse Patterns

Name: _____

Complete the following at the conclusion of *Kingdom in Peril* unit.

Based on your experience in the *Kingdom in Peril*, construct a scientific explanation for solar and lunar eclipse patterns observed from Earth. Use scientific language to describe the cause, frequency, duration and coverage of solar and lunar eclipses. Include data collected during the experience as evidence to support your explanation. Use appropriately labelled two dimensional models (diagrams) to enhance your explanation. Continue on the back of this sheet if more room is needed for your explanation.

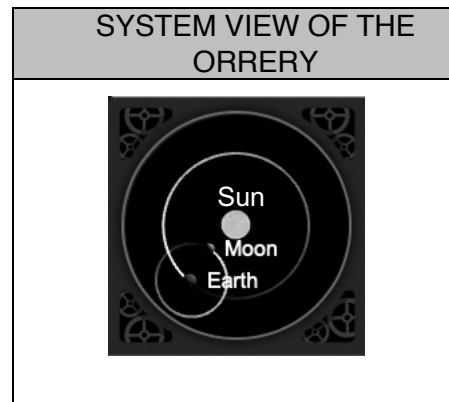
[illegible]

**(I) Modeling the Sun – Earth – Moon System (KEY)**

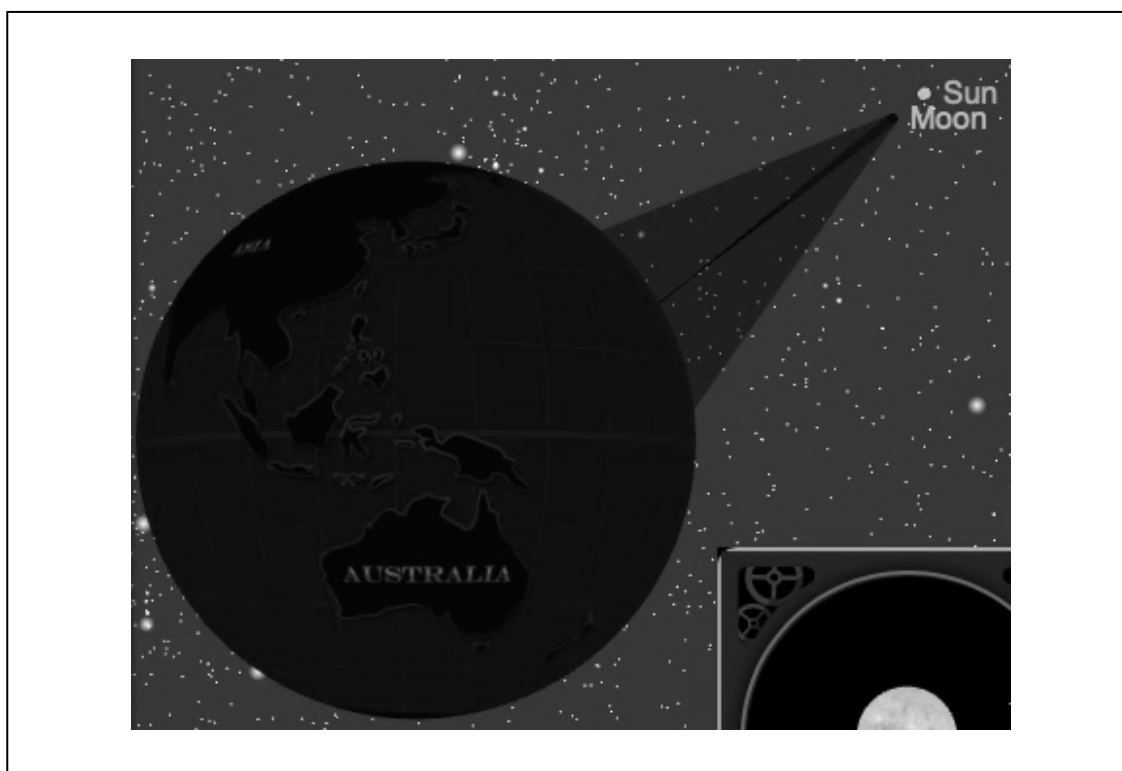
Complete the following as you work through the *Celestial Bodies* lesson.

1. Sketch the relative positions of the Sun - Earth – Moon model displayed in the system view of the orrery. Label the three celestial bodies represented.
2. What do you observe about shadows cast upon Earth by the Moon? Describe your observations.

Shadows on Earth appear circular with a small darker region in the middle surrounded by a large lightly shaded region. The shadow is much smaller than Earth's surface.



3. After experimenting with shadows, rotate the shadow so that Earth, Moon and Sun are visible on the orrery. Make a detailed drawing of what you observe including the dark and light shadow zones, Earth, Moon, and Sun.



**(K) Introduction to Solar and Lunar Eclipses (KEY)**

1. As the ruler of your kingdom, you need to select knowledgeable people to advise you on various matters. As you meet possible royal advisors, complete the chart below to indicate the type of knowledge the advisor possesses and how they know it. Does their knowledge come from personal experience, stories passed down through generations, spiritual beliefs, personal explanations of events, or observations and records of actual events?

Advisor	 Information Provided	Way of Knowing
Duke Gryvain	<i>Eclipses bring evil to those who see them</i>	<i>Spiritual beliefs and/or stories passed down</i>
Elwin the Wise	<i>Eclipses are a spell that can be cast off for money</i>	<i>Personal explanation and/or spiritual beliefs</i>
Lord Thistle	<i>Beasts eat the Sun, Earth, and Moon</i>	<i>Spiritual beliefs and/or stories passed down</i>
Lady Wright	<i>Historical record of eclipses and ability to predict future eclipses</i>	<i>Scientific evidence from actual events</i>

2. Explain who is selected as the royal advisor and why. How was it determined that the information was credible compared to the other advisors?
- Lady Wright is the only advisor who bases knowledge and understanding of eclipses on scientific evidence. She uses observations of historical events to support her claims and provide scientific explanations. The other advisors' ideas were based on ways of knowing that are not scientific. They have no evidence to support their beliefs.

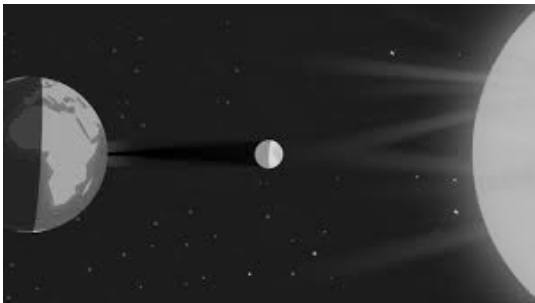
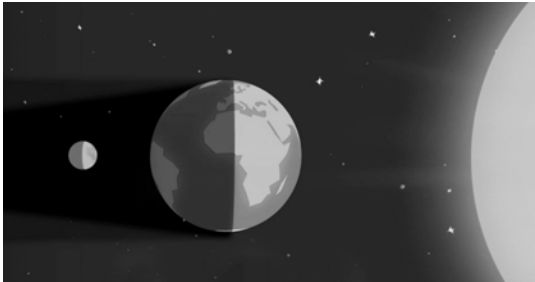


KINGDOM IN PERIL

Teacher Guide

(K) Introduction to Solar and Lunar Eclipses (KEY)

- Use the spaces below to record the positions of the Sun, Earth and Moon in solar and lunar eclipses. Include the shadow in your diagram. Make sure to indicate that your drawings are not to scale.

Solar Eclipse		
<i>Earth</i>	<i>Moon</i>	<i>Sun</i>
		
<i>Not to scale</i>		
<i>Mini Lesson Prediction Umbra and/or penumbra</i>		
Lunar Eclipse		
<i>Moon</i>	<i>Earth</i>	<i>Sun</i>
		
<i>Not to scale</i>		
<i>Mini Lesson Prediction Umbra and/or penumbra</i>		

Explain the relative positions of Sun, Earth and Moon for solar and lunar eclipses. Describe the shadows that form the eclipses.

In a solar eclipse, the Moon passes between the Sun and Earth casting a shadow on Earth's surface. The Moon is small compared to Earth, so the shadow is small covering only a small portion of Earth's surface. The shadow has a darker central portion. In a lunar eclipse, Earth passes between the Sun and Moon casting a shadow on the Moon. Earth's shadow is much larger than the Moon, so the entire light side of the Moon is darkened by Earth's shadow.

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**(L) Investigating Eclipses (KEY)**

In this simulation you will be collecting information about eclipses that will help you answer three key questions to save your kingdom from an impending revolt. Record your observations in the charts below then answer the key questions. Remember you cannot go back to previous pages in the simulation, so record information before advancing.

✍ **When will the revolt happen?**

	Lunar	Solar
Number of eclipses on record	8	4
Shortest interval	7 weeks	Not given

- ✍ 1. Your sources tell you that an eclipse is going to be used to signal a revolt. How soon could an eclipse occur?

The exact date of the next eclipse is not known, but it could be as soon as seven weeks

✍ **Where will the eclipse take place?**

	Lunar	Solar
Portion of Earth on which eclipse is visible	<ul style="list-style-type: none"> Eclipse is visible to about $\frac{1}{2}$ of Earth, <ul style="list-style-type: none"> the dark side 	<ul style="list-style-type: none"> Eclipse is visible to part of the light side <ul style="list-style-type: none"> much less than lunar eclipse most is partial eclipse
Duration	end time <i>10:25 AM</i> - start time <i>- 5:24 PM</i> = duration. <i>~ 7 hours</i>	end time <i>11:25 AM</i> - start time <i>- 9:10 AM</i> = duration. <i>2 hours 15 mins</i>
Relative shadow size	Earth's shadow is <u>larger</u> than the Moon.	Moon's shadow is <u>smaller</u> than Earth.



2. You have a large kingdom, spread across several continents. Which type of eclipse is most likely to be seen by your whole kingdom. Explain your answer.

A lunar eclipse will be seen by more people on Earth because it lasts longer and is visible to the entire night side of Earth.

- Why are the traitors using a blood Moon as their signal?**

The lunar eclipse or blood Moon makes a good signal because it is visible to all of the kingdom's colonies even though they are located on different continents and it is visible for a longer period of time, so more people are likely to see it. The Moon casts a small shadow on Earth that only part of the daylight side of Earth can see.

**(M) Confronting Flaws (1 of 2) (KEY)**

The orrery (model of the Sun – Earth - Moon system) helps explain solar and lunar eclipses. In this digital experience you discover that the orrery needs to be calibrated. You will determine the problem, collect data and revise the model to accurately reflect solar eclipses.

1. What is the problem with the orrery?

The orrery is predicting eclipses too frequently based on historical data.

✍ Summarize the tests conducted by completing the data table below.

Results of Adjustments to Orrery Eclipse Model

Adjustment	Radius	Speed	Tilt (°)			
			<u><i>23.5°</i></u>	<u><i>10°</i></u>	<u><i>15°</i></u>	<u><i>5°</i></u>
Result	<i>The Moon's shadow is smaller than what is observed</i>	<i>The Moon phase cycle is longer than what is observed</i>	<i>Creates fewer eclipses than no tilt</i>	<i>Does not create an eclipse on June 30th</i>	<i>Does not create an eclipse on June 30th</i>	<i>Creates an eclipse on June 30th</i>

**(M) Confronting Flaws (2 of 2) (KEY)**

2. What can you conclude about the Moon's orbit and the pattern of eclipses observed on Earth? Use results from the adjustments to explain the conclusion.

The 5° tilt of Moon's orbit is responsible for the patterns of eclipses observed on Earth.

Changing other variables of the orbit did not match the historical data.

**(O) Modeling Eclipses in Other Sun-Planet-Moon Systems (KEY)**

Complete the following chart using the link below.

<https://solarsystem.nasa.gov/moons/mars-moons/deimos/by-the-numbers/>

Comparing Earth and Mars Lunar Systems

	Mars		Earth
Distance from Sun (km)	227,900,000		149,600,000
Mean Diameter of Planet (km)	6779		12742
Number of Moons	2		1
Name of Moon	Deimos	Phobos	Moon (Luna)
Orbital Period	~ 30 hours	~ 8 hours	~ 27 days
Average Orbit Distance (km)	23,458	9376	384,400
Equatorial Diameter(km) (<i>diameter = 2 x radius</i>)	12.4 (2 x 6.2)	22.2 (2 x 11.1)	3475 (2 x 1737.5)
Orbital Inclination	0.93°	1.093°	5°

Work with your team to complete the following hypotheses regarding the patterns of Mars eclipses relative to Earth eclipses. Remember a hypothesis is a possible explanation, so there may be multiple answers. Discuss and consider all ideas before recording your hypotheses.

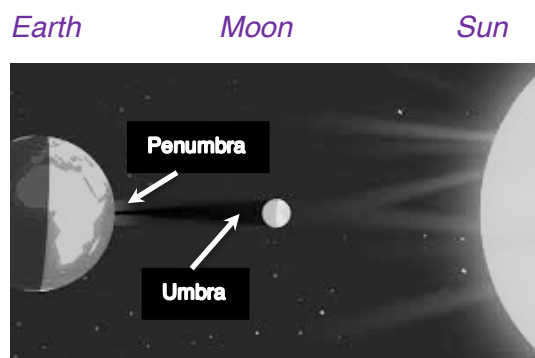
- 1. Frequency:** Mars is expected to have (more/less) frequent eclipses than Earth because Mars has two moons both with much shorter orbital periods than Earth's moon. However, the orbital tilts of Deimos and Phobos may have the effect of reducing the frequency of eclipses.
- 2. Duration:** Mars is expected to have (longer/shorter) eclipses than Earth because the moons of Mars, Phobos and Deimos are much smaller than Earth's moon and are travelling much faster, so the smaller shadows would cross the surface of Mars more quickly.

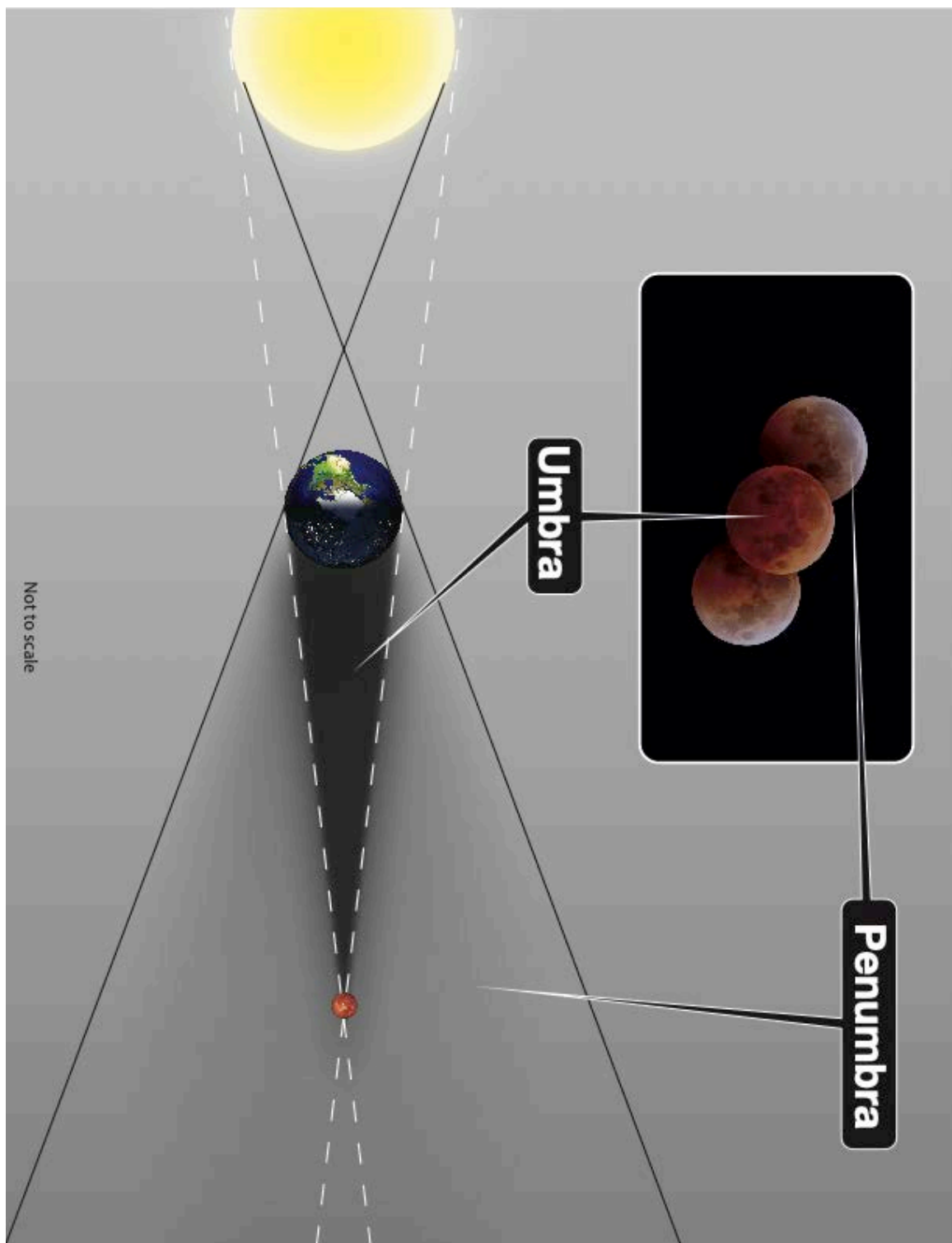
**(P) Explaining Predictable Eclipses (KEY)**

Complete the following at the conclusion of *Kingdom in Peril* unit.

Based on your experience in the *Kingdom in Peril*, construct a scientific explanation for solar and lunar eclipse patterns observed from Earth. Use scientific language to describe the cause, frequency, duration and coverage of solar and lunar eclipses. Include data collected during the experience as evidence to support your explanation. Use appropriately labelled two dimensional models (diagrams) to enhance your explanation. Continue on the back of this sheet if more room is needed for your explanation.

Eclipses are caused when a celestial body blocks Sunlight from reaching another celestial body. When the Moon blocks Sunlight, forming a shadow that strikes Earth, it is called a solar eclipse. Solar eclipses are only seen by a small portion of the daylight side of Earth. The central, dark part of the Moon's shadow is called the umbra and is only visible on a small path across Earth. Solar eclipses are observed less frequently than lunar eclipses due to this small shadow cast across the planet, the five-degree inclination of the Moon's orbit and the size of the Moon's shadow. When Earth blocks Sunlight forming a shadow on the Moon it is called a lunar eclipse. Lunar eclipses are seen by approximately half the surface of the Earth, the entire night side. The Moon turns red when it passes through the dark central part of Earth's shadow called the umbra. Lunar eclipses last several hours because Earth casts a large shadow for the Moon to pass through. Although the Moon is in the correct position for a lunar eclipse every month, it does not occur because the Moon's orbit is tilted five degrees from Earth's orbit.



(Q) Umbra/Penumbra Diagram

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