Solar System Explorer **Answer Key**

Vocabulary: astronomical unit, dwarf planet, eccentricity, ellipse, gas giant, Kepler's laws, orbit, orbital radius, period, planet, solar system, terrestrial planet

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

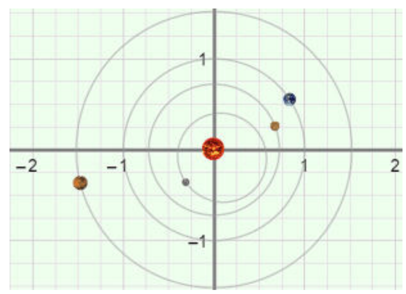
1. List all of the **planets** you can think of in our **solar system**. Try to list them in order from closest to farthest from the Sun.

   Answers will vary. [Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune]

2. Which planets are most like Earth? Which are most different from Earth? Explain.

   Answers will vary. [Venus and Mars are both rocky planets that contain atmospheres.]

Gizmo Warm-up
The *Solar System Explorer* Gizmo™ shows a model of the solar system. All of the distances, but not the sizes of the planets, are shown to scale. To begin, turn on **Show orbital paths** and click **Play** (▶). You are looking at the four inner planets.

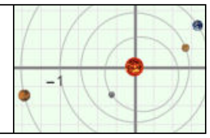


1. In which direction do planets go around the Sun, clockwise or counterclockwise? *Counterclockwise*

2. An **orbit** is the path of a body around another body. What is the shape of the planetary orbits around the Sun? *Planetary orbits are nearly circular.*

3. Click **Pause** (⏸). You can see the name of each planet by holding your cursor over the planet. What is the order of the eight planets, starting from the Sun? Click the "zoom out" button (–) to see the outer planets and Pluto, which is classified as a **dwarf planet**.

   The eight planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Activity A: **Classifying planets**	Get the Gizmo ready: • Click **Reset** ( ).	

Question: How are planets classified?

1. Think about it: How do you think astronomers group planets? *Answers will vary.*

2. Gather data: Select **Mercury** from the **Solar system** menu at left. Turn on **Additional data**. In the table below, record Mercury's **Mass**, **Mean radius**, and **Density**. Then repeat for each of the other planets as well as the dwarf planet Pluto. Include units.

Planet	Mass ($\bullet\ 10^{23}$ kg)	Mean radius (km)	Density (g/cm^3)
Mercury	*$3.3 \bullet 10^{23}$ kg*	*2,440 km*	*5.427 g/cm^3*
Venus	*$48.7 \bullet 10^{23}$ kg*	*6,052 km*	*5.243 g/cm^3*
Earth	*$59.7 \bullet 10^{23}$ kg*	*6,378 km*	*5.515 g/cm^3*
Mars	*$6.4 \bullet 10^{23}$ kg*	*3,397 km*	*3.933 g/cm^3*
Jupiter	*$18{,}990 \bullet 10^{23}$ kg*	*71,490 km*	*1.326 g/cm^3*
Saturn	*$5{,}680 \bullet 10^{23}$ kg*	*60,270 km*	*0.687 g/cm^3*
Uranus	*$869 \bullet 10^{23}$ kg*	*25,560 km*	*1.270 g/cm^3*
Neptune	*$1{,}020 \bullet 10^{23}$ kg*	*24,760 km*	*1.638 g/cm^3*
Pluto (dwarf planet)	*$0.1 \bullet 10^{23}$ kg*	*1,195 km*	*1.750 g/cm^3*

3. Analyze: What patterns do you notice in your data table?

   Answers will vary. [Mercury, Venus, Earth, and Mars all have masses below $100 \bullet 10^{23}$ kg, radii below 10,000 km, and densities greater than 3.0 g/cm^3. Jupiter, Saturn, Uranus, and Neptune all have masses above $800 \bullet 10^{23}$ kg, radii above 20,000 km, and densities less than 2.0 g/cm^3. Pluto has characteristics of both groups.]

4. Analyze: Based on the data you have collected, how would you divide the planets into two groups? Explain your reasoning. (Note: Do not include Pluto in these groups.)

   Answers will vary. [Astronomers divide the planets into two groups, the terrestrial planets (Mercury, Venus, Earth, and Mars) and gas giants (Jupiter, Saturn, Uranus, and Neptune).]

(Activity A continued on next page)

Activity A (continued from previous page)

5. Classify: Astronomers classify the eight planets in our solar system into two groups: **terrestrial planets** and **gas giants**. Terrestrial planets have rocky surfaces, while gas giants are composed mainly of gas. Based on your data, classify each planet as a terrestrial planet or a gas giant. (Hint: Look at the density of each planet.)

   Mercury: *Terrestrial planet*

   Venus: *Terrestrial planet*

   Earth: *Terrestrial planet*

   Mars: *Terrestrial planet*

   Jupiter: *Gas giant*

   Saturn: *Gas giant*

   Uranus: *Gas giant*

   Neptune: *Gas giant*

6. Summarize: Compare the masses, radii, and densities of the terrestrial planets and the gas giants.

   A. What do the terrestrial planets have in common?

      The terrestrial planets are all relatively low in mass and radius and high in density.

   B. What do the gas giants have in common?

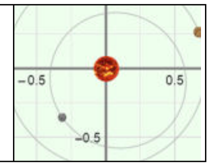
      The gas giants are all relatively high in mass and radius and low in density.

7. Extend your thinking: Why doesn't Pluto fit into either the terrestrial planet group or the gas giant group?

   Pluto's radius is too small to be classified as a gas giant. (Pluto is also small for a terrestrial planet.) Pluto's density is too low to fit into the terrestrial group and its density is too high to fit into the gas giant group. [In fact, Pluto is made of frozen ice.]

8. Think and discuss: Why do you think the inner planets are small and dense, while the outer planets are gas giants? If possible, discuss your ideas with your classmates and teacher.

   Answers will vary. [For an explanation, see the last page of the Teacher Guide.]

Activity B: Planetary orbits	<u>Get the Gizmo ready</u>: • Click **Reset**. • Click the “zoom in” button (+) several times to zoom in as far as possible.	

Introduction: Johannes Kepler (1571–1630) was a German astronomer who spent years poring over a vast store of planetary data compiled by his predecessor, Tycho Brahe. After many incorrect theories and other setbacks, Kepler at last determined the beautifully simple physical laws that govern orbiting bodies. These rules are now known as **Kepler’s laws**.

Question: What rules describe the size and shape of planetary orbits?

1. <u>Observe</u>: Select **Mercury** from the **Solar system** menu. Look at Mercury’s orbit.

   A. What do you notice? *Mercury’s orbit is not exactly a circle.*

   B. Is Mercury always the same distance from the Sun? *No*

   Kepler’s first law states that an orbit is in the shape of a slightly flattened circle, or **ellipse**. While a circle contains a single point at its center, an ellipse contains two critical points, called *foci*. The Sun is located at one focus of a planet’s orbit.

2. <u>Gather data</u>: The **eccentricity** of an ellipse describes how “flattened” it is. A circle has an eccentricity of 0, and a flat line segment has an eccentricity of 1.

   A. Look at the data displayed at left. What is the eccentricity of Mercury’s orbit? *0.206*

   B. Zoom out to look at the other orbits. Which object’s orbit is even more eccentric than the orbit of Mercury? *Pluto’s orbit (eccentricity = 0.248)*

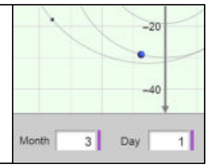
3. <u>Observe</u>: Zoom in all the way, and select **Mercury** again. Check that the simulation speed is **Slow** and click **Play**. Observe the speed of Mercury as it goes around the Sun.

   What do you notice? *Mercury changes speed. It moves fastest when it is closest to the Sun and slowest when it is farthest from the Sun.*

   Kepler’s second law states that a planet speeds up as it gets closer to the Sun, and slows down as it moves farther away.

4. <u>Confirm</u>: Charge the speed to **Fast** and zoom out to observe Pluto. Does Pluto follow Kepler’s second law? Explain.

   Yes, Pluto moves fastest when it is closest to the Sun and slowest when it is farthest from the Sun.

Activity C: **Planetary periods**	Get the Gizmo ready: • Click **Reset**. • Zoom out as far as possible. • Set the speed to **Fast**.	

Introduction: Kepler's third law describes the relationship between a planet's **orbital radius**, or its mean distance from the Sun, and the planet's **period**, or amount of time to complete an orbit.

Question: How does a planet's orbital radius relate to its period?

1. Predict: How do you think the period of a planet will change as its distance from the Sun

   increases? *Predictions will vary.*

2. Observe: Click **Play**, and observe the orbits of all the planets. What is the relationship between the speed of planets and their distance from the Sun?

   The planets closer to the Sun move more quickly than planets that are farther from the Sun.

3. Measure: Click **Reset** and zoom in as far as possible. Click **Play**, and then **Pause** when Earth is aligned with either the grid's *x*-axis or *y*-axis. Note the starting time below.

   Then click **Play**, and then click **Pause** again when Earth is in exactly the same position. Note the ending time below.

   Results will depend on the date that this lesson was completed.

Starting time	Month: _____	Day: _____	Year: _____
Ending time	Month: _____	Day: _____	Year: _____

4. Calculate: What is Earth's period? *One year (12 months)*

   Earth takes 12 months to complete an orbit, so Earth's period is 12 months, or one year.

5. Measure: The distance units shown are the grid are called **astronomical units** (AU). Look

   at Earth's orbit. How far is Earth from the Sun in AU? *About 1 AU*

   As you can see, one astronomical unit is equal to the mean Earth-Sun distance, which is approximately 150,000,000 kilometers.

(Activity C continued on next page)

Activity C (continued from previous page)

6. Gather data: Use the **Additional data** display to find the orbital radius and period of each planet. Record this data in the first two columns of the table below. Include units.

Planet	**Mean orbital radius (AU)**	**Period (Earth years)**	R^3	T^2
Mercury	*0.387 AU*	*0.240 years*	*0.057961*	*0.0576*
Venus	*0.723 AU*	*0.620 years*	*0.377933*	*0.3844*
Earth	*1.000 AU*	*1.000 year*	*1.000*	*1.000*
Mars	*1.520 AU*	*1.880 years*	*3.511808*	*3.5344*
Jupiter	*5.200 AU*	*11.860 years*	*140.608*	*140.6596*
Saturn	*9.550 AU*	*29.4600 years*	*870.9839*	*867.8916*
Uranus	*19.200 AU*	*84.010 years*	*7,077.888*	*7,057.6801*
Neptune	*30.100 AU*	*164.790 years*	*27,270.901*	*27,155.7441*

7. Analyze: What happens to the period as the orbital radius increases?

   As the orbital radius increases, the period increases as well.

8. Calculate: Kepler discovered a very interesting relationship between the cube of each planet's orbital radius and the square of its period. Use a calculator to find the cube of each planet's orbital radius, and record these values in the "R^3" column of the table. Record the squares of the periods in the "T^2" column.

   How do the numbers in the "R^3" and "T^2" columns compare?

   For each planet, the cube of the orbital radius is nearly equal to the square of the period.

   Kepler's third law states that the cube of the orbital radius is proportional to the square of the period for any orbiting body. If the orbital radius is measured in astronomical units and the period is measured in Earth years, the numbers are nearly identical.

9. Predict: Pluto has an orbital radius of 39.529 AU. Based on Kepler's third law, what is the approximate period of Pluto's orbit? *248.5271 Earth years*

   (Hint: Find the cube of the orbital radius first, and then take the square root.)

10. Confirm: Look up Pluto's actual period in the Gizmo. What is it, and how does it compare to the calculated value? *248.540 Earth years, almost exactly the same as the calculated value*