Name: ______________________________________ Date: ________________________

Student Exploration: Solar System Explorer

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.)

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.

 ____

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

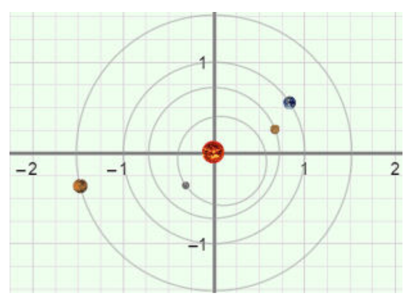
 ____

 ____

 ____

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? __________________________

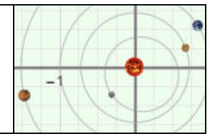
2. An **orbit** is the path of a body around another body. What is the shape of the planetary

 orbits around the Sun? ____

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**.

 ____

 ____

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? ____________________________

   ____

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 ($\times 10^{23}$ kg)	Mean radius (km)	Density (g/cm^3)
Mercury			
Venus			
Earth			
Mars			
Jupiter			
Saturn			
Uranus			
Neptune			
Pluto (dwarf planet)			

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

   ____

   ____

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.)

   ____

   ____

   ____

(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:	_______________	Jupiter:	_______________
Venus:	_______________	Saturn:	_______________
Earth:	_______________	Uranus:	_______________
Mars:	_______________	Neptune:	_______________

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? ___________________________

   ____

   ____

   B. What do the gas giants have in common? ________________________________

   ____

   ____

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

   ____

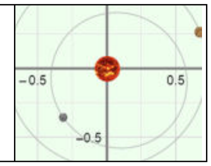
   ____

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.

   ____

   ____

   ____

Activity B: **Planetary orbits**	Get the Gizmo ready: • 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. Observe: Select **Mercury** from the **Solar system** menu. Look at Mercury's orbit.

   A. What do you notice? ____

   B. Is Mercury always the same distance from the Sun? ________________________

   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. Gather data: 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? _______

   B. Zoom out to look at the other orbits. Which object's orbit is even more eccentric than the orbit of Mercury? ____

3. Observe: 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.

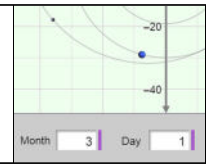
   What do you notice? ____

   ____

   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. Confirm: Charge the speed to **Fast** and zoom out to observe Pluto. Does Pluto follow Kepler's second law? Explain. ____

   ____

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? ____

   ____

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? ______________________

   ____

   ____

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.

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

4. Calculate: What is Earth's period? ____

   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? _____________________________

   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				
Venus				
Earth				
Mars				
Jupiter				
Saturn				
Uranus				
Neptune				

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

____

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? __________________________

   ____

   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? ____

   (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? ____