Kepler's Laws Activity Sheet: First Law

Course:	
Context:	Some basic geometric notions would be good to facilitate the discussion.
PhET sim:	Kepler's Laws: https://phet.colorado.edu/en/simulations/keplers-laws

Learning Goals

- *Explore how the velocity and position of a planet affect the shape of its orbit.*
- *Describe the characteristics of an ellipse and their relation to planetary orbits.*
- *Relate geometric concepts with real-life trajectories: solar system planets and moons, as well as space missions and other astronomical systems.*
- *Discover how Kepler's Laws apply for different bodies in the solar system*

Pre-lab Activity

1. Draw the first five planetary orbits of the Solar System. Discuss with your group to remember the correct order of the orbits.

2. Suppose you want to send a space mission from Earth's orbit to Mars. What route do you think it should take? Draw it on your map above.
3. What are the possible shapes an orbit could have? Mark which of the following shapes you think could be found in planetary orbits:

Shape	Drawing	Yes/No	Reason (if you have one)
Circle			
Triangle			
Square			
Ellipse			
Rectangle			
Parabola			

Share in a whole group discussion your answers.

Open Play

For this activity, we'll be exploring only the First Law Screen.

Play with the PhET sim for 5 minutes: Kepler's Laws - First Law. Describe three main things you have discovered:

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Share your discoveries with the rest of the group.

Collect and Interpret Data

The boundaries of the Solar System:

1. Find all of the ways you can change a body's orbit. Record your observations in the table below

Action	Effect on orbit shape and size	Sketch
Move body closer to the star		

   a. What do all orbits have in common?

   b. What variables affect the orbit's shape? List all of them

2. Describe at least 3 ways to reach edge cases in the simulation (the orbit becomes dashed and a warning message appears on screen). Write the warning message and what you did to reach that orbit.
   a.

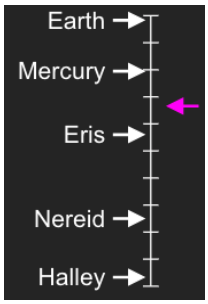
b.

c.

3. In each of those situations, how would you get back to a stable orbit?

Eccentricity

Toggle the Eccentricity and Foci checkboxes and create different orbits. You should see the panel below:



4. Changing the orbit, try to get the pink arrow to each label of the Eccentricity panel (see picture on the left). Describe the process you used to achieve this.

5. Create two different orbits with the same eccentricity as Eris. What is the same in those orbits, and what is different?

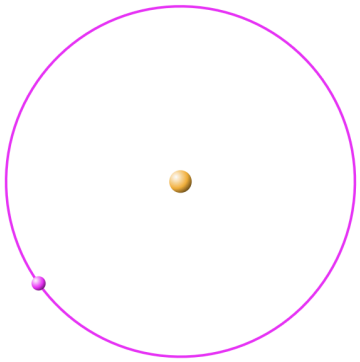
6. Describe in your own words: What is eccentricity?

7. What observations can you make about the Foci related to Eccentricity?

How velocity affects the orbits

Restart the sim. For these challenges, **move the velocity arrow only.**

8. Discover how to create a circular orbit. Sketch the velocity vector below:

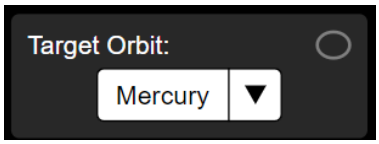


9. Create a highly eccentric orbit (eccentricity greater than 0.8) that doesn't escape or crash into the sun, what characteristics does the velocity have in this scenario?

Discuss with your group to see the different conclusions your peers arrived at

Mimicking the Solar System

For these challenges you can move the planet and alter its velocity.



10. Use the **'Target Orbit'** menu to recreate the orbits of the first 5 planets in the solar system and fill the next table with their values

Target Orbit	Semi-major axis, **a** (AU)	Semi-minor axis, **b** (AU)	Focal distance, **c** (AU)	Eccentricity

11. Use these data to draw a more scale realistic orbits of the first five planetary orbits of the Solar System

12. Look on the internet for the values of the other planets in the solar system, what do you think they are not represented in the simulation?

13. Compare your drawing with the one in the pre-lab. Did you learn something new about our solar system? Describe it

14. Space mission (Advanced & Optional)

In real space missions, it's impossible to drag the body around. The new challenge is to choose a target orbit and reach it, but only by changing the velocity and playing the sim. You can pause and make velocity adjustments whenever necessary.

Try to compete with your friends to see who can make the least amount of velocity changes to reach the target orbit. In reality, this would translate to the most efficient mission, with less fuel needed.

Synthesis of Kepler's First Law

15. Look on the internet or in books the statement of Kepler's first Law and write it here:

    a. Based on what you learned from this activity, try to explain this law to an elementary school student using your own words. You can include pictures and screenshots of the simulation!