Kepler’s Laws Activity Sheet: Third Law

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

Learning Goals

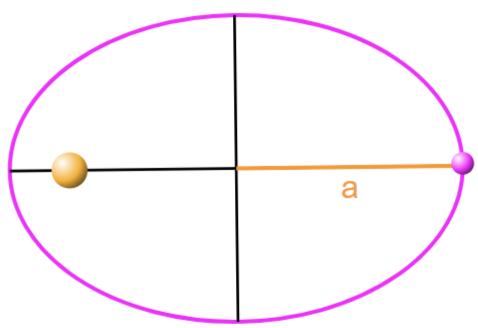
- Explore the relationship between the semi-major axis and the period of an orbit, and their corresponding powers described by the Kepler’s Third Law

Pre-lab Activity

Distances in the orbit

Unlike the circle, drawing an arbitrary diameter is not enough to measure an ellipse. Instead, we use two important lines called the *axes*, which are the smallest and biggest possible diameters (minor and major axis respectively).

The most important measurement of an ellipse is certainly the **semi-major axis** represented with the symbol **a**, which is the distance measured from the center to the border, along the major axis. The name also indicates that its length is exactly half of the major axis.



1. In the above image, use a ruler to verify that the longest distance from the center is indeed **a**.

2. Think of different shaped orbits. Is the orbital period related to any other property? List the orbital elements you think influence the period.

Open Play

Allow 5 min to play with the PhET sim. *Kepler's Laws - Third Law*. Describe three main things you have discovered:

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-
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Share your discoveries with the rest of the group.

Collect and Interpret Data

Measuring Periods

Now we will analyze how the Period of a planetary orbit is defined, and different ways to measure it within the simulation.

1. Based on the behavior of the Period Tool, how would you define the period of an orbit?

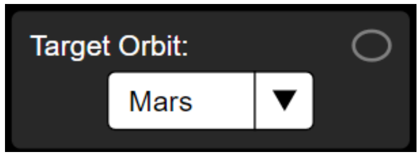
2. Take multiple period measurements of the same orbit. Does the starting point alter the measurement? Explain

3. Measure the period of a circular orbit, and compare with the period of more elliptical orbits but with **the same semi-major axis:**

Type	Period, T (years)	Semi-major axis, a (AU)
Circular		
Mildly Elliptical		
Highly Elliptical		

4. Compare the results with a partner. What's your conclusion? Does eccentricity impact the period of an orbit?

5. Now let’s make period measurements for different orbits of the solar system. Then, calculate the relation of T/a. For this, remember to use the **‘Target Orbit’** panel to recreate real world orbits:



	Period, T (years)	Semi-major axis, a (AU)	T/a (AU/years)
Mercury			
Earth			
Mars			

6. Do you see any patterns of Period vs Semi-major axis?
   a. Does the relation T/a change? How much?

   b. For which planets is it bigger?

   c. Draw the shape of the Graph:

7. Find the combination of **exponents** for which the relation **T/a remains constant** for all orbits. Include a screenshot or drawing of the graph, what shape does the graph have now?

Period power:	$T^{\square}$	Graph:
Semi-major axis power:	$a^{\square}$	

8. With the support of your teacher, find the equation of the curve that you just found.

9. Use the above equation to find out what the semi-major axis of Halley's Comet is, knowing that its period is 76 years.

10. Suppose that NASA just discovered an asteroid orbiting the sun with a semi-major axis of 3 AU. Can you use Kepler's Third Law to calculate its period in years?

Changing Star Mass

11. Describe what happens to the relation T/a when the mass of the star changes.

12. Can you find the new equation for Kepler's Third Law for a stellar system where the star's mass is twice as the sun's?

Post-lab Activity

13. 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!

14. **(Advanced and optional)** We can obtain a more general expression for Kepler's Third Law using Newton's Gravity equations. This new expression will work for orbits around any body in the universe (Such as Earth, the Moon, and even faraway planets, stars and galaxies). This is the "expanded Kepler's Third Law":

$$T^2 = \frac{4\pi^2}{GM} a^3$$

    a. Do you recognize any of these new symbols? Has the third law changed much? Discuss with your teachers the meaning of this equation and how to use it.