

## Kepler's Laws and Planetary Motion

Geology 1P

Mr. Traeger

Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

### Purpose

The purpose of this activity is to become more familiar with Kepler's Laws of Planetary Motion. This activity has been modified from the Genesis Mission *Search for Origins* Education Series.

[http://genesismission.jpl.nasa.gov/educate/scimodule/Destination\\_L1.html](http://genesismission.jpl.nasa.gov/educate/scimodule/Destination_L1.html)

### Materials

• Cardboard	• 2 Push Pins	• Cotton Twine
• Pencil	• Calculator	• Phet <a href="#">My Solar System</a> Animation
• Computer with Internet	• White 8.5-X 11+Paper	• Ruler

### Part 1: Drawing an Ellipse and Calculating Eccentricity: Kepler's First Law of Planetary Motion

- Obtain a piece of cardboard, two push pins, and a piece of string about 25 centimeters long.
- Tie your piece of string in a loop.
- Place your paper on the cardboard and put your push pins in the middle of the page length wise. The push pins should be about 10 centimeters apart. Changing this distance will change the shape of your ellipse.
- Put your loop of string over the ends of the push pins. Draw the loop tight with the tip of your pencil and form a triangle with your string. Keep the loop tight and draw an ellipse.
- Remove the string and push pins from your paper.
- Label each hole made by the push pins %focus 1+and %focus 2.+
- Choose one of these foci and label it %Sun.+
- Choose a place on the outline of your ellipse and place a dot there. Label the dot with a planet name of your choosing. Ex.) Planet Traegon.
- Find the point on the outline of the ellipse that is closest to the dot that you made the Sun. Label this point %Perihelion.+
- Find the point on the outline of the ellipse that is farthest from the dot that you made the Sun. Label this point %Aphelion.+
- Put an %+directly in the center of your ellipse exactly half way between the two foci.
- Draw a line from the %+to the dot that you denoted as the Sun. Label this line as %a+.
- Draw another line from the %+through the focus that does not denote the Sun and all the way to the point that you denoted %Aphelion.+Label this line as %a.+In math, we call this line the %semi-major axis.+It is similar to the radius of a circle.
- Eccentricity is the measurement of how stretched out an ellipse is. It ranges from zero to one. Zero is the eccentricity of a circle and one is the eccentricity of a straight line. Calculate the value of the eccentricity for the ellipse you drew by measuring the length of line %b+and measuring the length of line %a.+Calculate the eccentricity of the ellipse by taking %b+and dividing it by %a.+Put your data below.

Length of line "c" in centimeters	Length of line "a" in centimeters	Eccentricity of the ellipse you drew (c/a)

15. After doing this activity, what does Kepler's First Law of Planetary Motion say?

16. Staple the ellipse drawing that you made to this lab when you turn it in. Failure to do so will result in a lot of lost points!

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### Part 2: Calculating the Eccentricity of Planet Orbits

1. Calculate the eccentricity of each planet by using the formula  $e = c/a$ . Fill in your data in the chart below. State your answer in the proper number of significant figures.

Planet	Distance from center of ellipse to focus in Astronomical Units (c)	Semi-Major Axis in Astronomical Units (a)	Eccentricity (e)
Mercury	0.080	0.387	
Venus	0.005	0.723	
Earth	0.017	1.000	
Mars	0.142	1.524	
Jupiter	0.250	5.203	
Saturn	0.534	9.540	
Uranus	0.901	19.180	
Neptune	0.271	30.060	
Pluto (Dwarf Planet)	9.821	39.440	

2. Which of the planets' orbits is the most eccentric? Assume that Pluto is still a planet for this question.
  
3. Which of the planets' orbits is the least eccentric (closest to a circle's eccentricity of zero)? Assume that Pluto is still a planet for this question.
  
4. Which two planets have the most similar eccentricity?
  
5. Which planet has an eccentricity most similar to Earth's eccentricity?
  
6. The average eccentricity of the Moon's orbit around the Earth is 0.054900489. Would you say the eccentricity of the Moon's orbit is low, medium, or high with respect to most of the planets' orbits around the Sun?
  
7. How could the eccentricity of a planet's orbit affect the amount of solar radiation it receives from the Sun?

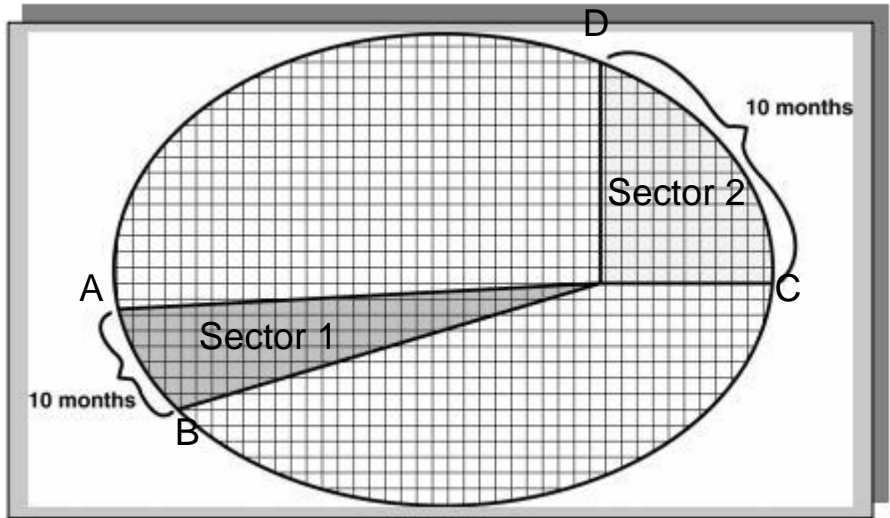
**Part 3: Kepler's Second Law of Planetary Motion**

1. Go to the *My Solar System Animation* link on the Internet Investigations section of the class website. Set up an orbit of a planet around the Sun that is fairly elliptical by adjusting the velocity vector of the orbit. Run the animation.
2. How does the speed of a planet's orbit at perihelion compare to the speed of a planet's orbit at aphelion? Why is there a difference in speed?

3. Look at the diagram below. **Count** the number of squares in sector 1 and in sector 2.

Squares in Sector 1: \_\_\_\_\_

Squares in Sector 2: \_\_\_\_\_



4. What can you say about the number of squares in Sector 1 compared to the number of squares in Sector 2? What does the number of squares imply about each sector's area?
5. If it takes the same amount of time for a planet to move from point A to point B as it does for a planet to move from point C to point D, then what must a planet do in terms of its speed in each sector? Speed equals distance over time. Note that the distance between A and B is shorter than the distance between C and D.

Speed from A to B (Faster or Slower?)	Speed from C to D (Faster or Slower?)

6. Based on what you have seen here, Kepler's Second Law says that planets sweep out equal \_\_\_\_\_ in equal \_\_\_\_\_. To do this, planets \_\_\_\_\_ when closer to the Sun and they \_\_\_\_\_ when farther from the Sun.

7. Earth's perihelion is in January and its aphelion is in July? Why is this not the reason for the seasons on Earth? If it was, the Northern Hemisphere on Earth would be hotter in January and colder in July. Think about it.

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### Part 4: Kepler's Third Law of Planetary Motion

Use the following chart to answer the questions that follow.

Planet	Mean Orbital Velocity and Mean Distance to the Sun								
	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Orbit Velocity in km/s	47.87	35.02	29.79	24.13	13.07	9.67	6.84	5.48	4.75
Mean Distance to the Sun (a) in Astronomical Units (AU)	0.39	0.72	1.00	1.52	5.20	9.54	19.19	30.07	39.48

- How does the distance from the Sun of a planet affect the planet's orbital velocity? In other words, do planets that are farther from the Sun travel faster or do they travel slower?
- Using the formula  $p^2 = a^3$  (where  $p$  = the period of a planet's orbit in years and  $a$  = the planet's average distance from the Sun in Astronomical Units), calculate the amount of time ( $p$ ) it takes each planet to go around the Sun. Show your work or at least tell me how you got your answers.

Rearrange the formula  $p^2 = a^3$  to solve for  $p$  BEFORE plugging in the numbers. Put this equation below.

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Orbital Period (p) in years (time it takes to go around Sun)									

- Based on your data above, what does Kepler's Third Law of Planetary Motion say?

### Conclusion

All of this work means nothing if you don't use it. How might Kepler's Laws be used by JPL to plan missions to other planets in terms of timing the mission launches? If you have time, go back to the *My Solar System* computer simulator and play with it to see how crazy planetary orbits can get!