Kepler's Laws and Planetary Motion

<u>Purpose:</u> 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://gensistmission.jpl.nasa.gov/educate/scimodule/Destination_L1.html

<u>Materials:</u>
Cardboard
Pencil
2 Push Pins
Calculator
Cotton Twine
Phet <u>My Solar System</u> Animation
https://phet.colorado.edu/sims/my-solar-system/my-solar-system_en.html
Laptop with Internet access
1 sheet of computer paper
Ruler

<u>Part 1: Drawing an Ellipse and Calculating Eccentricity: Kepler's First Law of Planetary Motion</u>

1. Obtain a piece of cardboard, two push pins, and a piece of string about 25 cm long.

2. Tie your piece of string in a loop.

3. Place your paper on the cardboard and put your pushpins in the middle of the page lengthwise. The pushpins should be about 10 cm apart. Changing this distance will change the shape of your ellipse.

4. Put your loop of string over the end of the pushpins. Draw the loop tight with the top of your pencil and for a triangle with your string. Keep the loop tight and draw an ellipse.

5. Remove the string and push pins from your paper.

6. Label each hole made by the pushpins focus 1 and focus 2.

7. Choose one of these foci and label it "Sun".

8. Choose a place on the outline of your ellipse and place a dot there. Label the dot with a planet name of your choosing (make sure it's appropriate; nothing NAUGHTY).

9. Find the point on the outline of ellipse that is closest to the dot you made the "Sun". Label this point Perihelion.

10. Find the point on the outline of ellipse that is furthest to the dot you made the "Sun". Label this point Aphelion.

11. Put an "X" directly in the center of your ellipse exactly half way between the two foci.

12. Draw a line from the "X" to the dot that you denoted as the "Sun". Label this line as "C".

13. Draw another line from the "X" 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.

14. 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 "C" and measuring the length of line "A". Calculate the eccentricity of the ellipse by taking "C" and dividing it by "A". Put your data below.

Length of line "C" in cm	**Length of line "A" in cm**	**Eccentricity of the ellipse you drew ("C"/"A")**

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

16. **Staple the ellipse drawing that you made to this lab when you turn it in. Failure to do so will result in a lower score than you anticipated.**

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 circles 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 Earths eccentricity?

6. The average eccentricity of the Moons orbit around the Earth is 0.054900489. Would you say the eccentricity of the Moons orbit is low, medium, or high with respect to most of the planets orbits around the Sun?

7. How could the eccentricity of a planets orbit affect the amount of solar radiation it receives from the Sun?

Part 3: Kepler's Second Law of Planetary Motion

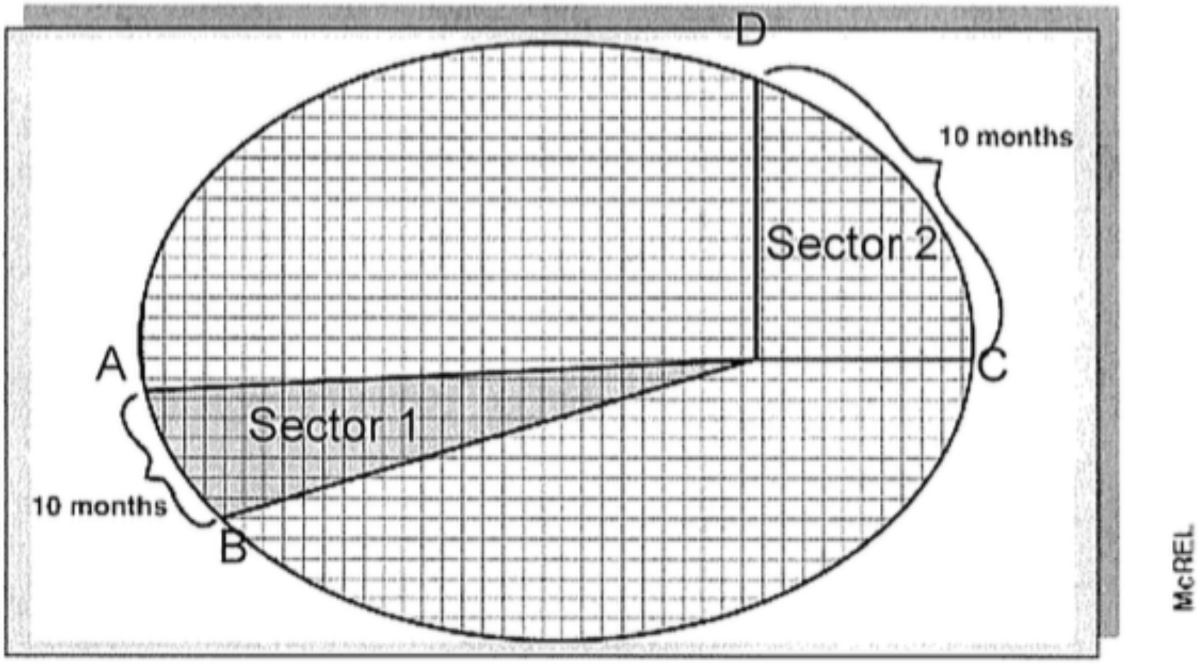
1. Go to the My Solar System Animation link posted in Schoology or type in the URL. Set up an orbit of a planet around the Sun that is fairly elliptical by adjusting the velocity vector of the orbit. Run the animation.

2. How does the speed of a planets orbit at perihelion compare to the speed of a planets orbit at aphelion? Why is there difference in speed?

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

   Squares in Sector 1:_______________

   Squares in Sector 2:_______________



4. What can you say about the number if squares in Sector 1 compared to the number of squares in Sector 2? What does the number of squares imply about the sectors 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	Speed from C to D
Faster or Slower	**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 were, the Northern Hemisphere on Earth would be hotter in January and colder in July. Think about it.

Part 4: Kepler's Third Law of Planetary Motion

Use the following chart to answer the questions that follow.

Mean Orbital Velocity and Mean Distance to Sun

Planet	**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

1. 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?

2. Based on your response to number 1 in Part 3 define Kepler's Third Law of Planetary Motion.

Conclusion:

All of this work means nothing if you don't use it. How might Kepler's Laws be used by JPL (Jet Propulsion Laboratory) to plan missions to other planets in terms of timing the mission launches? Use CER format.