Kepler's 1st and 2nd Law of Planetary Motion & The Orbit of Mercury

At about the same time that Galileo was publishing his observations of the moons of Jupiter and the Copernican model was gaining in popularity, Johannes Kepler, a young Danish astronomer, suggested that the planets revolve about the Sun in elliptical, rather than circular orbits. Kepler took over as Royal Astronomer from Tycho Brahe, inheriting Tycho's ingeniously designed observatory and his more than 20 years' of observational data. Based on Tycho's data and his own observations, Kepler proposed what are now known as "Kepler's Laws of Planetary Motion". These famous laws rank second only to Newton's Big Three in our understanding of classical physics and are studied by every beginning physics student.

In short, Kepler's Laws state:

1) **The planets move in elliptical orbits with the Sun at one focus;**
2) **A radius vector from the Sun to a planet sweeps out equal areas in equal periods of time;**
3) **The ratio of the cube of the average distance of any planet from the Sun to the square of its period of revolution is a constant.**

It was not until the latter part of the 1600's that Sir Isaac Newton provided a correct explanation of Kepler's Laws; based on his own three force laws (inertia, F=ma, and action/reaction) and his law of gravitation.

Procedure: Using the data table for Mercury, complete the following steps:

1. Place a dot in the center of your graph paper. This dot represents the Sun.

2. With a protractor, put dots at the angular distances indicated for each data point. Go counter clockwise, with 0 degrees on the right.

3. Use an appropriate scale that will fit on your graph paper. A suggested scale is 2 cm = .1 A.U. Measure the distance from the Sun for each data point and put a dot at that distance and label the data point. When you have plotted all 18 data points, connect the dots as smoothly as you can.
   You have now plotted the orbit of the planet mercury.

4. Choose data points 2 and 3 as one pair, and data points 10 and 11 as another pair. Draw the radius vector from the Sun to each of these data points. Label the sector formed by the radius vectors to points 2 and 3 "Sector A", and the sector formed by the radius vectors to points 10 and 11 "sector B".

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Kepler's 1st Law Questions:

1) How many days separate each observation?

2) Is the distance from the Sun to Mercury constant?

3) State Kepler's 1st Law of Planetary Motion

4) Is the Sun in the center of Mercury's orbit? Explain.

5) What shape is the orbit?

6) Is the orbit of Mercury highly elliptical or only a little elliptical?

... You can see that the orbit is not highly elliptical. In fact, if you erase (for a moment) the dot you made for the Sun, and only look at the path of Mercury, the orbit looks like a pretty good circle, doesn't it?

Actually, the farthest out planet, Pluto, has the most *eccentric* (elliptical) orbit, sometimes even coming inside the orbit of the second farthest planet, Neptune.

Kepler's 2nd Law Questions:

1) Using grains of rice, completely fill in Sector A and Sector B. **Please do not spill the rice.**

2) Count the rice grains in each sector. Record the number of rice grains per each sector:

Sector A: _____ Sector B: _____

3) The time separating data points 2 and 3 is equal to the time separating data points 10 and 11. Using the grains of rice, what relationship did you find between the areas of the sectors A and B?

4) When do you think Mercury is moving faster, from data point 2 to 3, or data point 10 to 11? Why?

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Mercury's Orbit

The degrees represent the angular distance Mercury has traveled during each time interval, and the distance measurements tell how far from the Sun Mercury is at each observation.

Note: The time for Mercury to complete one complete orbit is **88 days**.

Note: 1 Astronomical Unit (A.U.) = 150 million km, or 1.5 x 10^8 km, or 1.5 x 10^{11} meters.

observation #	degrees	distance from Sun (A.U.)
1	4	.35
2	**31**	**.32**
3	61	.31
4	**92**	**.31**
5	122	.32
6	**149**	**.35**
7	172	.38
8	**192**	**.41**
9	209	.43
10	**224**	**.45**
11	239	.46
12	**252**	**.47**
13	266	.47
14	**280**	**.46**
15	295	.44
16	**311**	**.42**
17	330	.40
18	**350**	**.37**

Staple your graph paper to this packet and turn in to the basket.
Make sure you have cleaned up all of your rice and returned to the bag.