Kepler's Laws and Planetary Orbits

Name______________

Purpose:

- To provide you with necessary skills to understand how to use Kepler's Laws of Planetary Motion
- To give you practice using Stellarium

Estimated Completion Time: 50 minutes
Resources needed:

- Calculator (preferably scientific)
- Textbook
- Web access is highly desirable

Questions

1. Use Stellarium to investigate the eccentricity of Earth's orbit. To do this look at how both the apparent diameter of the sun and the distance from Earth to the Sun changes during the year.

   a) Find the date at which the Sun is closest to the Earth and the perihelion distance – how does the apparent of the Sun relate to its distance from the Earth?

   Closest Jan 3
   Farthest July 4

   b) Find the date of aphelion and the aphelion distance.

   $r_a = 1.017$
   $r_p = 0.983$ AU

   c) Use the formula $e = \dfrac{r_a - r_p}{r_a + r_p}$ where e is the eccentricity and r_p and r_a are the perihelion and aphelion distances measured in AU to determine the eccentricity of Earth's orbit.

   $e = \dfrac{1.017 - 0.983}{1.017 + 0.983}$

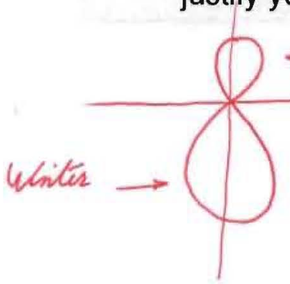
   $e = 0.017$

Figure 1 You can get both the apparent size and distance of the sun by clicking on the Sun and reading the information panel that opens.

2. How does your answer to question 1a) help resolve the common misconception that winter in the Northern Hemisphere occurs because we are farthest from the Sun then?

Sun is closest to us during the coldest part of the winter! Seasons are NOT caused by the varying Earth-Sun distance.

3. Discuss how the analemma that you were introduced to in the lecture on Motion of the Sun can be explained by using Kepler's 2nd Law. At what time during the year is Earth moving fastest around the Sun? Answer this by both showing when this occurs on the analemma as well as what evidence you can use from Stellarium to justify your answer.



We are closest to the Sun during our winter so, according to Kepler II earth moves most rapidly in its orbit at this time. This introduces the biggest error in the time of local noon which is what the analemma measures as shows.

4. Use Kepler's Third Law to answer the following:
   a. A minor planet is 4 AU from the Sun. What is its orbital period in years?

   $p^2 = a^3 \therefore p^2 = 4^3 = 64 \therefore P = \sqrt{64} = 8$ years.

   b. A comet has a closest approach of 0.2 AU from the Sun and an aphelion distance of 88.8 AU from the sun. What is its average orbital distance from the Sun?

   $r_{av} = \frac{1}{2}(r_p + r_a) = \frac{1}{2}(0.2 + 88.8) = \frac{1}{2}(89) = 44.5$ AU

   c. What is the orbital period for the comet in part b) above?

   $P^2 = (44.5)^3 = 88121.1 \quad \therefore \quad P = \sqrt{88121.1} = 296.9$ years

   d. Halley's comet has an orbital period of 75.3 years. Determine its average orbital radius.

   $P^2 = (75.3)^2 = 5670.1 \quad ; \quad p^2 = a^3 \therefore$

   $a^3 = 5670.1 \quad \therefore \quad a = \sqrt[3]{5670.1} = 17.8$ AU

5. A comet is observed to have a perihelion distance of 0.43 AU and an aphelion distance of 56.8 AU. What is the average radius and period for this comet?

$a = \frac{1}{2}(r_a + r_p) = \frac{1}{2}(56.8 + 0.43) = 28.62$ AU

$P^2 = a^3 = (28.62)^3 = 23430.5$

$p^2 = \sqrt{23430.5} = 153.1$ years

The comet has an average radius of 28.62 AU and a period of 153.1 years.