

## **Planetary Motion – Kepler’s First and Second Laws of Planetary Motion**

### **Student Page**

#### Purpose

To study Kepler’s First and Second Laws of Planetary Motion.

#### Before you Begin

1. When a planet is closer to the Sun, does it move faster or slower in its orbit?
2. Based on what you know of the Earth, does the Earth have an orbit with a low or high eccentricity?

#### A.J.J.A.R. Programs Required

Kepler’s First Law

Kepler’s Second Law

#### Questions

1. What happens to the shape of a planet’s orbit as its eccentricity increases?
2. What is the relationship between the position of the Sun and the position of the orbit’s foci?
3. Imagine you are on a planet orbiting a star with an orbital eccentricity of 0.70 (set up the simulations for this scenario). Approximately how many times farther away from the Sun are you at the maximum distance relative to the minimum distance?
4. Comet Halley (one of the most famous comets in history) has an orbital eccentricity of 0.967. Based on this, relatively how much time during each orbit will Comet Halley be near the Sun? Explain your answer.

#### Advanced Questions

1. At approximately what orbital eccentricity is the maximum orbital velocity twice as much as the minimum orbital velocity?

2. If you double the eccentricity you found in the previous problem, what is the relationship between the minimum and maximum orbital velocities?
  
3. The Sun appears slightly larger in the sky during January than it does during July. Based on this information, during which of these months is the Earth travelling faster in its orbit? Explain your answer.

## Planetary Motion – Kepler’s First Law

### Teacher Page

#### Purpose

To study Kepler’s First and Second Laws of Planetary Motion.

#### Possible Answers to Before you Begin

1. Planets move faster in their orbits when close to the Sun. Some students may predict the opposite, as a common misconception exists that the farther away you are from something, the GREATER the gravity. As an example, students often believe that the Earth’s gravity on the top of a mountain is greater than its gravity in the bottom of a valley. In reality, the opposite is true.
2. The Earth’s orbit has a very low eccentricity. This should not be surprising to most students. In fact, many may believe that the Earth’s orbit is perfectly circular with an eccentricity of zero. Obviously, this will be a difficult question to answer if the concept of eccentricity is not understood.

#### A.J.J.A.R. Programs Required

Kepler’s First Law

Kepler’s Second Law

#### Answers to Questions

1. The shape of a planet’s orbit becomes more elliptical as the eccentricity increases.
2. The Sun is always located at the position of one of the foci.
3. You are approximately 5 times farther away at the maximum distance relative to the minimum distance.
4. Comet Halley spends a very small percentage of its time in orbit near the Sun. When it is at its closest point to the Sun in its orbit (perihelion), it is travelling very quickly. When it is farthest from the Sun in its orbit (aphelion), it is travelling very slowly.

#### Answers to Advanced Questions

1. An eccentricity of 0.17 will yield a maximum orbital velocity of approximately twice as much as the minimum orbital velocity.

2. Doubling the eccentricity to 0.34 results in the maximum orbital velocity being approximately 4.1 times greater than the minimum orbital velocity.
3. Since the Sun appears larger during January, the Earth must be closer to the Sun at that time than it is during July. Therefore, the Earth will be travelling faster in its orbit during January.

### Additional Internet References

#### Kepler's Law of Equal Areas

<http://chabot.cosc.org/~arf/kepler.newton/Keplers2nd.html>

“Kepler actually came up with his so-called Second Law before he realized that the orbits were not circular.”

#### Kepler's Cube-Square Law and the Power of the Force

<http://chabot.cosc.org/~arf/kepler.newton/Keplers3rd.html>

“Kepler discovered his Third Law, that the cube of a planet's mean distance from the Sun is proportional to the square of its period, in 1617, more than ten years after his discovery of the first two laws.”

#### Folding an Elliptical Orbit

<http://chabot.cosc.org/~arf/kepler.newton/Keplers1st.html>

Kepler's First Law, that planets move in elliptical orbits with the Sun at one focus, is the easiest to state, and the hardest to prove, of any of his Three Laws of Planetary Motion.

#### Kepler's Second Law – A JAVA Interactive Tutorial

[http://www.phy.syr.edu/courses/java/mc\\_html/kepler.html](http://www.phy.syr.edu/courses/java/mc_html/kepler.html)

This site is another example of a JAVA applet providing an illustration of Kepler's Second Law.