

Orbital Motion – Kepler’s Laws

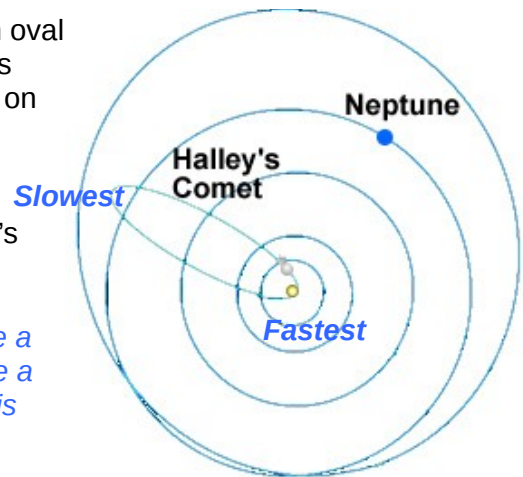
Answer Key

Vocabulary: astronomical unit, eccentricity, ellipse, force, gravity, Kepler’s first law, Kepler’s second law, Kepler’s third law, orbit, orbital radius, period, vector, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

1. The **orbit** of Halley’s Comet, shown at right, has an oval shape. In which part of its orbit do you think Halley’s Comet travels fastest? Slowest? Mark these points on the diagram at right.

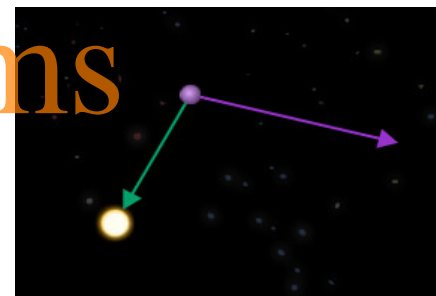


2. How might a collision between Neptune and Halley’s Comet affect Neptune’s orbit?

Answers will vary. [A collision would probably cause a small change in Neptune’s orbit, but would not have a drastic effect on Neptune’s orbit because Neptune is much more massive than Halley’s Comet.]

Gizmo Warm-up

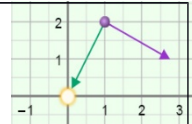
The path of each planet around the Sun is determined by two factors: its current **velocity** (speed and direction) and the **force** of **gravity** on the planet. You can manipulate both of these factors as you investigate planetary orbits in the *Orbital Motion – Kepler’s Laws* Gizmo.



On the **CONTROLS** pane of the Gizmo, turn on **Show trails** and check that **Show vectors** is on. Click **Play** (▶).

1. What is the shape of the planet’s orbit? *An oval*
2. Watch the orbit over time. Does the orbit ever change, or is it stable? *The orbit is stable.*
3. Click **Reset** (↺). Drag the tip of the purple arrow to shorten it and reduce the planet’s initial velocity. Click **Play**. How does this affect the shape of the orbit?

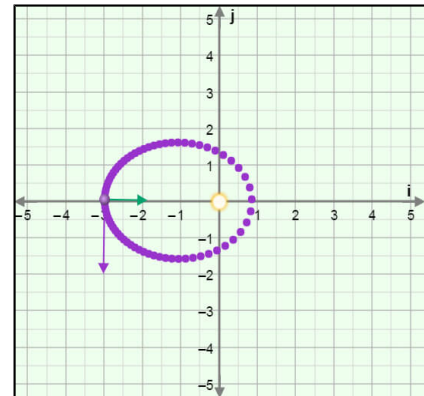
The orbit becomes smaller and more flattened.

Activity A:	Get the Gizmo ready:	
Shape of orbits	<ul style="list-style-type: none"> Click Reset. Turn on Show grid. 	

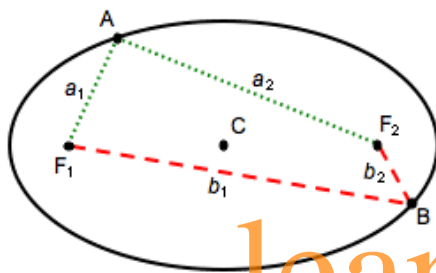
Introduction: The velocity of a planet is represented by an arrow called a **vector**. The vector is described by two components: the **i** component represents east-west speed and the **j** component represents north-south speed. The unit of speed is kilometers per second (km/s).

Question: How do we describe the shape of an orbit?

- Sketch:** The distance unit used here is the **astronomical unit (AU)**, equal to the average Earth-Sun distance. Place the planet on the **i** axis at $r = -3.00i$ AU. Move the velocity vector so that $v = -8.0j$ km/s ($|v| = 8.00$ km/s). The resulting vectors should look like the vectors in the image at right. (Vectors do not have to be exact.)



Click **Play**, and then click **Pause** (⏸) after one revolution. Sketch the resulting orbit on the grid.



- Identify:** The shape of the orbit is an **ellipse**, a type of flattened circle. An ellipse has a center (C) and two points called *foci* (F_1 and F_2). If you picked any point on the ellipse, the sum of the distances to the foci is constant. For example, in the ellipse at left:

$$a_1 + a_2 = b_1 + b_2$$

Turn on **Show foci and center**. The center is represented by a red dot, and the foci are shown by two blue dots. What do you notice about the position of the Sun?

The Sun is located at one of the foci of the ellipse.

- Experiment:** Try several other combinations of initial position and velocity.

A. What do you notice about the orbits?

Sample answer: The orbits all have an elliptical shape.

B. What do you notice about the position of the Sun?

The Sun is always located at one focus of the ellipse.

You have just demonstrated **Kepler's first law**, one of three laws discovered by the German astronomer Johannes Kepler (1571–1630). Kepler's first law states that planets travel around the Sun in elliptical orbits with the Sun at one focus of the ellipse.

(Activity A continued on next page)

