Ozobot Classroom Application: Demonstration of Kepler's Law of Areas

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Introduction

Johannes Kepler (1571-1630) discovered important regularities in the motion of planets, giving strong support for the Copernican theory, in which the sun is the reference body. These regularities ultimately became known as *Kepler's three laws of planetary motion*:

1. ***The Law of Orbits****—All of the planets move in elliptical orbits in which the sun is at one focus*.
2. ***The Law of Areas****—A line joining a planet to the sun sweeps out equal areas in equal times*.
3. ***The Law of Periods****—The square of the period of any planet about the sun is proportional to the cube of its mean radius from the sun*.

These three laws were empirical, as they only described his observed motion of the planets. They provided no theoretical interpretation, as the concept of force was not clearly understood at that time. It wasn't until Sir Isaac Newton formulated his laws of motion and gravitation that it became possible to derive Kepler's laws from those of Newton. Newton once said "If I have seen further [than others], it is by standing on the shoulders of Giants." Among these giants, Kepler would certainly be included.

Ozobot Demonstration of Kepler's Law of Areas

There are lots of Web-based screen animations that illustrate Kepler's Law of Areas, but there are virtually no widespread physical demonstrations using actual hardware—at least not until Ozobot made the scene! There is no better way to experience Kepler's Law of Areas first-hand than by observing an actual physical object move according to this law.

For ready reference while discussing this demonstration, a small copy of the map is shown in Figure 1. A full-page version that can be printed for actual use with Ozobot appears on the last page of this document. The solid black oval is the ellipse representing the orbit of a planet, asteroid, comet, or meteoroid, in its orbit with the sun at one focus of the ellipse, as per Kepler's Law of Orbits. The red and while "triangles" (they actually are curved on one side, so calling them triangles is an approximation) are all of equal area. The red hash marks along the ellipse separate equal time intervals as Ozobot travels about the sun. In order to carve out equal areas when nearest (at *perihelion*) to the sun, Ozobot must travel faster than when it is furthest (at *aphelion*) from the sun. For the ellipse on the map, Ozobot's speed at perihelion is approximately three times its speed at aphelion. The ability to adjust Ozobot's speed programmatically via OzoBlockly makes this demonstration possible. Ozobot will adjust its speed each time it crosses one of the red hash marks on the ellipse. The result is a very realistic physical demonstration of Kepler's Law of Areas.

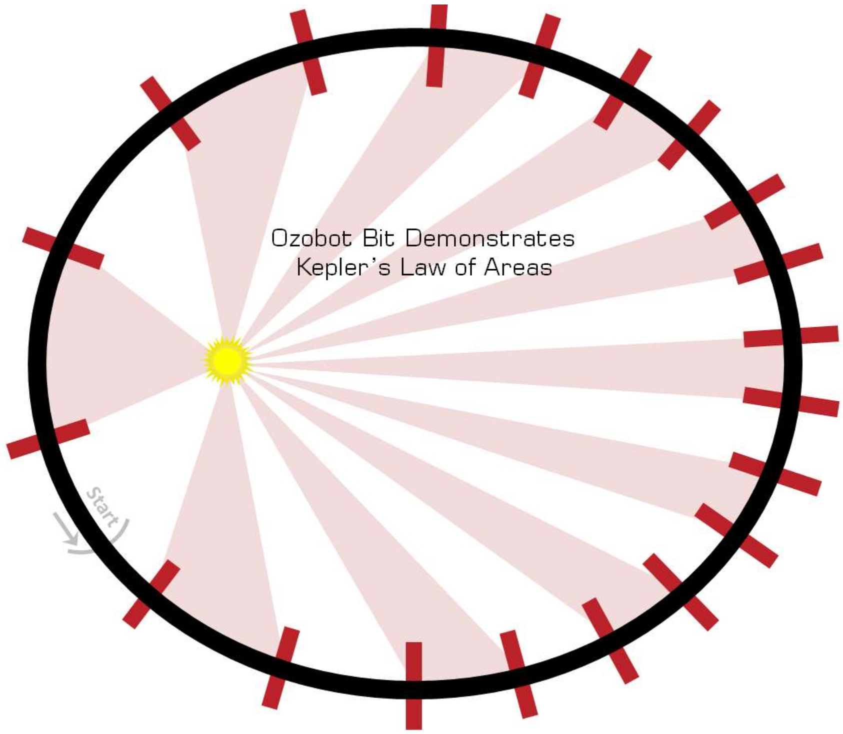


Figure 1

Procedure

1. Make copies of the map at the end of this document for each lab group.
2. Ozobot Bit or Evo should be loaded with the program *KeplerLawOfAreas.ozocode* **(share code is xskkyc)**.
3. Ozobot should always be placed at the Start location on the map facing the direction shown by the gray arrow.
4. Start the program.
5. Ozobot will show a RED LED, and will continue orbiting the sun until you stop him or until his battery runs out of charge.

Student Exercise #1: *Figure 2 shows an ellipse with definitions of some major characteristics of the ellipse. F and F' are the foci. VV' is the major axis. UU' is the minor axis. a and b are the length of semi-major, and semi-minor axes, respectively. The eccentricity of an ellipse is a measure how close to being circular it is. The eccentricity of a circle is 0.*

Have the students use a metric ruler to measure the length of the semi-major and semi-minor axes of the ellipse of the map that Ozobot travels on, and then ask them to use the formula shown in Figure 2 to determine its eccentricity e to three decimal places. [The eccentricity should be approximately 0.5].

Student Exercise #2: *Now that the students know the eccentricity of the orbit upon which Ozobot travels, ask them to pretend that Ozobot is an actual existing comet. Have then consult the Wikipedia article "List of periodic comets" and find the comet in that list that is closest to the eccentricity of Ozobot's ellipse. [Answers will vary depending upon the exact value obtained for the eccentricity. Ask the students to record the*

***designation** for the comet they selected, the **name** of the comet, its **eccentricity**, its **period**, its **perihelion distance**, and the **date of its next perihelion**.*

***Student Exercise #3:** Have the students calculate the amount of time that this comet would have between each of the red hash marks on the Ozobot map. [There are 20 spaces between the red hash marks for one orbit. So the students would need to divide the period by 20.]*

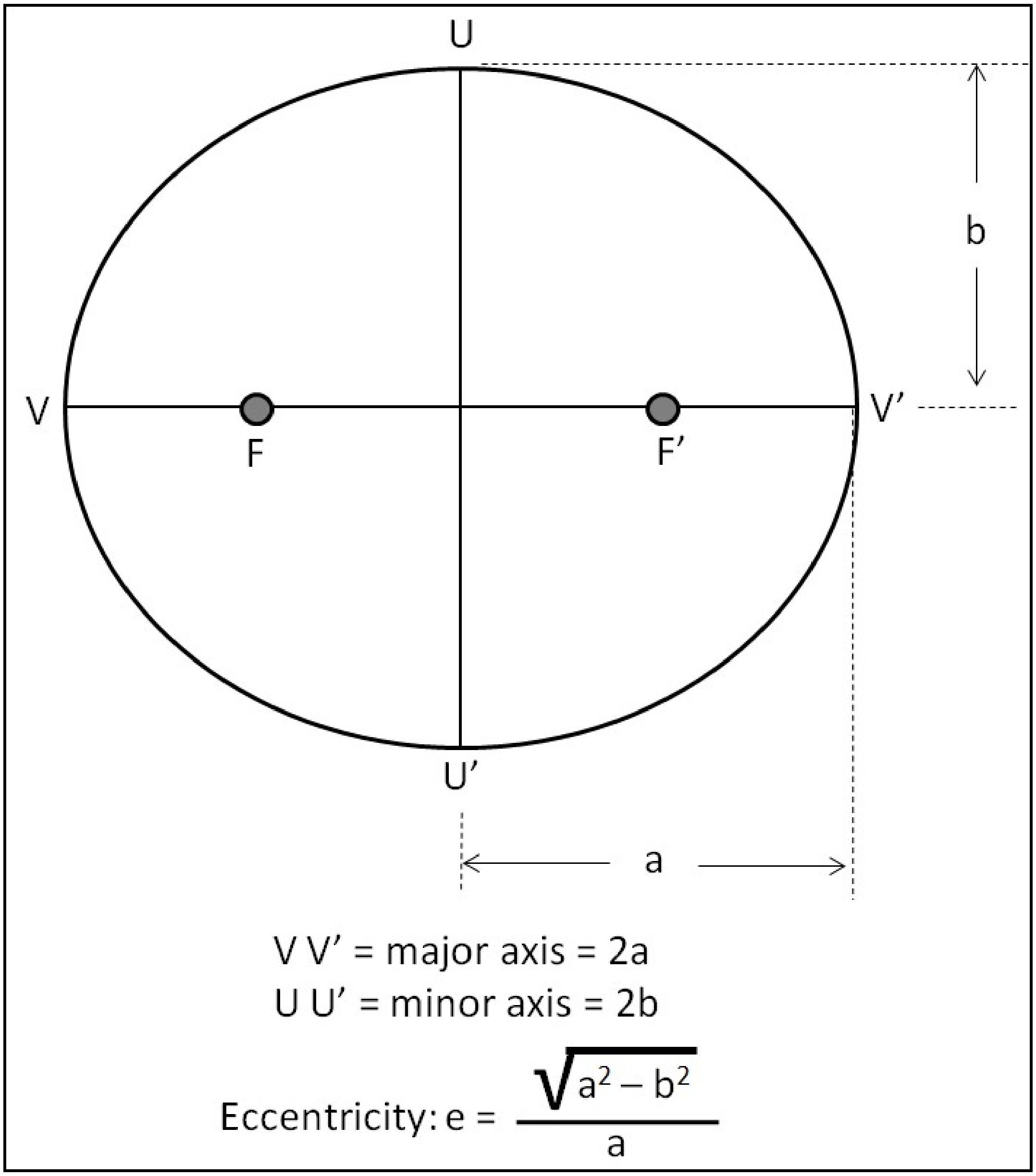
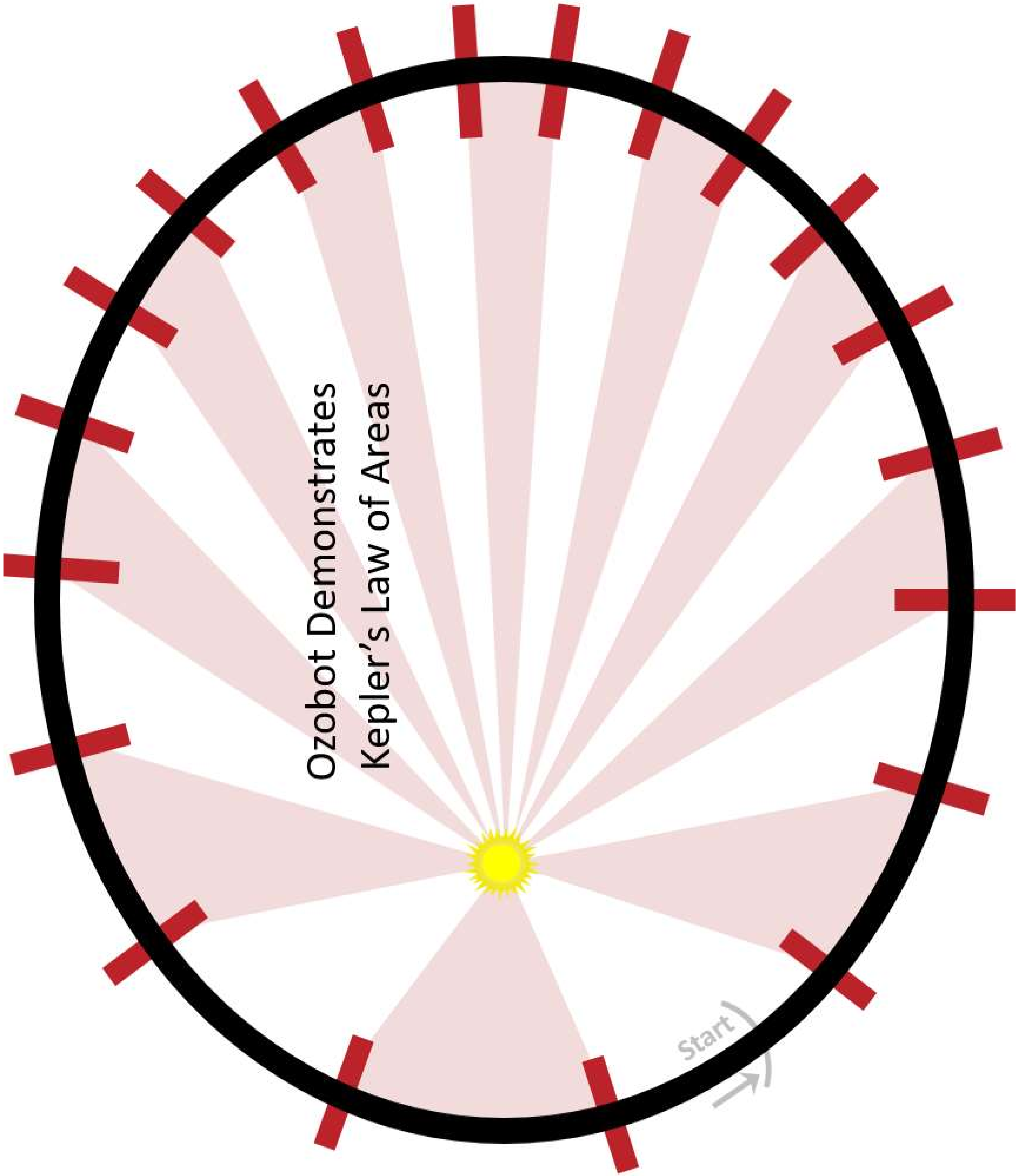


Figure 2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