

**Classroom Demonstration Guidelines  
(Planetary Orbit Simulator)**

The following sequence of directions are steps an instructor might choose to follow in demonstrating the Planetary Orbit Simulator in a classroom situation. We provide these suggestions with appropriate questions (shown in bold italics) to pose to the class as an aid in promoting interactivity. We encourage instructors to adapt these suggestions to their particular educational goals and the needs of their class.

<b>Animation Demonstration Directions</b>	<b>Interactive Questions</b>
<p>Start the applet in its default configuration. You will be on the <b>Kepler's First Law</b> tab viewing an ellipse with <math>a = 1</math> AU and <math>e = 0.4</math>.</p> <p>First change the <b>eccentricity</b> to <math>e = 0</math>.</p> <p>Change the <b>eccentricity</b> back to <math>e = 0.4</math>.</p> <p>Click <b>show center</b>.</p> <p>Click <b>show radial lines</b>.</p> <p>It is useful at this time to drag the planet around to illustrate that the sum is <math>2a</math>.</p> <p>Click <b>show semimajor axis</b>.</p> <p>Use the <b>set parameters</b> for menu to select the</p>	<p><i><b>What is Kepler's first law?</b></i> (all planets move in ellipses ....)</p> <p><i><b>What shape is this?</b></i> (a circle)  <i><b>Why is it a circle?</b></i> (all points are the same distance from the center)  <i><b>What is this distance called?</b></i> (the radius)</p> <p><i><b>Is the sun still at the center of the ellipse?</b></i>(no)  <i><b>What is at the center?</b></i> (nothing)</p> <p><i><b>What is the definition of an ellipse?</b></i> (a set of points equidistant from two points known as foci). Point out that the sum of the two distances is always equal to <math>2a</math>.</p> <p><i><b>Where is the sun located?</b></i> (a focus of the ellipse)  <i><b>What is at the other foci?</b></i> (nothing)</p> <p><i><b>How does one describe an ellipse?</b></i>(by the semi-major axis)</p> <p><i><b>If I increase eccentricity what will happen?</b></i> (the ellipse will become longer and thinner)</p> <p><i><b>When eccentricity is varied does the semi-major axis change?</b></i> (no – but realize that this is a programming choice. <math>e = c/a</math> and we have chosen to vary <math>c</math> and hold <math>a</math> constant.)</p>

<p>Earth and click OK. The earth's orbit will now be illustrated the main window.</p> <p>Use the <b>set parameters for</b> menu to select <b>Pluto</b> and click <b>OK</b>.</p>	<p><i>Does the Earth's orbit look very elliptical?</i> (No, <math>e = 0.017</math>)</p> <p><i>Does Pluto's orbit look very elliptical?</i> (Yes compared to the Earth, but the eccentricity of 0.25 is still small compared to many comet orbits.)</p>
<p>Move to the <b>Kepler's Second Law</b> tab.</p> <p>Change the eccentricity to <math>e = 0.6</math>. Click <b>start animation</b> to make the planet start revolving. (Set the <b>animation rate</b> and semi-major axis to values in the middle of their ranges.)</p> <p>Check the <b>sweep continuously</b> box. Click the <b>start sweeping</b> button. (The <b>adjust size</b> slider should be at a value near 1/16.)</p> <p>Change the <b>eccentricity</b> slider to 0.</p>	<p><i>Does the planet always move at the same speed ?</i> (No)</p> <p><i>When does it move faster?</i> (When it is closer to the planet)</p> <p>Explain that a new sweep is started every 1/16 of the orbital period.</p> <p><i>What are the shapes of the wedges like when the planet is near the sun?</i> (Short fat wedges)</p> <p><i>What are the shapes of the wedges when the planet is far from the sun?</i> (Long thin triangles)</p> <p><i>Which of these two types of triangles are bigger – have the larger area?</i> (They are the same by Kepler's 2<sup>nd</sup> Law).</p> <p><i>What would happen to the shapes of the wedges if I change the eccentricity to zero?</i> (They would all be the same shape.)</p>
<p>Move to the <b>Kepler's Third Law</b> Tab</p> <p>Use the <b>set parameters</b> for menu to select the Earth and click OK.</p> <p>Click show <b>solar system orbits</b>, <b>show solar system planets</b>, and <b>label the solar system orbits</b>. Change the object <b>semi-major axis</b> to its maximum value of 50 AU.</p>	<p><i>What is the period of the Earth's orbit?</i> (1 year)</p> <p><i>What is the semi-major axis of the Earth's orbit?</i> (1 AU) Note that this satisfies Kepler's 3<sup>rd</sup> Law --- that <math>P^2 = a^3</math>.</p> <p><i>Why aren't any of the planets moving?</i> (They are moving, just very slowly at this animation rate.) Kepler's 3<sup>rd</sup> Law tells us that planets</p>

<p>Change the object <b>semi-major axis</b> to a value of 2.5 AU.</p> <p>Change the object <b>semi-major axis</b> to a value of 21.6 AU.</p>	<p>move very slowly far from the sun.</p> <p>Explain how one can now see Kepler's 3<sup>rd</sup> Law at work in the inner solar system in that one can see a gradation of orbital speed from Mercury out to Mars.</p> <p><i>The cube root of 10,000 is 21.6. What would be the orbital period of a planet whose orbit had a semi-major axis of 21.6 AU?</i> (Note that the period must be the square root of 10,000 which is 100 years.) (4 AU and 8 Yrs are values many students can do in their heads.)</p>
<p>Move to the <b>Newtonian Features</b> Tab</p> <p>Change the object <b>semi-major axis</b> to a value of 1 AU and <b>eccentricity</b> of 0.6. Click <b>pause animation</b> when the object is at aphelion.</p> <p>Click the <b>show vector</b> box corresponding to the velocity vector.</p> <p>Click the <b>show vector</b> box corresponding to the acceleration vector.</p> <p>Click <b>start animation</b>.</p>	<p><i>In which direction is the object moving at this instant?</i> (Upward on the screen – a planet always moves in a direction tangent to the orbital path.)</p> <p><i>Is there a force and corresponding acceleration acting on the planet at this time?</i> (Yes, the gravitational force from the sun.)</p> <p><i>In which direction does this force act?</i> (Toward the sun – always on a line between the planet and the sun.)</p> <p>Point out to students how the velocity vector is always tangent to the orbit and the acceleration vector always points toward the sun at all points in the orbit. This is why planets are described as “always falling toward the sun”.</p> <p><i>Where does the acceleration have its maximum value?</i> (at perihelion)</p>