Classroom Demonstration Guidelines
(Eclipsing Binary Simulator)

  The following sequence of directions are steps an instructor might choose to follow in demonstrating the Eclipsing Binary 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. The following demonstration suggestions closely parallel those given in the student guide and make use of the same presets.

Animation Demonstration Directions	Interactive Questions
Start the simulator in its default configuration. You will see a typical binary system being simulated. Point out the **perspective from earth** label in the upper left. Click **start animation** and student can watch the eclipses occur. Click stop animation. Grab the red cursor in the light curve pane and drag it to the center of the large dip. The physical system will now demonstrate the eclipse and students will see that the light curve is graphing the total light from the system over time and that the two panels are closely linked. Point out to students that they can control the masses, radii, and surface temperatures of the stars as well as the eccentricity and semi-major axis of the orbit. The user also controls the perspective from which an Earth-based observer sees the system (i.e. the direction of Earth) through the inclination and the longitude parameters.	***What is the defining characteristic of an eclipsing binary system?*** (That at some point in its orbit one star eclipses the other along our line of sight.) ***How many eclipses occur during a complete orbital cycle?*** (Two for this system) Add that most systems have two eclipses but not all systems. ***When does the large dip in the light curve occur?*** (When the hot blue star is eclipsed.)
Select **Example 1** from the presets pull-down menu. Click **start animation**.	This is a very contrived system. The two stars have the same mass, they are in circular orbits, and we are viewing the system from along the plane of the orbit. ***Which star is larger?*** *(They are the same size.)* ***Which star is hotter?*** *(They have the same surface temperature.)*

Select **Example 2** from the presets pull-down menu. Note that these two stars have the same mass, surface temperature in circular orbits viewed edge on – but one star is twice as big as the other.

Increase the radius of star 1 using the **Star 1 Properties Radius** slider.

This is a good time to emphasize that the light curve is showing normalized flux and that as we change the radius of a star we are changing the value of the total flux. If you now decrease the radius of star 1 the eclipses will get deeper until the two stars have the same radius (Example 1) and then decrease in depth again.

Select **Example 3** from the presets pull-down menu. Note that these two stars have the same mass and radius in circular orbits viewed edge on – but one star is hotter than the other.

Which eclipse is deeper? (They have the same depth because they are the same size and temperature.) These two stars have exactly the same size and surface temperature, so they have the same luminosity. Since the inclination is 90°, the two eclipses are identical.

Are these eclipses total (a star is completely covered during an eclipse) or partial? (They are total but only for an instant – so they look just like partial eclipses having "pointed" dips in the light curve.)

Are these eclipses total (a star is completely covered during an eclipse) or partial? (They are both total implying that one star completely obscures/engulfs the other.)

What happens if we make star 1 bigger? (They depths of the eclipses decrease since the percentage of total star area we see that is covered during an eclipse is less now. The eclipses also get broader in the light curve since they are lasting longer in time.)

Which star is eclipsed when the deeper eclipse occurs? (The blue star since it the hotter of the two stars.)

What will happen to the light curve if the temperature of star 1 is increased? (The deep eclipse becomes deeper and the shallow eclipse becomes even more shallow.)

Select **Example 4** from the presets pull-down menu. Note that these two stars have the same radius and surface temperature viewed edge on – but one star is more massive than the other.	*How is the light curve for this system different from Example 1?* (They are identical – increasing one star's mass did not change the light curve.)
You may wish to toggle back and forth between Example 1 and Example 4 to illustrate that the light curve doesn't change. Note that the appearance of the systems will not be exactly the same due to different scaling factors.	
Unselect **lock on perspective from earth** and drag the system so that the observer is looking directly down on the system. Now toggle back and forth between Example 1 and Example 4.	*How is the appearance of this system different from Example 1 when you are looking down unto the plane of the orbit?* (Since the stars now have different masses they are not the same distance from the center of mass.)
	What will happen to the appearance of the system if the mass of star 1 is increased? (Star 1 will move closer to the center of mass and star 2 will move farther away.)
Select **Example 5** from the presets pull-down menu. Note that these two stars have the same radius, surface temperature and mass viewed edge on – but now the eccentricity is 0.4.	*What will happen to the light curve if the eccentricity is decreased to zero?* (The two eclipses will occur symmetrically in time.)
Return the eccentricity of 0.4.	*Is there a way to make the eclipses occur symmetrically in time without changing the eccentricity?* (Look at the system along the long axis – change the longitude to 90°.)
Point out to students that the eclipses occur symmetrically even though the eccentricity is not zero – this is a good example of how tricky it is to extract information from light curves.	*When the system is viewed from this orientation note how one eclipse is "fatter" than the other. Why is this?* (The stars move very rapidly when near perihelion yielding a narrow/short eclipse and very slowly near aphelion yielding a fat/lengthy eclipse.)

Select **Example 6** from the presets pull-down menu. This is Example5 but with stars of different masses. The changing speeds of the stars are even more apparent in this example.	*Note how the velocity of star 2 changes during its orbit. Does this remind you of a law of solar system motion?* (Kepler's 2nd law)
Select **Example 7** from the presets pull-down menu. Here we have stars of different masses and radii.	In the next two examples we will try to develop some intuition regarding what types of systems are eclipsing binaries.
	What variable would we change if we wanted to get rid of eclipses? (decrease inclination – although you can make the eclipse depths very small by creating great differences between the radii or surface temperatures of the stars.)
Slowly decrease the inclination until the eclipses completely disappear. This occurs some place around 48°.	
Select **Example 8** from the presets pull-down menu. The stellar parameters are identical with those in Example 7 except for the semi-major axis of the orbit which is much larger.	*Can we make the eclipses disappear by changing a system parameter as we did in Example 7?* (Yes – decrease inclination again.)
Slowly decrease the inclination until the eclipses completely disappear. This occurs some place around 80°.	*Why does the occurrence of eclipses require such a large inclination in this example?* (Because the stars are so much farther apart.)
	Can we know formulate some general words of wisdom regarding what type of binary systems have eclipses? (Eclipses will always occur for systems where the inclination is exactly 90° and are very likely when the inclination is near 90°. The radii and separation of the stars determines the exact cutoff value of inclination where eclipses cease.)
There are also a large number of datasets preloaded into the simulator. A full discussion of these capabilities is beyond the scope of this handout, however for one simple example select **Example 18: RT CrB** from the presets pull-down menu.	*Can we adjust a stellar parameter that will allow the system to match the data?* (Increase the value of the radius of star 1 will allow a pretty good match to the light curve.)