Classroom Demonstration Guidelines
(Lunar Phase Simulator)

The following sequence of directions are steps an instructor might choose to follow in demonstrating the Lunar Phase 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. These guidelines assume that students are familiar with the basic vocabulary related to phases and focus on the underlying concepts.

Animation Demonstration Directions	Interactive Questions
Hide the **Moon Phase** panel and the **Horizon Diagram** panel, the phase of the Moon is new.	***What percentage of the entire Earth is illuminated at any instant?*** (50%). ***What percentage of the entire Moon is illuminated at any instant?*** (50%).
Grab the Moon and drag it slowly around the Earth. Use the **Diagram Options**, **show lunar landmark** to highlight the rotation-revolution relationship of the moon. Return the Moon to the new position.	***Is the percentage of illumination changing as the Moon revolves around the Earth?*** (No it is always 50%)
Move the Moon to the full position.	***When any observer on the daylight side of the Earth looks at the Moon, how much illumination can they see?*** (0%, the dark side of the Moon is facing the Earth.) ***When any observer on the nighttime side of the Earth looks at the Moon, how much illumination can they see?*** (100%, the dark side of the Moon is facing away from the Earth.) Thus, since 50% of the Moon is always illuminated, lunar phases are due to the changing geometry – the fact that the angle between the Sun and the Moon as seen from the Earth is changing.
Move the Moon to the 3rd quarter position (toward the top of the screen). Show the **Moon Phase** panel.	***What would the Moon look like from the Earth in this phase?*** (50% of the visible surface of the Moon is illuminated – light on

Hide the **Moon Phase** panel. Drag the Moon to the waxing gibbous position (lower-right of the screen). Show the **Moon Phase** panel.	the left half and dark on the right – for a northern hemisphere observer.) We can use the phase panel to check our answer. ***What would the Moon look like from the Earth in this phase?*** (Most of the Moon is illuminated on the right hand side and a small amount on the left is dark.) We can check our answer in the phase panel. The important point is that we use the phase panel as a check for our geometric reasoning and not a replacement.
Use the **Moon Phase** panel to select the waxing crescent. In the **Diagram Options** panel, check **show angle**. Uncheck **show angle**. Use the **Moon Phase** panel menu to select the waning gibbous. Check **show angle** to check your answer – then uncheck **show angle**.	***What angular separation would an observer see between the Sun and Moon?*** (45°) We can use the applet to display the angle. ***What angular separation would an observer see between the Sun and Moon at this phase?*** (135°) Thinking about phases as the angle between the Sun and the Moon will be very helpful when we look at phases in a horizon diagram representation.
Hide the **Moon Phase** panel. In the **Diagram Options** panel, check **show time tickmarks**. Show the **Horizon Diagram** panel. Click **start animation** to demonstrate this. Click **pause animation** when finished. Drag the observer to the Sunrise position.	Note how the direction of incident Sunlight determines the timezones on the Earth. We are looking down at the Earth from the North Celestial Pole. ***How will the observer move due to the Earth's rotation as time advances?*** (Rotation will carry an observer on the Earth counterclockwise since our viewpoint is the NCP -- from Sunrise, through noon, to Sunset, etc.) ***How will the Moon move?*** (counterclockwise as well)

Drag the Moon to the last quarter position so that it is on the observer's meridian. Drag the observer to the 9 pm position. Show the **Moon Phase** panel to select waxing gibbous. Drag the observer to the 3 pm position. We can directly observe this in the horizon panel. Note that the Moon is just rising over eastern horizon – you may wish to rock the observer's position back and forth so students can see the Moon appearing on the eastern horizon.	***What phase of the Moon would this observer see high in the sky (on the observer's meridian)?*** (Last/Third Quarter) ***What phase of the Moon would this observer see on the observer's meridian at 9 pm?*** (waxing gibbous). ***If the waxing gibbous is on the meridian at 9 pm, at approximately what time did it rise?*** (3 pm, we are assuming that the Moon is above the horizon for 12 hours in this animation, so it rises 6 hours before its meridian time and sets 6 hours later.)
Can you tell the time from the location of the Sun? Students typically have difficulty in recognizing the 8 "special positions" – 3,6,9,12 am/pm in the horizon diagram. Move the observer to the noon position. Students will see the corresponding movement of the Sun to the observer's meridian in the horizon diagram Now move the observer to the Sunset position. Now move the observer back to the 3 pm position (the Moon should still be at the waxing gibbous position). Check ***show angle*** to verify. You will need to change the orientation of the horizon diagram to conveniently view this angle.	***What time is it now?*** (noon). ***What time is it now?*** (approximately 6 pm). ***What is halfway between noon and 6 pm***? (3 pm) ***What is the angle between the Sun and the Moon shown in the horizon diagram?*** (135º) The angle between the Sun and the Moon can be very helpful in the horizon diagram representation.

Uncheck the options in the **Diagram Options** panel and hide the **Moon Phase** and **Horizon Diagram** panels.	***What is the shape of the lunar orbit as shown in this animation?*** (a circle) ***Is the lunar orbit really a circle?*** (No – lunar eccentricity is 0.05) ***Let's scrutinize the scale used in this animation. The Earth is shown about 4 times as big as the Moon. Is that realistic?*** (Yes) **The size (radius) of the lunar orbit is shown to be about 5 times the radius of the Earth. Is that realistic?** (No, the radius of the lunar orbit is about 60 times bigger than the Earth's radius – or 30 Earth's lined up. The Moon should be much farther away from the Earth.)
Show the **Horizon Diagram** panel.	***The Sun and the Moon are shown on the celestial equator. Is that realistic?*** (Not realistic, but good enough for most practical purposes. The Sun can be as much as 23.5º off of the celestial equator and the Moon as much as 30º off of the ecliptic. ***Is the direction of Sunlight always the same?*** (No, this simulation sweeps synodic/sidereal issues under the rug.) Simulations typically show a useful, but simplified version of the real world.